

KINGDOM OF THAILAND
MINISTRY OF TRANSPORT
DEPARTMENT OF HIGHWAYS

SPECIFICATIONS

FOR

HIGHWAY CONSTRUCTION

(PART 2/2)

2003



KINGDOM OF THAILAND
MINISTRY OF TRANSPORT
DEPARTMENT OF HIGHWAYS

SPECIFICATIONS

FOR

HIGHWAY CONSTRUCTION

(PART 2/2)

2003

CONTENTS

Page

DIVISION 1 GENERAL

1.1 SCOPE OF WORK 1-1
1.1.1 Intent of Contract 1-1
1.1.2 Alteration of Plans and Characteristics of Work 1-1
1.1.3 Special Provision 1-1
1.1.4 Management and Maintenance of Traffic During Construction 1-1
1.1.5 Removal and Disposal of Structures and Obstructions 1-1
1.1.6 Final Clean Up 1-1
1.2 CONTROL OF WORK 1-2
1.2.1 Authority of the Engineer 1-2
1.2.2 Contract Document Precedence and Meaning of Contract Document 1-2
1.2.3 Coordination with the Department 1-2
1.2.4 Cooperation with Utilities 1-3
1.2.5 Cooperation between Contractors 1-3
1.2.6 Description of the Contract Works 1-3
1.2.7 Engineer's Facilities 1-3
1.2.8 Inspection of Work 1-3
1.2.9 Materials Transportation 1-4
1.2.10 Maintenance during Construction 1-4
1.3 CONTROL OF MATERIAL 1-5
1.3.1 Source of Supply and Quality Requirements 1-5
1.3.2 Designated Material Sources 1-5
1.3.3 Tool Equipment and Plant Inspection 1-5
1.3.4 Samples and Tests 1-6
1.3.5 Testing Fee of Material Testing 1-6
1.3.6 Delivery and Storage of Materials 1-6
1.4 RESPONSIBILITY OF THE CONTRACTOR 1-7
1.4.1 Laws to be Concerned 1-7
1.4.2 Public Convenience and Safety 1-7
1.4.3 Barricade and Warning Signs 1-7
1.4.4 Use of Explosive 1-8
1.4.5 Conservation of Natural and Environment 1-8
1.4.6 Responsibility of Properties and Damages 1-8
1.4.7 Opening Sections of Project to Traffic 1-8
1.4.8 Contractor's Responsibility for Work 1-9

CONTENTS

			Page
	1.5	WORK PERFORMANCE	1-10
		1.5.1 Notice to Proceed	1-10
		1.5.2 Subletting in Contract	1-10
		1.5.3 Progress Schedule	1-10
		1.5.4 Character of Employees	1-10
		1.5.5 Equipment and Tool	1-10
		1.5.6 Contract Time and Extension of Contract Times	1-11
		1.5.7 Failure to Complete on Time, Liquidated Damages	1-11
		1.5.8 Cancel of Contract	1-11
	1.6	QUANTITY OF WORKS AND PAYMENT	1-13
		1.6.1 Advance Payment	1-13
		1.6.2 Scope of Payment	1-13
		1.6.3 Quantities of Work and Construction Cost	1-14
		1.6.4 Omitted Items	1-14
DIVISION	**2**	**EARTH WORK**	
	2.1	CLEARING AND GRUBBING	2-1
		2.1.1 Construction Method	2-1
		2.1.2 Measurement and Payment	2-2
	2.2	ROADWAY EXCAVATION	2-3
		2.2.1 Material	2-3
		2.2.2 Equipment	2-4
		2.2.3 Construction Method	2-4
		2.2.4 Construction Control	2-5
		2.2.5 Measurement and Payment	2-6
	2.3	EMBANKMENT	2-7
		2.3.1 Earth Embankment	2-7
		2.3.2 Sand Embankment	2-12
		2.3.3 Rock Embankment	2-17
	2.4	SELECTED MATERIAL	2-21
		2.4.1 Selected Material B	2-21
		2.4.2 Selected Material A	2-25
DIVISION	**3**	**SUBBASE AND BASE COURSES**	
	3.1	SUBBASE	3-1
		3.1.1 Soil-Aggregate Subbase	3-1
		3.1.2 Soil-Cement Subbase	3-4

CONTENTS

			Page
	3.2	BASE COURSE	3-12
		3.2.1 Crushed Rock Soil Aggregate Type Base	3-12
		3.2.2 Crushed Gravel Soil Aggregate Type Base	3-16
		3.2.3 Cement Modified Crushed Rock Base	3-20
		3.2.4 Soil Cement Base	3-27
	3.3	SHOULDER	3-33
		3.3.1 Soil-Aggregate Shoulder	3-33
	3.4	MATERIAL TO CONTROL PUMPING UNDER CONCRETE PAVEMENT	3-37
		3.4.1 Sand Cushion Under Concrete Pavement	3-37
		3.4.2 Crushed Rock Layer Under Concrete Pavement	3-39
	3.5	SCARIFICATION & RECONSTRUCTION OF EXISTING PAVEMENT	3-43
		3.5.1 Materials	3-43
		3.5.2 Tools and Equipments	3-43
		3.5.3 Method of Construction	3-43
		3.5.4 Inspection	3-43
		3.5.5 Measurement and Payment	3-43
	3.6	SOIL-AGGREGATE TEMPORARY SURFACE	3-44
		3.6.1 Materials	3-44
		3.6.2 Tools and Equipments	3-45
		3.6.3 Method of Construction	3-45
		3.6.4 Inspection	3-47
		3.6.5 Measurement and Payment	3-47
DIVISION	**4**	**SURFACE COURSES**	
	4.1	SPRAYED ASPHALT TREATMENT	4-1
		4.1.1 Prime Coat	4-1
		4.1.2 Tack Coat	4-9
	4.2	SURFACE TREATMENT	4-16
		4.2.1 Materials	4-16
		4.2.2 Selection of Sizes of Crushed Aggregates	4-19
		4.2.3 Equipments	4-20
		4.2.4 Design Criteria for Specifying Quantity of Material	4-23
		4.2.5 Construction Method	4-26
		4.2.6 Measurement and Payment	4-33

CONTENTS

		Page
4.3	PENETRATION MACADAM SURFACE	4-34
	4.3.1 Materials	4-34
	4.3.2 Equipments	4-35
	4.3.3 Design Criteria for Specifying Quantity of Apreinforcing plying Materials	4-38
	4.3.4 Construction Method	4-39
	4.3.5 Measurement and Payment	4-42
4.4	ASPHALT CONCRETE	4-43
	4.4.1 Materials	4-43
	4.4.2 Usage	4-46
	4.4.3 Equipments	4-46
	4.4.4 Specification for Asphalt Concrete Mix Design	4-54
	4.4.5 Construction Method	4-56
	4.4.6 Inspection	4-71
	4.4.7 Quantity Measurement and Payment	4-73
4.5	ASPHALT CONCRETE SURFACE EDGE	4-74
	4.5.1 Materials	4-74
	4.5.2 Equipments	4-74
	4.5.3 Construction Method	4-74
	4.5.4 Quantity Measurement and Payment	4-74
4.6	COLD MIXED ASPHALT	4-76
	4.6.1 Materials	4-76
	4.6.2 Usage	4-78
	4.6.3 Equipments	4-78
	4.6.4 Design Criteria for Cold Mixed Asphalt	4-80
	4.6.5 Construction Method	4-82
	4.6.6 Inspection	4-84
	4.6.7 Quantity Measurement and Payment	4-84
4.7	SLURRY SEAL	4-86
	4.7.1 Materials	4-86
	4.7.2 Usage	4-88
	4.7.3 Equipments	4-88
	4.7.4 Criteria for Design of Slurry Mixture	4-90
	4.7.5 Construction Method	4-91
	4.7.6 Quantity Measurement and Payment	4-94

CONTENTS

		Page
4.8	CAPE SEAL	4-95
4.8.1	The first layer (Single surface treatment)	4-95
4.8.2	The Second Layer (Slurry Seal)	4-96
4.8.3	Additional Specification for Cape Seal	4-99
4.8.4	Quantity Measurement and Payment	4-100
4.9	PORTLAND CEMENT CONCRETE PAVEMENT	4-101
4.9.1	Materials	4-101
4.9.2	Equipments	4-109
4.9.3	Criteria for Concrete Mix Design	4-115
4.9.4	Construction Method	4-116
4.9.5	Inspection	4-132
4.9.6	Quantity Measurement and Payment	4-134
DIVISION 5	**STRUCTURES**	
5.1	PORTLAND CEMENT CONCRETE STRUCTURES	5-1
5.1.1	Materials	5-1
5.1.2	Testing of Material	5-8
5.1.3	Concrete Mix	5-10
5.1.4	Concrete Quality Control	5-26
5.1.5	Weighing and Measuring of Materials	5-28
5.1.6	Mixing Concrete	5-31
5.1.7	Temperature of Fresh Concrete	5-33
5.1.8	Transporting Concrete	5-34
5.1.9	Placing Concrete	5-35
5.1.10	Compacting Concrete	5-38
5.1.11	Curing Concrete	5-39
5.1.12	Reinforcement for General work	5-40
5.1.13	Reinforcement for Prestressed Concrete	5-46
5.1.14	Formwork, Bracing, Scaffolding and Falsework	5-56
5.1.15	Foundation	5-58
5.1.16	Epoxy-Resin-Base Bonding Compounds for Concrete	5-61
5.1.17	Joint Filler, Joint Primer and Joint Sealer	5-61
5.2	CONCRETE BRIDGE WORK	5-63
5.2.1	Tasks of the Engineer	5-63
5.2.2	Procedures for Foundation Works	5-64
5.2.3	Pile cap, Beam, Slab and Other Structures	5-67
5.2.4	Elastomeric Bearing Pad	5-67
5.2.5	Measurement and Payment for Concrete Bridge	5-69

CONTENTS

			Page
	5.3	RECTANGULAR REINFORCED CONCRETE CULVERT	5-72
		5.3.1 Procedures for Foundation works	5-72
		5.3.2 Structural Works of Rectangular Reinforced Concrete Culvert	5-72
		5.3.3 Measurement and Payment of Rectangular Reinforced Concrete Culvert	5-73
	5.4	REINFORCED CONCRETE PIPE CULVERT	5-74
DIVISION	**6**	**INCIDENTALS**	
	6.1	SLOPE PROTECTION	6-1
		6.1.1 Description	6-1
		6.1.2 Materials	6-1
		6.1.3 Construction Methods	6-2
		6.1.4 Measurement	6-5
		6.1.5 Payment	6-6
	6.2	SUB-SURFACE DRAINS	6-7
		6.2.1 Description	6-7
		6.2.2 Materials	6-7
		6.2.3 Construction Methods	6-8
		6.2.4 Measurement	6-9
		6.2.5 Payment	6-9
	6.3	MISCELLANEOUS STRUCTURES	6-10
		6.3.1 Description	6-10
		6.3.2 Materials	6-10
		6.3.3 Construction Methods	6-10
		6.3.4 Measurement	6-11
		6.3.5 Payment	6-11
	6.4	CONCRETE CURB AND GUTTER	6-12
		6.4.1 Description	6-12
		6.4.2 Materials	6-12
		6.4.3 Construction Methods	6-12
		6.4.4 Measurement	6-13
		6.4.5 Payment	6-13
	6.5	CONCRETE SIDEWALK	6-14
		6.5.1 Description	6-14
		6.5.2 Materials	6-14
		6.5.3 Construction Methods	6-14

CONTENTS

		Page
	6.5.4 Measurement	6-15
	6.5.5 Payment	6-15
6.6	GRASSING	6-16
	6.6.1 Description	6-16
	6.6.2 Materials	6.16
	6.6.3 Construction Methods	6-16
	6.6.4 Measurement	6-17
	6.6.5 Payment	6-17
6.7	TOPSOIL	6-18
	6.7.1 Description	6-18
	6.7.2 Materials	6-18
	6.7.3 Construction	6-18
	6.7.4 Measurement and Payment	6-19
6.8	GUARD RAIL	6-20
	6.8.1 Description	6-20
	6.8.2 Materials	6-20
	6.8.3 Construction Methods	6-21
	6.8.4 Measurement	6-22
	6.8.5 Payment	6-22
6.9	FENCING	6-23
	6.9.1 Description	6-23
	6.9.2 Materials	6-23
	6.9.3 Construction Methods	6-23
	6.9.4 Measurement	6-23
	6.9.5 Payment	6-23
6.10	MARKERS AND GUIDE POSTS	6-24
	6.10.1 Description	6-24
	6.10.2 Construction Methods	6-24
	6.10.3 Measurement	6-24
	6.10.4 Measurement and Payment	6-24
6.11	ROAD SIGNS	6-25
	6.11.1 Description	6-25
	6.11.2 Materials	6-26
	6.11.3 Design and Construction	6-31
	6.11.4 Inspection and Testing	6-40
	6.11.5 Measurement and Payment	6-40
6.12	STREET LIGHTING	6-41
	6.12.1 General	6-41
	6.12.2 Materials and Equipment	6-44

CONTENTS

		Page
	6.12.3 Construction Methods	6-50
	6.12.4 Measurement	6-52
	6.12.5 Payment	6-53
6.13	ROAD TRAFFIC SIGNALS	6-54
	6.13.1 General	6-54
	6.13.2 Materials and Equipment	6-54
	6.13.3 Design Principles	6-64
	6.13.4 Construction Methods	6-67
	6.13.5 Testing	6-68
	6.13.6 Measurement	6-68
	6.13.7 Payment	6-68
6.14	FLASHING TRAFFIC SIGNALS	6-70
	6.14.1 General	6-70
	6.14.2 Materials and Equipment	6-70
	6.14.3 Construction Methods	6-72
	6.14.4 Testing	6-72
	6.14.5 Measurement	6-72
	6.14.6 Payment	6-72
6.15	ROAD MARKINGS	6-73
	6.15.1 Description	6-73
	6.15.2 Materials	6-73
	6.15.3 Construction Methods	6-78
	6.15.4 Measurement	6-81
	6.15.5 Payment	6-81
6.16	PERMANENT TIMBER BARRICADES	6-82
	6.16.1 Description	6-82
	6.16.2 Materials	6-82
	6.16.3 Construction Methods	6-82
	6.16.4 Measurement	6-82
	6.16.5 Payment	6-82
6.17	BUS STOP SHELTER	6-83
	6.17.1 Description	6-83
	6.17.2 Materials	6-83
	6.17.3 Construction Methods	6-83
	6.17.4 Measurement and Payment	6-83
6.18	LANDSCAPING WORK	6-84
	6.18.1 Description	6-84
	6.18.2 Materials	6-84

CONTENTS

		Page
	6.18.3 Planting	6-84
	6.18.4 Sodding	6-85
	6.18.5 Maintenance Period	6-85
	6.18.6 Measurement and Payment	6-85
6.19	BRIDGE DRAINAGE	6-87
	6.19.1 Description	6-87
	6.19.2 Materials	6-87
	6.19.3 Construction Methods	6-88
	6.19.4 Measurement	6-88
	6.19.5 Payment	6-89

DIVISION 5

STRUCTURES

5.1 PORTLAND CEMENT CONCRETE STRUCTURES

This work refer to construction works that are, or include, structural concrete having properties in accordance with the specifications, with or without reinforcement, prestressed concrete and admixtures added concrete. The construction work must be according to desired alignment, level, size, and dimension as shown in the drawings that have been approved by the engineer.

Concrete is a mixture of Portland cement, water, coarse aggregates, fine aggregate and sometime some chemical additives are added.

5.1.1 Materials

5.1.1.1 Portland Cement

Portland cement to be used shall conform to the requirement of the Thai Industrial Standard TIS 15 "Portland Cement". There are 5 types of standard Portland cement:

Type I Ordinary Portland Cement: This type is to be used in structural concrete works that require no extraordinary cement and that are suitable for normal construction works not exposed to severe ambient environments or sulfate attacks. When mixed with water the generated heat must not increase to the level which causes deterioration to the structures.

Type II Modified Portland Cement: This type of cement possess less Tricalcium Aluminate ($3CaO.Al_2O_3$ or C_3A) and generates less heat than Type I Ordinary Portland Cement. However, the amount of Tricalcium Aluminate must not be greater than 8%. Type II Modified Portland Cement is suitable for moderate heat and medium sulfate resistant concrete works.

Type III High-Early Strength Portland Cement: This type of cement exhibits high early strength. The cement powder is finer than Ordinary Portland Cement from grinding during manufacturing processes and/or with added Tricalcium Silicate ($3CaO.SiO_2$ or C_3S) and Tricalcium Aluminate. It is useful for concrete that requires early usage or fast dismantling of formworks, e.g. prestressed concrete works. In using this Type III high-early strength Portland cement precautions must be exercised in temperature control not to exceed specified limits, else the concrete will be prone to cracking.

Type IV Low-Heat Portland Cement: Low-heat Portland cement contains small amounts of Tricalcium Aluminate but large proportions of Dicalcium Silicate ($2CaO.SiO_2$ or C_2S). This type of cement is extensively used in mass concrete constructions since it generates less heat during solidification than other types of cement.

Type V Sulfate-Resistant Portland Cement: This type of cement resists sulfate attack well because of less amounts of Tricalcium Aluminate which normally is less than 5% and is suitable for structures exposed to severe sulfate attack such as sea water, high alkalinity soil or water. Type V Sulfate-resistant Portland cement indicate less setting time than Type I Ordinary Portland cement.

On the usage of the various types of cement described above; generally Type I Ordinary Portland cement is used in most concrete mixes, and Type V Sulfate-resistant Portland cement is employed in structural works that need protection from salt water corrosion, saline soil and high sulfate content environments. Other types of cements shall be used in place of Ordinary Portland cement Type I only when there is permitted in written from the project's owner.

Bulk cement or cement from bags to be used must not have lumps or have formed into pellets. Cement from previously opened bags shall not be used.

5.1.1.2 Water

Water to be use for concrete mixing and curing must be approved by the engineer and must be clear without oil, acid, alkaline, salt, sugar, weeds or other materials that could be detrimental to the concrete or to the reinforcing steels. Water must come from the same source and when tested in accordance with American Association of State Highways and Transportation Officials AASHTO – T 26 "Water Quality Used in Concrete", must contain solution concentration levels not exceeding the as shown stipulated in Table 5.1-1

Table 5.1-1 Allowable Solution Concentration and Ion Levels in Water

Type of Structure	Solution Concentration Level in Water (ppm)		
	Other Ions	Chloride Ions	Sulfate Ions
Non-reinforced Concrete	2,000	2,000	1,500
Reinforced Concrete	2,000	1,000	1,000
Prestressed Concrete	2,000	500	1,000

Turbid water, if to be used, must be prepared to coagulate, flocculate and settle prior to usage. Final turbidity must not exceed 2,000 ppm.

In case of water with above characteristics cannot be found, or in case there are suspicions that the water may not conform to standard, or are unsuitable for used for mixing or curing, the water quality must be tested in accordance to AASHTO – T 106 "Compressive Strength of Hydraulic Cement Mortar". If the strengths of the cubes mixed from the water at 7 and 28 days are not less than 90% of the strengths of cubes mixed from distilled water, that water is suitable to be used for mixing and/or curing.

Water from water sources that are used for mixing and curing must be tested at least twice a year.

In case the engineer observes that the quality of water has changed, immediate tests must be carried out.

5.1.1.3 Chemical Admixtures of Concrete

These chemical additives can be added to the concrete mix before mixing or during mixing. These chemicals may be classified according to objectives into 7 categories:

(1) Category I Water-Reducing Admixture. This additive is added to the concrete mix to reduce the amount of water needed to retain its workability.

(2) Category II Retarding Admixture. This additive is added to the concrete mix to retard the setting time.

(3) Category III Accelerating Admixture. This additive is added to the concrete mix to accelerate setting time and hence gains high-early strength of the concrete.

(4) Category IV Water-reducing and Retarding Admixture. This additive is added to the concrete mix in order to reduce the amount of water as well as to retard setting time.

(5) Category V Water-reducing and Accelerating Admixture. This additive is added to the concrete mix in order to reduce the amount of water as well as to accelerate setting time, and hence gains high-early strength of the concrete.

(6) Category VI Water-reducing high range Admixture. This high-ranged water-reducing additive is added to the concrete mix which water reducing needed more than 12%

(7) Category VII Water-reducing high range and Retarding Admixture. This water reducing high-range and retarding additive is added to the concrete mix to reduce the amount of water by more than 12% as well as to retard setting time for suitable workability.

Each category of admixture can be further divided into liquid type and powder type. Admixtures to be used must possess properties in accordance with TIS 733 "Chemical Admixtures for Concrete". Admixtures must not contain chemicals in amounts that may deteriorate to the steel reinforcing bars and the cement.

In reinforced concrete works, additive admixture to be used must not contain Calcium Chloride in the chemical compositions of that particular admixture and must not contain other types of Chloride ions more than 0.5 % of the admixture.

In Prestressed concrete works, the additive by weight admixture to be used must not contain Calcium Chloride, Fluoride ions, Sulfate ions and Nitrate ions in the chemical compositions of that particular admixture and must not contain other types of Chloride ions more than 0.5 % by weigh of the admixture.

In the case of non-air entraining admixtures, the amount of air entrained in fresh concrete during test shall not be more than 3 % by volume. In air-entraining admixtures, the amount of air entrained in fresh concrete must be between 3.5 % to 7 % by volume.

5.1.1.4 Air-entraining Admixtures for Concrete

These refer to chemicals that can be added to concrete before or during mixing to create dispersed small air bubbles that remain in required volume to enhance workability.

There are 2 types of Air-entraining admixtures; powder type and liquid type. The air-entraining admixtures to be use must have properties conform to TIS 874 "Air-entraining Admixtures for Concrete"

5.1.1.5 Chemical Admixtures for Use in Producing Flowing Concrete

These refer to chemicals that can be added to concrete before or during mixing to enhance high workability in the characteristics of concrete flowing which give slump greater than 190 mm. The admixtures are categorized into 2 types according to usage:

(1) Category I Plasticizing Admixture. This admixture aids flowing characteristics of concrete without addition of water and will not retard concrete setting time.

(2) Category II Plasticizing and Retarding Admixture. This admixture aids flowing characteristics of concrete without addition of water but will retard concrete setting time.

There are 2 types of chemical admixtures for use in producing flowing concrete; powder type and liquid type. The admixtures to be used must have properties conform to TIS 985 "Industrial Chemical Admixture Products for the Use of Flowing Concrete".

All container units for chemical concrete admixtures, air-entraining concrete admixtures and chemical admixtures for use in producing flowing concrete at least must have alphanumeric labels and sign identifications legibly and clearly posted:

(1) Product name.
(2) Category and type.
(3) Principal chemical ingredients for each type of chemical concrete admixtures, air-entraining concrete admixtures and chemical admixtures for use in producing flowing concrete according to that stipulated in the Thai Industrial Standard.
(4) Residues from oven-dried process, relative density and other properties stipulated in the Thai Industrial Standard.
(5) Net amount as net weight or net volume.
(6) Month and year manufactured and lot code number.
(7) Name of manufacturer or company or trademark or trading agent.
(8) Usage details together with safety and storage guidance.

(9) Expiry date or usage duration.

All chemical concrete admixtures, air-entraining concrete admixtures and chemical admixtures for use in producing flowing concrete, if not specified in the design, must be approved in-written by the engineer prior to their usage.

All chemical concrete admixtures, air-entraining concrete admixtures and chemical admixtures for use in producing flowing concrete must be used strictly according to their usage details. If the results obtained in concrete works are not as required, the engineer may consider halting of usage.

Other concrete admixtures besides as described in 5.1.1.3, 5.1.1.4 and 5.1.1.5 must be approved in written by the project 's owner prior to their usage.

5.1.1.6 Coarse Aggregate

Coarse aggregate comprises of crushed rocks, stones and gravel that are angular or round, hard, resilient, solid, not too flat nor too elongate, clean without fines or other coating materials. Different types of coarse aggregate must not to be mixed or piled up together, or to be used together in continuously casting process works without prior permission from the engineer.

If not specified, otherwise, coarse aggregate to be used must have the following properties:

(1) Abrasion value when tested in accordance with DOH – T 202 "Wearing Property of Coarse Aggregate by the Use of Los Angeles Abrasion Machine" must not more than 40%
(2) It is not stone or gravel that exhibits high porosity. When tested after 24 hours immersion in water, the weight of the coarse aggregate must not increase by more than 10% of the original value.
(3) Chemical weathered losses when tested using Sodium Sulfate for 5 cycles in accordance with to DOH – T 213 "Soundness Test of Aggregate" shall not more than 9%
(4) Flakiness index when tested in accordance with DOH – T 210 must not more than 35%
(5) Elongation index when tested in accordance with to DOH – T 211 must not more than 35%
(6) Must not contain undesirable materials more than the amount specified in Table 5.1-2

Table 5.1-2 Maximum Amount of Undesirable Materials in Coarse Aggregates

Undesirable Material	Percent by Weight
Soil, Clay and friable particles	2.0
Coal and lignite	0.5
Aggregate finer than 0.075 mm (#200 sieve)	
- Soil, Clay particles	1.0
- Soil, Sand particles	1.5
Chloride salts	0.05

Testing for maximum amount of undesirable materials in coarse aggregate must be carried out at least once when there is a change in material source, or as deemed necessary.

(7) Gradation when tested in accordance with to DOH – T 204 "Gradation of Aggregate by Dry Sieving" within limits set out in Table 5.1-3. The maximum size of aggregate, if not specified in the design, should not be bigger than 1/5 of the thinnest part of the structure and must not be greater than 3/4 of the spacing of the reinforcing bars. All these have to be approved by the engineer supervisor prior to usage.

Table 5.1-3 Gradation of Coarse Aggregate for Concrete Structural Works

Nominal Size (mm)	Amount Passing Sieve in Percent by Weight									
	63 mm.	50 mm.	37.5 mm.	25.0 mm.	19.0 mm.	12.5 mm.	9.5 mm.	4.75 mm.	2.36 mm.	1.18 mm.
50 – 4.75	100	95-100	-	35-70	-	10-30	-	0-5	-	-
37.5 – 4.75		100	95-100	20-55	0-15	-	0-5	-	-	-
25.0 – 4.75		100	100	95-100	-	25-60	-	0-10	0-5	-
19.0 – 4.75			100	100	90-100	-	20-55	0-10	0-5	-
12.5 – 4.75				100	100	90-100	40-70	0-15	0-5	-
9.5 – 2.36					100	100	85-100	10-30	0-10	0-5

(8) Coarse aggregates must not be piled up which obstructs to traffic. Storage must be prevented from mixing with other materials, else it will have to be washed prior to usage. Aggregates from different sources and of different size must be stored separately. (If segregation occurs aggregates will have to be remix.)

5.1.1.7 Fine Aggregate

Fine aggregate comprises of natural sand or stone particles that is round or angular, not flat or flake, have rough texture and hard, durable, clean without fine coatings. Fine aggregate from different sources must not be mixed or piled up together or used in the same quality controlled continuous casting concrete works without prior permission from the engineer.

Unless specified otherwise, fine aggregate shall have the following properties:

(1) No soil clay, ashes, organic materials, alkali, inorganic materials of Chloride ions type or any other impurities that may exhibit detrimental effects on concrete and steel reinforcement more than that shown in Table 5.1-4

Table 5.1-4 Maximum Contents of Undesirable Materials in Fine Aggregate

Undesirable Materials	Percent by Weight
Soil, Clay and fines	1.0
Coal and lignite	1.0
Aggregate finer than 0.075 mm (#200 sieve)	3.0
Chloride salt	0.1

Other impurities such as shale, alkali, mica, coated grains, soft and flaky particles that will render reduction in concrete strength more than 5 % when compared to the strength obtained from concrete without those impurities

(2) Chemical weathered losses when tested using Sodium Sulfate for 5 cycles in accordance with to DOH – T 213 "Soundness Test of Aggregate" not more than 9%

(3) Clean, without must organic impurities in amounts that are detrimental to concrete, when tested in accordance with to DOH – T 201 "Organic Impurities in Fine Aggregate for Concrete" the color produced must not be darker than that of the standard color.

Fine aggregate that produce darker color than the standard color should not be used except when necessary. Tested in accordance with to AASHTO – T 71 "Effect of Organic Impurities in Fine Aggregate on Strength of Mortar" the compressive strength of 50 mm mortar cubes at 7 days and 28 days must not be less than 95% of cubes molded using the same fine aggregate that have been washed with Sodium Hydroxide 3% concentration and rinsed in clear water. All these are to be within the engineer 's judgement.

This method is also to be used in the Specifications for Highway Construction Volume 1 article 4.9.1.4 (3).

(4) Gradation when tested in accordance with to DOH – T 204 "Gradation of Aggregate by Dry Sieving" shall within the range specified in Table 5.1-5

Table 5.1-5 Gradation of Fine Aggregate for Concrete Structures

Sieve Size mm (in.)	Amount Passing Sieve, Percent by Weight
9.5 (3/8 in.)	100
4.75 (# 4)	95 – 100
1.18 (# 16)	45 – 85
0.300 (# 50)	10 – 30
0.150 (#100)	2 – 10

5.1.2 Testing of Material

All expenses incurred in material testing are to be borne by the contractor.

5.1.2.1 Testing of Portland Cement

In case the properties of the cement used is in doubt, the engineer must take sample for testing.

Sampling of the cement may be done at the manufacturing site or at the construction site in accordance with procedures detailed in TIS 15 "Portland Cement"

Testing of cement properties is to be conducted in accordance with to TIS 15 "Portland Cement"

Bulk cement from containers to be used must bear test results from the manufacturer, securely sealed and the seals must not to be broken prior to submission.

The contractor must arrange storage site together with a proper quality control system to be approved by the engineer prior to storage and usage.

5.1.2.2 Testing of Chemical Admixtures

The contractor must submit specific information and details of principal chemicals of the admixture, together with test results on concrete employing the admixture to be used for approval by the engineer prior to usage.

Testing of admixtures must be conducted according to work characteristics and physical and chemical properties conform to TIS 733 "Chemical Admixtures for Concrete"

Chemical admixtures for concrete that have already been certified of displaying conform to TIS 733 logo may be used without further testing.

5.1.2.3 Testing of Air-entraining Agents for Concrete

The contractor must submit specific information and details of principal chemicals of the air-entraining agents, together with test results of concrete employing the agents to be used for approval by the engineer prior to usage.

Testing of the air-entraining agents must be conducted according to work characteristics and physical and chemical properties conform to TIS 874 "Air-entraining Agents for Concrete"

Air-entraining agents for concrete that have already been certified of displaying conform to TIS 874 logo may be used without further testing.

5.1.2.4 Testing of Chemical Admixtures for the Use of Producing Flowing Concrete

The contractor must submit specific information and details of principal chemicals of the chemical admixtures for the use of producing flowing concrete, together with test results on concrete employing the admixtures to be used for approval by the engineer supervisor prior to usage.

Testing of the chemical admixtures for the use of producing flowing concrete must be conducted according to work characteristics and physical and chemical properties conform to TIS 985 "Chemical Admixtures for the Use of producing Flowing Concrete"

Chemical admixtures for the use of production flowing concrete that have already been certified of displaying conform to TIS 985 logo may be used without further tests.

5.1.2.5 Testing of Aggregates

Samplings of coarse aggregate and fine aggregate are to be conducted in accordance with AASHTO – T 2 "Sampling Aggregate"

Coarse aggregate and fine aggregates shall have desired properties according to the following test methods:

(1) Fine material is to be determined in accordance with to AASHTO – T 11"Amount of Material Finer Than 0.075 mm (#200) Sieve"
(2) Porosity of coarse aggregates is to be conducted, allowably, in accordance with DOH – T 207 "Specific Gravity Test for Coarse aggregate"
(3) Gradations of aggregates are to be conducted in accordance with DOH – T 204 "Gradation of Aggregate by Dry Sieving"
(4) Cleanness of aggregates are to be conducted according to DOH – T 201 "Organic Impurities Tests of Sand for Use in Concrete"
(5) Wearing of coarse aggregate is to be conducted in accordance with DOH - T 202 "Abrasion Test for Coarse Aggregate by Use of Los Angeles Abrasion Machine"

(6) Soundness of aggregate is to be conducted in accordance with DOH – T 213 "Soundness Tests for Aggregate"
(7) Flatness of coarse aggregate is to be conducted in accordance with DOH – T 210 "Flakiness Index Test"
(8) Elongation of coarse aggregate is to be conducted according to DOH – T 211 "Elongation Index Test"
(9) Mortar properties are to be conducted in accordance with AASHTO – T 71 "Effect of Organic Impurities in Fine Aggregate on Strength of Mortar"
(10) Lump and friable particles are to be conducted in accordance with AASHTO – T 112 "Clay Lumps and Friable Particles in Aggregate"
(11) Amount of coal and lignite are to be conducted in accordance with AASHTO – T 113 "Light Weight Pieces in Aggregate"

The contractor must submit 30 kg each sample of coarse aggregate and fine aggregate that have passed all tests to the engineer to be procured as standard materials until the concrete works have been completed. The engineer must issue documents concerning these aggregates' properties to the contractor as evidence.

For every 500 m^3 of concrete casting gradation test must be darried out for both coarse and fine aggregate, and cleanness of fine aggregates must be tested at least once.

If the coarse and fine aggregates exhibit deviated characteristics from the standard samples that have been procured, new aggregate sample must be taken for testing on certain property or all properties as deemed necessary by the engineer.

5.1.3 Concrete Mix

Prior to commencement of concrete structural works the contractor must arrange to obtain mix designs for each particular class of concrete according to desired properties. The mix designs properties should take into considerations regarding durability to ambient weather and environment, abrasion resistance, compressive strength, workability, ease of surface finishing, permeability, and concrete texture suitable for each class of application.

Generally, 3 specification methods for structural concrete may be specified. First method is to specify the minimum compressive strength and the mix proportions. Second method is to specify the minimum compressive strength and the minimum of cement content in accordance with Table 5.1-6 with no regards to the types of structure. Third method which not specify either the minimum compressive strength nor the mixed proportions, but rather the minimum cement content in accordance with the types of the structure detailed in Table 5.1-6

Table 5.1-6 Relationship between Concrete Quality Class, Compressive Strength, Type of Structure, Amount of Cement and Coarse Aggregate Nominal Size

Concrete Quality Class	Compressive Strength of 150 mm Concrete Cube at 28 days (Mpa)	Type of Structure	Minimum Cement Content (kg/m^3)	Nominal Size of Coarse Aggregate (mm)
A special	40	1. Precast prestressed concrete beams and piles 2. Cast – in situ prestressed concrete structures 3. Bearing unit slabs	400	19.0 –4.75
A	30	1. Concrete topping for prestressed concrete bridges 2. Reinforced concrete bridge decks 3. Approach slabs 4. Precast reinforced concrete pile	350	37.5 – 4.75
B	20	1. Reinforced concrete bridge piers, pile bents and braced beams 2. Abutments and bridge footings 3. Reinforced concrete retaining walls 4. Barriers, sidewalks and railings 5. Curbs and gutters 6. Box culverts including headwalls 7. Abutment protectors	350	37.5 – 4.75 or 19.0 – 4.75
C	18	1. Reinforced concrete pipe headwalls	320	

NB: a. 1 MPa = 10.197 ksc
b. Lean concrete mix is 1 : 3 : 6 by volume

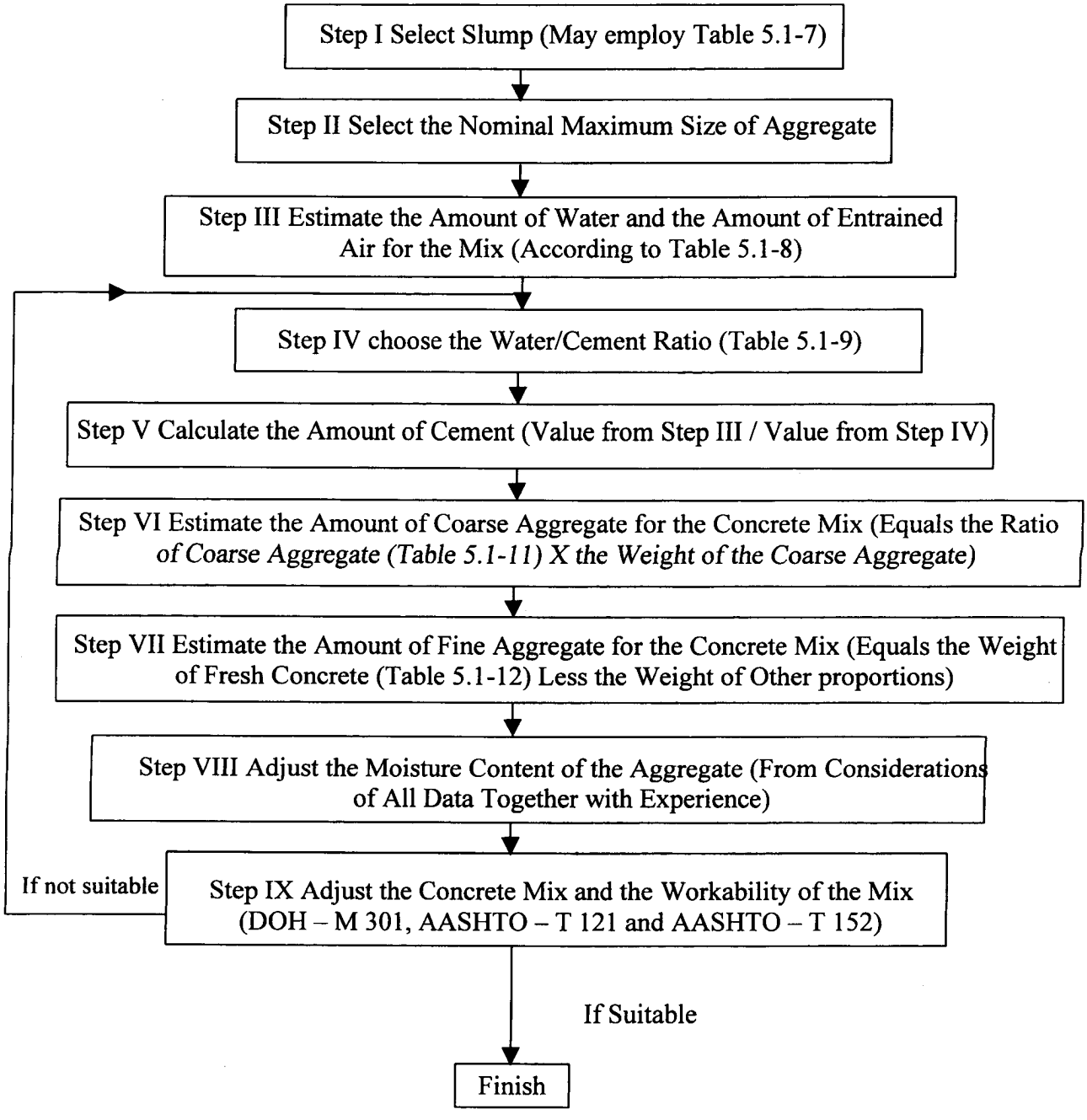
5.1.3.1 Concrete Mix Proportions

All materials employed in the concrete mix must comply to the specifications detailed in article 5.1.1

5.1.3.2 Concrete Mix Design

The steps of making concrete mix design are guidance for design of normal weight concrete. These steps are: (could also be followed up in the mix design flowchart)

(1) Step I Slump Selection. If slump is not specified, appropriate values may be guided as shown in Table 5.1-7 which are slump values of highest viscosity that could be placed into the formworks with the use of vibrating compactors



Mix Design Flowchart

Table 5.1-7 Slump Values for various Types of Structure

Types of Structure	Slump Value (mm)	
	Maximum	Minimum
Reinforced Concrete Foundation	75	25
Plain Concrete Foundations and Underground Structure	75	25
RC Beam, Walls and Retaining Walls	100	25
Structural Columns	100	25
RC Slabs	75	25
Mass Concrete	50	25

NB: Slump value may be greater than those in Table 5.1-7 when chemical admixtures or chemical additives for producing flowing concrete are used in accordance with articles 5.1.1.3, 5.1.1.5, 5.1.2.3 and 5.1.2.5

(2) Step II Nominal Maximum Size of Aggregate Selection. Since the nominal maximum size of coarse aggregate together with good gradation will produce less void than that of smaller well-graded nominal maximum size aggregate, less mortar is required for the same volume of concrete produced. Thus, generally the selection of the maximum nominal size of aggregate is intended for economy of less mortar for the same result.

The maximum nominal size of aggregate must not, however, be greater than 1/5 of the thinnest section of the formworks, or not greater than 1/3 of the thickness of the slab, or not greater than ¾ of the clear spacing between steel reinforcement or group of steel reinforcement or prestressed concrete wire strands. These limitations may be omitted in case of the use of highly workable concrete that does not create honeycomb and void in the concrete.

For structure that employs a large number of steel reinforcements or prestressed concrete reinforcement ducts, the contractor who design the concrete mix proportions must select the largest nominal size coarse aggregate that is workable but will not create voids and segregation problem.

When it is essential of using high strength concrete, the maximum nominal size of aggregate should be minimized for the high compression strengths required according to the specified water cement ratio.

(3) Step III Estimation of Water and Entrained Air for the Mix. The amount of water per unit volume of concrete depends on the maximum nominal size of coarse aggregate, aggregate shape and size, concrete temperature, amount of entrained air and the use of admixtures. The amount of water can be estimated using Table 5.1-8. Since shape and texture of aggregates affect the amount of water required, suggested value may be adjusted. However, in the design of concrete mixes these suggested values should be employed as starting figures.

Table 5.1-8
Approximate Amount of Water for Concrete Mixes (kg/m^3) and the Needed Amount of Entrained Air for Different Slumps and Maximum Nominal Sizes of Coarse Aggregate

Slump (mm)	Maximum Nominal Sizes of Coarse Aggregate (mm)					
	9.5	12.5	19	25	37.5	50
A. Without Air Entrained Agent added						
25 – 50	207	199	190	179	166	154
75 – 100	228	216	205	193	181	169
150 – 175	243	228	216	202	190	178
Approximate amount of entrained air (%)	3	2.5	2	1.5	1	0.5
Slump (mm)	Maximum Nominal Sizes of Coarse Aggregate (mm)					
	9.5	12.5	19	25	37.5	50
B. With Air Entrained Agent added						
25 – 50	181	175	168	160	150	142
75 – 100	202	193	184	175	165	157
150 – 175	216	205	197	184	174	166
Approximate amount of entrained air (%) for structure exposed to different ambient environments						
- Mild Exposure	4.5	4.0	3.5	3.0	2.5	2.0
- Moderate Exposure	6.0	5.5	5.0	4.5	4.5	4.0
- Severe Exposure	7.5	7.0	6.0	6.0	6.5	5.0

Notes:

1. In case of admixtures is used, the amount of water used for powder type admixture dissolving, or the amount of liquid admixture used, must be considered as a portion of the amount of water for the concrete mix.
2. Structures exposed to mild exposure are indoor and outdoor concrete structures that are not in contact with freezing conditions or in contact with substances that cause thawing such as salt, etc.
3. Structures exposed to moderate exposure are concrete structures in contact with freezing environments but are not immersed or dampened continuously long period and are not in contact with salt or other detrimental substances to that deteriorate concrete. Such as beams, columns, walls, joints, or slabs, etc. Which situated in very cold weather area but are not in contact with moist ground nor in areas where they are in contact with salt or other detrimental substances that deteriorate to concrete.

4. Structures exposed to severe exposure are concrete structures in constant contact with salt or other detrimental substances that deteriorate to concrete, or are immersed in water continuously for long time most of the time, e.g. concrete canal linings, water tanks or reservoirs, etc.

(4) Step IV Selection of Water/Cement Ratio. The compressive strength and durability must be taken into consideration since different types of aggregates or different types of cement of the same water-cement ratio will produce concrete of different compressive strength and durability.

In case of there is no information of the type of aggregates and the type of cement, rough water/cement ratio for Portland cement type I for various compressive strength may be derived from Table 5.1-9

Table 5.1-9
Relationship between Water/Cement Ratio and Compressive Strength

Compressive Strength @ 28 d (Mpa)	Water/Cement Ratio	
	Without Air Entrained Agent added	With Air Entrained Agent added
45	0.42	-
40	0.47	0.39
35	0.54	0.45
30	0.61	0.52
25	0.69	0.60
20	0.79	0.70

Notes:

1. The compressive strength at 28 days is obtained from 150 mm concrete cube at 28 days and cured in water.
2. The amount of air entrained in concrete without air entraining agent added must not be greater than 2%. For concrete with air entraining agent added the amount of air entrained for the concrete must not be greater than 6%
3. The maximum nominal size of coarse aggregate is between 19 – 25 mm

In the case that the concrete structures are to be exposed to severe ambient environments, the water/cement ratio shall not be greater than that specified in Table 5.1-10

Table 5.1-10
Maximum Value of Water/Cement Ratio
For Concrete Exposed to Severe Conditions that may Greatly Affect to Concrete Quality

Type of Structure	Damped Structures/Exposed to Alternate Wet and Dry Conditions	Structures Exposed to Sea Water or Sulfate
Thin concrete structures e.g. bridge slabs, bridge sides and bridge rails and those concrete structures with reinforcement cover thickness less than 25 mm	0.45	0.40
other structures	0.50	0.45

Notes:

For structures exposed to sea water or sulfate, if Portland cement type V is used the water/cement ratio could be increased, not more than 0.05

(5) Step V Calculation of the Cement content The cement for the concrete mix (kg/m^3) can be obtained by dividing the amount of water for the mix in step III by the water/cement ratio from step IV, then compared to the minimum cement content specified in the specifications (if stated) and the higher value of the cement content is used.

(6) Step VI Estimation of Coarse Aggregate Adopt the ratio of oven-dry-rodded coarse aggregate conform to proportion AASHTO T 19 "Unit Weight and Voids in Aggregate" in 1 unit of fresh concrete conform to Table 5.1-11 which depends on the maximum nominal size of the coarse aggregate and the fineness modulus of the fine aggregate.

Table 5.1-11
Ratio of Oven-dry-rodded Coarse Aggregate per a Unit of Fresh Concrete

Maximum Nominal Size of Coarse Aggregate (mm)	Ratio of Oven-dry-rodded basis Coarse Aggregate per a Unit of Fresh Concrete			
	Fineness Modulus of Fine Aggregates			
	2.40	2.60	2.80	3.00
9.5	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
19	0.66	0.64	0.62	0.60
25	0.71	0.69	0.67	0.65
37.5	0.75	0.73	0.71	0.69
50	0.78	0.76	0.74	0.72

Notes:

The ratio of oven-dry-rodded basis coarse aggregate in this Table shall be used for typical concrete structures. For works which need high workability such as pumped concrete, these ratios may be less not more than Hence, 10%. The slump and water/cement ratio for concrete suggested in the first and fourth steps must be maintained and must be conformed to specifications.

Step VII Estimation of Fine Aggregate proportion. This can be obtained by subtracting the weights of various other mix proportions in the 1 m^3 concrete mix – such as the total weight of water, cement and coarse aggregate - from the weight of fresh concrete. The fresh concrete weight may be preliminarily derived from Table 5.1-12

Table 5.1-12
First Estimate for the Weight of Fresh Concrete

Maximum nominal Size of Coarse Aggregate (mm)	First Estimate for the Weight of Fresh Concrete (kg/m^3)	
	Without Air Entrained Agent added	With Air Entrained Agent added
9.5	2,280	2,200
12.5	2,310	2,230
19.0	2,345	2,275
25.0	2,380	2,290
37.5	2,410	2,350
50.0	2,445	2,345

Notes: 1. The values in Table 5.1-12 can be calculated approximately from the equation:

$$U_M = 10\, G_m\, (100-A) + C_M(1-G_m/G_c) - W_M(G_m - 1)$$

Where

U_M is the unit weight of fresh concrete (kg/m^3)

G_m is the average bulk specific gravity of fine and coarse aggregates in saturated-surface-dry, or SSD basis)

G_c is the specific gravity of the cement, normally 3.15

A is the percent of entrained air in the concrete, in accordance with Table 5.1-8

W_M is the amount of water in the concrete mix, according to Table 5.1-8, kg/m^3

C_M is the cement content in the mix, kg/m^3

EXAMPLE

Given:

Maximum nominal size of coarse aggregate	=	25	mm
Slump	=	75 – 100	mm
Without air entraining agent added			

Assume:

G_m = 2.7

A = 1.5%

C_M = 300 kg/m^3

G_C = 3.15

W_M = 193 kg/m^3

U_M = 10x2.7(100–1.5)+300(1–2.7/3.15)–193(2.7-1)

= 27(98.5) + 42.857 – 328.1

= 2,659.5 + 42.857 – 328.1

= 2,374 kg/m^3

Which is close to the value in Table 5.1-12

2. For the unit weight used is varied from that in Table 5.1-8, the difference of every 5 kg of water (for slump 75 – 100 mm) will be inversely proportional to every 8 kg/m^3 of the unit weight of fresh concrete

For the cement content differs from 330 kg, every difference of 22 kg cement content will vary proportionally with every 3 kg/m^3 of the unit weight of fresh concrete. If the average specific gravity of the fine and coarse aggregates differs from 2.7, every difference of 0.1 will vary proportionally with every 60 kg/m^3 of the unit weight of fresh concrete.

For concrete with air entraining agent added, that contacts with ambient environment, the unit weight of fresh concrete will increase 1% the amount of entrained air decrease 1% from the original amount.

Step VIII Adjustment Resulting from Aggregate Moisture The amount of moisture in the aggregates must be employed in the concrete mix design. Aggregates that have more moisture contained in and around the surface will render more weight adjustment of the material. Moreover, the amount of water needed for the concrete mix must be reduced by the same amount of the free water presents in the aggregates.

Step IX Adjustment of Concrete Mix Proportions All calculated must be checked in accordance with DOH – M 301 "Standard in Mixing proportions of Fresh Concrete in the Laboratory". The produced fresh concrete must be tested for unit weight and other proportions in accordance with AASHTO T - 121 "Weight per Cubic Foot, Yield and Air Content (Gravimetric) of Concrete" and test for the percent of entrained air in accordance with AASHTO - T 121, or according to AASHTO T- 196 " Air Content of Freshly Mixed Concrete by Volumetric Method", or in accordance with AASHTO T - 152 "Air Content of Freshly Mixed Concrete by Pressure Method". Moreover, workability, segregation prevention and surface finishing of the fresh concrete must be taken into consideration as well.

Regarding the amount of water used for the trial concrete mix in the laboratory, If the produced that the slump is not correct, adjustment can be made by of adding or reducing.

In case air entraining agent for concrete is added, decreasing or increasing 3 kg water per 1 cubic meter of fresh concrete will increase or decrease the amount of air of entrained by 1%.

After adjusting, the proportions of the designed mix an be calculated according to trial mix for 1 cubic meter of concrete.

5.1.3.3 Target Compressive Strength

The design of trial mix should be conducted such that the average compressive strength of concrete is greater than the required minimum compressive strength in the specifications. Thus as specified that when 30 concrete specimens are tested for trial - mix, the average of target compressive strength calculated from the following formula must not less than of the specified minimum compressive strength.

$$F_{ck} = F_m + ZS \geq F_{cu}$$

Where

F_{ck} = The average of target compressive strength

F_m = The average compressive strength obtained from at least 30 specimens

$$= \sum_{j=1}^{N} \frac{F_{cj}}{N}$$

F_{cd} = Compressive strength of each specimens

N = Number of specimens to be tested (not less than 30)

S = The standard deviation of compressive strength from all tested specimens

$$= \sqrt{\frac{\sum (F_{cj} - F_m)^2}{N-1}}$$

$$= \sqrt{\frac{\sum (F_{cj}{}^2) - (\sum F_{cj})^2}{N-1}}$$

Z = Probability coefficient for number of test results that are less than the target average compressive strength. The accepted less value result which gives the valve Z is – 1.64 to be taken as 5%

F_{cu} = The required minimum compressive strength

In case of there is no previous information of similar mix proportions, it is recommended that the mix proportions shall be designed such that its compressive strength is greater than the required minimum compressive strength by not less than 5 MPa. Thereafter, adjustment can be made when results of trial compression strength are obtained.

EXAMPLE

Compressive strength results at 28 days of 150 mm concrete cubes from the previous mix proportions for concrete class A are shown in Table 5.1-6 which to be used for concrete topping of prestressed concrete bridges, as below :

J	F_{cd} (MPa)	$(F_{cd} - F_m)^2$
1	45	2.16
2	46	6.10
3	47	12.04
4	48	19.98
5	49	29.92
6	45	2.16
7	42	2.34
8	44	0.22
9	45	2.16
10	43	0.28
11	42	2.34
12	41	6.40
13	40	12.46
14	42	2.34
15	43	0.28
16	44	0.22
17	43	0.28
18	42	2.34
19	41	6.40
20	42	2.34
21	43	0.28
22	41	6.40
23	42	2.34
24	43	0.28
25	44	0.22
26	45	2.16
27	42	2.34
28	43	0.28
29	44	0.22
30	45	2.16
	F_{cd} = 1,306	$(F_{cd} - F_m)^2$ = 129.44

F_m = 1,306 / 30 = 43.53 MPa

N – 1 = 30 – 1 = 29

$$S = \sqrt{\frac{\sum (F_{cj} - F_m)^2}{N - 1}}$$

= 2.11

F_{ck} = $F_m + ZS$

= 43.53 + (-1.64 x 2.11)

= 43.53 – 3.46

= 40.07 MPa

For this case, in accordance with Table 5.1-6 there is no obtained minimum compressive strength is less than 30 MPa, hence this design concrete mix proportions is acceptable and can be used.

5.1.3.4 Concrete Mix proportions Calculation Example

The given data are as follows;

Property of concrete specified in the design (Quality category A concrete)		
- Without air entraining agent added in concrete		
- Average target compressive strength (Fck)	40	MPa
- Slump	75 – 100	mm
- Minimum cement content	350	kg/m^3
Coarse Aggregate		
- Maximum nominal size of coarse aggregate	37.5	mm
- Over dry-rodded basis unit weight of coarse aggregate	1,600	kg/m^3
- Absorption	0.5	%
Fine Aggregate		
- Absorption	0.7	%
- Fineness modulus	2.80	
Type of Cement		
- Portland cement type I		

Calculations of the concrete mix proportions can be detailed as follows;

(1) Step 1 Slump is between 75 to 100 mm

(2) Step 2 Maximum nominal size of coarse aggregate is 37.5 mm

(3) Step 3 Use Table 5.1-8 without air entraining agent added. From slump is 75 to 100 mm and maximum nominal size coarse aggregate is 37.5 mm, the amount of water required is 181 kg/m^3

(4) Step 4 The water cement ratio of without air entraining agent added in concrete and for compressive strength concrete 40 MPa can be obtained from Table 5.1-9 is 0.47

(5) Step 5 From step 3 and step 4 the cement content in the concrete mix proportions can be calculated, it is 181/0.47 = 385 kg/m^3

(6) Step 6 The proportion of coarse aggregate can be obtained from Table 5.1-11 using Fineness Modulus 2.80 and the maximum nominal size of coarse aggregate 37.5 mm. From the Table, the ratio of oven-dried dry-rodded basis of coarse aggregate per 1 cubic meter of fresh concrete is 0.71, or as by weight is 0.71 x 1,600 = 1,136 kg

(7) Step 7 Calculate the proportion of fine aggregate by deducting weights of other proportions from the weight of fresh concrete obtained from Table 5.1-12, thus:

Amount of water in the concrete mix	181 kg
Cement content	385 kg
Proportion of coarse aggregate	1,136 kg
Total	1,702 kg
Weight of fresh concrete from Table 5.1-12	2,410 kg
Hence, weight of fine aggregate = 2,410 – 1,702	= 708 kg

(8) Step 8 If the moisture of coarse aggregate is estimated to be 2% and that of fine aggregate is 6%, adjustment of the design mix can be calculated as follow;

Coarse aggregate (moisture content 2%) = 1,136 x 1.02 = 1,159 kg
Fine aggregate (moisture content 6%) = 708 x 1.06 = 750 kg
The amount of water absorbed into the coarse and fine aggregates shall not be included as part of the water needed for the concrete mix
The amount of free water outside the coarse aggregate = 2 – 0.5 = 1.5%
The amount of free water outside the fine aggregate = 6 – 0.7 = 5.3%
Thus, the amount of water required for the concrete mix
= 181 – 1,136(0.015) – 708(0.053)
= 126 kg

Hence, each cubic meter of the design concrete mix will consist of:

Water	126 kg
Cement	385 kg
Coarse Aggregate (2% moisture)	1,159 kg
Fine Aggregate (6% moisture)	750 kg
Total	2,420 kg

(9) Step 9 The concrete trial mix proportions in the laboratory is usually 0.02 m^3 (for ease of mixing). Thus, the water content in the fresh concrete will be 126 x 0.02 = 2.52 kg (from the calculations)

Try trial mix of 0.02 m^3 concrete as proportions obtained from calculation and measure the slump. If the slump is not according to the requirement water – adjustment by adding or reducing is made for trial mix.

Reason which the amount of water required does not the same as calculation due to variations of fresh concrete properties such as the property of coarse aggregate, the property of fine aggregate, the air temperature during mixing, etc.

Suppose the amount of water is increased another 7% from the calculated value (2.52 kg)

The revised amount of water required	= 2.70 kg
Cement content = 385 x 0.02	= 7.70 kg
Coarse Aggregate (2% moisture) = 1,159 kg x 0.02	= 23.18 kg
Fine Aggregate (6% moisture) = 750 kg x 0.02	= 15.00 kg
Total = 2.70 + 7.70 + 23.18 + 15.00	= 48.58 kg

After mixing, if slump is 50 mm, the unit weight of concrete in accordance with AASHTO - T 121 "Weight per Cubic Foot, Yield, and Air Content (Gravimetric) of Concrete" is 2,390 kg/m^3. Adjustment for the slump must be made to meet the requirement.

The amount of concrete produced is = 48.58 / 2,390 = 0.0203 m^3 the amount of water including from excess moisture from the coarse and fine aggregates (after absorption reductions)

= 2.70 + (0.015 x 1,136 x 0.02) + (0.053 x 708 x 0.02) = 3.79 kg

Hence, the amount of water per cubic meter = 3.79 / 0.0203 = 187 kg
According to recommendations in article 5.1.3.2 in step 9 the amount of water must be increased by 8 kg to increase the slump from 50 mm to be 75-100 mm. Thus, the amount of water required is 187 + 8 = 195 kg

When the amount of water is added, the water/cement ratio must be retained as 0.47 while retaining same value of cement content will be 195 / 0.47 = 415 kg

When these properties of concrete meet the requirements, the amount of coarse aggregate per cubic meter must correspond to that employed in the test mix That is, the amount of coarse aggregate will be

23.18 / 0.0203	= 1,142 kg (2% Moisture)
or = 1,142 / 1.02 kg	= 1,120 kg (Dry)
or = 1,102 x 1.005	= 1,126 kg (Saturated-Surface-Dry, SSD)

The amount of fine aggregate can be obtained from the calculation

= 2,390 – (195 + 415 + 1,126)	= 654 kg (SSD)
or = 654 / 1.007	= 649 kg (Dry)
or = 649 x 1.06	= 688 kg (6% Moisture)

Since the moistures of the coarse and fine aggregates are respectively 2% and 6%, and the coarse and fine aggregates in the fresh concrete are saturated-surface-dry (SSD) condition, there are excess amounts of water around the aggregates

The amount of water around the coarse aggregate
= 1,142 - 1,126 = 16 kg

The amount of water around the fine aggregate
= 688 - 654 = 34 kg

That is, the amount of water added to the mix
= 195 – 16 – 34 = 145 kg

Therefore, after all adjustments have been done, the mix proportions of the concrete to be used for each 1 cubic meter shall consist of

Water	145 kg
Cement	415 kg
Coarse Aggregate (2% Moisture)	1,142 kg
Fine Aggregate (6% Moisture)	688 kg
Total Weight	2,390 kg

The above example can be as a guideline for the concrete mix design to obtain the required properties.

5.1.3.5 Concrete Mix Control

When the engineer approves the mix design and materials testing details together with the concrete materials test results, the contractor must try trial mixes to check the workability, the water/cement ratio, compressive strength, texture of concrete and other necessary properties to evaluate the suitability of concrete for that particular structure. Moreover, the contractor must check how to transport fresh concrete and also the concrete compactors. All trial mixes must be approved by the engineer .

Trial mix according to designed proportions with suitable consistencies for each particular type of work must be made by using at least 3 values of different water/cement ratios, and each mix proportion must yield compressive strength not less than that specified. Trial mixes must be designed such that the slump different from the maximum design slump by not more than 25 mm. Temperatures of fresh concrete of trial mixes are to be measured.

Each mix with different water/cement ratio shall be made in accordance with DOH - M 301 "Standard for Mixing of Fresh Concrete in Laboratory" and molded into at least 9 concrete cubes in accordance with DOH – M 303 "Standard for Molding Concrete Cubes". These are to be cured for 28 days (or less). The cubes are then to be tested for compressive strengths in accordance witch TIS 409 "Method of Testing for Concrete Specimens". The strengths obtained must not less than the specified strength of concrete cubes at 28 days. From these tests, a graph depicting relationship between water/cement ratios and compressive strengths can be obtained. The water/cement ratio to be used in the actual work may be derived from the graph.

The engineer will approve of the water/cement ratio selected only when the compressive strength and the minimum cement (kg/m^3) are met.

Mix proportions that have been evaluated and approved shall not be altered. Over the types, sizes, gradations, material sources of all ingredients - unless allowed by the engineer who may request new test mixes before permission of mix alteration.

All these operations are to be finished prior to any concrete work. Expenses incurred shall be of the contractor's responsibility.

5.1.3.6 Ready Mixed Concrete

In case ready mixed concrete is used the contractor must seek mix design strictly accordingly to article 5.1.3. Ready mixed concrete that are manufactured conform to TIS 213 can be used when the quality category of the ready mixed concrete is selected that will yield concrete cube strengths at 28 days not less than the minimum compressive strength, and also must have properties in accordance with article 5.1.3 .

The DOH concrete class can be compared to the ready mixed concrete class manufactures conform to TIS standard shown in Table 5.1-13

Table 5.1-13
Comparison of Concrete Class of, DOH Standard and Ready Mixed Standard (TIS 213)

DOH Class	Ready Mixed Class
A Super	c 40/35
A	c 30/25
B	c 25/20
C	c 20/15

5.1.4 Concrete Quality Control

The contractor shall be responsible for the control of concrete quality to meet the construction specifications. Inspection by the engineer as specified in details does not exempt the contractor from final responsibility in the quality of concrete.

The contractor must acquire and procure equipment for slump testing and molds for 150 mm cube sufficiently in numbers at construction site.

5.1.4.1 Frequency of Testing

(1) Concrete Plant and Equipment they are to be inspected once of every 1,000 m^3 of concrete manufactured. In cases of concrete for important structures the engineer may order for prior inspection, or at any time, that the engineer deems necessary.

Weighing equipment for aggregates and cement, and containers for water and admixtures must be inspected according to that detailed in article 5.1.5

The contractor must inspect the concrete plant and equipment according to the methods that have been approved by the engineer.

(2) Fresh Concrete must be tested for slump at any time the engineer deem necessary, and at least once of every 25 m^3 of concrete manufactured at the beginning of the placement and when specimens of 150 mm concrete cube are collected.

(3) Testing of Concrete Compressive Strength shall be done to specimens molded from concrete sampled from each class. Frequency shall not be less than once a day during the placement of concrete, nor less than once for every 120 m^3 concrete manufactured, nor less than once for every 450 m^2 of floor and wall areas, nor less than once for placement of each concrete structure.

5.1.4.2 Preparation and Testing of Concrete Samples from Construction site.

Concrete specimens to be tested for compressive strength shall be made and cured in accordance with to AASHTO - T 23 "Making and Curing Concrete, Compressive and Flexural Strength Test Specimens in the Field". Curing method for concrete specimens must be done in similar to curing treatments on site – as shown in article 5.1.11

The average of compressive strength from 3 specimens, obtained in accordance with TIS 409 "Method of Testing for Concrete Specimen" shall not less than that specified in the drawings. No more than 1 sample is allowed to bear less compressive strength than the require minimum compressive strength, and that value must not less than of 85% as specified.

5.1.4.3 Inspection of Under-Standard Compressive Strength

In cases when testing of compressive strengths of concrete specimens do not comply to that detailed in 5.1.4.2 the contractor must strictly carry out other tests suggested by the engineer. In practice, if it is considered probable that the compressive strength test results obtained have certainly indicated lower load carrying capacity for the structure, the contractor may be ordered to take cored specimens from the structure which under suspicion in accordance with to AASHTO - T 24 "Obtaining and Testing Drilled Cores and Sawed Beams of Concrete". Three specimens shall be taken from the structure. Each specimen must not give less compressive strength than the required minimum compressive strength.

In cases when the compressive strengths of concrete, from cored specimens taken from the structure, are not according to the specification, the contractor may ask for actual load carry capacity testing on that structure, if and when it is considered and possible to do so.

Compressive strengths of cylindrical concrete specimens can be converted to that of cube samples in accordance with to Table 5.1-14

Table 5.1-14 Compressive Strength of Cylinders VS Cube Specimens

Compressive Strength of Cylinder (MPa)	Compressive Strength of Cube (MPa)
2.0	2.5
4.0	5.0
6.0	7.5
8.0	10.0
10.0	12.5
12.0	15.0
15.0	20.0
20.0	25.0
25.0	30.0
30.0	35.0
35.0	40.0
40.0	45.0
45.0	50.0
50.0	55.0

5.1.5 Weighing and Measuring of Materials

Weighing and measuring of materials to be used in concrete mixes must be conducted under approval from the engineer supervisor only at the plant site or in the vicinity of the concrete mixer. Concrete plants may be stationary type or mobile type. These plants must be equipped with proper weighing and measuring devices to ensure accurate processes.

5.1.5.1 Bins and Weighing Hoppers of Materials

Aggregates Bins must have good drainage system and must be partitioned for adequate coarse aggregate, and fine aggregate. Each compartment must have device which can efficiently control the flows of cement, coarse aggregate and fine aggregate to the weighing hoppers. These devices must be able to slow down of flowing when the amounts approach their required, and must be able to completely shut off with precision when the amounts are reached the requirements.

Weighing Hoppers must have auxiliary openings for access of materials, and can be able to be emptied when necessary.

5.1.5.2 Weighing Equipment

Weighing equipment for mix proportions must be of either balanced-beam type or dial type with no spring. These equipment must be able to weigh accurately within 0.4% of the maximum capacity. The contractor must acquire at least ten 25 kg standard weights at the site office to be used for checking the equipment accuracy. All parts of the equipment must always be kept clean.

In the case of balanced-beam equipment, there must be a dial pointer to indicate when the amount of material nearly reaches the required amount. The pointer must be set up and warning when 100 kg of the required amount is reached, and again if the amount is exceed the limit by 25 kg.

Weighing equipment and pointers must be positioned where the controller can watch easily and conveniently while the materials are being weighed. All control positions must be conveniently accessible.

Weighing of cement can be either direct weighing or judged from standard cement bag which is 50 kg per bag. If direct weighing is done, specific weighing equipment and weighing bin must be prepared, including an appropriator conveying system to transport weighed cement to the concrete mixer, and must be approved by the engineer.

Tolerances for concrete mix proportions are shown in Table 5.1-15

Table 5.1-15 Tolerances for Concrete Mix Proportions

Materials	Weight of each Materials in the Mix			
	More than 30% of the Maximum Capacity of the Weighing for Each proportion		Less than 30% of the Maximum Capacity of the Weighing for Each proportion	
	For Each Weighing	Total Weight from Each Weighing	For Each Weighing	Total Weight from Each Weighing
Cement	±1% of the cement weight, or ±0.3% of the maximum capacity of weighing device (Use the larger value)		Not less than specified, or not more than 4% from that specified	
Water (By Volume or By Weight)	±1	Not recommended	±1	Not recommended
Aggregate (%)	±2	±1	±2	±0.3% of the maximum capacity of the weighing device, or ±3% of the total weight from each weighing (Use the smaller value)
Admixture (By Volume or By Weight) (%)	±3	Not recommended	±3	Not recommended

5.1.6 Mixing Concrete

Thorough mixing of concrete is of prime importance in manufacturing consistency concrete. Hence the devices and methods to be used in concrete mixing, besides being suitable for general mixing of concrete, must be able to cope with the maximum size of aggregate and must be able to produce concrete with minimum slumps.

The contractor must acquire sufficient number of device and methods for concrete mixing suitable for the job including transportation and placement of concrete so that the work can be carried out continuously and finished as schedule.

5.1.6.1 Mixing Equipment

Concrete mixing equipment may be a stationary type at the concrete plant or may be portable type. Arrangement of the mixing paddles must be such that proportioned materials could be thoroughly mixed in the mixer while the mixer axis turns or revolves. Moreover, mixing and discharging for the mix must be convenient.

Concrete mixers can be categorized into 6 types:

(1) Tilting Drum Mixer. This type the drum can be tilted while mixing or while discharging. During the mixing process the drum axis can be tilted to horizontal plane.
(2) Non-tilting Drum Mixer. This type the drum axis is always in the horizontal plane. Thus, mixing and discharging of concrete have to be done while drum is in horizontal position.
(3) Vertical Shaft Mixer. This is a turbine or pan-type mixer that work by kneading. Paddles are positioned vertically within the mixer. There are of 2 types: stationary drums, and rotating drums in opposite direction to the paddles movement. While mixing the paddle can be speeded up or slowed down. This type of mixer is suitable for rather dry mixing. Which is used in laboratory as well as in concrete manufacturing industry.
(4) Paddle Mixer. This type of mixer has paddles fixed along horizontal shaft that can rotate produce high power. It is suitable for stiff concrete, which is used in concrete block industry.
(5) Truck Mixer. This can be divided into 2 types: rear-end discharging and front-end discharging. More favorable are the rear-end type with tilting axis. Both types have paddles installed within the rotating drum for mixing and the concrete can be discharged when the drum rotate in reverse direction.
(6) Continuous Mixing Equipment. This mixer has helical continuous paddles installed that can rotate at high speed. The axis is usually tilted 15 to 25 degrees to the horizontal plane.

5.1.6.2 (Central) Plant Mixed Concrete

This concrete is mixed at concrete producing for factory by using stationary plant then to be transported to the construction sites.

5.1.6.3 Truck Mixers / Transit Mixers

This concrete is produced by putting mix proportions in from materials that are weighed and measured and the fixed on a truck, Then mixing, The mixed concrete is then to be used for construction.

5.1.6.4 Charging and Mixing

Methods and sequence of materials charging into the mixers are very important and co effect to concrete mixing.

Mixer location in factory must be considered regarding continuous conveyance of materials into the mixer.

When mixing by truck mixer, charging of mix proportions into the drum must be prevented of lump forming, especially that between sand and cement. The front end of the drum can be prevented from lump forming by charging the drum with each 10% of coarse aggregate and water required into the mixer before charging of sand and cement.

Special care must be taken when adding water. Normally, ¼ to 1/3 of the required amount of water is added after other proportions have already charged. Water pipes must be well designed and adequate in size to enable full charge of water within ¼ of the total required time for mixing.

In cases when chemical admixture for concrete is used, all kinds of air-entraining agent and chemical admixture for producing flowing concrete must be added to the mix only during mixing. Liquid admixture must be added together along with water or moist fine aggregate, powder admixture must be added together along with other dry material.

If there are more than 1 type of admixtures to be used, separate charging must be made unless specified can be charged at the same time. In addition, liquid admixture must be diluted prior of charging.

(1) Mixing of concrete with mixing plant. Each batch must produce the amount of concrete not more than that specified by the manufacturers. Mixing time depends on the performance of concrete mixing plant which produced consistency quality of concrete for each batch according to recommendation by the manufacturer and specifications of the mixing. However, mixing time should rely on efficiency testing of the mixing plant, which should be conducted intermittently throughout its designed life. Mixing time for each batch must not be less than 1 minute. Mixing time is started after all proportions have been fed into the mixing. Timing clock must be audible and must have control device to prevent over-timing or under-timing. Mixing Plant should be prevented of more proportions being added during mixing process. Timing clock shall be used both in automatic concrete mixing plant as well as in ordinary mixing plant. Mixing Plant must be designed to work properly both when starts and finishes of concrete mixing with full loading of proportion

(2) Mixing of concrete with truck mixer. Generally truck drum is charged not over 63% of their capacity and will rotate 70 to 100 revolutions for well-mixing of proportions, but may have more or less revolutions as required, which is depend on the mixing truck efficiency and the amount of concrete being mixed. In any case, the drum shall not be mixed, more than 300 revolutions.

If required time is to be spared for concrete placement after mixing has been completed, the number of mixer is revolution must be decreased, or must be stopped for a while. Then the drum is to be revolved again approximately 30 revolutions for concrete consistency before discharging.

If time is needed for transportation, mixing must be done in dry condition, which means alteration the step of water charging. Water will be added when the dried-mix has arrived at the construction site. Aggregates for concrete in this circumstance must be of saturated-surface-dry to prevent hydration between water and cement. For this dry mixing, dry proportions are fed into the concrete mixing truck and transported to the site. Then water is added with pressure into the front and rear ends of the drum, simultaneously the drum is revolved 70 to 100 revolutions.

(3) Water. The amount of water required for the desired slump depends on the transport distance to the site, the time needed for concrete placement and the ambient temperature at the site. In cool weather with not so far transport distance and without waiting period, there should not much problem arise. However, if transport distance is rather for together with warm climate there will be losses of workability of the fresh concrete. This renders necessity in concrete temperature control, by using of retarding admixture, together with a good work plan. In cases when the method mentioned above is not effective, dry mixing is the only alternative to be used.

5.1.7 Temperature of Fresh Concrete

When concrete is mixed with mixing plant, the temperature of the fresh concrete will affect the slump, the amount of mixing water and the amount of entrained air. Thus, fresh concrete from the mix must have temperatures within the specified range to render concrete consistency while placing.

The temperature of concrete before placing into the formworks must be between 10 to 33 ^{o}C, and the temperature of place concrete at the process of setting must not over 70 ^{o}C. For large structure that requires a large amount of concrete the temperature during hydration could be higher than the specified limit. In this case the contractor must propose the methods to reduce the temperature of fresh concrete to the engineer for approval prior to commencement.

The temperature of fresh concrete can be estimated from the following formulae:

A. When Ice is not used

$$T = \frac{0.22\,(T_a W_a + T_c W_c) + T_w W_w + T_a W_{wa}}{0.22\,(W_a + W_c) + W_w + W_{wa}}$$

B. When Ice is used

$$T = \frac{0.22\,(T_a W_a + T_c W_c) + T_w W_w + T_a W_{wa} - 79.6\,W_i}{0.22\,(W_a + W_c) + W_w + W_i + W_{wa}}$$

Where

T_a	=	Temperature of the aggregate (°C)
T_c	=	Temperature of the cement (°C)
T_w	=	Temperature of the mixing water (°C)
W_a	=	Weight of the aggregate, dry (kg)
W_c	=	Weight of the cement (kg)
W_w	=	Weight of the mixing water (kg)
W_{wa}	=	Weight of the free water on the aggregate surface and the weight of water absorbed in the aggregate
W_i	=	Weight of the ice (kg)

5.1.8 Transporting Concrete

Transporting concrete may be done via concrete mixing truck, truck, vessel, chute, pipe, conveyor belt or any other forms of transport.

Transporting method must ensure effective arrivals of concrete at destinations without significant changes in the fresh concrete properties. Which are the water/cement ratio, slump, the amount of entrained air, and the consistency of the mix. Each transportation method has its advantageous and disadvantageous such as type of materials, mix proportions, transporting method to the sites, the placing amount of concrete, the locations of concrete plants, the local climate, etc. These conditions must be thoroughly examined before selecting the transporting method so that concrete with good quality and save economy can be attained.

5.1.8.1 Transporting Concrete via Mixing Truck.

This type of truck has paddles fixed within the concrete drum. While transporting the drum will revolve at the speed needed to mix the concrete. In using this type of mixing truck for fresh concrete transportation it is permissible to carry up to 80% of the drum capacity. Transportation must be completed within 45 minutes, unless retarding admixture is added.

5.1.8.2 Transporting Concrete via Opened-top Drum Truck With Paddles.

This type of truck has opened-top drum. Concrete can be discharged via the rear end of the truck when the drum is tilted, and also there is a gate for concrete flowing control.

The opening at the top must be covered while transporting in unfavorable weather, use of clean drum, and transportation on even road surface, will enhance good quality and efficient work. Transportation must be done within 45 minutes unless retarding admixture is added. In addition, ambient air temperature shall also be monitored.

5.1.8.3 Transporting Concrete via Containers on Truck or via chute

This is the usual method of transporting concrete from concrete mixing plant to the construction sites that are close to the plant. Loading of fresh concrete at the mixing plant must be done carefully to prevent segregation of concrete. Transportation must be done within 45 minutes, unless retarding additive is added.

5.1.8.4 Transporting Concrete via Concrete Pumps

This is to be detailed in article 5.1.9.5

5.1.9 Placing Concrete

Placing concrete means the action of taking the transported fresh concrete to fill up in the formworks for desired structural shape.

Placing of concrete requires various types of equipment, such as bucket, hopper, manual buggy, motor propelled buggy, chute, drop pipe, conveyor belt, pump, tremie, equipment.

5.1.9.1 Placing Concrete Planning

Quality and consistency of fresh concrete must be taken into considerations. Properties need to be considered are water/cement ratio, slump, the amount of entrained air, and consistency of the fresh concrete. Selection of concrete placing method must also be considered in accordance with the compaction method.

Preplanning will render the efficient of fresh concrete production and placing concrete. All tools for concrete placing must be kept clean and in good condition. When placing of concrete segregation preventing method must be provided segregation. Sufficient and well - arranged of tools and equipment at casting place must be prepared to avoid delay. There must be sufficient number of workers at the casting place for placing, compacting and also for surface finishing.

Where there are insufficient illuminations for placing the concrete, lighting systems must be provided for the work.

The contractor must prepare documents regarding concrete placing submit to the engineer. These must be checked and conformed to the specifications.

5.1.9.2 Reinforcement and Embedded Items to the Structures

Prior placing concrete, the reinforcement and embedded items to the structures must be checked for their cleanness, without oil and grease and other coatings that are undesirable in the structures which affect to bonding between the reinforcement and the concrete.

Reinforcement to be used must have size, spacing and lab splicing and also concrete covering according to the drawings and the specifications.

Reinforcement and embedded items to the structure must be in proper positions and must be securely fixed to prevent movements during placing concrete. This can be done by using sufficient number of mortar blocks and bar chairs in to assist the operation.

When water-stop is placed in the formwork, the contractor must provide method that secure the water-stop to prevent from bend which may cause honey-combed in concrete structure.

The contractor must always check the position of the reinforcement during placing concrete. For some types of structure the engineer must pay special attention to reinforcement and the embedded items.

5.1.9.3 Concrete Placing Procedures

(1) Equipment for placing concrete must enable concrete to flow vertically to the desired location. The flow must be in such a manner which not causes concrete segregation when placing concrete on existing concrete, if the existing concrete is beyond the period of initial setting – normally about 45 minutes after mixing – the contractor must roughen the existing surface so that the new concrete will homogenous bonds with the existing one. If new concrete is to be placed on existing concrete which was already placed more than 6 hours, bonding agent must be applied on the exiting surface prior placing concrete.

(2) Equipment selection of equipment for placing concrete is relevant to concrete placing method. If concrete placing is separately done for each job or as a set of the structure, the equipment to be chosen is usually of bucket, hopper, buggy etc. If the concrete placing is done continuously for long period the equipment to be chosen shall be conveyor belt and pump.

(2.1) Bucket or hopper must be of bottom-opening type. The diameter of the opening must be at least 5 times the maximum nominal size of the aggregate. The slope of the opening must be at least 60 degree to the horizontal. The opening must have control which can regulate the flow of concrete. This type of equipment is appropriate for normal concrete and also can be used for low-slump concrete Discharging of concrete too close to previously poured concrete, or discharging while the bucket is in motion may cause segregation. Spilled concrete from bucket must not be

reused. Bucket shall not be moved through new finished surface in order to avoid surface damaging . If rush time is required the contractor shall arrange 2 or more sets of bucket for each crane.

(2.2) Manual Buggy or Motor Propelled Buggy. Placing concrete with buggy is suitable when transport distance not more than 60 m and contained 0.2 m^3 of concrete at a time with a placing rate of 2 to 4 m^3 per hour (depending on the distance). Motor propelled buggy is suitable for distance not more than 300 m with 0.3 m^3 of concrete at a time with a placing rate of 11 to 15 m^3 per hour (depending on the distance).

(2.3) Chute, it shall be made of metal and in semi-circular shaped that prevents overflowing of concrete. The slope set up must be adequate to assist continuos flowing of concrete with designed slump without segregation

The use of this type of equipment is appropriate for transporting concrete from higher to lower place along the sloping of chute.

A precaution to be taken after transporting concrete along the slope of the chute, is to place concrete with care to avoid segregation.

(2.4) Drop pipe it may be made from rubber, plastic or metallic tube. Pipe is usually 2 to 3 m long and can be shortened to render ease of concrete placement. The upper end of the pipe should have diameter at least 8 times the maximum nominal size of the aggregate. Consecutive sections may have smaller diameters but should be at least 6 times the maximum nominal size of the aggregate.

This type of equipment is suitable for placing concrete vertically from higher to lower place. Pipe must be set up vertically straight and firm for efficient concrete transport and placing.
Pipe made from rubber or plastic shall be free from bends and bottlenecks that may obstruct smooth flowing.

(2.5) Slipforming, it is movable formworks that can be slide through concrete which has been placed long enough for setting and retains its shape as design. A precaution to be made regarding slipforming usage is the selection of suitable concrete mixed proportions together with the ambient air temperature during the concrete placing.

5.1.9.4 Mass Concrete

Equipment and methods for mass concrete must be able to prevent segregation of coarse aggregate from mortar. The contractor must disperse the coarse aggregate through out the mix before placing concrete. If coarse aggregate from to lump during

placing it will be impossible to rectify after that, even with the help of vibrators since coarse aggregate in mass concrete are usually very large.

Mass concrete to be placed must not be thicker than 600 mm per layer. It should not be placed in inclined layer, and should not produce any cold joints unless necessary. For very large mass concrete works placement of concrete must be done in layers, each must be being continuously placed. Previous layer must be vibrated while new layer is being placed. Each layer must not be too thick so that concrete can be homogeneously bonded between layers.

For large area mass concrete, area must be divided into blocks and each layer of concrete is to be placed approximately 300 to 450 mm. thick Placing is to be done from one side to the other in the divided block until the whole area is covered. Then the next layer is to be done, until the required thickness is attained.

5.1.9.5 Pumping Concrete

It is the concrete that to be conveyed under pressure through pipe or hose to the placing area. Pumping concrete may be used for general construction works, since operating cost is quite high, This shall be applied to access-limited structures.

The pump for pumping concrete is usually installed on a truck. Small pump will generate pressure of 1.7 to 2.1 MPa and can deliver concrete at the rate of 11 to 23 m^3/hour. Large pump can generate pressure more than 7 MPa and can deliver concrete up to 115 m^3/hour. In general, truck for pumping concrete mounted must also have boom installed for convenient when placing concrete.

Concrete pump requires appropriate concrete mix proportions that is suitable for pipe or hose. Moreover, efficiency of the concrete pump is depending on the length of pipe or hose.

Pumping system can be any type pump, pneumatic pump, or squeeze pressure pump.

Pipe or hose for pumping concrete, if made of metal, is usually with diameter between 75 to 200 mm. Favorable is 100 to 125 mm in diameter. Rubber hose is usually 75 to 125 mm in dimension normally, metallic pipe and rubber hose can be assembled together, for very long distance delivery only metallic pipe is favorable.

The maximum nominal size of coarse aggregate should not be greater than 33% of the inner diameter of the pipe or the hose to be used. Sand particles should pass through sieve #50 between 15% to 30%, and through sieve #100 between 5% to 10%, with a fineness modulus value between 2.40 to 3.00

5.1.10 Compacting Concrete

Internal vibrator is applied for efficient compacting concrete in plastic stage. This depends on the vibrator head diameter, vibrating frequencies and amplitude.

It is not permitted to use vibrator for the purpose of scattering concrete horizontally. Vibrator is to be immersed in, and pulled out vertically from the fresh concrete. When placing large amount of concrete set of vibrator shall be used.

Where it is inconvenient to use the internal vibrator, a form vibrator shall be applied.

Vibrator shall not be overused since this may cause damage to concrete. If it is necessary to repeat vibration with internal vibrator where it has already been compacted, This must be done prior to the initial set of the concrete.

For the purpose of continuous concrete placing, stand-by vibrators must be prepared on site with good maintenance system.

5.1.11 Curing Concrete

This is to maintain moisture and temperature of the concrete during the initial stage after placing the concrete in order to develop the various properties of concrete to its desired quality. If rapid evaporation occurs plastic shrinkage cracks in concrete will develop and concrete strength at the surface will be diminished.

5.1.11.1 Concrete Curing Methods

There are 2 characteristic for concrete curing:

(1) Water Curing. This is to provide continuous moisture to the concrete surface. Water curing is economical. Water for curing must be clean and has similar properties to that is used in the mixing. Water curing can be applied by various means such as fog spraying or sprinkling, ponding or immersion, or cover with damped burlap. Which covering with damped burlap one-half of width must be provided where overlapping.

(2) Evaporation Prevention. This is to compensate the problem of evaporation from the concrete surface if error occurs when water curing is applied water curing. These can be done by various means such as covering with plastic film of 0.1 mm thick, or with reinforced papers, spraying with liquid membrane-forming curing compound, etc. Liquid curing compound shall not be applied on surface where new concrete is to be place. If it is necessary to do so, liquid curing compounds must be removed and cleaned before placing the next concrete layer. And if the contractor intends to use this method, the proposal for using must be submitted for approval by the engineer.

5.1.11.2 Curing for concrete Pavement or slab on Ground

These types of structures are concrete pavement, concrete ditch outdoor parking lot, footpaths and outdoor concrete slabs. There structures, surfaces are exposed to environments so there are more chance of moisture losing initiate cracks on surfaces. Thus, the underneath area of these structures must be moistened before placing of concrete, and curing must be done immediately after concrete placing.

In case cracking initiates while the concrete is setting, liquid curing compound must be sprayed and then immediately covered with damped burlap.

The contractor must provide continuos curing for concrete pavements or concrete slabs on ground for 7 days or until the compressive strength 70% of the minimum specified compressive strength.

5.1.11.3 Curing for Structural Concrete

These types of structures are wall, column, indoor slab, beam, foundation, bridge deck, headwall, etc. These structures are to be provided curing immediately and continuously after placing. Curing may be by means of water spraying or covering with damped burlap. If it is necessary for the contractor to use liquid curing compounds, the proposal for using must be submitted for approval by the engineer. If concrete with water to cement ratio is equal to or less than 0.40, liquid curing compounds is not permitted for using.

The contractor must provide continuous curing for those mentioned structures for 7 days or until the compressive strength attains 70% of the minimum specified compressive strength.

5.1.11.4 Curing for Mass Concrete

This is applied to structure with large amount of concrete is placed which high temperature is attention. Temperature control is very importance, hence the contractor must provide continuously curing for at least 14 days, or he may submit proposal for using of liquid curing compounds.

5.1.11.5 Curing for Precast Concrete

Precast concrete refers to elements that have been placing and provided curing in the manufacturing yards before being installed on sites, Such as round pipes, walls, beams, and precast slabs, etc. The contractor must provide continuous curing for the above concrete elements for 7 days or until the compressive strength attains 70% of the minimum specified compressive strength specified.

5.1.12 Reinforcement for General work

This refers to the procurement of reinforcement and their fabrications that suit to categories, types, sizes and locations as shown in drawings and specifications

5.1.12.1 Round Bar

The proportions of round bar must conform to TIS 20 Round Bar reinforcement.

5.1.12.2 Deformed Bar

The properties of deformed bar must conform to TIS 24 Deformed Bar Reinforcement

5.1.12.3 Binding Wire

The properties of binding wire must conform to TIS 138 Binding Wire. Its diameter is 1.25 mm.

5.1.12.4 Material Procurement

Material procurement means the contractor purchases reinforcement then transports and storage at construction site. The contractor must always submit copies of certified documents regarding the manufacturers and specific information of each lot of purchased reinforcement to the engineer.

Transportation of the reinforcement must be done in bundle with tag labeled according to the industrial standard.

5.1.12.5 Sampling and Testing

Reinforcing steels must not exhibit cracks, scaled corrosion or localized corrosion, grease, etc. and must have desirable properties according to that shown in drawings and specifications. Testing must be done at the Department of Highways in accordance to the following procedures:

(1) Steel reinforcement samples must be submitted for testing prior to the steel reinforcement work to be started
(2) Samples shall be at least 1.00 m long, and must be taken from the lot that have been stored at the construction site.
(3) The number of samples for testing shall be calculated as the following formula:

$$S = K \sqrt[3]{N^2} \geq 2$$

Where S = the number of samples required for testing, not less than 2
K = an empirical constant = 0.04
And N = the number of same-sized reinforcing steels in the bundle, with the same length

In the above calculation, if the remainder is greater than 0.5, one more sample must be added.

5.1.12.6 Storage of Material

Reinforcing steels for the structures shall be transported and stored in a manner that will prevent bend or out of the desired and the unnecessary shape of dust, oil, or paint when placing in the formwork they must be free from dust, oil, grease, paint, mill scale and loose or thick rust.

5.1.12.7 Cutting and Bending

The reinforcing steel must be cut and cold bent to the desired shape as shown in the drawings and specifications with equipment and the methods approved by the engineer. Hot bent is not permitted.

5.1.12.8 Hook Bending

Standard hook refers to hooks which corresponding to one of as specified below:

(1) A 180 Degree Bend or a semi-circle Bend extends part must be provided beyond the end of the curve at least 4 times the nominal diameter of the bar, and at least 60 mm.
(2) A 90 Degree Bend or a Right-angled Bend, extend part must be provided beyond the end of the curve to the end of the bar at least 12 times the nominal diameter of the bar.
(3) Vertical Bars and Stirrups must be bent 90 degree or 135 degree, and extended part must be provided beyond the end of the curve to the end of the bar at least 6 times the nominal diameter of the bar, and at least 60 mm.

5.1.12.9 Bending

Smallest diameters for bending:

(1) For bending of deformed bar class SD 40, except bending of vertical bars and stirrups, the inner diameter of the bend must not be less than that shown in Table 5.1-16

Table 5.1-16 Smallest diameter for Bending of Reinforcement

Nominal Diameters	Smallest Diameter for the Bend
12 mm to 25 mm	6 times the nominal diameter of the bar
28 mm to 35 mm	8 times the nominal diameter of the bar

(2) For bending of deformed bar class SD 30 and of round bars class SR 24, except bending of vertical bars and stirrups, the inner diameter of the bend must not be less than 5 times the nominal diameter of the bar.

(3) For vertical bars and stirrups of all kinds reinforcement, the inner diameters of the bend must not be less than that shown in Table 5.1-17

Table 5.1-17 Smallest diameter for Bending of Vertical Bar and Stirrup

Nominal diameter	Smallest Diameter for the Bend
6 mm to 16 mm	4 times the nominal diameter of the bar
19 mm to 32 mm	6 times the nominal diameter of the bar

5.1.12.10 Arrangement of Reinforcement

Each reinforcing bar must be properly arranged, supported and secured in accordance with that specified in the drawing and specifications before concrete work begin reinforcement location deviation must be within the allowed tolerances. The engineer must inspect the reinforcement and approval before pacing concrete. After concrete is placed, it is not permitted to push or nail reinforcement into the concrete.

Spacer between reinforcement and formwork must be made from mortar, which the ratior of portend cement to send is 1 : 3 by weight. The shape and size of the spacer must be approved by the engineer and also it must be embedded with one end of binding wine. Intermediate spacer between reinforcement layers can be of mortar, bar chair, stirrup or tie bar.

5.1.12.10.1 Spacing of Reinforcement

(1) Spacing of paralleled reinforcement (except in column and between intermediate layers in beams) must not be less than the diameter of the reinforcement or 1 1/3 times the maximum nominal size of coarse aggregates used, or 25 mm, or as specified in the drawings, depending on which is greater.

(2) Spacing between each layer of intermediate reinforcement of two or more layers in the beam shall not be less than 25 mm or that specified in the drawings

(3) Spacing between vertical reinforcement of helical and single stirrup columns must not less than 1 ½ times the nominal diameter of the reinforcement, or 1 ½ times the maximum nominal size coarse aggregate used, or 40 mm, or as specified in the drawings, depending on which is greater.

(4) Spacing between spliced reinforcement and lap splicing reinforcement or between lap splicing reinforcement and other reinforcement shall be provided the same as normal spacing.

(5) Bundled reinforcement are several which bundled in parallel. Bundled bars shall be considered as single bar.

5.1.12.10.2 Reinforcement Covering

The thickness of reinforcement covering, if not specified otherwise, shall be:

(1) For foundation or other concrete structures embedded in the ground, the covering thickness for the reinforcement must not less than 75 mm

(2) For beams, columns, and other in-situ concrete structures which contact with the ground after the formwork stripping, the covering thickness for main bars (which are not vertical bars or stirrups) must not less than 50 mm For tie bars and stirrups the covering must not less than 35 mm

(3) For beams which no direct contact with the ground, the covering thickness for the reinforcing bars must not less than 30 mm

(4) For other concrete structures which no direct contact with the ground, the covering thickness for the inner face reinforcing bar on that side must not less than 25 mm

(5) For bundled bars, the covering thickness for the bundle must not less than the equivalent diameter which has the same cross sectional area as the total cross sectional of the bundle, but not greater than 50 mm, except on where to protect reinforcement from salt-contained water and salty soil.

(6) Where to protect reinforcement from salt-contained water or salty soil that may create severe corrosion, the covering thickness for the reinforcement and that portion must be increased by 25 mm.

(7) Exposed reinforcement, anchorage assemblies, or steel plates which are for future extension works must be covered the surfaces with concrete or other materials to inhibit corrosion.

Deviation of reinforcement from location after fixing must not more than 5 mm.

5.1.12.11 Splicing of Reinforcement

Splicing is not permitted unless necessary, except as shown in the drawings or approved in written by the engineer. There are 3 methods using for reinforcement splicing.

(1) Lap Splicing

Lap splicing is not permitted for reinforcement with diameter bigger than 25 mm. For deformed bars, the lap splicing must not less than 40 times the nominal diameter of the reinforcing bars for tension, and not less than 32 times the nominal diameter of the reinforcing bars for compression. For round bars, the lap splicing must not

less than 40 times the nominal diameter of the reinforcing bars for tension or compression, hooks must be provided at the ends of round bars

(2) Electric Arc Welding Splicing

Electric arc welding splicing must done as butt welds (2 beveled ends along the same alignment welded around until the two bars joined together). Which conform to TIS49 electrode type E 4903 with flux cover for electric arc welding of mild steels must be used. Welding procedures must conform to the American Welding Society (AWS) Reinforcing Steel Welding Code. Reinforcing bars with electric arc welding splicing when being tested under tension must not fail at the welded joint.

Since inspection and control of electric arc welding are difficult, thus, in order to control the quality of the reinforcing bars as specified in specifications, the contractor must submit procedures of electric arc welding to the engineer for approval before further execution.

Sampling of electric are welding splicing must be taken from reinforcements which have been welded. The number of samples to be tested can be calculated from the following formula:

$$S = 0.04 \sqrt[3]{N^2} \geq 3$$

Where S = the number of samples to be tested, but not less than 3

N = the number of electric are welding splicing

Length of each sample must not less than 1 m, with the welded part is at the middle.

(3) Mechanical Connection splicing

Splicing of reinforcing bars by mechanical connector must be conducted according to the detailed drawings that the contractor must submit in written to the engineer for approval. Reinforce steels with mechanical connection when being tested under tension must not fail at the connection. Samples for testing must be at least 3, each 1 m in length with the connector at the middle, submitted to the engineer including the operating method of the mechanical connector.

In general, splices must not in the same plane unless otherwise specified in the drawings. Only when necessary, these splices may be aligned on the same plane with permission by the engineer supervisor.

Splicing of reinforcing bars by electric arc welding and by mechanical connector that the contractor must responsible for expense of delivery, cost of testing and also for other fees.

5.1.12.12 Substitutions of Reinforcement

If there is the substitution of size of reinforcing steels the contractor must submit the detailed drawings for the new reinforcement arrangement together with the details of bar bending and the sequence of the reinforcing bars placing to be approved by the Department of Highways. The contractor must bear to all these expenses.

5.1.13 Reinforcement for Prestressed Concrete

This refers to the procurement of prestressing wires and their arrangements that suit to their positions and sizes, together with the tensioning of the wires by post-tensioning or by pre-tensioning in accordance to the drawings and specifications.

5.1.13.1 Post-tensioning

This is the method in prestressed concrete works that steel wires are tensioned after concrete has been placed.

5.1.13.2 Pre-tensioning

This is the method in prestressed concrete works that steel wires are tensioned before the placement of concrete.

5.1.13.3 Prestressing Wires

Prestressing wires must be steel wire or uncoated 7 wire stress-relieved strands or high-tensile alloy wire.

5.1.13.3.1 High-tensile Wire

High-tensile wire must be round, indented stress-relieved with properties in accordance with TIS 95 "High-tensile Wire for Prestressed Concrete Works". High-tensile prestressing wire must tightly wound in coil with internal diameter of the coil not less than 1.20 m for 4 mm and 5 mm wires, and internal diameter of coil not less than 1.80 m for 7 mm and 9 mm wires. Each coil must be of the same wire and without kinks. The coil of the wire must be labeled with detailed of the size, type, net weight, length, class, coil number, mold number and named the manufacturer or trademark on every coil.

High-tensile wire to be used must have characteristics according to the following specifications and must have mechanical properties as specified in Table 5.1-18

Table 5.1-18 Mechanical Properties of High Tensile Wire

Nominal Diameter, mm	Tensile Stress (MPa)		Proof Stress at 0.2% (MPa)	
	Not Less Than	Not More Than	Not Less Than	Not More Than
4.00	1,750	2,000	1,500	1,700
5.00	1,750	2,000	1,500	1,700
7.00	1,600	1,850	1,350	1,600
9.00	1,400	1,700	1,250	1,500

Tolerances and allowable indented depth must be in accordance with Table 5.1-19

Table 5.1-19 Tolerances of Size and Indented Depth

Diameters, mm	Diameter, mm	Allowable Tolerance, mm	Indented Depth Limit, mm	
			Not Less Than	Not More Than
4	4.00	± 0.05	0.05	0.20
5	5.00	± 0.05	0.05	0.20
7	7.00	± 0.05	0.10	0.25
9	9.00	± 0.05	0.15	0.25

5.1.13.3.2 High-tensile Wire Strand

High-tensile wire strand must be uncoated 7 wire stress-relieved strand that are manufactured in accordance with TIS 420 "Uncoated 7 wire Stress-relieved Strand" with indicated nominal size in inches or in mm, and must have properties as follows :

(1) The wire strand must consist of high carbon steel with 7 wires, one is as a core and 6 others wound tightly around with constraint pitch, the pitch must not less than 12 times and not more than 16 times of the nominal diameter. When the wire strand is cut without clamping or holding its ends, the wires must not loosen and scattered from their positions.

(2) Wire strand is divided 2 types: Normal Relieved (NR) and Low Relieved (LR)

(3) Each type of wire strand is divided into 2 classes: Class 1725 with tensile strength not less than 1,725 MPa and Class 1860 with tensile strength not less than 1,860 MPa.

(4) Wire strand must wind tightly as coil, with internal diameter of the inner axis not less than 600 mm. In each wire strand or each coil, the wire strand must be continuous throughout without any welded joints or lap splicing, and must be externally well protected from damages during transportation, with durable label indicating its net weight, size, class, coil number, mould number, and named the manufacturer or trademark securely fixed and clearly displayed on every coil. The surface of the wire strand must be free from oil and grease or other matters that will affect bonding between concrete and the wire strand, and must be without thick rust.

The wire strand must have physical properties in accordance with Table 5.1-20

Table 5.1-20
Nominal Size, Tolerance, Nominal Area, and Mass per Unit Length of Wire Strand

Classes	Standard	Diameter, mm		Minimum Difference, mm	Nominal Area, mm^2	Nominal weight kg/km
		Nominal	Tolerance			
1725	SPC 9 A	9.53	± 0.04	0.05	51.61	405
	SPC 12 A	12.70		0.08	92.90	730
	SPC 15 A	15.24		0.10	139.35	1,094
1860	SPC 9 B	9.53	+ 0.65 - 0.15	0.05	54.84	432
	SPC 12 B	12.70		0.08	98.71	775
	SPC 15 B	15.24		0.10	140.00	1,102

NB:

(1) Size label of wire strand indicates with SPC, which mean "Strand for Prestressed Concrete", followed by the diameter and a letter indicating the quality class; A is for class 1725, and B is for class 1860.

(2) Difference means the difference of the diameter of the core that is larger than those of the surrounding wires.

(3) Nominal area and nominal weight per unit length are only for guideline.

(4) Nominal area of wire strand is the sum of individually calculated of 7 wires.

The wire strand must have physical properties in accordance with Table 5.1-21 and Table 5.1-22

Table 5.1-21 Physical Properties of Normal Relieved (NR) Wire Strand

Standard	Yield Strength		Elongation % (min)	Minimum Max. Tensile, strength kN (kgf Approx.)	Maximum 10 Hour Creep, %
	Tensile Strength, kN (kgf)	Minimum Load at 1% extension, kN (kgf)			
SPC 9 A	8.9 (910)	75.6 (7,710)	3.5	89.0 (9,070)	3.0
SPC 12 A	16.0 (1,630)	136.2 (13,880)		160.1 (16,320)	
SPC 15 A	24.0 (2,450)	204.2 (20,820)		240.2 (24,490)	
SPC 9 B	10.2 (1,040)	87.0 (8,870)		102.3 (10,430)	
SPC 12 B	18.4 (1,880)	156.1 (15,910)		183.7 (18,730)	
SPC 15 B	26.1 (2,660)	221.5 (22,580)		260.7 (26,580)	

NB: Elongation in this Table is obtained from tests before the wire failure.

Table 5.1-22 Physical Properties of Low Relieved (LR) Wire Strand

Standard	Yield Strength		Elongation % (min)	Minimum Max. Tensile strength kN (kgf Approx.)	Maximum 10 Hour Creep %	
	Tensile, kN (kgf)	Minimum Load at 1% extension, kN (kgf)			100 hr	1,000 hr
SPC 9 A	8.9 (910)	80.1 (8,163)	3.5	89.0 (9,070)	1.75	3.5
SPC 12 A	16.0 (1,630)	144.1 (14,688)		160.1 (16,320)		
SPC 15 A	24.0 (2,450)	216.2 (22,041)		240.2 (24,490)		
SPC 9 B	10.2 (1,040)	92.1 (9,387)		102.3 (10,430)		
SPC 12 B	18.4 (1,880)	165.3 (16,857)		183.7 (18,730)		
SPC 15 B	26.1 (2,660)	234.7 (23,922)		260.7 (26,580)		

NB: Elongation in this Table is obtained from tests before the wire failure.

5.1.13.3.3 High-tensile Alloy Wire

High tensile alloy wire used must be the stress-relieved type. After stress relieving it must be elongated while cold with tensile load not less than 900 MPa. These high tensile alloy wire as mentioned above must have the following physical properties:

Maximum tensile strength	Not less than	1,000 MPa
Proof stress at 0.7%	Not less than	900 MPa
Modulus of Elasticity	Not less than	172,400 MPa
Elongation in 20 time dia. long	Not less than 4%	

Tolerance on diameter of high-tensile alloy wire is + 0.8 mm and–0.25 mm

5.1.13.4 Non-Prestressed Reinforcement

Non-prestressed reinforcement is normal reinforcing steel as specified in article 5.1.12, or prestressed reinforcing wires that are not subjected to external force for pre-stressing. As specified in the drawings and specifications.

5.1.13.5 Anchorage Assemblies

End anchorage assemblies must be specially designed for prestressed concrete works, and this must be previously used for similar works and function properly, durable, and suitable to this type of wok. The contractor must submit examples and documents showing detailed and relevant properties of the anchorage assemblies for inspection and approval by the engineer. A anchorage assemblies without prior inspection and approval from the engineer are not permitted for using. If the anchorage assemblies documents submitted for approval contain insufficient information showing they are suitable for this type of work, the engineer may collect samples and submit to the Department of Highways for testing. These anchorage assemblies must be capable of retaining the prestressing wire under tension not less than 95% of the minimum maximum load specified for that particular prestressing wire without being damaged. Approval by the engineer for using of the anchorage assemblies is not resulting the contractor from the responsibility of possible damages which may occur during or after the placement of concrete.

5.1.13.6 Couplers

When it is necessary to splice prestressing wire, the wire is to be continuously splice with special device for this particular work. This device must be that has been proven suitable for similar jobs and function properly durable and suitable for this type of work. The contractor must submit samples and documents showing details and relevant properties of the couplers for inspection and approval by the engineer prior of using. Couplers without prior inspection and approval from the engineer are not permitted for using. If the couplers documents submitted for approval contain insufficient information showing they are suitable for this type of work, the engineer may collect the samples and submits to the Department of Highways for testing. These couplers must be capable of transmitting the prestressing load under tension not less than 95% of the minimum maximum load specified for that particular prestressing wire without being damaged.

Approval by the engineer for using of the couplers is not resulting the contractor from the responsibility of possible damages which may occur during or after the placement of concrete.

5.1.13.7 Enclosures, Sheaths and Ducts

Enclosures, sheaths and ducts for prestressing wire must be corrugated metallic materials or have sufficient number of transverse indentations throughout the length of the duct in order to assist full development of bonding between the surface of the duct and concrete. Duct must strong enough to retain its shape and form under various load from the concrete placing, and must be able to prevent cement poise leaking into the duct. Inner diameter of the duct shall be according to recommendation or specification of the cable manufacturer.

The contractor must submit samples and documents showing details and relevant properties of the sheath and duct for inspection and approval by the engineer prior of using. Ducts without prior inspection and approval from the engineer is not permitted for using. Approval by the engineer for using of the duct is not resulting the contractor from the responsibility of possible damages which may occur during or after the placement of concrete.

In cases the contractor would like to drill holes or slots for the prestressing wire rubber hose or any other matter as molds while placing concrete, and to be removed before intrude the prestressing wire, the contractor must submit details and the procedures of making holes or slots for inspection and approval by the Department of Highways.

5.1.13.8 Wire and Anchorage Procurement

The contractor shall procure and transport in bulks of high-tensile wire, high-tensile wire strand, or high-tensile alloy wire that are to be used for the works. This is to facilitate inspection and approval which will be beneficial to the contractor.

High-tensile wire, high-tensile wire strand and high-tensile alloy wire that are to used for the works must be prevented from damages that may occur during transportation. Labels and tags or other informative documents and signs must be always attached displaying length, class and manufacturer.

Anchorage assemblies, couplers, enclosures, sheaths and ducts that the contractor has arranged to be transported for using at the construction sites must always have labels or stamps or other related documents to indicate their types, sizes and manufacturers, together with their deliveries.

5.1.13.9 Sampling for Testing

Sampling of samples for testing must only be collected at construction site with the presence of the engineer or his representative. The engineer or his representative is the person who submitting these samples for testing. All construction materials can only be used when their qualities have been tested and recommended.

Collecting samples on high-tensile wire or high-tensioned wire strands or high-tensile alloy wire shall be collected by the engineer for 1 sample of the wire or the strand from each coil, For anchorage assemblies, couplers, and enclosures, sheaths and ducts, the engineer or his representative shall select samples from each type that the contractor have purchased and stored at construction site. The contractor must fully facilitate the engineer or representative in sampling these samples.

The number of samples for each type of materials for testing shall be calculated from the transported quantities the contractor gathered to construction site as follows;

(1) Each high tensile wire sample must be at least 1 m long. The number of samples to be taken for the quality tests shall be according to the following formula:

$$S = 0.02 \sqrt[3]{N^2} \geq 2$$

Where

S = the number of samples needed to be taken for the tests, not less than 2, if fraction is more than 0.5 1 more sample is added

N = the number of coils of equal-length high-tensile wire, for the coil with 100 m to 300 m in length

(2) Each high-tensile wire strand sample must be at least 1 m long. The number of samples to be taken for the tests shall be according to the following formula:

$$S = K \sqrt[3]{N^2} \geq 2$$

Where

S = the number of samples needed to be taken for the tests, not less than 2, if fraction is more than 0.5 1 more sample is taken

K = 0.9 for the coil of shorter than 3,000 m

= 1.5 for the coil of longer than 3,000 m

N = the number of coil of equal-length high-tensile wire strand

(3) Each high-tensile alloy wire sample must be at least 60 times the diameter of that high-tensile alloy wire, but not less than 1 m. The number of samples to be taken for quality tests shall be according to the following formula:

$$S = W/5 \geq 2$$

Where

S = the number of samples needed to be taken for the tests, not less than 2, fractions more than 0.5 one more sample is added.

W = The weight of high-tensile alloy wire, in ton

(4) In case of anchorage assemblies and couplers, the number of samples to be taken for the tests shall be according to the following formula:

$$S = N/100 \geq 1$$

Where

S = the number of samples needed to be taken for the tests, not less than 1, if fraction is more than 0.5 one more sample is added.

N = The number of anchorage assemblies or couplers.

5.1.13.10 Construction Method

The contractor must prepare all necessary tools and equipment for construction and for prestressing work included prestressing system expertise, all of these must be approved by the engineer. In the case of hydraulic jack is to be used for prestressing, adequate numbers of accurate pressure must be installed also with calibrations of relationship data between the hydraulic jack and that guage, also included Table or chart showing those relationships to the engineer. For other types of jacks, proving rings with load relationships known must be installed for accuracy of the jack's pressure reading.

5.1.13.10.1 Storage of Material

All materials for using in the construction must be transported and stored in the manner that they are not be damaged or contaminated. The contractor must store each type of materials separately for ease of inspection and utilization. Materials and tools that have been inspected must be clearly separated from those are not yet inspected. The contractor must clearly separate materials for this job from which for others.

5.1.13.10.2 Layout of Reinforcement and Equipment

Prestressing steels, anchorage assemblies, couplers, enclosures and sheaths and ducts must be placed correctly and accordingly as shown in the drawings that stipulated and specifications. They must be secured so they will not be moved during placement of concrete or during concrete setting. This can be done by means of concrete mortar metallic supports, supporting devices, suspension devices, or any other devices that have been approved for fixing.

5.1.13.10.3 Pre-tensioning Method

Pre-tensioning may only be carried out after the prestressing steels have been accurately placed. Tensioning of the steel wire must continue until the stress in the prestressing steel has reached the value as shown in the drawings. The contractor must submit proposal of prestressing method for approval by the engineer prior to the works. The contractor must inform the engineer in advance and must arrange for all other necessary tools for inspection during tensioning.

Several structural elements may be simultaneously tensioning and concrete at the same bed line. However, enough gaps must be provided between ends of each prestressing unit for prestressing wires cutting. It is not permitted to cut prestressing wires before all lateral formworks have been dismantled, and that the concrete of those prestressed structural members can resist compressive stress as shown in the drawings by testing the samples that being cured in the similar environment to that of actual structural members. Transfer of loads from the prestressing steels to the prestressed concrete structural members must be conducted in such a manner that create the best balance of compressive stress in those elements.

5.1.13.10.4 Post-tensioning Method

(1) Placing of Tendon

For prestressing concrete construction by the post-tensioning method, prestressing cables can be placed before concreting or concrete can be placed before the placing of the prestressing cables, depending on appropriateness of the construction. A prestressing tendon may consist of several prestressing wire bundled together, or may be a single wire. Placing of tendon must be always approved by the engineer.

Before using the duct, it must be properly inspected and repaired where necessary. Repairing and cutting off damaged parts are under the judgements of the engineer. The contractor must provide suitable spacers for sucure tightness of the prestressing steels in their proper positions in the duct, and enough must be provided rooms around the prestressing steels in the duct for grouting material. The spacer must be made of metal.

Splicing of prestressing duct must be done by using connector or adhesive tape that can be bonded and not detrimental to concrete. Before using of prestressing duct, connector or adhesive tape, and cables spacer, they must be approved by the engineer.

(2) Placing of Prestressing Duct

Transporting, moving and placing of prestressing ducts must be done with care which shall cause breaking, kinky or too much bending of ducts. Ducts are to be positioned and secured with suitable devices and with consent from the engineer. Tolerance in positioning of the duct from as specified in the drawings must not greater than 6 mm. Tolerance of the bundle of ducts controid must not more than 3 mm. Ducts must not be moved while placing concrete, and also care must be taken to prevent duct and enclosure from damages.

Prestressing duct must be prepared with hoses for grouting and air reinitiating. The hoses for grouting and ventilating of the air must be able to resist leaking of grout material. Conduits or hoses used for grouting and for ventilating air must be securely placed.

After placing out and positioning the prestressing ducts with all other reinforcements in place, the ducts must be inspected before placement of concrete.

(3) Assembling and Installing of Anchorage and Couplers

Anchorage assemblies and couplers must be assembled and installed correctly in positions as shown in the drawings and must be as the same alignment as of the prestressing steels or cables, and must be securely place not to be moved during placement of concrete.

(4) Post-tensioning Procedure

Where post-tensioning procedures are not detailed in the drawings the contractor must propose the tensioning method and the type of jacks to be used for approval by the engineer prior starting the work. This post-tensioning proposal must consist of sequence of tensioning, the tensile forces to be applied and the elongation of the prestressing that result from the applied forces.

Compressive force must not be transferred to the concrete structure before the concrete gain strength to as that specified in the drawings. Testing of concrete sample specimens that have been cured under the same ambient environments as the actual structural members must be carried out before stressing. Compressive forces applied to the concrete structures must be conducted such a manner that create the best-balanced of compressive stress in those elements.

Before steel tensioning begin the anchorage assemblies, prestressing steels and ducts must be cleaned. Inspection of readiness of all equipment and tools must be carried out.

When tensioning, This must be arranged that the applied force, the elongation can be read and recorded at all times during tensioning. Tensile force must be read from fine accurate instruments. After anchorage is released and after prestressing steel slipping elongation occurs in the anchorage assemblies, the remaining steel must be recorded. Tendon with many prestressing wires bundled together must be carefully secured to the jacks so that each prestressing wire in the tendon is elongated at the same length.

The contractor must facilitate the engineer when inspection of the tensioning process and must record all data related to the tensioning procedures according to the forms as the engineer has specified. The contractor must immediately submit the recorded data to the engineer when the tensioning for the concrete structure has been completed. The substitution of damaged prestressing steels or the anchorage assemblies or couplers, they must be approved by the engineer.

Before gripping the prestressing steels with anchorage assemblies and grouting, they must be inspected and approved by the engineer.

(5) Substitution of Post-tensioning System

In case the contractor requires to use tensioning system or tensioning procedures which is different from as specified in the drawings it so, the contractor must submit, detailed drawings, included details of calculation to the Department of Highways for approval.

5.1.14 Formwork, Bracing, Scaffolding and Falsework

5.1.14.1 Formwork

Formwork must be made of wood, plywood, metal or other materials that have been approved. Formwork must be constructed according to shape, alignments, level, and dimensions as shown in the drawings. Formwork must be rigid, and must be braced to retain its shape frce from kinks bends or warps during placing, compacting and setting of concrete. Formwork must be able to support all loads incurred during these operations. Formwork joint must be tight, no leakage of cement paste. The contractor must responsible for appropriate designs and calculations of the formwork according to the specifications and also must responsible for damages in all cases that may have been caused by the formwork.

Formwork for prestressed concrete work must have characteristics that allow concrete structure to shrink when stressing. There must be a measure for preventing adhering of concrete to the bottom portion of mould. Moreover, designs must be made such the lateral sides can be dismantled without affecting the stability of the remaining formwork, or cause damages to concrete surface at the area.

Formwork for exposed external concrete surface that without surface finished must have continuous even inner surfaces on sides that are in contact with the concrete. When formwork is removed the surface of the concrete must be even, clean and aesthetic. If they are not clean or uneven, the contractor must have them brushed and repair. Moreover, the edges or the corners of the concrete that can be seen must be 20 mm chamfered.

Formwork must have nominal thickness not less than 25 mm, rigid and without rotten, free from kinks bends or warps, without cracks or large of loose knots that may split off. Edges must not wavy, free from defects that will diminish strength or caving damages to the structure after removing of formwork. Plywood to be used for formwork must be of water-resistant type with thickness not less than 10 mm. Plywood for formwork lining must not less than 4 mm. in thickness.

Formwork, if reused, must be repaired to the original shape, rigid with tight joint no leakage of cement paste, and must have clean smooth surface without undesirable dirt. Unrepaired used-formwork are not permitted for reusing.

Nails or other type that are used to secure the inner edges of the formwork must be arranged such that they can be removed from concrete surface not less 25 mm. or as

specified in the drawings without damaging that part of concrete. No metallic item is to be embedded in the concrete less than 25 mm. from its surface.

Formwork must be so constructed that easy cleaning out of any extraneous material inside the formwork can be achieved without disturbing formwork unready checked and approved by the engineer.

Materials and other device such as electrical conduit, drainage that are to be embed the concrete, slot or opening that have been prepared and arranged for intallations of other fixtures after the concrete hardened, are to be located and fixed and must not be moved while placing concrete. Method for fixing these fixtures which is not specified in the drawings, must be approved by the engineer.

The inner sides of the formwork must be clean and wetted thoroughly before placement of concrete, or as the judgement of the engineer. In case mould oil is to be used, it must be approved by the engineer. The engineer may require the contractor to conduct the trial test of mould oil for ensure that it will not affect to concrete color or damage the concrete surface in anyway. The contractor must take great care not to contaminate the oil to reinforcing steels or to what to be embedded in the concrete.

5.1.14.2 Bracing, Scaffolding and Falsework

The contractor must responsible for the design calculations of bracing, scaffolding and falsework which are used to brace and support formworks. He must responsible for all damages in any cases from inappropriate designs. Before the construction of scaffolding and other falsework the engineer may ask for calculations and details drawings of those structures from the contractor for approvals. Incase engineer has judge that there shall be a change of design as a whole or just a part of the falsework. This may not cause to relieve the contractor from any responsibility if damages do occur.

Bracing, scaffolding and falsework must be designed and constructed as rigid and strong enough to support all loads that induce during the construction. Only small settlement and deflection of the bracing, scaffolding and falsework that will not affect to change of shape, size, alignment, and level of permanent structure more than that of tolerance. Thus, the contractor must take a great care of foundation which supporting falsework.

The level of the formwork must be of as specified in the drawings plus deflections or minus heaves that occur due to the weight of the permanent structures and/or the compression from the prestressing steels, and plus the anticipated deflection or settlement of the falswork that supports formwork.

In case which, the contractor may found bracing or scaffolding on the permanent structure that have previously been constructed. This shall be approved in written by the engineer. If so, the engineer may ask that the contractor to submit analysis of the structure whether the permanent structure is strong enough to support loads from the falsework. If the analysis shows the necessity of increasing the reinforcement to the permanent structures and the engineer also approves of the procedure of shoring bracing or scaffold on the permanent structures, the additional expenses incurred must be solely responsible by the contractor.

5.1.15 Foundation

Foundation mean the lowest portion of the structure that has its role in supporting the whole weight of the upper structure. Types of foundation depend on the soil strata and properties that support underneath. Foundation can be largely divided into 2 groups, shallow foundation and deep foundation. Shallow foundation is the one which its depth from the ground level equal to or less than its breadth while deep foundation is the one which its depth from the ground level greater than breadth. In general, most foundations are spread footing foundation and pile foundation.

5.1.15.1 Spread Footing Foundation

This means to foundation that transfers loads from columns or walls to the ground or rock safety not exceeding the load bearing capacity of the underneath soil. Spread footing foundation prevent structure from settlement and tilt, and also it prevent uplifting from the ground due to strong wind. The level of foundation shall be at level where the soil will not be changed its volume due to groundwater. Before construction of foundation the soil must be leveled and compacted for in even load transfers.

There are 2 types of spread footing foundation:

(1) Spread footing foundation supporting the structure with one whole structure, i.e. raft foundation, or mat foundation, or floating foundation.

(2) Spread footing foundation supporting the structure individually, such as isolated footing, square and rectangular footing, for foundation near boundary line, combined footing (for group a pile), and wall footing (strip footing along a wall).

Construction Method

(1) Before starting of the spread footing foundation the contractor must carry out the tests for bearing capacity in accordance with AASHTO T 235 "Bearing Capacity of Soil for Static Load on Spread Footings". Allowable bearing capacity value must not exceed half of the tested figure.

In case the spread footing is to be situated on rock bed, the spread footing must be at least 0.50 m (at the shallowest point) embedded into the rock. To ensure the existing of rock bed, a proof shall be carried out that it is still a continuous of rock bed not less than 2 times the breath of the footing, from its edges, included an inspection of its thickness by drilling at least 2 holes in depth of 2 m. of diameter 2.5 mm.

(2) Concrete to be used in spread footing work must have to properties as specified in article 5.1. Reinforcement characteristics must as described in article 5.1.12, and reinforcing steel arrangement is as stated in article 5.1.12.10

(3) Concrete formwork characteristics is as stated in article 5.1.14.1

(4) In case of very thick spread footing, the contractor must propose methods and techniques in placing concrete to the engineer in writing prior to carrying out the job for examination and approval.

5.1.15.2 Pile Foundation

This means to foundation that transfers loads from columns or walls to the deep soil strata by means of piles for bearing and transferring the loads.

There are various types of pile. For pile foundation, the favorable ones are precast reinforced concrete pile, precast prestressed concrete pile, and prestressed spun pile.

5.1.15.2.1Precast Reinforced Concrete Pile

Precast reinforced concrete pile characteristics are to comply with that specified in the drawings. In case they are not as specified they must be conformed to TIS 395 "Precast Reinforced Concrete Pile". In soft soil, cut tip pile is to be used, in stiff and hard soil, pointed tip pile is prefored.

5.1.15.2.2 Precast Prestressed Concrete Pile

Precast Prestressed Concrete Piles is to be manufactured and quality controlled conform to cut tip TIS 396 "Reinforced Prestressed Concrete Pile". In soft soil, pile is to be used. In stiff and hard soil, pointed tip pile is preferred.

5.1.15.2.3 Prestressed Concrete Spun Pile

Pretressed Concrete Spun Pile is to be manufactured and quality controlled conform TIS 398 "Prestressed Spun Concrete Pile". In soft soil, pile is to be used. In stiff and hard soil, pointed tip pile is preferred cut tip.

5.1.15.2.4 Bored Pile

In case where the drawings is not specified of using bored pile, the contractor shall only by the Department of Highways construct subject to the approval.

In general, bored pile is classified into 2 types: small bored pile and large bored pile.

(1) Small Bored Pile. This means bored pile of diameter smaller or equal 600 mm. This type of bored pile requires small scaled tools and equipment and are not so complicated, easy to be moved and do not require large working area. Main equipment are steel tripods with single pulleys and air winch for boring, lifting, pulling or extracting steel casings.

(2) Large Bored Pile. This means bored pile of diameter bigger 600 mm. General standard diameters are 800, 900 1,000, 1,200 and 1,500 mm. Main equipment are large machinery.

There are 2 processes of bored pile construction;

(a) Wet Process. This is to be used for grounds where consists of sand strata or groundwater. Fluid compound i.e. bentonite, is used to increase pressure in bored hole for preventing bored hole collapsing.

(b) Dry Process. In certain area where there is no groundwater nor layers of dense sand exist where there is no collapse of the bored hole during boring, no liquid is necessary for bored hole collapse protecting.

Large bored pile procedures;

- Before Boring. The contractor must investigate the existing ground conditions and the water Table throughout the required depth of the bored pile. Permission in written for the proposed method of boring pile from the engineer must be obtained prior to operation.

- During Boing. After the location of the piles have been located, boring to the required dimension and depth may start. At the beginning section of the boring, through soft soil, steel casings shall be installed to prevent the upper part of the hole collapsing, then. Auger type drilling is operated.

If wet process is necessary, below the steel casing section must be filled with fluid to increase pressure for prevent in the bored hole collapsing bored hole, then bucket type drilly is operated.

- Inspection of Drilled Hole. After reaching the required pile tip, the depth of bored hole is measured. The diameter of the bored hole shall be measured with appropriate tools such as the drill hole monitoring device or as the engineer recommendation, also approval in writing preparation and installation of reinforcement.

- Normally, reinforcement is pre-fabricated and arranged appropriately in bulks. They must be cleaned and placing in the bored hole to their positions. Then they are located in positions and hung at the top of the bored hole preparing for concrete placing.

- Concrete Placement, placement of concrete underwater is applied. A tremie pipe of approximately 250 mm in diameter is lowered nearly to the bottom of the bored hole. Placing of concrete must be continually in each bored hole, also during the placement of concrete must the amount of the relation between the depth of the bored hole and the amount of filled concrete must be constantly monitored.

- Pulling out of the Steel Casing. This must be carried out with a vibro hammer equipment while the concrete is not yet set

For the above mentioned work procedures, the contractor must always arrange the detailed reports of every bored holes and submit to the engineer.

5.1.16 Epoxy-Resin-Base Bonding Compounds for Concrete

These are adhesive admixtures that bond or adhere concrete together. Materials consist at 2 parts: the epoxy resin and the curing agent, there may be filler included in one of the compound or in both of them.

The epoxy-resin-base bonding compounds must have characteristics conform to TIS 1026 "Epoxy-Resin-Base Bonding Compounds for Concrete". Since epoxy resin bonding compounds cannot set in damped condition, application on damped surface is prohibited. Permission in writing before using from the engineer is required.

When epoxy-resin-base bonding compounds for concrete in the water is to be applied, permission in writing from the project's owner is required.

5.1.17 Joint Filler, Joint Primer and Joint Sealer

5.1.17.1 Joint Filler for Concrete, Non-extruding and Resilient Type

This type of filler must have properties conform to DOH - A 301 "Specifications for Instant Joint Filler Materials for Concrete Expansion Joint, Non-extruding and Resilient Type with Asphalt Compound". Holes must be provided for dowel bars. Each joint filler pad must have thickness and depth as specified in the drawings.

Joint filler is allowed to be used for any length necessary provided that they are tight.

5.1.17.2 Concrete – Joint Filler, Sponge Rubber and Cork Type

These types of filler must have properties conform to TIS 1079 "Joint Filler for Concrete, Sponge and Cork Type". These joint fillers are manufactured from sponge or corks as in pad or strip insert at the expansion joint of brick or concrete. These can be divided into 3 types, as follows ;

(1) Sponge rubber type

(2) Cork type

(3) Self-expanding cork type

Sponge rubber type joint filler is made of elastic sponge rubber which may be synthetic rubber and/or natural rubber, without the mixing of ground valcanizate rubber.

Cork type and self-expanding cork type joint fillers are made from compositions of cork pellets adhering with synthetic resin.

Prior the use of joint filler, approval in writing by the engineer is required.

5.1.17.3 Joint Primer

Joint primer must be made of material that can highly penetrate into the concrete pores. When it is painted on concrete surface it must dry within 4 hours at 25 °C. When mortar block made of joint sealers is adhered to test specimen of hot-poured elastic type sealer which passed quality testing for bonding permissibly conform to TIS 479 "Concrete Joint-sealer, Hot Poured Elastic Type" cracking either, separation or opening which occurs must not deeper than 6.4 mm at any point between the test specimen and the mortar block during the test.

5.1.17.4 Concrete Joint-sealant, Hot Poured Elastic Type

This is an asphalt compound joint sealant for concrete which prevent permeate of dampness and other impurities. It must have clacticity and adhering properties, it can be melted by heading and can be continuously poured into joint without forming air voids, also shall not flow out from the joint or stick to vehicle wheels.

This type of joint sealer must have properties conform to TIS 479 "Concrete Joint-sealant, Hot-poured Elastic Type" and must be approved in writing by engineer before using.

5.1.17.5 Concrete Joint-sealant, Cold-application Type

This is an asphalt compound joint sealant for concrete that can be used at normal temperature without any heating required, which prevent permeate of dam press and other impurities. It must have elasticity and adhering properties. When applied, it shall not flow out from the joint or stick to vehicle wheels.

Concrete joint-sealant of this type is usually used for sealing the joint that is not less than 13 mm in width. It must have properties conform to TIS 917 "Concrete Joint-sealant, Cold-application Type" and must be approved in writing by the engineer before using.

5.2 CONCRETE BRIDGE WORK

5.2.1 Tasks of the Engineer

Before bridge construction begin the engineer must carry out the work as followings;

5.2.1.1 Check the plan and profile of the existing road, included at least 300 m of bridge approaches profile.

5.2.1.2 Survey of waterway cross section, at least 3 location. The first one is along the bridge alignment, and the others are at approximately 50 m of the left and the right of the bridge. Then the surveyed data are plotted for the correction of waterway and for appropriate location and size of the bridge.

5.2.1.3 In case there is a different of skew angle different from the design drawings, or the bridge is situated near to a waterway bend where erosion may occur but there is no erosion protection method specified in the drawings, remedies must be considered.

5.2.1.4 Check the construction, profile, then transfer the level from the benchmark to the construction site. In case where there are several benchmarks, investigation must be carried out and finding the correlation of these benchmarks, and they appropriately must be correlated.

5.2.1.5 Check the existing right-of-way with the Highway District and lay out the correct center- line alignment.

5.2.1.6 Compare all the previously obtained information to of the drawings, i.e.bridge deck profile, bridge length, high water level, low water level, clearance, skew angle, erosion, bridge span and appropriate location of each foundation. They are not appropriate, such as length is rather short, not enough clearance, etc. the engineer shall adjust them to suit the actual field conditions. If differences on important items are found, the engineer must report them to the project's owner.

5.2.1.7 The contractor must install traffic regulating devices during construction according to the specifications for highway construction of the Department of Highways.

5.2.1.8 In case the bridge to be constructed is on the existing road which open to traffic, order to the contractor to build detour bridge or detour road to facilitate traffic as stated in the contract is to be practiced as follows ;

(1) In case the Department of Highways is not the designer of the detour bridge, the contractor must design and responsible of not causing cause damages from the detour bridge. Hence, before detour bridge is to be constructed, the contractor must submit the design which is signed by engineer to the engineer for approval. The contractor shall comply to recommendations by the engineer to the changes or alterations of the design as deemed appropriate. These changes, however, will not relieve or lessen the contractor from responsibility resulting from any damages that may occur. When designing the detour bridge the contractor must

design to support truck load not less than HS 20, class or as deemed by the Department of Highways.

(2) Before closing of the traffic on the existing road to use the detour bridge, permission in written from the Bureau of Highway and the Highway District must be issued.

(3) The standard of the detour road surface must not be lower than that of particular road, except for concrete pavement asphalt surface can be provided throughout the operating period.

(4) The contractor must take care, monitor and maintain detour bridge and detour road to be in good condition and safe for users throughout the operating period.

5.2.1.9 Construction materials to be used for construction are to be sampled and tested. (Sampling methods and amount of samples shall be as stated in article 5.1)

5.2.1.10 Check the amount of construction materials according to their needs. The contractor is not permitted to use construction material which the result of testing is not yet passed.

5.2.1.11 Check the conditions, amounts and types of necessary tools and equipment for construction, including the amount of labor whether they are sufficient for the works.

5.2.1.12 When the contractor is proposed about to dismantle the existing bridge the engineer must check those structural members and parts that still can be used listed and handed to Highway District. Do not allow the contractor to take them for using unless otherwise specified in the contract.

5.2.1.13 Locate all foundations and also the bridge profile for the convenience of inspection.

5.2.2 Procedures for Foundation Works

Before the foundation is constructed, the contractor must survey and study geological characteristics, etc. to specify the suitable type of foundation as approval from the engineer.

5.2.2.1 Spread Footing

Spread footing is suitable for hard ground, gravelly soil or rock

(1) As stated in article 5.1.15.1

(2) The soil underneath the foundation must be able to bear load not less than that specified in drawings, which approval in written from the engineer is required.

(3) The level of the footing in the waterway must be located at least 2.50 m into the ground, or as specified in the drawings. Foundations near the banks shall be as possible located to the similar depths as the adjacent foundation in the waterway to avoid erosion in the future.

(4) In case the contractor cannot excavate to the required depth, report must be submitted to the projects owner. In case load bearing capacity test is necessary the contractor must responsible all costs incurred.

(5) The layers of all investigated soil strata at every foundations must be shown.

(6) Listed the level of all finished foundations on the drawings.

5.2.2.2 Driven Pile

Driven pile is suitable for soft ground, or where the field condition is not suitable for spread footing, such as in deep water, pond.

(1) As stated in article 5.1.15.2.1, 5.1.15.2.2 and 5.1.15.2.3

(2) The load bearing capacity of the pile calculated by using DOH formula must be according to that specified in the drawings. The contractor must submit details of all piles driving records to the engineer for examination before the bridge construction implemented.

In case the result of the pile driving is not according to as specified, the contractor may request for a pile load test with written consent from the engineer. A particular pile must be able to carry load not less than that specified out on the drawings

(3) In case the contractor using drop hammer for piling the weight of the drop hammer shall at least 50% of the weight of the pile to be driven, and the weight of drop hammer must not less
than 3.5 tons.

If the contractor proposes for other method for driving pile. This must be in accordance with Table 5.2-1

(4) Pile that has been driven and can carry load ad required must have penetration depth at least 1/3 of the distance from the tip of the pile to the underside level of the cap beam, and must not less than 3.50 m.

(5) Pile must be driven into position accurately as specified on the drawings. Eccentricity must less than 150 mm and the distance between 2 adjacent piles shall not differ from that specified on the drawings more than 150 mm. If it is more than that previous mentioned, this must be reported to the project owner.

(6) Each pile must be driven continuously until finish. If there is any problem which causes of driving has to be passed, immediate remedies must be made so that piling can be quickly resumed and completed.

(7) Absolutely no reinforced concrete pile with crack is to be used.

(8) When the pile being driven does not have enough length, the contractor must lengthen to the required length specified in the drawings. When the extended section has developed enough strength, driving may resume by gently driving at first until the pile begins to sink then normal piling operation may continue until finish.

(9) While driving, if there is crack or break of the pile by any cause, the contractor must pull out that pile and drive in a new pile. If the damaged pile cannot be pulled out, report must be made to the project owner.

(10) Pile tip levels of finished driving piles must be recorded on the as built drawings.

Table 5.2-1
Minimum Efficiency Specification for Pile Driving Hammer, Besides of Dropped Hammer

Driving Method	Minimum Weight of Hammer, Ton	Maximum Lifting Height	Energy Rate, kgf-m
1. Air/Stream hammer (Single Action)	3.50	1.00	3,500
2. Air/Stream Hammer (Double Action)	3.50	0.50	3,500
3. Diesel Hammer (Single Action)	1.35	2.60	3,500
4. Diesel Hammer (Double Action)	1.50	-	3,500
5. Steam Hammer (Differential Action)	6.35	0.40	4,900
6. Hydraulic Hammer	1.50	3.30	3,700

5.2.2.3 Bored Pile Foundation

Bored pile foundation is to be used only in case it is specified in the drawings, or where driven pile foundation cannot be constructed. This must be as specified stated in article 5.1.15.2.4, at least 1% reinforcement of cross sectional area must be provided throughout the entire length of the pile. Also the detailed drawings and design calculation must be approved in writing by Buroau of location and design.

5.2.3 Pile cap, Beam, Slab and Other Structures

Before starting of pile cap construction all spans length and pile spacing must be checked. If they are some errors, they must be corrected. It they cannot be done by site engineer, the engineer must report to Bureau of Location and Design.

Before starting of beam construction the sizes and profiles of cap beam and of bracing must be checked as specified in the drawings

Before starting of deck slab construction, profiles of slabs and the level and the positions of locations of drainage must be located to suit topography of the area.

5.2.3.1 Concrete mix proportions for various parts of the reinforced concrete bridge are as stated in articles 5.1.3, 5.1.4 and 5.1.5.

5.2.3.2 Mixing of concrete is as stated in article 5.1.6

5.2.3.3 Transportation of concrete is as stated in article 5.1.8.

5.2.3.4 Placement of concrete is as stated in article 5.1.9.

5.2.3.5 Compaction of concrete is as stated in article 5.1.10.

5.2.3.6 Curing of concrete is as stated in article 5.1.11.

5.2.3.7 Ordinary steel reinforcement is as stated in article 5.1.12.

5.2.3.8 Prestressed concrete steel reinforcement is as stated in article 5.1.13.

5.2.3.9 Formworks, bracing, scaffolding and temporary structures are as stated in article 5.1.14.

5.2.3.10 Epoxy resin for concrete, if used, is as stated article 5.1.16

5.2.3.11 Filler materials, if used, are as stated article 5.1.17.

5.2.4 Elastomeric Bearing Pad

Properties and dimensions of elastomeric bearing pad are as specified in the drawings or as the contractor has designed which conform to British Standard or AASHTO Standard under specified conditions and must be approved by the Bureau of Location and Design

Testing of physical and chemical properties must be as follows ;

5.2.4.1 Hardness

This must be tested in accordance with BS 903 "Part A 26 (Method N) or International Standard Organization Standard ISO 48 "Rubber, Vulcanized or Thermoplastic – Determination of Hardness (Hardness between 10 IRHD and 100 IRHD)"

or American Society of Testing Materials Standard ASTM D 2240 "Standard Test Method for Rubber Property – Durometer Hardness". The different of hardness between the tested value and of the specified must not exceed 5.

5.2.4.2 Tensile Strength and Ultimate Elongation

Tensile strength and elongations at break or ultimate elongation are in accordance with BS 903: Part A 2 "Using Dumb-bell Test Pieces" or ASTM D 412 "Standard Test Method for Vulcanized Rubber and Thermoplastic Rubber and Thermoplastic Elastomer – Tension". Tensile strengths from the tested sample must not less than 15.5 MPa, and ultimate elongation must not less than 400%.

5.2.4.3 Heat Resistance

Heat resistance is to be tested conform to BS 903: Part A 19 (Method A or B), or ASTM D 57 "Standard Test Method for Rubber – Deterioration in an Air Oven". Test result must be as follows ;

(1) Change of hardness must not exceed 10 IRHD.

(2) Change of Tensile strength must not exceed 15%

(3) Change of Ultimate elongation must not exceed 20%

5.2.4.4 Compression Set

Compression set of the elastomeric bearing pads is to be tested in accordance with BS 903: Part A 6, or ASTM D 395 "Standard Test Methods for Rubber Property – Compression Set". Value from the test must not exceed 30%

5.2.4.5 Ozone Resistance

Ozone resistance of the elastomeric bearing pads is to be tested in accordance with BS 903: Part A 43, or ASTM D 1149 "Standard Test Method for Rubber Deterioration – Surface Ozone Cracking in a Chamber". Ozone content is 25 PPHM of the air volume, at temperature 30 ± 1°C, elongation value is 20% and duration is 96 hours. After the test, there must be no crack on the specimen.

5.2.4.6 Bond of Elastomer during Vulcanization

Bond of elastomer during vulcanization is to be tested in accordance with BS 903: Part 21 (Method B). Value obtained from the test must not less than 7 Newton per 1 mm of width (for reinforced rubber sheet only).

5.2.4.7 Steel Laminate

Steel laminate used must be manufactured from rolled mild steel in accordance with BS 4360 Grade 43 A, or ASTM A 36 and A 570, or Japan Industrial Standard JIS G 3101 Grade SS – 41. Properties must be as follows ;

(1) Yield tensile strength must not less than 245 MPa

(2) Ultimate tensile strength must between 410 to 520 MPa.

(3) Ultimate elongation must not less than 21%

5.2.4.8 Raw Material used for producing the rubber pad must be pure neoprene (polychloroprene), or natural rubber (polyisoprene).

5.2.4.9 Rubber Pad must only be manufactured in accordance with BS 5400: Section 9.2 "Specification for Materials, Manufacture and Installation of Bridge Bearings", or ASTM D 4014 "Standard Specification for Plain and Steel-laminated Elastomeric Bearings for Bridge".

5.2.4.10 Test Samples

(1) Dimensions of the test sample: width and length or diameter and thickness, must be as specified in the drawings. In case of rolled rubber pad, or when it is not specified in the drawings, a 1 m long for each specimen is to be taken.

(2) For general test, the contractor must send 1 sample of each type of rubber for testing.

(3) For control test, the contractor shall collect the same type of rubber pad which passed the test as mentioned in 5.2.4.10 (2) at construction site. Then 1% of each type must be sampling but shall not less than 3 specimens for testing.

5.2.5 Measurement and Payment for Concrete Bridge

5.2.5.1 Measurement

Quantity estimation of each part of bridge must be estimated from total quantity of bridge, as follow;

5.2.5.1.1 Reinforced Concrete Bridge

(1) Foundation works completed	20%
(2) Abutment/piers works completed	25%
(3) Bridge deck slab completed	40%
(4) Side walk, railings and miscellaneous works completed	15%
Total	100%

5.2.5.1.2 Prestressed Concrete Bridge

(1) Foundation works completed	20%
(2) Piers works completed	25%
(3) Prestressed concrete beam completed and Transported to the site	15%
(4) PC beam installation and bridge deck slab completed	25%
(5) Side walk, railings and miscellaneous works completed	15%
Total	100%

5.2.5.1.3 Prestressed Concrete and Reinforced Concrete Combined Bridge

(1) Foundation works completed	20%
(2) Piers works completed	25%
(3) Prestressed concrete beam completed and Transported to the site	10%
(4) PC beam installation and bridge deck slab completed = $\frac{30 \times \text{Length of prestressed concrete section}}{\text{total length of the bridge}}$	....%
(5) Reinforced concrete bridge deck slab completed = $\frac{30 \times \text{Length containing reinforced concrete section}}{\text{total length of the whole bridge}}$	....%
(6) Side walk, railings and miscellaneous works completed	15%
Total	100%

5.2.5.1.4 Bridge Approach Structures

(1) Piles casting and driving	20%
(2) Ground beams completed	20%
(3) Columns and walls completed	20%
(4) Bridge Approach Slab completed	25%
(5) Side walk, railings and miscellaneous works completed	15%
Total	100%

5.2.5.1.5 Monthly measurement of completed work of each part for reinforced concrete bridge is estimated as follows ;

(1) Pile	in each or spread footing in group
(2) Abutment pier	in each
(3) Beam	in each
(4) Slab	in Lm or m^2

If pile caps are vary in sizes quantity shall be calculated as proportion to the total amount of pile cap works. If beams are vary in sizes, quantity shall be calculated as proportion to the total amount of beam works.

5.2.5.1.6 If construction cannot be done as usual which is resulting from traffic management or from any other unavoidable matters the completed works shall be calculated as proportion to that as stated in article 5.2.5.1.5

5.2.5.2 Payment

5.2.5.2.1 Payment for works as stated in article 5.2.5.1 shall include material costs, equipment costs, labor costs, etc. that are necessary for completion of construction in accordance with the specifications. Payment is calculated from unit cost as listed in the contract of the completed works for each installment.

5.2.5.2.2 Payment of works for the last installment in accordance with article 5.2.5.1 shall be done after the contractor has removed all formworks, bracing, scaffoldings and falseworks using for construction, cleaning all parts of the bridge structure, including the drainage systems, existing ground, waterways and other wastes (final clean-up)

5.3 RECTANGULAR REINFORCED CONCRETE CULVERT

Characteristics and dimensions of Rectangular Reinforced Concrete culvert must be as specified in the drawings.

5.3.1 Procedures for Foundation works

Before characteristics is constructed, the contractor must survey and study the geological and other necessary data then choose the appropriate types of foundation for approval by the engineer.

5.3.1.1 In case piles are not driven the contractor must excavate all mud until reaching to the stiff soil then sandy gravel or coarse sand or other soil aggregates is placed and compacted to the thickness as consented by the engineer. Leveling the bedding to support culvert then placing the culvert and casting lean concrete to the required thickness. If the thickness is not specified in the drawings, it shall not less than 100 mm with a concrete mix proportions of cement : sand : aggregates are 1:3:6 by volume.

5.3.1.2 In case piles are driven, which is usually in case where the bed of the waterway is consisted of soft clay or deep mud, the contractor must support culvert with piles as consented by the engineer.

5.3.2 Structural Works of Rectangular Reinforced Concrete Culvert

5.3.2.1 Concrete mix is as stated in article 5.1.3, 5.1.4 and 5.1.5

5.3.2.2 Mixing of concrete is as stated in article 5.1.6

5.3.2.3 Transportation of concrete is as stated in article 5.1.8

5.3.2.4 Placement of concrete is as stated in article 5.1.9

5.3.2.5 Compaction of concrete is as stated in article 5.1.10

5.3.2.6 Curing of concrete is as stated in article 5.1.11

5.3.2.7 Ordinary reinforcing steel works are as stated in article 5.1.12

5.3.2.8 Prestressed concrete reinforcing steel works are as stated article 5.1.13

5.3.2.9 Formworks, bracing, scaffoldings, and temporary structures are as stated in article 5.1.14

5.3.2.10 Epoxy resin for concrete, if used, is as stated in article 5.1.16

5.3.2.11 Joint sealant, if used, are as stated in article 5.1.17

5.3.3 Measurement and Payment of Rectangular Reinforced Concrete Culvert

5.3.3.1 Measurement

Measurement of rectangular reinforced concrete culvert works is to be calculated from the actual length that have been constructed in accordance with the drawings. Unit of the work is in meter, or as specified.

5.3.3.2 Payment

5.3.3.2.1 Payment for the works shall include material costs, equipment costs, labor costs, etc. that are necessary for completion of construction in accordance with the specifications. Payment is calculated from unit cost as listed in the contract of the completed works for each installment.

5.3.3.2.2 Payment of works for the last installment in accordance with article 5.2.5.1 shall be done after the contractor has removed all formworks, bracing, scaffoldings and falseworks using for construction, cleaning all parts of the rectangular RC box culvert, including the drainage systems, existing ground, waterways and other wastes (final clean-up).

5.4 REINFORCED CONCRETE PIPE CULVERT

Characteristics and dimensions of Reinforced Concrete pipe culvert are as specified in the drawings

5.4.1 The contractor must only cast the pipe culvert in accordance with the standard by placing and compacting the concrete with Packer Head or Spun Type equipment.

5.4.2 The pipe is to be tested by external load-crushing strength in accordance with DOH – T 301 / 2517 "Strength of Load-bearing Drainage Pipe by the Three-edge-bearing Method". The number of pipes to be tested shall be in accordance with TIS 128 "Reinforced Concrete Pipes Culvert for Drainage Works".

5.4.3 The contractor must compact the sub grade in accordance with that specified in the details and Specifications of Highway Construction regarding embankment works.

5.4.4 The ground for placing RC pipe culvert must be excavated to the required depth as shown in the drawings or as specified by the engineer.

5.4.5 The ground for placing RC pipe culvert must prepared in accordance with that specified in the drawing, which can be divided into 3 characteristics as follows ;

5.4.5.1 If the existing sub-grade is soft, concrete cradle bedding shall be applied.

5.4.5.2 If the existing sub- grade is stiff, ordinary bedding shall be applied.

5.4.5.3 If the existing sub-grade is rocky, bedding for rock or unyielding foundation is to be applied.

5.4.6 Installation of RC pipe must be in accordance with that specified in the drawings

5.4.7 When the bedding has been prepared and the pipes are placed as the specifications, back filled shall be done in layer and each layer must not thicker than 15 cm. Each layer must be compacted by mechanical tamper or vibratory compactor to the required level and the density must be in accordance with the specifications.

5.4.8 Measurement and Payment for Reinforced Concrete Pipe Culvert

5.4.8.1 Measurement

Reinforced concrete pipe works measurement is to be checked when the level and the density are as specified in the drawings. Quantity is in meter of actual length of pipes.

5.4.8.2 Payment

5.4.8.2.1 Payment for the works shall include material costs, machinery costs, labor costs, etc. that are necessary for completion of construction in accordance with the specifications. Payment is calculated in unit cost as listed in the contract of the completed works for each installment.

5.4.8.2.2 Payment of works for the last installment shall be done after the contractor has removed all formworks, bracing, scaffoldings and falseworks using for construction, cleaning all parts of the RC pipe culvert, including the drainage systems, existing ground, waterways and other wastes (final clean-up).

DIVISION 6

INCIDENTALS

6.1 SLOPE PROTECTION

6.1.1 Description

This work shall consist of the provision and installation of slope protection for stream banks, embankment slopes, cut slopes, bridge abutment slopes and other surfaces composed of erodible materials where protection is desired. Generally, the protection will form an impervious layer constructed in or on designated surfaces and shall have at its bottom and ends anti-scour devices such as cutoff walls, toe walls or sheeting. Slope protection may be constructed of concrete, stone riprap or sacked concrete as shown on the Drawings.

Slope protection shall also include impervious linings of concrete or stone riprap for ditches or gutters for the Conveyance of surface runoff. The linings shall be placed in ditches, gutters, chutes, outlets or other locations as shown on the Drawings, directed by the Engineer or as specified in these Specifications. Anti-scour devices may also be included with these items.

If directed by the Engineer, the various types of slope protection shall be constructed in the locations so directed, whether or not shown at those locations in the Drawings, in accordance with the Standard Drawings.

6.1.2 Materials

6.1.2.1 Riprap Stone

Stone for riprap shall consist of field stone or rough, un-hewn quarry stone as nearly rectangular as practicable. The stone shall be dense, resistant to the action of air and water, and suitable in all other respects for the purpose intended. The stone shall have percentage of wear of not more than 50% as determined by AASHTO test method T96, after testing riprap stone which has been broken up in small pieces in conformance with T96, the stones shall, in general, be of the wide flat type with their larger faces roughly rectangular and parallel. The minimum thickness of stone shall be 15 centimeters (measured perpendicular to face of riprap). No face dimension shall be less that the thickness of the stone. Riprap stones for ditch lining, chute or outlet lining shall have a minimum thickness of 10 cms. and minimum length and width dimensions of at least 25 cms. These stones shall not weigh less than 10 kilograms each and may range in weight between 10-25 kilograms. In other respects, the stones shall conform to the requirements described above.

6.1.2.2 Concrete Slope Protection

Concrete slope protection for embankments or cut slopes shall be a Class C concrete slab constructed to the dimensions and details shown in the Drawings. The concrete slab may or may not contain steel reinforcements, as required by the Drawings. Steel reinforcement shall conform to the requirement of Section 5.1.12

Concrete for lining ditches, gutters, outlets and chutes shall also be Class C concrete, with or without steel reinforcement, as detailed in the Drawings. Class C concrete shall conform to the provision of Section 5.1.3.

6.1.2.3 Mortar

This shall be composed of one part of cement and two parts of sand by dry loose volume and sufficient water to make a mortar that can be easily handled and troweled. Retempering of mortar that has not been used for periods of 45 minutes or longer will not be permitted. Cement for mortar shall conform to the requirement of Section 5.1.3.

6.1.2.4 Sacked Concrete Slope Protection

Sacked concrete slope protection shall consist of a mixture of aggregates and cement placed in a jute or cotton sack having a minimum capacity of 30 liters or larger and an average thickness of 20 centimeters. Sacks shall be a type which will allow water to penetrate them easily. Sacked concrete slope protection shall conform to the requirements as detailed in the Drawings.

6.1.2.5 Incidentals

All incidentals required in slope protection shall conform to the requirements as specified in the Drawings, and these Specifications. These incidentals include, but are not limited to, such items as joint sealer, weep-holes drain pipes and filter material.

Filter material required for bridge abutments and embankment slope protection shall be an accepted coarse aggregate material as specified in Section 3.2 of these Specifications, or as approved by the Engineer.

6.1.3 Construction Methods

6.1.3.1 General

Unless otherwise specified slope protection shall always be constructed as an impervious layer upon designated surfaces. Unless otherwise specified slope protection shall have mortared joints.

Reinforced concrete drain chutes, unless otherwise specified, shall be constructed where curb and gutter is used with embankment heights greater than 6 meters to safely convey surface runoff down the embankment slope.

The drain chutes shall connect the drop openings integrated into the curb with the toe of the slope. The curb and gutter installation shall be placed along each shoulder edge when the roadway is in a normal cross section and only long the lower edge in a superelevated section. Spacing of drain chutes shall be as indicated on the Drawings or as directed by the Engineer.

Mortared riprap protection shall also be placed at the toe of the drain chute as detailed in the Drawings.

Reinforced concrete drain outlets, unless otherwise specified, shall be constructed along the side slopes between the outlet of pipe culverts and the toe of embankment to guard against erosion wherever the vertical distance between the pipe outlet and toe of slope is declared critical by the Engineer. The drain outlet shall be a trapezoidal reinforced concrete gutter of a type as detailed in the Drawings. Mortared riprap protection shall be integrated into the discharging end of each drain outlet as detailed in the Drawings.

Concrete interceptor ditches, unless otherwise specified, shall be constructed at the toe of benches where depths of excavation exceed 5 meters and the subgrade material is subject to erosion. Interceptor ditch linings may be reinforced concrete or plain concrete and shall be as detailed in the Drawings or as directed by the Engineer.

Concrete, stone riprap or sacked concrete embankment slope protection shall be constructed at locations shown on the drawings or as directed by the Engineer. This type of slope protection shall generally be used where embankments intrude into streams or watercourses.

6.1.3.2 Preparation

Excavation or construction of embankments shall be processed to planned shapes and dimensions, as if there were no slope protection, to allow some excavation immediately prior to the placing of the slope protection. The Contractor is responsible for conferring with the Engineer in charge of construction, prior to the making of excavations or building of embankments in areas to be covered so that the proper procedure can be decided.

The areas to be covered shall, at the proper time, be laid out to intended positions, and all necessary cut and fill stakes batter boards and construction lines set up. Every effort shall be made to have the surfaces in such condition as to require some excavation immediately prior to the laying of the riprap. Where, however, low areas are encountered they shall be backfilled and thoroughly tamped at the earliest practical time in advance of the laying of masonry, to avoid settlement after placing riprap. It is not necessary that the entire area to be protected be excavated and fine graded in advance of the laying, work should be always laid upon a freshly excavated and stable surface.

Aggregates and cement for sacked concrete slope protection shall be mixed dry, by hand, or mechanically in the proportion of 1:10 (cement : aggregate) measured by volume until the mixture is uniform in colour. Aggregates shall meet the gradation and quality requirements as specified in the Drawings. The mixture shall be placed into the sacks and filled approximately 3 / 4 full, and shall be securely and substantially sewed, the ends forming a straight edge.

The sacks when filled shall have an average thickness or depth of 20 centimeters.

6.1.3.3 Cut off Trench or Sheeting

As a slope protection will usually be accompanied by a bottom cutoff trench, the excavation for same shall be provided for in advance of fine grading. Where the cutoff trench is composed of masonry, a trench shall be excavated to the dimensions contemplated for the masonry, dewatered, and the masonry placed directly in the trench, visually without any form. Where the cutoff trench is composed of sheeting, care shall be taken not to disturb, by excavation or otherwise, any natural ground, stream beds or other formations intended to be in front of the sheeting.

After laying has been completed, backfills shall be made around the edges and mechanically tamped. Special care shall be given to backfilling and compacting any spaces or volumes resulting from the removal of forms.

If the bottom of the slope protection does not occur in rock or other natural strata accepted as non-erodible, the riprap shall always be founded or sealed on the bottom with appropriate cutoff trenches or sheeting. For cutoff trenches composed of masonry, the prepared trench shall be dewatered and completely filled with stones and mortar. The trench shall first be filled approximately 60 per cent with mortar and immediately thereafter stones shall be dropped and pushed into the unset mortar or concrete so as to make a solid, dense masonry wall. Additional mortar or concrete may be added to the top so as to obtain a screeded, level top surface. Only such length of trench is to be worked upon at a time as to insure that all stones can be inserted in fresh concrete. Where the foundation under the slope protection is unstable and the masonry cutoff may settle or fail, the cutoff masonry will be omitted and sheeting as required shall be driven. The cutoff masonry and/or sheeting shall be constructed before laying the slope protection.

Where the cut-off trench is composed of sacked concrete and after laying and backfilling has been completed, the sacked concrete shall be thoroughly soaked by sprinkling with water to the satisfaction of the Engineer. The cut-off protection shall be constructed before laying the slope protection.

6.1.3.4 Laying Slope Protection

After cutoff masonry or sheeting has been placed and accepted the laying of slope protection shall be commenced in tight contact with the cutoff masonry or sheeting and laid from the bottom towards the top. Stone and precast concrete blocks shall be laid in close contact.

In the case of stone riprap, the interstices may be partly filled with spalls or small stones, and finally all remaining joints or openings filled solidly with mortar. Where the pieces are composed of precast concrete, they shall be laid with broken joints. As each course is laid, the top of the joint shall be filled with mortar so that the succeeding course can be shoved into position in a full bed of mortar. At the conclusion of a course or section, all joints between the precast sections shall be filled solidly with mortar and joints pointed flush with the surface of the slope protection.

Precast concrete slope protection shall be constructed on the site or other location at the Contractor's option. Forms shall be composed of wood or steel and the pieces cast in horizontal positions. Lifting holes may be provided or rings, hooks, or other devices inserted to facilitate handing. Holes are to be filled with mortar if exposed in completed work. Where slope protection is cast-in-place, the wet curing time, however, may be reduced to three days. Curing shall be with burlap or cotton mats. Otherwise construction of precast concrete slope protection shall be in accordance with Section 5.1.3.

Slopes which are to receive the precast slope protection shall be graded and trimmed, and filled, tamped and screeded if necessary to final grade immediately prior to laying. A row of blocks shall be laid on ends (40 centimeter dimension normal to the slope) under all edges of slope protection, except where same is contiguous to pier or abutment walls. These end or edge blocks shall be set in trenches excavated as nearly neat to the block as possible. Any spaces between the block and sides of the trench shall be backfilled and tamped. Slope protection concrete blocks shall then be laid wit broken joints, and all joints shall be mortared joints. As the edges is completed from bottom to top, backfill shall be placed against the completed edge and tamped. All blocks shall be full size, except where half blocks are required to complete courses. The competed exposed surface shall be accurate to a tolerance not exceeding one centimeter in 1.5 meters.

All blocks, slabs and stones shall conform to the dimensions and requirements stated on the Drawings.

In laying the sacked concrete slope protection, the prepared sacks shall be bedded on the prepared surface upon which they are placed with the sewn ends all in the same direction. Sacks shall be placed by hand, beginning at the bottom of the slope and laid with broken joints. The sacks shall be rammed and packed against each other and tamped on the surface so as to from a close and molded contact and secure a uniform surface.

Sacks ripped or broken during placing shall be removed and replaced. Immediately after placing and tamping the sacks, they shall be soaked thoroughly by sprinkling with water. Water shall not be applied under high pressure.

All slope protection shall conform to the dimensions and requirements shown in the Drawings, these Specifications or as directed by the Engineer.

6.1.4 Measurement

Slope protection for embankments, cut slopes, and bridge abutments, ditch linings, drain outlets and mortared riprap at toes of chutes or outlets will be measured on a two dimensional basis in square meters. Linear dimensions shall be taken in not less than two directions and of sufficient number so that averages can be obtained and the product of the averages shall be the area for payment. Where slopes exist, measurement shall be along the surface of the slopes. Concrete interceptor ditch lining and reinforced concrete drain chute will be measured on a linear meter basis, along the slope of the ditch or chute.

Cutoff masonry, sheeting and anti-scour devices will not be measured but will be considered incidental to the slope protection item.

6.1.5 Payment

Payment for the items shall include all materials, excavation, forms, screeding, curing, hauling of materials, backfill, mortar, joints, equipment, tools, labour and incidentals necessary to the proper completion of the work.

6.2 SUB-SURFACE DRAINS

6.2.1 Description

This work shall consist of providing drains for the removal of sub-surface water such as perforated pipe subdrains or layers of porous material placed below subgrade. The work shall be constructed with the lines, levels and dimensions as specified in the Drawings and these Specifications.

Subdrains may consist of perforated pipe placed in a trench and backfilled with sand and used to intercept and remove ground water encountered during excavation, usually in hilly or mountainous areas. The depth and location of subdrains shall be determined by the Engineer during construction when excavation reveals the location of ground water.

Subdrains may also a type of rock and coarse sand fill placed at the toe of embankment on side slopes where the roadway section is constructed in both cut and fill, which allows subsurface water to drain along the interface of rock and new embankment and out through the filter. The location of this type if subdrain shall also be determined by the Engineer during construction where seepage is evident.

6.2.2 Materials

6.2.2.1 Pipe

Pipe for subdrains shall be perforated poly vinyl chloride as detailed in the Drawings or as directed by the Engineer.

Perforated poly vinyl chloride pipe (PVC) shall be a D-plast rigid type, class 8.5 with plain ends and shall conform to the requirements of the Thai Industrial Standard 17-2523.

Pipe of other materials shall be permitted if approved by the Engineer.

6.2.2.2 Pipe Backfill

Porous backfill material for bedding and backfilling pipe subdrains shall meet the gradation and quality requirements as specified in the Drawings.

Impervious backfill material shall be a fine compactible material approved by the Engineer.

6.2.2.3 Rock Fill

Rock fill shall consist of broken rock of maximum 30 centimeter size and coarse sand as specified in the Drawings. Rock fill shall meet the requirements of rock embankment as specified in Section 2.3.3 of these Specifications.

6.2.3 Construction Methods

6.2.3.1 Trench and Bedding for Pipe Subdrains

Trenches shall be excavated to the width, line and grade as shown on the Drawings. Unless shown otherwise, the depth shall vary from one to 1.5 meters below the finished surface at the top of the trench where the construction is under a gutter, ditch or the roadbed, and to depths required for proper drainage at other locations. A ten centimeter bed of granular backfill material shall be spread in the bottom of the trench throughout its entire length and brought to a uniform grade.

6.2.3.2 Placing Pipe and Backfilling

Pipe of the kind and size required shall be embedded firmly in the bedding material.

Bell and spigot pipe shall be laid with the bell ends upgrade and the spigot ends fully entered in the adjacent bell and spot mortared to provide for centering of pipe, but not closed to the desired infiltration of water.

The joints of butt-jointed pipe shall be covered with two-ply tar paper strips not less than 15 centimeters in width and of sufficient length to permit the ends being turned outward and laid flat on the bedding material on either side of the pipe for a distance of 8 centimeters. In lieu of tar paper, the joints may be wrapped twice around with a strip of burlap or other approved material.

Perforated pipe shall be laid with the perforated side of the pipe down, and separate sections shall be firmly jointed with approved metal bands.

Polyvinyl chloride (PVC) pipe shall be perforated by drilling holes of one centimeter diameter at intervals of 10 centimeters extending along the length of the pipe. A crushed stone filter of maximum aggregate size 1/2 inch shall be placed at end joints around the pipe as detailed in the Drawings.

After the pipe has been laid and has been inspected and approved by the Engineer, porous backfill material shall be placed to the depth indicated on the Drawings. Care should be exercised not to displace the pipe or joint covering around and over the pipe. The upper portion of the trench shall then be filled with suitable material of either porous or impervious type as shown on the Drawings. All filling material shall be thoroughly compacted.

All work shall be constructed to the dimensions and other requirements stated on the Drawings or as directed by the Engineer.

6.2.3.3 Placing Rock Fill

Rock fill subdrains shall be placed in accordance with the requirements specified in clause 2.3.3.3 of these Specifications and compacted as specified in Section 2.3.3 as "Rock Embankment".

The rock fill material shall extend from the benches cut into the natural side slope to the embankment slope as detailed in the Drawings to permit sub surface water to drain.

The porous sand material to be used shall meet the requirement as specified in Section 3.4.1 of these Specifications.

6.2.4 Measurement

Subdrains with perforated PVC pipe shall be measured by the linear meter of pipe, the size of which shall be specified in the Tender and on the Drawings.

Subdrains with rock fill shall be measured by the cubic meter to the lines and dimension shown on the Drawings or authorized by the Engineer.

6.2.5 Payment

The payment shall be full compensation for trench excavation, furnishing and placing all materials, including outlets, backfilling, labor, equipment, tools and incidentals necessary to complete the work.

6.3 MISCELLANEOUS STRUCTURES

6.3.1 Description

This work shall consist of furnishing, constructing and/or installing miscellaneous types of structures built according to the Specification for concrete structures and in conformance with the Contract Drawings. Included are such items as inlet boxes, manholes, urban drains, irrigation slide gates, flap gates, retaining walls, spring boxes, pipe encasement, platforms, barriers and other incidental items not specified elsewhere.

6.3.2 Materials

Concrete shall conform to the requirements of Section 5.1.3 Reinforcement, where required, shall conform to the requirements of Section. 5.1.12 Iron castings for frames, covers and gratings for manholes and inlets shall conform to the requirements of AASHO. Standard Specification M 105 Class 30.

Manhole and inlet steps shall meet the requirements of the latest edition of the ASTM Designation A-207.

6.3.3 Construction Methods

Construction methods given under Section 5.1 shall apply for this item except as noted herein or in the Special Provisions.

Underground drainage structures, including earthwork and backfilling incidental thereto, shall be completed before the adjacent roadway surfacing is placed, but pipe endwalls shall not be constructed until grading has been completed, as developments during construction may justify alterations in design or location of such endwalls. Also manholes, catch basins and inlets shall not be completed to final grade until after the grading has been finished and all necessary arrangements have been made to insure suitable connections at proper grade and alignment with pavements, gutter, curbs, etc.

Grates, and frames for grates, and covers for inlets and manholes shall be set in full beds of mortar or be otherwise properly secured as indicated in the Drawings, so as to be held rigidly in place to proper grade and alignment.

Inlet and outlet pipe at inlets and manholes shall be set or cut flush with the inside faces of the walls of such structures and shall extend a sufficient distance beyond the outside faces of the walls to provide ample room for making proper connections. The joint around the pipe in the structure wall shall be completely and neatly closed with mortar, or other material as may be specified, so as to make it watertight.

Pipe encasement shall be constructed of class B concrete, unless otherwise specified. All work shall be constructed in accordance with the Drawings.

6.3.4 Measurement

Catch Basins of the type indicated will be measured as units each, complete in place in accordance with the Drawings or at the direction of the Engineer. Manholes type A, B, C, D, E, F and Drop inlets will be measured as units each, complete in place in accordance with requirements approved by the Engineer. Pipe headwalls, whether plain or reinforced, shall be measured by the cubic meter of concrete placed.

Reinforced Concrete Side ditch of the type specified and Retaining Walls, of the sizes specified, shall be measured on a linear meter basis. In the case of Retaining Walls, the height of the wall (H) shall be as measured from the top of the wall to the bottom of the footing.

6.3.5 Payment

The payment shall be full compensation for all necessary excavation and backfill, concrete, reinforcement, all materials including cast iron and steel, welding, equipment, tools and labor necessary for proper completion of the work.

6.4 CONCRETE CURB AND GUTTER

6.4.1 Description

Concrete curb, mountable curb, concrete curb and gutter and concrete barrier shown on the roadway drawings or required at locations determined by the Engineer, shall be constructed as shown in the standard details and in conformance with the requirements of these Specifications. Concrete type shall be Class B and shall be either precast or cast-in-place with the prior approval of the Engineer.

This work shall also include curb markings of black and white paint where shown on the Drawings or designated by the Engineer.

6.4.2 Materials

Bed course material, if any is shown on the Drawings, shall consist of clean sand, gravel, crushed stone or other approved porous material of 1 centimeter maximum size and conforming to the general requirements of Section 3.2.

Concrete shall be of the class indicated on the Drawings, and shall conform to the requirements of the Section 5.1 on Portland Cement concrete structures.

Paint shall be of approved industrial quality and shall conform to AASHTO M70-74.

6.4.3 Construction Methods

Excavation shall be made to the required depth, and the base upon which the curb, gutter, or combination curb and gutter is to be set shall be compacted to a firm even surface. All soft and unsuitable material shall be removed and replaced with suitable material. If shown on the Drawings bed course material shall be placed and compacted to form a bed of the required thickness.

When a curb is placed next to a concrete pavement, expansion joints in the curb shall be located opposite expansion joints in the pavement. Expansion joints shall be formed at the intervals shown on the Drawings using preformed filler 1 centimeter in thickness in accordance with the requirements of Section 5.1.17. Dummy joint with the concrete pavement shall not be measured and paid for separately but shall be considered incidental to the pay item for the curb.

Concreting shall be generally in accordance with the requirements of Section 5.1. Forms shall be removed within 24 hours after concrete has been placed. Minor defects shall be repaired with mortar containing one part of portland cement and two parts of fine aggregate. Repair will not be permitted on the faces and rejected portions shall be removed and replaced at the Contractor's expense. The exposed surfaces shall be finished while the concrete is still green, by wetting an soft brick or a wood block and rubbing the surfaces until they are smooth. The surfaces shall be wet thoroughly either by dipping the brick or block in water, or by throwing water on the surfaces with a brush. After the concrete has been rubbed smooth, using

water, it shall then be rubbed with a thin grout containing one part of portland cement and one part of fine aggregate. Rubbing with grout shall continue until a uniform colour is produced.

When completed, the concrete shall be covered with suitable materials and kept moist for a period of 3 days. The concrete shall be suitably protected form the weather until thoroughly hardened.

After the concrete has set sufficiently, the spaces in front and back of the curb and gutter shall be refilled to the required elevation with the proper material, which shall be tamped in layers of not more than 15 centimeters, until properly compacted.

The finished work shall be true to line grade and level to within 3 millimeters and shall present a smooth appearance free from kinks and distortion visible to the eye.

6.4.4 Measurement

The quantity measured for payment shall be the number of linear meters of concrete of the several types and sizes of concrete gutter, curb, and the combination curb and gutter completed in place and accepted. Concrete curb, gutter and combination curb and gutter shall be measured in place along the center of the gutter, or curb. No deduction shall be made for flattening of curbs for entrances or for curb drainage inlets.

Concrete Barrier will be measured by the linear meter along the longitudinal axis of the finished barrier, including the transitions at ends complete in place, as directed by the Engineer.

Curb Markings and Barrier Markings shall be measured on a two-dimensional basis by the square meter for the areas painted as directed by the Engineer.

6.4.5 Payment

Payment for Concrete Curb, Mountable Curb, Concrete Curb and Gutter and Concrete Barrier shall included all excavation backfilling, tamping, materials, formwork, equipment, tools, labor and all incidentals necessary to proper completion of the work.

Payment for Curb Markings shall include all paints of required colors and quality, labor, tools and incidentals necessary to the satisfactory completion of the work.

6.5 CONCRETE SIDEWALK

6.5.1 Description

This work shall consist of concrete sidewalks constructed of insitu concrete, concrete slabs or concrete blocks on prepared beds in accordance with this Specification and in accordance with the lines, levels, grades, dimensions and types shown on the Drawings. If shown on the Drawings the work shall include the construction of bed courses.

This work shall also include concrete for median and island paving in accordance with the locations and details shown on the Drawings or as directed by the Engineer.

6.5.2 Materials

Bed course material, if any is shown on the Drawings shall consist of sand, gravel, crushed stone or other approved porous materials of 1 centimeter maximum size.

Concrete shall be of the class shown on the Drawings and shall conform to the requirements of Section 5.1.

6.5.3 Construction Methods

Excavation shall be made to required depth, and the foundation shall be shaped to conform to the section shown on the Drawings and compacted to a firm, even surface. All soft and unsuitable material shall be removed and replaced with suitable material.

If indicated on the Drawings bed course material shall be placed and compacted to form a bed course of the required thickness.

Forms shall be made of metal or of straight and sound lumber at least five centimeters in thickness. They shall be free of wrap and of sufficient strength to resist springing out of shape under pressure of the concrete. Forms shall be staked securely in position at the correct line and elevation.

Concreting shall be generally in accordance with the requirements of Section 5.1. Preformed expansion joint filler of the dimensions shown on the Drawings shall be set in the positions shown of the Drawings before the placing of concrete is started.

The concrete sidewalk between expansion joints shall be divided into blocks by transverse cuts, extending to at least one-third the depth of the slab, where called for on the Drawings or directed by the Engineer.

The edges of the sidewalk and the transverse cuts shall be shaped with a suitable tool, so formed as to round the edges to a 1 centimeter radius.

All work shall be correct to line, grade and level to within 3 millimeters.

If shown on the Drawings, the Contractor shall construct the required sidewalk or island paving of individual precast concrete slabs or blocks of a size specified on said Drawings. If precast slabs are not specified, the Contractors electing to construct the required sidewalk, median or island paving in this manner must have the prior written approval of the Engineer.

6.5.4 Measurement

This work shall be measured on a square meter basis, complete and accepted in place.

6.5.5 Payment

Payment for Concrete slab for island, median or sidewalk shall include all materials, sand bedding, equipment, tools, labor and all work incidental to satisfactory completion.

6.6 GRASSING

6.6.1 Description

This work shall consist of furnishing seed, sprigs or sods as required or permitted and planting them to give a healthy stable covering of grass which will maintain its growth in any weather and prevent erosion of the material in which it is planted.

This work includes the providing of block sodding or strip sodding on the topsoil covered slopes of embankment, subbase and shoulder and on other areas subject to erosion as shown on the Drawings and where required by the Engineer.

6.6.2 Materials

Grass shall be of species native to Thailand, harmless and inoffensive to people and animals and not of a kind recognized as a nuisance to agriculture. It shall be free of disease and noxious weeds, deep rooted and sufficiently rapid growing and spreading to give complete cover over the planted area within two years of planting.

The term "grass" embraces sods, sprigs and seeds and, if the Engineer permits, may include plants of other types capable of giving effective protection.

Fertilizer shall be approved lime or mixtures of plant nutrients or both.

Sods and sprigs shall be planted with their root system substantially undamaged and packed around with moist earth in which they have grown.

6.6.3 Construction Methods

Seeds shall be planted by a method that ensures reasonably uniform coverage and that the seeds will germinate and strike root without being washed out.

Sprigs shall be planted in a regular pattern such that surface water flowing over the area will have no clear channels to flow through but will be diverted into winding course by the presence of the sprigs. Sprigs shall be planted at a spacing of 30 centimeters or as required in the Contract Documents.

Sodding shall be done by planting sods to give continuous cover over the whole area.

Strip sodding shall be done by planting strips of sods not less than 8 centimeters wide, not more than 45 centimeters apart (centre to centre) or as required in the Contract Documents.

Strip sodding shall be planted with the strips lying along contours.

All sprigs and sods shall be planted with roots well buried in firm material.

Grass shall be planted at such a time and the work shall be done in such a way that at the time of the final construction inspection all areas to be grassed are substantially covered with healthy, well established, firmly rooted grass and the planted area is free form erosion channels. In the case of strip sodding bare strips between the strips of sods will be permitted at the time of the construction inspection, In the case of sprigging bare patches between sprigs will be permitted provided clear paths for erosion channels for not exist.

Occasional small bare patches will not be cause for rejection. Any bare areas which, in the Engineer's opinion, may permit erosion shall be made good and replanted with Sodding.

Surfaces to be planted shall be trimmed in such a way that the ground surface after planting shall be as shown on the Drawings.

Fertilizer shall be added at the time of planting if required in the Contract Documents or if it is necessary to ensure good ground cover within the required time.

Whenever a slope is completed, dressed and ready for grassing, the Contractor shall proceed with block sodding or strip sodding as designated on the Drawings or instructed by the Engineer. The Contractor shall maintain the grass at his expense until the end of the Maintenance Period. Maintenance shall consist of preserving, protecting and replacing grass, and such other work as may be necessary to keep it in a satisfactory condition to prevent erosion and to present a dense and uniform appearance. The Contractor shall be responsible for satisfactory growth and shall water, fertilize and mow the grass at such intervals as will ensure good ground cover of live grass all through the Maintenance Period.

6.6.4 Measurement

The quantity measured for payment shall be grassing (if the type is not specified) or seeding, strip sodding, sodding or sprigging measured as the number of square meters of planted surface (whether horizontal or sloping) measured on the slope, of required and accepted grassing well established in place. Fertilizer will not be measured. In the case of strip sodding planted surface shall mean the whole area including that initially uncovered between the strips.

6.6.5 Payment

Payment for Block sodding and/or Strip Sodding, shall include all materials, handling, storage, site preparation, placing, maintenance, equipment, tools, labor, incidentals and satisfactory disposal of all unsuitable or surplus materials.

6.7 TOPSOIL

6.7.1 Description

This work shall consist of furnishing, transporting and spreading topsoil removed from approved sources, in accordance with this Specification.

6.7.2 Materials

Topsoil furnished by the Contractor shall consist of a natural friable surface soil without admixture of undesirable soil, refuse or foreign materials, It shall be reasonably free from roots, hard clay, coarse gravel, stones larger than 5 centimeters in any dimension, noxious weeds, tall grass, brush, sucks, stubble or other litter, and shall have indicated by a healthy growth of crops, grasses, trees or other vegetation that it is free-draining and non-toxic.

6.7.3 Construction

The Contractor shall notify the Engineer at least 5 days before he intends to start topsoil stripping operations. After inspection and approval by the Engineer, and prior to stripping any topsoil, the Contractor shall remove noxious weeds and tall grass, brush, stones larger than 5 centimeters in any dimension, and roots.

The topsoil shall be evenly spread on the designated areas to a depth which, after settlement and compaction, shall be that shown on the Drawings. Spreading shall not be done when the ground or topsoil is excessively wet or, otherwise in a condition detrimental to the work. The roadway surface shall be kept clean during hauling and spreading operations.

After spreading has been completed, large clods, stones larger than 5 centimeters in any dimension, roots, stumps and other litter shall be raked up and removed.

Where shown on the Drawings and where instructed in writing by the Engineer, topsoil shall be placed on the slopes of embankment, subbase, shoulders and cuts and in ditches and other areas in a thickness of 10 cm. measured perpendicularly to the slopes. To reduce erosion as much as possible, the placing of topsoil and the subsequent grassing shall be done simultaneously with or right after the placing and compacting of the individual layers of the embankment, subbase, shoulders or right after completing the cut.

Within the right-of-way no topsoil materials shall be obtained from areas outside the limits of earthworks, as stated in Section 2.1 of these Specifications but they may, if acceptable to the Engineer, be obtained from borrow pits, roadway excavation, channel excavation, excavation for structures and from areas under embankment. When obtained from areas outside the right-of-way, the Contractor must obtain permission or make contracts and pay any necessary fees.

Where layers of embankment fill are made from excavation of clayey silty materials conducive to the growth of grass, such layers may be extended in width to the outer surface of the prescribed layer of topsoil and no topsoil shall be placed thereon. The volume of fill corresponding to the prescribed layer of topsoil will not be measured as embankment, but will be measured and paid for as topsoil.

In the event sodding shall be placed and the root systems of the sods are as specified in Section 6.7.3 of these Specifications, topsoil may not be required. If, in the opinion of the Engineer, topsoil is not required under sods, it will not be measured for payment.

6.7.4 Measurement and Payment

The quantity measured for payment shall be the number of cubic meters of required topsoil of the designated thickness complete and accepted in place.

The price paid shall be full compensation for furnishing and placing all material, including labor, equipment, tools and incidental necessary to complete the works.

6.8 GUARD RAIL

6.8.1 Description

This work shall consist of furnishing and installing the specified type or types of guardrail at locations indicated on the Drawings or as directed by the Engineer.

The work shall include all required posts, rails, cables, fixtures and fastenings, beams, anchorages and attachments as well as aligning and painting, if required, and all the processes necessary to complete the work.

6.8.2 Materials

6.8.2.1 Post

Steel posts shall be galvanized standard carbon steel pipe with round shape, outside diameter not less than 100 mm. and thickness not less than 4 mm., and shall conform to the requirements of T.I.S 248/2525.

6.8.2.2 Concrete and Reinforcement

Concrete shall conform to the requirements of Section 5.1.3. Reinforcement shall conform to the requirements of Section 5.1.12.

6.8.2.3 Guard Rail

Rail elements shall be made from steel of thicknesses not less than 3.2 mm. for Class 1 and 2.5 mm. for Class 2. Rail elements shall meet the strength requirements and have the mechanical properties shown in Table 6.8-1 below, and shall conform to the requirements of T.I.S 248-2525

Table 6.8-1

CLASS	TYPE	TENSILE STRENGTH kg/sq.mm.	ELONGATION NOT LESS THAN (%)	DEFLECTION			
				TRAFFIC FACE UP		TRAFFIC FACE DOWN	
				KG.	DEFLECTION NOT MORE THAN (MM)	KG.	DEFLECTION NOT MORE THAN
1	1	41	21	910	50	720	50
	2			1,360	75	1,090	75
2	1	41	21	680	50	545	50
	2			910	75	720	75

The beam strength shall be determined with the rail element freely supported on a clear span of 365 cm. and the load shall be applied through an 8 cm. wide flat surface at the center of the span. Rails and joints between rails shall both be tested in the same manner. When the joint is tested, it shall be at the center of the span. Terminal sections shall meet the same requirements as for rail elements except for the beam strength test.

Type 1 guardrail elements not intended to be painted shall receive a zinc coat galvanizing of the least 550 g/m^2.

6.8.2.4 Bolts and Nuts

Bolts, nuts. rings and other hardware shall be galvanized in accordance with AASHTO standard M232-78 (ASTM A153-78) and all connections shall be able to withstand a side pull in any directions of 2,200 kilograms.

6.8.2.5 Paint

Paint shall be applied in the number of applications and of the type indicated in the Contract Documents. Paint shall conform to the appropriate specification as follows:

Read Lead paint	A.A.S.H.O	M 72
White and tinted paint	A.A.S.H.O	M 70 Type 1 Class B
Aluminum paint	A.A.S.H.O	M 69
Zinc chromate paint	A.A.S.H.O	M 142

6.8.3 Construction Methods

6.8.3.1 Posts

Posts shall be set vertically in position to the lines and levels shown on the Drawings. Post holes shall be back filled with approved material well tamped in layers of not more than 10 centimeters thickness. If driving of posts is permitted the tops of posts shall have substantially

the same dimensions as the body of the posts. Damage to posts in driving will be cause for rejection.

6.8.3.2 Rail

Rails shall be erected in a manner that will result in a smooth continuous taut rail closely conforming to the line grade of the highway or as shown in the Drawings.

6.8.3.3 Steel Rails

Steel rails shall be supplied to the site fully fabricated requiring only bolting on site. Bolts shall be drawn tight except where otherwise required at expansion joints.

6.8.3.4 Concrete Rails

Concrete rails shall be erected in conformity with the requirements of Section 5.1 Reinforced Concrete or 5.4 Prestressed Concrete as appropriate.

6.8.3.5 Painting

All metal work not galvanized shall be given one prime coat of red lead or zinc chromate or a rust inhibiting primer of a type approved by the Engineer and two field coats of white paint. All metal parts which are galvanized shall be given one field coat of white paint.

6.8.3.6 Relocation of Existing Steel Guard Rail

Where shown on the Drawings or directed by the Engineer, the Contractor shall carefully remove existing steel guard rail and posts, clean, paint and otherwise refurbish the various elements and reinstall in a location shown on the Drawings or indicated by the Engineer. All new bolts and nuts shall be used in the relocation of existing steel guard rail.

6.8.4 Measurement

Steel guard rail shall be measured by the linear meter along the rail elements from center to center of posts for each continuous installation. Terminal sections will not be measured separately but will be considered incidental to the work. Steel beam guard rail barricade will be measured as a unit each, complete in place, as shown in the Contract Drawings.

6.8.5 Payment

Payment for Steel Guard Rail, Relocate Steel Guard Rail and Steel Beam Guard Rail Barricade shall include furnishing and installing all steel rail elements, terminal sections, steel posts, brackets and splice plates, nuts, bolts, miscellaneous materials and backfill as well as all equipment, labor and incidentals necessary to the proper execution of the work.

6.9 FENCING

6.9.1 Description

This work shall consist of fences and gates of the type indicated constructed in accordance with this Specification at the locations and in accordance with the lines, grades, levels, designs and dimensions shown on the Drawings.

6.9.2 Materials

Concrete shall conform to the requirements of Section 5.1.2 Reinforced Concrete Structures. Timber shall be sound timber free from shakes, splits, wavey edges and heart wood. The timber shall be well seasoned, treated in accordance with the requirements indicated on the Drawings and of the dimensions indicated. The species of timber shall be as stated in the Drawings or in the Special Provisions. Cable, chain link and barbed wire shall be of the gage, weight, size and type indicated on the Drawings or in the Special Provisions and shall be galvanized. Hinges and fittings shall be of the size and type indicated in the Drawings or in the Special Provision.

6.9.3 Construction Methods

Posts shall be set vertically to the depth shown on the Drawings and maintained in accurate alignment while fencing is erected and backfilling is done. Backfilling shall be done with suitable material, not necessarily the material excavated, and shall be well tamped into compacted layers not exceeding 10 centimeters thickness. On completion of erection the fence shall be firm with no loose or movable parts and true to lines grades and levels to within 10 centimeters. Gates shall be hung horizontally. Anchor shall be securely buried and backfilled as for posts and shall show no signs of movement when wires are strained tight.

Painting shall be in conformity with the requirements stated on the Drawings or in the Special Provisions.

6.9.4 Measurement

The quantity measured for payment shall be the number of linear meters of each type of fencing and the number of gates of each type, all as finally installed in the place required and accepted.

6.9.5 Payment

Payment for the items shall be full compensation for furnishing all materials and for all labour, equipment, tools and incidentals necessary to complete the work

6.10 MARKERS AND GUIDE POSTS

6.10.1 Description

This work shall consist of guide posts, kilometer stones and right – of –way monuments furnished and installed in accordance with details shown on the Drawings and these Specifications.

This work shall also include the removal, rehabilitation and relocation of existing guide posts or kilometer stones on road rehabilitation or reconstruction projects as directed by the Engineer and in accordance with these Specifications.

6.10.2 Construction methods

Details of construction materials, placing, painting, lettering, etc. are shown and fully described on the Drawings. Concrete and reinforcement steel shall conform to the requirements as specified in Section 5.1.3 and 5.1.12 of these Specifications. Any guide post or kilometer stone shown on the Drawings or designated by the Engineer to be removed and relocated shall be carefully excavated, removed, cleaned, repainted and refurbished to a like-new condition and installed in the proper location as directed by the Engineer.

6.10.3 Measurement

This work shall be measured as the number of respective units each, properly constructed or relocated as accepted by the Engineer.

6.10.4 Measurement and Payment

Payment for Guide Post, Relocated Guide Post, Kilometer Stone, Relocated Kilometer Stone and Right-of-way Monument shall include, furnishing and placing all materials, labor, equipment, tools and incidentals necessary to complete the work.

6.11 ROAD SIGNS

6.11.1 Description

6.11.1.1 General

This work shall consist of furnishing, assembling and erecting posts, signs, sign frames and illuminated signs of a permanent nature in accordance with the details shown on the Drawings and as specified herein and in the Special Provision at the locations shown on the Drawings and as directed by the Engineer.

The work shall include all necessary foundations, excavation, backfill, anchorages, fixtures and fastenings, brackets lighting units and electrical installations where required, application of paints and finishes, testing and all the processes necessary to complete the work. Design of signs and associated electrical installations may be included in the work.

For this project, this work consists of non-illuminated sign boards, frames and posts constructed at locations shown on the Drawings. Three types of sign boards used shall be Regulatory Signs, Warning Signs and Guide Signs. Road signs shall be manufactured and erected in accordance with the Drawings and Section 6.11 of these Specifications Subject to the Requirements contained herein.

Sign posts shall be of reinforced concrete, Class B, 10 cms. By 10 cms.

This work shall also include the removal, cleaning, restoration and reinstallating of existing road signs and posts which are in good condition but not presently in the proper location for the finished road construction. This work will be directed and approved by the Engineer on an as-needed basis.

6.11.1.2 Sizes, Colours Types

Unless otherwise indicated on the Drawings or in the Special Provisions, or otherwise directed by the Engineer, signs and their supports shall be of the sizes, colours and types prescribed by, and sited in accordance with the recommendations of the latest edition of the Department's Traffic Control Device Manual and subsequent supplements and amendments.

6.11.1.3 Alternative Designs and Materials

The Contractor may submit or recommend alternative designs and construction materials to those specified in the Special Provisions or on the Drawings but the Engineer's approval of any alternative shall be subject to the prior consent of the Department.

6.11.2 Materials

6.11.2.1 Mounting Posts

a) Reinforced Concrete Posts – Material shall conforms to the requirements of Section 5.1.3 of these Specifications. Concrete shall be Class A unless otherwise specified on the Drawings or in the Special Provisions.

b) Prestressed Reinforced Concrete Posts – Materials shall conform to the requirements of Sections 5.1.3 of these Specifications.

c) Steel Posts – Steel posts shall be in the form of round tubes or pipes of not less than 6 centimeters outside diameter or other approved sections of adequate torsional rigidity and strength complying with the appropriate specifications of the American Society for Testing Materials, the British Standards Institution, the American Association of State Highway officials or a similar internationally recognised body.

d) Aluminium Alloy Posts-Posts shall be manufactured from one of the following alloys:

Either (i) Alloy 6061-T6, 6062–T6 or 6063-T6 complying with the following ASTM specifications where appropriate:

B 210 Drawn Seamless Tubes
B 211 Extruded Bars, Roads and Shapes
B 235 Extruded Tubes
B 241 Pipe
B 308 Structural Shapes, Rolled or Extruded.

or (ii) Alloy HT 30-WP to British Standard 1471-Drawn Tube
Alloy HV 30-WP to British Standard 1474-Extruded Round Tube and Hollow Sections
Alloy HE 30-WP to British Standard 1476-Bbars and Sections

or (iii) Approved alloy sections to other internationally recongnised specifications acceptable to the Engineer.

e) Timber Posts – Unless otherwise stated on the Drawings or in the Special Provisions, timber shall be Mai Teug, Rung, Takhien or an equivalent naturally decay-resistant species with an adequate heartwood content, approved by the Engineer. The timber shall be sound, fully seasoned, of straight grain and free from shakes, knots and other defects.

f) Post Caps – Caps for hollow posts or other hollow sections used in construction may be approved cast or sheet metal or a suitable weather resisting plastics material.

6.11.2.2 Base Housings

Base housings for metal posts carrying illuminate signs shall be of fabricated steel or aluminium alloy not less than 4.5 millimeters thick or of cast iron or cast aluminium alloy having an average thickness of not less than 8 millimeters and a minimum thickness of 6.5 millimeters.

Steel shall comply with the requirements of 6.11.2.1 c. Cast iron shall be A.S.T.M. Designation A48, Class 30. Fabricated aluminium alloy bases shall be of material complying with the requirements of 6.11.2.1 d. Cast aluminium alloy bases shall be either A.S.T.M. Designation B26 or B108, Alloy SG 70A, Condition T6.

6.11.2.3 Sign Plates

Sign plates and panels shall be manufactured from one of the following materials:

a) Aluminium Alloy

(i) Elat sheets and plates shall be one of the following alloys:
Either Alloy 5052-H34, 6061-T6 or 3003-H18 complying with A.S.T.M. Specificaiton B209.

or Alloy NS3-3/4 H, NS4-1/2 H, or HS30-WP complying with British Standard 1470

or Approved alloy sheet or plate complying with such other internationally recognised specification as is acceptable to the Engineer.

(ii) Extruded panels shall be one of the following alloys:
Either Alloy 6063-T6 complying with A.S.T.M. Specification B221

or Alloy HE9-WP, HE9-P or HE30-WP complying with British Standard 1476.

or Approved alloy complying with such other internationally recongnised specification as is acceptable to the Engineer.

b) Steel Plate, Sheet or Strip – The material shall comply with A.S.T.M. Specification A245, Grade B, British Standard 1449, British Standard 2989 or such other internationally recongnised specification as is acceptable to the Engineer.

c) Plastics, Reinforced Plastics, Treated Hardboard and other materials.
Plastics materials shall be self coloured or capable of being indelibly marked and shall be manufactured in one of the following forms:

(i) Composed entirely of plastics materials.

(ii) In which the informative face or faces are entirely composed of plastics materials

(iii) Constructed with a core entirely enclosed in plastics materials. Laminated or fibrous cores (e.g. plywood, fibreboard) shall be weatherproofed by impregnation.

Hardboard shall be of the fused or tempered type and smooth on both sides.

Sign plates (or boards) shall be manufactured from 2 mm. thick aluminium alloy panels conforming to the Drawings and to Section 6.11.2.3 a) (i) of these Specifications.

For all signs, direct contact between aluminium and concrete or between aluminum and steel shall be prevented by means of 2 mm. thick rubber, or a substitute material approved by the Engineer.

6.11.2.4 Frames and Stiffening

Except as otherwise provided in the Drawings or Special Provisions sign plates requiring frames or stiffening as specified under sub-clause 6.11.3.5 shall have adequate ribs or flanges as an integral part of the sign plate or shall have frames or stiffening members of material complying with the following.

a) A metal frame or stiffening bars constructed of structural sections in steel or aluminium alloy complying with the appropriate specifications of sub-clauses 6.11.2.1 and 6.11.2.3.

b) A timber frame of material complying with 6.11.2.1e.

Metal frames for signs mounted on a single post shall be constructed of 40x40x4 mm. steel angles, galvanized as defined in the Drawings in conformance with Section 6.11.2.1 (C) of these Specifications.

6.11.2.5 Fixtures and Fittings

Brackets and clips shall be manufactured from approved cast metal, steel, stainless steel or aluminium alloy.

Screw, bolts, nuts and washers shall be of steel, aluminium alloy or of a high tensile non-corroding metal. Washers in contact with surfaces which may be damaged by overtightening of nuts or bolts shall be of a suitable soft and weather resisting material.

Steel fixings and fittings which are in contact with aluminium shall be coated with zinc or cadmium. All steel fittings shall be rustproofed. Rivets shall be made from copper, brass, aluminium alloy or pure aluminium. Brass, copper, lead or nickel shall not be used in contact with aluminium.

Bolts shall be galvanized of ∅ 10 mm. or ∅ 3/8" as shown on the Drawings.

6.11.2.6 Electrical Components – General

Electrical equipment and parts shall comply with the provisions of sub-clauses 6.12.1.2, 6.12.1.3 and 6.12.1.4 of these Specifications.

6.11.2.7 Wiring

The provisions of sub-clause 6.12.2.2 of these Specifications shall apply except that for "lighting columns" and "columns" read "illuminated signs".

6.11.2.8 Switching

The provisions of sub-clause 6.12.2.3 of these Specifications shall apply.

6.11.2.9 Preservatives, Paints and Finishes

All coatings, paints, varnishes and enamels used in the preparation and finish of the signs, posts and fittings shall be of the best quality, specially made for the purpose they shall serve, and of brands and types acceptable to the Engineer. To ensure compatibility, primers, undercoats and finishing costs shall, wherever possible, be of the same manufacture. All materials shall be stored, and used within such time limits, as specified or recommended by the manufacturers or in accordance with the directions of the Engineer.

Zinc coating (galvanizing) on steel parts shall comply with A.S.T.M. Specification A 123 or A 153 as appropriate.

All paint used for steel parts, other than finishes on a sign face, shall be high zinc oxide content coating material of approved formulation containing a minimum of seven kilograms of zinc oxide (acicular type) per one hundred litres of coating material (sixty pounds per one hundred U.S gallons). The colour of the primer shall be different form succeeding coatings.

Priming paints for aluminium alloys, when required, shall be pigmented with chromates or chromes (excluding lead chromes) except on sign faces where the specified finish is unsuitable for use with such primers.

Reflective sheeting shall be " Scothchlite" Engineer Grade or other approved colourfast reflective material applied in accordance with the manufacturer's specifications or instructions.

Plastics sheeting, film, sheathings and sprayed plastic finishes shall be of approved types and thicknesses, of durable colour and weather resistant, and shall be fully compatible with any materials with which they will come into contact. Such finishes shall be applied in accordance with the manufacturer's specifications or instructions.

These coatings shall be in accordance with Section 6.11.2.9 of these Specifications except that all aluminium sheeting and other members shall be anodized by a process approved by the Engineer.

Sign plates shall be covered with "Scotchlite" Engineer Grade or other approved colorfast reflective plastic sheeting over the whole front surface to the specified background colors.

All plastic sheeting shall be affixed to the sign plate with a heat activated adhesive properly applied in accordance with the sheeting manufacturer's specification and instructions. All joints in the sheeting shall be overlapped (from the top when practicable) and no butt joints will be permitted. Overlaps shall be not less than 6 mm. and sheeting shall extend over top and bottom edges and down side legs by at least 3mm. Words, figures and other symbols shall be applied to this sheet material by the silk screen method using a translucent paint for colored parts and an opaque paint for black parts all as approved by the manufacturer of the "Scotchlite" or other approved sheeting.

The whole of the face and edges of each finished sign plate shall have a full glossy coat of clear lacquer applied at the time of fabrication of the sign, and of a type specified or supplied by the manufacturer of the sheeting material.

Back of aluminum sign plates shall not be painted. Galvanized steel framers, brackets, bolts and nuts shall not be painted.

6.11.2.10 Reflective Beads

Beads for reflectorization of signs shall be of good quality, optically clear, lead-free glass with not less than 90% reasonable spherical and free from flaws. The beads shall contain not more than one per cent of sharp angular particles and not more than one half per cent of foreign matter and shall be free flowing under normal atmospheric conditions.

For reflectorizing white and yellow, the beads shall have a reflective index of not less than 1.90. For reflectorization of other colours the refractive index shall be not less than 1.60 and not greater than 1.70.

The beads shall contain not less than 80% by weight within one of the size ranges specified below.

Size Range Microns	**Size Range U.S. Sieve Sizes**
250-177	60-80
210-149	70-100
177-125	80-120
149-105	100-140
125-88	120-170
105-74	140-200

The binder for the beads shall be formulated so as to provide maximum bead retention, high specular reflection and a firm bond with the surface to which it is applied.

6.11.3 Design and Construction

6.11.3.1 General

Wherever possible, signs shall be mounted on existing posts, lamp columns, walls and structures. The obstruction of sidewalks shall be avoided. Design and construction of signs shall be such that all sign plates, posts, fittings, lighting units, electrical equipment and conduit can be assembled and erected without site modification.

All signs considered by the Engineer to be in the way of reconstruction or rehabilitation works shall be carefully removed in accordance with section 2.1 of these Specifications. Road signs so removed but in good condition and still necessary to the proper signing of the road shall be reinstalled in accordance with Section 6.11.3.26 of these Specifications.

6.11.3.2 Mounting Posts

Posts shall be adequate in number and size to support the signs and any lighting fittings attached to the frames or posts. Where apertures are cut in posts for cable entry etc. due allowance shall be made to ensure that the post will be of adequate strength.

Post shall be such that, at a wind pressure of 150 kilograms per square meter, the maximum deflection at the centre of the sign is limited to one fortieth ($1/40^{th}$) of the height measured from the ground for signs mounted on a single post and to one eightieth ($1/80^{th}$) for signs mounted on more than one post.

The lengths of posts shall be adequate for the requirements allowing for embedment in the ground and/or extensions for lighting fittings. All posts shall be effectively prevented form rotation in the ground and if necessary in the case of metal posts, suitable metal base plates shall be provided for this purpose. Unless otherwise shown on the Drawings base plates shall be not less than 4.5 millimeters thick and shall have an area of not less than five times the plan area of the post. Effective means for securing the base plate to the post shall be provided.

Where a post has to be sited close to a wall either the top of the post shall be angled away from the wall to provide adequate clearance for the sign or an adequate bracket or brackets shall be provided form the post for this purpose. In either case the post shall be of adequate strength and rigidity to withstand the additional bending moments and torsion resulting form the arrangement.

All open ended posts, or other hollow sections used in construction shall be effectively capped to prevent the entry of water.

Construction of reinforced concrete and prestressed reinforced concrete posts shall be in accordance with Section 5.1.3 of these Specifications, respectively, and as approved by the Engineer. All surfaces above ground shall receive a rubbed finish.

Timber posts above ground shall be smooth planed.

6.11.3.3 Base Housings

Base housings for posts shall have ample accommodation for the electrical components to be fixed therein. Suitable means shall be provided for fastening the posts firmly to the base housings. Base plates shall have an area not less than two and a half times the plan area of the base housings and shall be not less than 4.5 millimeters thick in the case of steel and aluminum plate and not less than 6.5 millimeters thick for cast housings.

A service door or panel of rigid construction shall be provided to give ready accessibility for maintenance purposes. The door or panel shall be weatherproof and shall be capable of being secured with key fastenings. Screws shall be of non-corrosive metal and captive. Screws of a self tapping type shall not be used.

Ventilation and drainage, sufficient to prevent undue condensation, shall be provided and the bottom of the housing shall be sealed to prevent the upward seepage of water. Arrangements shall be made for the service cable or conduit to enter the base housing at any depth between 15 and 30 centimeters below ground level and it shall be possible to lift away the post and housing without breaking the service joint. Cable entry holes shall be sealed, with a suitable gland, against the entry of dirt or water. Adequate earthing arrangements shall be provided.

6.11.3.4 Sign Plates

Aluminum alloy plates and panels shall have a minimum thickness of 2 millimeters. Steel plates and panels shall have a minimum thickness of 1.5 millimeters. Hardboard panels shall have a minimum thickness of 5 millimeters. Sign plates constructed of other materials shall be of adequate rigidity and strength and shall be suitable for the finishes which are to be applied to them. Where the Engineer so directs, tests shall be carried out to determine the suitability of a material and its finish for use as a sign plate.

Extruded plank type aluminium panels may be of either the interlocking or bolted type. Cold formed plank type steel sections bolted together through the flanges may also be used for panels. Where such panel sections are used the ends of the sections shall be covered to present a flanged appearance such that the edges of the sign present the same appearance all round.

Sign plates and panels shall be cut accurately to the shapes and sizes specified on the Drawings or as required by the Department's Traffic Control Device Manual. All mounting holes shall be accurately located and, after drilling or punching, any burrs, rough spots and loose material shall be removed. All holes shall be drilled before painting.

6.11.3.5 Frames and Stiffening

Except where ribs or flanges are an integral part of the sign plate and provide the necessary stiffening, sheet metal sign plates exceeding one meter in any dimension shall be stiffened by the attachment of a frame or stiffening member (s) to the back of the sign plate.

The post or posts supporting a sign may be taken into consideration for stiffening purposes. A bracket may form the stiffening frame or part of it.

The frame for a sign plate or plates shall be simple in design and shall have the minimum number or members to give it the required stiffness.

The stiffening or frame for a sheet metal sign plate may take the form of flanges round the edges of a sign, welded ribs or steel or aluminium sections with a minimum thickness of 2 millimeters. Where flanges are provided they shall be uniform on all edges of the sign.

Where metal frame members join they may be welded or joined with suitable brackets and nuts and bolts but in all cases the joints shall be strong enough to withstand the stresses induced in them.

Timber frames shall be constructed from smooth planed section of adequate cross-sectional area with half lapped joints. Particular attention shall be given to stiffness and weatherproofing of joints.

6.11.3.6 Fixture and Fittings

Where necessary or desirable signs shall be mounted on existing suitable highway furniture, buildings or structures by means of a properly designed bracket or brackets.

The method of fixing sign plates, frames and brackets to posts shall be such as will facilitate removal for replacement or maintenance purposes and permit adjustment in the position of a sign without detaching it from its post or posts, but the sign and any framing shall be held firmly enough to withstand the load to which it will be subjected. Signs mounted on single posts shall have fixing to prevent the forced rotation of the signs on the posts. Clips and brackets shall be shaped to secure a firm hold on the post without placing any bending strain on the sign plate.

Where materials with different coefficients of expansion are fixed together, allowance for this shall be made so that the sign will not fail by shearing or buckling of fixing bolts, rivets or welds.

Where dissimilar metals are joined together, precautions shall be taken to prevent electrolytic action, particularly in the case of screws and rivets. This may be accomplished by using paint, lacquer or other suitable means to eliminate metal to metal contact.

Brackets used in the construction of signs may be manufactured from sheet or strip aluminium alloy, extruded sections, cast aluminium alloy or may be fabricated from steel

sections. The minimum thickness of material shall be 3 millimeters. Welded joints shall be sound and their surfaces smooth. Holes shall be drilled before painting and shall be accurately located.

Steel or aluminium strip used for clips shall not be less than 2 millimeters thick.

Screws and bolts shall not be less than 8 millimeters (5/16 inch) in diameter and of adequate length, but without excessive projection of the screwed ends. In any situation where, if a screw were removed, the assembly would be insecure, that screw shall have not less than four full threads engaged when it is tight and shall be fitted with a locknut or a spring washer.

Where hollow rivets are used to connect sign plates to frames or fixings the holes shall be effectively blocked to prevent light shining through. Screw bolt or rivet heads on the face of a sign shall be as unobtrusive as possible and each shall match the colour of the part of the sign where it is located.

Caps for posts of hollow section shall be shaped to shed rainwater to the outside of the posts and adequate means of securing the caps to the posts shall be provided.

6.11.3.7 External Lighting Lanterns (Electric)

Full details of lanterns, including dimension, shall be submitted by the Contractor to the Engineer before commencement of the work.

a) Materials and design. The body of the lantern and its fittings shall be of robust construction, of ample dimensions, and shall be made of cast or sheet metal, or of weather-resisting plastics material. Sheet metal shall have a thickness of not less than 1.5 millimeters.

Both the exterior and interior surfaces shall be reasonably smooth to prevent the accumulation of dirt and to facilitate cleaning. The upper surface shall be shaped to shed rainwater.

The lantern shall be of the enclosed type and access to the interior shall be by a hinged bowl or door, which shall seat closely when fastened. The fastenings shall be key operated.

If a gasket is used it shall be capable of withstanding the operation conditions without deformation or softening, and shall be attached in such a way that it will be retained in position when the bowl or door is repeatedly opened for maintenance purposes.

When closed the lantern shall be waterproof and means of ventilation shall be provided.

b) Electrical components – Two lampholders, wired in parallel, shall be provided, securely mounted and correctly located, for the lamps appropriate to the size of sign, as given below.

Lanterns shall be capable of accommodation tungsten filament pearl lamps of any of the ratings given below.

Size of sign			**No. of lamps and rating**			
Up to 0.6	x 0.6	meter	2	x	25	watt
Up to 1.25	x1.25	meter	2	x	40	watt
Up to 1.8	x1.8	meter	2	x	60	watt

Alternatively, the lantern may be arranged for approved tubular fluorescent lamps. All lanterns shall be supplied complete with the necessary lamps.

The electrical wiring shall be totally enclosed in conduit. A readily accessible terminal block so insulated or shrouded as to prevent the accidental contact of a person with the live terminal, and an earthing terminal shall be provided. A 3-pin socket may be used instead of the terminal block and earthing terminal. Conduit tubing shall not be visible form the front of the sign.

c) Optical components – Separate reflectors shall be of anodized aluminium, vitreous enamelled steel or other suitable material. The surface of refractors not wholly within the lantern shall be protected by a hermetically sealed cover plate. Diffusers shall be of glass or plastics material and shall have smooth interior and exterior surfaces.

d) Finish – The surface of lanterns shall be finished with approved paint, enamel or vitreous enamel.

e) Photometric Performance – The light distribution of the lantern shall be such that when it is mounted with the appropriate sign the following conditions are satisfied in respect of the white portions of the sign :

(i) The average luminance of the sign shall be between 40 and 110 cd/m^2 (4 and 10 cd/Sq.ft).

(ii) The maximum luminance of the sign shall not exceed 325 cd/m^2 (30 cd/Sq.ft).

(iii) The distribution of illumination shall be reasonably uniform and the illuminated sign shall not present a patchy appearance. The ratio between the maximum and minimum luminance shall not exceed the following values.

Size of sign			Limiting ratio		
0.6	x 0.6	meters	10	:	1
1.25	x 1.25	meters	30	:	1

1.8 x 1.8 meters	40 : 1

(iv) No light shall be emitted direct from the lantern towards oncoming traffic and light spill shall be kept to a minimum.

f) Lantern Brackets – The length of the conduit bracket supporting the lantern shall be such that the outside edge of the lantern does not project more than the following distance from the front surface of the sign :

Depth of sign (meters)	0.75	1.20	1.80	2.70	3.60
Maximum outreach (meters)	0.45	0.60	0.90	1.10	1.35

The lantern shall be mounted so that :

a. the main illumination is downwards
b. the lantern does not obscure part of the sign

Conduit brackets shall be of adequate dimensions to minimize relative movement between the lantern and the sign due to vibration. Means shall be provided to prevent the lantern turning on the bracket.

6.11.3.8 Internally Illuminated Signs

a) General – Full details of the signs and their fittings, including dimensions, shall be submitted by the Contractor to the Engineer before commencement of the work.

The exterior of the sign shall have no sharp edges or protuberances and the exterior and interior surfaces shall be reasonably smooth to prevent the accumulation of dirt and to facilitate cleaning. The upper surface shall be shaped to shed rainwater.

b) Sign Housing – Sign housings shall be of cast or sheet metal or of weather-resisting plastics material, of adequate rigidity and strength, and so designed and constructed that light sources and any electrical gear are readily accessible for cleaning and maintenance purposes.

The housing shall be such that the assembled sign is waterproof and means of ventilation shall be provided.

Access doors or panels shall be of rigid construction, designed to seat closely when fastened and fastenings shall be key operated. Screws used for securing access doors and panels shall be non-corrosive and captive. Screws of a self tapping type shall not be used.

Gaskets shall be capable of withstanding the operating conditions without becoming permanently deformed, softened or hardened and any adhesive used for fixing them shall be chemically compatible with the gasket material and with the material to which the gasket is fastened.

Gaskets used to retain the face of a sign shall be so designed that the face is not easily removable by unauthorised persons and shall be positively held in position so as not to work loose during maintenance operations. Circular signs shall have means to prevent the sign face rotating.

Cable entry holes shall be sealed with a suitable gland against the entry of dirt or water.

The method of fixing the housing to the mounting post or posts shall allow easy removal for maintenance or replacement purposes and provision shall be made to prevent the forced rotation of a sign when it is mounted on a single post. Fixing holes and holes for reflectors shall be made before painting. The internal finish of metal housings shall be of approved white enamel.

c) Sign Face – The material used for the sign face shall be clear, opal or self coloured acrylic sheet with a minimum thickness of 3 millimeters or toughened glass with a minimum thickness of 4 millimeters. Other materials may be used provided their optical properties and mechanical strength in resistance to bending and impact are at least equivalent to those of acrylic sheet or toughened glass.

The legend symbol or border appearing on the sign face may be of plastics material in the form of foil or sheeting, paint, ink or screening paste, or an other material which is chemically compatible with the material used in the sign face and appropriate to the method of construction. Paints, inks or screening pastes used on acrylic sheet shall be acrylic based, material used in bonding acrylic sheet and forming fillets shall be approved bonding acrylic cement and any adhesive or solvent used on acrylic sheet shall be chemically compatible with it. In all cases, colours and diffusing surface shall have a uniform appearance.

Due allowance shall be made for differential expansion between the sign face and any retaining material and holes for fixing purposes shall have adequate clearance. Holes drilled in acrylic sheet shall be positioned to that their edges are not less than their own diameter from the edge of the sheet.

d) Electrical Components – Lampholders shall be provided, securely mounted and correctly located, for two standard tubular fluorescent lamps wired in parallel or one such lamp normally alight plus a second lamp (which may be a tungsten filament pearl type) arranged to come into service when the first on fails. For small signs the alternative of two tungsten filament pearl lamps may be acceptable. The lampholders, ancillary gear and wiring shall be to a three pin plug and shall be mounted on a frame so that the whole assembly can be removed from the sign without the use of tools.

A readily accessible terminal block and fuses shall be provided in the base of a supporting post for each illuminated sign. The terminal block shall be so insulated or shrouded as to prevent the accidental contact of a person with the live terminal and an earthing terminal shall be connected to the lampholders and to the base housing.

e) Optical Performance – The following conditions shall be satisfied in respect of white portions of the sign face when in new and clean condition.

(i) The average luminance of the illuminated portions shall be between 45 and 215 candelas per square meter.
(ii) The variation of luminance when viewed normally to the surface shall not exceed a ratio of 15 of 1.
(iii) The luminance at any point shall not exceed 540 candles per square meter.

6.11.3.9 Preparation and Painting

a) General – All painting and finishing shall be carried out in clean, dry surroundings using heat lamps for drying and ovens for baking as may be needed. All paints shall be applied with a pressure spray to form a smooth even film and all surfaces and edges shall be coated unless stated otherwise. Paint shall be applied only when the surface or previous coat is dry.

The following requirements shall, unless otherwise provided in the Special Provisions or on the Drawings, apply to preparation and painting of sign components other than the finish on sign faces, but excluding plastics signs and components with finishes of reflective and plastics sheeting, film, sheathings and other proprietary finishes.

b) Aluminium Alloys – Aluminium alloys, other than sign faces, shall not be treated or painted unless they are in contact with earth. Surfaces in contact with earth shall be prepared as described in the next paragraph and two coats of approved asphaltic paint shall be applied.

Before painting, the surfaces of aluminium alloy sign plates shall be thoroughly degreased and pretreated by anodising or by an equivalent process or by using an etching primer.

The prime coat shall then be applied. The back and edges of the plate shall receive a finish coat of light grey enamel.

c) Steel Surface – All Steel components shall be rustproofed by galvanishing, cadmium plating or other approved treatment prior to painting. Where necessary the surface shall be cleaned and degreased before painting. All surface other than screws, bolts, nuts and washers, shall then receive one prime coat of high zinc oxide paint. All surfaces, other than sign faces shall receive a finish coat of high zinc oxide paint, tinted light grey.

d) Cast Iron – Cast iron surfaces shall be cleaned and painted with red lead primer. Subsequent painting shall comprise at least one undercoat and one top coat.

e) Hardboard – The surface shall be thoroughly clean and dry before painting. The whole surface shall be painted with an approved primer and the back and edges shall then receive a finish coat of light grey enamel.

6.11.3.10 Finish of Sign Faces

Recommendations by the manufacturers of paint, reflecting materials, plastics sheeting or other finishes, regarding the preparation of surfaces prior to the application of the finish and protection of the finish, shall be carefully followed.

The finish on the face of a sign shall present an even surface free form twists, cracks or faults or any other blemishes. When reflecting sheeting or film is used it shall, where possible, be in complete sheets. Joints shall be kept to a minimum but where they are necessary they shall be constructed in accordance with the maunfacturer's instructions. Care shall be taken to ensure a proper day and night colour match at joints.

Enamel surfaces shall consist of one undercoat and one top coat, applied and stoved, of uniform thickness, homogeneous and uniform in colour with an egg shell flat finish.

Legends shall be carefully coloured at their edges to ensure true proportions. On signs where light colours are applied over dark, at least two coats of light colour shall be applied.

Bead type reflectors shall be securely fixed to signs without appreciable reduction of the effective area of the beads. The beads shall be uniformly and closely spaced, giving a smooth and easily cleaned surface without interstices which can retain dirt or moisture. Beads shall not cover the black portions of signs.

6.11.3.11 Excavation and Reinstatement

The provisions of sub-clause 6.12.3.1 of these Specifications shall apply.

6.11.3.12 Concrete Embedment of Posts

Where so indicated on the Drawings the bases of posts shall be embedded in concrete. Concrete shall be class C and shall contain the minimum quantity of water necessary to produce a mix that can be tamped and rammed round the base of the post such that the post will be firmly held in position immediately after completion of placing and compaction.

The minimum thickness of concrete embedment and its height shall be as shown on the Drawings.

The post shall be carefully positioned and plumbed and struts and stays applied as necessary to hold it in position during embedment. The concrete shall then be placed round the post in uniform lifts not exceeding 20 centimeters and each lift thoroughly rammed. Care shall be taken to avoid contamination of the concrete from the surrounding surface and soils. Any contaminating material falling into the concrete shall be immediately removed.

All the concrete embedment for a post shall be provided in one operation and where the surface of the concrete embedment is above the level of the surrounding surface the exposed

portion shall be formed to present a neat and tidy appearance and sloped to shed water away from the post.

6.11.3.13 Conduits and Fittings

The provisions of sub-clause 6.12.3.3 of these Specifications shall apply.

6.11.3.14 Pull Boxes

The provisions of sub-clause 6.12.3.4 of these Specifications shall apply, except that inscriptions on covers shall be "Road Signs".

6.11.3.15 Relocation of Existing Road Signs

Existing road signs and posts which, in the opinion of the Engineer, are still in good and usable condition and necessary to the proper signing of the completed road, shall be removed, cleaned thoroughly repainted if necessary and reinstalled nearby in the location designated by the Engineer. Road signs not designated to be reused or relocated shall, upon removal, be cleaned and transported to a location as directed by the Engineer.

6.11.4 Inspection and Testing

Testing of electrical installations shall be in accordance with the provisions of sub-clause 6.1.2.3.5 of these Specification.

Before fabrication of signs the Contractor shall supply an example of each type of sign with information concerning equipment and procedures and state the location of the workshops manufacturing the sings. The Engineer will inspect the facilities and, if satisfactory, issue approval to fabricate the remaining signs.

When so requested by the Engineer, samples of preservatives, paints and finishes shall be supplied by the Contractor and shall be tested by him as directed by the Engineer for the appropriate conditions (exposure, compatibility of materials, bondings, reflectance etc.) Testing shall be carried out for sufficient time to ascertain the quality and/or suitability of the materials.

6.11.5 Measurement and Payment

The contractor shall make his own templates dimensioned in accordance with the standards of the Department and shall supply all frames, bolts, nuts, washers, straps, temporary jigs and strutting, etc. necessary to erect the complete signs correctly positioned and aligned at locations shown on the Drawings or as directed by the Engineer.

Payment for Sign Posts and Road Signs shall be full compensation for furnishing and erecting all materials including labor, tools, testing, frames, hardware and incidentals necessary to complete the work.

6.12 STREET LIGHTING

6.12.1 General

6.12.1.1 Description

This work shall consist of the supply of all lanterns complete, brackets, columns and other supporting devices, bases, cables, switchgear and all necessary ancillary equipment together with the transportation, storage, assembly, erection, connection and testing of the same in order to supply a complete street lighting system in accordance with the details shown on the plans and as specified herein and in the Special Provisions if any. Design of the system may be included.

If shown in the Contract Drawings and designated in the Tender document, this work shall consist of modifying and/or adding to an existing street lighting system or construction a new street lighting system, as the case may be. To the greatest extent possible all materials, above ground and underground, used in existing lighting system in accordance with the following articles of these Specifications shall be prepared by the Contractor and submitted in three copies including design calculations, drawings, Wiring diagrams and requirement and materials list to the Engineer within three (3) months after the commencement date of the Contract.

All underground utilities are not necessarily shown on the Drawings and locations of underground utilities as shown on the Drawings are approximate only.

The Contractor shall search for and take special precautions to protect any existing utility services such as power lines, telephone lines, gas and oil pipelines, sewers and water works affected by his operations at his own cost, and shall minimize and be responsible for any damage cause thereby. He shall at all times and at his own expense conduct his operations in accordance with the requirements of the Utility Authorities having jurisdiction.

The following data shall be furnished by the Contractor to the Engineer and shall be included in the design documents:

a) catalogs of electrical components; lanterns, ballast, etc.

b) Plans and circuit diagrams, ground road connection diagram.

c) Photometric data ;

- i) Utilization Curve
- ii) Isocandela Diagram
- iii) Horizontal Iso Foot Candle Diagram
- iv) Polar Light Distribution Curve

d) Details of columns, brackets, base plates.

6.12.1.2 Responsibility for Design and Materials

Items of equipment and parts shall have maker's specifications agreeing with those of the U.S.A. Standards Institute, the American Society for Testing Materials, the American Association of State Highway Officials, the National Bureau of Standards, the British Standard Institute, the British Institute of Electrical Engineers Regulations of other similar internationally recognised body. All works shall be done and all goods shall be made in strict accordance with the requirements of the Electrical Code of the Kingdom of Thailand and of the regulations of the Electricity Supply authority concerned.

The Contractor shall be solely responsible for the adequate design and the co-ordinated functioning of all goods and construction furnished under this contract. All the component parts shall be designed so as to ensure their proper co-ordinated functioning and operation. All equipment shall be of the maker's standard models and shall include all recent improvements in design and materials. All materials used in manufacture and construction shall be of high quality and fully in accordance with the best modern practice.

The equipment offered and the work done shall be suitable for continued trouble-free operation under adverse climatic conditions of heavy rain, high humidity and intense sunlight. The equipment must be able to withstand over long periods ambient air temperatures varying from a normal of 40 C° to a maximum of 50 C°.

6.12.1.3 Compliance with Manufacture's Specifications

The Contractor shall ensure that the equipment and parts used will be entirely suitable for the work to be performed and that they will be manufactured to proper clearances and fit. He shall further ensure that the loading of equipment will under all normal circumstances not exceed the maximum laid down or agreed in writing by the manufacturer.

The Contractor shall be responsible for the inspection of all equipment and parts before their incorporation in the works to ensure that they comply with the conditions of the Contract and that they are not defective in any way as regards materials or work-manship. Should any such non-compliance or defects be found during the inspection, the Contractor shall correct or cause to be corrected such non-compliance and defects, all at the Contractor's expense and to the satisfaction of the Engineer.

6.12.1.4 Maintenance Period

All repairs and replacements required during the Maintenance Period shall be carried out with despatch and an adequate supply of spares shall be available for this purpose.

6.12.1.5 Electricity Supply

The Contractor shall carry out negotiations with the Electricity Supply Authority concerned for an electricity supply to the installation, and any costs associated with obtaining this supply shall be included in the Contract rates. The Contractor must ensure that the equipment supplied will function correctly at the supply voltage, and must allow for normal variations and surges.

6.12.1.6 Definitions

Unless specifically defined herein, definitions shall be as given in British Standard 892 : 1967 "Glossary of Highway Engineering Terms" and in British Standard Code of Practice CP 1004 "Street Lighting" both as amended at the time of Tender.

a) Lantern A housing for one or more lamps comprising the body and any refractor, reflector, diffuser or enclosure associated with the lamp or lamps.

b) Outreach The distance measured horizontally between the center of a lantern mounted on a bracket and the center of the column or wall face.

c) Overhang The distance measured horizontally between the center of a lantern and the adjacent edge of the pavement.

d) Mounting Height The vertical distance between the center of lantern and the surface of the pavement.

e) Spacing The distance measured parallel to the center line of road, between successive lanterns. In a staggered arrangement, this distance is measured parallel to the center line from the center of a lantern on one side of the road to the center of the next lantern on the opposite side.

f) Beam That portion of the light output of the lantern contained by the solid angle subtended at the effective light center of the lantern containing the maximum intensity but no intensity less than 90% of the maximum intensity.

g) Luminous Flux The light given by a light source of lantern or received by a surface, irrespective of the direction in which it is distributed. The unit of luminous flux is the lumen.

h) Lower hemispherical Flux or Downward Flux The luminous flux emitted by a lantern in all directions below the horizontal.

i) Peak Intensity Ratio The ratio or the maximum intensity to the mean hemispherical intensity of the light emitted below the horizontal.

j) Mean Hemispherical Intensity The downward flux divided by 6.28. (This is the average intensity in the lower hemisphere).

k) Intensity Ratio The ration of actual intensity in any direction of lantern to the mean hemispherical intensity.

l) Luminous Intensity the light giving power of a lantern in any particular direction. The unit of luminous intensity is the candela (cd).

m) Beam Center A direction midway between the directions for which the intensity is 90 percent of the maximum in a vertical plane through the maximum and on a conical surface through the maximum.

n) Isocandela Curve A curve traced on an imaginary sphere with the source at its center and joining all the points corresponding to those directions in which the luminous intensity is the same, or a plane projection of this curve.

o) Isocandle Diagram An array of isocandela curves.

p) Polar Curve Curve of light distribution using polar coordinates.

6.12.2 Materials and Equipment

6.12.2.1 Lanterns

a) Lanterns shall be of the cut-off or the semi-cut-off type as shown on the Drawings or as specified in the Special Provisions. Non-cut-off lanterns shall not be used.

b) Unless otherwise specified, the mounting height shall be not less than 7.6 meters (or 25' 0") nor more than 12.2 meters (or 40' 0"). At junctions, or where high mast lighting is specified, this maximum height may be exceeded, but in such case, a means must be provided to lower the lanterns for repair and cleaning.

c) Where there is no speed limit on the road or where there is speed limit of more than 60 kilometers per hour the minimum clearance between columns and the edge of the pavement shall normally be 1.5 meters but where this is not reasonably attainable, the minimum clearance may with the previous permission of the engineer be reduced to 1.0 meter.

Where there is a speed limit of less than 60 kilometers per hour the minimum clearance between columns and the edge of the pavement should be 1.5 meters but this may be reduced to:

0.50 meter for crossfalls of not more than 1 in 40 towards the curb
0.60 meter for crossfalls of between 1 in 40 and in 24 towards the curb
0.75 meter for crossfalls of more than 1 in 24 towards the curb
with the previous permission of the Engineer.

d) Each lantern should normally direct two beams along the length of the road. The polar curves of the lanterns in both horizontal and vertical planes should be smooth and free from any abrupt variations so that the luminous intensity diminishes smoothly and progressively from its maximum. For centrally mounted lanterns the beams should be approximately axial; for lanterns mounted at the sides of the roadway, the maximum toe-in of the beam will be 15°. Adequate but not excessive light should be directed towards the curbs and outer edge of the road. Where area illumination is required using high mast lighting, these provisions shall not necessarily apply.

e) For cut-off lanterns, the beam should be in a direction about 65° from the downward vertical. The peak intensity ratio shall be between 2.0 and 4.0; the intensity in the zone 0° to 30° below a horizontal plane through the lantern shall be between 0.3 and 2.0. An intensity ratio of 1.2 shall lie between elevations of 72° and 78° from the downward vertical in the vertical plane parallel to the axis of the roadway and the horizontal intensity ratio in the same plane shall be not greater than 0.15.

f) In the case of semi-cut-off lanterns, the beam should lie in a direction about 75° from the downward vertical. The peak intensity ratio shall be between 1.8 and 4.0. The intensity ratio in the 0° to 30° zone below a horizontal plane through the lantern shall be between 0.3 and 1.7. An intensity ratio of 1.2 shall lie between elevations of 78° and 84° from the downward vertical in the vertical plane parallel to the axis of the roadway and the horizontal intensity ratio in the same plane shall be not greater than 0.6 except that in the case of sodium lamps, the intensity ratio of 1.2 shall lie similarly between 80° and 86° and the horizontal intensity ratio in the same plane shall not exceed 0.7.

g) The siting of lanterns shall be in accordance with the following table which gives minimum required illumination. Particular care shall be taken with the siting of lanterns on bends and summit vertical curves. At junctions and roundabouts, lantern spacing shall be designed so as to give at least the minimum illumination required by the following tables and also lanterns shall be spaced and sited, where possible, so as to delineate the course of the roadway plainly to road users approaching from any normal direction without any possible misleading impressions. The level or illumination provided at road junctions and roundabouts shall be at least as high as that on any of the approach roads and in the case of roundabouts shall be at least as high as that on any of the approach roads and in the case of roundabouts, a minimum level of illumination at any curb line of 10 lumens per square meter shall be provided.

Required Minimum Average Horizontal Illumination in Lumens per Square Meter (Lumens per Square Foot)

	Central Urban Areas	Sub-Urban Areas	Rural Areas
High Grade Motorways	21.5 (2.0)	15.0 (1.4)	10.75 (1.0)
At Junctions	21.5 (2.0)	21.5 (2.0)	15.0 (1.4)
Main Route	21.5 (2.0)	13.0 (1.2)	9.7 (0.9)
Secondary Routes	13.0 (1.2)	9.7 (0.9)	6.5 (0.6)
Local Roads	9.7 (0.9)	6.5 (0.6)	2.1 (0.2) (Residential areas only)

The Contractor shall certify that the design of the installation has been done in accordance with "American Standard Practice for Roadway Lighting," (D 12.1-1963) published by the Illuminating Engineering Society, 345, East 47th street, New York, or in accordance with British Standard Code of practice CP 1004 of 1963 "Street lighting" published by the British Standards Institution 2, Park Lane, London, W.1, except in so far as these have been varied by the provisions of these specifications or any special provisions.

All lanterns shall be new, totally enclosed, side entry, dustproof, insect proof and water tight and tested for these requirements. All lanterns shall be supplied complete with all the necessary control gear fully wired and fixed and ready for erection. The gear shall be integral with the lanterns. The lantern wiring shall be of a size and insulated with materials that will effectively withstand the current, voltage and temperatures expected within the lantern during both the starting and operating modes in the ambient temperatures of the site. The lamp compartment of the lantern shall be accessible via a hinged bowl which shall, in the closed position, bed firmly upon a soft resilient gasket which shall be firmly secured to the lantern by means of stainless steel clips and large pins. In the lowered position the bowl shall be restrained from becoming detached or blown against the other parts of the lantern or column arm or bracket. Reflector, if used, shall be mirror type and made of anodised aluminium sheet. The bowl (refractor), if made of transparent acrylic, shall not display any drop in output due to colour changes within the first five (5) years of service.

A sample lantern of the type proposed for use in this Contract is to be supplied to the Engineer for his approval, together with a certificate of approval by the Electricity Authority concerned before any installation is made. Transverse and longitudinal cross-section drawings of the lantern at 1: 10 scale shall also be furnished to the Engineer.

6.12.2.3 Switching

The switching supplied for control of lanterns shall be of a type approved by and agreed with the Electricity Supply Authority. If approved by the Supply Authority photoelectric relay switching will be permitted, each device controlling a group of lanterns.

Switching shall be by photo - electric relay.

6.12.2.4 Columns and Brackets

a) Columns shall be of steel construction and shall consist of tapered round bellow shafts with anchor bases. Each column shall be provided with a suitable cable slot and a weatherproof service door fitted with a tamperproof lock. All locks shall be of the same pattern, and six keys shall be provided for them.

b) A non-hygroscopic mounting board composed of electrically insulating material shall be fitted in an easily accessible position inside the column, and shall be of suitable size to take all necessary electrical equipment. Adjacent to this mounting board, there shall be provided on the inside of the column two stainless steel studs, not less than 4 centimeters long nor less than 8 millimeters diameter and complete with stainless steel lock nuts and washers, for use as earthing connections.

c) Brackets to provide the required outreach shall be of sufficiently strong construction to support the lantern under all normal conditions without significant movement, and shall be provided with suitable fittings to take the lanterns. When in position, brackets shall be inclined upwards at an angle of approximately 15° to the horizontal, and shall be fixed to their supports by suitable welding, fastenings or wall plates.

d) Columns and brackets shall be structural steel having the following mechanical properties:

-	Thickness of sheet steel (min)	4	mm.
-	Ultimate Tensile Strength (min)	4,000	kg/cm^2
-	Yield point (min)	2,500	kg/cm^2
-	Elongation (min)	21%	

e) Straightness. That part of the column above the ground shall not deviate form straightness by more than an amount calculated at a rate of 2 mm per meter of column length.

6.12.2.5 High Mast Lighting

a) Columns carrying high mast lighting shall be designed to permit the whole of the lantern carriage to be easily, safely and quickly lowered to ground level for maintenance works. The columns shall be designed in accordance with British Standard 449 or other internationally accepted standard for design of structural steelwork in buildings, except that the temporary horizontal deflection of the top of the column may be up to 7½ % of the height above ground. In calculating the bending moment at ground level due to wind load, it shall be assumed that the wind speed at a point ten meters above ground level is 60 kilometers per hour, and the design of the column shall be such that wind excited oscillations are damped as much as possible. Adequate allowance shall be made for the stresses produced by such oscillations. Details shall be given of the vertical and horizontal load and the bending moment at the foundations.

b) The base plate shall be free from laminations and all dimensions of the base plate shall be provided, including details of the holding down bolts. A cable entry hole of not less than 30 centimeters diameter shall be provided centrally in each base plate, and the bottom of the mast shall pass through the base plate and be welded on both sides. An alternative construction of equal strength may be accepted by the Engineer, but a butt weld on to the base plate will not be accepted.

Each holding down bolt shall be tensioned to the design value, and within the maintenance period, the bolts shall be checked and retightened as necessary, after which the nuts shall be repainted.

c) The columns shall be delivered to the site in the minimum practicable number of lengths. Any joints necessary shall be positioned as near the top of the columns as possible.

d) The lantern carriage shall support the designed number of lanterns without significant sway or movement, and shall be capable of supporting these lanterns and a cradle with two men for maintenance work. The lantern carriage shall be protected to prevent damage to the painted surface of the columns, rotation of the carriage during raising and lowering shall be prevented and correct location when raised shall be ensured by some positive means. It shall be possible to remove the lantern carriage without lowering the column.

e) The lantern carriage shall be raised and lowered by a self sustaining winch capable of being operated either by hand or by a portable electrically operated tool. It shall be possible to lock the winch in any position by a simple, robust and easily operated mechanism. The worm gear shall have a ratio of at least 20:1

f) The winch shall have removable handles, and it shall be mounted within the base compartment at a convenient working height. The opening in the column shall be of sufficient size to allow proper operation and maintenance of the winch mechanism. A weatherproof label shall be fixed in an obvious position within the column base, giving a full lost of all lubricating points on the winch and other mechanism, and details of recommended lubricants. Winch fixed inside the column shall be provided with a substantial cover to fully protect them from falling dirt and dust.

g) A sufficient number of turns of the hoisting cable shall be left on the winch drum when the carriage is fully lowered to ensure that the cable anchorage on the drum does not take the full load of the carriage at any time.

h) The last 30 centimeters of travel to the fully raised position of the carriage shall be by hand operation, and for this purpose either a limit switch shall be provided to cut off the power supply to the portable electric tool at the appropriate time, or else some form of indication shall be provided to indicate when the carriage is 30 centimeters from the fully raised position.

j) The winch cable shall be of stranded stainless steel wires and shall have sufficient capacity to carry safely the lantern carriage complete with lanterns and a cradle with

two men attached thereto. Great care shall be taken during installation to ensure that the hoisting cables do not twist or kink, and any set twist or kink shall be sufficient reason for the rejection of that cable.

k) All parts of the raising and lowering mechanism which are inaccessible after erection of the columns shall be adequately protected against moisture, dirt and corrosion. Where necessary, pulleys shall be fitted with shields to prevent the winch cable becoming displaced. Pulleys for electrical cables shall be of sufficient diameter that the cable will not be bent to a smaller radius than that permitted by local regulations or those of the British Institution of Electrical Engineers, 14th Edition. Where necessary for continued trouble free operation, metal parts shall be of stainless steel or other approved non-corrodible material.

m) When power tool operation is used, a suitable power outlet shall be provided and the operator shall be adequately safeguarded against any electrical shocks. The power tool shall preferable be designed to work on a reduced voltage and in this case, a suitable approved type of transformer shall be provided. The power tool shall be designed so that continuos operation will cause no harmful effects on either the winch or the tool, and in the event of power failure the winch shall be self locking. Conversion from power to hand operation and vice versa shall be quick and easy and shall not require special tools. Full information on the type of power tool proposed shall be give with the tender.

6.12.2.6 Protection Against Corrosion

Unless otherwise specified, columns, bracket arms, and brackets shall be protected against corrosion either by painting or galvanizing as follows:

a) Painting:

i) Columns and masts shall be treated internally with hot asphalt under high pressure so as to give a complete and unbroken asphaltic covering or other approved anticorrosion treatment shall be applied to give at least equally good protection. Bases shall be similarly treated up to a level of 25 centimeters above ground level.

ii) Before delivery to the site, columns, masts, steel brackets, and external fittings shall have all external welds ground down and all external surfaces cleaned by shot blasting or other approved method to a white metal finish free of all signs of rust. Immediately following this treatment the items shall be painted with two coats of tropical red lead undercoat followed by two coats aluminum paint or they shall be treated in a similar and not less effective manner acceptable to the Engineer to prevent subsequent corrosion. After erection, all imperfections and damages shall be made good to the Engineer's satisfaction and the items shall be given a final coat of aluminum paint.

b) Galvanizing:

i) Before delivery to the site, columns, masts, steel brackets, and external fittings shall have all external welds ground down. Poles and other ferrous materials shall be galvanized both inside and outside by the hot dip process in accordance with ASTM A525. Weight of zinc coating shall not be less than 550 grams per square meter.

ii) Bases of columns, both inside and outside, shall be coated with bituminous paint up to a level of 25 centimeters above the base plate.

6.12.3 Construction Methods

6.12.3.1 Excavation and Reinstatement

Excavation for cable or conduit laying or for foundations and reinstatement shall be carried out in accordance with the provisions of Section 2.5 of these Specifications. Reinstatements shall be such that the surface is restored to at least its original standard.

6.12.3.2 Concrete Work

All necessary foundations and footings or other concrete work shall be carried out in accordance with Sections 5.1.3 and 5.1.12 of these Specifications. Unless otherwise specified on the Drawings or in the Special Provisions, concrete shall be class B. Foundations shall be placed in one operation except that the top 5 centimeters may be placed after the superimposed structure is in position. The exposed portions of foundations shall be formed to present a neat and tidy appearance and sloped to shed water away from the structure supported. Where existing obstructions prevent the construction of foundations as shown on the plans, then an effective alternative may be provided subject to the prior approval of the Engineer.

6.12.3.3 Conduits, Fittings and Boxes

Conduits, fittings and boxes shall be provided and installed except that chemically stable tough plastic conduits, fittings and boxes, according to samples previously approved by the Engineer, will be permitted providing that they do not soften when exposed to high ambient temperature.

The Contractor may use a larger size of conduit than that specified, at no extra charge, if he wishes, but in this case the entire run shall be of the same size. No reducing couplings will be permitted.

When metal conduits are used, cuts shall be made square and true and all couplings shall be screwed up until the ends of the conduits are brought together in order to provide a good electrical contact throughout. The threads on all ferrous metal conduits shall be painted with a rust preventing paint before couplings are made up. Where the coating on ferrous metal conduit

has been damaged in handing, such damaged places shall be painted with rust preventing paint before installation.

All conduit ends shall be threaded and capped until wiring is started. When caps are removed, the threaded ends shall be provided with approved conduit bushings.

Conduits shall be laid to a depth of not less than 50 centimeters below paved footwalks and medians and not less than 75 centimeters below the roadway surface. The location of all conduits at curb lines shall be marked by means of a "Y" at least 10 centimeters high incised in the face of the curb directly above the conduit. Conduit terminating in standards, cabinets or pedestals shall extend at least 5 centimeters vertically above the bottom of the box. Such conduit shall be sloped towards the top of the box to facilitate pulling. Conduit entering the bottom of the box shall enter in the direction of the run.

6.12.3.4 Pull Boxes

Pull boxes shall be installed as show on the plans and in any case at not more than 60 meters intervals. The Contractor may install additional pull boxes without extra charge if he wishes. Pull boxes shall be of reinforced concrete not less than 10 centimeters thick and may be of approved pre-cast design. Reinforced concrete covers, secured by two recessed brass bolts shall be used on footwalks, the covers being inscribed "Street Lighting" on the outside. Under the roadway, covers shall be of steel or cast iron, inscribed as specified above, and laid in a suitable concrete footing to withstand traffic loads. Metal covers shall be effectively earthed to an earthing rod inside the box. Tops of pull boxes shall be effectively level with the surrounding paved areas, whether footwalk or roadway, but in unpaved areas the tops of pull boxes shall be buried 30 centimeters below ground level. The bottom of pull boxes shall be bedded in sand and cement or crushed rock. Permanent markers shall be provided and erected to show the position of all pull boxes.

6.12.3.5 Testing

A functional test shall be made on completion of the work in order to demonstrate that every part of the equipment and installation functions as intended and specified. This test shall consist of not less than five nights continuous and satisfactory operation. If any defects or unsatisfactory operation are revealed, this condition shall be corrected and the test continued until the required five nights of satisfactory operation have been performed.

Prior to the functional test, the Contractor shall carry out the following tests to the entire satisfaction of the Engineer.

i) Each circuit shall be tested for continuity
ii) Each circuit shall be tested for earthing
iii) A 'megger' test shall be made between each circuit and earth. The insulation resistance shall be shown to be at least that specified within the relevant Codes.

The distribution horizontal illumination value of specified spacing in each code item, in rate of lux measured between two luminaries every two meters along longitudinal and transverse roadway lines, are essentially measured to show maximum, mean and minimum illumination and also uniformity ratios.

$$\text{Uniformity ratio} = \frac{\text{minimum illumination}}{\text{average illumination}}$$

$$= \text{not less than } 0.40$$

$$\text{and} = \frac{\text{maximum illumination}}{\text{minimum illumination}}$$

$$= \text{not less than } 6.0$$

iv) Rainproof Test

The lantern under test shall be mounted in its normal orientation on an adjustable support as shown is BS 1788, 1964 so that the fitting is near the center of the area described by the oscillating tube.

After being switched on for one hour, the lantern shall be subjected to a spray of water at a temperature not exceeding 20°C and at a pressure of approximately 5.7 $1bf/in^2$ (0.4 kg/cm^2), the tube being oscillated so as to describe an angle of 60 degrees from the vertical and in both directions from it. This treatment shall be continued for 20 minutes, the fitting being switched off after 10 minutes.

At the end of this test, there shall be no damage to the lamp or enclosure and no visible evidence of water having accumulated in the fitting.

On the completion of testing, the Contractor shall supply to the Engineer three copies of 'as built' plans and circuit diagrams, which shall clearly indicated any modifications which have been made to the original design.

6.12.4 Measurement

Prior to the preparation of the design drawing referred to in Section 6.12.1.1 of these Specifications, the Contractor together with the Engineer shall inspect the entire existing electrical lighting system (if any) to determine the condition of any present installations and the ability of its components to be reused. Tapered steel lighting poles and column high mast mountings, with height and single or double bracket requirements specified on the drawings and/or in the Tender and fitted with high pressure sodium lamps, will be measured as sets complete including all connecting cable and ancillary items required for the operation of the street lighting system.

6.12.5 Payment

The payment for the items shall include the full compensation for all materials, labour, equipment, tools and incidentals needed to complete the work. All materials and work necessary for satisfactory completion of the installation which are not specifically mentioned in the Bill of Quantities shall be deemed to be included in the items shown.

Tapered steel poles, single or double brackets, and column high mast mounting, with high pressure sodium lumps, will be paid for at the Contract unit prices per set, complete and accepted in place, which prices shall be all inclusive of junction boxes, poles, bracket arms, luminaries, painting, rectro-reflective sheets, ballast, pole foundations, transformers (where necessary or as specified), transformer bases, cable, conduit, trenching, pull wires, cable and conduit markers, labor, equipment and incidentals necessary to the complete operation of the lighting system.

6.13 ROAD TRAFFIC SIGNALS

6.13.1 General

6.13.1.1 Description

This item shall consist of the supply of all signal heads, supports, controllers, detectors, cables, switchgear with all necessary ancillary equipment together with the transportation, storage, erection, connection and testing of the same in order to supply a complete traffic signal installation in accordance with the Drawings and as specified herein and in the Special Provisions. Design of the system may be included.

6.13.1.2 Responsibility for Design and Materials

The provisions of sub-clause 6.12.1.2 shall apply.

6.13.1.3 Compliance with Manufacture's Specifications

The provisions of sub-clause 6.12.1.3 shall apply.

6.13.1.4 Maintenance Period

The provisions of sub-clause 6.12.1.4 shall apply.

6.13.1.5 Electricity Supply

The provisions of sub-clause 6.12.1.5 shall apply.

6.13.1.6 Definitions

The provisions of sub-clause 6.12.1.6 of these Specifications shall apply.

6.13.2 Materials and Equipment

6.13.2.1 Signal Face

Each signal face shall consist of three electrically operated and controlled optical units arrange vertically. The top unit shall show red, the centre amber and the lowest green. Additional optical units may be added if required for special facilities. Suitable visors will be fitted to all optical units. Louvres and sighting screens shall be supplied if required to give the most efficient operations under all conditions. Each signal face shall conform to the sample supplied to and approved by the Department.

6.13.2.2 Optical Units

Optical Units shall consist of a lens, a reflector, a lampholder and a clear traffic signal lamp visible to the traffic to be controlled. They shall be housed in a non-ferrous corrosion resistant casing which shall be weather tight and capable of being securely fixed in direction and elevation. Access shall be provided by hinged doors which when shut shall be forced against a neoprene gasket on the body and fastened by a simple, corrosion resistant, non-detachable fastening device which does not required special tools for operation.

6.13.2.3 Lenses

Lenses shall be made from best quality glass, free from imperfections, and shall conform to the latest requirements of the relevant ASA or British Standards for colour and transmittance. All lenses will be unlettered and shall be mounted so as to display a circular area 20 centimeters (8 inches) in diameter towards the traffic to be controlled. The lens shall be so designed and finished that when it is installed in an optical unit as herein described, that unit shall, when the lamp is illuminated, display a uniformly bright area to traffic without any shadows or dark areas. The polar curve shall be reasonably smooth and free from sudden changes or secondary maxima. The mounting of the lens shall ensure that there will be no escape of light from the lamp, apart from that passing through the lens itself.

6.13.2.4 Reflectors

Reflectors may be of silvered glass or metal. Silvered glass reflectors shall conform to Clause 8.02 of the Institute of Traffic Engineers Technical Report No.1 "Adjustable Face Vehicle Traffic control signal Head Standard" as approved by the American Standards Institute. Metal reflectors shall be of non-ferrous metal not less than 0.55 millimeter thick plated with nickel and then chromium plated, or other suitable construction which is not less effective. Metal reflectors shall be stiffened and supported to prevent distortion.

6.13.2.5 Lampholders

Each lampholder shall be suitable for an Edison screw lamp or other type approved by the Engineer and the dielectric shall be of a tough incombustible insulating material which will not be affected by prolonged heating to 200°C nor by prolonged immersion in water. The lampholder shall be permanently positioned in such a way that the lamp filament shall be at focal centre of the reflector. A means shall be provided to rotate either the lampholder or the reflector so that the lamp lead-in wires will be at the top, and there shall be a suitable clamp to ensure that the lamp will not unscrew due to vibration. The lampholder shall be provided with two insulated wires of sufficient length to reach the specified terminal block at all times. The metal parts of the lampholder shall be electrochemically compatible with other contiguous metals.

6.13.2.6 Lamps

The lamps shall be Edison screw type, or such other type as approved by the Engineer, having an output of 665 lumens minimum.

6.13.2.7 Wiring

All lampholders shall be wired to a suitable terminal block mounted in the housing, and shall be ventilated to avoid condensation. Wires shall be P.V.C. insulated and free of all joints except in terminal blocks and shall be permanently colour coded to facilitate maintenance and repair. At each signal location unless shown otherwise on the Drawings there shall be a terminal compartment provided on the mounting which shall be provided with a terminal block containing 12 poles each with two screw type terminals of suitable size. A weathertight cover shall be provided to the terminal compartment which will give ready access to the terminal block, and the terminal compartment and cover shall be of sufficient strength to remain intact if the mounting pole is knocked down. Ventilation or other suitable means shall be provided in the terminal compartment to avoid excessive condensation. Connections from the signal face to the terminal compartment, where external, shall be protected by approved metallic tubing. Buried cables from the controller to signals and detectors shall be suitably armoured or laid in approved conduit and free of all joints except at terminal blocks of junction boxes. Wiring to signal will not be run to a terminal block on a signal pedestal unless it is to be connected to a signal that is mounted thereon. Sufficient conductors shall be provided to perform the functional operation of the signal system throughout and in addition between the controller and the signals three spare conductors shall be provided of size equal to the largest conductor in the run except neutral. Wires subject to bending due to opening and closing of doors shall be stranded. All metallic parts not carrying current shall form an electrically continuous system which shall be earthed, or they shall be separately earthed, using bare copper conductors with a minimum cross-sectional area of 4 square millimeters (0.006 square inches). All items below ground level shall be so designed and installed that they will continue to operate without fault if immersed in ground water.

6.13.2.8 Pedestals

Pedestals shall consist of solid drawn or longitudinally butt welded mild steel tube, 11.5 centimeters (4 ½ inches) outside diameter and not less than 4.5 millimeters (11/64 inch) wall thickness. The length of the pedestal shall be sufficient so that the centre of the lowest signal aspect will be at least 2.15 meters above ground when the foot of the pedestal is buried at least 60 centimeters below ground. A suitable base plate and finial shall be provided for each pedestal. Where necessary or desirable, signal heads may be mounted on existing suitable street furniture or buildings by means of a properly designed bracket or brackets, and where mounting has to be done close to a wall the signal head may be attached to the pedestal via a bracket, but in this case the pedestal shall be at least 12.7 centimeters (5 inches) outside diameter and at least 16.5 centimeters (6 ½ inches) outside diameter for one meter above ground level and of sufficient length so that the base of the signal head will be at least 2.4 meters above ground. Bracket shall be so designed that they will allow full adjustment of the signal heads and will support the signal heads rigidly under all normal conditions. Pedestals shall be provided with cable slots near the base and with the required cable bush holes in correct position. All cable

slots and holes shall be free of burrs and rough edges. Suitable means shall be provided to fasten base plates, brackets and signal heads firmly to pedestals and to allow adjustment where required. All nuts, bolts, fastenings, hinges and adjusting brackets on pedestals, finial, terminal compartment and signal heads shall be cadmium plated or of stainless steel or made corrosion resistant in a not less effective manner.

6.13.2.9 Painting

Pedestals and brackets shall be provided with a prime coat and two coats of undercoat before delivery and sufficient finishing coat shall be provided for final painting after erection. The signal heads, terminal compartments, visors, louvers, and sighting screens shall be delivered primed and with two undercoats and a finishing coat. Controller and other cases shall be finished with two coats of an approved aluminum paint on the outside and shall have priming, two undercoats and one finishing coat of paint on the interior. A coating of sprayed molten zinc will be accepted as an alternative to painting of cabinets.

6.13.2.10 Detectors

Detectors where vehicle actuated signals are required, shall be either pneumatic one way or two way or inductive loops.

a) Inductive Loops

Inductive loops shall consist of a loop or loops of insulated conductor, a sensor unit relay and a power source. The loop detector shall operate on the principle that a vehicle standing or crossing over the loop will cause a change in inductance which will be detected by the sensor unit, so-operating the detector relay in the signal controller. The loop shall be installed in slots cut in the highway surface or laid under the wearing course and the depth, orientation and dimensions of the loop shall be as recommended by the manufacturer. The sensor unit shall be a solid state electronic device capable of sensing changes in the inductance of one or more loops and mounted in a waterproof container which will be located and suitably housed under the roadway or footwalk close to the loop or loops.

The detector shall be so designed constructed and adjusted that:

i) It shall respond only to a vehicle passing over or standing over any portion of the loop.
ii) It shall detect vehicles passing over it at speeds up to 100 kph.
iii) The detector relay shall be de-energised immediately after a vehicle passes over it.
iv) It shall re-balance to ignore parked vehicles and shall thereafter detect subsequent vehicles passing over it.
v) It shall operated normally under any range of weather, temperature and humidity conditions and it shall not be affected by normal variations of line voltages.

vi) Where operating as a speed detector which will influence the operation of the controller, the detector shall be fully capable of detecting differences of speed which are consistent with the capabilities of the controller.

Inductive loop detectors shall detect over the entire width of the approach road leaving no gaps of more than 40 centimeters. Where required for separate detection, individual detectors will be provided for each traffic lane, and these shall be so designed and installed that there will be no mutual interference between them.

b) Pneumatic Detectors

Pneumatic detectors shall be designed to be bolted securely into a metal frame set flush in the roadway so that the detector may be replaced without disturbing the roadway surface. The detector frame shall be designed to take the full live loading to be expected on the road. The detector shall extend the full width of the approach with no gaps of more than 40 centimeters, and where required separate detectors shall be provided for each traffic lane. Operation shall be by pressure operating a pressure sensitive electrical switch which relays a demand to the controller. The pressure sensitive switch shall be waterproof and located in a waterproof container located under the roadway or the footwalk in such a way that the switch will be readily available for inspection and checking after installation. Means shall be provided to ensure that arcing in operation is reduced to a minimum so that the switch will not require frequent cleaning or adjustment.

The detector tread rubber shall extend over approximately the whole length of and the detector and shall have the following properties.

When new:	
Shore Durometer Type 'A' Hardness	- 62 to 70
Tensile strength at break	- 175 kilograms per square centimeter (2500 pounds per square inch) minimum
Elongation at break	- 500% minimum
After ageing in a Geer Over for 120 hours at 70°C	
Tensile strength at break	- 140 kilograms per square centimeter (2000 pounds per square inch) minimum
Elongation at break	- 400% minimum
After ageing in oxygen bomb for 120 hours at 70°C and 21.2 kilograms per square centimeter (300 pounds per square inch) pressure	
Tensile strength at break	- 105 kilograms per square centimeter (1500 pounds per square inch)

Elongation at break - 350% minimum

The Contractor shall provide certified test sheets from an approved laboratory for each batch for tread rubber, or other satisfactory evidence that the tread rubber is of approved type. The number of joints between the rubber tread and the pressure sensitive switch shall not exceed two. The tube connecting the tread and the pressure switch shall be readily replaceable and laid within a protective conduit which shall be kept free of water. A separate pressure switch shall be provided for each tread.

Pressure sensitive detectors shall be capable of being operated by wheels having a wheel load of 25 kilograms or more. Detectors shall actuate at speeds up to 100 kilometers per hour under normal conditions. When provided with suitable relay equipment, directional detectors shall operate to make a demand on the controller when a vehicle crosses in one direction but not when it crosses in the opposite direction. When a detector is required to operate as a speed detector, the treads shall be spaced sufficiently far apart that differences of speed will be detected which are consistent with the capabilities of the controller.

For each detector, whether inductive or pressure sensitive, a button shall be provided at the controller which can simulate a demand on that detector. An ON/OFF switch shall also be provided at the controller for each detector to allow that detector to be switched out of circuit independently of any other detector. Both buttons and switches shall be clearly and permanently labelled to indicate which detector is controlled and switches shall have the On and OFF positions labelled, the detector being in the circuit when the switch is in the ON position.

6.13.2.11 Controller

The controller shall be a complete electrical mechanism for controlling the operations of the traffic control signals, including the timing mechanism and all necessary auxiliary equipment, securely mounted in a cabinet. Preference will be give to solid state circuitry and to designs having replaceable units for ease of maintenance. Interval timing shall be by electronic and not by mechanical means. The colour sequence of signal indications shall be as given in sub-clause 6.13.3.1 and there shall be control to ensure that green will not be shown at the same time on opposing phases under any circumstances. Operation shall be either by fixed time sequences, (variable by time switch) or shall be by vehicle actuation or by combination of both, as specified in the Special Provisions, and as herein described.

The operating voltage shall be as given in the Special Provisions and the controller shall be designed to operate satisfactorily with voltage variations up to +17.5% or –20.0% from that specified. The timing of the controller shall be within ±7.5% of correct at the rated voltage and shall not be affected by more than ±10% for a ±10% change in voltage or a ±4% change in frequency of the supply.

The controller shall be so designed that temperature variations between 10°C and 70° C shall not change the timing by more than 5% or otherwise the cabinet shall be artificially ventilated to keep the internal temperature within satisfactory limits. In the event of power

failure, the controller shall shut down and re-commence operations without the necessity for manual re-setting.

The controller shall be provided with suitable mechanism for closing and opening signal circuits, which shall be positive and without any dark intervals, flickering or conflicting signal indications. All contact points which carry make or break current shall be of fine silver, silver alloy or an alternative better material and shall be capable of carrying, making or breaking a current of 150% of maximum demand load through one million operations without electrical or mechanical trouble.

Every current interrupting device shall be equipped with a suitable radio interference suppressor installed at the input power point. Interference suppressors shall be of a design which will minimise interference on both broadcast and aircraft frequencies.

The controller shall provided for the proper phase intervals and sequences as herein specified or as may be required by traffic conditions. The setting of time intervals shall be by means of a positive method against a scale calibrated in seconds. This timing scale shall be easily accessible and identifiable within the controller and it shall not be necessary to remove or change wires or contacts to adjust the time intervals.

a) Manual Operation

Manual operation shall be possible by means of an approved key or by external buttons on the controller housing. If push buttons are used, they shall be inoperative until the controller has been switched to manual operation by means of a switch mounted under a lockable cover. The automatic operation of the controller shall not be upset by manual operation, and automatic control shall resume without the need for any manual adjustment at the end of manual operation.

Provision shall be made for the following manual operations:

i) substitution of flashing signals in place of the normal cycle (where flashing signals have been specified)
ii) allocating right of way to approaches independently of the pre-set timing of the controller
iii) switching signals to "OFF"

Provision shall be made that under no circumstances will an approach lose its right of way without having at least the appropriate minimum green time plus amber time.

b) Time Switch

Where a time switch is required this shall be capable of two 'ON-OFF' periods per day of a minimum length of sixty minutes each and with a minimum period of sixty minutes between successive 'ON-OFF' positions. The setting dial shall clearly distinguish between day and night, and the switching mechanism shall be fitted with a selective device enabling all

switching to be eliminated on any one day in the week or early or late switching on two selected days. The week dial shall be clearly marked with the days. The time mechanism shall be fitted with a first quality mechanical movement which shall be electrically would and shall have a minimum spring reserve of twelve hours.

c) Flashing Signals

Where flashing operation is called for, this shall permit either amber or red flashing on any or all approaches. The flashing unit shall generate signal indications at the rate of not more than 60 nor less than 50 per minute, and the rapidity of flashes shall remain constant. The illuminated period of each flash shall be approximately equal to the non-illuminated period. A switch or fuse shall be provided which will allow the controller to be isolated and shut down when the flashing signals are in operation.

d) Switches and Fuses

The controller shall be provided with a main switch and fuse which will isolate the complete installation. There shall also be provided one general purpose outlet and fuse. All fuses and switches shall be adequately and permanently labelled.

e) Controller Housing

The controller shall be housed in a weatherproof cabinet of aluminium, sheet metal, glass fiber or other approved material having sufficient strength and rigidity to protect the contents from the effects of water, dust and accidental blows. Sheet metal shall be at least 2 millimeters in thickness at all points and reinforced where necessary. Ferrous metal shall not be buried and it shall be rust-proofed by galvanising or some other equally effective means. If aluminium or aluminium alloy is used, it shall be suitably protected against electrolytic for chemical corrosion and in the base of the housing it shall contain at least 8% of silicon.

The housing shall be securely fixed to a concrete base through which connections shall be made to detectors and signals. All doors shall be hinged with concealed hinges, and provided with locks, the door hinges and pins being of non-corrodible metal which shall require lubrication not more often than once per year. Doors shall open and shut freely without binding on the frame or the base. Otherwise, doors may consist of a stiff removable panel having self positioning interlock joints provided with suitable gaskets. Such panels shall be provided with at lease two locks. All locks shall be captive, flush – fitting and non-corrodible and shall operate by a standard key which will fit all housings.

The controller shall be sited in such a way that it will not cause an obstruction or hazard to traffic or pedestrians, and where it will not be subject to accidental damage from traffic.

The cables running to signals and detectors shall be terminated in a convenient and readily accessible position on blocks having the required number of terminals and provided with non-hygroscopic non-inflammable insulating bases. Sufficient space shall be left between

terminals and between blocks to enable external cables to enter and be formed in a neat manner without obstructing individual terminal points. Electrical connection between controller and the terminals shall be by approved plug and socket connections.

Each terminal point and connection shall be clearly marked by colour coding or by a numbering system. Ends of all spare conductors shall be shielded, covered or insulated so that no live parts will be exposed.

f) Identification

All equipment and replaceable assemblies shall be marked with a part number and any other identification which is required for re-ordering.

g) Records

The following records shall be provided and kept within the housing, either fixed to the inside of the main door or placed within a metal pocket provided thereon.

i) a wiring diagram of the system showing the colour coding or number of the conductors,
ii) a layout plan of the intersection showing the detectors, the signals controlled by each phase and the cycle details, and
iii) a suitable ruled card shall be fixed within the controller upon which space is provided to record maintenance undertaken, the date of visit and the name of the person doing the maintenance.

The signal serial number shall be stencilled in two conspicuous locations on the outside of the housing in letters not less than 2.5 centimeters high.

h) Fixed Time Signal Controller

In addition to the foregoing requirements, where fixed time signals are required, the controller shall be capable of carrying out the following operations, although it shall not necessarily be limited to these:

i) allocation of right of way by suitable timed green aspects to the various approaches in accordance with the timings previously set on the controller,
ii) changing from one phase to another by means of the correct sequence of aspects as herein given (6.13.3.1) and maintaining the correct pre-set amber periods throughout. It shall be possible to vary the length of intergreen period without use of special tools,
iii) allowing a late start or early cut off on one or more phases as may be specified,
iv) displaying left or right filter arrows as may be specified.

By means of a time switching device, it shall be possible to alter the phase and cycle lengths to allow for varying traffic conditions. It shall be possible to operate at least three such programmes during a period of 24 hours.

It shall be possible to integrate the controller into a linked system working under a master controller if required, and to add a facility for vehicle counting. The sequence of phase shall be capable of alteration without any modification to the controller. When specified, it shall be possible automatically to dim the traffic signal lights during the hours of darkness.

j) Vehicle – actuated signal Controller

In addition to the foregoing requirements, where vehicle actuation is called for the controller shall be capable of, but not necessarily limited to the following operations.

i) In the absence of detector actuation, the right of way shall remain on the phase on which the last demand was made. However, a recall switch shall be incorporated into each phase which, when closed, will result in the right of way automatically returning to that phase without further demand. (Automatic Reversion)

ii) When the right of way is transferred to a phase in response to a demand, this right of way shall continue for at least a pre-set and adjustable minimum period. (Minimum Green Time)

iii) Continued demands beyond a predetermined number on a phase having the right of way shall cause the initial minimum right of way period to be extended, the extension being proportional to the additional demands. (Vehicle Extension Periods)

iv) In the absence of demands from other phases continued demands on the phase having the right of way shall hold that right of way. When a demand is made from another phase, the phase holding the right of way shall lose it, even in the event of continuing demands, after a pre-set adjustable maximum period (Maximum Green Period). The timing of the maximum green period shall commence from the first receipt of a demand from another phase.

v) Should there be outstanding demands on the phase losing the right of way or should further demands be made on a phase during the clearance period, then right of way shall revert automatically to the phase losing it once demands of other phases have been satisfied.

vi) The transfer of right of way shall take place only after an adjustable clearance period, which may differ between different phases. (Inter-green Period)

vii) Provision shall be made for green filter arrows and late-start or early cut-off facilities on any phase. If these are not required at the outset, there shall be provision for their inclusion at a later stage if required.

viii) It shall be possible to incorporate the controller into a linked system under a master controller if required, and there shall be facilities for resumed

independent operation either on a time basis or as a result of altered traffic conditions.

ix) Traffic counting and queue detection, if not specified, may be required at a later stage and facilities for these should be incorporated or it should be possible to add them easily when required.

k) Vehicle actuated Controller with speed measuring equipment

When the controller is to be used with speed measuring detector, the following additional facilities will be required on the controller, as well as items (i) to (ix) above:

i) The minimum green time referred to in 6.13.2.11.j(ii) above shall be reduced according to the number of demands that have been made below the predetermined number (6.13.2.11.j(iii), so that if there are less than the pre-determined number of vehicles waiting for the right of way only sufficient time will be give for that number to clear the Junction before right of way is given to another phase that has made a demand. (Variable minimum green time)

ii) The vehicle extension period 6.13.2.11.j(iii) above shall be variable in length and not fixed, the length of each vehicle extension period being inversely proportional to the speed of the vehicle making the demand at the detector pad (Variable vehicle extension period)

iii) If a demand is made on a phase not having the right of way and all demands have been met on the phase having the right of way, then the right of way shall be given to the phase making the demand after a minimum inter-green period. However, if at the expiration of the maximum green period on the phase having the right of way there are still vehicle extension periods outstanding, the inter-green period shall be lengthened by the introduction of an all-red period if required to ensure that the right of way is not given to an opposing phase before fast traffic has cleared the junction on the phase losing the right of way. (Variable Inter-green period)

6.13.3 Design Principles

This clause is intended to give general guidance in the principles to the followed in design where the Contractor is required to undertake this function.

6.13.3.1 The sequence of aspects on any one signal face shall be:
Red
Red and Amber
Green
Amber
During any aspect, there shall be no visual flicker of the signal illumination.

6.13.3.2 Siting of Signals

Siting of signals will be carried out in detail at the junction and shall be agreed by the Engineer. Each approach road shall be served by a minimum of two signal faces as follows.

The Primary signal which will be located not less than 1.0 meter beyond the Stop Line on the nearside of the road. Where there is a central median, a second primary signal may be provided similarly on the offside of the approach, and

The Secondary Signal which will be on the diagonally opposite side of the junction facing the approach, that is, on the back of the primary signal serving the opposite approach in the case of a four arm junction. The secondary signal may be opposite the offside of the approach where there is a central median, but in any case should not be outside an angle of 30° extended from the centre line of the approach at the Stop Line to the offside. Where the distance from the Stop line to the secondary signal is more than 50 meters, additional secondary signals should be provided.

No part of any signal or pedestal shall be within 50 centimeters of the kerbline, and the height of the centre of the green aspect shall be not less than 2.15 meters nor more than 3.0 meters from the ground.

The axes of the beams from the optical systems shall be directed at a point 45 meters away from the primary signal face at a point approximately 1.5 meters above the centre line of the approach, unless sharp gradient changes make this undesirable.

6.13.3.3 Stop Lines

Stop Lines shall be located as shown on the site layout plan. Unless otherwise specified in the Special Provisions, Stop Lines will be placed by the Department.

6.13.3.4 Detectors

Detectors, where vehicle actuation is specified, shall be not more than 45 meters nor less than 30 meters from the stop line on each approach, although on difficult approaches carrying only slow traffic, this minimum may be reduced to 20 meters. On high speed roads, where secondary detectors are called for, these shall be placed at not more than 165 meters from the stop line.

6.13.3.5 Phases

The number of phases at the intersection shall be kept to the minimum required to avoid dangerous conflict of traffic. Where additional phases are called for by unusual traffic conditions at certain times, these additional phases shall be suppressed when not required. In designing the number of phases and the details of the cycle, the principle shall be to arrive at the arrangement which will at all times give minimum average delays to traffic with adequate capacity and maximum safety to both vehicles and to pedestrians.

6.13.3.6 Filter Signals

Filter Signals mounted at the side of the main signal may be used to allow a movement in one direction. A green filter arrow indication shall always be followed by an amber an red aspect, and if this cannot be done on the main signal, separate amber and red aspects must be provided for the filter signal. Particular care shall be taken to ensure that filtering traffic does not form an undue hazard to pedestrians crossing and guard rails, slip roads, islands or some resting of the stop line may be required to avoid this. Filtering traffic will not be permitted when it will have to merge with through traffic. Where an early cut-off is used for offside turning traffic, an offside filter arrow will be provided to indicate to turning traffic that it is safe to proceed.

6.13.3.7 Clearance Period

Clearance Periods shall have a minimum length of four seconds. Where required for safety or to allow turning traffic to clear a longer clearance period may be introduced but this should be kept to the shortest period which is consistent with the demands of traffic and safety at any time.

6.13.3.8 Linked Systems

When a linked system is called for, or where linking with nearby signals appears desirable, this system shall be designed to give progression of green periods in both directions along the routes involved and at speeds which will give high capacity. The speeds through the system shall be as uniform as possible and the demands of cross traffic shall be fully met. With fixed time signals, there shall be the facility to change automatically the programme of linking, if necessary, so as to give preference to the heavier flows at different times of the day. With vehicle actuated signals, local controllers shall be free to revert to independent operation when there ceases to be a continuous demand providing that this will not interfere with the overall progression through the system. All calculations done for linked systems will be submitted for checking.

6.13.3.9 Signal Timing

Signal Timing will be done on the basis of traffic demands as estimated from the traffic flows. Verification and adjustment will be required on site after the system is in operation, but the Contractor must show by calculations that the system proposed is capable of handling the estimated maximum and normal flows in an efficient manner and with minimal delays. With fixed time signals, he will submit details of phases and cycles for each approach throughout the day. In the case of vehicle actuated signals, he will give similar details of maximum cycle time, maximum and minimum green times, vehicle extension periods and inter-green periods.

6.13.4 Construction Methods

6.13.4.1 Excavation and Reinstatement

The provisions of sub-clause 6.12.3.1 shall apply.

6.13.4.2 Concrete Work

The provisions of sub-clause 6.12.3.2 shall apply.

6.13.4.3 Conduits, Fittings and Boxes

Conduits, fittings and boxes shall be provided and installed except that chemically stable, tough plastic conduits, fittings and boxes, according to samples previously approved by the Engineer, will be permitted providing that they do not soften when exposed to high ambient temperature.

The Contractor may use a larger size of conduit than that specified, at no extra charge, if be wishes, but in this case the entire run shall be of the same size. No reducing couplings will be permitted.

When metal conduits are used, cuts shall be made square and true and all couplings shall be screwed up until the ends of the conduits are brought together in order to provide a good electrical contract throughout. The threads on all ferrous metal conduits shall be painted with a rust preventing paint before couplings are made up. Where the coating on ferrous metal conduit has been damaged in handling, such damaged places shall be painted with rust preventing paint before installation.

All conduit ends shall be threaded and capped until wiring is started. When caps are removed, the threaded ends shall be provided with approved conduit bushings.

Conduit shall be laid to a depth of not less than 50 centimeters below paved footwalks and medians and not less than 75 centimeters below the roadway surface. The location of all conduits at curb lines shall be marked by means of a 'Y' at least 10 centimeters high incised in the face of the curb directly above the conduit. Conduit terminating in standards, cabinets or pedestals shall extend at least 5 centimeters vertically above the foundations and shall be sloped towards the handhold opening. Conduit entering pull boxes shall terminate at least 5 centimeters inside the box wall and at least 5 centimeters vertically above the bottom of the box. Such conduit shall be sloped towards the top of the box to facilitate pulling. Conduit entering the bottom of the box shall enter near the sides or end to level the centre clear. All conduit shall enter in the direction of the run.

6.13.4.4 Pull Boxes

Pull boxes shall be installed as shown on the plans and in any case at not more 60 meter intervals. The Contractor may install additional pull boxes without extra charge if he

wishes. Pull boxes shall be of reinforced concrete not less than 10 centimeters thick and may be of approved precast design. Reinforced concrete covers, secured by two recessed brass bolts shall be used on footwalks, the covers being inscribed Traffic Signals on the outside. Under the roadway, covers shall be of steel or cast iron, inscribed as specified above, and laid in a suitable concrete footing to withstand traffic loads. Metal covers shall be effectively earthed to an earthing rod inside the box. Tope of pull boxes shall be effectively level with the surrounding paved areas, whether footwalk or roadway, but in unpaved areas, the tops of pull boxes shall be buried 30 centimeters below ground level. The bottom of pull boxes shall be bedded in sand and cement or crushed rock. Permanent markers shall be provided and erected to show the position of all pull boxes.

6.13.5 Testing

A functional test shall be made on completion of the work in order to demonstrate that every part of the equipment and installation functions as intended and specified. This test shall consist of not less than five days continuous and satisfactory operation. If any defects or unsatisfactory operation are revealed, this condition shall be corrected and the test continued until the required five days of satisfactory operation have been performed.

Prior to the functional test, the Contractor shall carry out the following tests to the entire satisfaction of the Engineer,

i) Each circuit shall be tested for continuity
ii) Each circuit shall be tested for earthing
iii) A "megger" test shall be made between each circuit and earth. The insulation resistance shall be shown to be at least that specified within the relevant Codes. On the completion of testing, the Contractor shall supply to the Engineer three copies of "as built" plans and circuit diagrams, which shall clearly indicate any modifications which have been made to the original design.

6.13.6 Measurement

This item will not be measured, payment being made on a lump sum basis.

The details of the work to be included in the lump sum measurement shall be as shown on the Contract Drawings and as specified in these Specifications.

6.13.7 Payment

The lump sum payment for the traffic signal system shall be full compensation for furnishing all labour, materials, tools equipment, supervision and incidentals and for doing all the work involved in furnishing and installing the system shown on the Drawings and as specified herein and in the Special Provisions, and as directed by the Engineer, including any necessary backfill, concrete foundations, restoration of footwalk, roadway, curbing and appurtenances

damaged or destroyed during construction and in making all tests. It shall also cover the costs of design if this is called for.

The lump sum payment shall be deemed to include full compensation for all additional materials and work not shown on the Drawings or specified which are necessary to complete the installation.

6.14 FLASHING TRAFFIC SIGNALS

6.14.1 General

6.14.1.1 Description

This item shall consist of the supply of all signal heads, supports control devices, cables, switchgear and necessary ancillary equipment together with the transportation, storage, erection, connection and testing of the same in order to supply a complete flashing traffic signal installation in accordance with the drawing and as specified herein and in the Special Provisions.

6.14.1.2 Responsibility for Design and Materials

The provisions of sub-clause 6.12.1.2 shall apply.

6.14.1.3 Compliance with Manufacture's Specifications

The provisions of sub-clause 6.12.1.3 shall apply.

6.14.1.4 Maintenance Period

The provisions of sub-clause 6.12.1.4 shall apply.

6.14.1.5 Electricity Supply

The provisions of sub-clause 6.12.1.5 shall apply.

6.14.1.6 Definitions

The provisions of subsection 6.12.1.6 of these Special Provisions and general Specifications shall apply

6.14.2 Materials and Equipment

6.14.2.1 Signal Face

Each signal face shall consist of one electrically operated and controlled optical unit, which shall be fitted with either amber or red glass as specified in the Special Provisions. Suitable visors shall be fitted to all optical units. Louvres and sighting screens shall be supplied if required to give the most efficient operation under all conditions. Each signal face shall conform to a sample supplied to and approved by the Department.

6.14.2.2 Optical Units

Optical units and all the parts thereof shall conform in all respects to the provisions of sub-clauses 2, 3, 4, 5 and 6 of Clause 6.13.2.

6.14.2.3 Wiring

The provisions of sub-clause 6.13.2.7 shall apply.

6.14.2.4 Pedestals and Painting

The provisions of sub-clauses 6.13.2.8 and 6.13.2.9 shall apply.

6.14.2.5 Flash Control Unit

The flash control unit shall consist of a compact and complete unit which shall operate by switching the ungrounded side of the A.C. mains. It shall not include nor depend upon any mechanical or electromechanical operations, the entire control and switching action being done by means of solid state electronic devices. The control unit shall be capable of controlling either one or two lamp circuits, the maximum load on any circuit being not more than one Kilowatt. The power input to the control unit shall not exceed five Watts over and above the circuit load at nominal voltage.

Every current interrupting device shall be equipped with a suitable radio interference suppressor installed at the input power point. Interference suppressors shall be of a design which will minimise interference on both broadcast and aircraft frequencies.

The control unit shall produce flashing of the optical units to which it is connected at the rate of between 50 an 60 flashes per minute. This rate shall not vary by more than two per cent at any time at constant temperature, nor by more than two per cent due to the range of ambient temperature normally experienced in Thailand. The illuminated period of each flash shall be approximately equal to the non-illuminated period, and when two circuits are controlled the illuminated periods shall be of the same length for both circuits. The control unit shall be housed in a weather and dust proof housing of aluminium sheet metal, glass fiber or other approved material having sufficient strength and rigidity to protect the contents from the effects of water, dust and accidental blows. Sheet metal shall be at least 2 millimeters (0.08 inches) in thickness at all points and reinforced where necessary. Ferrous metal shall not be buried and shall be rust proofed by galvanising or some other equally effective means. Aluminium or aluminium alloy shall be suitably protected against electrolytic and chemical corrosion and shall contain at least 3% of silicon.

The control unit housing shall be securely mounted on the signal pedestal or other approved position by means of corrosion resistant bolts or fastenings. The inspection door shall be hinged with concealed hinges the hinges pins being corrosion resistant metal. Otherwise, a stiff removable panel may be provided having self positioning interlock joint and a suitable gasket. A captive flush fitting and corrosion resistant lock shall be provided, complete with keys

for either door or panel, whichever is proposed. The cables running to the signal heads shall be terminated in the housing in a convenient and readily accessible position on a block or blocks having the required number of terminals and provided with a non-hygroscopic and non-inflammable base. Sufficient space shall be left between terminals and between blocks to enable cables to enter and to be formed neatly without obstructing individual terminal points. Electrical connections between the terminal block or blocks and the control unit shall be by approved plug and socket connections.

Each terminal point and connection shall be clearly marked or colour coded. Ends of all spare conductors shall be taped. Connectors shall be provided with suitable strain relief clamps where necessary. Terminals which are accessible from the inspection opening shall be shielded, covered or insulated so that no live parts will be exposed.

6.14.2.6 Switches and Fuses

The control unit shall be provided with a main switch and fuse within the housing which will isolate the complete installation.

6.14.3 Construction Methods

The provisions of Clause 6.13.4 shall apply.

6.14.4 Testing

The provisions of Clause 6.13.5 shall apply.

6.14.5 Measurement

The item will not be measured, payment being made on a lump sum basis.

The details locations of the work included in the lump sum measurement shall be as shown on the Contract Drawings and as specified in these Specifications.

6.14.6 Payment

The lump sum payment for the flashing signal system shall be full compensation furnishing all labour, materials, tools, equipment, supervision and incidentals and for doing all the work involved in furnishing and installing the system shown on the Drawings and as specified herein and in the Special Provisions, and as directed by the Engineer, including any necessary backfill, concrete foundations, restoration of footwalk, roadway, curbing and appurtenances damaged or destroyed during construction and in making all tests.

The lump sum payment shall be deemed to include full compensation for all additional materials and work not shown on the Drawings or specified which are necessary to complete the installation.

6.15 ROAD MARKINGS

6.15.1 Description

This work shall consist of the application of continuous or intermittent lines, letters or figures and the supply and installation of reflecting road studs, including any necessary excavation, grouting and finishing of the pavement, to the dimensions and at the locations shown in the Contract Documents or as directed by the Engineer, including the supplying of all labour, tools and equipment, materials, warning and traffic guidance signs as necessary for the safe and efficient completion of the entire work.

This work shall also include the construction of raised bar divisors in accordance with the details and locations shown in the Drawings or directed by the Engineer.

In the areas of major junctions, hot applied reflectorized thermoplastic with ballotini surface shall be used. The location and extent of these areas will be designated by the Engineer, and the materials shall be supplied and the work done in accordance with Section 6.15.2.1(b) and 6.15.3.1 of these Specifications.

Elsewhere, cold applied reflectorized road marking paint shall be used, and the materials shall be supplied and the work done in accordance with Section 6.15.2.2 and 6.15.3.2 of these Specifications. Section 6.15.2.2 of these Specifications also refers to the Department Specification No. DH-SP 602/2523 and Section 6.15.2.4 of these Specifications refers to Department Specification No. DH-SP 601/2521.

6.15.2 Materials

6.15.2.1 Hot Applied Thermoplastic Materials

The laid material shall be one of three types (a), (b), or (c) detailed below as required by the Contract Documents or as directed by the Engineer, and conforming to DOH standard 604-2524

a) Non-reflectorized Thermoplastic – The thermoplastic material shall be factory mixed, from an approved manufacturer and shall be suitable for the type and location of application. The material shall possess adequate thermoplastic properties over the range of climatic conditions of the location viz. resistance to spreading under traffic at the highest road temperatures and retention of plasticity at the lowest road temperatures and shall give a marking which is effective for at least eighteen months under normal traffic conditions. The composition of the material with minimum and maximum proportions and grading of the constituents, the acid value of the binder, the temperature range of mixing and application, the setting time, the softening point (C^0) and the open flash point (C^0) shall be stated.

The material shall be supplied in containers which do not contaminate the contents and which protect the contents from contamination and shall be stored in accordance with the manufacturer's instructions.

b) Reflectorized Thermoplastic – The material shall be in accordance with (a) above except that ballotini (glass beads) shall be incorporated in the mixture during the manufacture of the thermoplastic material. The quantity of ballotini included shall be between 13% and 22% by weight of the total mix and shall be counted as part of the aggregate. The whole of the ballotini shall pass a No.12 U.S. sieve and not more than 10% shall pass a No. 40 U.S. sieve. The ballotini shall be free of sharp angular particles and not less than 80% shall be of transparent glass, reasonably spherical and free from flaws.

c) Reflectorized Thermoplastic with Ballotini Surface – The material shall be in accordance with (b) above except that a layer of ballotini shall be superimposed in the surface of the hot thermoplastic immediately after laying to give immediate reflectivity. The superimposed ballotini shall be of the same quality as that incorporated in the reflectorized thermoplastic but may be smaller in size; not more than 20% shall pass a No. 70 U.S. Sieve. Ballotini shall be applied at rate of 250-450 grams per square meter (0.8-1.5 ounces per square foot) such that the combined total of ballotini incorporated in and superimposed on the thermoplastic shall be between 20% and 26% by weight of the material.

6.15.2.2 Reflectorized Road Marking Paint

a) Description – The paint shall be a cold-applied ready mixed paint suitable for application to cement concrete or asphaltic pavements. The paint shall be durable and made reflectorized by superimposing glass beads (ballotini) on the surface of the paint. The paint shall also be suitable for applying by brush or mechanical means. The following particulars of the paint shall be supplied:

i) composition (analysis by weight)
ii) application
iii) type and maximum amount of reducer (thinner)
iv) drying time (to touch)
v) setting time (to recoat)
vi) recommended coverage (liters per square meter)
vii) heat resistance (max. road temperature)
viii) details of any primer, undercoat of tack coat required.

The paint shall be supplied fresh and ready for use in sealed containers which shall be stored in accordance with the manufacturer's instructions.

b) Color – The paint color shall be the type as detailed on the Drawings or as directed by the Engineer.

i) White – The white paint shall have a directional reflectance of not less than 80 percent when compared with a magnesium oxide sample when tested in accordance with the Federal Test Method Standard No. 141, Method 6121.
ii) Yellow – The yellow paint shall have a directional reflectance of not less than 40 percent when compared with a magnesium oxide sample when

tested in accordance with the Federal Test Method Standard No. 141, Method 6121.

The C.I.E. chromaticity color coordinates shall be within the limits as specified in the Table 6.15.1.

Table 6.15.1 Limits of Chromaticity Color Coordinates

X	Y	Test Method No.
0.490	0.455	
0.511	0.433	
0.514	0.480	4525 Federal Standard 141
0.535	0.458	

c) Properties – The paint shall conform to the requirement as specified in paragraphs (a) and (b) and Table 6.15-2 and Thai Industrial Standard 415-2531.

Table 6.15-2 Quantitative Requirements

Characteristics	Requirements		Test Method No.
	Min	Max	
Nonvolatile Vehicle (% by weight)	38.0	44.0	4051 Federal Std. 141
Total Dry Solids (% by weight)	67.0	77.5	4041 Federal Std. 141
Consistency, Krebs Unit (K.U.)	65.0	85.0	1281 Federal Std. 141
Unit Weight (kg/liter)			
White	1.35	-	4184 Federal Std. 141
Yellow	1.38	-	4084 Federal Std. 141

Table 6.15-3 Drying Time Test

Drying Time	Requirements		Test Method No.
	Min	Max	
No Pick-up (minutes)	-	40.0	ASTM D-771

The paint shall also have the property to adhere to the pavement surface firmly for a long period of time. The paint shall have the same properties, as samples tested which the Department has found to contain other properties not shown in Table 6.15-2 such as Ti02, CaC03, solvent type, etc,. The tolerance between sample and paint shall not exceed 5 percent.

d) Sampling – Random samples of paint shall be taken as noted below for testing.

Number of Containers of Material (5 gallon capacity)	Samples Required
less than 120	1
121 - 200	2
201 – 300	3
301 – 400	4
401 – 500	5
more than 500	One sample for every 200 containers

Samples of paint supplied in containers larger than 5 gallons shall have the same ratio of number to volume as shown above. Each sample shall contain a minimum of 2 gallons of paint taken as described below.

i) Open the container and pour off the surface oil into another dry and clean container.

ii) Stir the remaining paint immediately and gradually add the oil to the original container while stirring until the paint and oil are thoroughly mixed.

iii) Pour the paint into the empty container and back again into the original container as many times as required until the paint and oil are thoroughly mixed.

iv) Pour out a 2 gallon sample of paint while stirring into a clean, dry container and cover with a tight – fitting lid. The sample container shall then be made air-tight by sealing with paraffin wax or with a tight rubber sheet. In the event the paint is supplied in 5 gallon containers, one sealed container may be taken as a sample.

e) Testing - Testing of all paint samples shall conform to the requirements as detailed in this Section of the Special Provisions and as listed below.

i) Federal Specification TT-P-85D dated June 26, 1969

ii) Federal Test Method Standard No. 141 "paint, Vanish, Lacquer and Related Materials, Method of Inspection, Sampling and Testing.

iii) ASTM Specification D-771.

6.15.2.3 Reflecting Road Studs

Reflecting road studs shall be of an approved design with self-cleansing reflecting units from a reputable manufacturer. Each stud shall be provided with at least two reflecting lenses for each traffic direction and the reflecting surface of each lens shall be at least 80 square millimeters. The lenses shall be capable of withstanding impacts and no contact shall be possible between the lenses and vehicle tyres. The studs shall not project more than 20 millimeters above the level of the surrounding road surface and the lowest part of the lenses shall be more than 5 millimeters above the surrounding road surface. The reflecting units shall be interchangeable and capable of easy and quick replacement without disturbance of the road surface. The design shall be such as to ensure ample key to the road pavement with adequate load distribution and such that it shall not be possible for heavy equipment such as road rollers and tracked vehicles travelling in the direction of the road axis to meet with any sharp edges whereby the removal of the stud might be facilitated.

6.15.2.4 Glass Beads

a) Description - Glass beads (ballotini) in this Specification means the glass beads used for superimposing on the surface of road marking paint as specified in clause 6.15.2.2 of these Specifications. The glass beads shall be transparent, clean, free of color and shall conform to T.I.S. 543-2528.

Glass beads shall have a spherical shape and be free of flaws and sharp angular particles. These characteristics, when tested in accordance with Test Method T 1207, Department of Main Roads, N.S.W., Material Testing Manual, shall not be less than 70 percent by weight.

b) Properties - Glass beads shall be resistant to chemicals and shall retain their brightness after soaking in the following solutions.

- Buffered acid solution
- 1 N calcium chloride
- Distilled water which is free from carbon dioxide gas. This water when titrated with 0.1 N hydrochloric acid at the amount of not more than 2.5 milliliters will reach a neutral point.
- The glass beads when soaked in sodium sulfide shall not turn black.

All testing regarding the brightness of glass beads shall be in accordance to the requirement of Federal Specification TT-P-85 b.

i) Index of Refraction - The index of refraction of the glass beads shall be not more than 1.50 when tested by the immersion method in accordance with Test Method T 1203, Department of Main Roads, N.S.W., Material Testing Manual.

ii) Sizes – Glass beads shall meet the gradation requirements as specified below in accordance with Department Standard Test Method 204/2516.

Table 6.15-4 Grading Requirements for Glass Beads

Sieve Designation	Percentage by Weight Passing
No. 22	100
No. 30	95 – 100
No. 40	30 – 80
No. 60	10 – 30
No. 100	0 – 5
No. 200	0 - 1

c) Sampling – Random samples of glass beads shall be taken from each sack for testing. The number of samples shall be one percent of the total sacks of the glass beads supplied. Each sample shall contain a minimum of two kilograms of beads which shall be collected by use of a sample splitter or by quartering.

d) Testing – All testing required for glass beads shall be as specified herein in paragraphs (a) and (b) in clause 6.15.2.4.

6.15.2.5 Raised Bar Divisor

Materials for raised bar divisor shall be asphalt concrete, cement concrete or other material approved by the Engineer.

6.15.3 Construction Methods

6.15.3.1 Thermoplastic Materials

a) Preparation of Road Surface – The material shall be applied only on a surface which is clean and dry. It shall not be laid over loose detritus, mud or similar extraneous matter, or over an old paint marking, or over an old thermoplastic marking which is faulty. In the case of smooth polished surfaces e.g. smooth concrete, old asphalt surfacings with smooth polished surface stones, and/or where the method of application requires or the Engineer directs, a tack coat shall be applied to the surface prior to the application of the material. The tack coat and the rate of application shall be as the manufacturer of thermoplastic material shall recommend, with the approval of the Engineer.

b) Preparation of Thermoplastic Material – The material shall be melted in accordance with the manufacturer's instructions in a heater fitted with a mechanical stirrer to give a smooth consistency to the thermoplastic and such that local overheating shall be avoided. The temperature of the mass shall be within the range specified by the manufacturer and shall on no account be allowed to exceed the maximum temperature stated by the manufacturer. The molten material shall be used as expeditiously as possible and for thermoplastics which have natural rosin binders or are otherwise sensitive to prolonged heating the material shall not be maintained in a molten condition for more than 4 hours.

c) Laying – Center lines, lane lines and edge lines shall be applied by approved mechanical means and shall be laid to a regular alignment. Other markings may be applied by hand-screed, hand-propelled machine or by self-propelled machine as approved or directed by the Engineer. After transfer to the laying apparatus the material shall be maintained within the temperature range specified by the manufacturer and stirred to maintain the right consistency for laying.

In the case of screeded application the material shall be laid to a thickness of not less than 3 m.m. (approx. 1/8 inch) or more than 6 m.m. (approx. 1/4 inch) unless specifically authorized by the Engineer when laid over an existing marking. In the case of sprayed application the material shall be laid to a thickness of not less than 1.5 m.m unless specifically authorised by the Engineer. In all cases the surface produced shall be uniform and appreciably free from bubbles and streaks. Where the Contract Documents require, or the Engineer directs, that ballotini shall be applied to the surface of the markings, these shall be applied uniformly to the surface of the hot thermoplastic immediately after laying such that the quantity of ballotini firmly embedded and retained in the surface after completion complies with the requirements of 6.15.2.1(c).

Road marking of a repetitive nature, other than centre lines, lane lines, etc. shall unless otherwise directed by the Engineer be set out with stencils which comply with the size and spacing requirements of the Department.

d) Reuse of Thermoplastic Material – At the end of the day's works as much as possible of the material remaining in the heater and/or laying apparatus shall be removed. This may be broken and used again provided that the maximum heating temperature has not been exceeded and that the total time during it is in a molten condition does not exceed the requirements of 6.15.3.1 (b).

6.15.3.2 Road Marking Paint

a) Preparation of Road Surface - The paint shall be applied on a surface which is clean and dry. It shall not be laid over loose detritus, mud or similar extraneous matter or over a thermoplastic marking or over an old paint marking which is faulty or incompatible with the paint being applied. If a primer or undercoat is necessary to ensure proper adhesion of the marking paint to the road surface without bleeding or other discoloration the primer or undercoat shall be fully compatible with the marking paint and the road surface and shall be applied only if, and at the rate of application, approved by the Engineer.

b) Preparation of Paint - All cold-applied paint shall be thoroughly field mixed before applying in order to keep the pigments in uniform suspension. Hot-applied paints shall be heated in a properly designed heater, preferably thermostatically controlled, to the correct laying temperature at which it shall be maintained as required for the method of application. The paint shall on no account be allowed to exceed the maximum temperature specified by the paint manufacturer. The use of thinners or other additives shall not be permitted unless otherwise agreed by the Engineer.

c) Laying – Centre lines, lanes lines and edge lines shall be applied by approved mechanical means and shall be laid to a regular alignment. Other markings shall be applied by brush, spray, screed, hand-propelled or self propelled machine according to the marking configuration and the type of paint approved for use or as directed by the Engineer. The rate of application of the paint for each coat shall be that recommended by the manufacturer unless otherwise directed by the Engineer.

When more than one coat is used the succeeding coat shall not be applied until the previous coat has fully set.

Road markings of a repetitive nature, other than centre lines, lane lines etc. shall, unless otherwise directed by the Engineer, be set out with stencils which comply with the size and spacing requirements of the Department.

Glass beads shall be superimposed on the surface of the freshly applied paint immediately after laying to give immediate reflectivity. Glass beads shall be applied at a rate of 250-450 grams per square meter, unless otherwise directed by the Engineer.

d) Protection of Marking – All markings shall be protected from traffic until they have dried sufficiently to show no pick-up of tire marks. The Engineer in the field shall determine a time period in which traffic will not be allowed to pass over the particular road markings being used.

6.15.3.3 Reflecting Road Studs

Excavation of the road pavement to form a cavity for each stud shall be carried out in accordance with the manufacturer's instructions. In the case of concrete surfaced roads cavities shall be at least 5 centimeters from an expansion joint and shall be clear of dowel bars at the joint. Care shall be taken to ensure a reasonably level floor and vertical sidewalls without projections into the cavity and that all loose material produced in excavating the cavity is cleaned out. A layer of approved stone (1/4 inch to dust chippings) shall be laid and compacted level on the cavity floor. The stud shall be prepared in accordance with the manufacturer's instructions and firmly bedded on the levelling layer such that the correct projection of the stud above the road surface is achieved. A template shall be used to check the line and level of the bedded stud. The cavity walls shall be brushed with asphaltic tack coat and the whole of the remaining cavity grouted with hot filled asphalt in accordance with the recommendations of the manufacturer until level with the road surface. Care shall be, taken to ensure that no asphalt is spilled on the projecting portion of the stud. Any asphalt inadvertently spilled shall be carefully removed so that a clean workmanlike job is presented with a fully effective reflector unit. Traffic shall no be permitted to pass over the stud until the grout has firmly set.

6.15.3.4 Defective Materials or Workmanship

Materials which are defective or have been applied in an unsatisfactory manner or to incorrect dimension or in a wrong location shall be removed, the road pavement made good and

the materials replaced, reconstructed and/or properly located, all at the contractor's expense and to the satisfaction of the Engineer.

6.15.3.5 Protection of Traffic

The Contractor shall protect pedestrian, vehicular and other traffic adjacent to the working area against damage or disfigurement by construction equipment, tools and materials or by spatte, splashes and smirches of paint or other construction materials and shall during the course of the work provide and maintain adequate signs and signals for the warning and guidance of traffic.

6.15.3.6 Raised Bar Divisor

Raised bar divisors shall be constructed in accordance with the details and in the locations shown on the Drawings or directed by the Engineer.

6.15.4 Measurement

6.15.4.1 Thermoplastic or Road Marking Paint

Marking shall be measured by the area in square meters completed, accepted and measured in place. Where the width or length of laid marking proves to be greater than that specified and is accepted by the Engineer the specified width or length shall be used when calculating areas for payment. Where the width or length of laid marking proves to be less than that specified and is accepted by the Engineer the actual width or length of laid marking shall be used when calculating areas for payment.

6.15.4.2 Reflecting Road Studs

The quantity to be paid for shall be the actual number of studs supplied, installed and accepted.

6.15.4.3 Raised Bar Divisor

Raised bar divisors shall be measured by the linear meter along the longitudinal axis of the raised bar itself.

6.15.5 Payment

Payment for reflectorized thermoplastic markings and reflectorized road paint markings of the colors specified shall include all materials, preparation of surfaces, equipment, labor, tools, and incidentals necessary to the proper completion of the work.

Reflecting road stud will be paid for at the Contract unit price each complete, installed and accepted in place. Raised bar divisor shall include all material, labour, equipment, tools and incidentals necessary to the proper completion of the work.

6.16 PERMANENT TIMBER BARRICADES

6.16.1 Description

The work shall consist of furnishing materials and erecting permanent timber barricades with these Specifications, at the location and in conformity with the sizes, dimensions and design shown on the Drawings or as directed by the Engineer.

6.16.2 Materials

Posts and railing for the barricades shall be timber of the Mai Teng, Rung or Takhien types. Timber posts shall be treated as specified in AASHTO M-122-73. Timber railing small receive three coats of paint as specified on the Drawings. With the approval of the Engineer, the Contractor may substitute 20 cm reinforced concrete posts for hardwood posts with no change in unit price. Reinforced concrete post shall be constructed with Class B concrete.

All fastening shall be either wrought iron or medium steel and shall be galvanized in accordance with the requirements of ASTM Specification A-153.

Paints shall be of a high quality and before use shall be tested by the Contractor and subject to the approval of the Engineer. White paint used in the painting shall possess a highly reflective quality.

Concrete encasement used in the post holes shall conform to the requirements of Class C concrete, Section 5.1.3 of these Specifications.

6.16.3 Construction Methods

Barricades shall be constructed to conform to the sizes and dimensions shown on the Drawings and in these Specifications.

6.16.4 Measurement

Permanent Timber Barricades shall be measured by the number of linear meters form center to center of the end posts completed and accepted in place.

6.16.5 Payment

Payment for Permanent Timber Barricades shall be full compensation for furnishing all materials, excavations, placing and aligning, backfilling and all equipment, labor, tools and incidentals necessary to complete the work.

6.17 BUS STOP SHELTER

6.17.1 Description

This work shall consist of the furnishing and erecting of shelters at bus stop locations shown on the Drawings or as directed by the Engineer. This work shall also include the careful dismantling, refurbishing and reconstruction of existing bus stop shelters which in the opinion of the Engineer, are in suitably good condition and conductive to relocation.

6.17.2 Materials

Timber shall be Mai Teng, Rung, Takhien or other types accepted by the Engineer.

Concrete used in the reinforced concrete slab shall be class B as shown on the Drawings.

6.17.3 Construction Methods

Construction of shelters shall be in accordance with accepted building practices and standards. Details of construction are shown on the Drawings which are based on Department Standard Drawings numbered MD-302 to MD-311

All timber surfaces shall be preserved against decay and insect damage by preservative paints approved by the Engineer and in accordance with AASHTO Designation M-133-73. The roof of the shelter shall be factory painted.

Any changes or substitutions of materials as detailed on the Drawings are subject to approval by the Engineer.

6.17.4 Measurement and Payment

The quantities measured for payment shall be the actual number of bus stop shelters constructed or relocated and accepted by the Engineer.

Payment shall be full compensation for furnishing and placing all materials, labor, equipment, tools and incidentals necessary to complete the work, including maintenance of the shelter during the contract period.

6.18 LANDSCAPING WORK

6.18.1 Description

This work shall consist of planting for landscaping areas in accordance with these Specifications to the lines, levels, grades, dimensions and types as indicated on the Drawing.

6.18.2 Materials

6.18.2.1 Top Soil for Landscaping Area

Top soil shall be natural loam from the local area, free from large stones, roots, sticks, clay, weeds and shall be obtained from rice fields, gardens, foothills or other approved source. It shall be soil having a pH between 6.5 to 7.5 and having more than 3% of organic matter without any toxic materials harmful to plant growth.

6.18.2.2 Fertilizer

Fertilizer shall be urea, containing not less than 46% of nitrogen (N) or other fertilizers in 15-15-15 (N-P-K) grade or organic fertilizer as directed by the Engineer. Fertilizer shall be delivered to the site in the original unopened containers, showing the manufacturer's guarantee and analysis. It shall be stored in a dry and ventilated area before use.

6.18.2.3 Plants and Sods

Plants shall be of the type, size and dimensions as shown on the Drawings. All plants shall be of complete form and free from any sickness and shall, as much as possible, be delivered from a single plant nursery as approved by the Engineer. The plants shall, at time of delivery, be clearly marked with a name plate tied to the trunk. Shrubs and ground covers shall be of complete form and fine grown in standard flower pots.

Sod sheets shall be 50 x 100 cm., obtained from the local area, free from noxious weeds and burned spots and shall have a complete mat with healthy root systems. Sod stored more than 3 days before use shall be rejected.

6.18.3 Planting

Tree and shrub pits shall be 60 cm greater in diameter than the ball earth or spread of roots of the tree and sufficiently deep to allow for a 30 cm. Thick layer of loam (topsoil) beneath the ball or roots.

The depth of planting beds and pits shall be adjusted as necessary to permit a minimum of 10 cm of topsoil over the balls or roots of all plants.

Plant pits shall not be backfilled with topsoil until they have been approved by the Engineer. If pits are prepared and backfilled with topsoil on grade prior to planting, their

location shall be marked and recorded on the Drawings so that when planting proceeds they can easily be found. Plants shall be planted at the densities noted in the schedule.

After the plants are set in the center of pits plumb and straight, topsoil shall be compacted around bases of balls to fill all voids. All burlap, ropes or wires shall be removed from the balls. After planting, trees and shrubs shall be secured by stakes or wires as long as necssary to ensure a satisfactory growth.

Topsoil around roots or balls shall be thoroughly compacted and watered. Immediately after the plant pit is backfilled, a shallow basin slightly larger than the pit shall be formed with a ridge of soil to facilitate watering and to preserve water.

After planting, ground cover shall be covered with approved covered materials to protect against the sun for as long as necessary to promote growth.

Fertilizer shall be added at the time of planting if necessary to acquire a healthy growth. The type of fertilizer shall be appropriate for each type of plant (conforming to the principles of Botany) as recommended by the nursery and as approved by the Engineer.

6.18.4 Sodding

The subgrade of areas to be sodded shall be raked and all rubbish, sticks and lumps of soil shall be removed. Topsoil, conformed to Clause 6.18.2.1 of this section shall be spread and lightly compacted to a depth of 10 cm. Over areas to be planted, with fertilizer applied as recommended. Sods shall be placed in a solid strip laid edge to edge with staggered joints. The combined thickness of the sod and topsoil shall be at least (13 cm). Careful handling of the sods and maintenance of the sodded area as mentioned in Section 6.6.3 of these Specifications shall be followed.

6.18.5 Maintenance Period

The Contractor shall maintain the plants at his expense until the end of the Maintenance Period. Maintenance shall consist of preserving, trimming, and protecting plants as well as replacing dead plants. The Contractor shall water and fertilize the plants as such intervals as may deemed necessary for the healthy growth of the plants during the Maintenance Period. Dead plants shall be replaced by the Contractor as soon as possible.

6.18.6 Measurement and Payment

Plants shall be measured for payment by the number of each type complete in place and accepted. Excavation and carrying to waste of excavated material as well as fertilizer will not be measured but considered incidental to the work of planting. Sod shall be measured for payment by the area of each type including topsoil and fertilizer, completed in place and accepted. The maintenance of plants and sod shall also be incidental to the work and shall be undertaken by the Contractor up until the end of the "Maintenance Period"

Sodding of the road embankment shall be measured and paid for seperately in Section 6.6

The pay items included in the Bills of Quantities for landscaping works shall constitute full compensation for all the specified requirements of these Specifications and all requirements not shown on the Drawings or specified which are necessary to complete the work, covering the furnishing and placing of all materials shown on the Drawings including all labour, equipment, tools and incidentals necessary to complete the work.

6.19 BRIDGE DRAINAGE

6.19.1 Description

This work consists of furnishing and erection of drain outlets on the viaduct, approach structures and other structures, at interchanges, overpasses and underpasses including piping, gullies, gratings, inserts, fittings and other incidental parts necessary to provide for supports of drain pipes in accordance with the lines, levels, grades sizes, dimensions and types shown on the Drawings.

6.19.2 Materials

6.19.2.1 Gully and Grating

The size and strength of gullies shall be as indicated on the Drawings. The Contractor is at liberty to propose alternative gullies of similar quality. Gratings shall be made of structural steel galvanized in accordance with AASHTO Standard Specification M111. All gullies shall be approved by the Engineer.

6.19.2.2 Cast Iron Piping

Cast iron piping and fittings shall comply with TIS 249-1977 or other internationally recognised standards approved by the Engineer.

6.19.2.3 PVC Pipes

All PVC pipes and fittings shall comply with TIS 17-1980, class and type shall be as indicated on the Drawings.

6.19.2.4 Inserts

Inserts shall be carried out of steel conforming to AASHTO Standard Specification M183 (ASTM A36) or as approved by the Engineer.

6.19.2.5 Fittings and Other Incidentals

Material to be as indicated on the Drawings or as approved by the Engineer.

6.19.3 Construction Methods

6.19.3.1 Storage and Handling of Materials

The steel and PVC parts shall be carefully handled and stored on blocking, racks or platforms so as not to be in contact with the ground and the steel parts shall be protected from corrosion. Materials shall be kept free from dirt, oil, grease and other foreign matter.

6.19.3.2 Gully

Gullies are to be cast into the structure at the location as indicated on the Drawings. Special care must be taken to avoid displacement of gullies during concreting operations.

6.19.3.3 Cast Iron Piping

The pipe shall be provided with suitable joints that prevent lateral displacement. The pipes shall be embedded in the locations as indicated on the Drawings. During casting of concrete the piping shall be kept in the correct position by means approved by the Engineer.

6.19.3.4 PVC Pipes

The jointing shall be of a type recommended by the manufacturer of the pipes. Bends shall be of long sweep, free from kinks.

Embedded pipes shall be cast into the structure in the locations as indicated on the Drawings. During casting of concrete the piping shall be kept in the correct position by means approved by the Engineer.

Exposed pipes shall be parallel or at right angles to walls, slabs and girders. All exposed pipes shall be attached to concrete, steel, masonry or timber by galvanized malleable iron or galvanized steel straps, clamps or hangers of an approved type, held at not less than two points by galvanized steel bolts or lag screws. The runs shall be supported at not greater than 1 meter centers on horizontal or near horizontal runs, unless otherwise specified and not less than 5 centimeters clear of the supporting members.

All ends of pipes installed during construction shall be closed against the intrusion of foreign material.

6.19.4 Measurement

This work shall be measured as the actual number of gully and grating of size indicated and shall include all cast iron piping, fittings, inserts, relevant erosion protection (if any) and other incidental parts necessary to provide for further support of drain pipes, satisfactorily completed and accepted.

No payment shall be made for the drain pipes and any other drain facilities shown on the Drawings. They shall be considered incidental to the gullies.

6.19.5 Payment

The price and payment shall constitute full compensation for furnishing all materials as indicated on the Drawings including delivery, erection, surface treatment and finishing and for all labour, equipment, tools and incidentals necessary for the completion of the work.