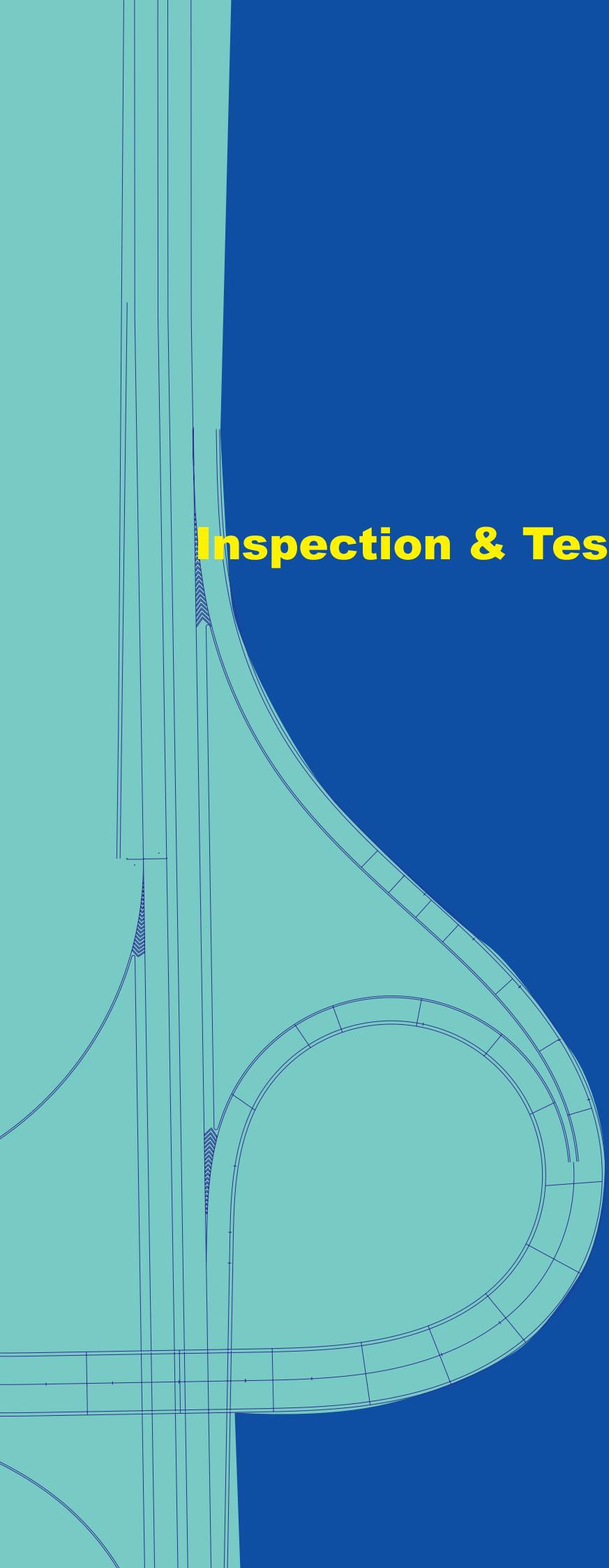

Guidelines for Inspection & Testing of Roadworks

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GUIDELINES FOR INSPECTION AND QUALITY CONTROL TESTING OF ROAD WORKS EXECUTED BY CONTRACT

C O N T E N T S

Guidelines for inspection and quality control testing of road-works executed by contract

Introduction

It is long established international practice in civil engineering that a contractor must notify the engineer responsible for supervision of construction of his intention to proceed with each and every item of work, and obtain the engineer's approval of his long term and day to day work programmes before any works are executed. This enables the engineer to ensure that the works are scheduled in accordance with the specifications and established good practice, and to make satisfactory arrangements for their inspection and testing. It is assumed that this system of construction supervision will be applied to all contract road works in Malaysia, through incorporating the necessary provisions in the contract documents.

It is not intended herein to discuss the contractual relations of contractor and supervising engineer, or the latter's responsibility for ensuring sound management of the works, or even his function of measuring the works for payment; suffice it to say that for many items of work the measurement function may often be combined satisfactorily with technical inspection. Rather, the purpose of these guidelines is to describe the appropriate levels of technical inspection and quality control testing that should be carried out for each item of work to preclude the incorporation of faulty or substandard materials in the works, and to enable unsatisfactory workmanship to be detected and rectified.

Needless to say, to ensure that contract road works are carried out in accordance with specifications and established good practice, the technical inspection and quality control testing should be performed, as appropriate, by suitably experienced engineers, technical assistants, inspectors, clerks of works and technicians well versed in the activities in hand and thoroughly familiar with the relevant standards and correct technical procedures.

Of course different activities require different levels of inspection and testing. For example bush clearing and ditch excavation require only nominal inspection of work in progress, a final inspection (and measurement) of the completed work, and no testing whatever. Whereas construction of an asphaltic concrete carriageway surface requires more or less continuous inspection of all phases of the work, comprehensive checking of finished lines and levels, and thorough testing of materials for quality and level of compaction achieved.

In cases where both inspection during execution and testing are required for effectual quality control of an item of work, it is important to balance the two functions. Limited testing resources can often be compensated for by increasing the level of inspection, and vice versa. For example, this is particularly true of mixing concrete, and compacting earth or aggregates in road embankments and pavements.

Although many inspection and quality control testing functions are normally carried out by sub-professional staff, all inspection and testing work should be directed and supervised by engineers. Engineers should also be responsible for the review, analysis and interpretation of all inspection reports and test results.

These guidelines are set out in two distinct parts, the first covering inspection requirements for the items of work frequently occurring in road works contracts, and the second presenting complementary materials testing programmes. The guidelines are not hard and fast rules, but represent desirable minimum levels of inspection and testing for road construction, improvement and periodic maintenance performed by contract under normal conditions of work in Malaysia.

For ease of reference a tabulated index of the inspection requirements and materials testing programmes for each item of work is appended.

For any work not explicitly covered herein,

technical inspection and quality control testing requirements can be deduced from those set forth for items of work of similar importance with comparable characteristics and/or materials. In all cases, quality control testing programmes should be appropriate to the specifications for the materials involved.

Part 1 - Technical Inspection

For the purposes of these guidelines, 4 categories of inspection personnel have been defined on the basis of JKR's technical staff grades, and comparable staff grades used by consulting engineering firms. These categories are as follows.

Class	Inspection Personnel
A	Senior Engineer
B	Junior Engineer, with support and occasional assistance of a Senior Engineer
C	Technical Assistant or Inspector or Clerk of Works, with support and occasional assistance of an Engineer, especially during final inspection of items of work
D	Technician or Laboratory Assistant or Laboratory Technician, with support and occasional assistance of an Engineer, especially during final inspection of items of work

Note : In Classes B, C and D, support and occasional assistance of a Senior Engineer (Class B), or an Engineer (Classes C and D), means support and assistance provided at the locations of items of work being inspected, as well as in the (Site) office.

Inspection personnel of all classes are technical representatives of the JKR Superintending Officer, or the Engineer, responsible for the supervision of the Works, and will normally be employees of either JKR or a consulting engineering firm engaged by JKR for supervision of construction. All inspection personnel should be experienced in the particular types of work to which they are assigned, and should be familiar with the relevant Specifications and correct technical procedures.

For each item or part of the Works, the inspection personnel should ensure, as far as is practicable, that:

- all materials and workmanship are in accor dance with the Specifications and accepted good practice

- quality control testing of materials and work manship is carried out in accordance with Part II of these guidelines

- the work conforms to the lines, levels, grades, dimensions, and cross-sections shown on the Drawings, or otherwise speci fied in the Contract Documents, and/or required by the JKR Superintending Officer's, or the Engineer's, Representative on Site.

This will normally require that the inspection personnel have with them at the locations of the work copies of:

- the Specifications appropriate to the items or parts of the Works being inspected

- these Guidelines for Inspection and Quality Control Testing

- all relevant Drawings

They will also need simple measuring equipment appropriate to the items or parts of the Works being inspected. Such equipment could include measuring rules and tapes, spirit levels, straight edges, templates, asphalt thermometers, other types of thermometer, etc.

The inspection personnel should complete daily inspection reports on standard forms as described in Chapters 5 and 9 of JKR's Construction Supervision Manual for Contract Road Works. For ease of reference a draft of

JKR's standard form for inspection reports is included herein on Page 11. These reports should be submitted promptly to the JKR Superintending Officer's, or the Engineer's, Representative on Site. In particular, all shortcomings in the work being carried out should be noted and reported to the JKR Superintending Officer's, or the Engineer's, Representative on Site as soon as possible. Such shortcomings should also be brought to the attention of the Contractor, or his Agent on Site, without delay. However the daily inspection reports should not be used for this purpose and should not be shown to the Contractor or his staff.

In addition to the daily inspection reports, separate records for pile driving, the in situ construction of bored piles, and pile load tests should be kept on standard forms especially prepared for these purposes. The forms should be the standard JKR forms or similar. The details of pile driving, bored pile construction, and pile load tests are important construction records which should be kept in especially designated files arranged by structure and/or part of structure.

In the table commencing on the next page, minimum desirable levels of inspection are set forth for all items of work commonly included in road construction, improvement and periodic maintenance contracts. Both the amount of inspection required, and the class of inspection personnel to be provided are specified. It may not always be possible to meet these requirements in full due to staff shortages. In such circumstances, as much inspection as is possible should be undertaken by as high a class of inspection personnel as can be made available. In critical cases, the JKR Superintending Officer's, or the Engineer's, Representative on Site should order the Contractor to suspend some or all of the work operations until satisfactory levels of inspection can be provided.

	Items of Works	Inspection Requirements
1	Clearing, grubbing, bush trimming, etc.	Identification of saleable timber and other materials and/or property to be salvaged or preserved, spot checks on work in progress, and final inspection - Class D
2	Topsoil stripping,stockpiling or spreading	Spot checks on work in progress, and final inspection - Class D
3	Excavation in all types of material (including rippable rock) for roadway cuts, drainage channels, structures, common borrow, select material, etc.	Initial inspection and spot checks to verify the type of material being excavated, and final inspection - Class D When selection or separation of different types of material is involved, part-time inspection, 30-40%, should be provided - Class C. During final stages of excavation for foundations of structures, full-time inspection should be provided - Class B.
4	Drilling and blasting hard rock, boulders, etc.	Initial inspection to verify the class of material, spot checks of all phases of the work, and final inspection - Class D Particular attention should be paid to safety measures by a suitably experienced inspector - Class A or C.
5	Spoil disposal	Spot checks on work in progress, and final inspection - Class D
6	Embankment, fill/backfill and select fill/backfill construction (including granular bedding, etc.), and subgrade preparation, including placing and shaping of fill materials, adjusting moisture content, compaction and final shaping	Initial inspection of work area, inspection of materials, part-time inspection, 40-50%, of all phases of the work, and final inspection - Class D For backfill to structures, inspection should be full-time. Particular attention should be paid to checking the quality of select fill/backfill materials.
7	Construction or rehabilitation of unbound pavement courses: - lower subbase - road shoulders (earth or gravel) - drains through shoulders	Initial inspection of work area, inspection of materials, full-time inspection of all phases of the work, and final inspection (including thickness checks) - Class D When cement or lime stabilization of soils or

	- gravel surfacing - subbase - roadbase	aggregates is involved, inspections should be Class B.
8	Construction or making good of bituminous prime coat	Initial inspection of work area, inspection of equipment and materials, full-time inspection of all phases of the work, and final inspection - Class C Particular attention should be paid to checking and monitoring spray rates.
9	Construction, strengthening, or rehabilitation of bituminous pavement courses: - surface dressing - penetration macadam - bituminous macadam (roadbase, binder course, wearing course, levelling course, overlay) - asphaltic concrete (binder course, wearing course, levelling course, overlay) - slurry seal - seal coat or black seal	Initial inspection of work area, inspection of equipment and materials, full-time inspection of all phases of the work (including tack coat when appropriate), and final inspection - Class C As appropriate, particular attention should be paid to checking and monitoring spray rates of bituminous materials, and paving thicknesses. When plant mixed materials are involved, inspection of equipment and materials at the plant, and full-time inspection of the mixing process should also be provided - Class C.
10	Minor repairs of bituminous pavements: - pothole repairs - edge failure repairs - surface patching, etc.	Inspection of materials, part-time inspection, 50-60% of all aspects of the work, and final inspection - Class C
11	Pile driving (including splicing/jointing)	Inspection of piles and equipment, full-time inspection equipment, full-time inspection of driving, and preparation of driving records for each pile - Class C Particular attention should be paid to checking pile types, sizes and lengths, inspecting all splices and joints, and-recording the tip elevation and final driving penetration rate for each pile.
12	Construction of bored piles	Inspection of materials and equipment, including casing when required, full-

		time inspection of drilling, inspection of reinforcement before and after placing in borehole or casing, full-time inspection of concrete mixing and pouring, and preparation of pile records - Class C Pile records should include for each pile details of cross-section, casing, reinforcement, tip elevation, length and weight of concrete poured.
13	Pile load tests	Inspection of all testing equipment, full-time inspection of loading and unloading, and preparation of comprehensive load-time-settlement records - Class C
14	Reinforced (or mass) concrete construction for cast in situ structures, or precast elements, or rigid pavement	Inspection of materials, inspection of reinforcement after fixing or placing, and inspection of formwork before and after erection - Class C Full-time inspection of concrete mixing and pouring - Class C Particular attention should be paid to checking and monitoring the proportions of cement, aggregates and water being mixed. Spot checks during curing, and final inspection after formwork removal - Class B
15	Prestressed concrete construction	Inspections should be as for reinforced concrete construction with additional inspections as follows. Inspection of prestressing equipment and materials, inspection of ducts and cables after fixing, and full-time inspection of prestressing operations and duct grouting - Class A
16	Placing prefabricated elements, in structures, especially beams in bridges Note: Complicated bridges and structures are beyond the scope of these guidelines.	Inspection of all equipment and prefabricated sections, inspection of all bearings, supports and fastenings both permanent and temporary, full-time inspection of all phases of the work - Class C
17	Asphaltic damp-proofing of concrete surfaces	Inspection of prepared concrete surfaces and materials, full-time inspection of the work, and final inspection - Class C
18	Assembly of culvert pipes from precast concrete or	Inspection of materials, part time inspection, 40-50%, of all phases of the work, and final

	steel elements, and box culverts from precast concrete sections, including preparation of foundations and bedding	inspection - Class C Particular attention should be paid to checking each and every culvert section prior to assembly, and each and every joint after assembly. For steel pipes, each section should be assembled in the correct location and sequence with all joints and fastenings completed all as per the manufacturer's instructions. When the bedding material is con crete, full-time inspection of concrete mixing and pouring should be provided.
19	Construction of subsoil drains	Inspection of trench and materials, part-time inspection, 40-50%, of the work, and final inspection (before backfilling) - Class C
20	Miscellaneous works: - concrete blinding - brickwork or masonry - installation of gabions - construction of grouted or ungrouted stone pitching (or rip-rap) - installation of guardrail and other road furniture - application of road markings	Inspection of materials, part-time inspection, 30-40%, of the work, and final inspection - Class D
21	Grassing : - sodding - sprigging - seeding	Inspection of materials, spot checks on work in progress, and final inspection - Class D
22	Hydroseeding	Initial inspection of work area, inspection of equipment and materials, and full-time inspection of spraying - Class C Particular attention should be paid to checking and monitoring spray rates.

In addition to construction of the Permanent Works, the inspection personnel are also required to inspect continually the Contractor's maintenance of all roads affected by the Works, and the construction and maintenance of all Temporary Works provided for the use of the travelling public, including:

- diversions, temporary roads, temporary road surfaces, temporary bridges, etc.
- traffic signs and traffic control systems needed for the safe passage of the travelling public in and/or around work areas, and on diversions, temporary roads and temporary road sur faces.

The inspection requirements for road maintenance, and the construction and maintenance of such Temporary Works are described in Chapter 11 of JKR's Construction Supervision Manual for Contract Road Works, and in Arahan Teknik (Jalan) 2C/85, Manual on Traffic Control Devices, Temporary Signs and Work Zones Control.

JABATAN KERJA RAYA CAWANGAN JALAN CONTRACT JKR/PERS/IP/ /	INSPECTION REPORT	FOR RESIDENT ENGINEER'S STAFF USE ONLY NAME: POSITION: DATE:

WORK / OPERATION INSPECTED	TIME	CHECKS									COMMENTS (DEFICIENCIES, DEGREE OF COMPLETION,WEATHER,OTHER)
		1	2	3	6	5	6	7	8	9	

CHECK - LIST		CHECK MARKS		INSPECTOR'S
1 SETTING OUT	6 MATERIALS	ALL AS REQUIRED	v	SIGNATURE:
2 PRIOR WORK	7 TESTING	DEFICIENT	X	
3 DIMENSIONS	8 COMPACTION	NOT APPLICABLE	-	RESIDENT
4 EQUIPMENT	9 WORKMANSHIP	NOT CHECKED	O	ENGINEER'S
5 LABOUR				SIGNATURE:

Part 11 - Quality Control Testing

1 General

As far as practicable, all quality control testing of materials and workmanship should be directed and carried out by the staff of the JKR Superintending Officer, or the Engineer, responsible for supervision of construction, and/or the staff of JKR laboratories. As a general rule, the initiation and execution of quality control testing must not be left to the Contractor.

Normally a project laboratory for the exclusive use of the JKR Superintending Officer, or the Engineer, responsible for supervision of construction will be provided for each road works contract. For small projects and other contract works for which a project laboratory is not provided, testing should be carried out at the most conveniently located JKR laboratory with the necessary facilities. This may be the laboratory for a nearby project, the laboratory at a nearby JKR District Office or JKR Felda Regional Office, or one of the JKR Regional Laboratories, or the JKR Central Laboratory.

It is assumed herein that project laboratories and Regional Laboratories will be equipped for all the routine tests frequently required in supervision of contract road works, but that less frequently required tests, especially those requiring expensive apparatus or unusual expertise, will be carried out at the JKR Central Soils and Materials Laboratory in Kuala Lumpur. In the event that a test assumed herein to be carried out at the JKR Central Laboratory can in fact be performed at a project laboratory or Regional Laboratory, then the minimal frequencies for that test stated herein should be increased twofold or threefold. All methods of testing should be as stipulated in the Specifications. Normally they will be methods specified in Malaysian Standards, or internationally recognized standard methods of testing specified by agencies such as the British Standards Institution, the American Association of State Highway and Transportation Officials (AASHTO), the American Society for Testing and Materials (ASTM), etc. However occasionally the Specifications may require variations of such standard test methods, or special non-standard methods of testing.

In the event that the Specifications do not stipulate a method of test, then an appropriate Malaysian, or internationally recognized, standard method should be designated by the Representative on Site of the JKR Superintending Officer, or the Engineer, responsible for construction supervision. In such case:

- if a Malaysian Standard exists it should be adopted
- if there is no Malaysian Standard, the British Standard should be adopted
- if there is no Malaysian or British Standard, the AASHTO Standard should be adopted
- if there is none of the above stan dards, the ASTM Standard should be adopted, and if there is also no ASTM Standard, any known stan dard in international or national use (in any country) may be adopted.

All test results should be recorded on standard forms especially prepared for the purpose. Forms should be as recommended in the specified methods of testing, or should be the standard JKR forms or similar. The-test records should be kept in special files, separate from other contract documents and records.Compaction test results should be arranged by item of work and location in the Works. Materials quality test results should be arranged by type and/or source of material, and intended use and/or location in the Works. All test records should be kept, including those for substandard materials not approved for use in the Works, and those for materials which, after testing, the Contractor elects not to use for whatever reason.

It must be remembered that testing takes time. For example it takes at least a week to carry out a soaked CBR test and its associated compaction test. It also takes a week to carry out a sodium sulphate soundness test, plus possibly another two or three weeks for the sample to be transported to the Central Laboratory for testing, and for the results to be reported back to the Site. Accordingly, the staff of the JKR Superintending Officer, or the Engineer, should continually prompt the Contractor to submit samples for testing well in advance of the intended time for using each and every material and product in the Works. This is particularly important for manufactured materials and products, including steels, bitumens, cements, culvert pipe sections, etc., for which testing will normally be carried out off Site and may include complicated and time consuming procedures.

Works performed in relatively small quantities, or with relatively variable materials, or with relatively low levels of inspection, should be subjected to more intensive testing than described in these guidelines. On the other hand, if conditions are unusually uniform, or if inspection has been very thorough for some parts of the works, then less frequent testing than described may be adequate for those parts. That is to say the guidelines should be applied with discretion.

2 Compaction Control of Earth Materials and Aggregates

Representative samples of each material to be compacted should be taken from the work area immediately prior to compaction and subjected to the appropriate method of compaction test as determined from the Specifications. This should normally be the B.S. 1377 Compaction Test (4.5 kg rammer method). Field density testing, using the sand replacement method as far as practicable, or such other method as is stipulated in the Specifications, should be performed on completion of compaction. The core cutter method of field density testing is generally not very satisfactory, and is inherently less accurate than the sand replacement method. Thus the core cutter method should only be used when special circumstances preclude using the sand replacement method, or such other method as is stipulated in the Specifications.

The results of compaction control tests are often needed quickly, in which case, the compaction tests may be carried out in advance of the compaction operations. However care must be taken to ensure that the samples tested are representative of, and can be identified with, specific portions or areas of the work. Also, if absolutely necessary, the field density testing procedure can be accelerated by carrying out the moisture content determinations on site using a frying pan (or wok) and portable stove. However in such circumstances, duplicate moisture content samples should also be oven dried in the project laboratory in the normal way to check the results obtained by the field method.(Note: The Speedy Moisture Tester is generally not suitable for determining moisture contents as part of the field density testing procedure. It usually underestimates the moisture contents of fine grained soils and pavement materials, especially those containing some clay. This, in turn leads to an overestimation of dry density.)

In general, 1 compaction test should be carried out for every 2-4 field density tests in variable materials, and for every 5-8 field density tests for relatively uniform materials. The frequencies for field density tests should be as shown in the table on the next page.

Material	Field Density Testing Frequency
Earth embankment (or fill)	1 Test per 500 m^2 for each layer of compacted material
Top 300 mm of subgrade Lower subbase	1 Test per 300 m^2 for each layer of compacted material
Gravel surfacing Subbase	1 Test per 200 m^2 for each layer of compacted material
Crushed aggregate roadbase	1 Test per 150 m^2 for each layer of compacted material
Shoulders (earth or gravel)	1 Test per 150 m^2 for each layer of compacted material
Granular bedding for culverts and pipes	1 Test per layer per 25 m length of culvert or pipe
Granular bedding for other structures	1 Test per layer per 25 m length of structure, or per-footing, or per 200 m^2 of foundation slab as appropriate
Backfill for structures (including culverts)	2 Tests per layer per structure (1 on each side of the structure) for each 25 m length of structure
Backfill for subsoil drains	1 Test per layer per 50 m length of trench

3 Quality Control of Earthwork and Flexible Pavement Materials

3.1 Embankment, Fill/Backfill and Select Fill/Backfill

Generally, soils and aggregates should only require careful visual examination by an experienced earthwork inspector to determine whether or not they are satisfactory for their proposed uses in embankment, fill or backfill construc tion. However in marginal cases, and for special purpose materials, a few labora tory tests should be carried out, as appropriate to each material's specification, as follows:

- determination of Atterberg limits, swelling or shrinkage characteristics and/or content of organic material in soils thought to be possibly unsuitable for common embankment material

- determination of plasticity index and/or gradation analysis of material proposed for granular fill, granular bedding, drainage blanket, porous/ granular backfill to structures, aggregate filters/drains, etc.

3.2 Lower Subbase and Top 300 mm of Subgrade

To ensure compliance with the Specifications and as a check of the pavement design assumptions, comprehensive testing of these materials is required. The following tests should be carried out for each 1,500 m^3 of material to be placed, i.e. a frequency of 1 - 2 tests per km of road depending on the thickness involved:

- Atterberg limits and plasticity index - gradation analysis

- B.S. 1377 Compaction Test (4.5 kg rammer method)

- CBR test (4 days soak with sur charge and swell measurement).

3.3 Earth Shoulders

Testing should be the same as for lower subbase.

3.4 Gravel Shoulders, Gravel Surfacing, Subbase and Crushed Aggregate Roadbase

Routine tests, for which the project laboratories (where provided) or the Regional Laboratories are equipped, should be carried out, as appropriate to each material's specificatcn, for every 750 m^3 of material stockpiled for or placed in the Works. These tests include, but are not necessarily limited to:

- Atterberg limits and plasticity index

- gradation analysis

- B.S. 1377 Compaction Test (4.5 kg rammer method)

- CBR test (4 day soak with surcharge and swell measurement)

- determination of flakiness index

- determination of % particles with a fractured face.

Other quality tests which are appropriate to the Specifications, but cannot be performed on Site or in the project laboratory or Regional Laboratory, should be carried out at the Central Laboratory in Kuala Lumpur. In such cases at least one test should be performed for each source of material. Additional tests should be carried out if a source proves to be unusually variable and/or the quality of the material is suspect. These tests include, but are not necessarily limited to:

- sodium sulphate soundness test

- aggregate crushing value test.

When cement or lime stabilization of soils or aggregates is specified, routine tests appropriate to the specification of the stabilized material should be carried out at the project laboratory for every 250 m^3 of stabilized material placed in the Works, and at least once for each section of work completed at one time. These tests could include, but may not necessarily be limited to:

- Atterberg limits and plasticity index
- B.S. 1377 Compaction Test (4.5 kg rammer method) - CBR test (as specified)
- compressive strength test (soil cement)
- wetting and drying test (soil cement).

In addition, if problems are being experienced with cement stabilized materials, it may be necessary to determine the cement content of samples cut from the Works. This testing would probably need to be done at the Government Chemical Laboratory.

3.5 Aggregates for Bituminous Surface Dressing and Penetration Macadam (Semi-grout Surfacing)

Routine tests, for which the project laboratories (where provided) or the Regional Laboratories are equipped, should be carried out, as appropriate to each aggregate's specification, as folows:

- for aggregates of nominal size 25mm or less, 1 set of tests for every 200m^3 of material stockpiled for the Works
- for aggregates of nominal size greater than 25 mm, 1 set of tests for every 400 m^3 of material stockpiled for the Works.

These tests include, but are not necessarily limited to:

- gradation analysis
- particle shape tests such as determination of flakiness index, % of elongated particles, etc.
- determination of % particles with a fractured face.

Other quality tests which are appropriate to the Specifications, but cannot be per formed on Site or in the project laboratory or Regional Laboratory, should be carried out at the Central Laboratory in Kuala Lumpur. In such cases at least one test should be per formed for each source of material. Additional tests should be carried out if a source proves to be unusually variable and/or the quality of the material is suspect. These tests include, but are not necessarily limited to:

- specific gravity and absorption test - sodium sulphate soundness test
- aggregate crushing value test - polished stone value test
- bitumen stripping test.

3.6 Aggregates for Asphaltic Concrete and Asphaltic Concrete Mixtures

For all projects there should be provisions in the Contract Documents for each mixing plant to be provided with its own small laboratory, staffed by an experienced asphalt technician and an assistant, and equipped for the routine tests set forth hereunder. However, for minor works, for which the mixing plant is within convenient reach of a project laboratory or a Regional Laboratory, say within 15 minutes travelling time, then some or all testing could, if necessary, be handled by that laboratory.

Test	Frequency
Gradation analysis of stockpiled aggregates	1 Test per stockpile per 2,500 tons (or 1,000 m^3) of asphaltic concrete produced
Particle shape tests such as determination of flakiness index, % of elongated particles, etc., as appropriate	1 Test per stockpile (coarse aggregates only) per 2,500 tons (or 1,000 m^3) of asphaltic concrete produced
Determination of % particles with a fractured face	1 Test per stockpile (coarse aggregates derived from crushed gravel only) per 2,500 tons (or 1,000 m^3) of asphaltic concrete produced
Specific gravity and water absorption of stockpiled aggregates	1 Test per stockpile per 2,500 tons (or 1,000 m^3) of asphaltic concrete produced
Gradation analysis of aggregates in mixing plant hot bins	1 Test per hot bin per day of production (for drum mix plant sample cold feed bins)
Gradation analysis of mineral filler (if used)	1 Test per day of production (mineral filler includes ordinary Portland cement added as anti-stripping agent)
Atterberg limits and plasticity index of blended aggregate fines (if plastic)	1 Test per day of production (sample from fines hot bin, or for drum mix plant from cold feed belt)
Comprehensive Marshall method test and analysis of asphaltic concrete as follows: - preparation of specimens for standard stability and flow test - determination of bulk specific gravity of the specimens - determination of stability and flow values - analysis to determine .% of voids in compacted aggregate, % of these voids filled with bitumen, and % of air voids	1 Test per 200 tons of asphaltic concrete produced (samples to be taken at plant), and at least one test for each plant operating session

in compacted mix	
* Extraction of bitumen from asphaltic concrete	1 Test per 200 tons of asphaltic concrete produced (samples to be taken at plant), and at least one test for each plant operating session
* Gradation analysis of aggregate extracted from asphaltic concrete	1 Test per 200 tons of asphaltic concrete produced (samples to be taken at plant), and at least one test for each plant operating session
Determination of maximum specific gravity of asphaltic concrete (if necessary due to absorptive aggregates)	1 Test per 200 tons of asphaltic concrete produced (samples to be taken at plant), and at least one test for each plant operating session

* It may also be necessary for these tests to be carried out on samples of asphaltic concrete cut from the road surface if problems occur during paving, or if the material looks unsatisfactory or performs poorly after paving.

A sample of compacted asphaltic concrete should be obtained using a core drill fitted with a diamond bit for every 500 m2 of asphaltic concrete laid in the Works. These samples should be used to determine the thickness of the paving layer and the bulk specific gravity of the compacted mixture.

Other quality tests which are appropriate to the Specifications, but cannot be performed in the mixing plant laboratories, should be carried out at the Central Laboratory in Kuala Lumpur. In such cases at least one test should be performed for each source of material. Additional tests should be carried out if a source proves to be unusually variable and/or the quality of the material is suspect. These tests include, but are not necessarily limited to:

- sodium sulphate soundness test
- aggregate crushing value test - polished stone value test
- bitumen stripping test.

3.7 Aggregates for Bituminous Macadam and Bituminous Macadam Mixtures

Testing should be the same as described above for asphaltic concrete, except that for bituminous macadam, the comprehensive Marshall method test and analysis of the asphaltic mixture is not normally required.

4 QUALITY CONTROL OF CONCRETE AND STRUCTURES

4.1 Concrete Aggregates

Coarse aggregates for concrete should not contain alkali reactive silicas such as chalcedony, chert or flint. The best indicator of the absence of such silicas is the previous long-term successful use of aggregates from a particular source in concrete works. However

aggregates, especially from new or recently exploited sources, and particularly from gravel sources, should be carefully physically examined for alkali reactive silicas. This can be done on Site or in a Regional Laboratory or at the Central Laboratory in Kuala Lumpur by a person of appropriate qualifications and experience.

Routine tests, for which the project laboratories (where provided) or the Regional Laboratories are equipped, should be carried out at the following frequencies.

Test	Frequency
Gradation analysis aggregate	1 Test per stockpile per 100 tons of
Specific gravity and absorption test	1 Test per stockpile per 1,000 tons of aggregate
Particle shape tests such as determination of flakiness index, % of elongated particles, etc.	1 Test per stockpile per 1,000 tons of aggregate (coarse aggregates only)
Determination of clay and silt content	1 Test per stockpile per 1,000 tons of aggregate
Organic impurities test	1 Test per stockpile per 1,000 tons of aggregate (fine aggregates only)

Other quality tests which are appropriate to the Specifications, but cannot be performed on Site or in the project laboratory or Regional Laboratory, should be carried out at the Central Laboratory in Kuala Lumpur. In such cases at least one test should be performed for each source of material. Additional tests should be carried out if a source proves to be unusually variable and/or the quality of the material is suspect. These tests include, but are not necessarily limited to:

- sodium sulphate soundness test (coarse and fine aggregates)
- aggregate crushing value test (coarse aggregates only)
- determination of chloride content
- determination of sulphate content.

Marine aggregates, both coarse and fine, should be regularly tested for chloride content at the Site. This can be done very simply using manufactured titrator strips such as "Quantab" brand manufactured by Ames Company (a division of Miles Laboratories Inc.) of Elkhart, Indiana, 46514, U.S.A. A frequency of 1 Test per 100 tons of aggregate stockpiled, or 2 tests per batch or source of material, whichever is greater, is recommended.

The above testing frequencies may be relaxed somewhat for aggregates to be used in

blinding and mass concrete or other low quality types.

4.2 Water for Concrete

In cases where water quality is doubtful, e.g. excessive acidity or alkalinity, or sulphate content, or chloride content, etc. is suspected, testing and analysis should be performed. Samples should be sent to the Central Laboratory in Kuala Lumpur to determine the effects on mortar setting time and compressive strength, and to the Government Chemical Laboratory (also in Kuala Lumpur) for chemical analysis.
Samples should be collected and stored in clean glass containers. About 10 litres is required for the mortar tests at the Central Laboratory and 5 litres for analysis at the Government Chemical Laboratory.

4.3 Concrete

The sampling frequencies of different classes or types of concrete for compressive strength testing should be as stipulated in the Specifications. If sampling frequencies are not specified, then on each day of production at a particular location, 1 batch of each class or type of concrete made should be sampled.
Each sample should be tested for workability by the slump test, and used to mould 3 standard compressive, strength test cubes, 1 for testing at 7 days and 2 for testing at 28 days.

In addition, slump tests should be performed frequently and regularly during concrete production to ensure good consistency and workability of the mix at all times.

4.4 Reinforcing, Prestressing and Structural Steel

From each batch of materials delivered to the Site, 3 representative samples of each size of each type of material should be cut, weighed and measured, to check that weights per unit length and general dimensions and shapes conform to the Specifications.
Following these basic tests on Site, the samples should be sent to the Central Laboratory in Kuala Lumpur for tensile strength tests.

4.5 Welding

The skill and competence of the Contractor's welder (or welders) should be tested and shown to be of a satisfac tory standard in the type (or types) of welding to be carried out, before any welding is done for the Works.

For butt welding of reinforcing steel for concrete, each welder should make at least 2 trial welds in situations reflecting the working conditions on Site (e.g. overhead welding, welding in confined spaces, etc. as appropriate). The trial welds should be subjected to transverse bend tests.

For other types of welding, comparable trials should be carried out. Trial welds should be subjected to bend testing, ultrasonic testing, or X-ray inspection as appropriate.

4.6 Precast Concrete Culvert Pipes

Concrete culvert pipe sections cast at the Site should be subject to inspection and testing of materials and workmanship in the same way as other concrete works.
In addition, samples of each class of each size of pipe should be load tested 28 days after casting, to test for compliance with the relevant load bearing specifications. At least 5% of pipe sections of each class of each size of pipe fabricated should be tested to their specified proof (or cracking) loads. At least 2% of pipe sections of each class of each size of pipe fabricated should be load tested to failure (ultimate load test).

Load testing of concrete culvert pipe sections should be carried out at the Site,

or at a concrete products factory with suitable test facilities. The Contractor should be responsible for organizing and arranging the testing, and for paying all the costs thereof. However the selection of samples for testing, and the actual load tests, should be carried out, or at least closely supervised and directed, by an engineer or other senior technical representative of the JKR Superintending Officer, or the Engineer, responsible for construction supervision.

The JKR Central Laboratory maintains a list of approved manufacturers and factories of concrete culvert pipe sections. When the Contractor elects to purchase concrete culvert pipe sections from a factory on this list, samples of each class of each size of pipe being purchased should be load tested 28 days after casting, to test for compliance with the relevant load bearing specifications. At least 3% of pipe sections of each class of each size of pipe purchased should be tested to their specified proof (or crack ing) loads. At least 1% of pipe sections of each class of each size of pipe purchased should be load tested to failure (ultimate load test). In the case of spun pipes with elliptical reinforcement, particular attention should also be paid to the correct and clear identification and marking of the loading axis on each and every section of pipe.

When the Contractor elects to purchase concrete culvert pipe sections from a source which is not on the list of approved factories, the matter should be referred to the Central Laboratory, to find out if the source has been or is to be subject to inspection and testing by the Central Laboratory. For non-approved sources, the inspection and testing programme should be the same as that for concrete culvert pipe sections cast at the Site, including the inspection and testing of all materials and workmanship, as well as the load testing of finished pipe sections. Again, in the case of spun pipes with elliptical reinforcement, particular attention should also be paid to the correct and clear identification and marking of the loading axis on each and every section of pipe.

In all cases, the Contractor should be responsible for organizing and arranging the inspection and testing of materials, workmanship and completed pipe sec tions, all at his own and/or the manufacturer's expense. Materials testing, when required, should be carried out at the project laboratory and other laboratories in the same way as for concrete works on Site. Pipe load tests should be carried out at the source factory or another factory with suitable test facilities. However the selection of samples, and the actual load tests, should be carried out, or at least closely supervised and directed, by an engineer or other senior technical representative of the JKR Superintending Officer, or the Engineer, responsible for construction supervision.

5 QUALITY CONTROL OF ROAD SURFACE REGULARITY AND TEXTURE

5.1 Surface Regularity of Carriageways and Shoulders

Longitudinal traverses with a rolling straight-edge or wedge and straight-edge device should be carried out for every 300 m of completed road surface. At least one traverse should be made in each traffic lane and, when appropriate, on each shoulder.

Measurements of transverse regularity should be made using a 3 m straight-edge at intervals of not more than 50 m along completed sections of road surface, and at any areas which appear uneven. At each measurement position, the full width profile of the carriageway and shoulders should be checked.

Areas of carriageway and/or shoulder where surface regularity does not comply with the Specifications should be accurately identified, fully delineated, and marked for correction

5.2 Surface Texture of Concrete Road Surfaces

For each section of concrete pavement constructed in a single production run, the texture depth should be measured by at least 1 set of 10 sand patch tests. For large construction runs, 1 set of 10 sand-patch tests should be carried out for every 500 m^2 of pavement constructed.

6 QUALITY CONTROL OF MANUFACTURED MATERIALS

The JKR Central Laboratory maintains lists of approved manufacturers and fac tories for certain materials, including bitumens and some bituminous materi als, cements, corrugated metal culvert pipes, guardrail, materials for road marking and road signs, etc. For these and other manufactured materials, com prehensive testing would generally require facilities and apparatus not avail able on Site or in the project laboratory or Regional Laboratory, and in many cases not available at the Central Laboratory in Kuala Lumpur.

For a material from an approved source, manufacturer's certificates should gener ally suffice as a guarantee of quality, however, such tests as can be done should be done. Testing, as appropriate to each material, should include, but not necessarily be limited to:

- physical measurements of weights, densities, and dimensions
- physical measurements of protective coating thicknesses
- compressive strength tests
- tensile strength tests
- moisture content tests
- setting or curing or hardening time tests
- flow rate tests
- penetration tests, etc.

For material from a source which is not on the appropriate list of approved factories, or for material of a type for which the Central Laboratory does not have a list of approved factories, and in cases where the quality of a material is suspect and/or diffi culties are being experienced on Site, less reliance can be placed on manufacturers' certificates, and more thorough and fre quent inspection and testing should be car ried out. The testing of materials in these categories should be referred through the project laboratory or Regional Laboratory to the Central Laboratory for advice and assistance. If possible, the Central Laboratory should test representative sam ples of the material, or otherwise arrange for testing elsewhere (e.g. Government Chemical Laboratory, independent private sector laboratories, etc.).

Materials to be handled in this way would include, but not necessarily be limited to:

- penetration graded bitumens
- cut-back bitumens
- bitumen emulsions
- cements
- manufactured structural elements and fittings
- welding materials
- corrugated metal culvert pipes
- clay and plastic pipes for drains - bridge

bearings
- bricks
- joint sealants
- joint fillers
- waterproofing and damp-proofing materials
- paints
- thermoplastic materials for road marking
- materials for road signs and support ing structures
- geotextiles
- fabric (or wick) filter materials
- gabion cages
- guardrail
- railing and fencing materials, etc.

ITEM OF WORK	INSPECTION REQUIREMENTS	TESTING REQUIREMENTS	
		MATERIAL QUALITY CONTROL	COMPACTION CONTROL
Clearing	Page 7, Item 1	-	-
Grubbing	Page 7, Item 1	-	-
Bush trimming	Page 7, Item 1	-	-
Topsoil	Page 7, Item 2	-	-
Excavation:			
- common excavation (including rippable rock)	Page 7, Item 3	Page 15, Sections 3.1 to 3.3	-
- drilling and blasting hard rock, boulders, etc.	Page 7, Item 4	-	-
Spoil disposal	Page 7, Item 5	-	-
Embankment	Page 7, Item 6	Page 15, Section 3.1	Page 14, Section 2
Fill/backfill:	Page 7, Item 6	Page 15, Section 3.1	Page 14, Section 2
Backfill to structures	Page 7, Item 6	Page 15, Section 3.1	Page 14, Section 2
Select fill/backfill:	Page 7, Item 6	Page 15, Section 3.1	Page 14, Section 2
- granular fill			
- granular bedding			
- drainage blanket			
- porous/granular backfill to structures			
- aggregate filters/drains, etc.			
Subgrade	Page 7, Item 6	Page 15, Section 3.1	Page 14, Section 2
Top of subgrade	Page 7, Item 6	Page 15, Section 3.2	Page 14, Section 2
Lower subbase	Page 7, Item 7	Page 15, Section 3.2	Page 14, Section 2
Subbase	Page 7, Item 7	Page 15, Section 3.4	Page 14, Section 2
Roadbase:			
- crushed aggregate	Page 7, Item 7	Page 15, Section 3.4	Page 14, Section 2
- bituminous macadam	Page 8, Item 9	Page 18, Section 3.7	Page 18, Section 3.7

ITEM OF WORK	INSPECTION REQUIREMENTS	TESTING REQUIREMENTS	
		MATERIAL QUALITY CONTROL	COMPACTION CONTROL
Shoulders:			
- earth	Page 7, Item 7	Page 15, Section 3.3, and when appropriate Page 21, Section 5.1	Page 14, Section 2
- gravel	Page 7, Item 7	Page 15, Section 3.4, and when appropriate Page 21, Section 5.1	Page 14, Section 2
- drains through shoulders	Page 7, Item 7	Page 15, Section 3.1	-
Gravel surfacing	Page 7, Item 7	Page 15, Section 3.4, and when appropriate Page 21, Section 5.1	Page 14, Section 2
Bituminous prime coat	Page 8, Item 8	Page 22, Section 6	-
Bituminous tack coat	Page 8, Item 9	Page 22, Section 6	-
Bituminous surface dressing	Page 8, Item 9	Page 16, Section 3.5 Page 22, Section 6 when appropriate Page 21, Section 5.1	-
Penetration macadam (semi-grout surfacing)	Page 8, Item 9	Page 16, Section 3.5 Page 22, Section 6 when appropriate Page 21, Section 5.1	-
Bituminous macadam : - roadbase - binder course - wearing course - levelling course - overlay	Page 8, Item 9	Page 18, Section 3.7, Page 22, Section 6 when appropriate Page 21, Section 5.1	Page 18, Section 3.7
Asphaltic concrete: - binder course - wearing course - levelling course - overlay	Page 8, Item 9	Page 16, Section 3.6, Page 22, Section 6 when appropriate Page 21, Section 5.1	Page 16, Section 3.6
Slurry seal	Page 8, Item 9	Page 22, Section 6	-
Seal coat or black seal	Page 8, Item 9	Page 22, Section 6	-

ITEM OF WORK	INSPECTION REQUIREMENTS	TESTING REQUIREMENTS	
		MATERIAL QUALITY CONTROL	COMPACTION CONTROL
Minor repairs of bituminous pavements: - pothole repairs - edge failure repairs - surface patching	Page 8, Item 10	Pages 15 to 18, Section 3.3 to 3.7, and Pages 22, Section 6	-
Reinforced concrete piles			
- casting	Page 8, Item 14	Pages 18 to 20, Sections 4.1 to 4.5	-
- driving (including splicing/jointing)	Page 8, Item 11	Pages 18 to 20, Sections 4.1 to 4.5	-
- load testing	Page 9, Item 13	-	-
Prestressed concrete piles:			
- fabricating	Page 9, Item 15	Pages 18 to 20, Sections 4.1 to 4.5	-
- driving (including splicing/jointing)	Page 8, Item 11	Pages 18 to 20, Sections 4.1 to 4.5	-
- load testing	Page 9, Item 13	-	-
Steel piles:			
- fabricating	-	Page 20, Sections 4.4 and 4.5	-
- driving (including splicing/jointing)	Page 8, Item 11	-	-
- load testing	Page 9, Item 13	-	-
Timber (including bakau) piles:			
- driving and splicing	Page 8, Item 11	-	-
- load testing	Page 9, Item 13	-	-
Bored piles:			
- construction	Page 8, Item 12	Pages 18 to 20, Sections 4.1 to 4.5	-
- load testing	Page 9, Item 13	-	-
Concrete, mass or reinforced: - cast in situ structures	Page 9, Item 14	Pages 18 to 20, Sections 4.1 to 4.5 and for rigid pavement	-
- precast elements - rigid pavement		Pages 21 to 22 Sections 5.1 to 5.2	

ITEM OF WORK	INSPECTION REQUIREMENTS	TESTING REQUIREMENTS	
		MATERIAL QUALITY CONTROL	COMPACTION CONTROL
Concrete, prestressed	Page 9, Item 15	Page 18 to 20 Sections 4.1 to 4.5	-
Placing prefabricated elements in structures, especially beams in bridges	Page 9, Item 16	Page 22, Section 6	-
Asphaltic damp-proofing of concrete surfaces	Page 9, Item 17	Page 22, Section 6	-
Culvert assembly (also see Select fill and Concrete for bedding materials testing requirements):			
- precast concrete pipe culverts	Page 9, Item 18	Page 20, Section 4.6	-
-corrugated metal pipe culverts	Page 9, Item 18	Page 22, Section 6	-
-precast concrete box culverts	Page 9, Item 18	Page 18 to 20, Sections 4.1 to 4.5	-
Subsoil drains	Page 10, Item 19	Page 15, Section 3.1, and Page 22, Sections 6	Page 14, Section 2
Miscellaneous works:			
-concrete blinding	Page 10, Item 20	Page 18 to 20, Sections 4.1 to 4.3	-
-brickwork	Page 10, Item 20	Page 22, Sections 6	-
-masonary	Page 10, Item 20	-	
-gabions	Page 10, Item 20	Page 22, Section 6	-
-stone pitching, grouted or ungrouted	Page 10, Item 20	-	
-rip-rap	Page 10, Item 20	-	-
-guardrail	Page 10, Item 20	Page 22, Section 6	-
-road furniture	Page 10, Item 20	Page 22, Section 6	-
-road markings	Page 10, Item 20	Page 22, Section 6	-
Grassing:	Page 10, Item 21	-	-
-seeding			
- sprigging			
-sodding			
Hydroseeding	Page 10, Item 22	Page 22, Section 6	-