(3) Traffic

The design analysis are based on cummulative expected 18-kip equivalent single axle loads (ESAL) during the analysis period. The traffic loading classes applicable in the country is proposed in Chapter 4.

(4) Reliability

Reliability concept is introduced in AASHTO Guide 1986 to account for chance variations in both prediction and performance prediction. Reliability of 50 percent is adopted in the Guide, which is the lowest level suggested by AASHTO Guide 1988.

10.2.2 Performance Criteria

The primary measure of serviceability is the Present Serviceability Index (PSI) which ranges from 0 (impassable) to 5 (perfect road). The following assumptions are adopted in this Manual.

Gravel Road : Overall serviceability loss 3.0
(P_i = 3.5, P_t = 0.5)
Allowable rut depth 2.5 inches

SBST/DBST/BMP: P_i = 4.2, P_t = 1.5

AC : For Light Traffic Loading Classes
P_i = 4.2, P_t = 2.0

For Heavy Traffic Loading Classes
P_i = 4.2, P_t = 2.5

PCC : For Light Traffic Loading Classes
P_i = 4.5, P_t = 2.0

For Heavy Traffic Loading Classes
P_i = 4.5, P_t = 2.5

10.2.3 Material Property

The material properties of pavement materials are discussed in Chapter 5.

10.2.4 Structural Characteristics

(1) Drainage

The effects of certain levels of drainage on predicted pavement performance are important consideration in pavement design.

Table 10.2-2 presents the general definitions corresponding to different drainage levels from pavement structure.

TABLE 10.2-2 DRAINAGE LEVELS

Quality of Drainage	Water Removed Within
Excellent	2 hours
Good	1 day
Fair	1 week
Poor	1 month
Very Poor	(water will not drain)

In accordance with drainage level, AASHTO recommends m_i-values for modifying structural coefficients of base and subbase materials for flexible pavements and value of drainage coefficients Cd for rigid pavements.

In this Manual, m_1 of 0.9 and Cd of 0.9 are used.

(2) Load Transfer (Rigid Pavement)

The load transfer coefficient, J, is a factor used in rigid pavement design to account for the ability of a concrete pavement structure to transfer (distribute) load across discontinuities, such as joints or cracks.

In this Manual, load transfer coefficient of 4 is used considering from effect of plain joint.

10.2.5 Rehabilitation Works

(1) Gravel-Surfaced Road

When the condition of the initial pavement structure reaches at the terminal serviceability, (P_t = 0.5) the rehabilitation works will be applied. For gravel-surfaced roads, re-gravelling is proposed to remedy the thickness of gravel loss.

(2) SBST, DBST and BMP

As a rehabilitation works, reconstruction of surface course is proposed so that the structural strength of pavements after rehabilitation works will be the same as the initial pavement structures.

(3) Asphalt Concrete Pavement

The overlay with asphalt concrete of 5 cm. was adopted. The structural strength of pavement after overlay was estimated based on the following formula.

$$SN_y = SN_{01} + F_{RL} \cdot SN_{xeff}$$

where:

SN_y = total structural capacity required to support the overlay traffic

SN_{01} = structural capacity of overlay

SN_{xeff} = effective structural capacity of existing pavement immediately prior to time of overlay.

F_{RL} = Remaining life factor which accounts for damages of existing pavement, 0.7.

(4) Portland Cement Concrete Pavement

For PCC pavements, AC overlay with 5 cm in thickness was also adopted. The structural strength of flexible overlay-rigid existing is estimated based on the following formula.

$$SN_y = SN_{01} + F_{RL} \cdot (A_{2r} \cdot D_o + SN_{eff} - rp)$$

where:

A_{2r} = Structural layer coefficient of existing cracked PCC pavement layer, 0.4

D_o = Existing PCC layer thickness

SN_{eff-rp} = Effective (in-situ) structural capacity of all remaining pavement layers above subgrade except for existing PCC layer.

10.3 STANDARD DESIGN

The structural analysis of selected pavement types based on the design criteria and assumption previously mentioned was carried out by an electric computer, the outputs of which are reported in Appendix III. The traffic growth rate was assumed 3% per year.

Table 10.3-1 summarizes the outputs of analysis as the standard pavement design.

From this table, the economic pavement structures for each pavement type may be selected depending on traffic volume converted into the number of 1st year ESAL and strength of subgrades represented by CBR value.

TABLE 10.3-1 STANDARD PAVEMENT DESIGN

GRAVEL

First Year ESAL	CBR 3	CBR 4	CBR 6	CBR 8	CBR 10	CBR 15	CBR 20	Performance Period (Year)
0 - 1,300	GR-3	GR-2	GR-2	GR-2	GR-2	GR-2	GR-1	3-4
1,300 - 3,000	GR-5	GR-5	GR-4	GR-3	GR-3	GR-2	GR-2	

SBST

First Year ESAL	CBR 3	CBR 4	CBR 6	CBR 8	CBR 10	CBR 15	CBR 20	Performance Period (Year)
0 - 3,000	-	SBST-5	SBST-5	SBST-4	SBST-4	SBST-3	SBST-2	
3,000 - 8,000	-	-	-	SBST-5	SBST-5	SBST-4	SBST-3	3-5
8,000 - 14,000	-	-	-	-	-	SBST-5	SBST-4	

DBST

First Year ESAL	CBR 3	CBR 4	CBR 6	CBR 8	CBR 10	CBR 15	CBR 20	Performance Period (Year)
0 - 3,000	-	DBST-5	DBST-5	DBST-4	DBST-4	DBST-3	DBST-2	
3,000 - 8,000	-	-	-	DBST-5	DBST-5	DBST-4	DBST-3	5-8
8,000 - 14,000	-	-	-	-	-	DBST-5	DBST-4	

BMP

First Year ESAL	CBR 3	CBR 4	CBR 6	CBR 8	CBR 10	CBR 15	CBR 20	Performance Period (Year)
0 - 3,000	BMP-5	BMP-4	BMP-3	BMP-3	BMP-2	BMP-1	BMP-1	
3,000 - 8,000	-	BMP-5	BMP-5	BMP-4	BMP-3	BMP-2	BMP-1	8-10
8,000 - 14,000	-	-	-	BMP-5	BMP-4	BMP-3	BMP-2	

(CONT.) TABLE 10.3-1 STANDARD PAVEMENT DESIGN

AC

First Year ESAL	CBR 3	CBR 4	CBR 6	CBR 8	CBR 10	CBR 15	CBR 20	Performance Period (Year)
3,000 - 8,000	AC-4	AC-3	AC-3	AC-2	AC-2	AC-1	AC-1	10-15
8,000 - 14,000	AC-5	AC-4	AC-3	AC-3	AC-3	AC-2	AC-1	
14,000 - 21,000	AC-5	AC-4	AC-4	AC-3	AC-3	AC-2	AC-2	
21,000 - 30,000	-	AC-5	AC-4	AC-4	AC-3	AC-3	AC-2	
30,000 - 60,000	-	AC-5	AC-5	AC-5	AC-4	AC-3	AC-3	
60,000 - 100,000	-	-	-	AC-5	AC-5	AC-4	AC-3	
100,000 - 150,000	-	-	-	-	AC-5	AC-4	AC-4	
150,000 - 200,000	-	-	-	-	-	AC-5	AC-4	

PCC

First Year ESAL	CBR 3	CBR 4	CBR 6	CBR 8	CBR 10	CBR 15	CBR 20	Performance Period (Year)
8,000 - 14,000	PCC-2	PCC-2	PCC-1	PCC-1	PCC-1	PCC-1	PCC-1	15-20
14,000 - 21,000	PCC-2	PCC-2	PCC-2	PCC-2	PCC-2	PCC-2	PCC-2	
21,000 - 30,000	PCC-3	PCC-3	PCC-3	PCC-2	PCC-2	PCC-2	PCC-2	
30,000 - 60,000	PCC-4	PCC-4	PCC-3	PCC-3	PCC-3	PCC-3	PCC-3	
60,000 - 100,000	PCC-4	PCC-4	PCC-4	PCC-4	PCC-4	PCC-4	PCC-4	
100,000 - 150,000	PCC-5	PCC-5	PCC-5	PCC-5	PCC-5	PCC-5	PCC-5	
150,000 - 200,000	PCC-5	PCC-5	PCC-5	PCC-5	PCC-5	PCC-5	PCC-5	

10.4 RECOMMENDED PAVEMENT TYPES

The life cost analysis of standard structures of each pavement type was conducted. Figure 10.4-1 and 10.4-2 graphically demonstrate the outputs of analysis such as the initial cost and life cycle cost of standard pavement structures in case of CBR value of 3, 8 and 20, respectively.

Figure 10.4-3 shows an example of recommendation on economical pavement types in case of CBR value of 8, which may be considered the average strength of subgrade. The recommendation may be summarized as follows:

Primary Major Road

. 1st year ESAL	0 ~ 1,300 (AADT 100)	:	Gravel
. 1st year ESAL	1,300 (AADT 100) ~ 8,000 (AADT 400)	:	DBST/BMP
. 1st year ESAL	8,000 (AADT 400) ~ 30,000 (AADT 1,000)	:	AC
. 1st year ESAL	30,000 (AADT 1,000) ~ Over	:	PCC

Secondary Major/Minor Roads

. 1st year ESAL	0 ~ 3,000 (AADT 200)	:	Gravel
. 1st year ESAL	3,000 (AADT 200) ~ 8,000 (AADT 400)	:	DBST/BMP
. Over 8,000		:	Same as primary major roads

It is, however, noted that the discussion on economic pavement types involves uncertainty in performance prediction and traffic prediction, an overestimate of which can result in finance being invested prematurely. Moreover, the results of economic analyis can be sensitively affected by the economic condition in the country including prices of pavement materials and construction cost, construction conditions in locality and acceptance of people on pavement condition since the serviceability which is the basis of pavement structural analysis is subjective judgement of people.

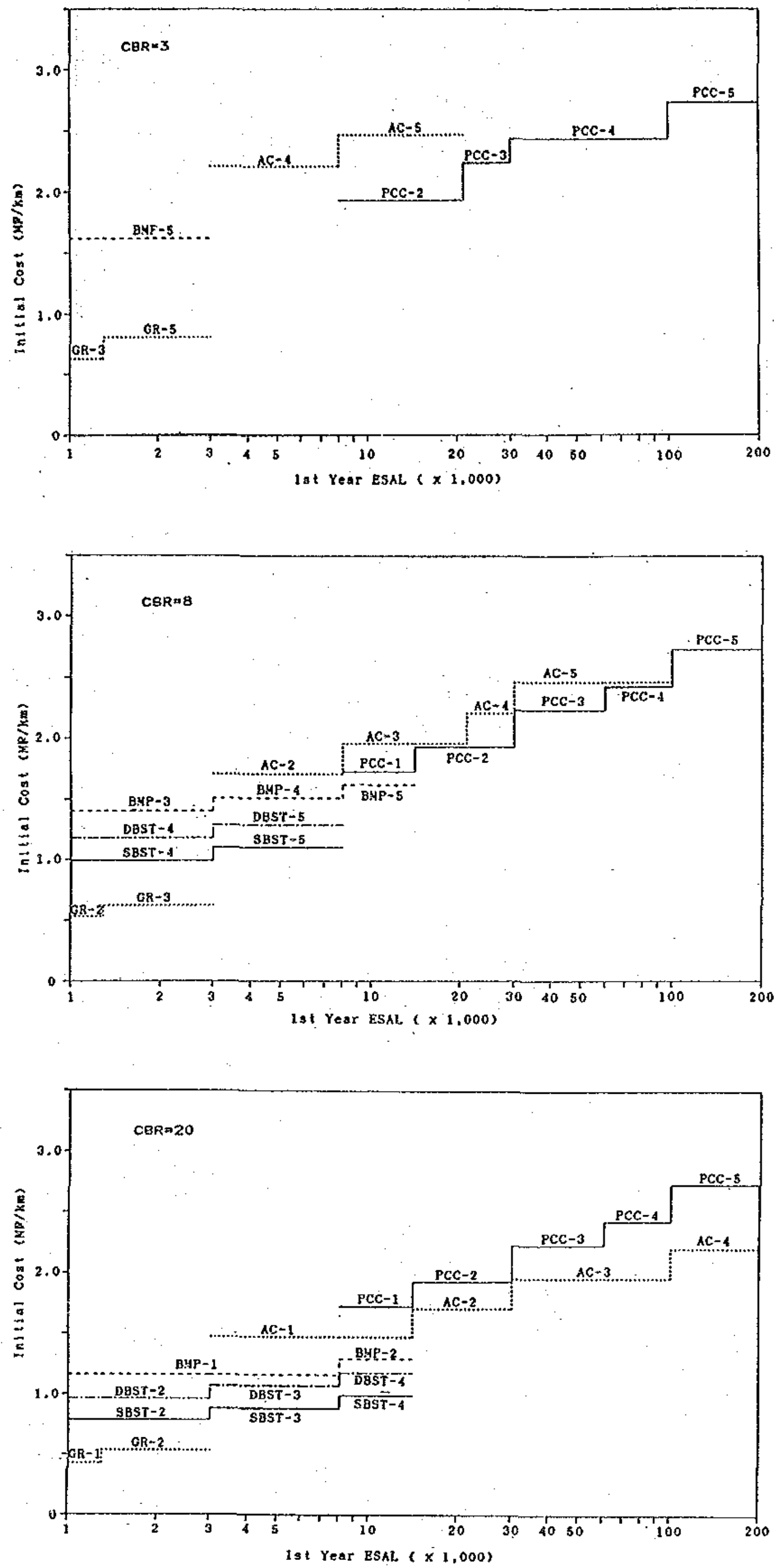


Fig. 10.4-1 INITIAL COST OF PAVEMENT STRUCTURES

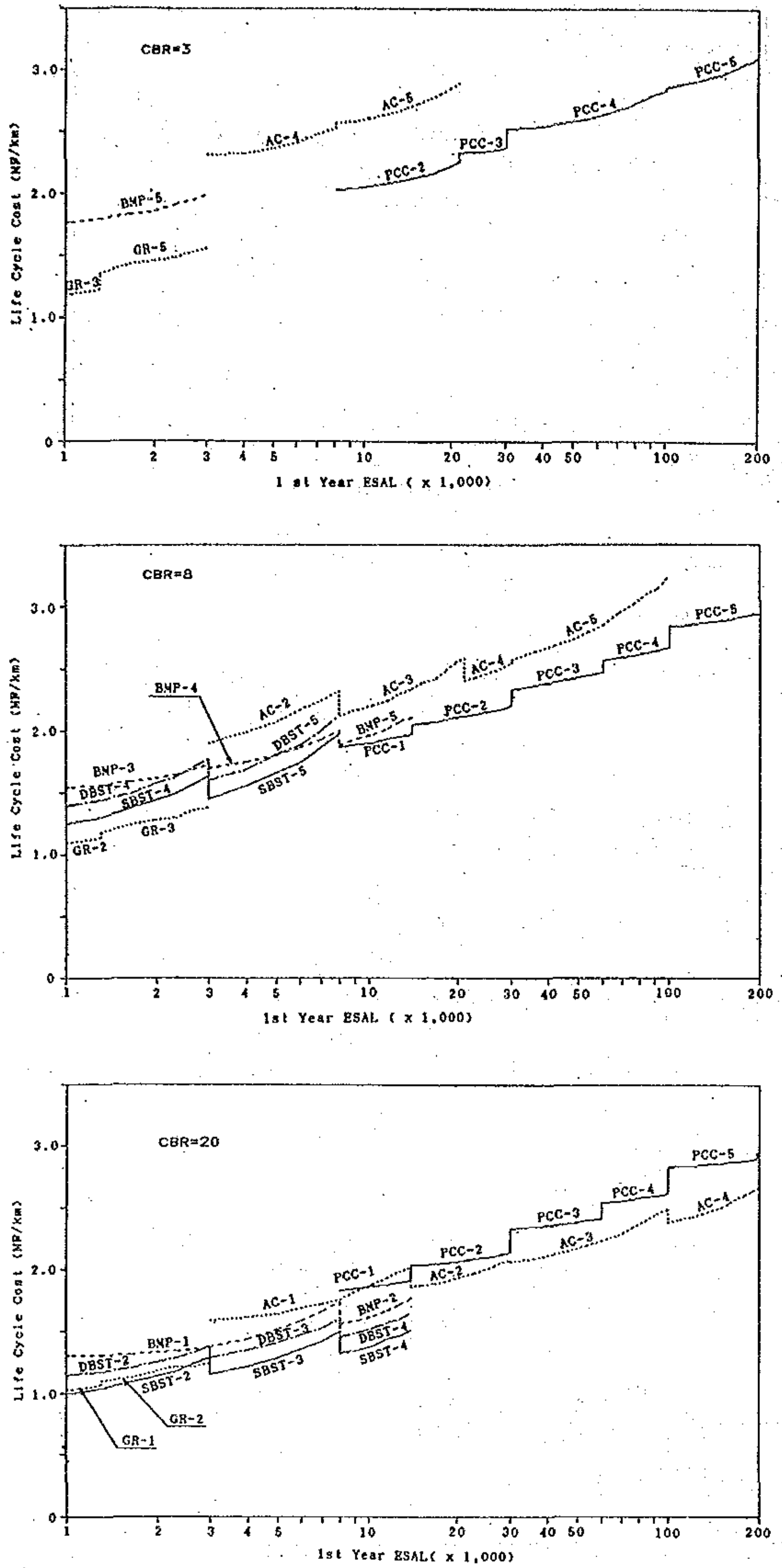
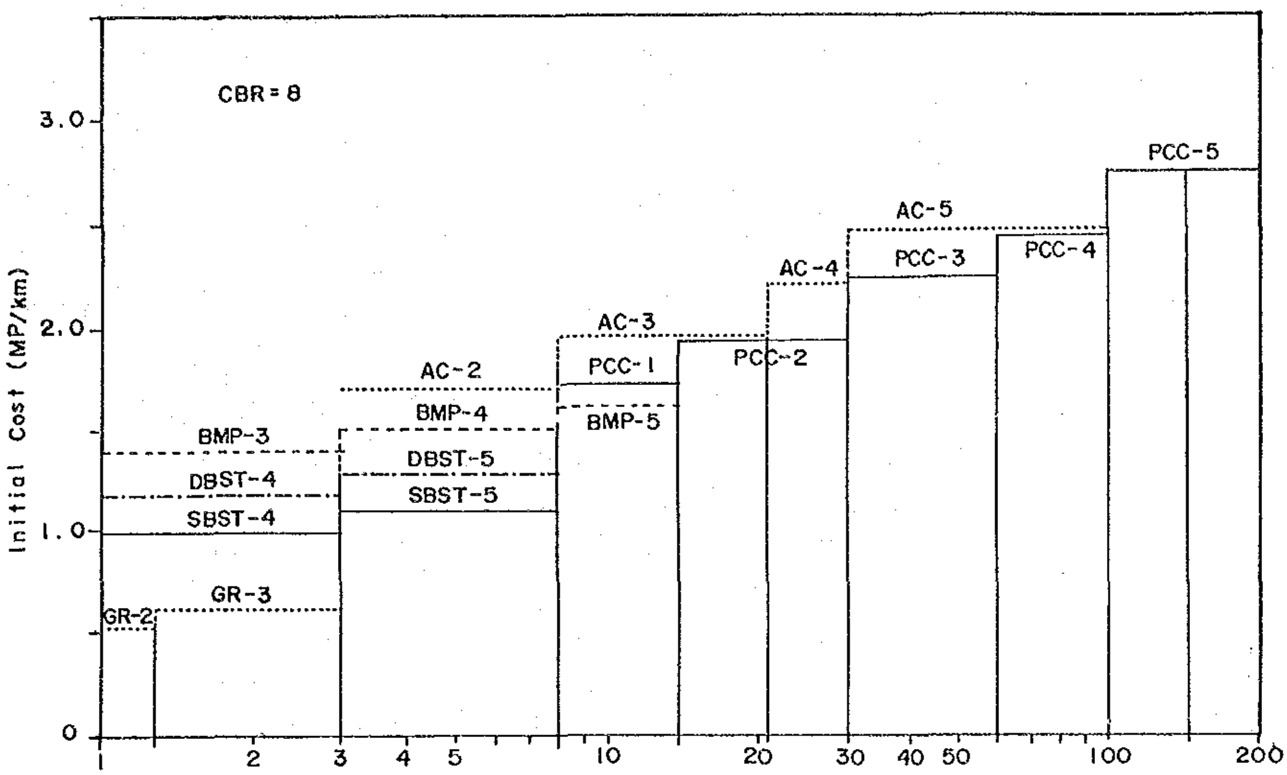


Fig. 10.4-2 LIFE CYCLE COST OF PAVEMENT STRUCTURES



1st Year ESAL (x 1,000)

Traffic	Light Loading Traffic						Heavy Loading Traffic			
Loading Class	R_{1-1}	R_{1-2}	R_{2-1}	R_{2-2}	R_{3-1}	R_{3-2}	A_{1-1}	A_{1-2}	A_{2-1}	A_{2-2}
No. of ESAL in 1st Year	1,300	3,000	8,000	14,000	21,000	30,000	60,000	100,000	150,000	200,000
Assumed AADT	100	200	400	600	800	1,000	1,500	2,000	3,000	4,000
Recommended Pavement Types Primary Major Roads	GR	DBST / BMP		AC/PCC			PCC			
Secondary Major / Minor Roads	GR		DBST/BMP	AC/PCC			PCC			

FIG. 10.4-3 AN EXAMPLE OF RECOMMENDATION ON PAVEMENT TYPES

PART III

C O N S T R U C T I O N

CHAPTER 11

SUBGRADE

11.1 GENERAL

Since bearing strength of the subgrade is an important determining factor for the pavement thickness, preparation of the subgrade for the pavement construction should be carefully made so as to prevent its bearing strength from dropping.

11.2 SUBGRADE PREPARATION

The subgrade should be constructed and finished in accordance with the required cross-section and profile. Compaction of the subgrade soil requires proper comprehension of the soil properties. Where cohesive or high water content soil is involved, special care should be taken to avoid its disturbance and over-compaction. To locate the existence of any spot of inadequate or unsatisfactory compaction, proof-rolling is advisable.

11.3 FILTER COURSE

The filter course is constructed by spreading and levelling the material in uniform thickness, and then compacting it by means of either a light roller, a bulldozer or a small soil compactor. Compaction should be performed uniformly and briefly to avoid disturbance of the spread material or intrusion of subgrade soil into it.

In cases where the desired effect is hard to achieve, the layer may be compacted together with a 10 to 15 cm layer of subbase material spread on it.

Since the effect of compaction is hard to achieve in a filter course, no standard requirement has been established for it. Materials used in filter layer construction include river sand, sea sand, pit-run gravel and high quality pit-sand.

11.4 WEAK SUBGRADE

11.4.1 General

A weak subgrade is generally either a soft soil composed largely of silt, clay, organic deposits such as peats, or loose sand, having high void ratio and usually also high water content.

11.4.2 Embankment Method

This method consists of embanking of high quality material on the existing soil, and is used in constructing subgrades in areas of high groundwater table and low soil strength, such as in a paddy field.

In applying this method, attention should be paid to the following points:

1) Where the groundwater table is high, and where a fountainhead exists, it is necessary both to lower the groundwater table and to drain the subsurface water.

2) Embankment material in principal should be placed in layers of about 20 cm compacted thickness. In the case of an initial layer where this thickness is insufficient to prevent the subsoil from rising to the surface, or to achieve adequate trafficability of transport and construction equipment, a thicker initial layer should be placed.

   Note: Where it is necessary to prevent the embanked material from penetrating a weak subgradde soil or to transmit the load of embankment uniformly over it, a flexible net or membrane may be underlaid prior to placing the embankment material.

11.4.3 Soil Replacement Method

Soil replacement is used for road cuts where excessively weak subsoil is encountered or where raising the design grades is not allowable in spite of unsuitable subgrade soil conditions, as is often in the case of street construction.

By this method, the unsuitable soil is excavated to a required depth and replaced by a material of higher quality, having a bearing strength of CBR 3 or more.

In applying the construction method, attention should be paid to the following points:

1) That excavation should be carried out to the designated depth with great care taken not to disturb the soil below.

2) That the refilled soil should be throughly compacted.

CHAPTER 12

SUBBASE COURSE

12.1 GENERAL

For the construction of a subbase course, economic material available within easy reach of the site is generally selected. Such materials include crusher-run, slag, pit gravel, sand and pit-run gravel, and must conform with the standards stated previously in Sections 2.2.3 and 3.3.

Substandard locally-available economic materials should also be exploited after undergoing mechanical stabilization or other treatment to improved its CBR or to lower its Plasticity Index.

12.2 GRANULAR AGGREGATE SUBBASE

(1) Materials

Materials used for the subbase course include crusher-run, pit sand, sand and pit-run gravel. The desirable maximum particle size is 50 mm or less. Standard grading is shown in Table 12.2-1 and CBR value should be 25% or more.

(2) Construction

1) Loading, transporting and spreading of subbase course materials should be carefully conducted, avoiding the mixing of deleterious substances, such as mud, and segregation of materials.

2) Subbase course materials should be spread using a motor grader or a bulldozer. The thickness of each finished layer is to be 20 cm or less.

3) Compaction should be performed at approximate optimum water contents using a 10 ton macadam roller or larger, an 8 to 15 ton pneumatic tire roller or an equivalent vibrating roller. Compaction should be repeated until the required density and proper grain interlock are achieved.

4) Materials of a larger particle size may be used for the subbase course if it is unavoidable, if the particle size is neither larger than one half of the thickness of one layer for finishing, nor larger than 100 mm. For this case, compaction should be conducted, preventing the segregation of materials.

Table 12.2-1 DESIRABLE GRADING AND PI VALUE OF MATERIALS FOR SUBBASE COURSE

Sieve Size, mm	Passing Percent by Weight
50	100
25	55 - 85
9.5	40 - 75
0.075	0 - 12
Plasticity Index	Not more than 12

Source: DPWH : Standard Specification Item 201 Aggregate Subbase Course

12.3 CEMENT STABILIZED SUBBASE

In this method, locally available materials and other supplemental materials are treated to add to cement. Cement stabilization is generally conducted at the site.

(1) Materials

a) Cement

Portland cement, blast-furnace slag cement or fly-ash cement may be used as materials for this method.

b) Aggregate

While no standards are specified for the grading of aggregate, it is desirable that aggregate include coarse fractions and be continuously graded for easy mixing and compaction. PI values of material used as aggregate should be 10 or smaller for facilitating construction and durability.

(2) Mix Design

The procedure of mix design is as follows:

1) The optimum moisture content for cement-aggregate mix is obtained based on the estimates of an appropriate cement content, which is normally about 2 to 3%.

2) Based on the optimum moisture content, thus obtained, test specimens are prepared with cement contents varying in 2% intervals, centering at the estimated appropriate amount.

Unconfined compression tests are conducted on test specimens after 6 days of curing and 1 day of water immersion. The relation between the amount of additive and the unconfined compressive strength is plotted as shown in Figure 12.3-1. The required amount of cement (%) is obtained, which corresponds to the required unconfined compressive strength in Table 12.3-1.

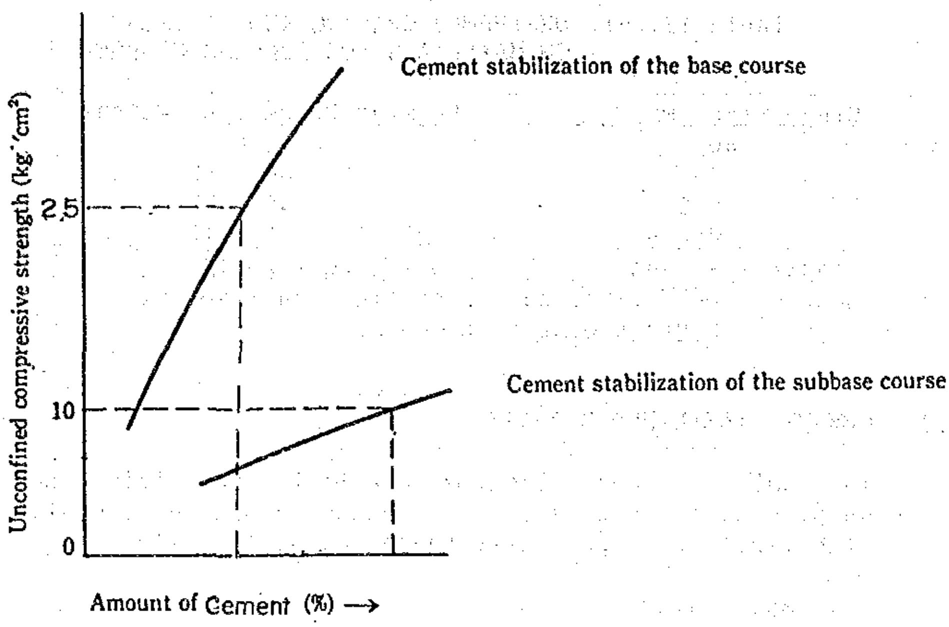


FIGURE 12.3-1 RELATION BETWEEN AMOUNT OF CEMENT AND UNCONFINED COMPRESSIVE STRENGTH

TABLE 12.3-1 TARGET UNCONFINED COMPRESSIVE STRENGTH FOR CEMENT STABILIZED MATERIALS

Course	Unconfined Compressive Strength (kg/cm), 7 days curing
Base	25
Subbase	10

(3) Construction

1) The materials to be stabilized are spread on the leveled subgrade. When stabilizing an existing gravel layer, the surface is leveled to form the approximate finished shape before being scarified to a specified depth and reshaped using the ripper of a motor grader.

2) If necessary, supplemental materials are spread over the subgrade after the above operation.

3) Bagged cement is distributed at specified intervals throughout the construction area. Then, the bags are opened and the cement uniformly spread out.

4) The materials are mixed without any additive using a road stabilizer. When the moisture content in the materials is insufficient, water is added during the mixing process.

5) When a road stabilizer is operated in rows parallel to the direction of the road, care should be taken to mix the entire surface. This is done by mixing a part of the preceding row with the current row. When soil cannot be mixed due to structures, materials of such places should be excavated and combined with materials of places easy to mix and refilled in their original location after mixing.

6) After uniformly mixed, the soil is leveled and shaped to its required form, either manually or with the use of a motor grader. The materials spread are to be lightly compacted using a road roller before reshapping.

7) After the required cross section is achieved, the mixture should be thoroughly compacted until the required density and approximate optimum moisture content is obtained. The mixture can be effectively compacted through using a combination of road rollers. Table shows the standard values required for the thickness after compacting of the cement stabilization.

8) At transverse construction joints, the finished end should be vertically cut and removed before fresh materials are placed against it. If fresh materials are placed against the cut section after a period of time, the construction joints could develop cracks.

CHAPTER 13

BASE COURSE

13.1 GENERAL

In constructing the base course, materials should be uniformly spread until obtaining the required thickness, and thoroughly compacted until the prescribed degree of compaction and smoothness are achieved.

13.2 CRUSHED AGGREGATE BASE

13.2.1 Materials

Materials used for Base Course include crusher-run and crushed stone. The desirable maximum particle size is 40 mm or less. The CBR or granular aggregate should be 80% or more and PI values of the fraction passing the 0.425 mm sieve should be 6 or less. The desirable grading and PI value of materials for crushed-aggregate base course is shown in Table 13.2-1.

13.2.2 Spreading

Base Course Materials should be spread using a motor grader. The thickness of each finished layer is to be 15 cm or less.

13.2.3 Compaction

After the materials spread on the surface are lightly rolled, the surface is trimmed using a motor grader or other equipment before fully compacting the mixture to the point of prescribed density. The moisture content of the material should be close to the optimum moisture content for compaction.

Special care should be taken when compacting the areas in the vicinity of structures and the road side.

An 8 to 10 ton macadam roller, an 8 to 15 pneumatic tire roller or an equivalent vibrating roller should be used in the compacting process. Having a higher moisture content than the optimum value should be scarified for aeration and drying. When the base course is mechanically stabilized utilizing the existing gravel layer, the surface gravel layer should be lightly leveled and, then, the layer should be scarified to the required depth of treatment using a motor grader. Lumps of gravel are then crushed, removing cobblestone, and supplementary materials are mixed together with it.

13.2.4 Plant Mixing and Spreading

A continuous mixer or batch mixer is used for plant mixing. The moisture content of the materials at the time of mixing is to be adjusted so that the approximate optimum moisture content is achieved. Uniformly mixed materials are transported to the construction site and, then, spread using a motor grader, a small size bulldozer or manually to achieve the required shape.

TABLE 13.2.4 DESIRABLE GRADING AND PI VALUE OF MATERIALS FOR CRUSHED- AGGREGATE BASE COURSE

Sieve Size (mm)	Passing Percent by Weight
37.5	100
19	60 - 85
4.75	30 - 55
0.425	8 - 25
0.075	2 - 14
Plasticity Index	Not more than 6

Source : DPWH Standard Specification Item 202
Crushed-Aggregates Base Course

13.3 MECHANICAL STABILIZED BASE

In this method, several types of materials are mixed, spread and compacted with a view of achieving excellent grading. Since materials for mechanical stabilization are well graded, they are easy to spread and compact, and are suitable for construction using machinery.

13.3.1 Selection and grading of materials

Materials used for mechanical stabilization are either mechanically stabilized crushed stone or a combination of crushed stone, crusher-run, slag, pit sand, sand, or screenings in appropriate proportions, having a combined grading conforming to the requirements specified in Table 13.2-1.

The CBR of material for mechanical stabilization should be 80% or more and PI values of the fraction passing the 425 um sieve should be 4 or smaller.

13.3.2 Construction

1) Mixing and spreading

Mixing methods of materials for mechanical stabilization are classified by mixing equipment as follows (the plant mixing method is generally preferred for the construction of pavement for general traffic):

Mixed-in-place method:	Mixing using a lateral shaft type road stabilizer
Plant mixing method :	Mixing using a continuous mixer or a batch mixer.

Mixed-in-place

After leveling the subbase course, materials to be mixed are spread over all the surface of the road, based on the mix design, in the order of the size of the material (materials with the largest particle size are to be spread first).

When the road surface is mixed using a road stabilizer with two rows equalling the width of the road, care must be taken to mix all of the surface by including part of the previously mixed row.

Dry materials should be mixed while adding water.

13.4 CEMENT STABILIZED BASE

Cement stabilization treats locally available materials and supplementary materials with cement. This improves the strength of the material, protecting it from any loss of strength resulting from a change in moisture content and enhances its durability. Materials used in this method are usually mixed in a plant.

The procedures for material selection, mix design and construction described in Section 4.3-3 apply, as well as the following instructions:

1) The standard range of grading and PI value of materials used for cement stabilization are listed in Table 13.4-1.

2) When using the plant mixing method, materials used for cement stabilization are mixed in a soil plant and transported to the construction site for spreading.

3) The cement stabilized layer should be sealed by spraying about 0.5 to 1.0 liter/m^2 of asphalt emulsion as a cover layer. The surface courses should be constructed as soon as possible after sealing.

TABLE 13.4-1 DESIRABLE GRADING AND PI VALUE OF MATERIALS FOR CEMENT STABILIZATION

Sieve Size (mm)	Passing Percent by Weight
37.5	100
4.75	50 - 80
2.0	20 - 60
0.075	0 - 15
Plasticity Index	Not more than 10

13.5 PRIME COAT

Prime coating should be applied immediately after the base course is finished. Bituminous material used as a primer include emulsified asphalt type or cutback asphalt type MC-70 for normal cases, and cutback asphalt type MC-250 for particularly absorbent base course material.

The primer should be selected taking into consideration the type and surface condition of base course material, as well as the time of execution. Generally, for use on finely textured base course surfaces, a high permeability primer is preferrable.

Since the required quantity of a primer depends on the quantity of permeation in 24 hours, it is advisable that test application be made to establish the basis for quantity determination. Normally, an average of 1 to 2 liters of a primer is applied to every square meter of base course surface.

When it is unavoidable to allow traffic on a surface that has been treated with a prime coat, coarse sand should be spread on the surface to avoid removal of the prime coat by wheels of vehicles. If loss of the prime coat is caused by traffic, another prime coat should be applied without delay. Before the construction of the surface or binder courses, loose coarse sand should be swept away from the surface.

CHAPTER 14

GRAVEL SURFACING

14.1 GENERAL

This method is to construct a well compacted and smooth riding surface course for low traffic roads using natural occuring granular materials, mostly either seiver-run sandy gravel or pit-run sandy gravel.

The important characteristics of the granular materials used for gravel roads are:

a) Composition of the gravel, sand and silt-clay mixture. Well graded sandy gravel composed of gravel and sand and silt-clay ratio of about 5:4:1 provides the well compacted layer and adequate bearing capacity for traffic loads, and

b) Plasticity properties of the finer or silt-clay size particles. The presence of necessary amount of fines, that is called as soil binder, provides the binding ability or cohesive action that resists the abrasion action of traffic directly imposed on this layer.

The layer contains particle size of over 40 mm and cobble makes the surface bumpy. Too much excess of silt-clay fines comes to muddy surface during rainy season and dusting problem during dry season. Therefore, selection of adequated well graded sandy gravel is the key to good gravel surface course.

14.2 MATERIALS

Sandy gravel is classified by source of product into river-run sandy gravel and pit-run sandy gravel. Therefore, sandy gravel tends to vary more widely in quality and grading, its use should be based on proper investigation of their properties.

The preferable *quality requirements are listed in Table* 14.2-1.

TABLE 14.2-1 PREFERABLE QUALITY REQUIREMENTS OF SANDY GRAVEL FOR GRAVEL SURFACE

Grading	
Sieve Size (mm)	Passing Percent by Weight
40	100
9.5	45 - 75
4.75	35 - 65
0.075	5 - 15
Liquid Limit	Not greater than 35
Plasticity Index	4 - 9
CBR Value	Not less than 30

14.3 CONSTRUCTION

1) Loading, transporting and spreading gravel surface materials should be conducted, avoiding the mixing of deleterious materials such as mud and over size stone such as cobbles.

2) Gravel layer materials should be spread by a motor grader or a bulldozer.

3) Compaction should be performed at approximate optimum water content by necessary watering at the site using 10 ton macadam roller, an 8 to 15 ton pneumatic tired roller or an equivalent vibratory roller. Compaction should be repeated until the required density and proper aggregate grain interlock are achieved.

4) Segregation of materials should be avoided in order to attain a well compacted, dense and smooth finished surface.

CHAPTER 15

BITUMINOUS SURFACE TREATMENT

15.1 GENERAL

15.1.1 Single Surface Treatment

A single application of asphalt to any kind of road surface followed immediately by a single layer of aggregate of as uniform size as practicable. The thickness of the treatment is about the same as the nominal maximum size aggregate particles. A single surface treatment is used as a wearing and waterproofing course.

15.1.2 Double Surface Treatment

Two surface treatments placed one on the other. The aggregate maximum size of each successive treatment is usually one-half that of the previous one, and the total thickness is about the same as the nominal maximum size aggregate particles of the first course. A double surface treatment may be a series of single treatments that produces a pavement course up to 20 mm. A double surface treatment is a denser wearing and waterproofing course than a single surface treatment, and it adds some strength.

15.1.3 Triple Surface Treatment. (Double Surface Treatment with Seal Coat)

A triple surface treatment has a smooth denser and waterproof wearing surface, and durable strength.

15.1.4 Seal Coat

A thin surface treatment used to improve the texture of and waterproof an asphalt surface. Usually the method is the same as 18.1.1 single surface treatment.

15.2 MATERIALS

15.2.1 Asphalt

To select the proper grade of asphalt for a surface treatment, consideration should be given to:

1) Temperature of the surface to which asphalt will be applied.
2) Air temperatures
3) Humidity and wind
4) Condition of the surface
5) Type and condition of the aggregate to be applied
6) Equipment to be used

The correct grade of asphalt for the surface treatment will:

1) When applied, be fluid enough to spray properly and cover the surface uniformly.
2) After application, retain the proper consistency to wet the applied aggregate.
3) Cure and develop adhesion quickly.
4) After rolling and curing, hold the aggregate tightly to the road surface to prevent dislodgment by traffic.
5) When applied in the right amount, not bleed or strip with changing weather conditions.

The proper grade of liquid asphalt, including asphalt emulsions, will satisfy these requirements. In hot, dry weather, the softer grades of asphalt cement are quite satisfactory when dry aggregate is placed immediately after spraying. More specifically, asphalts, rapid-setting emulsions, and the 120 to 150 and 200 to 300 penetration asphalt cements are usually best suited for most surface treatments.

Medium-curing liquid asphalts can be used successfully provided sufficient curing time is permitted before traffic is allowed on the treatment.

15.2.2 Control of Asphalt Spraying Temperatures

Asphalt is a thermoplastic material that becomes more liquid (decreases in viscosity) with increasing temperatures. The spraying temperature then should be selected carefully because the ability to spray at a certain temperature (temperature-viscosity relationship) is not always the same for different types and grades, or for asphalts of the same grade from different sources. The recommended viscosity range for spraying is 20-120 centistokes, kinematic (approximately 10-60 seconds, Saybolt Furol), however, there is no recommended lower limit for prime or tack coating applications.

15.2.3 Asphalt Quantities Required

After a surface treatment has been subjected to traffic for some time the aggregate particles will have oriented into their densest positions. The particles will be lying on their flattest sides and voids between them will usually be about 20 percent of the total volume. The asphalt used for the treatment should fill 60 to 70 percent of this void space. See Figures 15.2-1 to 15.2-4. Typical application rate for asphalt is shown in Table 15.2-1.

15.2.4 Aggregates

Most hard aggregates such as sand, gravel, crushed stone, and crushed slag can be used successfully for surface treatments. The aggregate selected, however, must meet certain requirements of size, shape, cleanliness, and surface properties.

15.2.5 Size of Aggregates

The aggregate should be as close to uniform size as is economically practical so the surface treatment will have only one layer of aggregate. If there is much difference between the largest and the smallest size particles, the asphalt film may completely cover the smaller sizes and prevent proper embedding of the larger particles. If this happens, the courser ones may be whipped off easily by high speed traffic.

Generally, the largest size for a surface treatment aggregate should be no more than twice the smallest size, with a reasonable tolerance for oversize and undersize to allow for economical production.

The maximum size of the aggregate used also will determine the smoothness and quietness of the riding surface. It has been found that aggregates smaller than one-half inch diameter are best for these criteria.

15.2.6 Shape of Aggregates

Shape of the particles is important in aggregates for surface treaments - the ideal shape being cubical or pyramidal. A large amount of flat and elongated particles is undesirable because they may be completely covered if enough asphalt is used to hold the cubical particles (see Figure 15.2-1). If all particles are flat and elongated it takes so little asphalt to hold them that control becomes difficult. Figure 15.2-3 illustrates this.

TABLE 15.2-1 QUANTITIES OF ASPHALT AND AGGREGATE FOR SINGLE SURFACE TREATMENT AND SEAL COAT

Line No.	Size of Aggregate	Weight of Aggregate kg/m² 1, 2	Volume of Asphalt lit/m² 3, 4	Hot Weather (25 C+) Hard Aggregate	Absorbent Aggregate
1	3/4 to 3/8 in (20 to 10 mm)	22 - 27	1.8 - 2.3	120 - 150 RC/MC 3000 RS 2 RS-2K, RS-3K	RC/MC 3000 RS/2K,RS-3K
2	1/2 to No. 4 (13 to 6 mm)	14 - 16	1.1 - 1.4	200 - 300 RC/MC 250,800 RS 1, RS 2 RS-2K, RS-3K	RC/MC 250,800 RS 1, RS 2 RS-2K,RS-3K
3	3/8 to NO. 8 (10 to 3 mm)	8 - 11	0.7 - 0.9	RC/MC 250,800 RS 1, RS 2 RS-2K, RS-3K	RC/MC 250,800 RS 1, RS 2 RS-2K, RS-3K
4	1/4 to No. 8 (6 to 3 mm)	5 - 8	0.5 - 0.7	RC/MC 250,800 RS 1, RS 2 RS-2K, RS-3K	RS/MC 250,800 RS 1, RS 2 RS-2K, RS-3K
5	Sand	5 - 8	0.5 - 0.7	RC/MC 250,800 RS 1, RS 2 RS-2K, RS-3K	RC/MC 250,800 RS 1, RS 2 RS-2K, RS-3K

Source : The Asphalt Institute, Manual Series No. 13 (MS-13), ASPHALT SURFACE TREATMENT

* These quantities and types of materials may be varied according to local conditions and experience.

1. The lower application rates of asphalt shown in table should be used for aggregate having gradings on the fine side of the limits specified. The higher application rates should be used for aggregate having gradings on the coarse side of the limits specified.
2. The weight of aggregate shown in the table is based on aggregate with a specific gravity of 2.65. In case the specific gravity of the aggregate used is less than 2.55 or more than 2.75 the amount shown in the table above should be multiplied by the ratio which the bulk specific gravity of the aggregate used bears to 2.65.
3. Under certain conditions, MC liquid asphalts may be used satisfactorily.
4. In some areas persistent difficulty in retaining aggregate has been experienced with 200-300 penetration asphalt cements.

NOTE: Single Surface Treatments. The maximum size aggregate should not be over 1/2 inch. Use line 2. For lighter surface treatments. use line 3 or 4; however, lines 3 and 4 are more for light seal coats. For sand seals use line 5.

Double Surface Treatments. The maximum size can be up to 3/4 inch. First course, use line 1; second course, use line 3 or 4. For lighter double surface treatments use for first course, line 2; for second course, line 3 or 4.

Triple Surface Treatments. The maximum size aggregate is usually 3/4 inch. The following is recommended; first course, line 1; second course, line 2; third course, line 3 or 4. For most situations, the best probably is lines 1, 2 and 4 for the three courses.

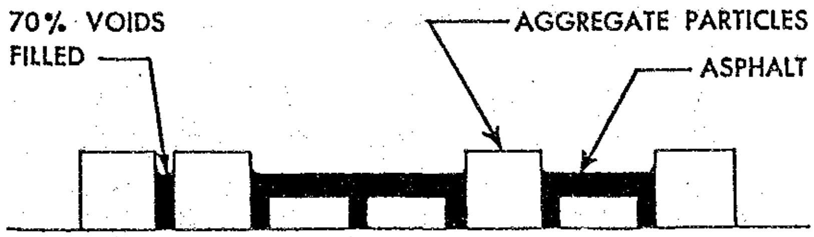


FIGURE 15.2-1 FLAT PARTICLES ARE COVERED WHEN ENOUGH ASPHALT IS USED TO HOLD CUBICAL PARTICLES

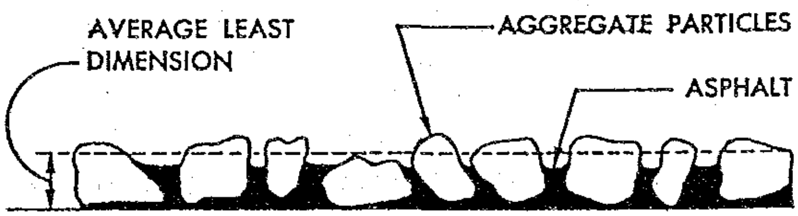


FIGURE 15.2-2 AGGREGATE PARTICLES DROPPED BY SPREADER LIE IN UNARRANGED POSITIONS

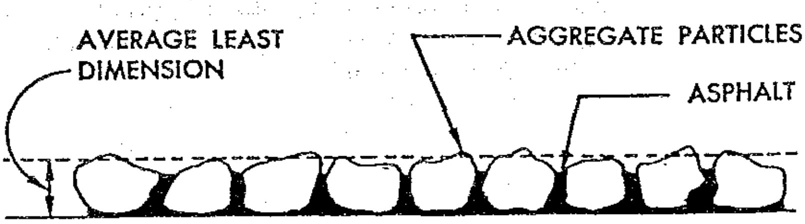
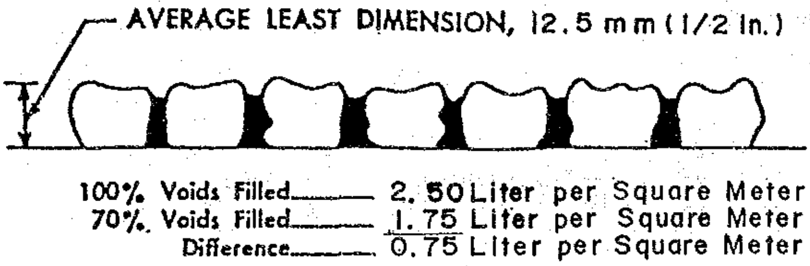
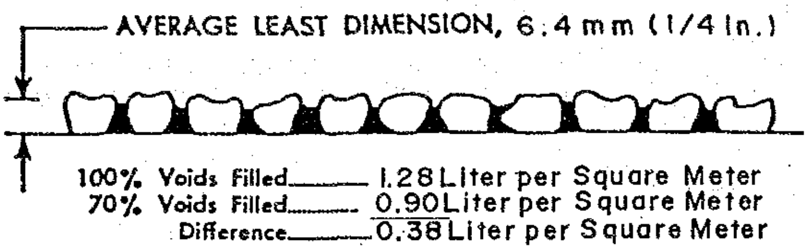


FIGURE 15.2-3 AFTER BEING SET BY TRAFFIC, PARTICLES LIE ON FLATTEST SIDE





Example : Average Least Dimension 12.5 mm

Void of Aggregate = 20% x 0.0125 m^3/m^2 = 2500 cm^3/m^2

70% Void Filed with Asphalt = 70% x 2500 cm^3/m^2

= 1.75 l/m^2

FIGURE 15.2-4 SURFACE TREATMENT WITH LARGER AGGREGATES ARE LESS SENSITIVE TO SMALL VARIATIONS IN ASPHALT APPLICATION THAN WHEN SMALLER AGGREGATES ARE USED

15.2.7 Cleanliness of Aggregates

Clean aggregate is extremely important. If the particles are dusty or coated with silt or clay, the asphalt may not stick as the dust produces a film which will prevent adhesion to the aggregate. Good results cannot be assured with dusty or dirty aggregate.

15.2.8 Adhesion

Good adhesion between the aggregate and the asphalt and the ability to retain it are essential to a successful surface treatment. Adhesion, however, is influenced by the many variables described in the preceding sections of this chapter and often there are jobs where ideal conditions cannot be obtained.

For example, wet clean aggregates do not adhere as well as dry clean ones and the best adhesion is obtained when they are hot and dry. Field conditions are such that clean cover aggregates will often contain some moisture and must be used this way. This presents no serious field problem when the work is done in warm, dry weather which promotes rapid drying. However, aggregate having free water will seldom provide a satisfactory treatment.

Adhesion between asphalt and aggregate often can be helped by a thin coating of kerosene on the aggregate applied by misting at the rate of 2 to 4 liters of kerosene per ton of aggregate while it is being loaded into the trucks by a belt conveyor or from a bin at the plant.

Precoating the aggregate with a very thin film of asphalt usually will solve the dust problem and provide good adhesion of the asphalt to the aggregate. The aggregate is run through an asphalt mixing plant dryer, cooled to under 90 C, then mixed in the pugmill with about one percent MC-70 to coat each particle thoroughly. The small amount of asphalt does not change the aggregate from a free flowing material which can still be applied with aggregate spreaders. The precoating adds to the cost of the aggregate but the additional cost is often justified by the better results obtained.

15.2.9 Coarse Aggregate

Coarse aggregate is defined as all mineral material retained on a No. 8 sieve (approximately 2.5 mm).

15.2.10 Fine Aggregate

Fine aggregate is defined as all mineral matter passing a No. 8 sieve. It may consist of natural or manufactured material.

15.2.11 Aggregate Quantities Required

Studies have shown that except unusual conditions, only one layer of aggregate will stick when it is spread over sprayed asphalt - any amount over that will be wasted. It is, therefore, essential for economy that the quantity of aggregate needed be determined carefully.

15.3 EQUIPMENT

15.3.1 General

Successful surface treatments depend to a large extent on the equipment used, its condition, and the way it is handled. This is why specifications generally require that the equipment be in good mechanical condition, properly adjusted and free from wear which would impair the quality of the work. But, whether required or not, it is always good practice to make a careful inspection before operations begin to be sure all pieces are clean, calibrated, and in top operating form.

15.3.2 Asphalt Distributor

The most important piece of equipment on a surface treatment is the asphalt distributor. It is made specifically to apply the asphalt product uniformly to a surface in proper quantities and to maintain the specified rate for the entire load, regardless of change in grade or direction.

The asphalt distributor consists of a truck (or trailer) on which is mounted an insulated tank with a heating system, usually oil burning, with heat from the flue passing through the tank. An armored thermometer, located in a well in the side of the tank is provided for checking the temperature of the asphalt. The distributor also has a power-driven pump which will handle products ranging from light, cold application liquid asphalt to heavy asphalt cements heated to spraying viscosity. At the back end of the tank is a system of spray bars and nozzles through which the asphalt is forced under pressure onto the surface of the road. These spray bars will cover widths from 1.8 meter to 7.5 meter in one pass, depending on the pump capacity.

15.3.3 Aggregate Spreaders

The piece of equipment next in importance to the asphalt distributor is the aggregate spreader. A good spreader, operated properly, will conserve aggregate and produce a uniform spread. Spreaders range from the simple vane type attached to a truck tail gate to the highly efficient self-propelled type.

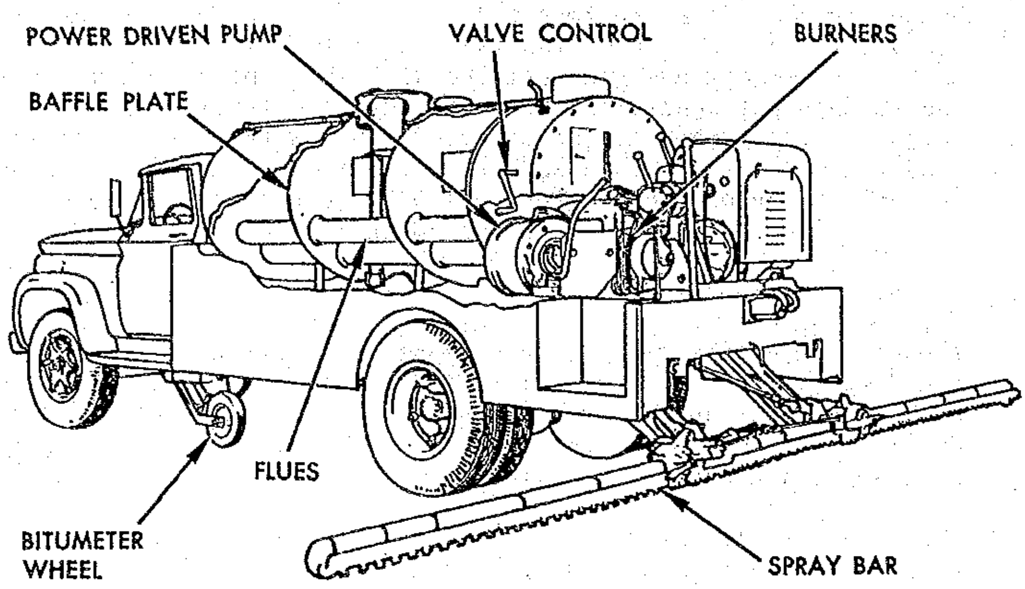


FIGURE 15.3-1 ASPHALT DISTRIBUTOR

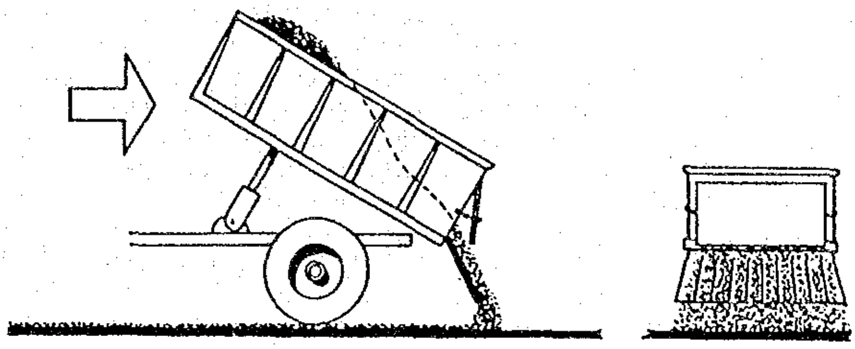


FIGURE 15.3.2 VANE SPREADER

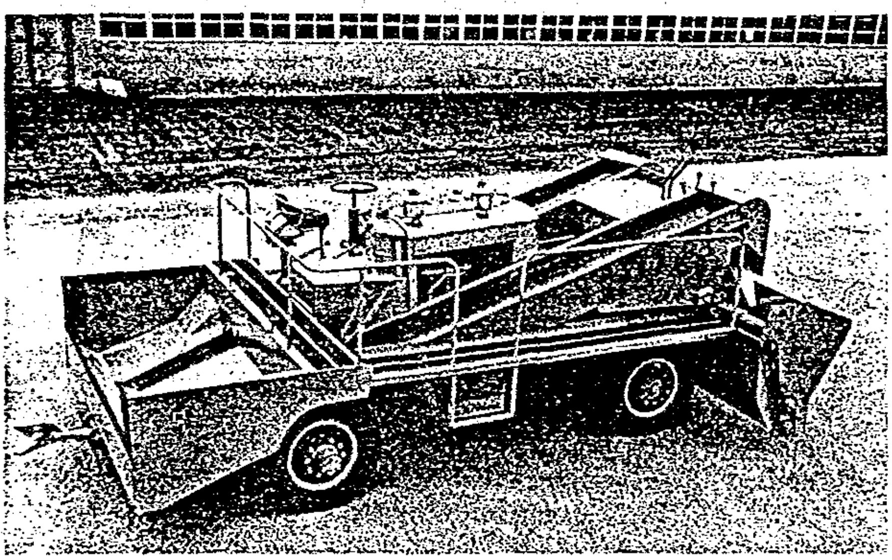


FIGURE 15.3.3 SELF-PROPELLED AGGREGATE SPREADER

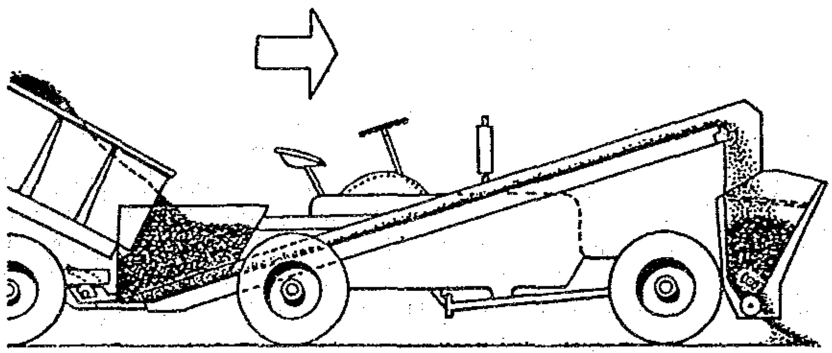


FIGURE 15.3.4 FLOW OF AGGREGATE THROUGH A SELF- PROPELLED SPREADER

15.3.4 Rollers

Proper seating of the aggregate particles is a very important part of the surface treatment operation. For this purpose self-propelled smooth-tread pneumatic-tired rollers be used on surface treatments. The resilient tires on these rollers force the aggregate firmly into the asphalt binder without crushing the particles. Steel-wheeled rollers will bridge over the smaller size particles and small depressions in the surface and fail to press the aggregate in these places into the asphalt. These rollers also may crush the softer particles so that degradation takes place even before traffic uses the new surface. If steel-wheeled rollers are used, they should be used only to supplement prenumatic-tired rollers.

All rollers proposed for use on a job must be inspected for compliance with the project specifications before operations begin. Where applicable, check the following:

1) Total weight
2) Weight per inch of width (steel-wheeled rollers only)
3) Average contact pressure in pounds per square inch (pneumatic-tired rollers only).
4) Mechanical condition, especially as to ability to start, stop and reverse smoothly
5) Precise steering

In addition to the items listed above, all tires should be checked for specified inflation. The pressure of all tires must not vary more than five pounds per square inch between high and low. Tires should also be visually inspected for good condition and smooth tread. Oscillating wheels should be tested for freedom to move vertically.

Steel-wheeled rollers should be inspected with a sharp metal straight-edge for wear of wheel rims. If grooves or pits have worn into the rolling surface of the wheel, the roller should not be used on the job. The king pins should be tested for slackness and corrected if not right. If the wheel bearings are found to be worn excessively, they must be replaced before operations begin.

15.4 PREPARATION FOR CONSTRUCTION

15.4.1 General

When all needed repairs have been made within the project limits, there are still several steps to coordinate before the surface treatment operation can start. The weather has to be right, the surface must be cleaned, the material must be on the job, and the equipment must be in good working order.

15.4.2 Weather

Weather has an important role in the success of surface treatments. A time of year should be selected for the surface treating program when weather conditions are most likely to be hot and dry during, and for some weeks after, the treatment.

Many specifications require that the air temperature in the shade be at least 50 F before surface treatment operations can begin. Some are even more realistic and require that the temperature of the surface of the road be above 80 F before work can start - the sound reasoning being that no matter how hot the asphalt is when sprayed, it will cool to the temperature of the pavement surface within one minute or less.

Surface treating should never be started while the surface is wet or when it is threatening to rain. The combination of water, fresh surface treatment, and traffic will result in loss of most of the cover aggregate.

15.4.3 Cleaning the Surface

The surface to be treated must be cleaned immediately before the asphalt is sprayed. All hardened mud and other foreign matter must be removed and the surface thoroughly swept with power brooms.

15.4.4 Material on the Job

The delivery of materials to the job should be coordinated so that there will be no delays after the work starts. If the aggregate source is not within a short distance of the project, a sufficient number of trucks should be used to assure a continuous supply or enough aggregate to finish the whole job should be stockpiled near the job site. The stockpile should be built well enough in advance of starting work so that excess water will have drained from the aggregate.

Asphalt delivery should be arranged so that there is enough on the job to complete each day's work without delays.

15.4.5 Equipment in Good Order

Before work starts, all pieces of equipment should be examined to make certain they are in good working condition. The distributor operator should make sure that the spray bar is the correct height above the surface and that all nozzles are clear and spraying freely - even if they have been checked the night before. The aggregate spreader should be checked to be sure that it is working properly.

At the end of each day's operation the equipment should be inspected and cleaned. All necessary preventive maintenance should be performed at this time, too. Clean equipment that seldom breaks down on the job not only saves money, it promotes pride of workmanship.

15.5 SURFACE TREATMENT OPERATION

15.5.1 General

The asphalt in high quality surface treatments will hold the aggregate and, without over-filling the voids, will waterproof and airproof and airproof the surface. To do this, a thin membrane of asphalt must be sprayed over the surface without streaking, drilling, or distortion of any kind.

The cover aggregate should be uniformly spread in less than one minute after the asphalt application. This requires enough trucks loaded with the aggregate to be standing by to cover completely the asphalt in the specified time. Careful timing and coordination are absolutely necessary to produce the desired results. Immediately after application, the aggregate should be set in place by rolling to produce a smooth, tight surface of even texture. As soon as the asphalt has a definite set or hardening, rolling should be discontinued or the bond between the surface and aggregate may be broken by the roller. Traffic should be detoured or controlled to a speed of less than seven miles per hour until the asphalt initially sets. This time will vary according to weather conditions.

The first phase of the operation should not begin until the entire operation is ready to be completed without any delays.

15.5.2 Priming

Priming is the initial incorporation of asphalt into the surface of a non-asphalt base course for the following purposes:

1) To waterproof the surface of the base
2) To plug capillary voids
3) To coat and bond loose mineral particles
4) To harden or toughen the surface
5) To promote adhesion between the base and the surface treatment

From 0.2 to 0.5 gallon per square yard of low viscosity liquid asphalt is sprayed on the prepared surface of the base and allowed to penetrate as far as possible. If the asphalt is not entirely absorbed by the base within 24 hours, the excess should be blotted with just enough sand to prevent pickup under traffic. Before beginning the surface treatment all of the asphalt prime volatiles must have evaporated and all loose sand should be swept from the base.

15.5.3 Spraying the Asphalt

Before the surface treating operation starts, a line should be placed along the edge of the road to guide the driver of the distributor truck. This can be done by establishing about two feet outside the area to be surfaced a line of markers. (Rocks will do). On city streets, the gutter line or the curb line can be used as a guide. The distributor operators must be very careful to match the curb or gutter line and not cut it short or overlap it. It is desirable to protect the curb and gutter from splash or overlap with a shield or building paper.

Each length of spread should be determined before beginning each asphalt application. The length of spread should be based mainly on the number of loaded aggregate trucks on hand when operations begin. Another important factor is elapsed time between the spraying of asphalt and the spreading of the aggregate. No more asphalt should be applied than can be covered with aggregate within one minute. Other considerations in setting the length of spread are the amount of traffic to be controlled and intersections with other roads.

After all adjustments and checks discussed in Chapter II are made, including heating the asphalt to proper spraying viscosity, application at the correct rate should present no problems. The distributor driver merely has to maintain the preset speed is indicated on the dial of the bitumeter.

Checks on the amount of asphalt used should be made after each run with the distributor. This can be done quickly and easily by calculating the gallons per square yard applied using, in the formula below, the length and width of spread and gauge stick measurements made in the tank before and after the run.

Basic Formula

$$S = \frac{L}{W \times R}$$

where:

S = Distributor Speed, m/min.
L = Distributor Pump-output, lit/min.
W = Sprayed Width, m
R = Rate of Spraying, lit/m

Calculation Example No. 1

R = 1.2 lit/m
W = 3.1 m.
L = 200 lit/min.

$$S = \frac{200}{3.1 \times 1.2} = 53.8 \text{ m/min.} = (32 \text{ km/hr.})$$

Calculation Example No. 2

R = 2.0 lit/m
W = 3.1 m
L = 300 lit/min.

$$S = \frac{300}{3.1 \times 2.0} = 48.4 \text{ m/min.} = (29 \text{ km/hr.})$$

15.5.4 Transverse Joints

Rough and unsightly transverse joints can be avoided by starting and stopping the asphalt and aggregate spread on building paper. The paper should be placed across the lane to be treated and it should be placed so that the forward edge is at the desired joint location. The distributor, traveling at the correct speed for the desired application rate, should start spraying on the paper so that when it reaches the exposed surface the spray bar is making a full, uniform application. A second length of building paper should be placed across the lane at the predetermined cut-off point for the distributor. This will give a straight, sharp transverse joint. After the aggregate spreader has passed over it, the paper should be removed immediately and destroyed.

For the next application, the leading edge of the paper should be placed on the previously laid treatment so it will be within one-half inch of the cut-off line. This will prevent a gap between the two spreads.

15.5.5 Longitudinal Joints

Full width applications of asphalt and aggregate will eliminate longitudinal joints, but in most surface treatment work traffic must be maintained and the joint is necessary. In addition, full width coverage of asphalt should never be done unless the distributor can apply full pressure to all parts of the spray bar and advance provisions are made to follow immediately with full width coverage of aggregate.

In order to prevent aggregate from building up on the longitudinal joint, the edge of the aggregate spread should coincide with the edge of the full thickness of applied asphalt. This will allow a width which can be overlapped when the asphalt is applied in the adjacent lane. Then, when the aggregate is spread for the full width in the next lane there will be no build-up at the joint. The width of the asphalt strip left exposed will vary, depending on whether the height of the spray bar is set for a double or a triple lap and on the spacing of the nozzles.

If at all possible, the longitudinal joint should be along the center line of the pavement being treated. An established guide line should be used to assure a straight longitudinal joint.

15.5.6 Spreading the Aggregate

All aggregate needed for the planned spread should be on hand before starting. When the distributor moves forward to spray the asphalt, the aggregate spreader should start right behind it. It is essential that the asphalt be covered within one minute or the increase in viscosity that takes place within that time may prevent good wetting and binding of the aggregate. It is also important that the aggregate be spread uniformly at the proper rate. In a single application, aggregate normally will not stick more than one particle thick to the asphalt, so it is useless and wasteful to apply it at a rate greater than a single layer in thickness.

A high degree of control is possible with mechanical spreaders pushed by a truck or with self-propelled spreaders. A uniform application rate can be assured with a properly adjusted spreader if a tachometer is used to maintain uniform speed. Another help in controlling distribution rates is laying off the length which each truck load of aggregate should cover.

Excess aggregate, if placed in some areas, should be removed immediately with square end shovels. In areas where application is insufficient, additional aggregate should be added. With properly adjusted and operated aggregate spreaders, however, hand work should not be necessary.

15.5.7 Rolling

Rolling seats the aggregate in the asphalt and thus promotes the bond which is necessary to resist traffic stresses.

The Asphalt Institute recommends that a pneumatic-tired roller be used on all surface treatment jobs. While both prenumatic-tired and steel-wheeled rollers have been used successfully, the former will give a uniform pressure over the entire area while the steel-wheeled roller will hit only the high spots. In addition, the contact pressures of the pneumatic-tired roller can be lowered to prevent crushing of soft aggregate. In any case, two self-propelled rollers should be used with each aggregate spreader.

Rolling should begin with a pneumatic-tired roller immediately after distribution of the cover material and continue until the aggregate is properly seated in the binder. As soon as the asphalt has a definite set or hardening, rolling should be discontinued or the bond between the surface and aggregate might be broken by the roller. Rolling should begin at the outer edge of the treatment and proceed in a longitudinal direction, working toward the center of the road. Each trip should overlap the previous trip by about one-half the width of the front wheels or roll.

15.5.8 Brooming

Properly distributed aggregate will require no redistribution and drag brooms should be prohibited. Broom dragging tends to shift the smaller particles to the bottom and prevents adhesion of the larger particles. Drag brooms also tend to displace the stuck aggregate by turning the asphalted side up so that the wheels of passing traffic will pick it up.

15.5.9 Removing Excess Aggregate

In spite of all precautions, there usually will be some loose aggregate on the road surface after the rolling operation is completed. Before the adjacent lane is covered with asphalt, loose aggregate should be swept from along the joint and, if necessary, from the rest of the uncovered lane.

Aggregate which does not stick creates a problem since tires on fast-moving vehicles will pick up the loose particles and throw them against following vehicles, often damaging headlights, windshields, and finish. This loose aggregate may be removed by lightly brooming with a rotary power broom during the cool of early morning, after final set of the asphalt has occurred.

15.5.10 Traffic Control

Control of traffic through the work area is important to high quality work. High speed traffic over a fresh surface treatment displaces the aggregate and produces a slick, black surface. Traffic should be detoured or allowed only in the lane not under construction. When work is completed and initial asphalt set has occurred, traffic should be controlled to less than 30 kms per hour until final asphalt set. The time until final set will vary with the weather. Traffic should be directed through the work area in a manner designed to provide maximum safety for the workmen and the least possible interruption of the work. Traffic control should be maintained throughout the job. The best way to control traffic is with warning signs, flagmen, and a pilot truck, leading vehicles past the work.

Traffic control also should extend to the hauling equipment. The aggregate trucks should be routed to the aggregate spreader in a direction opposite to the progress of the surface treatment operation. This prevents them from turning on the freshly placed treatment. All trucks should be required to turn around at a designated spot away from the new work for their return trip to the stockpile.

15.6 DOUBLE SURFACE TREATMENT

The largest size aggregate is placed in the lower course with succeeding courses using smaller aggregate. A good general rule is that the second course aggregate should be about half the size of the first course aggregate.

For example, if the first course aggregate is predominantly one inch to one-half inch in size, the second course should be one-half inch to one-quarter inch. The total thickness, using normal aggregate, for a double surface treatment with the first two aggregates would be about one inch. With large percentages of flat particles in the aggregate, thicknesses would be less.

The quantity of each size of aggregate for a double surface treatment is that amount required to cover the surface one stone thick. This spread quantity should be determined with no allowance being made for spreading inaccuracies.

Construction procedures for double surface treatments are essentially the same as those for single surface treatments except that the process is repeated. The procedure for a double surface treatment consists of the following steps:

(1) Placing first course asphalt
(2) Placing first course aggregate
(3) Rolling first course aggregate
(4) Placing second course asphalt
(5) Placing second course aggregate
(6) Rolling second course aggregate

There should be proper curing between each treatment.

For a three course surface treatment steps 4, 5 and 6 are repeated for the third course.

15.7 EXAMPLES OF SURFACE TREATMENT

(1) A prime and single surface treatment on a newly-constructed (fully cured) cement stabilized gravel base: Expected traffic 100 commercial vehicles per day.

Prime: MC-70 cut-back bitumen applied at the rate of 0.7 lit./m^2

Surface Treatment: MC-3000 cut-back applied at 1.1 l/m^2 and covered with 10 mm nominal-sized cubical chippings applied at the rate of 12 kg/m^2 .

(2) A prime and double surface treatment on a newly-constructed dense crushed-stone natural gravel base: Expected traffic 200 commercial vehicles per day.

Prime: MC-70 cut-back asphalt applied at the rate of 0.9 lit./m^2.

First: MC -3000 cut-back applied at the rate of 1.0 l/m^2 covered with 14 mm cubical chippings at the rate of 14 kg/m^2.

Second Treatment: MC 3000 cut-back asphalt applied at the rate of 1.2 l/m^2 and covered with 10 mm (3/8 in) chippings at 12 kg/m^2.

Note: Best results will be obtained with double surface treatment if the sizes of chippings used in the two treatments differ by at least 50 per cent and if the second dressing is delayed for some months after the road is opened to traffic, in which case each dressing should be designed as a single surface treatment as outlined in (1) above.

These examples are given to indicate the kind of design likely to give satisfactory surface treatment in the circumstances quoted. It is recommended that the engineer responsible should derive designs suitable for local conditions using available materials from carefully-conducted road trials.

(3) Double Bituminous Surface Treatment (DBST) with Seal Coat in the Province of Cavite

The following DBST pavement construction was carried out on the low to medium traffic volume Provincial Roads in the Province of Cavite since 1982 to 1984. Its length is about 97 km and those DBST pavements showed mostly adequate performance for more than five years after their completion. Some road sections of those DBST pavements are now under rehabilitation with 5cm of asphalt concrete overlay. In other road sections where the underground water table is low and subgrade bearing capacity is relatively high, DBST pavements are still showing good performance after 7 years traffic services.

a) Base Course : Well graded crushed stone aggregate and the standard thickness of 15 cm.

b) Prime Coat : Emulsified Asphalt CSS-1h, Application rate is 1.2 to 1.4 l/m^2 for the diluted emulsified asphalt by an equal volume water to facilitate its penetration into the base course surface.

c) Application Rates for Asphalt Binder and Chippings:

These are shown in Table 15.7-1

TABLE 15.7-1 QUANTITIES OF MATERIALS AND SEQUENCE OF OPERATION

Double Bituminous Surface Treatment with Seal Coat using Emulsified Asphalt CSS-1h

(DBST Pavement Construction in the Province of Cavite)

	Bituminous Binder kg/m^2	Aggregate kg/m^2		
		3/4" 20-10mm	3/8" 10-5mm	1/4" 6-2mm
First Layer:				
Spray Bit. Binder	1.3 to 1.4			
Spread Aggregate		18		
Second Layer:				
Spray Bit. Binder	1.6 to 1.8			
Spread Aggregate			11	
Seal Coat:				
Spray Bit. Binder	0.8 to 1.0			
Spread Aggregate				6

(4) Equipment:

Emulsified Asphalt was sprayed by asphalt distributor and aggregates were immediately spread on the sprayed top by mechanical spreader mounted at the rear of dumptruck. Rolling, immediately following the aggregate spreading, was insured by pneumatic tired roller.

CHAPTER 16

BITUMINOUS PENETRATION MACADAM PAVEMENT

16.1 GENERAL

This method is to construct a surface course with a high stability by supporting the load through the use of interlock of aggregate spread on the base course and preventing the movement of aggregate by means of adhesion and viscosity of bituminous materials sprayed and penetrated in to the surface course.

This method is achieved through hot or cold spraying of bituminous materials, according to their viscosity.

16.2 MATERIALS

16.2.1 Asphalt

Asphalt used for penetration macadam includes straight asphalt, asphalt emulsion and cut-back asphalt.

1) The penetration of straight asphalt should range from 85 to 200, based on traffic volume and temperature at the time of construction. In warmer seasons, those with a penetration of 85-100 are commonly used. Appropriate asphalt should be chosen, taking into consideration the previous construction experience in the region.

2) Typical asphalt emulsion used is cat-ionic emulsion. These cationic emulsion products have better adhesion to aggregate than anionic emulsion and can be effectively used for construction when vehicles are allowed to use the pavement shortly after construction.

3) Cut-back asphalt commonly used are MC-800 and 3000. Products having higher viscosity at normal temperature should be heated before spraying, until the temperature suitable for spraying is attained.

16.2.2 Aggregate

Aggregate for this method is single-sized crushed stone. The particle shape should be carefully checked, as improper shape will lose the interlock capabilities of the aggregate. Especially when considering crushed gravel more than 75% by weight percentage of the fraction retained on a 4.75mm sieve should have two or more fractured surfaces.

Crushed stone should have a clean surface, because of the importance of its adhesion to bituminous materials. Consequently, care should be taken to prevent the mixing of dust or mud during its storage.

In addition, crushed stone should be solid and hard to break. If crushed stone breaks during compaction, bituminous materials may not adhere to some of the fractured surfaces of the crushed stone, or gaps between the crushed stone be eliminated, resulting in the prevention of the penetration of bituminous materials. The crushed stone used for this method should have low water absorption.

16.2.3 Standard Quantities of Materials

Figures 16.2-1 to 16.2-3 show standard quantities of materials. The uppermost layer is seal coat. Table 16.2-1 also shows the example of quantities of materials and sequence of operation for using emulsified asphalt. It is desirable that the spraying amount of each layer be changed depending on the season of construction; more in the lower layers being in hot season, and more in the upper layers in cool season.

The surface course of the penetration macadam method should always be provided with a seal coat to make the surface impermeable, as the penetration of rain water could significantly affect its durability.

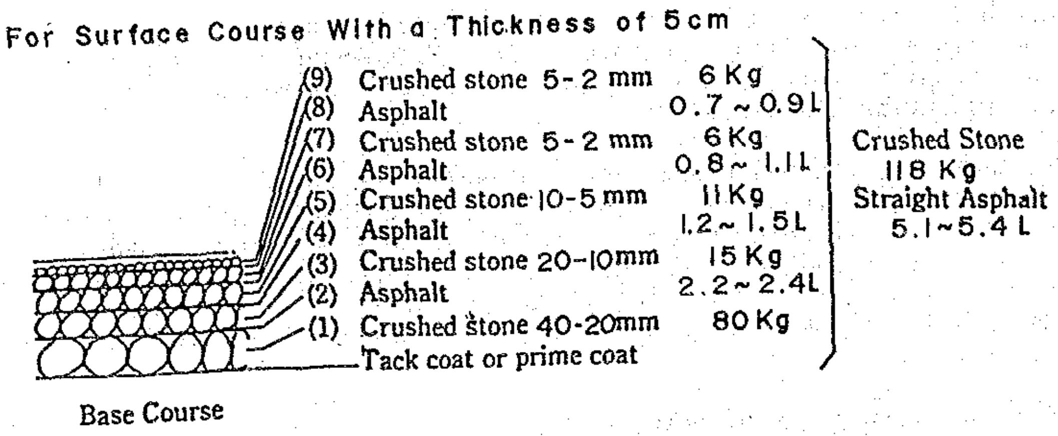


FIGURE 16.2-1 MATERIALS STANDARD QUANTITIES FOR PENETRATION MACADAM (ASPHALT CEMENT)

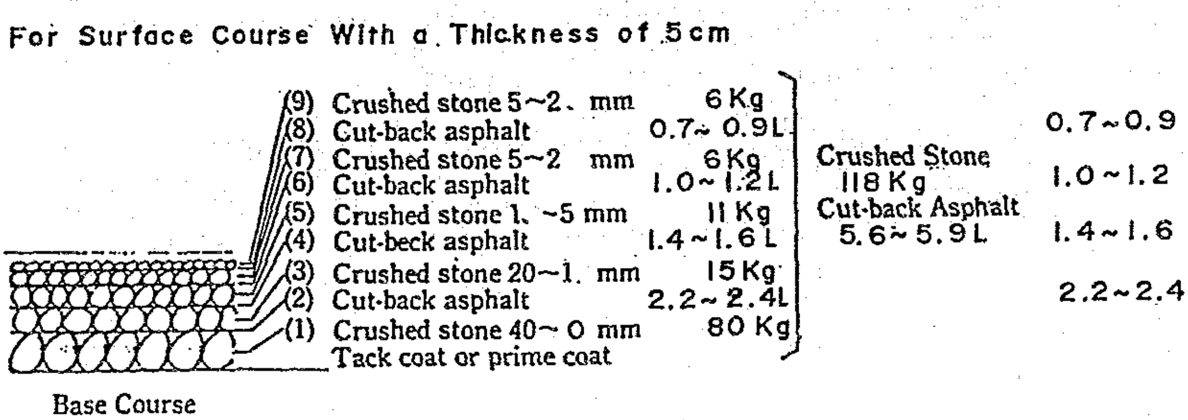


FIGURE 16.2-2 MATERIALS STANDARD QUANTITIES FOR PENETRATION MACADAM (CUT-BACK ASPHALT)

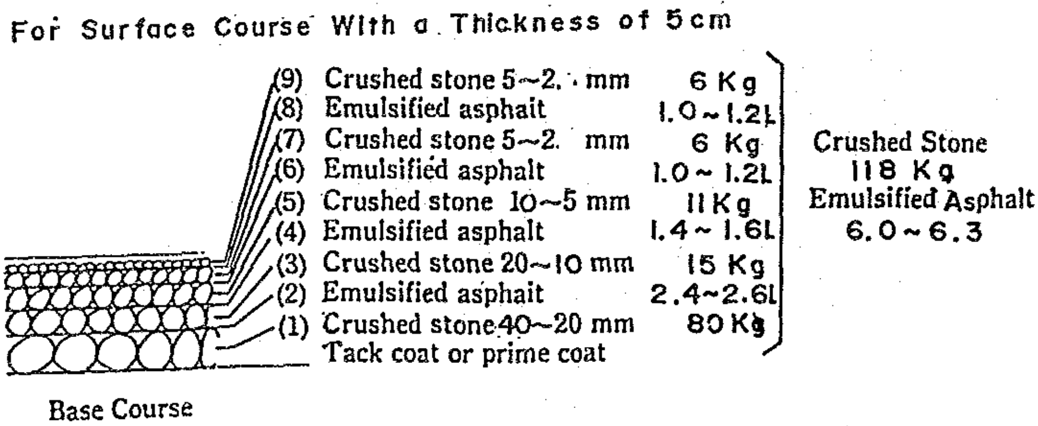


FIGURE 16.2-3 MATERIALS STANDARD QUANTITIES FOR PENETRATION MACADAM (EMULSIFIED ASPHALT)

TABLE 16.2-1 QUANTITIES OF MATERIALS AND SEQUENCE OF OPERATION FOR ASPHALT PENETRATION MACADAM EMULSIFIED ASPHALT: 5cm THICKNESS

Layer	Emulsified Asphalt	Aggregates			
		Base 40-20mm	Keystone 20-10mm	Keystone 10-5mm	Cover Sand
		kg/m^2			
Macadam Base Layer: Spread Aggregates		80			
First Layer: Spray Asphalt	2.7				
Spread Aggregates			13		
Second Layer: Spray Asphalt	1.8				
Spread Aggregates				11	
Third Layer: Spray Asphalt	1.5				
Spread Aggregates					8
Total	6.0	112			

16.3 EQUIPMENT

The main equipment for the construction of asphalt penetration macadam are mostly same as that of asphalt surface treatment.

(1) Asphalt distributor or pressurized asphalt sprayer
(2) Aggregate spreader
(3) Rollers :

a) Macadam roller - for compaction of macadam base layer.
b) Pneumatic tired roller - for compaction of keystone and cover aggregate layers.

16.4 CONSTRUCTION

Prior to construction, the base course should be checked if it is thoroughly compacted and is free of foreign matter, such as dust. After applying a tack coat to the base course, the surface course should be constructed in the following manner.

Note: When the surface course is constructed immediately after the construction of the base course, a tack coat is not applied.

16.4.1 Spreading of macadam base aggregate

Aggregate should be evenly and uniformly spread in the required amount, either manually or using a spreader. It should be carefully spread, as the thickness of the spread aggregate controls the thickness of the finished surface course.

After spreading the macadam aggregate, that with excessively large size, or flat or elongated shape and pieces of wood or foreign matter should be removed.

16.4.2 Compaction of macadam base aggregate layer

Compaction is desirably conducted using a roller not so heavy as to crush the aggregate, until the aggregate achieves a full interlock, at a speed of 3km/h or less, using a macadam roller of 10 tons or more.

Compaction should be conducted longitudinally, starting from the road side to center line, making an overlap of half of the width of the rear wheel.

16.4.3 Spraying of asphalt

Generally, asphalt should be sprayed by a distributor or an engine sprayer. The spraying machine should be able to provide sufficient pressure to assure the penetration of the bituminous material into the aggregate layer. It should be equipped with a meter if possible.

During spraying care should be taken not to spray on the strip already sprayed.

Straight asphalt and cut-back asphalt should be heated so that the viscosity in the range of 50 to 200 cSt(Saybolt-Failure viscosity 25 to 100 seconds). Direct heating of cut-back asphalt with fire should be conducted carefully, as careless operation may cause a fire due to its inflammability (a fire extinguisher should be on hand).

16.4.4 Keystone and cover aggregate

Keystone should be uniformly spread in the required amount to fill the gaps in the macadam aggregate. Cover aggregate should be spread in the required amount to fill the gaps on the surface. Since cover aggregate tends to be spread unevenly and pile up, it should be spread evenly using a broom.

When spraying heated bituminous materials, keystone and cover aggregate should be spread while the sprayed bituminous materials are still warm.

Aggregate should be spread immediately after the spraying of the asphalt emulsion, and before breaking of the emulsion takes place.

16.4.5 Compaction of keystone and cover aggregate

Keystone and cover aggregate should be lightly compacted, because, unlike macadam aggregates, they are expected to play a role as a wedge forced into the surface. Excessive compaction using a heavy steel wheel roller should be avoided, as it could loosen the interlocking of the aggregate.

On the day of construction, traffic should only be permitted at a speed of 20km/h or less, to avoid the disturbance of the surface by passing vehicles.

For some time after the construction, the pavement should be carefully observed as it gradually settles through the compaction by passing vehicles and its density increases. Any defects observed should be immediately corrected.

CHAPTER 17

HOT MIX ASPHALT CONCRETE COURSE

17.1 GENERAL

Asphalt concrete surface course which is under the immediate influence of traffic load and exposed to the elements, constructed of hot asphalt mix. The type of hot mix used is selected based on conditions of use, traffic, climate, etc.

In designing the hot mix, particular care should be taken in material selection, grading of aggregates, and determination of the asphalt content in order to achieve the required properties.

In construction, aggregates should be properly dried, heated and mixed before being used. The hot mix delivered to job site should be uniformly spread and leveled, rolled and compacted while hot to achieve the required density as well as an even and homogenous surface. Since workmanship has an important bearing on the quality of the resultant pavement, it is essential that work performance be properly controlled.

The standard types of asphalt mix used in surface courses, as shown in Table 17.1-1 are designated as dense graded asphalt concretes.

17.2 MIX DESIGN

17.2.1 General

The asphalt mix should be designed, using materials of the required quality, to achieve a product of high stability, durability, skid resistance and workability throughout the processes of mixing, placing, compacting and finishing operations.

In principle, mix designs for surface courses should base on the Marshall method. However, where the use of a certain mix design and the materials involved has been proved by past experience to be of satisfactory result, and where the scale of pavement construction is small, such design process can be omitted.

17.2.2 Mix Design Process

The process of mix design is as follows:

1) Test specimen are prepared from samples of selected materials which satisfy the quality requirements and are available in sufficient quantity and with consistent quality.

2) The mix proportion of aggregates is determined so that the combined grading of the mix complies with the grading requirements specified in Table 17.2-1, and forms a satisfactory grading curve when graphed.

3) The design asphalt content corresponding to the combined aggregate is determined in accordance with the method described in Section 17.2.3.

4) Test mixing is performed at the plant, based on presumed mix ratios of materials from the cold feeder and the hot bin. Qualities of the test mix are compared again with the criteria of satisfactory mixes, and the condition of test pavement is observed in the field. According to interpretations of these results, the laboratory mix formula is modified if necessary, to establish the design job mix. Where a permanent plant is used, test mixing is performed with reference to the quality control data of the daily operation.

Note 1. Normally, the curve produced by connecting the medium values of the ranges of aggregate size shown in Table is taken as the target grading curve. However, where it is difficult to achieve a grading which coincides with the target curve, the closest possible grading curve within the required range is taken as the alternative.

Note 2. Grading of the aggregate sample used during the design process is determined taking into consideration the estimated quantity of the oversized fraction removed at the plant, and the fine fraction removed by the dust collector.

Note 3. A gap graded aggregate is normally obtained by combining a single-sized coarse aggregate with fine sand, and it should be noted that a gap graded material cannot be achieved if fine sand is unavailable. Where unavoidable it is advisable to devise a mix type and mix formula which consist of the obtainable grading and at the same time satisfies the performance requirements.

Note 4. The proportion of aggregate passing a 0.074 mm sieve against the quantity of asphalt is normally 0.8 to 12.0 times for common regions.

Note 5. In combining screenings and natural sand, it is desirable that proportion of the screenings be smaller than that of the sand.

Note 6. It is desirable that of a combined aggregate, the fraction passing a 0.075 mm sieve consists of smaller proportion of dust from the bag filter than that from the mineral powder bin.

TABLE 17.1-1 TYPICAL DENSE GRADED ASPHALT CONCRETE

	DPWH Specification 1987 Hot Plant Mix Bituminous Concrete		Japan Road Association Manual for Asphalt Pavement 1989	
	Type D	Type F		
Finished Thickness cm.	3~5		3~5	
Sieve Size	Percentage Passing by Weight			
25 mm. 1in.			100	
19 mm. 3/4 in.	100	100	95-100	100
12.5 mm. 1/2 in.	95-100	95-100	75-90	95-100
9.5 mm. 3/8 in	74-92	-		
4.75 mm. No. 4	48-70	45-65	45-65	55-70
2.36 mm. No. 8	33-53	33-53	35-55	35-55
0.600mm. No. 30	15-30	-	18-30	18-30
0.300mm. No. 50	10-20	10-20	10-21	10-21
0.075mm. No. 200	4-9	3-8	4-8	4-8
Asphalt Content (%)	5~7			
Asphalt Cement Penetration Grade	60~70 85~100			

17.2.3 Design Asphalt Content

(1) The design asphalt content corresponding to the unit volume of design aggregate mix of a satisfactory combined grading is determined by the following process.

a) Within the range indicated in Table 17.2-1 for the selected mix type, Marshall test specimens are prepared of alternative asphalt mixes, with the asphalt content varying at 0.5% intervals.

b) Density, stability and flow value of the specimens are determined and the total voids in the mixture and the percent of the aggregate voids filled with asphalt are computed.

c) Test results are graphed in smooth curves as illustrated in Fig. 17.2-1 using arithmetic scales to indicate the asphalt content on x-axis; and the density of the total mix, the total voids, the percentage of voids filled with asphalt, the stability, and the flow value respectively on the y-axis of the individual curves.

d) The ranges of asphalt content which satisfy the individual criteria specified in Table 17.2-1 are found from the curves thus produced.

e) The common range of asphalt content which satisfies all the criteria (hereinafter referred to as the common range) is obtained, and its medium value is taken as the design asphalt content for normal cases. In cases of pavements in common regions where visible rutting is likely to develop, a smaller value within the common range may be adopted; and for pavements of light traffic roads a larger value within the common range may be chosen.

(2) If any known example of pavement constructed of the same material and mix design exists and demonstrates satisfactory performance the asphalt content of such pavement can be adopted as the design asphalt content.

TABLE 17.2-1 TYPICAL MARSHALL DESIGN CRITERIA FOR DENSE ASPHALT CONCRETE SURFACE MIXTURE

Marshall Method Mix Criteria		Surface Course Min.	Max.
Stability	(kg.)	500	_
Flow	(0.01 cm)	20	40
Percent Air Voids	(%)	3	6
Aggregates Void Filled With Asphalt	(%)	70	85

Source: Japan Road Association, Manual For Asphalt Pavement 1981.

17.3 MIXING AND TRANSPORTING OPERATIONS

17.3.1 General

The asphalt mix is produced at a mixing plant and transported to construction site on demand. The mixing plant should be capable of satisfying the demand both quantitatively and qualitatively and should also be furnished with all necessary means of environmental protection, such as dust control facilities.

Two types of asphalt plants which differ in the system of material measurement exist, namely: batch mix plants and the continuous mix plants. A batch mixer weighs the individual materials separately by batches whereas a continuous mixer has a feeder which measures all the materials by volume in continues operation.

A permanent plant should be capable of coping with the anticipated market demand, whereas, a temporary plant established for use in a specific construction project should be capable of catering for the material requirements of that project.

17.3.2 Mixing Plant

Functional elements of a mixing plant generally include the facility site, material storage facilities, the plant, the truck scale, power facilities, equipment storage, the laboratory, the office, personnel quarters, equipment maintenance sheds, etc. Since each functional element needs to be in harmony with the others in order to be fully used, proper planning and consideration should be made in establishing a mixing plant.

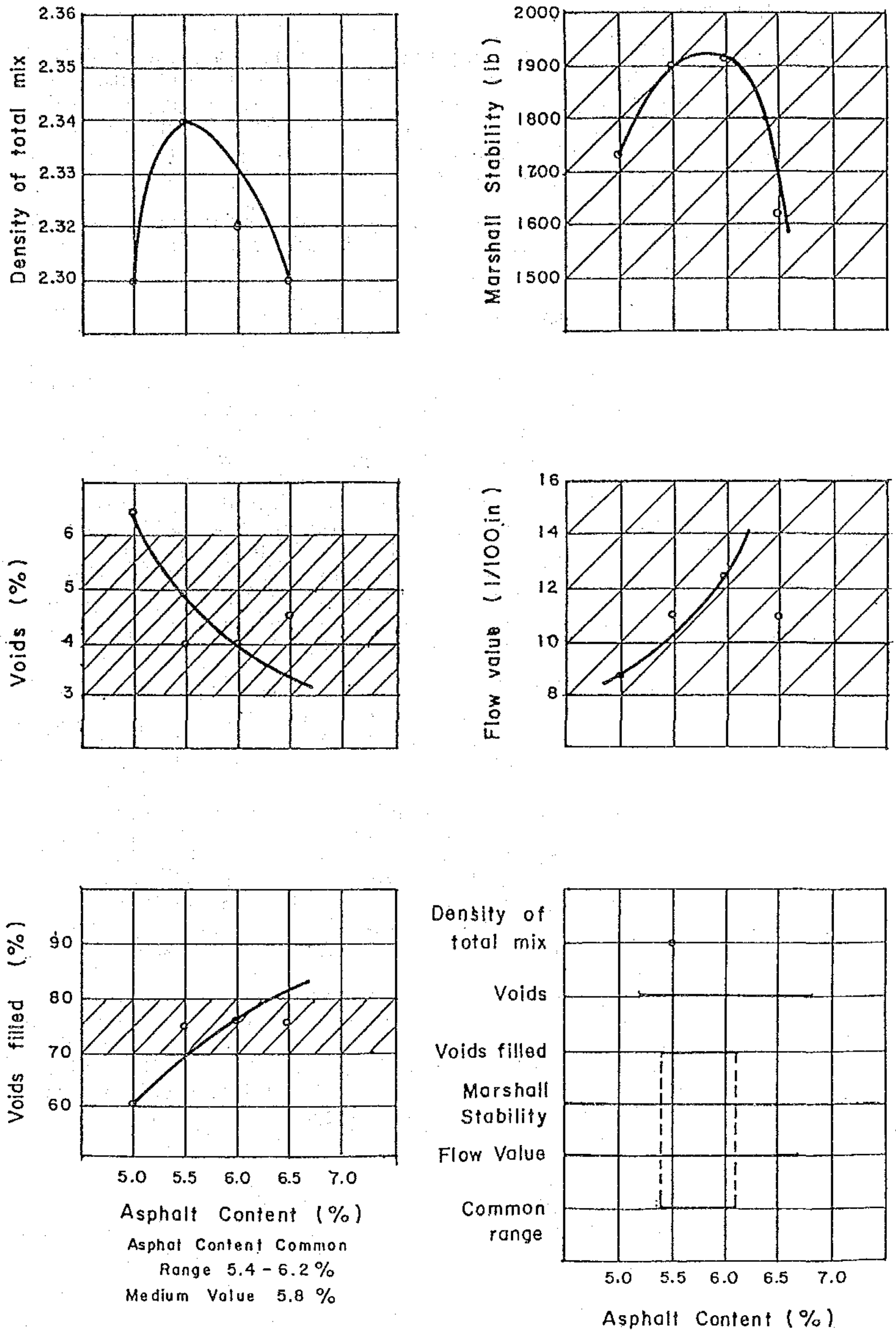


FIGURE 17.2-1 EXAMPLE OF GRAPHICS FOR DETERMINATION OF DESIGN ASPHALT

17.3.3 Mixing Operation

(1) General. In order that the required mix is always be safely and continuously produced, it is vital that equipment be inspected and adjusted prior to the mixing operation and that performance of such operation be properly controlled. Of the two types of mixers stated previously, this section deals with batch mix plants.

(2) Preparation for Mixing Operation. The usual process of preparing mixing operation for a batch mix plant is as follows:

1) Inspection and adjustment of the plant.
2) Determining the job mix formula.

   i) In accordance with the proportion of aggregate mix determined by laboratory mix design, and the capacity of the plant (tons/hr.), the cold feeder gate is adjusted and aggregates are fed.

   ii) After mixing and heating, the combined aggregate is sieved and divided by grading into classified hot bins.Samples are then taken from the individual hot bins. Based on sieve analyses, the proportions of aggregate from individual hot bins is then determined in accordance with the combined grading of the laboratory mix design.

   iii) The weight to be measured from each bin of aggregate, mineral powder and asphalt is then determined based on the mixing capacity per batch of the plant and the mix ratios of hot-bin aggregates.

3) Trial batch test. After determining the mix proportions of hot bins based on laboratory test mix results, trial batch testing should be performed at the plant to confirm the quality of the product mix and also to establish the operation standards. In the case of permanent plant, such a trial batch testing operation should be performed on a regular basis or whenever a change of any material is planned.

   Quality control of the plant operation is aimed at consistency of the product based on the target job mix formula determined by trial batch test. The major points to be observed, confirmed and determined during trial batch testing are as follows:

i) Confirmation of the proportioning of hot-bins.

- The combined grading is checked against gradings of the hot-bin materials and the mix formula, and test mixing of material sampled from individual bins is performed to confirm whether the resultant grading satisfies the target aggregate grading requirement.
- The balance between the quantity consumed and that remaining in stock is checked.

ii) Determining the asphalt content.

- Trial batch testing is performed based on the optimum asphalt content obtained in a laboratory mix, together with alternative mixes having slight variation in asphalt content (normally-optimum asphalt content +0.3%).

- Trial mix are subjected to Marshall test specimens and the test data is compared with the test results of the laboratory mix. The aggregate grading and asphalt contents of the trial mixes are confirmed by sample testing.

- The asphalt content is determined based on studies mentioned above and also observation of the resultant mixes.

iii) Determining the mixing time. The mixing time is determined based on observation of the coating conditions on the aggregate.

iv) Determining the mixing temperature.

- The mixing temperature is determined based on consideration of the compaction temperature and the heat loss during transporting and paving operations.

- The temperature of the heated aggregate required to achieve the mixing temperature is determined from the temperature of the mix immediately after its production.

v) Observation of the mix. Observation of the mix are made to answer the following questions.

- Is the asphalt content appropriate ?
- Is the mix dry ?
- Is the mixing temperature appropriate ?
- Is there any sign of material segregation in the mix ?
- Is the mix easy to work with ?
- Is the mix easy to compact ?

vi) Determining the job mix. The final job mix formula is determined based on results of tests stated in above paragraphs i) through iv) and observation of the trial mix stated in paragraph v).

(3) Daily Inspection of the Plant. All parts of the plant should be properly inspected daily before beginning operation. Such daily inspection should be conducted systematically on a check-list basis.

(4) Mix Production. During mix production, the batching plant should be operated, paying attention to any cautions mentioned in its operation instructions.

17.3.4 Transportation

For transporting the asphalt mix, a clean vehicle should be used. To preserve its heat and to prevent contamination by foreign matter, it is advisable that the mixture be covered by means of a sheet for example, during transportation. In order to prevent adhesion of the asphalt mix, it is advisable to coat the inside surfaces of the loading bed of the vehicle with oil. However, attention should be paid to minimizing the amount of oil coat since it tends to cut back the asphalt.

17.4 PAVING OPERATION

17.4.1 General

As workmanship of binder and surface course construction has an important bearing on traffic safety, wear and weather resistance qualities of the pavement, paving operation should be performed to satisfying the following objectives :

1) To correctly and evenly finish to the required cross section and profile.
2) To achieve as high a density as possible.
3) To obtain a uniform texture in accordance with the type of asphalt mix.

17.4.2 Paving Equipment

Principal paving equipment includes asphalt finishers for spreading and leveling the hot mix, and compacting machines. Paving tools include distributors, asphalt sprayers, etc. for spraying asphalt.

Examples of combined use of various pavement equipment are shown in Table 17.4-1.

17.4.3 Preparation of Paving Operations

(1) Preparation of Paving Equipment

1) Inspection and adjustment of equipment. Prior to paving operations , the number, condition, wear and tear of parts, and availability of spares of the equipment and tools should be examined so that no retardation of work will be caused by any unsatisfactory equipment situation during execution of the works.

Particular attention should be paid in checking the condition of the distributor, finisher, roller etc. Since their breaking down would greatly influence the progress of pavement execution.

TABLE 17.4-1 EXAMPLES OF COMBINATION OF PAVING EQUIPMENT

	Plant Capacity		Remarks
	30t/hr.	60t/hr	
For hot mix spreading and levelling : Finisher	1 unit	1 unit	
For compaction : Macadam roller Tandem roller Pneumatic tire roller	 1 (1) 1	 1 1 1	 10 tons or more 8 tons or more 15 tons or more
For spraying asphalt : Asphalt distributor Asphalt sprayer	 (1) 1	 1 (1)	 For prime and tack coating
For pavement Cleaning : Sweeper	 (1)	 1	For sweeping of binder, base or subbase courses, any convenient means such as a broom, a deck brush etc. may be used.

Tools: Rake, lute, tamper, smoother, cutter, form, pin, small kettle, wheeled tool heater, hammer, shovel etc.
Note : Figures in ( ) indicate optional equipment.

2) Heating of tools. Shovels, rakes, tampers, smoothers, and other tools should be heated prior to their use for working ease and prevention of adhesion of the asphalt mix.

(2) Inspection of the Base Course

1) Before placing the asphalt mix, the base course surface should be cleared of dirt, mud, pebbles and so on.

2) The base course should be examined to discover any defect, such as an unstable spot having locally unsuitable asphalt content, or any local softening of material due to the presence of water, or any uneven surface. All such defects should be mended when discovered.

17.4.4 Tack Coating

A tack coat is applied to the surface of an underlying course by spraying emulsified asphalt uniformly over it, to facilitate a tighter bond with the asphalt mix laid upon it. After tack coating the surface course should be laid immediately to avoid the adhesion of any extraneous matter. The unit quantity of emulsified asphalt used in tack coating is within the range 0.4 to 0.8 l/m^2 .

17.4.5 Spreading

In the use of hot mix for pavement construction, it is very important that all operations involved be completed before the mixture cools. It is therefore essential that the mixture be spread, levelled and shaped uniformly to the correct form immediately after its delivery to the site.

Laying of the asphalt is normally done by means of an asphalt finisher. However, manual execution is also done where mechanical execution is not possible, such as in the cases of a narrow section, the transitional area of an intersection, the bordering areas between the pavement and a structure, a curve with a very small radius, or a small scale pavement work.

17.4.6 Compaction

Immediately after spreading and levelling, the hot mix asphalt should be compacted thoroughly to the required density. Equipment used for pavement compaction includes steel-wheeled rollers, tire rollers, etc.

17.4.7 Joints

The density of pavement material tends to be insufficient at transverse joints, longitudinal joints and junctions with structures. Consequently, this causes the development of steps, cracks, and other defects. Compaction at such locations should therefore be done with particular care to achieve sufficient density.

CHAPTER 18

PORTLAND CEMENT CONCRETE PAVEMENT

18.1 MATERIALS

(1) Portland Cement

Hydraulic Cement, Type I Portland Cement shall be used for concrete slab.

(2) Fine Aggregate

It shall consist of natural sand, stone screening or other inert materials with similar characteristics, or combinations thereof, having hard, strong and durable particles.

It shall not contain more than three (3) percent of material passing the 0.075 mm (No. 200 sieve) by washing nor more than one (1) percent each of clay lumps or shale.

If the fine aggregate is subjected to five (5) cycles of the sodium sulfate soundness test, the weighted loss shall not exceed 10 percent.

The fine aggregate shall be free from injurious amounts of organic impurities.

The fine aggregate shall be well-graded from coarse to fine and shall conform to Table 18.1-1.

Table 18.1-1 GRADING REQUIREMENTS FOR FINE AGGREGATES

Sieve	Percent Passing by Weight
9.5 mm (3/8 in)	100
4.75 mm (No. 4)	95 - 100
1.18 mm (No. 16)	45 - 80
0.300 mm (No. 50)	5 - 30
0.150 mm (No. 100)	0 - 10

(3) Coarse Aggregate

It shall consist of crushed stone, gravel or other approved inert materials of similar characteristics, or combinations thereof, having hard, strong, durable pieces and free from any adherent coatings, and the grading shall comform to Table 18.1-2.

It shall contain not more than one (1) percent of material passing the 0.075 mm (No. 200) sieve, not more than 0.25 percent of clay lump, nor more than 3.5 percent of soft fragments.

If the coarse aggregate is subjected to five (5) cycles of the sodium sulfate soundness test, the weighted loss shall not exceed 12 percent.

It shall have a percent of wear not exceeding 40 when tested by AASHTO T 96.

TABLE 18.1-2 GRADING REQUIREMENT FOR COARSE AGGREGATES

Sieve	Percent Passing by Weight	
	Grading B	Grading C
63.0 mm (2 1/2 in.)	100	100
50.0 mm (2 in.)	90 - 100	95 - 100
37.5 mm (1 1/2 in.)	35 - 70	-
25.0 mm (1 in.)	0 - 15	35 - 70
19.0 mm (3/4 in.)	-	-
12.5 mm (1/2 in.)	0 - 5	10 - 30
4.75 mm (No. 4)	-	0 - 5

(4) Water

Water used in mixing and curing shall be reasonably clean and free from oil, salt, acid, alkali, grass or other substances injurious to the finished product. Portable water may be used without test. Where the source of water is shallow, the intake shall be so enclosed as to exclude silt, mud, grass or other foreign materials.

(5) Reinforcing Steel

Tie bars shall be deformed bars. Dowels shall be plain round bars. Before delivery to the site, one-half of the length of each dowel shall be painted with one coat of approved lead or tar paint.

The sleeves of dowels shall be metal of approved design to cover 50 mm, plus or minus 5 mm of the dowel, with a closed end, and with a suitable stop to hold the end of the sleeve at least 25 mm from the end of the dowel. Sleeves shall be of such design that they will not collapse during construction.

(6) Joint Fillers

Poured joint fillers shall e mixed asphalt and mineral or rubber filler conforming to the applicable requirements for joint filler materials.

18.2 STORAGE OF CEMENT AND AGGREGATE

All cement shall be stored, immediately upon delivery at the site, in weatherproof building which will protect the cement from dampness. The floor shall be raised from the ground. Provisions for storage shall be ample, and the shipments of cement as received shall be separately stored in such a manner as to allow the earliest deliveries to be used first and to provide easy access for identification and inspection of each shipment.

Bulk cement, if used, shall be transferred to elevated air tight and weatherproof bins. Stored cement shall meet the test requirements at any time after storage.

The handling and storing of concrete aggregates shall be such as to prevent segregation or the inclusion of foreign materials.

18.3 MIX DESIGN

Mix design shall be prepared based on the absolute volume method as outlined in the American Concrete Institute (ACI) Standard 211.1, "Recommended Practice for Selecting Proportions for Normal and Heavyweight Concrete".

It is required approximately 9.0 bags of cement per cubic meter of concrete based on a 40 kg per bag of cement for standard mixes. However, leaner or richer mixes which may be used in order to meet the minimum strength requirements shall be determined from laboratory tests of the materials to be used, the cement content and the proportions of aggregate and water that will produce a workable concrete having a slump of between 40 and 75 mm if not vibrated, or between 10 and 40 mm if vibrated, and a flexural strength of not less than 3.8 MPa (550 psi) when tested by the third-point method or 4.5 MPa (650 psi) when tested by the mid-point method; or a compressive strength of 24.1 MPa (3,500 psi) when tested at fourteen days in accordance with AASHTO T 97, T 177 or 22, respectively. Slump shall be determined using AASHTO T 199.

18.4 MIXING AND TRANSPORTING OPERATION

(1) Batching Plant and Equipment

a. General. The batching plant shall include bins, weighing hoppers and scales for the fine aggregate and for each size coarse aggregate. If cement is used in bulk, a bin, a hopper, and separate scale for cement shall be included. The weighing hopper shall be properly sealed and vented to preclude dusting operation. The batch plant shall be equipped with a suitable non-resetabble batch counter which will correctly indicate the number of batches proportioned.

b. Bins and Hoppers. Bins with adequate separate compartments for fine aggregate and for each size of coarse aggregate shall be provided in the batching plant.

c. Scales. Scales for weighing aggregateS and cement shall be of either the beam type or the springless-dial type. They shall be accurate within one-half percent (0.5%) throughout the range of use. Scales shall be inspected and sealed as often as the Engineer may deem necessary to assure their continued accuracy.

d. Automatic Weighing Devices. Batching plants shall be equipped with automatic weighing devices of an approved type to proportion aggregates and bulk cement.

(2) Mixers

a. General. Concrete may be mixed at the site of construction or at a central plant or wholly or in part in truck mixers.

b. Mixers at site of Construction. Mixing shall be done in an approved mixer capable of combining the aggregates, cement and water into a thoroughly mixed and uniform mass within the specified mixing, discharging and distributing the mixture without segregation on the prepared grade. The mixer shall be equipped with an approved timing device which will automatically lock the discharge level when the drum has been charged and release it at the end of the mixing period. In case of failure of the timing device, the mixer may be used for the balance of the day while it is being repaired, provided that each batch is mixed 90 counter which shall correctly indicate the number of batches mixed.

c. Truck Mixer and Truck Agitators. Truck mixers used for mixing and hauling concrete, and truck agitators used for hauling central-mixed concrete shall conform to the requirements of AASTHO M 157.

d. Non-Agitator Trucks. Bodies of non-agitating hauling equipment for concrete shall be smooth, mortar-tight metal containers and shall be capable of discharging the concrete at a satisfactory controlled rate without segregation.

(3) Handling, Measuring and Batching Materials

The batch plant site, layout, equipment and provisions for transporting material shall be such as to assure a continous supply of material to the work. Stockpiles shall be built up in layers of not more than one (1) meter in thickness. Each layer shall be completely in place before beginning the next which shall not be allowed to "cone" down over the next lower layer. Aggregates from different sources and of different gradings shall not be stockpiled together.

All washed aggregates and aggregates produced or handled by hydraulic methods, shall be stockpiled or binned for draining at least twelve (12) hours before being batched.

When mixing is done at the site of the work, aggregates shall be transported from the batching plant to the mixer in batch boxes, vehicle bodies, or other containers of adequate capacity and construction to properly carry the volume required. Partitions separating batches shall be adequate and effective to prevent spilling from one compartment to another while in transit or being dumped.

The mixer shall be charged without loss of cement. Batching shall be so as to result in the weight to each material required within a tolerance of one (1) percent for cement and two (2) percent for aggregates.

Water may be measured either by volume or by weight. The accuracy of measuring the water shall be within a range of error of not over one percent (1%).

a) Mixing Concrete

The concrete may be mixed at the site in a central mix plant, or in truck mixers. The mixer shall be of an approved type and capacity. Mixing time will be measured from the time all materials, except water, are in the drum. Ready-mixed concrete shall be mixed and delivered in accordance with requirements of AASHTO M 157, except that the minimum required revolutions at the mixing speed for transit-mixed concrete may be reduced to not less than that recommended by the mixer manufacturer. The number of revolutions recommended by the mixer manufacturer shall be indicated on the manufacturer's serial plate attached to the mixer.

When mixed at the site or in a central mixing plant, the mixing time shall not be less than fifty (50) seconds, nor more than ninety (90) seconds, unless mixer performances tests proved adequate mixing of the concrete is a shorter time period.

Four seconds shall be added to the specified mixing time if timing starts the instant the skip reaches its maximum raised position. Mixing time ends when the discharge chute opens. Transfer time in multiple drum mixers is included in mixing time. The contents of an individual mixer drum shall be removed before a succeeding batch is emptied therein.

The volume of concrete mixed per batch shall not exceed the mixer's nominal capacity in cubic meter, as shown on the manufacturers standard rating plate on the mixer, except that an overload up to ten (10) percent above the mixer's nominal capacity may be permitted provided concrete test data for strength, segregation, and uniform consistency are satisfactory, and provided no spillage of concrete takes place.

The batches shall be so charged into the drum that a portion of the mixing water shall enter in advance of the cement and aggregates. The flow of water shall be uniform and all water shall be in the drum by the end of the first 15 seconds of the mixing period. The throat of the drum shall be kept free of such accumulations as may restrict the free flow of materials into the drum.

Mixed concrete from the central mixing plant shall be transported in truck mixers, truck agitators or non-agitating trucks. The time elapsed from the time water is added to the mixed until the concrete is deposited in place at the site shall not exceed 45 minutes when the concrete is hauled in non-agitating trucks, nor 90 minutes when hauled in truck mixers or truck agitators, except that in hot weather or under other conditions contributing to quick hardening of the concrete.

Retempering concrete by adding water or by other means shall not be permitted, except that when concrete is delevered in truck mixers, additional water may be added to the batch materials and additional mixing performed to increase the slump to meet the specified requirements, provided all these operations are performed within the 45 minutes after the initial mixing operation and the water-cement ratio is not exceeded. Concrete that is not within the specified slump limits at the time of placement shall not be used.

b) Limitation of Mixing

During hot weather, steps shall be taken to prevent the temperature of mixed concrete from exceeding a specified maximum.

Concrete not placed within 90 minutes from the time the ingredients were charged into the mixing drum or that has developed initial settlement shall not be used. Retempering of concrete or mortar which has partially hardened , that is remixing with or without additional cement, aggregate, or water, shall not be permitted.

In order that the concrete be properly protected against the effects of rain before the concrete is sufficiently hardened, it is required to have at all times available materials for the protection of the edges and surface of the unhardened concrete.

18.5 PAVING AND FINISHING OPERATION

(1) Preparation

a) General

After the subgrade or base has been placed and compacted to the required density, it shall be trimmed to the proper elevation extending the work at least 30 cm beyond both edges of the proposed concrete pavement.

The subgrade or base shall be uniformly moist when the concrete is placed.

b) Setting Forms

Forms shall be of steel or wood, of an approved section, and of a depth equal to the thickness of the pavement at the edge. The base of the forms shall be of sufficient width to provide necessary stability in all directions.

All forms shall be rigidly supported on a bed of thoroughly compacted material during the entire operation of placing and finishing the concrete.
Forms shall be set sufficiently in advance of the point where concrete is being placed. After the forms have been set to correct grade, the base shall be thoroughly tamped, mechanically or by hand, at both the inside and outside edges of the base of the forms. The forms shall not deviate from true line by more than one (1) cm at any point.

c) Grade and Alignment

The alignment and grade elevations of the forms shall be checked and corrections be made immediately before placing the concrete. Testing as to crown and elevation, prior to placing of concrete can be made by means of holding a template in a vertical position and moved backward and forward on the forms.

d) Conditioning of Subgrade or Base Course

When side forms have been securely set to grade, the subgrade or base course shall be brought to proper cross-section. High areas shall be trimmed to proper elevation. Low areas shall be filled and properly compacted. The finished grade shall be maintained in a smooth and compacted condition until the pavement is placed.

(2) Placing Concrete

Concrete shall be deposited in such a manner to require minimal rehandling. Unless truck mixers or non-agitating hauling equipment are equipped with a means to discharge concrete without segregation of the materials, the concrete shall be unloaded into an approved spreading device and mechanically spread on the grade in such a manner as to prevent segregation. Placing shall be continuous between transverse joints without the use of intermediate bulkheads. Necessary hand spreading shall be done with shovels, not rakes. Workmen shall not be allowed to walk in the freshly mixed concrete with boots or shoes coated with earth or foreign substances.

Where concrete is to be placed adjoining a previously constructed lane and mechanical equipment will be operated upon the existing lane, that previously constructed lane shall have attained the strength for 14-day concrete. If only finishing equipment is carried on the existing lane, paving in adjoining lanes may be permitted after three (3) days.

Concrete shall be thoroughly consolidated against and along the faces of all forms and along the full length and on both sides of all joint assemblies, by means of vibrators inserted in the concrete. Vibrators shall not be permitted to come in contact with a joint assembly, the grade, or a side form. In no case shall the vibrator be operated longer than 15 seconds in any one location.

Concrete shall be deposited as near as possible to the expansion and contraction joints without disturbing them, but shall not be dumped from the discharge bucket or hopper into a joint assembly unless the hopper is well centered on the joint assembly. Should any concrete material fall on or be worked into the surface of a complete slab, they shall be removed immediately.

(3) Strike-off of Concrete and Placement of Reinforcement

Following the placing of the concrete, it shall be struck off to the required cross-section and elevation such that when the concrete is properly consolidated and finished, the surface of the pavement shall conform to the elevation shown on the plans.

(4) Joints

Joints shall be constructed of the type and dimensions, and at the locations. All joints shall be protected from the intrusion of injurious foreign materials until sealed.

a) Longitudinal Joint

Deformed steel tie bars of specified length, size, spacing and materials shall be placed perpendicularly to the longitudinal joints; they shall be placed by approved mechanical equipment rigidly secured by chair or other approved supports to prevent displacement. Tie bars shall not be painted or coated with asphalt or other material, or enclosed in tubes or sleeves. When adjacent lanes of pavement are constructed separately, steel side forms shall be used to form a keyway along the construction joint. Tie bars, except those made of rail steel, may be bent at right angles against the form of the first lane constructed and straightened into final position before the concrete of the adjacent lane is placed, or in lieu of bent tie bars, approved two-piece connectors may be used.

Longitudinal formed joints shall consist of a groove or cleft, extending downward from and normal to, the surface of the pavement. These joints shall be effected or formed by an approved mechanically or manually operated device to the dimensions and line indicated on the Plans and while the concrete is in a plastic state. The groove or cleft shall be filled with either a premolded strip or poured material as required.

The longitudinal joint shall be continuous, and there shall be no gaps in either transverse or longitudinal joints at the intersection of the joints.

Longitudinal sawed joints shall be cut by means of approved concrete saw to the depth, width and line. Suitable guide lines or devices shall be used to assure cutting the longitudinal joint on the true line. The longitudinal joint shall be sawed before the end of the curing period or shortly thereafter before any equipment or vehicles are allowed on the pavement. The sawed area shall be thoroughly cleaned and, if required, the joint shall be immediately filled with sealer.

Longitudinal pavement insert type joints shall be formed by placing a continuous strip of plastic material which will not react adversely with the chemical constituent of the concrete.

b) Transverse Expansion Joint

The expansion joint filler shall be continuous from form to form, shaped to the subgrade and to the keyway along the form. Preformed joint filler shall be furnished in lengths equal to the pavement width or equal to the width of one lane. Damaged or repaired joint filler shall not be used.

The expansion joint filler shall be held in a vertical position. An approved installing bar, or other device, shall be used if required to secure preformed expansion joint filler at the proper grade and alignment during placing and finishing of the concrete. Finished joint shall not deviate more than 6 mm from a straight line. If joint filers are assembled in sections, there shall be no offsets between adjacent units.

No plugs of concrete shall be permitted anywhere within the expansion space.

c) Transverse Contraction Joint

It shall consist of planes of weakness created by forming or cutting grooves in the surface of the pavement and shall include load transfer assemblies.

a. Transverse Strip Contraction Joint. It shall be formed by installing a parting strip to be left in place.

b. Formed Groove. It shall be made by depressing an approved tool or device into the plastic concrete. The tool or device shall remain in place at least until the concrete has attained its initial set and shall then be removed without disturbing the adjacent concrete, unless the device is designed to remain in the joint.

c. Sawed Contraction Joint. It shall be created by sawing grooves in the surface of the pavement of the width, depth, and at the spacing and lines shown in the Plans, with an approved concrete saw. After each joint is sawed, it shall be thoroughly cleaned including the adjacent concrete surface.

Sawing of the joints shall commence as soon as the concrete has hardened sufficiently to permit sawing without excessive ravelling, usually within 24 hours. All joints shall be sawed before uncontrolled shrinkage cracking takes place. If necessary, the sawing operations shall be carried on during the day or night, regardless of weather conditions. The sawing of any joint shall be omitted if crack occurs at or near the joint location prior to the time of sawing. Sawing shall be discounted when a crack develops ahead of the saw. In general, all joints should be sawed in sequence. If extreme condition exists making it impractical to prevent erratic cracking by early sawing, the contraction joint groove shall be formed prior to initial set of concrete as provided above.

d) Transverse Construction Joint

It shall be constructed when there is an interruption of more than 30 minutes in the concreting operations. No transverse joint shall be constructed within 1.50 m of an expansion joint, contraction joint, or plane of weakness. If sufficient concrete has been mixed at the time of interruption to form a slab of at least 1.50 m long, the excess concrete from the last preceding joint shall be removed and disposed off as directed.

e) Load Transfer Device

Dowels, when used, shall be held in position parallel to the surface and center line of the slab by a metal device that is left in the pavement.

The portion of each dowel painted with one coat of lead or tar shall be thoroughly coated with approved bituminous materials, e.g., MC-70, or an approved lubricant, to prevent the concrete from binding to that portion of the dowel. The sleeves for dowels shall be metal designed to cover 50 mm plus or minus 5 mm, of the dowel, with a watertight closed end and with a suitable stopper to hold the end of sleeves at least 25 mm from the end of the dowel.

In lieu of using dowel assemblies at contraction joints, dowel may be placed in the full thickness of pavement by a mechanical device.

(5) Final Strike-off (Consolidation and Finishing)

a) Sequence

The sequence of operations shall be the strike-off and consolidation, floating and removal of laitance, straight-edging and final surface finishing. Work bridges or other devices necessary to provide access to the pavement surface for the purpose of finishing, straight-edging, and making corrections shall be provided.

In general, the addition of water to the surface of the concrete to assist in finishing operations will not be permitted. If the application of water to the surface is permitted, it shall be applied as fog spray by means of the approved spray equipment.

b) Finishing at Joints

The concrete adjacent to joints shall be compacted or firmly placed without voids or segregation against the joint material, also under and around all load transfer devices, joint assembly units, and other features designed to extend into the pavement. Concrete adjacent to joints shall be mechanically vibrated.
After the concrete has been placed and vibrated adjacent to the joints the finishing machine shall be brought forward, operating in a manner to avoid damage or misalignment of joints. If uniterrupted operation of the

finishing machine, to, over and beyond the joints causes segregation of concrete, damage to, or misalignment of the joints, the finishing machine shall be stopped when the front screed is approximately 20 cm from the joint. Segregated concrete shall be removed from in front of and off the joint. The front screed shall be lifted and set directly on top of the joint and the forward motion of the finishing machine resumed. When the second screed is close enough to permit the excess mortar in front of it to flow over the joint, it shall be lifted and carried over the joint. Thereafter, the finishing machine may be run over the joint without lifting the screeds, provided there is no segregated concrete immediately between the joint and the screed or on top of the joint.

c) Machine Finishing

i) Non-vibratory Method. The concrete shall be distributed or spread as soon as placed. As soon as the concrete has been placed, it shall be struck off and screeded by an approved finishing machine. The machine shall go over each area of pavement as many times and at such intervals as necessary to give the proper compaction and leave a surface of uniform texture. Excessive operation over a given area shall be avoided. The top of the forms shall be kept clean by an effective device attached to the machine and the travel of the machines on the forms shall be maintained true without wobbling or other variation tending to affect the precision finish.

During the first pass of the finishing machine, a uniform ridge of concrete shall be maintained ahead of the front screed in its entire length.

ii) Vibratory Method. Uniform and satisfactory density of the concrete shall be obtained by the vibratory method at joints, along forms, at structures, and throughout the pavement.

d) *Hand Finishing*

Concrete, as soon as placed, shall be struck off and screeded. An approved portable screed shall be used. A second screed shall be provided for striking off the bottom layer of concrete if reinforcement is used.

The screed for the surface shall be at least 60 cm longer than the maximum width of the slab to be struck off. It shall be of approved design, sufficiently rigid to retain its shape, and constructed either of metal or other suitable material shod with metal.

Consolidation shall be attained by the use of a suitable vibrator or other approved equipment.

In operation, the screed shall be moved forward on the forms with a combined longitudinal and transverse shearing motion, moving always in the direction in which the work is progressing and so manipulated that neither end is raised from the side forms during the striking off process. If necessary, this shall be repeated until the surface is of uniform texture, true to grade and cross-section, and free from porous areas.

e) Floating

After the concrete has been struck off and consolidated, it shall be further smoothened, trued and consolidated by means of a longitudinal float, either by hand or mechanical method.

i) Hand Method. The hand-operated longitudinal float shall be not less than 360 cm in length and 15 cm (6 inches) in width, properly stiffened to prevent flexibility and warping. The longitudinal float, operated from foot bridges resting on the side forms and spanning but not touching the concrete, shall be worked with a sawing motion while held in a floating position parallel to the road center line, and moving gradually from one side of the pavement to the other. Movement ahead along the center line of the pavement shall be successive advances of not more than one-half the length of the float. Any excess water or soupy material shall be wasted over the side forms on each pass.

ii) Mechanical Method. The mechanical longitudinal float shall be a design approved and shall be in good working condition. The tracks from which the float operates shall be accurately adjusted to the required crown. The float shall be accurately adjusted and coordinated with the adjustment of the transverse finishing machine so that a small amount of mortar is carried ahead of the float will lap the distance on each transverse trip. The float shall pass over each area of pavement at least two times, but excessive operation over a given will not be permitted. Any excess water or soupy material shall be wasted over the side forms on each pass.

iii) Alternative Mechanical Method. As an alternative, a machine composed of a cutting and smoothing flat or floats suspended from and guided by a rigid frame may be used. The frame shall be carried by four or more visible wheels riding on, and constantly in contact with the side forms. If necessary, following one of the preceding methods of floating, long handled floats having blades not less than 150 cm in length and 15 cm in width may be used to smooth and fill in open-textured areas in the pavement. Long handles floats shall not be used to float the entire surface of the pavement in lieu of, or supplementing, one of the preceding methods of floating. When strike off and consolidation are done by the hand method and the crown of the pavement will not permit the use of the longitudinal float, the surface shall be floated transversely by means of the long-handled float. Care shall be taken not to work the crown out of the pavement during the operation. After floating, any excess water and laitance shall be removed from the surface of the pavement by a 3-m straight-edge or more in length. Successive drags shall be lapped one-half the length of the blade.

f) Straight-edge Testing and Surface Correction

After the floating has been completed and the excess water removed, but while the concrete is still plastic, the surface of the concrete shall be tested for trueness with a 300 cm long straight-edge. For this purpose, an accurate 300-cm straight-edge swung from handles 100 cm longer than one-half width of the slab shall be used. The straight-edge shall be held in contact with the surface in successive positions parallel to the road center line and the whole area gone over from one side of the slab to the other as necessary. Advances along the road shall be in successive stages of not more than one-half the length of the straight-edge. Any depressions found shall be immediately filled with freshly mixed concrete, struck off, consolidated and refinished. Special attention shall be given to assure that the surface across joints meets the requirements for smoothness. Straight-edge testing and surface corrections shall be continued until the entire surface is found to be free from observable departures from the straight-edge and the slab conforms to the required grade and cross-section.

g) Final Finish

If the surface texture is broom finished, it shall be applied when the water sheen has practically disappeared. The broom shall be drawn from the center to the edge of the pavement with adjacent strokes slightly overlapping. The brooming operation should be so executed that the corrugations produced in the surface shall be uniform in appearance and not more than 1.5 mm in depth. Brooming shall be completed before the concrete is in such condition that the surface will be unduly roughened by the operation. The surface thus finished shall be free from rough and porous areas, irregularities, and depressions resulting from improper handling of the broom. Brooms shall be of the quality, size and construction and be operated so as to produce a surface finish.

If the surface texture is belt finished, when straight-edging is complete and water sheen has practically disappeared and just before the concrete becomes non-plastic, the surface shall be belted with a 2-ply canvass belt not less than 20 cm wide and at least 100 cm longer than the pavement width. Hand belts shall have suitable handles to permit controlled, uniform manipulation. The belt shall be operated with short strokes transverse to the center line and with a rapid advance parallel to the center line.

If the surface texture is drag finished, a drag shall be used which consists of a seamless strip of damp burlap or cotton fabric, which shall produce a uniform of gritty texture after dragging it longitudinally along the full width of pavement. For pavement 5 m or more in width, the drag shall be mounted on a bridge which travels on the forms. The dimensions of the drag shall be such that a strip of burlap or fabric at least 100 cm wide is in contact with the full width of pavement surface while the drag is used. The drag shall consist of not less than 2 layers of burlap with the bottom layer approximately 15 cm wider than the layer. The drag shall be maintained in such condition that the resultant surface is of uniform appearance and reasonably free from grooves over 1.5 mm in depth. Drag shall be maintained clean and free from encrusted mortar. Drags that cannot be cleaned shall be discarded and new drags be substituted.

h) Edging at Forms and Joints

After the final finish, but before the concrete has taken its initial set, the edges of the pavement along each side of each slab, and on each side of transverse expansion joints, formed joints, transverse construction joints, and emergency construction joints, shall be worked with an approved tool and rounded to the radius required by the Plans. A well-defined and continuous radius shall be produced and a smooth, dense mortar finish obtained. The surface of the slab shall not be unduly disturbed by tilling the tool during the use.

At all joints, any tool marks appearing on the slab adjacent to the joints shall be eliminated by brooming the surface. In doing this, the rounding of the corner of the slab shall not be disturbed. All concrete on top of the joint filler shall be completely removed.

All joints shall be tested with a straight-edge before the concrete has set and correction made if one edge of the joint is higher than the other.

(6) Surface Test

As soon as the concrete has hardened sufficiently, the pavement surface shall be tested with a 3-m straight- edge or other specified device. Area showing high spots of more than 3 mm but not exceeding 12 mm in 3 m shall be marked and immediately ground down with an approved grinding tool to an elevation where the area or spot will not show surface deviations in excess of 3 mm when tested with 3 m straight-edge. Where the departure from correct cross-section exceeds 12 mm, the pavement shall be removed and replaced.

(7) Curing

Immediately after the finishing operations have been completed and the concrete has sufficiently set, the entire surface of the newly placed concrete shall be cured in accordance with either one of the methods described herein. Failure to provide sufficient cover material of whatever kind the Contractor may elect to use, or lack of water to adequately take care of both curing and other requirements, shall be cause for immediate suspension of concreting operations. The concrete shall not be left exposed for more than 1/2 hour between stages of curing or during the curing period.

a) Cotton or Burlap Mats

The surface of the pavement shall be entirely covered with mats. The mats used shall be of such length (or width) that as laid they will extend at least twice the thickness of the pavement beyond the edges of the slab. The mat shall be placed so that the entire surface and the edges of the slab are completely covered. Prior to being placed, the mats shall be saturated thoroughly with water. The mat shall be so placed and weighed down so as to cause them to remain in intimate contact with the surface covered. The mats shall be maintained fully wetted and in position for 72 hours unless otherwise specified.

b) Waterproof Paper

The top surface and sides of the pavement shall be entirely covered with waterproof paper, the units shall be lapped at least 45 cm. The paper shall be so placed and weighed down so as to remain in intimate contact with the surface covered. The paper shall have such dimensions but each unit as laid will extend beyond the edges of the slab at least twice the thickness of the pavement, or at pavement width and 60 cm strips of paper for the edges. If laid longitudinally, paper not manufactured in sizes which will provide this width shall be securely sewed or cemented together the joints being securely sealed in such a manner that they do not open up or separate during the curing period. Unless otherwise specified, the covering shall remain in place for 72 hours after the concrete has been placed. The surface of the pavement shall be thoroughly wetted prior to the placing of the paper.

c) Straw Curing

When this type of curing is used, the pavement shall be cured initially with burlap or cotton mats, until after final setting of the concrete or, in any case, for 12 hours after placing the concrete. As soon as the mats are removed, the surface and sides of the pavement shall be thoroughly wetted and covered with at least 20 cm of straw or hay, thickness of which is to be measured after wetting. If the straw or hay covering becomes displaced during the curing period, it shall be replaced to the original depth and saturated. It shall be kept thoroughly saturated with water for 72 hours and thoroughly wetted down during the morning of the fourth day, and the cover shall remain in place until the concrete has attained the required strength.

d) Impervious Membrane Method

The entire surface of the pavement shall be sprayed uniformly with white pigmented curing compound immediately after the finishing of the surface and before the settlement of the concrete has taken place, or if the pavement is cured initially with jute or cotton mats, it may be applied upon removal of the mats. The curing compound shall not be applied during rain.

Curing compound shall be applied under pressure at the rate of 4 liters to not more than 14 m^2 by mechanical sprayers. The spraying equipment shall be equipped with a wind guard. At the time of use, the compound shall be thoroughly mixed with the pigment uniformly dispersed throughout the vehicle. During application, the compound shall be stirred continuously by effective mechanical means. Hand spraying of odd widths or shapes and concrete surface exposed by the removal of forms will be permitted. Curing compound shall not be applied to the inside faces of joints to be sealed, but approved means shall be used to insure proper curing at least 72 hours to prevent the intrusion of foreign material into the joint before sealing has been completed. The curing compound shall be of such character that the film will harden within 30 minutes after application. Should the film be damaged from any causes within the 72-hour curing period, the damaged portions shall be repaired immediately with additional compound.

e) White Polyethylene Sheet

The top surface and sides of the pavement shall be entirely covered with polyethylene sheeting. The units used shall be lapped at least 45 cm. The sheeting shall be so placed and weighed down so as to remain in intimate contact with the surface covered. The sheeting to be use shall have such dimension that each unit laid will extend beyond the edges of the slab at least twice the thickness of the pavement. Unless otherwise specified, the covering shall be maintained in place of 72 hours after the concrete has been placed.

(8) Removal of Forms

Forms for concrete shall remain in place undisturbed for not less than twenty four (24) hours after concrete pouring. In the removal of forms, crowbars should be used in pulling out nails and pins. Care should be taken so as not to break the edges of the pavement. In case portions of the concrete are spilled, they shall be immediately repaired with fresh mortar mixed in the proportion of one part of Portland Cement and two parts fine aggregates. Any area or section so removed shall not be less than the distance between weakened plane joint nor less than the full width of the lane involved.

(9) Sealing Joints

Joints shall be sealed soon after completion of the curing period and before the pavement is opened to traffic. Just prior to sealing, each joint shall be thoroughly cleaned of all foreign materials including membrane curing compound and the joint faces shall be cleaned and surfaced dry when the seal is applied.

The sealing material shall be applied to each joint opening to conform to the details. Sealing materials applied hot shall be stirred during heating so that localized overheating will not occur. The pouring shall be done in such a manner that the material will not be spilled on the exposed surfaces of the concrete. The use of sand or similar material as a cover for the seal will not be permitted. Seals shall be installed by suitable tools, without elongation and secured in placed with an approved lubricant adhesive which shall cover both sides of the concrete joints. The seals shall be installed in a compressive condition and shall at time of placement be below the level of the pavement surface by approximately 6 mm.

The seals shall be in one piece for the full width of each transverse joint.

CHAPTER 19

QUALITY CONTROL AND INSPECTION

19.1 GENERAL

As contrasted with other types of civil engineering works, road pavements are widely exposed to the elements and the influence of loads, and are moreover constructed with no consideration of any structural safety margin. For these reasons, a pavement is not free from the possibility of sustaining defects unexpectedly early. In executing pavement works, therefore, it is essential that material qualities and workdone should be properly controlled by careful and diligent inspections, with tests and measurement performed whenever required.

Preliminary inspection and tests are conducted prior to the commencement of work to confirm the compatibility of materials and equipment with project requirements, and also to establish the necessary criteria for use in job control.

Material and work control refers to the effort endeavored towards economic accomplishment of a pavement project with work and materials meeting the requirements of contract specification and plans.

Inspection is made to confirm whether the constructed pavement complies with requirements of the specification and plans.

19.2 PRELIMINARY INSPECTION AND TESTS

Since the pavement structure is designed in accordance with the quality of base and subbase materials as well as surface materials involved, it is necessary that quality of all materials be verified with the requirements prior to execution and also prior to any change of material or mix design during construction.

To produce necessary data for use in work control and inspection, such as the maximum dry density and the optimum water content which are needed for determination of the degree of compaction, it is also necessary to conduct material tests beforehand. Furthermore, inspection of the performance and precision of principle equipment should also be conducted in advance. Inspection and test conducted to fulfill the above requirements are designated collectively as preliminary inspection and tests.

Quality inspection on a standardized product can be substituted by checking of the test report furnished by the manufacturer. Other preliminary inspection and testing may also be substituted by examining of valid reports of inspection and test conducted in the past, where such is available.

19.2.1 Base and Subbase Materials

1) Prior Inspections. Prior inspections should be made in advance, to confirm the material procurement situation, with regards to the following points ;

i) That the aggregates used for the base and subbase satisfy the required quality standards.

ii) That sustained material supply is secured from reliable source of adequate manufacturing capability and capacity.

iii) That the material is economical.

During the investigation, it is necessary that the manufacturing process be properly studied so that in the event of a quantitative or qualitative production problem, prompt measures can be taken to cope with it.

2) Material Tests. Materials should be subjected to the testing as listed in Table 19.2-1 to confirm their compliance with requirements of quality standards.

TABLE 19.2-1 TESTS FOR BASE AND SUBBASE MATERIALS

Test Item	Test Method	Remarks
Water Content	AASHTO T255 - 77	All tests are to be conducted prior to commencement of work and prior to any change of material or mix design.
Grading	AASHTO T 27 - 78	
Liquid Limit Plasticity Limit	AASHTO T 89 - 76 AASHTO T 90 - 70	
Specific Gravity Water Absorption	AASHTO T 84 - 77 AASHTO T 85 - 77	
Soundness of Aggregate	AASHTO T104 - 77	
Abrasion Loss	AASHTO T 96 - 77	
CBR Test	AASTHO T193 - 72	
Compaction Test	AASHTO T180 - 74 AASHTO T 99 - 74	
Unconfined Compressive Test	ASTM D1633	

3) Mix Design. Base and subbase material mixes should be designed based on results of tests listed in Table 19.2-1 depending on the type of work involved.

19.2.2 Asphaltic Surface

1) Prior Inspection. Prior inspection of the aggregates should be made to determine whether they meet the quality requirements and standards of aggregates of an asphaltic surface whether their supply can meet the demand of the project and whether they are economic.

2) Material Standard Tests. Materials are required to be tested in accordance with test methods listed in Table 19.2-2

TABLE 19.2-2 STANDARD TESTS FOR ASPHALTIC SURFACE MATERIALS

	Test Item	Test Method	Notes
Coarse and Fine Aggregates	Grading	AASHTO T27 -78	All tests are to conducted prior to commencement of work and any change of material or mix change of material or mix design
	Specific gravity Water absorption	AASHTO T84-77 AASHTO T85-77	
	Abrasion loss	AASHTO T84-77	
	Soundness of aggregate	AASHTO T104-77	
	Content of deleterious substances	AASHTO T71	
Mineral Filler	Grading	AASHTO T37 -77	
Asphalt Cement Cut-Back Asphalt Emulsified Asphalt	Physical Test	AASHTO Related Test	

3) Asphalt Concrete Design Tests. Asphalt Concrete Mixes should be subjected to mix design testing listed in Table 19.2-3 and others as required for the study of their properties.

TABLE 19.2-3 ASPHALT CONCRETE MIX DESIGN TESTS

Test Items	Test Method	Purpose	Notes
Marshall Stability Test	AASTHO T245	Mix design	To be conducted prior to commencement of work and prior to any change of material or mix design.

19.2.3 Mixing Plant

1) Preliminary Inspection of Plant Equipment. Preliminary inspection of plant equipment should be made regarding its make and performance features so as to confirm its capability of supplying to the material demand of the project both quantitatively and qualitatively.

2) Inspection of Plant Operation Conditions. All equipment should be properly examined to ensure that a consistent supply of mix will be obtained. Particular care should be taken to examine the condition of weighing devices which are the principle means for quality determination of the product mix.

   Regular inspections of equipment include the following:

   i) Periodical inspection. Conducted twice annually to examine the measuring performance of weighing devices, using standard loads.

   ii) Daily inspection. Conducted daily before beginning of operation, to visually discover any irregularity of the equipment.

19.2.4 Trial Paving

In large-scale projects, trial pavings are at times made after trial mixing and before actual paving operation. The purpose of a trial paving is to establish a standard work procedure using the same materials and equipment as in the actual construction, in order to achieve the required quality and shape of the pavement. Table 19.2-4 lists examples of achievements which can be obtained through a trial paving operation.

TABLE 19.2-4 EXAMPLES OF ATTAINABLE ACHIEVEMENTS THROUGH TRIAL PAVING OPERATION (ASPHALT CONCRETE)

1. Confirmation of the standard execution method

   a) Suitability of the paving machine
   b) Selection and combination of the compacting machines

2. Confirmation of properties of the job mix

   a) Grading of mix
   b) Asphalt content
   c) Workability, likelihood of material segregation material texture, etc.

3. Establishment of critical criteia for rejection of asphalt mix delivered at the field

4. Determining the required loose depth per unit compacted thickness

5. Determination of compacting conditions

   a) Temperature
   b) Rolling sequence
   c) Number of pass of rollers
   d) Rolling speed

19.3 QUALITY CONTROL AND INSPECTION FOR MEDIUM AND LARGE SCALE PROJECTS

This chapter deals with quality control and inspection for medium and large scale pavement construction projects of 10,000 m^2 or more targets and limits of allowable deviation for material quality and work done. Generally, minimizing of deviations from targeted material quality and work done will result in saving of materials and reducing of retouching operations, and it is therefore economically desirable.

In controlling the quality and work done, attention should be paid to the following fundamental points.

1) Throughout the process of procurement and storage, effort should be made to secure consistency of material. Work procedures should be standardized based on results of trial batch test and trial paving. A supervision system should be established to effectively implement material quality and work control.

2) Measurements should be made in the simplest and fastest possible way, such as using an automatic recording device attached to the weighing equipment on a continuous basis during the entire process of paving operation, in order to promptly discover the occurrence of any irregularity.

3) Methods of work should be modified when required based on results of routine inspection, tests and measurements.

For this purpose, it is essential to minimize errors in testing and measuring operations, and to promptly process and compile the obtained results.

Since all aspects of the workmanship of a pavement cannot be evaluated by test results, and also since local irregularities are difficult to discover through daily inspection, it is essential that field engineers should diligently and carefully inspect work performance in detail during their daily supervision activities.

19.3.1 Work Done Control

Work Done control of the pavement refers to geometrical properties of the finished pavement which aims at finishing the product with grades, widths, thickness and surface evenness complying with the requirements of contract plans and specifications.

Daily supervision is the most important since, if the work done deviates from the design requirements, it should require retouching which is costly.

Results of measurement taken during pavement construction should be promptly compiled and should always be reflected in the subsequent works.

Quality control tolerance used in works supervision are generally established taking inspection criterion and execution capability into consideration. Table 19.3-1 indicates the frequency of measurements and quality control tolerance used.

TABLE 19.3-1 FREQUENCY OF INSPECTION AND TOLERANCE FOR GEOMETRICAL PROPERTIES OF FINISHED PAVEMENT

Pavement Component	Quality	Frequency of Inspection	Tolerance
Subbase	Grade	every 20m	+4cm
	Thickness	every 20m	-4.5cm
	Width	every 40m	-5cm
Aggregate Base	Thickness	every 20m	-2.5cm
	Width	every 100m	-5cm
Cement Stabilized Base	Thickness	every 20m	-2.5cm
	Width	every 100m	-5cm
Surface	Thickness	every 1,000m	-0.7cm
	Width	every 100m	-2.5cm
	Evenness	throughout the length of every lane	2.4mm or less

1) Grade. Lateral profile levelling is generally done every 20m using finishing stakes. The locations of measurements in each operation include the center of carriageway and the edge of the shoulder.
2) Width. Measurement of the width in principle covers the full width of the pavement. Where divided by a median, the separated widths are individually measured.

TABLE 19.3-2 FREQUENCY OF QUALITY INSPECTION AND STANDARD QUALITY CONTROL CRITERIA

Pavement Component	Control Item	Method of Test or Control	Frequency of Inspection	Control Criteria Standard Case	Action Required when test Result is Unsatisfactory
Subbase	Water Content	AASHTO T255-77	Whenever irregularity is observed		Aeration or application of water
	Grading	AASHTO T27-78	-do-		Checking received shipment of material or modifying job mix formula
	PI	AASTHO T90-70	-do-		Changing material or stabilization by lime or cement
	Density	AASTHO T191	Every 1,000m^2		Additional rolling compaction or replacement of material
	Uniformity	Proof rolling	Any time		
Base	Water Content PI	AASTHO T255-77 T90-70	Whenever irregularity is observed		Aeration or application of water or changing material
	Grading	AASHTO T27-78	Every 1,000m^2	Percent passing sieve 2.5mm:±15% (0.074mm:-±6%)	Checking received shipment of material or modifying job mix formula
	Density	AASHTO T191	Every 1,000m^2	100% or more	Additional rolling compaction or replacement of material
Cement Stabilized Base	Grading	AASHTO T27-78		Percent passing sieve 2.5mm:±15% (0.074mm:-±6%)	Checking received shipment of material or modifying job mix formula
	Cement Content		1-2 times/day	(+1.2%)	Verification of quantity of admixture applied

(CONT.) TABLE 19.3-2 FREQUENCY OF QUALITY INSPECTION AND STANDARD QUALITY CONTROL CRITERIA

	Density	AASTHO T191	Every 1,000m^2	100% or more	Additional rolling compaction or replacement of material
	Water Content	AASTHO T255-77	Whenever irregularity is observed		Aeration, application of water or changing material
Surface courses (hot asphalt mix)	Temperature		Any time		Maintain the prescribed temperature
	Grading	Sampling & Sieve Analysis	1 to 2 times per day	Percent passing Sieve 2.5mm: ±12% 0.074mm: ±5%	Checking stocks of aggregates on yards or in cold feeders
	Asphalt Content	Sample tests	1 to 2 times per day	+0.9%	Checking asphalt and aggregate weighing equipment or conducting sample tests
	Density	Core tests	Every 1,000m^2	100% or more	(Work control should be based on core test data during early work execution, and then by regulating the material temperature and amount of compaction)
	Visual appearance		Any time		(Observed with particular attention paid to the appearance of material segregation and hair cracking)

3) Thickness. The thickness of an asphalt concrete surface course is checked by measuring sampled cores, and the thickness of other types of pavement components are interpolated by computing the difference between the top and the bottom levels.

4) Evenness. Measurement of the evenness is made along the center line throughout the length of every lane, using the method described in Appendix IV.

19.3.2 Quality Control

Quality control is conducted as shown in Table 19.3-2 by type of pavement component.

When used as a basis of work performance control, quality inspection of work results, such as density testing should be performed after every 1,000 m^2 of progress or 1 to 2 times every day. After reaching a steady and satisfactory performance level, control of work performance can be effected by regulating the number of passes of compaction equipment instead of operating based on quality tests results.

Where the asphalt plant is furnished with an automatic weight recorder, print-out data of the recorder can be used as the basis for controlling the grading and asphalt content.

The following is an example of the daily control method using a "Quality Control Chart".

(1) Preparing the "Quality Control Chart".

As in Fig. 19.3-1, code numbers of cores are shown on the abscissa and the quality index is scaled on the ordinate. Lines are drawn to show the design value and the upper and lower limits of tolerance. The data is then plotted on the chart.

(2) Interpreting the Chart.

Distribution of the data on the chart should be examined to see if any data goes out of the tolerance, if the data distribution is unsteady, if the range of dispersion is excessively wide, or if the data concentration is eccentric in relation to the design value. A positive answer to any of these question is a warning sign. The cause of it should be investigated and proper countermeasures should be taken.

To evaluate the test results, the mean value ($\bar{x}$) of the obtained data and the estimated standard deviation(Δ) are calculated, and if the following inequalities are satisfied, the result is considered satisfactory.

Estimated Standard Deviation

$$\bar{x} + 2\Delta < U$$
$$\bar{x} - 2\Delta > L$$

where:

x = mean value

Δ = estimated standard deviation
U = upper limit of tolerance, and
L = lower limit of tolerance.

If any data falls beyond the tolerance during the early stage of work, when the number of available data is still small, an evaluation of the situation using this method should be made, in which case the required number of about 10 data should be produced quickly by provisionally increasing the frequency of testing.

(3) Example.

For a surface course asphalt mix having a 6% design asphalt content, the upper and the lower limits of tolerance according to Table 19.3-2 are as follows :

Upper limit of tolerance (U)=6.0+0.9=6.9%
Lower limit of tolerance (L)=6.0-0.9=5.1%

The sample test result turns out to be 4.9% in the second day morning after beginning of work when test are conducted at the frequency indicated in Table 19..3-2. In order to confirm whether this test results means the existence of a problem, the frequency of testing during the third day is increased to 6 times to produce a total of 10 data as shown in the following table. (Note: Normally when 5 successive points in the chart are located on one side of the central line between the limits of tolerance, the work process should be investigated.)

Date(Example)	Oct.5		Oct.6		Oct.7					
Daily Sample No.	1	2	1	2	1	2	3	4	5	6
Asphalt Content(%)	6.1	5.4	4.9	5.8	5.1	5.7	5.9	5.3	5.9	5.1

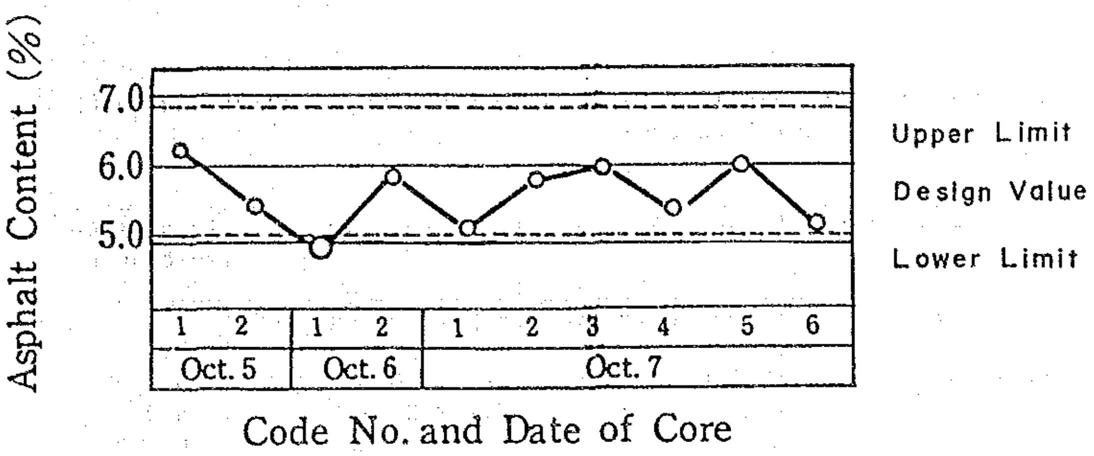


FIGURE 19.3-1 QUALITY CONTROL CHART

In the above case, the mean value x is 5.52% and the estimated standard deviation of the individual test value is as follows :

$$\Delta = \sqrt{\frac{(5.52-6.1)^2 + (5.52-5.4)^2 + (5.52-4.9)^2 + \ldots + (5.52-5.1)^2}{10-1}}$$

$$= 0.41$$

$$\bar{X} - 2 = 5.52 - 2 \times 0.41 = 4.70 < 5.1 \text{ (L)}$$

The result indicates that the work is not satisfactory according to requirements. This is due to the eccentric distribution of the data in relation to the design value. The required countermeasure in this case is to increase the asphalt content by about 0.5% to render it close to 6%.

19.4 QUALITY CONTROL AND INSPECTION FOR SMALL SIZE PROJECTS

19.4.1 Preliminary Inspection and Tests

It is necessary to conduct materials test prior to the construction. However, other preliminary inspection and testing may be substituted by examining of valid reports of inspection and tests conducted in the past, where such is available.

19.4.2 Quality Control and Inspection

The standard values for quality control are shown in Table 19.4-1. The number of items to be inspected is smaller and the tolerance limits are slightly looser than those of the pavement for medium to large size projects.

TABLE 19.4-1 QUALITY CONTROL STANDARDS FOR PAVEMENT FOR SMALL SIZE PROJECTS

Pavement Course		Control Item	Frequency	Inspection Tolerance
Subgrade		Proof rolling	Any time required	
Subbase		Height	Every 20 m	±5.0 cm
		Thickness	Every 20 m	-5.0 cm
		Width	Every 20 m	-10.0 cm
		Moisture Content	Any time required	-
		Grading	Any time required	-
		Proof rolling	Entire Surface	-
Base	Aggregate Base	Thickness	Every 20 m	-3.0 cm
		Width	Every 20 m	-5.0 cm
		Water Content	Any time required	±15.0%
		Grading 2.36mm 75 mm	1-2 times/1,000m^2 or any time required	±6.0%
		Degree of Compaction	Every 1,000 m^2 any time required	93.0%
	Cement Stabilized Base	Thickness	Every 20 m	-3.0 cm
		Width	Every 20 m	-5.0 cm
		Grading 2.36 mm	1-2 times/1000 m^2 or anytime required	±15.0% ±6.0%
		Cement Content	Any time required	-
		Degree of Compaction	Every 1,000 m^2 any time required	93.0%
Surface	Asphalt Concrete	Thickness	Every 20 m	-0.9 cm
		Width	Every 20 m	-3.0 cm
		Temperature	Any time required	-
		Grading 2.36 mm 75 mm (Hot bin)	1-2 times/day or any time required	±12.0% ± 4.5%
		Asphalt Content	1-2 times/day or any time required	±1.5%
		Degree of Compaction	Every 1,000m or any time required	100%
	Other Asphalt Surface	Thickness	Every 20 m	-
		Amount of Material	Any time required	-
		Proof rolling	Entire surface	-

TABLE 19.4-2 CRITERIA FOR JUDGMENT OF WORKMANSHIP FOR PAVEMENT FOR SMALL SIZE PROJECTS (cm)

Pavement Course		Inspection Item	Individual Measurement	Average of 10 Measurements (x10)
Subgrade		Height	±5.0	-
		Width	-5.0	-
		Thickness	-4.5	-2.0
Base	Crushed Aggregate Base	Width	-5.0	-
		Thickness	-2.0	-0.8
		Width	-5.0	-
		Thickness	-3.0	-1.2
	Cement Stabilized Base	Width	-5.0	-
		Thickness	-3.0	-1.2
	Lime Stabilized Base	Width	-5.0	-
		Thickness	-3.0	-1.2
Surface		Width	-2.5	-
		Thickness	-0.9	-0.3