ENGINEERING AND CONSTRUCTION STANDARD

FOR

ROAD SURFACING AND PAVEMENTS

CONTENTS :

PAGE No.

1. SCOPE

This Standard deals with different aspects of design and construction principles and data a criteria for the design of pavement of roads, streets, parking areas, sidewalks for the Iranian Petroleum Industries' projects and presents criteria for the same.

This Standard is written in general terms and its application to any particular project may be subject to the special requirements of the work under consideration. Generally it should be in accordance with regulations of Ministry of Roads and Transportation.

2. REFERENCES

In this Standard the following standards and codes are referred to and to the extent specified form a part of this Standard.

2.1 National and International Standards

AASHO (AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS)

a) "Standard Specification for Materials for Aggregate and Soil-Aggregate Subbase Base and Surface Course" (M 147-65)

b) "Interim Guide for Design of Pavement Structures", 1972

PBO (PLAN AND BUDGET ORGANIZATION)

c) "General Technical Specification for Road No. 101"

AI (THE ASPHALT INSTITUTE)

d) Manual MS-13 "Asphalt Surface Treatment", 1965

e) Manual MS-1 "Thickness Design", 1962

f) Specification Series (S.S.1) "Specifications and Construction Methods for Hot-Mix Asphalt Paving for Streets and Highways", 1962

g) Specification Series, (S.S.3) "Specifications and Construction Methods for Asphalt Curbs and Gutters", 1966

IPS (IRANIAN PETROLEUM STANDARDS)

h) E-CE-110 "Soil Engineering"

i) C-CE-112 "Earthworks"

3. UNITS

This Standard is based on International System of Units (SI), except where otherwise specified.

4. SOIL AND SUBGRADE INVESTIGATIONS

This Clause includes the following factors which have vital importance in the design of highways:

a) test pits, including spacing requirements;
b) test borings at cut sections, shallow and high fill sections;
c) auger holes, including spacing requirements;
d) soundings and probings;
e) ground water observations;
f) sub-surface explorations, records and reports.

The above factors are discussed in API-E-CE-110 "Soil Engineering" and API-C-CE-112 "Earthworks" Standards.

4.1 Soil Classification and Subgrade Testing

4.1.1 Unified classification system

The Unified Soil Classification System shall be used to classify all soils utilized in road design and construction.

4.1.2 Detailed criteria

For detailed soil classification criteria reference is made to IPS-E-CE-110 "Soil Engineering" and IPS-C-CE-112 "Earthworks".

4.1.3 Modifications for roads

For additional behavior characteristics pertinent to roads see Table 1.

Modifications are discussed below:

a) Base materials

In Column 3, basic soil group GM and SM have been subdivided into two groups, d and u which represent desirable and undesirable base materials.

The d denotes a liquid limit of 25 or less and a plasticity index of 6 or less; u represents liquid limits greater than 25 or plasticity indexes greater than 6.

b) Frost actions

The potential frost actions of various soil groups are shown in Column 10. Inorganic soils containing less than 3 percent (by weight) of grains finer than 0.02 mm in diameter usually are not frost susceptible.

TABLE 1 - SOIL CLASSIFICATION PERTINENT TO ROADS

MAJOR DIVISIONS (1)	(2)	SYMBOL LETTER (3)	MATCHING (4)	COLOR (5)	NAME (6)	VALUE AS SUBGRADE WHEN NOT SUBJECT TO FROST ACTION (7)	VALUE AS SUBBASE WHEN NOT SUBJECT TO FROST ACTION (8)	VALUE AS BASE WHEN NOT SUBJECT TO FROST ACTION (9)	P
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW		RED	WELL GRADE GRAVELS OR GRAVELD-SAND MIXTURES, LITTLE OR NO FINES	EXCELLENT	EXCELLENT	GOOD	NONE TO V
		GP			POORLY GRADED GRAVELS OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GOOD TO EXCELLENT	GOOD	FAIR TO GOOD	NONE TO V
		GM d		YELLOW	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	GOOD TO EXCELLENT	GOOD	FAIR TO GOOD	SLIGHT TO
		GM u				GOOD	FAIR	POOR TO NOT SUITABLE	SLIGHT TO
		GC			CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES	GOOD	FAIR	POOR TO NOT SUITABLE	SLIGHT TO
	SAND AND SANDY SOILS	SW		RED	WELL GRADED SANDS OR GRAVELLY SANDS, LITTLE OR NO FINES	GOOD	FAIR TO GOOD	POOR	NONE TO V
		SP			POORLY GRADED SANDS OR GRAVELLY SANDS, LITTLE OR NO FINES	FAIR TO GOOD	FAIR	POOR TO NOT SUITABLE	NONE TO V
		SM d		YELLOW	SILTY SANDS, SAND-SILT MIXTURES	FAIR TO GOOD	FAIR TO GOOD	POOR	SLIGHT TO
		SM u				FAIR	POOR TO FAIR	NOT SUITABLE	SLIGHT TO
		SC			CLAYEY SANDS, SAND-CLAY MIXTURES	POOR TO FAIR	POOR	NOT SUITABLE	SLIGHT TO
FINE GRAINED SOILS	SILTS AND CLAYS LL IS LESS THAN 50	ML		GREEN	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY	POOR TO FAIR	NOT SUITABLE	NOT SUITABLE	MEDIUM TO
		CL			INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS	POOR TO FAIR	NOT SUITABLE	NOT SUITABLE	MEDIUM TO
		OL			ORGANIC SILTS AND ORGANIC SILT-CLAYS OF LOW PLASTICITY	POOR	NOT SUITABLE	NOT SUITABLE	MEDIUM TO
	SILTS AND CLAYS LL IS GREATER THAN 50	MH		BLUE	INORGANIC SILTS MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS	POOR	NOT SUITABLE	NOT SUITABLE	MEDIUM TO
		CH			INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	POOR TO FAIR	NOT SUITABLE	NOT SUITABLE	MEDIUM
		OH			ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS	POOR TO VERY POOR	NOT SUITABLE	NOT SUITABLE	MEDIUM
HIGHLY ORGANIC SOILS		Pt		ORANGE	PEAT AND OTHER HIGHLY ORGANIC SOILS	NOT SUITABLE	NOT SUITABLE	NOT SUITABLE	SLIGHT

Notes:

1) Column 3 division of GM and SM groups into subdivision of d and u are for roads only. Subdivision is on basis of Atterberg limits: suffix d (e.g.,GMd) will be used when the liquid limit is 25 or less and the plasticity index is 6 or less; the suffix u will be used otherwise.

2) Column 14, unit dry weights are for compacted soil at optimum moisture content for modified AASHTO compaction effort.

4.2 Subgrades

The properties of soils have been discussed in IPS-E-CE-110 "Soil Engineering". It has been shown that soil strength is a function of soil type, moisture content, and density; which are interrelated factors.

The design of subgrades involves a thorough study of the strengths of soil and the establishment of density and moisture-content requirements to be specified for construction.

4.2.1 Types of subgrades

The thickness design of a flexible pavement depends to a large extent upon the type of subgrade. Soils which contain large quantities of mica or organic material are elastic and subject to rebound upon removal of load.

Subgrades on these soils should be avoided as far as possible, but if pavements must be constructed upon them, it is necessary to increase compaction requirements to achieve high densities.

Soft, organic and other unsuitable subgrades must be removed for their entire depth or special provision should be made to consolidate them.

Frost-susceptible soils in cold climates should always be given special consideration. Isolated pockets of frost-heaving silt may be removed in some cases to permit the use of the standard-design cross section.

If potentially shrinking or swelling soils are anticipated, these soils should be compacted at moisture contents and to densities that show the best compromise between swelling on saturation and settlement under load.

4.2.2 Subgrade drainage

Water-Bearing strata should be intercepted some distance away from the roadway section. Ditches should be constructed to such a depth as to ensure that free water in the ditch will always be below base-course level.

In dealing with the problems of subgrade drainage, due consideration should be given to both ground-water and surface infiltration.

4.3 Construction

The effectiveness of subgrade and base-course design is dependent upon adequacy of construction. Field inspection is particularly important to make certain that the design assumptions are carried out.

4.3.1 Design tests

Design tests made for determination of the type and thickness of pavement are based either upon strength tests made in the laboratory or on field tests made during construction

Frequent density tests must be made during construction to ascertain that the design compaction criteria are met. Preparation of the subgrade to receive the base or subbase courses should be given special attention. All soft spots should be removed and replaced with suitable compacted material.

5. SELECTION FACTORS FOR PAVEMENTS

5.1 Loading

Pavements shall be proportioned for the loads in accordance with Appendix to Technical Instruction No. 11 of Ministry of Road and Transportation.

5.2 Climatic Factors

Climatic factors have an important effect upon the bearing capacity of subgrade and base course-subgrade combinations. Desert conditions, varying temperature and rainfall zones, and frost actions are all major factors that can affect flexible-pavement design.

6. TYPES OF PAVEMENTS

Pavements can be classified into two groups, i.e. flexible and rigid.

6.1 Flexible Pavements (Subbase, Base, Binder, And Surface Courses)

Flexible pavement is made up of a series of layers, with the highest-quality materials at or near the surface. Subbases are generally composed of inexpensive, locally available materials, while the base courses contain high-quality processed materials. In most cases the base course consists of crushed stone or gravel.

For typical road cross-section see Fig. 1.

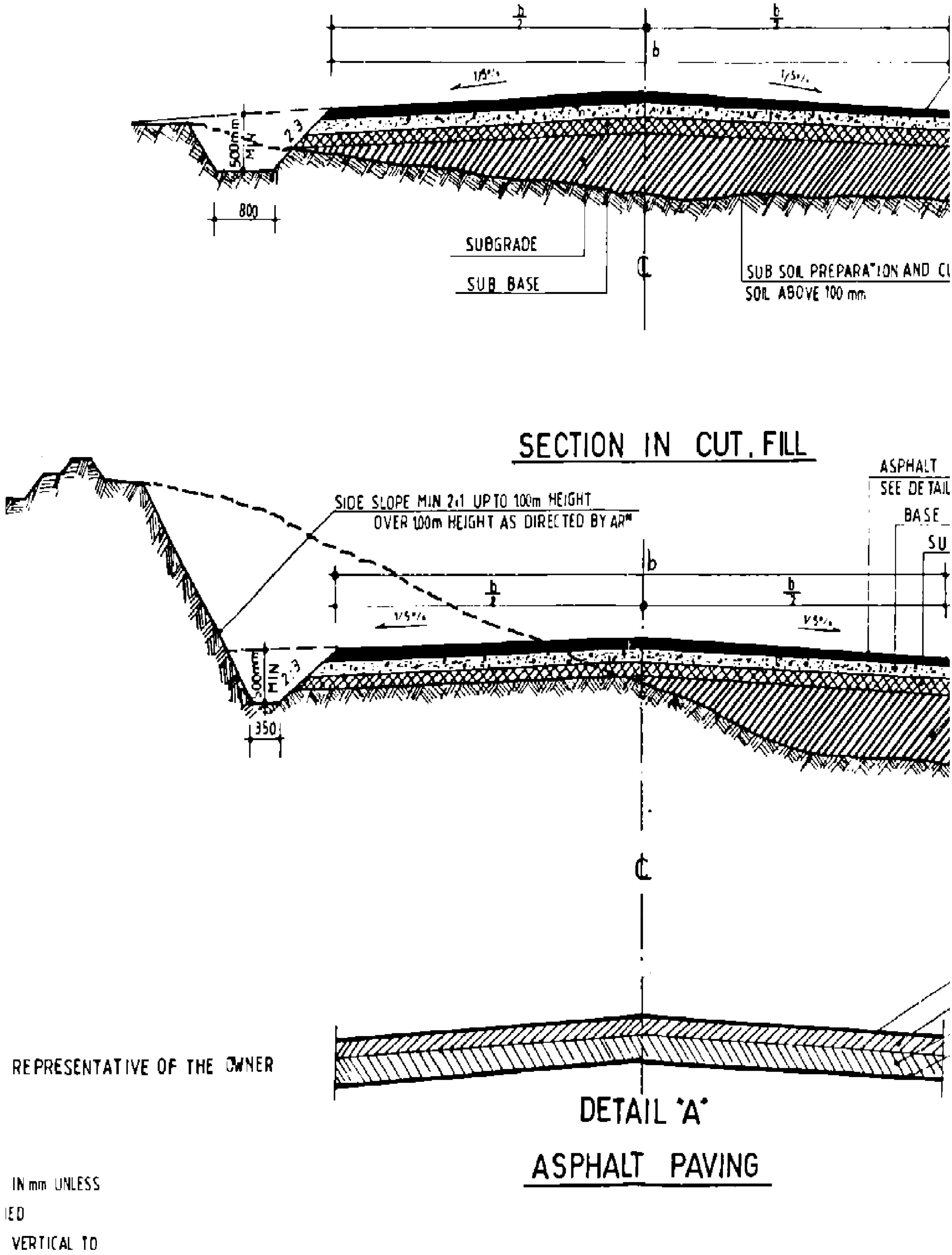
6.1.1 Subbase course

Soil-Aggregate mixtures shall consist of natural material having essentially the same quality of angularity or surface irregularities as broken stone and conforming to specified quality and requirements when combined within the required grading limits.

The combined mineral aggregate shall be of such size that the percentage composition by weight, as determined by method given in AASHTO designation T27, will conform to one of the gradings specified in Table 2, unless otherwise specified in the special provisions.

TABLE 2 - GRADING REQUIREMENTS FOR SUBBASE

PERCENT BY WEIGHT PASSING SQUARE MESH SIEVES						
SIEVE GRADING DESIGNATION	GRADING A	GRADING B	GRADING C	GRADING D	GRADING E	GRADING F
(50 mm)	100	100				
(25 mm)		75-95	100	100	100	100
(9.5 mm)	30-65	40-75	50-85	60-100		
No. 4 (4.75 mm)	25-55	30-60	35-65	50-85	55-100	70-100
No. 10 (2.00 mm)	15-40	20-45	25-50	40-70	40-100	55-100
No. 40 (0.425 mm)	8-20	15-30	15-30	25-45	20-50	30-70
No. 200(0.075 mm)	2-8	5-20	5-15	10-25	6-20	8-25



TYPICAL ROAD CROSS SECTION
Fig. 1

Notes:

1) Coarse aggregate shall have a percentage of wear by the Los Angeles test AASHTO T 96 of not more than 50 percent.

2) Fraction passing No .200 sieve shall not be greater than two-thirds of fraction passing No. 40 sieve.

3) Fraction passing No. 40 sieve shall have liquid limit not greater than 25 percent and a plasticity not greater than 6 percent.

6.1.1.1 Spreading and compacting

The subbase material shall be spread upon the prepared subgrade by means of vehicles equipped with approved spreading devices.

Segregation of large or fine particles of aggregate shall be avoided and the material as spread shall be free from pockets of large or fine materials. Segregated materials shall be remixed until uniform.

Deposing and spreading shall commence at that part of the work farthest from the point of loading and shall progress continuous with breaks.

Where the required thickness is 150 mm or less, the subbase material shall be spread and compacted in one layer.

Where the required thickness is more than 150 mm; the subbase material shall be spread and compacted in two or more layers of approximately equal thickness. The maximum compacted thickness of any one layer not exceeding 150 mm; each layer to be spread and compacted in a similar manner.

The subbase material, after spreading as specified above, shall be shaped by means of a blade grader to such thickness that after watering and compacting, the completed subbase will conform to the required grade and cross-section.

The subbase shall then be watered as directed by the AR* and compacted by smooth wheel roller weighing not less than 12 tons or with pneumatic-tired rollers.

Rolling shall commence at the outside of the subbase material and progress toward the center of road bed. Under no circumstances shall the center of the subbase material be rolled first.

The finished subbase, where not controlled by adjacent structure or features, may vary not to exceed 30 mm above or below the planned grade, providing it is uniform and free from sharp breaks. The cross-section of the finished subbase shall be free from ridges or valleys and be within 1.5 mm above or below the theoretical section at any point of the cross-section.

Finished subbase that does not conform to the above requirements shall be bladed, watered and thoroughly recompacted to conform to the above requirements.

6.1.2 Base course

Base course shall consist of mineral plant crushed aggregate, spread and compacted on a prepared subbase in conformity with the lines, grades and dimensions shown on the plans or typical cross-sections.

The mineral aggregates shall be free from vegetable matter and other deleterious substances and shall be of such character that it can be compacted readily under watering and rolling to form a firm and stable base.

The combined mineral aggregate shall be of such size that the percentage composition by weight, as determined by laboratory sieves, will conform to one of the gradings specified in Table 3.

***AR - Authorized Representative of Owner.**

TABLE 3 - GRADING REQUIREMENTS FOR BASE COURSE GRANULAR AGGREGATES

PERCENT BY WEIGHT PASSING SQUARE MESH SIEVES								
SIEVE DESIGNATION	GRADING A	GRADING B	GRADING C	GRADING D	GRADING E	GRADING F	GRADING G	GRADING H
50 mm	100	100	—	—	—	—	—	—
37.5 mm	—	70-100	100	100	—	—	—	—
25 mm	—	55-85	—	70-100	100	100	—	—
19 mm	—	50-80	—	60-90	—	70-100	100	100
9.5 mm	—	40-70	—	45-75	—	50-80	—	—
4.75 mm (No. 4)	20–50	30-60	25-55	30-60	30-65	35-65	35-65	45-80
2 mm (No. 10)	—	20-50	—	20-50	—	20-50	—	30-60
0.42 mm (No. 40)	—	10-20	—	10-30	—	15-30	—	20-35
0.075 mm (No. 200)	0–10	5-15	0-10	5-15	0-10	5-15	0-10	5-15

When combined within the specified grading limits, the mineral aggregate shall conform to the following quality requirements:

Liquid limit	(AASHTO T89, T90, T91)	25% Max.
Plastic Index	(AASHTO T89, T90, T91)	6% Max.
Sand Equivalent	(AASHTO T176)	25% Min.
Abrasion of coarse aggregate by Los Angeles Machine	(AASHTO T96)	45% Max.
Soundness of Aggregate; Sodium Sulfate	(AASHTO T104)	12% Max.
CBR test on Compacted Samples	(AASHTO T180)	80% Min.
Grain Size Sieve Analysis	(AASHTO T27)	

When the mineral aggregate does not contain sufficient natural cementing material to be compacted readily under watering and rolling, a binder material consisting of rock screenings or disintegrated granite, or other cementaceous material approved by the AR shall be added to and incorporated in it.

Binder material shall be uniformly graded from coarse to fine, out of which from 90 percent to 100 percent shall pass a No. 4 laboratory sieve.

When the mineral aggregate is produced by crushing and screening, the binder material shall be added to the producing plant by means of a manually operated gate or a mechanical feeder, and spreading the binder material, if required, shall be incorporated with the aggregate by a method, approved by the AR, that will uniformly distribute throughout the aggregate.

When binder material is added to the mineral aggregate the combination shall conform to all of the quality and grading requirements specified for the aggregate.

6.1.2.1 General properties of granular bases

6.1.2.2 Density and gradation

The stability of a granular base course depends upon particle-size distribution, particle shape, relative density, internal friction, and conhesion.

Internal friction and subsequent shearing resistance depend to a large extent upon density, particle shape, and grain-size distribution, the latter being the most important.

6.1.2.3 Base course drainage in cold regions

The main factors of drainability are dimension and slope. In some areas, natural deposits of granular material are drainable, but in others it in necessary to use prepared crushed materials. In all cases adequate drainage should be provided for the base course to prevent subgrade saturation and pavement breakup due to freezing and thawing in cold regions. Generally, a base course is not likely to become saturated if the subgrade is relatively pervious.

6.1.2.4 Low-Cost road

For small amounts of traffic, unsurfaced gravel or stone roads give satisfactory performance. The design of such roads is essentially the same as that of bases and subbases, with several exceptions. The primary consideration should be stability.

The quality of fines required to adequately stabilize a granular material is one in which the voids are filled with a soil.

Whenever untreated surface are used, sufficient binder must be provided to add cohesion to the mix.

However the base must not have a plasticity index higher than 8 to 12, or loss of stability will result. The liquid limit should be less than 25 percent to satisfy stability requirements.

6.1.3 Binder course

From the pavement surface downward the second course is usually called the binder course.

6.1.3.1 Aggregates

Aggregates for binder courses may differ from those in the surface course as follows:

- **a)** coarse aggregate may contain a smaller percentage of crushed pieces, and
- **b)** percentage of wear may be slightly higher.

Therefore high stability is the important characteristic of the binder course. The void content can be somewhat higher than in the surface course, and less mineral filter is required.

6.1.4 Surface course

6.1.4.1 Properties and functions

The surface course of a flexible pavement structure must have the following characteristics and perform the following functions:

- **1)** provide a smooth, quiet surface for traffic;
- **2)** be resistant to wear of traffic;
- **3)** be highly stable to resist any surface deformation;
- **4)** have a high coefficient of friction;
- **5)** be of sufficient density to be waterproof to retard weathering.

6.1.4.2 Stability

The asphalt and aggregate used develop stability. Stability of asphalt mixes is closely related to density and compressibility of the mix. Compressibility is a function of:

a) amount and viscosity of asphalt,
b) gradation of aggregate, and
c) characteristics of the aggregate.

6.1.4.3 Asphalt-Aggregate mixture

The job mix formula for the surface course shall be within the limits for dense mixtures as indicated in Table 3 of ASTM D 3515.

The asphalt aggregate mixture shall be prepared and tested in accordance with ASTM D 1559 and meet the following criteria:

Stability		2.3 KN min. (500 lbs)
Flow value measured in 0.25 mm graduations	:	between 8-20
Voids in total filled, %		
surface/wearing course	:	3-5
binder course	:	3-11
Aggregate voids filled, %		
surface/wearing course	:	65-85
binder course	:	65-75
Compaction, Number of blows at each end test specimen	:	35

A mix specified by a local agency will be considered if it has been shown to have a satisfactory history of performance.

6.1.4.4 Voids

Stability of the compacted aggregate is generally increased as void content is decreased and aggregate density approaches that of a solid. Compacted paving mixes (aggregate plus asphalt) having low void content are more durable than mixes having high void content. On the other hand, a paving mix must contain a certain minimum amount of voids to provide a reservoir for expansion of the asphalt during hot weather and the slight amount of additional compaction under traffic, thereby preventing possibility of flushing.

6.1.4.5 Surface coefficient of friction

A satisfactory coefficient of friction can be obtained for asphaltic concrete through the following controls:

1) The aggregate must be hard and tough with high resistance to wear or degradation.
2) The mix must have sufficient voids to take up expansion of the asphalt in hot weather and prevent flushing.

6.1.4.6 Design of surface-course mix

A wide range of aggregate gradations and penetration grades of asphalt are used to produce economical, heavy duty pavements. Methods and criteria for the design of asphalt mixes are covered in Asphalt Institute's Manual MS-13 "Asphalt Surface Treatment" and "Specifications and Construction Methods for Hot-Mix Asphalt Paving for Streets and Highways" of the Asphalt Institute, Specification Series No. 1. Aggregate gradations are specified in AASHTO's "Interin Guide for Design of Pavement Structures, 1972.

Surface-course asphaltic concrete is usually prepared by plant mixing of heated aggregates, mineral filler, and asphalt cement. Plant mixing of cold aggregates and specially formulated asphalt also give satisfactory performance, and also by mixing the composition in place with liquid asphalts or asphalt emulsions.

Construction specifications usually require that before a surface course is placed, liquid bituminous material be applied on untreated aggregate base courses as a prime coat, and on treated base courses and between layers of the surface course as a tack coat.

6.1.5 Thickness

The minimum total thickness requirements for surface, binder and base courses, shall be in accordance with Table 4.

TABLE 4 - MINIMUM THICKNESS REQUIREMENTS FOR SURFACE, BINDER, AND BASE COURSES

MINIMUM THICKNESS IN mm					
Traffic classification	Total asphalt surface and binder course	Asphalt base course	Total thickness using asphalt base	Non-asphalt base course	Total thickness using nonasphalt base
Very heavy	100	75	175	150	250
Heavy	75	65	140	125	200
Medium	75	40	115	75	150
light	50	40	90	75	125

In practice the following thicknesses are used for surface and binder courses:

TRAFFIC CLASSIFICATION	BINDER COURSE THICKNESS (mm)	SURFACE COURSE THICKNESS (mm)
Very heavy	60	40
Heavy	45	30
Medium	45	30

On the basis of the data established above, the traffic should be classified in accordance with Table 5.

TABLE 5 - CLASSIFICATION TRAFFIC

TRAFFIC CLASSIFICATION	TRAFFIC DENSITY MAXIMUM, PER LANE, PER DAY	
	DAILY VOLUME OF PASSENGER CARS AND LIGHT TRUCKS	DAILY VOLUME OF COMMERCIAL TRUCKS AND BUSES
Light	25	5
Medium	500	25
Heavy	Unlimited	250
Very heavy	Unlimited	Unlimited

6.1.6 Paving grade asphalts

All asphalt used in Iran is produced from petroleum. Such asphalt is produced in verity of types and grades. Paving asphalts are thermoplastic, which means that their consistency of fluidity is affected by changes in temperature. They are ductile and tacky and adhere well to most aggregates. In various grades of paving asphalts are classified by penetration; The higher the penetration values the softer the asphalt. The specifications include five grades based on penetration values at a temperature of 25°C. These are 40-50, 60-70, 85-100, 120-150 and 200-300.

Normally, paving grade asphalts are used for high type pavements involving heavy traffic. In most instances either the 85-100 or 60-70 grades are used for asphalt concrete in Iran.

6.1.6.1 Grades

Paving asphalts classified by penetration are tested in accordance with standard method of tests of the AASHTO. The grades of asphalts shall conform to the requirements set forth in Table 6.

TABLE 6 - CLASSIFICATION OF ASPHALTS

SPECIFICATION DESIGNATION	AASHTO TEST METHOD	GRADE				
		40-50	60-70	85-100	120-150	200-300
Flash point P.M.C.T. °F., Min.——	T73	460	450	440	425	400
Penetration of original sample at 77°F.————	T49	40-50	60-70	85-100	120-150	200-300
Loss on heating, 5 hrs. at 325°F., % Max. (alternate method may be test method No. calif. 346)————	T179	0.75	0.80	0.85	1.00	1.50
Pen. after loss at 325°F.,% of orig. pen., Min.———	T49	52	50	47	44	40
Ductility at 77 °F., cm. after loss at 325°F. Min.	T51	50	50	75	75	75
Penetration ratio $\frac{\text{pen. 39.2°F. - 200 gm. -1 Min.}}{\text{pen. 77°F. - 100 gm. - 5 secs.}} \times 100$	T49	25 Min.	25 Min.	25 Min.	25 Min.	25 Min.
Furol viscosity at 275°F.———	T72	120-430	100-325	85-260	70-210	50-150
Solubility in trichloro-ethylene. % Min.———	T44	99	99	99	99	99
Heptane xylene equiv., % Max.[1]————	T102	35	35	35	35	35

1) Normal spot test and glass plate test repeated at end of 24-hour period will not be required.

Recommended guide for selection of asphalt, is shown in Table 7.

TABLE 7 - ASPHALT TYPE SELECTION

TRAFFIC CLASSIFICATION	CLIMATE CONDITION			
	HOT & DRY	HOT & HUMID	MODERATE	COLD
Roads:				
Heavy & very heavy	60 - 70	60 - 70	60 - 70	85 - 100
Light & medium	85 - 100	85 - 100	85 - 100	120 - 150
Streets:				
Heavy & very heavy	60 - 70	60 - 70	60 - 70	85 - 100
Light & medium	85 - 100	85 - 100	85 - 100	85 - 100

6.2 Rigid Pavements

A rigid pavement is designed primarily on the basis of its resistance to bending, and essentially, Portland cement concrete is the sole type of pavement in this category.

The application of mechanics to concrete-pavement design requires a knowledge of the behavior of the pavement, among which are included subgrade soils, subbase materials, concrete aggregates, cement, reinforcing steel, dowel and tie bars, etc. Likewise the external forces which act on the pavement must be thoroughly considered. As this type of pavement has very limited use in the Oil Industries' roads, therefore only reference is made to relevant publications of important organizations, i.e. AASHTO, etc. stated in Clause 2 of this Standard.

7. PAVING APPURTENANCES

In modern street and road building the following appurtenances should be considered:

7.1 Shoulders (Asphalt Paved or Treated)

Design of shoulders depends upon volume and intensity of traffic. A secondary road may require simply wellconsolidated granular material for such width that only at intervals it is required to have ample room to drive completely off the pavement, as at mail boxes or public telephone boots. Asphalt treatment depends largely upon the rate of erosion of the untreated materials.

On highways, however, it is essential that shoulders be continuously of ample width to accommodate the largest vehicles and strong enough to support these loads without deformation.

Generally the same material used in the subbase, base, or even the surface of the pavement is completely carried across the shoulder to the ditch slope during original construction, in order to permit uniform consolidation from ditch to ditch and eliminate possible settlement at pavement edge.

7.2 Curbs and Gutters

Curbs and gutters are standard on all city streets. The chief functions of a curb are to control drainage and deter vehicles from leaving the roadway. Items of particular importance in constructing asphalt curbs are the asphalt content, placement temperature, mix gradation, and adequate compaction, as discussed in Asphalt Institute's "Specifications and Construction Methods for Asphalt curbs and Gutters", Information Series, No. 92.

7.3 Ditches

Ditches occur parallel to the rural highway at the foot of the outer embankment. Such ditches should be sufficiently wide and so shaped that the heaviest rainfall is carried away smoothly and without overflowing.

The type of paving will depend upon gradient and type of soil. In areas of very erodible soils careful design is of great importance. In general, hot mixtures are best for the purpose, although penetration macadam has been used successfully. High asphalt content is necessary to ensure durability and water-proofness.

7.4 Slope Paving

Slope paving has two forms:

1) The face of a cut slope, at some distance above the ditch to prevent under cutting and consequent slides, and;
2) The embankment slope

Actually, the first is merely an extension of the outer side of the ditch itself, although it may be of different thickness.

The essential item, in addition to dense composition, is firm anchorage to prevent intrusion of water under the top edge. Sometimes weepholes should be provided to relieve hydrostatic pressure.

Embankment paving is employed only where it is not practical to develop vegetation and where erosion is a serious matter. In latter case the same design principles apply as for cut-slope paving.