Chapter 3
Design Considerations

FUNDAMENTALS OF DESIGN

Many types of asphalt pavement structures exist, along with a number of different methods for designing the thickness of each element in any pavement. Fundamental to each design are the following:

1. Traffic loading (volume and weight)
2. Soil-support capability (including drainage considerations)
3. Material specifications (aggregate and asphalt)

Each element is an important variable in the structural design process. The economic life of the final product could depend on the close attention given to detail when analyzing traffic loadings, soil-support capability, and material specifications.

The degree of detail needed in a specific design situation is related to the type of use intended for the pavement and the sensitivity of each variable. For example, a freeway design with large traffic volumes and heavily-loaded trucks requires a careful estimate of traffic; however, the number of bicycles and the loading on a bicycle path would not be significant factors in the path's structural design.

An obviously unstable soil condition (noted, perhaps, from previous experiences) indicates the need for a soil analysis during the thickness design process of almost any type of pavement. Because drainage and soil-support values are major factors in pavement life, it is important to know the quality of the supporting soil. This is especially true for a facility that will require a large construction investment.

On the other hand, a specific traffic study or soil analysis for a residential street or parking lot may not be deemed necessary in a certain location. For example, a location having a long and successful record of asphalt pavements constructed for a specific use (e.g., driveways and residential streets) provides the designer with a background for selecting acceptable values.

For the users of this Design Guide, much of the design work has been done – design charts are presented for selecting pavement thickness. Traditionally, many designers group pavements according to use and "use tables" are commonly applied throughout the United States. Chapter 4 provides design tables by specific type of facility use.

TRAFFIC

Because the primary function of a pavement is to transmit and distribute wheel loads of vehicles to the supporting subgrade, information about the traffic stream is required. Pavement must be designed to serve traffic needs over a period of years. Therefore, the volume of traffic and the various types of vehicles using the facility must be estimated for the pavement's anticipated life.

A traffic assignment is made based on: (1) historic records of traffic volumes on comparable types of highways and the anticipated function of the highway under consideration, and (2) the percentage of trucks. The traffic analysis procedure determines the repetitions of an equivalent single axle load (ESAL). This parameter is defined as the equivalent number of applications of an 18,000-pound, single-axle load during the pavement's design life.

The effects of truck traffic on a pavement can be dramatic. Tests have shown that a single-unit, fully loaded, 80,000-pound truck can cause pavement damage equivalent to that caused by 6,000 automobiles. This illustrates why carefully made estimates of expected traffic are critical to proper pavement design.

In The Asphalt Institute's Asphalt Pavement Thickness Design (IS-181), traffic is separated into classes. This Design Guide follows the Institute's traffic class style by breaking traffic into six classes, I through VI. Each class is defined by an average daily traffic range, the average number of heavy trucks expected on the pavement during the design period, and the appropriate type of street or highway.

TRAFFIC CLASSIFICATIONS

Class I
(Very Light) Less than 50 autos per day, less than 7,000 heavy trucks expected during design period.
- Parking lots, driveways
- Light traffic farm roads
- School areas and playgrounds
- Seasonal recreational roads
- Sidewalks and bicycle paths
- Golf cart paths
- Tennis courts

Class II
(Light) Up to 200 autos per day, 7,000 to 15,000 trucks expected during the design period.
- Residential streets
- Rural farm roads
- Parking lots of less than 500 stalls
- Airports - 7,500 pound maximum gross weight

Class III
(Medium) Up to 700 autos per day, 70,000 to 150,000 trucks expected during design period.
- Urban minor collector streets
- Rural minor collector streets
- Parking lots - more than 500 stalls
- Airports - 15,000 pound maximum gross weight.

Class IV

(Medium) Up to 4,500 autos per day, 700,000 to 1,500,000 trucks expected during design period.

- Urban minor arterial and light industrial streets
- Rural major collector and minor arterial highways
- Industrial lots, truck stalls
- Bus driveways and loading zones
- Airports - 30,000 pound maximum gross weight.

Class V

(Heavy) Up to 9,500 autos per day, 2,000,000 to 4,500,000 trucks expected during design period.

- Urban freeways, expressways and other principal arterial highways
- Rural interstate and other principal arterial highways
- Local industrial streets
- Major service drives or entrances
- Airports - 60,000 pound maximum gross weight

Class VI

(Very Heavy) Unlimited autos, 7,000,000 to 15,000,000 trucks expected during design period.

- Urban interstate highways
- Some industrial roads
- Airports - over 60,000 pounds maximum gross weight

For more information on this subject refer to the Asphalt Institute's publications Thickness Design-Asphalt Pavements for Highways and Streets (MS-1) and Asphalt Pavement Thickness Design (IS-181).

SOIL SUPPORT CAPABILITY

The ability of the subgrade to support loads transmitted from the pavement is one of the most important factors in determining pavement thickness. The subgrade must serve as a working platform to support construction equipment and as a foundation for the pavement structure that supports and distributes traffic loads. Thus, it is essential to evaluate the strength of the subgrade before beginning the structural design of the pavement. Figure 3-1 shows the spread of wheel load through the pavement structure and on to the subgrade.

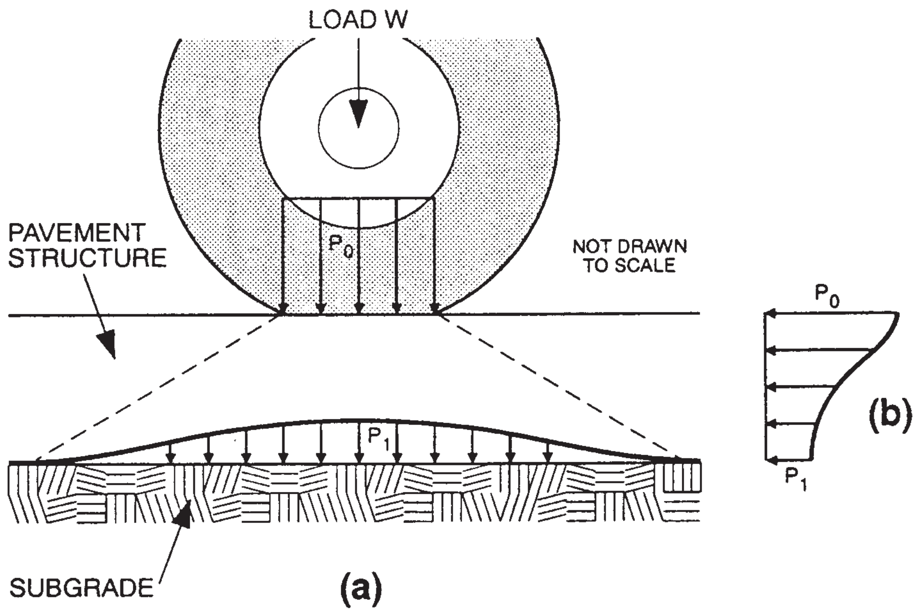


Figure 3-1. *Spread of wheel-load through pavement structure.*

If sufficient pavement thickness is not provided, the applied loads could cause greater stresses on the subgrade than it can resist. This may result in deflection of the pavement and ultimately in its failure.

In street and highway construction, the subgrade provides the foundation for the pavement. Different types of soils have different abilities to provide support. A sandy soil, for example, will support greater loads without deformation than a silty clay soil. Thus, for any given traffic volume and weight of vehicles using the roadway, a greater pavement thickness must be provided on clay soils than on sandy soils.

Soil Classifications

Soil is classified for road and street construction in order to predict subgrade performance on the basis of a few simple tests. The American Association of State and Highway Transportation Officials (AASHTO) classification system for soils is commonly used as a test for subgrade-support value.

According to the AASHTO system, soils that have approximately the same general load-carrying capabilities are grouped in classifications of A-1 through A-7. (See Table 3-1.) In general the best highway subgrade soils are A-1, and the worst are A-7. The classification is based on the sieve analysis, plasticity index, and liquid limit of the soil being tested.

Table 3-1. Classification of Soils and Soil-Aggregate Mixtures (With Suggested Subgroups)

General Classification	Granular Materials (35% or Less of Total Sample Passing No. 200)							Silt-Clay Materials (More than 35% of Total Sample Passing No. 200)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7 A-7-5 A-7-6
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				
Sieve Analysis, percent passing:											
No. 10	50 max										
No. 40	30 max	50 max	51 min								
No. 200	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing No. 40:											
Liquid Limit				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity Index	6 max		NP	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min
Usual Types of Significant Constituent Materials	Stone Fragments, Gravel & Sand		Fine Sand	Silty or Clayey Gravel and Sand				Silty Soils		Clayey Soils	
General Rating As Subgrade	Excellent to Good							Fair to Poor			

The state of Iowa has been subdivided into surface soil areas that reflect their engineering soil classification. The accompanying figure provides a general soil classification map of Iowa. In addition, soil bulletins with more complete and detailed descriptions of soil types are available for each Iowa county. Note that these maps provide only a general grouping of a range of soils. Local spots may vary considerably.

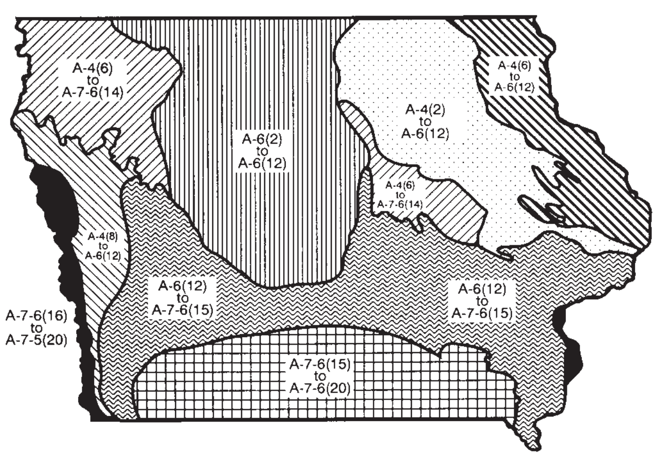
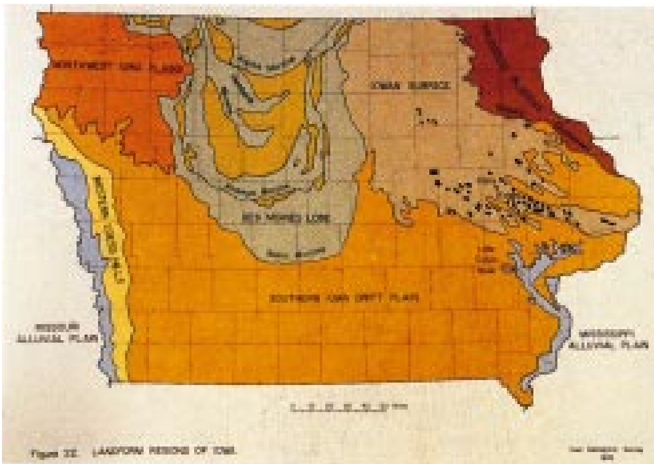


Figure 3-2. *General Soil Classification Areas*



Subgrade Strength

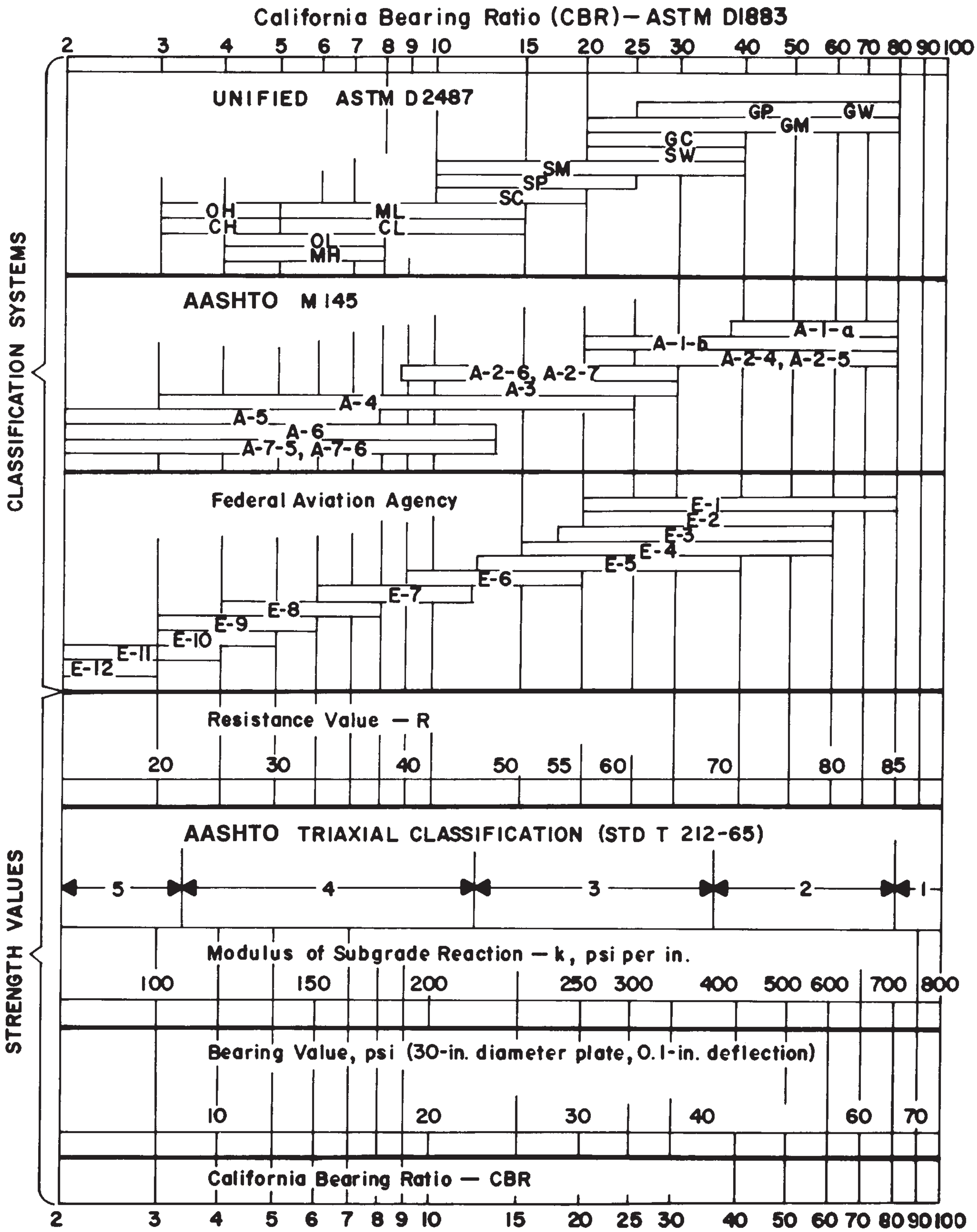
Because thickness calculations depend on the strength of the finished subgrade, the soil must be tested for this information. Tests are based on bearing capacity related to the moisture and density of the soil. The California Bearing Ratio (CBR) is one of the most widely used methods of designing pavement structure. Once the CBR value is determined, the soil classification can be identified. Or, when the soil classification is known, a relative CBR value can also be identified.

The lower the CBR value of a particular soil, the less strength it has to support the pavement. This means that a thicker pavement structure is needed on a soil with a low CBR rating than on a soil with a high CBR rating. Generally, clays have a CBR classification of 6. Silty loam and sandy loam soils are next with CBR values of 6 to 8. The best soils for road building purposes are sands and gravels whose CBR ratings normally exceed 10.

The change in pavement thickness needed to carry a given traffic load is not directly proportional to the change in CBR value of the subgrade soil. For example, a one-unit change in CBR from 5 to 4 requires a greater increase in pavement thickness than does a one-unit CBR change from 10 to 9.

A number of soil classification-strength systems are currently in use for roads and airports. A correlation chart follows for a general soil overview.

CORRELATION CHART SOIL CLASSIFICATION-STRENGTH



Soil Testing

A qualified laboratory can conduct tests to provide soil classification and subgrade strength information (such as the CBR). Such testing is necessary to ensure a proper structural design and is part of all major projects. However, such soil testing is relatively expensive, especially for small projects, and may not be available for all projects.

Subgrade Classes

For the designs recommended in this manual, all soils have been divided into three classes: good (G), Moderate (M), and poor (P), CBR design values are assigned to these different subgrade classes.

Good

Good subgrade soils retain a substantial amount of their load-supporting capacity when wet. Included are the clean sands, sand-gravels, and those free of detrimental amounts of plastic materials. Excellent subgrade soils are relatively unaffected by moisture or frost and contain less than 15 percent passing a No. 200 mesh sieve. A soil classified as good will have a CBR value of 9 or greater.

Moderate

Moderate subgrade soils are those that retain a moderate degree of firmness under adverse moisture conditions. Included are such soils as loams, silty sands, and sand gravels containing moderate amounts of clays and fine silts. When this soil becomes a cohesive material, it should have a minimum proctor density of 110 pounds per square inch. A soil classified as moderate will have a CBR value of 6 to 8.

Poor

Poor subgrade soils are those that become quite soft and plastic when wet. Included are those soils having appreciable amounts of clay and fine silt (50 percent or more) passing a No. 200 sieve. The coarse silts and sandy loams may also exhibit poor bearing properties in areas where deep-frost penetration into the subgrade is encountered for any appreciable periods of time. This also is true where the water table rises close to the surface during certain periods of the year. A soil classified as poor will have a CBR value of 3 to 5.

Very poor soils (those with a CBR of 3 or lower) often perform poorly as pavement subgrades. However, to improve their performance, these soils can be stabilized with granular material or a geotextile. Lime, fly-ash, asphalt cement, portland cement, and combinations of cement stabilizers also can be added to improve the subgrade support. The selection of a stabilizing agent, the amount to use, and the application procedure depend on the soil classification and the subgrade-support value desired. These should be determined through appropriate laboratory testing.

DRAINAGE

General Considerations

Highway engineers recognize the importance of good drainage in the design, construction, and maintenance of any pavement. Probably no other single factor plays such an important role in determining the ability of a pavement to provide trouble-free service throughout long periods of time.

The accumulation of water in the subgrade, or in an untreated aggregate base course, usually creates problems. When the soil is saturated, application of dynamic wheel loads induces pore pressures and lowers the resistance to shear. Some soils have a high volume change (when water is added), which causes differential heaving. The subsequent weakening of the pavement structure causes it to lose stability and its capability to support traffic loads.

The combination of water in the pavement's asphalt layers and dynamic, repeated traffic loading can strip or separate the asphalt film from the aggregate. This reduces the load-carrying capacity of the mixture.

When developing the features of a highway drainage system, it is important to consider the system's principal purposes: (1) to collect and drain away both surface water and subsurface water; (2) to lower the groundwater table, if necessary; (3) to intercept water from surrounding areas and carry it away from the roadway; and (4) to prevent or retard erosion.

There are two basic categories of drainage – surface and subsurface. Surface drainage includes the disposal of all water present on the pavement surface, shoulder surface, and the adjacent ground when sloped toward the pavement. Subsurface drainage deals with water in the subbase, the surrounding soil, and in the several pavement courses. Inadequate attention to either of these two drainage conditions can lead to premature pavement failure.

Surface Drainage

In surface drainage conditions, the pavement and shoulders must be crowned or cross-sloped to facilitate the flow of water off of the roadway. Normally, the cross-slope moves the water to a curbed or inverted-shaped gutter and then off of the pavement into a storm sewer or flume to a ditch.

On parking areas or playgrounds, the cross-slope or crown may be inverted toward a center swale with a grated inlet for drainage interception.

Shoulders can best be drained if the entire shoulder width has an asphalt-paved surface. If the shoulder is not asphalt, its cross-slope should be steeper in order to minimize seepage through the aggregate or grass shoulder.

Surface drainage from the pavement and from the adjacent land areas must be intercepted and disposed of. If a curbed section is provided, drainage is accumulated in the gutter area and periodically discharged into either a pavement inlet or a ditch through a flume. The determination of inlet locations requires technical calculations and studies to maintain a tolerable spread of water on the pavement.

Drainage ditches are constructed along the edges of non-curbed roadway sections. Water flowing from the pavement and shoulder surfaces moves down the roadway foreslope into a rounded ditch area. A backslope leads from the bottom of the ditch up to intercept the adjacent land. The adjacent land is frequently sloped toward the ditch and can contribute to a sizable portion of the drainage flow.

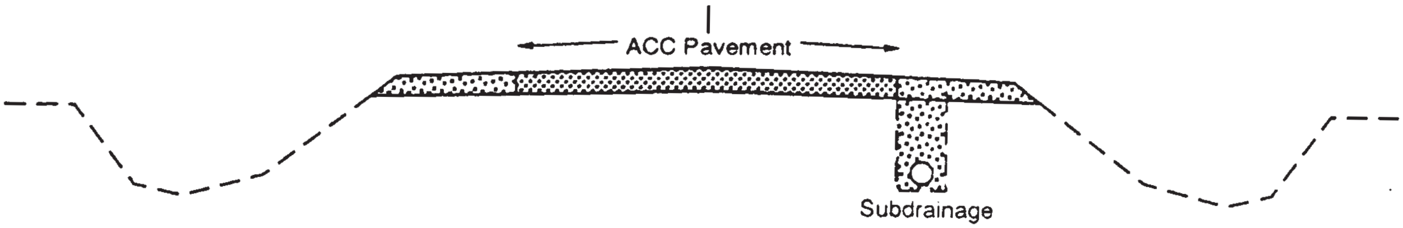


Figure 3-3.

Good design practices will provide cross-slopes both on the surface and in the underlying pavement courses and subgrade. In this way, water will not accumulate but will flow laterally to the sides.

Subsurface Drainage

Subsurface water is free water that percolates through, or is contained in, the soil beneath the surface. When it emerges or escapes from the soil, it is referred to as seepage water. The point of emergence is called a seepage area or a spring.

Pavement subsurface water usually is present as free water that flows under the force of gravity or as capillary water that moves under capillary action in the soil.

Water will rise from the underlying soil through the subgrade and into an untreated aggregate pavement course. This free water will move readily into an untreated aggregate base to a low point on the profile. If steep grades are present, and the subsurface water flowing in an untreated aggregate base to the low spot is not intercepted, a hydrostatic head may result. This lifting force will cause a failure of the pavement structure. Water in the pavement courses also may contribute to the stripping of asphalt films from the aggregate particles.

Subdrains

When water collects in the structural elements of the pavement, subdrains are required. Identification of these areas and determination of drain locations require the technical expertise and insight of an engineer. The choice of drain filter material and the design of the drainage system must be given careful attention by experts. Perforated and slotted pipe usually serve to move the free water from the trouble spot to a drainage area.

Check Drainage During Construction

Regardless of the care used in the preliminary investigation, the soil survey, and in the pavement structure's design, it is usually not possible to determine from borings the exact elevation of water-bearing strata or the rate of flow that will develop. For this reason, it is essential that the engineer reevaluate the conditions and check the need for, and the adequacy of, any subsurface drainage indicated on the plans.

Soil conditions should be observed during the grading and subgrade preparation work. Any wet, soft, or spongy areas encountered at grade should be investigated and provisions made for their proper drainage. Even a minor rate of seepage may build up to a large quantity of water over a period of time if a means of escape is not provided. Such a soft spot usually forewarns of a structural failure at a later date-even shortly after traffic has used the new facility. After the pavement is in place, corrective measures are costly, create traffic problems, and can cause poor public relations.

DESIGN TYPES

In general, the design of a new asphalt pavement structure involves two basic pavement types: (1) full-depth pavements, and (2) pavements with an untreated aggregate base course.

Full-depth, Asphalt Concrete paving is one in which asphalt mixtures are used for all courses above the subgrade. Such pavements are less affected by subgrade moisture and are more conducive to staged construction. Full-depth asphalt pavement is used in all types of highway construction and where high volumes of traffic and trucks are anticipated.

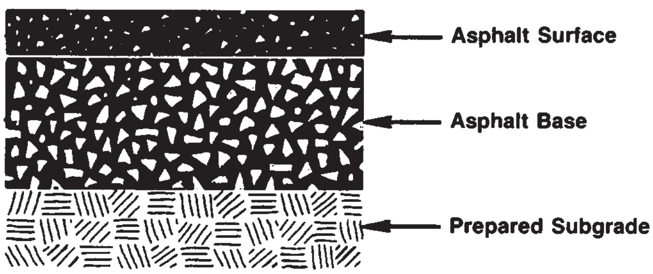


Figure 3-4

Untreated aggregate base pavements may be used where local aggregates and subsurface drainage conditions are suitable and where traffic loadings are minimal. The untreated aggregate base is placed and compacted on the prepared subgrade. In general, an asphalt binder and surface course are used to complete the pavement structure. Although the initial cost for untreated aggregate base asphalt pavements may be lower than the cost for full-depth, hot mix types, the former type should be used with caution. Moisture in the base may cause pavement failure.

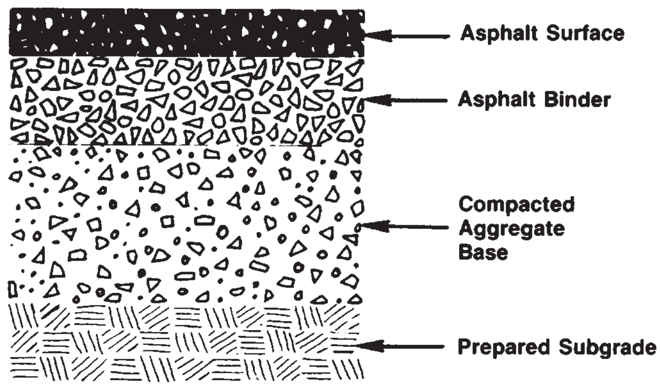


Figure 3-5

ASPHALT CONCRETE SPECIFICATIONS

It is recommended that specifications for Asphalt Concrete follow Iowa Department of Transportation Standard Specifications for the particular class and mixture size required. This will result in uniformity and economy because most APAI-member contractors may have job mixes on several mixtures already prepared for state and local agency use. In the absence of a previously prepared job mix, the contractor or private testing should develop a job mix formula for the desired project, and intended use.

The following gradations are suggested guidelines for the class and mixture size specified. The asphalt cement content is a guide only and may need to be adjusted to meet local aggregate conditions and intended use.

Quality of aggregates (according to factors such as freeze and thaw, abrasion, plasticity index, etc.) for the various mixes can be obtained from the Iowa DOT Standard Specifications in the 3 sections listed in the following tables.

Salvaged and Reclaimed Material

Recycling of reclaimed asphalt pavement (RAP) material into new asphalt concrete has become a routine and accepted process for use of the salvaged product. The contractor substitutes reclaimed aggregate and binder for virgin materials at varying ratios from 10-50% by weight. The salvaged material may be taken from the project or a stockpile provided by the contractor. Control of the use and quality of the recycled mix shall be through the job mix formula process. Salvaged material may be used in the base, binder, and surface courses of type A or B mixes for which it qualifies. Historical test reults from milled material taken from Iowa DOT projects indicate that millings are falling within the following limits.

Table 3-2 Gradation of sample RAP material

Sieve Size	%Passing Rang	%Passing AVERAGE
3/4"	98-100	100
1/2"	94-100	98
3/8"	84-98	93
No. 4	65-88	77
No. 8	51-74	62
No. 16	36-57	49
No. 30	28-42	36
No. 50	17-30	24
No. 100	11-26	18
No. 200	9-22	14

Salvaged materials, whether previously processes or not, shall be sized for the intended mix use. Final gradation of the recycled mix shall meet the requirements for the specified mix size and type.

Aggregate for Type B. Asphalt Concrete

Aggregate for Type B asphalt concrete shall meet the requirements as specified in Section 4126, lowa DOT Standard Specifications.

Gradation: The job mix formula for the mixture size specified, when tested by means of laboratory sieves, shall meet the following requirements:

Table 3-3. Gradation of Job Mix: Type B Asphalt Concrete

	Percent Passing Class 1 and 2* Mixture Size			
SieveSize	1 inch	3/4 inch	1/2 inch	3/8 inch
1-1/2 inch	100			
1 inch	92-100	100		
3/4 inch	77-92	98-100	100	
1/2 inch	60-80	76-95	92-100	100
3/8 inch	—	60-88	70-94	98-100
No. 4	34-55	42-70	50-75	63-89
No. 8	20-38	30-56	36-60	44-68
No. 30	7-20	14-32	16-34	20-37
No. 200	2-7	3-7	3-7	3-7
Asphalt Cement Content: 5-7%				

AC-5 grade recommended for Type B Base
AC-10 grade recommended for Type B Surface
*Class 1 - 30 percent crushed particles (minimum)
*Class 2 - no minimum percentage of crushed particles
50 - Blow Marshall mix criteria normally specified

Aggregate for Type A Asphalt Concrete

Aggregate for Type A asphalt concrete shall meet the requirements as specified in Section 4127, lowa DOT Standard Specifications.

Gradation: The job mix formula for the mixture size specified, when tested by means of laboratory sieves, shall meet the following requirements:

Table 3-4. Gradation of Job Mix: Type A Asphalt Concrete

	Percent Passing Mixture Size			
Sieve Size	1 inch	3/4 inch	1/2 inch	3/8 inch
1 -1/2 inch	100			
1 inch	92-100	100		
3/4 inch	77-92	98-100	100	
1/2 inch	60-80	76-95	92-100	100
3/8 inch	—	60-88	70-94	98-100
No. 4	37-58	42-70	50-75	63-89
No. 8	28-44	30-56	36-60	44-68
No. 30	13-27	14-32	16-34	20-37
No. 200	3-7	3-7	3-7	3-7
Asphalt Cement Content: 5-7%				

AC-10 grade recommended for Type A Concrete
*60 percent crushed particles (minimum)
50 - Blow Marshall mix criteria normally specified

Standard Mix Descriptions

It is recommended that designs and specifications for Asphalt Concrete follows the Iowa Department of Transportation standards for the specific type and mix design required. Instructional Memorandum on Field Inspection manuals published by the Central Office of Materials, are available from the DOT storeroom. Designated mix descriptions follow.

Recycled Asphalt Concrete

Recycled asphalt concrete mixtures are composed of a combination of virgin gravel, crushed stone, sand and salvaged/reclaimed asphalt paving (RAP) materials. The combined aggregates are mixed with asphalt cement through a hot mix plant mix process to produce a recycled mix.

Job mix formulas are required by the specifications to determine the target percent asphalt binder for a specified mix type and gradation. Recycled materials are routinely used in base, binder, and surface courses. These mixtures may be designed as type A or B asphalt concrete with the same quality requirements, therefore requiring no name change or designation.

Type B Asphalt Concrete

Type B Asphalt Concrete base, binder, leveling, strengthening, and surface course mixtures are composed of gravel; crushed stone; or combinations of gravel, stone, and sand, produced from approved sources and formulated to provide service for roads carrying low to moderate traffic. The formulation procedure results in a job mix formula for each aggregate combination along with a recommended percentage of asphalt cement.

Type B Asphalt Concrete may be placed as a base, binder, or surface course depending upon mix class and size. Type B specifications are used in secondary road systems, municipal streets, parking lots, and other areas. To meet all appropriate requirements, and because several options are available, care must be exercised in selecting the mix class, lift thickness, and mix size during the various stages of design and construction.

Job mix formulas are required by the specifications for all aggregate combinations. The formulas are comprised of the aggregate percentages, percent asphalt, and gradation as limited by the specification requirements.

Type A Asphalt Concrete

Type A Asphalt Concrete binder, leveling, strengthening, and surface course mixtures are composed of combinations of high-quality gravel, crushed stone, and sand produced from approved sources and formulated for service on road surfaces carrying a high volume of traffic; and as surface courses with lower-quality base courses for other uses. Because four mix sizes are available, care must be exercised in selecting the lift thickness and mix sizes during the various stages of design and construction so that appropriate requirements are met.

Job mix formulas are required by the specifications for all aggregate combinations. The formulas are comprised of the aggregate percentages, percent asphalt, and gradation as limited by specified tolerances for each controlling sieve size.

CONSTRUCTION OF ASPHALT PAVEMENTS

Construction Equipment

It is the responsibility of the contractor to provide equipment that will produce results in compliance with the plans and specifications of the contract. The following section contains information on the basic equipment used to produce and construct Asphalt Concrete pavements.

Asphalt Mixing Facilities

The mixing facility produces the Asphalt Concrete mixture placed as pavement. The facility should be designed and coordinated to produce mixtures within specified job mix tolerances.

Asphalt storage tanks must have a device for the controlled heating of material to temperature requirements as specified. Heating should be accomplished so that no flame will come in contact with the tank. The circulating system should be large enough to ensure proper and continuous circulation of asphalt between storage tank and mixer during the entire operating period. While the pump is in operation, the discharge end of the circulating pipeline should be kept below the surface of the asphalt in the tank.

The facility should have an accurate means for feeding the aggregate into the dryer to ensure uniform production and a constant temperature. The facility should contain a rotary drum dryer that will continuously agitate the aggregates during the heating, drying, and mixing processes.

For batch mixing processes, screens may be positioned over the hot aggregate storage bins to separate all aggregates to sizes required for proportioning to meet the job mix formulae. Where no such screens are used, proportioning must be handled as part of the cold-feed system.

If drum mixers or continuous mixing plants are used in the production of mixes, approved materials must be fed into the cold-feed system in the proper proportions to meet the job mix formulae.

The facility must have the means to obtain the required percentage of asphalt in the mix within the tolerance specified. This can be accomplished by weighing, metering, or measuring volumetrically. Steam jacketing or other insulation should maintain the specified temperature of asphalt in pipelines, meters, buckets, spray bars, flow lines, and other containers.

A thermometer ranging from 200°F to 400°F should be placed in the asphalt feed line or tank.

The facility should have a dust collector, a mixer cover, and whatever additional housing necessary to ensure proper dust control.

Adequate and safe stairways to the mixer platform and guarded ladders to other units of the facility should be provided. All gears, pulleys, chains, sprockets, and other dangerous moving parts should be well guarded and protected. A platform for sampling and inspection of the mix should be located near the facility.

The use of surge or storage bins is permitted for storing asphalt pavement materials.

Hauling Equipment

Haul trucks are used to bring the Asphalt Concrete from the asphalt mixing facility to the paving site. Equipment used in hauling bituminous mixtures should be clean and have tight bodies to prevent material loss. These units can be equipped with suitable covers to protect the mixture in transit during unfavorable weather conditions.

Spreading Equipment

Spreading equipment is used to place the Asphalt Concrete as pavement. Where feasible, the Asphalt Concrete should be placed and spread by a mechanical spreader. Mechanical, self-powered pavers should be capable of spreading the mix within the specified tolerances and true to the line, grade, and crown indicated on the plans. A motor patrol may be used for the leveling course.

Pavers should be equipped with efficient steering devices and should be capable of traveling both forward and in reverse. They should be equipped with hoppers and distributing screws that place the mix in front of screeds. The screed unit should be adjustable in height and crown and equipped with a controlled heating device for use when required. The screed must strike off the mix to the depth and crown section specified without the aid of manual adjustment during operation. Pavers should be capable of spreading mixes without segregation or tearing and producing a finished surface of even and uniform texture.

Compaction Equipment

Compaction equipment is used to compact the Asphalt Concrete to attain density after placement. The compaction equipment should be of the type or types that will produce the required density and pavement smoothness. Steel-wheeled rollers are of four types – three-wheeled, two-axle tandem, three-axle tandem, and vibratory. These rollers should be equipped with power units. Rollers should be in good working condition and equipped with a reversing clutch. Rollers should have adjustable scrapers to keep the wheel surfaces clean and an efficient means of keeping them wet to prevent mixes from sticking. These surfaces should have no flat areas, openings, or projections that will mar the surface of the pavement.

Pneumatic-tired rollers should be self-propelled. The rollers should be equipped with pneumatic tires of equal size and diameter that are capable of exerting average contact pressure.

The wheels of the roller should be spaced so that one pass will accomplish one complete coverage equal to the rolling width of the machine. There should be a minimum of 1/4 inch-overlap of the tracking wheels. The roller should be constructed so that the contact pressure will be uniform for all wheels and the tire pressure of the tires will not vary more than 5 pounds per square inch. The rollers should be constructed with enough ballast space to provide uniform wheel loading as may be required. The operating weight and tire pressure of the roller may be varied to obtain contact pressures that will result in the density.

Cold Milling

Cold milling is the most common pavement scarification method for salvaging material. This method uses a self-propelled milling machine with a rotating drum containing special teeth that cut the pavement to a predetermined depth and reduce the size of the salvaged material. Single-pass cutting widths of up to 12 feet and depths of 4 inches have been attained with this type of machine. The drums are hydraulically controlled and are capable of maintaining road profile and depth of cut to 1/8 inch. Milled material is usually suitable for hot or cold recycling with little additional breakdown.

Construction Practices

Preparation of Subgrade

Remove all large rock, debris, and topsoil from the area to be paved. All vegetation, including root systems, should be removed. To prevent future growth, the subgrade should be treated with an approved herbicide. Install all drainage and utility facilities and then properly backfill and compact.

The subgrade must be properly shaped to meet true lines and elevations and compacted to not less than 95 percent of maximum laboratory density. The surface of the compacted subgrade should not vary more than 3/4 inch from the established grade.

Areas showing pronounced deflection under construction traffic indicate instability in the subgrade. If the situation is not corrected by reworking and additional rolling, the areas must be removed and replaced with suitable material and compacted or stablized using a geotextile. The use of Asphalt Concrete base or course granular material is recommended.

Constructing Asphalt Concrete Base

The Asphalt Concrete base may consist of one or more courses placed on a prepared subgrade. It must have a total compacted thickness as indicated on the plans or as specified. In general, a base with total thickness of 4 inches or less should be placed in one lift. A base with a total thickness of more than 4 inches may be placed in two or more lifts with the bottom lift having a minimum of 3 inches.

Untreated Aggregate Base

The crushed aggregate base course may consist of one or more layers placed directly on the prepared subgrade. The material must be spread and compacted to the required thickness, grades, and dimensions indicated in the plans or as specified. The minimum compacted thickness of each lift should be no less than two times the size of the largest aggregate particle, or 4 inches, whichever is greater. The maximum compacted lift thickness should be 6 inches.

Binder and Surface Courses

The upper lifts of the pavement may consist of one or more courses of Asphalt Concrete placed on the previously constructed Asphalt Concrete base. In general, the top or wearing course must not be constructed to a depth greater than 3 inches. Where a thickness greater than 3 inches is indicated, it should be placed in two courses consisting of a binder and a surface or wearing course. The minimum lift thickness must be 1 inch, but this thickness should never be less than two times the maximum particle size.

Tack Coat

A tack or bond coat of CSS-1, SS-1, MC-70 or an approved alternate should be applied between each course at an undiluted rate of 0.02 to 0.05 gallons per square yard. The surface must be cleaned of all dust, dirt, or other loose material before the bond coat is applied. If emulsion is used, it should be diluted with equal parts of water or as specified in the proposal.

Minimum Grade

It is recommended that the minimum pavement grade be not less than 2 percent (approximately 1/4 inch per foot) to ensure proper surface drainage.

Pavement Markings

Pavement markings have an important function in traffic control. They convey certain regulations and warnings in a clearly understandable manner without diverting the driver's attention from the roadway. An asphalt pavement clearly has an advantage in providing highly visible, attention-attracting markings – even under adverse weather conditions. White- and yellow-painted markings or thermo markings stand out on the black background.

All pavement markings on public highways must comply with the Manual on Uniform Traffic Control Devices (MUTCD). Standards for color, materials, width, shape, and concept are set forth in the MUTCD.

The most frequently used pavement markings are longitudinal markings. The basic concept is to use yellow lines to delineate the separation of traffic flows in opposing directions or to mark the left edge of pavement of divided highways and one-way roads. Solid yellow lines are also used to mark no passing zones. White lines are used to separate traffic lanes flowing in the same direction or to mark the outside edge of pavements.

The patterns and width of longitudinal lines vary with use. A broken line is formed by segments and gaps, usually in the ratio of 1:3. On rural highways, a recommended standard is 10-foot segments and 30-foot gaps. A normal line is 4 to 6 inches wide.

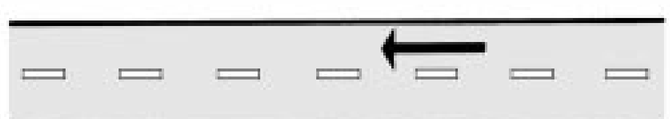


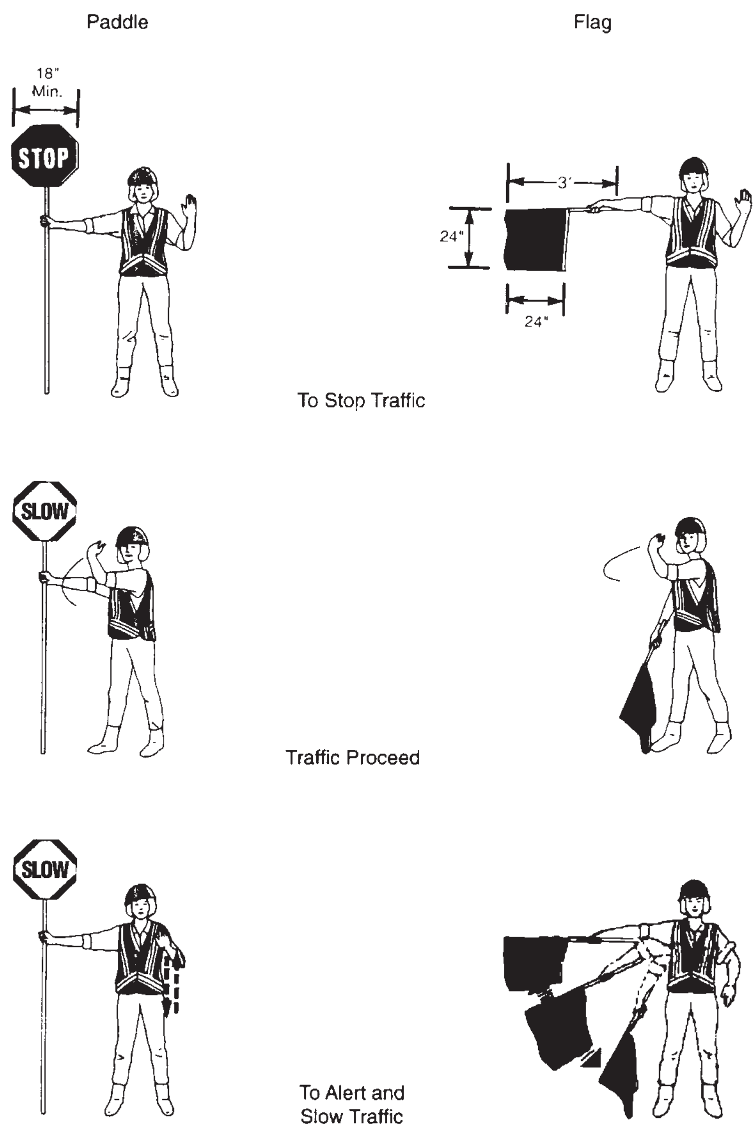
Figure 3-6

It is beyond the scope of this Design Guide to present these standards in more detail. The user should refer to these standards when placing pavement markings. All city and county engineering offices and most other transportation engineering organizations have a copy of the MUTCD.

Traffic Control Through Work Areas

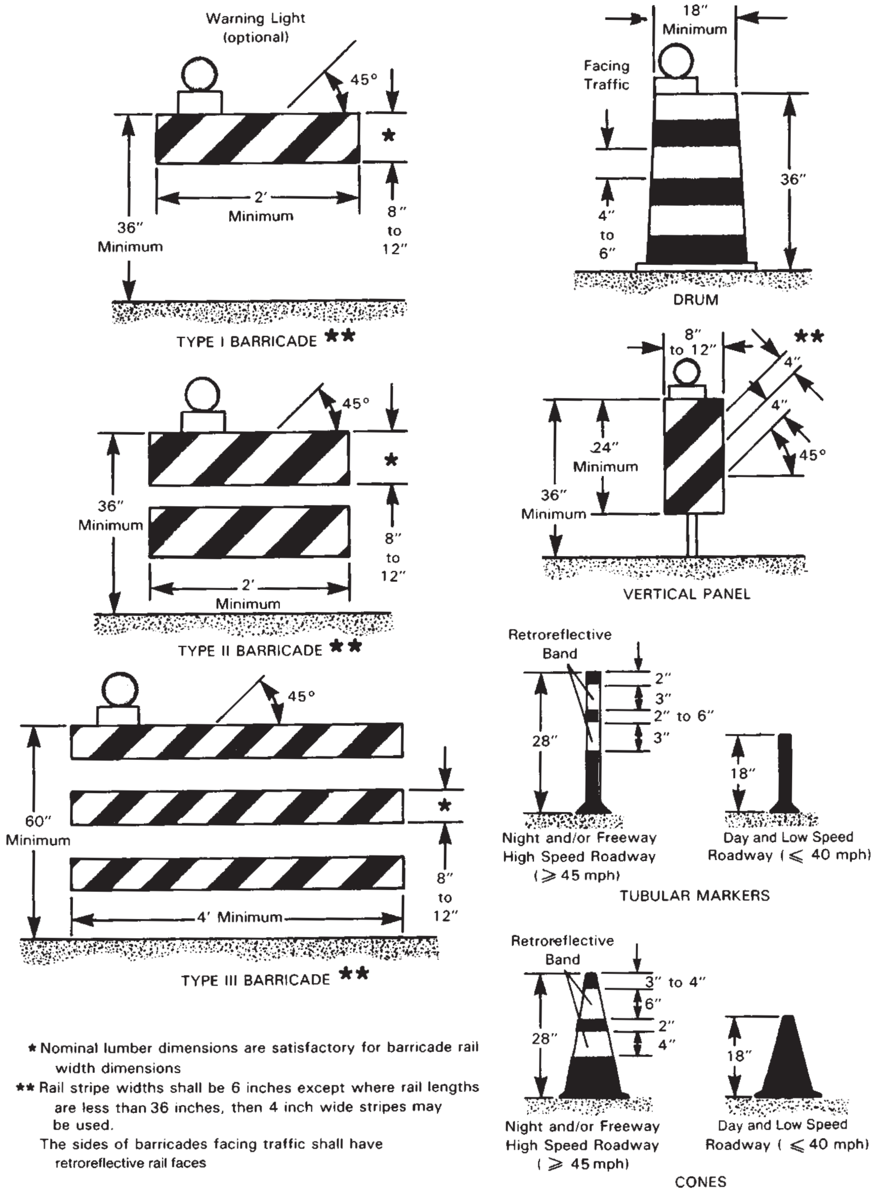
The control of traffic through work areas in a safe and expeditious manner, while maintaining good public relations, is an essential part of highway construction and maintenance operations. In today's litigious society, efficient traffic control may mean the difference between no liability and a large financial award should an accident occur. No agency, owner, or construction company is immune from alleged responsibility for an accident.

Because of the multitude of construction and maintenance applications, it is impossible to list the standards for signs, barricades, and markings in this publication. For more detailed information on a specific application, refer to Part VI in the MUTCD and to the Iowa DOT.



Flaggers may be needed for safety. It is important that they be properly dressed and instructed in flagging standards. Flagging procedures are set forth in Part XI of the MUTCD, and the Iowa DOT provides supplemental information and training booklets.

Figure 3-7. *Use of hand devices by flagger.*



Barricades are portable devices used to control traffic by closing, restricting, or delineating construction areas. The MUTCD specifies the type of barricade to use for a specific situation and describes barricade characteristics. The diagonal stripes slope downward either left or right from the upper to lower panel and should "slope downward in the direction toward which traffic must turn in detouring."

Figure 3-8. *Channelizing devices.*

When a road or a site normally used by traffic is closed, it should be barricaded and signed in accordance with the MUTCD.

Aggregate Weighing-Job Mix Formulas

Compaction Testing-Nuclear Gauge

TESTING AND INSPECTION

Inspection and testing of the production and placement of Asphalt Concrete – or of any material – is necessary to ensure a quality product. Plant and field inspections include: (1) the preparation of the aggregate; (2) the Asphalt Concrete plant setup and operation; (3) the control of the Asphalt Concrete mixture; (4) the delivery and placement; and (5) the final finishing and compaction.

It is beyond the scope of this Design Guide to do more than emphasize the importance of a quality testing and inspection program. The Iowa DOT publishes manuals on asphalt plant inspection and field testing that are available through the DOT Storeroom. Training courses on this subject are offered by APAI and other agencies.

Hot Box Sample

Smoothness Testing-California Profilograph