MATERIALS

PRELIMINARY ENGINEERING

AND

DESIGN MANUAL

PREPARED BY HIGHWAYS DIVISION -
MATERIALS SECTION

THIRD EDITION - MARCH 1989

Revised to Change Letter No. 2
(March 1992)

MATERIALS PRELIMINARY ENGINEERING AND DESIGN MANUAL

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ARIZONA DEPARTMENT OF TRANSPORTATION

HIGHWAY DIVISION - Materials Section
1221 North 21st Avenue - Phoenix, Arizona 85009-3740

FIFE SYMINGTON
Governor

CHARLES E. COWAN
Director

GARY K. ROBINSON
State Engineer

December 1991

MEMO TO: HOLDERS OF PRELIMINARY ENGINEERING AND DESIGN MANUAL

FROM: DOUGLAS A. FORSTIE
ASSISTANT STATE ENGINEER
MATERIALS SECTION

RE: DISTRIBUTION AND REVISION OF MATERIALS
PRELIMINARY ENGINEERING AND DESIGN MANUAL

The Materials Preliminary Engineering and Design Manual has been developed by the Materials Section of the Arizona Department of Transportation and issued most recently in its entirety in March 1989 as the Third Edition. This manual incorporates the "1986 AASHTO Guide for Design of Pavement Structures", adapted to our experience and practice, and also for the soil and climate conditions found in our state.

This manual is revised as necessary by Change Letter as described in "Changes in Preliminary Engineering and Design Manual".

A listing of manual holders in maintained by Materials Section for notification of revisions. Please notify Gregg Inman of Materials Section Testing Services of any changes in address or location so the distribution list may be kept current. If at any time you need addtional information to keep your manual current, please contact Mr. Inman at (602)255-8085.

ADOT personnel are reminded that manuals in their use are the property of the Arizona Department of Transportation and must be returned to same upon termination of employment.

If you have questions concerning information contained in this manual, please contact either George Way at (602)255-8085, or John Lawson at (602)255-8130.

Douglas A. Forstie

CHANGES IN THE MATERIALS PRELIMINARY

ENGINEERING AND DESIGN MANUAL

1. All changes in the Materials PE & Design Manual shall officially originate from the Materials Section in Phoenix. They will be identified on a standard Materials Manual Change Letter, as shown in the example on the following page.

2. A copy of the change letter will be sent to each holder of a manual. All manual holders shall be responsibile for keeping assigned manuals up to date. All change letters issued shall be numbered consecutively, beginning with No. 1.

3. Change letters should be kept in the manual in order to provide documentation of the changes that have been made. The items affected by the change letter will be listed under "Subject" and a description of each change shall be included in the letter. New pages to be inserted in the manual will be dated with the change letter date.

4. Change letters will be signed by the Assistant State Engineer, Materials Section.

ARIZONA DEPARTMENT OF TRANSPORTATION * MATERIALS SECTION

206 S. 17th AVENUE (127A), PHOENIX, ARIZONA 85007 PHONE (602) 255-7231

Gary L. Cooper
Assistant State Engineer

CHANGE LETTER

MATERIALS P.E. AND DESIGN MANUAL	CHANGE LETTER NO. 1
SUBJECT: Figure 106.01-2b. Sections 200.05 and 301.01.	DATE OF ISSUE: September 1989 EFFECTIVE DATE: September 1989

SUMMARY

1. Figure 106.01-2b - "Materials Survey Soil and Aggregate Tabulation Laboratory Card".
   This figure has been revised to show changes made to the laboratory card. Replace page 58 with the attached page 58.

2. Section 200.05 - "Traffic Analysis".
   The second paragraph of this section has been revised. Replace page 75 with the attached page 75.

3. Section 301.01 - "Deflection Measurement".
   Subsection A (The Falling Weight Deflectometer) and Subsection B (The Dynaflect) have been revised. Replace pages 141 and 142 with the attached pages 141, 142, and 142a.

Gary L. Cooper

Gary L. Cooper
Assistant State Engineer
Materials Section

Attachments

EXAMPLE

FOREWORD

INTRODUCTION

The Arizona Department of Transportation (ADOT) has used the American Association of State Highway and Transportation Officials (AASHTO) Design Guide for Pavements since 1962 when the first design guidelines were published as a result of the 1958-1960 Road Test. In 1986 AASHTO published a comprehensive revised version of the Pavement Design Guide (1). As in previous versions, AASHTO asked each state to review and modify the guide based upon their unique climate, materials, pavement performance, construction and maintenance practices. Arizona's present pavement design guide was developed by Materials Section in 1981 and revised in 1984 (2). Each service area; Materials Testing, Pavement, and Geotechnical, contributed to the development of this manual. In particular, the following individuals made significant contributions.

* George Way
* Jim Demaree
* Jim Delton
* John Eisenberg
* John Lawson
* Brad Mortensen
* Gregg Inman

The manual generally incorporates the principles of the new AASHTO Design Guide with appropriate Arizona modifications. The use of this new pavement guide presently impacts about 125 project pavement designs per year, with a value approximating 200 million dollars.

DISCUSSION

The pavement designer's job is to design a pavement structure sound enough to resist premature failures, such as poor ride, excessive cracking, potholes due to poor structural support, permanent deformation (rutting), low skid resistance, stripping (asphalt debonding) and raveling, in a cost effective manner and perform as expected during its predicted life. To do this a myriad of factors assumptions and predictions need to be addressed.

Traffic loading has consistently been a troublesome factor to predict. Equivalent Single Axle Loads (ESAL's) have historically been calculated by the AASHTO procedure with a few simplifying assumptions; which include setting the structural number equal to five (5), the concrete thickness to nine (9) inches and the terminal serviceability to 2.5 psi. These simplifying assumptions are in keeping with the method used by the Federal Highway Administration to calculate ESAL's as a part of their annual Truck Weight Study (also referred to as the loadometer study). To further improve the traffic loading predictions Arizona has not only incorporated the growth of future traffic, but also truck loading increases and tire pressure into the new 1988 traffic loading calculation. These new calculations reflect heavier trucks and heavier steering axle loads, which can be 5 to 10 times more damaging then dual tire, tandem axle loading. In addition, tire pressures are now estimated at 105 PSI instead of the AASHTO Road Test 75 PSI. These changes are in keeping with research conducted by the University of Arizona (3) and Austin Research Engineers (4). These traffic loading changes are an interim step to the ultimate use of weigh-in-motion data. It is Materials Sections goal in cooperation with Transportation Planning to incorporate weigh-in-motion data in the 1989 traffic loading estimates. The net effect of all of these changes is that the predicted traffic loading estimates have doubled since 1987 and will probably increase again when WIM Data is implemented. Although this represents an improvement over past practice, estimating future traffic is still a major area of concern in areas of the state experiencing tremendous growth. With this in mind, many design values have been selected to provide insurance against under estimating traffic. Higher service levels were selected to reflect the need to reduce maintenance and traffic interruption on high traffic volume highways.

Environment and climate also impact pavement performance by changing the moisture content of highway materials and imposing damage by freezing and thawing. The new manual describes these changes in terms of a seasonal variation factor, which is equivalent to the Arizona regional factor. This approach was selected because previous Pavement Management research (5) indicated that regional factor strongly influenced pavement performance. In addition a method for determining the depth of frost damage has also been added.

The interaction of moisture and climate alters the roadbed soil strength. This relationship was expressed by equating results of the R-value test to soil strength in terms of Resilient Modulus (M_R). After much discussion and review of the 1986 AASHTO Pavement Design Guide, as well as, the review of previous Arizona Research (6)(7), it was determined the R-value soil strength relationship should be changed to better match the actual long term soil strength (moisture) conditions in the field. In particular, soil strength is a function of the seasonal variation factor, thus the same soil in Flagstaff will have a lower soil strength than in Phoenix due to the higher rainfall and severe freezing and thawing climatic conditions. Another change in characterizing soil strength involves using the average soil strength of the predominant soil type instead of the current practice of representing the poorest soil. Also, geosynthetics will now be given credit for improving the subgrade quality. In general, the philosophy of the new manual is to either remove, stabilize or control the subgrade materials in such a manner that the average subgrade soil strength occurs as uniformly as practical.

The interaction of moisture, soil strength and traffic loading can be very damaging. The 1986 AASHTO Guide places special emphasis on drainage. Likewise, Arizona has given value to geosynthetics, drainage layers, trenches and pipes to remove moisture rapidly and mitigate damage. Methods to remove excess moisture under the pavement will become more common in the higher rainfall areas of the state.

Predicting pavement damage and pavement performance is a difficult forecasting problem. To help improve the quality of the forecasted performance, Arizona has relied upon its pavement management data base which represents 15 years of historical pavement performance data. In addition, present serviceability index factors are set to conform with the Department's published Pavement Preservation Policy (8). To achieve the policy standards, high traffic volume roads need to be rehabilitated at a much higher terminal serviceability index, which for consistency are reflected in the design values. To use any lower terminal servicability values would unduly increase the cost of future maintenance and rehabilitation.

The reliability or confidence that a pavement will perform as designed has indirectly been a part of the AASHTO Pavement Design process. Because of the previously discussed numerous changes in the 1986 AASHTO pavement design, as well as Arizona changes in pavement design, reliability factors had to be tested at various levels to be sure that the selected factors would yield designs of at least the same structural number or thickness for the same soil and traffic.

To help illustrate these changes a limited sensitivity analysis involving three levels of traffic was conducted (9). AASHTO traffic refers to typical calculated traffic loads in 1987. Truck and tire pressure traffic loading reflect new changes in calculation due to predicting heavier trucks and higher tire pressure. A weigh-in-motion (WIM) traffic loading was estimated from previous sample information and reflects the anticipated higher loading. In general, greater traffic loading equates to a 5 to 20 percent increase in AC/PCCP thickness. To be more specific the increase in AC thickness will be about 20 percent, primarily because there is a greater increase in the AC pavement safety factor. Under the new manual AC thickness can be reduced by improving the subgrade strength and/or improving drainage. Concrete thickness increases only about 5 percent primarily because it already had a safety factor of two. With very heavy traffic the design concrete thickness can become very large. The new manual provides a means for reducing thickness by using load transfer dowels or continuously reinforced concrete. In addition, tied concrete shoulders will also reduce the concrete slab thickness.

Given the myriad of possible designs, Life Cycle Cost Analysis will be routinely performed on most major construction projects.

The rehabilitation portion of the manual reflects the findings of previous Arizona Research (10). Additions have been made to accommodate milling and recycling.

The remainder of the manual deals with practices and procedures that need to be followed in order to develop an acceptable geotechnical investigation and pavement design.

FOREWORD REFERENCES

1. "AASHTO Guide for Design of Pavement Structures," American Association of State Highway and Transportation Officials. Washington, D.C., 1986.

2. "Materials Preliminary Engineering and Design Manual," Arizona Department of Transportation, Phoenix, Arizona, 1984.

3. Jimenez, R.A., "Structural Design of Asphalt Pavements," The University of Arizona, Tucson, Arizona, 1975.

4. Hudson, S.W., Seeds, S.B., Finn, F.N., Carmichael, R.F., "Evaluation of Increased Pavement Loading," Austin Research Engineers, Austin, Texas, 1987.

5. Kulkarni, R., Golabi, K., Finn, F., and Alvit, E., "Development of a Network Optimization System, Volumes 1 and 2," Woodward-Clyde Consultants, California, May, 1980.

6. Way, G., "Environmental Factor Determination from In-Place Temperature and Moisture Measurements Under Arizona Pavements," Arizona Department of Transportation, Phoenix, Arizona, September 1980.

7. Mamlouk, M., Houston, W., Houston, S., Zaniewski, J., "Rational Characterization of Pavement Structures Using Deflection Analysis," Arizona State University, Tempe, Arizona, September, 1987.

8. "Pavement Preservation Policy for the Fiscal Years 1991 to 1993 Priority Program," The Arizona Department of Transportation, Phoenix, Arizona, November, 1987.

9. Way, G., "ADOT/AASHTO Design Guide for Pavements," 37th Annual Arizona Conference on Roads and Streets, University of Arizona, Tucson, Arizona, April, 1988.

10. Eisenberg, J., Way, G., Delton, J., Lawson, J., "Overlay Deflection Design Method for Arizona," Arizona Department of Transportation, Phoenix, Arizona, March, 1984.

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INTRODUCTION

MATERIALS SECTION ORGANIZATION

Materials Section, headed by an Assistant State Engineer, is made up of three services; Materials Testing Services, Pavement Services and Geotechnical Services.

MATERIALS TESTING SERVICES

This service is under the direction of the Testing Engineer. It is commonly referred to as the "Central Laboratory", and its primary functions include, but are not limited to, the testing of preliminary engineering samples and construction materials, mix designs, and the standardization of equipment and testing procedures. Testing Services is divided into the Materials Testing Branch and the Quality Assurance Branch.

A. Materials Testing Branch

1. Preliminary Engineering Samples

Samples of materials to be tested are delivered to the central laboratory from the field with the proper description of the material, the source, and instructions for testing.

The material may be from existing highways, for proposed highways, or from proposed material sources. The laboratory performs the required tests and determines the required mix designs. The data is tabulated and a copy of the results are submitted to Pavement Services for analysis and use in pavement design and materials source designation.

Some of the principle tests made are:

a. Sieve Analysis
b. Abrasion
c. Sand Equivalent
d. Moisture-Density
e. "R" Value
f. Plasticity Index
g. pH and Resistivity
h. Specific Gravity and Absorption
i. Bituminous Mix Designs

A more detailed outline of the function and test procedures used may be found in the "Materials Testing Manual."

2. Construction Samples

A list of samples required by the contract specifications is prepared by the central laboratory. Many of the materials are tested in the Project, Area or District Laboratories and the testing of these materials in the Central laboratory is primarily for correlation purposes. Products for which the project, area or district laboratories are not equipped to test are all tested in the Central laboratory. When these samples are submitted to the laboratory the required tests are made and the results tabulated and forwarded to the project and other proper agencies. The purpose of the tests is for acceptance of materials incorporated into the project.

3. Final Record Samples

Final record samples, taken and submitted by the Geotechnical Services core drill unit, are tested as required and reports submitted.

B. Quality Assurance Branch

The principle functions of the Branch are:

1. Visiting the department laboratories and examining the equipment to determine if it conforms with the specifications and reporting the findings.

2. Examining the test procedures used in the department laboratories by review with the supervisor or visual observation of actual tests being performed and reporting any deviation from requirements.

3. Refurbishing, standardizing and calibrating equipment sent in from materials laboratories statewide.

4. Maintaining the Quality Assurance Program and Independent Assurance Sampling Testing Program.

PAVEMENT SERVICES

This service is under the direction of the Pavement Engineer. The service is divided into the Pavement Design Branch and the Pavement Management Branch. Pavement Design is responsible for determining the thickness and quality of material of all layers of the pavement structure. Design thicknesses are determined from the analysis of traffic loading, soil strength, climate and other project specific information. The quality of each layer in terms of its support capability (strength, stability, and durability) is also used to determine the layer thickness. Typical projects considered by Pavement Design include new construction, reconstruction, rehabilitation, overlaying and/or seal coating. Within each project a structural pavement section or sections is determined after analyzing a variety of possible layer materials such as asphaltic concrete, concrete, aggregate base, cement treated base and/or recycling to name a few. In addition, a large number of possible thicknesses of each is also considered. The final design section is incorporated in the plans. All important information pertinent to the pavement design is stated in the "Special Provisions" of the contract specifications.

Pavement Management annually inventories each mile of the 6,000 mile State Highway System for ride roughness and cracking. In addition skid resistance tests are taken as requested and as time permits for inventory. Reports detailing the results of these tests are made available to Pavement Design in order to improve overlay and rehabilitation designs. In addition, the inventory data is used to help derive management standards for highway performance. Given these standards, inventory data and other pertinent data, a Five-Year-Preservation Program is developed. After consultations with each District, this program is taken through the priority planning process by Materials Section, and ultimately becomes the Department's Five-Year-Preservation program. Generally, each preservation project is tested for deflection by Pavement Management. Results of these tests are used by Pavement Design to help determine overlay thickness. Pavement condition data is also collected, as time permits, on the State Airport System.

Due to the type of data collected by Pavement Management considerable use of the data is made by other departmental areas, including Transportation Planning, Maintenance, Development and each District. Occasionally, outside needs require testing for City or County Agencies as well as the Department of Public Safety and Attorney General's Office.

GEOTECHNICAL SERVICES

This service is under the direction of the Geotechnical Engineer. The service is responsible for functions relating to soils and geotechnical engineering (with the exception of research) required for the planning, design, construction and maintenance of roads and bridges under ADOT's jurisdiction. The principle functions include but are not limited to preliminary subsurface investigation of proposed roadways, existing roadways materials sources, structure foundation design, building foundation design, water wells, waste water disposal (leach fields), existing highway problems and problems encountered during construction projects (slope stability, landslides, etc.). The service is also responsible for determining slope ratios and excavation factors.

The investigations may include the following:

a) drilling or excavations
b) sampling
c) instrumentation
d) laboratory testing
e) engineering analysis
f) preparation of reports documenting the investigation, analysis and recommendations.

The service is separated into two branches: The Materials Investigation Branch and the Foundation and Geologic Investigation Branch.

I. Materials Investigation Branch

This branch is supervised by the Senior Materials Investigation Engineer and consists of backhoe crews, core drill crews and the pit development group (a location crew and several office employees.) The backhoe crews perform investigations of proposed roadways, existing roadways and materials sources. The core drill crew performs investigations on existing roadways proposed for rehabilitation projects and obtains final record samples, which are taken to measure thicknesses of various pavement components after they have been placed on the roadway. Final Record samples and measurements are taken at approximate one-mile intervals on each roadway and frontage road, and one on each ramp and crossroad. Records are prepared and reports made to the Federal Highway Administration on all Federal Aid projects.

The Pit Development Group performs a number of functions including:

a) Assist in obtaining licenses on new pits and renewing licenses on existing sources.

b) Locate new sources and recommend extensions of existing sources.

c) Maintain pit files and assist persons desiring to review them.

d) Perform all drafting for Materials Section.

e) Provide Pavement Design Memorandum attachments.

f) Develop preliminary archaeological and environmental information on sites.

g) Assist in processing and filing test results and other information.

h) Assist in providing field crews with various information required for investigations.

2. Foundation and Geologic Investigation Branch

This branch is supervised by a Senior Materials Investigation Engineer and consists of two drill crews. The crews are headed by an Engineering Geologist. The crews perform subsurface investigations including but not limited to:

a) Structure Foundations

b) Building Foundations

c) Water Wells

d) Waste water (leach field) disposal

e) Proposed roadways

f) Quarry Sources

g) Existing highway problems

h) Problems encountered during construction projects

MATERIALS REFERENCE INFORMATION

Each Materials Service develops considerable information in the form of test results, analysis data, reports, memos, drawings, etc. which are stored in various files. Generally all test results ultimately reside in the computer by project number, route and milepost, stationing or pit number. The following special files containing reports and memos are described in greater detail.

MATERIALS PAVEMENT DESIGN FILES

The Materials Pavement Design file is compiled in Materials Pavement Services. This file includes the project number, both Preliminary Engineering and Construction, the project name and termini, and is filed in numerical order according to the preliminary engineering number, regardless of the letter prefix.

The file contains all correspondence, a copy of consultant contract if any, all preliminary engineering data such as subgrade sampling, copies of materials pit logs and test results, all Design Memos and any other data pertinent to the materials pavement design.

GEOTECHNICAL REPORT FILES

These files are prepared and maintained by Geotechnical Services. Generally, all investigations are formalized in report form. The report documents the procedures and method of the investigation, all test results, calculations and includes a summary and recommendations, if appropriate.

The files are maintained in numerical order, with a cross reference to project or pit number. Copies of the reports are also placed in the appropriate pavement design or pit file.

MATERIAL PIT FILES

Once investigation has begun on a materials pit, a pit serial number is assigned to it by Geotechnical Services and a pit file set up. This file contains the original documents prepared in the field; i.e., pit sketch, logs, check sheet, and any field notes that may have been made. It also contains the tabulations of the test results, the aerial photograph, the final pit sketches, the pit license and all correspondence pertaining to the pit and its usage.

CONSTRUCTION FILES

Once a project is advertised for bid, a construction file is compiled by Testing Services by construction project number, and includes a copy of the contract specifications, plans, soil profile, change orders, field and laboratory test results on materials samples, correspondence and any other pertinent data.

GLOSSARY OF TERMS

AGGREGATE
Any hard, inert mineral material used for mixing in graduated fragments. It includes sand, gravel, crushed stone and blast-furnace slag.

a. Coarse aggregate for portland cement concrete - that retained on a No. 8 Sieve.

b. Fine aggregate for portland cement concrete - that passing a 3/8" Sieve and almost entirely passing a No. 4 Sieve, and predominantly retained above the No. 200 Sieve.

ALLIGATOR CRACK
A crack caused by fatigue of the asphaltic concrete surface layer or excessive movement of the underlying layers. Typically alligator cracks form an interconnected network of irregularly shaped polygons varying in size from a few square inches to 1 square foot.

ASPHALT CEMENT
Asphalt that is refined to meet specifications for paving, industrial or special purposes.

ASPHALT CONCRETE (AC)
Asphaltic concrete - A controlled hot mixture of asphalt cement and well-graded aggregate, thoroughly compacted into a uniform dense mass.

ASPHALTIC CONCRETE FRICTION COURSE (ACFC)
A hot mixture of asphalt cement with an open-graded aggregate (20% to 25% air voids) with a maximum size of 3/8 inch used as a surface course.

ASPHALT, EMULSIFIED
A heterogeneous system containing two normally immiscible phases (asphalt cement and water) with a small amount of emulsifying agent. It exists in a liquid state at normal temperatures. Emulsified asphalts may be anionic, with electronegatively charged asphalt globules; or cationic, with electropositively charged asphalt globules, depending upon the emulsifying agent.

ASPHALT EMULSION SLURRY SEAL
A mixture of slow-setting emulsified asphalt, fine aggregate and mineral filler, with water added to produce a slurry consistency.

Asphalt, Liquid

Cutback - Asphalt cement which has been liquefied by blending with petroleum solvents. Upon exposure to atmospheric conditions the dilutents evaporate, leaving the asphalt cement to perform its function. These are further classified as Rapid Curing (RC), Medium Curing (MC), or Slow Curing (SC). Presently only MC is specified by the Department.

Medium Curing (MC) - Composed of asphalt cement and a kerosene-type dilutent of medium volatility.

Asphalt Pavement

Pavement which has a surface course of mineral aggregate coated and cemented together with asphalt cement.

Asphalt Rubber (AR)

A mixture of asphalt cement and rubber used as a crack sealent, binder, or membrane.

Backfill

Material placed to fill an excavated space.

Base Course and Aggregate Base (AB)

The layer of specified material placed on a subbase course or subgrade to support a surface course.

Bituminous Road Mix

A mixture of aggregate and asphalt prepared in place on the roadway.

Bituminous Treated Base (BTB)

A mixture of asphalt and aggregate placed as a base course.

Bleeding (or Flushing)

1. Upward migration of bituminous material resulting in a film of asphalt on the surface.

2. Escape of water from freshly placed concrete commonly observed as an accumulation on a horizontal surface.

Block Crack

A crack caused by shrinkage of the bound surface material. Typically block cracks form an interconnected network of nearly square shapes varying in size from 1 square foot to several square feet.

Blowup

A raising of concrete pavement at the joints caused by compressive stresses.

Borrow Pit (or Site)
The location of suitable material excavated from sources outside the roadway prism, used primarily for embankment (fill).

Cement Treated Base (CTB)
A mixture of well-graded aggregate, cement, and water placed as a base course.

Cement Treated Subgrade (CTS)
A mixture of cement and water with the in-place subgrade.

Clay (Clay Soil)
Fine-textured soil or the fine-grained portion (smaller than 200 microns) of a soil that can be made to exhibit plasticity within a range of water contents and that breaks into clods or lumps when dry.

Compaction
The densification of a soil, base course or surfacing course by means of mechanical manipulation.

Continuously Reinforced Concrete Pavement (CRCP)
Concrete pavement with continuous longitudinal steel reinforcement and no contraction joints. Typically 0.4% by area or more of steel is used.

Corrugations
Regular transverse undulations upon a pavement surface.

Crack
A fissure or open seam not necessarily extending through the body of a material.

Cracking Index
A relative measure of the amount of cracking in an AC surface expressed as percent. Currently done in Arizona by comparison with standard photos of roads for which the amount of cracking has been previously determined.

Culvert
Any structure under the roadway with a clear opening twenty feet or less measured along the center of the roadway.

Density (Unit Weight)
Weight of a material per unit volume.

DRAINAGE COEFFICIENTS
Factors used to modify layer coefficients in flexible pavements or stresses in rigid pavements as a function of how well the pavement structure can handle the adverse effect of water infiltration.

DRAINAGE LAYER
A pavement course with high air voids and high permeability to facilitate the movement of moisture.

DURABILITY (D) CRACKING
A series of closely-spaced cracks adjacent and roughly parallel to concrete pavement joints. Caused by the freezing and thawing of unsound aggregates that have a high moisture content.

EMBANKMENT OR FILL
1. A raised structure, constructed of soil, rock, or aggregate to required line and grade.

2. The material, such as soil, rock or gravel, used in the construction of an embankment structure is also referred to as embankment or fill.

EQUIVALENT SINGLE AXLE LOADS (ESAL'S)
Summation of equivalent 18,000-pound single axle loads used to combine mixed traffic to design traffic for the design period.

EXCAVATION FACTOR
An estimate in terms of percent, of the change in volume of a material when excavated, placed in an embankment section, and compacted to specification density.

EXPANSION JOINT
A joint located to provide for expansion of a rigid slab.

FAULTING
A difference in elevation of two adjacent concrete slabs at a joint. Primarily caused by the traffic-induced movement of base material particles from under one joint edge to under the adjacent joint edge.

FINISHED SUBGRADE ELEVATION
The prepared surface that supports the pavement structure.

FLEXIBLE PAVEMENT
An asphaltic pavement structure with sufficiently low resistance to bending to maintain contact with and distributes loads to the subgrade and depends upon aggregate interlock, particle friction, and cohesion for stability.

FOG SEAL COAT (OR FLUSH COAT)
The application of bituminous material with a sand blotter to an AC surface.

FROST ACTION
Freezing and thawing of moisture in materials and the resultant effects on these materials and on structures of which they are a part or with which they are in contact.

GEOSYNTHETICS (GEOMATRIX, GEOMEMBRANE AND GEOTEXTILE)
Thin fabrics, membranes and composites placed on soils for reinforcement or to retard the migration of clay into the pavement structure or placed between pavement layers for reinforcement or to retard crack propagation from an underlying layer to the one above it.

GRADATION
Proportion of each grain-size category present in a material sample.

GRADE-IN/GRADE-OUT POINTS
The intersection of the natural ground surface with the finished grade line on a highway.

GRANULAR
Material that does not contain more than 35 percent of soil particles which will pass a No. 200 sieve.

GRAVEL
Rounded or semi-rounded particles of rock that will pass a 3 inch U.S. Standard Sieve and be retained on a No. 10 U.S. Standard sieve.

GRINDING
The removal of the top of a pavement surface to improve ride and skid resistance.

GROOVING
Producing grooves in a concrete pavement surface to improve frictional characteristics.

GROUND COMPACTION
The compensation, in feet, for the reduction of original ground elevation caused by the construction operation.

HEAVE
Upward movement of soil caused by expansion or displacement resulting from phenomena such as moisture absorption, removal of overburden, driving of piles, frost action, etc.

Hydrophobic Aggregate
An aggregate having little or no affinity for water compared to bitumen.

Hydrophyllic Aggregate
An aggregate having a great affinity for water compared to bitumen.

Jointed Concrete Pavement (JCP)
Concrete pavements that contain no reinforcing steel for crack control. Load transfer devices may be placed at the joints. Slabs are usually 13 feet to 17 feet long.

Jointed Reinforced Concrete Pavement (JRCP)
Concrete pavement with some reinforcing steel between joints; dowels at transverse joints and longer slabs than JCP.

Joint Sealant
A material used as a filler in concrete pavement joints to prevent infiltration of water, soil and other fine particles.

Layer Coefficient (a_1, a_2, a_3)
The empirical relationship between structural number (SN) and layer thickness which expresses the relative ability of a material to function as a structural component of the pavement.

Lean Concrete Base (LCB)
A mixture of aggregate, cement, and water used directly under concrete pavement. Has a lower modulus of rupture than the concrete pavement, and a higher compressive strength than cement treated base.

Leveling Course (LC)
A course of variable thickness used to eliminate irregularities in an existing surface.

Life cycle Cost (LCC)
An economic estimate of the cost to provide a serviceable pavement over the expected life of a pavement; usually 20 to 40 years.

Liquid Limit (LL)

1. The moisture content which is the boundary between the liquid and plastic states for the minus No. 40 fraction of a soil.

2. That moisture content at which a soil fraction will close a standard groove for a length of 1/2 inch when subjected to 25 blows in a liquid limit device.

Load Transfer Device
A mechanical means designed to carry loads across a joint in a rigid slab.

Longitudinal Joint
A joint normally placed between traffic lanes in rigid pavements to control longitudinal cracking.

Milling
The removal of a portion of the pavement surfacing with a milling machine.

Mineral Aggregate (MA)
Aggregate to be mixed with asphalt cement to produce an asphaltic concrete.

Modulus of Rupture (Sc)
The flexural strength at failure of concrete beams.

Modulus of Subgrade Reaction (k)
Westergaard's modulus of subgrade reaction for use in rigid pavement design (the load in pounds per square inch on a loaded area of the roadbed soil or subbase divided by the deflection in inches of the roadbed soil or subbase, psi/in.).

Moisture Content
1. The proportion of moisture in any material, expressed as a percent of the dry weight.

2. Optimum Moisture Content. The percentage of moisture at which the greatest density of a particular soil can be obtained through compaction by a specified method.

Overburden
Material of inferior quality which overlies material of desired quality and which must be removed to obtain the desired material.

Overlay
One or more courses of asphaltic concrete construction placed on an existing pavement.

Passing Lane
The left lane of a two lane roadway with both lanes going in the same direction.

Pavement Performance
The trend of serviceability with load applications.

PAVEMENT STRUCTURE
The combination of subbase, base course, and surface course placed on a subgrade to support the traffic load and distribute it to the subgrade.

PERMEABILITY
That property of a material which permits a liquid to flow through its pores or interstices.

pH
An index of the acidity or alkalinity of a soil in terms of the logarithm of the reciprocal of the hydrogen ion concentration; e.g., a pH indication of less than 7.0 is acidic, whereas a reading of more than 7.0 is alkaline.

PLASTICITY
The property of a soil which allows it to be deformed beyond the point of elastic recovery without cracking or appreciable volume change.

PLASTICITY INDEX (PI)
Numerical difference between the liquid limit and the plastic limit. This is an indication of the clay content of a soil or aggregate.

PLASTIC LIMIT (PL)

1. The water content corresponding to the transition point between the plastic and semi-solid states of consistency of a soil.

2. Water content at which a soil will just begin to crumble when rolled into a thread about 1/8 inch in diameter.

POLISHED AGGREGATE
The aggregate in a pavement surface worn smooth by traffic.

POROSITY
The ratio, expressed in percent, of the volume of void space (pores) of a material to the total volume of its mass.

PORTLAND CEMENT CONCRETE PAVEMENT (PCCP)
A mixture of aggregate, cement and water that forms a very stiff and rigid pavement.

PRESENT SERVICEABILITY INDEX (PSI)
An index number based on roughness (slope variance), cracking, patching and rutting.

PRESENT SERVICEABILITY RATING (PSR)
A road users opinion, expressed as number between 0 to 5, of a roads ride quality. Higher numbers indicate higher serviceability (smoother ride). Often used in lieu of PSI.

PRESTRESSED CONCRETE PAVEMENT (PCP)
Portland cement concrete pavement containing high-tensile strength wire which is used to apply tensile stresses to the pavement slabs or panels.

PRIME COAT
An application of a low viscosity liquid bituminous material to coat and bind particles preparatory to placing a base or surface course. Generally applied to an aggregate material (AB or ASB).

PROFILE (AND PROFILE GRADE)
The trace of a vertical plane intersecting the top surface of the proposed wearing surface, usually along the longitudinal centerline of the roadbed. May mean either the elevation or the gradient of the trace depending on the context.

PROJECT
The specific section of the highway and all construction to be performed under the contract.

PUMPING
The ejection of foundation soil through joints or cracks, or along edges of rigid slabs, due to vertical movements under traffic.

R-VALUE
A confined compression test for determining strength of subgrade materials. Used to derive the subgrade modulus (M_r) used in the AASHTO equation for pavement design.

RANDOM CRACK
A crack that is not a longitudinal or transverse crack and that has little or no interconnection with other cracks. May be caused by movement of the pavement structure and/or subgrade.

RAVELLING
Progressive disintegration of a pavement surface through the loss of aggregate particles.

RECONSTRUCTION
The improvement of an existing roadway section by substantially removing and replacing the major portion of the base and surfacing materials.

Recycling (Pavement)
The re-use of paving materials in a new pavement structure.

Reflective Cracking
Cracking in a pavement surface layer caused by the high stresses from movements of a cracked underlying layer.

Rehabilitation
The improvement of an existing roadway surface by improving the existing surface or placement of additional pavement layers.

Relative Density
The density of a subgrade material or pavement component, after compactive efforts, expressed in percentage of the density obtained by specific laboratory tests performed on the same material.

Reliability
The probability that a pavement will perform satisfactorily for the design period.

Resistivity
A measure of a substance's resistance to the flow of electricity through it, expressed in ohm-centimeters. Used on soils to determine coating requirements for new pipe and used to determine the extent of corrosion of existing metal pipes.

Rigid Pavement
Pavement structure consisting of a portland cement concrete slab of relatively high bending resistance.

RipRap
Rock used for the protection of embankments, cut slopes, etc., against agents of erosion, primarily water.

Roadbed
The prepared layer under the pavement structure.

Roadway
That portion of the right-of-way required for construction, limited by the outside edges of slopes, including ditches, channels and all structures pertaining to the work.

Rock
Natural solid mineral matter occurring in large masses or fragments.

Rutting
Formation of longitudinal depressions by the displacement of soils or surfaces under traffic.

SAMPLE
A small portion of a large quantity of material used for testing purposes to estimate the engineering properties of the material.

SAND
Particles of rock that will pass the No. 4 sieve and be retained above the No. 200 sieve.

SATURATED-SURFACE-DRY (SSD)
Term used to describe the condition of an aggregate in which the pores of all the particles are completely filled with water, but their surfaces are free from moisture.

SCALING
A delamination of a thin portion of the top of portland cement concrete.

SEAL COAT (SC)
A thin treatment consisting of bituminous material, usually with cover material aggregate, applied to a surface course. The term includes but is not limited to sand seal, chip seal, slurry seal, and fog seal.

SEASONAL VARIATION FACTOR (SVF)
An index number that ranges from 0.0 to 5.0 to represent the climatic and environmental conditions at a pavement location. The number becomes larger with increasing severity of climate and environment.

SERVICEABILITY
The ability of a pavement to serve the automobile and truck traffic using it.

SETTLEMENT
The reduction in elevation of pavement or structures due to compression of underlying soils.

SHOULDER
The portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use and for lateral support of base and surface courses.

SHOVING
Displacement of flexible pavement caused by high shear stresses.

SILT
Material passing the No. 200 sieve that is non-plastic or very slightly plastic and that exhibits little or no strength when dry.

SKID RESISTANCE
The frictional force between a locked tire and a pavement, which resists motion.

SOIL
Sediments or other unconsolidated accumulations of solid particles produced by the chemical and physical disintegration of rocks, and which may contain organic matter.

SOIL PROFILE
The vertical section of a soil showing the nature and sequence of the layers.

SOUNDNESS
Resistance to both physical and chemical deterioration.

SPALLING
Peeling away of a surface, particularly portland cement concrete.

SPECIAL PROVISIONS
Additions and revisions to the standard and supplemental specifications covering conditions and requirements peculiar to an individual project.

SPECIFICATIONS
The compilation of provisions and requirements for the performance of prescribed work.

STABILITY
Property of a material which enables it to retain its other essential characteristics throughout the range of conditions expected in service.

STANDARD PLANS
Drawings approved for repetitive use, showing details to be used where appropriate. (C-Standards)

STANDARD SPECIFICATIONS
Specifications approved for general application and repetitive use.

STONE
Crushed or naturally angular particles of rock that will pass a 3 inch sieve and be retained above a No. 10 sieve.

STRESS-ABSORBING MEMBRANE INTERLAYER (SAMI)
A low-stiffness mixture of asphalt cement, rubber, and mineral aggregate placed between layers of pavement to retard the transfer of stresses between the layers.

Stripping
Separation of bituminous films from aggregate particles due to presence of moisture.

Structural Number (SN)
A number expressing the required structural strength of a pavement structure for a given combination of subgrade modulus, total equivalent 18-kip single-axle loads, terminal serviceability index, and seasonal variation factor. The required SN must be converted to actual thickness of surfacing, base, and subbase by means of appropriate layer coefficients representing the relative strength of the material to be used for each layer.

Structures
Bridges, culverts, catch basins, drop inlets, retaining walls, cribbing, manholes, endwalls, buildings, sewers, service pipes, underdrains, foundation drains and other features which may be encountered in the work and not otherwise classed herein.

Subbase Course (ASB)
A layer of specified material of designed thickness placed on a subgrade to support a base course. In rigid pavement, the base course.

Subgrade (SG)
The roadbed materials beneath the pavement structure.

Supplemental Specifications
Approved additions and revisions to the Standard Specifications.

Surface Course
One or more layers of a pavement structure designed to accommodate the traffic load, the top layer of which resists skidding, traffic abrasion, and the disintegrating effects of climate.

Surface Recycling
Recycling an existing pavement surface by heating, scarifying, remixing, releveling, compacting and rejuvenating with an emulsified recycling agent.

Surface Treatments
Fog coats, fog seal coats, and flush coats.

Tack Coat (TC)
An application of bituminous material to a surface to provide bond with a subsequent course.

Test Hole
A hole dug for the purpose of taking a sample. Test holes may be dug in the ground of proposed construction sites, in materials pits or in existing highways.

Tie Bars
Reinforcement steel placed in concrete pavements to provide load transfer at longitudinal joints.

Top Soil (TS)
Usually the upper 6 inches of native soil and that portion used in dressing and landscaping earth slopes.

Transverse Crack
A crack approximately perpendicular to the centerline caused by longitudinal shortening of the bound surface layer; sometimes called temperature cracks as the shortening is often caused by contraction from temperature changes. Typically, transverse cracks extend across the full width of the pavement.

Travel Lane
When used to distinguish between passing lane and travel lane, the travel lane is the right lane of a two lane roadway with both lanes going in the same direction. Usually both the passing lane and travel lane are considered travel lanes with the passing lane considered the left travel lane and the travel lane considered to be the right travel lane.

Void
Space in a mass not occupied by solid mineral matter; it may be occupied by air, water, or other fluids.

Warping
Deviation of pavement surface from original profile caused by temperature and moisture differentials.

CHAPTER 1

GEOTECHNICAL INVESTIGATION PROCEDURES

100.00 INTRODUCTION

This chapter presents the investigation procedures of the Arizona Department of Transportation. This chapter sets forth minimum geotechnical requirements/standards to be accomplished and documented in a geotechnical report. Geotechnical Services has prepared "Guidelines for Geotechnical Investigation and Geotechnical Report Presentation", for use on all ADOT related projects. These guidelines are included in this manual as APPENDIX C. They supplement the information herein, and contain more comprehensive requirements for subsurface investigations. All geotechnical investigations started after December 31, 1991 will be expected to follow these guidelines and reports will be reviewed accordingly.

101.00 SOURCES OF INFORMATION FOR OFFICE SURVEY

To be effectively carried out, the field survey should be preceded by a thorough study of the project in the office, which should include the following sources of supporting information.

101.01 LOCATION AND DESIGN SECTIONS

Project maps, profiles, and notes of the survey are available from Location Section. A "typical section" showing a generalized cross section of the roadway prism is distributed by Plans Services. Generally, preliminary construction plans are not available at the time the materials investigation is performed. If there are no preliminary plans available, the location map and profile can be used for planning and conducting the geotechnical investigation. The location map shows the horizontal alignment and the profile shows the vertical alignment of the finished gradeline and the native ground in the vertical plane through the roadway centerline. Plans show the horizontal alignment and the profile on the same sheet. There is more survey information on the location map than there is on the plans; however, preliminary plan profiles contain more information than the original profile. For instance, there may be preliminary earthwork data on the profile of the preliminary construction plans. Strategic location of subgrade soil samples can be recommended in the office through intelligent use of plans, maps, and profiles.

101.02 PHOTOGRAMMETRY AND MAPPING

Materials Section has several types of aerial photographs available on file. There is a complete set of Army Map Service (A.M.S.) photographs with an accompanying index. These photographs were taken in 1954 and range in scale from 1:50000 to 1:60000.

There are photographs that follow the alignment of the existing primary and interstate highways at a scale of 1:24000. The primary highway photographs were taken in 1964 and the interstate in 1975.

Also available are photographs of many of the materials pits that were taken at an average scale of 1:6000. These are being taken on a continuing basis and their primary use would be for pit status, especially ownership boundaries and remaining materials quantities in pits.

Photogrammetry and Mapping Services has photo coverage of many areas of the state. Scales may range from 1:3000 to 1:6000. In the compilation of county maps they are obtaining coverage at a scale of 1:60000 over most of the areas.

Special problem areas may require that aerial photography be taken before the investigation of a project can proceed. This might be the case in extremely mountainous areas.

Photogrammetry and Mapping Services will supply special aerial photography on request. Any special request should be made as far in advance as possible so that the work may be scheduled to coordinate with their other work.

101.03 EARTHWORK COMPUTATIONS (PLANS SERVICES)

If preliminary earthwork computations have been accomplished, a soil profile, cross sections, earthwork data, and a mass diagram will be available from Plans Services. These are invaluable sources of information during the office survey and the field survey.

101.04 MATERIALS INVENTORY

A Materials Inventory of the state has been compiled by the Materials Section. Separate inventories have been prepared for each county. These inventories contain generalized geologic information and geologic maps, the location of materials pits and quarries and the engineering properties of the pit materials with representative laboratory test data. They also contain land status maps which show the ownership or jurisdictional boundaries within the counties. The Inventory is valuable in locating existing and possible future materials sources and determining land status.

101.05 PREVIOUS PROJECTS

Information on file in Materials Section and Engineering Records Services from prior materials investigations and as-built construction project records can be beneficial. As-built plans are essential for investigation of existing roadways for overlay design.

101.06 U.S. GEOLOGICAL SURVEY

Aerial photography is available from the U.S. Geological Survey. Most of the film available is black and white panchromatic. For some purposes, color films or a false color film, such as infrared have been made and will furnish a larger amount of information. Another film of limited usage is black and white infrared.

U.S.G.S. topographic maps are especially valuable aids for location of Public Land Survey monuments. The Materials Section generally updates its file of these maps every three years. The scale of these maps is either 1:24000 or 1:62500.

Rock formations and soil types can be identified from geologic maps that are published by the U.S.G.S. and the State Geological Survey.

101.07 BUREAU OF MINES

The Arizona Bureau of Mines publishes Arizona geologic maps that are helpful in the location of possible aggregate sources.

101.08 SOIL CONSERVATION SERVICE

The Soil Conservation Service of the United States Department of Agriculture has conducted soil surveys that are portrayed on soil maps. These maps have limited engineering value because of the shallow depth explored.

101.09 ARIZONA LAND DEPARTMENT

Well-drilling logs are now required by the State from drilling contractors. These logs are on file at a number of agencies. The Arizona Land Office and the U.S.G.S. have the most complete records. Reports, papers, and technical publications may be researched to obtain detailed information about an area.

101.10 RIGHT-OF-WAY SECTION

Right of entry is necessary prior to entering and doing any work upon any property. The preliminary office survey should include a check with the Right-of-Way Section to be certain that right of entry has been obtained for materials investigation before any field work is begun.

101.11 LAND USAGE

A check should be made to determine the current and proposed land usage so that materials pits may be properly located and will not interfere with proposed usage or reduce land values.

101.12 ROADSIDE DEVELOPMENT SERVICES

Roadside Development Services provides information pertaining to location of rest areas and prepares plans for their design. This service also may request information from the Materials Section as to sources of water or possible well sites for water supply for rest areas.

101.13 GAME AND FISH DEPARTMENT

The Game and Fish Department provides information pertaining to their proposed use of areas involved in construction, access roads that may be required, and specific requirements on land under their control.

102.00 CENTERLINE INVESTIGATION OF NEW CONSTRUCTION AND RECONSTRUCTION PROJECTS

The investigation of the centerline of a new construction or reconstruction project should include a thorough exploration and sampling of the subgrade, the estimation of shrink or swell factors and compensation for ground compaction, the determination of appropriate cut and fill slopes, recommendations for cut-widening, investigation of water conditions and supplies, investigation of possible slide conditions, and an estimate of necessary clearing.

To properly record observations and data during the investigation, a working soil profile should be developed and pertinent information recorded on this profile. The base document for the working soil profile should be the final centerline profile provided for ADOT by the Location Section.

On reconstruction projects, the procedure can be simplified as no major reconnaissance is needed and sample locations will generally follow the existing centerline. Test hole excavation is also greatly simplified since most holes will be fairly shallow.

102.01 SUBGRADE EXPLORATION AND SAMPLING

The first phase of the subgrade exploration and sampling should be a reconnaissance trip by the crew supervisor, and as many crewmen as may be necessary, equipped with plans, maps, photographs, and other information that has been provided. This trip should include an on-site review of the entire project to enable the supervisor to familiarize himself with the terrain, the location of the centerline, and to note anything that might help in efficiently organizing and executing the work. Each cut and fill section should be studied, noting any possible problem conditions that may develop (possible slide conditions, saturated soils, etc.). Anticipated soils or geological problems should be discussed with the Geotechnical Investigation Engineer at this time so that drilling or special studies, if required, can be started at this stage.

102.02 SAMPLE LOCATIONS

The supervisor should then proceed with the location of proposed test holes. The location of the holes should be determined by an on-site study of the proposed centerline profile and cross sections. Where the terrain has no appreciable side slope and is generally cut-and-fill the holes should be located on the centerline. One hole should be located at each of the "grade in" and "grade out" points. One hole should be located approximately 100 feet in from each of the "grade in" and "grade out" holes and from 100 to 300 feet apart throughout the balance of the cut as required to produce samples that will reasonably represent the material in the cut.

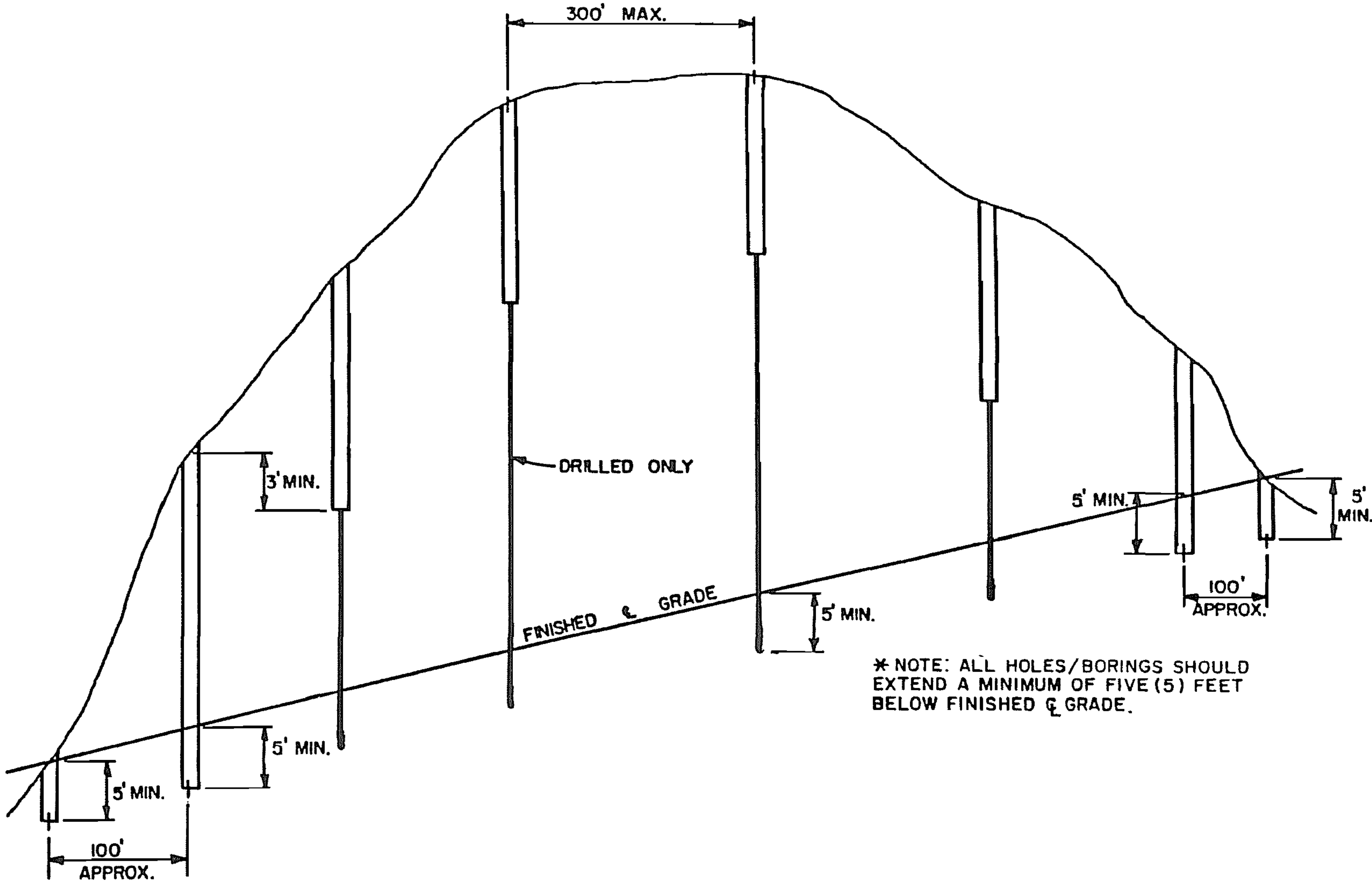
The width of the entire roadway section should be considered when locating subgrade test holes. The profile represents only the relationship of the centerline finished grade with the natural ground line. One or both of the edges of the roadway section may be cutting into a sidehill even though the centerline profile shows a fill section. The crew supervisor should refer to the cross-sections on cuts that involve sidehill excavation, see Figure 102.02-3. Levels should be run to determine the approximate extent of the cut into the sidehill and fill; additional test holes should be located, offset from the centerline, to produce samples that will reasonably represent the material. The distance right or left of centerline, together with the elevation of the top of the test hole, should be recorded on the sample log and on the soil profile. The estimated uniformity of the material would determine the frequency of sampling. (See Figures 102.02-1, 102.02-2 and 102.02-3).

Once the holes are located, they should be marked on the profile and numbered consecutively. A stake should then be placed at each location. This stake should have a metal tag attached identifying the number of the hole, the station, and the depth to which it is to be dug.

The depth of the holes should be determined by the supervisor if they have not previously been designated on the profile sheet. Where it is impracticable to excavate holes to the desired depths, drill holes should be placed to indicate the nature of the material below the excavated depth.

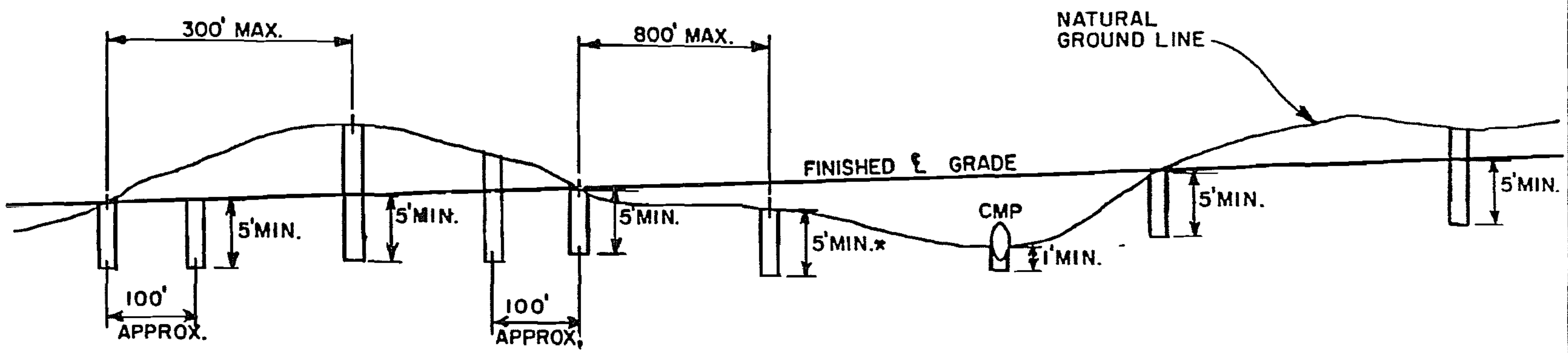
At the "grade out" and "grade in" points, holes should be excavated to a minimum of five feet below finished grade. The remainder of the holes should extend to a depth at least 5 feet below finished grade. On sections where the depth of the cut is quite large, the holes on the lower slopes should extend 5 feet below the finished grade and the other holes should extend at least 3 feet below the top of the adjacent lower hole elevation (see Figure 102.02-1). If the subgrade elevation is out of reach of the usual equipment available to the crew, the Geotechnical Investigation Engineer should be contacted and a decision on whether to use a drill rig will be made.

The crew supervisor should carefully note any evidence of change in the characteristics of the material in each cut section and place the test holes at the proper locations and to the proper depths to reasonably represent all of the various types of material that may be encountered in each cut section. On all embankment sections test holes should be placed, approximately at the point of maximum fill height no more than



TYPICAL LOCATION OF HOLES IN CUTS GREATER THAN TEN (10) FEET IN HEIGHT

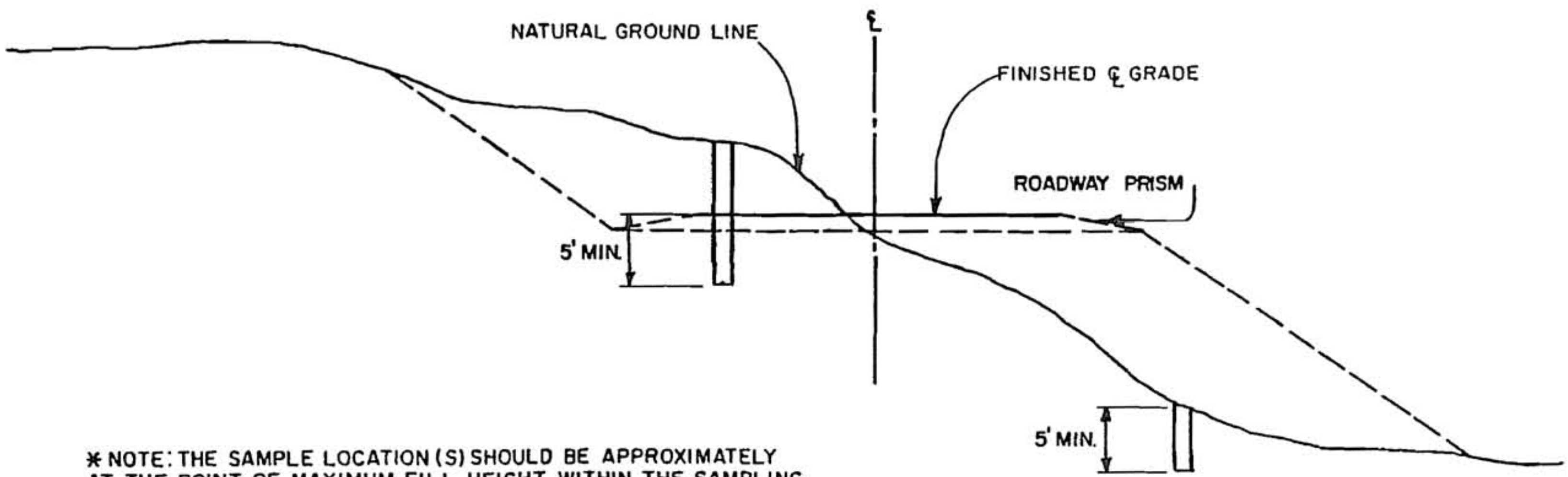
FIGURE 102.02-1



*NOTE: THE SAMPLE LOCATION (S) SHOULD BE APPROXIMATELY AT THE POINT OF MAXIMUM FILL HEIGHT WITHIN THE SAMPLING SECTION(S). IF THE FILL IS GREATER THAN 20 FEET IN DEPTH, THE HOLE/BORING SHOULD EXTEND TO A DEPTH OF THE HEIGHT OF THE FILL OR TO FIRM MATERIAL.

TYPICAL LOCATION OF HOLES IN ALL FILLS AND IN CUTS LESS THAN TEN (10) FEET IN HEIGHT

FIGURE 102.02-2



* NOTE: THE SAMPLE LOCATION (S) SHOULD BE APPROXIMATELY AT THE POINT OF MAXIMUM FILL HEIGHT WITHIN THE SAMPLING SECTION(S). IF THE FILL IS GREATER THAN 20 FEET IN DEPTH, THE HOLE/BORING SHOULD EXTEND TO A DEPTH OF THE HEIGHT OF THE FILL OR TO FIRM MATERIAL.

TYPICAL LOCATION OF OFFSET HOLES

FIGURE 102.02-3

800 feet apart and dug to a depth of at least 5 feet below the ground line or deeper (see Figure 102.02-2 and 102.02-3), so that they may reasonably represent the various types of material that may be underlying each embankment section.

102.03 EXCAVATION

All holes located should be excavated. Excavation may be done by hand shovel or mechanical equipment, whichever may be the most expedient. It may, in some cases, not be practicable to build an access road into a test hole location. Wherever such a situation exists it may be necessary to excavate by hand shovel.

The excavation should be done in a neat manner with the holes no larger than necessary to provide access for observation and sampling. All holes should be backsloped to the proper Occupational Safety and Health Administration standard. In rock excavation where drilling and blasting may be necessary, all blasting should be done in accordance with approved safety requirements. The test holes should be blasted and excavated to a depth that will indicate the nature of the material, and provide access for visual observation and sampling. A drill hole should then be placed in the bottom of the hole and extended to the required depth to confirm uniformity of the material.

Holes which are to be left open for an extended period of time may present a possible hazard and should be fenced or covered in a manner to make then reasonably inaccessible.

The Crew Supervisor should make a visual observation of each hole, make the log of materials and take the samples in accordance with Section 106.00 Sampling Techniques. If the material is stratified, each stratum should be sampled.

102.04 R-VALUE AND SPECIAL SAMPLES

After the test holes have been excavated and the standard samples have been taken as per Section 106.00, the Crew Supervisor should again go over the centerline and, utilizing the open test holes, determine what he considers to be the control condition in each cut or at grade section for R-value sampling and to ensure that each material type has been represented. The Crew Supervisor shall then obtain a 75 to 100 pound R-value sample (depending on rock content) from each site. In some larger cut sections it may be necessary to obtain more than one sample if enough change is noted in the materials within the cut. The Crew Supervisor and the Geotechnical Investigation Engineer will then review each test hole location and give special attention to the R-value sample locations. If the Geotechnical Investigation Engineer desires different (or additional) samples, he shall so direct. Upon completion of the review, the supervisor will proceed with shipment of the samples to the central laboratory.

The minimum number of R-values required is as follows:

1. Projects, sections of roadway, including intersection improvements, turning bays, bridge approaches, etc., where the total length under construction is less than 1000 feet shall be represented by a minimum of 2 R-value samples. If the materials vary, additional tests may be required.

2. On projects where the total length is between 1000 feet and 5000 feet, a minimum of 3 R-value samples shall be obtained, with at least 2 R-values per major soil type (i.e. 3 major soil types - obtain 6 R-values).

3. On projects where the total length is between 5000 and 16000 feet, a minimum of 4 R-value samples shall be obtained, with at least 2 R-values per major soil type.

4. On projects longer than 16000 feet, a minimum of 2 R-value samples per mile shall be obtained, with at least 2 R-values for each major soil type (i.e. - 5.5 mile project, minimum 11 R-values).

It is stressed that the above are minimal requirements. The responsible engineer should analyze each project to determine actual sample locations and frequency.

One test hole should be placed at each corrugated metal pipe location shown on the plans or profile. If these locations are not shown, the test holes should be placed in any wash or drainage where a pipe might be required. The test hole should be located in the stream bed area and should be staked and marked in the same manner as other test holes. They should be dug to a minimum depth of 3 feet, logged and sampled. If the material in the adjacent drainage channel appears to be of a type that could be abrasive, this should be noted on the working profile. Existing pipe should be visually inspected by the supervisor. Pipe type, coating and condition should be noted on the working soil profile.

The Crew Supervisor should carefully note the type of materials exposed by test holes in the various cut sections, and if it appears that there is a possibility that the excavated materials will be satisfactory for the production of sub-base, base, or surfacing materials, he should report the possibility to the home office. A Geotechnical Investigation Engineer should then visit the site and make a decision regarding the use of the excavated material for base or surfacing materials. If the decision is affirmative, the cut section or sections involved should then be prospected in accordance with the requirements for Materials Pits (Section 104.00).

102.05 EXCAVATION FACTORS AND GROUND COMPACTION FACTORS

As the centerline investigation progresses, the Crew Supervisor should carefully observe each test hole, noting the characteristics of the materials, the amount of overburden, the apparent density of the material in place and make a detailed evaluation of all his observations so that he may estimate excavation factors for the full length of the project. The estimation of excavation factors should be based on experienced judgement, careful observation of the test holes, the ease or difficulty of excavation and by comparison with similar type material from previous projects where the factors have been established. In-place density tests on soil materials will be required, as noted in the following paragraph. The nature of the terrain should also be observed and the possibility of maintaining true lines, grades and slopes should be considered. These factors should then be indicated on the working profile. All stations where there will be excavation should be represented by an excavation factor.

After the estimation of excavation factors, the supervisor should determine the locations for density sampling. It is the intent that this testing be conducted at the same locations selected for classification and soil support determinations. A minimum of 3 locations for each estimated change in excavation factor in soil material shall be tested for an in-place density in accordance with Arizona Test Method 231. If the material within the limits of the estimated factor consists of more than one major soil type, additional tests should be performed to assure that all types are adequately represented. Areas of obvious swell materials will not require in-place density testing.

Each test hole location selected shall be tested at every change in material type. However, if the material within the test hole is the same throughout the full depth, an in-place density shall be performed within each 6-ft. depth. For example, assuming that the in-place testing will be conducted on a 6 inch depth, a 12 foot cut of one material type will require in-place testing at 2 depths; one plan could consist of conducting tests of 0-6" and 6'-6'6".

At each location where in-place density testing is performed, a sample for laboratory density determination shall be obtained and submitted for testing in accordance with Arizona Test Method 225 or 226.

On projects where the estimated quantity of roadway excavation is 10,000 cubic yards or more, a minimum of 4 locations plus at least 1 additional location for each additional 25,000 c.y. should be tested, regardless of soil uniformity.

The Crew Supervisor should recommend the most likely manner in which the excavation may be accomplished and indicate on the working profile whether it can be dug, ripped or the amount of blasting that may be required during construction.

In addition, an estimate should be made showing the amount of ground compaction (in feet) that should be compensated for. In preparing this estimate, the amount of clearing and grubbing should be taken into consideration because of the loss of material in these operations. The surface of the existing ground should be carefully studied and then the estimate made. Estimated compaction factors should be noted on the working profile covering all embankment stations.

These excavation factors, excavation method and ground compaction estimates should be checked and approved by a Geotechnical Investigation Engineer during the field review. Any changes should be noted on the working profile and initialed and dated by the Geotechnical Investigation Engineer.

102.06 SLOPES

The Crew Supervisor should carefully observe all materials that will be excavated from cut sections and placed in embankment sections and estimate whether the slopes designated in the "ARIZONA DEPARTMENT OF TRANSPORTATION CONSTRUCTION DETAILS" (C-Standards) should be applied to the project. If the nature of the material appears competent and a steeper slope likely may be used, or if it is a material that will not stand on the standard slopes, he should so recommend and note on the working profile. In snow country, consideration should be given for flatter slopes to "daylight" the cut and allow sunlight exposure to the roadway surface. All stations shall have slopes designated.

The estimate of slopes should be checked and approved by a Geotechnical Investigation Engineer during the field review. The Geotechnical Investigation Engineer may determine that testing and further analysis are necessary. Any changes should be noted on the working profile and signed and dated by the Geotechnical Investigation Engineer.

102.07 CUT WIDENING RECOMMENDATIONS

The Crew Supervisor should study the terrain and note on the working profile any area where the cuts should be widened beyond the standard widths. Some conditions that should be considered are: possible snow pack that might damage the subgrade; additional room needed for storage of snow or falling rocks; erosion control requirements; storage of cut slough or slides; etc.

These recommendations should be checked and approved by a Geotechnical Investigation Engineer when he reviews the project with the Crew Supervisor and if there are differences of opinion, they should be discussed on the site and a final decision made. Any changes should be noted on the working profile, signed and dated by the Geotechnical Investigation Engineer.

102.08 INVESTIGATION OF TROUBLESOME SURFACE WATER, SPRINGS, AND SUBSURFACE WATER

The Crew Supervisor should carefully examine the project site and surrounding areas to see if there are any possible stream flows, springs, or underground water that might cause problems during construction or damage to the finished roadway and note such conditions on the working profile. Such conditions should be called to the attention of the Geotechnical Investigation Engineer.

102.09 INVESTIGATION OF POSSIBLE SLIDE CONDITIONS

The crew supervisor should carefully examine all cut sections to ascertain if any incipient slide conditions are indicated and note such locations on the working profile. Such conditions should be called to the attention of the Geotechnical Investigation Engineer, who will further investigate and decide upon the appropriate action.

102.10 CULTURAL AND PALEOTOLOGICAL RESOURCES

Any evidence of Indian ruins, historic sites or fossils on or near the proposed roadway are to be reported to the Geotechnical Investigation Engineer who will transmit the information to the proper authority for investigation. No field work shall be done on such sites without prior clearance.

103.00 INVESTIGATION FOR REHABILITATION OF EXISTING ROADWAY

Instructions in this section are to be used when there are no substantial grade or alignment changes and the project will consist of work on only the existing base and/or surfacing course. It includes such features as overlays, recycling, etc. Where there are substantial grade changes, line changes or substantial widening beyond the existing roadway refer to 102.00.

103.01 SAMPLING EXISTING ROADWAYS

At intervals of approximately 2500 feet (or less as designated by the Geotechnical Investigation Engineer), holes should be placed through the pavement structure, to the top of the subgrade. There should be at least one hole in each pavement typical section and additional holes should be placed in areas that are obviously in a distressed condition. The thickness of the surface course(s) should be measured and recorded and samples taken. Special samples of the existing asphaltic concrete may be required on proposed recycling projects. The Crew Supervisor will be informed when these type samples are needed.

For recycling analysis and design, at least three 6" cores (or equivalent quantity) at each selected sampling location should be obtained. In no case should less than 12 locations in the right wheel path be sampled, uniformly spaced throughout the project, in order to provide enough material for a recycle mix design.

103.02 OBSERVATIONS OF EXISTING ROADWAYS

The investigation should include observations of all conditions that might need consideration in an improvement project. The Crew Supervisor should provide notes concerning the pavement condition where the samples are taken.

A. Pavement Conditions

The pavement should be inspected closely and the condition recorded, with particular emphasis on the nature and extent of cracking, potholing, rutting or any other form of deterioration. A general description of the pavement condition should be written, with notes on the degree of deterioration at specific locations. For example: Milepost 100, cracking - small longitudinal and some transverse cracks up to 1/4"; rutting 1/4" in right wheel path; no pot holes, etc. Milepost 100.5, cracking severe, alligator cracking up to 3/4" with considerable spalling; rutting 1/2" in both wheel tracks; extensive patching, etc.

B. Roadside Conditions

Any roadside conditions that need attention should be noted and recorded. This may include, but is not limited to, the condition of the shoulders, poor drainage areas, erosion problems, etc.

C. Moisture

Any excessive moisture or evidence of previous moisture conditions should be noted and recorded.

D. Other

Any other conditions that might influence the design or construction of the project should be noted and recorded.

104.00 MATERIALS PITS

Available sources of materials to be incorporated in construction projects will sometimes be specified. Locating, prospecting, sampling and testing of these sources and the preparation and presentation of the test data developed should be made available for materials design, estimating and for the contractor's use in bidding.

Before any field work begins, the crew supervisor should study the material provided for him from the office survey, such as maps, aerial photographs, previous projects in the area, etc., to determine in advance what might be the most likely acceptable locations.

The Crew Supervisor, with his crew, should then make a reconnaissance trip and visually check the prospective sources.

There are several factors that result in restrictions on the location of a material pit. The major ones are:

A. A pit should be located no closer than 1500 feet from the roadway unless it is concealed from view and should not be located on the side of a hill visible from the roadway where it will create an unsightly scar, regardless of the distance from the roadway.

B. Wherever possible, pits in waterways should be located upstream from the roadway. If a pit must be located downstream careful consideration should be given to the scouring and erosion possibilities and the pit should be located in such a manner that it will cause the least trouble.

C. Materials sources located in floodplains should not be within one mile upstream and two miles downstream of any highway structure.

D. Materials pits should not be located where the excavation or haul road crosses any utility, either underground or overhead. The utility location should be marked with a 4 inch by 4 inch by 36 inch yellow post, placed 18 inches into the ground.

E. Any evidence of Indian ruins, historic sites or fossils on or near the proposed pit area are to be reported to the Geotechnical Investigation Engineer. No further work shall be done until notification.

104.01 RIGHT-OF-WAY REQUIREMENTS

Right-of-Way for materials sources usually is obtained from one or more of three sources: privately owned land, State owned land or Federally owned land.

A. Privately Owned Land

A Right-of-Way Acquisition Agent may work directly with the field crew and complete the acquisition of the license prior to beginning actual work on the site.

When it appears that suitable material is available, the Crew Supervisor should first attempt to contact the property owner and obtain his permission to enter upon the land. A description of the property sufficient to do a title search can be determined. The legal description of the property, together with the name of the owner when obtainable, should be reported to the Geotechnical Investigation Engineer. The Crew Supervisor should not proceed with the materials investigation until the license has been obtained or permission to waive this requirement has been granted by the Geotechnical Investigation Engineer.

B. State Owned Land

When it has been determined that the land to be investigated is owned by the State Land Department, the Crew Supervisor should report to the Materials Site Supervisor the legal description of the property he wishes to explore. The Materials Site Supervisor then should prepare a written request for right of entry for investigation purposes and forward it to the State Land Department. When permission has been received, the Crew Supervisor should be notified to proceed.

After the prospecting has been completed, if it is evident that the materials will be usable, a formal request should be made to the Right-of-Way Section for a pit license.

C. Federally Owned Land

If the land to be investigated is Federally owned the same procedure is followed as with State owned land, with the request made to the appropriate federal agency.

104.02 BORROW PITS

Borrow pits are located to provide a source of material to complete the embankment in the roadway.

In addition to the restrictions outlined in Section 104.00, there are several important factors to consider in choosing the location and prospecting a borrow pit.

A. Quality of Material

Although there are usually no specification requirements on borrow, there is definitely a difference in quality of various types of materials. With other factors being relatively equal, the highest quality of material available should be chosen. The quality may be measured by the "R"-value, Plasticity Index, and the percent passing the #200 sieve. Material with low expected "R"-values or highly plastic or fine material should be avoided if other material is available. The plasticity of the material should be checked continually during the prospecting operation, by screening samples through a #40 hand sieve, wetting the portion that passes and rolling it in the hand to estimate the plasticity.

B. Haul Distance

The plans and profile of the proposed project should be studied to estimate where the bulk of the borrow will be used; and the pit should be located in the nearest area where suitable material is available.

C. Prospecting

After the site for the borrow pit has been selected, the backhoe should be moved in and test holes dug. Where the terrain and materials are fairly uniform, holes should be dug in a grid pattern approximately 300 feet apart. If there are obvious changes in the characteristics of the material in various areas of the pit, additional holes should be dug so that each type of material is represented. Sufficient area should be prospected to develop the required amount of material or to delineate the limits of the area of available usable material. If a test hole within the pit area indicates unsuitable material surrounded by satisfactory material, additional holes should be dug to outline the unsuitable area.

Test holes should usually extend to the maximum depth that can be dug safely with the backhoe. All holes should be backsloped in accordance with Occupational Safety and Health Administration requirements. If the material appears to be suitable at additional depths, an occasional selected hole should be extended by bulldozing a hole large enough to provide a working area for the backhoe so that a hole may then be dug in the bottom to indicate additional depth of suitable materials.

If unsuitable material is found at depths less than the capacity of the backhoe, then the holes may be dug only to the bottom of the suitable material. Every test hole should indicate the bottom condition. If applicable, "B.S., N.S." (bottom same, not sampled) should be noted on the log.

Each test hole should be sampled as soon after digging as is practicable. Sampling and logging should be done in accordance with Section 106.00. After all sampling is complete, the samples should be sent to the Central Laboratory.

The "R"-value sampling of the borrow pits shall compare basically with the procedure noted above. First the borrow pit should be laid out, excavated and sampled as required. After the standard samples (P.I., Gradation, Density and pH and Resistivity) have been taken, the Crew Supervisor shall observe the open test holes and determine which holes within the pit area should be sampled for R-values to assure that each material type within the pit has been represented by at least 3 R-value tests. This should include only the material which is intended to be designated for use and should not consist of clay bottoms or other unsuitable material that would be avoided in actual construction. These R-value samples should be 75 to 100 pounds and retained adjacent to the test hole until the Geotechnical Investigation Engineer reviews the locations and tells the supervisor to proceed with their shipment.

A minimum of 3 locations for each major type of soil material encountered should be selected for density sampling. Each location shall be sampled and tested as noted in Section 102.05, "Excavation Factors and Ground Compaction Factors".

On sources where the estimated quantity of material is greater than 50,000 c.y., a minimum of 4 locations plus at least 1 additional location for each additional 100,000 c.y. should be tested, regardless of soil uniformity.

A metal tape should be prepared on a tapewriter showing the test hole number and the depths of the various strata. For example:

No. 1 - 0/11
No. 2 - 0/4/11
No. 3 - 0/4/6/11

This tape shall be nailed to a wooden stake and placed in the ground near the hole, where it is readily visible and will be preserved. If the pit is in an area that is subject to flooding, the stake should be nailed to a nearby tree, or attached to a post and the post placed in the hole with the tape above ground. Any other suitable method of preserving the tape at the approximate location of the test hole will be satisfactory.

When all pit excavation and sampling has been completed, the Crew Supervisor should call for the pit inspection. The Geotechnical Investigation Engineer should examine each test hole and check the log to verify the accuracy of the depth and description and to be sure that the identifying tape is accurate. If additional samples are required, they should be taken at that time. The Geotechnical Investigation Engineer should also observe the holes within the pit where "R"-values were taken and approve or designate new or additional test locations.

As soon as possible after the inspection, backfilling should begin. Each hole should be filled and the surrounding area left in a neat and relatively smooth condition.

104.03 AGGREGATE PITS

Aggregate pits are located to provide a source of aggregate for the pavement structure of the roadway. In addition to the restrictions outlined in Section 104.00, there are several important factors to consider in choosing the location and prospecting an aggregate pit.

A. Quality of Material

The quality of material in an aggregate pit is of more importance than the proximity to the project as the material must meet more strict requirements than borrow material. For this reason, careful consideration should be given to the selection of aggregate sources, and although the actual quality of the material may not be determined until the material has been sampled and tested, experience and judgement should be exercised in selecting aggregate pit locations.

B. Prospecting

After the site for the aggregate pit has been selected, the backhoe should be moved in and test holes dug. The holes should be on a grid pattern approximately 100 to 250 feet apart. The holes should be to the maximum depth that can be safely dug with the backhoe equipment, or to the bottom of the suitable material, whichever is less. If it is apparent that suitable material extends below the depth to which the backhoe will extend, selected holes in the area should be deepened by bulldozing a hole large enough for the backhoe to operate in and then digging a hole in the bottom. If the depth of the suitable material is greater than the capacity of the equipment, it should be so noted on the pit log. Sufficient area should be prospected to develop the required amount of material or to delineate the limits of the area of the available usable material.

If unsuitable material is found at depths less than the capacity of the backhoe, this should be noted and the bottom marked, as previously indicated. The hole should be deepened into this unsuitable material to attempt to determine its extent, and whether usable material exists below the unsuitable material.

After the holes have been dug, they should be sampled and logged as soon as is practicable. After all sampling is complete, the samples should be sent to the Central Laboratory.

After sampling, each hole should be identified with the metal tape, inspected and backfilled as previously described in Section 104.02.

C. Designation of Aggregate Sources

Test results of the pit samples should be analyzed to determine the quality and characteristics of the material and what it may be used for. The pit should then be designated as a source for one or more of the following: Aggregate Subbase, Aggregate Base, or rejected as a possible source of material, depending on the quality of the material as indicated by the test results.

Frequently, the same pit may be provided for more than one project. When this is the case, the pit should be divided into separate areas, one for each project, in order to provide a work area for each contractor if the projects are constructed simultaneously.

If the pit is in a stream bed or wash that may be subjected to flooding and is to be used for more than one project, the area should be generally allotted from the upstream portion to the earliest scheduled project, and then proceeding downstream for the other projects in the order in which they are scheduled.

104.04 QUARRY INVESTIGATIONS

In the absence of suitable sand and gravel for base and surfacing, a search should be made for a possible quarry source. Quarries will generally be a competent limestone, basalt, quartzsite, or granite formation.

The same restrictions applying to Section 104.02 (borrow pits) and Section 104.03 (aggregate pits) should be observed in locating quarry pits.

A. Quality of Material

Since a quarry pit will be used for aggregate, the quality of the material is of great importance. The cost of investigation of a quarry pit is high compared to that of sand and gravel; therefore, a source should be examined very carefully in the preliminary investigation. Evidence of clay seams, overburden and other deleterious material should be studied. The location of outcroppings of the rock will help to determine the extent of the available, suitable material and will serve to indicate what might be expected in the investigation.

B. Prospecting

After the site for the quarry has been determined, the equipment should be moved in and the test borings made. One or more borings may be blasted to open a hole for inspection and sampling. Two or more holes will be core drilled at each site to provide a permanent record.

The location of the test borings should be determined by judgement rather than by any specific pattern. Because of the cost, the pit should be developed with as few borings as possible, but sufficient borings should be made to delineate an area of suitable material sufficient to meet the requirements. A minimum of five borings is recommended and the Geotechnical Investigation Engineer should approve the plan in advance.

A log of all drilling should be kept. This log should show the depth and type of material encountered and the drilling time involved for each type. The log of cores will be made by a geologist and cores removed should be sent to the Phoenix Geotechnical Office for storage and possible future inspection by contractors.

After the holes have been drilled or blasted, they should be sampled in accordance with Section 106.00.

After sampling, each hole should be identified with the Metal tape, inspected, and backfilled as previously described in Section 104.02, or fenced.

C. Designation of Quarry Source

Quarry pits should be designated as aggregate sources as described in Section 104.03.

104.05 CUT WIDENING FOR BORROW AND AGGREGATE

In the absence of available borrow and/or aggregate, the possibility of widening the roadway cuts should be investigated. This decision should be made in cooperation with Plans Services and the Right-of-Way Section. If a decision is made to consider using the cuts for additional borrow or aggregate, then the roadway cuts should be controlled by the grade lines established by Plans Services.

104.06 PIT SKETCHES AND PHOTOGRAPHY

A field sketch shall be made of the pit area to a scale of from 200 feet to 600 feet to the inch, depending on the size and detail of the pit. The sketch should show the pit location with ties to the roadway alignment and also section ties where possible (see Figures 104.06-1 and 104.06-2). This sketch, or a

FIGURE 104.06-1

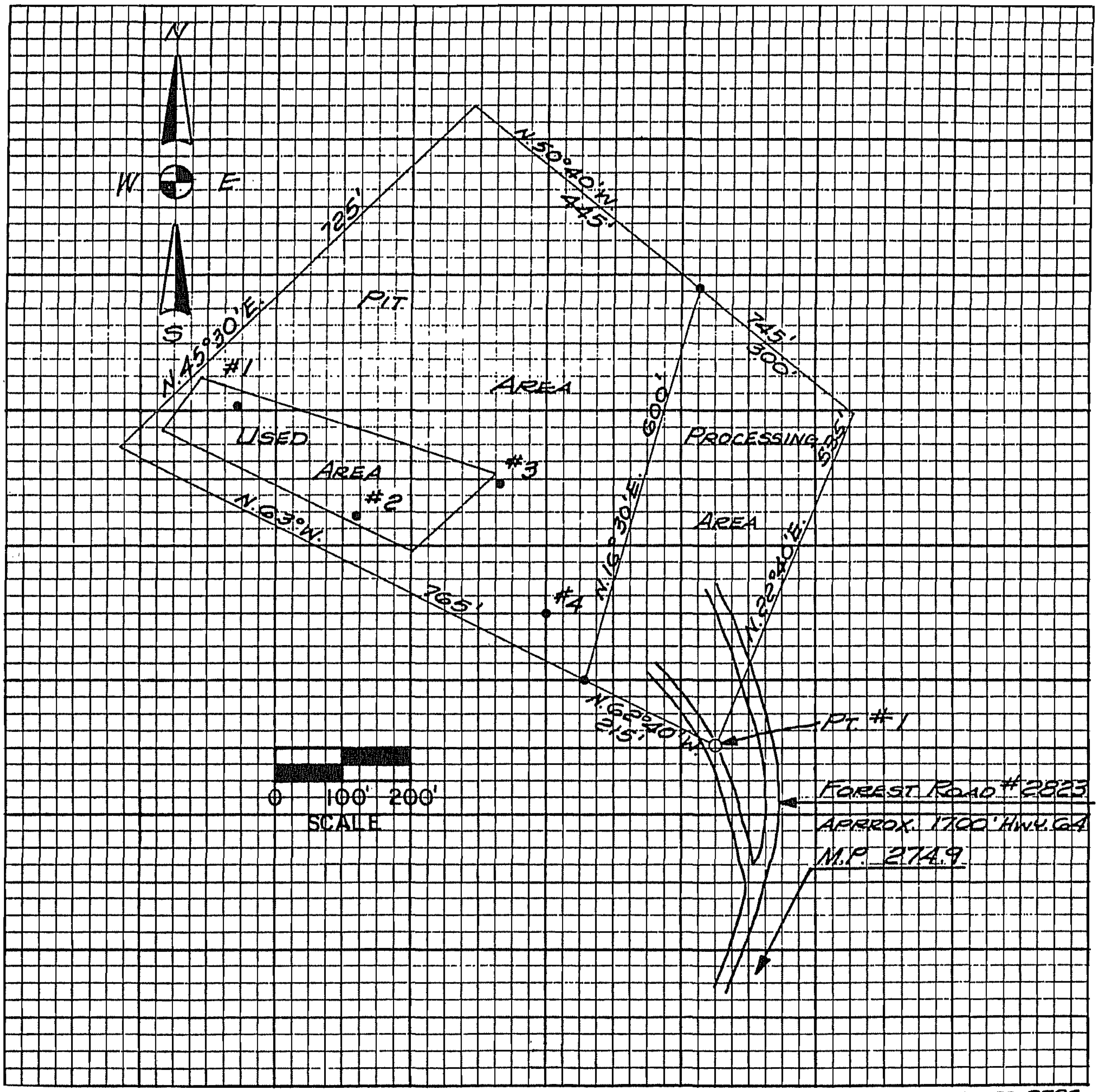
ARIZONA DEPARTMENT OF TRANSPORTATION
MATERIALS SECTION

FIELD REPORT ON LOCATION OF AGGREGATE PIT SERIAL NUMBER 8726

FROM GRAND CANYON - CAMERON HIGHWAY SOURCE OF MATERIAL FLAT

PROJECT NUMBER F-033-1-406 PROSPECTED BY RON MUENKS

A.F.E.______ DATE 2/10/88 LOCATION OF PIT SITE SECS. 3 & 4, T.29N., R.6E.



PIT SERIAL NUMBER 8726

FIGURE 104.06-2

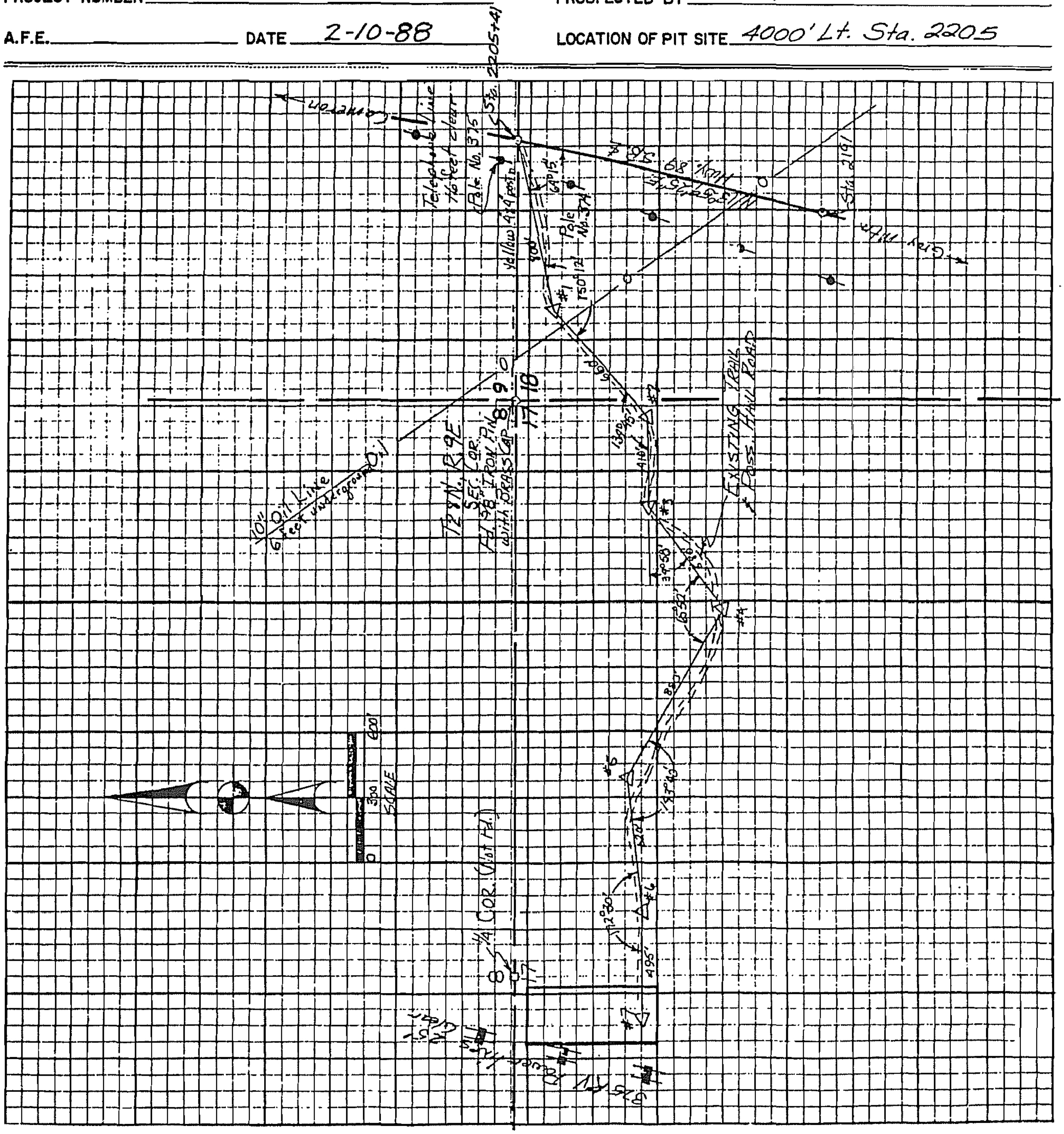
ARIZONA DEPARTMENT OF TRANSPORTATION
MATERIALS SECTION

FIELD REPORT ON LOCATION OF Borrow PIT SERIAL NUMBER 8390

FROM Gray Mtn. - Cameron HIGHWAY SOURCE OF MATERIAL Flat

PROJECT NUMBER F037-1-407 PROSPECTED BY Best

A.F.E. ______ DATE 2-10-88 LOCATION OF PIT SITE 4000' Lt. Sta. 2205



supplemental sketch, shall show the most feasible haul route from the pit to the project. Both sketches should include such physical features (powerline, water line, fences, roads, pit excavations, etc.) that would help to identify the location and/or affect the contractor's operations at the source.

After the test holes have been dug and sketched, targets must be placed at specific identified points to aid in determining the scale and location of certain points and objects on the aerial photographs that will be taken of the haul road and pit area (see Figure 104.06-3).

Two points, approximately 500 feet apart and at approximately the same elevation, shall be marked by white plastic panels 18 inches wide with each leg being 10 feet long and forming a cross pattern. The distance between the centers of these targets shall be measured, by chain, to the nearest 0.01 foot, and shown on the sketch. Targets shall also be placed on the survey centerline station that the pit is located from and on the station the haul road is tied to. Where the centerline is on an existing road or highway, these targets should be placed on the side of the roadway opposite the station. If the existing road is asphalt surfaced, a small white cross can be painted on the pavement.

Targets shall also be placed on the closest section corner 1/4, or 1/16 corner available in the vicinity of the pit. The target on all section markers shall be placed forming a "Y" with three white plastic strips 18 inches wide and 10 feet long with the marker at the center.

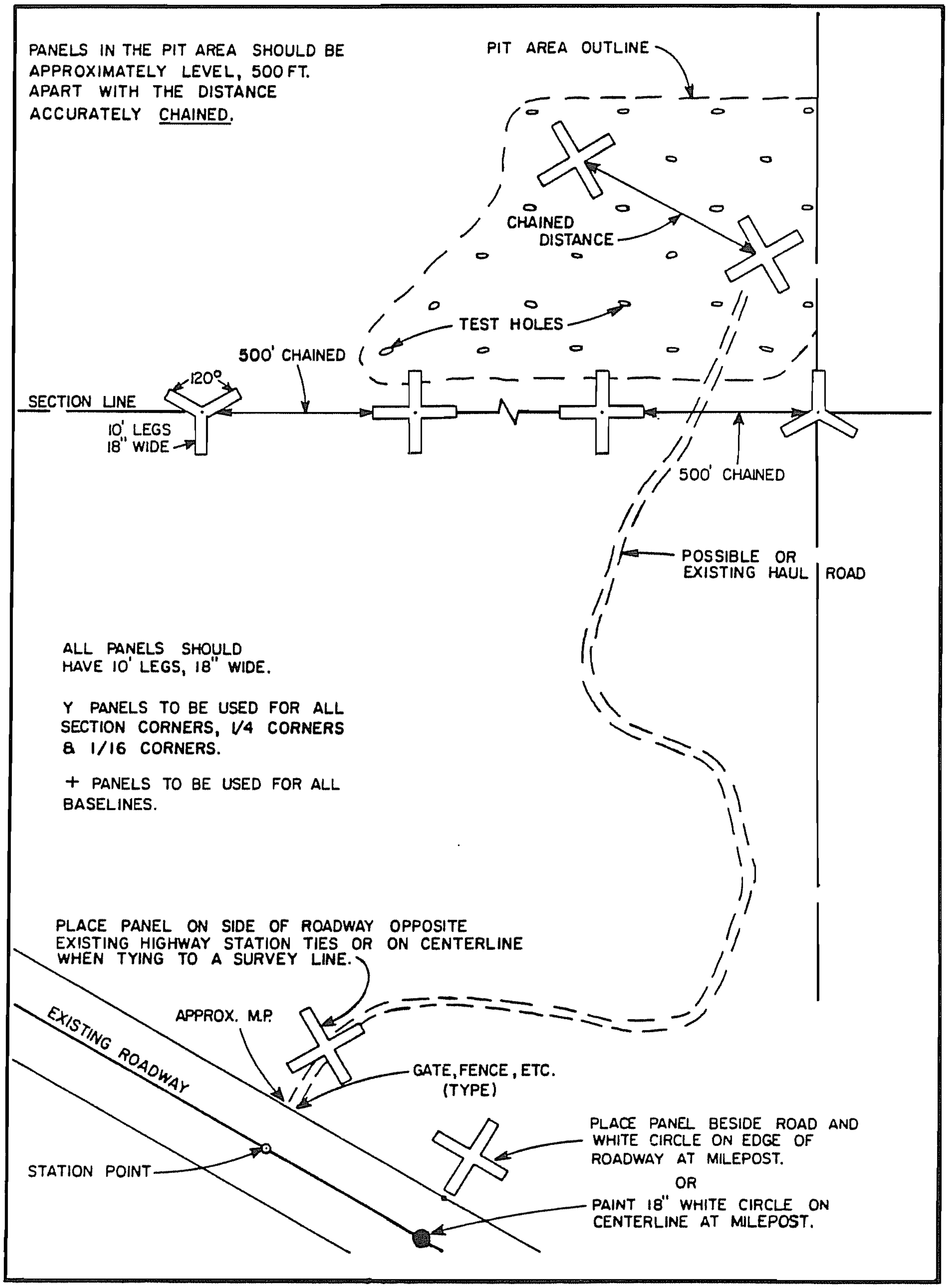
The location of all targets shall be accurately shown on the pit and/or haul road sketch.

Targets shall be placed on all pits at the completion of the materials investigation.

When all the pit sketches are received in the Phoenix Geotechnical Office, the Drafting Supervisor shall furnish Photogrammetry and Mapping Services with a flight plan for these pits on existing photography or maps, showing the pit location with the desired flight line and scale.

Normally a scale of one inch to 500 feet is adequate for the preparation of final pit sketches. In some instances, a scale of up to 1 inch to 2000 feet will be requested if more area is to be photographed, or a smaller scale may be requested if more detail is required.

FIGURE 104.06-3



When the photographs are received in the drafting area, the field sketches, with the aid of the targets placed on the ground, will be redrawn on the photographs (see Figures 104.06-4, 104.06-5 and 104.06-6).

In some cases, owners may require a development plan before granting right-of-way. In other cases, a plan of pit operation should be developed with pertinent drawings showing the proposed method and manner of removal of material. This plan should be mutually acceptable to all parties involved.

105.00 FIELD REVIEW

The Crew Supervisor responsible for the preliminary engineering soil investigation of a project should notify his supervisor immediately prior to completion so that a schedule can be set up for a field review. The Geotechnical Investigation Engineer, will review and approve the work or direct additional work to be performed. All field recommendations shall be reviewed and finalized.

The Geotechnical Investigation Engineer shall verify compliance to approved procedures on all phases of materials investigation. He shall in addition make observations as to the types, quality, and quantity of materials involved and make such observations to form a preliminary evaluation of design features and construction problems involved. Complete records must be made of all observations. The "R"-value locations both on the centerline and within the borrow pits shall be reviewed and approved or additional samples requested.

Complete acceptance of the field survey data must be obtained before the field materials investigation is considered complete. This may, in some cases, result in several visits to the project site.

After the field review has been completed and approved, the field party is to backfill or fence test holes. Backfilling or fencing should be accomplished as soon as possible.

105.01 WATER SUPPLY AND DUST CONTROL

The party responsible for the preliminary engineering subsurface investigation of a project should also ascertain the closest practical source of water for construction and dust control requirements.

FIGURE 104.06-4

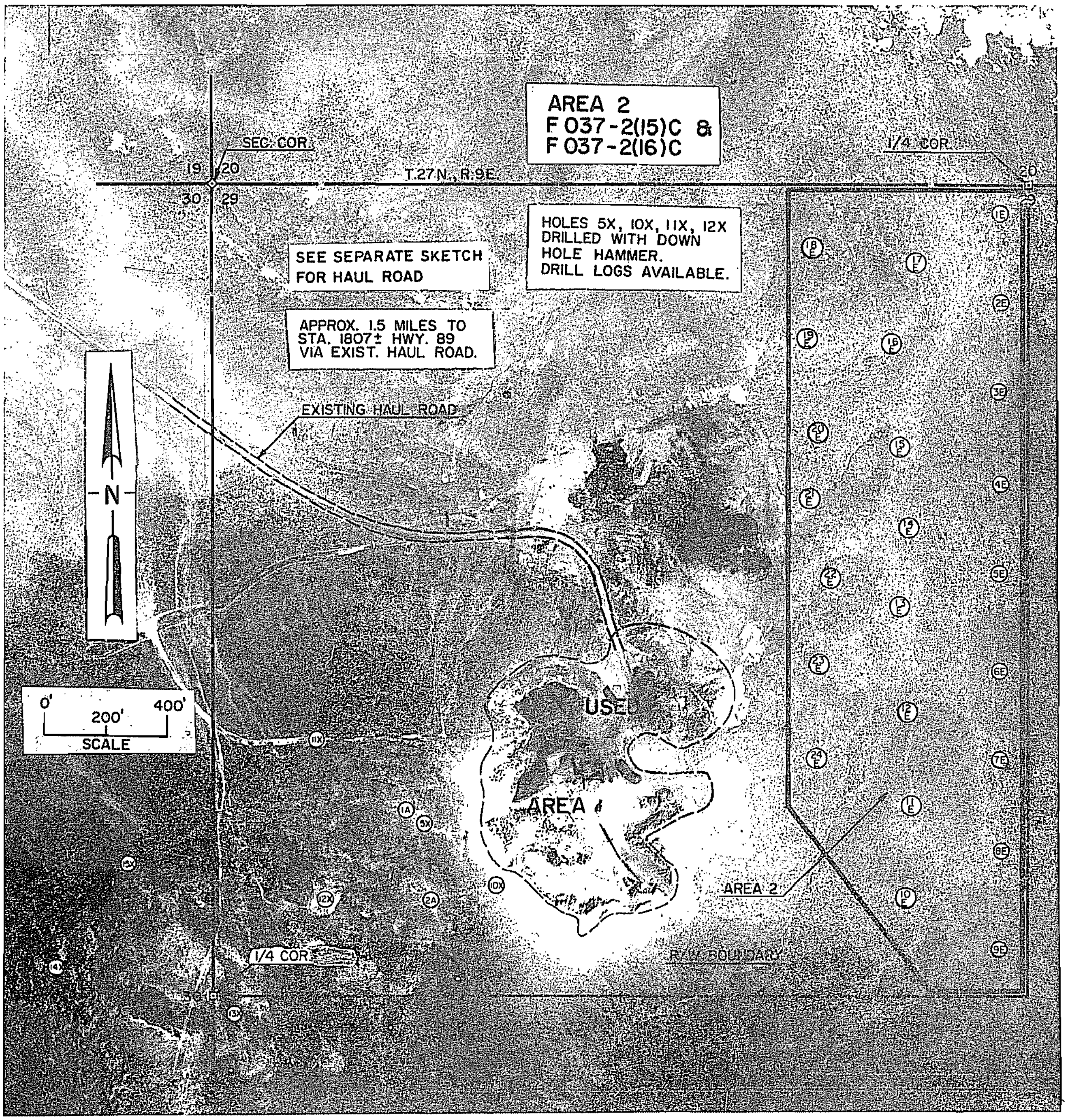
ARIZONA DEPARTMENT OF TRANSPORTATION
MATERIALS SECTION

FIELD REPORT ON LOCATION OF BORROW & AGGREGATE PIT SERIAL NUMBER 8491

FROM GRAY MOUNTAIN - CAMERON HIGHWAY SOURCE OF MATERIAL RIDGE & FLAT

PHOTO DATE 5-18-84 LOCATION OF PIT SITE NW1/4 SEC. 29 T.27N., R.9E.

PROSPECTED BY MUENKS DATE 3-1-84 SKETCH DATE 6-6-84



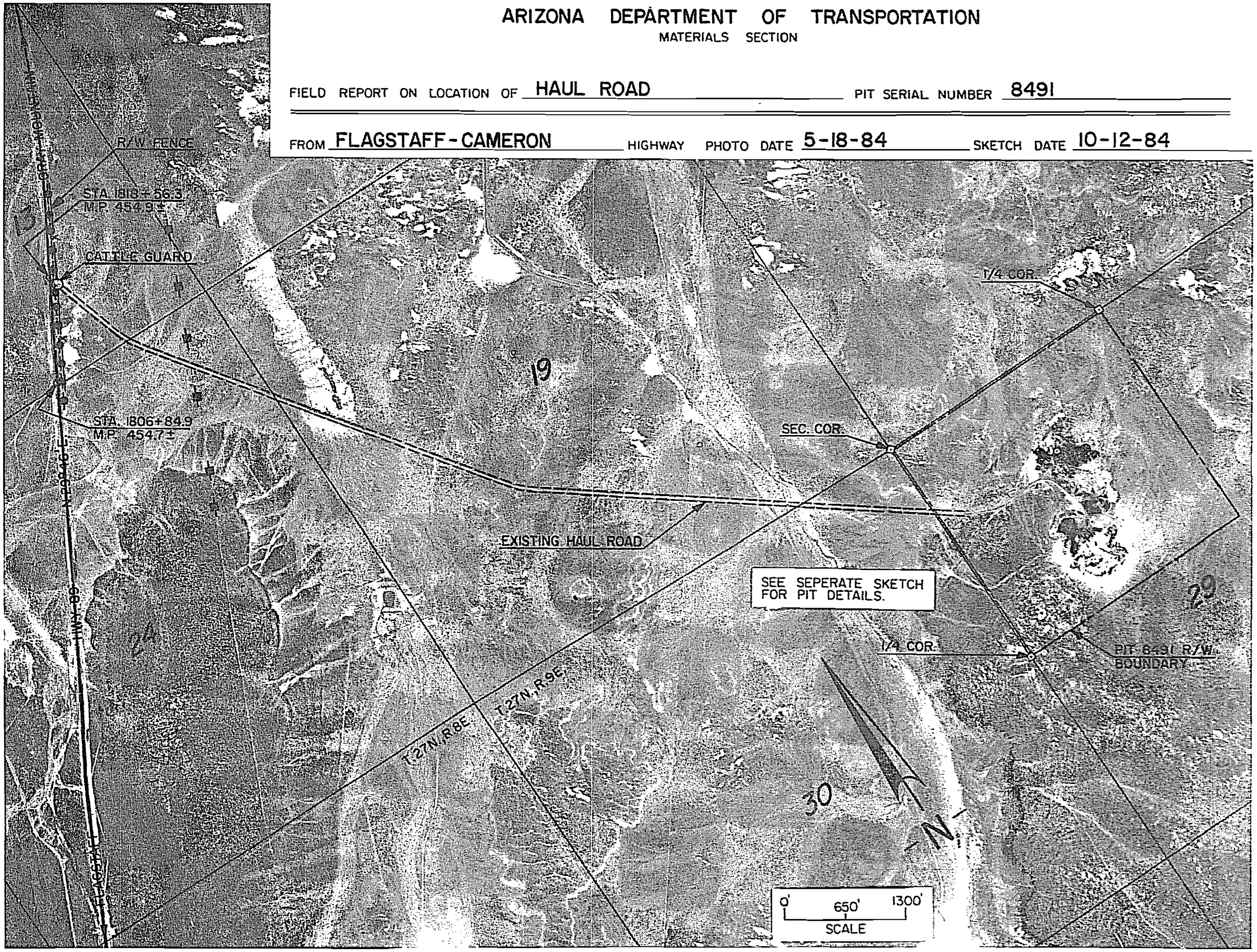


FIGURE 104.06-5

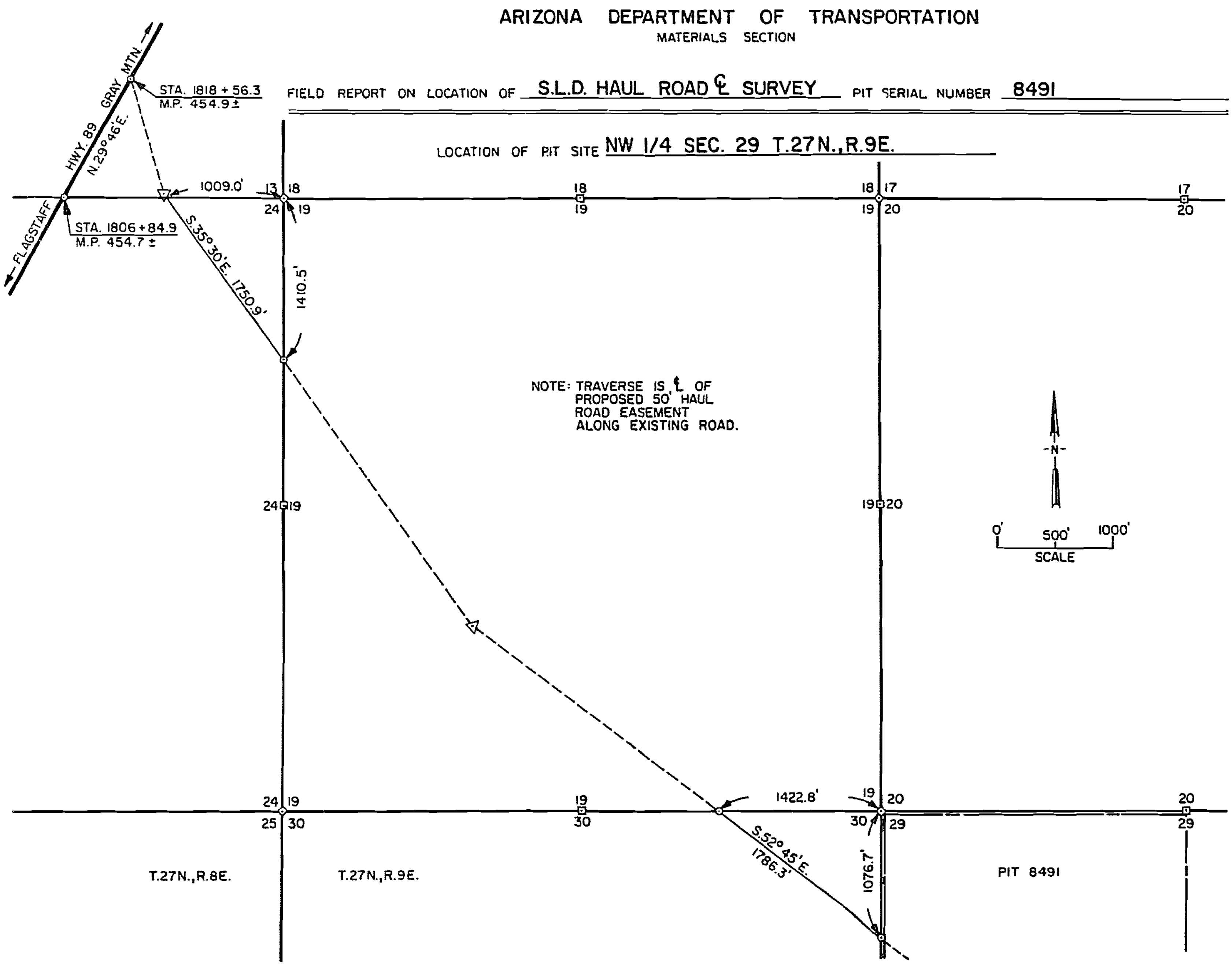


FIGURE 104.06-6

At the time of the field review, this proposed source of water will be reviewed and accepted or rejected on practical and economic merit. Factors which should be considered are:

A. Haul distance.

B. Quantity available (GPM...etc.)

C. Possible royalty charges.

D. Type of terrain project is located in; such as blow sand, clay, rock, etc.

E. Quantity required.

105.02 WASTE AREAS

On projects where the nature of the terrain will necessitate considerable waste of in-place materials, the Crew Supervisor and Geotechnical Investigation Engineer shall designate areas where a waste material may be deposited and determine their probable capacity. These recommendations are based on estimated waste quantities and may need revision during actual construction if the quantity is significantly different. Prior approval will sometimes be required due to environmental considerations.

An attempt should be made to utilize waste material where practicable. Flatter fill slopes (right-of-way permitting), rest areas, and emergency pull-outs are examples of utilization of waste materials.

When material pits contain overburden material that must be wasted, the material should be placed to avoid contamination of unused areas of the pit that may be needed for future projects. At times this material can be utilized as borrow or as a dike to protect the pit during use. Waste material should be placed so future flow in drainage channels is not modified.

106.00 SAMPLING TECHNIQUES

The securing of a relatively small sample to represent a large quantity of material is one of the most important functions in the materials design process. This may only be accomplished by: 1) careful consideration of all material types that are exposed in a test hole or on a pit face; 2) the ability of the sampler to make the proper value judgement in selecting the point of sampling; 3) then "cutting" a representative sample. Since this is the absolute beginning of the physical handling of materials, it is extremely important to secure a sample that represents the proposed material source or subgrade.

In all cases, applicable safety regulations shall be followed.

In the sections that follow, four different sampling techniques to fit four different situations will be discussed.

106.01 SAMPLING ALLUVIAL MATERIALS

Alluvial materials are sand, gravel, soil, silt, clay or similar materials that have been deposited by water.

The ability to take a representative sample of alluvial material comes after one has acquired the knowledge to distinguish between the different strata exposed by a test hole and to select the area of the test hole that will constitute the best representation of the exposed material. The sample is then secured from the selected area on the vertical face of the test hole.

A. Tools and Equipment

1. Prospector's Pick
2. Sampling Canvas
3. Four-foot Straight Edge
4. Sugar Scoop
5. Two-inch Paint Brush
6. Supply of Sample Bags
7. Twelve-foot Steel Tape
8. Ladder

B. Sampling Procedure

Immediately after the test hole has been excavated and is determined to be safe for entry, the following procedure shall be followed:

1. Lower the ladder into the test hole and enter the test hole.

2. Survey the exposed material and select the sampling point.

3. Place the sampling canvas in the bottom of the test hole.

4. Use the prospector's pick to cut a trench along the vertical face for the entire thickness of the stratum (layer) to be sampled. The width and depth of the trench shall be uniform. Care should be taken that all material from the trench falls on the canvas and care should also be taken that materials from other areas of the hole do not fall onto the canvas. A sufficient amount of material shall be cut to allow the mixing and quartering of the sample with one-quarter of the sampled material filling a sample bag. (An "R"-value sample generally will not require quartering.)

5. Immediately remove the material from the test hole, measure the thickness of the stratum that was sampled and record this information along with a description of the material on the sample log sheet (Figure 106.01-1a or 106.01-1b).

6. From the data on the sample log sheet, prepare the sample ticket (Figure 106.01-2a) that is to be tied to the sample bag (see Section 106.05). Figure 106.01-2b is the matrials survey soil and aggregate tabulation laboratory card. The back of this card, Figure 106.01-2c, contains codes to be used in filling out the sample ticket. For convenience the material codes and roadway codes are also shown on the back of the sample ticket.

7. The material shall then be thoroughly mixed and quartered with a straightedge if necessary.

8. All but one quarter of the material shall be removed from the canvas. The remaining material shall be placed into the sample bag with the scoop.

9. The paint brush shall be used to brush all remaining fines clinging to the sample canvas into the scoop and this material shall be placed into the sample bag.

10. The sample bag shall be tied and the sample ticket affixed to the tying string (see Section 106.05).

11. Each stratum shall be sampled in the same manner.

ARIZONA DEPARTMENT OF TRANSPORTATION – MATERIALS SECTION
PRELIMINARY ENGINEERING SUBGRADE LOG
(USE CAPITAL LETTERS ONLY)

PROJECT NUMBER S 482-408 PROJECT LOCATION Colter Road SAMPLED BY Smith

PROJECT TERMINI Sta. 420 to 732 DESIGNER Jones CONSTRUCTION TYPE New Rdwy.

SAMPLE NUMBER	DISTANCE	R OR L	RDWY.	MILEPOST OR STATION	DEPTH		INVEST. MODE	MATL. DESC.		DATE YEAR 84		MATERIAL DESCRIPTION	TESTS REQUIRED OTHER THAN GRADATION & PI
					FROM	TO		#1	#2	MO.	DAY		
15	12.5	R	E.B.	603+45	0'	3'	01	31		10	8	Clayey Silt, Damp, Tan	R-Value

FIGURE 106.01-1a

ARIZONA DEPARTMENT OF TRANSPORTATION — MATERIALS SECTION
PRELIMINARY ENGINEERING MATERIALS PIT LOG
(USE CAPITAL LETTERS ONLY)

PROJECT NUMBER I-10-3(306) PROJECT LOCATION Jacks T.I. - East PIT NUMBER 9002

PIT LOCATION 1800' Lt. Sta. 425+50(W.B.) SAMPLED BY Smith MATERIAL Aggregate

TEST HOLE NO.	SUFFIX	DEPTH		INVEST MODE	MATL. DESC.		DATE YEAR 84		MATERIAL DESCRIPTION	TESTS REQUIRED OTHER THAN GRADATION & PI
		FROM	TO		#1	#2	MO.	DAY		
8		0'	12'	01	23		10	3	Sand & Gravel, Thin Silt layer @ 6'	pH & Resist.
		12'	12'	01	23		10	3	Water	N.S.

PIT NUMBER 9002

FIGURE 106.01-1b

FIGURE 106.01-2a

44-9349 R4/89

SAMPLE TABULATION FOR MATERIALS SURVEY

LAB NUMBER	PROJ CODE	MATL	TYPE	PURPOSE	TEST NO.	SUFFIX
M 1		SG		S	15	

PURPOSE: S = MAT. SURVEY; F = FIN. REC.; I = INVEST.; R = RESEARCH

SAMPLED BY	MON. DAY YEAR	REQ. THICK OR PIT NO.	FROM	TO
SMITH	100884		0.0	3.0

SAMPLED FROM	DISTANCE	M=MI. F=FT.	R-L	RDWY	STATION PLUS
RDWY CUT	12.5	F	R	EB	603+45

IF MILEPOST INPUT DECIMAL IN COL. 69

INVEST MODE	MATL. DESC.	MATL DESC	PROJECT NUMBER	PROJECT NAME
01	31		S-482-408	COLTER ROAD

REMARKS

M 2 R-VALUE

NEW RDWY

Milepost for existing rdwy. subgrade samples — top lift AC/PC

KEYPUNCH INSTRUCTIONS: Duplicate col. 3 thru 7 on all cards

44-9349 R4/89

SAMPLE TABULATION FOR MATERIALS SURVEY

LAB NUMBER	PROJ CODE	MATL	TYPE	PURPOSE	TEST NO.	SUFFIX
M 1		AG		S	8	

PURPOSE: S = MAT. SURVEY; F = FIN. REC.; I = INVEST.; R = RESEARCH

SAMPLED BY	MON. DAY YEAR	REQ. THICK OR PIT NO.	FROM	TO
SMITH	100384	9002	0.0	12.0

SAMPLED FROM	DISTANCE	M=MI. F=FT.	R-L	RDWY	STATION PLUS
PIT	13000	F	L	WB	425+50

IF MILEPOST INPUT DECIMAL IN COL. 69

INVEST MODE	MATL. DESC.	MATL DESC	PROJECT NUMBER	PROJECT NAME
01	23		I-10-3 (306)	JACKS T.I. - EAST

REMARKS

M 2 PH ¢ RESISTIVITY

Milepost for existing rdwy. subgrade samples — top lift AC/PC

KEYPUNCH INSTRUCTIONS: Duplicate col. 3 thru 7 on all cards

MATERIAL CODES

- SG = SUBGRADE
- SB = STRUCTURE BACKFILL
- AS = AGGREGATE SUBBASE
- SS = SUBGRADE SEAL
- NG = NATURAL GROUND
- BM = BEDDING MATERIAL
- AB = AGGREGATE BASE
- CM = COVER MATERIAL
- BL = BLOTTER MATERIAL
- MA = MINERAL AGGREGATE
- CA = COARSE AGGREGATE
- FA = FINE AGGREGATE
- AG = AGGREGATE
- EM = EMBANKMENT
- CB = CEMENT TREATED BASE
- LC = LEAN CONCRETE BASE
- CS = CEMENT TREATED SUBGRADE
- LS = LIME TREATED SUBGRADE
- RR = RIP RAP
- FM = FILTER MATERIAL
- BO = BORROW
- GR = GRANULATED RUBBER
- TS = TOP SOIL
- BF = BACKFILL
- AC = ASPHALTIC CONCRETE
- BB = BITUMINOUS TREATED BASE
- FC = ACFC
- NM = PNEUMATICALLY PLACED MORTAR
- MS = MEMBRANE SEAL
- RM = ROAD MIX
- RC = RECYCLED ASPHALTIC CONCRETE

RDWY CODES:

- NB = NORTHBOUND
- SB = SOUTHBOUND
- ETC
- RA = RAMP A
- RB = RAMP B
- ETC
- FR = FRONTAGE ROAD
- XR = CROSS ROAD

FIGURE 106.01-2b

MATERIALS SECTION
SOIL & AGGREGATE TABULATION
MATERIALS SURVEY

RECEIVED DATE ____________________

LAB NUMBER	PROJ CODE	MATL	TYPE	PURPOSE (S = MAT SURVEY, F = FIN REC., I = INVEST, R = RESEARCH)	TEST NO	SUFFIX
M 1		SG		S	15	

SAMPLED BY	MON. DAY YEAR	REQ. THICK OR PIT NO.	FROM	TO
SMITH	10 08 84		0.0	3.0

SAMPLED FROM	DISTANCE	M=MI. F=FT	R-L	RDWY	STATION	PLUS
RDWY CUT	125	F	R	EB	603	+45

IF MILEPOST INPUT DECIMAL IN COL. 69

INVEST MODE	MATL. DESC.	MATL DESC	PROJECT NUMBER	PROJECT NAME
01	31		S-482-408	COLTER ROAD

REMARKS

M 2 R-VALUE

NEW RDWY.

KEYPUNCH INSTRUCTIONS: Duplicate col. 3 thru 7 on all cards

% OVERSIZE

M 3	+3"□	+6"□	COARSE FACTOR (no punch)

	WEIGHTS RETAINED	% RET.	% PASS
3" □			
2½"			
2"			
1½"			
1"			
3/4"			
1/2"			
3/8"			
1/4"			
#4			
-#4			
Total			

Test		Value
Liquid Limit, (LL)	T - 87, D - 421	
Plastic Limit (PL)	T - 89, D - 423	
Plasticity Index (PI) = LL – PL	T - 90, D - 424	
Sand Equivalent, SE = $\frac{S}{C}\times 100$	T - 176, D - 2419	
Abrasion (A,B,C,D)	T - 96, C - 131	
@ 100 Revolutions		%
@ 500 Revolutions		%
Absorption, H_2O	ARIZ - 211, T - 85, C - 128	%
Specific Gravity, OD	" "	
Density Method (A,C,D,1)		
Optimum Moisture		%
Max. Dry Density		PCF
Moisture Content = $\frac{W-D}{D}\times 100$	T - 255, C - 566	
pH		
Resistivity (ohm-cm)		
R-Value @ 300 psi		

T = AASHTO Tests

C & D = ASTM Tests

M 4	WT PASS #4	SPLIT	FINE SIEVE FACTOR (no punch)

	WEIGHTS RETAINED	% RET.	% PASS
#8			
#10			
#16			
#30			
#40			
#50			
#100			
#200			
-#200			
Total	Dry Weight		
Elutriation			

M 5	MISCELLANEOUS TESTS	
Hydrometer	(Smaller than) .020 mm	%
	(Smaller than) .002 mm	%
	(Smaller than) .001 mm	%
Mortar Strength		%
	Test Code	
	Test Code	
	Test Code	
	Test Code	
	Test Code	

MISCELLANEOUS TEST CODES

01 Soluble Salts
02 Organic Impurities
03 Sodium Sulphate Soundness
04 Swell
05 Shear
06 Consolidation
07 % Limestone
08 % Cement
09 % Lime
10 % Flyash
11 Unit (loose) Weight
12 Stripping Test (accelerated)
13 Permeability
14 Freeze-Thaw
15 CBR
16 Flakiness Index
17 Fractured Faces
18
19
20

NOTE:
Input decimal point as needed for results on miscellaneous tests

44-9351 R3/86

FIGURE 106.01-2c

MATERIALS SURVEY CODES

INVESTIGATIVE MODE CODES

01	Backhoe
02	D&S - Backhoe
03	D&S - Backhoe - Fines wasted
04	Backhoe - Fines wasted
05	Face Sample - Backhoe
06	Backhoe - Crushed
07	D&S - Backhoe - Crushed
08	D&S - Backhoe - Fines wasted - Crushed
09	Backhoe - Fines wasted - Crushed
10	Face Sample - Backhoe - Crushed
21	Hand shovel
22	D&S - Hand shovel
23	D&S - Hand shovel - Fines wasted
24	Hand shovel - Fines wasted
25	Face Sample - Hand shovel
26	Hand shovel - Crushed
27	D&S - Hand shovel - Crushed
28	D&S - Hand shovel - Fines wasted - Crushed
29	Hand shovel - Fines wasted - Crushed
30	Face Sample - Hand shovel - Crushed
35	2" Drill hole
41	4" Auger
42	4" Auger - Fines wasted
43	4" Auger - Crushed
44	4" Auger - Fines wasted - Crushed
50	4½" Drill hole
55	6" Auger
56	6" Auger - Fines wasted
57	6" Auger - Crushed
58	6" Auger - Fines wasted - Crushed
60	8" Auger
61	8" Auger - Fines wasted
62	8" Auger - Crushed
63	8" Auger - Fines wasted - Crushed
70	2' Sq. Jackhammer Sample
71	4" Core
72	6" Core
73	8" Core
74	12" Core

MATERIAL DESCRIPTION CODES

01	Basalt (Malpais)
02	Cinders
03	Andesite or rhyolite
04	Tuff or compacted ash
05	Diabase
06	Granite
07	Disintegrated (Decomposed) Granite
08	Slate
09	Schist
10	Quartzite
11	Shale
12	Siltstone
13	Sandstone
14	Conglomerate
15	Limestone
16	Chert (Flint)
17	Caliche
18	
19	
20	Sand and gravel, with cobbles or boulders.
21	Silty-Sand and gravel, with cobbles or boulders.
22	Clayey-Sand and gravel, with cobbles or boulders.
23	Sand and gravel
24	Silty-Sand and gravel
25	Clayey-Sand and gravel
26	Sand
27	Silty-Sand
28	Clayey-Sand
29	Sandy Silt
30	Silt
31	Clayey Silt
32	Clay or silty-clay, gravelly
33	Clay or silty-clay, sandy
34	Clay or silty-clay
35	Clay

MATERIAL CODES

SG = SUBGRADE
SB = STRUCTURE BACKFILL
AS = AGGREGATE SUBBASE
SS = SUBGRADE SEAL
NG = NATURAL GROUND
BM = BEDDING MATERIAL
AB = AGGREGATE BASE
CM = COVER MATERIAL
BL = BLOTTER MATERIAL
MA = MINERAL AGGREGATE
TS = TOP SOIL

CA = COARSE AGGREGATE
FA = FINE AGGREGATE
AG = AGGREGATE
EM = EMBANKMENT
CB = CEMENT TREATED BASE
LC = LEAN CONCRETE BASE
CS = CEMENT TREATED SUBGRADE
LS = LIME TREATED SUBGRADE
RR = RIP RAP
FM = FILTER MATERIAL
GR = GRANULATED RUBBER

BF = BACKFILL
AC = ASPHALTIC CONCRETE
BB = BITUMINOUS TREATED BASE
BO = BORROW
FC = ACFC
NM = PNEUMATICALLY PLACED MORTAR
MS = MEMBRANE SEAL
RM = ROAD MIX
RC = RECYCLED ASPHALTIC CONCRETE

RDWY CODES:

NB = NORTHBOUND
SB = SOUTHBOUND
ETC
RA = RAMP A
RB = RAMP B
ETC
FR = FRONTAGE ROAD
XR = CROSS ROAD

106.02 SAMPLING QUARRY PITS

The sampling of a quarry pit requires the use of judgement as well as routine technique. The purpose of the sample is to provide material that may be processed to produce an end product as close as possible to what would be expected during construction.

The test hole should be chosen carefully to note any change in material. This change is usually evident in the color and the degree of hardness. If there is more than one type of material in the test hole, each type should be represented by a sample of approximately 60 pounds. The sample should be taken from the material excavated from the hole.

The test hole should be hand picked with care being exercised to select material representing only the stratum being sampled. The sample should include only rock that will pass a 6 inch sieve. The material should be placed in bags and tagged showing the location and extent of the stratum it represents. The words "Quarry Crush" should appear on all identifying tags.

At least two samples from each of the usable strata should be marked "For Abrasion", with a minimum of three samples for the entire pit.

An additional sample shall be taken from every second or third test hole for information only. These samples should consist of the fine material generated from the blasting operation, together with approximately an equal amount of the fine material extracted from the fracture seams and bedding planes exposed in the test hole. These samples shall be marked "FINES - FOR INFORMATION ONLY". The number of the test hole the sample was taken from also should be shown on the card.

106.03 SAMPLING EXISTING ROADWAYS

Care should be exercised in sampling existing roadways in order to accurately represent the thickness and characteristics of each pavement component and the subgrade.

A. Existing Pavement

The existing pavement should be cut to a neat line for an area approximately two feet by two feet. The pavement should be carefully removed to the elevation of the next component. Generally, the material may later be used for backfilling the hole or discarded, unless a sample has been requested. If a sample has been requested, then the pavement material should be placed in a sample sack, tied, and tagged as described in Section 106.05. Samples are logged on the form shown in Figure 106.01-1a. A core drill can often be utilized to obtain existing pavement samples when such equipment is available. The sampling method will be determined by the Geotechnical Investigation Engineer.

B. Base Course Components

Each of the base course components should be removed separately. The material may be removed by hand, using a scoop or a spoon. Care should be taken to remove all of the material of the particular components, using the hands or the spoon and brush to clean up the fines. All of the material removed should be placed on the sample cloth. If there is not more than one bag full, all of the material should be placed in a sample bag. If there is more material than is required for a sample, the material should be thoroughly mixed and divided with the straight edge until there is approximately enough material in a sample portion to fill one bag. It should then be bagged, tied, and tagged as described in Section 106.05. Samples are logged on the form shown in Figure 106.01-1a.

C. Subgrade

After the pavement and each base component have been removed, excavation should continue at least six inches into the subgrade with the material sampled in the same manner as the base course components. For reconstruction projects, "R"-value samples in addition to normal samples, will be taken from these subgrade materials which the supervisor determines to be control conditions. The R-value samples shall be taken beneath the pavement; sampling from the shoulder will not be permitted.

The R-value sampling requirements for reconstruction projects are the same as in Section 102.04 with a minimum of 3 per project. On investigation for rehabilitation projects, no R-value samples need be taken unless there has been a specific request for them.

D. Backfill

After each component of the pavement structure has been sampled the hole should be backfilled, using the surplus material and other suitable material. It should be hand tamped and the top six inches should be replaced with asphaltic mix. The District in which the work is to be done should be notified of the location of the holes in case they choose to do the backfilling with the District Maintenance Forces. In no case, however, should a hole be left in the pavement when opened to traffic.

106.04 SAMPLING OVERSIZE AGGREGATE

The percentage of material retained on the 3 inch and 6 inch sieves in aggregate pits is important from several standpoints. It indicates the amount of crushing required and it influences the job mix formula in asphaltic concrete mix designs. For these reasons, it is important to make a concerted effort to determine as closely as possible the amount of oversize rock that is indicated by the test holes. There are several steps involved: selection of holes to be sampled, taking the sample, weighing the sample and calculating the percentage of each size.

A. Selection of Holes to be Sampled

After all test holes have been excavated, a study should be made of each hole from the standpoint of oversize rock; then three or more representative holes should be chosen to represent the pit or pit area. It is desirable to select holes that cover the entire pit area; if one area of the pit appears to contain a significantly different amount of oversize, a separate determination for the individual areas may be more appropriate.

B. Sampling

Because of the influence of one large rock, it is essential that a fairly large sample should be taken, particularly if the percentage of oversize is great. Hence, a minimum of 1000 pounds of material should be removed from the test hole. This may be accomplished by cleaning out the bottom of the hole with the backhoe and removing as much of the loose material as possible, then with the backhoe bucket, as carefully as possible, remove material from the face of the test hole. The operation should begin at the bottom, taking a shallow cut towards the top, trying to get a uniform sample.

C. Weighing

All material removed as a sample should be weighed. Since it is not practicable to have a large scale on the project, it should be weighed in increments that can be easily lifted and handled, with a hand scale. As each increment is weighed, the weight should be tabulated and the tabulations totaled to determine the entire weight of the sample. This weight should be entered for each test hole sampled (see Figure 106.04-1).

As each increment of material is removed from the container in which it was weighed, it should be dumped on a 3 inch sieve. All material retained on the 3 inch sieve should be saved and after the entire sample has been weighed, the material retained

FIGURE 106.04-1

ARIZONA DEPARTMENT OF TRANSPORTATION
MATERIALS SECTION

FIELD REPORT ON LOCATION OF AGGREGATE PIT SERIAL NUMBER 8686

FROM LAKESIDE STREETS HIGHWAY SOURCE OF MATERIAL WASH

PROJECT NUMBER E044-1-301 PROSPECTED BY RON MUENKS

A.F.E. ____ DATE 2/10/88 LOCATION OF PIT SITE 6 Mi. Lt. MP 337.1 HWY. 26

FIELD SCREEN ANALYSIS

HOLE NUMBER	TOTAL WEIGHT	WT. RET. ON 6" SCREEN (1)	WT. RET. ON 3" SCREEN (2)	SIEVE ANALYSIS % RET. 6" (3)	% RET. 3" (4)	% PASS 6" (5)	% PASS 3" (6)
# 6	1378	45	219	3.27	15.89	96.73	80.84
# 16	1570	100	150	6.37	9.55	93.63	84.08
# 19	1547	50	245	3.23	15.84	96.77	80.93
# 37	1622	50	289	3.08	17.82	96.92	79.10
# 40	1574	45	176	2.86	11.18	97.14	85.96
# 46	1900	75	318	3.95	16.74	96.05	79.31

(1) Only the material that will not pass a 6" screen.

(2) Only the material that will not pass a 3" screen, exclusive of that material retained on the 6" screen.

(3) Weight of material retained on the 6" screen divided by the total weight.

(4) Weight of material retained on the 3" screen divided by the total weight.

(5) 100% Minus percent retained on the 6" screen.

(6) Percent passing the 6" screen minus the percent retained on the 3" screen.

on the 3 inch sieve should be passed over a 6 inch sieve and separated. The portion retained on the 6 inch sieve should be weighed and the weight entered in column (1). The balance of the oversize (retained on 3") should be weighed and the weight entered on the form in column (2). All weights entered should be to the nearest pound. Boulders larger than approximately 15 inches should not be included in the sample.

D. Calculating the Percentage of Each Size

After all weights are entered, the percentage retained on each sieve and the percentage passing each sieve should be calculated to the nearest tenth of a percent according to instructions on the form and the percentage for each sieve entered in the appropriate column (see Figure 106.04-1).

106.05 IDENTIFYING SAMPLES

All samples should be identified by filling out the sample ticket (see Figure 106.01-2a). This ticket is a multiple copy form. The original should be removed and placed in the sample bag. The second copy should be attached to material log. The third copy should be attached to the outside of the bag to serve as a shipping tag. The ticket should be carefully filled out to provide the necessary information.

A. Name of Material:

The name of the material being sampled should be entered in the appropriate place. This would usually be one of the following: Subgrade, Borrow, Special Backfill, Aggregate or Oversize. There may be other materials sampled on occasion, such as Riprap Rock, Blending Material, etc. The "R"-value samples shall be identified on the sample ticket under REMARKS.

B. Identification Marks:

Because there is usually more than one sample, each sample should be identified by number. These numbers should correspond with the test hole. The sample taken in each stratum is given the number of the test hole and further identified by the location of the stratum. For example, #14 - 2′ to 9′, #14 - 9′ to 12′.

C. Date:

The date the sample is taken should be entered on the identification ticket in the place indicated.

D. Sampled By:

The name of the party responsible for the sampling should be entered on the identification ticket in the place indicated. If the sample is taken by a Field Crew, the name of the Crew Supervisor should be used. If the sampling is under the direction of a Geotechnical Investigation Engineer or District personnel, the name of the person supervising the sampling should be used.

E. Sampled From:

The point from which the sample is actually taken should be entered on the identification ticket in the place indicated. This may include a test hole in the subgrade or pit, it may be from a stockpile, from the bins of a plant, or a railroad car, and should be so indicated. If the sample is taken from a test hole or windrow in the roadway, the station should be indicated.

F. Quantity Represented:

The quantity represented should be entered on the identification ticket in the place indicated. If the sample is taken from a test hole it should indicate the location and thickness of the stratum sampled; for example, 0′ to 11′.

If the sample is taken from a stockpile, it should indicate the estimated amount of material in the stockpile. If it is taken from an operating plant, it should indicate the amount of production represented.

G. Location of Supply:

The specific location of the source of the supply of material sampled should be entered on the identification ticket in the appropriate place. If the source is an Arizona Department of Transportation pit, the serial number of the pit should be given if one has been assigned, or, if it is a new pit and no number has been assigned, the location of the pit as it will appear on the pit sketch should be used. If it is the roadway, it should be so indicated. If it is a commercial plant it should be so stated with the location of the plant indicated and its number, if one has been assigned. For example: Commercial Plant, United Metro #1, (CM 0059), Phoenix.

H. Highway:

When the location of the supply is related to a Station or Milepost, the name of the appropriate highway on which the

Station or Milepost is located should be entered in the place indicated.

I. Project Number:

The number of the project for which the material is being sampled should be indicated in the appropriate place.

J. Remarks:

Any pertinent information may be included under the remarks, such as the type of test for which the material was sampled, any special instructions for handling the sample or the name of an individual to be contacted regarding the sample.

106.06 SIZE AND NUMBER OF SAMPLES

The size of the sample required is determined by the number and type of tests that are to be made. In general, one sample should be taken from each stratum of material in each test hole for Sieve Analysis and Plasticity Index (PI) tests, together with other samples for specific tests as required. The size of samples and number of samples to be taken are shown in Table 106.06-1.

107.00 COMPLETION OF SAMPLING OPERATIONS

Prior to moving the equipment from the project site, all test holes should be filled or fenced, debris cleaned up and the work area restored.

Any test hole that is to be left open for future inspection should be fenced in accordance with details shown on Figure 107.00-1.

All papers, empty cans, bottles or debris of any kind developed in the materials investigation should be picked up and disposed of.

The work area should be restored as nearly as is practicable to its original condition. All piles of materials should be leveled and all excavations backfilled.

TABLE 106.06-1

SAMPLING SCHEDULE

A. Subgrade and Borrow Pits

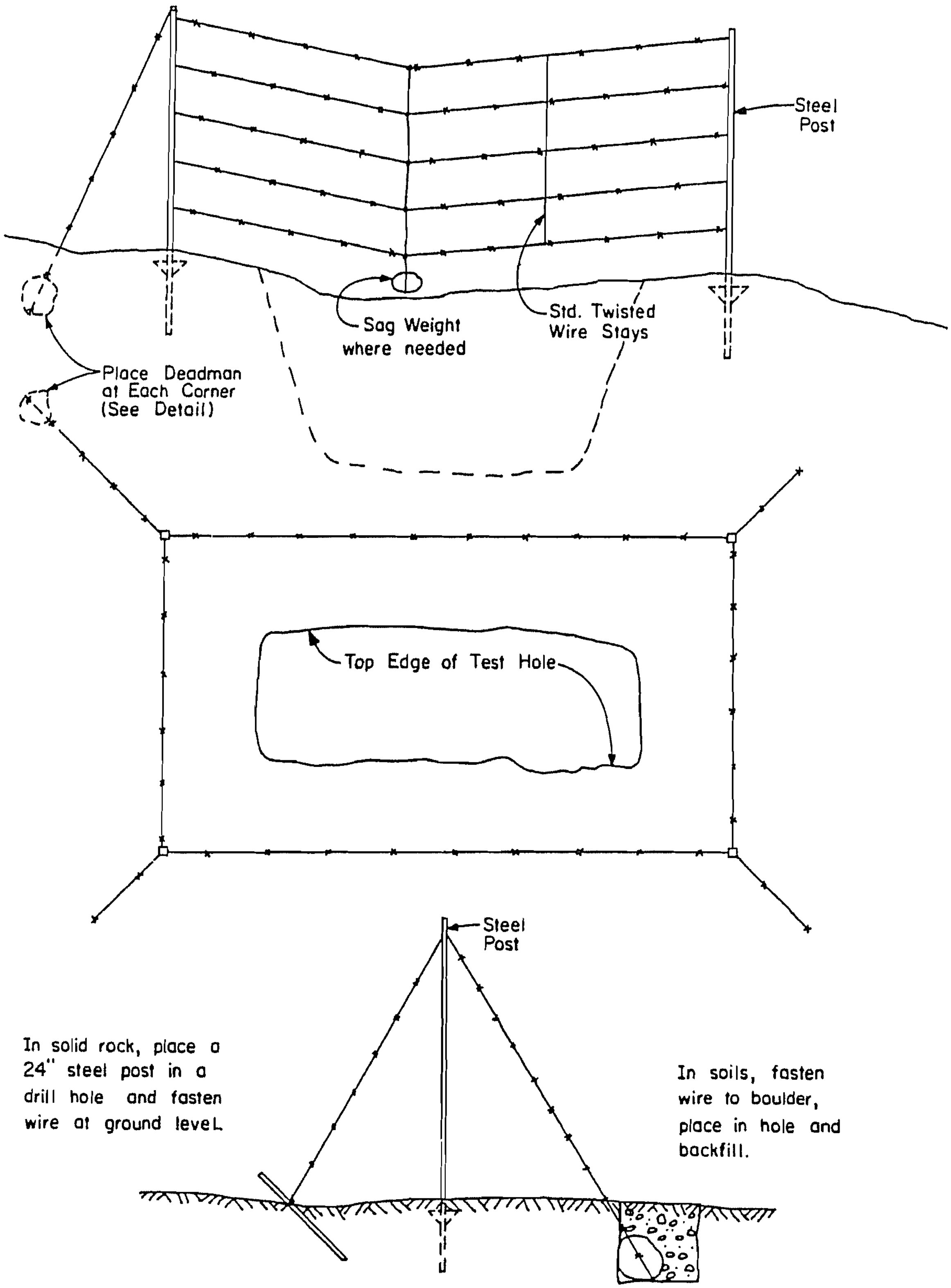
Type of Test	Number of Samples	Size of Each Sample
1. Sieve Analysis and P.I.	1 for each stratum of each test hole.	25 - 30 lbs.
2. Density	At least one at locations of in-place density test. Minimum of 3 for each pit.	75 - 100 lbs.
3. pH and Resistivity	1 for each CMP location on roadway Minimum of 3 for each pit.	25 - 30 lbs.
4. "R" Value	At least 1 for each "Control" point on centerline as directed by the Geotechnical Investigation Engineer and a minimum of 3 each in the borrow pits from controlling locations.	75 - 100 lbs.
5. Soluble Salts	Minimum of 3 for each borrow pit.	25 - 30 lbs.
6. Frost Susceptibility	Minimum of 3 for each soil type in a pit or subgrade (unless engineer gives other instructions).	25 - 30 lbs.

B. Aggregate Pits

Type of Test	Number of Samples	Size of Each Sample
1. Sieve Analysis and P.I.	1 for each stratum of each test hole.	25 - 30 lbs.
2. Density	Minimum of 3 for each pit.	75 - 100 lbs.
3. pH and Resistivity	Minimum of 3 for each pit.	25 - 30 lbs.
4. Abrasion	Minimum of 3 for each pit.	60 - 75 lbs.
5. Oversize	Minimum of 3 for each pit.	75 - 100 lbs.
6. % Limestone Determination	Minimum of 2	75 - 100 lbs. (1 large sack-including oversize)

FIGURE 107.00-1

FENCING OF OPEN TEST HOLES



CHAPTER 2

PAVEMENT DESIGN

200.00 INTRODUCTION

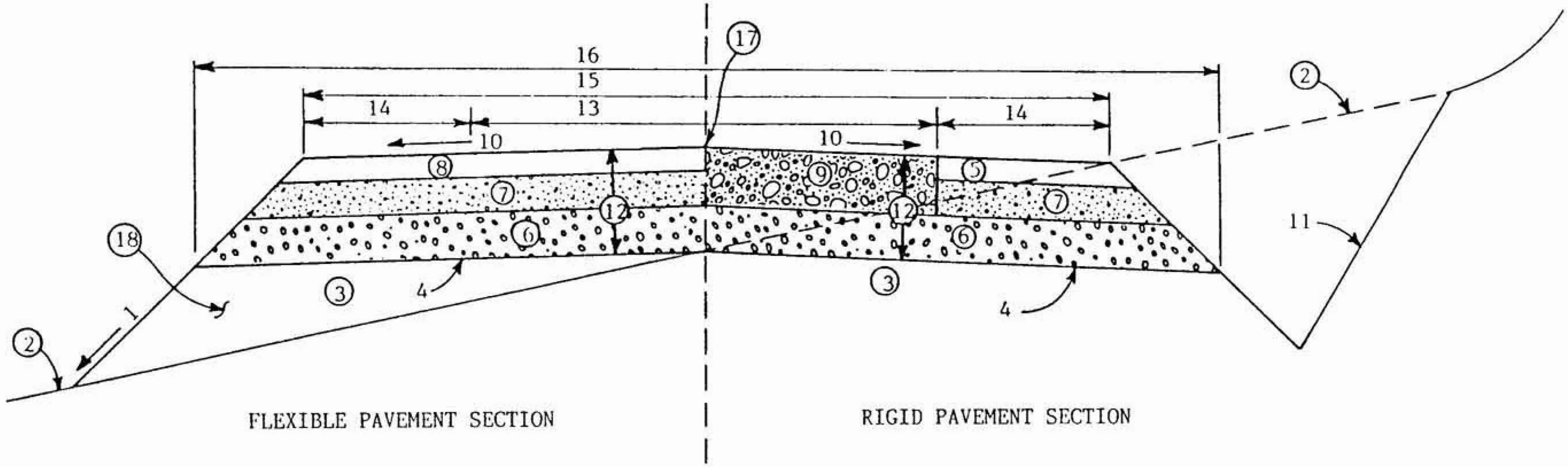
The remaining chapters deal with the procedures used by the Arizona Department of Transportation for the different facets of materials design of new pavements and rehabilitation of existing pavements; both rigid and flexible. This chapter will provide a guide for determining pavement structures similar to the ones shown in Figure 200.00-1. The design procedures provided will include the determination of the total pavement thickness as well as the thickness and structural value of each of the individual pavement components, the determination of alternate designs and the selection of optimum designs based on costs, conservation of materials or some other aspect will also be discussed.

Regardless of what type of design is involved (new construction, rehabilitation, widening, etc.) the collection and analysis of the information available on a project is the foundation for all that follows in the materials design process. The designer must integrate this information into the Materials Design Package (Materials Design Memo, Design Summary and Preliminary Pavement Structure Cost Estimate) that will provide the necessary documentation and communication of this design process. The information provided in Figure 200.00-2 gives an idea of some of the data required for the design analysis of different types of projects.

In the subsections that follow, this process will be discussed in detail.

200.01 PROJECT DETERMINATION

Whether it be from the scope of work, project assessment, design concept report or from the original project request form, the determination of a project's location and intent is the starting point for the design process. With this information the preliminary sampling, testing and data requirements for the project can usually be determined.



1 - FILL SLOPE
2 - NATURAL GROUND LINE
3 - SUBGRADE
4 - FINISHED SUBGRADE ELEVATION
5 - SHOULDER SURFACING
6 - SUBBASE COURSE
7 - BASE COURSE
8 - SURFACE COURSE
9 - PAVEMENT SLAB
10 - CROSS SLOPE
11 - CUTSLOPE
12 - PAVEMENT STRUCTURE
13 - TRAVEL LANES
14 - SHOULDER
15 - ROADWAY SURFACE
16 - ROADBED
17 - FINISHED ℄ GRADE
18 - FILL/EMBANKMENT

TYPICAL SECTION FOR RIGID OR FLEXIBLE PAVEMENT STRUCTURE

FIGURE 200.00-1

DATA REQUIRED FOR DIFFERENT TYPES OF CONSTRUCTION PROJECTS

DATA REQUIRED	NEW CONSTRUCTION	RECONSTRUCTION	WIDENING	AC PAVEMENT REHABILATATION	PCCP REHABILATATION	SURFACE TREATMENTS
SCOPE OF WORK	H	H	H	H	H	M
DESIGN CONCEPT REPORT	H	H	H	M	M	L
EXISTING AS-BUILT INFORMATION	N/A	H	H	H	H	H
ROUGHNESS, SKID, CRACKING (TYPE AND %)	N/A	L	M	H	H	H
DEFLECTION TESTING	N/A	L	H	H	M	L
FIELD INVESTIGATION	H	H	H	H	H	H
EXISTING PAVEMENT CONDITION	N/A	L	M	H	H	H
ENVIRONMENT & DRAINAGE	H	H	H	M	M	L
SUBGRADE SAMPLING & TESTING	H	H	M	L	L	N/A
MATERIAL SOURCES	H	H	H	M	M	L
TRAFFIC DATA (ADT AND ADL)	H	H	H	H	M	L

LEVEL OF NEED H = HIGH, M = MODERATE, L = LOW

FIGURE 200.00-2

200.02 DATA COLLECTION

For projects on the State Highway System the existing information is obtained from the pavement management history file which includes project numbers, date of construction, layer types and history sorted by route and milepost. For projects involving existing pavements on the State Highway System the data obtained by the annual surveys of the Pavement Management Unit is available. This survey information includes ride roughness, percent cracking, patching, flushing, skid resistance and rutting (interstate only) of the existing pavement. Additionally, although not done annually, Dynaflect or Falling Weight Deflectometer test results may also be available. Additional information is available at Engineering Records and includes, but is not limited to the following:

A. As-built Plans

B. Design and Construction Files

C. Location Surveys

D. Materials Files

E. Drainage Reports

For those projects not on the State Highway System, the information is usually available from the responsible agency.

200.03 FIELD INVESTIGATION

On new construction, reconstruction and widening projects the materials design survey should be held in conjunction with the geotechnical field review.

On rehabilitation projects a field survey should take place shortly after the existing information available has been analyzed. The importance of a field survey on rehabilitation projects cannot be over emphasized, for the information obtained concerning the existing pavement condition and apparent distress is necessary for reliable rehabilitation strategy selection. The following is a partial check list for items that should be investigated during the field survey for pavement rehabilitation projects:

A. Existing Pavement Condition

1. Cracking (type and percentage)
2. Surface Course (type and condition)
3. Maintenance (type and percentage)

4. Shoulder or Distress Lane Condition
5. Change in condition, distress, or surface type

B. Related Items

1. Drainage
2. Terrain
3. Roadway Grade and Section (cross slope)
4. Soils

C. General

1. Project Limits (Verification and Reasoning)
2. Bridge Structures (Clearance and Surface Type)
3. Ramp and Crossroad Pavement Condition
4. Ride Quality
5. Embankment Slopes and Guard Rail Height
6. Curb Heights and Overlay Buildup in Gutter

200.04 GEOTECHNICAL INFORMATION

A. Centerline Working Profile

During the centerline investigation of new construction projects, data is recorded that should be analyzed and used in the design process.

1. Test Holes

The location and depth of the holes are shown, and should be studied to determine if the roadway cuts are reasonably represented by samples.

2. Excavation Factors

The excavation factors for each cut are shown on the profile.

3. Cut Slopes

The recommended cut slopes are shown on the profile.

4. Ground Compaction

The amount of ground compaction to be compensated for is shown on the profile.

5. Miscellaneous Notes

Unusual conditions encountered during the investigation are noted on the profile. Examples include underground springs, slides or potential slides, piping, unusual erosion, or other phenomena. These should be studied and recommendations made in the memo.

B. Logs

The log of the test hole indicates the Field Supervisor's desciption of the material. It also indicates if the material was removed with or without blasting and indicates depths of various stratas of different materials. Also indicated is the material type at the bottom of the test hole.

C. Special Reports

If there were any unusual conditions found during the materials investigation that required special investigation and study, the report of these investigations and studies should be analyzed and recommended measures included in the design process.

D. Pit Sketches and Pit Field Reports

Pit sketches and Pit Field Reports should be analyzed to determine the following information to be incorporated in the Materials Design Memorandum on the pit data sheet.

1. Pit Sketches

Pit sketches will provide the following data:

a. Location

The pit sketch (Figure 104.06-4 and 104.06-5) will give the location of the pit usually in relation to a Station on the adjacent highway. It should also show the Section, Township and Range. The memo need only include the reference to the Station. For example: pit ADOT Serial No. 8491, located approximately 1.5 miles from Station 1807 (US 89) on a ridge.

b. Quantity

The quantity of available material may be calculated by multiplying the area shown on the pit sketch by the average depth of the usable material. It should be expressed in cubic yards. Because the area of the pit is usually irregular, the area may best be determined by use of planimeter. The calculation of quantity available should be conservative, assuming there will be a certain amount of waste and some areas that may not be workable. The shrink or swell factor should be applied in determining the final quantity.

2. Pit Report

The Geotechnical Analysis will include the following information:

a. Detailed description of the type of pit and nature of material within.

b. Haul road requirements.

c. Description of Pit Environment.

E. Geotechnical Report

The geotechnical report is used to summarize and document the geotechnical information obtained on a project. This information is used during the design process and for completing the geotechnical portion of the Materials Design Memo.

200.05 TRAFFIC ANALYSIS

The calculation of projected traffic is determined from data furnished by either the Transportation Planning or the Local Government Coordination Group. Generally, the Local Government Coordination Group provides data for all urban areas, except Tucson and Maricopa County for which this data is furnished by Pima Association of Governments (PAG) and Maricopa Association of Governments (MAG). Data for all other areas is provided by Transportation Planning.

The calculation of the estimated cumulative number of 18-Kip equivalent single axle loads (ESAL) for a design (or performance) period is performed by the Materials Section for all State highways. The calculations are performed at least once every year and computer reports distributed to those involved with the pavement design process.

For more details concerning traffic data procedures and analysis see Appendix A.

200.06 PRELIMINARY PLANS

The preliminary plans show the geometrics of the major roadway section. In addition to the major roadway, designs should be provided for all ramps, crossroads, frontage roads, access roads, and roadside rest areas. Provision should also be made, where applicable for detours, turnouts, median paving and other incidental work called for on the plans.

201.00 GENERAL PAVEMENT DESIGN CONSIDERATIONS - NEW CONSTRUCTION

The performance of a pavement structure is directly related to the properties and condition of the roadbed soils. The design procedures in this manual are based on the assumption that most soils can be adequately represented for pavement design purposes by mean values of the soil's resilient modulus (M_R), for flexible pavements, or the modulus of subgrade reaction (k), for rigid pavements. However, certain soils such as those that are excessively expansive, resilient, frost susceptible, or highly organic require that additional steps be taken to provide for adequate pavement performance.

Since the borrow may provide the control for the design of the pavement structure, the test data for designated borrow sources should be carefully studied. The quality of the material will be indicated by the R-value with the lowest number, indicating the poorest material. If the materials source is fairly uniform the mean R-value of the material should be used for the control. However, if most of the source is uniformly high in quality with perhaps only a few test holes with a low R-value, the source should be studied to see if the unfavorable materials may be isolated and eliminated from the pit area so the mean R-value of the higher quality material may be used for the design and construction of the project.

Where there is more than one borrow source on a project and there is considerable difference in the R-value of the various sources, a cost study should be made to determine the feasibility of hauling the higher quality material longer distances versus using the lower quality materials which will require additional pavement structure. The results of these studies will help to determine the final selection of the borrow sources.

Many projects will not have designated borrow sources and it will be the contractors responsibility to locate needed material. The pavement designer will need to anticipate the likely R-values of borrow material for the project and design the project accordingly. The anticipated mean R-value and associated standard deviation will need to be specified for inclusion in the project specifications. The contractor will be required to provide borrow sources, and test results demonstrating that his sources meet or exceed the mean and standard deviation requirements.

A. Subgrade Tabulations

The subgrade tabulations contain essentially the same test information as the borrow tabulations with the location of the test holes identified in relation to a Station on the project.

The subgrade tabulations should be studied carefully together with the preliminary construction profile to determine the design controls for each pavement structure. Only that material which is expected to be placed within the top 3 feet of finished subgrade elevation should be included in the statistical analysis of R-values. At the time the pavement structure is designed, there is usually no earthwork computation available to indicate this, therefore judgement should be exercised in determining the length of each pavement design section. This may be subject to adjustment when earthwork quantities are available.

Isolated small areas of poor quality material may be omitted in the design by specifying that the material be removed to a depth of 3 feet below finished subgrade elevation and replaced with acceptable material. The removed material may be placed in embankment sections a minimum of 3 feet below finished subgrade elevation.

In the analysis of the subgrade, careful consideration should be given to areas where test results indicate conditions that might generate problems in construction and performance of the pavement structure. Such conditions may include, but not necessarily be limited to, low R-values, high plasticity, high percentage passing the #200 sieve, expansive clays, high moisture content, frost susceptibility, settlement, collapsible soil, etc. Each such condition should be examined and engineering judgement applied to determine what should be recommended in the pavement design memo to preclude such problems.

Other problems related to roadbed soils are the nonuniform support that results from wide variations in soil type or condition; the additional densification under traffic of soils that are not adequately compacted during construction; and construction difficulties, particularly those associated with compaction of cohesionless sands and wet, highly plastic clays.

With these problems in mind, the following adverse conditions listed below should be considered in design. If necessary, the Soils Engineer should be consulted to assist in identifying the problem and recommending a solution. It should be noted that the solutions given for each condition are not the only answer and each problem area should be studied on an individual basis. Appropriate statements of recognition of the problems and solutions should be included in the design memo.

1. Soils that are excessively expansive should receive special consideration. Generally, expansive soils have high plasticity indices, high percentage passing the #200 sieve, low "R"-values, and are A-6 and A-7 soils according

to the AASHTO Soil Classification System. One solution may be to cover these soils with a sufficient depth of selected material to overcome the detrimental effects of expansion. Expansion may often be reduced by tight control of the compaction water content. In some cases, it may be more economical to treat expansive soils by stabilizing with suitable admixture, such as lime or cement, to over excavate and replace the material or to encase a substantial thickness in a waterproof membrane to stabilize the water content. Also, widening and deepening the cut ditches and providing the shoulder slopes with a membrane, may help to stabilize the roadway section.

2. Low shear strength soils generally are those soils that have low "R"-values, (15 or less). Although these soils can be compensated for by increasing the structural thickness, it may be more economical in the long term to treat them with a suitable admixture such as lime or cement. In some cases geosynthetics may be appropriate. Additionally, the shear strength may be improved by blending with a granular soil. If the low shear strength soil is in limited areas, it may be most economically treated by over-excavating and replacing with a selected material.

3. In areas with a freezing index, the pavement design should include an analysis of the effects of frost in addition to the analysis for traffic loadings. A complete explanation of the design procedures for frost conditions is contained in Appendix B.

4. Problems with highly organic soils are related to their extremely compressible nature, and are accentuated when deposits are extremely nonuniform in properties or depth. Local deposits, or those of relatively shallow depth, may be most economically excavated and replaced with suitable selected material. Problems associated with deeper and more extensive deposits may be alleviated by placing surcharge embankments for preconsolidation, sometimes with special provisions for rapid removal of water to hasten consolidation.

5. Special provisions for unusually variable soil types and conditions may include: scarifying and recompacting; treatment of an upper layer of roadbed soils with a suitable admixture; using appreciable depths of more suitable roadbed soils; overexcavation of cut sections, and placing a uniform layer of selected material in both cut and fill areas; adjustment in the thickness of subbase at transitions from one soil type to another, particularly when the transition is from cut to fill section, or the use of geosynthetics.

6. Although the design procedure is based on the assumption that provisions will be made for surface and subsurface drainage, unusual situations may require that special attention be given to design and construction of drainage systems. Drainage is particularly important where continual flows of water are encountered (i.e., springs or seeps); where detrimental frost conditions are present; or where soils are particularly susceptible to expansion or loss of strength with increase in water content. Special subsurface drainage may include provision of additional layers of permeable material beneath the pavement for interception and collection of water, and pipe drains for collection and transmission of water. Special surface drainage may require such facilities as dikes, paved ditches, and catch-basins. For additional information on subsurface drainage see FHWA Reports RD-73-14, TS-80-224, and TS-86-208.

7. Certain roadbed soils pose difficult problems during construction. These are primarily the cohesionless soils, which are readily displaced under equipment used to construct the pavement; and wet clay soils, which cannot be compacted at high water contents because of displacement under rolling equipment and require long periods of time to dry to a suitable water content. Measures that may be applied to alleviate such construction problems include; blending with other soils or adding suitable admixtures to sands to provide cohesion, or to clays to hasten drying or increasing shear strength; covering with a layer of more suitable selected material to act as a working platform for construction of the pavement, or use of a geosynthetic to provide additional stability.

After a systematic evaluation of results of the soils investigation, the process of designing pavement structures consists of applying these results to a rational pavement structure design procedure. The design procedures will yield the approximate thicknesses of subbase, base course, and surface course. The following sections will describe those procedures employed by the Arizona Department of Transportation for the designing of pavement structures for flexible pavements, rigid pavements, asphaltic concrete overlays and other pavement rehabilitation strategies.

202.00 PAVEMENT DESIGN

202.01 - GENERAL INFORMATION

The Arizona Department of Transportation is adopting the 1986 AASHTO Guide for Design of Pavement Structures for new construction of both flexible and rigid pavements. This AASHTO publication significantly changes pavement design and the reader is advised to obtain a copy of it for additional background material. Because of the numerous changes embodied in the AASHTO Guide, it is not possible in this manual to cover all design aspects for both flexible and rigid pavements. In this respect the Materials Section Preliminary Engineering and Design Manual presents how the AASHTO Guide will be applied for the Arizona Department of Transportation (ADOT). Thus, much of what is presented here will be ADOT's modifications and conventions necessary to obtain designs that will perform as well or better than the tentative AASHTO Guide and with greater reliability. In addition criteria are presented to facilitate the use of new materials and concepts consistent with construction control practices and pavement management policies. In general the designer should have a greater opportunity to try different designs, with the goal of obtaining the most cost effective design. Many of the following concepts can be applied to both flexible and rigid pavements, however, in keeping with the AASHTO Guide flexible pavements will be discussed first.

202.02 - FLEXIBLE PAVEMENT DESIGN

A. The basic design equation used for flexible pavements is as follows:

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left[\dfrac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \dfrac{1094}{(SN + 1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

Where

W_{18}	=	predicted number of 18-kip equivalent single axle load applications (Flexible)
Z_R	=	standard normal deviate,
S_o	=	combined standard error of the traffic prediction and performance prediction,
ΔPSI	=	$P_0 - P_t$
P_0	=	initial design serviceability index
P_t	=	design terminal serviceability index,
M_R	=	resilient modulus (psi).

SN is equal to the structural number indicative of the total pavement section required:

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

Where

a_1	=	i^{th} layer coefficient,
D_1	=	i^{th} layer thickness (inches) and
m_2	=	i^{th} layer drainage coefficient.

B. W_{18} Determination

The calculation of the estimated cumulative number of 18-Kip equivalent single axle loads (ESAL) for a design (or performance) period is performed by the Pavement Management Branch of the Materials Section for all State highways. The calculations are performed at least once each year and computer reports distributed to those involved with the pavement design process.

The calculation of the estimated ESAL is based on:

1) traffic volume (ADT) (Average Daily Traffic plus growth factor)
2) vehicle equivalencies (Growth factor and tire pressure)
3) vehicle classification

All of these traffic data are obtained from the Transportation Planning Division for state highway project design. Local Government groups will furnish the traffic information for their projects. Traffic estimates and calculations can be very difficult to obtain for ramps, crossroads and frontage roads. Ramps and crossroads should be estimated to have traffic loads of at least five percent of the mainline traffic loading. Likewise, frontage roads should be estimated to be at least one percent of the mainline traffic loading. If actual traffic measurements give larger calculated traffic values, these actual measures should be used.

A detailed explanation of the assumptions, equations and calculations for the determination of the traffic loading used for pavement design is given in Appendix A.

C. Z_R Determination

Standard normal deviate is a measure of how likely a pavement is to fail within the design period. If Z_R of -2.327 is selected there is only one chance in a hundred that the pavement will fail during its design period. Conversely, there is a 99 percent chance a pavement will not fail within the design period, which can be called the level of reliability. Table 202.02-1 gives the level of reliability in percent, as well as the Z_R values that should be used for design.

D. S_0 - In keeping with the AASHTO Guide a combined standard error of 0.45 for flexible pavements.

E. ΔPSI - Over a 20 year design period there will be a change in present serviceability index. Arizona's pavement management data base indicates that this change is a function of highway type as shown below in Table 202.02-2.

F. M_R - Resilient Modulus of Subgrade

For flexible pavement design, the primary soil strength measure used by ADOT is the Resilient Modulus, M_R, as determined thru R-Value analysis. Due to the much greater amount of time and expense of the R-value sampling and testing process, a method of estimating R-values and hence, M_R values, from other more common tests has been developed.

TABLE 202.02-1

LEVEL OF RELIABILITY (PERCENT)

Divided Highways, Freeways and Interstates	99%
Non-Divided, Non-Interstate Highways, 10,000+ ADT	95%
2,001 - 10,000 ADT	90%
501 - 2,000 ADT	85%
≤500 ADT	75%

Z_R values for each level of reliability:

75%	=	-0.674
80%	=	-0.841
85%	=	-1.037
90%	=	-1.282
95%	=	-1.645
99%	=	-2.327

TABLE 202.02-2

SERVICEABILITY INDEX

	P_o	P_t	ΔPSI Change in PSI
Divided Highways, Freeways & Interstates	4.2	3.0	1.2
Non-Divided, Non-Interstates Highways, 10,000+ ADT	4.2	2.8	1.4
2,001-10,000 ADT	4.1	2.6	1.5
501-2,000 ADT	4.1	2.6	1.5
≤ 500 ADT	4.0	2.4	1.6

Extensive regression and correlation analyses have been performed using the gradation and the Plasticity Index, Liquid Limit and Sand Equivalent test as indicators and predictors of R-value. Of the many candidate equations and relationships considered, a family of curves was finally chosen as the best workable relationship between gradation and Plasticity Index. The general form of the equation is:

$$\log \text{R-Value at 300 psi} = 2.0-0.006(\text{Pass } 200)-0.017(\text{PI})$$

A soil strength correlation table has been constructed to simplify the solution to the mathematical relationships developed between R-value, Plasticity Index and Percent Pass #200 sieve (Table 202.02-3) For example, given a PI of 12 and a percentage pass the #200 sieve of 39, Table 202.02-3 produces an R-value of 36.

For design purposes, the design R-Value used should be determined from the correlated R-value, R_c, results (from PI and 200's) as well as from actual R-value, R_t, tests (AASHTO T 190).

All soil samples delivered to the testing laboratory should be accompanied by a field log and work instructions initialed by the requestor. All samples will be tested for Gradation (coarse screen and fine screen/elutriation) and plasticity index. Additionally, tests such as densities, pH and resistivities etc., will be performed as instructed, with the exception of R-value tests. Prior to performing R-value tests, all soil sample results will be analyzed to determine the samples on which to run actual R-values.

The correlated R-values will be analyzed and representative samples will be selected from those that were initially sampled for R-values. Those selected samples will actually be tested for R-values. It is recommended that if the lowest correlated R-value is greater than 65, and the designer determines that an R-value higher than this will not significantly change his pavement design, that it may be advisable not to perform any actual R-values and use a representative correlated R-value instead.

This process of eliminating R-value tests is a recommendation to minimize testing and expedite the design process. The designer may opt to have all R-value tests run.

After R-value testing is completed, all test results will be relayed to the designer for further evaluation. If after analysis, the test results suit the designers needs, no further sampling or testing will be required. If not, the designer may request additional sampling and testing.

TABLE 202.02-3

BODY OF TABLE IS R-VALUE AT 300 psi EXUDATION PRESSURE

PERCENT PASSING #200 SIEVE

PI	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	78	81	84	87	90	93	96
0	100	96	92	88	85	81	78	75	72	69	66	63	61	58	56	54	52	49	47	45	44	42	40	39	37	35	34	33	31	30	29	28	27
1	96	92	89	85	81	78	75	72	69	66	64	61	58	56	54	52	50	48	46	44	42	40	39	37	36	34	33	31	30	29	28	27	26
2	92	89	85	82	78	75	72	69	66	64	61	59	56	54	52	50	48	46	44	42	40	39	37	36	34	33	31	30	29	28	27	26	25
3	89	85	82	79	75	72	69	67	64	61	59	56	54	52	50	48	46	44	42	40	39	37	36	34	33	32	30	29	28	27	26	25	24
4	86	82	79	76	72	70	67	64	61	59	56	54	52	50	48	46	44	42	41	39	37	36	34	33	32	30	29	28	27	26	25	24	23
5	82	79	76	73	70	67	64	62	59	57	54	52	50	48	46	44	42	41	39	37	36	34	33	32	30	29	28	27	26	25	24	23	22
6	79	76	73	70	67	64	62	59	57	54	52	50	48	46	44	42	41	39	37	36	35	33	32	30	29	28	27	26	25	24	23	22	21
7	76	73	70	67	64	62	59	57	55	52	50	48	46	44	43	41	39	38	36	35	33	32	31	29	28	27	26	25	24	23	22	21	20
8	73	70	67	65	62	59	57	55	52	50	48	46	44	43	41	39	38	36	35	33	32	31	29	28	27	26	25	24	23	22	21	20	19
9	70	67	65	62	60	57	55	53	50	48	46	45	43	41	39	38	36	35	33	32	31	29	28	27	26	25	24	23	22	21	20	19	19
10	68	65	62	60	57	55	53	51	49	47	45	43	41	39	38	36	35	33	32	31	30	28	27	26	25	24	23	22	21	20	19	19	18
11	65	62	60	57	55	53	51	49	47	45	43	41	40	38	36	35	33	32	31	30	28	27	26	25	24	23	22	21	20	20	19	18	17
12	63	60	58	55	53	51	49	47	45	43	41	40	38	36	35	34	32	31	30	28	27	26	25	24	23	22	21	20	20	19	18	17	17
13	60	58	55	53	51	49	47	45	43	41	40	38	37	35	34	32	31	30	29	27	26	25	24	23	22	21	20	20	19	18	17	17	16
14	58	55	53	51	49	47	45	43	41	40	38	37	35	34	32	31	30	29	27	26	25	24	23	22	21	21	20	19	18	17	17	16	15
15	56	53	51	49	47	45	43	42	40	38	37	35	34	32	31	30	29	27	26	25	24	23	22	21	21	20	19	18	17	17	16	15	15
16	53	51	49	47	45	43	42	40	38	37	35	34	33	31	30	29	28	26	25	24	23	22	21	21	20	19	18	17	17	16	15	15	14
17	51	49	47	45	44	42	40	38	37	35	34	33	31	30	29	28	26	25	24	23	22	22	21	20	19	18	17	17	16	15	15	14	14
18	49	47	45	44	42	40	39	37	35	34	33	31	30	29	28	27	25	24	23	22	22	21	20	19	18	18	17	16	15	15	14	14	13
19	48	46	44	42	40	39	37	36	34	33	31	30	29	28	27	26	24	23	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13
20	46	44	42	40	39	37	36	34	33	31	30	29	28	27	26	25	24	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12
21	44	42	40	39	37	36	34	33	32	30	29	28	27	26	25	24	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12
22	42	41	39	37	36	34	33	32	30	29	28	27	26	25	24	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12	11
23	41	39	37	36	34	33	32	30	29	28	27	26	25	24	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12	11	11
24	39	37	36	35	33	32	30	29	28	27	26	25	24	23	22	21	20	19	19	18	17	16	16	15	14	14	13	13	12	12	11	11	10
25	38	36	35	33	32	31	29	28	27	26	25	24	23	22	21	20	19	19	18	17	16	16	15	14	14	13	13	12	12	11	11	10	10
26	36	35	33	32	31	29	28	27	26	25	24	23	22	21	20	19	19	18	17	16	16	15	15	14	13	13	12	12	11	11	10	10	10
27	35	33	32	31	29	28	27	26	25	24	23	22	21	20	19	19	18	17	16	16	15	15	14	13	13	12	12	11	11	10	10	10	9
28	33	32	31	30	28	27	26	25	24	23	22	21	20	19	19	18	17	17	16	15	15	14	13	13	12	12	11	11	10	10	10	9	9
29	32	31	30	28	27	26	25	24	23	22	21	20	20	19	18	17	17	16	15	15	14	13	13	12	12	11	11	10	10	10	9	9	9
30	31	30	28	27	26	25	24	23	22	21	20	20	19	18	17	17	16	15	15	14	13	13	12	12	11	11	11	10	10	9	9	9	8
31	30	29	27	26	25	24	23	22	21	20	20	19	18	17	17	16	15	15	14	14	13	12	12	11	11	11	10	10	9	9	9	8	8
32	29	27	26	25	24	23	22	21	21	20	19	18	17	17	16	15	15	14	14	13	12	12	11	11	11	10	10	9	9	9	8	8	8
33	27	26	25	24	23	22	21	21	20	19	18	17	17	16	15	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7
34	26	25	24	23	22	21	21	20	19	18	17	17	16	15	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7
35	25	24	23	22	22	21	20	19	18	17	17	16	15	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7
36	24	23	22	22	21	20	19	18	18	17	16	15	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7	6
37	23	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7	7	6
38	23	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7	7	6	6
39	22	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7	7	6	6	6
40	21	20	19	18	18	17	16	16	15	14	14	13	13	12	12	11	11	10	10	10	9	9	8	8	8	7	7	7	7	6	6	6	6
42	19	19	18	17	16	16	15	14	14	13	13	12	12	11	11	10	10	10	9	9	8	8	8	7	7	7	7	6	6	6	6	5	5
44	18	17	16	16	15	15	14	13	13	12	12	11	11	10	10	10	9	9	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5
46	17	16	15	15	14	13	13	12	12	11	11	10	10	10	9	9	9	8	8	8	7	7	7	6	6	6	6	5	5	5	5	5	4
48	15	15	14	13	13	12	12	11	11	11	10	10	9	9	9	8	8	8	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4
50	14	14	13	12	12	11	11	11	10	10	9	9	9	8	8	8	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4
52	13	13	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3
54	12	12	11	11	10	10	9	9	9	8	8	8	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3
56	11	11	10	10	9	9	9	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3
58	10	10	10	9	9	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3
60	10	9	9	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3
62	9	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2
64	8	8	8	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2
66	8	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2
68	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2
70	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2
72	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2
74	6	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	1
76	5	5	5	5	4	4	4	4	4	4	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1

G. Mean R-Value Determination

1. The following items should be considered in the selection of the Mean R-value for design.

a. Determine the soil types that will compose the finished subgrade.

b. Will the subgrade be composed of in-place material, roadway excavation or borrow?

c. If roadway excavation controls, estimate to what limits the material will be placed.

d. Different types (AASHTO SOIL CLASSIFICATION) of material in the cuts?

e. The approximate volume each material type represents.

f. The location within the cut of each material type (at grade, horizontal stratum, etc.).

g. Length and depth of fill areas adjacent to the cut.

h. Feasibility of stabilizing (lime and cement) soils with a low R-value (R less then 15). Such stabilized layers will be characterized by a structural coefficient based upon strength.

i. Feasibility of controlling placement of excavation.

(1) Specify station limits for hauling excavation.

(2) Specify material not used within 3 feet of finished subgrade elevation.

j. Feasibility of using Geosynthetics. For purposes of the design the mean subgrade R-value should be increased by 10 when a geosynthetic is used.

k. Possibility of using material in a place where the soil strength is not critical (e.g., dike construction, slope plating). Wasting poor material should also be considered.

l. Over excavation (especially at grade-in and grade-out points) and replacement with a better material.

m. Stripping of overburden and placement in lower level of fills.

2. Determine the Mean and Construction Control R-values by analysis of the test data for the soil types(s) that will compose the finished subgrade. Test results from soils that will not be part of the 3 feet immediately below finished subgrade elevation should not be included in this analysis. If borrow will be used, the test results from the borrow will need to be either incorporated into the analysis or analysed separately. Both correlated (Rc) and actual (Ra) R-values should be incorporated into the analysis. The means of the Rc and Ra values are determined separately and combined thru the formula to arrive at the mean R-value.

$$R_{mean} = \frac{N_t R_t \sigma_c^2 + N_c R_c \sigma_t^2}{N_t \sigma_c^2 + N_c \sigma_t^2}$$

Where N_t = number of actual R-values
N_c = number of correlated R-values (from PI & 200)
R_t = mean of the actual R-values
R_c = mean of the correlated R-values
σt = standard deviation of the actual R-values
σc = standard deviation of the correlated R-values

The standard deviation of the Rc values that were used in determining the mean R-value should also be used in determining the construction control R-value.

H. Resilient Modulus Determination

Once the mean R-value has been determined, it should be converted to a resilient modulus value, M_r, thru the equation:

$$M_R = \frac{1815 + 225*(R_{mean}) + 2.40*(R_{mean})^2}{0.6(SVF)^{0.6}}$$

Where SVF is the seasonal variation factor from Figure 202.02-1. For further clarification Table 202.02-4 shows SVF values for each city shown on the map.

This M_R value is used as the input value for the AASHTO Flexible Pavement design equation. The M_R value is also used to determine the modulus of subgrade reaction (k) for input in the rigid pavement design equation. Figure 202.02-2 graphically presents the relationship between M_R, SVF and mean R-value. Generally, the design M_R value for subgrade materials should not exceed 26,000 psi.

FIGURE 202.02-1

SEASONAL VARIATION FACTOR

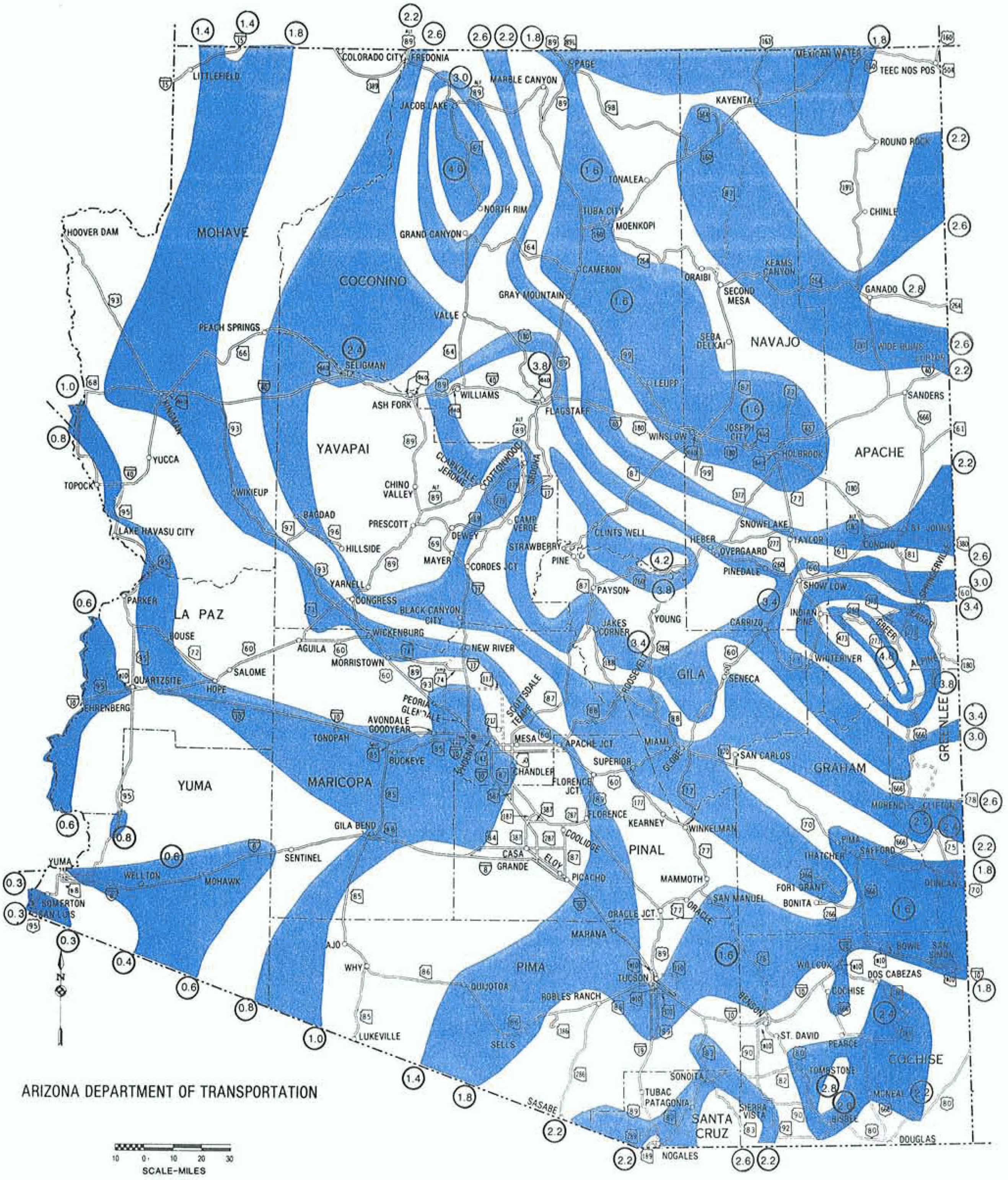


TABLE 202.02-4

LOCATION	SEASONAL VARIATION FACTOR
Aguila	1.1
Ajo	1.2
Alpine	3.8
Apache Junction	1.2
Ash Fork	2.7
Avondale	1.0
Bagdad	2.3
Benson	1.9
Bisbee	2.6
Black Canyon City	2.5
Bonita	2.1
Bouse	1.0
Bowie	1.7
Buckeye	0.9
Cameron	1.5
Camp Verde	2.1
Carrizo	3.3
Casa Grande	1.0
Chandler	1.0
Chinle	2.1
Chino Valley	2.7
Clarkdale	2.3
Clifton	2.6
Clints Well	4.1
Colorado City	1.9
Concho	2.2
Congress	1.7
Coolidge	1.0
Cordes Junction	2.6
Cottonwood	2.2
Dewey	2.7
Dos Cabezas	2.4
Douglas	1.9
Duncan	1.7
Eager	3.7
Ehrenberg	0.5
Eloy	1.1
Flagstaff	3.5
Florence	1.3
Florence Junction	1.9

TABLE 202.02-4 (Cont'd.)

LOCATION	SEASONAL VARIATION FACTOR
Fort Grant	2.1
Fredonia	1.9
Ganado	2.6
Gila Bend	0.8
Glendale	1.0
Globe	2.6
Goodyear	1.0
Grand Canyon	2.6
Gray Mountain	2.0
Greer	4.2
Heber	3.1
Hillside	2.6
Holbrook	1.7
Hoover Dam	1.0
Hope	1.0
Indian Pine	4.1
Jacob Lake	3.1
Jakes Corner	2.4
Jerome	2.6
Joseph City	1.7
Kayenta	1.8
Keams Canyon	2.4
Kearney	2.1
Kingman	1.7
Lake Havasu City	0.5
Leupp	1.5
Littlefield	1.2
Lukeville	1.2
Lupton	2.2
Mammoth	2.1
Marana	1.6
Marble Canyon	1.7
Mayer	2.7
McNeal	1.9
Mesa	1.0
Mexican Water	1.8
Miami	2.8
Moenkopi	1.7
Mohawk	0.5
Morenci	2.6
Morristown	1.5
New River	1.5
Nogales	2.3

TABLE 202.02-4 (Cont'd.)

LOCATION	SEASONAL VARIATION FACTOR
North Rim	4.0
Oracle	2.3
Oracle Junction	2.1
Oraibi	2.0
Overgaard	3.3
Page	1.5
Parker	0.5
Patagonia	2.5
Payson	3.5
Peach Springs	1.8
Pearce	1.9
Peoria	1.0
Phoenix	1.0
Picacho	1.3
Pima	1.6
Pine	3.9
Pinedale	3.1
Prescott	3.2
Quartzsite	0.6
Quijotoa	1.6
Robles Ranch	1.8
Roosevelt	2.3
Round Rock	1.9
Safford	1.6
Salome	1.0
San Carlos	2.0
San Luis	0.3
San Manuel	1.9
San Simon	1.6
Sanders	2.0
Sasabe	2.2
Scottsdale	1.0
Seba Delkai	1.8
Second Mesa	1.8
Sedona	2.4
Seligman	2.7
Sells	1.6
Seneca	3.4
Sentinel	0.6
Show Low	3.4
Sierra Vista	2.0
Snowflake	2.5
Somerton	0.3

TABLE 202.02-4 (Cont'd.)

LOCATION	SEASONAL VARIATION FACTOR
Sonoita	2.1
Springerville	3.7
Strawberry	4.1
St. David	2.1
St. Johns	2.1
Superior	2.1
Taylor	2.5
Teec Nos Pos	2.1
Tempe	1.0
Thatcher	1.6
Tombstone	2.2
Tonalea	1.9
Tonopah	1.0
Topock	0.7
Tuba City	1.7
Tubac	2.0
Tucson	1.7
Valle	2.6
Wellton	0.5
Whiteriver	3.6
Why	1.2
Wickenburg	1.5
Wide Ruins	2.2
Wikieup	1.5
Wilcox	1.8
Williams	3.3
Winkelman	2.1
Winslow	1.7
Yarnell	3.1
Young	3.4
Yucca	1.2
Yuma	0.4

R—VALUE TO MODULUS CONVERSION CHART

Note: Generally the subgrade design Mr should not exceed 26000 psi

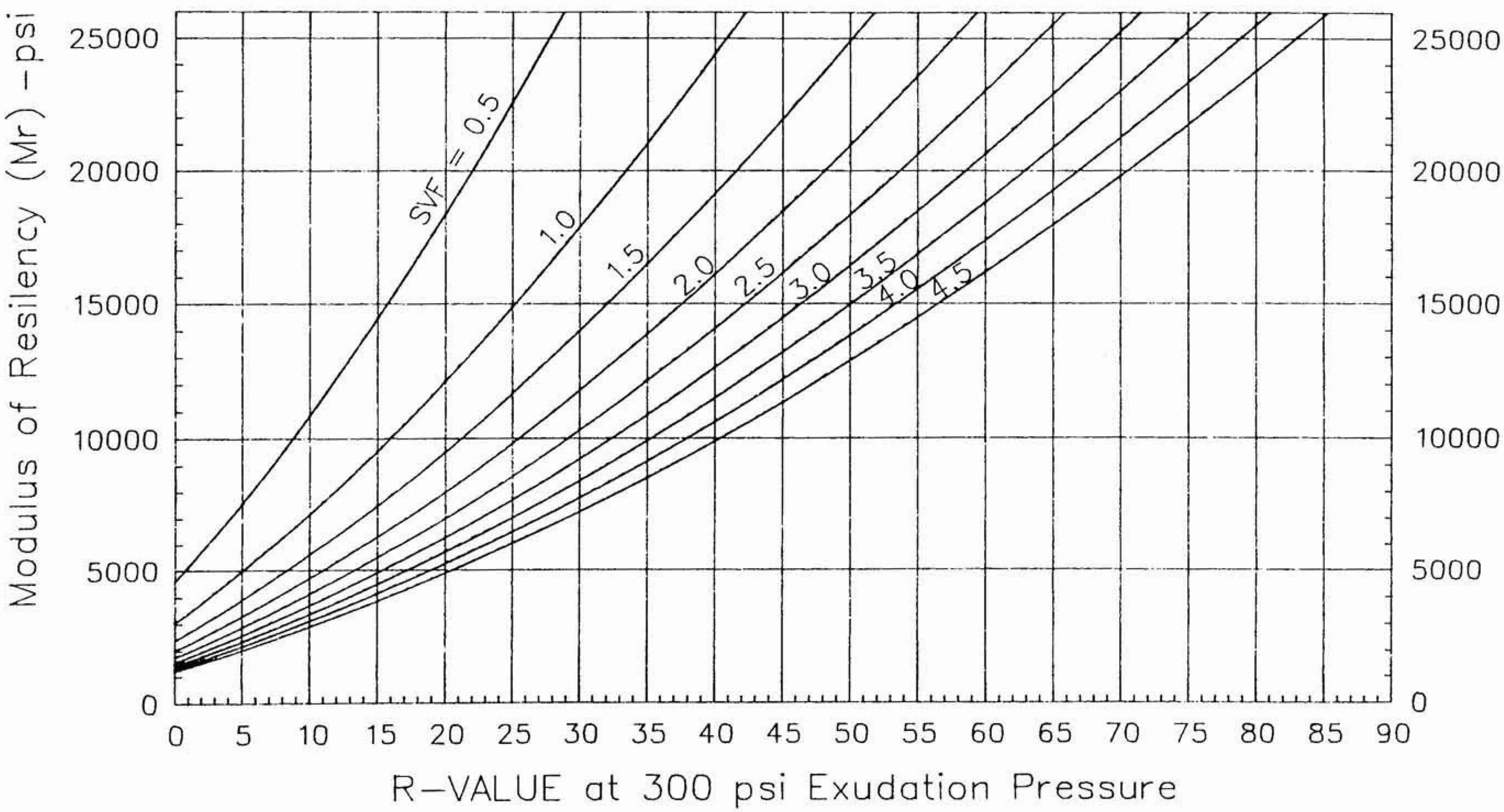


FIGURE 202.02-2

I. Construction Control R-Value Determination

For construction control, the minimum acceptable Rc-value (correlated R-value) should be determined as follows:

For a confidence level of 90%, find the critical value from Table 202.02-5 of the t distribution and for n-1 degrees of freedom.

Multiply the critical t value times the standard deviation from the mean Rc-value determination. Subtract this product from the mean Rc-value. The result will be the minimum Rc-value for construction control purposes.

J. SN - Structural number represents the overall structural capacity needed in the base and surfacing to accommodate the expected traffic loading. It is solved for iteratively to nearest hundredth of a decimal point.

K. a_i - Following the solution of structural number the layer coefficient is determined for each supporting layer. Table 202.02-6 coefficients to be used for a variety of base and surfacing materials.

Circumstances may exist that warrant the use of new materials and/or new variations of materials in such a way that normal coefficients may need to be checked. In addition to this some materials may be substantially altered during construction to the extent that the structural coefficient may need to be changed. If the material in question is statistically controlled with a penalty schedule then coefficient adjustment may not be necessary. With the above conditions in mind the following equations and nomographs should be used to determine the coefficient in question.

Asphaltic Concrete -AC

For AC mixes such as a 1/2" AC, 3/4" AC, recycle, emulsion treated base or any other asphalt material the following equation, which was adapted from the Asphalt Institute along with Figure 202.02-3 can be used to estimate the coefficient.

$$\mathrm{Log}_{10}(E_{AC}) = 6.427936+0.019476*(\text{Pass } 200)-0.03476*(\text{voids}) + 0.070377*(\text{visc @ } 70^{o}\text{F})-0.28646*(\%\text{ Asph})^{0.5}$$

TABLE 202.02-5

Critical t Value

Degrees of Freedom (Number of Tests-1)	90% t Value
2	1.886
3	1.638
4	1.533
5	1.476
6	1.440
7	1.415
8	1.397
9	1.383
10	1.372
11	1.363
12	1.356
13	1.350
14	1.345
15	1.341
16	1.337
17	1.333
18	1.330
19	1.328
20	1.325
21	1.323
22	1.321
23	1.319
24	1.318
25	1.316
26	1.315
27	1.314
28	1.313
29	1.311
30	1.310
40	1.303
60	1.296
120	1.289
Over 120	1.282

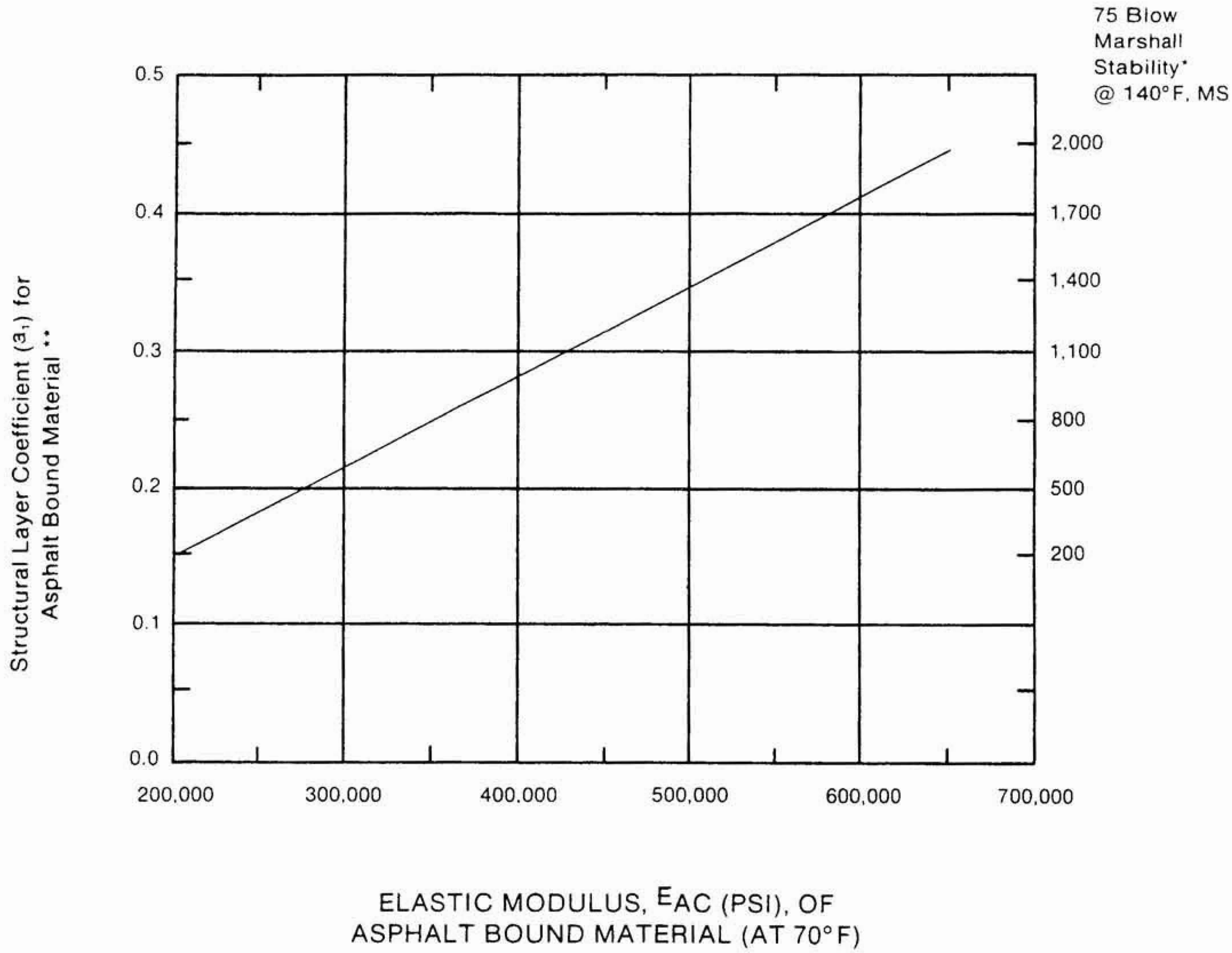
TABLE 202.02-6

SURFACING AND BASE COEFFICIENTS

	Maximum coefficient
Asphaltic Concrete (3/4" or 1/2" Mix; Virgin or Recycled)	.44 - a_1
Cement Treated or Bituminous Treated Base	.28 - a_2
Cement or Lime Treated Subgrade	.23 - a_2
Aggregate Base	.14 - a_2
Aggregate Subbase	.11 - a_3

FIGURE 202.02-3

Chart for estimating structural layer coefficient of asphalt bound material based on elastic modulus or marshall stability



* Flow must be between 8-16

** Coefficient cannot be lower than 0.15 or higher than 0.44.

$a_1 = 0.02 + 6.4 \times 10^{-7}(E_{AC})$

$a_1 = 0.12 + 1.61 \times 10^{-4}(MS)$

Where

E = Elastic Modulus of AC (psi)
For values less than 275,000 psi or 500 marshall stability no coefficient should be assigned. Either re-design mix or consider it a base course. If greater than 650,000 psi or 2,000 marshall stability the coefficient is .44.

Pass 200 = Percent passing the #200 sieve. For purposes of design calculations use the minimum design criteria value.

Voids = Effective voids. For purposes of design calculations use the maximum design criteria value.

Visc.@70°F = Viscosity at 70°F.

$$\text{Visc.@}70^{\circ}\text{F} = 29508.2 * \left[\frac{\text{Abs. Visc. @ } 140^{\circ}\text{F}}{303{,}625}\right]^{1.7490}$$

For purposes of design calculations use the smallest allowable absolute viscosity at 140°F for the design asphalt grade.

% Asph. = Percent asphalt by weight. For recycle mixes use only the new asphalt.

Cement Treated Base - CTB

Figure 202.02-4 shows that the CTB coefficient is a function of the seven (7) day unconfined compressive strength. If the compressive strength is less than 200 psi than the material should be considered as aggregate base and the coefficient re-calculated. A coefficient of 0.28 will apply to CTB with 800 psi or more strength.

Bituminous Treated Base - BTB

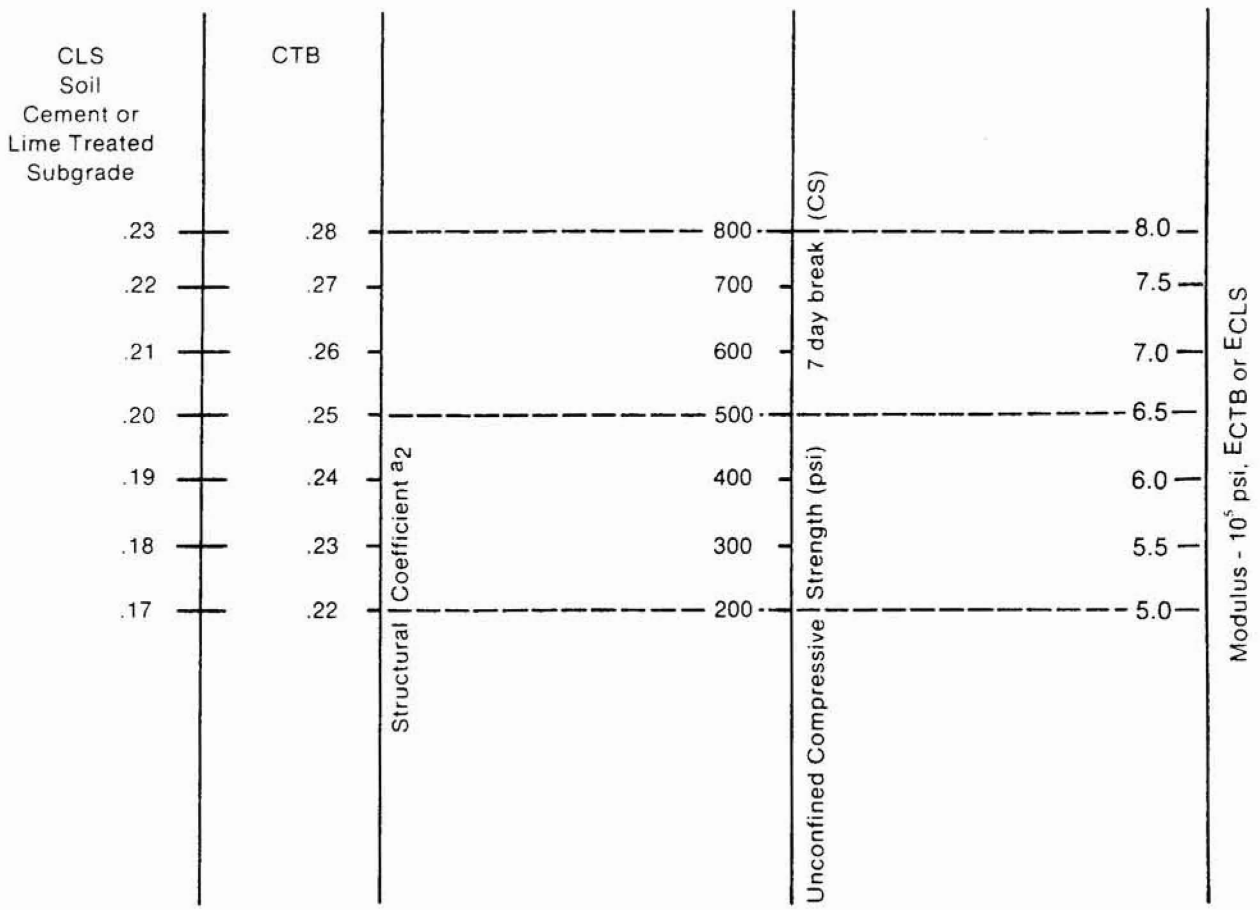
This base will be used primarily as a drainage layer and should be given a coefficient of 0.28.

Soil Cement or Lime Treated Subgrade

Figure 202.02-4 shows that for these materials the coefficient is a function of the seven (7) day unconfined compressive strength. The coefficients are less than CTB because of subgrade variability and construction control. If

FIGURE 202.02-4

Chart for estimating structural layer coefficient of cement treated base (CTB) and stabilized soil subgrade based on unconfined compressive strength or elastic modulus



$a_2 = 0.20 + 0.0001\ (CS_{CTB})$
$a_2 = 0.15 + 0.0001\ (CS_{CLS})$

$a_2 = 0.12 + 2\times10^{-7}\ (E_{CTB})$
$a_2 = 0.07 + 2\times10^{-7}\ (E_{CLS})$

the compressive strength is less than 200 psi than the material should be considered subgrade. A coefficient of 0.23 will apply to those materials with 800 psi or more strength.

Aggregate Base and Subbase

Figure 202.02-5 shows that the aggregate base and subbase coefficient is a function of R-value, either tested or correlated from PI and -200. For aggregate base material with a 79 R-value or higher the coefficient is 0.14. For a subbase material with a 70 R-value or higher the coefficient is 0.11. For both materials an R-value below 63 is considered subgrade.

L. DRAINAGE COEFFICIENT - M_i

Table 202.02-7 should be used to determine drainage coefficients.

For base materials a drainage coefficient should be applied consistent with the seasonal variation factor (Figure 202.02-1 and Table 202.02-4).

The Seasonal variation factor is used to determine percent of time of saturation exposure.

Definitions of Quality of Drainage are:

Excellent - Specially designed bituminous bound or unbound aggregate porous drainage base layer with at least 2,000 Ft/Day permeability connected to drainage system (Trenches and Pipes).
Good - Specially designed bituminous bound or unbound aggregate porous drainage base layer with at least 2,000 Ft/Day permeability, no drainage system (Trenches and Pipes).
Fair - Typical Aggregate Base.
Poor - Typical Aggregate Subbase.
Very Poor - Subgrade-like material

M. ASPHALT GRADE SELECTION

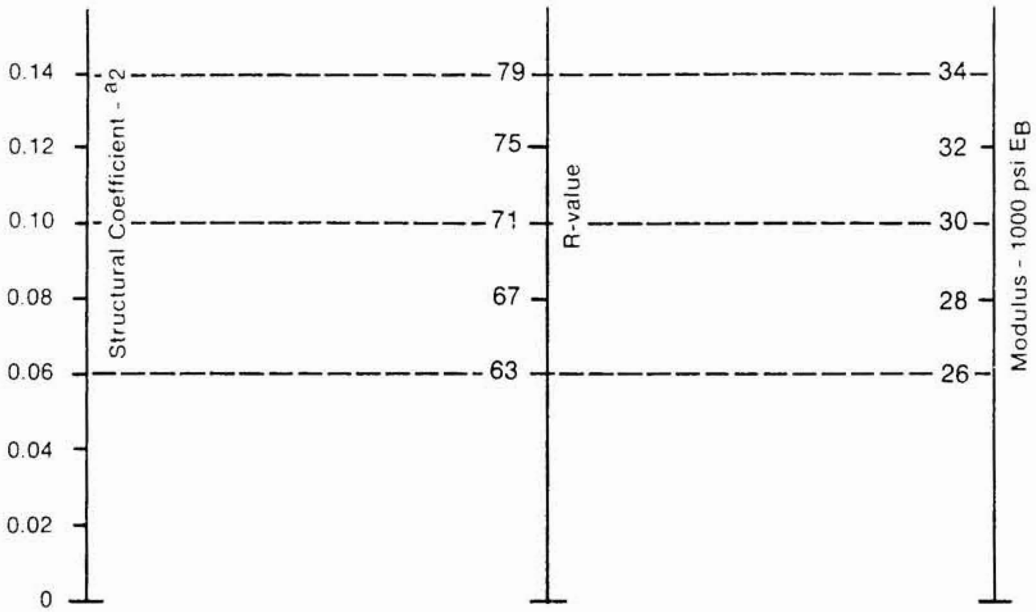
Table 202.02-8 give asphalt grade guides. The grade to be used will be determined by the Bituminous Engineer.

N. MINIMUM INDEX OF RETAINED STRENGTH

Minimum index of retained strength shall be in accordance with Figure 202.02-6 noting that pavement for interstate highways and other high volume roadways will ordinarily require an additional 10%. The retained strength required will be determined by the Bituminous Engineer.

FIGURE 202.02-5

Chart for estimating structural layer coefficient of unbound granular base determined by R-value or elastic modulus.



$a_2 = -0.2550 + 0.0050\ (\text{R-Value})$

$a_2 = -0.20 + 1.00\text{X}10^{-5}(E_B)$

TABLE 202.02-7

ESTIMATE OF DRAINAGE COEFFICIENT (M_i)
AS A FUNCTION OF QUALITY OF DRAINAGE
AND SEASONAL VARIATION FACTOR

	SEASONAL VARIATION FACTOR		
QUALITY OF DRAINAGE	<1.7	1.7 - 2.7	>2.7
EXCELLENT	1.15	1.23	1.32
GOOD	1.07	1.17	1.27
FAIR	1.00	.92	.84
POOR	.93	.83	.74
VERY POOR	.86	.75	.64

TABLE 202.02-8

ASPHALT CEMENT GRADE*
SELECTION CHART

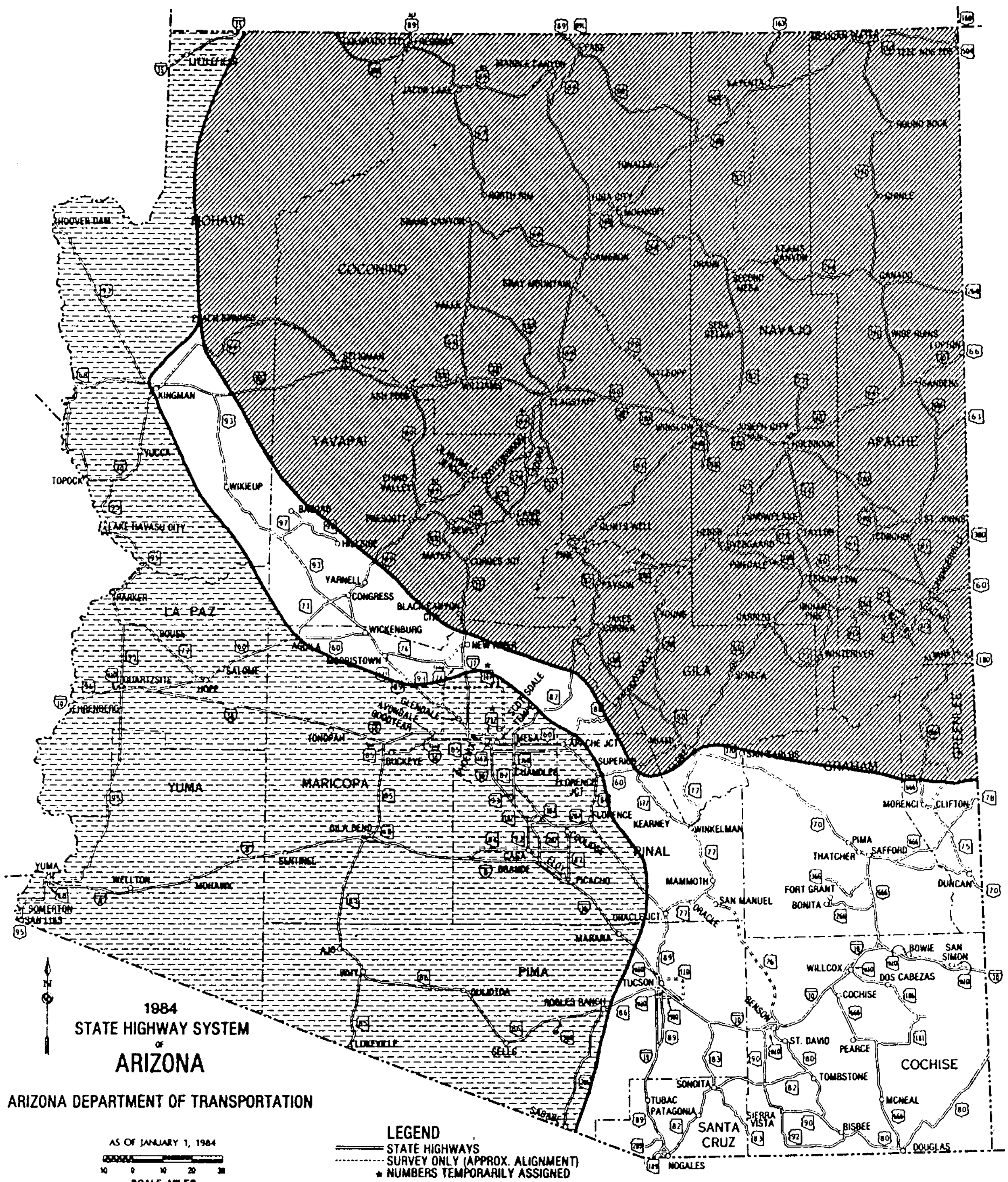
ELEVATION	18 KIP ESAL/YEAR	
	LESS THAN 60,000	MORE THAN 60,000**
0 - 2000′	AC-30	AC-40
2001 - 4000′	AC-30	AC-30
4001 - 6000′	AC-20	AC-30
ABOVE 6000′	AC-20	AC-20

* The grade to be used will be determined by the Bituminous Engineer.

** Includes all Interstate.

FIGURE 202.02-6

INDEX OF RETAINED STRENGTH SELECTION



* An additional 10% is required for Interstate highways.

40% Retention Area *

50% Retention Area *

60% Retention Area *

202.03 - RIGID PAVEMENT DESIGN

The basic design equation for rigid pavements is as follows:

$$\log_{10}(W_{18}) = Z_R \times S_o + 7.35 \times \log_{10}(D + 1) - 0.06 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.5 - 1.5}\right]}{1 + \frac{1.624 \times 10^7}{(D + 1)^{8.46}}}$$

$$+ (4.22 - 0.32 \times p_t) \times \log_{10}\left[\frac{S'_c \times C_d \times (D^{0.75} - 1.132)}{215.63 \times J \left[D^{0.75} - \frac{18.42}{(E_c/k)^{0.25}}\right]}\right]$$

Where

W_{18}	= predicted number of 18-kip equivalent single axle load applications (Rigid), (Appendix A).
Z_R	= standard normal deviate, same as flexible, Table 202.02-1.
S_o	= combined standard error of the traffic prediction and performance prediction, equal to 0.35.
D	= thickness (inches) of pavement slab, cannot be less than nine (9) inches.

S'_C = Average modulus of rupture (psi) for portland cement concrete used on a specific project, fixed at 670 psi. The typical minimum construction control (Sc) value is 500 psi.

C_D = Drainage coefficient same as flexible, Table 202.02-7.

E_C = Modulus of elasticity (psi) for portland cement concrete. It can be estimated from concrete compressive strength (f'_C), by the following formula.

$$E_C = 57000\ (f'_C)^{0.5}$$

For purposes of design f'_C is equal to 5,000 psi and E_C is equal to 4,000,000 psi, based on a minimum f_C equal to 4,000 psi and an average f'_C of 5,000 psi at 28 days as determined by AASHTO T-22.

P_o = Initial design serviceability index, same as Flexible, Table 202.02-2.

P_t = Design terminal serviceability index, same as Flexible, Table 202.02-2.

J = Load transfer coefficient used to adjust for load transfer characteristics of a specific design, Table 202.03-1.

k = Modulus of subgrade reaction is found by first determining the subgrade modulus (see flexible design Section 202.02 (F, G and H). For a full depth design subgrade modulus can be converted to k value with the following formula.

$$k = \frac{M_R}{19.4}$$

Where

M_R = Resilient modulus of subgrade

The design k value is found by correcting for loss of support by using Figure 202.03-1, Figure 202.03-2 and Table 202.03-2.

TABLE 202.03-1

J FACTORS

	Tied Concrete Shoulders: Load Transfer Devices	Tied Concrete Shoulders: No Load Transfer Devices
Plain Jointed, (No Dowels)	N/A	3.9
Jointed Reinforced,(Dowels)	2.8	N/A
CRCP	2.5	N/A

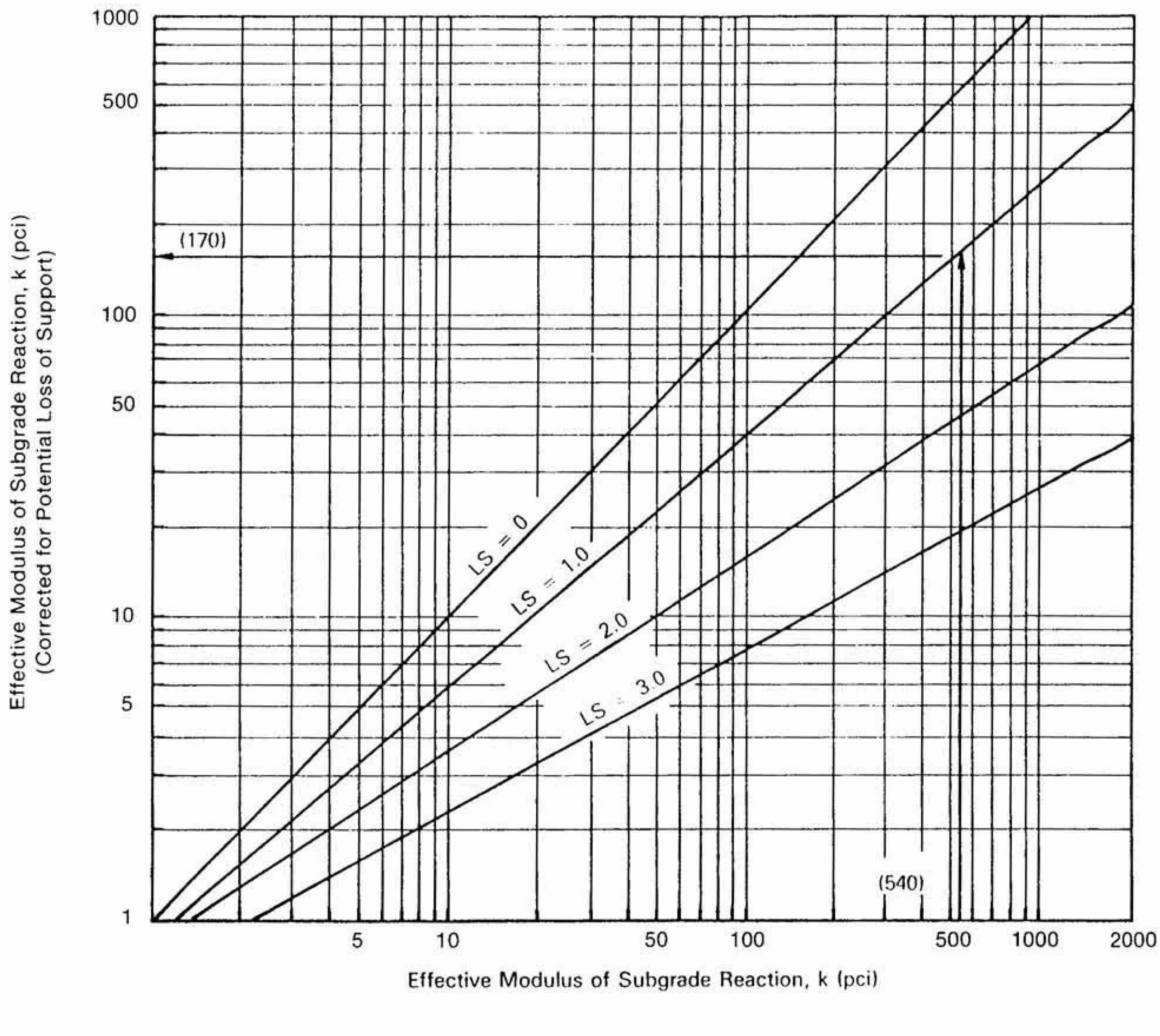
TABLE 202.03-2

LOSS OF SUPPORT

		Loss of Support As a Function of Seasonal Variation Factor		
	Modulus	0-1.7	1.8-2.7	2.8+
Asphaltic Concrete	650,000	0	0	0
Lean Concrete Base	650,000	0	0	0
Cement Treated Base	600,000	0	0	0
Cement Treated Subgrade	500,000	0	0.5	1.0
Lime Treated Subgrade	500,000	0	0.5	1.0
Aggregate Base	36,000	0	0.75	1.5
Aggregate Subbase	23,000	0	1.0	2.0
Subgrade		0.5	1.5	2.5

FIGURE 202.03-1

Correction of effective modulus of subgrade reaction for potential loss of subbase support.



$LOG(K)_{CORR} = A_O + A_1 * LOG(K)$

Where: $A_O = -0.0844 * LS^{0.6924}$

$A_1 = 1.0 - 0.1566 * LS$

(NOTE: Logs are in Base 10)

FIGURE 202.03-2

Chart for estimating composite modulus of subgrade reaction, k_∞, assuming a semi-infinite subgrade depth. (For practical purposes, a semi-infinite depth is considered to be greater than 10 feet below the surface of the subgrade.)

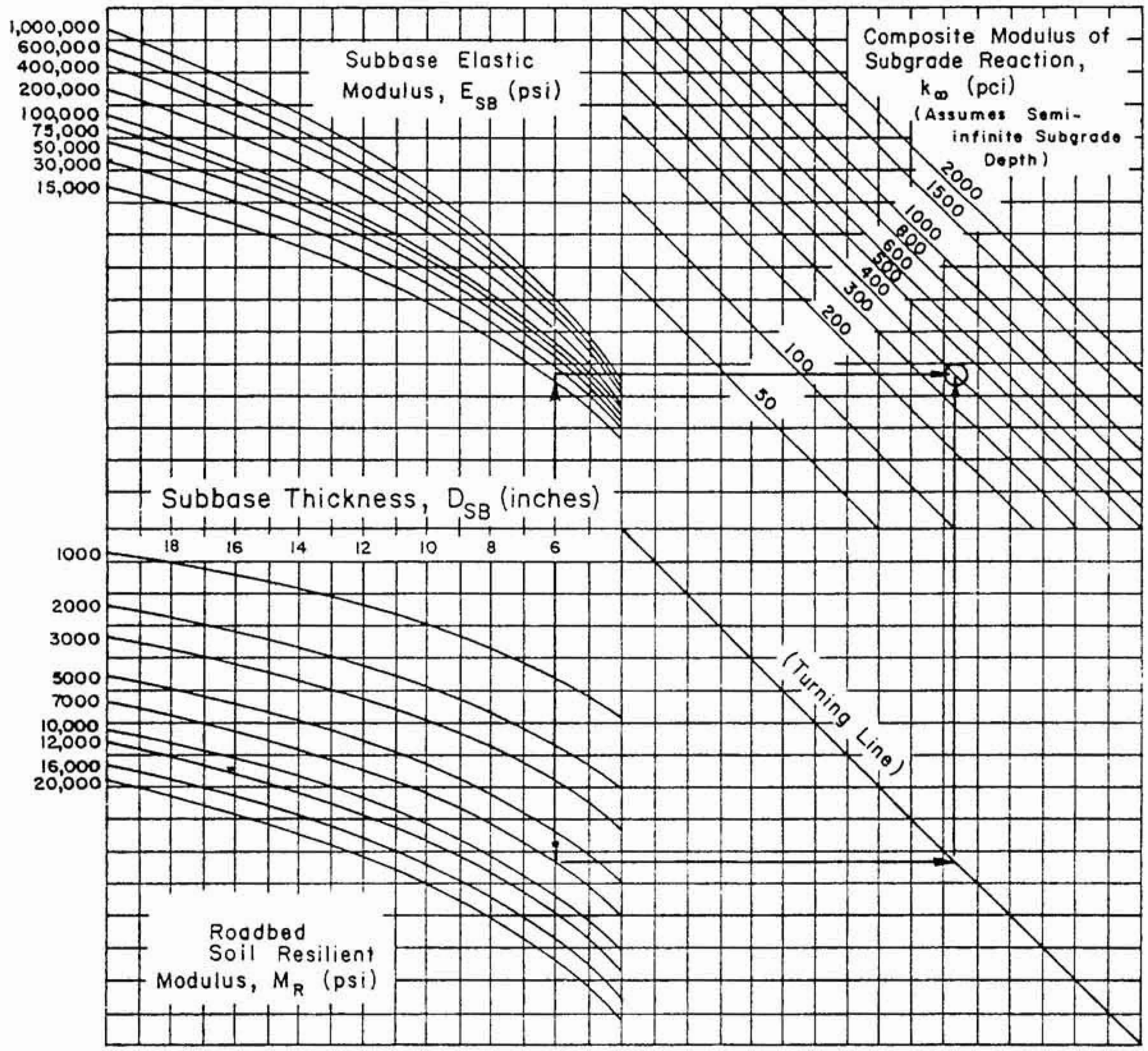
Example:

D_{SB} = 6 inches

E_{SB} = 20,000 psi

M_R = 7,000 psi

Solution: k_∞ = 400 pci



For those designs using an unbound or bound base or subbase Table 202.03-2 should be used to determine the modulus, as well as the loss of support. Figure 202.03-2 should then be used to determine the composite K value. The design composite K value is then found by entering Figure 202.03-1 with the appropriate loss of support value.

202.04 - MINIMUM PAVEMENT DESIGN CONTROLS

The AASHTO Road Test structural design equations are based on traffic-induced fatigue failures. There are other criteria which must be considered to avoid impractical designs. Some of these are:

1. Ease of construction
2. Maintenance considerations
3. Current engineering judgement and practice
4. Failure under the action of a few heavy wheel loads

Taking this criteria into account, minimum designs for flexible and rigid pavements were developed.

A. Mainline Highways

The minimum structural number chart should be used to check the adequacy of design. In addition it can be used to estimate a design section when it is not possible to complete the design due to unusual circumstances. For turning bays, bridge replacement, culvert replacement, minor roadway widening or any other highway work involving small areas or small quantities of mainline highway paving, the design structural section should match the existing structural number. If the existing structural number is less than the minimum required then use the larger value. Generally full depth construction is preferable for all small area paving projects, except for widening, which should match the in-place section. For mainline highways the following minimums apply.

Flexible Pavements:

For flexible pavements the minimum is expressed as a structural number which is further qualified by minimum asphaltic concrete thickness. Additionally, on layered sections using aggregate bases, a minimum thickness of 4" shall be used for the base material. Table 202.04-1 shows the minimum requirements for flexible pavements.

TABLE 202.04-1

FLEXIBLE PAVEMENTS MINIMUM STRUCTURAL NUMBERS AND COMPONENT THICKNESS

ROADWAY CLASSIFICATIONS	MINIMUM STRUCTURAL NUMBER			MINIMUM AC THICKNESS
	RURAL		URBAN	
	ESAL'S			
Freeways, all Interstates, non-Interstates with greater than 10,000 ADT	10,000,000<	>10,000,000		
	SN	SN	SN	
Main Roadway	3.00	3.50	3.50	5.0"
Ramps & Crossroads	2.25	2.25	3.50	4.0"
Frontage Road	2.25	2.25	2.72	4.0"
Detours	2.25	2.40	2.40	3.0"
	ESAL's			
Arterials, (ADT 2,001-10,000)	2,500,000<	>2,500,000		
	SN	SN	SN	
Main Roadway	2.50	2.75	2.75	4.0"
Detours	1.75	2.00	2.00	2.5"
	ESAL'S			
Collectors (ADT 500-2,000)	750,000<	>750,000		
	SN	SN		
Main Roadway	2.00	2.25	2.25	3.0"
Detours	1.50	1.75	2.00	2.0"
	ESAL'S			
Local (ADT 500<)	100,000<	>100,000		
	SN	SN		
Main Roadway	1.35	1.75	1.75	2.0"
Detours	0.75	1.50	1.50	*1.5"

* On low volume, short duration detours of 30 days or less, a prime coat may be used in lieu of the minimum AC thickness.

Rigid Pavements:

For rigid pavements the minimum is expressed as a minimum pavement section. The minimum rigid pavement section for all roadways is 9" of Portland Cement Concrete Pavement on 4" of base.

Gravel Roadways:

At least 6" of base should be placed.

B. Non-Mainline Pavements

The following minimum structural number and/or minimum thickness apply to turnouts, driveways, rest areas, parks and any other non-mainline highway pavement. In order to facilitate the design process it is recommended that for rest areas, parks and similar pavements that the traffic loading be estimated to be one percent of the adjoining mainline traffic. Any other design traffic loading estimate will require Materials Section approval.

Flexible Pavements Minimum Structural or Component Thickness

Turnouts and Driveways	Minimum	2" AC on 4" AB
Rest Areas and Parks	Minimum	SN=2.25; 4" AC

202.05 - SELECTION OF OPTIMAL DESIGN

In choosing the optimal design for the pavement structure there are many things to consider.

A. Continuity of Pavement Type

To maintain uniform driving conditions for the motoring public, consideration should be given to continuing the same type of existing pavements, especially if a new project is a relatively short one.

B. Location and Local Conditions

Although there are many pavement designs that will meet the requirements of the design equation, there are situations when local conditions, such as underground utilities close to the surface, poor drainage, flooding, snow pack, etc., where one design might function more efficiently than another. Past experience and judgement should be used in the final selection of the design.

C. Conservation of Natural Resources

A cost comparison computer program determines quantities of aggregates required for each pavement design, and some programs take into consideration the future value of the materials used as well as their salvage value. Conservation of natural resources should be considered in the evaluation of the pavement design, and in areas where aggregate is scarce, it should be given considerable weight.

D. Anticipated Construction Problems

Consideration should be given to the feasibility of the proposed design in regard to standard construction methods.

E. Costs

Comparative costs provided in the pavement design procedure should be given consideration in the selection of the pavement design.

1. Life Cycle Cost

Designers are encouraged to conduct a life cycle cost analysis to determine the most cost effective structural design whenever reasonable to do so. Although structural designs encompass a 20 year period, highway facilities generally are in service much longer and therefore a 35 year analysis period should be used.

In addition to the initial construction cost, several other inputs are needed, including rehabilitation strategies, unit costs, salvage value, user delay cost, maintenance cost, discount rate and traffic control cost. The following describes these inputs in more detail.

a. Construction costs - Cost data is available from ADOT Contracts and Specifications Services in their annual cost summary publication as well as current project bid data. Designers are encouraged to use these references as a guide and to document the sources of all cost estimates. Generally Contracts and Specifications data will be used to referee any disputes about cost estimates.

b. Rehabilitation Strategies - Life cycle performance estimates for new pavements and rehabilitation can be obtained from the pavement management branch of Materials Section. Table

202.05-1 can be used as a guide for most typical pavement designs and rehabilitation strategies. For those design situations not routinely covered further consultation with pavement management is suggested. Any deviations from Table 202.05-1 must be documented and approved by Materials Section.

c. Salvage Value - The following formula will be used to estimate the salvage value as a percentage of the initial cost.

Percent Salvage Value =

$$1 - \frac{((P * (IC + RM - (THN*RV))) + ((1 - P) * (RH - (THR*RV))))}{IC} *100$$

Where:

P = Chance of rebuilding the highway at the end of the analysis period. Historical performance indicates a 0.50 value at 35 years.

IC = Initial cost of the design section in $/sy. Design section includes paving and base layers.

RM = Cost in $/sy to remove paving material during reconstruction.

THN = Thickness of new bound layer in inches.

THR = Thickness of rehabilitated bound layer in inches.

RV = Worth of recycled bound layer in $/sy-in. $0.25/sy-in for AC and zero for all other materials.

RH = Rehabilitation Cost in $/sy.

Salvage values generally fall into the following ranges shown in Table 202.05-2.

d. User delay costs refer to the time that drivers are inconvienced due to reconstruction, rehabilitation or maintenance activities. Research indicates a cost of $0.06 per vehicle mile. By knowing the ADT at time of the activity (day, night and/or weekend), length of project and number of working days the user delay cost can be calculated. User delay costs are not computed for new construction on a new alignment, since other factors such as excavation, drainage etc. will control.

e. The discount rate will be set to four percent.

TABLE 202.05-1

EXPECTED PERFORMANCE LIFE

Flexible Pavements	Years of Service Before Rehabilitation
New Construction 20 Year Design	15
AC Overlays or Recycling 10 Year Design	10

Rigid Pavements	Years of Service Before Rehabilitation
New Construction, 20 year Design	20
Grinding plus Joint Re-sealing	14
Grooving plus Joint Re-sealing	10
AC Overlay of Concrete Full Structural Section (Typically 4" or More)	10
Three Layer System Asphalt Rubber(ACFC, AR, ACFC) Asphalt Rubber AC (Typically 1.5"-2")	5 - 7

TABLE 202.05-2

	Salvage Value as Percentage of Initial Cost
AC pavement with or without base and mill and fill.	31 to 39%
All concrete with or without base and grinding.	-2 to 27%
All concrete with or without base and a three layer overlay.	22 to 39%

f. Maintenance Cost

Maintenance costs were estimated from actual costs compiled from the Pecos maintenance cost file and are shown in Table 202.05-3. Any changes in these costs need to be approved by the Pavement Services Engineer.

F. Summary

Normally the pavement design that satisfies the structural requirements and represents the least cost would be selected. However, as discussed previously, there may be times when the least cost design would not necessarily be the most appropriate design. To the degree possible the designer should take these considerations into account in determining the recommended pavement section. Alternative designs for further review may be appropriate in a situation where no one design seems capable of satisfying all the constraints. For additional information on design consideration the designer should consult the 1986 AASHTO Guide.

TABLE 202.05-3

ESTIMATED MAINTENANCE COSTS

	Cumulative Annual Maintenance Costs	Year Maint. Begins
AC Pavements	\$500/lane-mile	1
Concrete without dowels	\$100/lane-mile	15
Concrete with dowels	\$150/lane-mile	17
Concrete with Reinforcing Steel (CRCP)	\$250/lane-mile	19

203.00 DESIGN DOCUMENTATION AND PRESENTATION

This section deals with the documentation and presentation of the information developed during the design process. The method used to present this information is called the Materials Design Package. The Materials Design Package consists of three separate parts, the first is the Pavement Design Summary, the second is the Materials Design Memorandum and the third is the Preliminary Pavement Structure Cost Estimate. A description of each part and the function it serves is presented in the following paragraphs:

203.01 PAVEMENT DESIGN SUMMARY

A pavement design summary is prepared for each project to show the basis for the proposed design. It provides information necessary for review of the design and supports the design recommendations.

The pavement design summary should include the description, location, and reason for a project. Visual observations made by the designer should be listed, especially on rehabilitation projects. Subsoil conditions and geology should be discussed and test results pertinent to the design such as R-values, PI, gradation, moisture, pH and Resistivity, etc. should be mentioned.

For reconstruction or new construction, the selection of the design resilient modulus value should be discussed. Other factors important in the design should be listed including traffic loading and their source, seasonal variation factor, terminal serviceability index, drainage coefficients, and structural coefficients for materials considered. Likewise, for rehabilitation projects similar information, as well as, the deflection analysis should be discussed. If the project is to be divided into sections with different design recommendations, support should be shown for this division, such as, different soil type, different traffic loading, or different existing pavement conditions.

The pavement design summary should list different design alternatives, an economic cost comparison and a discussion explaining the reason for each alternative chosen. Unit costs and total costs should be listed for each design considered.

To be complete, the pavement design summary will give the recommended pavement structure and reasoning for selecting one alternate over the others. A support argument for the design chosen should be made.

203.02 OUTLINE OF PAVEMENT DESIGN SUMMARY

Pavement Design Summary

Project Number

Project Name

I. INTRODUCTION

A. Location (include limits)

B. Description of project

C. Scope of work

II. EXISTING PAVEMENT HISTORY AND VISUAL OBSERVATIONS

A. Existing pavement structure (component thicknesses and dates constructed).

B. Existing pavement condition (list percent cracking and type, ride, surface type and condition, etc.).

C. Observed geologic features, terrain and drainage conditions.

D. Unusual conditions. (Low bridge clearances, cattle guards, railroad crossings, equipment crossings, utilities, curb and gutter, guardrail height, etc.)

III. TEST DATA

A. Pavement Management System Information (skid, ride and cracking values).

B. Dynaflect and falling weight deflectometer information.

C. Soils information (R-values, PI, gradation, pH, resistivity, moistures, frost susceptibility, swell, soil classification and description, etc.).

IV. DESIGN CALCULATIONS AND DISCUSSION

A. New Pavement Design

1. List values used in design equation and explain origin (traffic W_{18}, reliability , effective resilient modulus M_R, Z_R, S_o, PSI, etc.)

2. Discuss design selected and alternates considered as well as life cycle cost if appropriate (list SN required, component layer coefficients, drainage coefficient, seasonal variation factor, costs, special considerations, etc.).

3. Rigid Pavement - if rigid pavement is considered, discuss selection of rigid pavement type, life cycle cost analysis, and values used in rigid design equation.

B. Pavement Rehabilitation Design

1. List basis of design (structural need, deflection design, fatigue related, distress related, etc.).

2. Discuss strategies considered.

V. RECOMMENDATIONS

A. Give pavement section recommended and reasons for selection.

B. Discuss pavement components, special considerations, and pavement surface treatment selection.

VI. SIGNATURE

A. Person submitting design summary shall attach signature.

B. Design summary shall be checked and approved by a Professional Engineer. (Attach Signature).

203.03 MATERIALS DESIGN MEMORANDUM

A Materials Design Memo is prepared for each project to present the outcome of the design process and provide the information and specifications on the recommended pavement structure. The information provided in the Memo is supported by the recommendations made in the Pavement Design Summary and Geotechnical Report.

The Memo provides the recommended pavement structure for each design section including the limits for each design section and the component type and thickness in inches for each section. Additionally the surface course or treatment shall be listed and on new or widened pavements the total thickness should be included.

In addition to providing the pavement structure for each design section, the Memo provides the procedures and specifications for each pavement component or process, which may include the following: existing pavement removal, subgrade preparation, subgrade acceptance, subbases, bases, surface treatments, pavements, etc. If the item is covered by the standard specifications then reference to the standard specification is all that is needed.

Also included in the Memo is information provided by the Geotechnical Report including:

Materials Sources and haul distances, Earthwork Factors and Slopes, Ground Compaction Requirements, Water Requirements and Sources, Pipe Life Information, Special Conditions, etc.

Much of the memo is made up of Design Memo Standard Items and these should be used whenever applicable. The format of the following example should be adhered to as closely as practical.

203.04 OUTLINE AND EXAMPLE OF MATERIALS DESIGN MEMORANDUM

The Materials Design Memo shall contain the memorandum number, the project reference and the materials design information.

A. Memorandum Number

Memos are numbered consecutively beginning with the number one with a prefix of the last two digits of the year in which it is written, e.g., 88-1. Subsequent memos for the same project are given consecutive suffix numbers beginning with the number one, e.g., 88-1-1, when minor changes are made. If the original memo becomes very old or completely obsolete, a new number is assigned.

B. Project Reference

Each Memo refers to a specific project and to identify the project the following information is listed: the name of the highway and route number, the location of the project on that highway (project name), the construction number, the preliminary engineering number, the type of construction, and the beginning and ending milepost and corresponding stationing. For example:

PROJECT

MEMORANDUM #88-5

CORDES JCT.-PRESCOTT HWY (SR 69)
PRESCOTT VALLEY-PRESCOTT, UNIT II
F-029-1 (6) C
F-029-1-406 PE
WIDENING, OVERLAY & NEW CONSTRUCTION
MP 289.62 (STA. 4668+00) TO MP 294.68 (STA 4930+00)

MEMORANDUM TYPE:
INITIAL FOR REVIEW

C. Design Information

The design information is presented in sections with each section broken into items, as follows:

SECTION I - PAVEMENT STRUCTURE

ITEM 1 - STRUCTURAL THICKNESS (In Inches)

The structural thickness includes the termini of each design section, the type and thickness of each pavement component, and the total thickness, all expressed in inches (The total thickness need not be included on rehabilitation projects). For example:

Station	AB	AC(3/4)	ACFC	Total Thickness
4668+00 to 4789+00 (Widening)	15	7 1/2*	1/2	23
4789+00 to 4837+70 (Widening)	6	7 1/2*	1/2	14
4837+70 to 4854+30 (Widening)	18	7 1/2*	1/2	26
4854+30 to 4910+55 (New Cst)	18	7 1/2	1/2	26
4910+55 to 4930+00 (Widening)	18	7 1/2*	1/2	26

*Includes a 2 1/2 inch overlay on existing SR 69.

On overlay projects where the existing roadway is out of section or has a rough ride an item designating additional quantities for leveling should be included.

ITEM 2 - ADDITIONAL QUANTITIES FOR LEVELING

An additional 1,500 tons of asphaltic concrete (3/4) shall be estimated for leveling purposes. 500 Tons of the material shall be utilized for miscellaneous paving and spot patching or blade laid leveling of the roadway prior to the placement of overlay. 1,000 Tons of the material shall be added to the overlay for leveling purposes between Sta. 4668+00 to Sta. 4854+30.

Typically, the second page of the Design Memorandum is a vicinity map showing the project location and the location of any materials pits involved. (Figure 203.04-1).

Following the vicinity map is the Typical Section Sheet or sheets. (Figure 203.04-2). The typical section shows a graphic illustration of the roadway typical sections and the pavement structure. The pavement structure shows the type, thickness, and placement of each pavement component and lift. Figure 203.04-3 shows the recommended symbols for each pavement component and treatment to be used on the typical sections.

SECTION II - SUBGRADE, SUBBASES AND BASES

This section sets forth the recommended specifications for subgrade, subbases and bases. These items should be listed in the order of their placement during construction and may include, but are not limited to the following:

Subgrade Construction Control
Cement Treated Subgrade
Aggregate Subbases
Cement Treated Base
Lean Concrete Base
Aggregate Bases

ITEM 1 - SUBGRADE CONSTRUCTION CONTROL

This item is to be included on projects that involve new subgrade construction. The subgrade acceptance chart (Figure 203.04-4) shall be included in the Memo following the typical sections or an equivalent equation shall be included when there is no designated borrow source.

The attached subgrade acceptance chart should be used during construction for determining whether subgrade materials are suitable as outlined in Section 203.06 of the ADOT Construction Manual.

FIGURE 203.04-1

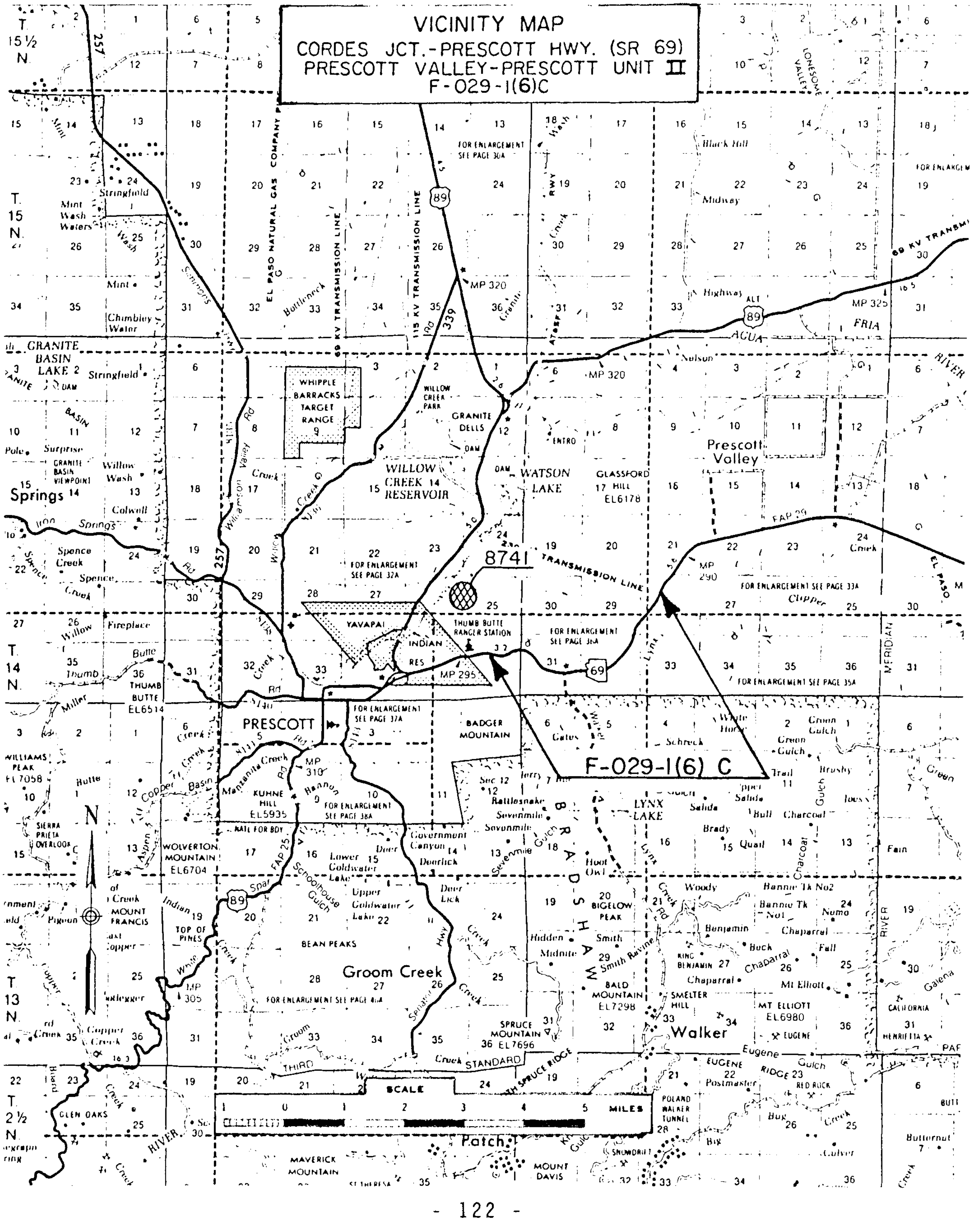
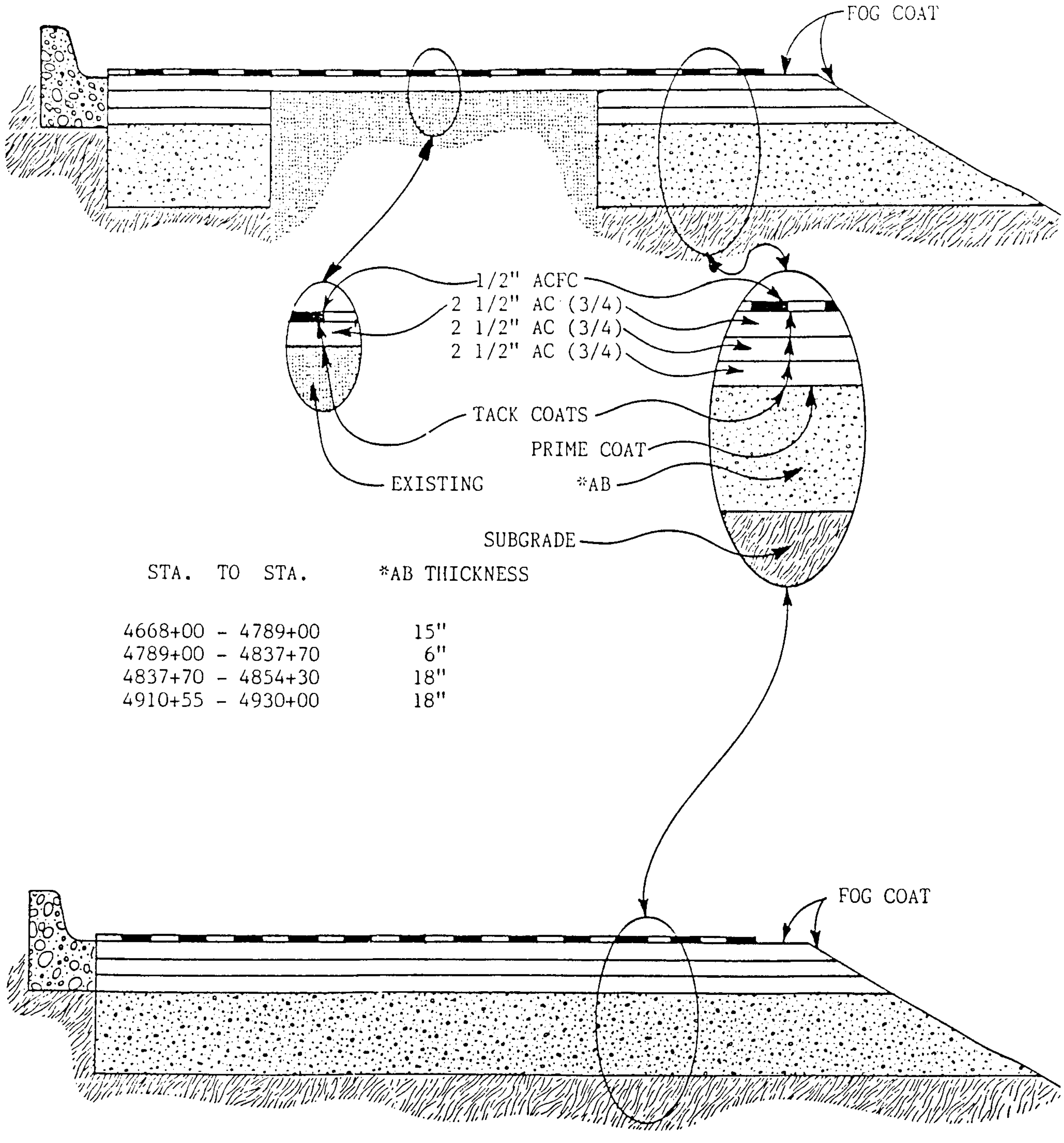


FIGURE 203.04-2

TYPICAL SECTIONS

F-029-1(6) C
PRESCOTT VALLEY - PRESCOTT, UNIT II

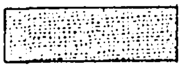
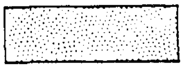
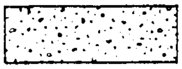
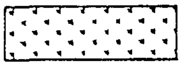
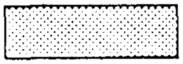
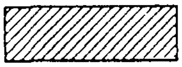
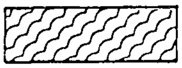
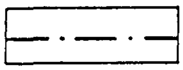
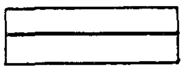
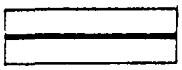
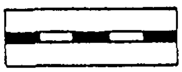
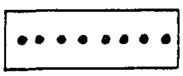


STA. TO STA.	*AB THICKNESS
4668+00 - 4789+00	15"
4789+00 - 4837+70	6"
4837+70 - 4854+30	18"
4910+55 - 4930+00	18"

STA. TO STA.	*AB THICKNESS
4854+30 - 4910+55	18"

FIGURE 203.04-3

TYPICAL SECTION SYMBOLS

LEGEND	DESCRIPTION
	SUBGRADE
	EXISTING ASPHALTIC CONCRETE / BASE
	CEMENT TREATED SUBGRADE / LIME TREATED SUBGRADE
	AGGREGATE SUBBASE
	AGGREGATE BASE
	CEMENT TREATED BASE / LEAN CONCRETE BASE
	ASPHALT TREATED BASE
	DRAINAGE LAYER / ARRESTER BED AGGREGATE
	ASPHALTIC CONCRETE
	RECYCLE PAVEMENT
	REMOVE AC & REPLACE W/NEW AC
	PORTLAND CEMENT CONCRETE PAVEMENT
	MEMBRANES / GEOTEXTILES / GEOGRIDS
	PRIME COAT
	TACK COAT / FOG COAT
	CHIP SEAL COAT
	ASPHALT CONCRETE FRICTION COURSE
	GRIND OR GROOVE PCCP / RECYCLE EXISTING BITUMINOUS SURFACE
	BORROW

ITEM 2 - AGGREGATE BASE

Aggregate base should be Class 3, and shall be as specified in Section 303 of the Standard Specifications. The grading shall be as follows:

Sieve Size	% Passing
1"	100
3/4"	80 - 100
3/8"	55 - 75
#8	30 - 45
#200	0 - 8

The plasticity index shall not exceed 3.

For estimating purposes the haul distance is approximately 6 miles.

SECTION III - SURFACE TREATMENTS AND PAVEMENTS

This section sets forth the recommended specifications for the various pavement components. Those components should be listed in the order of their placement during construction and may include, but are not limited to, the following:

Prime Coat
Tack Coat
Asphalt Rubber Stress Absorbing Membrane
Asphaltic Concrete
Asphaltic Concrete Finishing Course
Portland Cement Concrete Pavement
Chip Seal Coat
Fog Coat
Blotter Material

The Standard Specifications cover most of the items; however, where there is a deviation from, or not covered in the Standards the specification should be detailed in the item.

ITEM 1 - PRIME COAT

The prime coat shall be as specified in Section 404 of the Standard Specifications.

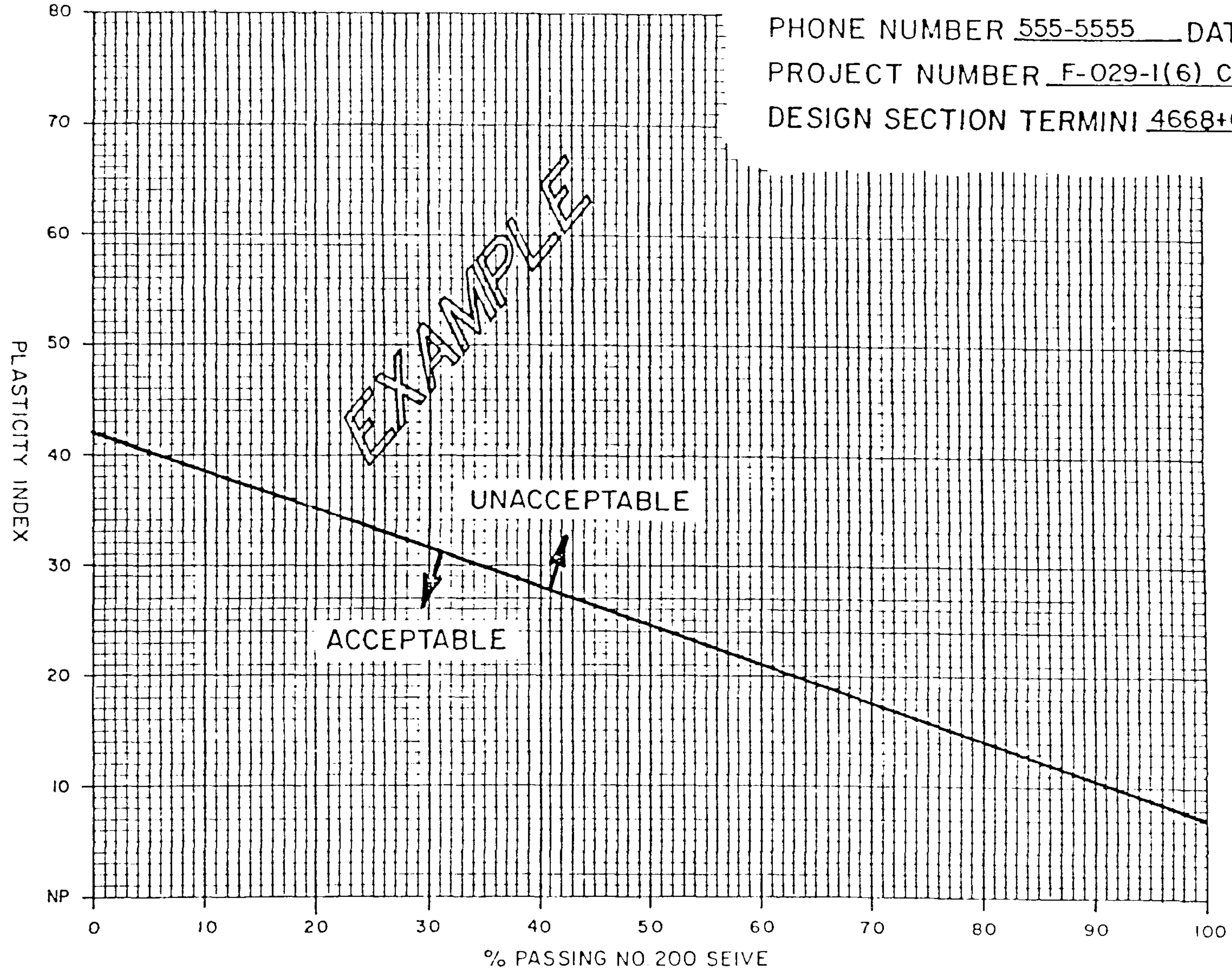
The prime coat should be applied to the surface of the aggregate base at an approximate rate of 0.5 gallon per square yard.

DESIGNER X. JONES

PHONE NUMBER 555-5555 DATE 8-19-87

PROJECT NUMBER F-029-1(6) C

DESIGN SECTION TERMINI 4668+00 TO 4930+00



ARIZONA DEPARTMENT OF TRANSPORTATION

MATERIALS SECTION SUBGRADE ACCEPTANCE CHART

FIGURE 203.04-4

ITEM 2 - TACK COAT

A tack coat shall be applied as necessary to provide proper bonding prior to the placement of each lift of AC or ACFC over an underlying bituminous surface. The tack coat shall be as specified in Section 404 of the Standard Specifications.

ITEM 3 - ASPHALTIC CONCRETE (3/4) (END PRODUCT)

The asphaltic concrete shall be as specified in Section 416 of the Standard Specifications.

For estimating purposes the unit weight of the bituminous mix is 150 pounds per cubic foot, the asphalt is 4.7%, and the haul distance is 6 miles.

The asphalt type shall be AC-20.

The minimum index of retained strength shall be 60%.

The effective voids shall be 6.0%$\pm$0.2%.

The combined bulk specific gravity range shall be 2.35 to 2.85.

The combined water absorption range shall be 0 to 2.5.

ITEM 4 - ASPHALTIC CONCRETE FRICTION COURSE

The asphaltic concrete friction course shall be as specified in Section 407 of the Standard Specifications.

Quantities are estimated on a spread rate of 59 lbs. per square yard which includes 25% for leveling to provide a minimum 1/2 inch thickness, however, the exact spread rate shall be determined by the Engineer.

The asphalt shall be 5.5% of type AC-20 and the estimated haul distance for the ACFC is 6 miles.

It has been determined that the average elevation of the roadway for this project is 5400 feet.

One percent (by weight of the asphalt) of an approved asphalt cement liquid additive shall be added to the asphalt.

ITEM 5 - FOG COAT

The fog coat shall be as specified in Section 404 of the Standard Specifications except for the following:

The bituminous material shall be ERA-25, diluted with 1 part water to 1 part ERA-25.

The bituminous material shall be applied at a rate of 0.10 gallons per square yard.

When a fog coat is specified for new asphaltic concrete, it shall be applied as soon as practicable after placing the asphaltic concrete.

ITEM 6 - BLOTTER MATERIAL

The blotter material shall be as specified in Section 404 of the Standard Specifications.

An application of blotter material may be required following the placement of a fog coat and prior to opening the roadway to traffic. The Engineer may direct that after the bituminous material has been allowed to adequately penetrate, blotter material be applied in one or more applications for a total application of 2 pounds per square yard.

The estimated haul distance is approximately 6 miles.

SECTION IV - MATERIAL SOURCES - GEOTECHNICAL ANALYSIS

The materials sources section designates sources of borrow and special backfill. Each source is listed separately showing the data pertaining to that source. Material sources for mineral aggregate and aggregate base are not usually designated since commercial sources are usually available. These would be described as non-designated sources.

Geotechnical analysis includes the pertinent items that were developed during the geotechnical investigation and are usually obtained from the geotechnical report. The geotechnical analysis items may include but are not limited to the following:

Ground Compaction
Earthwork Factors (Shrink/Swell)
Slope Factors
Water Requirements and Sources
Pipe Life Information (pH and Resistivity
Special Conditions

ITEM 1 - NONDESIGNATED SOURCES

No State designated aggregate source is set up for this project. Materials sources shall be as specified in Section 1001 of the Standard Specifications.

ITEM 2 - BORROW

DATE OF REPORT: January 1986

PIT SERIAL NUMBER: #8741

MATERIAL DESIGNATION: BORROW

LOCATION AND DESCRIPTION:

This source is located approximately 2600 feet southeast of Station 1595 (MP 314.5) on US 89 adjacent to a City of Prescott landfill site. The materials available at this source consists of cemented sands, gravels, and cobbles with traces of clay. The materials will require ripping in most areas of the pit to develop the borrow quantities.

EXTRACTION OF PIT MATERIAL:

Light clearing of grass and small brush will be required on portions of the pit area. Stripping will not be required. The estimated quantity of borrow material available for this project at this source is in excess of 60,000 cubic yards after an excavation factor has been applied. The materials shall be removed to the lines and grades obtained from the City of Prescott.

INVESTIGATION:

The investigation of this source consisted of the excavation of 12 test holes in May, 1985. The test holes were dug to depths of from 2.5 to 47 (face sample) feet. No water was encountered at the time the test holes were dug.

INFORMATION AVAILABLE TO BIDDERS:

The following information is available at the office of the Materials Section, 206 South 17th Avenue, Phoenix, Arizona 85007:

1. Drillers logs and laboratory test results on the test holes dug in May, 1985.

2. Aerial photographs and geologic maps of the general pit area.

HAUL ROAD AND HAUL DISTANCE:

Moderate to heavy blade work will be required to construct a haul road from the pit area to connect with an existing haul road utilized by the City of Prescott, a distance of approximately 1000 feet. The haul distance to the project via Sundog Ranch Road, Slaughter House Road, and US 89 to the west end of the proposed project is estimated at 2 miles. Legal loads will be required.

MISCELLANEOUS INFORMATION:

The usable materials will have a compacted weight of approximately 125 pounds per cubic foot and an even excavation factor.

ITEM 3 - GROUND COMPACTION

The following ground compaction factors shall be compensated for on embankment sections outside the existing roadway prism.

Station	Ground Compaction (ft.)
4668 to 4724	0.20
4724 to 4770	0.15
4770 to 4835	0.25
4835 to 4854	0.20
4854 to 4882	0.10
4882 to 4905	0.20
4905 to 4930	0.30

ITEM 4 - EARTHWORK FACTORS AND SLOPES

The following excavation factors and slopes shall be used for project development.

Station	Excavation Factors	Slopes
4668 to 4690	15% Shrink	C-2.20
4690 to 4719	10% Shrink	C-2.20
4719 to 4731	15% Shrink	C-2.20
4731 to 4742	Swell 5%	C-2.20 Lt.,3/4:1 Rt.
4742 to 4756	10% Shrink	C-2.20
4756 to 4776	Even	C-2.20
4776 to 4790	5% Shrink Lt.,Swell 5% Rt.	Daylight Lt.,1/2:1 Rt.
4790 to 4805	10% Shrink	C-2.20
4805 to 4814	Swell 5%	1:1
4814 to 4819	Even Lt.,Swell 10% Rt.	1:1 Lt.,3/4:1 Rt.
4819 to 4825	Even Lt.,Swell 5% Rt.	1:1 Lt.,Daylight Rt.
4825 to 4837	Even	1:1 Lt.,3/4:1 Rt.
4837 to 4845	Even Lt.,Swell 5% Rt.	1:1 Lt.,3/4:1 Rt.

Station	Excavation Factors	Slopes
4845 to 4856	Even	3/4:1
4869 to 4895	Even	C-2.20
4895 to 4908	Even	1:1
4908 to 4918	Swell 5%	1:1
4918 to 4930	15% Shrink	C-2.20

ITEM 5 - WATER

Approximately 65 gallons of water per cubic yard, should be estimated for compaction of base materials. Water can most likely be obtained from the City of Prescott, an approximate haul distance of 2 miles.

ITEM 6 - pH AND RESISTIVITY

If a corrugated metal pipe culvert is to be used, then the type of metal pipe and coating should be determined by the pH and resistivity of in-place materials listed below.

This information should be used in conjunction with Figure 203.04-5.

In-Place Materials:

Station (Location)	pH	Resistivity(ohm-cm)
4683+16 (60′ Rt.)	7.8	1200
4689+80 (60′ Rt.)	8.0	2000
4703+90 (50′ Rt.)	8.0	2600
4719+10 (50′ Rt.)	8.0	5900
4746+35 (40′ Rt.)	7.8	2700
4762+80 (45′ Rt.)	7.9	2000
4772+45 (40′ Rt.)	7.9	2300
4789+77 (45′ Rt.)	6.9	3900
4792+90 (89′ Rt.)	6.9	3900
4803+83 (45′ Rt.)	6.9	4300
4813+53 (40′ Lt.)	6.9	4400
4823+80 (45′ Lt.)	7.4	3400
4829+18 (40′ Lt.)	7.9	1900
4865+50	7.9	700
4873+80 (50′ Rt.)	6.8	1300
4896+75	8.0	1100
4903+00	7.6	1500

ALLOWABLE TYPES OF CULVERT PIPE FOR ph RANGE 5.0 to 9.0[1]

Resistivity (ohm-cm)	Allowable Pipe
2000 or Greater	A[2]-B-C-D
500-1999	C-D
Less than 500	D

TYPES OF CULVERT PIPE

A) Galvanized Coated Steel
AASHTO M-36

B) Aluminum Coated Steel
AASHTO M-36

C) Aluminum Alloy
AASHTO M-196

D) Bituminous Coated
AASHTO M-190

Notes: (1) If ph is outside the range of 5.0 to 9.0, a special study of the situation should be made.

(2) Not allowed when ph is less than 6.0

REVISED 2/83

FIGURE 203.04-5

ITEM 7 - ROADWAY EXCAVATION

Any subgrade material encountered at the following locations which does not meet the subgrade controls set for these areas shall be removed to a depth of 3 feet below finished subgrade elevation and replaced with suitable material. The material removed from these areas may be used in the lower reaches of the larger fills (3 feet below finished subgrade elevation).

Right Station 4810+80 to 4811+80
Right and Left Station 4858+00 to 4866+00

Any additional areas encountered, which in the opinion of the Engineer may cause an unstable condition shall also be removed to a depth of 3 feet below finished subgrade elevation and replaced with suitable material.

The estimated quantity for subgrade removal and replacement is 7500 cubic yards.

SECTION V - MISCELLANEOUS

Miscellaneous Section includes items that would not be covered under the other sections.

ITEM 1 - TURNOUT CONSTRUCTION

Minor turnouts and driveways designated to be surfaced as shown in the project plans shall be constructed of 2 1/2 inches AC (3/4) placed over 4 inches AB Class 3. Major crossroads shall have the same pavement section as the main roadway.

ITEM 2 - TEMPORARY CONNECTIONS AND DETOURS

The temporary surfacing should consist of 2 1/2 inches of AC (3/4) placed over 5 inches of Aggregate Base (Class 3).

At a time specified by the Engineer, the bituminous surfacing and the base material shall be broken up and picked up separately and stockpiled individually at sites designated by the Engineer. The remaining detour roadways shall be removed, and the natural subgrade shall be restored as nearly as practicable to the condition existing prior to the construction of the detour.

No measurement for payment will be made for the work of removing the detours and stockpiling the material, the cost being considered as included in the cost of the contract items.

The Materials Design Memorandum shall be signed by a Professional Engineer.

Submitted by ______________________________ P.E.

Approved by ______________________________ P.E.

203.05 PRELIMINARY PAVEMENT STRUCTURE COST ESTIMATE

A pavement cost estimate for each project is developed from the recommended pavement structure. This cost estimate should not be confused with the economic cost comparison of alternate designs used in the design summary, for this estimate represents the anticipated bid prices of the recommended pavement section. The cost estimate gives only the costs for the pavement structure and related items, and does not represent the total costs for a project. The Preliminary Pavement Structure Cost Estimate is used for comparison purposes to ensure reasonable compliance with the programmed amount for pavements on each project. An example of a Preliminary Pavement Structure Cost Estimate and the recommended format are shown in Figure 203.05-1.

204.00 DESIGN REVIEW AND DISTRIBUTION

204.01 REVIEW AND APPROVAL OF MATERIALS DESIGN MEMORANDUM BY MATERIALS SECTION

After the Pavement Design Engineer has completed a Materials Design Memorandum and it has been typed in draft form, it is checked by other Services within Materials Section to assure that items regarding their function are correct. This may include; review by the Geotechnical Engineer for update of pit information, earthwork items, slope ratios, and other related items, review by the Testing Services Engineer for asphaltic concrete and other materials specifications; review by the Pavement Services Engineer, and finally review by the Assistant State Engineer, Materials Section. Any changes that need to be made are noted and made. A vicinity map showing the location of the project and designated pits is included with the memo along with a typical section of the proposed design. Also included is a subgrade acceptance chart when appropriate.

PRELIMINARY PAVEMENT STRUCTURE COST ESTIMATE <—— Heading

F-029-1(6) C <—— Construction #

Prescott Valley - Prescott, Unit II <—— Project Name

ITEM DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT
Aggregate Base, Class 3	Cu. Yd.	214,000	$ 9.50	$ 2,033,000
Asphalt Cement (AC-30) (3/4" Mix)	Ton	3,422	185.00	633,070
Asphalt Cement (AC-20) (ACFC)	Ton	293	200.00	58,600
Bituminous Tack Coat	Ton	155	120.00	18,600
Apply Bituminous Tack Coat	Hour	480	110.00	52,800
Fog Coat	Ton	10	200.00	2,000
Provisional Seal Coat	Ton	120	175.00	21,000
Apply Provisional Seal Coat	Hour	40	100.00	4,000
Blotter Material	Ton	23	25.00	575
Asphaltic Concrete (3/4" Mix)	Ton	72,800	18.00	1,310,400
Mineral Admixture (3/4" Mix)	Ton	1,456	90.00	131,040
Asphaltic Concrete Friction Course	Ton	5,318	20.00	106,360
			TOTAL	$ 4,371,445

EXAMPLE

Preliminary Cost Estimate:
Subject to design changes,
additions, alterations,
and corrections.

Pavement Costs = $ 4,371,445
Programmed Amount for Pavement = Unknown
Total Programmed Amount = $ 9,100,000

FIGURE 203.05-1

204.02 DISTRIBUTION OF MATERIALS DESIGN MEMORANDUM

The Materials Preliminary Design Report (MPDR) and Initial Design Memo are prepared and distributed for information, review and comment. The MPDR is typically a one page overview of the most likely design section and geotechnical factors including ground compaction, slopes and shrink and swell when applicable. This report is issued as soon as sufficient information (historical or laboratory) is available to make a reasonable estimate. The purpose of the report is to provide adequate information to prepare the initial plans and earthwork calculations. The initial memo is circulated internally within Materials Section for comments. Following this it is distributed for review and comments to other ADOT services and sections and district offices, as well as, the Federal Highway Administration when applicable. Reviewers are asked to make comments within ten working days after receipt.

205.00 FINALIZATION OF DESIGN, FINAL DESIGN MEMO

If after the review period some comments have not been returned the designer should call to ascertain any comments. Giving each comment appropriate consideration, the Final Memo should be prepared as soon as practical (generally no more than two weeks after the review period ends). The Final Memo should be circulated for review and comments within materials, typed, signed and distributed typically within a subsequent two week period to other ADOT Services, Sections, District Offices and the Federal Highway Administration when applicable.

Since the Final Memo is distributed typically at least three months before the bid date, the designer may have to issue an addendum to Contracts and Specifications Services to update any last minute specification changes.

205.01 SOIL PROFILE

Under the direction of the Geotechnical Site Supervisor of Geotechnical Services, a soil profile should be prepared. This soil profile should show the location of the test holes, the depth of the test holes, the plasticity index, sieve analysis and R-value of the material in the various strata and the general description of the material.

The soil profile is prepared by placing the pertinent data on a copy of the profile as prepared for the final plans of the project. This soil profile, together with other materials information is available for examination by prospective bidders at the offices of the Assistant State Engineer, Materials Section.

A. TEST HOLES

The test holes should be drawn on the profile at the locations and elevations indicted on the field working profile and test hole log which has been prepared by the field crew. Care should be taken to indicate the hole at the proper elevations and offset from the centerline.

B. PLASTICITY INDEX, SIEVE ANALYSIS DATA AND "R"-VALUE

The plasticity index, sieve analysis data and "R"-value data of the various strata of materials in each test hole should be shown on the soil profile. This may be accomplished by pasting a copy of the subgrade test data from the computer print-out as close to the test hole as possible with an arrow pointing to the hole or portion of the hole to which the data applies. If there is no computer printout available, the data should be printed on the profile.

C. MATERIALS DESCRIPTION

A general description of the type of material found in each stratum of each test hole should be shown at the proper location on the soil profile. The information for this description may be found in the log of the subgrade test holes prepared by the Field Crew Chief.

205.02 CHECKING OF PLANS AND SPECIAL PROVISIONS

As soon as they are available prior to bid call, the plans and special provisions should be checked by the Materials Design Engineer who prepared the materials design recommendations to ascertain if they are all in agreement. Any deviations from the intent of the materials design as stated in the materials memo should be noted on the file copies of both the Assistant State Engineer and Materials Pavement Engineer. If the deviation is sufficient to warrant a change, the proper section should be notified of the required change.

205.03 ASSEMBLING MATERIALS DATA FOR FINAL PLANS AND FOR DISTRICT INFORMATION

When a construction project is advertised for bids, a notice from the Contracts and Specifications Services is forwarded to the Materials Section showing the project number, the termini of the project, and the serial numbers of the pits to be used on the project.

On all projects involving Federal funds, one complete set of roadway plans should also be requested in the "Special Instructions" space and this set of plans should be delivered to the Supervisor of the Final Records and Samples, for use by his crew.

206.00 CONSTRUCTION PROBLEMS

When a project has gone to contract the Materials Design Engineer shall be prepared to answer questions pertaining to the materials design or materials field problems which may be encountered during construction. The materials questions and field problems need to be handled expeditiously in order to prevent construction delays.

One of the common materials problems during construction occurs at the time the subgrade is being tested for acceptance. On projects involving subgrade preparation the materials design memo contains a subgrade acceptance chart. (Figure 203.04-4) The chart is used by field construction personnel for determining the design acceptability of the subgrade soils. When a subgrade sample falls within the unacceptable region the field personnel will notify the materials designer of the test results. The designer compares this information with the results of the original design. The construction personnel continue sampling the unacceptable material in increments of 100 feet until the limits of the failing material has been determined. Using this information the designer determines the best method of dealing with the unacceptable subgrade material. Some of the methods used to treat this material are as follows.

1. Overexcavate and replace with acceptable material.

2. Cement or lime stabilization.

3. Use geosynthetics (fabrics, grids, membranes, etc.).

4. Increase the pavement structural number to compensate for weaker soils.

In addition to unacceptable subgrade material, other construction problems relating to materials may occur, a few of which are as follows.

1. Subgrade moisture problems.

2. Slope problems.

3. Drainage or erosion problems.

4. Out of specification material.

As with all questions relating to field problems, these items should be analyzed and expedited by the Design Engineer as judiciously as possible.

CHAPTER 3

PAVEMENT MANAGEMENT AND EVALUATION

300.00 PAVEMENT MANAGEMENT

Pavement Management annually surveys each mile of the State Highway System for ride roughness and pavement cracking. In addition, rut depth measurements are taken annually on all interstate highways. Skid resistance measurements are taken on a priority basis, with special requests given top priority, whereas routine inventory tests are conducted as time permits. Airports under the State Airport System are also annually surveyed for ride and cracking as time permits. The reports detailing the results of these tests are made available to pavement designers in order to improve overlay and rehabilitation designs. In addition, the survey data is used in the development of the Five Year Construction Program. Each Preservation Project in the 5-year program is tested for deflection and the results of these tests are used to help determine overlay thickness and type of material.

300.01 PAVEMENT MANAGEMENT GOALS AND OBJECTIVES

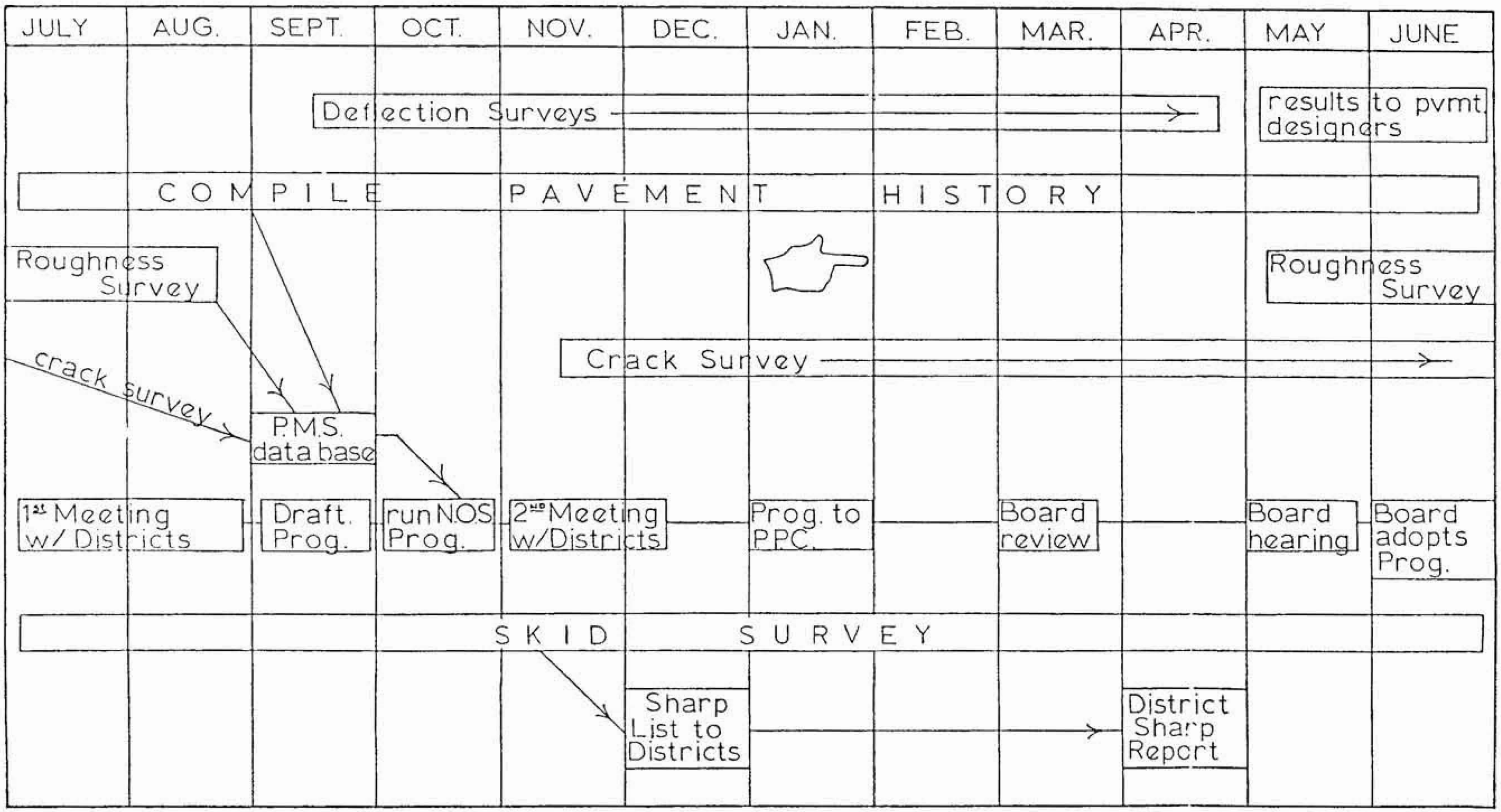
1. Complete the annual pavement condition inventory on schedule.

2. Analyze the data collected on a network basis for network optimization to determine the appropriate maintenance strategy for the various highway segments. The pavement condition data, traffic data and climate data are used to predict pavement distress in future years. An optimization program uses prediction models in matrix form, as well as, other input constraints to determine the least cost set of pavement improvements (seal coats, overlays etc.) to maintain the highway network.

A five year preservation program is developed from the data and interaction with Districts and ADOT Management. For the first three years, specific projects are identified and funded. In the last two years a budgeted amount of money is estimated to fund projected preservation projects.

The yearly work program for the major duties of Pavement Management and Evaluation is shown in Figure 300.01-1.

PAVEMENT PERFORMANCE WORK SCHEDULE



P.M.S. – Pavement Management System
N.O.S. – Network Optimization System
P.P.C. – Priority Planning Committee
SHARP – Skid Highway Accident Reduction Program

FIGURE 300.01-1

3. Provide deflection data to the pavement designers for the purpose of determining the structural adequacy of each preservation project.

4. Maintain, as resources allow, a computer file of pavement condition, history, traffic, materials tests and all other pertinent data for the pavement management and design process.

5. Complete a condition inventory of airports within available time constraints.

6. Respond to requests from various government agencies such as the Attorney General, Department of Public Safety, Federal Highway Administration, Transportation Research Board, AASHTO, Universities, Foreign Countries and others.

7. On a three year cycle develop in cooperation with management a pavement preservation policy, which documents pavement management goals on a highway network basis.

301.00 PAVEMENT EVALUATION

Pavement Evaluation encompasses those functions relating to the field testing of the highway system to obtain all or part of the data needed for Pavement Management and pavement structural design.

301.01 DEFLECTION MEASUREMENT

Deflection measurements on pavements are made by ADOT currently with two devices, the Dynaflect and the Falling Weight Deflectometer (FWD). These are electro-mechanical systems for measuring deflections of pavements from an applied load.

The following is a brief description of both of these devices:

A. THE FALLING WEIGHT DEFLECTOMETER

The Falling Weight Deflectometer (FWD) is a testing apparatus that transmits to the pavement an 18,000 pound single axle load by a falling weight. The FWD applies a specified pavement loading, and measures the actual applied load and deflections. The FWD provides test results that can be used to determine the modulus of the subgrade and the pavement layers.

The FWD trailer includes the falling weight load plate, a force transducer, and seven deflection transducers. A computer processes the test data and produces a printout. By using a computer program, the modulus (E-value) can be calculated from the test data.

B. THE DYNAFLECT

The Dynaflect is a testing apparatus which uses a 1000 pound cyclic load and records deflections to determine the response of a pavement.

The Dynaflect trailer includes an eight cycle per second 1000 lb. force generator, deflection sensors, and a data acquisition system.

To test the deflections due to the cyclic loading, the first sensor is lowered to a point midway between the two force wheels. The remaining four geophones are placed on one foot center-to-center spacing from the 1st sensor. The load is applied and the deflections from the sensors are recorded.

C. DATA ANALYSIS

The data obtained from the FWD or the Dynaflect may be plotted to form a "deflection basin", which may be useful in evaluating structural adequacy of the roadway at the test site. Also, index values are utilized to numerically define the shape of the deflection basin. Those index values are:

1. Surface Curvature Index (S.C.I.), defined as the numerical difference between measured deflections of the first sensor and the second sensor.

2. Base Curvature Index (B.C.I.), defined as the numerical difference between measured deflections of the last sensor and the next to the last sensor.

3. The Maximum Deflection (M.D.), is defined as the value of the measured deflection of the first sensor.

4. The Spreadability Index (S.I.) is defined as the sum of all the sensor readings divided by the number of sensors times the first sensor reading and that result is then multiplied by 100.

$$SI = \frac{(d1 + d2 + d3 + d4 + \ldots dN)}{N \times d1} \times 100$$

By observing the S.C.I., B.C.I., M.D., and the S.I. a qualitative analysis is available for the structural adequacy of the roadway at the test site.

301.02 SURFACE ROUGHNESS MEASUREMENT

One of the major criteria of an adequate roadway is the comfortable and safe ride it provides the travelling public. It is important that there be a method to objectively determine if the road is sufficiently smooth.

Effective February 1, 1992, ADOT has converted all of the existing Mays-meter historical data to true Mays-meter data in accordance with the standard methods in NCHRP Report #228, "Calibration of Response-Type Road Roughness Measuring Systems". All references to and use of Mays-meter data following February 1, 1992 are based on the new, true Mays-meter values. All references in this manual reflect those changes through the issuance of Change Letter No. 2, March 1992.

The equipment used by ADOT to measure road roughness is the Mays Ride Meter. It measures the roughness of the pavement surface by recording the movement between the rear axle and the body of the car.

The Mays ride meter is mounted in a full-sized car equipped with coil springs, firm shock absorbers, and front and rear anti-roll bars.

The roadway roughness is measured in one tenth of an inch increments (counts) by a transmitter that is rigidly mounted in the trunk directly above the axle. As the rear axle moves up and down relative to the car body the transmitter rotates and provides the counts.

The recorder in the front seat receives the roughness counts from the transmitter and prints out the accumulated total and the distance traveled during the test.

The counts from the transmitter are converted to inches per mile by dividing the total roughness counts by the distance over which they were measured (usually 1 mile). These results are adjusted by the calibration for the specific vehicle. The final results are normally used for indicating roughness although they may be converted to a present serviceability rating (PSR) by the equation:

$$PSR = \left[4.6836 * \left[0.9970^{(((\text{Mays-meter value})-4.255)/0.54)} \right] \right] + 0.3488$$

301.03 VISUAL OBSERVATIONS AND PHYSICAL MEASUREMENTS

Although the surface roughness is the predominant factor in determining the serviceability level of a pavement, there are 3 other factors that have a bearing on serviceability. Cracking, patching, and rutting are usually measured visually over a specified area. A surface condition survey of the entire state highway system is performed each year. The amount of cracking, patching, rutting, and flushing at every milepost is recorded to determine the present condition of the roadway.

301.04 MEASUREMENT OF FRICTIONAL CHARACTERISTICS

One important characteristic of a pavement is surface friction. Test Information is used to determine the adequacy of surface friction on roadways to meet the traffic demands. Collection of friction data is done as manpower is available after condition survey, and roughness surveys are accommodated. Every attempt is made to assure that testing is done on any problem areas that are identified. Whenever possible, proposed rehabilitation projects are also tested.

The device used by ADOT to determine surface friction is the Mu-meter, a continous recording friction measuring trailer. It measures the side-force friction generated between the test surface and the two pneumatic tires which are each set at a fixed toe-out angle of 7-1/2 degrees. This frictional force is sensed by a transducer located near the apex of the trailer's frame. During a test, water is sprayed under the test tires to simulate wet pavement conditions. For special studies, dry tests can also be performed. Generally tests are made for 500 feet and inventory tests normally begin at the milepost.

301.05 FLEXIBLE PAVEMENTS

A. Cracking

The amount of cracking of the pavement is recorded as a percentage of a 1000 square foot area at each milepost. A procedure was originally developed from an analysis of pictures of road surfaces with different levels of cracking subdivided into a 1000-compartment grid.

To estimate cracking on the roadway, previously analyzed pictures of known percent cracking are compared to the road surface and the percent cracking of the area is determined.

B. Patching

The amount of patching is reported as a percentage of a 1000 square foot area at the milepost. Patching is defined as any surface treatment placed by maintenance forces. Patching is usually found in small isolated spots but can occasionally be seen over the entire width of the roadway for a hundred feet or more.

C. Flushing

Flushing results from an excess of asphalt on the surface of the pavement.

Flushing is recorded as a severity rating from 1 - severe and bleeding, to 5 - no flushing.

D. Rut Depth

Rut depth is defined as the mean depth of a rut in the wheelpaths of the pavement where the rut is the depression under the center of a four foot straight edge.

301.06 RIGID PAVEMENTS

A. Patching

Patching is reported the same way as for flexible pavements.

B. Faulting

Faulting at the joints occurring in the 1000 square foot area, is measured and reported to the nearest 0.01 inch.

301.07 DATA INTERPRETATION

Table 301.07-1 describes qualitatively the meaning of various pavement management data.

TABLE 301.07-1

GUIDELINES USED FOR CATEGORIZING PAVEMENT

MU-METER NUMBER:	
HIGH	43-99
MEDIUM	35-42
LOW	Less than 35
ROUGHNESS:	
SATISFACTORY	**0-93 in/mile**
TOLERABLE	**94-142 in/mile**
OBJECTIONABLE	**143 + in/mile**
PERCENT CRACKING:	
LOW	Less than 10
MEDIUM	10-30
HIGH	Greater than 30
ANNUAL MAINTENANCE COST (PER LANE MILE):	
LOW	0-333
MEDIUM	334-666
HIGH	Greater than 666
TRAFFIC - AVERAGE DAILY TRAFFIC (ADT)	
VERY LOW	≤500
LOW	501-2000
MEDIUM	2001-10,000
HIGH	Greater than 10,000
TRAFFIC - 10 YEAR CUMULATIVE 18 KIP SINGLE AXLE EQUIVALENT LOADS (ESAL's):	
LOW	0-50,000
MEDIUM	51,000- 375,000
HIGH	376,000-1,250,000
VERY HIGH	Greater than 1,250,000
SEASONAL VARIATION FACTOR:	
LOW	Desert 0-1.7
MEDIUM	Transition 1.8-2.7
HIGH	Mountains Greater than 2.7

TABLE 301.07-1 (Cont'd.)

GUIDELINES USED FOR CATEGORIZING PAVEMENT

DEFLECTION: FIRST GEOPHONE - MILS (1 mil = 0.001 inch)

	Dynaflect	FWD
LOW	Less than 1.0	Less then 25
MEDIUM	1.0 - 1.5	25 - 40
HIGH	1.5+	40+

SPREADABILITY INDEX:

STRONG STRUCTURE	46 or More
MEDIUM	35 - 45
WEAK	Less than 35

RUT DEPTH

LOW	.0 - .25 IN.
MEDIUM	.26 - .50 IN.
HIGH	.51+ IN.

CHAPTER 4

PAVEMENT REHABILITATION

400.00 INTRODUCTION

Rehabilitation generally involves restoring the ride to a new condition, repairing surface problems such as cracking, rutting and pothole patches and providing good skid resistance. To accomplish this may require overlaying, milling, recycling, grinding, crack sealing and/or joint sealing, as well as, other activities associated with a preservation, widening or in rare cases a reconstruction project. Designs for rehabilitation differ from new construction in that considerable information about the pavement structure and performance already exists. In addition, structural capacity can be measured with deflection equipment. Rehabilitation design guides are based on deflection measurements augmented by experience and do not directly follow the new AASHTO Design Guide. Table 400.00-1 shows the data required for a rehabilitation design. In addition the designer should be familiar with the traffic loading information presented in Chapter 2, as well as, the cost data compiled by Contracts and Specifications Services. As in pavement design for new construction, rehabilitation designs should reflect the most cost effective solution although life cycle cost analysis would not routinely be conducted.

400.01 FLEXIBLE PAVEMENT REHABILITATION

The procedure used to design overlays in Arizona is to determine the structural adequacy by deflection testing. When the 18k equivalent loading is less than 100,000 for the design period, deflection testing and design is rarely warranted; therefore deflection testing and analysis is not required for those projects. Except in unusual situations, the design period for overlay/rehabilitation projects is 10 years and the corresponding ten year traffic loading is used for design. For divided highways or highways with four or more lanes, the design traffic for the high traffic lane is reduced by ten percent for each additional traffic lane. The other traffic lanes are therefore each ten percent of the design traffic. Generally, milling out some depth of asphalt bound material in each traffic lane and replacing with new or recycled AC is more cost effective than a simple overlay. Mill out depths and overlay thicknesses can be determined from deflection measurements. Typically three to five measurements per mile are taken in each traffic lane using the falling weight deflectometer (FWD) or dynaflect.

TABLE 400.00-1

DATA REQUIRED FOR DIFFERENT TYPES OF CONSTRUCTION PROJECTS

Data Required	Reconstruction	Widening	ACP Rehabilitation	PCCP Rehabilitation	Surface Treatments
Existing As-Built Information	H	H	H	H	H
Roughness, Skid, Cracking (Type & %)	L	M	H	H	H
Field Data	H	H	H	H	H
Pavement Surface Condition	L	M	H	H	H
Traffic Data (ADT & ADL)	H	H	H	M	L
Subgrade Sampling & Testing	H	M	L	L	N/A
Deflection Testing	L	H	H	M	L
Material Sources	H	H	M	M	L
Environment & Drainage	H	H	M	M	L

Level of Need: H = High M = Moderate L = Low N/A = Not Applicable

Materials Section uses the SODA (Structural Overlay Design for Arizona) method, which is based on analysis of all 7 FWD or 5 dynaflect sensor readings.

A. SODA METHOD

The SODA method uses as input values:

1) Total traffic loads expected over the design period (18 kip ESAL's) for the given lane.

2) Road roughness (Mays-meter value)

3) Seasonal Variation Factor

4) Spreadability Index (SI) (Section 301.01.C.4)

5) FWD #7 or Dynaflect #5 sensor readings

The equation for thickness is:

$$T = \frac{(\text{Log } L-3.255)+(0.104*SVF)+\left[\dfrac{0.000578*(Po-4.255)}{0.54}\right]-(0.0653*SIB)}{0.0587 * \left[2.6 + (32.0 * D5)\right]^{0.333}}$$

Where:
- L = Design 18 kip ESAL's
- SVF = Seasonal Variation Factor
- Po = Roughness, inches/mile
- SIB = Spreadability Index before Overlay
  For the FWD
  $SIB = 2.7 * (FWD\ SI)^{0.82}$
- D5 = #5 Dynaflect sensor reading in mils
  For the FWD
  $D5 = 0.16 * (FWD\ D7)^{1.115}$

The thickness should be determined at each test location and the mean value of thickness for all test locations in a design section is then used as the overlay thickness. No statistical manipulations are needed as they were incorporated into the development of the method.

Any individual test location results less than zero are assigned a value of zero and any results over 6 inches are assigned a value of 6 inches.

If milling is involved then the roughness is set to 50 inches per mile. In addition the spreadability index before overlay is calculated to be a function of the depth of milling, representative of the new or recycled asphaltic concrete that will be placed in the milled out trench and is set equal to the SIM value in the following equation.

$$SIM = (0.899 * ET) + SIB$$

$$ET = \left[2.6 + (32 * D5) \right]^{0.333} * MILL$$

Where:
- SIM = Spreadability Index after milling and replacement.
- ET = Equivalent thickness adjusted to reflect milling and replacement.
- MILL = Depth of mill out and replacement in inches.

B. OTHER SODA CONSIDERATIONS

From past experience if the #7 FWD sensor reading is less than 0.67 mil, or less than 0.1 mil for the #5 dynaflect sensor, the thickness of the overlay probably will be too thick. Given the other physical distress measurements, such as ride and/or cracking the designer may elect to reduce the overlay thickness to a value sufficiently thick to meet or exceed Table 400.01-1 guidelines.

If the #7 FWD sensor is greater than 2.4, or the #5 dynaflect sensor is greater than 0.4, the subgrade is weak and the overlay thickness may be underestimated. For this case historical soil support logs, R-value tests and drainage should be investigated. Increased thickness and/or subgrade drainage may be necessary.

If the SODA design thickness is less than 2.5 inches or the traffic is less than 100,000 18 kip ESAL's, the designer should review the pavement management data base, the design review team data and design recommendation, as well as, personal project review notes in light of Table 400.01-1. This table contains the most common type of repair activities and range of thickness for a particular distress. The selected design should consist of a sufficiently thick overlay and/or mill and replace section to meet or exceed Table 400.01-1 guidelines.

C. OVERLAYS OTHER THEN SODA

There may be circumstances where an overlay is warranted for reasons of stage construction, continuity (widening, structures) or preventative maintenance. For these cases a minimum two inch overlay should be considered.

TABLE 400.01-1

OVERLAY GUIDELINES

When SODA overlay is 2.5 inches or less
or traffic loading less than 100,000 18 Kip ESAL's

ROUGHNESS:

Satisfactory	0-93 in/mile	No Action or Seal Coat
Tolerable	94-142 in/mile	2" Overlay
Objectionable	143+ in/mile	Minimum 2.5" Overlay

NOTE: See Table 400.01-2 for additional leveling thickness.

PERCENT CRACKING:

Low	Less than 10	No action or Seal Cracks
Medium	10-30	2" Overlay with or without milling
High	Greater than 30	Minimum 2.5" Overlay with or without milling

NOTE: Consider special treatments for reflective cracking.

MU-METER NUMBER:

High	43-99	No action
Medium	35-42	ACFC or Seal Coat
Low	Less than 35	ACFC or Seal Coat

NOTE: Milling should also be considered.

RUT DEPTH:

Low	0-.25 in.	No action
Medium	.26-.50 in.	Minimum 2" mill out and replacement
High	.51+ in.	Minimum 2.5" mill out and replacement

ANNUAL MAINTENANCE COST (PER LANE MILE):

Low	$0-333	No action
Medium	344-666	Minimum 1.5" Overlay
High	Greater than 666	Minimum 2" Overlay

NOTE: If patching material unstable milling will be necessary.

In addition to overlay thickness, the designer should consider the use of a special treatment to alleviate a troublesome problem. Large transverse or longitudinal cracks are difficult to control with just an overlay and can produce a reflective cracking problem. Special treatments such as asphalt rubber, fabrics or elastic tape material should be considered. Reflective cracking may also occur if the overlay thickness or the combined thickness of mill and replace pavement plus the overlay is less than the thickness of the remaining or existing old pavement. In order to reduce the incidence of reflective cracks, either the overlay thickness or milling thickness should be increased to be at least equal to the thickness of the remaining or existing old pavement. If this is not practical, then other special treatments such as asphalt rubber or fabric should be considered. Rutting problems may not be alleviated by just overlaying, milling of unstable material should also be considered. Bleeding pavements may also need to be milled in conjunction with the surface treatment. If cracks have been sealed by maintenance with asphalt rubber, they should be milled off before overlay to improve the overlay ride. To correct ride or rutting problems by only overlaying, a leveling quantity as shown on Table 400.01-2 should be specified.

Recycling of either milled material or stockpiled salvaged AC from other projects should be considered on all overlay projects. If recycling is not possible, but milling is necessary, milled material can be either stockpiled or used for shoulder buildup. Unusual drainage problems, such as springs, should be addressed with pavement reconstruction incorporating a drainage layer and/or geotextile separation layer. If swelling soil is in evidence then waterproof membranes such as asphalt rubber or a geomembrane to intercept water should be considered.

400.02 RIGID PAVEMENT REHABILITATION

Concrete structural damage, which may be evidenced by random cracks, should be determined from deflection testing. Figure 400.02-1 indicates the maximum deflection at the center of slab for a new plain jointed concrete pavement. This figure can be used to determine qualitatively the degree of structural damage and the type of rehabilitation to be considered (as shown on Table 400.02-1). If an overlay is warranted only minor slab repairs should be considered and normally only spalled joints would be repaired with AC patching material, no joint sawing or sealing would be necessary.

Other concrete surface distress problems such as rough ride (with or without faulting) or low skid resistance also create a need for rehabilitation. Table 400.02-2 shows typical

TABLE 400.01-2

LEVELING REQUIREMENTS ON OVERLAY PROJECTS

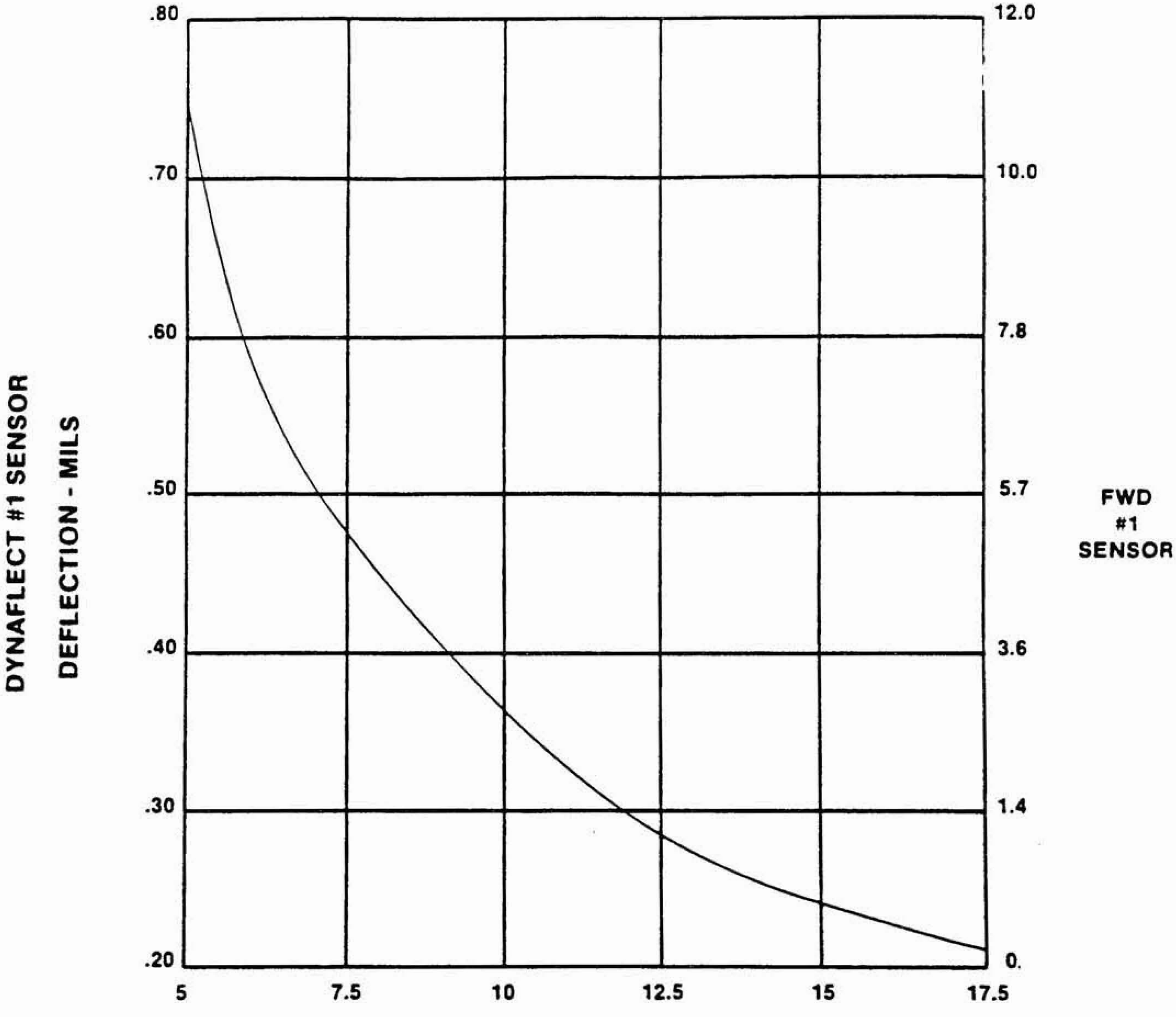
ROUGHNESS (MAYS)	ADDITIONAL THICKNESS FOR LEVELING IN INCHES	IN FEET
0 - 93	0 - 1/4	0 - 0.02
94 - 142	1/4 - 1/2	0.02 - 0.04
143 - 193	1/2 - 3/4	0.04 - 0.06
194+	3/4+	0.06+

RUT DEPTH	*LEVELING REQUIRED PER LANE (TONS/MILE)
1/4 Inch	50 Tons
1/2 Inch	100 Tons
3/4 Inch	150 Tons
1.0 Inch	200 Tons
1 1/4 Inch	250 Tons
1 1/2 Inch	300 Tons

*Leveling Based on a Three Foot Rut Width

FIGURE 400.02-1

**DEFLECTION
VS
PCC PAVEMENT THICKNESS**



$$DYNA = 3.6\left(\frac{1}{THK}\right) \qquad FWD = 76.6\left(\frac{1}{THK}\right) - 4.94$$

TABLE 400.02-1

CONCRETE STRUCTURAL REHABILITATION

Deflection* Ratio	Rehabilitation Action
1.0 or Greater	No structural damage
.99-.71	Consider asphalt rubber overlay, or minimum five inch AC overlay with or without break and seat, or membrane interlayer.
.7 or Less	Consider asphalt rubber overlay, or minimum six inch AC overlay with or without break and seat, or membrane interlayer, or total replacement.

* Ratio of new concrete deflection from Figure 400.02-1 to in service field deflection.

NOTE: Break and seat refers to mechanically cracking or breaking the PCCP slab into approximately two foot square pieces followed by rolling or seating the cracked PCCP with a heavy (40 ton) roller.

In areas with a seasonal variation factor of two or higher, edge drains should be considered.

Structural rehabilitation analysis generally is only considered if significant random cracks are present.

TABLE 400.02-2

CONCRETE NON-STRUCTURAL REHABILITATION

Ride Roughness	Rehabilitation Action
0-93 in/mile	No action
94+ in/mile	Grind* or three layer asphalt rubber overlay or asphalt rubber overlay
Skid Resistance	
43 or more	No action
35-42	Groove*
Less than 35	Groove*

* Joints would be sawn and resealed.

NOTE: Localized spalled areas at joint should be patched. In addition, slabs with significant cracking may need to be repaired or replaced.

rehabilitation methods to be considered. If the concrete is to be ground or grooved and there are asphalt shoulders, concrete shoulders of at least seven inch thickness should be considered.

400.03 WIDENING

Some projects may involve widening the existing highway together with overlaying or mill out with replacement. If the widening is less than a full lane (12 feet) or of a temporary nature (intersection, or stage design) then the existing pavement and pavement structure should be used to design the overlay and widening. Normally the widening would match the in place structural number or minimum structural number, whichever is greater. The full width overlay or mill out plus overlay would be determined by the flexible overlay method, Section 400.01. If no overlay is needed, at least a minimum thickness (two inches) would be placed for continuity.

If the widening was one lane or wider and at least 1500 feet long, it would be designed in accordance with section 202.00. The remaining in-place pavement would be designed in accordance with section 400.01, except it would be a twenty year design and would be considered the inside lane. Thus the new widening would be designed with 90 percent traffic loading and the overlay with 10 percent traffic loading. If possible, the total thickness of the new AC and base should closely match the thickness of the existing pavement section. If the existing pavement did not need an overlay then at least a minimum thickness (two inches) would be placed for continuity.

CHAPTER 5

CONSULTANT AND LOCAL GOVERNMENT PROJECTS

500.00 CONSULTANT AND LOCAL GOVERNMENT PROJECTS

The nature and extent of involvement by the Materials Section will depend upon the exact nature of the project.

For local government projects which are Federally funded, the geotechnical investigation and pavement design may be performed by the Local Government or by a consultant under contract to the Local Government. In either case, the Arizona Department of Transportation (ADOT) becomes involved as the agent for contracting, and in some cases, for contract administration. It is the responsibility of the Materials Section to evaluate the geotechnical investigation and pavement design submitted by the Local Government for compliance with ADOT and FHWA policies and standards.

The Materials Section is also responsible for reviewing the geotechnical and pavement design work performed by Design Consultants hired by ADOT. When ADOT has retained a Management Consultant for administration of design contracts, that firm has the primary responsibility for review and approval of the Design Consultant's submittals. However, the Management Consultant will also forward the submittals to Materials Section for review and comment.

The Local Government or Consulting Engineer is responsible for coordinating all activities related to accomplishing the preliminary survey and pavement design which may involve obtaining permits and/or having an approved traffic control plan. Field sampling work, pavement design, and design information presentation should be done in accordance with the procedures and guidelines listed in the other chapters of this design manual.

500.01 MATERIALS SECTION CONTACTS FOR LOCAL GOVERNMENTS AND CONSULTING ENGINEERS

To assist local governments or consulting engineers with any questions which may arise about ADOT Materials procedures or methods, the following persons may be contacted within the Materials Section at 255-7231:

Pavement Engineer
Testing Engineer
Geotechnical Engineer

The Pavement Engineer shall be contacted prior to commencement of the preliminary engineering survey or pavement design so that the appropriate Materials Section Design Engineer is identified. Communications between the local government or consulting engineer and Materials personnel should be maintained to ensure that the preliminary engineering survey and design will meet the requirements of the Materials Section. This will eliminate any unnecessary delays during the review process which could affect the scheduled construction date.

On projects which have a Management Consultant, references to notices or submittals to ADOT shall be interpreted to mean notices or submittals to the liaison designated by the Management Consultant. Similarly, ADOT Urban Highways Section will designate a liaison for projects under their jurisdiction.

500.02 TYPES OF PROJECTS

Preliminary engineering soils surveys, laboratory procedures, and pavement designs done by local government or consulting engineers for a wide range of projects will require review by, and close cooperation with, Materials Section. Project types may include, but are not limited to, new pavement construction, widening of existing pavement structures, realignment of existing roadways or streets, rehabilitation of existing pavement surfaces, reconstruction of existing pavement sections, and other miscellaneous pavement improvements.

It should be noted that a wide range of construction alternatives are possible for each type of project, and an effort should be made to consider a number of alternatives so that efficient use of funds may be obtained.

500.03 DESIGN DEVELOPMENT GUIDELINES FOR LOCAL GOVERNMENT AND CONSULTING ENGINEERS

In order to assist local governments and consulting engineers in the development of their project, a guideline outlining required design development procedures follows:

A. COMMENCEMENT OF WORK

Before beginning work on a project, the sponsoring agency or the consultant should contact the Materials Section Geotechnical Services to discuss the geotechnical requirements of the project and to obtain any pertinent information that may be available.

B. INFORMATION AVAILABLE FROM ADOT MATERIALS SECTION

Information which may be useful in the design preparation for a proposed project may be supplied by ADOT Materials Section if it is available for that location.

Traffic information is currently available for any roadway which is part of the state system, including interstates, primary and secondary roads. Traffic counts are encouraged for all local government projects. Assistance may be provided by ADOT Transportation Planning Support Section at 255-7893.

Information on aggregate or borrow pits under permit to ADOT, or in the process of being acquired, may be obtained from Materials Section. Each materials pit has a file which includes a location map of the pit and a summary of laboratory tests conducted on samples from exploration of the pit.

If the project is, or at one time was, part of the State system, as-built information may be available. As-built information should be sought on all rehabilitation projects to obtain knowledge of the existing construction prior to commencing field work.

For rehabilitation projects on the state system, deflection data, ride data, and skid data may also be available, since a regular pavement survey is done by Pavement Management, Materials Section. A maintenance history of the pavement is also available.

C. INFORMATION AVAILABLE FROM THE ADOT ENGINEERING RECORDS

Engineering Records Services at ADOT has many publications available as well as as-built records for most projects constructed on the state system. A publications brochure which is normally distributed when any purchase is made lists all available publications and the prices. Some of the publications which may be useful to the local government or consultant are listed below:

ADOT MATERIALS MANUALS
- Materials Testing Manual
- Preliminary Engineering and Design Manual
- Policy and Procedures Directives Manual

STANDARDS AND SPECIFICATIONS

ADOT Standard Drawings
Part (1) - Construction Details
Part (2) - Structures
Part (3) - Traffic Signals and Lighting
Part (4) - Signing and Marking
ADOT Standard Specifications for Road & Bridge Construction
MAG Specifications
MAG Standard Details
City of Phoenix Supplemental Specifications
City of Phoenix Supplemental Details
ADOT Telephone and Mail Directory

Numerous reports and studies are also available for purchase. These include studies done by ADOT personnel as well as other funded studies, and are listed on the publications brochure distributed by ADOT Engineering Records.

501.01 PRELIMINARY SURVEY WORK

It is the responsibility of the local government or consulting engineer to determine what ownerships are involved with the roadway alignment and any proposed pit locations. The consultant or local government sponsoring agency shall contact each property owner for permission to enter before entering upon the property for exploration purposes. Written license should be obtained before prospecting materials sources. An Environmental Impact Statement and clearance may also be necessary on both centerline and pit sites depending on project location.

All preliminary engineering survey work performed by the local government or an engineering consultant should follow the procedures of this manual. Materials Investigation Procedures are listed in Chapter 1 and Pavement Management and Evaluation Procedures are listed in Chapter 3.

501.02 CENTERLINE INVESTIGATION OF NEW CONSTRUCTION AND RECONSTRUCTION PROJECTS

For new pavement construction, reconstruction, widening of existing roads, or realignment, subgrade exploration and sampling for R-value, PI, Gradation and in-place density should follow procedures listed in Chapter 1 of this manual which are minimal requirements. The Engineer preparing the Geotechnical Report may elect to do additional work in order to more fully describe and document any unusual or special materials and/or conditions.

To properly record observations and data during the investigation, a working soil profile should be developed and pertinent information recorded and noted on this profile. The base document for the working profile should be the centerline profile provided by the sponsoring agency or, if plans and profiles have already been prepared, the plan profile may be used.

On projects involving new corrugated metal pipe installation, pH and resistivity tests are also required at the proposed pipe location. On projects where existing pipes are to be extended, generally they will be matched in kind and no sampling will be needed unless the project is within a corrosive area, then at least half the pipe locations or a minimum of three locations, whichever is greater, should be sampled and tested. Refer to other sections of the Manual for any additional items that may be required.

501.03 INVESTIGATION FOR REHABILITATION OF EXISTING ROADWAY

For rehabilitation projects, subgrade and base materials do not need to be sampled unless deemed necessary by the responsible Engineer. Asphalt cores should be taken to verify the condition and thickness of the existing surfacing. See Section 103 for coring requirements.

Evaluation of the existing pavement surface should be done at a minimum of 5 locations per project or at least 3 per mile of roadway, whichever is greater. The evaluation should include the following:

1. Cracking - location, percentage, type, width
2. Pavement rutting - locations, depth, width
3. Pavement flushing - location, extent
4. Stripping - location, extent, type
5. Ravelling - location, cause
6. Maintenance patches - location, type, purpose
7. Drainage problems
8. Shoulder condition

A written record should be made of the pavement evaluation by location with photographs or drawings to visually record the types of problems which are evident on the pavement surface.

On projects where overlay of existing pavement is not possible or where cracking of the existing pavement is very extensive, removal of the existing pavement may be necessary.

This is especially true where curb and gutter is present. On projects where recycling of the existing pavement is to be considered, at least 3 six inch cores at selected sampling locations should be taken for recycling tests. In no case should less than 12 locations be sampled, at uniformly spaced locations thru-out the project, in order to provide enough material for a recycle mix design.

In addition, deflection testing should be done if the design traffic is greater than 100,000 18K ESAL's. Deflection test results may be available from ADOT if the roadway is on the state system. If deflection tests are needed, testing can be done by a consultant. If this is not possible Materials Section will conduct the tests upon request.

501.04 INVESTIGATION OF MATERIAL PITS

On projects where borrow will be required, a materials pit will probably be necessary. If the proposed source is one which has not been previously explored by Materials Section, then exploration of the pit would be necessary. Questions regarding pit exploration requirements should be discussed with a Geotechnical Investigation Engineer of the Materials Section. Normally a source is not designated if the required quantity is less than 5,000 cubic yards.

Exploration of materials pits should follow the procedure listed in Chapter 1. The requirements for R-Value tests on borrow sources should be noted.

501.05 EXPLORATION EQUIPMENT AND SAMPLING

Most sampling of subgrade soils for new roadway construction is done with a backhoe. Utilization of a backhoe is encouraged since it will provide a large uncontaminated sample and will allow visual inspection of the different soil horizons, layering and soil structure. Materials pits are also generally explored in this manner for the same reasons.

Samples taken on reconstruction and rehabilitation projects are often taken with coring equipment in order to minimize the disruption of the existing road and because of the shallow depths usually required. These soil samples should include at least the two feet immediately below the existing pavement structure.

Samples should be taken in a manner which will provide an adequate sample size with a minimum of contamination. Care should be exercised in sampling to prevent contamination of materials. Other methods of sampling are possible provided contamination can be prevented. Sampling techniques other than those listed in the design manual will not be used without prior approval by the Geotechnical Services Engineer. A Field Review of projects contracted to a consulting engineer on the state road system may be conducted from time to time by the Geotechnical Investigation Engineer of Materials Section for informational purposes.

502.00 MATERIALS TESTING

All testing of samples should be performed in compliance with procedures outlined in "Arizona Department of Transportation Materials Testing Manual".

On projects which will utilize cement or lime treatment for base support, ADOT Materials Testing Services Engineer should be contacted for testing requirements.

503.00 TRAFFIC INFORMATION

A good pavement design should be sufficient to provide the required life under the traffic which will be imposed on it. Pavement design traffic information for State Highways is available from Materials Section. For non-state highways and local government projects Appendix A should be reviewed to determine how to calculate pavement design traffic loadings.

504.00 PAVEMENT STRUCTURE DESIGN

The design of all pavement structures should be done according to the design methods listed in Chapters 2 and 4 of this manual. These chapters include the AASHTO Method as modified by ADOT for flexible pavements, ADOT's adoption of AASHTO's method for design of rigid pavements, and an overlay design procedure based upon deflection testing. Minimum pavement designs should be noted as listed in Chapter 2.

505.00 CONSULTANTS OR LOCAL GOVERNMENTS REPORT

The report presented to ADOT should consist of three parts, each of which will stand separately. These are the Geotechnical Report, Pavement Design Summary, and Design Memorandum. Examples of each are available from the Materials Design Engineer or Local Government Services, as well as; shown in Chapter 2. Each of the three reports mentioned shall be signed and sealed by an Arizona registered engineer.

A. GEOTECHNICAL REPORT

The geotechnical report should primarily be a summary of the field exploration, laboratory testing, interpretations and recommendations. It should include the project concept, scope and a site plan. All Geotechnical Reports should contain the following basic information.

1. A summary of the information gathered during field exploration should be presented with visual observations, geology, sample conditions, sample logs, in-place density data, groundwater information, record of existing pavement conditions and existing pavement section measurements should be included when necessary.

2. Laboratory or in situ test data should be presented showing all test results including, but not limited to, R-Value, Plasticity Index, gradation analyses, moisture content, pH, resistivity, proctor density, shear strength, consolidation, sulfate and asphalt tests.

3. A section containing interpretation and analysis of data should be included. This section should contain ground compaction factors, excavation factors, slope ratios and associated testing.

4. Specific recommendations for design.

5. Geotechnical special provisions.

6. A soils profile which clearly illustrates the location, depth and soils physical properties.

7. A section on recommendations, complete with justifications, should be composed as the summary. All references utilized should be listed.

8. An appendix containing engineering calculations shall be submitted.

9. Pit information should include reference to pit numbers, site maps, pit gradation and plasticity indexes, R-values, unit weights, pH and resistivity data, in-place density test data, haul distance and availability.

B. PAVEMENT DESIGN SUMMARY

The pavement design summary is necessary to show the basis for the proposed design. It also provides information necessary for the review of design. The pavement design summary should support the design recommendations made.

The pavement design summary should include a description, location, and reason for the project. Visual observations made by the designer should be listed, especially on rehabilitation projects. Subsoil conditions and geology should be discussed and test results pertinent to the design such as R-values, PI's, gradations, moistures and frost susceptibilities should be listed.

A support argument for the design chosen should be made. For new construction, the selection of the design R-value should be discussed. Other factors important in the design should be listed including traffic numbers and their source, seasonal variation factor, terminal serviceability index, structural coefficients for materials in the pavement section, and required structural number with all factors considered. For rehabilitation projects utilizing deflection design, all results of deflection test should be listed along with the method used. If the project is to be divided into sections with different design recommendations, support should be shown for this division, such as different soil type or different existing pavement conditions.

The pavement design summary should list different design alternatives, an economic cost comparison and a discussion explaining the reason for the alternative chosen. Unit costs and total costs should be listed for each design considered. The Materials Design Engineer can give assistance with regard to recent costs of various pavement materials.

C. DESIGN MEMORANDUM

This is the final part of the report to be supplied by the consulting engineer or local government. Chapter 2 explains the design memo preparation and what should be contained therein. The design memorandum describes what will be constructed and the information it contains is included in the overall project design and plans. It also tells ADOT Contracts and Specifications Services what materials will be used so that the proper specification is included in the contract. It includes other recommendations for construction as well as earthwork factors and sources of any materials.

Much of the memo is made up of standard items which call out a standard or stored specification. Copies of these items are available from ADOT. These items are being constantly updated, and the consultant is encouraged to request the latest version from ADOT Materials Section or Local Government Services.

The incorporation of any specification by reference, other than an ADOT Specification, is not an acceptable procedure. Reference should be made to the appropriate ADOT specification. If another specification is specifically desired for a project which is not on the State highway system, the specification must be written out in full, and will be subject to review and approval by ADOT.

D. PRELIMINARY PAVEMENT STRUCTURE COST ESTIMATE

A pavement cost estimate for each project is developed from the recommended pavement structure following the economic comparison of alternate designs. The cost estimate gives only the costs for the pavement structure and related items. The Preliminary Pavement Structure Cost Estimate is used for comparison purposes to ensure reasonable compliance with the programmed amount for pavements on each project an example format is shown in Figure 203.05-1.

E. REVIEW PROCEDURE

The preparer of the design memorandum should work closely with the Materials Design Engineer associated with the project. Normally, Materials Design Memos are reviewed at least two times prior to being finalized. The local government, their design engineer or ADOT contracted design engineer responsible for the engineering survey and design should submit a preliminary geotechnical report, pavement design summary and design memorandum directly to Materials Section for preliminary review. If close cooperation has been maintained throughout, these reports should be in the proper form at that time. Materials Section personnel will make comments and ask questions concerning these reports and they will be returned to the consultant or local government for revision where necessary.

After revisions have been made as requested, these items will be resubmitted for another review. If revision is complete and acceptable the local government or consulting engineer will be contacted, and ADOT will accept the geotechnical report and pavement design summary and submit the design memo to the necessary locations in ADOT. If revision is not sufficient, these items will be returned to the consultant or local government for more revision. This will continue until these items are acceptable.

F. LOCAL GOVERNMENT AND CONSULTANT SUBMITTALS

The following items are to be submitted:

1. Soil information, including soils classifications, soils profile for new alignments, and log of core samples.

2. Geotechnical Report

3. Design Summary, including an economic comparison of design alternatives.

4. Initial Design memo for review

5. Preliminary pavement structure cost estimate.

6. Final Design Memo

The final version of Geotechnical Report, Design Summary, and Design Memo must be signed and sealed by an Arizona registered engineer.

APPENDIX A

TRAFFIC DATA PROCEDURES AND ANALYSIS

INTRODUCTION

Generally ADOT can provide or determine traffic loading information in 18 kip ESAL's on all state highways under ADOT jurisdiction. The following procedure describes how ADOT developes these traffic loadings.

SOURCES OF TRAFFIC DATA

The Transportation Planning Division (TPD) is responsible for the collection and the publication of traffic data. There are three types of traffic data which must be collected to determine the traffic loading.

1. TRAFFIC VOLUME

The TPD has Automatic Traffic Recording (ATR) devices that obtain samples from 983 locations. These data are published annually in the "Traffic on Arizona Highway System Logbook".

The Materials Section maintains a computer file containing the last ten years of traffic volume data from which traffic volume and growth factors are calculated using regression analysis.

2. TRAFFIC CLASSIFICATION

Samples of the traffic mix are collected annually at 129 locations. This operation has been done by a manual count of the number of vehicles in each of the following categories:

	Abbreviation
* Light Trucks	LT
* Medium Trucks	MT
* Tractor Semi-trailer	TS
* Tractor Trailer	TT
* Tractor Semi-trailer Trailer	TST
* Buses	
* Automobiles	

The "commercial vehicles" include the first five vehicle categories shown above.

A five-year moving average of classification data is used to estimate the percentage distribution among the vehicle categories.

Figure A-1 shows the typical configuration of each of these vehicles types and their grouping into one of the general categories shown above.

3. TRAFFIC WEIGHT

Every other year the TPD conducts a Truck Weight Study (also called a loadometer study) which is a sample of the axle weights of 13 vehicle types. These data are sent to Washington, D.C. where a computer program generates a report consisting of six tables of data, labelled W-2 through W-7. The W-4 table contains the information needed to develop the representative 18 Kip ESAL's for each vehicle category. The calculation of vehicle equivalencies is based on regression analysis performed on the data from the last six Truck Weight Studies. The equivalencies of the TS, TT, and TST vehicle classes increase with time. The equivalency equations in effect for 1988 for these vehicles are:

Flexible Pavements @ 110 PSI Tire Pressures

$$TS = -0.98126 + 0.02771 * YR$$
$$TT = -0.22238 + 0.02041 * YR$$
$$TST = -1.44956 + 0.04182 * YR$$

Rigid Pavements @ 110 PSI Tire Pressures

$$TS = -1.62774 + 0.03750 * YR$$
$$TT = -0.85942 + 0.026655 * YR$$
$$TST = -1.83450 + 0.041815 * YR$$

where these AASHTO parameters hold:

Pt = 2.5
SN = 5.0 for Flexible Pavements
D = 9.0 for Rigid Pavements

and

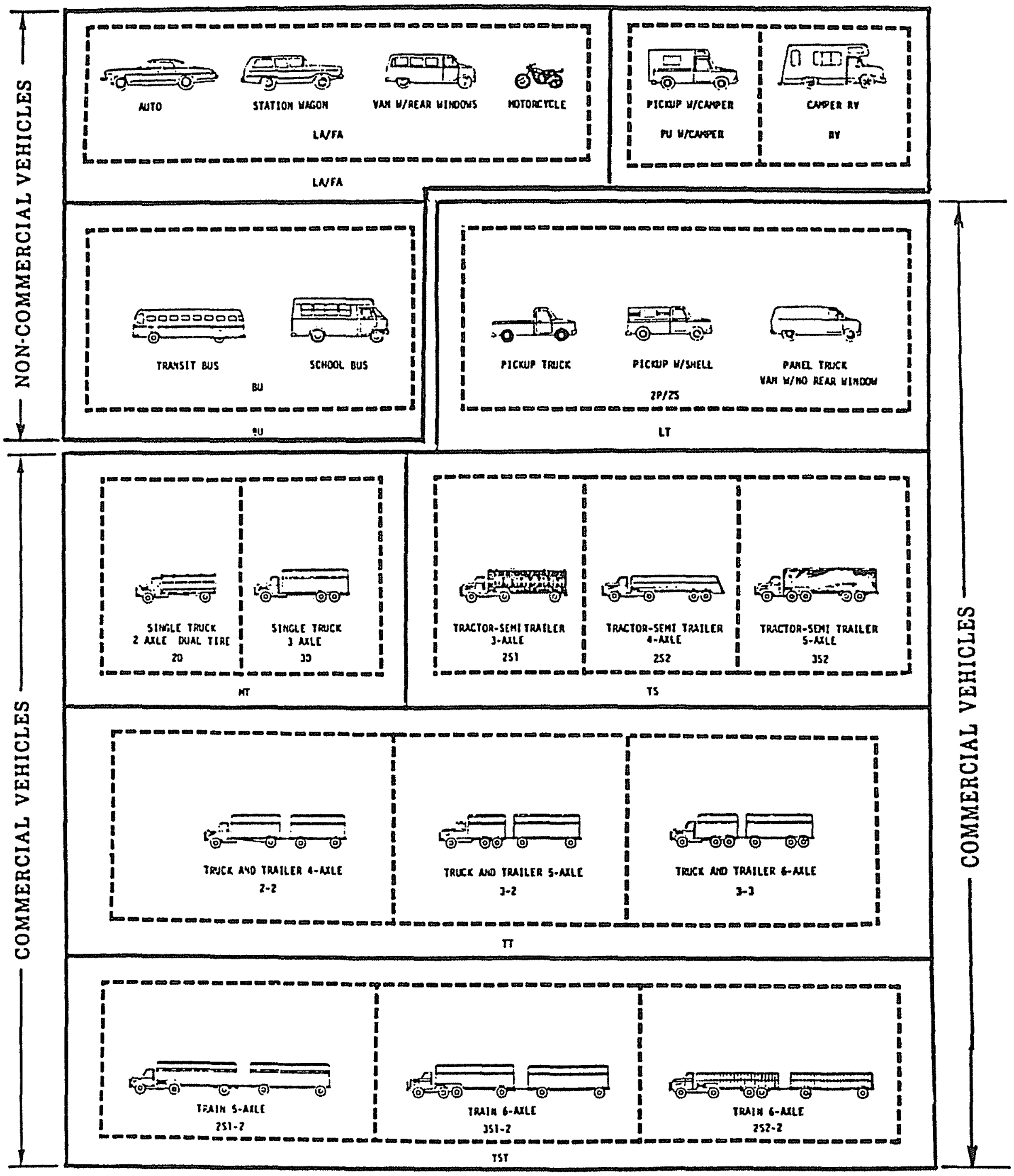
YR = YEAR - 1900

YEAR is the mid-year of the design analysis (performance) period. For example, for a 20 year pavement design from 1987 to 2008, YEAR = 1998 and

YR = 1998 - 1900
= 98

FIGURE A-1

VEHICLE CLASSIFICATIONS



The other four vehicle classification equivalencies do not change with time or with pavement type, they are:

Automobiles	=	0.0008
Buses	=	0.2500
LT	=	0.0100
MT	=	0.4000

The three heavy vehicle equivalencies have been calculated and are tabulated in Table A-1.

By multiplying the traffic loading factors for each vehicle type by the number of vehicles of each type over the design period and summing it is possible to find the cumulative number of 18 kip ESAL's. However, it may be necessary to use an approximation to estimate design traffic loadings (TTL) when vehicle classification data is not available in sufficient detail to use the seven vehicle equivalencies employed by ADOT.

This method requires:

A. An estimate of the number of heavy trucks (TS, TT, and TST) for the design period.

B. An estimate of the relative loads of the heavy trucks based on these guidelines:

Heavy - Similar to interstate truck loadings.

Medium - Similar to a US highway.

Light - Similar to a state secondary highway or urban highway.

C. Assign equivalencies based on the category of truck loading chosen:

Heavy = 1.2

Medium = 1.0

Light = 0.8

D. Multiply the total number of heavy trucks expected during the design period times the equivalencies to obtain the design 18 kip ESAL's.

TABLE A-1

HEAVY VEHICLE EQUIVALENCIES 1987-1997

RIGID PAVEMENTS

YEAR	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
YR	88	89	90	91	92	93	94	95	96	97	98
TS	1.6723	1.7098	1.7473	1.7848	1.8223	1.8598	1.8973	1.9348	1.9723	2.0098	2.0473
TT	1.4862	1.5129	1.5395	1.5662	1.5928	1.6195	1.6461	1.6728	1.6995	1.7261	1.7528
TST	1.8452	1.8870	1.9289	1.9707	2.0125	2.0543	2.0961	2.1379	2.1797	2.2216	2.2634

FLEXIBLE PAVEMENTS

YEAR	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
YR	88	89	90	91	92	93	94	95	96	97	98
TS	1.4572	1.4849	1.5126	1.5403	1.5681	1.5958	1.6235	1.6512	1.6789	1.7066	1.7343
TT	1.5737	1.5941	1.6145	1.6349	1.6553	1.6757	1.6962	1.7166	1.7370	1.7574	1.7778
TST	2.2306	2.2724	2.3142	2.3561	2.3979	2.4397	2.4815	2.5233	2.5652	2.6070	2.6488

4. TRAFFIC DATA COLLECTION IMPROVEMENTS

A. Weigh-In-Motion (WIM) Study

The TPD has two WIM devices that automatically sense the dynamic weight of moving axles, estimate vehicle velocity, and classify vehicles by type. This method may be implemented in the future to replace static weighing procedures.

B. Ports of Entry (POE) Data

There are 14 POE locations in Arizona which regularly weigh commercial vehicles. The weight data are collected and recorded manually by the Motor Vehicle Division (MVD). The present procedures do not offer a convenient means of utilizing the POE truck weight data for traffic loading estimates. Recommendations have been made to the MVD to automate the scales and the truck weight data management. These data could then be included with the other truck weight data to increase sample size and improve the quality of the traffic loading estimates.

APPENDIX B

PAVEMENT DESIGN FOR FROST ACTION

Depth of frost penetration is related to the freezing index. Figure B-1 shows Arizona freezing index values representing the average of the four coldest winters between 1931 and 1970. This figure should be used to estimate the depth of frost penetration using the following formula.

$$D_F = (FI)^{0.5}$$

D_F = Depth of frost penetration in inches

FI = Freezing index from Figure B-1

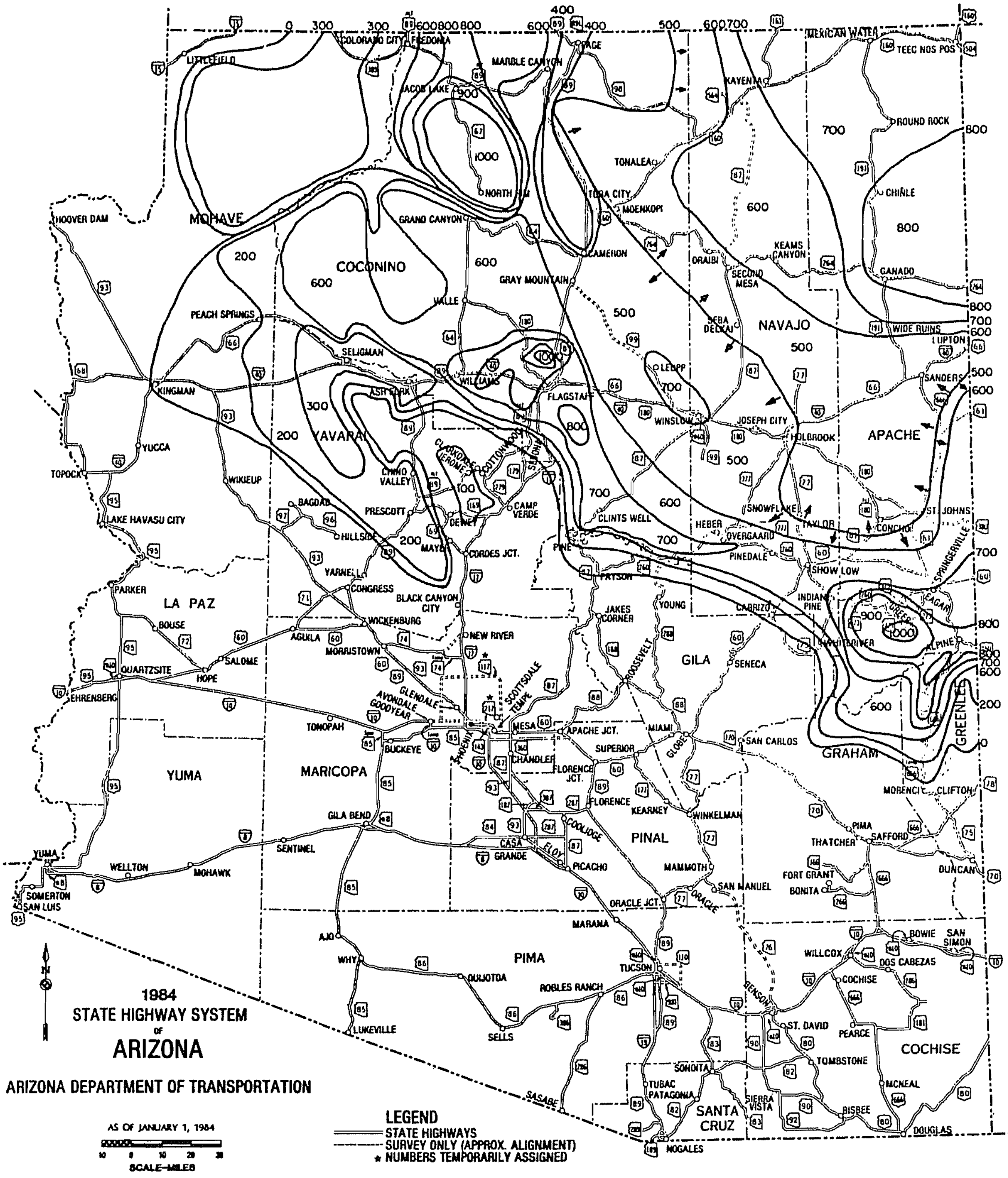
For purposes of pavement design all highways constructed within an area of the state with some freezing index shall consist of non-frost susceptible materials. These materials include pavement, bound bases and unbound base with no more than six (6) percent passing the number 200 sieve.

If the depth of frost penetration is greater than the required pavement structural section (pavement plus base), then additional non-frost susceptible base should be included to prevent frost damage.

If other constraints such as utilities, drainage, traffic access, etc., prohibit the construction of a completely frost free structural section, then the thickest section practical should be built.

FIGURE B-1

FREEZING INDEX



APPENDIX C

GUIDELINES FOR GEOTECHNICAL INVESTIGATION AND GEOTECHNICAL REPORT PRESENTATION

The following document, dated September 1991 and entitled "Guidelines for Geotechnical Investigation and Geotechnical Report Presentation", has been prepared by Geotechnical Services. The guidelines contained therein are for use on all ADOT related projects. These guidelines supplement the information given in Section 100 of this manual, and contain more comprehensive requirements for subsurface investigations. All geotechnical investigations started after December 31, 1991 will be expected to follow these guidelines and reports will be reviewed accordingly.

GUIDELINES FOR GEOTECHNICAL INVESTIGATION

AND

GEOTECHNICAL REPORT PRESENTATION

GEOTECHNICAL SERVICES, MATERIALS SECTION
ARIZONA DEPARTMENT OF TRANSPORTATION
PHOENIX, ARIZONA

GUIDELINES FOR

GEOTECHNICAL INVESTIGATION

AND

GEOTECHNICAL REPORT PRESENTATION

SEPTEMBER 1991

GEOTECHNICAL SERVICES, MATERIALS SECTION
ARIZONA DEPARTMENT OF TRANSPORTATION
PHOENIX, ARIZONA

INTRODUCTION

These guidelines have been developed primarily as an aid to geotechnical consultants and engineers engaged in working on highway projects for the Arizona Department of Transportation. They are meant to supplement, not supersede, the contract documents or publications mentioned below. In the preparation of these guidelines, material has been taken from and consideration given to the recommendations made in the following publications:

1. American Society for Testing and Materials; 1990 Annual Book of ASTM Standards Vol. 04.08.

2. American Association of State Highway and Transportation Officials, Inc.; Manual on Subsurface Investigations; 1988.

3. American Association of State Highway and Transportation Officials; Standard Specifications for Transportation Materials and Methods of Sampling and Testing; 15th Edition; Part I, Specifications; 1990. (AASHTO Designation R-13-88, pp. 873-877)

4. Arizona Department of Transportation; Materials Preliminary Engineering and Design Manual, Third Edition; March 1989.

5. Federal Highway Administration, U. S. Department of Transportation; Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications; October 1985.

6. Oregon Department of Transportation Soil and Rock Classification Manual; 1987

Subsurface conditions are often highly varied and complex. Subsurface exploration procedures cannot be reduced to a few guidelines to fit all conditions. Each project must be evaluated according to its specific geologic conditions and the type of proposed facility (AASHTO, 1988). Generally, the subsurface explorations are carried out in two stages:

1. Preliminary Investigation
2. Final Investigation

Please note that the goal is to conduct the geotechnical exploration program in one phase. However, roadway and bridge design processes often require preliminary information before certain items (alignment, grade, foundation location and depth) can be firmly established. Planning and scheduling must be conducted accordingly, and every attempt made to provide the geotechnical information efficiently and effectively.

A preliminary exploration program generally will consist of widely spaced test borings to define the principal geologic parameters to be evaluated during initial project planning and cost estimating. Preliminary information should be obtained and reported regarding the following conditions during early stages of design:

1. Geologic Conditions
2. Hydrologic Conditions
3. Soil Classification, Consistency and Density
4. Rock Quality - Condition and Discontinuities
5. Obstructions (e.g. Boulders)
6. Hazards (e.g. Methane Gas)

A final exploration program will provide specific recommendations. Final alignment, grade and geometry, bridge pier and abutment locations and foundation depths should have been selected prior to completion of the final report. The information obtained from preliminary investigations should be considered a part of the final exploration program.

GENERAL COMMENTS

It is anticipated that the drilling equipment will use sampling devices which yield samples 1.5 inches to 6.0 inches in diameter. For all types of investigation,

1. A boring must not be ended in a soft or loose soil stratum (N<10) or in an unsuitable material. N= number of blows of Standard Penetration Test (ASTM D 1586-84).

2. SPT sampling will be performed at 2, 5, and 10 foot depths where spread footings may be placed on natural soils. Otherwise, SPT sampling will be performed at 5 foot depth intervals or at significant changes in strata, whichever provides the most samples.

3. In rock, continuous core will be obtained for the top 10 foot or to the required depth for structural foundation, whichever is deeper. The percentages of core recovery and RQD will be determined and reported in accordance with ASTM D 2113-83.

4. For groundwater, water levels encountered at the completion of the boring and at least 24 hours after completion will be recorded on boring logs.

The following are the guidelines for determining the MINIMUM number and depths of borings to be made in each case:

I. BRIDGE STRUCTURE

A. Number for preliminary investigation:

1. each isolated structure over a waterway - one boring at each abutment location and one boring as close to the middle of the waterway as possible.

2. each isolated structure not over a waterway - one boring at each abutment location.

3. at each interchange, for all structures - 4 to 6 borings.

B. Number for final investigation (See Fig. 1):

1. one boring per substructure unit (abutment, bent or pier) 100 feet or under in width.

2. two borings for each substructure unit greater than 100 feet in width.

C. Depth

A boring must be advanced into competent material of suitable bearing capacity.

1. in soils - three times the width/diameter of the foundation or a minimum of 20 feet below the base of the spread footing or tip elevation for pile or drilled shaft.

2. in bedrock - a minimum of 10 ft. below the base of the spread footing or tip elevation for pile or drilled shaft.

II. RETAINING WALL

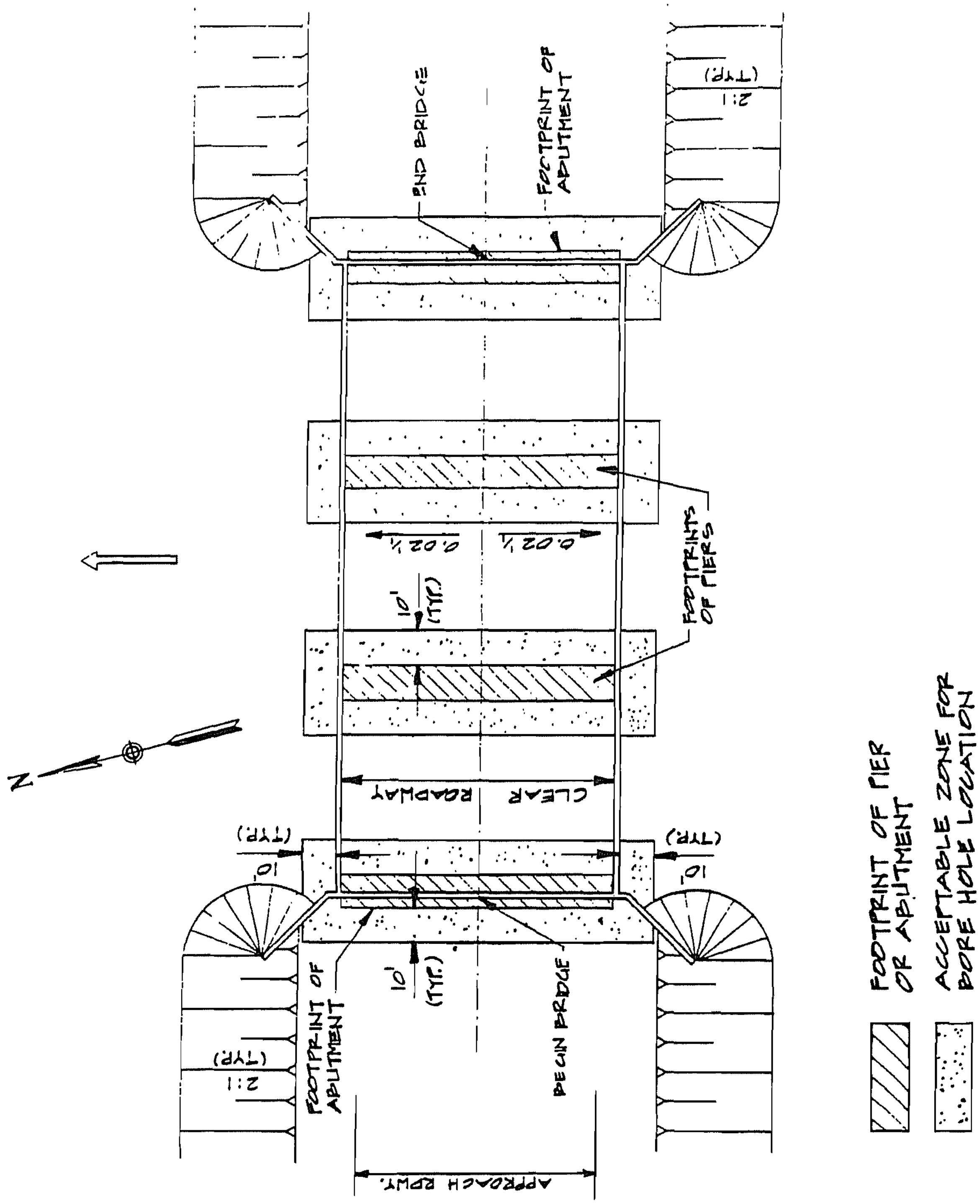
A. Number for preliminary investigation:

one boring for each wall up to 500 feet in length and then one boring for each 500 ($\pm$) feet.

B. Number for final investigation:

1. walls less than 100 feet long - one boring

2. walls 100 feet or longer - borings at approximately 150 feet intervals staggered back and front of wall footing.



EXAMPLE OF BORE HOLE LOCATION AREAS FOR BRIDGE STRUCTURES

C. Depth

The depth of boring shall be either

1. two times the height of the wall, or

2. a minimum 10 feet in bedrock

III. CUTS, FILLS AND SUBGRADE

A. Number for preliminary investigation - borings or backhoe pits at 1200 - 1500 feet intervals.

B. Number for final investigation - per ADOT Materials PE&D Manual.

C. Depth for preliminary and final investigation - per ADOT Materials PE&D Manual.

D. R-values and other special test results should be obtained per ADOT Materials PE&D Manual.

IV. CMP

A. Number for preliminary investigation - one boring in each major drainageway, preferably near the mid-length.

B. Number for final investigation - as above.

C. Depth

The minimum depth of borings shall be to 3 feet below the invert elevation.

V. AGGREGATE AND BORROW PITS

A minimum number of 5 backhoe pits or borings will be required for preliminary investigation. Final investigation to follow ADOT PE&D Manual. Samples will be obtained at 5 foot depth intervals or at significant changes in strata, whichever provides the most samples. Enough material will be collected for performing R-value tests, PI tests and grain size analyses of soil.

VI. LOG OF BORING SHEET

The Logs of Borings sheet shall be included as part of the Geotechnical Investigation Report. The location of each boring or test pit in plan view should be shown elsewhere. Logs of all borings shall be shown in an elevation or profile view, each log being on a separate sheet. Information which should be shown on each plot of test borings is as follows:

1. Date, diameter and type of borings.
2. Name of driller and field geologist/engineer.
3. Location of borings with respect to stationing along survey lines and offset from it.
4. Elevation of the top of boring and water table.
5. Results of the Standard Penetration Test (ASTM D-1586-84).
6. Description of stratum material for soils according to ASTM D2487-85 but modified to exclude most of the numerical data obtained from in-situ or laboratory testing.

VII. WRITTEN REPORT

A geotechnical investigation report shall be required of all proposed pavement and structure projects. The study and report shall be made by an Arizona Professional Engineer who specializes in Geotechnical Engineering and who shall seal each report and each plans sheet.

A written report shall contain information, analyses and interpretation of the subsurface conditions based upon all available sources of information and data. Data may come from new or previous exploration programs, laboratory testing, nearby construction experience, performance of nearby existing pavement or structures, etc. A short description of site topography and local geology shall be included. Emphasis should be placed on slope stability of fills, cuts and excavations, unusual groundwater conditions, springs, etc. All sources of information should be cited. The materials and conditions which may be encountered during construction shall also be discussed. Anticipated problems involving design and construction should be mentioned, and recommendations made for their solution.

The recommendations shall be brief, concise, and complete. Reasons for recommendations and supporting data shall be included. Methods and equations of models used for calculating pile or drilled shaft capacities and soil bearing capacities should be mentioned. Data and information which are of no use to the designer or Resident Engineer, should be omitted. Any judgements and opinions regarding the rippability or excavability of rock or soil should not be included; however, if the consultant or engineer feels that these opinions are important to include, they should be reported concisely and shall include a statement that the information is the judgement of the writer and that other interpretations are possible. The same applies to methods for rock or soil removal.

Any recommended geotechnical Special Provisions should be included; these should be developed considering the requirements of ADOT's Standard Specifications, and using these, where appropriate.

The ground compaction, excavation factors (shrink and swell), pH, resistivity and slopes should be provided by stationing. Also, this information should be summarized (in tabular form, if applicable), in the report.

In general, a geotechnical investigation report should contain the following sections:

1. Introduction

2. Project Description: Project Concept and Scope

3. Site Description: Including a vicinity map, site plan and existing pavement conditions and section measurements as necessary.

4. Geologic Description

5. Field Investigation: Including boring location plan and any in-situ testing.

6. Laboratory Investigation: Generally, the tests will include gradation analysis, plasticity index, moisture content, R-value, AASHTO T-99 density, consolidation, pH resistivity, shearing strength of soils and unconfined compressive strength of rocks.

7. Discussion of Information, Analyses and Recommendations

8. Geotechnical Special Provisions

9. References Cited

9. Appendix A

   a. Test drilling equipment and procedure

   b. Terminology used for various descriptions

   c. Explanations of symbols and abbreviations used on boring logs.

   d. Boring Logs in Graphical Form

10. Appendix B

   a. Laboratory Testing Procedures and Standard Test Number (Arizona Test Method, AASHTO Test Method or ASTM Test Method Designations).

   b. Summary of Test Data

   c. Tables and Special Test Data

VIII. MISCELLANEOUS COMMENTS

1. On boring logs, the general descriptive sequence for soils will be as follows:

   Group Name
   Group Symbol
   Moisture Condition
   Color
   Relative Density/Consistency
   Particle Angularity/Plasticity
   Cementation
   Structure
   Other pertinent descriptive information

All descriptions will follow the recommendations of ASTM D-2488-84. For relative density refer to Table 1.

2. On boring logs, the general descriptive sequence for rocks will be as follows:

   Rock Name
   Color
   Degree of Weathering - Refer to Table 2
   Relative Hardness - Refer to Table 3
   Structure
   a. Stratification - Refer to Table 4
   b. Joint and Bedding Spacing - Refer to Table 5
   Other pertinent descriptive information

   Formation Name
   Percent Core Recovery and Rock Quality Designation (RQD) if not already reported elsewhere on the log.

3. On boring logs, the N-value (ASTM D-1586-84) should be reported only in one of the three following ways:

   a. 10 blows/zero inch

   b. N blows/foot, where N is the blow count less than 100.

   c. 50 blows/X inches, where X is the sampler penetration, in inches but less than 6 inches.

4. If during auger drilling, refusal is met, mention "Refusal at ________ feet." Do not indicate the type and nature of material in which refusal was met, unless additional boring was done or a sample otherwise obtained from this material.

5. Raw data from the field or laboratory test should not be included in the report; only final values and information required for design or construction should be provided.

TABLE 1: TERMS FOR RELATIVE DENSITY, CONSISTENCY AND FIRMESS OF SOILS

A. RELATIVE DENSITY OF COHESIONLESS SOILS		B. RELATIVE CONSISTENCY OF COHESIVE SOILS		C. RELATIVE FIRMESS OF CEMENTED SOILS *	
N-VALUE	TERM	N-VALUE	TERM	N-VALUE	TERM
0-4	Very Loose	0-2	Very Soft	0-4	Very Soft
5-10	Loose	3-4	Soft	5-8	Soft
11-30	Medium Dense	5-8	Medium Stiff	9-15	Moderately Firm
31-50	Dense	9-15	Stiff	16-30	Firm
> 50	Very Dense	15-30	Very Stiff	31-50	Very Firm
		30-60	Hard	> 50	Hard
		> 60	Very Hard		

* Provided by Sergent, Hauskins & Beckwith, Phoenix, Arizona.

TABLE 2: SCALE OF RELATIVE ROCK WEATHERING

Designation	Field Identification
Fresh	Crystals are bright. Discontinuities may show some minor surface staining. No discoloration in rock fabric.
Slightly Weathered	Rock mass is generally fresh. Discontinuities are stained and may contain clay. Some discoloration in rock fabric. Decomposition extends up to 1 inch into rock.
Moderately Weathered	Rock mass is decomposed 50% or less. Significant portions of rock show discoloration and weathering effects. Crystals are dull and show visible chemical alteration. Discontinuities are stained and may contain secondary mineral deposits.
Predominantly Decomposed	Rock mass is more than 50% decomposed. Rock can be excavated with geologist's pick. All discontinuities exhibit secondary mineralization. Complete discoloration of rock fabric. Surface of core is friable and usually pitted due to washing out of highly altered minerals by drilling water.
Decomposed	Rock mass is completely decomposed. Original rock "fabric" may be evident. May be reduced to soil with hand pressure.

TABLE 3: SCALE OF RELATIVE ROCK HARDNESS

Term	Field Identification
Extremely Soft	Can be indented with difficulty by thumbnail. May be moldable or friable with finger pressure.
Very Soft	Crumbles under firm blows with point of a geology pick. Can be peeled by a pocket knife. Scratched with finger nail.
Soft	Can be peeled by a pocket knife with difficulty. Cannot be scratched with fingernail. Shallow indentation made by firm blow of geology pick.
Medium Hard	Can be scratched by knife or pick. Specimen can be fractured with a single firm blow of hammer/geology pick.
Hard	Can be scratched with knife or pick only with difficulty. Several hard hammer blows required to fracture specimen.
Very Hard	Cannot be scratched by knife or sharp pick. Specimen requires many blows of hammer to fracture or chip. Hammer rebounds after impact.

TABLE 4: STRATIFICATION TERMS

Term	Characteristics
Laminations	Thin beds (< 1/2 inch)
Fissile	Tendency to break along laminations
Parting	Tendency to break parallel to bedding, any scale
Foliation	Non-depositional, e.g., segregation and layering of minerals in metamorphic rocks

TABLE 5: JOINT AND BEDDING SPACING TERMS

Spacing	Joint Spacing Terms	Bedding/Foliation Spacing Terms
Less than 2 in.	Very close	Very thin (laminated)
2 in. - 1 ft.	Close	Thin
1 ft. - 3 ft.	Moderately close	Medium
2 ft. - 10 ft.	Wide	Thick
More than 10 ft.	Very wide	Very thick (massive)