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AN INTRODUCTION TO SUPER PAVE ASPHALT CONCRETE MIX DESIGN SYSTEM

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1- ABSTRACT

Two important aspects of an asphalt concrete mix are aggregate structure and the binder content. Relative to asphalt mixture design, two methods are used most commonly by highway authorities to select the proper amount of binder. One is based on Marshall Test and the other on Hveem Stabiliometer. With recent increases in traffic, both in terms of repetitions and heavier axle loads as well as increase in tire pressures, increased rutting has been observed. In both Marshall and Hveem methods, criteria for mixture design are based on past correlations of laboratory test results with field performance. Unfortunately, the conditions under which criteria were developed have changed in recent years resulting to mixtures which exhibit rutting.

The Strategic Highway Research Program (SHRP) was established in 1987 as an independent unit of National Research Council, USA. One of the major tasks of the SHRP program involved in asphalt binder and asphalt mixtures research. From October 1987 through March 1993, SHRP conducted a $50 million research effort to develop new ways to specify, test, and design asphalt materials.

Superpave (Superior Performing Asphalt Pavements) is the final product of the Strategic Highway Research Program (SHRP) Asphalt Research Program. This is a comprehensive performance based system of asphalt mix design. The mix design system was developed to consider and minimize permanent deformation, fatigue cracking and low temperature cracking. Superpave represents an improved system for specifying component materials (Asphalt binder and Aggregate), asphalt mixture design and analysis and pavement performance prediction. The system includes test equipment, test methods and criteria.

2- INTRODUCTION

The Strategic Highway Research Program (SHRP) was eastablished in 1987 as an independent unit of National Research Council. One of the major tasks of the SHRP program involved in asphalt binder and asphat mixtures research. The pertinent results from these research programs related to permanent deformation assessments of asphalt binders and asphalt mixtures are presented below:

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Asphalt Binder

One part of the Superpave consists of a new asphalt binder (PG-Grade) specifications. Some of the asphalt binder specifications are shown in Table 1. This new system for specifying asphalt binder is performance based and specifies the binders on the basis of climate and attendant pavement temperatures in which the binder is expected to serve.

To charcterize the visco-elastic propertise of the binder the dynmic shear rheometer (DSR) is used. To perform this test a small sample of binder is sandwiched between two parallel plates, and is subjected to oscillatory shear stresses to measure the shear modules (G*) and phase angle (θ). The binder specifications $G^* / \sin\theta$ tested at the specified temperatures is intended to limit be rutting susceptibility of the binder. For example, if a PG-70-X (where X for all low temperature ranges) binder is specified, the $G^*/ \sin \theta$ value of the binder tested at 70 °C should have a minimum value of 1.00 Kpa for adequate rutting resistance requirement.

Aggregates

In the Superpave system no new aggregate test procedure is developed. However, existing procedures were more refined to fit within the Superpave system. For each of the 5 gradations (nominal maximum size of 37.5 mm, 25 mm, 12.5 mm, 9.5 mm and 6.0 mm), control points and restricted zones are specified see Figure-1. A Superpave aggregate structure by this approach is believed to develop strong stone skeleton, avoiding developing tender mixes, more resistant to permanent deformation while achieving sufficient void space for durability of the mixture.

Asphalt Mixtures

Testing of asphalt mixtures in the Superpave system has two key features, laboratory compaction and performance testing. A Superpave Gyratory Compactor (SGC) is used to compact the test specimens of asphalt concrete.

Performance-based testing and performance prediction models for asphalt mixtures, are the most important developments of the SHRP asphalt reasearch program. The test procedures and performance prediction models allow the designer to estimate the

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Performance-based testing and performance prediction models for asphalt mixtures, are the most important developments of the SHRP asphalt reasearch program. The test procedures and performance prediction models allow the designer to estimate the estimated to carry the estimated traffic without exceeding a prescribed level of rutting. In level B testing, a series of tests are performed to estimate the amount of rutting to be developed in a specific environment for an estimated level of traffic. It may be noted here that level A and level B testing are the portions of Superpave Level 2 and Level 3 mixture design procedures respectively.

In the first level, simple shear constant height repeated tests are performed at a single stress condition and a single temperature. The amount of rutting has been related to the maximum shear strain occurring in the upper part of the pavement layer and both the parameters are determined by finite element analysis of a representative pavement structure using conventional asphalt concrete mixes and selected value of tire contact pressure.

In the second level, a series of tests using simple shear equipment are performed with shear stiffness measurement obtained at multiple temperatures. This makes a direct use of the finite element analysis and the measured mix characteristics for the prediction of rutting for a specific traffic and environmental conditions. Table 3 presents the main characteristics of the permanent deformation analysis system. The complete step-by-step procedure of the level A and level B analysis is described in NRC report (SHRP-A-415, 1994). Schematic frameworks for both of the systems are shown in Figures 5 and Figure 6, respectively.

There is no doubt that the Superpave system of mixture design is a very comprehensive mixture design system addressing the different modes of pavement distress, and allowing the engineer to predict the pavement performance under variable environmental conditions. However, due to the complexity of the procedure and intensive testing requirements using sophisticated Superpave equipment, its broad implementation of Level 2 and Level 3 by the asphalt industry, is questionable. Currently the cost of SST and IDT machines is estimated at $ 500,000. An estimated cost for performing a complete Superpave Mix Design (including Level 1, 2, and 3) is about 30,000 to 45,000. Due to this, the asphalt paving industry has voiced its concern and urged to develop an alternate approach. The National Asphalt Paving Association (NAPA) has recommended the use of the Georgia LWT for this purpose. Use of Superpave level 1 in conjunction with the LWT can provide a simple and expedient way to implement a procedure for evaluating permanent deformation characteristics of the asphalt mixtures(Shami, H.I. 1996).

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Table 1. Performance Graded Binder Specifications.

Performance Grade	PG 52							PG 58					PG 64					PG 70			
	-10	-16	-22	-28	-34	-40	-46	-16	-22	-28	-34	-40	-16	-22	-28	-34	-40	-10	-16	-22	-28
Average 7-day maximum pavement design temperature, C (a)	<52							<58					<64					<70			
Minimum pavement design temperature, C (a)	>-10	>-16	>-22	>-28	>-34	>-40	>-46	>-16	>-22	>-28	>-34	>-40	>-16	>-22	>-28	>-34	>-40	>-10	>-16	>-22	>-28
Original Binder																					
Flash point temperature, T48: minimum C	230																				
Viscosity, ASTM D 4402: (b) Maximum, 3 Pa s (3000cP) Test Temp, C	135																				
Dynamic Shear, TP5: (c) G*sin S, minimum, 1.00kPa Test temp @ 10 rad/s, C	52							58					64					70			
Pressure Aging Vessel Residue (PP1)																					
PAV aging temperature, C (d)	90							100					100					100 (110)			
Dynamic shear, TP5: G*sin S, maximum, 5000kPa Test temp @ 10 rad/sec, C	25	22	19	16	13	10	7	25	22	19	16	13	28	25	22	19	16	34	31	28	25
Physical hardening (e)	Report																				
Creep stiffness, TP1: (f) S, maximum, 300 MPa m-value, minimum, 0.300 Test temp, @ 60 sec, C	0	-6	-12	-18	-24	-30	-36	-6	-12	-18	-24	-30	-6	-12	-18	-24	-30	0	-6	-12	-18
Direct Tension, TP3: (f) Failure strain, minimum, 1.0% Test temp @ 1.0 mm/min, C	0	-6	-12	-18	-24	-30	-36	-6	-12	-18	-24	-30	-6	-12	-18	-24	-30	0	-6	-12	-18

Table 2. Superpave Mix Design Levels.

SUPERPAVE MIX DESIGN LEVELS

Traffic, ESALs	Design Level	Testing Requirements*
ESALs < 10^6	1	Volumetric design
10^6 < ESALs < 10^7	2	Volumetric design + performance prediction tests
ESALs > 10^7	3	Volumetric design + enhanced performance prediction tests

* In all cases, moisture susceptibility must be evaluated using AASHTO T283.

Table 3. Distinguishing Characteristics of Permanent Deformation Analysis System.

DISTINGUISHING CHARACTERISTICS OF PERMANENT DEFORMATION ANALYSIS SYSTEM

Variables		**Level A** Abbreviated analysis with limited cyclic shear testing	**Level B** Comprehensive analysis with full testing
Testing	Type	Cyclic shear	Constant height simple, shear, uniaxial strain, and volumetric tests at 40C (104F) with frequency sweeps at 4, 20, 40, and 60C (39, 68, 104, and 140F)
	Temperature	Critical Temperature, Tc	
In Situ Conditions	Traffic	Equivalent ESALs at Tc, 85th percentile tire pressure	ESALs by temperature class, 85th percentile tire pressure
	Structure	Critical shear stress under "standard" load at Tc	Complete stress/strain pattern from finite element analysis
	Temperature	Frequency distribution at 5 cm. (2in.) depth	Frequency distribution throughout surface layer
Analysis	Mechanistic	Finite element analysis with nonlinear viscoelastic surface properties*	Finite element analysis with nonlinear viscoelastic surface properties
	Damage	Pre-analysis (temperature equivalency factors for design ESALs)	Integral part of finite element analysis

* It is possible that sufficiently accurate results for shear stress may be determined Using multi-layer elastic analysis as experience is developed.

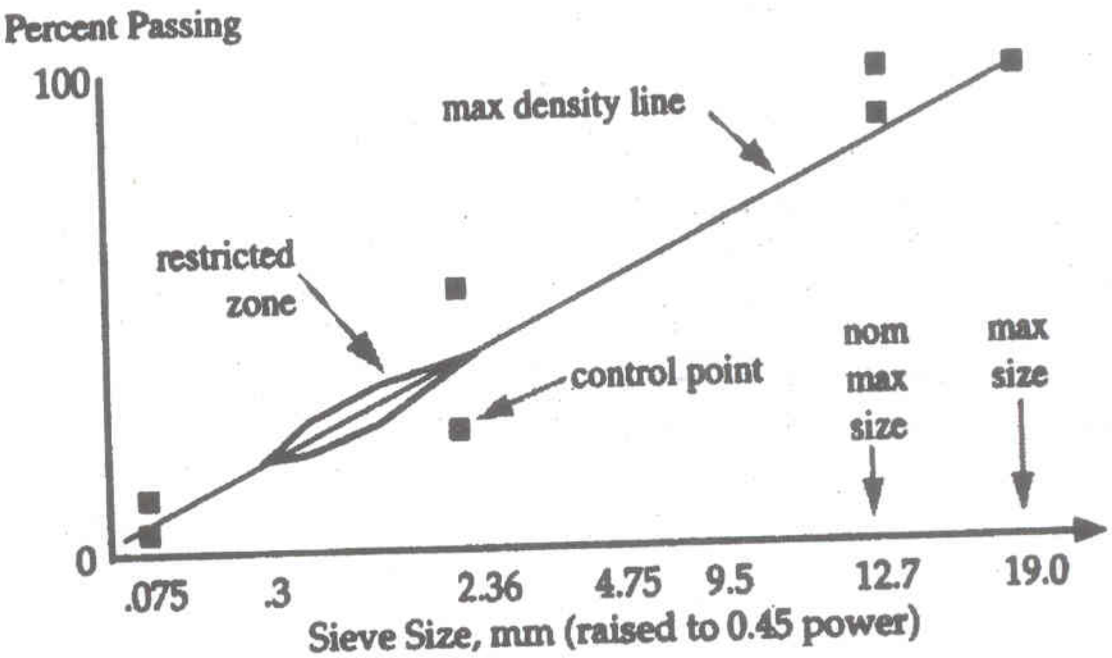

Figure 1. Superpave Gradation Limits 12.5 mm Mixture.

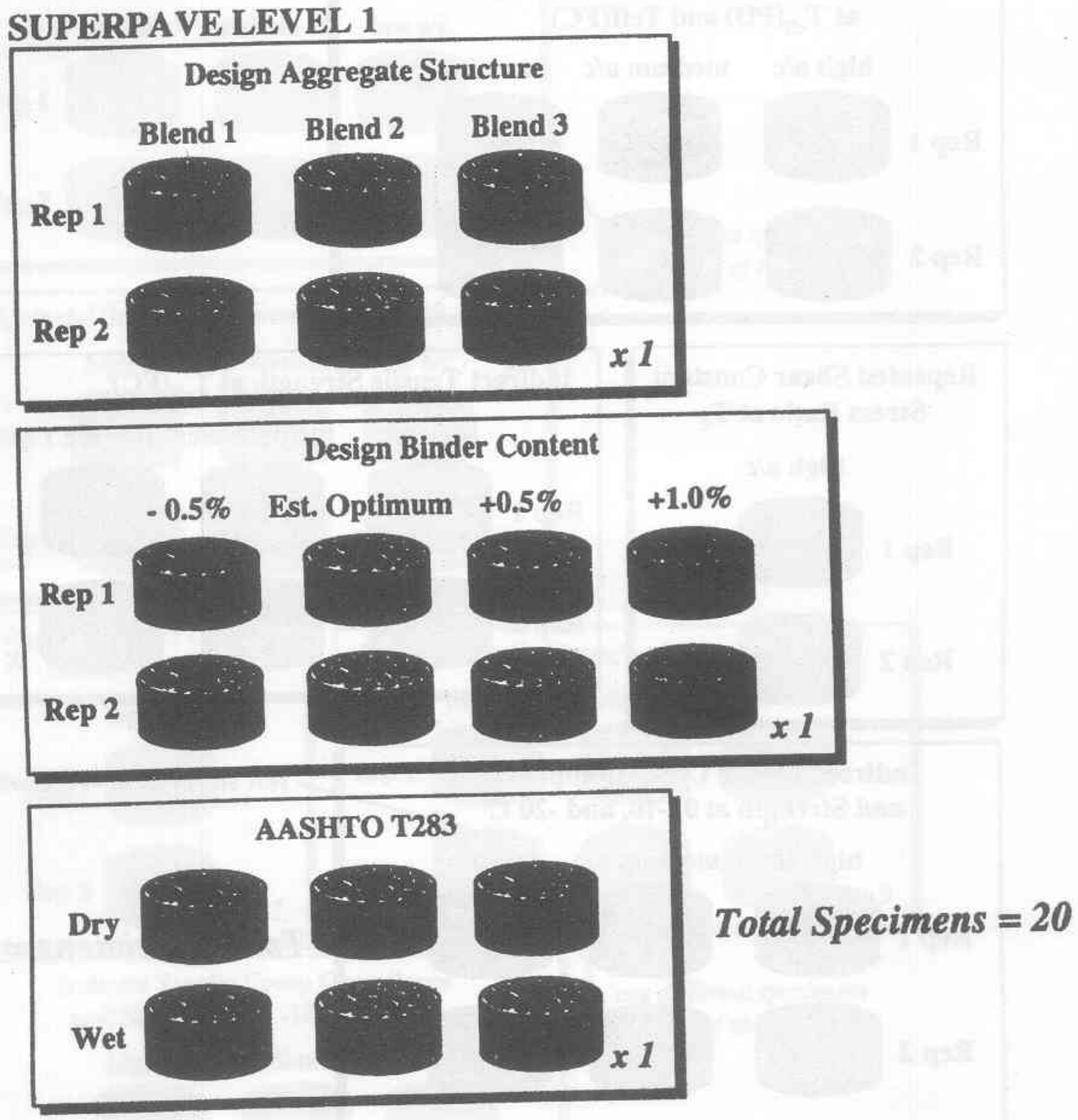

Figure 2. Superpave Level 1, Testing Requirements.

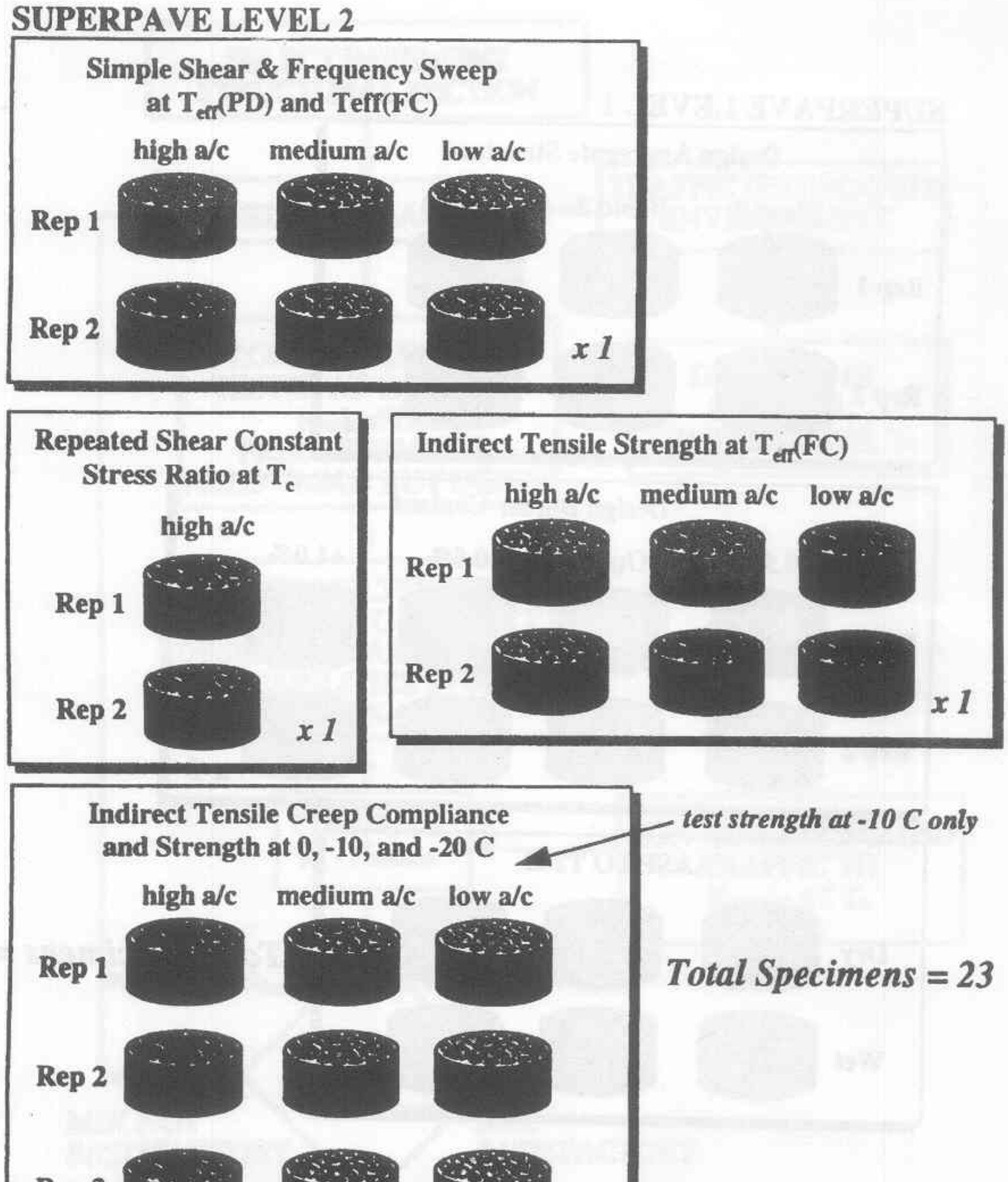

Figure 3. Superpave Level 2, Testing Requirements.

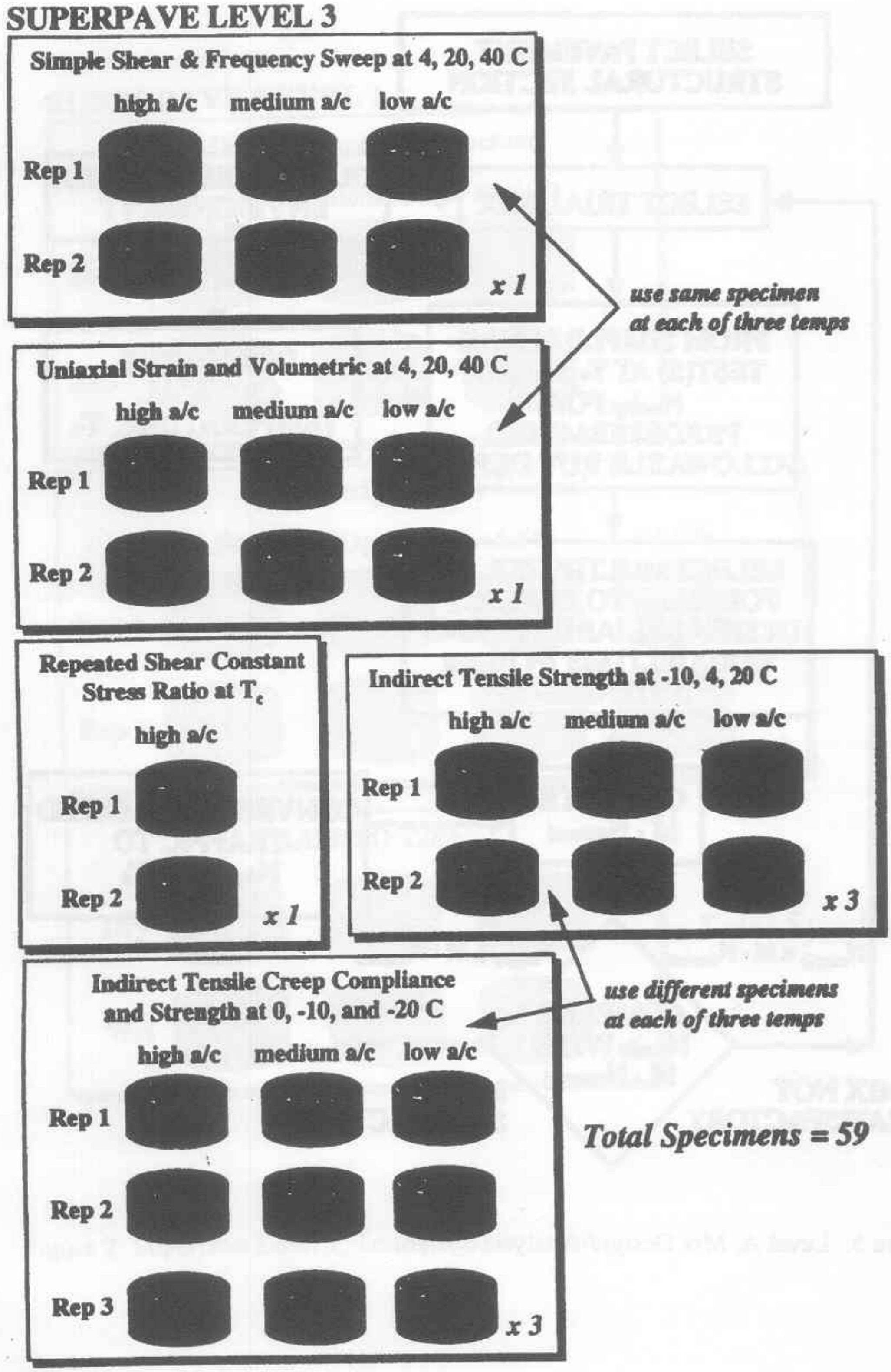

Figure 4. Superpave Level 3, Testing Requirements.

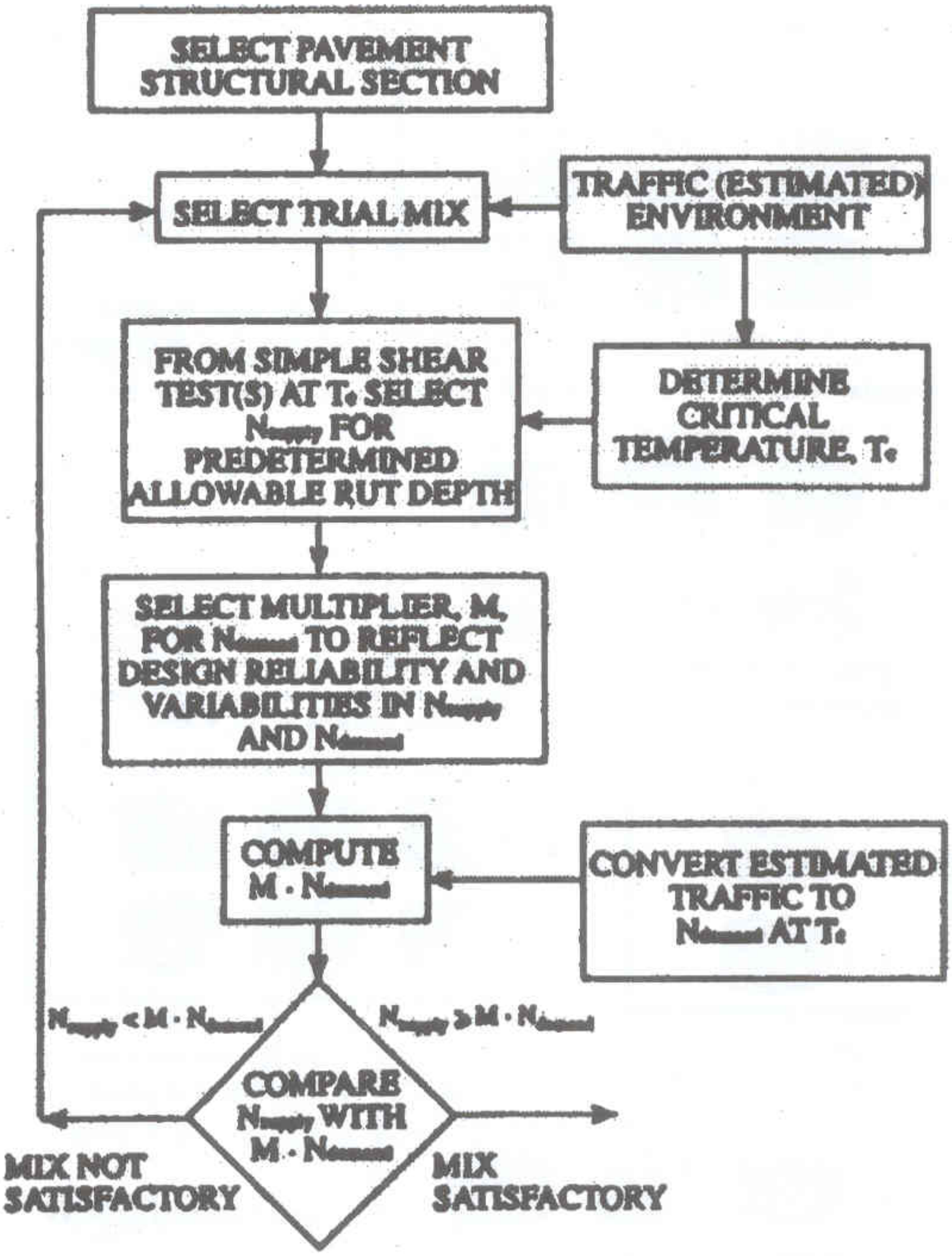

Figure 5. Level A, Mix Design/ Analysis System

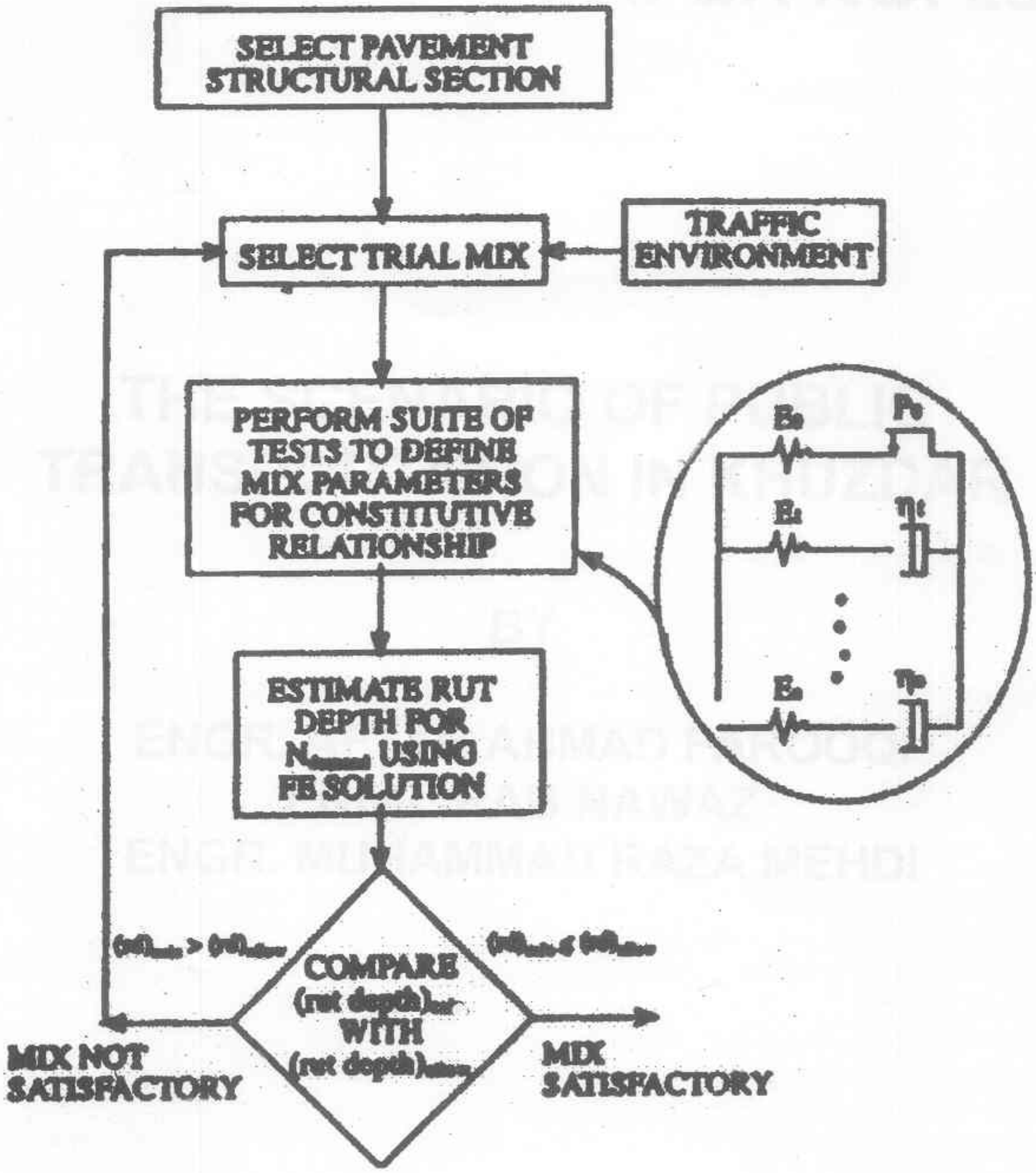

Figure 6. Level B, Mix Design/ Analysis System