CHAPTER 3
PROPERTIES OF MATERIALS AND MIX DESIGN METHODS

3.1 General

In this chapter the materials used in the experimental investigation will be discussed. One of the two commonly used methods for designing bituminous concrete mixes, namely the Marshall method will be described, the other, the Hveem method together with modifications for designing SEA mixtures can be found in reference 16.

3.2 Bitumen*

The bituminous material used in the investigation was asphalt cement of 80-100 penetration grade. It is the type commonly used in Thailand. Some physical characteristics are given in Table 6.

Table 6. Some physical characteristics of AC 80-100

Characteristics	ASTM test method	AC 80-100
Penetration at 25^{o}C, 100 g, 5 s	D 5	90
Flash point ^{o}C (Cleveland open cup)	D 92	249
Ductility at 25^{o}C, cm	D 113	$>$100

3.3 Aggregates

The aggregate used in the study was limestone which is the most common aggregate in southern Thailand. It is also found throughout the country. Two gradings of aggregates are used one for the determination of optimum SEA content, the other for the study of effects of compaction temperature. Both gradings were obtained by blending the sieved portions of the source aggregate so that they conform with the specification limits for wearing course(29) of the Thai Department of Highways. The two trial gradings are given in Table 7 and plotted in Figure 6.

*The term bitumen will be used interchangeably with asphalt in this work.

TABLE 7. SPECIFICATION LIMITS AND TRIAL GRADATIONS OF AGGREGATE.

SIEVE SIZES (US.)	TOTAL PASSING PERCENT BY WEIGHT		
	DOH Specs.*	1st Gradation	2nd Gradation
3/4 IN.	100	100	100
3/8 IN.	60-80	75	85
NO. 4	40-65	55	65
NO. 8	30-50	38	47
NO. 16	20-40	28	37
NO. 30	15-35	20	27
NO. 50	10-25	15	20
NO. 100	7-17	10	10
NO. 200	5-9	5	5

*DEPARTMENT OF HIGHWAYS OF THAILAND SPECIFICATION FOR WEARING COURSE OF 3 - 6 cm THICKNESS

3.4 Sulphur

The sulphur used was elemental sulphur of commercial grade in powdered form. Typical specifications for this type of sulphur are shown in Table 8.

Table 8. Typical specifications for sulphur[30]

Characteristic	Value
Purity, dry basis, pct[1]	97.5 Minimum
Moisture, solid sulfur, pct[2]	2.00 Maximum
Ash, pct[1]	1.00 Maximum
Carbon content, pct[1]	1.00 Maximum
Acidity (as H_2SO_4), pct[2]	.05 Maximum

[1]Primary tests.

[2]Supplementary tests as needed.

3.5 Mix design for bituminous concrete

3.5.1 Objectives

The design of bituminous paving mixes is essentially a matter of selecting and proportioning materials to obtain the desired properties in the finished construction.

The overall objective for the design of asphalt paving mixes is to determine an economical blend and gradation of aggragates (within the limits of the project specifications) and asphalt that yields a mix having:[31]

1) Sufficient asphalt to ensure a durable pavement.
2) Sufficient mix stability to satisty the demands of traffic without distortion or displacement.
3) Sufficient voids in the total compacted mix to allow for a slight amount of additional compaction under traffic loading without flushing, bleeding, and loss of stability, yet low enough to keep out harmful air and moisture.
4) Sufficient workability to permit efficient placement of the mix without segregation.

3.5.2 Marshall method of mix desing

The method was originally formulated by Bruce Marshall of the Mississippi State Highway Department. The test procedure was subsequently improved by the U.S. Corps of Engineers who ultimately developed mix design criteria.

The Marshall Method consists of the following major steps:

1) Aggregates are blended in proportions that meet the required specifications.
2) The mixing and compacting temperatures for the asphalt cement being used are obtained from the temperature-viscosity graph. These temperatures are those required to produce viscosites of 170 $\pm$ 30 centistokes for mixing and 280 $\pm$ 30 centistokes for compacting.
3) A number of briquettes 101.6 mm in diameter and 60-65 mm in height are mixed using 1200 grams of aggregates and asphalt cement at various percentages both above and below the expected optimum content.
4) Density of the briquettes is measured to allow calculation of the voids' properties.
5) Briquettes are heated to 60^{o}C. Stability and Flow values are obtained in a compression test in the Marshall apparatus to measure strength and flexibilty.

   The flow is the deformation (measured in units of 0.25 mm) that occurs in the specimen between no load and maximum load during the stability test.

   Photographs of the Marshall test apparatus are shown in Appendix A.

The Marshall test procedures have been standardized by the American Society for Testing and Materials. Procedures are given in ASTM Designation D 1599,(32) RESISTANCE TO PLASTIC FLOW OF BITUNINOUS MIXTURES USING MARSHALL APPARATUS, and are listed in Appendix B.

Table 9. Shows the Marshall design criteria for the various traffic classifications.

Table 9. Marshall Design Criteria

Marshall Method Mix Criteria[1]	Light Traffic[2] Surface & Base Min.	Max.	Medium Traffic[2] Surface & Base Min.	Max.	Heavy Traffic[2] Surface & Base Min.	Max.
Compaction, number of blows each end of specimen	35		50		75	
Stability, *N	2224		3336		6672	
(kg)	227	-	(346)	-	(681)	-
Flow, 0.25 mm(0.01 in.)	8	20	8	18	8	16
Percent Air Voids	3	5	3	5	3	5
Percent Voids in Mineral Aggregate (VMA)			(See Table 10.)			

[1]All criteria, not stability value alone, must be considered in designing an asphalt paving mix.

Hot-mix asphalt bases that do not meet these criteria when tested at 60°C(140°F) are satisfactory if they meet the criteria when tested at 38°C (100°F) and are placed 10 cm(4 in.) or more below the surface. This recommendation applies only to regions having a range of climatic conditions similar to those prevailing throughout most of the United States. A different lower test temperature may be considered in regions having more extreme climatic conditions.

[2]Traffic Classifications:

Light: Traffic conditions resulting a Design EAL $< 10^4$.

Medium: Traffic conditions resulting a Design EAL between 10^4 and 10^6.

Heavy: Traffic conditions resulting in a Design EAL $> 10^6$.

*N = Newton

Table 10. Minimum Percent Voids in Mineral Aggregate (VMA)

U.S.A. Standard Sieve Designation*	Nominal Maximum Particle Size		Minimum Voids in Mineral Aggregate, Percent
	in.*	mm*	
No. 16	0.0469	1.18	23.5
No. 8	0.093	2.36	21
No. 4	0.187	4.75	18
3/8 in.	0.375	9.5	16
1/2 in.	0.500	12.5	15
3/4 in.	0.750	19.0	14
1 in.	1.0	25.0	13
1 1/2 in.	1.5	37.5	12
2 in.	2.0	50	11.5
2 1/2 in.	2.5	63	11

*Standard Specification for Wire Cloth Sieves for Testing Puposes, ASTM Designation E 11 (AASHO Designation M 92).

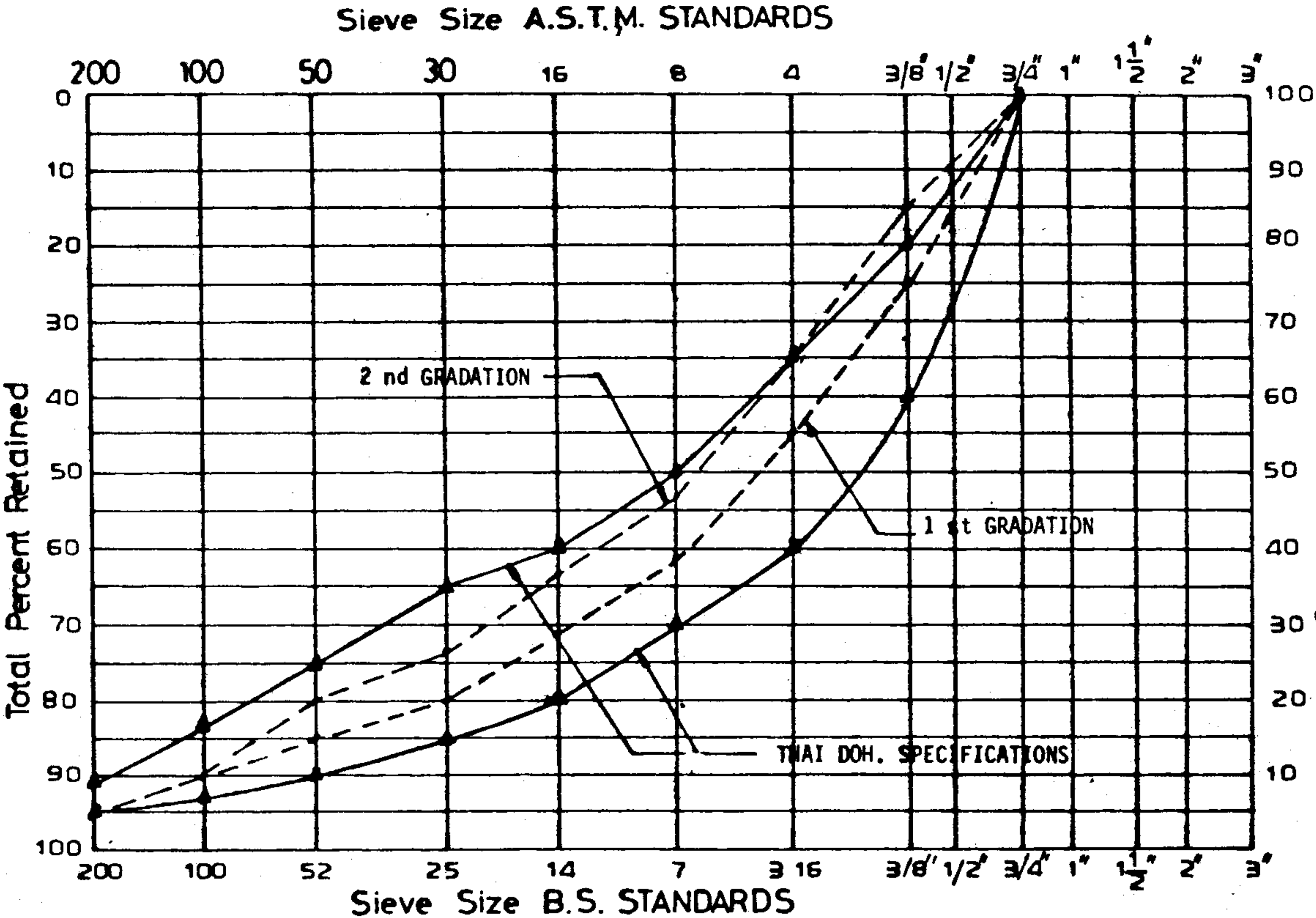

FIGURE 6. GRADATIONS OF AGGREGATE