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The durability of hot mix asphalt with petroleum contaminated soils

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ABSTRACT

The Durability of Hot Mix Asphalt with Petroleum Contaminated Soils

by
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Petroleum contaminated soils are considered solid waste They must be taken to solid waste facilities such as landfills or some other method must be found to deal with them. Landfills are becoming limited and is looked upon by the government as the least attractive option. One method that looks promising is to use petroleum contaminated soils in Hot Mix Asphalt Concrete.

In the research program the following are examined: 1) Investigation of material properties of the petroleum contaminated soil and aggregates 2) The proper procedure to produce a design blend of asphalt concrete. 3) Establishing the test procedure protocol to determine if asphalt concrete is durable 4) Field test design for the testing of asphalt concrete durability.

This thesis also discusses the durability aspect of using petroleum contaminated soil in Hot Mix Asphalt. Test were performed to determine if petroleum contaminated soil can withstand varying temperatures and comparable loads to heavy traffic. In order to determine the durability of petroleum contaminated soil in Hot Mix Asphalt , the freeze-thaw, wet-dry, and Marshall Strength test were used to determine the tensile strength ratio, percentage swell, and the stability of asphalt concrete. The test showed asphalt concrete can be determined durable if it retains 80% of its strength during the first freeze-thaw or wet-dry cycle. From this experimental program, it is concluded that asphalt concrete with petroleum contaminated soils is durable under cyclic temperatures

THE DURABILITY of HOT MIX ASPHALT with PETROLEUM CONTAMINATED SOILS

by

Bonnie H. DuBose

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Stability is the ability to resist deformation from imposed compressive loads.

Durability is the ability of paving mixture to resist the detrimental effects of water, temperature, oxygen in air, and traffic loads.

Hot Mix Asphalt Concrete is the blend of aggregates, asphalt cement, sand, and fillers.

Volume of Mineral Aggregate is the total intergranular void spaces between the aggregate particles in compacted paving mixtures.

Air Void is the individual air spaces between the coated aggregate particles in a compacted paving mixture.

Theoretical Specific Gravity is the ratio of the weight of an uncompacted bituminous paving mixture to the weight of equal volume of gas-free distilled water at a specific temperature

Flow is the change in deformation as load is imposed on paving material in 1/100 of an inch.

Specific Gravity is the ratio of the weight of a unit volume of material to the weight of the same volume of water at 20 to 25°C.

Tensile Strength Ratio is the strength of a water saturated specimen to the strength of a dry specimen.

Swell is the ratio of the volume change of a material to the initial volume of the material.

Permeability is the ability of air to penetrate the surface of paving material.

Asphalt Cement is the elastic, viscous liquid product used in the paving process.

Asphalt Concrete is the solid cementious product made up of fine and coarse aggregate, sand, filler, and asphalt cement.

CHAPTER 1

INTRODUCTION

1.1 Background

Millions of underground storage tanks throughout the United Stated which are estimated to be leaking gasoline and fuel oils. This estimate does not even include the many spills and leaking underground pipes. The United State Environmental Protection Agency (USEPA) suggests that the leachates from these tanks are thought to be a primary source of ground water contamination. Due to continued weathering and corrosion these gasoline and fuel tanks which are estimated, on average, to have been in the ground for 20 years have begun to deteriorate and will possibly have a detrimental effect on the environment.

This problem has become a major environmental issue which is being addressed by the USEPA act 40 CFR-280 and the May 1990 Amendment. These tanks are to be removed and the contaminated soil, left behind, are to taken to waste facilities. The petroleum contaminated soils (PCSs) are not classified as hazardous waste, but cannot be used as clean fill. Therefore, it is classified as solid waste.

There is a significant amount of soil being removed from contaminated sites with limited means of disposing of this material. It is approximated that the removal of each leaking tank produces an estimate of 30-50 cubic yards of contaminated soil. This is a substantial amount of soil which has to be dealt with. These figures are projected to increase over the next few years which give rise to the question, How do we deal with this problem? The availability of the solid waste disposal facilities are becoming limited with increasing governmental regulations. Land filling is considered the least attractive action when disposing of waste material. Thermal methods are thought to be too expensive and is known to create an environmentally unsafe condition, as air pollution. Biological methods are cheaper but time consuming. For this procedure, it is impossible to determine that complete mixing of treatment reagents with petroleum components for low permeability soils such as clays is ensured.

1.2 A Viable Solution

One technique, in the development stages and which is a viable solution in treating PCS, is the option of using PCS in Hot Mix Asphalt. It is cost effective and is relatively easy to put such a technique into practice. It has been shown that petroleum contaminated soil can be used as a partial substitute for virgin aggregate without reducing the strength or durability of the asphalt concrete (Meegoda et al, 1991) It is viewed that petroleum products in the soil will not adversely affect the asphalt concrete matrix because asphalt cement, which is one of the major components of asphalt concrete, is also a by-product of crude oil just like gasoline or fuel oil.

This process can beneficially treat PCS because of the hot mix process will incinerate, dilute, and solidify the contaminants. Part of the petroleum is used as fuel and is burned during the process of asphalt production. Thus, the majority of the contaminants are eliminated. There is spreading and dilution because the remaining contaminants are mixed and distributed throughout the aggregate blend. The asphalt cement acts as a binder in the asphalt process and the remaining diluted contaminants are solidified and stabilized in the final asphalt concrete.

1.3 Objectives

Durability of PCSs in hot mix asphalt concrete is determined with the objective of investigating if petroleum contaminated soils in asphalt concrete can withstand varying temperatures and comparable heavy traffic loads. Since the test for cyclic temperature testing for durability is not well established, the durability testing procedure was proposed based on experimental tests after reviewing the applicable ASTM standards and specifications. Then based on the proposed testing procedure for durability, laboratory compacted HMA with six different PCSs was tested and reported in this thesis. Then the production of HMA with PCSs was field implemented and the durability of several field produced and compacted HMA with PCSs was tested and reported also

CHAPTER 2

EXPERIMENTAL PROGRAM

2.1 Investigation of Material Properties

2.1.1 Background

Soil samples from six different sources around New Jersey were used in this program The soil was obtained in weathered states. The soil samples from the six different sites were stored in a closed and cool environment to ensure obtaining a representative sample for experimentation. Sample selection is just as important as testing. Procedure for selecting samples is given in ASTM D75. The aggregates and asphalt cement obtained from the Newark Asphalt Company. Table 1, page 32, shows the classification, the moisture content, and the contaminants level for the six soils.

2.1.2 Particle Size Distribution

Sieve analysis for aggregates gradation and of Petroleum Contaminated Soils (PCSs) were determined by dry sieve method (ASTM D421) and by wet sieve method (ASTM D422). These methods were employed to obtain the relative particle sizes distribution of the different PCSs. The sieve analysis reflects the proportioning of the soil sample. Hydrometer analysis was performed on soils that contained silt dust or clay passing No. 200 sieve. The specific gravity (ASTM D854) was determined for each of the aggregate relative particle size.

2.1.3 Material

The petroleum contaminated soils (PCSs) consisted of various mixtures of sand, silt, and clay with petroleum product. Some of the soil arrived with large unfractured stone contained along with finer particles. These stone were separated before any test or sieving were done. The PCSs ranged from poorly graded sand to clayey, silty soil. Soil #1 or PCS

#1 contained a well graded sand, PCS #2 a clayey silt, PCS #3 a silty clay, PCS #4 a poorly graded sand, PCS 5 a silty sand, and PCS #6 a poorly graded sand with silt.

The coarse and fine aggregate received from the asphalt company were of 3/4, 3/8, 1/4 inch aggregates, sand, and stone dust. The coarse aggregates were dark grey irregular shape crushed stone with smooth surface texture. Irregular shape stone have more internal friction than round stone. Surface texture is considered to be more important than the shape of aggregate particles. The strength and durability are dependent on the aggregate shape and the surface texture. A smooth-round particle can be easily coated with asphalt cement but with a rough- irregular stone asphalt cement will adhere to it more readily.

2.1.4 Moisture Content

Contaminated soils arrived in weathered state. The in-situ moisture contents of the soils had a wide range of values. The water content values range varied from 7- 25 percent. Depending on the location of the soil and climatic factor along with the soil characteristics, the quantity of water can vary considerably.

2.1.5 Contamination Level

The level of contamination was considerably below the three percent or 30,000 ppm petroleum contaminant soil level suggested by the state of New Jersey to be considered as a hazardous waste. The soils contamination levels ranged between 0.11-0.66% (1,100-6,600 ppm) and from 0.0025-0.15% or (25- 1500 ppm) for gasoline. Soxhlet grease and oil extraction test was used to determine the degree of contamination

CHAPTER 3

USING PETROLEUM CONTAMINATED SOIL IN HMA

3.1 Typical Design Mix

A typical Hot Mix Asphalt (HMA) composition consist of 55% coarse aggregate, 40% fine aggregate, 5% mineral filler and 5.5% asphalt cement. Course aggregate contains sizes as large as 1.5 inch to US #4 sieve, fine aggregate contains sizes finer than #4 sieve and retained on # 200 sieve. Normally, aggregates passing the No. 200 sieve is limited between 2-10% of the total mixture. It is suggested that the total material passing the No. 200 sieve should not exceed 6% and a ratio of 95% virgin to 5% contaminated soil is a reasonable figure in producing a quality HMA. The aggregate blend with the right proportion of asphalt cement determines the strength of the HMA.

3.2 Determining the Design Mix for HMA

Before stability and durability testing occurs, it is essential to determine of the maximum percentage of PCS that may added to the Hot Mix Asphalt. First step is to classify the particle sizes; Table 2, page 33, shows the sieve analysis data for the aggregates. The Liquid Limit Test and the Plastic Limit Test were used to classify the fines passing the No. 200 sieve (0.075 mm). Sieving Tests were employed to find the particle size distribution of the aggregate and PCS. Table 3, page 34, shows those of PCSs.

Asphalt concrete specification requires that particles sizes be within a certain range of sizes and each particle size to be present in a certain proportion. The distribution of particle sizes within the aggregate is called the gradation curve of the aggregate. Sieve numbers and sizes for grading of asphalt concrete are also given in the Asphalt Handbook, MS-4, 1989. Paving mixtures are classified according to the maximum size or nominal maximum size of aggregate. The maximum size is the smallest sieve through which 100%

of aggregate can pass. The nominal size is described as the largest sieve that retain aggregate particles

The size distribution of HMA may vary according to state specification. There are three categories of paving mixes used in New Jersey and they are listed below.

1 I-1, I-2 (Base Course)

2 I-3 (Surface Course, Bottom Layer)

3. I-4, I-5, I-6 (Surface Course, Top Layer)

The maximum size for each category is as follows I-1 is 1", I-2 is 1 5", I-3 is 1", I-4 is 3/4", I-5 is 3/8", and I-6 is No 4 sieve. All the asphalt concrete tests with PCS were performed for an I-3 Mix intended for the bottom layer of the surface course.

The aggregate blend determines the strength of the HMA concrete. A good gradation curve for the design mix should be as linear as possible, and in the middle of the upper and lower limits of the state specifications plotted on a power graph (X axis-- Log ($size^{0.45}$) and Y axis - percent passing) The aggregate blend must be able to be placed and rolled during road construction, therefore, it is crucial to design a mix which is workable To have a workable mix it should be slightly upwardly or downward curved away from a straight line portion of the curve in the mid range of the specifications as shown in Figure 1, page 38,. The design blends for the PCSs are shown in Table 4, page 35

3.3 Durability of HMA with PCS

Durability is the ability of asphalt concrete to resist detrimental environmental conditions such as freeze-thaw and wet-dry cycles which influence asphalt cement hardening The cause of age-hardening is the oxidation and volatilization of lighter oils of asphalt cement This results in the change in molecular size, structures, and functional group content The functional group constituents of asphalt cement are nitrogen, sulfur, oxygen, and trace elements; they are directly involved in the mechanism of stripping. This oxidation and volatilization are characterized by the hardening of asphalt cement which eventually cracks and allows water to enter into the asphalt concrete matrix. Eventually, this action leads to stripping (asphalt cement and aggregate no longer bonding due to moisture damage) and rutting (permanent deformation). The associative forces that provide bonding between asphalt and the force which hold the molecules together is dependent on this functional group. If aggregate are hydrophilic (clays) by nature, additive or anti- stripping agents may be added to asphalt cement to enhance asphalt's performance.

Changes in asphalt composition have a direct effect on pavement performance. The size and structure of asphalt cement molecules influence the viscosity (stiffness) and elasticity of asphalt. Asphalt cement behavior is based on the combination of these physical properties. A mixture with petroleum contaminated soils would basically act the same way as any other asphalt concrete mixture would behave with the addition of asphalt cement. At low temperatures the pavement tends to be more susceptible to cracking. As temperature drops, pavement try to contract and the pavement is not able to absorb the stress of the contraction if the binder is too viscous. Repeated strains in the asphalt concrete, as a result of cold cycles, reduces the life of pavement considerably. If the aggregate is densely compacted then mixture is more resistant to displacement of asphalt from the aggregate. This allows the asphalt concrete to be more durable, having a longer service life.

Thicker filming around the aggregate are more resistant to age- hardening because the asphalt reduces the size of air voids, and seal them off making it hard for water or air to permeate the asphalt concrete. But, greater film thickness is also prone to rutting and bleeding There is always a drawback with thicker film coating; the asphalt coating give asphalt concrete its durability. It is well known that too much asphalt fill the air voids in paving material, the asphalt would act as an lubricant and ooze to the surface of asphalt concrete making roadways slick and dangerous. In hot mix asphalt process there is a point where asphalt concrete reaches its maximum strength and asphalt cement content reaches it critical value. If the asphalt cement content is greater than this critical value than the mixture would tend to rut. Therefore, finding that critical value is very important in the Hot Mix Asphalt process not only to obtain the maximum strength to make sure paving material does not loses any of its serviceability.

3.4 Stability of HMA with PCS

Durability is depend on the stability of a mix and stability is dependent on the size, shape, texture of aggregate. If the aggregate is densely compacted then asphalt concrete mixture is more resistant to displacement of aggregates. This allows the asphalt concrete to be more durable, having longer serviceability The internal friction between the aggregate and cohesion of asphalt to the aggregate are properties which give this strength to asphalt concrete. Internal friction is influenced by toughness and surface texture. The size and grading of aggregates is dependent on the job specifications. There is not much one can do about size and grading, the job requirements controls what sizes and percentages of aggregate are needed in a design mix for HMA with PCS.

Type and shape of particles has a definite effect on the strength of asphalt concrete. Irregular shaped particles tend to resist deformation than rounded particles, although round particles have more workability. Asphalt concrete has to be tough enough to be able to overcome the constant wearing down and abrasive forces imposed on it by tire action, compaction, and placing of paving mixtures. Asphalt surface layers requires greater toughness than bottom layers. Surface Texture is important for the workability and strength of paving materials; the rougher the texture the more internal friction an aggregate has A rougher material has more internal friction then a smoother aggregate; a smoother aggregate is more workable. There always must be a balance of smooth and coarse material used in HMA That is why sand and coarse, angular material is added along with PCS in Hot Asphalt Mix.

CHAPTER 4

EXPERIMENT SETUP AND PROCEDURES TO DETERMINE THE DURABILITY OF PCS IN HMA

4.1 Equipment Setup

The Marshall testing apparatus with a linear variable differential transformer (LVDT) and a load cell was used in this study to collect and evaluate data from the durability tests. A LVDT was employed to measure the deformation of a sample, load cell was used to determine the maximum compressive force (stability) of the given asphalt concrete specimen. To perform the various tasks associated with testing almost simultaneously, a microcomputer was used together with a data acquisition board and a signal conditioner. During specimen testing, compression data was automatically displayed on a computer screen by using a data acquisition program, Acquire. The compression equipment was setup to apply a diametrical deformation at 2 inches per minute.

4.2 Marshall Test

The Marshall test (ASTM 1559-82) is applicable only for laboratory design and is only used in conjunction with Hot Mix Asphalt. The maximum size of aggregate that is allowed in this test is 1 inch stone. This test is employed to determine the optimum asphalt content as well as to evaluate if a design mix is suitable for a job specification Tests were performed to evaluate the strength and flow of Hot Mix Asphalt with petroleum contaminated soil. These value along with VMA, air voids, and density are needed to determine of a design mix is acceptable by state codes and job requirements.

Before using this process the bulk specific gravity, which determines the volume of mineral aggregate, density and air voids in a sample are measured. The volume of mineral (VMA) is the voids in the mineral. This value is usually shown as a percentage and generally decreases with increasing percent of asphalt up until a minimum VMA is reached and then the volume of mineral aggregate starts increasing. Air void is also given as a percentile and it usually decreases with increasing asphalt content.

Optimum asphalt content is determine by finding the maximum stability, and unit weight at an minimum VMA. All three properties would show some correlation in obtaining the optimum asphalt content. Asphalt content values corresponding to the maximum density and stability, and the minimum VMA would indicate the optimum asphalt content used in the durability test.

4.3 Marshall Test Procedure

4.3.1 Specimen Compaction

The sieved aggregate of various different sizes were collected and stored along with the petroleum contaminated soils (PCSs). To find the optimum asphalt content, 15 samples were prepared with different percentages of asphalt cement. Three specimens had 3.5 % asphalt, three had 4.0%, and so on, increasing by 0.5 % up until an asphalt content of 5.5%. Specimen at every asphalt content was tested to find the critical value at which the asphalt concrete would achieve it maximum strength without affecting its durability.

Aggregates were divided into different groups based on their relative sizes. Each sample contained a certain percentage of the different sized aggregates; the total aggregate mixture would eventually weigh approximately 1200 grams and eventually placed in the oven. Table 4, page 35, shows the percentages of aggregates used for the six PCS specimens. The PCSs are also considered as aggregate and weighed. All the aggregates were heated to 130°C.

State code allows up until 3/4 inch aggregate in asphalt mix for a I-3 mix with heavy traffic, a surface course paving material. The mixture of aggregate is placed in the oven at a temperature of 130°C to dry, to make sure any moisture is driven off. Spatula, molds, metal mixing bowl, base plate are placed in oven along with the prepared aggregate mixture. Asphalt cement is heated to 350°F. Predetermined amount asphalt cement is added in the mixture. This PCS/aggregate/asphalt cement mix is mixed for 1 5 minutes Timing is very important at this point in the process. If mixing is too long instead of having a plastic mixture a unworkable solid mass forms While the mixture is still plastic it is spaded into the heated mold. This mold along with its base plate and collar is placed onto a pedestal where compaction takes place. The actual setup is such: base plate, mold, and then collar, respectively. Filter paper is placed at the bottom of the mold to prevent the mixture from sticking to the base plate. The plastic mixture is spaded 15 times around the inner perimeter of the 4 inch diameter mold with a heated spatula and 10 times over the interior. The material is slightly mounded within the mold before another filter paper is place within the mold. At this point a 10 pound hammer is placed in the mold on top of the mound and dropped 75 times from a height of 18 inches. The collar is removed along with the base plate from the mold so the mold can be rotated 180 degrees. The equipment is reassembled and another 75 blows is delivered to the mix making a specimen that is approximately 2.5±0.2 inch thick and 4 inch diameter. The base plate and collar is again removed from the mold and placed in the oven for the compaction of next specimen. The mold and its content is cooled to room temperature minus the filter paper. The filter paper is removed while the specimen is still warm. The specimen is extruded from the mold and is left to stand for 5-12 hours before any data is collected.

4.3.2 Data Collection Process

The sample height (ASTM D-3549) is determined after compaction. The face of the cylindrical specimen is divided into four sections by a marker, also mark the specimen for identification. At each marking a reading is taken by a caliper to measure the height of the sample. The average of each of the heights is designated as the specimen height. If the specimen height is not exactly 2 5 in (63.5 mm) then a correction factor is needed to determine the actual Marshall strength of a specimen In the Asphalt Handbook under the section covering the Marshall Test a table is given with all the correction factor values. For example, a specimen height of 2.0 inch has a correction factor of 1.47. This value is multiplied by the maximum stability value, value which is determined while the specimen is being crushed. This resulting value is the actual Marshall strength of the specimen.

If the specimen is outside the of 2.5±0.2 inch, adjust quantity of aggregate included in a specimen using:

$$Q=2.5/h*1200$$

where:

Q= Weight of aggregate required for adjusted height, grams

H= Height of specimen, inch

If the height is outside the range of specifications, make new specimen and repeat procedure. The specimen is weighed in air and then submerged in water then weighed again to determine the bulk specific gravity (ASTM D-2726). After asphalt mix has absorbed water, weigh it in air under saturated but surface dry condition according to AASHTO T-166.

4.3.3 Destructive Testing of Specimen

After bulk (ASTM D-2726) and theoretical (ASTM D-3203) specific gravity are determined, the sample can be tested for strength, flow, and durability. Test for durability (freeze-thaw and wet-dry test) will be explain later. The Marshall test is applied.

To find the stability and flow, the specimen is placed in a bath at 60°C for 30 minutes. While the specimen is in the bath, the Marshall test apparatus is set up for the compression of the specimen or specimens. Take a specimen from the bath and place the specimen into the lower testing head of the Marshall test device and then place the upper testing head on top of the sample. Make sure that the specimen is centered between the two testing heads. Place the load cell and LVDT flush with the top testing head; make sure the load cell is centered on the testing head. Then switch on the apparatus. A diametrical deformation at 2 inch per minute is applied to the specimen until maximum load is reached. Data is automatically displayed on a computer screen. A typical Marshall Strength graph is shown in Figure 2, page 39. The graph displays the deformation on the X-axis and the compressive force on the Y- axis. A typical Marshall graph shows the maximum compressive load, the load at which the specimen fails, and the flow. The flow value indicates whether paving mixes will experience permanent deformation or premature cracking under traffic loads.

4.4 Freeze-Thaw and Wet-Dry Test

To determine the durability of a specimen, the freeze-thaw and wet-dry methods are employed. These tests are used to evaluated if asphalt concrete matrix can withstand harsh weather and does not have accelerated aging beyond the normal aging process. It measure the effect of moisture damage on asphalt concrete. This test measures the tensile strength of a moisture conditioned specimen to a dry conditioned one. The tensile strength ratios of the contaminated specimens are compared to the tensile strength ratios of the control specimens The strength retained after subsequent freeze/ thaw cycle and wet/ dry cycle will determine if petroleum contaminated soils in Hot Mix Asphalt can withstand harsh conditions.

The wet-dry and freeze-thaw test (ASTM 4867-88) were conducted using the asphalt concrete mixture with PCSs having optimum asphalt contents. This method is used to test asphalt concrete mixtures in conjunction with mixture design testing. The control specimen was also tested with the optimum asphalt content.

4.4.1 Freeze-Thaw Procedure

Six specimens are usually prepared for this test. These six specimen are divide into two subsets. Three specimen for moisture condition testing and three for dry conditioning. The preparation, compaction is the same as in the Marshall test procedure (see 4.3 sections 1 and 2). The specimen bulk and theoretical specific gravity are determined as well as the air voids. The aggregates were assumed to be non-absorptive. Store the three specimens that are to be dry conditioned at room temperature. The other three specimens are partially saturated to between 55% to 80% with distilled water using a vacuum chamber. The vacuum pressure is adjusted to the degree which will achieve this objective. Any specimen that is above 80% saturation is discarded. Wrap the partially saturated specimens tightly in two layers of plastic using masking tape. Then put specimens in leak proof plastic bags with 3 ml of distilled water. Seal and mark the plastic bags and placed them into a freezer at −18°C. After at least 24 hour, take the specimen out of freezer and place it in a bath for three minutes so the specimen can thaw When these three minutes are over take specimens out of bath, remove the bags and plastic coverings, and gently place the specimens back into the bath for another 24 hours. Repeat this freezer/bath procedure for as many cycle is needed or until specimen failure. After the freeze- thaw procedures, measure the specimen in air and then in water again to determine the bulk specific gravity. Determine the height(ASTM D-3549), volume (ASTM D-2726), and swell. Swell is calculated by dividing the change in specimen volume by the initial specimen volume. Place moisture conditioned specimens along with the dry conditioned specimens in the bath for 30 minutes. After the 30 minutes are over, perform the Marshall test to obtain the maximum load, such as in the Marshall test procedure section 3 for each specimen in both of the subsets.

Calculate the tensile strength as shown below:

$$S_t=2*P/(pai*t*D)$$

where:

S_t= tensile strength, psi

P= maximum load, lbs

t= specimen height, in.

D= specimen diameter, in.

pai= 3.1416

Calculate the tensile strength ratio as shown below.

$$TSR=(S_{tm}/S_{td})*100$$

where:

TSR= tensile strength ratio, %

S_{tm}= average tensile strength of moisture conditioned subset, psi

S_{td}= average tensile strength of the dry conditioned subset, psi

4.4.2 Wet-Dry procedure

Six specimens are also prepare in the same way such as in the freeze- thaw procedure. The same procedures were followed for compaction, data collection, and destructive testing as it is in the previous sections. The only difference with these procedure from that of the freeze-thaw test is that the specimens are not placed in the freezer instead it is place in an oven at 60°C. After the bulk and theoretical specific gravity are determined, the specimens are placed in a convection oven at a temperature of 60°C for 24 hours. After this 24 hour period is completed, the specimens are removed from oven and placed in a water bath at a temperature of 60°C and let stand for another 24 hours. Repeat the above procedure for as many cycles as needed or until failure and then continue to follow the same procedures that is written in the previous section to find the strength and flow. Calculation for swell, tensile strength, and tensile strength ratio (TSR) is also determine in the same way as in the freeze-thaw section.

CHAPTER 5

DURABILITY PROTOCOL

5.1 Experimental Program

After deciding upon conducting research on durability of asphalt concrete made with contaminated soil, an extensive literature search was performed on this topic. There were several articles on the applicability of using PCS in HMA by modifying the plant or field test detailing experience of several companies processing PCSs in HMA, but there were no articles on the durability of asphalt concrete made with petroleum contaminated soil when subjected to cyclic temperatures. The only published information that was available about freeze-thaw and wet-dry cycles was in the ASTM standard (vol. 04.03). This standard discussed the test procedure on how to find the effect of moisture on asphalt concrete mixture, a factor which is very important for the durability of concrete. It had a section which discussed a freeze-thaw conditioning cycle of a mixture. However, the freeze-thaw and wet-dry tests were only subjected to one cycle each of freeze-thaw or wet-dry. There was no justification why ASTM selected only one cycle when in the real world asphalt concretes are subjected to several freeze-thaw and wet-dry cycles under service conditions before they are removed for resurfacing. Therefore, eighteen HMA specimens with PCS #3 were compacted to evaluate the durability of HMA subjected to several durability cycles. Two specimens were subjected to Marshall stability test to obtain the Marshall strength without subjecting to environmental conditioning. Eight specimens were subjected to freeze-thaw cycles. After one cycle of freeze-thaw two were taken out and the Marshall stability test was performed to obtain the Marshall stability and the TSR value after one cycle. The rest of the specimens were continued on freeze-thaw cycles and after three cycles two more were taken out and tested for Marshall stability. The rest of the samples were tested after seven and fourteen cycles. The remaining eight specimen were subjected to a series of wet-dry cycles similar to that of freeze-thaw tests. Before the Marshall test, the percentage swell and percentage change in weight of the samples were also calculated. The results of this test series is plotted in Figure 3 and 4. Figure 3 shows the tensile strength ratio and percentage swell against the number of freeze-thaw cycles and Figure 4 shows the similar data for wet-dry tests

Testing for 1,3,7, and 14 cycle proceeded for HMA with PCS #3 and with each cycle taking approximately 48 hours to complete Upon completing the 14 cycles of freeze-thaw and wet-dry test, data was collected and graphically displayed. It is concluded that as the temperature drops for the freeze-thaw sample the asphalt concrete contracts and become brittle, creating tiny cracks on the surface of the specimen which provide entry points for water. Water inside the specimen cause moisture damage due to stripping and volume expansions during subsequent freeze cycle. As the number of freeze-thaw cycles increase, the cracks get larger letting more water into the specimen which eventually lead to failure of the specimen The data from cyclic freeze-thaw test indicated that the percentage swell increased rapidly for the first cycle and then gradually reached maximum percentage swell before specimen failed. It is believed that when the specimen reaches its maximum percentage swell specimen is totally saturated with water, stripping occurs, and then complete failure happens. The tensile strength ratio also declined after the first cycle and then also began leveling off until a zero strength after 14 cycles. It seem that there is some correlation between the percentage swell and the tensile strength ratio. From the data, it shows that most of the strength is lost during the first cycle, and hence there was no need to test beyond one freeze-thaw cycle as suggested by the ASTM.

The cyclic wet-dry test also indicated that the first cycle was the point where attention must be focused. For the wet-dry test, the tensile strength ratio declined during the first cycle and increased thereafter. This is believed to be due to oxidation of asphalt during the drying cycle Therefore, it was concluded that the first wet-dry test yielded the critical conditions Freeze-thaw and wet-dry tests with one cycle indicating whether a specimen is durable, a strength loss of more than 20 % indicates that the specimen will not withstand harsh weathering conditions Research program continued with freeze-thaw and wet-dry tests. The tests were performed for each of the six PCSs pretty much in accordance with the ASTM standard.

Based on tests determined for the two specimens tested by the Marshall stability test, the average stability of the specimen were approximately 2995 lb -force which is much greater than the allowable stability for NJ heavy traffic paving mix, 1800 lb.-force. For the freeze-thaw and wet-dry specimens to be durable the specimens should retain at least 80% of its strength after the first cycle. In Table 5, page 36, one can compare the tensile strength ratio of the freeze-thaw and wet-dry specimens to the two specimens tested for stability earlier. The variation of percentage swell and tensile strength ratio with the number of cycles are plotted in Figures 3 and 4. Figure 3, page 40, shows the increase of percentage swell and the tensile strength ratio of the freeze-thaw specimens.

The percentage swell of the freeze-thaw test for the first cycle is from 0% to 2.5%, the largest percentage swell increment for the freeze-thaw test. The second cycle had a percentage swell from 2.5% to 4.8%, a large but not as significant as the first cycle. The wet-dry test showed that after the first cycle the percentage swell increased from 0% to 1.2% also the largest percent increase for the wet-dry test. From the test it is concluded that the first cycle determines whether a paving material will be durable under freeze-thaw and wet-dry conditions. The swell values of wet-dry and freeze-thaw increased rapidly and level off to an average value of 5.18% for the freeze-thaw and 1.79% for the wet-dry tests at the seventh cycle. At the fourteenth cycle, the specimens for the freeze-thaw test collapsed, therefore the percentage swell was not determined.

The tensile strength ratio (TSR) was also determined. As the data indicates in Figure 3, page 40, the tensile strength ratio for the freeze-thaw test declined rapidly for the first cycle from approximately 100% to 80% of its original strength. The specimens for PCS #3 retained more than 80% of its strength which confirms the results found by percentage swell that PCSs can be used as a paving material even though it is subjected to freeze-thaw and wet-dry cycling. The freeze-thaw test continued onto fourteen cycle at which time the specimens tensile strength ratio was 0% indicating a total failure. This is the point at which stripping occurred in which the aggregate and the asphalt cement no longer retained its bonding forces because of the attractive force between the water and the asphalt cement. The wet-dry test shows that the TSR also declined rapidly after the first cycle to a value of 94 27% and then increased in strength after the first cycle to 99% at the seventh cycle. From the trends of the percentage swell and the tensile strength ratio, the first cycle's strength is the determining factor in deciding whether an asphalt paving mixture is thought to be durable. Therefore, one cycle of freeze-thaw and wet-dry was used as test protocol which confirmed the ASTM test procedure.

CHAPTER 6

LABORATORY TEST RESULTS AND DISCUSSION

6.1 Durability Test Results and Discussion

Knowing that the first cycle is one of the key parameter in the determination of durability. Test for a freeze-thaw and wet-dry cycle were performed for all of the other PCSs in the experimental program. The PCSs tensile strength ratios are comparable to the control samples. The control, has no petroleum contaminated soil, retained 91.7 % of its strength after the first cycle of wet-dry testing, and 82 3 % after the freeze-thaw testing. These results are shown in Table 5, page 36. In fact, PCS #1 and #5 did even better than the control for the wet-dry cycle. They retained a great deal of their strength, more than 80%. PCS #4 and PCS #5 retained approximately 87% and 98 %, respectively, of its strength for the freeze-thaw test. PCS #4 was less successful than the rest of the specimens in retaining its strength for the first cycle of wet-dry. It had a TSR value of 83.8%, the lowest value determined among the PCSs specimens, Although it was the lowest value, this value is quite above the limiting value for a durable mix. The wet-dry TSR value and freeze-thaw values were good, indicating that petroleum contaminated soil in HMA is better than HMA with virgin aggregates in HMA. PCS #5 which contained clay even shows that it is durable in Hot Mix Asphalt. Although the HMA laboratory test results were promising, more testing was recommended for petroleum contaminated clays in HMA. Asphalt concrete with clays is usually more prone to moisture damage A densely compacted specimen with just the right percentage of asphalt cement content may give a high tensile strength ratio and may prevent water from permeating into the specimens and causing moisture damage.

CHAPTER 7

FIELD TEST RESULTS AND DISCUSSION

7.1 Durability Test Results and Discussion

7.1.1 Background Information

Field test were conducted to evaluate the applicability of adding PCS in HMA. The test was conducted at Continental Paving Inc., Londonderry, New Hampshire on two separate occasions. These of the field tests were carried out in order to investigate the possibility of using clay soils in modified drum mixed asphalt plants and to determine the strength and durability of HMA made with PCS in the field. For a detailed description of modified plant design see "Construction Use of Petroleum Contaminated Soils", by Namunu J. Meegoda, De-Rong Huang, Bonnie DuBose, Yaoging Chen, and Robert T. Mueller.

In order to further investigate the feasibility of using clayey soils in modified drum mixed asphalt plants, a laboratory experiment was conducted prior to field test. A clayey soil, PCS #5, was heated to various temperatures to remove the crystalline water and to determine the influence of soil temperature on the soil mineralogy. At temperatures above a threshold value, clay particles looses the crystalline water causing an aggregation of clay particles. This caused a decrease in the surface area of clays. It was attempted to simulate this process in the asphalt plant with PCS #5, to determine the feasibility of processing large quantities of clay type PCS.

7.1.2 Determining a Design Mix for Field Test

It was necessary to perform a new aggregate blend for the aggregates available at the site for the first visit. The Continental Paving Company provided the average of ten gradation tests for each aggregate type in the stockpiles. The gradation results and the NJ I-3 specification were used to obtain a new blend for the soil which was referred to PCS #5 earlier in this thesis. PCS #5 was brought from New Jersey to be used in the field test. All debris and large unfractured particles were removed by Continental Paving Co. prior to our field visits. The calculation for the new blend resulted in the following

3/4 Stone--- 30.0%

1/2 Stone--- 16.5%

3/8 Stone--- 20 5%

Sand-------- 24.0%

PCS #5------ 9.0%

The above blend was used with a asphalt content of 4.5%. The asphalt extraction test showed an asphalt content of 4.8%.

7.1.3 Field Test Results

Soils with high clay contents pose a potential stripping problem hence the percentage of fine in the percentage of fines in the final product is usually limited to about 5%. PCS #5 was field evaluated for the acceptability with respect to handling the stripping action of high clay content PCS in the modified HMA plant in Londonderry, NH. Based on the liquid limit, plastic limit, clay content and influence of temperature on clay mineralogy, a soil temperature of 350°C was found to be sufficient to aggregate the clay. In the plant, the soil was heated to 750°F in the modified dryer and collected for analysis. Soil tests results for PCS #5 from the plant site before and after the dryer was determined, before the dryer the clay content was 8.0 % and after the content was 4.0%.

For the purpose of description, tests were divided into four different groups on the first field visit. However, only two different kinds of soil were used, namely PCS #5 and another oil contaminated soil supplied by Continental Paving Inc. which is referred to as PCS #7.

The variations in the test #1 through #4 are as follows:

Test #1. PCS #5 was run through the dryer, after which aggregate was added. This is the usual procedure for the modified plant to produce HMA with PCS. Soil samples were taken before it entered the dryer and after it ran through the dryer.

Test #2: PCS #5 was not run through the dryer , but used as a replacement for the aggregate in one of the cold aggregate bins.

Test #3: The same as test #1 except PCS #7 was used.

Test #4: The same as test #2 except PCS #7 was used

Nine samples each weighing approximately 1250 grams were taken and compacted into Marshall samples (cylindrical molds) and were brought back to the NJIT laboratory for further testing. This was done for each of the four test. There was particle aggregation, the clay content increased after the soil passed through the dryer. It is believed that the above was due to particle splitting. When a sudden temperature gradient is introduced to wet clays, the sudden evaporation of water molecules caused the particle to split (similar to making popcorn). Marshall test, freeze/thaw, and wet/dry tests were run on compacted asphalt concrete samples. In the second field visit, three test were performed. The Soil #8, another oil contaminated soil supplied by the Continental Paving Inc. was used in the following composition:

Test #1B: Soil #8 was run through the dryer, after which aggregate was added in the following percentage to produce a filling product for subbases.

3/4 Stone------- 50.0%

Soil #8---------- 50.0%

The above blend was used with an asphalt content of 2.0%. The soil came out of the dryer at a temperature of approximately 650°F.

Test #2B Soil #8 was run through dryer, after which aggregate was added in the following percentages to produce a 3/4" base mix.

3/4 Stone--------- 27 9%

1/2 Stone--------- 4.1%

3/8 Stone--------- 27.3%

Sand-------------- 20.5%

Soil #8------------ 20.2%

Design asphalt content was 4.9 and the actual asphalt content, from extraction test was 5.17%. The soil come out of the dryer at a temperature of 750°F.

Test #3B Soil #8 was run through the dryer, after which aggregate was added in the following percentages to produce a 3/8" surface mix.

3/8 Stone---------- 27.3%

Sand--------------- 43.4%

Soil #8------------- 17 0%

The above test were performed while actual production of HMA with PCS #8 was being mixed to be used in the paving of roads. All of the soil specimens were brought back to the laboratory where freeze-thaw and wet-dry test were run on the asphalt concrete specimens. The durability test results for the field specimens are shown in

Table 6, page 37.

All the specimens retained much of their strength for the first cycle. Specimen 3A and 3B were the only specimens that did not retain at least 80% of its strength in the freeze-thaw test. This may be due to poor compaction in the field. Although 3A and 3B did not fair as well in the freeze as the other specimens, it retained most of it strength in the wet-dry test. Matter of fact, 3A did better in the wet-dry test than most of the specimens in this study The TSR values for 3A and 3B for the wet-dry test are 99.0% and 81.0%, respectively. The field test values indicate that the specimens are more susceptible to moisture damage during the freeze-thaw cycle. The freeze-thaw specimens shows a lower tensile strength ratio than the wet-dry test. Also, Table 6, page 37, shows that 2B and 3B had low stability values. This is believed to be due to a deficiency in the fraction passing sieve # 4 in the design blend in the field test.

CHAPTER 8

SUMMARY AND CONCLUSION

The problem of leaking underground storage tanks produces a substantial amount of petroleum contaminated soil. This soils have to be removed and readied for disposal or for treatment. There is a growing need to find a sound method that is cost effective and easy to implement in dealing with this problem of petroleum contaminated soil. One such solution is to use petroleum contaminated soil in Hot Mix Asphalt concrete. This method is viewed as being a very promising and an innovative technology. Test for durability and stability have shown that using PCSs in HMA is feasible and can work with good results

However, it is believed that not all soil particles are suitable for inclusion in a Hot Mix Asphalt. This is true as high clay contents tend to weaken asphalt concrete mixtures. This phenomenon is true whether the clay soil is contaminated with petroleum or not. Clay has an affinity for water which may cause stripping problems in asphalt concrete; water retards the bonding force (cohesion) between aggregate and asphalt cement. Because of this factor, normally only a small percentage of clay, usually 5%, in HMA. But, findings shows that a greater percentage of clays can be used. Laboratory tests and field test reveals that a greater percentage of clays can be used to achieve a strong mix. It is evident that more test is needed to determine whether a larger percentage of asphalt can be used in this process.

It is important to note that stability and hence durability of a paving mixture is dependent on how densely compacted the material is. Properties such as size, texture, shape of the aggregate as well as the viscosity of the asphalt cement determines whether the strength of asphalt concrete is sufficient to withstand the imposed loads. The PCSs within HMA are shown to have approximately the same strength as concrete mixes without contaminants. In fact, test shows that some of the petroleum contaminated soils retained its strength better than the control mixes.

This technology seems to be an option that is worth taking another look at. It should be understood that more field test and laboratory test are required before this process can be viewed as a viable reuse option. But from the results of this test experimental program, it seems that a good start has been made in achieving an answer to the problem of petroleum contaminated soil

APPENDIX

Table 1 Data on Six Contaminated Soils from NJ

	Soil Type					
	PCS #1	PCS #2	PCS #3	PCS #4	PCS #5	PCS #6
Soil Classification	Well graded	Clayey silt	Silty sand	Poorly graded	Silty clay	Poorly graded sand with silt
In Situ Moisture Content (%)	7.3	14.3	24.7	14.4	19.6	10.1
Level of Contamination	0.11% Heating oil	0.12% Heating oil	0.66% Heating oil	25 ppm Gasoline	1500 pm Gasoline	330 ppm Gasoline

Table 2 Grain Size Distribution for Aggregates

Size or US Sieve	Percent Retained				
	3/4" Aggregate	3/8" Aggregate	1/4" Aggregate	Stone Dust	River Sand
3/4"	32.0				
3/8"	61.0	78.0	5.0		
#4	7.0	22.0	65.0	3.0	
#10			30.0	32.0	
#40				37.0	50.0
#100				10.0	46.0
#200				4.0	2.0
Pan				14.0	2.0

Table 3 Grain Size Distribution for PCS

Size or US Sieve	Percent Retained					
	PCS #1	PCS #2	PCS #3	PCS #4	PCS #5	PCS #6
3/4"						2.2
3/8"						5.0
#4	5.0	12.0		2.0	5.0	5.9
#10	5.0	7.0	3.0	6.0	10.0	3.0
#40	52.0	9.0	22.0	42.0	20.0	12.8
#100	20.0	6.0	54.0	50.0	11.0	58.7
#200	13.0	3.0	5.0		9.0	7.3
Pan	5.0	63.0	16.0		45.0	5.1

Table 4. Design Blend for PCSs for I-3 Mix

Aggregate / Soil Type	Control (%)	Soil #1	Soil #2	Soil #3	Soil #4	Soil #5	Soil #6
3/4 Size	10.0	12.0	10.0	10.0	10.0	8.0	10.0
3/8 Size	35.0	28.0	30.0	30.0	35.0	30.0	30.0
1/4 Size	25.0	25.0	20.0	15.0	25.0	20.0	15.0
Stone Dust	15.0	0.0	10.0	25.0	15.0	12.0	30.0
Sand	15.0	0.0	20.0	0.0	0.0	20.0	0.0
PCS	0.0	35.0	10.0	20.0	15.0	10.0	15.0

Table 5 Tensile Strength Ratios for Wet/dry and Freeze/Thaw Tests

HMA MIX	Wet/Dry Test	Freeze/Thaw Test
Control	91.7	82.3
HMA with Soil #1	98.0	89.0
HMA with Soil #2	89.3	102.0
HMA with Soil #3	87.2	93.9
HMA with Soil #4	83.8	87.0
HMA with Soil #5	93.4	98.4

Table 6 The Durability Test Results for the Field Samples

Test #	Freeze & Thaw Test		Wet & Dry Test	
	Stability	TSR (%)	Stability	TSR (%)
1A	2100	80.0	2445	93.0
2A	1700	86.0	1842	93.0
3A	1342	76.0	1768	99.0
4A	1260	100.0	1140	99.0
1B	N.D.	N.D.	N.D.	N.D.
2B	1575	96.0	1772	100.0
3B	920	79.0	949	81.0

N.D. : Not Done

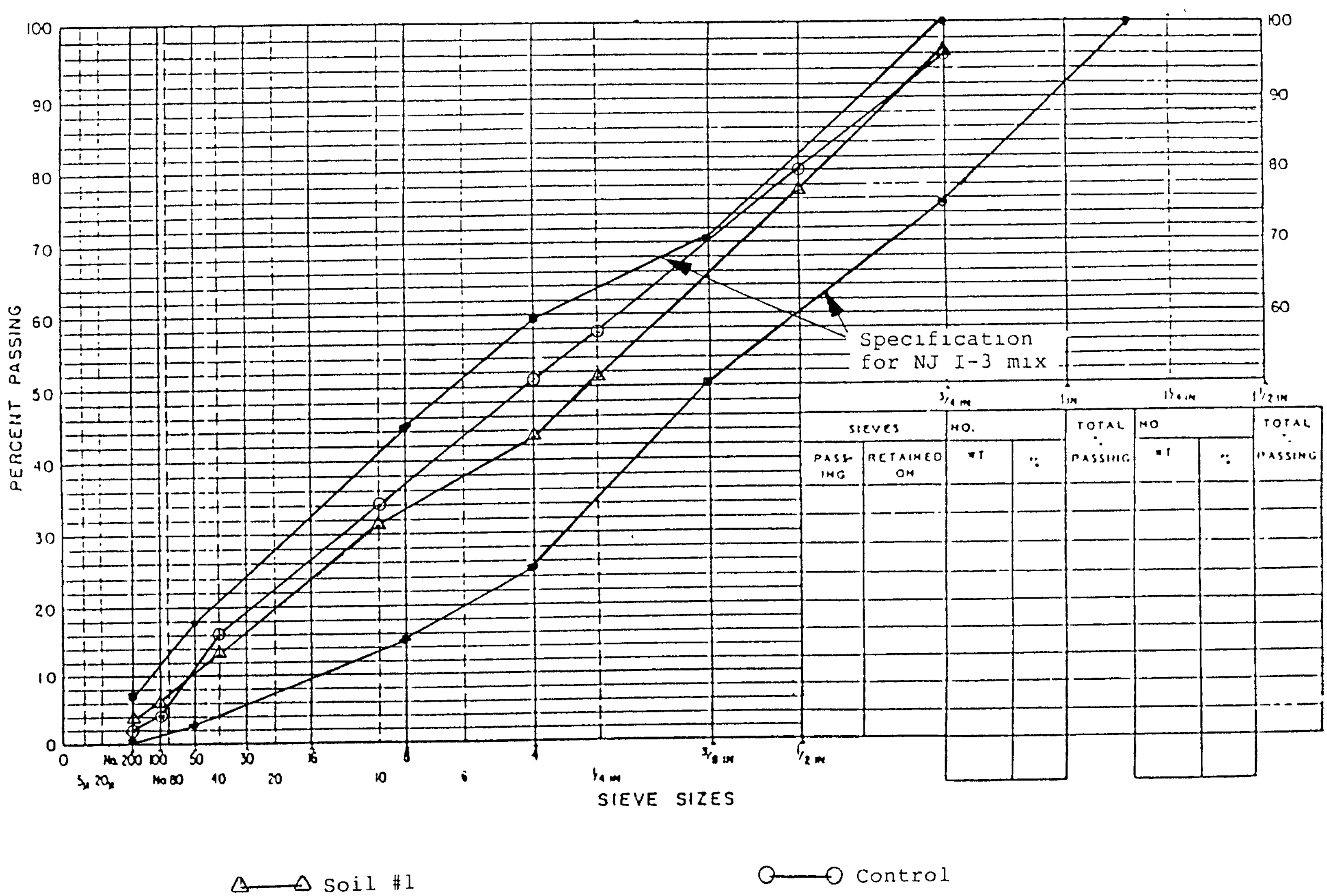

Figure 1. The Grain Size Distribution of the Control and the Mix with PCS #1

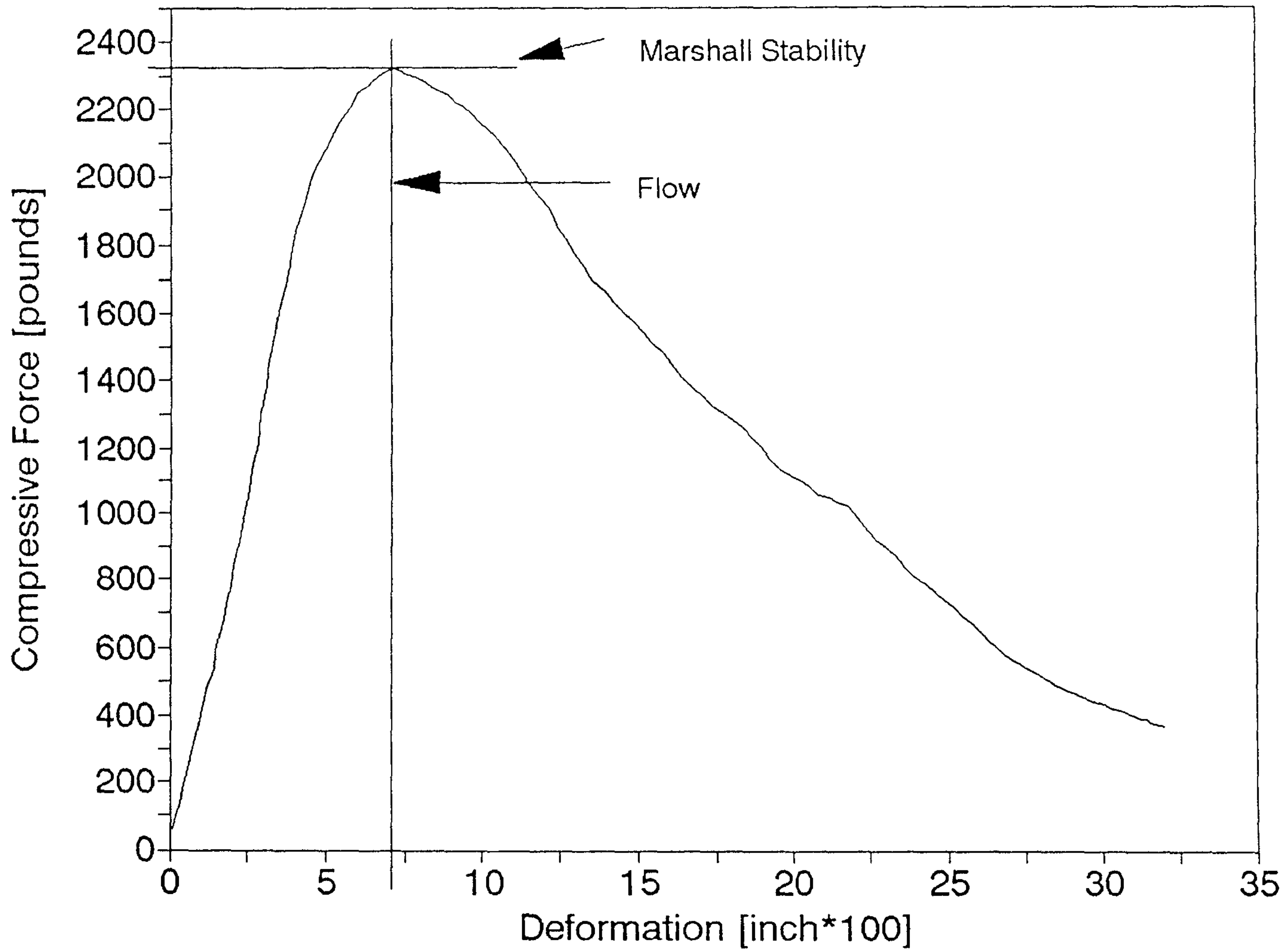

Figure 2. A Typical Marshall Test Result

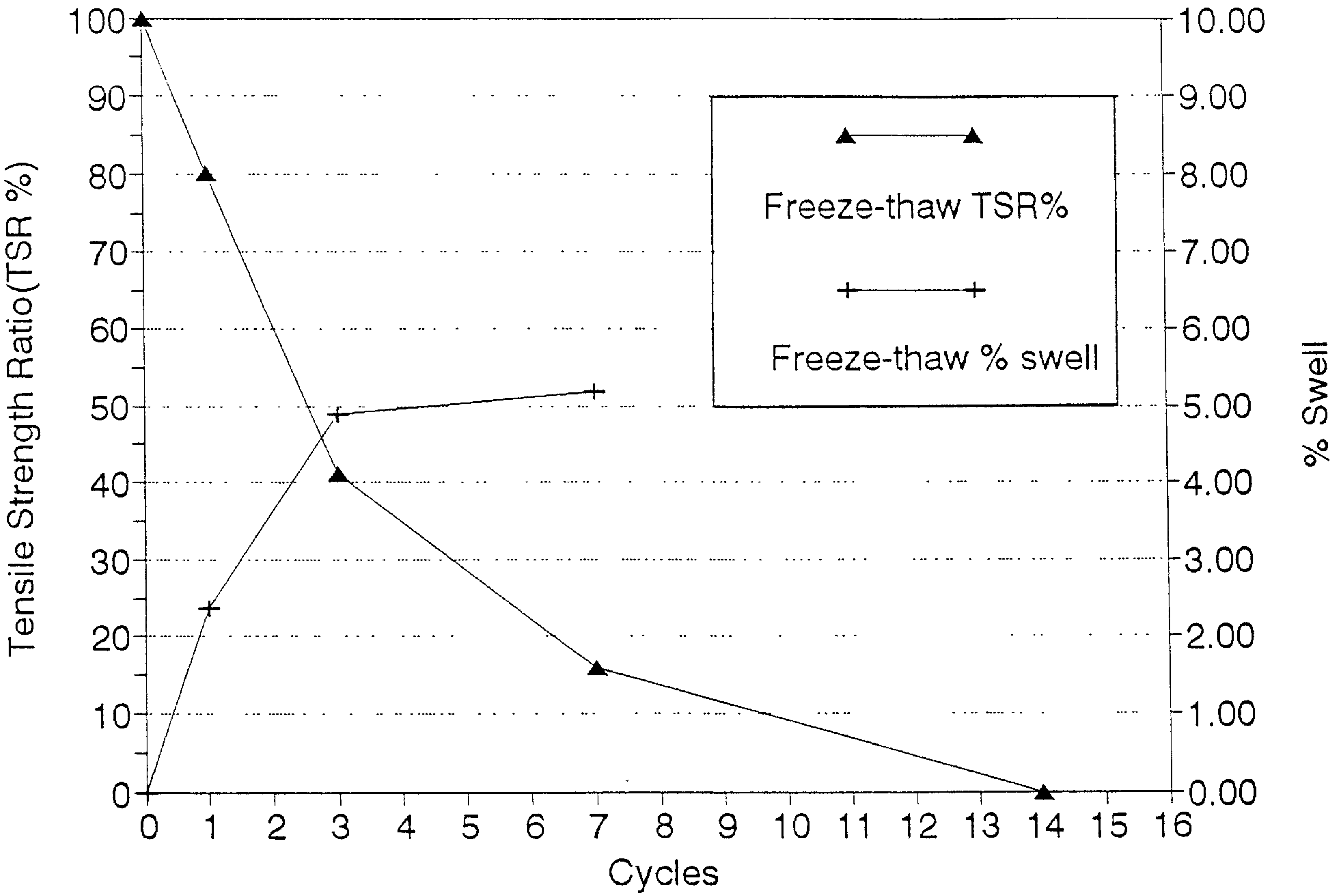

Figure 3. Tensile Strength Ratios and Percentage Swells of Freeze-thaw Test

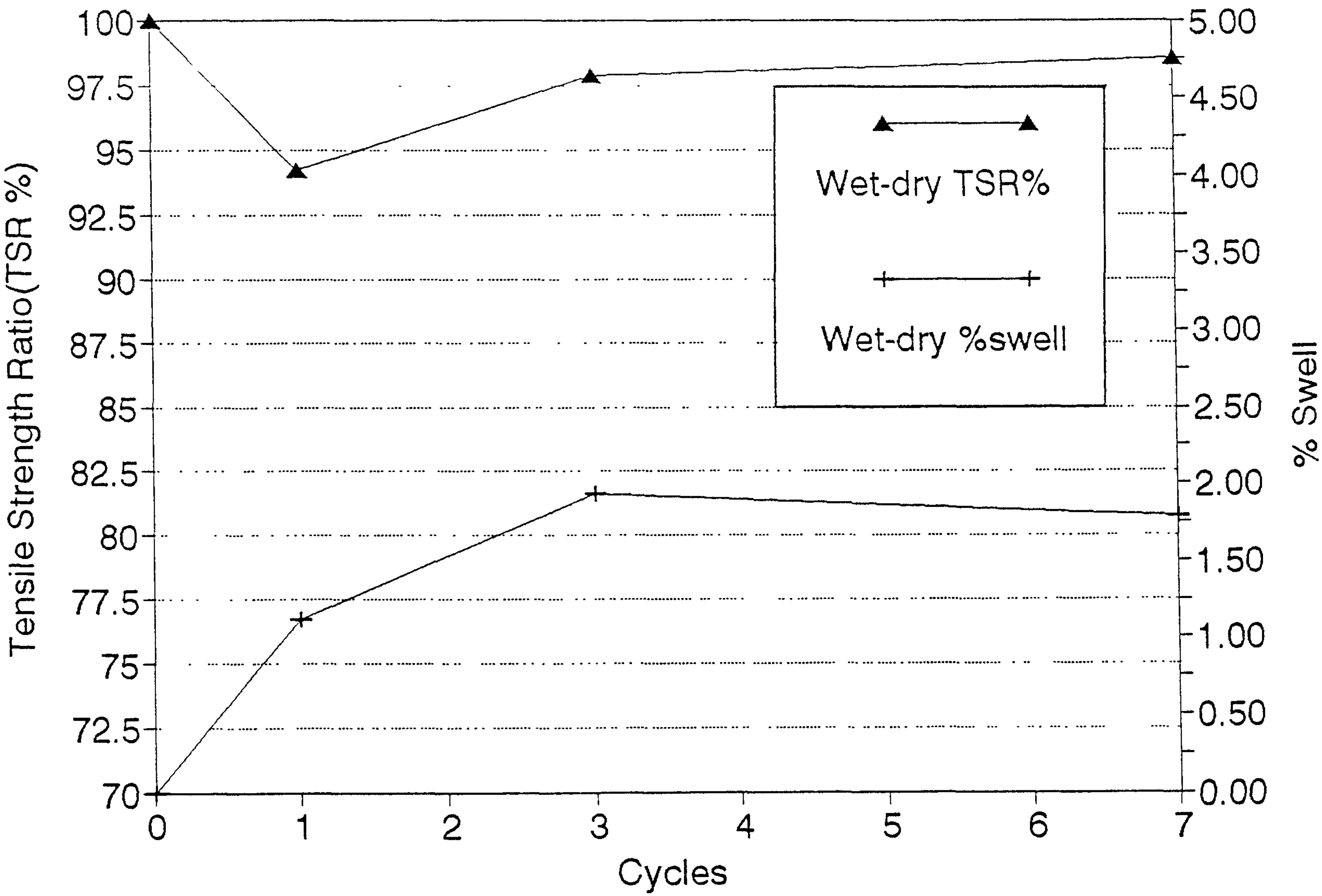

Figure 4. Tensile Strength Ratios and Percentage Swells of Wet-dry Test

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