EFFECTS OF AGGREGATE GRADATIONS ON MIX CHARACTERISTICS

By Lowell J. Zearley

A specification in the New Division 2, effective for the October letting, will limit the number of trial mixes that will be done without charge. By evaluating the gradation of the aggregate before we do laboratory testing on the mix, we can predict with a great amount of accuracy what characteristics are going to result. By this small amount of preliminary work in combining aggregates, we can reduce to a large extent, the additional laboratory work that is now involved.

Figure 1 is a maximum density chart in which the straight line shows the maximum density gradation of 3/4" size aggregate. The sieve sizes are shown horizontally and the percent passing is shown on the vertical scale. The straight line represents the particle size distribution in which the largest solid volume is obtained, or putting it another way - in which the smallest aggregate voids are obtained. In other words, the medium sized aggregate particles fill the voids resulting from the largest particles; the smaller sized aggregate particles fill the voids left by the medium sized particles. This holds true for all aggregates, and the reason all aggregates do not end up with the same compacted density is because of different specific gravities of the individual aggregate sources, and because the difference in surface texture influences how different aggregates respond to compactive effort.

The problem that results from the maximum density gradation is that not enough aggregate voids are available to allow the use of a satisfactory amount of asphalt. These mixes result in low asphalt contents with low film thicknesses and short durability.

The approach to solving this problem is by changing the gradation of the aggregate away from the maximum density line. The most effective method is by raising or making finer the upper and middle screens and lowering the bottom screens.

The influence of the material passing the #200 sieve is by far the most important part of the mix. By reducing this portion we increase the aggregate voids, and allow the use of higher asphalt contents. The gradation shown in Figure 2 would seldom be acceptable, because most of the middle and upper screens are still on or near the maximum density curve.

If we reduce the -200 material by 2.65 percent, we have allowed an increase of one percent of asphalt, because aggregates have an average specific gravity of 2.65, and asphalt has a specific gravity of 1.0, and so we have traded equal volumes.

Figure 3 shows a more typical gradation, especially of pit run gravels, which generally allow satisfactory asphalt contents.

Figure 4 shows a gradation with a so-called "sand hump". The preponderance of sand size particles determines that almost all other aggregate particles be in contact with a sand particle, resulting in very high asphalt contents, low stabilities and tender mixes.

In our trial mix formulas we report the total asphalt content recommended to start the job. We should probably refer more to effective asphalt content, which is that asphalt left after a portion of the asphalt has been absorbed by the aggregate, and this non-absorbed asphalt is the only material that is effective as the binder. A mix that contains 5.5 percent asphalt with one percent asphalt absorption in reality contains 4.5 percent asphalt. A still more meaningful term is to refer to asphalt contents by film thickness. This terminology takes into account the asphalt absorption, and it also considers the surface area that the asphalt has to coat. Saying a mix contains 6 percent asphalt is like saying you have 6 gallons of paint to paint a building. How weathered is the wood, and how large is the building?

In dense graded mixes we are dealing with extremely thin asphalt film thicknesses. A film thickness of 7.5 microns is approximately one-tenth the thickness of a sheet of yellow paper of a legal pad.

To illustrate how the surface area is increased by the -200 material; if a +4 aggregate particle is crushed to pass the 200 screen, the surface area is increased by approximately 130 times, and consequently it would take 130 times as much asphalt to result in comparable film thicknesses.

When we approve a mix based on the criteria on which we design, it is approved only for the aggregate grading as shown. It does not mean the aggregate grading can use the full tolerances and still be acceptable. The tolerances are used only to the extent the mix remains satisfactory.

The most typical problem at present is the increase in the -200. This increases density, increases stability, decreases the room for asphalt, reduces the air voids, and increases the surface area. To control the proper air voids in the pavement a reduction in asphalt content is required in a mix that may already have become unsatisfactory with regard to film thickness.

The advantages for a contractor, to avoid an increase in the -200 area: (1) The film thickness reduction dries up the mix which makes it more difficult to control segregation.

(2) The increase in -200 also increases the stability, making it more difficult to obtain the required density. These are two areas with which most of us are familiar.

A quotation from Highway Research Board, Special Report 131, "Compacting of Asphalt Pavement" states as a general rule, the percentage of filler passing the No. 200 sieve should never exceed the percentage of asphalt used in the mixture.

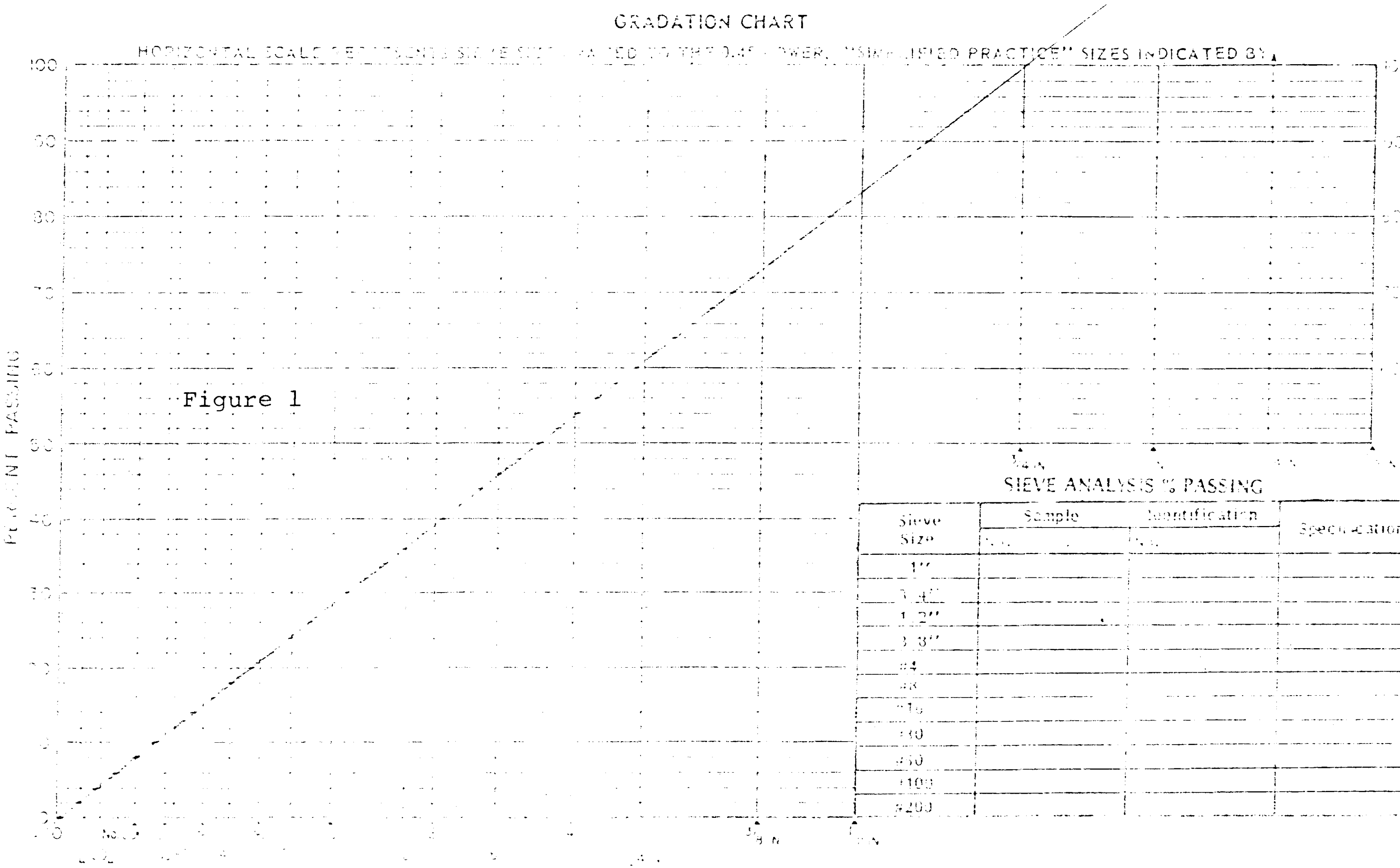
LeFebvre in his report given at an A.A.P.T. meeting stated that mineral filler increases stability. However, it is a void filling material which takes the place of bitumen. Since bitumen content has to be reduced in conjunction with its use, it can be detrimental to the durability of the pavement. While some aggregates require mineral filler in order to improve stability, its use should be limited to those cases where laboratory data indicates that it can be beneficial. One of the most serious problems encountered in the design of dense-graded bituminous paving mixtures is the lack of adequate void space in the mineral aggregate itself.

This subject was chosen not because of any information it might impart toward reducing the number of trial mixes we do, but because 8-9 or 10 percent minus 200, with 5 or 6 percent asphalt in our pavements reduce the pavement life by approximately one-half..

FORM 820?.3
8-75

DEPARTMENT OF TRANSPORTATION

GRADATION CHART



SIEVE ANALYSIS % PASSING

Sieve Size	Sample	Identification	Specification
1"			
3/4"			
1/2"			
3/8"			
#4			
#8			
#16			
#30			
#50			
#100			
#200			

TYPE, UNIT, LOCATION IN PROJECT

TYPE, SOURCE, PRODUCER OF AGG.

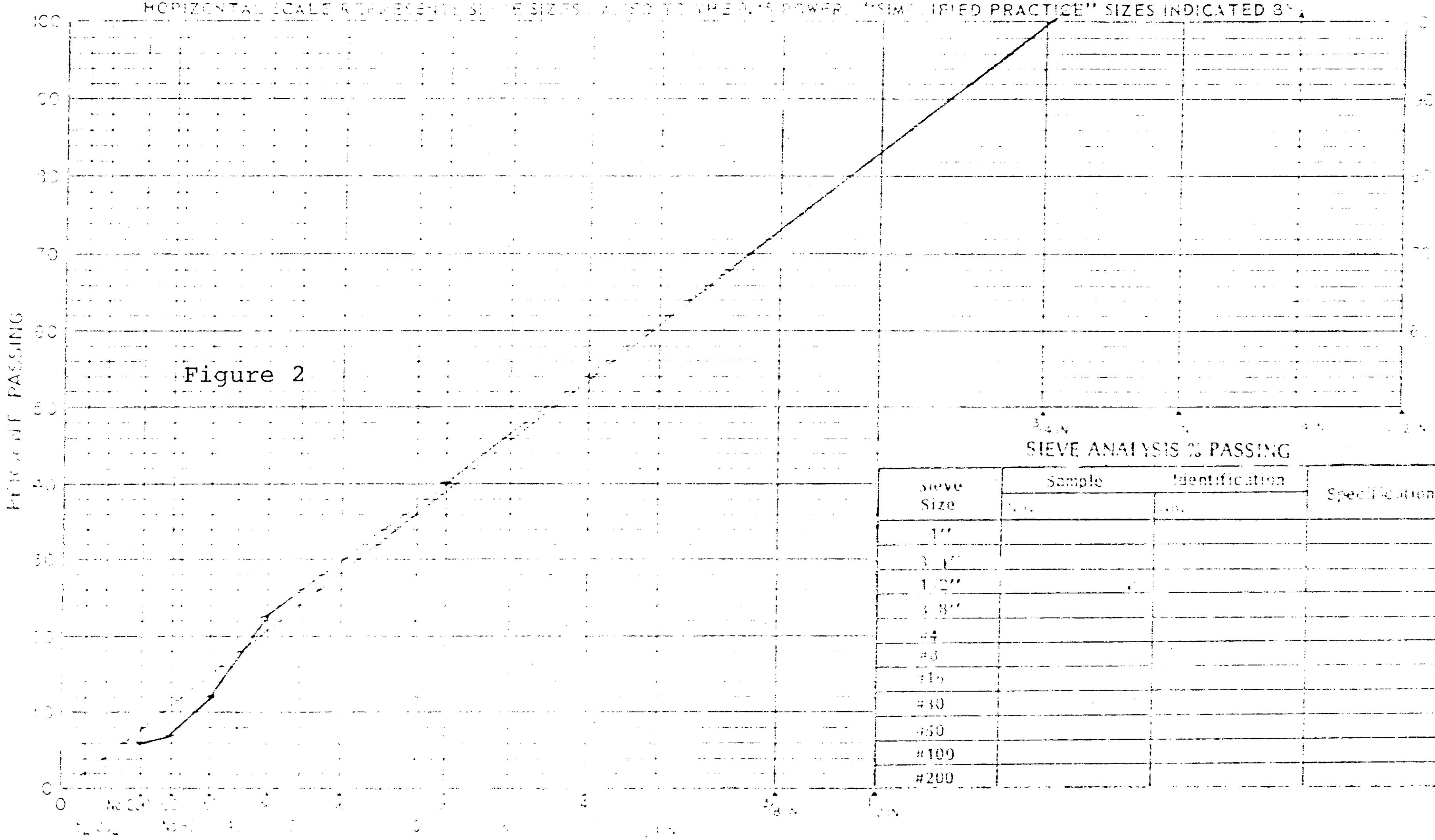
SAMPLED FROM ... SIEVE METHOD | REMARKS

FORM 820921
8-75

IOWA DEPARTMENT OF TRANSPORTATION

GRADATION CHART

HORIZONTAL SCALE REPRESENTS SIEVE SIZES RAISED TO THE 0.45 POWER. "SIMPLIFIED PRACTICE" SIZES INDICATED BY ▲



SIEVE ANALYSIS % PASSING

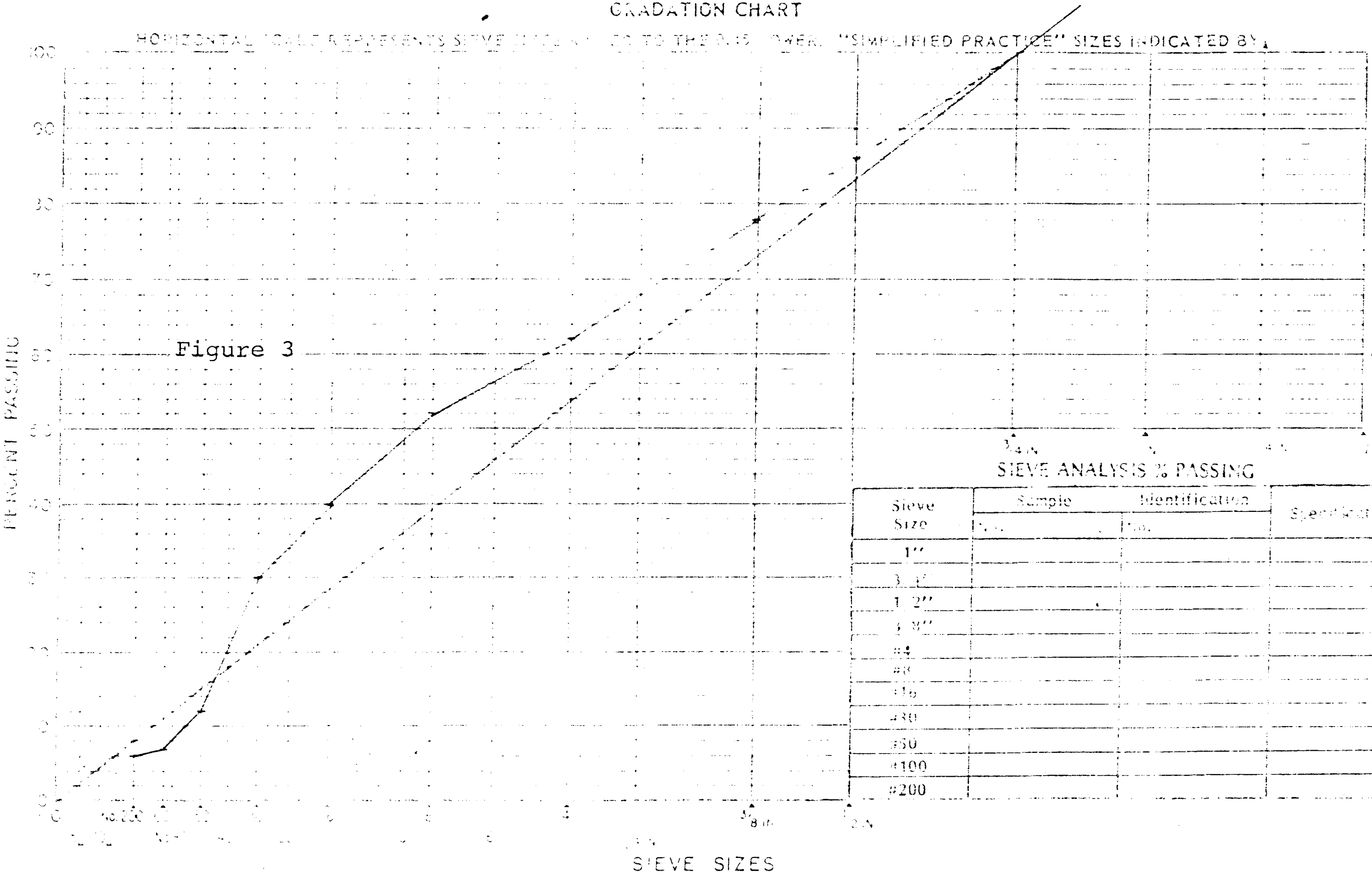
Sieve Size	Sample Identification		Specification
	No.	No.	
1"			
3/4"			
1/2"			
3/8"			
#4			
#8			
#16			
#30			
#50			
#100			
#200			

Co.	PROJECT NO.	TYPE CONST; LOCATION ON PROJECT
TYPE, SOURCE, PRODUCER OF AGG.		

SAMPLED FROM	SAMPLED BY	DATE	QUANT. REPRESENTED	LAB NO.	DATE	SIEVE METHOD	REMARKS

DEPARTMENT OF TRANSPORTATION

GRADATION CHART



SIEVE ANALYSIS % PASSING

Sieve Size	Sample Identification No.	No.	Specification
1"			
3/4"			
1/2"			
3/8"			
#4			
#8			
#16			
#30			
#50			
#100			
#200			

CO. PROJECT NO. | TYPE CONST., LOCATION ON PROJECT

TYPE, SOURCE, PRODUCER ...

SAMPLED FROM | ... | SIEVE METHOD | REMARKS

FORM 820925
8-75

DEPARTMENT OF TRANSPORTATION

GRADATION CHART

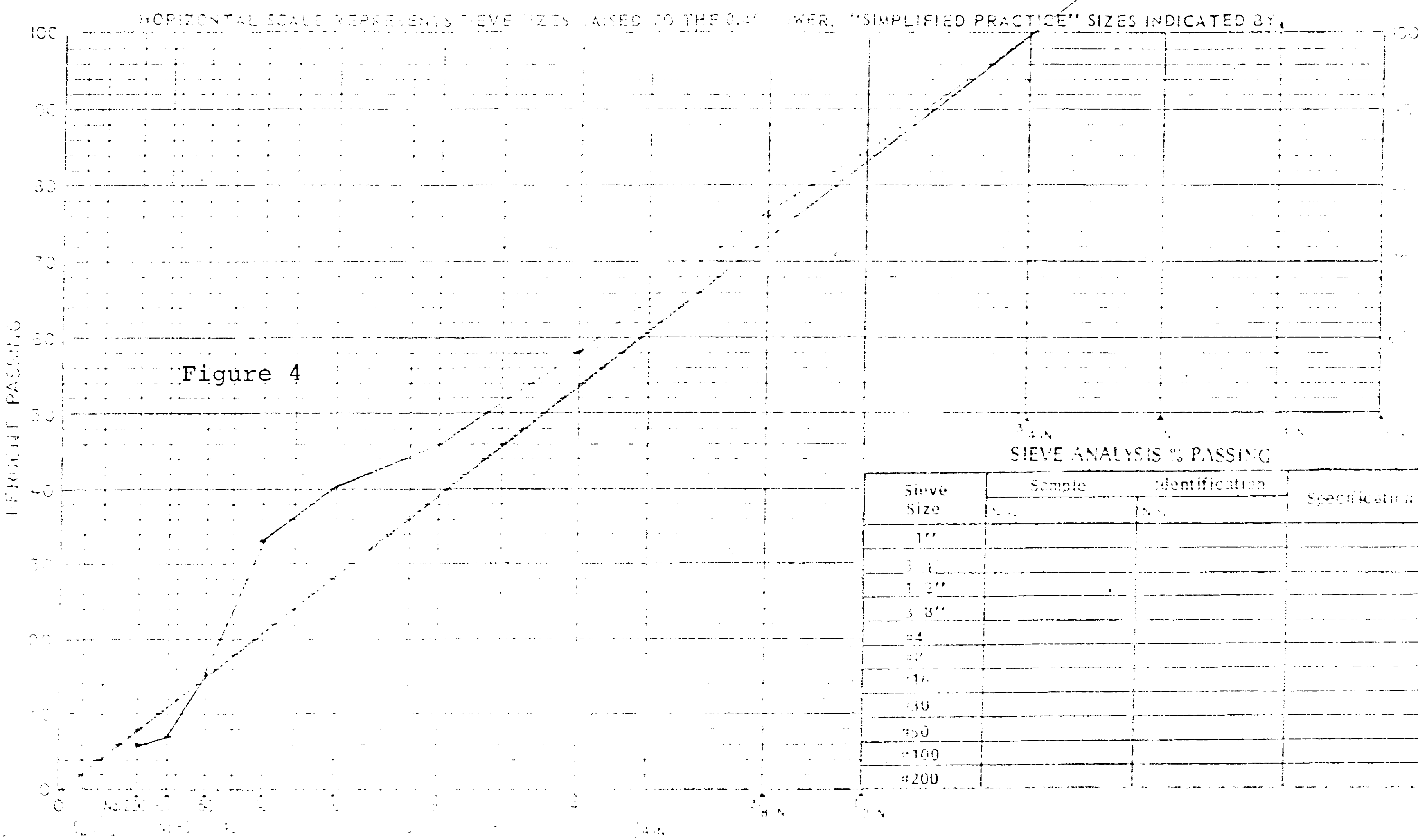


Figure 4

SIEVE ANALYSIS % PASSING

Sieve Size	Sample No.	Identification No.	Specification
1"			
3/4"			
1/2"			
3/8"			
#4			
#8			
#16			
#30			
#50			
#100			
#200			

Co

TYPE, SOURCE, PRODUCER OF A...

TYPE CONST; LOCATION ON PROJECT

SAMPLED FROM | SAMPLED BY | DATE | SIEVE METHOD | REMARKS