THE UNIVERSITY OF NEW SOUTH WALES

WATER RESEARCH LABORATORY

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An Appraisal of Sands Available in Sydney for use in Hydraulic Models

by

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The University of New South Wales

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Report on -

AN APPRAISAL OF SANDS AVAILABLE IN SYDNEY FOR USE IN HYDRAULIC MODELS.

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SUMMARY

Sand is commercially available in Sydney from a variety of sources. Samples were obtained from commercial suppliers and sieve analysis and properties are compared with sands recognised as suitable for use in hydraulic models.

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An Appraisal of Sands Available in Sydney for use in Hydraulic Models

Report by

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INTRODUCTION

Sands are used in hydraulic models to represent movable beds. The term 'movable bed' is the portion of the model or the prototype over which the water moves and in the process shapes the material, which is usually granular, into a distinct shape or pattern corresponding to a given pattern of water movement and given solid limits or boundaries of the full scale features under consideration.

Water movement may be classified in two types for the purpose of considering the construction of an hydraulic model as follows:-

(1) Rapid transporting movement associated usually with high turbulence, various degrees of over saturation of the bed layers, impingement or vortices as in scour occurring at an engineering structure.

(2) Gentle but persistent movement principally moving the bed material grain by grain along its surface with little change in bed saturation with a tendency for redisposition in characteristic areas and erosion in others following a continous change in the overall geometry such as is characterised by river or estuarine flow.

(3) Water movement, which, by changes in its pattern from place to place, results in the movement of material in suspension and its deposition in characteristic fashion or area.

The latter class of water movement and its effect on sediments cannot be simulated by any material coming under the general description of sand and is therefore not applicable to this discussion.

The first two classifications may still further be reduced, for the sake of brevity interminology, to, firstly, scouring movements and, secondly, as distinct from scouring, eroding movements.

With our present knowledge of the mechanics of movement of granular materials in open channels, the special conditions of grain behaviour can be more readily appreciated and put to use to design a suitable hydraulic model to carry out prescribed tests.

Motion of Granular Materials in Scour Movements.

The motion of the grains of sediment under scouring movement of water is usually a combination of saltation or "projected" suspension and bed movement. The initial movement of the grains is chacteristically brought about by the action of vortices, jets or "boils" and the particles are carried on a heterogeneous path until under the action of gravity and in the more subdued conditions beyond the centre of scour they resettle.

The fall velocity of the particle and the water velocity pattern determines the average gross displacement of the particle in a given time. The fall velocity is another means of describing the water drag on the particle and for turbulent flow within a limited range of velocity the drag is proportional to v^2.

The gravitational force ratios on particles and water alike are proportional to the linear scale and the model generally conforms to the prototype when Freude velocity and time scales are adopted. In regions outside the general scene of scour activity, strict similarity may not apply and bank slopes may differ slightly where sediment transport is effected under quieter flow conditions. These regions, being regions of build-up or agradation, are not so important as far as the purpose of the model is concerned unless the sediment used in the model is excessively coarse when an erroneous impression will be created by an excessively high bank surrounding the scour hole.

To avoid this kind of error the choice of a finer sand is recommended. The limit of particle size is then such that excessive quantities of sand will not bewashed from the precincts of the model.

Motion of Granular Materials as Bed Load in Models

To simulate movement of alluvial materials in rovers the model is usually designed with a limited amount of scale distortion. The horizontal scale is smaller than the vertical scale in order to attain turbulent flow in the model as in the prototype. The ratio of horizontal to vertical scale is limited by the necessity to avoid excessive distortion on deposited banks of alluvial material which form at the natural angle of repose.

The choice of horizontal scale is usually limited by model space available and the choice of movable material is limited to a class of material which will be moved as bed load by the velocities occurring in the model. Materials which are too light or are of too small grain size may be thrown into suspension and may remain there. Materials which are not kept in suspension by the flow but are suitable to represent bed movement fall in a very narrow band of grading.

Experiments with sand have shown that movement commences with rising flow as one or two visible particles are moved in a region. As flow rates are increased a progression of moving or stopping grains is established. At the threshold of movement it has been shown that the movement of the grains is a function of velocity fluctuation in the flow and that turbulent flow must exist. Further, the threshold of movement occurs at values of $\frac{D}{\delta'}$ 0.40 to 0.53 where D = grain size δ' = laminar sublayer thickness. When with increasing flow the value of $\frac{D}{\delta'}$ exceeds 0.53 ripples begin to form and the ripples give place to dunes as $\frac{D}{\delta'} - 1$. Ripples formed in a model create bed formations which, if allowed to grow, would be much out of scale with prototype bed forms.

The bed material selected for such a model must therefore be selected such that it is mobile but not of a grain size susceptible to the formation of ripples.

Although not possessing the experimental and theoretical material now available on this topic, Kramer (Proc.A.S.C.E. Vol. 60.No.4 Pt.1. April 1934) conducted experiments and as a result of his experiments prescribed three types of sand gradings which in general meet the restrictions applicable to these above.

Of these sands, one known as Kramer's No.III grading, has perhaps the best characteristics of the three. These characteristics are given in the following table:-

Size of grains. M.M.	Median Dia. of grains	Uniformity Modulus	Critical Tractive Stress lb/sq.ft.
0.385 to 5.0	0.55	0.414	0.100

Such a sand would be suitable for use in models where the working water depths ranged 3.7 inches to 0.77 inches with bed slopes ranging 1:1000 to 1:400.

This sand prescribed by Kramer is used in this report in a comparison of sands available in Sydney from commercial supply.

Sands Commercially available in Sydney.

The following sands which are commercially available in Sydney were sampled:-

Table I

Name of Sand	Origin of Supply	Colour and Description	Median grain size mm.	M Uniformity Modulus
Botany Sand	Sand hills south of Sydney	Yellow, free from silt, fine.	0.14	0.413
Nepean Sand	Nepean River west of Sydney. Dredged and screened from river.	Washed and screened, small amount of silt.	0.19	0.309

(Table I cont'd)

Name of Sand	Origin of Supply	Colour and Description	Median grain size mm.	M. Uniformity Modulus
Narrabeen Sand	Narrabeen Beach north of Sydney Beach dune sand.	Brown, small amount of shell.	0.26	0.462
Roseville Sand	Dredged from Upper Middle Hbr. Sydney, washed.	Grey. slight trace of salt free of silt.	0.28	.387
Lane Cove Sand	Dredged from Lane Cove River, Sydney, washed	Grey, Slight trace of salt, free of silt	0.260	.522
Georges River Sand	Dredged Georges River south of Sydney.	Brown - small amount of silt	0.18	

The sieve analyses of each of the sands shown in the above table have been plotted on diagrams 1 to 6 and the sieve analyses of the Kramer No.III sand has been shown on each for comparison purposes.

It will be seen that no sand commercially available in Sydney conforms very well with the grading of Kramers No.III sand for use in river models with movable beds. All are too fine and would therefore be susceptible to excessive ripple formation. Crushed aggregate as used by the Water Conservation and Irrigation Commission in scour control models is coarser than Kramers No.III sand and may only be suitable for models of comparatively large scale.

The results plotted in Figs. 1 to 6 are taken from individual samples and some variation is expected if sampling procedures were extended to reduce errors of sampling. The samples taken may be regarded as typical, however, and are very useful in making a comparison of sands for hydraulic model purposes.

Recommendations

For the purpose of making a recommendation, the classes of hydraulic model to which the recommendations would be applicable have been divided into two groups as follows:-

Group I - Models for scour studies

II - Models in which bed movement and deposition is the principal object of study.

For Group I - Scour Studies

The selection of a sand to meet the needs of Group I does not require special attention as any sand in the group would give reasonably satisfactory results. It should be noted, however, that finer sands produce an equilibrium scour hole more rapidly than coarser sands. A programme of experiment will therefore be speeded if finer sands are used. Sands which are finer may tend to wash out of models constructed to larger scales and their use could result in excessive loss of sand in the drain system. A coarser sand should then be tried until loss from this cause is reduced to a satisfactory extent.

For Group II - Bed Movement Studies

Sydney sands are in general too fine for use in movable bed models. Nepean sands and Georges River sand are known to vary widely in grain size. Those tested were finer than could possibly be obtained from these sources by deliberate selection. Sands from Botany, Lane Cove, Roseville and Narrabeen on the other hand are relatively consistent in grain size and may be regarded generally as too fine for movable bed models of the usual range of scale and bed tractive stress.

Coarser sands from Nepean are therefore recommended for general use and if necessary the grading should be adjusted by adding screened crushed stone of about median size 0.5 to 0.8 mm and by screening out excessive quantities of material below a grain size of 0.3 mm.

AN APPRAISAL OF SANDS AVAILABLE IN SYDNEY FOR USE IN HYDRAULIC MODELS

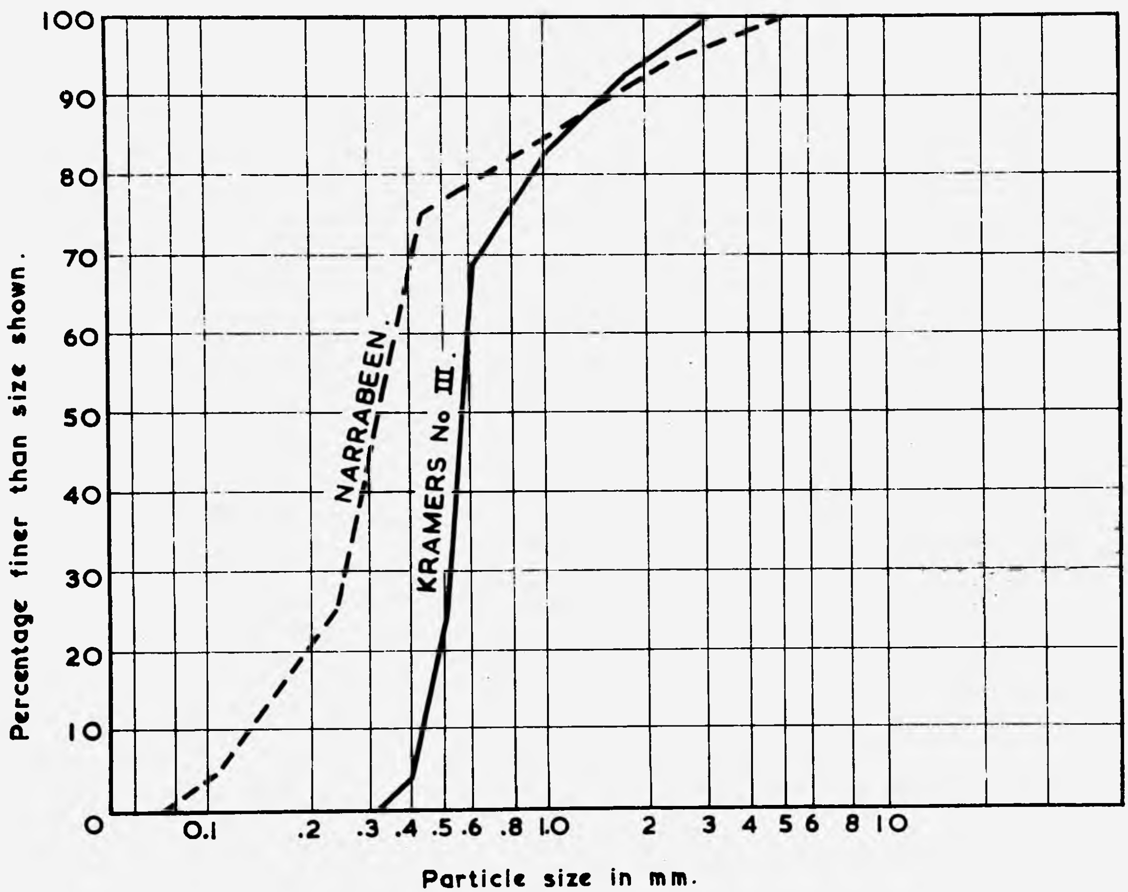

Fig. 1.

AN APPRAISAL OF SANDS AVAILABLE IN SYDNEY FOR USE IN HYDRAULIC MODELS

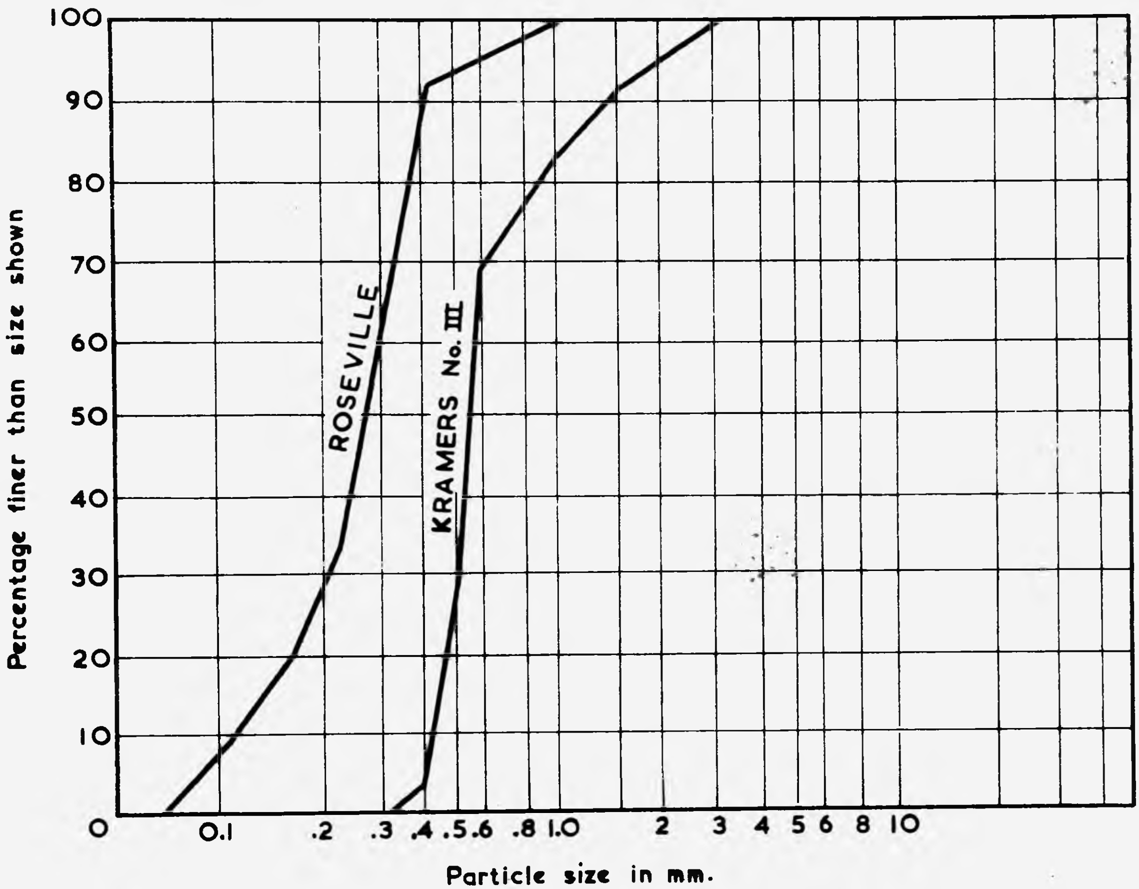

Fig. 2.

AN APPRAISAL OF SANDS AVAILABLE IN SYDNEY FOR USE IN HYDRAULIC MODELS

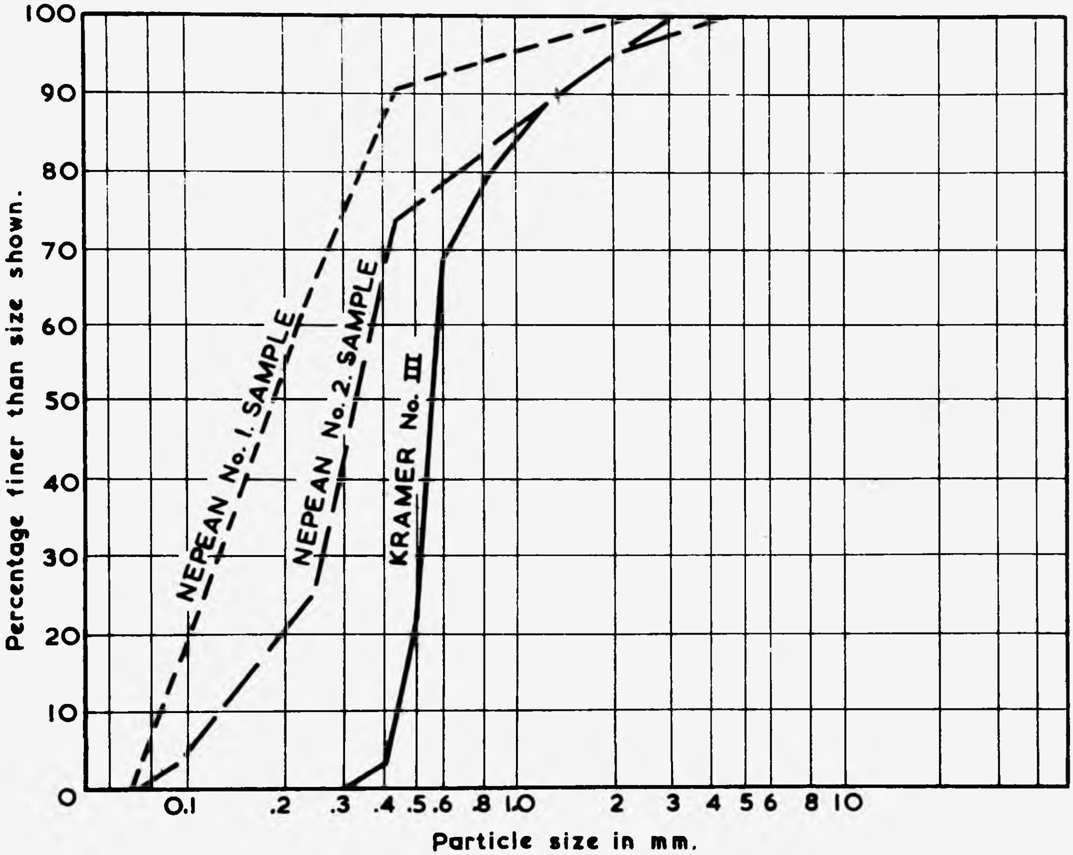

Fig. 3.

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AN APPRAISAL OF SANDS AVAILABLE IN SYDNEY FOR USE IN HYDRAULIC MODELS

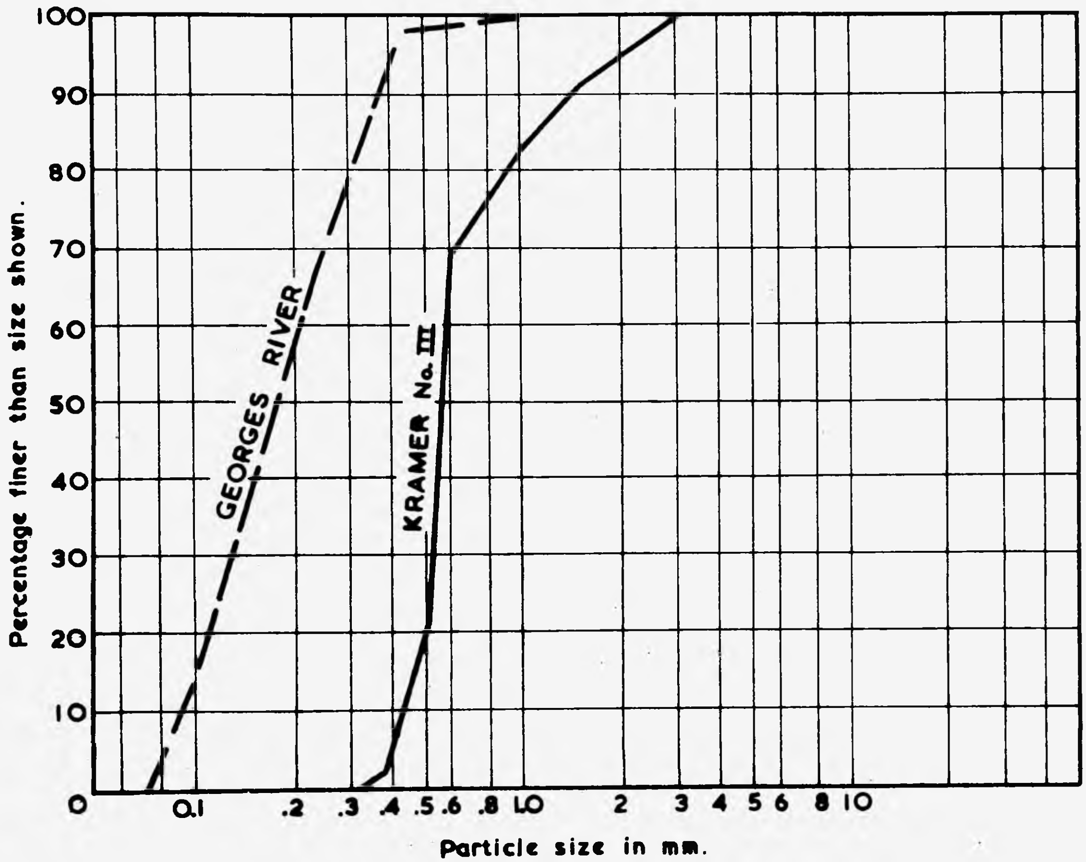

Fig. 4.

CE-E-2450

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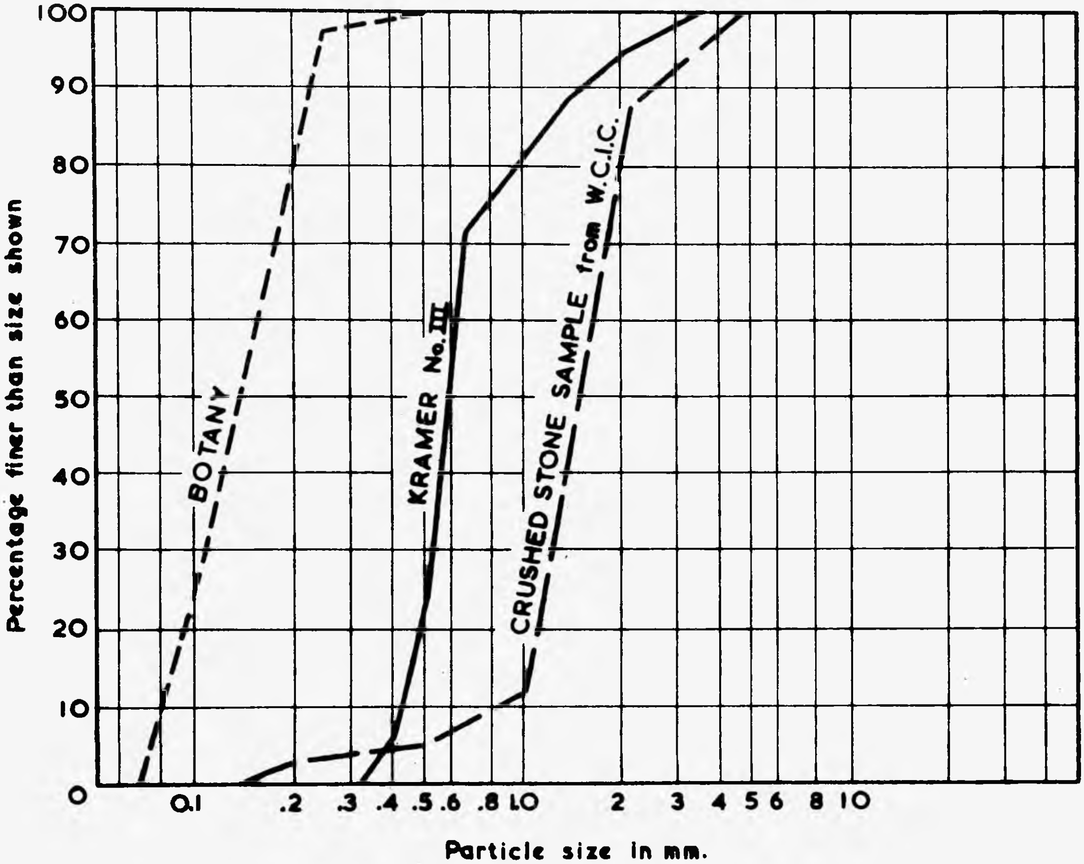

Fig. 5.

CE-E-2451

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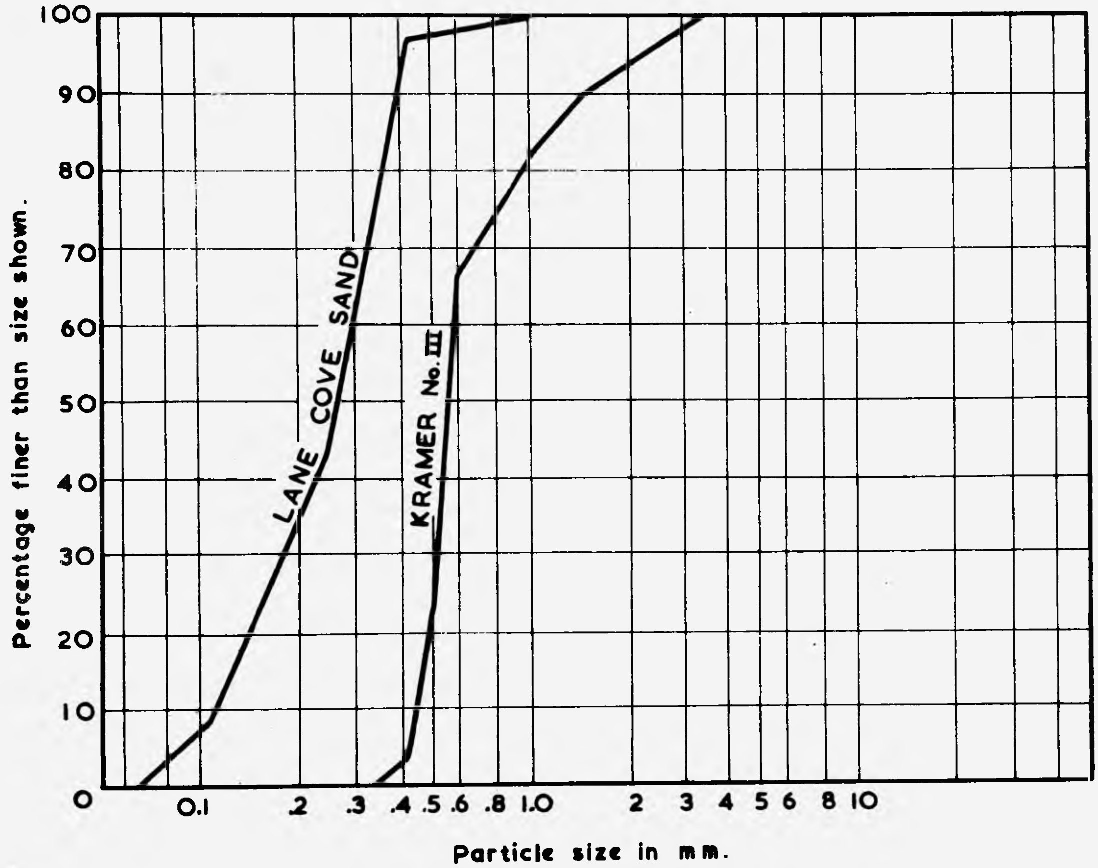

Fig. 6.

CE-E-2452