A COMPARATIVE ASSESSMENT OF MALIR SAND AS A FINE AGGREGATE IN BUILDING CONSTRUCTION

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Various physical and chemical tests carried out on the sand from the river bed of Malir near Karachi indicate that although it is essentially a calcareous aggregate, yet it is suitable for building construction. Properties like grading, soundness, voids and specific weight of the aggregate, compressive strength, autoclaving and fire endurance of cement sand mortars have been compared with other siliceous fine aggregates.

Introduction

Many types of aggregates, both natural and artificial, are used in building construction; the aggregates are relatively inert particles that act as filler. Natural aggregates are produced by the natural disintegration of rocks, and are generally of a siliceous nature. Fine aggregate or sand is defined in British Standard Specifications as an aggregate made up mainly of particles below 3/16 inches in size. A good fine aggregate consists of hard tough grains of different sizes and it should be free from minerals of weak friable nature,[1] adherent coatings and vegetable matter. It should not contain any appreciable amount of clay balls or pellets.

The sand from the river bed of Malir (near Karachi), which is extensively employed as a fine aggregate in building construction, is a calcareous aggregate consisting of 59.85% of calcium carbonate and 31.57% of silica. Although low silica content in a fine aggregate is not considered desirable, nevertheless Malir sand is being extensively used and gives good strength with portland cement. A detailed investigation of the physical as well as chemical characteristics was therefore taken up in order to determine the reason for the superior behaviour of this sand in spite of the unfavourable indications of the chemical analyses.

The sand has been studied by microscopic and X-ray techniques. The quality of the aggregates has been tested by making them into cement mortars and carrying out acceptance tests as described in the latter part of this paper. Siliceous sand from the river bed of Ravi (near Lahore) has been used wherever necessary for the comparison of different characteristics.

Silt and Organic Matter

The silt content in Malir sand is only 2.70% B.S. 882: 1954[2] (Natural fine aggregate for concrete) specifies the maximum limit of 3% of clay, silt and fine dust. For plastering, rendering and mortar the limit for silt is extended to 5%. Harmful organic impurities, if present in sufficient quantities, affect adversely the strength or durability of the concrete and mortar. These impurities, in this sand, are found only in traces.

Microscopic and X-ray Analysis

Malir sand on microscopic examination was found to consist of two distinct types of particles: (i) yellow brown separate rounded particles with pitted and rough surfaces and (ii) white crystals with sharp angles and polished surfaces. The X-ray studies revealed that the brown particles are calcareous and the white crystals are α-quartz. Table 1 shows the chemical composition of Malir sand, brown particles and quartz grains. The chemical analysis confirms the microscopic and X-ray investigations. The brown particles of Malir sand are mainly calcareous containing 79.4% of calcium carbonate and the white particles are siliceous, consisting of 97.2% of silica.

TABLE 1.—CHEMICAL ANALYSIS OF MALIR AND RAVI RIVERS SANDS.

No.	Description	SiO_2	CaO	MgO	R_2O_3	Ignition loss
1.	Malir sand	31.57	33.5	2.85	2.89	28.09
2.	Malir sand Quartz particles	97.20	1.00	traces	1.20	—
3.	Malir sand Brown particles	8.90	44.50	3.80	3.5	38.28
4.	Ravi sand	80.50	—	2.27	13.61	2.85

Grading

The grading of a sand is one of the most important properties for determining its suitability

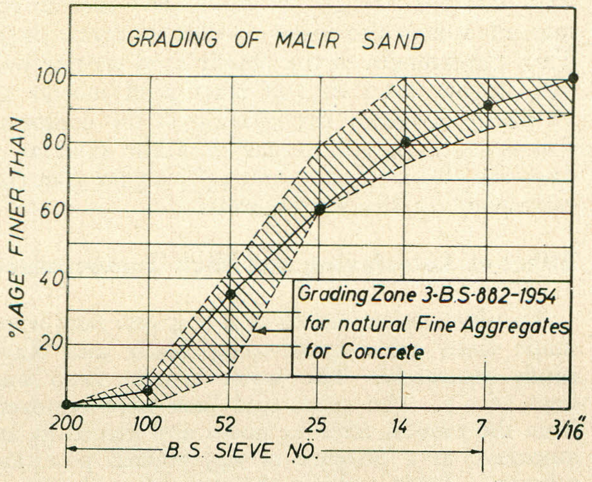

Fig. 1.—Grading of Malir sand.

for use in building construction. The B.S. Specifications specify different grades of sand for different uses. Figure 1 shows the grading of the Malir sand which lies in zone No. 3 as specified for fine aggregate in B.S.S. 882 (1954)[2] for concrete. The Malir sand is suitable for concrete mortar, in plain or reinforced brick work, block walling, masonary, external rendering and internal cement plastering. If coarse particles retained on sieve No. 7 are removed, Malir sand can also be used for the finishing coat of plaster.

In grading Malir sand, one has to see whether the hard quartz particles are well distributed in the matrix of soft calcareous particles or whether they are segregated in certain fractions of the sand. The chemical analyses of different fractions were performed. The results are shown in Table 2. The fraction retained on sieve No. 16 contains

TABLE 2.—SILICA AND CALCIUM CARBONATE IN DIFFERENT FRACTIONS OF MALIR SAND.

Sieve No.	Percentage of Malir sand retained	Percentage in each fraction	
		Silica	$CaCO_3$
16	12.5	17.77	80.90
36	30.5	27.94	70.00
52	12.0	38.55	60.00
72	15.0	47.42	51.00
85	10.0	68.48	26.00

17.77% of silica and 80.90% of calcium carbonate, while that retained on sieve No. 85 consists of 68.48% of silica and 26.80% of calcium carbonate. The chemical analysis of different fractions shows that the finer portion contains more of quartz particles and the coarser fraction consists more of brown particles. Since Malir sand is composed mostly of coarse particles, it is on the whole calcareous in nature. On the basis of above findings one can conclude that such an aggregate will give concretes that are not very resistant to abrasion, and that this sand should not be used with high alkali cements.

Voids and Specific Weight

It is a general practice to wash a sand to remove silt which results in an increase of 5 to 10% oi the moisture content. This moisture will hold the particles apart in voids which is important to the engineers as the mix is generally specified by volume on the basis of dry aggregates. Figure 2 shows the effect of moisture on percentage voids and specific weight of dry coarse Malir sand and fine Ravi sand. The voids in dry Malir and Ravi sands are 34.0 and 44.4%, respectively. Therefore Malir sand falls within the limits for a good fine aggregate. The specific weights of both sands at different water contents are also given in Fig. 2.

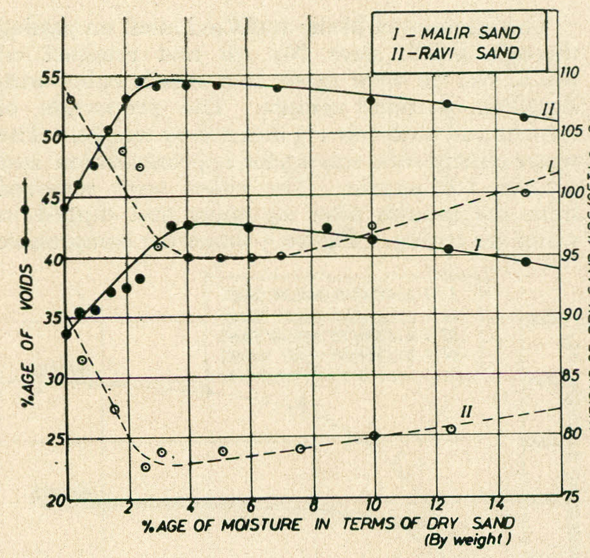

Fig. 2.—Effect of moisture on percentage of voids and specific weights of Malir and Ravi sands.

Soundness

The soundness test of an aggregate indicates its behaviour in sulphate and saline water. The different sieve fractions of four sands, namely (i) Ravi sand (fine silica sand), (ii) Manghopir sand (coarse silica sand), (iii) Thana Bulakhan sand (fine silica sand), and (iv) Malir sand have been compared according to A.S.T.M. designation C88-55T.[3] Table 2 shows the disintegration in magnesium sulphate solution after 7 cycles of alternate dipping and drying. The least disintegration is observed in Malir sand fractions.

TABLE 3.—DISINTEGRATION OF DIFFERENT SANDS ON 7 CYCLES OF ALTERNATE DIPPING AND DRYING IN MAGNESIUM SULPHATE SOLUTION.

Aggregate fraction	Malir sand	Ravi sand	Manghopir coarse silica sand	Thana Bulakhan fine silica sand
Passing sieve No. 14 retained on sieve No. 36	6.0	—	12.00	9.5
Passing sieve No. 36 retained on sieve No. 52	4.0	—	7.00	12.0
Passing sieve No. 52 retained on sieve No. 72	6.5	11.09	—	10.0
Passing sieve No. 72 retained on sieve No. 85	5.5	9.0	—	12.0

Compressive Strength

The fractions of Malir and Ravi sands on passing through B.S.S. sieve No. 36 and retained on B.S.S. No. 72 were made into 2-inch cubes with Zeal-Pak portland cement. The proportion of cement and sand was 1:3 and 1:6 by weight. The water cement ratio was 0.5 for 1:3 composition and 0.7 for 1:6 mortar. The cubes were removed from the moulds after 24 hours and dipped in water for curing. Figure 3 shows the compressive

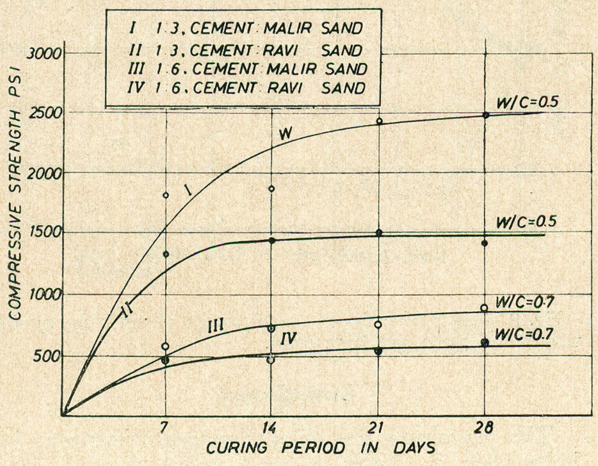

Fig. 3.—Compressive strength of mortar cubes at different ages.

strength obtained on 2-inch cubes of the mortars made from Ravi and Malir sands at intervals of 7, 14, 21 and 28 days. The strength of Malir sand mortar at 7 days of 1:3 ratio is about 32% higher than that of the Ravi sand of the same proportion. The strength of Malir sand mortar of the above mix increased considerably at 28 days but the strength of Ravi sand mortar remained almost the same as that at seven days. Thus the strength of the Malir sand mortar was 79% higher than that of Ravi sand mortar at 28 days. Similarly the increase in the compressive strength in 1:6 mortar of Malir sand at 7 days and 28 days was 24 and 43% higher than the corresponding Ravi sand mortar.

Effect of Autoclaving and High Temperature

Two-inch cubes and 16 × 4 × 4 cm. bars were made from 1:6 mortar using Malir and Ravi sands separately. The water cement ratio was kept at 0.7. The cubes and bars were removed from the moulds after 24 hours and placed in an autoclave at a pressure of 135 pounds p.s.i. for 3 hours. Table 4 shows the strength and expansion obtained on the autoclaved samples cooled to room temperature. Malir sand mortar developed less compressive strength and showed more expansion than that of Ravi sand mortar.

The Malir sand mortar cubes of the above specifications were autoclaved for 10 hours also at the same pressure but there was no further increase in the strength of the mortar than that obtained by 3-hour steam curing. The increased strength in the case of Ravi sand mortar may be due to the reactions between siliceous aggregate and calcium hydroxide liberated. The silicate formation similar to sand-lime brick formation increases the strength and reduces expansion of the mortar.

TABLE 4.—EFFECT OF AUTOCLAVING AT 135-LBS. PER SQ. INCH FOR 3 HOURS ON STRENGTH AND EXPANSION OF MORTARS.

Description	Compressive strength in lbs. per sq. inch	Expansion in m.m.
Malir sand mortar (1:6)	790	0.12
Ravi sand mortar (1:6)	1130	0.033

TABLE 5.—EFFECT OF HEATING ON THE COMPRESSIVE STRENGTH OF MORTAR CUBES.

Description	Compressive strength in lbs./sq. inch 3 months		Percentage loss of strength on heating
	Normal	Heated to 600°C.	
Malir sand cubes	1248	728	41.6
Ravi sand cubes	1120	450	59.5

Two-inch mortar cubes using both sands separately were cured for 3 months in water. The compressive strength of these cubes was obtained before and after heating them at 600 °C. Table 5 shows the loss in strength on heating. The percentage loss of compressive strength is less in the case of Malir sand.

Conclusion

From the various physical and chemical tests it is seen that Malir sand is essentially a calcareous aggregate. When ordinary water curing is carried out, it developes better compressive strength than the Ravi sand which is a siliceous aggregate. The superior compressive strength appears to be due to the coarser nature of Malir sand and makes it quite suitable building material. However, in the manufacture of precast units or pipes where steam curing is required, a siliceous aggreagte would be more suitable. The soundness test indicates that concrete made with Malir sand will be more resistant to saline and sulphate attack. There is also less loss of compressive strength in mortars made from Malir sand when exposed to high temperatures. This indicates that calcareous aggregate will have better fire resistant properties than a siliceous aggregate.

References

1. M. O. Withey and G. W. Washa, *Materials of Construction* (John Wiley and Sons Inc., New York).
2. British Standards Specification No. 882 (1954).
3. A. S. T. M. Standards, Part 3 (1955).