Investigation of Utilization of Manufactured Sand in Cement Mortar

D.L.W. Padmasiri[1] and S.M.A. Nanayakkara[2]
Department of Civil Engineering, University of Moratuwa, Sri Lanka

ABSTRACT: This paper presents results of an experimental investigation carried out to study the influence of particle shape and fines content of crushed rock fines on workability and strength of cement mortar. Different types of crushed rock fines such as commercially available manufactured sand (i.e. plastering M-sand, concrete M-sand), processed and unprocessed quarry dust are considered in this investigation. The flow cone test is used to evaluate angularity of particles. The flow table test and ball drop methods are used to evaluate the workability of mortar. Results show that strength of harden mortar increases with the increase of angularity of particles. However, when the fines content is high, strength decreases even with a high angularity. It is also observed that workability of fresh mortar decreases with the increase of angularity and fines content of fine particles.

Key words: Manufactured sand, Angularity, Fines content, Strength, Workability

1 INTRODUCTION

River sand has been used as a fine aggregate for concrete and mortar for many centuries. With the increase of infrastructure development projects, demand for the river sand has increased and excessive and uncontrolled river sand extraction has caused huge environmental problems. River sand is not a renewable natural resource and hence it has come to a situation where it is necessary to find an alternative material for river sand.

This research was focused on effective utilization of manufactured sand and quarry dust for cement mortar. Their specific gravity, particle size distribution, shape and surface texture influence markedly the properties of mortar and concrete in fresh state according to Goncalves **(**2007**).** As mentioned in Goncalves **(**2007**)** the mineralogical composition, toughness, elastic modulus and degree of alteration of aggregates are generally affecting the properties of mortar and concrete in the hardened state. According to Westerholm et al (2008), shape and fines content of fine aggregate has a significant impact on water demand of mortar.

River sand has a rounded shape than manufactured sand due to weathering whereas manufactured sand and quarry dust have angular shapes due to crushing process of manufacturing. In the case of fines content, river sand has less amount of fines compared with other two alternatives.

This paper describes the experimental investigation carried out to study the influence of physical properties of fine aggregates especially fines content and angularity of particles on properties of fresh and hardened mortar.

2 EXPERIMENTAL INVESTIGATION

2.1 *General*

Five different types of fine aggregates were used in this study including river sand (RS), plastering manufactured sand (PMS), concrete manufactured sand (CMS), unwashed manufactured sand (UMS) and unprocessed quarry dust (QD). All sand types were sieved by 2 mm sieve for the preparation of mortar.

Several physical properties of fine aggregates were investigated. Flow cone test and sieve analysis were carried out to evaluate angularity factor and particle size distribution of fine aggregate particles respectively.

2.1.1 *Flow Cone Test*

The apparatus for the flow cone test was fabricated based on the dimensions given in Alford et al (1979**).** Angularity number for a given fine aggregate type is calculated based on the flow time of particles passing through the flow cone. First, weight of sample is corrected for the specific gravity of aggregate to compensate the flow time due to difference in specific gravity of aggregates. RS was taken as the reference material and correction factor for difference in specific gravity of particles was calculated using the following equation.

$$\frac{sgA}{sgB} \text{ x M} = c$$

1 Former Student 2 Professor e-mail: sman@civil.mrt.ac.lk

Where, sgA is specific gravity of aggregate, sgB is specific gravity of RS, M is mass of RS and C is corrected weight.

Then corrected flow time with respect to corrected weight was calculated using following equation.

$$\frac{c \times T0}{1000} = Tc$$

Where, T0 is original flow time for 1000 g of sample and Tc is corrected flow time.

Corrected weight for initial weight of 1000 g, corresponding corrected flow time and angularity number for different fine aggregate types are given in Table 1. For the calculation, specific gravities given in Table 2 have been used.

Table 1: Angularity of different fine aggregates

Fine aggregate type	Corrected weight (g)	Original flow time (s)	Corrected flow time (s)	Angularity number
RS	1000	18.82	18.82	1
PMS	1000	21	21	1.12
CMS	1030.30	23.6	24.32	1.29
QD	1041.67	39.31	49.95	2.65
UMS	1037.88	52.21	54.19	2.88

Shapes of particles were observed using enlarged images of photographs taken. Particles in the range of 1.88 mm - 2 mm were selected for the observation. RS shows rounded shape while other particles show angular shapes. All sand types other than RS show a crystalline appearance. Fig 1 shows images of different types of fine aggregate particles according to the ascending order of angularity number.

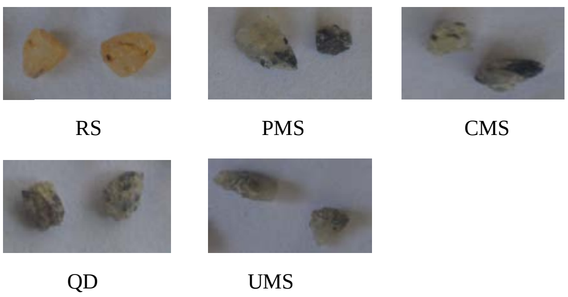

Figure 1: Particle shapes of different fine aggregates

2.1.2 *Sieve Analysis and Water Absorption*

Fines content and particle size distributions were determined using sieve analysis in accordance with BS 812:103.1 (1985) and grading curves are shown in Fig.2. Water absorptions of different types of sands were determined in accordance with BS 812 (1995) and test results are given in Table 2.

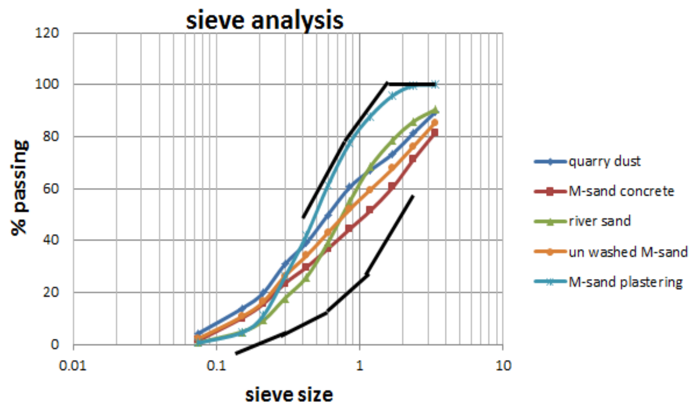

Figure 2: particle size distribution

Table 2: Physical properties of different fine aggregates

Fine aggregate type	Water absorption (%)	Fines content (%)	Specific gravity
RS	0.9	0.66	2.64
PMS	0.7	0.58	2.64
CMS	0.52	1.53	2.72
QD	0.45	4.29	2.75
UMS	0.34	2.27	2.74

2.1.3. *Tests on Mortar*

Tests on mortar were carried out in accordance with BS 4551(1980).

Mix Proportion

In this study, constant water/cement ratio of 0.5 with 1:3 cement to fine aggregate by volume ratio was used for all mortar mixes. Mortar was prepared according to the recommendations given in BS 4551 (1980) using a mortar mixer.

2.1.4 *Strength Properties*

Compressive strength at 7 days was obtained in accordance with BS 4551 (1980). Tensile strength was determined by carrying out splitting tensile test (at 7 days) in accordance with BS 1881-117 (1983).

2.1.5 Workability

Flow table and consistency tests were carried out in accordance with BS 4551 (1980). The ball dropping test was used to measure the consistency of the fresh mortar.

1 Former Student 2 Professor e-mail: sman@civil.mrt.ac.lk

3 RESULTS AND DISCUSSION

3.1 *Particle shape, size distribution and fines content*

From Table 1, it can be seen that RS is having comparatively rounded and smooth shape considering angularity number. Also PMS has the least fines content(less than 75 µm), almost similar to RS. This is due to removal of fines as a result of excessive washing during PMS production. As expected, other three fine aggregate types have higher fines contents than RS. The grading curves are shown in Fig 2. All sand types used in the study are within the acceptable range for plastering and rendering mortar as specified in BS 1199 (1976).

3.2 *Compressive and Tensile Strength of mortar*

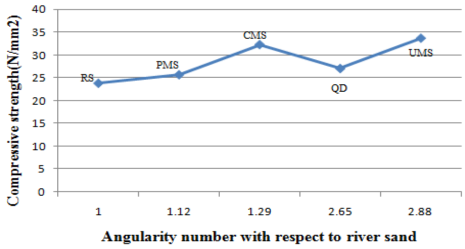

Figure 3: Compressive Strength with Angularity

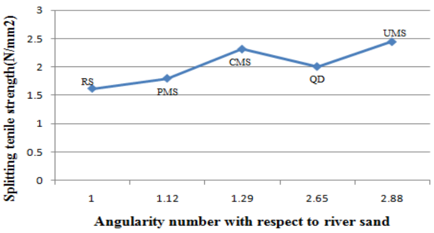

Figure 4: Splitting Tensile Strength with Angularity

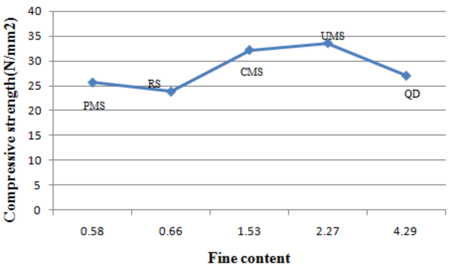

Figure 5: Compressive Strength with Fines Content

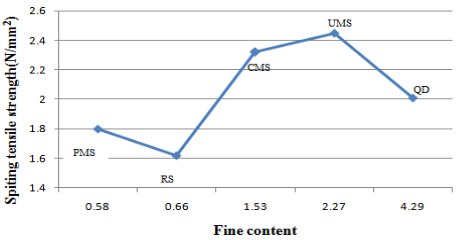

Figure 6: Splitting tensile Strength with Fines content

According to the test results shown in Fig 3 & Fig 4, the both compressive and tensile strengths increased with the increase of angularity number. Higher angularity number indicates that higher angularity and roughness of particles. When angularity is higher, particles can make effective bond compared with rounded shape particles. Hence increase of angularity number is resulting higher compressive strength and splitting tensile strength.

According to the test results shown in Fig 5 & Fig 6, both compressive and splitting tensile strengths have increased with the increase of fines content up to a limit and there after strengths have decreased. The probable reason for this behavior may be due to insufficient paste content to coat aggregate in the mix when there is higher fines content, and this leads to decrease in strength. In the case of quarry dust, it is not following the angularity number and strength relationship mentioned above. This is due to high fines content which has caused the decrease in strength.

3.2 *Workability of Cement Mortar*

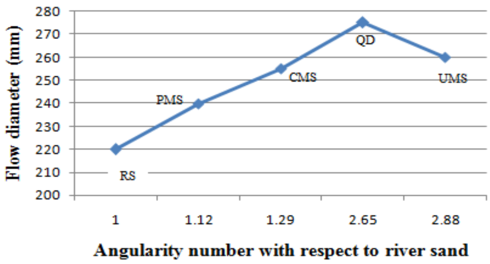

Figure 7: Flow Diameter with Angularity

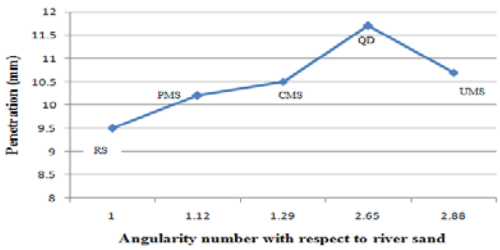

Figure 8: Penetration with Angularity

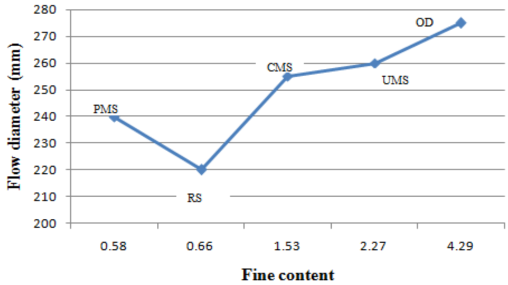

Figure 9: Flow Diameter with Fines Content

1 Former Student   2 Professor   e-mail: sman@civil.mrt.ac.lk

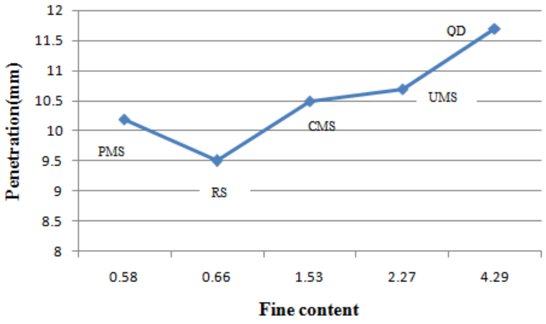

Figure 10: Penetration with Fines content

As mentioned in Cortes et al (2008), workability decreases when flow diameter is high for mortar in dry condition. Also when mortar is in dry condition, higher consistency indicates higher workability. Consistency of mortar is measured by the penetration of the ball in to the mortar sample. Here lower the penetration indicate higher consistency, because when mortar in dry condition cohesiveness of particle cause to resist the penetration.

According to the test results shown in Fig 7 & Fig 8, workability decreases with increase of angularity number. This is because of water demand is increasing with the increase of surface roughness of fine aggregate.

According to the test results shown in Fig 9 and Fig 10 increase of fines content of fine aggregate cause to the reduce the workability. As mentioned in Westerholm et al (2008**)** higher amount of fines increase the required amount of water to wet the particle surface adequately and to maintain a specific workability in the mixture. As strength properties of mortar, workability of QD is not following the angularity number and workability relationship mentioned above. This is due to high fines content which reduce the workability.

4 CONCLUSIONS

According to experimental results, it can be concluded that strength of hardened mortar increases with the increase of angularity number of fine aggregates. However, this is not valid for the fine aggregates having higher fines content excess of 4%. High fines content causes to decrease in strength of mortar.

It was also found that workability of fresh mortar decreases with the increase of angularity number of fine aggregates. Fines content of fine aggregates also has an effect on the workability of mortar. It was observed that when the fines content increases, the workability decreases.

Experimental results of sieve analysis show that the particle size distribution of all sand types used in the study are in the acceptable range for plastering and rendering mortar.

According to the experimental results, workability and consistency characteristics and physical properties of hardened mortar with PMS is close to RS compared with CMS, UMS and QD. Hence it can be concluded that PMS can be utilized for plastering and rendering mortar as an alternative for RS.

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1 Former Student 2 Professor e-mail: sman@civil.mrt.ac.lk