Advanced Materials Research Vol 1115 (2015) pp 160-165
© (2015) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMR.1115.160

Submitted: 2015-01-09
Accepted: 2015-03-26

Physical and Mechanical Properties of Concrete Incorporating Manufactured Sand

Maisarah Ali[1, a], Muhammad Hariz Nordin[1, b] and Siti Asmahani Saad[2, c]

[1] Manufacturing and Material Engineering Department, International Islamic University Malaysia, P.O. Box 10, 50728, Kuala Lumpur

[2]Civil Engineering Department, University of Technology Petronas, Bandar Seri Iskandar, 31750, Tronoh, Perak, Malaysia

[a]maisarah@iium.edu.my, [b]mhariznordin90@gmail.com and [c]asmahani.saad@gmail.com

Keywords: Manufactured sand; Concrete; Fine Aggregate; Compressive Strength; Workability; Water Absorption.

Abstract. Concrete is a common material that widely used in construction industry. Excessive usage of this material causes exhaustibility to its components, especially fine aggregate or sand. In this regard, the use of manufactured sand is considered as a part of the solutions to fix this problem as it is readily available. In this research, the manufactured sand is used at 40%, 50% and 60% to replace natural river sand. SEM analysis reveals the rough surface texture of manufactured sand. The manufactured sand has angular shape and sieve analysis reveled that it has a considerable amount of fine particle. Slump test shows that concrete using manufactured sand pass the standard. On the other hand, compressive test shows that concrete cubes using manufactured sand do not achieved the target strength. Water absorptive test on the cubes revealed that M-Sand I has higher absorptivity property compared to river sand . SEM analysis revealed the existance of microcrack as well as porosity in in concrete cubes incorporating of manufactured sand. It can be concluded that it can be concluded that the higher the percentage of manufactured sand in the concrete mix the lower is the comprensive strength.

Introduction

Concrete is categorized as ceramic composite material made from coarse and fine granular material engrained in a matrix of binder made from Portland cement and water. Composition ratio in the concrete system has a wide range of which the common compositions are having a 7 to 15% Portland cement, 14% to 21% water, 0.5% to 8% air, 24% to 30% fine aggregates (sand), and 31% to 51% coarse aggregates (gravel) [1].

Aggregates are some of the reinforcing components of the concrete of which their distribution can affect greatly on the properties of the concrete material. Aggregates are usually made up of 60 to 80 % of the concrete volume and it is very important that the cement and the aggregates are bonded completely by having the proper amount of water to help with the proper binding [2]. Natural aggregates can be obtained from pits, river banks and beds, gravelly or sandy terraces, beaches, and dunes, as well as other means of getting granular material for which can be processed with neither minimal effort nor the cost [3]. In Malaysia, the main source of fine aggregate is from river bed. The usage of natural source of fine aggregate has caused environmental pollution especially to the rivers where the sand is being mine. In this regard the utilization of manufactured sand in concrete production is highly relevant towards a greener concrete production practices.

Manufactured sand is a type of sand of which had gain much popularity in the concrete industry as a replacement of natural sand due to the reduction of natural sand supplywhich has resulted in the price hike of such sand. Manufactured sand is the by-product of the crushing of natural stone to produce aggregates of nominal sizes 20 mm and 10 mm of which the amount of crusher dust as well as stone chips in the size range of 2 to 6 mm can be obtained significantly [4]. Moreover, the usage of current modern crushers in aggregate processing enable to produce cubical shape, comparatively smooth textured and well graded sand This manufactured sand has a great capacity to replace the natural sand to a certain amount in a concrete. The use of manufactured sand in replacing certain percentages of natural sand is desirable as to reduce the amount of natural sand used for the making of concrete. Besides, production of manufactured sand is easier and cheaper in comparison with natural sand as it is a by product quary when producing 10 and 20 mm course aggregate. The use of manufactured sand lead towards conservation of the natural resources for sustainable development in construction industry [5].

Methodology

Materials. Cement paste used in this research was Ordinary Portland Cement (OPC) which in compliance with ASTM C150 type 1 for hydraulic cement. Fine and coarse aggregate were obtained from local supplier. The fine aggregate is classified in zone 3, passing 5mm sieve size. Meanwhile, the coarse aggregate used was crushed aggregate with maximum size of 20mm according to BS 812-103.2 1989 [6].

In this research, two types of manufactured sand were incorporated namely M-Sand I and M-Sand II which was obtained from two quarries. The manufactured sand is a by-product from crushing and impacting processes to produce coarse aggregate.

Mix Design. In this study, grade 40 concrete was selected in the design. A total number of 24 concrete cubes of 150mm size were prepared using both types of manufactured sand. All samples were cured in curing tank for 28 days until testing days. Table 1 shows the details of concrete mix proportion using manufactured sand as replacement of conventional natural river sand.

Table 1. Mixture proportion of grade 40 concrete at various manufactured sand replacement percentage for M-Sand I and M-Sand II types.

Manufactured sand replacement (%)	Cement (kg/m^3)	Fine aggregate (manufactured sand) (kg/m^3)	Fine aggregate (natural river sand) (kg/m^3)	Water amount (kg/m^3)	Water to cement ratio (w/c)
40%	436.0	233.6	350.4	205.0	0.50
50%	436.0	292.0	292.0	205.0	0.50
60%	436.0	350.4	233.6	205.0	0.50

Experimental Methods. Characterization of aggregate was carried out using Scanning Electron Microscopy (SEM), visual inspection and sieve analysis. Visual inspections were carried out to determine the surface texture and particle shape of both manufactured sand and natural river sand.

Sieve analysis was carried out in accodance to BS 810: Part 103: 1985. Meanwhile, slump tests of fresh concrete mix were conducted inline with BS 1881: Part 102: 1983. As for mechanical property evaluation, compression test was carried out based on BS EN 12390-4 for 150mm cubic sample. Lastly, concrete absorption test was acrried out in accordance to BS 1881:122.

Results and Discussion

Fine Aggregate Surface Texture and Particle Shape. According to the SEM analysis, it was found out that the surface textures of the natural river sand and the pit sands were smooth in appearance as compared to the surface textures of M-Sand I and M-Sand II, which have rougher surfaces. In this regard, manufactured sand may reduce the workability of the fresh concrete. However, the use of such sand may improve on the mechanical bonding that occur with the cement paste due to the larger surface area exposed to the cement paste [7]. Fig. 1 illustrates the SEM images of the surface textures of natural river sand, pit sand, M-Sand I and M-Sand II.

On the other hand, it was also observed that manufactured sand has a more angular shape compared to the natural river sand. This was due to the crushing and impacting processes in coarse aggregate production. The sharp edges and corners possessed by the manufactured sand may lead to greater interparticle interactions during mixing and handling thus reduced the workability of the fresh concrete mix.

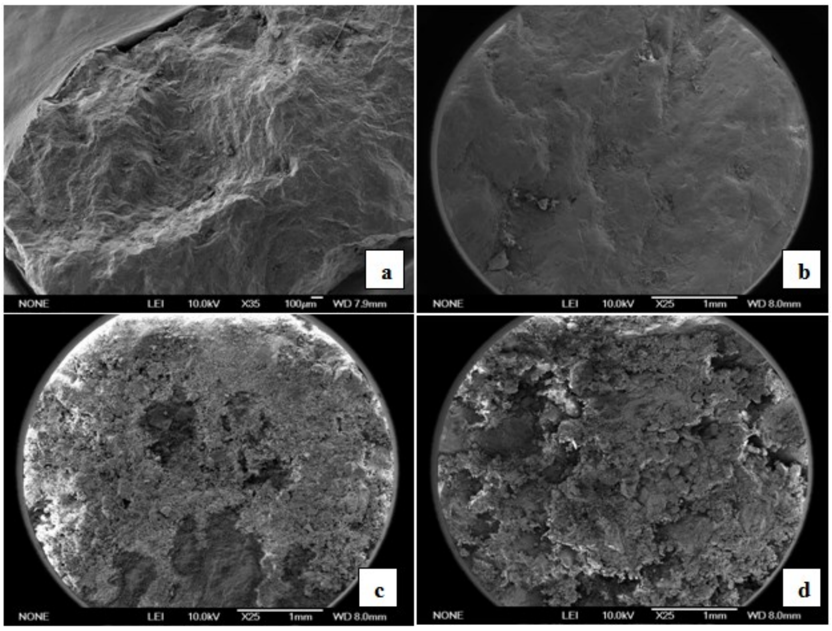

Fig. 1. Surface texture of sand at 25x magnification (a) Natural river sand, (b) Pit sand, (c) M-Sand I type and (d) M-Sand II type.

Sieve Analysis. As for sieve analysis, the percentage of passing for both types of manufactured sand were slightly higher than of the natural river sand. This indicated that manufactured sand contained greater amount of fine particles as compared to the natural river sand. Fig. 2 shows the graph of percentage passing of all types of fine aggregates examined.

Basedon the fineness modulus (FM) determination, pit sand and natural river sand were recorded to have a significant large amount of FM as compare to M-sand I and M-sand II. Meanwhile, manufactured sand had captured a lower FM value since the sand contained finer sand particle than those of natural river sand. Table 2 tabulated the fineness modulus of the four types of sand analyzed.

Workability. Referring to the workability result of the fresh concrete mix, it was observed that the concrete mix with 60% substitution for both manufactured sand gave the highest value. This finding showed that good workability can be achived with higher amount of manufactured sand percentage replacement. Fig. 3 illustrates the slump value recorded for each type of concrete mix.

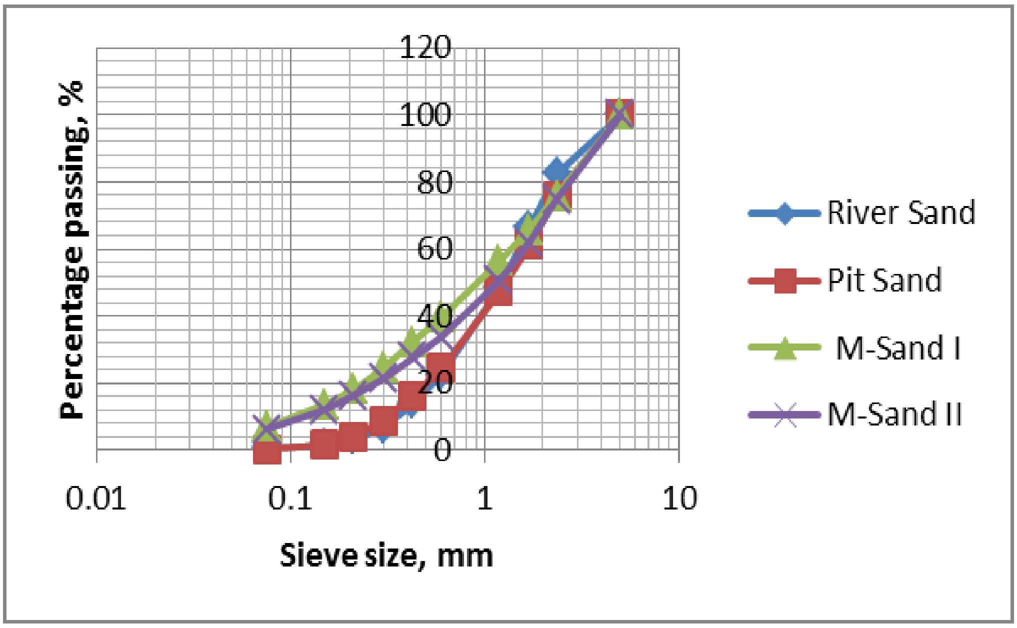

Fig. 2. Percentage passing of various types of sand graph.

Table 2. Fineness modulus of various types of sand.

Sieve size (mm)	Cumulative percentage retained (%)			
	Pit Sand	Natural river Sand	M-Sand I	M-Sand II
5.00	0	0	0	0
2.36	24.20	17.60	24.10	25.30
1.18	52.80	51.50	43.70	49.40
0.60	75.50	77.40	60.30	66.30
0.30	91.04	93.18	75.40	78.60
0.15	98.38	98.36	86.40	87.90
Σ	341.92	338.04	289.90	307.50
FM	341/100=3.41	338/100=3.48	289/100=2.89	307/100=3.07

Compressive Strength. The results of compression test are presented in Fig. 4. Based on the result, it can be seen that only pit sand and natural river sand concrete had average strength values above 40 MPa, which is above the target strength. However all concrete cubes that were made with manufactured sand replacement have compression strength less that 40 MPa. The lower compresive strength as compared to target strength is highly undesirable. Among the manufactured sand replacement concrete cubes it is found that the cubes with 50% and 60% replacements have lower compresive value as compared to 40% replacement.This also means that the higher the percentage of manufactured sand repacement the lower is the compresion strength. This trend is similar for both types of manufactured sand.

Water Absorption Analysis. From the results in Fig.5, it can be observed that the water absorption percentage of concrete cube of pit and natural river sand were almost similar and comparable. The water absorption of concrete cube of M-sand I was recorded to has a significantly lower value than of concrete cube of M-sand II. Concrete cubes of M-sand II have a higher water absorption value of the pit and natural river sand cubes. Higher water absorption values is related to the greater volume of pore space in the concrete of which the fluid can penetrate easily into the system.

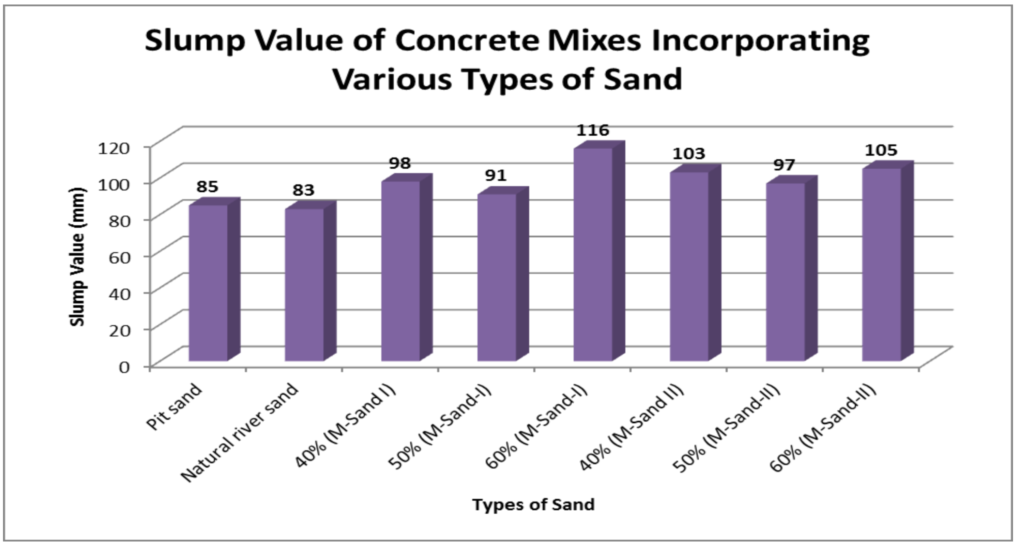

Fig. 3. Slump value for each fresh concrete mix in measured in millimeters.

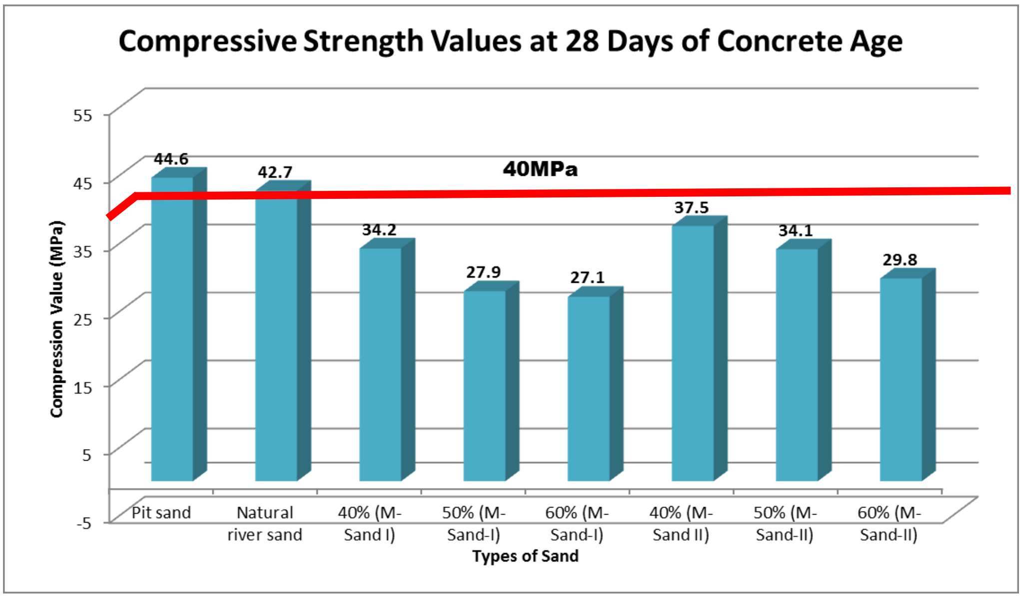

Fig.4. 28 days compressive strength results of concrete at various manufactured sand percentage, pit sand and natural river sand incorporation.

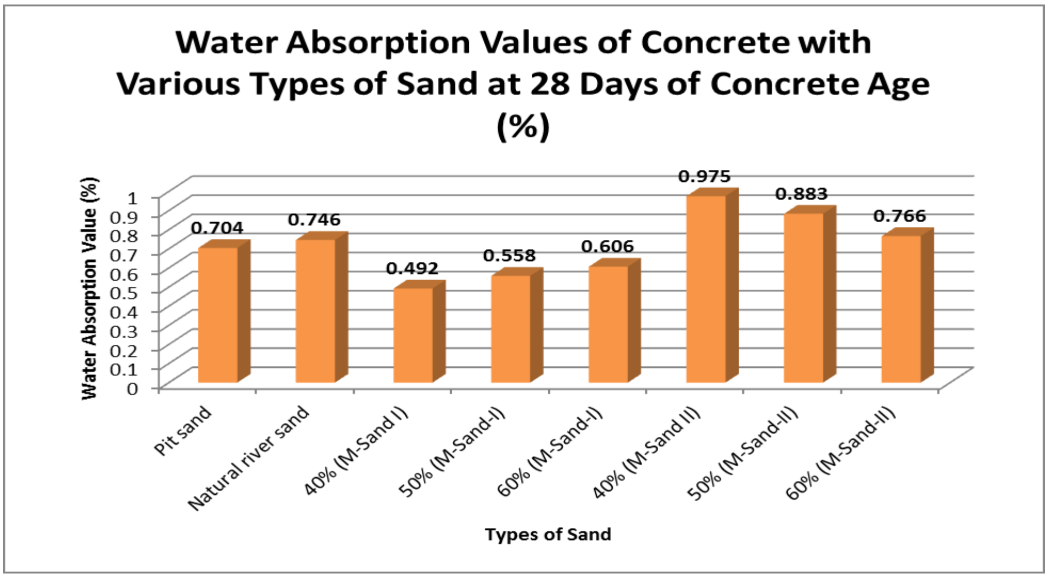

Fig.5. 28 days water absorption values of concrete at various manufactured sand percentage, pit sand and natural river sand incorporation.

Conclusion

Manufactured sand has properties of rough surface, angular in shape, as well as contain considerable amount of fine particle. The workability of freshly made concrete of manufactured sand provide better workability than of natural sand and pit sand concrete. As for water absorption capacity of hardened concrete, M-Sand I concrete has low water absorptivity property as compared to natural river sand and pit sand concrete. However, M-Sand II concrete possesses highest water absorption capacity among all types of sand used in this research. The hardened concrete of manufactured sand exhibits low compressive strength as compared to the ones made from pit and natural river sand, in which all of the samples are having compression values below the target strength of 40Mpa. In this regard, it can be concluded that the higher the percentage of manufactured sand in the concrete the lower is the comprensive strength. The replacement of manufactured sand above 40% is not advisable as the compressive strength obtained is lower that the target strength.

Acknowledgements

The authors would like to thank the Kulliyyah of Engineering for financing the research and the technicians in Kulliyyah of Engineering and Kulliyyah of Architecture and Environmental Design, IIUM for their assistance throughout this research.

References

[1] W.F. Smith and J. Hashemi, *Foundation of Materials Science and Engineering (SI Units)*, (4th Edition, McGraw Hill, 2011).

[2] Callister, *Material Science and Engineering – An Introduction*, (7th Edition, Wiley, 2007).

[3] M. Alexander and S. Mindess, *Aggregates in Concrete*. (Taylor and Francis, 2005).

[4] M.R. Chitlange, P.S. Pajgade and P.B. Nagamaik: Emerging Trends in Engineering and Technology (2008), pp. 1050-1054.

[5] V.R. Supekar and P.D. Kumbhar: International Journal of Engineering Research and Technology (IJERT), Vol. 1, Issue 7, (2012).

[6] BS 812-103.2, Testing Aggregates. Method for Determination of Particle Size Distribution, Sedimentation Test (1989).

[7] S. Mindess, J.F. Young and D. Darwin, *Concrete, Second Edition*, (Prentice Hall, 2003).