AN EXPERIMENTAL STUDY ON STRENGTH AND DURABILITY OF CONCRETE WITH PARTIAL REPLACEMENT OF SAND BY CRUSHED BRICK GRIT

MihirKanti Gop[1], Gopinandan Dey[1]

1. National Institute of Technology Agartala, India

ABSTRACT. River sand which is the major source of fine aggregate is recently not abundantly available because of its continuous use. Tripura a state of north-east India also faces this problem. Besides, the local sand available in rivers is very fine in nature and it belongs to grading Zone-IV as per Indian Standard code IS: 383. This type of sand does not give very good strength; moreover there may be excessive shrinkage. To overcome this problem, upgradation of grain size of local sand with suitable replacement by relatively coarser material is explored in this paper. Crushed brick grit is one such relatively coarser material and this is widely available in Tripura. This grit is a screened out waste product of crushed brick aggregates. In this study, this grit has been used for partial replacement of the local sand to make upgradation of fine aggregate. After partial replacement it is found that the local sand is upgraded to Zone –III from Zone- IV. Compressive strength, workability and shrinkage property of concrete made with this upgraded local sand with different water cement ratio have been explored and compared with the control mix made with naturally available local sand. The results indicate an improvement in strength with satisfactory workability and shrinkage property.

Keywords: Fine aggregate, River sand, Upgradation of grading zone, Crushed brick grit, Drying shrinkage

Mihir Kanti Gop is a serving Superintending Engineer, Rural Development Department, Govt. of Tripura, India and also a Post Graduate Research Scholar under Civil Engineering Department of National Institute of Technology, Agartala, India. His research interest includes quality assessment of river sand in Tripura and upgradation of its property.

Gopinandan Dey is an Assistant Professor in Civil Engineering Department of National Institute of Technology, Agartala, India. His research interest includes concrete strength, durability and performance as well as non-destructive evaluation and electrical prosperities of cement based materials.

INTRODUCTION

Sand is the usual and common ingredient for mortars as well as concrete. Due to huge increase of construction activity the availability of river sand becomes more difficult and consequently it is becoming expensive day by day. Further, due to large-scale depletion of these resources creates environmental problems. Continuing extraction of sand from river beds is losing water retaining sand strata, deepening of the river courses and causing bank slides, loss of vegetation on the bank of rivers, exposing the intake well of water supply schemes, disturbs the aquatic life as well as affecting agriculture due to lowering the underground water table. Hence, at present search for alternative materials and partial replacement of river sand becomes a topic of interest in research area.

In Tripura, a north eastern state of India the river sand mostly belongs to the grading zone – IV as per IS:383-1970,whichis not normally recommended for use in concrete. However, due to lack of alternative source of fine aggregate it is used for all construction activities in the state. Fine and coarse aggregate constitute about 75% of total volume and sand makes up about 25%to 35% of the volume of aggregate used. It is therefore, important to obtain right type and good quality aggregate at site, because the aggregate forms the main matrix of concrete or mortar [1]. As fine aggregate comprises a large volume of aggregate, consequently gradation and fineness modulus of sand are among principal factors affecting the performance of fresh and hardened concrete. [2]. Good quality aggregate should consist of particles of adequate strength and desirable engineering properties as well as resistance to exposure conditions. The aggregate properties affect the strength, stiffness, and long-term deformation of hardened concrete [3]. Aggregate source, shape, size and grading can influence concrete workability and strength [4]. Sand constitutes bulk of the mortar volume. Sand grading can influence the characteristics of mortar and masonry [5].

Therefore, a study on quality assessment is essential to have a ready guide to builders and engineers about the suitability of sand available in Tripura. In this study, Crushed brick grit is used for partial replacement of river sand. Crushed brick grit is a waste product which comes in the process of brick aggregate preparation using crusher machine. The percentage at which the crushed brick grit is to be mixed for upgradation of river sand has been explored in this study. Subsequently, workability, compressive strength and shrinkage property of concrete have been experimented and compared. A desired gain in strength in concrete has been noticed.

MATERIAL FOR CONCRETE

Cement

In this experimental study OPC 43 grade cement has been used. The specific gravity of cement is 2.98.

Natural Sand

The natural sand as available in the local rivers and streams have been explored for use. The river sand is comparatively more finer and normally used for filling in plinth or similar nature of filling works. The sand available in small streams is relatively coarser than river sand and this sand is mostly used for different construction works in Tripura. Accordingly, natural

sand as available in a place named as Kanchanmala from quarrying a small stream in West Tripura District was collected and sieve analysis was done as per Indian Standard Code IS: 383-1970 to find the particle size distribution i.e. grading zone. The result of the sieve analysis is presented in Table 1. It is found that the particulars of the sample match the criteria of Grading Zone – IV except some differences in the particulars of 300 micron size. Thus, the sample nearly conforms to grading Zone-IV. The specific gravity of this sample of natural sand is found to be 2.58.

Table 1 Gradation of natural sand sample

IS SIEVE SIZE (mm/ micron)	PERCENTAGE PASSING	CRITERIA FOR GRADING ZONE- IV AS PER IS : 383	REMARKS
4.75	100	95-100	The sample nearly conforms to Grade zone-IV
2.36	99.80	95-100	
1.18	99.60	90-100	
600	99.20	80-100	
300	4.20	15-50	
150	1.00	0-15	

Crushed brick grit

There is a site at Jirania under West Tripura District where brick aggregate is prepared commercially by using crusher machine by few private agencies. In process of preparing brick aggregates a good quantity of brick grit comes out as wastage. They normally dispose this brick grits as a waste. From this site of Jirania a sample of 150 kg crushed brick grit have been collected. Sieve analysis of this sample of crushed brick grit has been done and accordingly results are placed below in Table 2. It is found that the particulars of the sample of crushed brick grit match the standard of grading Zone-II. The Specific gravity of brick grit has also been tested and found to be 2.54.

Coarse aggregate

Coarse aggregate (Crushed stone aggregate) in Tripura is normally imported from outside the state either from Assam or from nearby country of Bangladesh. The aggregate sample was collected from a local supplier from Akhaura road, Agartala under West Tripura district. The specific gravity of stone aggregate is found to be 2.68.

Table 2 Gradation of the crushed brick grit sample

IS SIEVE SIZE (mm/micron)	PERCENTAGE PASSING	CRITERIA FOR GRADING ZONE- II AS PER IS : 383	REMARKS
4.75	97.60	90-100	Sample conforms to Grading Zone – II
2.36	81.00	75-100	
1.18	61.60	55-90	
600	43.60	35-59	
300	8.30	8-30	
150	0.70	0-10	

Partial replacement of fine aggregate

Partial replacement of sand is experimented by using crushed brick grit with the percentage of 10% to 40% till the sample is upgraded to next zone. The improvement in gradation of the mixed samples have been analyzed and compared with Table 3. Accordingly, results are tabulated below in Table 4.

Table 3 Gradation of the Zones as per IS : 383

IS SIEVE SIZE(mm/micron)	GRADING ZONE-II	GRADING ZONE-III	GRADING ZONE-IV
4.75	90-100	90-100	95-100
2.36	75-100	85-100	95-100
1.18	55-90	75-100	90-100
600	35-59	60-79	80-100
300	8-30	12-40	15-50
150	0-10	0-10	0-15

From the comparison of figures of Table 3 & 4, it is observed that the sieve analysis particulars of 40% are very nearly matching to the criteria of Zone-III except some difference in respect of 300 micron size. Thus, this mixed sample of river sand with 40% replacement upgrades from grading Zone-IV to Zone –III. Accordingly, 40% replacement by brick grit has been chosen and further experimentation has been done with this sample.

Table 4 Gradation of the mixed sample with different percentage of replacement

Sieve mm/ micron	Percentage passing of mixed sample for respective replacement			
	10%	20%	30%	40%
4.75	99.76	99.52	99.28	99.04
2.36	97.92	96.04	94.16	92.28
1.18	95.80	92.00	88.20	84.40
600	93.64	88.08	87.92	76.96
300	4.61	5.02	5.43	5.84
150	0.97	0.94	0.91	0.88

Mix Design

Mix design was made to have a comparison of cube strength at different water cement ratio by using the upgraded fine aggregate sample of river sand with 40% replacement by brick grit. For taking care of strength and workability certain percentage of admixers was also added in samples using the upgraded aggregate. Similarly, for having a comparison, mix design using plain river sand was also done without any partial replacement and without mixing any admixer. The ratio of proportion in mixing is tabulated in below.

Table 5 Mix Proportion (in weight) using natural sand and upgraded fine aggregate

WATER CEMENT RATIO	RATIO OF PROPORTION USING UPGRADED AGGREGATE	PERCENTAGE OF ADMIXERS ADDED	RATIO OF PROPORTION USING NATURAL SAND
0.50	1 : 2.11 : 3.93	0.8	1 : 2.13 : 3.96
0.46	1 : 1.86 : 3.61	1.0	1 : 1.87 : 3.60
0.42	1 : 1.64 : 3.27	1.20	1 : 1.65 : 3.27

As per the provision laid down in Indian Standard Code IS: 10262 –2009, the mix design was done and the necessary calculations were accordingly made. According to the respective water cement ratio, the quantity of materials in the mix is detailed in Table 5.

Sample for Testing of compressive strength

Six samples of 150mmx150mmx150mm size with mix proportion for each of the above proportion ratio cited in Table 5 with respective water cement ratio and admixers content were prepared. Similarly sample by using natural sand was also prepared. Workability in terms of slump was also simultaneously measured for each of the sample mix. The samples

were demolded after 24 hours of casting. Then the samples were submerged in water for normal curing.

Figure 1 Cube for Testing

On completion of 28 days the samples were taken out from curing tank for testing. The samples were tested in a digital compression testing machine of 2000 KN capacity after making those surface dry.

Sample for shrinkage testing

For conducting drying shrinkage test, cement mortar in 1:3 proportion (cement: fine aggregate) at three respective water cement ratio as adopted for cube test with 40% replacement of river sand by crushed brick grit was used.

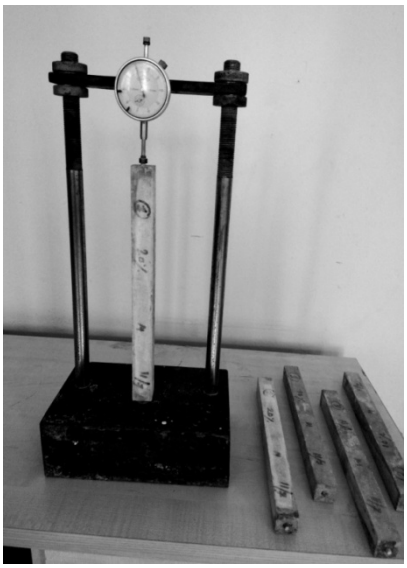


Figure 2 Drying Shrinkage Test

Using the mortar paste, prism measuring 25 mm x 25 mm x 275 mm size was prepared and accordingly measurement of shrinkage after 6 days curing and 36 days curing were recorded. Subsequently percentage shrinkage was calculated for all the samples. The shrinkage result was then also compared with result of using only natural sand in cement mortar i.e. with 0% replacement.

RESULTS AND DISCUSSION

Compressive strength and workability

18(eighteen) nos. cubes with respective water cement ratio as prepared with 40% of partial replacement of fine aggregate by crushed brick grit were tested in Compression Testing Machine after 28 days curing. Similar no. of cubes made with natural sand was also tested. For each water cement ratio, 6(six) samples were made, tested and average of results were taken. The test results are tabulated in below in Table 6 & 7.

Table 6 Compressive strength of concrete & Slump with natural sand

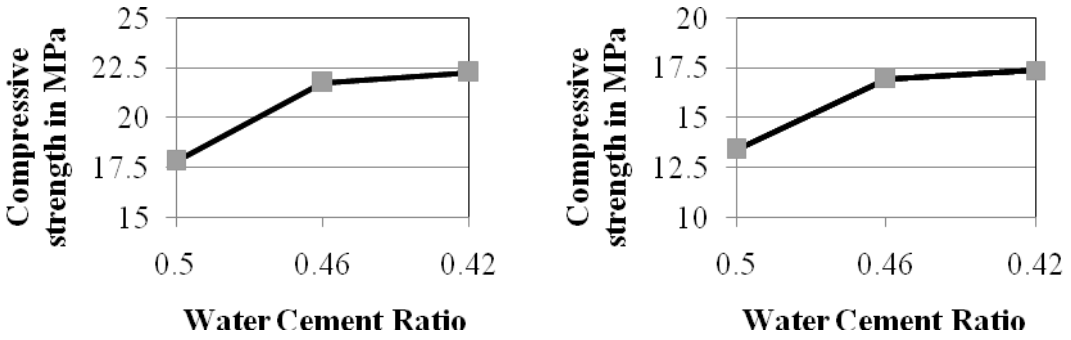
Water cement ratio	Ultimate Compressive Strength (in MPa)	Characteristic Compressive Strength (in MPa)	Workability in terms of slump (mm)
0.50	20.00	13.40	85
0.46	23.55	16.95	65
0.42	24.00	17.40	45

By analyzing the results in Table 6 & 7, it has been found that the target strength comes for the mix prepared by using 40% replacement of river sand with crushed brick grit. The concrete also gains increased strength when 40% replacement is done in comparison to that with natural sand. The slump results are also satisfactory.

The results in turn indicate that as much as gradation of fine aggregate is improved from Zone-IV to Zone –III, the compressive strength is also increased at every water cement ratio. As the water cement ratio is lowered down, the mix ratio becomes richer and that also influences in increase in compressive strength of concrete.

Table 7 Compressive strength of concrete & Slump with upgraded fine aggregate

WATER CEMENT RATIO	ULTIMATE COMPRESSIVE STRENGTH (IN MPA)	CHARACTERISTIC COMPRESSIVE STRENGTH (IN MPA)	WORKABILITY IN TERMS OF SLUMP (MM)
0.50	24.44	17.84	75
0.46	27.77	21.77	55
0.42	28.90	22.30	30



(a) Using upgraded Sample (b) Using natural Sand

Figure 3 Variation of strength using upgraded fine aggregate and natural sand

Considering the slump result and compressive strength it may be proposed here that 40% replacement of river sand by using crushed brick grit and water cement ratio 0.46 may be opted with a mix ratio of 1 : 1.86 : 3.61 for better strength of concrete with satisfactory workability. The achieved compressive strength at water cement ratio of 0.46 is found 28.40% more in comparison to the strength of concrete by using plain river sand at the same water cement ratio.

Drying shrinkage

The prisms as prepared with 1:3 cement mortar for respective water cement ratio by using the upgraded fine aggregate samples with partial replacement of 40% were tested after 6 days curing and after 36 days curing. Similar shrinkage test was also conducted for prisms using only natural sand for making a comparison. Average of three samples was taken for each percentage replacement. Out of these observed results of 6 days and 36 days percentage shrinkage were accordingly calculated and listed in Table 8. From the result obtained in drying shrinkage test it is found that average shrinkage percentage is increased with the increase in water cement ratio. Also it is observed from the comparison of result particulars of 40% and 0% replacement that shrinkage is more in case of replacement by brick grit.

Table 8 Variation of Shrinkage for different water cement ratio

Water cement ratio	Average shrinkage using 40% partial replacement (in %)	Average shrinkage using natural sand (in %)	Remarks
0.50	0.18	0.019	Shrinkage is more in case of using brick grit as replacement.
0.46	0.22	0.023	
0.42	0.26	0.025	

There are many factors that may affect the shrinkage like humidity, water cement ratio. The magnitude of drying shrinkage is also function of fineness of gel. The finer the gel the more is shrinkage. Cement paste shrinks more than mortar and mortar shrinks more than concrete [6].

On being studied the reason of more shrinkage in case of using brick grit we may look into the grain particulars of it. In this particular study, if we analyze the sieve analysis result in Table 1, 2, 3 & 4 of fine aggregate with different percentage of replacement it is seen that the percentage passing through 300 micron varies from 4.61 to 5.84. So a good quantity of fine particles is present in fine aggregate and as we are increasing the percentage of replacement that quantity also increases to some extent. The fine particles of brick dust those present in the crushed brick grit sample may affect the shrinkage property. The shrinkage percentage increase with the increase in percentage replacement may be due to this fact. But, considering the upgradation found in quality of fine aggregate, also the corresponding gain in strength of concrete and satisfactory workability the result of drying shrinkage seems acceptable.

CONCLUDING REMARKS

The idea of partial replacement of natural river sand by crushed brick grit as highlighted in the present experimental study could improve the utilization of natural river sand for enhanced compressive strength. It also facilitates to reduce the requirement of quarrying sand from river and conserving the scarcely available natural sand for sustainable development. In addition to this, the crushed brick grit which is actually now being disposed off as an waste material would be a usable material as fine aggregate by mixing with natural river sand.

In this study, 40% replacement of sand is proposed with brick grit, which is applicable for this specific sample only which could be established for other samples using the same method proposed here. From the results, we conclude that by replacement of natural river sand with crushed brick grit, the river sand is upgraded from Zone-IV to Zone–III and compressive strengths concrete made with this upgraded sample of fine aggregate are enhanced substantially for all water to cement ratios. However, shrinkage is increased nearly 10 times of the shrinkage of controlled specimen made with natural sand without any replacement which may be attributed to the presence of some fine dust in the brick grit sample the. This shrinkage may be reduced by omitting the dust part of the brick grit sample which is a part of our future research.

ACKNOWLEDGMENTS

The authors convey the acknowledgement to the faculty and staff of Structural Engineering Laboratory, Geotechnical Laboratory, Transportation laboratory of NIT, Agartala for offering all necessary guidance and help in conducting the experimental study.

REFERENCES

1. PRIYANKA A. JADHAV, DILIP K. KULKARNI, Effect of replacement of natural sand by manufactured sand on the properties of cement mortar, International Journal of Civil and Structural Engineering, 2013, Vol. 3, No 3, ISSN 0976 – 4399.

2. SABIH G., TAREFDER R. A., JAMIL S. M., Optimization of gradation and fineness modulus of naturally fine sands for improved performance as fine aggregate in concrete, Elsevier, Procedia Engineering, 2016, Vol. 145, pp 66 – 73.

3. HASDEMIR S., TUGRUL A., YILMAZ M., The effect of natural sand composition on concrete strength, Construction and Building Materials, 2016, Vol. 112, pp 940–948.

4. OKONKWO V.O., ARINZE E.E., Effects of Aggregate Gradation on the Properties of Concrete, Journal of Steel Structures & Construction, dx.doi.org/10.4172/2472-0437.1000109.

5. REDDY B.V.V., GUPTA A., Influence of sand grading on the characteristics of mortars and soil–cement block masonry, Construction and Building Materials, 2008, Vol. 22, pp 1614–1623.

6. SHETTY M.S., Concrete Technology, 2009 Edition, ISBN : 81-219-0003-4, Code 10308.