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Experimental investigation for partial replacement of fine aggregates in concrete with sandstone

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Abstract. This research study focuses on utilizing sandstone which is overburden waste rock in coal mines to use in concrete as a replacement of fine aggregate. Physical properties of sandstone like water absorption, moisture content, fineness modulus etc., were found to be similar to conventional fine aggregate. Scanning Electron Microscope (SEM) analysis was carried out for analysing elemental composition of sandstone. There was no sulphur content in sandstone which is a good sign to carry the replacement. Fine aggregate was replaced with sandstone at 25%, 50%, 75% and 100% by volume and moulds of concrete cubes and cylinders were prepared. Compressive strength of concrete cubes was tested after 3, 7 and 28 days and split tensile & flexural strength was determined after 28 days. The strength was found to be increasing marginally with increase in sandstone content. Fine aggregate that was replaced by 100% sandstone gave highest strength among all the replacements for the compressive, split tensile and flexural strengths. Though increase in strength was marginal, still sandstone can be an effective replacement for sand in order to save the natural resource and utilize the waste sandstone.

Keywords: coal mine overburden; waste rock; sandstone; fine aggregate; concrete; strength

1. Introduction

Concrete is one of the basic requirements for creation of any infrastructure, buildings, roads, etc. Concrete requires natural aggregates, which are obtained from quarries. The fine aggregates generally used is the river sand. Such deposits do not require much processing other than size grading. Most of the tropical and subtropical countries still depend upon river sand for fine aggregates. But now it is well understood that indiscriminate sand mining causes irrepairable and irreversible damages to the ecological system. Both coarse and fine aggregates are natural resources, once used cannot be replenished.

Sand mining causes many problems to flora and fauna also. Excessive sand mining causes unpredicted water course causing floods in surrounding areas, water pollution etc. A study carried out on Kulsi river, Assam in India revealed that one of the factors that resulted in the decline of

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0.15 mm sieve (Prashanth *et al*. 2010). A study on Jharia coal mining fields in India revealed that 98% of the particles were retained on 75 μm and higher sieve sizes while washing sandstone (Rai *et al*. 2011). A study conducted in Raniganj coal field found that there was 96% of sand content in the over burden and the presence of clay and silt particles was very low. In this material, the presence of nitrogen, potassium and phosphorus contents are very less and the waste rock is not useful for plantation (Yaseen *et al*. 2012). Another study carried out on the coal mine overburden of the Basundhara (west) opencast mine revealed that the sand content in the samples are more than 80%. The study suggested that the fresh mine spoil to attain the soil features of native forest soil through the process of reclamation takes 28 years, provided the spoil habitat is not subjected to any other interferences like erosion, vegetational degradation, etc., which is a very difficult task to achieve (Maharana and Patel 2013).

The replacement of fine aggregate with sandstone in concrete paving block showed the maximum strength at 50% and beyond that it reduced the strength of the paving block (Santosh *et al*. 2013). Beams made with coarse aggregate as sandstone resulted in excessive deflection under service loads due to lower stiffness of sandstone aggregates, but it was within the acceptable limits (Kumar *et al*. 2007).

Sandstone tends to have low compressive strength than natural aggregates and have a scattered variance on its mechanical properties and very sensitive to time dependent mechanical deterioration. Sandstone tend to perform well in dry conditions but in wet conditions it is poor when used for unbound forest roads (Rodgers *et al*. 2009)

Yilmaz and Tugcrul (2012) replaced coarse aggregate with sandstone aggregate, the results obtained revealed that, subarkose-arkose, sublitharenite-litharenite and arkose aggregates (different grades of sandstone) which have clay cement caused approximately 40-50% reduction in concrete strength when compared to subarkose, quartz sandstone and arkose aggregates which have carbonate cement, because these aggregates resulted in weaker bonding between aggregate and cement than others. Five different aggregate types such as gabbro, basalt, quartzite, limestone and sandstone were found to produce high strength concrete. It was found that gabbro concrete showed the highest compressive strength and while sandstone showed the lowest compressive strength (Uysal 2012).

Quartz sandstone obtained from Dholpur, eastern most part of Rajasthan state of India was used as replacement of coarse aggregates. Increase in compressive strength resulted for varied ratios of combined gradation and decreased after attaining a specific gradation due to segregation and increase in void spaces due to the usage of bigger sized aggregates (Kumar *et al*. 2016).

Wu *et al*. (2016) investigated the effect of replacing sandstone with incineration bottom ash and different water-cement ratio and different aggregate sizes in concrete brick preparation. The compressive strength of 11 different mix proportions exceeded the traditional red bricks by 14 MPa with water-cement ratio of 0.55. Permeability co-efficient was within general permeable pavement specifications. Hence, it was recommended to use for bicycle ways, sidewalks and landscaping but not for high traffic flow.

Yang *et al*. (2013) made numerical and experimental investigations on the effect of pore structures on the static mechanical properties of porous sandstone. The laboratory test verified the developed physical models which have consistent geometric and statistical characteristics of pores with those of real sandstone. The split mechanical properties of the physical models have good agreement with the predictions of numerical simulations.

Faiz *et al*. (2015) studied the effect of different micro-silica (MS) contents of 5, 10 and 15 wt.% as partial replacement of cement on mechanical and durability properties of high volume fly ash-

Ordinary Portland Cement of 43 grade of ACC brand used for experimental purpose. Physical properties of cement were determined as per IS8112-2013 and tabulated in Table 1.


(a)


(b)

Fig. 1 Sandstone overburden dump of an opencast coal mine where the samples were collected

Table 1 Physical properties of cement

Properties	Experimental results	As per IS code requirement
Specific gravity	3.11	3.10-3.15
Initial setting time (min)	70.00	30 (min)
Final setting time (min)	350.00	600 (max)
Fineness (%)	1.70	10 (max)

2.1.2 Aggregates

Locally available river sand used as fine aggregate initially. Gravels constitute major part of coarse aggregates. Physical properties of river sand and gravels were determined as per IS 383-1970 and the details are given in Table 2.

Table 2 Physical properties of aggregates

Property	Fine aggregates	Coarse aggregates
Specific gravity	2.64	2.74
Water absorption (%)	1.30	0.80
Moisture content	Nil	Nil
Maximum size (mm)	4.25	20

2.1.3 Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. The water used was clean and free from deleterious matter.

fine aggregates.

Table 4 Cumulative percentage passed for all samples

IS sieve size (micron)	Cumulative percentage retained (%)				
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
4750	1.56	1.24	3.05	2.80	1.90
2360	3.75	3.88	5.68	5.90	3.20
1180	15.57	14.26	16.38	18.52	15.32
600	41.43	42.95	41.44	38.93	39.91
300	71.79	72.54	75.77	71.91	70.98
150	89.51	90.54	87.74	88.78	91.90
75	93.83	93.33	94.61	92.99	93.14
Fineness modulus	2.23	2.25	2.30	2.26	2.23

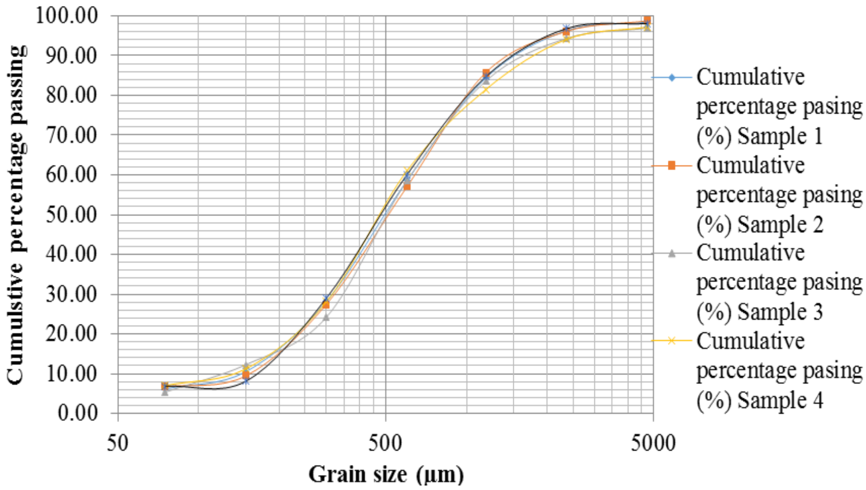
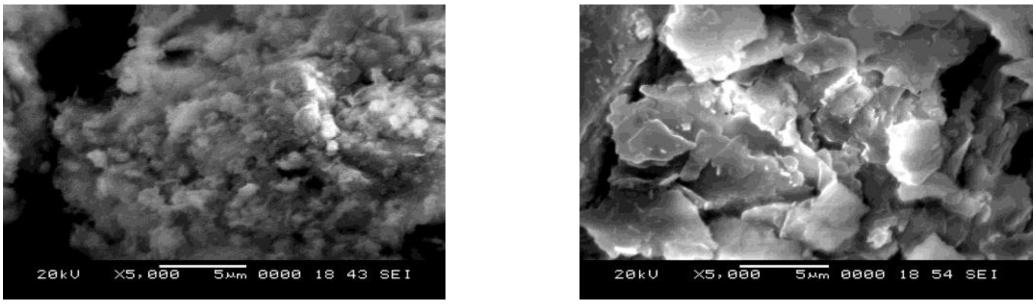


Fig. 2 Particle size distribution for all samples

3.1.2 Specific gravity and water absorption

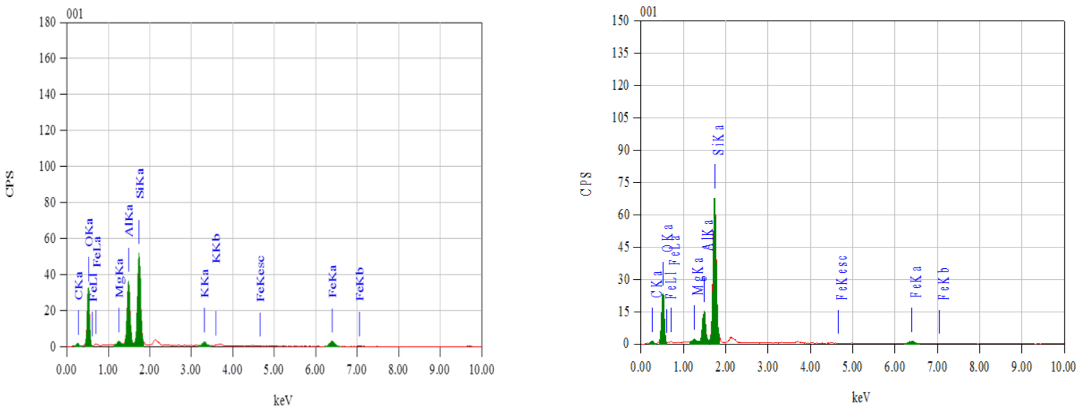
Specific gravity of the material was tested using Pycnometer and the results are given in Table 5. The specific gravity of 5 samples 2.56, 2.57, 2.55, 2.57 and 2.55. There is no deviation for any samples for more than 0.02 with average specific gravity of 2.56 for the mix design purposes. This value is closer to conventional fine aggregate and also very close to the previous studies reported by Prashanth *et al.* (2010). So the weight of the cubes do not change much when the fine aggregate is replaced with sandstone.

Water absorption test is continuation of specific gravity test and done with pycnometer for 5 samples. The water absorptions for 5 samples was found to be 2.21%, 2.33%, 2.24%, 2.19% and 2.28% with an average of 2.25%. The water absorption for Conventional fine aggregate was found to be 0.5%. So when the concrete is prepared with replacing sandstone as a replacement, the extra amount of water has to be added to prevent the concrete from the workability point of view.



(a) (b)

Fig. 3 Microscopic view for the sample



(a) (b)

Fig. 4 Different elements in the sandstone sample

Table 7 SEM analysis results

Elements	Percentage of element (%) for sample-1	
	Face 1	Face 2
C	20.48	12.21
O	55.46	61.46
Al	11.87	16.19
Si	7.40	8.97
Ti	0.28	0.23
Fe	4.52	0.95

properties such as compressive strength, split tensile strength and flexural strength.

3.4 Workability of fresh concrete

Workability of concrete is tested for each mix when it was casted as per IS1199-1959. The workability was getting increased with increase in replacement of fine aggregate with sandstone as it is fine compared with conventional fine aggregate. In all the cases, the type of slump was true.

3-days strength: The 3-days strength at 0% replacement was found to be 13.78 N/mm^2 which is quite good for M20 grade concrete. The variation of strength with replacement of sandstone is shown in Fig. 7. With 25% replacement, compressive strength was increased just by 0.8% with an average of 13.89 N/mm^2. From 25% to 50% replacement, strength was increased by 8.07%, which is a noticeable variation. From 50% to 75% strength got increased by 4.44% and for 100% replacement it showed same strength as 75% replacement. Overall the 3-days compressive strength was increased by 14.51% for 100% replacement with sandstone. To correlate the increase in compressive strength with increased percentage of replacement of sandstone, regression analysis was done. The regression Eq. (1) is shown below

$$CS=0.5889X+13.1 \tag{1}$$

Where,
CS=Compressive strength
X=Percentage of replacement
The regression co-efficient is 0.898, which shows very good correlation.

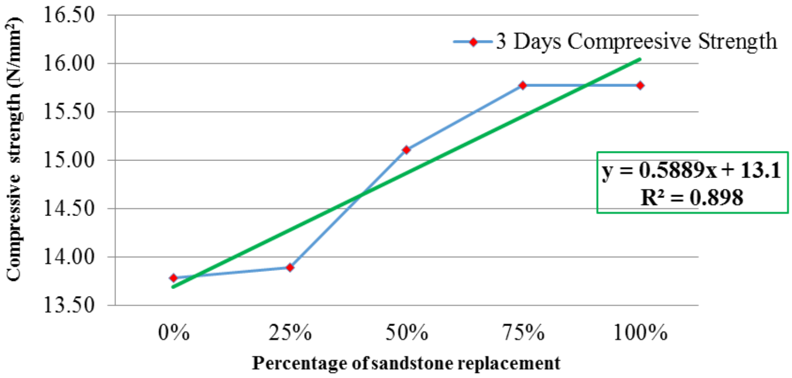


Fig. 7 Variation of 3-days compressive strength with sandstone replacement

7-Days strength: 7-Days strength of concrete with 0% replacement found to be 17.22 N/mm^2. The variation of strength with different percentage of replacement is shown in Fig. 8. For the replacement of 25% with sandstone there is no increment in strength. From 25% to 50%, strength was increased by 5.16%. From 50% replacement to 75% replacement strength was increased by 1.21%. From 75% to 100% strength was increased by 1.25%. Overall the 7-days compressive strength was increased by 13.4% for 100% replacement with sandstone. To correlate the increase in compressive strength with increased percentage of replacement of sandstone, regression analysis was done (Fig. 8). The regression Eq. (2) is shown

$$CS=0.3778X+16.756 \tag{2}$$

Where,
CS=Compressive strength
X=Percentage of replacement
The regression co-efficient is 0.9031, which shows very good correlation.

28-Days strength: Even though the 3 and 7 days compressive strength was determined, but the

The main reason might be the presence of small percentage of cementitious content that was present in sandstone. But the total strength increase was less than 10 per cent, which is very marginal.

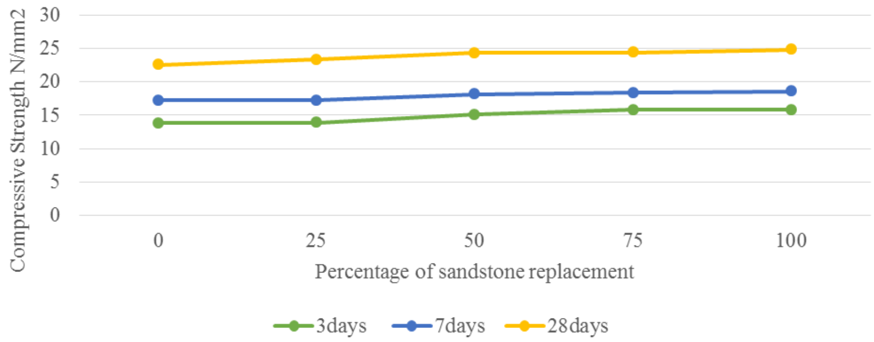


Fig. 10 Compressive strength comparison for different curing days with different % of sandstone replacement

Earlier studies carried out by Wu *et al.* (2016) investigating the effect of replacing sandstone with incineration bottom ash and different water-cement ratio and different aggregate sizes in concrete brick preparation shown that the compressive strength of 11 different mix proportions exceeded the traditional red bricks by 14 MPa with water-cement ratio of 0.55. Though there is a slight variation of these studies with ours, but the results are in close relationship.

3.6 Split tensile strength

Concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete samples may crack. The cracking is a form of tension failure as shown in Fig. 11.

The split tensile strength was conducted as per IS: 5816-1999. At 0% replacement, it is found to be 3.18 N/mm^2 which is quite good for M20 grade concrete. The variation of strength with replacement of coal mine overburden is shown in Fig. 12. With the 25% replacement, strength was increased by 2.20%. From 25% to 50% replacement, strength was increased by 4.25%. From 50% to 75% strength got increased by 2.18% and for 100% replacement it showed same strength as 75% replacement. Overall the split tensile strength was increased by 8.46% for 100% replacement with sandstone.

To correlate the increase in split tensile strength with increased percentage of replacement of sandstone, regression analysis was done. The regression Eq. (4) is as shown

$$TS=0.0778X+3.1182 \tag{4}$$

Where,
TS=Split tensile strength
X=Percentage of replacement
The regression co-efficient is 0.9167, which shows very good correlation.

$$FS = 0.14X + 2.94 \quad (5)$$

Where,
FS=Flexural strength
X=Percentage of replacement
The regression co-efficient is 0.9245, which shows very good correlation.

Fig. 13 Flexural Strength arrangement and cracked beams

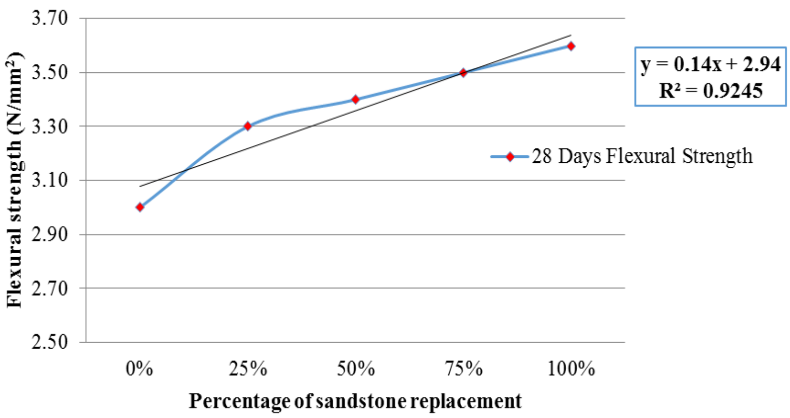


Fig. 14 Variation of flexural strength with sandstone replacement

Comparison among the strengths obtained for 28 days curing for various percentages of replacement of sandstone with base mix. It can be observed in Table 9 that, there is increase in the strengths for 100% replacement of fine aggregates in concrete as shown in Fig. 15. As the values of split tensile strength and flexural strength are almost same, the both curves are over lapping in Fig. 15. Though the increase in strength is very marginal, still it is advisable to replace fine aggregate with sandstone because the natural sand utilization can be reduced and at the same time dumping problem, dump stability problem at the mine site can be avoided.

The summary of the regression analysis done with equations corresponding to compressive strength, split tensile strength and flexural strength with the R^2 values are given in Table 10.

Table 11 Percentage of variation in strength with respect to base mix

Mix	Percentage of variation in strength with reference to base mix				
	Compressive strength			Split tensile strength	Flexural strength
	3 days	7 days	28 days	28 days	28 days
25% sandstone replacement	0.79	0.00	3.43	2.28	10.00
50% sandstone replacement	9.65	5.17	7.60	6.73	13.33
75% sandstone replacement	14.51	6.47	7.52	8.95	16.67
100% sandstone replacement	14.51	7.76	9.09	8.95	20.00

The percentage of increase in compressive strength is a maximum of 9.09%, in split tensile strength 8.95% and in flexural strength 20.0%. The increase in compressive and tensile strength is not very significant, but it is higher than the river sand mixed concrete strength. So, replacing river sand with sandstone is better as it saves river sand which is a natural resources and on the other hand utilization of sandstone produced as a waste material in mining reduces many environmental problems to mining industry and saves a lot of waste dump land. 100 per cent replacement of sand can be adopted as the complete independence from sand can be achieved as many local governments have banned sand mining in rivers.

4. Conclusions

Based on the experimental investigations carried out to assess the suitability to use sandstone for partial replacement of fine aggregates in concrete, the following conclusions were drawn.

• Sieve analysis results depicted an S-curve conforming as well-graded aggregate for sandstone, which can be a substitute for fine aggregates.

• The fineness modulus of the sandstone obtained as 2.25 and its clearly indicating it is a good replacement for fine aggregate.

• Specific gravity and water absorption are near to the conventional fine aggregate and doesn’t show any negative impact on workability.

• Moisture content denotes that the material is feasible for easy transportation.

• SEM Analysis indicates that there is presence of different oxides and high carbon content in sandstone. But there are no harmful elements such as sulphur and calcium.

• Workability of the concrete increased with increasing in percentage replacement of fine aggregate. For all the cases true slump was observed.

• 25% replacement with sandstone didn’t encounter much variation in strength when compared to base mix. But replacement of 50% and 75% rendered a very high early strength to base mix. Even the 100% replacement was slightly greater than 75% in terms of early strength.

• Compressive strength of concrete cubes increased with the increase in percentage replacement of fine aggregate for 3, 7 and 28 days. The maximum increase was in 28 days compressive strength with 100% sandstone. Maximum increases was 9.09%.

• Split tensile strength of concrete was increased with increase in percentage of replacement of fine aggregate with sandstone. The maximum split tensile strength was observed at fine aggregate replaced with 100% sandstone. Maximum increases was 8.95%

• Flexural Strength of concrete was increased with increase in percentage of replacement of fine aggregate with sandstone. The maximum flexural strength was observed at fine aggregate replaced with 100% sandstone and the maximum increase was 20%.

• Based on the above results, it can be concluded that fine aggregates in concrete can be replaced with sandstone which is a waste rock in coal mines, without compromising on any strength aspect. In fact utilization of mine waste in concrete reduces a lot of environmental problems like dust pollution, erosion, loss of vegetation on surrounding areas, etc.

References

Balkacem, B., Madani, B., Khadra, B. and Michele, Q. (2014), "Effect of the type of sand on the fracture and mechanical properties of sand concrete", *Adv. Concrete Constr.*, **2**(1), 13-27.

Barapanda, P., Singh, S.K. and Pal, B.K. (2001), "Utilization of coal mining wastes: An overview", *Proceedings of the National Seminar on Environmental Issues and Waste Management in Mining and Allied Industries*, Regional Engineering College, Rourkela, Orissa, India.

Biao, K., Enyuan, W., Zenghua, L., Xiaoran, W., Xiaofei, L., Nan, L. and Yongliang, Y. (2016), "Electromagnetic radiation characteristics and mechanical properties of deformed and fractured sandstone after high temperature treatment", *Eng. Geol.*, **209**, 82-92.

Chandar, K.R., Chaitanya, V. and Raghunandan, M.E. (2015), "Experimental study for the assessment of suitability for vegetation growth on coal over burden", *J. Mining Miner. Eng.*, **6**(3), 218-233.

Chandar, K.R., Raghunandan, M.E. and Manjunath, B. (2016), "Partial replacement of fine aggregates with laterite in GGBS-blended-concrete", *Adv. Concrete Constr.*, **4**(3), 221-230.

Chandar, K.R., Sastry, V.R., Hegde, C. and Shreedharan, S. (2016), "Prediction of peak particle velocity using multi-regression analysis: Case studies", *Geomech. Geoeng.*, 1-8.

Chenna, K.N. (2009), *Textbook of Engineering Geology*, MacMillan, New Delhi, India.

Dos Santos, C.R., Do Amaral Filho, J.R., Tubino, R.M.C. and Schneider, I.A.H. (2013), "Use of coal waste as fine aggregates in concrete", *Geomater. Sci. Res.*, 54-59.

Faiz, S., Sachin, K. and Shailesh, K. (2015), "Effect of micro silica on mechanical and durability properties of high volume fly ash recycled aggregate concretes (HVFA-RAC)", *Adv. Concrete Constr.*, **3**, 317-331.

Feijoo, J., Ottosen, L.M. and Pozo-Antonio, J.S. (2015), "Influence of the properties of granite and sandstone in the desalination process by electrokinetic technique", *Electrochim. Acta*, **181**, 280-287.

IS: 10262 (2009), *Concrete Mix Proportioning-Guidelines*, Bureau of Indian Standards, New Delhi, India.

IS: 1199 (1959), *Methods of Sampling and Analysis of Concrete*, Bureau of Indian Standards, New Delhi, India.

IS: 2386 (1963), *Methods of Tests for Aggregates for Concrete*, Bureau of Indian Standards, New Delhi, India.

IS: 2720 (1973), *Part II: Methods of Tests for Soils*, Bureau of Indian Standards, New Delhi, India.

IS: 383 (1970), *Specifications for Coarse and Fine Aggregates from Natural Sources of Concrete*, Bureau of Indian Standards, New Delhi, India.

IS: 456 (2000), *Code of Practice for Plain and Reinforced Concrete*, Bureau of Indian Standards, New Delhi, India.

IS: 516 (1959), *Methods of Test for Strength of Concrete*, Bureau of Indian Standards, New Delhi, India.

IS: 5816 (1999), *Splitting Tensile Strength of Concrete-Method of Test*, Bureau of Indian Standards, New Delhi, India.

Kumar, P.S. (2006), "A study on high performance concrete using sandstone", Ph.D. Dissertation, University of Malaysia, Kuala Lumpur, Malaysia.

Kumar, P.S., Mannan, M.A., Kurian, V.J. and Achuytha, H. (2007), "Investigation on the flexural behaviour of high-performance reinforced concrete beams using sandstone aggregates", *Build. Environ.*, **42**(7), 2622-2629.

Kumar, S., Ramesh, C., Gupta, S.S., Lazlo, C. and Blessen, S.T. (2016), "Preliminary study on the use of quartz sandstone as a partial replacement of coarse aggregate in concrete based on clay content, morphology and compressive strength of combined gradation", *Constr. Build. Mater.*, **107**, 103-108.

Maharana, J.K. and Patel, A.K. (2013), "Physico-chemical characterization and mine soil genesis in age series coal mine overburden spoil in chromosequence in a dry tropical environment", *Phylogen. Evolut. Biol.*, **1**(1), 1-7.

Mohan, R.S.L. (2000), *The 'Blind' River Dolphins of India*, Conservation of Nature Trust, Tamil Nadu, India.

Muhit, I.B., Raihan, M.T. and Nuruzzaman, M. (2014), "Determination of mortar strength using stone dust as a partially replaced material for cement and sand", *Adv. Concrete Constr.*, **2**(4), 249-259.

Musah, J.A. and Barkarson, B.H. (2009), *Assessment of Sociological and Ecological Impacts of Sand and Gravel Mining-A Case Study of East Gonja District (Ghana) and Gunnarsholt (Iceland)*, Land Restoration Training Programme.

Prashant, M., Ghosh, C.N. and Mandal, P.K. (2010), "Use of crushed and washed overburden for stowing in underground mines: A case study", *J. Min. Meta. Fuels*, **58**(1&2), 7-12.

Punmia, B.C., Kumar, A. and Jain, A.K. (2005), *Soil Mechanics and Foundations*, Lakshmi Publications, New Delhi, India.

Rai, A.K., Paul, B. and Singh, G. (2010), "A study on the bulk density and its effect on the growth of selected grasses", *J. Environ. Sci.*, **1**(4), 677-684.

Rodgers, M., Hayes, G. and Healy, M.G. (2009), "Cyclic loading tests on sandstone and limestone shale aggregates used in unbound forest roads", *Constr. Build. Mater.*, **23**(6), 2421-2427.

Ronnie. (2006), *Illegal Sand Mining Affecting Bird Life*.

Sastry, V.R. and Chandar, K.R. (2013), "Dump stability analysis of an open cast coal mining project", *Min. Eng. J.*, **15**(1), 16-23.

Sunil, B.M., Manjunath, L.S., Lolitha, R. and Subhash, C.Y. (2015), "Potential use of mine tailings and flys ash in concrete", *Adv. Concrete Constr.*, **3**(1), 55-69.

Uysal, M. (2012), "The influence of coarse aggregate type on mechanical properties of fly ash", *Constr. Build. Mater.*, **37**, 533-540.

Wu, M.H., Lin, C.L., Hang, W.C. and Chen, J.W. (2016), "Characteristics of pervious concrete using incineration bottom ash in place of sandstone graded material", *Constr. Build. Mater.*, **111**, 618-624.

Yang, J., Yongming, Y., Ruidong, P. and Lingtao, M. (2013), "Effect of pore structure on statistical mechanical properties of sandstone", *J. Geotech. Geoenviron. Eng.*, **139**, 1745-1755.

Yaseen, S., Amit, P., Siddharth, S. and Dar, I.Y. (2012), "A study of physico-chemical characteristics of overburden", *Glob. J. Sci. Front. Res.*, **12**(1-H), 7-13.

Yılmaz, M. and Tugrul, A. (2012), "The effects of different sandstone aggregates on concrete strength", *Constr. Build. Mater.*, **35**, 294-303.

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