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STONE BLOCK

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Precast stone masonry block using red lateritic aggregate

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Laterite has long been used as a building material in the country in the form of blocks. These blocks are cut at the quarry site and dressed at the construction site which gives rise to a lot of waste. An investigation was carried out by the Central Building Research Institute to study the feasibility of using lateritic stone and its waste from Goa region in making precast stone masonry blocks. A detailed investigation of the physico-chemical and mechanical properties of the aggregates was carried out and it was found that these aggregates can be suitably used in plain concrete. On the basis of laboratory results a field trial for manufacturing precast stone masonry blocks using locally available laterite stone at Panaji was carried out. Results obtained in the laboratory and the field are discussed in the paper.

Red laterite and lateritic soils cover much of the tropics, subtropics and warm temperate regions of the earth. Laterite is the end product of severe weathering and leaching of large varieties of different rocks. Laterite is rich in secondary oxides of iron and aluminate such as goethite and hematite, gibbsite and bohemite. It is nearly void of bases but many contain large amounts of silicon dioxide in the form of quartz and hydrous alumino-silicate in the form of kaolinite.

In India, lateritic soils and rock occur in coastal areas of Maharashtra, Goa, Kerala, Tamil Nadu, Andhra Pradesh, Orissa, Assam, Meghalaya, Karnataka and Bengal[1]. Laterite has been long used as a building material in our country. In Goa itself it is being used since 1887. Laterite blocks cut from the rock at the quarry sites form the chief walling material. However, this form of construction is time consuming and needs skilled labour. The external face of the wall is generally pointed maintaining the stone texture, while the internal face is plastered, although in some places of India both faces are plastered. The average thickness of the plaster required is fairly excessive due to unevenness of stone surfaces. These blocks are also required to be kept for long periods for air curing before use so that they become hard enough due to concentration of ferric hydrate and its partial dehydration. There is a general fear that lateritic stones could not be used as sound aggregate for making concrete[2, 3]. Keeping in view the above difficulties, an investigation was carried out by Central Building Research Institute to study the suitability of lateritic stone from Goa for use as an aggregate in concrete and precast stone masonry blocks.

Experimental

Laterite coarse and fine aggregate, from Goa were subjected to various physico-chemical tests according to *Indian Standard methods of test for aggregates for concrete, IS: 2386-1963*, prior to their use in mortar and concrete. Physical properties of these aggregates; *viz*, bulk density, water absorption, specific gravity, voids and bulking with moisture were determined according to standard procedures laid down in IS:2386(part III)-1963. Particle size distribution and fineness modulus of fine aggregate were determined according to IS:2386 (part I)-1963. Presence of deleterious and organic impurities in these aggregates were determined according to IS: 2386 (part II)-1963. Soundness and presence of reactive minerals (alkali-aggregate reactivity) in coarse and fine aggregate were also determined according to standard procedures given in IS: 2386 (part V) and (part VII)-1963, respectively.

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Mechanical properties of coarse aggregate like crushing value in terms of percentage of fines obtained on the application of 40-tonne load, the load required in tonnes for 10 percent fines (−2.38-mm) and impact value in terms of fines (−2.38-mm) were determined according to IS: 2386 (part IV)-1963.

The mortar making properties of these lateritic fine aggregates were determined according to IS: 2386 (part VI)-1963, under which compressive strength test specimens, 7.06-cm cubes were cast and after 24 hours atmospheric curing were immersed in water till their testing at the age of 7 and 28 days. 7.06-cm cubes of 1:3 and 1:6 cement-sand (IS Standard Ennore sand) mix at 110±5 percent flow were cast and tested after 7 and 28 days of water immersion, for comparative study.

To study the performance of these fine and coarse lateritic aggregates in concrete, two nominal mixes; *i.e.*, 1:2.5:3.5 and 1:1.5:3, by volume, using these aggregates having compaction factor of 0.85 were prepared for making 10-cm concrete cubes and tested after 7 days and 28 days water curing.

Stone masonry blocks of size 300×200×150mm using lateritic boulders (50 to 250-mm), coarse lateritic aggregate (−10-mm) and lateritic fine aggregate (−4.75-mm) were made on the same lines as given in literature[4]. The blocks were cured for 28 days and tested. The test results on blocks using lateritic stone boulders and 1:3:6 cement: lateritic fine aggregate: lateritic coarse aggregate mix as the binding material are given in *Table* 7. The results with conventional aggregates have also been given for comparison.

Results and discussion

Table 1 gives the particle size analysis of lateritic fine aggregate from Goa. The fineness modulus of this

TABLE 1 Sieve analysis of Goa lateritic fine aggregate sample

Sieve size	*Percentage retained*	*Percentage passing*	*Cumulative percent retained*	*Grading zone according to IS: 383-1970*
4.75-mm	1.00	99.0	1.0	
2.38-mm	24.60	74.40	25.60	
1.18-mm	31.24	43.16	56.84	I
600-μ	15.62	27.54	72.46	
300-μ	20.84	6.70	93.30	
150-μ	0.10	6.60	93.40	
−150-μ	6.50	—	99.90	

lateritic aggregate sample was found to be 2.97 which falls under grading zone no 1 according to *Indian Specification for coarse and fine aggregates from natural sources for concrete. IS:383-1970*. This shows that these aggregates can suitably be used in making mortar and concrete. *Table* 2 shows that the water absorption values

Table 2 Physical characteristics of Goa lateritic fine and coarse aggregates

Serial no.	*Characteristics*	*Fine*	*Coarse*
1.	Bulk density, kg/litre	1.78	1.10
2.	Water absorption, percent by weight	12.8	9.2
3.	True specific gravity	2.60	2.21
4.	Apparent specific gravity	2.51	1.60
5.	Voids, percent	31.60	35.3
6.	Fineness modulus	2.97	—
7.	Grading zone for concrete according to IS: 383-1970	I	—
8.	Suitability for mortar according to IS:2116-1965	Yes	—

of these aggregates are quite high 9.2 to 12.8 percent, which may be due to clayey or porous nature of aggregates. This property of these aggregates does not satisfy the quality of good aggregate because according to IS:383-1970, this should not be more than 5 percent.

Goa lateritic aggregates pass the IS specification for soundness because the percent loss obtained in fine and coarse aggregates treated with sodium sulphate solution are 3.35 and 0.62 percent against the standard value of 10 to 12 percent. The presence of deleterious materials like clay and silt, clay lumps, coal and lignite and material passing 75-μ seive in fine and coarse aggregates are given in *Table* 3. All the deleterious materials except coal and lignite are of higher order as compared to the IS specification in the case of fine aggregate, while in the case of coarse aggregate these are within limits. Organic impurities were found to be absent in both cases. The clay and silt content in fine aggregate is quite high as compared to standard values which may cause excessive drying shrinkage in mortar or concrete. This point should be kept in mind at the time of using this fine aggregate in concrete.

The reduction in alkalinity, R_c, and soluble silica content, S_c values which indicate the presence of reactive minerals in aggregates have been given in *Table* 3 and these values are within limits as specified in IS:383-1970.

The mechanical properties of coarse aggregate like crushing value in terms of percent fines obtained on applying a 40-tonne load, for 10 percent fines and impact

TABLE 3 Physico-chemical properties of Goa lateritic fine and coarse aggregates

Serial no.	*Characteristics*	*Fine*	*Coarse*
1.	Soundness, percent loss	3.35	0.62
2.	Deleterious materials, percent		
	clay and silt	11.5	0.46
	clay lumps	4.7	0.30
	coal and lignite	nil	nil
	material passing 75-μ sieve.	8.0	nil
	Total deleterious materials, percent	12.7	0.30
3.	Organic impurities	traces	traces
4.	Reactive minerals, milli moles/litre		
	Reduction in alkalinity, R_c	12.72	24.60
	Soluble silica content, S_c	0.90	1.60

value in terms of percent fines as given in *Table* 4 are 41.03 percent, 3.56 tonnes and 34.0 percent, respectively. These values also satisfy the requirements of IS:383-1970. This data shows that these aggregates can be used in ordinary concrete.

TABLE 4 Mechanical properties of lateritic coarse aggregate of Goa

Serial no.	*Properties*	*Values*
1.	Aggregate crushing value at 40-t load, percent fine	41.03
2.	Aggregate crushing value for 10 percent fine, t	3.56
3.	Aggregate impact value, percent of fine aggregate	34.0

Table 5 shows the mortar making properties of Goa lateritic fine aggregate tested according to IS:2386 (part VI)-1963. The properties of control mix using the three fractions of Ennore sand and cement are also been given in this table. The consumption of saturated and surface dried fine aggregate per 2kg of cement was found to be 5.1kg. The mortar mix becomes slightly muddy due to clayey nature of aggregate. The high water absorption value of aggregate also affects their requirement in mortar for same flow. As the compressive strength values of 1:3 and 1:6 mortar cubes at the age of 7 and 28 days are 104, 188 and 33.6, 59kg/cm², respectively as compared to 102, 198 and 31.4, 51kg/cm² obtained in the case of control mix, these aggregates can suitably be used in making mortar and concrete.

TABLE 5 Mortar making properties of Goa lateritic fine aggregate

Site	*Cement,* kg	*Saturated surface dry material,* kg	*Flow,* percent	*Compressive strength,* kg/cm² *according to IS: 2386-1963* Water-cement ratio 0.6		*flow 110 ± 5 percent* 1:3		1:6 mortar	
				7-day	28-day	7-day	28-day	7-day	28-day
Goa	2.0	5.1	100	200	223	104	188	33.6	59
Control	—	—	—	—	—	102	198	31.4	51

Table 6 gives the data on cubes of mix like 1:2.5:3.5, 1:1.5:3 and 1:3:6 by volume using Goa fine and coarse lateritic aggregates. The values of control mix have also been given in this table. The results obtained indicate that the compressive strength values of these mixes after 7 and 28 days water curing are of the order of 59 to 81 and 81 to 143kg/cm², respectively as compared to 51 and 62kg/cm² for the 1:3:6 control mix. These results show that these aggregates can be used in making plain concrete.

TABLE 6 Concrete making properties of Goa lateritic fine and coarse aggregates

Serial no.	*Mix by vol*	*Mix by weight*	*Compaction factor*	*water-cement ratio*	*Compressive strength,* kg/cm² 7-day	28-day
1.	1:2.5:3.5	1:3:2.67	0.84	1.5	81	117
2.	1:1.5:3.0	1:1.8:2.3	0.85	1.05	108	143
3.	1:3:6	1:3:4.7	0.85	1.7	5.9	81
4.	1:3:6 (control)	1:3:6	0.85	1.25	51	62

Note: Water-cement ratio is abruptly high in the case of lateritic aggregates due to higher water absorbing nature of these aggregates

On the basis of above results, stone masonry blocks using 1:3:6 cement concrete mix made with Goa lateritic fine and coarse aggregates as binder and Goa lateritic boulders were made and tested and the results obtained show that the compressive strength of 85kg/cm² can be achieved as compared to 100kg/cm² in the case of using river sand and shingles as conventional materials, *Table* 7.

TABLE 7 Compressive strength of stone masonry blocks after curing for 28 days

Serial no.	*Mix, by volume*	*Size of block,* mm	*Load, t*	*Compressive strength,* kg/cm²
1.	1:3:6	300×200×150	51	85
2.	1:3:6 (control)	300×200×150	60	100

Field demonstration at Goa

On the basis of above results and to study the commercial feasibility of making stone masonry blocks using locally available lateritic stones, a field trial was conducted at the quarry site of a contractor in Goa. Lateritic boulders available at the quarry site were crushed and sieved to various sizes ranging from 40-mm to fine dust. River sand was also collected and used as a fine aggregate instead of lateritic fine aggregate. Basalt coarse aggregate and dust were also collected for comparative study. On the basis of experience and convention, various mixes of 1:5:8 composition using cement, lateritic coarse aggregate, fine aggregate, river sand, basalt coarse aggregate and dust were prepared as given in *Table* 8. A few hundred precast stone masonry blocks of size 300×200×150mm of different mixes were cast by hand compaction, plate vibration or a 'Shirke' concrete block making machine and cured in water for 27 days after 24 hours of casting. The water-cement ratio in these mixes was kept at 1.0 due to higher water absorbing nature of lateritic aggregates. River sand was used in place of lateritic fine aggregate in order to eliminate the clayey material from the concrete matrix. Lateritic boulders of different sizes varying from 50 to 250mm were put in the blocks either in the exposed or middle position to see the effect of position of boulders on the strength of masonry blocks. The results obtained after 28 days water curing are given in *Table* 8.

TABLE 8 Compressive strength of stone masonry blocks made during field demonstration

Mix no.	*Concrete mix composition,* by volume	*Average crushing load,* t	*Average compressive strength,* kg/cm²
1	Cement: sand: — 12-mm lateritic coarse aggregate 1:5:8	32.5	54.0
2	Cement: sand: —20-mm, lateritic coarse 1:5:8 aggregate	48.0	80.0
3	Cement: lateritic fine aggregate: sand: —40-mm lateritic coarse aggregate, 1:3:2:8	43.0	71.5
4	Cement: sand: —10-mm lateritic coarse aggregate with lateritic boulders in middle, 1:5:8	33.5	56.0
5	Cement: lateritic fine aggregate: sand: —10-mm lateritic coarse aggregate with lateritic boulders at bottom, 1:3:2:8	23.5	39.0
6	Cement: lateritic fine aggregate: sand: —10-mm lateritic coarse aggregate with lateritic boulders in middle, 1:3:2:8	24.0	40.0
7	Cement: sand: basalt dust: —10-mm coarse basalt aggregate with lateritic boulders in middle, 1:3:2:8	51.5	85.8

During the field trial it was also noticed that with 1:5:8 mix about 35 blocks of size 300×200×150mm without boulders were manufactured with one bag of cement of 50kg, whereas, using boulders with the same mix and size of blocks, 42 blocks could be produced per bag of cement. This shows that an increase in production by about 20 percent can be obtained using boulders.

It may be seen from *Table* 8 that blocks of compressive strength 70 to 80kg/cm² without boulders, 40 to 56kg/cm² with lateritic boulders and 85.8kg/cm² with basalt dust and coarse aggregate using lateritic boulders in the middle can be produced, while the compressive strength of local lateritic block quarried and dressed at quarry site generally lies between 15 to 25kg/cm². The cost of precast stone masonry blocks on the field data comes out to be a little less as compared to conventional quarried blocks at the construction site in addition to certain advantages.

Lateritic stone available in the form of pebbles, coarse and fine aggregates as a waste material from any quarry can suitably be used in making mortar and concrete provided the aggregate to be used should not contain high amount of deleterious matter, specially clayey matter, do not have high water absorption and are hard enough to pass IS specification. The aggregate should be sound and unreactive with alkali (Na_2O and K_2O) of cement as laid down in IS:383-1970. Block making by vibration technique is recommended.

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