Engineering properties of laterite stone scrap blocks

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Abstract: Study was conducted to determine the engineering properties *viz.* compressive strength, toughness index and water absorption capacity of the laterite stone scrap blocks. Paddy husk ash, saw dust and processed fly ash were used as other constituents and added to the laterite stone scrap in the range of 3% to 9%, 3% to 9%, 20% to 30%, respectively. The cement was used as binding material and added in the range of 8% to 16%. The maximum compressive strength 13.6 N/mm^2 was observed for the block having 68% laterite stone scrap, 8% cement and 20% processed fly ash. The maximum toughness index of 14.3 was observed for the block having 81% laterite stone scrap, 16% cement and 3% paddy husk ash. The minimum water absorption capacity of 18.6 was observed for the block having 84% laterite stone scrap and 16% cement. The lowest cost of laterite stone scrap block was found to be Rs. 22.94 for the block having 85% laterite stone scrap, 12% cement and 3% paddy husk ash which satisfies BIS standards.

Keywords: remote sensing, wireless sensors, irrigation management, sustainability

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1 Introduction

In Konkan region of Maharashtra, the laterite stone is commonly used for the construction purpose. There are several laterite stone quarries in Konkan region. During excavation of laterite stone, around 25% – 30% lateritic stone scrap is generated. It is estimated that about 2.83 cum (100 ft^3) of the laterite stone scrap is generated during excavation of about 11.33 cum (400 ft^3) of the laterite stone. This laterite stone scrap creates problem in quarries and needs removal for further excavation. In order to add value to this waste material, it is felt necessary to manufacture the blocks using different constituents that are suitable for the construction.

Rangwala, et al. (1969) evaluated the procedure for studying toughness index and suggested that if the value of toughness index found to be below 13, the block is not tough. If it ranged between 13 and 19, the block is moderately tough and if it exceeds 19, the toughness of the block is said to be high. Phonghirun, Sawangpanich and Poluthai (1998) found that for manufacturing of bricks from laterite soil the most suitable ratio and the least use of cement was 19% of water to cement ratio of 70:30 for less water absorbing capacity.

Ratthachoo, et al. (2000) in an experiment of manufacturing concrete block with sawdust, showed that the compressive stress reduced when amount of sawdust increases. Also result showed that water absorption increases as the sawdust proportion increases. Lasisi and Ogunjide (2003) found that the higher the laterite cement ratio, the lesser was the compressive strength and that the finer the grain size range, the higher was the compressive strength. Pawar and Naik (2005) observed the engineering properties of natural laterite stone. The engineering properties of the stone such as water absorption, porosity, saturation coefficient, and compressive strength were in the range of 5.11% to

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15.4%, 5.2% to 21.7 %, 0.73 to 1.51, 2.1 to 3.8 N/mm^2 respectively. Hawkins (2006) observed that while making stabilized soil cement block, addition of 10% to 15% of Portland cement produces nice and smooth soil cement blocks. Eko, *et al*. (2006) conducted studies on some hydraulic, mechanical, and physical characteristics of three types of compressed earth blocks. Levels of cement mixed with soil were 0, 6%, 8%, and 10%. The increasing cement level in the soil-cement mixtures improved the mechanical characteristics of the fully stabilized compressed earth blocks whereas the hydraulic and physical parameters decreased with cement level.

Research efforts showed that the quality of the blocks made from local laterite stone scrap can be improved by adding ordinary Portland cement to produce masonry units with strengths high enough to meet building standards. Locally available paddy husk is also used as it contains silica, which improves engineering properties.

The objective of this study was to determine the engineering properties viz. compressive strength, toughness index and water absorption capacity of laterite stone scrap blocks prepared with different additives like cement, saw dust, paddy husk ash and processed fly ash and to study the cost economics.

2 Materials and methods

The laterite stone scrap was procured from quarries of laterite stone (Figure 1) located nearby Dapoli, Dist. Ratnagiri (MS). The cement was used as binding agent. The sawdust was dipped into water for 24 hours and then used for preparing blocks. The paddy husk ash was prepared by burning the paddy husk. The average particle size of laterite stone scrap was measured by sieve analysis.

Figure 1 Laterite stone quarry found in Konkan region

In all 25 treatments with different proportions of stone scrap (range from 58% to 92%) cement (range from 8% to 12%), sawdust (range from 3% to 9%), paddy husk ash (range from 3% to 9%) and processed fly ash (range from 20% to 30%) were taken. The blocks were made using block making machine with capacity of 30 blocks/h as shown in Figure 2.

Figure 2 Laterite stone scrap block making machine while in operation

Water curing of blocks was done for 21 days duration. For each treatment, five replications were taken. Details of the different constituents used to prepare the laterite stone scrap blocks are given in Table 1. The dimensions of the block are 300 mm (L)×200 mm (W) ×150 mm (T).

Table 1 Different constituent materials used to prepare laterite stone scrap blocks

Treat-ment	Stone scrap, kg (%)	Cement, kg (%)	Saw dust, kg (%)	Paddy husk ash, kg (%)	Processed fly ash, kg (%)
T1	23.00 (92.00%)	2.00 (08.00 %)	-	-	-
T2	22.00 (88.00%)	3.00 (12.00 %)	-	-	-
T3	21.00 (84.00%)	4.00 (16.00%)	-	-	-
T4	22.85 (89.00%)	2.00 (08.00 %)	0.75 (03.00 %)	-	-
T5	21.50 (86.00%)	2.00 (08.00 %)	1.50 (06.00 %)	-	-
T6	20.75 (83.00%)	2.00 (08.00 %)	2.25 (09.00 %)	-	-
T7	21.25 (85.00%)	3.00 (12.00 %)	0.75 (03.00 %)	-	-
T8	20.50 (82.00%)	3.00 (12.00 %)	1.50 (06.00 %)	-	-

Treat-ment	Stone scrap, kg (%)	Cement, kg (%)	Saw dust, kg (%)	Paddy husk ash, kg (%)	Processed fly ash, kg (%)
T9	19.25 (79.00%)	3.00 (12.00 %)	2.25 (09.00 %)	-	-
T10	20.25 (81.00%)	4.00 (16.00%)	0.75 (03.00 %)	-	-
T11	19.50 (78.00%)	4.00 (16.00%)	1.50 (06.00 %)	-	-
T12	18.75 (75.00%)	4.00 (16.00%)	2.25 (09.00 %)	-	-
T13	22.25 (89.00%)	2.00 (08.00 %)	-	0.75 (03.00 %)	-
T14	21.50 (86.00%)	2.00 (08.00 %)	-	1.50 (06.00 %)	-
T15	20.75 (83.00%)	2.00 (08.00 %)	-	2.25 (09.00 %)	-
T16	21.25 (85.00%)	3.00 (12.00 %)	-	0.75 (03.00 %)	-
T17	20.50 (82.00%)	3.00 (12.00 %)	-	1.50 (06.00 %)	-
T18	19.25 (79.00%)	3.00 (12.00 %)	-	2.25 (09.00 %)	-
T19	20.25 (81.00%)	4.00 (16.00%)	-	0.75 (03.00 %)	-
T20	19.50 (78.00%)	4.00 (16.00%)	-	1.50 (06.00 %)	-
T21	18.75 (75.00%)	4.00 (16.00%)	-	2.25 (09.00 %)	-
T22	18.00 (72.00%)	2.00 (8.00%)	-	-	5.00 (20.00 %)
T23	15.50 (62.00%)	2.00 (8.00%)	-	-	7.50 (30.00 %)
T24	17.00 (68.00%)	3.00 (12.00%)	-	-	5.00 (20.00 %)
T25	14.50 (58.00%)	3.00 (12.00%)		-	7.50 (30.00 %)

In all 125 blocks were manufactured (Figure 3) and the compressive strength, toughness index and water absorption capacity were determined as per procedure laid in Bureau of Indian Standards viz. IS: 1077–1957, IS: 5218–1969, IS: 1077–1970 respectively. According to the methodology specimen of size 2.5 cm×2.5 cm×2.5 cm and 4.0 cm×4.0 cm×4.0 cm were cut and used for the testing. The compressive strength and toughness index was determined by compression and impact testing machine respectively. The toughness index is a number say 'n' if the specimen breaks at n^{th} blow. The blow should be of 20 N and dropped from the distance of 1 cm intervals i.e. 1 cm, 2 cm, 3 cm and so on. Further, six best treatments were selected on the basis of ranking with regard to quality and those satisfying BIS codes. The blocks of these six treatments were again manufactured and tested for compressive strength, toughness index, and water absorption capacity with three replications.

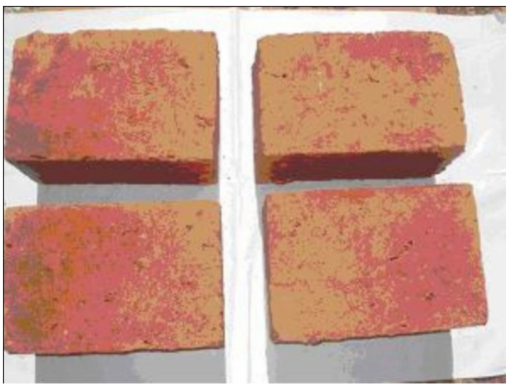

Figure 3 Blocks made from laterite stone scrap

3 Results and discussion

The stone scrap was analyzed for determining the average particle size. Fineness modulus and average diameter of particle were found to be 3.66 and 0.423 mm respectively. All the 25 combinations were tested with five replications for engineering properties. The results are presented in Table 2.

3.1 Crushing test

Results obtained for crushing test on sample blocks are given in Table 2. The compressive strength is the load applied per unit area to crush the block. It was observed that the compressive strength of stone scrap block was found in range of 7.63 to 11.50 N/mm^2. It was observed that as the cement proportion increases compressive strength increases. In case of stone scrap block with additive saw dust, compressive strength ranges from 3.88 to 12.00 N/mm^2. Study revealed that by keeping the cement proportion constant and increasing the sawdust proportion the compressive strength decreases. In case of stone scrap block with additives paddy husk ash, compressive strength ranges from 7.13 to 12.25 N/mm^2. It was found that as the paddy husk ash proportion increases keeping the cement proportion constant the compressive strength decreases. The compressive strength of stone scrap block with additive processed fly ash was found in the range of 11.25 to 13.50 N/mm^2. The increase in processed fly ash decreased the compressive strength.

Table 2 Compressive strength, toughness index and water absorption capacity of blocks for different treatments

Treat-ments	Compressive strength, N/mm^2							Toughness index							Water absorption capacity, %						
	R1	R2	R3	R4	R5	Mean	Rank	R1	R2	R3	R4	R5	Mean	Rank	R1	R2	R3	R4	R5	Mean	Rank
T1	7.50	7.50	7.50	8.13	7.50	7.63	20	6	5	6	6	6	5.8	21	21.91	19.54	22.13	19.17	20.43	20.64	14
T2	8.75	8.75	8.75	9.38	8.75	8.88	12	10	9	8	10	10	9.4	14	20.58	18.21	18.42	18.03	19.52	18.95	7
T3	10.00	11.88	11.20	10.63	13.75	11.50	6	13	14	13	12	13	13.0	8	21.01	15.76	19.82	16.84	19.18	18.52	5
T4	6.98	6.64	6.75	6.26	7.14	6.75	23	4	4	3	5	4	4.0	23	22.66	21.01	19.84	20.53	20.88	20.98	15
T5	4.67	5.21	5.13	5.10	5.13	05.00	24	4	4	4	3	4	3.8	24	23.79	24.30	24.94	22.43	18.18	22.73	19
T6	4.10	3.98	3.56	3.61	4.15	03.88	25	4	4	4	4	3	3.8	24	23.49	22.79	24.50	24.79	25.08	24.13	23
T7	11.24	9.76	10.13	9.94	10.20	10.25	8	10	8	8	8	9	8.6	16	18.94	19.33	19.46	19.44	19.76	19.39	8
T8	8.95	7.91	8.73	9.37	8.18	08.63	15	6	9	7	6	9	7.4	18	19.31	20.29	19.19	18.94	21.09	19.76	10
T9	6.84	8.74	7.48	8.36	7.31	07.75	19	9	6	8	6	6	7.0	19	22.59	22.62	23.47	23.41	22.46	22.91	20
T10	11.83	12.36	11.38	12.40	12.11	12.00	4	12	11	13	11	11	11.6	10	16.56	19.86	18.62	15.57	16.68	17.46	1
T11	8.75	8.75	8.75	9.38	8.75	08.88	12	11	10	9	10	9	9.8	13	18.12	18.11	19.12	19.37	16.25	18.19	3
T12	8.52	7.79	7.64	8.35	8.37	08.13	18	9	9	8	9	10	9.0	15	16.25	23.17	17.46	18.92	26.17	20.39	13
T13	8.75	7.50	8.75	7.50	8.75	08.25	17	7	8	8	9	9	8.2	17	27.80	28.71	20.00	14.88	18.27	21.93	17
T14	8.13	7.50	6.88	6.88	6.25	07.13	21	6	7	7	7	6	6.6	20	24.14	25.43	22.99	23.80	23.81	24.03	22
T15	6.25	7.50	8.13	7.50	6.25	07.13	22	6	5	5	5	4	5.0	22	23.75	25.38	27.45	26.77	29.42	26.55	25
T16	10.00	10.63	10.00	10.00	10.00	10.13	9	14	13	14	14	14	13.8	4	17.35	18.17	20.09	20.75	21.42	19.56	9
T17	9.38	9.38	9.38	7.50	8.13	08.75	14	14	13	13	14	13	13.4	6	21.17	22.16	22.13	21.86	22.63	21.99	18
T18	7.50	8.75	8.75	9.38	8.75	08.63	16	11	10	10	12	10	10.6	12	24.32	23.66	23.51	25.85	24.00	24.27	24
T19	12.50	12.5	12.50	11.25	12.50	12.25	3	18	18	19	19	20	18.8	1	20.02	19.63	18.58	17.51	16.83	18.51	4
T20	8.13	9.38	11.25	9.38	9.38	09.50	10	16	15	15	14	12	14.4	2	20.10	24.17	23.12	19.87	21.47	21.75	10
T21	8.75	8.75	8.75	10.00	9.38	09.13	11	10	11	10	12	12	11.0	11	22.85	22.62	23.68	20.49	26.20	23.17	21
T22	12.03	11.56	12.87	11.43	12.11	12.00	5	13	14	13	12	14	13.2	7	19.97	18.59	18.89	19.63	22.10	19.84	12
T23	11.98	10.45	11.59	10.20	12.01	11.25	7	13	12	12	14	13	12.8	9	19.42	18.28	18.99	20.36	21.99	19.81	11
T24	13.69	12.89	13.48	12.48	14.97	13.50	1	15	13	14	15	13	14.0	3	18.17	18.01	17.29	20.10	19.11	18.54	6
T25	13.67	12.53	13.25	12.23	13.81	13.10	2	13	13	14	14	14	13.6	5	17.56	18.51	18.11	17.74	18.24	18.03	2
	SE=0.31							SE=0.40							SE=0.90						
	CD(0.05)=0.86							CD(0.05)=1.12							CD(0.05)=2.53						

3.2 Impact test

Results on impact test obtained from testing of various types of blocks are given in the Table 2. It was observed that the toughness index for stone scrap block ranges from 5.6 to 13.0. Study revealed that as the cement proportion increases, toughness of block increases. The toughness index of stone scrap block with additive saw dust ranges from 3.8 to 11.6. It was observed that as the sawdust proportion increases keeping the cement proportion constant, the toughness index decreases. The toughness index of stone scrap block with additive like paddy husk ash is in the range of 5.0 to 18.8. It was observed that as the paddy husk ash proportion increases by keeping cement proportion constant, the toughness index decreases. The toughness index of stone scrap blocks with additive processed fly ash ranges from 12.80 to 14.00. The increase in the amount of processed fly ash decreases the toughness of blocks.

3.3 Water absorption test

It was observed from Table 2 that the water absorption for the stone scrap with 2 kg (8%), 3 kg (12%) and 4 kg (16%) cement was 20.64%, 18.95% and 18.52% respectively. As the cement content increases the water absorption capacity decreases. Also, with the additive sawdust, water absorption capacity was in the range of 17.46% to 24.13%. As the quantity of sawdust increases the water absorption by blocks increases. In case of the stone scrap block with additive paddy husk ash, the water absorption capacity was observed in the range of 18.51% to 26.56%. As the paddy husk ash increases water absorption increases. The water absorption capacity of stone scrap blocks with additive processed fly ash was in the range of 18.03% to 19.84%. The increase in quantity of processed fly ash, the water absorption capacity of blocks is found to be decreased.

Six best treatments were selected among 25 treatments on the basis of ranking and those satisfying BIS codes. The Table 3 and 4 showed the comparative results based on Indian standards and ranking.

Table 3 Comparative results of different treatments based on Indian standards

S.No.	Test	BIS requirements	Satisfying the BIS requirement
1	Compressive strength	Not less than 3.5 N/mm^2	T1 to T25
2	Toughness index	<13 - Not tough 13-19 - Moderate tough >19 - High	T1, T2, T4 – T15, T18, T21 T3, T16, T17, T19, T20, T22, T24, T25 -Nil-
3	Water absorption	Not greater than 20% by weight	T2, T3, T7, T8, T10, T11, T16, T19, T22, T23, T24, T25

Table 4 Comparative results based on statistical tools

S.No.	Test	Statistically best ranks	Best of 25 treatments
1	Compressive strength	Up to 9th rank	T3, T7, T10, T16, T19, T22, T23, T24, T25
2	Toughness index	Up to 8th rank	T3, T16, T17, T19, T20, T22, T24, T25
3	Water absorption	Up to 12th rank	T2, T3, T7, T8, T10, T11, T16, T19, T22, T23, T24, T25

Table 5 shows the details of the six treatments. The blocks were again made which were retested for crushing test, impact test and water absorption test. The engineering properties namely compressive strength, toughness index, and water absorption capacity are shown in Table 6.

Table 5 Constituents of six best treatments conforming statistics and BIS

Treat-ment	Soil, kg (%)	Cement, kg (%)	Paddy husk ash, kg (%)	Processed fly ash, kg (%)	Renumbering of treatments
T3	21.00 (84.00%)	4.00 (16.00%)	-	-	BT1
T16	21.25 (85.00%)	3.00 (12.00 %)	0.75 (3.00%)	-	BT2
T19	20.25 (81.00%)	4.00 (16.00%)	0.75(3.00%)	-	BT3
T22	18.00 (72.00%)	2.00 (8.00%)	-	5.00 (20.00%)	BT4
T24	17.00 (68.00%)	3.00 (12.00%)	-	5.00 (20.00%)	BT5
T25	14.50 (58.00%)	3.00 (12.00%)	-	7.50 (30.00%)	BT6

Table 6 Engineering properties of laterite stone blocks of best six treatments

Treatments	Compressive strength, N/mm^2				Toughness index				Water absorption capacity, %			
	Replications			Mean	Replications			Mean	Replications			Mean
	R1	R2	R3		R1	R2	R3		R1	R2	R3	
BT1	11.41	11.56	10.94	11.30	13	14	11	12.67	18.32	19.88	17.63	18.61
BT2	9.74	10.51	10.23	10.16	13	13	13	13.00	20.11	19.88	19.64	19.88
BT3	11.90	12.83	11.65	12.13	19	18	18	18.33	18.58	20.21	19.23	19.34
BT4	11.30	12.52	13.11	12.31	13	15	13	13.67	20.12	19.10	19.81	19.68
BT5	12.96	13.86	13.94	13.59	14	13	16	14.33	19.23	20.40	19.10	19.58
BT6	12.67	13.31	14.68	13.55	12	13	15	13.33	18.85	19.16	19.36	19.12
SE ±	0.33				0.75				0.38			
CD (5%)	1.05				2.36				1.19			

The data of compressive strength revealed that treatment BT2 differs significantly from all other treatments. The treatment BT3 differs significantly from BT4, BT5 and BT6. The treatment BT3 differs from BT5 and BT6. Also, treatment BT4 differs significantly from BT5 and BT6.

The analyses of toughness index showed that treatment BT1, BT2, BT4, BT5 and BT6 differ significantly from BT3. The treatment BT1, BT2, BT4, BT5 and BT6 among themselves were found homogenous.

As far as water absorption capacity is considered all the treatments are found to be homogeneous. Comparative data for the first year and the second year for the best six treatments is shown in Table 7.

The manufacturing cost of blocks for the best six treatments was calculated by assuming the cost of laterite stone scrap Rs. 0.10 /kg, cement Rs. 6.00 /kg, paddy husk ash Rs. 3.75/kg, processed fly ash Rs. 2.45/kg and manufacturing cost Rs. 0.50/kg. The cost of blocks was found to be Rs. 26.0, Rs. 22.9, Rs.28.8, Rs. 26, Rs.32 and Rs. 37.8 for the best treatments BT1, BT2, BT3, BT4, BT5 and BT6 respectively. Thus, the lowest cost of laterite stone scrap block was found to be Rs. 22.9 for the block with 85% laterite stone scrap, 12% cement and 3% paddy husk ash and the highest cost of laterite stone scrap block was found to be Rs. 37.8 for the block with 58% laterite stone scrap, 12% cement and 30% processed fly ash.

Table 7 Comparative data of engineering properties of laterite stone blocks

Treatment	1st Year			2nd Year		
	Compressive strength /N·mm^{-2}	Toughness index	Water absorption capacity /%	Compressive strength /N·mm^{-2}	Toughness index	Water absorption capacity /%
T3/BT1	11.50	13.00	18.52	11.30	12.67	18.61
T16/BT2	10.13	13.80	19.56	10.16	13.00	19.88
T19/BT3	12.25	18.80	18.51	12.13	18.33	19.34
T22/BT4	12.00	13.20	19.84	12.31	13.67	19.68
T24/BT5	13.50	14.00	18.54	13.59	14.33	19.58
T25/BT6	13.10	13.60	18.03	13.55	13.33	19.12

4 Conclusions

It was concluded from the study that

1) The maximum compressive strength (13.59 N/mm^2) was observed for the block with 68% laterite stone scrap, 8% cement and 20% processed fly ash.

2) The maximum toughness index (14.33) was observed for the block with 81% laterite stone scrap, 16% cement and 3% paddy husk ash.

3) The minimum water absorption capacity (18.61%) was observed for the block with 84% laterite stone scrap and 16% cement.

4) The lowest cost of laterite stone scrap block found to be Rs. 22.9 for the block with 85% laterite stone scrap, 12% cement and 3% paddy husk ash which satisfies BIS standards and recommended for construction.

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