THE PARTIAL REPLACEMENT OF COARSE AGGREGATES BY CRUSHED ROOF CLAY TILES/CLAY BRICKS IN THE INTERLOCKING PAVING BLOCK PRODUCTION

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Concrete interlocking paving blocks have become a popular paving material due to their attractive characteristics as a paving material. However, the scarcity of raw materials and price escalation of such materials are major challenges faced by the paving block manufacturing industry. Coarse aggregate is one such raw material.

Roof clay tile/clay brick waste generated during construction as well as during production, has good potential to be used as coarse aggregates in the production of interlocking paving blocks due to their nature of such wastes. Further, this would be an initiative towards sustainability. This potential had been highlighted by quite a few previous studies (especially in relevance to concrete) as well.

Accordingly, this study undertook the task of reviewing the possibility of the partial replacement of coarse aggregates by crushed roof clay tiles/clay bricks in the production of interlocking paving blocks. An experimental study was conducted by varying partial replacement percentages of crushed clay bricks and crushed roof clay tiles, separately. Based on the results of this study, these materials were identified to have a good potential to be used to partially replace coarse aggregates in interlocking blocks, in terms of the characteristics of the strength and skid resistance. However, there is a need for further study on this topic as it certain concerns were observed in relation to controlling water absorption, as per the results of the study.

Keywords: Interlocking blocks, coarse aggregates, sustainability

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INTRODUCTION

Concrete interlocking blocks are a popular material for paving applications in both industrial and domestic sites. Additionally, these paving blocks are used as paving for rural roads on which a low volume of traffic is expected. Desirable characteristics, such as minimum disturbances for rainwater infiltration, their competitive cost, their aesthetically pleasing appearance, requiring less construction time, etc have contributed to the popularity of interlocking blocks.

However, the scarcity and price escalation of raw materials such as aggregates have become a major concern for the production of interlocking blocks as well as for other concrete products. Coarse aggregates for interlocking blocks are obtained from rock quarries in Sri Lanka. The scarcity of rock formations with the desired characteristics, the environmental impact to the natural environment during rock blasting, the noise and vibration problems that occur during blasting, etc. are some major concerns that have contributed to the scarcity of aggregates and their price escalation.

Therefore, studying the possibility of using alternative materials to produce concrete products like interlocking blocks would be beneficial in both the financial and environmental sustainability aspects. Accordingly, this study focused on studying the possibility of the partial replacement of coarse aggregates, in interlocking paving block production, with brick and roof clay tile waste. As per the studies done on roof clay tile waste **(**Dembatapitiya et al, 2013) and brick waste **(**Rameezdeen et al, 2004) in Sri Lanka, it has been reported that roof clay tiles and brick waste in the construction industry is 3-4% and 14%, respectively from total production respective products. Hence, there is great potential to use the waste of roof clay tiles and bricks for this purpose. There are few previous studies (Akshay et al,2022, Apebo et al, 2013, Priyanka et al, 2019) that have focused on the usage of crushed clay bricks and roof clay tiles in production of concrete. However, none of these have considered using these alternative materials to partially replace coarse aggregates in interlocking block production.

METHODOLOGY

It was decided to consider strength class 3 (as per SLS 1425: part 1) to study the possibility of the partial replacement of coarse aggregates, in interlocking blocks, with broken clay brick particles and broken roof clay tile particles separately. The partial replacement percentages of 20%, 40%, and 60% were selected for this, considering the results of previous studies on concrete (Akshay et al,2022, Apebo et al, 2013, Priyanka et al, 2019). The maximum particle size coarse aggregates in all cases were maintained at 10mm considering local industrial practices and the recommendations of IS 15658:2006, which is the Indian standard for interlocking paving block production. The potential coarse aggregates produced of broken clay brick particles and broken roof clay tile particles were checked against the limits specified in BS 812 through sieve analyses. The results of these sieve analyses are presented in Figures 1 and 2 in relation to broken clay brick particles and broken roof clay tile particles, respectively. According to the results, it is clear that maintaining the particle distribution of broken brick tiles within specified limits is not exactly possible due to the breakage of bricks during crushing. However, particle distribution could be maintained very close to the specified limits with broken roof clay tiles.

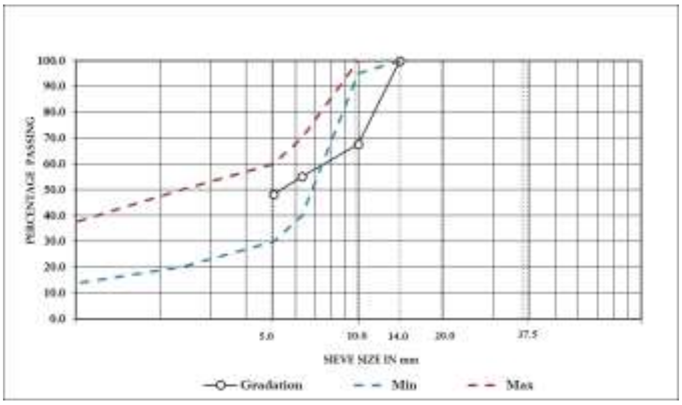

Figure 1: Particle size distribution of crushed brick waste

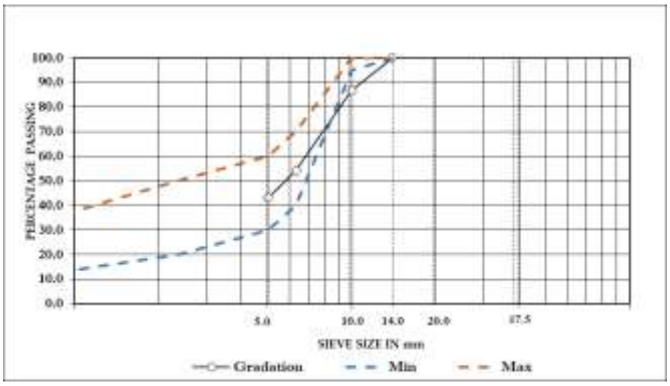

Figure 2: Particle size distribution of crushed roof clay tile waste

Ordinary Portland cement complying with SLS107 was used as the binder for the production of samples. River sand was used as fine aggregates. The mix designs of the samples were carried out based on the DOE method and study of Baskaran & Gopinath (2013) and the quantities of constituents were calculated under different partial replacement percentages are presented in Table 1.

Table 1: Calculated quantities of constituents under different partial replacement percentage

Mix %	Cement (Kg)	Fine (Kg)	Coarse-Crushed Stone (Kg)	Coarse-Tile/Brick (Kg)	Water (l)
General Mix	0.675	1.368	2.31	0.0	0.393
20	0.675	1.368	1.848	0.462	0.393
40	0.675	1.368	1.386	0.924	0.393
60	0.675	1.368	0.924	1.386	0.393

Accordingly, sample interlocking blocks were cast with partial replacement percentages of 20%, 40%, and 60% of coarse aggregates with broken brick and broken roof clay tile particles separately. The curing of samples was done by immersing them in water after the initial setting time. The 220mm x 110mm x 80mm (Length x Width x Thickness) standard size Non-Rectangular shape moulds (complying with SLS 1425- Part I: 2011) were used for the production of samples, as it was one of the most common shapes used in the industry. The typical shape of the block is shown in Figure 3.

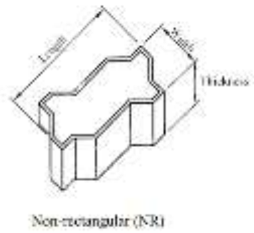

Figure 3: The typical shape of the block used for the study

Photographs of the alternative course aggregates produced and those taken during the production of samples are presented in Figures 4 and 5, respectively.

Figure 4 : Photographs of the alternative coarse aggregates produced

Figure 5: Photographs taken during the production of samples

RESULTS AND DISCUSSION

A standard compressive strength test of samples was carried out as per the standard procedure of SLS 1425: part 2. The average compressive strength results at 7 days and 28 days are presented in Figure 6.

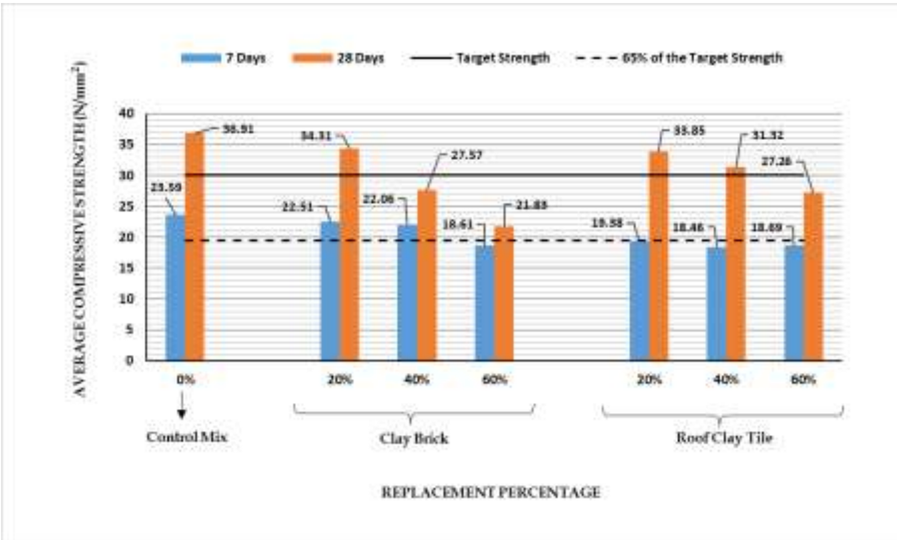

Figure 6: Average compressive strength results at 7 days and 28 days

According to the results, the highest average compressive strength was reported in the control samples at both 7 days and 28 days. In the case of samples where the partial replacement of coarse aggregates was done using broken brick or roof clay tile particles, the target 28 days compressive strength was achieved only in the samples that had the partial replacement of coarse aggregates of 20% of broken clay brick particles, 20% of roof clay tile particles, and 40% of broken roof clay tile particles.

Even though SLS 1425 does not specify the requirement of flexural strength, a flexural strength test was also performed as per the Indian standard (IS 15658:2006) as SLS 1425 also indicate specifying the flexural and tensile tests in its future revisions. The average 28 days flexural strength of the considered samples are presented in Figure 7. As per the results, the highest average flexural strength was reported in samples that had 20% partial replacement of coarse aggregates with broken clay bricks. All other samples using broken clay bricks also showed a higher average strength than the average flexural strength of control samples. However, all samples using broken roof clay tile particles showed a lesser average flexural strength than the average flexural strength of the control samples. The availability of a higher percentage of fine particles with the broken clay bricks would be a probable reason for this observation (the percentage of material passing the 5mm sieve size in broken clay bricks is close to 50% and while it is only about 40% with broken clay tiles: refer Figures 1 and 2). However, the flexural strengths shown by all the samples have satisfied the criteria specified for the heavy duty/industrial roads as per the Indian standard.

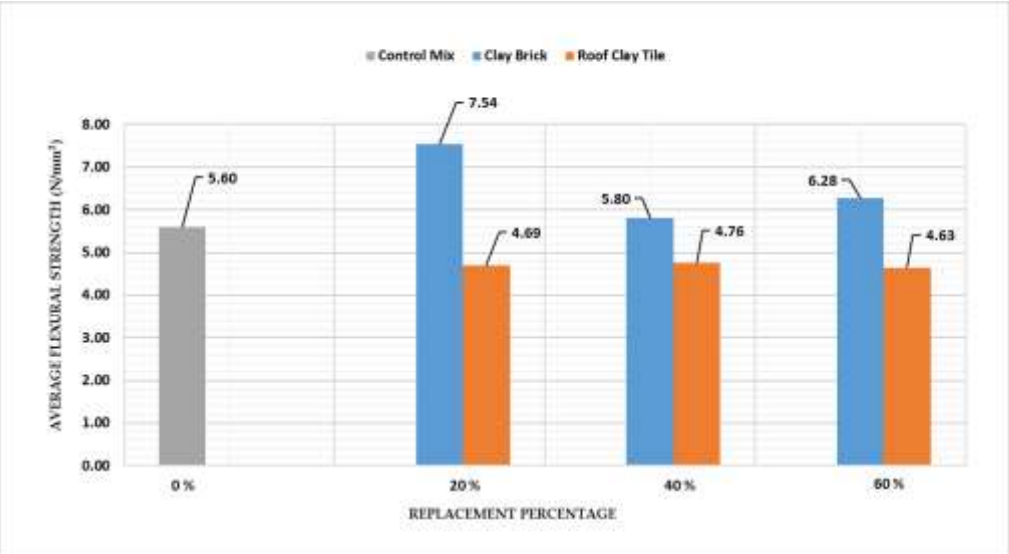

Figure 7: Average Flexural strength of samples

The skid resistance test was performed only in cases that showed the best average flexural strength results and in the control samples. Accordingly, it was carried out for samples that had a 20% partial replacement percentage of coarse aggregates with broken clay bricks, 40% partial replacement percentage of coarse aggregates with broken clay tiles, and in the control samples. The results of the tests are presented in Table 2. The results of all samples satisfy the specified acceptance criteria of the Road Development Authority (RDA) of Sri Lanka for skid resistance.

Table 2: Results of skid resistance test

Mix		Side	Test Readings (USRV)			Mean Value (URSV)	Testing Temp. (°C)	Mean value of both side (USRV)	Specification Limit (USRV)
			3rd	4th	5th				
Control	0%	1st side	80	75	70	75	28	75	≥ 55
		Opposite	75	75	80	77			
Brick	20%	1st side	85	80	75	80	28	80	≥ 55
		Opposite	80	85	80	82			
Roof Tile	40%	1st side	75	80	75	77	28	80	≥ 55
		Opposite	80	80	85	82			

The results of the standard water absorption test are presented in Table 3. According to these results, all samples except the control sample have shown to have higher water absorption percentages than the maximum allowable water absorption percentage (6%) specified in SLS 1425. The higher void percentages presence in broken bricks and tile particles than the conventional coarse aggregates could be the probable reason for this observation. The water absorption percentages of blocks with broken brick particles showed higher water absorption percentages than the blocks with broken roof clay tile particles with respect to each partial replacement percentage.

Table 3: Results of standard water absorption test

Sample	Replacement (%)	Wet Weight(g)	Dry Weight(g)	Water Absorption (%)
Control Mix	0%	4936.0	4663.5	**5.84**
Brick	20%	5040.0	4637.5	**8.68**
	40%	4965.0	4531.0	**9.58**
	60%	4958.5	4439.0	**11.70**
Roof Tile	20%	4597.5	4239.0	**8.46**
	40%	4456.0	4109.5	**8.43**
	60%	4782.5	4350.5	**9.93**

As the overall best result in terms of structural and durability aspects was reported with the 40% partial replacement of coarse aggregates with roof clay tiles, a comparative cost analysis of the alternative and conventional products was carried out based on the present market prices. A percentage saving of about 4.4% (Rs. 3.75 per block) was observed. This would be a considerable saving when considering bulk production.

CONCLUSIONS/RECOMMENDATIONS

The main aim of this study was to analyze the possibility of the partial replacement of coarse aggregates in interlocking paving block production with brick and roof clay tile waste. According to the compressive and flexural strengths, as well as the skid resistance test results, the best results were observed when 40% of coarse aggregates was replaced with clay tiles waste. The test results of the samples, in which 40% of coarse aggregates had been replaced with roof clay tiles waste, complied with the requirements specified in SLS 1425: Part 1 except the specification relevant to water absorption. Hence, the replacement of coarse aggregates with brick waste cannot be recommended in relation to Strength class 3.

However, as per Amendment No 436: 2012 of SLS 1425: Part 1, the controlling of water absorption to below 6% is not applicable for the interlocking blocks of strength class 4. Therefore, there is a good potential to use roof clay tile waste for the partial replacement of coarse aggregates of interlocking blocks of strength class 4 and a detailed study relevant to this is recommended. This has been further justified by the cost saving observed with the alternative product in this study.

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