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IMPROVING WORKABILITY, STRENGTH AND APPEARANCE IN INTERLOCKING BLOCKS USING GRINDED PADDY HUSK ASH

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Abstract
Road paving plays a vital aspect in urban development prospect. "Uni Natural" Interlocking blocks (Size: 220mm x 110mm x 80mm) are becoming very common in many parts of the country. With the initial field studies; it was found that the mix proportions were roughly, 1: 2: 1½: ½ {Cement: River Sand: Chips: Quarry Dust} and the water Cement ratio is around 0.4. These blocks were mainly produced with mechanical vibration. During the casting process; it was observed that, when removing off the casted blocks with the pallet board, some of the blocks break (approximately 10%) which results in a fairly rough surface. To overcome this problem it is proposed to introduce grinded paddy husk ash (GPHA) as a filler material, which is freely available in most parts of the country. In brief, different percentages of grinded paddy husk ash was added to the mixture and blocks were tested after the curing process. In addition, workability, compressive strength was also tested using the available standard tests. The best mix proportion which was obtained will help to introduce a paving block with high strength and pleasing visual properties. Since the paddy husk ash is freely available in many part of the country and the current disposal method is burning; this project will lead to an environment friendly and cost effective paving block manufacturing process.

Key words*: Road* paving*, workability, strength, appearance, best mix proportion*

Introduction
Interlocking blocks were first introduced in Holland in 1950's and became very popular all over the world. As cited in the web, NBM Media Construction Information **(**2009) it can be used in all countries in various conditions such as Non traffic, light traffic and Medium traffic areas, pedestrian, parking lots, traffic intersections and container yards. As cited in the web, Paver Blocks manufacturers, buyers and sellers (2012) the *Paver blocks* can absorb stress such as small earthquakes, freezes and thaws, and

slight ground erosion by shifting each tile slightly. Unlike the concrete and asphalt pavements; Interlocking concrete block pavement is an environment friendly method since the blocks can be removed and replaced by same existing materials during the pavement repair. Furthermore, since the casting and paving of the blocks being done by the automatic machineries nowadays, this can be a low labour input technology in the view of costing.
An interlocking block pavement consists of individual blocks of hand held size units laid on a thin bed of sand or dust layer, called bedding layer and edges can be restrained on either side by concrete backing. Since Sri Lanka is a developing country; the main aspect of the development is improving the road network and providing convenient mobility. Normally the roads are classified into four categories; which are ‘A’, ‘B’, ‘C’ & ‘D’ classes and Sri Lanka has two major road construction and maintaining institutions which are Road Development Authority entrusted with ‘A’ & ‘B’ class roads while Road Development Department assigned ‘C’ & ‘D’ class roads. The rural roads are maintaining by local authorities such as, Municipal Councils, Urban Councils and Divisional Councils. Nowadays, concrete roads are the most commonly practiced method in the rural areas. But in the aspects of strength properties and cost effectiveness, this method cannot be considered as most suitable for the rural roads which are experiencing low traffic flows. In such a situation; the interlocking block paving can be an effective method to satisfy the adequate requirements of the rural roads. Therefore; the interlocking blocks should have proper strength, physical and mechanical properties, shape, dimension and visual aspects to satisfy the above proposal. Therefore it’s necessary to improve these properties in a suitable level via economically feasible method.

In this platform; there was several research activities had been carried out by researchers all over the world to improve the properties of Interlocking blocks by adding admixtures or by replacing the designed materials. Ghassan Abood Habeeb and Mahmud HB (2010) have presented that grinded paddy husk ash can be replace the 20% of cement content in the concrete mixture and it showed a 10% of strength improvement. Also, in such a way Dixit N. Patel and Jayeshkumar R. Pitroda (2014) have illustrated, that the cement content can be partially replaced by foundry sand, which is the by product of metal-casting industry; can give the improvements in strength. M.C.Nataraja and Lelin Das (2014) have presented, that the improvements in water absorption by replacing the coarse aggregate using the crushed aggregates. G.Navya and J.Venkateswara Rao (2014) have presented, coconut fibre can be used to improve the water absorption and the compressive strength in interlocking blocks.

In the view of above, the GPHA was introduced as a filler material for the normal mix of the precast interlocking paving blocks since the Paddy husk is an agricultural residue, which is freely available all over the world since the rice production is booming day by day. As Dinesh Aggarwal (2013) has illustrated, though the paddy husk is using as a fuel in household and small industries in certain regions; most of the paddy husk is being disposed by burning.

Figure 1, Uni natural shape Precast Interlocking block

Figure 2, Interlocking block casting Machine

In this background, utilizing the paddy husk ash as a filler material in the production of interlocking blocks could be an environment friendly and cost effective method.

Aim and Objective

The main aim of the study was to understand how GPHA affect the properties of the paving blocks. For this purpose, followings were identified as the key objectives of the research,

- To find out how GPHA affects the workability of the paving block mix.
- To find out how the GPHA affects the quality and the strength of the finished paving block.
- To find out how GPHA affects skid resistance of the paving block.
- To find out how GPHA affects the percentage of the water absorption for the paving blocks during adverse climate conditions.
- To find the best mix proportion to introduce a paving block with high strength and pleasing visual properties.

Research Methodology

To achieve the above said objectives following methodology was adopted by adding GPHA in volume percentage (1% - 10%) to the normal mix and the workability was checked using the slump test. Then; after the casting and curing process, the standard testing methods were adopted to check the compressive strength, skid resistance, tensile splitting strength, water absorption and comparison of visual appearance for all sample types of mixtures. In addition to this, a cost comparison analysis was done for all the mixture samples.

3.1 MATERIALS USED

3.1.1 *Grinded Paddy Husk ash*: Paddy husk ash is a combustion product of rice husk. Initially the rice husk was burnt and grinded by the ball mill and sieved to get fine Paddy husk ash. Paddy husk ash is a highly siliceous material and can be used as an admixture in concrete. The characteristic of the ash depends on the components, temperature and the time of burning. Rice husk contains nearly 20% silica, which presents in hydrated amorphous form. As Gintautas Skripkiunas, Giedrius Girskas, Jurgita Malaiskiene and Evaldas Semelis (2014) have illustrated, during the controlled temperature combustion process (below 800^{o}C), silica converts to crystobalite, which is a crystalline form of silica. Although GPHA would reduce to its average particle size and it can act as a filler material, it was the main factor which will affect the properties of the final mix.

Figure 3, Burning of Rice husk

Figure 4, Ball mill to grind the burnt husk

Figure 5, Grinded Paddy husk ash

3.1.2 *Cement*: Three types of cement were used.
In Sri Lanka the most popular types are SLS 107 (ordinary Portland cement), SLS 1247 (Pozzolana cement- Blended Hydraulic) and SLS 1253 (Portland Limestone Cement). As cited in the web, The Difference between cement and concrete (2010) has illustrated Hydraulic cement refers to any cement that uses water to begin a chemical reaction that hardens the mixture and creates a water resistant product. This reaction is independent and it hardens even in underwater. Non-hydraulic cements to which do not harden when exposed to water. But this type is cheaper than the hydraulic cement. With this background it’s a good practice to apply these types of cement for the aforesaid mix and carry out the research in the aim of the improvements in the behavior of the interlocking block properties and the effect of mixing

GPHA. The finding can be used to identify the suitability of interlocking blocks, during several adverse climatic and loading conditions.

3.1.2.1 Ordinary Portland Cement (SLS 107) strength class 42.5N

This type of cement has been widely used for many years in general and large construction projects, ready mix preparation and in pre-cast concrete production. It is also being used in mortars and grouts. As W S S Jayamanna, Ranathunga, and Y. P. S Siriwardena (2010) have illustrated Ordinary Portland Cement is being used in the construction industry when there is no exposure to Sulphates in the soil or in ground water.

3.1.2.2 Portland Pozzolana Cement (SLS 1247) strength class 42.5N

As cited in the web, The Island (2004) has illustrated, it is manufactured either by inter grinding Portland cement clinker, pozzolanic material/slag and gypsum or by blending pozzolanic material/slag with Ordinary Portland Cement. Pozzolanic material (volcanic ash) contains natural silica in reactive form. In the presence of water, reactive silica in volcanic ash chemically react with calcium hydroxide released from ordinary Portland cement to form a stable calcium silicate, which posses binding properties like calcium silicate on ordinary Portland cement. Additional calcium silicate formation enhances the strength gain of Portland Pozzolana cement improving its long term durability under aggressive environment and also it is a low heat cement.

3.1.2.3 Portland limestone cement (SLS 1253) Strength class 42.5N.

As E.Ghiasvand, A. A. Ramezanianpour and A. M. Ramezanianpour (2013) have illustrated, Portland limestone cement consists of an intimate and uniform blend of ordinary Portland cement and limestone, and it is produced either by inter grinding Portland cement clinker, or by blending ordinary Portland cement and finely ground limestone. This is a hydraulic cement consisting of two or more inorganic constituents (at least one of which is limestone) which separately or in combination to contribute in the improvement of the properties of cement.

3.1.2.4 Standard chemical composition and physical properties of the selected cement types according to Sri Lankan Standard Institution (2011)

Table 1, Chemical composition and Physical Properties of the cements

	Description	Standard requirement for SLS 107	Standard requirement for SLS 1247	Standard requirement for SLS 1253
1	**Chemical composition**			
	Sulphur Trioxide (SO_3) %	Max : 3.00	Max : 3.50	2.5 to 3.5
	Chloride (Cl) %	Max : 0.10	Max : 0.10	Max: 0.06
	Lime Saturation Factor (LSF) %	0.88-1.02	---	---
	Limestone Content ($CaCO_3$)%	---	---	2 to 20
	Loss on ignition %	Max : 4.00	---	Max: 7.5
2	**Physical Properties**			
	Finess (Blaine) cm^2g	Min : 2250	---	Min: 3300
	Expansion soundness (Le-Chaterlier) mm Autoclave %	 Max: 10.00 Max : 0.80	 Max: 10.00 Max : 0.80	 Max : 10.00 Max : 0.80
	Time of setting (Vicat)Initial (Minutes)	Min : 60.00	Min : 30.00	95 to 150
	Compressive Strength (N/mm^2) 2 Days 28 Days	 Min : 10.00 42.5 to 62.5	 19.00 50.50	 21 to 30 45 to 65

3.1.3 *Sand*: Natural river sand was obtained and uniformly graded. The specific gravity was found to be 2.65.

3.1.4 *Quarry dust*: Quarry dust is the fine particles of rock. The specific gravity was around 1.95. Wet sieving of quarry dust through a 90 micron sieve was found to be 78% and the corresponding bulking value was 34.13%.

3.1.5 *Chips***:** Graded chips were used with the nominal size of 10mm and the specific gravity was found to be as 2.73.

3.2 PREPARATION OF MIX AND CASTING

Initially the usual mix was prepared for SLS 107 cement by mixing cement, sand, chips and quarry dust in the ratio of 1:2:11/2:1/2. At the beginning of the process; cement, Sand and GPHA were mixed thoroughly. Then the quarry dust was added since its mixing ability was very low with the mix. Finally the chips were added and the mix was prepared. The allowable water cement ratio of 0.4 was maintained for all the mixes.

This procedure was repeated for SLS 1247 cement & SLS 1253 cement. During the casting process the adequate mechanical vibration was carefully handled by experienced skilled men, Because of the lack of adequate vibration, the blocks may break or start to develop cracks. During the casting, mould was filled by the mix roughly for the first time and the first vibration was applied, then again the mould was filled by the mix up to the top level of the mould then the upper mould was released and vibrated. A fully merged curing was given for the casted blocks in clean water for next 7 days.

For the testing, 3 no. of representative samples were selected from each mix, with the consideration of deviations according to Sri Lankan Standard Institution (2011) and British Standards Institute (2003).

Table 2, Permissible deviations on the work dimensions

Block Thickness (mm)	Length (mm)	Width (mm)	Thickness (mm)
< 100	± 2	± 2	± 3
≥ 100	± 3	± 3	± 4

4 Results and observations

4.1 SLUMP TEST

Slump test was done for each mix using the slump cone. Since the interlocking block mix was considerably dry when compared to the normal concrete mix, the slump value is 0. As cited in the web, Concrete and mortars-all about slump (1997) has illustrated the normal practice 25mm of slump can be allowed for the mix.

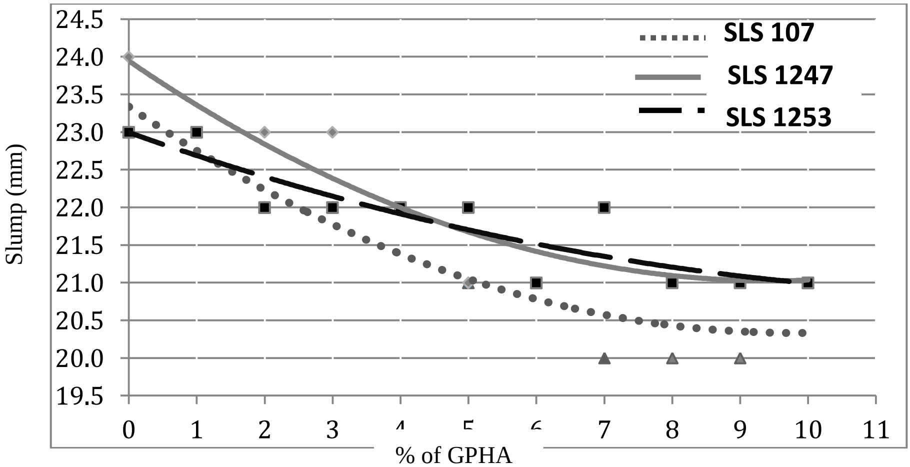

Figure 6, Slump (mm) Vs GPHA (%) graph

As per the results, with the percentage increase of GPHA all the cement types show a gradual fall in the slump value in a uniform manner. This is because; with the increment of GPHA the mix increases the water demand. Compared to the SLS 1247 and SLS 1253 cements, the SLS 107 shows lower values after 1% of GPHA mix. Here, at 0% of GPHA in SLS 1247 mix reaches the maximum value of 24.0mm and the minimum value of 20.0 mm by the 7%-9% of GPHA added SLS 107 cement. However, it can be considered that all the values of the mixes were within the allowable limit of 25mm.

4.2 COMPRESSIVE STRENGTH.

3 no. of random samples were selected from each mix and the compression test was conducted. The load was applied at a constant rate of 15± 3 N/mm^2/ minute until the block breaks. As per the Sri Lankan Standard Institution (2011) the minimum strength requirements and block thickness were defined as follows.

Table 3, Minimum strength requirements and blocks thickness

Strength Class	Average compressive strength (N/mm^2)	Individual compressive strength (N/mm^2)	Block thickness (mm)
1 (Vehicular)	50	40	80, 100
2 (Vehicular)	40	32	80, 100
3 (Vehicular)	30	25	80, 100
4 (Pedestrian)	15	12	60

According to Sri Lankan Standard Institution (2011) and British Standards Institute (2003) the compressive strength was corrected by the correction factors as follows.

Table 4: Thickness and chamfer correction factors for compressive strength

Work size thickness (mm)	Correction Factors	
	Plain Block	Chamfered Block
60	1.00	1.06
80	1.12	**1.18**
100	1.18	1.24
Blocks with chamfer of work size greater than 5 mm width.		

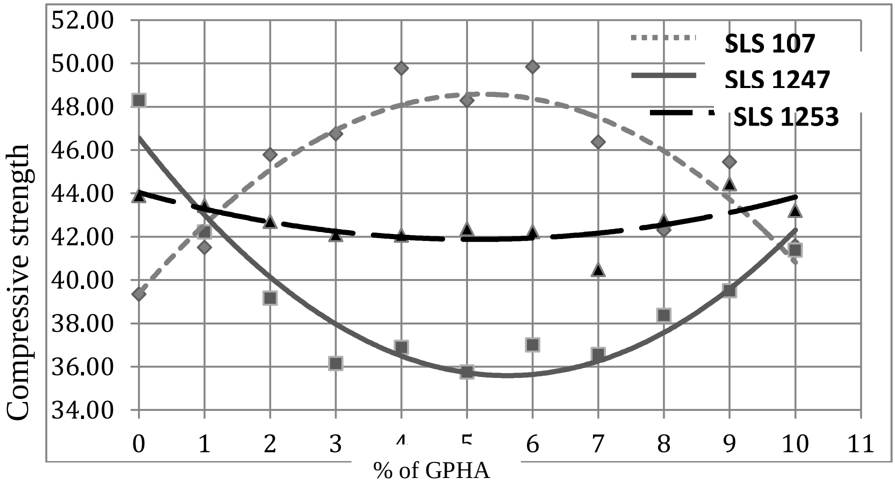

Figure 7, Compressive strength (N/mm^2) Vs GPHA (%) graph

As per the compression test results, the compressive strength of the blocks were considerably influenced by the percentage of GPHA added to each mixture. The SLS 107 cement mixture shows a good improvement in strength with the increment of GPHA and the SLS 1247 cement mixture and SLS 1253 cement mixture shows the drop. Furthermore, at the 6% GPHA SLS(107) mix shows a peak value of 49.84N/mm^2 than SLS 1247 cement and SLS 1253 cement, and all the mixes were achieved strength beyond the standard value. In SLS 1247 cement mix, it shows a peak value of 48.82 N/mm^2 in 0% GPHA and reaches a lowest value of 35.75 N/mm^2 and it shows a negative variation from 0% GPHA to 5% GPHA. In SLS 1253 cement mix; it reaches a peak value of 44.44 N/mm^2 at 9% of GPHA and it doesn't show a vast variation in the strength by adding the GPHA. Though the SLS 1247 & SLS 1253 mixes shows the drop in strength with the percentage increment of GPHA is some regions, none of the mixtures reach the lower value of 30N/mm^2 which shows the efficient improvement in adding GPHA to all the mixes.

4.3 SKID RESISTANCE.

The pendulum friction tester was used to test the skid resistance of the blocks. According to Sri Lankan Standard Institution (2011) and British Standards Institute (2003) the allowable skid resistance for interlocking blocks is $\geq$ 45.

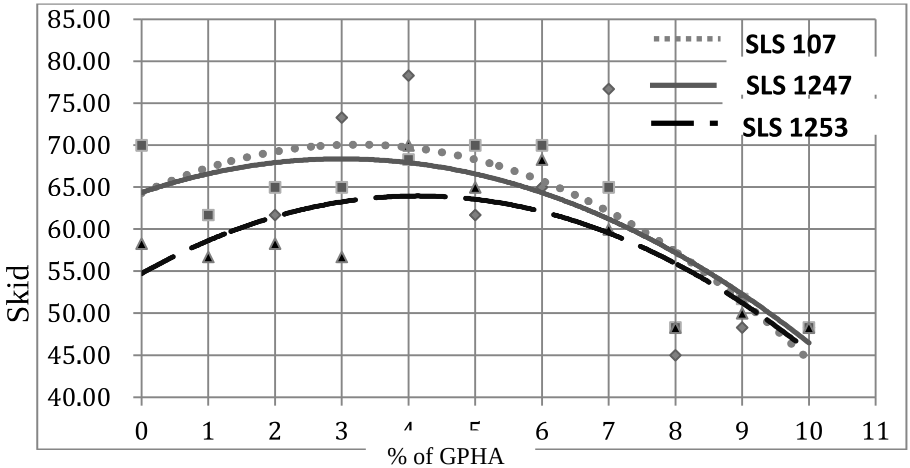

Figure 8, Skid Resistance Vs GPHA (%) graph.

As per the skid resistance test results, it shows a rise up to 4% of GPHA of all mixtures and then the values fall gradually. Further, none of the mixtures has fallen below the standard minimum value of 45. It shows though the surface smoothness was improved by adding the GPHA to the mixtures, the skid resistance values were not changed drastically. Compared to the SLS 107 and SLS 1247 cements, the SLS 1253 cement shows lower values always. At 4% of GPHA in SLS 107 mix reaches the maximum value of 78.3 and the minimum value of 45.0 was reached by the 8% of GPHA added SLS 107 cement. All the values were within the allowable limit.

4.4 TENSILE SPLITTING STRENGTH.

Splitting tensile strength was calculated according to British Standards Institute (2003). Normally tensile splitting value can be compared with the compressive strength values for the strength comparison.

The results show the positive incremental variation in the SLS 107 cement mix and it reaches a peak value of 2.47 at 10% of GPHA mix. In the SLS 1247 cement mix, it shows an increment up to 6% of GPHA and the SLS 1253 cement shows the reduction in the values within that range. Compared to the SLS 107 and SLS 1247 cements, the SLS 1253 shows a negative variation. Here at 6% of GPHA in SLS 1247 mix reaches the maximum value of 2.53 N/mm^2 and the minimum value of 1.82 N/mm^2 was reached by the 4% of GPHA added to the SLS 1253 cement.

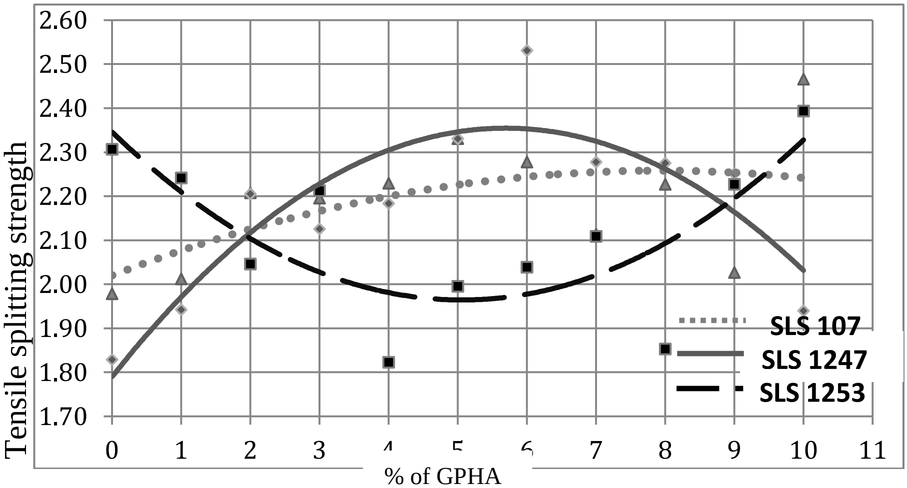

Figure 9, Tensile splitting strength (N/mm^2) Vs GPHA (%) graph

4.5 WATER ABSORPTION.

Water absorption is a measure of voids in hardened blocks which is occupied by water in saturation condition. The test was done according to Sri Lankan Standard Institution (2011) and the standard maximum allowable water absorption for the Interlocking block is $\leq$ 6%.

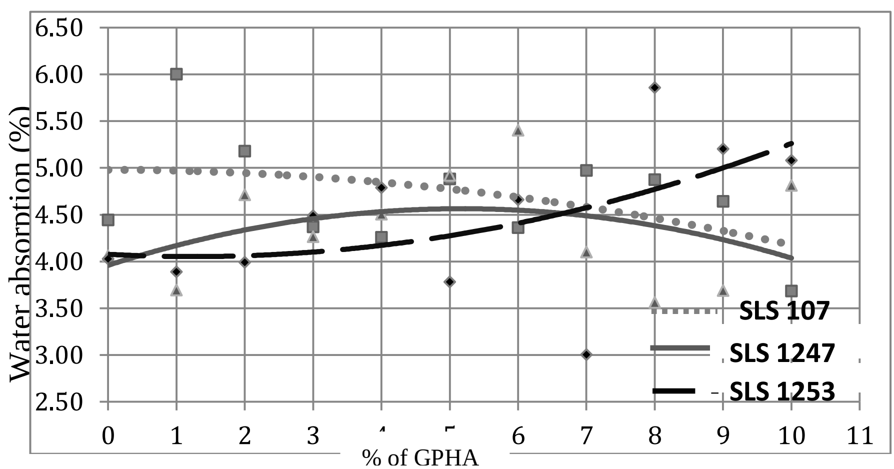

Figure 10, Water absorption (%) Vs GPHA (%) graph.

The results indicate that the water absorption values decreases with increase in the % of GPHA added for SLS 107 cement type and SLS 1247 cement type while SLS 1253 cement shows an increase in the values. At 1% of GPHA in SLS 107 mix reaches the maximum value then it drops gradually.

The minimum value of 3% was reached by the 6% GPHA added to the SLS 1253 cement. It is noticeable that, all the values were within the allowable limit.

4.6 VISUAL INSPECTION

Visual inspection was done in the natural daylight according to the British Standards Institute (2003) Annex H Method for verifying visual properties. Under this method the blocks were laid on the leveled floor in a square shape and observed from a distance of 2m for cracks and flaking. Also pleasing appearance was checked by the comparison of each block in a mixture. For easy inspection; the mixtures were named as from A0 to A10 according to the percentage of GPHA for SLS 107 Cement; accordingly, SLS 1247 cement and SLS 1253 Cement mixture samples were named as B and C.

Table 5, Visual inspection summary.

	Rough	Fairly Rough	Fairly Smooth	Very Smooth
SLS 107 (A)	A0, A1	A2,A3	A4, A5, A6	A7, A8, A9, A10
SLS 1247 (B)	B0	B1, B2, B3	B4, B5, B6, B7	B8, B9, B10
SLS 1253 (C)	C0, C1	C2, C3, C4	C5, C6, C7	C8, C9, C10

During the inspection it was noticed that beyond the 7% of the GPHA, all the mixtures give a smooth and pleasing appearance for all types of cements and there are no cracks or distresses were observed in the samples.

5.0 Cost analysis

Cost analysis for 1 Block of SLS 107 cement mix with 1% of GPHA

Cost for Paddy Husk (1%)
(Loading, Unloading & Transport 20km) = Rs. 8.00
Cost for Cement (1 Bag- 50kg) = Rs. 870.00
Cost for other Materials
(River sand, Quarry dust and Chips) = Rs. 545.42
Cost for material transport (Allow 20 km) = Rs. 250.00
Cost for Labour (4 Nos) = Rs. 600.00
Cost for Electricity (Allow) = Rs. 10.00
Cost for 1 Bag of Cement (70 No of Blocks) = Rs. 2,283.42

Cost for 1 No of Interlocking Block (1% GPHA) = Rs. 32.62
Cost for 1 No of Interlocking Block (0% GPHA) = Rs. 32.51

As per the above analysis the cost of the paddy husk for 1 Block is Rs. 0.11, and that is a 0.35% of the total production cost of 1 Block. Such a way, the production cost of 1 Block in 10% of GPHA mix will be Rs.33.65. So that the increment in the production cost is Rs.1.03 from 0% of GPHA to 10% of GPHA and it's nearly 3% compare to the production cost of 1 Block in the normal mixing proportion.

6.0 Conclusion

This research was involved in the improvement of strength and appearance in the interlocking blocks using GPHA. Overall results show a considerable improvement in the quality of the blocks by adding GPHA for all the cement types. SLS 107 cement showed a positive improvement in the strength between 0% to 5% of GPHA mix range and it has nearly a 30% of strength improvement compared to the normal mix. It also showed a fair visual appearance in that range. As the results of skid resistant values, though the values show a peak in 4% to 6% of GPHA, the values fall as expected since the voids were filled by GPHA. It is notable that none of the mixtures reached the minimum allowable limit. The tensile splitting strength can be compared with the compressive strength. SLS 107 cement and SLS 1247 cement showed the similar patterns and SLS 1247 showed a 30% of strength improvement while SLS 107 showed 12%. The water absorption variation was expected as the GPHA fill the voids. In the aspect of water absorption reduction SLS 107 and SLS 1247 showed around 20% of drop while SLS 1253 cement did not shows any. The visual property was improved in all the mixtures especially beyond 7% of GPHA as expected, because of the filling ability of the GPHA and blocks showed a considerable pleasing appearance. Since the price of the cement bags were nearly the same for all three types in Sri Lanka, adding GPHA does not affect the cost vastly. So that, it is the cheapest method to improve the strength in Interlocking Blocks. Further, this project could be an environment friendly approach for utilizing available waste materials (Paddy husk ash) in an effective way.

In conclusion, SLS 107 cement reacts more relatively to the GPHA in all the properties of the blocks. According to that, adding GPHA is an effective method to improve the strength properties of the interlocking blocks in an environment friendly approach. Though the SLS 1247 cement and SLS 1253 cement types did not reach all the objectives of the research, they showed good improvements in most of the properties and it will lead us to utilize the blocks in other appropriate places according to the various requirements.

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