EXPERIMENTAL INVESTIGATION OF MODIFIED CEMENT MORTAR CONTAINING RICE HUSK ASH AND POLYMER ADHESIVE

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INTRODUCTION

Cement mortar is one of the vital materials in the building construction industry. Cement mortar can be used mainly for block work and wall plastering. In most of the buildings, there are many defects due to the lack of bonding and low tensile strength of plaster, such as surface cracks in plaster, and the deboning and flaking of plaster. Thermal expansion and drying shrinkage are the main causes for the above defects. To improve cement mortar properties, Rice husk ash (RHA) and polymer adhesives can be used (Ogwang, 2021).

The new cement mortar mix, which is made by mixing rice husk ash and a polymer adhesive with conventional cement mortar, provide a quality mortar mixture that has good mechanical properties and durability. The enhanced bonding properties of new cement mortar will be helpful to reduce surface cracks in plaster. The new mortar mixture can be easily prepared and used for any type of building. In addition, the new mortar mixture reduces the amount of cement content by replacing RHA. This will minimize the cost for plastering and environmental problems due to the disposing of RHA in an uncontrolled manner.

The production of paddy rice was close to 774 million tons globally in 2013, with Asian countries comprising nearly 91% of it (Rashid, 2016). In Sri Lanka, there are so many small rice mills, where rice husk is wasted and disposed by burning. Sometimes, this bulk waste is reused in the paddy fields as a fertilizer and used in some industrial applications. However, most are disposed without any use. The rice husk contains about 75% - 80% organic volatile material and balance while 20% - 25% of the weight of this husk is converted into ash during the firing process, which is known as rice husk ash. The RHA usually contains around 80% - 97% amorphous silica with small amounts of alkalis and other trace elements (Rashid, 2016). According to G. Ogwang (2021), amorphous ash is formed at an incineration temperature of 550°C to 800°C, while the change occurs from amorphous to crystalline form at approximately 800°C to 900°C. When RHA is mixed with cement mortar, it reacts with calcium hydroxide and produces calcium silicate hydrate, which improves the strength and other mechanical properties of the cement mortar.

Polymers are being used in the construction industry to enhance properties of cement mortar or concrete. Their good binding properties result in good adhesion with aggregates and fine materials. Polymers have been attained by a long chain structure process, which helps to develop the long-range network structure of bonding. As a result, polymer materials enhance compressive, tensile, and flexural strengths of the cement mortar (Kim, 2020). Polyvinyl Acetate (PVA) is one of the best polymers which increases the flexural strength of conventional cement mortar. The PVA-mixed cement mortar will delay or prevent the formation of cracks and can be used for the plastering of walls. However, when the PVA concentration is too high (2.0%), the mortar performs poorly and is difficult to mix uniformly (Fan et al., 2019).

The objective of this study is to blend the RHA and PVA polymer adhesive with conventional cement mortar and investigate the improvement of the mechanical properties of the cement mortar. The findings of this study will help to reduce the cement usage in the cement mortar by adding the RHA and enhance the crack resistance of the cement mortar plastering.

METHODOLOGY

Conventional cement mortar consists of cement, water, and fine aggregates. In this study, different percentages of RHA and PVA were mixed in 1:3 (cement: sand) ratio with conventional cement mortar and the optimum mix proportions that offers the best flexural and compressive strength properties were determined.

The RHA was prepared by burning rice husk at 650°C for three hours in a furnace (Figure 1). The RHA used in the experiment was produced by sieving it through 0.15 mm sieve (Figure 2). PVA and Ordinary Portland Cement that were available in the market were used for this study. A sieve analysis was carried out for river sand (with sieve sizes of 4.75 mm, 3.35 mm, 2.36 mm, 2 mm, 1.18 mm, 0.6 µm, 0.425 µm, and 0.3 µm) and a well graded sand was used for the cement mortar.

Figure 1. Burnt rice husk

Figure 2. Sieved rice husk ash

Different RHA and PVA percentages were taken as the test variables for this study. The water to cement ratio used for all the test specimens was 0.45. Seven mix designs were considered in this study, which were named as S1, S2, S3, S4, S5, S6, and S7. The details of the test variables and mix proportions of the mix designs are given in Table 1 and Table 2, respectively.

Table 1. Test variables

Mix Design Name	RHA (%)	PVA (%)	w/c	Remarks
S1	0	0	0.45	Control sample
S2	5.0	0.6	0.45	
S3	5.0	1.0	0.45	
S4	5.0	3.0	0.45	
S5	20.0	0.6	0.45	
S6	20.0	1.0	0.45	
S7	20.0	3.0	0.45	

Table 2. Mix design for one cubic meter

Specimen	Cement (kg)	Sand (kg)	Water (kg)	RHA (kg)	PVAs (kg)
S1	558	1674	251.1	0	0
S2	530.1	1674	238.54	3.18	27.9
S3	530.1	1674	238.54	5.30	27.9
S4	530.1	1674	238.54	15.90	27.9
S5	446.4	1674	200.88	2.68	111.6
S6	446.4	1674	200.88	4.46	111.6
S7	446.4	1674	200.88	13.39	111.6

Sample Preparation

For each mortar mix, 6 cuboids were casted to check flexural and compressive strength after 14 and 28 days. All the specimens were cured under water for 7 days before testing. The size of the test specimen is 40 mm x 40 mm x 160 mm, and 3 cuboids were tested for each mix design. Compressive and flexural strength tests were conducted according to BS EN 1015/11. Figures 3 and 4 show the experimental setup for flexural and compressive strength test, respectively. As stipulated in BS EN 1015/11, the broken parts of the flexural test were used for the compressive strength test.

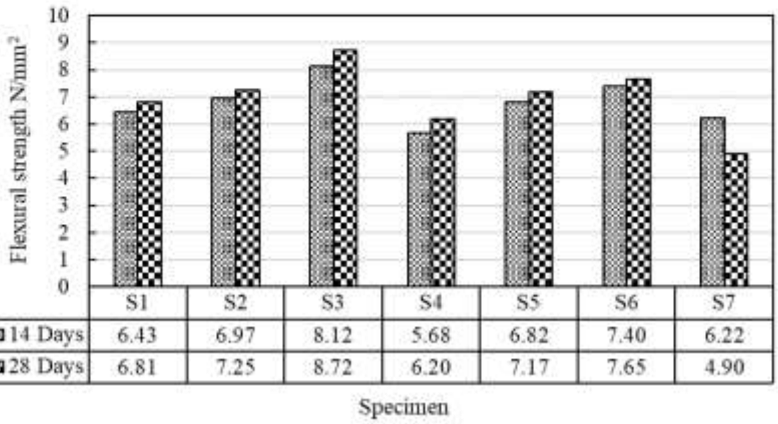
Figure 3. Flexural strength test

Figure 4. Compressive strength test

RESULTS AND DISCUSSION

Flexural Strength Test Results

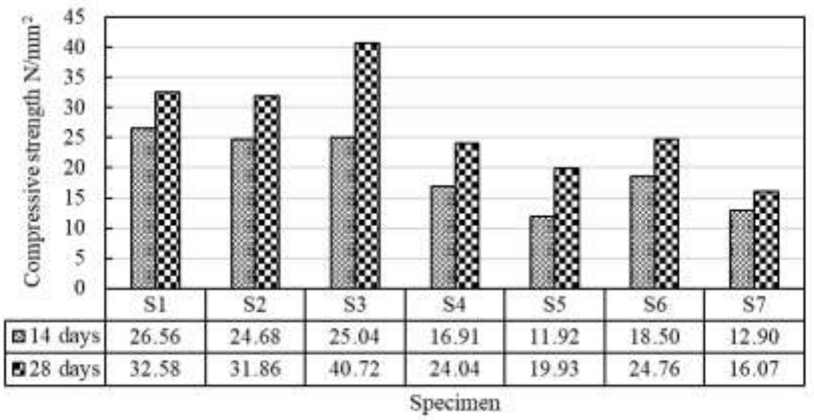
Figure 5 shows the flexural strength test results. Specimen S3 indicated significantly high flexural strength compared to the control specimen. Furthermore, when the PVA content was increased up to 3% in specimens S4 and S7, the flexural strengths (both 14 and 28 days) had noticeably reduced compared to that of specimens S3 and S6, respectively. This could be due to the covering up of the cement and RHA particles by the high PVA polymer content in specimens S4 and S7. Calcium silicate hydrate (C-S-H) primary gel and calcium hydroxide (C-H) are formed when cement reacts with water. Moreover, the RHA produces a calcium silicate hydrate secondary gel when silica reacts with calcium hydroxide. The C-S-H is the governing compound that contributes to the strength of cement mortar, whereas the compound C-H had a negative impact on the cement mortar strength. When the PVA content was gradually increased up to 1% (in specimens S3 and S6), the flexural strength of cement mortar had increased due to the binding effect of PVA. However if the PVA content is further increased (up to 3% in specimens S4 and S7), it may act as a protective coating for cement and RHA particles, and reduce the formation of C-S-H gel by the hydration reaction.



	S1	S2	S3	S4	S5	S6	S7
14 Days	6.43	6.97	8.12	5.68	6.82	7.40	6.22
28 Days	6.81	7.25	8.72	6.20	7.17	7.65	4.90

Figure 5. Flexural strength test results

Figure 6 shows the compressive strength test results. Compared to all the test specimens, specimen S3 showed the highest compressive strength in 28 days. The compressive strength of the cement mortar decreased when the RHA replacement was increased from 5% to 20%. On the other hand, the compressive strength of 28 days was reduced in specimens S4 and S7 compared to the control specimen (Figure 6). Similar to the flexural strength reduction in specimens S4 and S7, the compressive strength was also affected by the PVA coating formation around the cement and RHA particles, while it decreased the formation of the C-S-H gel during the hydration process.



	S1	S2	S3	S4	S5	S6	S7
14 days	26.56	24.68	25.04	16.91	11.92	18.50	12.90
28 days	32.58	31.86	40.72	24.04	19.93	24.76	16.07

Figure 6. Compressive strength test results

CONCLUSIONS

This study describes an experimental investigation of modified cement mortar containing rice husk ash and polymer adhesive. The following conclusions are drawn.

- The 5% replacement of rice husk ash in the conventional cement mortar gave the optimum flexural and compressive strengths. At 20% replacement of RHA, the characteristic compressive strength of the conventional cement mortar decreased by 24% or more.
- The mix design of S3 (5% of RHA and 1 % of PVA) gives the best mechanical properties in the cement mortar (compressive strength of 40.72 N/mm^2 and flexural strength of 8.72 N/mm^2).
- When the PVA content is increased beyond 1%, both the compressive and flexural strengths of the cement mortar are significantly reduced.

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