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THE EFFECT OF CONCRETE ROOF TILE COMPOSITE (CRTC) USING SAYONG CLAY AND RICE STRAW FIBRE ON THE FLEXURAL STRENGTH

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Abstract

The flexural strength of CRTC composite when combined with rice straw fibre (RSF) and clay was analyzed in this research. The clay was sourced from Sayong Kuala Kangsar, Perak in Malaysia while the rice straw fibre was collected from Kuala Kurau, Perak in Malaysia. Different percentage of clay (10%, 20% and 30%), different percentage of rice straw (1.0%,1.5% and 2.0%) and different length of rice straw (0.1-2.0cm, 2.1-4.0cm and 4.1-6.0cm) were added to a mix ratio 1: 2 for cement and sand to produce concrete roof tile composite plates. The result showed that the rise in the percentage of rice straw increased the flexural strength continuously until 5.51N/mm² for the 2.0% of rice straw tested in 300 days whereas the increase of clay percentage and length of rice straw decreased the flexural strength of concrete.

Keywords: *bonding agent; amorphous compounds; flexural strength; development of cracks; internal defects and elastic modulus*

1.0 INTRODUCTION

Natural fibre reinforced (NFR), as concrete reinforcement is a very beneficial technique to strengthen cement-based. This technique is used in a number of applications to increase the shear capacity of nonstructural building material. This feature is achieved by applying e.g. rice straw fibre (RSF) as reinforced material that was blended into the cement mortar with clay. Cement mortar bonding with natural material would be beneficial to produce a strengthening system that is thermal resistant and it also significantly lowers the carbon dioxide emission of retrofitting on existing construction material. An experimental investigation was conducted on shear behavior of concrete roof tile composite (CRTC) that is strengthened using RSF as reinforcement with cement and clay as bonding agents. The flexural strength of tiles samples was determined as portrayed in ASTM C1492- 03(2016), standard specification for Concrete Roof Tile.

2.0 MATERIALS USED AND THEIR PROPERTIES

2.1 Cement:

The Ordinary Portland Cement CEM 1 was used as the main binder for the experiment which fulfilled the requirements of MS 522: Part1: 2007 for compositions, specifications, and conformity criteria in common cements. This cement chemical and physical criterion comply with the BSEN 196 and the test procedures which follows the ASTM C 150. The chemical composition and physical properties of OPC used in this study are presented in Table 1.

Table 1: Chemical composition and physical properties of OPC used in present study

Chemical composition OPC	Mass (%)
SiO_2	20.5
Al_2O_3	5.09
Fe_2O_3	3.10
CaO	65.33
MgO	1.57
SO_3	2.91
Physical Properties	**Specification**
Specific surface area (m^2/kg)	1043.2
Specific gravity (g/cm^3)	3.02
Initial setting time (mins)	124
Final setting time (mins)	309

2.2 Fine Aggregate:

The fine aggregate used was uncrushed quartzite natural river sand. The properties of sand in the present study are shown in Table 2.

Table 2: Properties of Fine aggregate

Properties	Testing Procedures	Value
Fineness modulus		3.26
Particle density, oven dry (Mg/m^3)	BS 812-2	2.55
Particle density, saturated surface dry (Mg/m^3)	BS 812-2	2.58
Apparent particle density (Mg/m^3)	BS 812-2	2.83
Water absorption (%)	BS 812-2	1.06
Moisture content	BS 812-109	0.31

2.3 Clay:

The clay used in this study was taken from Sayong, Kuala Kangsar Perak, Malaysia which is well- known for clay pottery products making. Arifin (2015) found from his study that the best clay to produce pottery is clay from Sayong river bank. The chemical composition and physical properties of Sayong clay in percentage (%) is presented in Table 3.

Table 3: Chemical composition and physical properties of Sayong clay

Chemical composition	Mass (%)
SiO_2	54.58
TiO_2	0.44
Al_2O_3	27.04
Fe_2O_3	2.85
MnO	0.02
MgO	0.2
CaO	0.13
Physical Properties	**Specification**
Density (g/cm^3)	2.60
Specific gravity (g/cm^3)	2.76
Median particle size (µm)	2.9

2.4 Rice Straw Fibre:

The rice straw was taken from Kuala Kurau, Perak, Malaysia after harvesting season. Water treated samples of rice straw were used in this study. It is because this treatment does not eliminate amorphous compounds such as lignin and hemicellulose to preserve the original strength and also could remove some inorganic impurities and organic compounds from the rice straw during washing procedure (Ataie, 2018). The chemical compositions and physical properties of rice straw fibre that were tested are presented in Table 4. Rice straw fibre thickness was measured as the weight volume ratio using a helium pycnometer and the test of rice straw fibre tensile was carried out according to ASTM D 3822-01 (standard for tensile properties of single fibre) using a Instron 3342 tensile testing machine with a 100 N load cell at 5% strain per minute.

Table 4: Chemical composition and physical properties of rice straw fibre

Chemical composition	**Mass (%)**
SiO_2	18.69
TiO_2	Bdl
$Al2O_3$	0.36
$Fe2O_3$	0.14
MnO	0.14
MgO	0.28
CaO	1.19
Na_2O	0.05
K_20	2.89
P_2O_5	0.59
Physical Properties	**Specification**
Average Length	2.0, 4.0, 6.0 cm
Average Diameter	0.05 cm
Specific Gravity	0.95g/cm³
Tensile Strength	480 MPa
Young Modulus	24 Pa

3.0 EXPERIMENTAL PROGRAMME

The experimental program was designed to compare the flexural strength of CRTC with different replacement levels of clay (10%, 20%, 30%) and rice straw fibre (1.0%, 1.5% and 2.0%) in 0.1 - 2.0, 2.1-4.0 and 4.1-6.0cm. In order to achieve CRTC adequate strength, constant cement-sand ratio of 1:2 and water cement ratio started from 0.45 and increased according to the specified flow table standard at 105-115mm. Three plate samples were tested after curing in a store room and heated to 45°C in 24 hours. Table 5 shows the mix design proportions of 40 CRTC samples.

Table 5: shown the mix design proportions

Sample	**Types of mix**	**Rice straw size (%)**			**Sample**	**Types of mix**	**Rice straw size (%)**		
		0.1-2.0 cm	**2.1-4.0 cm**	**4.1-6.0 cm**			**0.1-2.0 cm**	**2.1-4.0 cm**	**4.1-6.0 cm**
CO	Control	0	0	0	C20RS 1.5B	20% Clay	0	1.5	0
C10RS 1A	10% Clay	1	0	0	C20RS 1.5C	20% Clay	0	0	1.5
C10RS 1B	10% Clay	0	1	0	C20RS 2A	20% Clay	2	0	0
C10RS 1C	10% Clay	0	0	1	C20RS 2B	20% Clay	0	2	0
C10RS 1.5A	10% Clay	1.5	0	0	C20RS 2C	20% Clay	0	0	2
C10RS 1.5B	10% Clay	0	1.5	0	C30RS 1A	30% Clay	1	0	0
C10RS 1.5C	10% Clay	0	0	1.5	C30RS 1B	30% Clay	0	1	0
C10RS 2A	10% Clay	2	0	0	C30RS 1C	30% Clay	0	0	1
C10RS 2B	10% Clay	0	2	0	C30RS 1.5A	30% Clay	1.5	0	0
C10RS 2C	10% Clay	0	0	2	C30RS 1.5B	30% Clay	0	1.5	0
C20RS 1A	20% Clay	1	0	0	C30RS 1.5C	30% Clay	0	0	1.5

C20RS 1B	20% Clay	0	1	0	C30RS 2A	30% Clay	2	0	0
C20RS 1C	20% Clay	0	0	1	C30RS 2B	30% Clay	0	2	0
C20RS 1.5A	20% Clay	1.5	0	0	C30RS 2C	30% Clay	0	0	2

This method was utilized according to the ASTM C1492-03(2016) test machine, with two lower metals were certainly rounded within a horizontal plan which the center was divided at 2/3 into the hanging length through the tile. In addition, two rounded metal upper bearers were positioned centrally relating to the lower bearer. The concrete tile samples were set over the test machine. It was loaded uniformly and continuously, without shock, at rate not exceeding 1000 lbf (4550N/min) until failure occurs. The average of three samples maximum loaded was recorded.

4.0 RESULT AND ANALYSIS

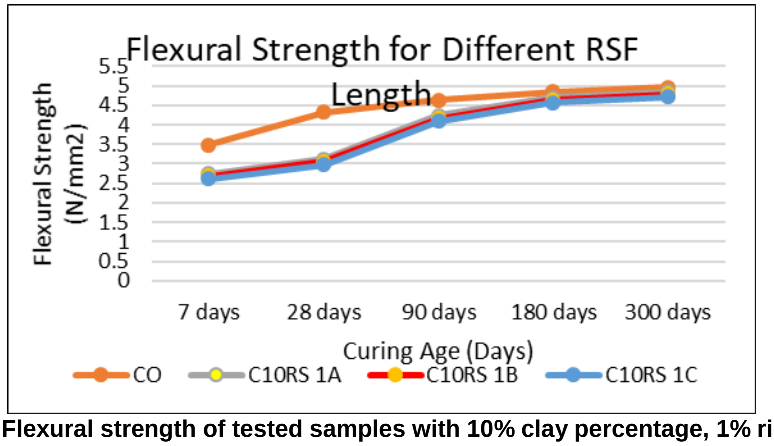

Figure 1: Flexural strength of tested samples with 10% clay percentage, 1% rice straw and various length of rice straw

Figure 1 shows the short fibre of RSF-reinforced cementitious composite has better flexural strength than the long fibre. This situation happens in other natural fibre used as reinforcement in concrete like in a study by Wang et al., (2019) the value of modulus of rupture reduces with the basalt fibre length increasing from 24.0 mm to 36.0 mm for specimens. According to Wang et al., (2019), this reduction may be attributed to fibre clumping described earlier especially for longer fibre lengths. Moreover, the longer the fibre length, the higher the water absorption since the incorporation of long coir fibre into the mix decreased the workability and increased void spaces. Short fibre becomes mineralized earlier than long fibre. In short fibre-reinforced composite, there are more endpoints which create facilities for the penetration of cement hydration products. Consequently, the loss of flexibility of the fibre is accelerated.

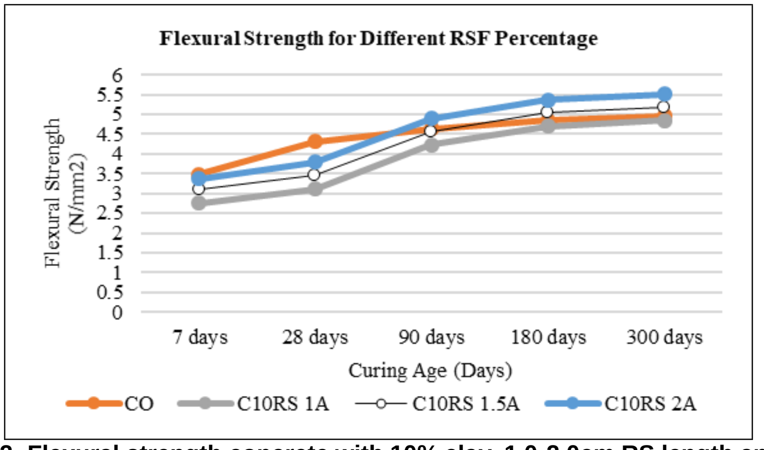

Figure 2: Flexural strength concrete with 10% clay, 1.0-2.0cm RS length and with various volume fractions of rice straw (1.0%, 1.5% and 2%)

Figure 2 shows rice straw with clay cementitious flexural strength significantly increased by increasing the rice straw up to 1%, 1.5% and 2%. It shows incorporation of fibre content in the concrete composite influences the flexural strength of the composites. This is because there are tiny cracks in the concrete structure before adding straw fibre which has a strong impact on its strength (Wang and Han, 2018). The structure will have brittle fracture under very small flexural force when the concrete structure is pressed. Based on Wang and Han (2018), adding straw fibre can effectively reduce the production of cracks, control the development of cracks and improve the internal defects of the materials.

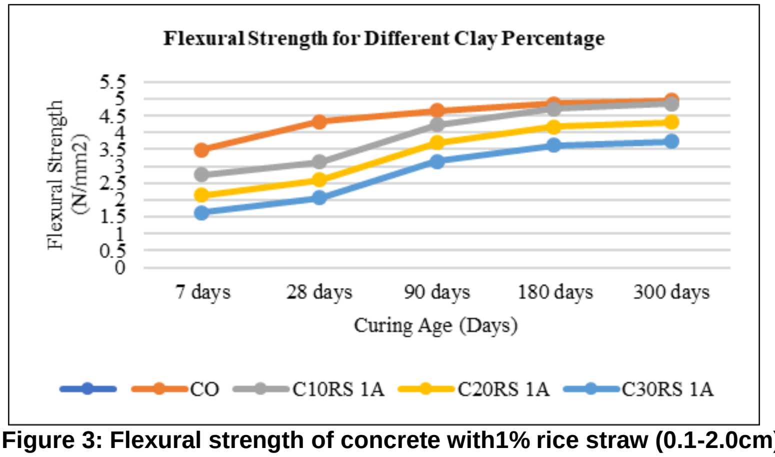

Figure 3: Flexural strength of concrete with1% rice straw (0.1-2.0cm) and various clay percentage

Figure 3 shows that clay content in concrete increased the flexural strength directly proportional with curing age. However, the increase of clay percentage significantly diminished the concrete strength. It also shows the increase of flexural strength became slower when curing age expended.

5.0 CONCLUSIONS

The following conclusions can be drawn from the results presented in this study:

I. The increase of rice straw fibre in CRTC increased the concrete flexural strength. It is because of the increase in silica content above the surface area of rice straw, which actuates the pozzolanic response with the cement. This fibre provided an additional bonding connection for each particle to support its strength and remained connected due to the brittleness of the low density. The high inclusion of rice straw fibre recorded better flexural strength due to more amounts of the fibre equally spreading the strength on the whole concrete mix.

II. The increase of rice straw fibre length diminished the flexural strength. It is due to the increment of the straw particles critical length. The straw critical fracture length is defined as twice the length of straw embedment, which will cause straw fibre failure during the pull-out. Therefore, the shorter rice straw particles fibre tends to be pulled out whereas the longer fibre tends to break. The shorter straw fibre length means it has better strength property. The length contribution however is not that significant to increase the strength improvement.

III. Increase in clay percentage also reduces concrete flexural strength because clay has high crystalline material that can reduce bonding of the concrete particle.

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