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The advantage of natural polymer modified mortar with seaweed: green construction material innovation for sustainable concrete

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Abstract

One important innovation of green construction material is natural polymer modified mortar. In this research, polymer modified mortar used natural polymer from seaweeds, they are Eucheuma Cottonii (gel) and Gracilaria Sp. The research conducted in two parts, pre-experiment and main-experiment. Pre-experiment aimed to investigate compressive strength of natural polymer modified mortar with seaweed gel (Eucheuma Cottonii) and seaweed powder (Gracilaria Sp.). The pre-experiment followed by main-experiment which investigated compressive strength and splitting tensile strength. The research has shown that natural polymer modified mortar with seaweed powder (Gracilaria Sp.) performed great compressive strength and splitting tensile with optimum mix composition of KM-0.5.

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Keywords: seaweed; natural; polymer modified mortar; green; construction material; sustainable concrete

1. Introduction

Green construction material takes important role in sustainable development. Brundtland Report (1987) about sustainability has driven the global concept of sustainability [1] as well as the sustainability of infrastructure. Since

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concrete has become the most popular construction material in the world, sustainable concrete will determine the sustainability of infrastructure. Several efforts have been done to achieve the sustainable concrete.Those efforts make the concrete technology innovation 'green', less energy, and less carbon emission. There is a concept to make concrete becoming green construction material, "Triangle of Virtuous Concrete Principle" which is stated by Susilorini [2]. The "Triangle of Virtuous Concrete Principle" is connecting the 3 aspects of sustainable development, infrastructure development, and carbon footprint reduction to be unity. Connecting the three aspects in the "Triangle of Virtuous Concrete Principle", concrete will trully become virtuous and green construction material.

It is known that concrete technology innovations have been implemented in construction industry. However, those innovations are still limited to meet criteria of green construction material. Therefore, we need more breakthroughs of concrete technology to fulfil the worlwide needs of green construction material.

Sustainable concrete needs 'extra' life-time that means longer durability. Hence, concrete shall be stronger, denser, and more durable. Since 70 years ago, polymer cementitious material has been produced to increase concrete performance to enhance its properties. Polymer made by polymerization of monomer to be more complex structure [3]. For application, polymer added into mortar or concrete which is called polymer mortar or polymer concrete. When polymer added together with cement and also aggregate into mortar or concrete, it is called polymer modified concrete or polymer modified mortar [4]. Polymer modified cementitious material has good binding properties and adhesion to aggregates, therefore it is useful for concrete repairing and retrofitting in modern construction [4,5].

In ancient period, organic polymer has already used as construction materials [5]. For examples, natural polymer asphalt used in Babylonia (fourth millenium BC) as well as bituminous mortar in Mohenjo-daro and Harappa (3000 BC) and also inTigris (1300 BC). The facts also tell us about the use of mortar containing albumen, blood, rice paste, etc., and glutinous rice paste lime mortar in Great Wall of China construction (second century BC). In modern era, polymer modified system has introduced natural rubber latexes that was improved to synthetic resin such as polyvinyl acetate latexes, chloroprene rubber (Neoprene) latex, styrene-butadiene rubber, polyacrylic ester, poly(vinylidene chloride-vinyl chloride) modified mortars and concretes, latex-modified concretes, etc. [5,6].

The innovations of polymer modified mortar has been developed with application of organic polymer such as rubber, latex, etc., but the use of natural polymer, especially carbohydrates polymer is very rare. This research wants to investigate the use of seaweed as natural polymer for polymer modified mortar. Eucheuma Cottonii (gel) and Gracilaria Sp. (powder) are used in this research because they contain agarans and carrageenans. Eucheuma Cottonii is polysaccharide that contains kappa carrageenan. It has advantage as emulsifier, suspensor, condenser, and stabiliser [8]. Gracilaria Sp. is also polysaccharide which contains agarose and agaropectin that make strong gel [9]. It is also noted that Cottonii (gel) and Gracilaria Sp. (powder) have rheological properties as gelling and thickening agents that [7] which can perform as epoxy resin in polymer modified mortar. According to the advantage of seaweed, this natural polymer modified mortar is expected to perform excellent bonding mechanism, strength, and durability as the key factor to achieve sustainability. Hence, this research aims to investigate the compressive strength and splitting tensile strength of natural polymer modified mortar with those seaweeds. Those compressive strength and splitting tensile strength are expected to perform good characteristics of green construction material for sustainable concrete.

1. Experimental Works

1.1. Materials and Mix Compositions

Materials used in this research are mortar and seaweed as natural polymer. The species of seaweed used are Eucheuma Cottonii (gel) and Gracilaria Sp. (powder). The Eucheuma Cottonii is extracted from raw boiled seaweed (Fig. 1a) and Gracilaria Sp. is in powder (Fig. 1b).

(a) (b)

Fig. 1.(a) EucheumaCottonii, raw seaweed and gel [10,11] (b) Gracilaria Sp., powder [10,12]

This research used mortar mix composition [13] as 1 : 1 : 0.6 (cement : sand : water) while the composition of seaweed in the mortar is described in Table 1.

Table 1. Composition of gel and powder seaweed in the mortar

Stage of experiment	% seaweed gel of the cement weight	% seaweed powder of the cement weight
Pre-experiment	0.1; 0.5;1;5	0.1; 0.5;1;5
Main-experiment	-	0.1; 0.2; 0.5;1;2; 5

1.2. Pre-Experiment

The research conducted in two parts, pre-experiment and main experiment. Pre-experiment aimed to investigate compressive strength of natural polymer modified mortar with seaweed gel (Eucheuma Cottonii) and seaweed powder (Gracilaria Sp.) in age of 7 and 14 days. There were 4 (four) compositions of seaweed in the mortar as shown in Table 1. The results of pre-experiment will determine which species of seaweed be used for the main-experiment.

1.3. Main-Experiment

The pre-experiment was followed by main-experiment which investigated compressive strength and splitting tensile strength of natural polymer modified mortar with seaweed determined by results of pre-experiment. There were 6 (six) compositions of seaweed in the mortar as shown by Table 1. All compressive strength specimens tested in 7, 14, and 28 days while splitting tensile strength in 28 days. Those natural polymer modified mortar with seaweed specimens will be compared to control specimens.

1.4. Specimens and Tests

Specimen used for pre-experiment were mortar cubes of 50 mm x 50 mm x 50 mm, while for main-experiment were mortar cubes 50 mm x 50 mm x 50 mm and also cylinders of 150 mm x 300 mm. For each mix composition, there always 5 (five) specimens were produced. Pre-experiment specimens subjected to compressive strength (f'_c) test referred to ASTM C-39, while main-experiments subjected to compressive strength (f'_c) test referred to ASTM C-39 and also splitting tensile strength (f_{ct}) test referred to ASTM C-496.

2. Result, Analysis and Discussion

2.1. Result and Analysis

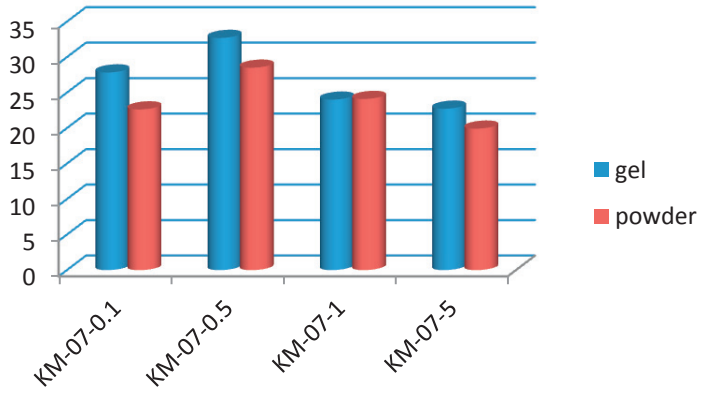

Fig. 2.Compressive strength at age 7 days, of natural polymer modified mortar with seaweed gel and powder (modified from [10,11,12])

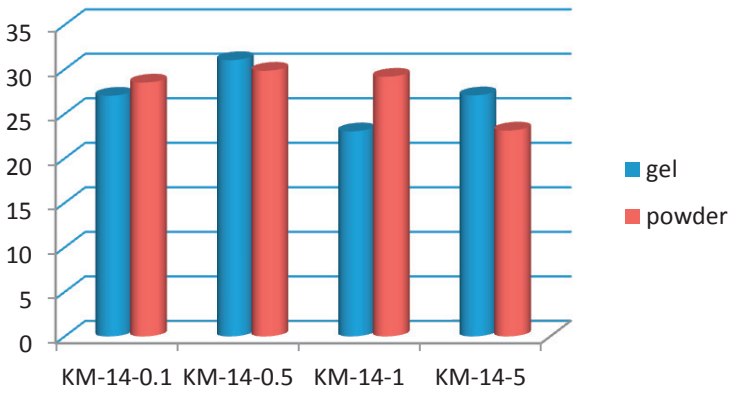

Fig. 3.Compressive strength at age 14 days, of natural polymer modified mortar with seaweed gel and powder (modified from [10,11,12])

Pre-experiment has shown higher compressive strength on natural polymer modified mortar with seaweed gel at age 7 days for 4 (four) mix compositions. The maximum compressive strength at age 7 days achieved by KM-07-0.5 gel (32.7 MPa) as described by Fig. 2. It is interesting observing at age 14 days that the mix composition KM-14-1 gel (23.03 MPa) was getting lower compared to KM-14-1 powder (29.17 MPa) as described by Fig. 3. According to the trend shown by Fig. 2 and Fig. 3, specimens of KM 07 and 14 powder perform stable performance of compressive strength. As mentioned in the first pharagraphs of this paper, natural polymer modified mortar with

seaweed gel (Eucheuma Cottonii) and seaweed powder (Gracilaria Sp.) have properties as gelling and thickening agents. Hence, the agarose and agaropectin of Gracilaria Sp. must form stronger gel compared to kappa carrageenan of Eucheuma Cottonii that increase the bonding mechanism of mortar. The results of pre-experiment has determined the seaweed powder of Gracilaria Sp. becomes natural polymer for polymer modified mortar specimens of main-experiment.

Main experiment investigated compressive strength and splitting tensile strength of 6 (six) mix compositions of polymer modified mortar with seaweed powder specimens and 1 (one) as control specimens. It is shown by Fig. 4 that mix composition of KM-0.5 has the highest compressive strength (29.28 MPa at 7 days; 29.64 MPa at 14 days; and 30.36 MPa at 28 days) among all mix compositions at all ages (7, 14, and 28 days). It should be noted that compressive strength of KM-0.1, KM-0.2, and KM-0.5 have gradually increased from age 7 days to 14 and 28 days. In the opposite, compressive strength of KM-1, KM-2, and KM-5 have gradually decreased from age 7 days to 14 and 28 days. Control specimens have shown lower compressive strength (18.85 MPa at 7 days; 19 MPa at 14 days; and 25.33 MPa at 28 days) compared to other mix compositions, except of KM-5 at 28 days. The results of main-experiment have shown that high dosage of mix compositions (KM-1, KM-2, and KM-5) will not give great improvement of bonding mechanism. It seems that optimum mix composition achieved by KM-0.5.

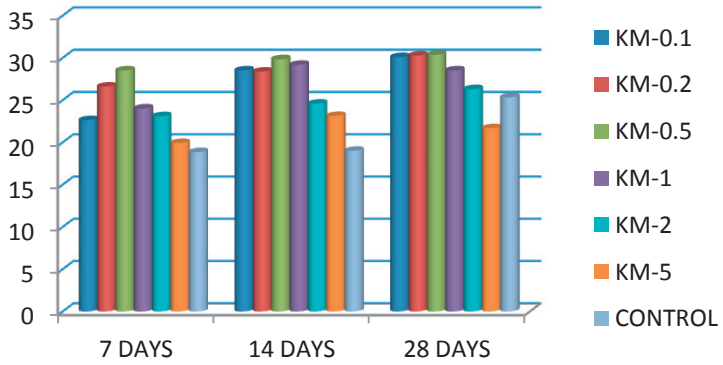

Fig.4. Compressive strength at age 7, 14, and 28 days of natural polymer modified mortar with seaweed powder (modified from [10,12])

Since the mortar and concrete are excellent in compressive strength but not very good in tensile strength, the influence of seaweed powder is expected to increase its tensile strength. Fig. 5 and Fig. 6 have shown the splitting tensile strength that is achieved by mix composition of KM-0.5. It is obvious that KM-0.5 has the highest splitting tensile strength (6.27 MPa that is 21.35% of its compressive strength) among the others mix compositions and control specimens (3.26 MPa that is 12.87% of its compressive strength). Unlike the results of compressive strength, KM-1 has high splitting tensile strength (5.63 MPa) that is closed to KM-0.5. It is emphasized that the agarose and agaropectine have made very strong gel and increased the bonding mechanism that make the performance of natural polymer modified mortar with seaweed powder becoming excellent.

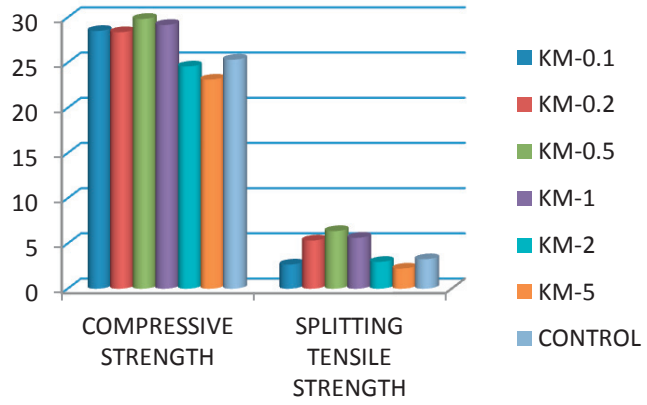

Fig. 5. Compressive strength and splitting tensile strength of natural polymer modified mortar with seaweed powder (modified from [10,12])

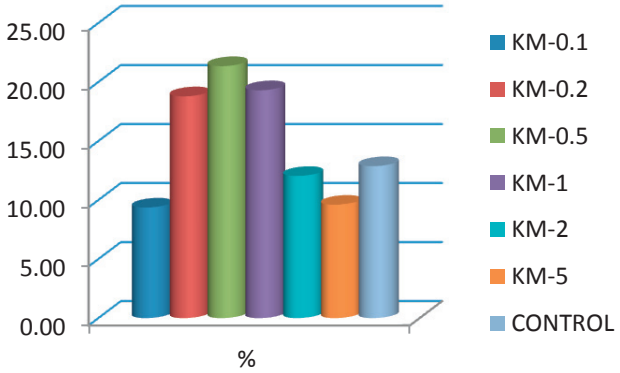

Fig.6. Percentage of splitting tensile strength by compressive strength (modified from [10,12]))

2.2. Discussion

Polymer modified mortar has good binding properties and adhesion to aggregates and it is very useful for repairing and retrofitting. When used together with cement, polymer will fill the porous parts and strengthen cement performance. Gracilaria Sp. and Eucheuma Cottonii have similar properties in gelling and thickening. They contain agarans and carrageenans that work at cement hydration phase. According to Arham et al. [14], Gracilaria Sp. has lower shrinkage but better ductility compared to Eucheuma Cottonii. It may cause the results of pre-experiment performed better compressive strength performance of natural polymer modified mortar with seaweed powder compared to seaweed gel. It should be noted that raw boiled seaweed (Eucheuma Cottonii) has been boiled in high temperature before applied into mortar and experienced cement hydration. It means that Eucheuma Cottonii seaweed has boiled twice that may reduce its bonding capability.

Gracilaria Sp. seaweed powder is very effective in gelling and thickening. Since Gracilaria Sp. has low shrinkage and great ductility, it will increase bonding mechanism and density. Hence, it can be understood that main-experiment results performed great compressive strength and tensile strength of KM-0.5. The results have shown that high dosage of mix compositions (KM-1, KM-2, and KM-5) will not give increasing of compressive strength but decreasing. The result may caused by ‘killing-set’ of mortar hardening because of excessive portion of natural polymer applied into mortar. It is obvious that low dosage of mix compositions (KM-0.1, KM-0.2, and KM-0.5) will increase the compressive strength. Since Gracilaria Sp. has characteristic of low shrinkage and great ductility

performance, it is shown by the results that splitting tensile strength of natural polymer modified mortar was increased. It should be noted that among the mix compositions, KM-0.5 is the optimum.

4. Conclusions

Eucheuma Cottonii (gel) and Gracilaria Sp. (powder) can be used as natural polymer. They are very effective in gelling and thickening and may increase bonding mechanism and density. The research has shown that natural polymer modified mortar with seaweed powder (Gracilaria Sp.) performed great value of compressive strength and splitting tensile compared to control specimens. KM-0.5 is the optimum mix composition. Natural polymer modified mortar with seaweed powder is very promising to become green construction material for sustainable concrete.

Acknowledgements

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