THE IMPORTANCE OF NATURAL MATERIALS FOR 'GREEN CONCRETE'

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The concrete structure has become the most popular construction around the world because of its strength, durability, and low environmental impact. In term of durability, concrete gives positive contribution in environmental revitalization, especially the 'green concrete'. The 'green concrete' is basically supported by 'green' materials. Several researches have proved that natural materials can be defined as 'green materials because its advantage. This paper meets conclusions: (1) Natural pozzolan such as Trass Muria Kudus, natural fiber such as coconut fiber, and also natural admixtures such as sugar and sugar cane liquid have ability to achieve higher performance of concrete, therefore the use of natural materials for 'green concrete' is necessity; (2) The optimum value compressive strength for specimen with Trass Muria Kudus is 29.802 MPa, 51.27% higher than plain specimen; while splitting tensile strength for specimen is 2.975 MPa, 34.99% higher than plain specimen; and elastic modulus is 9176.466 MPa, 9.68% higher than plain specimen; (3) The maximum splitting-tensile of concrete with coconut fiber is 4.339 MPa for fiber length of 80 mm. It is 13.62% higher than plain concrete; and (4) The dosage of sugar and sugar cane liquid admixture of 0.03% by weight of cement can perform as retarder while the dosage of 0.3% by weight of cement as accelerator

Keywords: natural, materials, 'green concrete'

1. INTRODUCTION

The concrete structure has become the most popular construction around the world (as described by Figure 1) because of its strength, durability, and low environmental impact [1]. Concrete must be survived from the destruction process, weather, chemical attack, etc; hence it will remain in its original form, quality, and serviceability while exposed to the environment [2]. In term of durability, concrete gives positive contribution in environmental revitalization to achieve sustainable concrete.

It is interesting that there are some efforts to achieve more durable and sustainable concrete structure. In USA, sustainable construction technology has been implemented by Infrastructure Reclamation Bureau [3] such as dam, pump, channel, tunnel, from Arizona to Montana. Another breakthrough has been improved in Netherlands to combine the environment engineering with technology that is based on civil engineering [4]. The combination of two disciplines proves that it can solve the problem of construction, management, and maintenance that is related to environment, nature, and landscape of road and coastal.

Figure 1. Modern concrete structure in Singapore
(Photograph by Susilorini, November 2008)

The sustainability of concrete is lately supported by the existence of 'green concrete' [1], [5], [6]. The 'green concrete' is environmental friendly. It is basically supported by 'green' materials. Several researches have proved that natural materials can be defined as 'green materials' because its advantage. This paper wants to deliver several researches about the advantages of natural material using such as natural pozzolan (i.e. Trass Muria Kudus), natural fiber (i.e. cocnut fiber), and also natural admixtures (i.e. sugar and sugar cane liquid). Hence, the use of natural materials for 'green concrete' is necessity.

2. DURABILITY, SUSTAINABILITY, AND 'GREEN CONCRETE'

Durability of concrete cannot be apart from sustainability of concrete. Durable concrete will provide sustainable concrete. In general, the term of sustainability in civil engineering is defined as a guarantee of the structure that still performs appropriately as its design and function during its life-service [7]. Wider definition is conceived by Susilorini [8], a sustainability of a structure. A sustainable structure is constructed properly then the social effects during its life-time and life-service are less, therefore it should be safe in design and performance. It can be said that sustainable concrete involves several aspects such as material using, structural engineering design, failure analysis, and environmental concern, need to be a necessity. Most concrete structure has been paid attention to the sustainability of structure due to its durability and environmental awareness as it is done by apartments in Singapore (Figure 2). Durable and sustainable concrete is the main purpose of 'green concrete' existence. The 'green concrete' considers the selection of materials, failure structural analysis, and environmental impact [8].

Figure 2. 'Environmental friendly' apartment structure in Singapore
(Photograph by Susilorini, November 2008)

The climate change has given serious impact for the world. It comes together with global warming issue and challenges the countries to make appropriate social economic policies [9]. Construction activities contribute the highest CO_2 emission and green house gases. The cement industry has a responsibility in creating 5% of CO_2 emission and 3% green house gases [10]. Supartono [11] also emphasizes that the energy used for cement production (8-9 MJ/kg) is 90% of total energy consumed in concrete production (4000-5200 MJ per m^3). People must be realized that the challenge of energy saving and cement production efficiency [12] is an answer to put the environment far away from the catastrophic destruction.

'Green concrete' means the efficiency of resources, hence, it copes the environment reservation. The efficiency of resources includes the application of recycled materials, pozzolan as cement substitution, and innovative admixture as explained by the next chapter. Several researches have proposed innovative materials for concrete mixture such as recycled materials [1], [13]; natural pozzolan to reduce cement consuming [14], [15], [16], [17], [18], [19]; coconut and palm oil fiber [20], [21], [22]; and also natural admixture of sugar [23], [24], [25] and sugar cane liquid [26], [27], [28].

3. SELECTED RESEARCHES ON 'GREEN MATERIAL'

The use of natural materials for 'green concrete' is obviously a necessity. Several advantages of concrete that is mixed by natural materials have been proven. Those 'green materials' will be explained briefly as follow.

3.1.Trass Muria Kudus, natural pozzolan from Central Java

Pozzolan is defined as finest powder material that is added to calcium mortar or Portland cement mortar to increase durability, especially, the calcium mortar can increase setting significantly [29]. ASTM gives more complete definition of pozzolan as material that consists of silica or alumina silica, has little or even no cementitious value, but in finest form in moisture condition, it will be chemically reacted with hydroxide calcium at room temperature to form compound that has cementitious

ability. One should be noted that there is characteristic change of hydraulic and non-hydraulic calcium mortar because of the pozzolan.

In very simple categorization, pozzolan divided into natural pozzolan and artificial pozzolan [30]. Natural pozzolan includes volcanic ash, pumice, tuff, diatomaceous earth, and opaline shale; while artificial pozzolan includes fly ash, rice husk ash, brick dust, calcined kaolin, condensed silica fume, GGBS and some metallurgical slag. Trass is categorized as natural pozzolan. It can be defined as products of volcano eruption that suffers weathering in such level [31]. Trass performs with colour of dark grey whitish, grey, dark grey reddish, yellowish, or light orange.

Gibbons [29] explains the setting of mortar which is added by pozzolan as follow. Simple non-hydraulic lime mortar is hardened by drying and carbonation. The process goes by conversion of calcium hydroxide (slaked lime) to calcium carbonate with atmospheric carbon dioxide. In hydraulic mortars, this hardening process is provided by chemical reactions between calcium hydroxide and reactive silicates and aluminates in the presence of water. In natural hydraulic limes, the reactive silicates and aluminates are supplied by clay minerals in the limestone. The pozzolan is added when a hydraulic set is required in a lime mortar but these minerals are not naturally present, or are not present in sufficient quantities.

Trass Muria Kudus is popular as material for cement mortar mix, concrete bricks, concrete mix, and mortar or soil infill [16], [18]. The research and study about the using of Trass Muria Kudus as fine aggregate for concrete mix have been delivered by [14], [15], [16], [17], [18], [19]. The laboratory test shows that Trass Muria Kudus consists of 42,02% SiO_2 and 28,08% Al_2O_3. It is found that volume ratio of (1:2:3) for (cement : Trass Muria Kudus : split) is the optimal mix for compressive strength, splitting tensile strength, and elastic modulus performance. The optimum value compressive strength for specimen with Trass Muria Kudus is 29.802 MPa, 51.27% higher than plain specimen. It also shows that splitting tensile strength for specimen with Trass Muria Kudus is 2.975 MPa, 34.99% higher than plain specimen; while elastic modulus for specimen with Trass Muria Kudus is 9176.466 MPa, 9.68% higher than plain specimen.

According to *technology-based development planning* [16], the Trass Muria Kudus application as natural material for ‘green concrete’ is supported by its availability, simple production, reasonable price, durable and good strength performance.

3.2. Coconut fiber for fiber concrete

The concrete structures, some times, behave unsatisfactorily because of its brittleness. According to Bazant [32], the failure of concrete structures relates to the strain-softening of distributed cracking and localized crack that grows to larger fracture prior to failure, and also bridging stresses at the fracture front. Therefore, the suppression of fracture of concrete can be implemented by improving higher toughness and higher tensile ductility [33]. It should be noted that the behaviour of interface between fiber and matrix and its stress transfer takes an important role in determining the whole composites properties, selecting the main ingredients of composites, and predicting the failure of composites’s structure [34].

The need of better performance is fulfilled by the birth of several types of fiber based material [34] such as Fiber Reinforced Concrete (FRC), High Performance Fiber Reinforced Cementitious Composites (HPRFCC) which is known as Engineered Cementitious Composites (ECC).

Several innovation of fiber materials have been applied included synthetic fibers and natural fibers. A previous research [20], [21], investigates the performance of fiber concrete using coconut fiber (called *coir*) which is represented by its splitting-tensile strength. The volume of coconut fiber is 0.25% of concrete volume with fiber length 60-100 mm. The maximum splitting-tensile is 4.339 MPa for fiber length of 80 mm. It is 13.62% higher than plain concrete.

3.3. Sugar and sugar cane liquid, natural admixtures

The main purpose of concrete admixture is improving particular properties of concrete or mortar [36]. Some admixtures are used as retarder and accelerator. Concrete retarder is used to delay cement setting while the concrete accelerator is the opposite. It is believed that sugar has been found to delay cement setting [37]. The common dosage of sugar as retarder is ranged 0.03%-0.15% by weight of cement, while the dosage above 0.25% will generate rapid setting of cement [36]. However, certain dosages of sugar can delay [36], [38], or even accelerate cement setting [36].

Previous research of [23], [24], [25] purposed to use sugar as 'green' materials for concrete retarder admixture. The research tries to deliver two extreme dosages of sugar retarder admixture, it is 0.03% and 0.3% of cement weight that becomes ingredient of concrete mixture. The dosage of sugar admixture of 0.03% by weight of cement can perform as retarder because its value of compressive strength of mortar and concrete at days 7 is lower than plain mortar and concrete. The dosage of sugar admixture of 0.3% by weight of cement can perform as accelerator because its value of compressive strength of mortar and concrete at days 14 is higher than plain mortar and concrete. The use of sugar as concrete admixture will fulfill the need of safe and 'green' concrete admixture.

It is interesting that sugar cane liquid can be applied as 'green' retarder and accelerator concrete admixture. Sugar cane is popular as raw material for sugar production. Previous researches have proved that sugar cane significantly increase the performance of bricks [37] and performs very high pozzolanic activity [39]. The dosage of sugar cane liquid admixture of 0.03% by weight of cement can perform as retarder because its value of compressive strength of mortar and concrete on days 7 and 14 is the lowest compared to plain mortar and concrete. The dosage of sugar cane liquid admixture of 0.3% by weight of cement can perform as accelerator because its value of compressive strength of mortar and concrete on days 7 and 14 is the highest compared to plain mortar and concrete even though it decreases at days 28. The sugar cane liquid can be used as 'green' concrete admixture. It is briefly explained that the natural admixtures such as sugar and sugar cane liquid have ability to achieve higher performance of concrete.

4. CONCLUSIONS

This paper meets conclusions:

(1) Natural pozzolan such as Trass Muria Kudus, natural fiber such as coconut fiber, and also natural admixtures such as sugar and sugar cane liquid have ability to achieve higher performance of concrete, therefore the use of natural materials for 'green concrete' is necessity

(2) The optimum value compressive strength for specimen with Trass Muria Kudus is 29.802 MPa, 51.27% higher than plain specimen; while splitting tensile strength for specimen is 2.975 MPa, 34.99% higher than plain specimen; and elastic modulus is 9176.466 MPa, 9.68% higher than plain specimen

(3) The maximum splitting-tensile of concrete with coconut fiber is 4.339 MPa for fiber length of 80 mm. It is 13.62% higher than plain concrete

(4) The dosage of sugar and sugar cane liquid admixture of 0.03% by weight of cement can perform as retarder while the dosage of 0.3% by weight of cement as accelerator

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