A short review on the use of coconut shell powder as filler in cement concrete

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Abstract. Environmentally-friendly composites had been the interest of researchers nowadays. Therefore the use of natural sources to gradually replace the conventional materials had been rapidly developed. Besides the use of natural fibres as reinforcement in polymer matrix composites, the use of fillers from natural sources, such as rice husk and corn cobs, was implemented in ceramic matrix composites. Solid waste like coconut shell is one of the potential material to be used as filler in these composites. Coconut shell in powder forms is usually used together with cement to produce high strength, more durability and lightweight concrete for structural component in construction area. Based on this review paper, coconut shell concrete showed comparable mechanical properties to the conventional concrete, in terms of its compressive strength. These properties suggested coconut shell powder as potential material to replace course aggregate in concrete.

1. Introduction
In 21st century, many sectors receiving challenges to develop new innovation by using eco-friendly materials from agricultural waste products to be converted into biocomposites [1][2]. One of the sector is ceramic matrices composites (CMC) [3]. CMC is a compound ceramic substrate which are blended together with ceramic fibers. Producing an eco-friendly CMC, some natural fibers such as rice husk, groundnut husk and corn cobs is added to the fabrication [3].

Coconut tree, known as an economical plant, is one of the beneficial raw material to be embedded with CMC to develop an environmental friendly product. Every single part of this economical plant can be benefited which provides foods from its fruit and soft trunk, water and oil from its fruit, roof and broom from its leaves, and bridges from its trunk [3]. Furthermore, in construction sector, timber and wood can be replaced by coconut trunk as the main structure. Husk, leaves and shell of coconut can also be being used as low cost materials since they are known as agriculture waste products [3].

Compared to husk and leaves, coconut shell can be more effective to be used in composites, since it is a solid agro waste products [4][5]. Coconut shell can be used as filler material to produce a high
strength to weight ratio CMC while reducing the use of conventional fillers [4]. Coconut shell has comparable mechanical properties to the mineral filler, which this plant sources also benefits in low cost, low density and renewability [6]. The use of coconut shell also can reduce the health hazard to a minimal level [6]. In addition, coconut shell has favourable properties in manufacturing fields, which it causes less abrasion to the machine leads to less possibility of machinery break down [6].

Since coconut shell is good in abrasive, which cause less damage to the machinery, it is known as one of the potential material for long lasting use. In terms of chemical composition, coconut shell properties are almost similar to hard wood [6][7][8]. Therefore, it was possible for the coconut shell powder to be used as a potential material in the development of hardwood industries, to improve the strength of building structure [6][7].

2. Coconut shell powder (CSP)

Coconut shells are generally found as waste materials in a semi sphere shape, which the water and inner soft part of the fruit had been removed. There are several processes in preparing coconut shell powder (CSP) from the waste coconut shell to be used as fillers in CMC. Figure 1 shows the preparation process of CSP cement.

![Figure 1. Procedures to prepare coconut shell powder (CSP) cement.](image)

Hairy fibres surround the coconut shell was removed before the dry coconut shell was crushed into small pieces of coconut shell chips, [9][10][11]. A crusher machine was then used to produce CSP from the chips, continue with the sieving of CSP to obtain the desired size. The sieved CSP was oven dried at 105 °C to remove moisture [9][10][12]. The properties of prepared CSP were listed in Table 1. These properties suggested CSP as a potential material in developing a coconut shell concrete.

| Properties          | Result  |
|---------------------|---------|
| Specific gravity    | 1.33    |
| Water absorption    | 23      |
| Impact value        | 15.6%   |
| Crushing value      | 2.58%   |

Table 1. Properties of coconut shell powder. [10]

It was reported from the X-Ray Fluorescence (XRF) analysis that the chemical compound found in the CSP was also normally found in the concrete. Therefore, the use of CSP in concrete can be beneficial to the properties of concrete. Table 2 shows the chemical composition of CSP obtained from the XRF analysis [13].
Table 2. XRF analysis of coconut shell powder. [13]

| COMPOUND                  | FULL NAME            | CONCENTRATION |
|---------------------------|----------------------|---------------|
| Coconut shell powder (g)  |                      | 5             |
| Wax (g)                   |                      | 5             |
| C                         | Carbon               | 10.00 %       |
| K₂O                       | Potassium Oxide      | 1.21%         |
| SiO₂                      | Silicon Dioxide      | 0.98%         |
| Cl                        | Chlorine             | 0.79%         |
| Fe₂O₃                     | Iron (III) Oxide     | 0.35%         |
| MgO                       | Magnesium Oxide      | 0.31%         |
| Na₂O                      | Sodium Oxide         | 0.29%         |
| CaO                       | Calcium Oxide        | 0.23%         |
| MoO₃                      | Molybdenum (VI) Oxide| 0.17%         |
| S                         | Sulphur              | 0<LLD         |
| Al                         | Aluminium            | 0<LLD         |
| P                         | Phosphorus           | 0<LLD         |

3. Mechanical properties of coconut shell powder (CSP) composites

The IS 10262-1982 standard method was applied in blending CSP with cement in the laboratory to ensure the fabrication achieved the standard concrete grade M-20 [14]. A mixer was used to blend all together CSP, sand and water to produce the coconut shell (CS) concrete in various ratio of each material. Fabricated CS concrete can be used not only as construction material, but also in replacing the conventional pipelines. The properties evaluation of concrete need to be carried out on the 7th and 28th days in terms of compressive strength [15] [16] [17]. The coconut shell powder was normally used to replace the coarse aggregate in concrete. Table 3 shows the compressive strength of CS concrete reported by previous researchers.

Table 3. Compressive strength of coconut shell (CS) concrete.

| Ratio CA:CS (%) | Compressive strength (N/mm²) | Ref.   |
|-----------------|------------------------------|--------|
|                 | 7 days                       | 28 days|
| 100:0 (C)       | 24.6                         | 28.3   | [18]   |
| 95:5            | 15.7                         | 25.6   |        |
| 80:20           | 9.2                          | 22.2   |        |
| 100:0 (C)       | 11.11                        | 22.33  | [19]   |
| 90:10           | 5.16                         | 13.56  |        |
| 80:20           | 7.82                         | 9.33   |        |
| 100:0 (C)       | 20.53                        | 27.58  | [20]   |
| 90:10           | 18.14                        | 23.46  |        |
| 50:50           | 11.05                        | 15.48  |        |
| 100:0 (C)       | 21.25                        | 28.54  | [21]   |
| 90:10           | 18.17                        | 25.47  |        |
| 50:50           | 10.15                        | 14.63  |        |

Control sample was not reported [22]

90:10           | 18.87                        | 21.25  |
70:30           | 8.88                         | 9.88   |

Control sample was not reported [23]

90:10           | 19.98                        | 21.79  |
80:20           | 13.56                        | 15.25  |
It was depicted from Table 3 that replacement of aggregate at 5% and 10% marked slightly lower compressive strength compared to the conventional 100% course aggregate concrete. Except one study reported a distinct lower value to the conventional [23] [24], which is more than 40% difference, other studies showed bright potential of replacing the course aggregate with CSP. Although the minimum percentage replacement used could not achieve the conventional strength, the small difference can be overcome in the next future [25] [26]. In all studies, several ratios were tested to analyse their effects to the compression properties. The table also listed the maximum percentage replacement of CSP in each study, to give the overview of the lowest compressive strength of concrete being produced with the respective amount of CSP [27].

4. Conclusion

The compressive strength of coconut shell concrete is comparable to the conventional, leads to a bright potential for its use as replacement to the course aggregate in concrete. The use of coconut shell powder will result in a more environmentally friendly composites, which its applications especially in pipeline under the water can reduce the harm to the living things in the sea. A lightweight composite can also be being produced, as well as increasing the market value of the waste material from the coconut shell. Future studies need to be carried out to enhance the properties of these CS concrete and further its applications in other types of ceramic matrix composites.

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