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Impact resistance of oil palm shells concrete reinforced with polypropylene fibre

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HIGHLIGHTS

- Total of 36 sample was prepared by cutting the cube specimens which is a new suggested method for preparing the samples.
- Different volume fractions of polypropylene (PP) fibre and various thickness were investigate.
- There was a strong linear relation between volume fraction of PP fibre and impact resistance as well as crack resistance ratio and this relation was indefeasible by changing the thickness from 20 mm to 30 mm and 40 mm.
- Increasing the thickness improves the impact resistance significantly, but the effect was more pronounced for ultimate failure crack resistance than the first crack resistance.
- The optimum ductility has been offered by specimens with 0.3% VF of PP fibre and 30 mm thickness.

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ABSTRACT

This study examines the results from an investigation on the impact resistance of oil palm shells (OPS) concrete. The use of OPS as a substitute for regular aggregate in lightweight concrete will help reduce its negative environmental influence. There is a lack of research on the impact resistance and crack behaviour of concrete; specifically in OPS lightweight concrete reinforced by polypropylene (PP) fibre. The replication of a low-velocity projectile effect on slab samples was achieved by dropping two types of steel ball (weighing 0.380 kg and 1.25 kg), with drop height of 360 mm, through the utilization of a self-fabricated drop-weight impact test rig. A total of 12 cube specimens, with dimensions 100 × 100 × 100 mm, were used to prepare 36 slabs with various thicknesses. The 36 slabs were prepared using a concrete cutting machine to excise the three cube specimens from each mixture, into 20, 30 and 40 mm thicknesses. Impact resistance tests were then performed on them. The results demonstrate that there was a strong linear relation between volume fraction of PP fibre and impact resistance; as well as crack resistance ratio. This relation was indefeasible by changing the thickness from 20 mm to 30 mm and 40 mm. Although increasing the thickness improved the impact resistance significantly, the effect was more pronounced for ultimate failure crack resistance than for first crack resistance.

1. Introduction

Oil palm shells (OPS), which are recognized as a major agricultural discard, is currently being considered as an alternative aggregate in lightweight concrete. It is appropriate for use in such concrete, as OPS has a density that is considerably lower than ordinary aggregates.

The crafting of plans for some types of buildings necessitates a good comprehension of concrete behaviour when subjected to dynamic loadings. Impact resistance refers to the capability of concrete to fend off cracking and spalling when exposed to persistent traumas [1].

The structural stability and impeccability of concrete may spoil once subjected to impact load. The use of mass or high-performance concrete to withstand impact loads leads to higher construction costs of structures. Adding fibre to concrete has the advantage of improving the impact strength and ductility of concrete to rehabilitate the brittleness of lightweight aggregate. The inclusion of fibre is just one method of enhancing the compressive strength and mechanical characteristics of OPS concrete.

The development and progression of cracks is caused by an increase in compression loading. As a progressing crack draws

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close to a fibre, de-bonding is set off at the fibre-matrix interface because of tensile stresses occurring to the anticipated route of the crack. Upon the arrival of the crack at the interface, the potency of its tip stress is reduced; this circumstance serves to subdue and impede the further proliferation of the crack. This describes the bridging effect or crack curtailing capacity of concrete treated with fibres [2–4]. The process by which fibres accomplish the connection bridge to deter crack proliferation is shown in Fig. 1.

The fibres utilized for this purpose can be classified as metallic, polymeric or natural [5]. Concrete is saddled by its brittleness. This weakness is due to its low crack prevention capacity, depleted tensile strength, and poor strain capacity [6]. Fibres reinforce the cement matrix by taking on a portion of the load applied. More importantly, they improve the crack and pore-bridging capacities of the concrete [7]. Previous studies have revealed that the inclusion of fibres also enhanced the formability and bending capability of concrete [3]. The most popular means of averting vibration-related crack development attributed to paste contract, is through the introduction of fibres. Preferably, these fibres should be slender, with a volume below 0.5% [8].

A volume of above 0.5% steel fibre was most used to improve the impact resistance of concrete [9–11]. Beside steel fibre, synthetic fibres such as polypropylene (PP) and nylon fibres were used in concrete and these fibres were found to amend the impact resistance of concrete [12,13,2]. Although synthetic fibre reinforced concrete provides lower impact resistance than steel fibre, the predominant characteristics of synthetic fibre are non-corrosive and light [8,11,14].

Meanwhile, the thickness of slabs is a principal factor for slab elements to resist impacts. Impacts result in cracking of the concrete on the back face. This happens due to reflected tensile waves propagating from the point of impact. Spalling of the concrete interior can occur from the impact. When slabs are highly reinforced, even though they have high impact energy resistance, they may fail due to punching shear. Upon impact, localized damage is noticed at the point of contact. This damage may be due to compression failure near the point of contact.

Several investigations have focused on the impact resistance of bamboo fibre reinforced oil palm shells concrete slabs. These investigations revealed that the best possible achievements for initial and ultimate crack resistance were realized with a bamboo fibre volume of 2% [15]. The impact resistance of an OPS fortified 20 mm thick concrete slab, subjected to varying levels of geogrid content was also examined [16]. Results from a low velocity impact analysis [17] showed that the impact resistance of the concrete slab was best enhanced with the utilization of steel fibres. A separate investigation examined the usage of recycled coarse aggregates [18]. This revealed that the generation of strain energy in concrete was significantly raised with 50% and 100% inclusion of recycled coarse aggregates.

This study endeavours to ascertain the impact and crack resistance of PP fibre and hybrid fibre reinforced OPS concrete.

It was found that the orientation of the geogrid had no influence on impact resistance. The maximum ultimate crack resistance of geogrid reinforced slabs was 633.9 Mpa. The test results indicated that the specimens reinforced by geogrid had an EA_u of 20.1 times more than their control specimens [1].

In another research into the impact resistance performance of green construction materials using bamboo reinforced lightweight palm shells, concrete slab panels were tested for impact resistance using a self-fabricated drop weight with a steel ball of 1.2 kg at a height of one metre. The amount of OPS in use was varied between 0.45 and 0.6%, while the spacing of the bamboo reinforcement was kept constant for all samples.

The correlation between service and ultimate crack resistance versus slab thickness was also linear; whereby, for an OPS content of 0.45% an increase of 81% and 31% were observed for service and ultimate crack resistance, respectively. The increment in slab thickness was also found to have more influence on crack resistance, compared to the diameter of the bamboo [19].

Another study was conducted by Z.C. Muda on the impact resistance of OPS lightweight concrete slabs reinforced with bamboo fibre. The study aimed to examine the correlation between compressive strength, crack resistance and impact energy absorption.

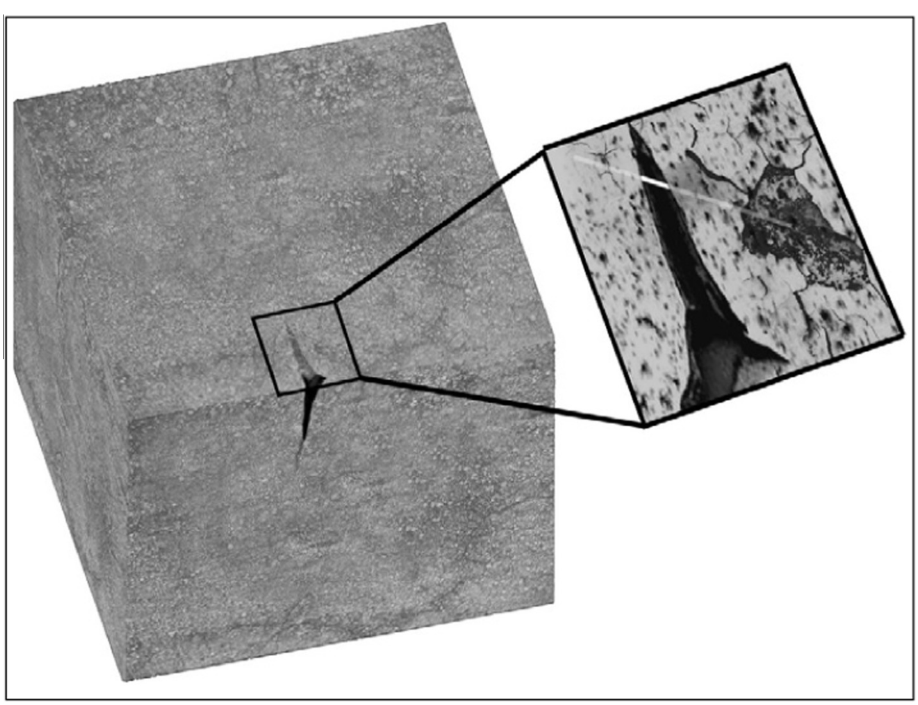

Fig. 1. Graphical schematic of the prevention of the crack propagation by forming connection bridge by fibre [3].