Using plastic to generate sustainable concrete

This literature review will look at previous researchers’ effort of using plastic to produce new type of sustainable concrete, in order to gather key data and give a general direction of the primary research process

I ntroduction

In fast developing countries, the rapid urban population growth gave rises to a lot of problem, two important problem is the number of plastic waste and sand shortage. India for example, approximately 15000 tons of plastic waste were sent to the landfill every day (The Time of India, 2015), and they also suffer from shortage of sand due to their rapid development.

Plastic are low density but have relatively high strength, very low cost and have a long life, these properties allows us to use them everywhere, from food packaging to industrial use.

Studies have shown that these characteristics of waste plastic made it possible for them to be used to make concrete. For this reason, a lot of researcher are willing to investigate how to produce concrete with with an optimal plastic content. (Anggraini et al., 2018)

However, recycled plastic is often contaminated, they may have food remains form food packaging or paper and stickers from labeling, which will make them very complicated to recycle (Ragaert et al., 2017). Using waste plastic in concrete as fine or coarse aggregates could be a solution for this recycling challenge.

The engineering properties of waste plastic are different from ordinary aggregates we used, pre-treatment given to waste plastic could also change the properties of them. (Anggraini et al., 2018)

We will look at the effect of adding plastic to concrete by gathering findings of the change in fresh properties (Workability, Fresh and Dry Density) and mechanical properties (Compressive strength, tensile strength) in the literature.

Fresh properties

Workability

“ Workability is the property of freshly mixed concrete which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished.”(Sharma and Bansal, 2016)A common test for workability of concrete mix is the slump test. Factors that directly related to workability are the shape of particles, water-cement ration particle size grading and the amount of plasticizer in the mix. (Anggraini et al., 2018) Different studies of the effect of using plastic in concrete mix have been preform by various researcher.

Rai et al. (2012) studied the effect when plastic flakes are used in concrete. They replaced sand with 5%-15% of recycled plastic flakes. They found out that the workability decreased by 37% when 15% of sand are replaced. In the slump test, 5%-15% replacement rate without superplasticizer experienced a decrease in the slump value, which is from 55mm to 35mm.

Ismail and Al-Hashmi (2010) investigated the effects of using waste plastic particle in concrete. They mixed in 5% worth of sand weight into the concrete mix, the plastic particle they used had a wide range of sizes, widths varied from 0. 15mm-4mm and lengths varied from 0. 15 to 12 mm. It was found that the 5% addition of plastic particle decreased the workability by 25%.

Saikia and Brito (2014) presented the effect of the shape of waste plastic particle on the workability of concrete. In their experiment, they shaped the plastic particle in three ways: heat-treated pellet in cylindrical or spherical, shredded in fine range and shredded in coarse range. The slump test results show that the heat-treated pellet increases the slump value of the concrete mix while fine and coarse particle with sharper edges lowered the slump value of concrete mixes.

Rahmani et al (2013) stated that sand have less specific surface area when comparing with PET particles, this means that the friction between PET particles are larger than sand, result in loss in workability in the mixtures.

When fine plastic particle is used to replace sand, workability decreases as the amount of plastic added increase. However, an opposite trend is observed when coarse aggregate is replaced by waste plastic. Dhanani and Bhimani (2016)and Ramesan and Babu (2015) used recycled plastic as coarse aggregate replacement in their studies, they found that the slump of their concrete mix increases as the percentage replacement increase up until 40% replacement. This is due to low water absorption by recycled plastics, they made more water to be available from the mix.

F resh and Dry Density

Recycled plastic usually has lower density when comparing to ordinary aggregates, so is it not surprising that the fresh and dry density will both decrease when the substation level increase. This is confirmed by Hannawi et al. (2010), Sosoi et al. (2018) and Kumar et al. (2015). Bigger and flakier particles will affect the decrease of density more. (Silva et al., 2013) When ordinary aggregates were replaced by waste plastic at 25%, 50%, 75% and 100%, the 28-day concrete dry density was reduced by 7%, 20. 5% 33. 5% and 42. 3% when compared to the reference concrete (Anggraini et al., 2018)

Mechanical Properties

Mechanical properties are the most important factor in determining whether using waste plastic in concrete mix is practical for structural uses. This section will try to summaries the effect of waste plastic in concrete to compressive strength and tensile strength in the literature.

C ompressive Strength

Malagaveli (2011) reported that compressive strength increased when 3. 5% HDPE fiber was added in the 7 and 28 days design mix. 28 days after casting, the compressive strength was found increased by 7. 69%, however, when the replacement ratio is more then 3. 5%, the strength if the concrete start to decrease. Prahallada and Parkash (2013) observed an increase of compressive strength up to 50% replacement, the increase is 11%. When the replacement ratio exceeds 50%, the compressive strength started to decrease.

Kou et al.(2009) studied the effect of PVC granules in concrete mixes in a replacement of sand for up to 50%. 28 days after casting, 50% compressive strength loss comparing to reference mix was found. At 30 % replacement, a 25% strength loss was found.

Rahmani et al. (2013) presented that on 5% replacement of sand by PET particle, the compressive strength resulted in an increase of 8. 86% and 11. 97% for w/c ratio of 0. 42 and 0. 52 respectively. When 10% and 15% replacement is used, a similar result as the literature above is shown here, strength of concrete decreased. According to the authors, this is due to weak cohesion between the PET particles and the texture, they act as a barrier blocking the cement paste from the aggregates, prevent them to adhere to each other. This ultimately led to reduction the compressive strength.

Rai et al. (2012) replace 15% of the fine aggregates by waste plastic flakes, they found that the compressive strength was reduced by 9. 52%, this is due to the same reason as discussed above: low adhesive property of plastic surface and it act as a barrier. With 15% replacement of sand instead, they found an increase of 5% compressive strength.

Raghatate (2012) concluded that addition of plastic pieces will affect the compressive strength of concrete. They compared a 0. 2%, 0. 4%, 0. 6%, 0. 8% and 1. 0% replacement ratio with a reference concrete, for the 1% plastic replacement, the reduction of compressive strength 28 days after casting was found to be approximately 20%.

Albano et al. (2009) reported a similar trend, they used PET particles that are irregularly shaped, in the size of 2. 6mm and 11. 4mm to replacement 10% and 20% of sand with water cement ratios of 0. 50 and 0. 60 for all test mixtures. The result indicated that higher the replacement ratio, lower the compressive strength.

Cordoba et al. (2013) concluded that 1. 5mm of PET plastic flake is the optimal size when 2. 5% of the fine aggregates are replaced by volume. They used 0. 5mm, 1. 5mm and 3mm PET plastic flake for 1%, 2. 5% and 5% replacement volume. They also found that the concentration of PET flakes and the curing time is two important factors toward the compressive strength value. When smaller PET particle sizes are used at lower concentrations, compressive strength of concrete increase, this is confirmed by Scanning electron microscopy (Sharma and Bansal, 2016).

Yang et al. also have similar findings in their self-compacting concrete. They found an increase of compressive strength when the replacement ratio is below 20%, higher replacement ratio still resulted in a decrease in compressive strength. According to the authors, this is because of their source of plastic are from industrial waste plastic floorboards and car bumpers, they could have been harder then the plastic other researcher used in their studies.

Tensile strength

It is difficult to measure tensile strength of concrete directly, a split tensile test is therefore a good indirect method to determine the tensile strength of concrete.

The partial replacement of natural aggregates with recycled plastic are expected to affect the tensile properties of concrete (Anggraini et al., 2018).

Ruiz-Herrero et al. (2016) reported a reduction in splitting strength of PVC mixed concrete when the replacement level is 2. 5% to 20%.

Saikia and Brito (2014) concluded that split tensile strength have a negative relationship with content of PET particles, higher the replacement of sand, lower the split tensile strength. The smooth surface of PET particles makes it possible for free water to appear at the surface of the aggregate, making the bonding between aggregate and cement paste weaker. These results confirmed the conclusions of Rahmani et al. (2013). They concluded that the smooth surface texture of PET particles will cause a negative effect to the tensile strength due to an increase of surface area.

Albano et al. (2009) reported that with higher replacement percentage, higher the tensile strength lost. The same effect occurred in replacement of larger size particles. They concluded the effect due to an increase in air voids within the concrete. Frigione (2010) confirmed this by replacing only 5% by volume of sand with a fine PET plastic, the loss in tensile strength was only recorded to be 2%.

Summary

In the literature, it was found that the addition of waste plastic in concrete will result in decrease of workability, compressive strength and tensile strength. However, with proper understanding and preparation of plastic particle, the negative effect can be reduced significantly.

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