Revision Study of Green Concrete

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Abstract: It is very crucial to minimize the environmental impact that induced from the development of industry, by applying strict policies and innovate eco-friendly industries. Indeed, construction manufacture considered as one of the most industries that affect the environment, especially concrete production and usage in structural buildings. For instance, traditional concrete, which is consists of a high amount of cement, is contributed to the emission of CO_2. Therefore, researchers seeking to develop a new technology of concrete by replacement some amount of cement by materials which are considered to become more friendly to the environment. Nowadays, this new technology is known as Green Concrete. The importance of using green concrete is not only to decrease the emission amounts of CO_2 but also to replace cement by industrial waste. In this paper, a review has been presented to understand green concrete benefits and materials that may be used instead of cement and aggregate.

Index terms: green concrete, CO_2, waste materials, environment

I. INTRODUCTION

Concrete is considered as a crucial construction material which used in many infrastructures such as residence, bridges, highways, industries and roads, etc. [1]. Cement gives a brilliant rendering as a binder substance in concrete, but unfortunately, its industrialization is an energy bushy operation. First of all, the raw materials are mining; smashing, mixing, and then, the temperatures of these materials rising to 1500^o C. At the final step, the heated output grinding to produce fine powder of cement. In the meantime, the cement manufacturing release a considerable amount of carbon dioxide CO_2 emission Actually, the reported rate of CO_2 released due to cement production reaches 7 % of global emission in 2004 [2]. To override this environmental issue, eco-friendly materials can use to produce a new type of concrete which called as green concrete, table (1), with the huge concrete consumption, this green concrete technology, will minimize potentially the globe emission of CO_2 gas by 1.5 - 2% [3].

The cement type and quantity has a main impact on the environmental characteristics of concrete. The consumption of energy (MJ/Kg) of an edge concrete beam during the whole concrete life cycle terms is shown in Fig. (1) [5]. However, the production of cement induces an energy consumption of larger than 90 % of the gross consumption of energy of the whole constituent substances and maybe 1/3 of the overall life cycle consumption of energy [4].

TABLE 1

Replacement materials for green concrete [1]

No.	Traditional Ingredients	Replacement materials for Green Concrete
1	Cement	Eco-cement, Sludge Ash, Muncipal Solid Waste Fly Ash.
2	Coarse Aggregates	Recycled aggregates, Waste Ready Mix Concrete, Waste Glass, Recycled aggregate with Crushed Glass, Recycled aggregate with Silica Fume.
3	Fine Aggregates	Fine Recycled aggregate, Demolished Brick Waste, Quarry Dust, Waste Glass Powder, Marble Sludge Powder, Rock Dust and Pebbles, Artificial Sand, Waste Glass, Fly Ash and Micro Silica, Bottom Ash of Muncipal Solid Waste.

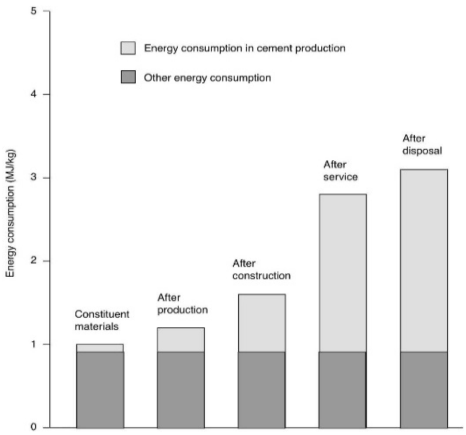

Fig. 1. Consumption of energy through the whole life cycle terms [5]

Recently, there is huge growing attention of the government, public and industry in the development of sustainable and environmental issues for the structures. Therefore, there is an active trend toward this new technology of the green concrete which is depending mainly on additional steps in the design of mixture and placements to guarantee a sustainable and long life construction with a minimum maintenance requirement [6]. Indeed, the technology of green concrete becomes a historical revolution in the concrete industry. The first fabricated green concrete had done by Dr WG. in Denmark in 1998 [7].

The classic design of structures that built up by concrete depends on the stage of construction, which is lead to enhance the short extent performance and the costs of construction. On the other hands, sustainable evolutions raise a powerful necessity for completed life cycle design, in which it should consider all stages through the whole life service of the structure, see Fig. (2)[8].

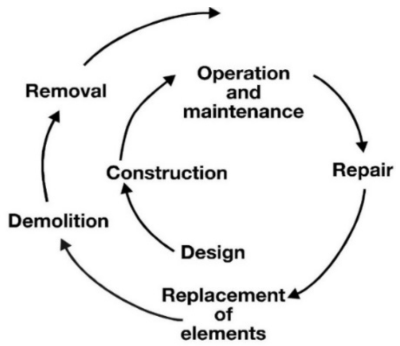

Fig. (2): Life cycle inventory for the concrete structure [8]

In the current work, a review of the past literature on green concrete has presented; moreover, materials used in the mixtures of green concrete are listed to figure out what is the most useful substance used in this kind of industry.

II. BENEFITS AND GOALS OF GREEN CONCRETE

1. Green concrete industrialization will help to decrease the emissions of CO_2 by more than 80 % [9].

2. As compared with concrete that made from Portland cement, green concrete has a low shrinkage rate and earns strength more rapidly. Moreover, when using green concrete in structures, it will survive under fire conditions at temperatures reach to 1315 °C. On the other hand, green concrete can hold against corrosion, that is much crucial to the environment pollution effect (acid rain extremely minimize the lifetime of building constructed by using traditional materials). Therefore, buildings that made by green concrete will persist much longer than these constructed with normal concrete [3].

3. The consumption of energy could be minimized when made a concrete mixture with less quantity of Portland cement and more amount of fly ash. The reason is that materials utilized in preparing Portland cement need large amounts of natural gas or coal to warm up it until a suitable temperature to switch them into fine Portland cement. While fly ash exists already in another industrial process as a by-product, therefore, there is no need to spend more energy to use it in green concrete. Moreover, the green concrete building can resistant the outside changes in temperature. That will help the architect to design buildings more efficiently by saving energy that used in heating and cooling [9].

4. Green concrete can be made using waste results from industry, for instance, rather than a 100 % of Portland cement, fly ash from anywhere can be used in the mixture of green concrete up to 25 %. In fact, fly ash results as a by-product of combustion of coal, then, it is collected from the power plant chimneys. There are huge quantities of this by-product wastes, thousands of acres of lands are buried by fly ash. Therefore, the increase of green concrete usage in buildings will help to use up fly ash up, and then, make thousands of acres of land free from fly ash [3].

III. MATERIALS

1. Quarry Dust

It is known as remains or by-product trash results from the treatment and extraction of rocks to create soft particles with size about 4.75 mm or less. Moreover, quarry dust, see Fig. (3), is produced during crushing, screening and blasting coarse aggregate. In this case, it will be consisting of sharp, angular and rough particles, which is increasing the interlocking between them. That is why quarry dust earns much more strength. Also, rock quarry dust used in concrete improves the resistance against acid and sulphate, with low permeability, as compared to concrete made from conventional Portland cement. However, in some cases, the using of quarry dust increases the amount of cement that required to keep workability within the allowable rates. The use of quarry sand is generally limited due to the high cement paste volume needed to obtain an adequate workability of concrete [9]. Generally, the usage waste materials such as like quarry dust, will minimize concrete production cost.

Fig. (3): Quarry dust [8]

2. Fly Ash

It is highly soft powder created as a by-product of the coal combustion. Commonly, Fly ash is taken from the coal-fired chimneys of the electrical power plants. In fact, there are two kinds of ash, coal ash which is used in the concrete mixture, and bottom ash, that is extracted from the coal furnaces bottom, see Fig. (4). According to the texture and origin of the burned coal, the composition of fly ash is varied, however; all kinds of fly ash mainly consist of calcium oxide (CaO) and silicon dioxide (SiO_2) [10].

Theoretically, it is likely to use fly ash instead the whole amount of Portland cement, but when the rate of replacement reaches 80% or above, then, the use of chemical activator is highly recommended. There are several benefits of using fly ash; first of all, it can improve the durability of concrete, by generation minimum hydration heat. Secondly, fly ash makes concrete workability much better and also increases the durability and strength of hardened concrete. Finally, it can reduce the water used in the mixture, and then improve the flow behaviour [9].

Fig. (4): Fly ash [8]

3. Masonry and Concrete Waste

The recycled coarse masonry or concrete, are gradated aggregates generated from useable concrete or masonry waste that typical for use in road applications. The substance may consist of tiny amounts of crushed rock gravel, bricks, or other shapes of stony substance as mixed material. In the meantime, recycled fine aggregates may be indicated to as smashed concrete fines. However, the grading form and an excessive quantity of fines may influence the rate of bleeding, finishing ability, and concrete workability [9].

4. Silica Fume

This material can be considered as a by-product material to a few industries, but, unfortunately, silica may cause pollution to the air. Therefore, to minimize the effect of silica to air pollution, micro silica is combined with cement. The resulting concrete will be more sustainable, and the strength of concrete will increase when replacing 5 to 15 percent with silica. While it is not recommended to increase this rate of replacement by 20 per cent; because it may decrease the strength of concrete. The fume of silica is finer than cement, and also can easily react with ingredients of concrete; therefore, silica fume will maximize the cement normal consistency, and then, gained a high strength in minimum time in contrast with conventional concrete [11].

5. Marble Waste

Since ancient decades, marble has been utilized as a construction material. On the other hand, the most worldwide environmental problems are the disposal of marble industry waste, which is consist of highly fine powders, see Fig. (5). Yet, these waste substances can economically and successfully be used to develop some characteristics of fresh and hardened concrete [9].

Fig. (5): Marble waste and quarries [8]

6. Crushed Glass

The glass is an uncoloured, fragile, hard, and transparent material. As referred to ASTM, glass is defined as an inorganic substance with a 6.5 hardness. When it is state changed from the molten to a colder case, glass becomes much more solid with no crystallisation. The essential glass constituent is the Silica, however, it can be found CaO, MgO, Na_2O and Al_2O_3 in the glass. Investigations have found that it is likely to utilize glass in the mixture of concrete as one of the three formats; soft glass aggregate, rough glass aggregate, and finally, soft glass powder. If the glass and cement are mixed together, the glass will be subjected to a chemical action, and the result is a miner calcium silicate hydrated and the reaction of pozzolana with hydrated cement [12]. Researches demonstrate that the rise in the glass waste magnitude, it will minimize the concrete specific weight and also the concrete compressive strength, due to the decrease in adhesion with glass [13]. However, the reduction of particle size will develop workability, but cement compressive strength at 28-day will reduce. The blending of rough and fine glass will develop absorption in water, which made the shrinkage of concrete to its minimum rates [14].

7. Polyethylene Terephthalate

Polyethylene terephthalate can be considered as a long-chain polymer that has a polyester structure. Its components consist of ethylene glycol and pure terephthalic acid, and both of them are petroleum products. The processes of polyester include some chemicals which made through the polymerisation between alkali and acid. Polyethylene terephthalate is considered as an amorphous glass substance. Using the waste of Polyethylene terephthalate in concrete could keep the environment safe. A microstructure of lightweight PET (Polyethylene terephthalate) aggregates was analysed via Yoon et al. (2005) [15]. They test the influence of the grainy slag for molten metal on it. They found that the density of concrete, consisting of PET aggregates, will increase from 1940 to 2260 kg/m3. in the meantime, a transition region between cement paste and PET particles will be expanded more, as compared with normal aggregates. Generally, it was predictable that is the slag grain of molten metal could increase the limit and level of the transition zone for the PET, which is leading to the calcium hydroxide reactions. Experiments done by Sehaj et al. (2004) [16] and Won et al. (2009) [17] have shown that the using of PET in the concrete will rise ductility and minimize cracks that occurred due to shrinkage. On the other hand, a high-quality, lightweight concrete can be manufactured via PET, because its specific density is relatively lower as contrasts with normal aggregates [18]. The increase in PET amount to 15% will minimize the concrete compressive strength by 15.9 % to 18 %, modulus of elasticity will also reduce by 20% to 23%, and the loss of specific weight reduced by 3.1% to 3.3% [19].

8. Ceramic and Tile

Ceramic can be defined as non-organic and non-metallic material; moreover, there are two kinds of it, they are noncrystalline and crystalline, see Fig. (6). While the tile defined as a slice of artificial stone that has a few millimetres thickness, its surface is smooth and soft on the top side. Waste of ceramic and tile may be formed during the transfer operation, at burning or after that, due to manufacturing or human error or may be introduced from the use of an unsuitable substance and highly from building destruction [20]. Numerous investigations have done to utilize a specific type of waste in the concrete. The outcomes of experiments demonstrate that it could be practical to employ tiles in concrete as an aggregate or pozzolan [21-22]. While, when white ceramic used as soft aggregate, and replaced with rates of 10% to 50%, the concrete quality will be better improved [23]. Moreover, if porcelain sanitary waste is used as coarse aggregate in concrete at a rate of 3% to 9%, its resistance is more than that of concrete without additives at a rate of 2% to 8% [24]. Another study, done by Medina et al. (2012), showed that when the curing takes about 28 days, and a waste of porcelain sanitary used from 5% to 20% of the aggregates, then the resistance will increase [25-26].

Fig. (6): Ceramic and tiles waste [20]

9. Clay Bricks

In fact, fired bricks have been scaled in a kiln. The majority of them consist of lime, silica, magnesia, alumina, and iron oxide. Due to this chemical composition, it is practical to use bricks in concrete manufacturing. Suggestions had offered by researchers about various mixtures to produce this kind of concrete. Among these studies, one investigation appeared that the concrete compressive strength has trended downward. In mixtures with coarse aggregate, the lowering was about 10% to 35%, while in fine aggregates the decreasing was about 30% to 40% [27]. Indeed, when clay bricks are used in concrete as sand water absorption will be increased, unfortunately, this will affect the concrete durability. Therefore, this issue requires a lot of investigations [28]. On the other hand, rebars corrosion time could be reduced when using concrete rich with aggregate made from clay brick, despite this type of concrete will gain a suitable freezing and dissolving performance. Moreover, as the bricks quantity increased, the penetration stability of chloride ion will minimize. This decreasing may be due to bricks high absorption, which is a result of bricks porosity. A 28-day concrete compressive strength for coarse brick aggregates was found to be a little bit more than it for the control specimen. In addition, the workability of concrete was improved by maximising the quantity of the concrete coarse brick aggregates [29].

10. Rubber and Tyres

Actually, the usage of tyre residue in concrete as an aggregate is modern. Vehicle tyres consist of natural rubber, polybutadiene, carbon black, silica, and styrene-butadiene. The central thought of employing this material, which of course elastomeric, in a cementitious form is to minimize concrete stiffness. Therefore, concrete flexibility will increase and the resistance of fire will be improved [30].

Finally, a histogram is drawn to demonstrate which materials used in the green concrete, and also, their frequencies in the past studies. This, of course, reflects which materials that mostly used in the production of the green concrete, see figure (7). From this figure, it can see that the fly ash and the silica fume is the dominated substances in the green concrete manufacturing.

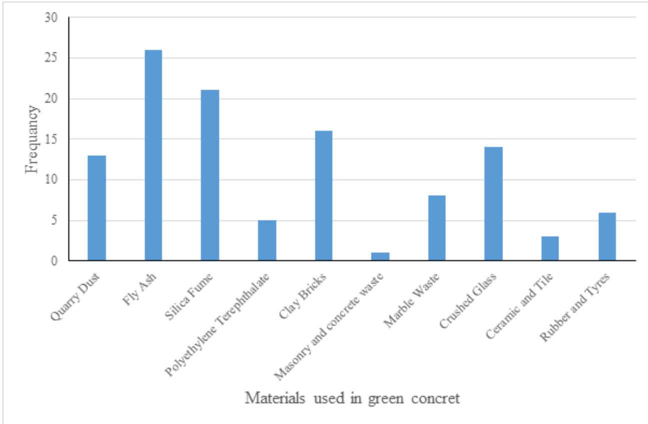

Fig. (7): Green concrete materials and their frequency in past studies

IV. CRITERIA OF PRODUCT SELECTION

1. Resource adequacy: It essentially includes some properties such as durability, renewable, natural, recyclable, reusable, recycled content, remanufactured and locally available.
2. Indoor Air Quality (IAQ): It is boosted by employing substances that fit some properties like non-toxic or low, least emission of chemicals, healthfully maintained and moisture resistant.
3. Energy competence: Mainly it is indicated to the energy applied for concrete production. Actually; such materials are preferable that requires energy at lower amount during the concrete construction time.
4. Water preservation: It is preferable to use materials that assist in water preservation at landscaped zones. This will help to save water during the construction time or may be to minimize the consumption of water in constructing materials [9].

V. CONCLUSIONS

In this paper; a literature review has been presented to demonstrate the benefits induced from using green concrete and types of materials that might be use as a replacement of an amount of cement and aggregates. From the recent investigation, it can be concluded that:

1. Using industrial wastes in green concrete is considered as the most crucial benefit because this will conserve natural raw materials for our generations in future.
2. In green concrete, the mixture has designed with extra steps by adding some materials which enhance the concrete properties and lowering the negative impact

on the environment. The gained concrete will be sustainable and has a long life period with a relatively low cost for maintenance [6].

3. It is utterly true; that CO_2 content in cement is relatively high. Thus, using a large quantity of cement in the construction of buildings will dramatically harm the global climate. For such reason, when an amount of cement has been replaced by industrial waste materials, the emission of CO_2 will be decreased, and also minimize the negative influence on the environment [11].
4. Green concrete production cost is relatively low from traditional concrete.
5. The fly ash and the silica fume is considered the most used substances in the manufacturing of the green concrete.

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