

Green Concrete: A Literature Review

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Abstract- Development and Growth of construction industry is addicted to Concrete and fossil fuels, and these two are the biggest issues making CO₂ growing in the environment. About 8-10% of carbon dioxide (CO₂) emissions are generated from manufacturing and transporting by the concrete industry. CO₂ is major gas just after steam causing the greenhouse effect. Moreover, when natural aggregates are crushed and heated at elevated temperatures, greenhouse gases are released to the atmosphere creating environmental burdens. There is a necessity to build a bright and sustainable future. In order to outline the sustainability of modern construction sector, this review study is aimed to examine the effectiveness of using green concrete. Green concrete is defined as a concrete which uses waste material as at least one of its components, or its production process does not lead to environmental destruction, or it has high performance and life cycle sustainability. The main aim of this literature review is to identify how green concrete can help towards promotion of sustainable built environment. The present study outlines literature related to green concrete manufactured from some industrial wastes such as fly ash, silica fume, slag modified, glass modified, rubber modified and recycled aggregate concrete. The suitability of green concrete as an alternative for demolishing the carbon emissions is studied, hence reduces negative impact on environment and improves the sustainability of concrete structures. Based on the results of literature reviewed in the present study, it can be concluded that green concrete has the ability to minimize waste and encourage sustainability. The emphasis is given to encourage the usage of green concrete as it is not just because of simple carbon dioxide reduction but also overall waste could be minimized.

Keywords- Concrete, cement, fly ash, carbon emission

I. INTRODUCTON

With the development and growth of infrastructure industry the demand of concrete is intensively increased. The major initiative infrastructures in any developing country are express highway, bridges, power projects, airports, industries, etc. essential to cope up with the requirements of globalization. In the construction of any infrastructure, concrete plays an important role. But as such concrete is major source of carbon emission. About 8 – 10% of CO₂ emissions are generated from concrete production and transportation. Global warming gas is released when the raw material of cement, limestone and clay is crushed and heated in a furnace at high temperature ($\pm 15000^{\circ}\text{C}$). Each year, approximately 1.89 billion tons of cement (which is a major component of concrete) has been produced worldwide. Moreover, when natural aggregates are crushed and heated at elevated temperatures, greenhouse gases are released to the atmosphere creating environmental burdens [1]. At recent

time according to various researchers the production of one ton cement produces approximately one ton of carbon dioxide in atmosphere. Some researchers take an initiative to reduce the emissions of Carbon dioxide from concrete by replacing the same amount of cement by various supplementary cementitious materials. Different kinds of strategies are being implemented to improve sustainability of concrete. One of the strategies includes incorporating recycled materials in concrete. Another important goal is to reduce CO₂ emissions by reducing the Portland cement content, binding agent used in concrete. This can be achieved by partially replacing Portland cement with cementitious by-product materials. Lastly, reduce long-term resource consumption, and select low impact construction methods [1, 2]. Hence the concept of 'green concrete' is accomplished.

II. GREEN CONCRETE

Green concrete is defined as a concrete which uses waste material as at least one of its components, or its production process does not lead to environmental destruction. It should also have high performance and life cycle sustainability. In other words, green concrete is an environment friendly concrete. Green concrete improves the three pillars of sustainability: environmental, economic, and social impacts. The key factors that are used to identify whether the concrete is green are: amount of Portland cement replacement materials, manufacturing process and methods, performance and life cycle sustainability impacts. Green Concrete is cheap to produce because it is prepared by waste materials which lowers the energy consumption, increases its strength and durability. Green Concrete was first developed by Dr.W G in 1998. The various aspects such as mechanical properties, fire resistance, durability, strength, thermodynamic properties, environmental properties, etc. were included to prepare green concrete. Green concrete should follow reduce, reuse and recycle technique or any two process in the concrete technology. The three major objective behind green concept in concrete is to reduce greenhouse gas emission (carbon dioxide emission from cement industry); to reduce the use of natural resources such as limestone, shale, clay, natural river sand, natural rocks that are being consume for the development of human mankind that are not given back to the earth; and the use of waste materials in concrete that results in the air, land and water pollution. This objective behind green concrete will result in the sustainable development without destruction natural resources. The components of concrete that can be replaced to avail the green concrete are as such some portion

of cement can be replaced by fly ash, sludge ash or any material having cementitious properties. Coarse aggregates can be replaced by silica fume, waste glass, etc. whereas fine aggregates by quarry dust, iron slag, with the required proportion.

III. LITREATURE REVIEW

A. Fly Ash Concrete

An experimental investigation was undertaken specifically concentrating on the mechanical and durability properties of polymer concrete. Recycled glass sand, fly ash (FA) and meta kaolin (MK) were used as fine aggregates in the concrete mix design. Five concrete mixes were prepared from which one was the control mix (no FA or MK content). The mixes were cast into moulds from which specimens in form of cylinders and prisms were prepared. These specimens were then tested to evaluate the performance of polymer concrete [3]. It is perceived that MK and FA mixes exhibited higher compressive strengths compared to the control mixes. After 28 days, the strength started to increase significantly. Mixes containing 15% FA attained the highest compressive strength after 28 days [10]. Another experimental investigation was carried out to study the properties of self-compacting concrete (SCC) comprising FA and ground granulated blast furnace slag (GGBFS) admixtures. Portland cement was replaced with FA and GGBFS by rates of 20%, 30% and 40%. One control mix mixture, three FA mixtures and three GGBFS mixtures were prepared [1]. The results shows that the compressive strength of FA mixes were slightly lower than the control mixes. After three days, the strength of 20% FA dropped by 5MPa. However, after 90 days the strength of all mixes was almost the same as the control mix [4].

B. Silica Fume Concrete

A laboratory investigation was performed to examine the properties of concrete comprising FA and SF. Cement was substituted with SF at portions ranging between 0-10%. Mixtures comprising both FA and SF were found to be effective in improving the strength properties of concrete. In addition, chloride resistance of concrete was also improved [5, 6]. An experimental research was performed to study the effects of SF on mechanical and physical properties of recycled aggregate (RA) concrete. Portland cement was replaced with SF by rates of 0%, 5% and 10%. Moreover, RA was replaced with natural aggregates (NA). The compressive strength results suggested that SF recycled aggregate concrete experienced reductions in early age compressive strength. However, after 28 days the strength of these mixes increased when compared to the control mix. Concrete mixes comprising 10% SF exhibited better performances in terms of mechanical and physical properties [7].

C. Slag Modified Concrete

The relationship between mixing proportion parameters of self-compacting concrete (SCC) were examined in a further research. In that same research, the environmental impacts of SCC were also examined. Sixteen portions of SCC mixtures incorporating various by-products such as FA, slag and meta kaolin were created. The test results suggested

that the addition of by-products reduced CO₂ emissions. Furthermore, adding three mineral mixtures into SCC was more operative in reducing the environmental impact compared to the addition of single or two mineral admixtures. Therefore, addition of by-products such FA, slag and meta kaolin not only reduced CO₂ emissions but also reduced environmental impacts [1]. Laboratory study was performed to study the effects of concrete containing a combination of high volume fly ash (HVFA) and slag. Four different mixtures with various contents of HVFA and slag were prepared. After the mixes were prepared, specimens were constructed and tested. The test results suggested that the compressive strength of HVFA concrete was lower than PC concrete. Moreover, addition of slag to the concrete mix further reduced the strength. However, HVFA concrete displayed better fire performance compared to PC concrete. It was recommended not to mix slag with FA as it reduced the strength of concrete [8].

D. Recycled Aggregate Concrete

A study was performed to examine the properties of self-compacting concrete using RA. NA was replaced with RA by rates of 10%, 20%, 30% and 40%. Six different mixes were prepared. Thereafter, specimens were created and tested. Test results suggested that an increase in RA content lead to a reduction in compressive strength, flexural strength and split tensile strength. Moreover, the properties of concrete in terms of strength were not improving when RA were used in the mix. Additionally, 30% replacement of RA helped to achieve the required compressive strength [9].

E. Glass Modified Concrete

A laboratory investigation was performed by towards macro and micro properties of concrete containing liquid crystal glass (LCD) glass. Cement was replaced with waste LCD by rates of 10%, 20%, 30%, 40% and 50%. In addition, natural sand was replaced with glass sand by rates of 10%, 20% and 30%. Various tests were performed to evaluate the performance of LCD glass. The test results suggested that addition of glass sand enhanced the compressive strength. Moreover, glass sand provided higher resistance and it improved properties of concrete with age. By utilizing glass in concrete, usage of cement and sand could be minimized which could help preserve the natural resources and reduce carbon emissions [10].

F. Rubber Modified Concrete

In one research, the properties of concrete tactile blocks prepared with recycled tire rubber were studied. Sand was replaced with waste tire rubber by proportions of 10%, 20%, 30%, 40% and 50%. Six concrete mix designs were prepared, out of which one was the control mix. From each concrete mix, three specimens of sizes 150 x 150 x 500mm were prepared for flexural and compressive strength test. The test results revealed that rubber modified concrete obtained the same consistency as the control mix. The highest compressive strength was achieved when 10% rubber was cooperated in the mix design. This strength was also found to be higher than the control mix. It was concluded that 10% recycled tire mix could be used to make tactile paving blocks

[11].The reduction in CO₂ emissions can be done through: (a) the substitution of cement with fly ash, (b) the use of ground granulated blast furnace slag from steel plants, (c) use of micro silica, (d) the use of pozzolanic materials and limestone powder, (e) various kinds of ash from the burning of domestic waste and bio-fuels, and (f) crushed waste glass [12] (Nielsen & Glavind, 2007).

Uzal, Turanli, and Mehta [13] reported that their initial research results with the concrete containing natural pozzolana high volume (50% of the mass of cementitious material), which was named the High Volume Natural Pozzolana (HVNP) indicates achievement that promises to structural applications, reaching 14 MPa strength (aged 3 days) and 38 MPa (age 28 days). Natural pozzolana used is a low-calcium fly ash and granulated blast furnace slag. The larger portion of the fly ash can be used to substitute cement the reduction of CO₂ emissions in the cement manufacturing process will also be reduced. Glavind & Jepsen [14] has prioritized taking 4 steps to go green concrete in Denmark, namely: (a) improving the utilization of residual products such as fly ash in large scale, (b) the use of residual products from concrete plant, such as: stone dust, and concrete slurry, (c) the utilization of residual products of other industries, such as fly ash from bio-fuels and combustion of sewage sludge ash in waste processing installations, and (d) the use of a new type of cement that is more environmentally friendly, such as mineralized cement, the addition of limestone, and waste derived fuels. The comparison of CO₂ emissions generated in the service life cycle of a bridge pillar located in aggressive environments (50 years, as a special case) by 4 kinds of different design principles, namely: (a) Reference column, made of conventional reinforced concrete, (b) A column made of green concrete (containing 40 ~ 50% fly ash), (c) B column made of green concrete (containing 40 ~ 50% fly ash) with stainless steel reinforcement, and (d) column C is made of green concrete (containing 40 ~ 50% fly ash) with stainless steel cladding have been investigated. It appears that the use of the three green concrete could reduce CO₂ emissions by up to less than 30% compared to conventional concrete. According to Mehta [15] there are 3 structural engineer's tools for sustainability of the cement industry or reducing CO₂ emissions: (a) consume less concrete for new structures, by developing innovative architectural concepts and structural design, using highly durable concrete, and using pre-fabricated elements for easy assembly, (b) consume less cement in concrete mixtures by using super plasticizer instead of more mixing water and cement to obtain the required consistency of fresh concrete, and optimizing the size and grading of aggregates, and (c) consume less clinker in the cementing material by selecting blended portland cements and concrete mixtures that contain high volume of coal fly ash, granulated blast-furnace slag, natural or calcined pozzolanas, silica fume, and reactive rice-husk ash.

IV. CONCLUSION

It was important to note that the quantity of by-product or waste replacement played a vital role to the properties of concrete. In addition, the choice of by-product waste such as FA also played an important role to the hardened properties

of concrete. Concrete containing by-product waste such as FA, SF and slag had improved mechanical and durability properties. In addition, sorptivity and water absorption rates for by-product waste concrete was found to be reducing which suggested that these kind of concrete required less water contents. Green concrete was cost effective and environmentally friendly. It helped to reduce mining of river sand. Moreover, it helped to reduce carbon emissions that were generated from manufacturing cement and crushing of aggregates. It helped to conserve natural resources and reduces landfill space. Green concrete could be used in a wide range of applications. If concrete's compressive strength showed improvement, it would be used for structural applications. However, if there was no improvement in terms of strength, it could be used for non-structural applications. Overall it can be concluded that green concrete help towards promotion of sustainable built environment. It helps to minimize the carbon emission and waste, thus encourage sustainability.

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