GREEN CONCRETE AND ITS DEMAND ON THE SUSTAINABLE CONSTRUCTION INDUSTRY

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ABSTRACT- Concrete is one of the most important components of construction materials. The world is converting into concrete jungles at a very fast rate, which is involving high consumption of energy and other resources, thus leading to adverse environmental impact. Consequently there is need to carry out sustainable growth in the field of concrete industry. Such sustainable development can be attained by use of environmentally friendly green concrete leading to decrease in greenhouse gas emissions. Green cement concrete is produced by using recycled waste materials such as activated fly ash and recycled concrete aggregates. Other concrete alternatives can be equally used to significantly increase the sustainability and durability. Secondly, one must plan for structural designs involving environmentally friendly maintenance strategies which will need less of energy and resources. Although green concrete seems to be providing lot of benefits, still one needs to consider the potential barriers on its way. They are increase in cost of recycling and reusing along with use of additional energies and resources for the same and the fear of failure of the green concrete as it is made from reused products. One can conclude that overcoming the above demerits would help to use green cement concrete with a potentially new environmental friendly world.

Keywords: Recycled cement aggregates, sustainability, green concrete, greenhouse gas

1. INTRODUCTION

"Go Green!" This statement is one that has been heard in almost every aspect our lives within the past few years. It relates to sustainable lifestyles and to a mindset that must be adopted by everyone for true success. As the world continues to develop its definition of sustainability, each engineering discipline has tried to focus its efforts to improve the quality of life while maintaining and improving, if possible, the environment and other areas of social interest. The civil engineering community is not exempt from "going green." Civil engineers are responsible for bettering the lives of the public through infrastructure. They are responsible for accomplishing this in an efficient and cost-effective way, and now it must also be done in a sustainable or "green" manner.

Concrete is everywhere and is an excellent material to make long-lasting and energy-efficient buildings. It contains four basic ingredients: water, cement, fine aggregate (sand) and coarse aggregate. The manufacturing of traditional concrete using Portland cement (PC) releases a large amount of greenhouse gases such as CO₂. It is the second most consumed material after water and it shapes our built environment in the form of homes, schools, hospitals, offices, roads and footpaths. However, even with good design, human needs change and potential waste will be generated [1].

A potentially sustainable new form of concrete has been recently created that might make it the most environmentally friendly type of building material. Concrete in its traditional form is made from cement, mixed with a range of coarse aggregates such as gravel, limestone or granite, and some finer particle aggregates such as sand or fly ash. These are mixed together with water, to form a quick drying bonded structure, which can easily be manipulated into many forms such as the surface of roads, or driveways or footings for structures. It is the most commonly used building material in the world-some estimate that in the region of 7 cubic kilometers of concrete are manufactured each year, and that there already is 1 cubic meter of concrete for every human on earth. Unfortunately concrete is
not an environmental friendly material, either to make, or to use, or even to dispose of. To gain the raw materials to make this material, much energy and water must be used, and quarrying for sand and other aggregates causes environmental destruction and pollution. Concrete is also claimed to be a huge source of carbon emissions into the atmosphere. Some claim that concrete is responsible for up to 5% of the world's total amount of carbon emissions, which contribute to greenhouse gases. The reason for the huge popularity of concrete is the result of a number of well-known advantages, such as low cost, general availability, and wide applicability. But this popularity of concrete also carries with it a great environmental cost. The billions of tons of natural materials mined and processed each year, by their sheer volume, are bound to leave a substantial mark on the environment. Most damaging are the enormous amounts of energy required to produce Portland cement as well as the large quantities of $CO_2$ released into the atmosphere in the process.

This paper summarizes the various efforts underway to improve the environmental friendliness of concrete to make it suitable as a “Green Building” material. Foremost and most successful in this regard is the use of suitable substitutes for Portland cement, especially those that are byproducts of industrial processes, like fly ash, ground granulated blast furnace slag, and silica fume. Also efforts to use suitable recycled materials as substitutes for concrete aggregate are gaining in importance, such as recycled concrete aggregate, post-consumer glass, tires, etc. The paper also discusses some of the economic drivers which determine the degree of commercial success. Simply deposing of waste materials in concrete products is unlikely to succeed except in unusual situations. But by identifying and exploiting specific properties inherent in various waste materials or byproducts, it is possible to add value to such materials and increase their chances of success in a market-driven economy of supply and demand.

2. SUSTAINABILITY

As used in everyday speech, sustain means to support or to keep a process going, and the goal of sustainability is that life on the planet can be sustained for the foreseeable future. There are three components of sustainability: environment, economy, and society. To meet its goal, sustainable development must provide that these three components remain healthy and balanced. Furthermore, it must do so simultaneously and throughout the entire planet, both now and in the future. At the moment, the environment is probably the most important component, and an engineer or architect uses sustainability to mean having no net negative impact on the environment. Thus the term sustainable has come to be synonymous with environmentally sound or friendly and “green.” The environmental component has our attention now because deterioration of our environment is driving the current worldwide focus on sustainable development.

2.1 SUSTAINABILITY OF CONSTRUCTION MATERIALS

In order to estimate the environmental impact of a construction material, it is necessary to consider all stages in the life of the material (Fig.1). Each construction material is manufactured from some combination of raw materials, with some expenditure of energy, and with associated wastes. Therefore manufacture is an essential element in computing the environmental impact, and manufacture is probably the element most widely cited when considering the environmental impact of construction materials. Are the raw materials renewable? Are they scarce? Are they important to the global environment? How much energy is required in the manufacture? How much waste is produced during the manufacture? What impact do these wastes have on the environment? These questions are very important and this phase probably receives the most attention, both from the general public and from the government. The construction process also involves some expenditure of energy and produces some waste. There are several important questions. How much of each manufactured material is used? Can materials be used that have less environmental
impact? How much energy is used? How much waste is produced? What is the impact of the waste on the environment? Some of these questions can only be answered for a specific structure. Increasing attention is being given to the construction phase as part of global and regional efforts to make development more sustainable. The lifetime of the structure has a direct impact on sustainability. When the structure deteriorates, it must be destructed and rebuilt. The lifetime is directly controlled by the durability of the construction materials. It is further influenced by the adaptability of the design to repair and renovation, and repair and renovation themselves have environmental impacts. Finally, the lifetime of a structure is influenced by cultural and market forces. When a structure no longer serves an important function (not necessarily the function for which it was constructed), it is likely to be destructed. And if it is not aesthetically pleasing, it may be destructed. So materials and design considerations directly affect the lifetime of a structure and the lifetime must be considered when computing environmental impact.

Fig. 1: Stages considered when estimating environmental impact

2.2 SUSTAINABILITY OF CONCRETE
Concrete is manufactured from aggregates (rock and sand), hydraulic cement, and water. It usually contains a small amount of some chemical admixture, and (at least in the USA) it often contains a mineral admixture replacing some portion of the cement. A typical concrete formulation contains a large amount of coarse and fine aggregate, a moderate amount of cement and water, and a small amount of admixture. Most of these constituents are themselves manufactured products, byproducts, or materials extracted by mining. In order to assess the environmental impact of concrete manufacture, it is necessary to consider the impact of each separate constituent. The aggregates are usually obtained by mining. The coarse and fine aggregates are usually mined separately. Occasionally aggregate is obtained as a by-product of some other process (e.g., slag or recycled concrete). Aggregates may be crushed and may be washed. They are usually separated into various size fractions and reconstituted so as to satisfy the grading requirements. They may need to be dried. A modest amount of energy is involved in all these processes. The principal wastes are dust and water, neither of which is especially damaging to the environment. The dust may be used in some other process or may be disposed in a landfill.

3. WHY GREEN CONCRETE?
- Huge impact on sustainability
- Most widely used material on Earth
  - 30% of all materials flow on the planet
- 70% of all materials flow in the built environment.
  - > 2.1 billion tonnes per annum.
  - >15 billion tonnes poured each year.
  - Over 2 tonnes per person per annum.

4. WHAT IS GREEN CONCRETE?
Today the word green is not just limited to colour, it represents the environment, which is surrounding us. Concrete which is made from concrete wastes that are eco-friendly are called as “Green concrete”. The other name for green concrete is resource saving structures with reduced environmental impact for e.g. Energy saving, CO₂ emissions, waste water. “Green concrete” is a revolutionary topic in the history of concrete industry. This was first invented in Denmark in the year 1998 by Dr.WG.
5. FEATURES OF GREEN CONCRETE

Where does the Carbon Dioxide come from in concrete?

Cement production accounts for more than 6% of all CO2 emission which is a major factor in the world global warming (Greenhouse gas). India is the third largest cement producer in the World and one of the largest consumers of cement per capita in the world. Rough figures are that India consumes about 1.2 Ton/year/capita, while as World average is 0.6 Ton/year/capita. There have been a number of efforts about reducing the CO2 emissions from concrete primarily through the use of lower amounts of cement and higher amounts of supplementary cementitious material (SCM) such as fly ash, blast furnace slag etc. CO2 emissions from 1 ton of concrete produced vary between 0.05 to 0.13 tons. 95% of all CO2 emissions from a cubic meter of concrete is from cement manufacturing. It is important to reduce CO2 emissions through the greater use of SCM.

i) CEMENT

Most of CO2 in concrete is from the cement manufacturing process. A typical cubic meter of concrete contains about 10% cement by weight. Out of all ingredients, cement gives out most carbon dioxide. The reaction in the process of Cement manufacture is:

\[ \text{CaCO}_3 = \text{CaO} + \text{CO}_2 \]

ii) AGGREGATE

Use of virgin aggregates contributes about 1% of all CO2 emissions from a typical cubic meter of concrete. Therefore, the use of alternate aggregate is desirable. The use of local and recycled aggregates is desirable as it can reduce transportation and fuel cost and support sustainable development.

III) RESOURCES

The growing shortage of natural aggregate and sand is another aspect the construction industry must consider. While this may not appear to be a priority topic, pressure from environmentalist and conservationists worldwide will continue to encourage both legislators and construction engineers to look for viable alternatives to natural resources. Use of recycled materials like aggregate, water is some ingredient which should be encouraged since fresh resources are becoming increasingly scarce.

iv) GREEN CONCRETE

Obtaining the most suitable mix based on the specification or suggesting improvements in the mix is to assist with the most suitable concrete for the project. The concrete which can fall in the category of green must have the following characteristics.

- Optimizes use of available materials
- Better Performance
- Enhanced cohesion workability / consistency
- Reduced shrinkage / creep.
- Durability - Better service life of concrete
- Reduced carbon footprint
- No increase in cost
- LEED India Certification

Green concrete mix is designed with the principle of "Particle-Packing Optimization" to meet requirements of plastic and hardened properties.

6. NEED OF GREEN CONCRETE

Cement-based materials are the most abundant manufactured materials in the world. Today’s exciting trend is the Green building is in our country. The potential environmental benefit to society of being able to build with green concrete is huge. Green Concrete as the name suggests is eco friendly and saves the environment by using waste products generated by industries in various forms like rice husk ash, micro silica, etc to make resource-saving concrete structures [2-4]. Use of green concrete helps in saving energy with emissions, waste water. Green concrete is very often also cheap to produce as it uses waste products directly as a partial substitute for cement, thus saving energy consumption in production of per unit of cement. Over and above all green concrete has greater strength and durability than the
normal concrete. It is realistic to assume that the technology can be developed, which can reduce the CO\textsubscript{2} emission related to concrete production. Generally the construction industry accounts for a massive environmental impact due to its high demand of energy. As a result of the awareness built during the past few years about green house effect and damage to the nature, more people and countries became conscious about their future. Traditional ready mix concrete is a significant cause of production of green house gases, less in regards to GHG emissions per m\textsuperscript{3}, but in particular in regards to the high quantity produced world-wide [5]. New available technologies allow the use of different types of concrete and advanced ways of production which represent a lesser hazard to the environment. Green concrete capable for sustainable development is characterized by application of industrial wastes to reduce consumption of natural resources and energy and pollution of the environment. Marble sludge powder can be used as filler and helps to reduce the total voids content in concrete. Natural sand in many parts of the country is not graded properly and has excessive silt on other hand quarry rock dust does not contain silt or organic impurities and can be produced to meet desired gradation and fineness as per requirement. Consequently, this contributes to improve the strength of concrete. An attempt has been made to durability studies on green concrete compared with the natural sand concrete by usage of quarry rock dust and marble sludge powder as hundred percent substitutes for natural sand in concrete [6]. Recent focus on climate change and the impact of greenhouse gas emissions on our environment has caused many to focus on CO\textsubscript{2} emissions as the most critical environmental impact indicator. These issues made researchers to put efforts to reduce greenhouse gas emissions [7, 8].

7. GREEN CONCRETE TECHNOLOGY

It is a concept of thinking environment into concrete, considering every aspect from raw materials manufacture over mixture design to structural design, construction, and service life. Traditionally the concrete industry has been considered a major producer of GHG emissions, mainly due to the high environmental footprint of cement. The carbon footprint is a measure of the quantity of carbon dioxide emitted through fossil fuel combustion (Fig.2). It is often expressed as tons of carbon emitted per annum [9-11].

- Cementing material Supplementary instead of Portland cement.
- Local resources of Aggregates.
- Aggregates and Waste water are reused and
- The Aggregates cooling system eliminates dust and reduces the large amount of water required
- The Green concrete formed result in high quality concrete with low water to cement ration and zero carbon emission.
8. TYPES OF SUPPLEMENTAL CEMENTITIOUS MATERIALS

8.1 PULVERIZED-FUEL ASH (PFA) OR FLY ASH

PFA is a by-product of burning pulverized (finely ground) coal to generate electric power. The shales and clays (contents of silica, alumina and iron oxide) and other contents in coal, melt while in suspension, and then with rapid cooling they are carried out by the flue gases and form into fine spherical particles. Fly ash particles are generally spherical in shape and range in size from 0.5 μm to 100 μm. They consist mostly of silicon dioxide (SiO2). Fly ash is an important pozzolanna, which has a number of advantages compared with regular Portland cement. First, the heat of hydration is lower, which makes fly ash a popular cement substitute for mass structures. Previous studies have found that the use of fly ash as an additive material for concrete gives positive results in terms of mechanical and chemical properties. [12, 13]

8.2 SILICA FUME (SF)

SF is a by-product of the manufacture of silicon and ferrosilicon alloys from high purity quartz and coal in a submerged-arc electric furnace. It is a powder with particles having diameters 100 times smaller than those of anhydrous Portland cement particles. The most important influences in the use of silica fume as an admixture in cement based materials are increases in tensile strength, compressive strength, compressive modulus, flexural modulus and the tensile ductility, but decreases in the compressive ductility, it enhances the freeze-thaw durability, the vibration damping capacity, the abrasion resistance, the bond strength with steel rebar, the chemical attack resistance and the corrosion resistance of reinforcing steel. Furthermore, it decreases the alkali-silica reactivity, the drying shrinkage, permeability, creep rate, coefficient of thermal expansion and dielectric constant.

8.3 GROUND GRANULATED BLAST FURNACE SLAG

Ground granulated blast furnace slag (GGBS or GGBFS) is obtained by quenching molten iron slag (a by-product of iron and steel making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Use of slag or slag cements usually improves workability and decreases the water demand due to the increase in paste volume caused by the lower relative density of slag.

8.4 RICE HUSK ASH (RHA)

Globally, approximately 600 million tons of rice paddy is produced each year. On average, 20% of the rice paddy is husk, giving an annual total production of 120 million tons. Rice husk is an external covering of rice, which is generated (about 90% by mass) during de-husking of paddy rice. The RHA is rich in silica content, obtained by burning rice husk to remove volatile organic carbon such as cellulose and lignin. It is estimated that, one ton of rice yields 200kg of husk and about 40kg of ash. According to Mehta, the amorphous silica powders with high surface area are more reactive than the crystalline form of silica. The fineness of ash will significantly affect the reactivity of RHA in lime, mortar or concrete mix.

8.5 PALM OIL FUEL ASH (POFA)

Palm oil fuel ash (POFA) is produced as a result of the burning of palm oil shell and husk (in equal volume) as fuel in palm oil mill boiler to produce steam for electricity generation and palm oil extraction process. Both physical properties and chemical analysis indicated that POFA is a pozzolanic material. Various researchers reported that POFA has pozzolanic properties and highly reactive and can be used as a unique cement replacement for building construction materials if the POFA is ground to reduce the particle size (GPOFA), the median particle size is reduced to 10 μm.

8.6 MET KAOLIN (MK)

Met kaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous alumina silicate that is reactive in concrete. Replacing Portland cement with 8% -
20% (by weight) met kaolin produces a concrete mix which exhibits favorable engineering properties, including: the filler effect, the acceleration of OPC hydration, and the pozzolanic reaction.

9. TYPES OF OTHER GREEN MATERIALS THAT CAN BE USED IN PRODUCING GREEN/SUSTAINABLE CONCRETE

9.1 RECYCLED CONCRETE
Construction and demolition waste (C&D waste) constitutes a major portion of all generated solid waste. With the increasing scarcity of suitable aggregate, construction industry has find ways of substituting recycled concrete aggregate (RCA) for natural aggregate. The technical problems of incorporating RCA into new concrete mixes are well known and have been addressed through research. Recycled aggregates have generally lower densities than the original material used, Although RCA is often considered with suspicion, it may be quite acceptable for many applications, and if higher performance specifications are to be met, a blend of virgin and recycled aggregate may make economic and technical sense. [14-16]

9.2 POST-CONSUMER GLASS
Post-consumer glass is another example of a suitable aggregate for concrete. The only technical problem, namely the alkali–silica reaction (or ASR) and other potential problems can be solved. By exploiting the zero water absorption of glass, its high hardness and good abrasion resistance, its excellent durability and chemical resistance, and in particular the aesthetic potential of colored glass, true value is added to the glass. Making commodity products such as paving stones economically viable is a difficult proposition.

9.3 OTHER RECYCLED MATERIALS
In the United States, 100 million tons of sand is used in foundries for the production of steel and other metals. Most of such foundry sands are discarded and available to be recycled. Naik et al. have shown that such foundry sands are suitable for the production of concrete. Another potential source for concrete production is dredged material. The Port Authority of New York and New Jersey needs to dredge about three million cubic meter of sediment each year to keep shipping lanes open and also to deepen them to accommodate the larger new vessels. Since dumping in the open ocean is no longer an option, the material has to be deposited in engineered landfills at great cost, because much of it is highly contaminated with heavy metals, dioxins, PCBs, oils, etc. Similar problems are faced by many other world ports. Treatment methods are already available, which render the material suitable for concrete production, because the heavy metals can be encapsulated chemically such that they cannot leach out. Further research is needed before this technology can be applied in real practice. Recycled carpet fibers have also been proposed to replace virgin fibers in fiber-reinforced concrete. Millions of tons of old carpets need to be disposed of each year, constituting another sizeable fraction of solid waste. Since carpet fibers are typically made of nylon, recycled fibers have been shown to improve some mechanical properties of concrete.

10. SUITABILITY OF GREEN CONCRETE IN STRUCTURES
a) Reduce the dead weight of a façade from 5 tons to about 3.5 tons.
b) Reduces crane age load, allow handling, lifting flexibility with lighter weight.
c) Good thermal and fire resistance, sound insulation than the traditional Granite rock.
d) Improve damping resistance of building, speed of construction, shorten overall construction period

e) Speed of construction, shorten overall construction period.

11. ADVANTAGES

11.1 ADVANTAGE OF GREEN CONCRETE
There are numerous advantages in usage of Green concrete in fresh stage such as Enhances the rheology of the mix, workability, Deficiency in sand is corrected by providing sufficient fines, which makes the concrete ideal for pumping, No bleeding & No cold joints .It will give enhanced
cohesion so user friendly - easier to place, compact & finish concrete. Some other advantages of such mix are:

- Optimized mix designs mean easier handling, better consistency and easier finishing
- Reduction in shrinkage & creep
- Green Concrete uses local and recycled materials in concrete.
- The heat of hydration of green concrete is significantly lower than traditional concrete
- This result in a lower temperature rise in large concrete pours which is a distinct advantage for green concrete.

11.2 IMPROVED ENGINEERING PROPERTIES

- Mix can result in a reduced paste volume within the concrete structure resulting in a higher level of protection against concrete deterioration.
- Higher strength per kilogram of cement
- Increased durability & lower permeability
- More aggregates typically mean higher Modulus of elasticity.

12. CONCLUSIONS

Concrete continues to play a pivotal role in overall economic growth both locally and globally. In order to improve the sustainability of all concrete structures, there is a need to understand the interactive effect of the many issues from ‘cradle to grave’ in the design phase, during construction and end-of-life and, most importantly, the energy savings achievable during the use phase. The importance of assessing a building structure’s impact is via a life-cycle assessment.

One must not forget to achieve the sustainable construction. There are various means to achieve sustainable construction and one of the means is through green concrete. Green concrete technology is one of the major steps that a construction industry can implement to achieve sustainable construction with various means as discussed above. With Green concrete Technology we can save the natural materials for future use or the generations to come and sustain it for good amount of time. With the time, the virgin material will deplete and so the cost for the material will increase which will add to more cost for the construction but if we use waste materials for construction the virgin materials will become a sustainable material and as well the cost will be reduced. With waste material as alternative we can help reduce the environmental problems and protect the naturally available materials for future generations as well.

Green concrete having reduced environmental impact with reduction of the concrete industries CO₂ commissions by 30%. Green concrete is having good thermal and fire resistant. In this concrete recycling use of waste material such as ceramic wastes, aggregates, so increased concrete industry use of waste products by 20%. Hence green concrete consumes less energy and becomes economical. So definitely use of concrete product like green concrete in future will not only reduce the emission of CO₂ in environment and environmental impact but also economical to produce.

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