Eco-concrete: Opportunities and Challenges

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ABSTRACT

Concrete is a hard composite material obtained by mixing fine aggregates, coarse aggregates and cement with adequate quantity of water. The manufacture of concrete brings about a great amount of CO_2 emissions, which is 0.1 to 0.2 Tonnes per Tonne of produced concrete. The Kyoto Protocol calls for the imperative need to reduce the CO_2 emissions in all the processes. These emissions can be brought down by using the raw materials of concrete judiciously.

Also, the National Green Tribunal has restricted the mining and sale of sand. The same could transpire to coarse aggregate in due course of time. The building industry in India and throughout the world is rapidly growing and a great amount of natural resources viz. sand and coarse aggregates are consumed every year. In due course of time when the natural resources would be depleted and one will have to look at alternatives for construction materials.

The 3Rs of environment calls for a focus on Reduce, Reuse and Recycle. This paper deals with the 3Rs as 1) Reduce the use of natural aggregates, 2) Reuse the material as fine and coarse aggregates and 3) Recycle them as fine and coarse aggregates. This paper presents the results of recycling of construction debris such as mosaic tiles, porcelain, vitrified tiles, Mangalore tiles being used partially as a substitute to coarse aggregates; and the Iron and Steel plant fly ash as the partial substitute to fine aggregate in concrete. The partial use of these construction materials increases the life of the natural materials like sand and coarse aggregates. The use of the construction debris also brings about the reduction in the CO_2 generation. It also brings about the reduction in the cost of production of concrete and also reduced charges for disposal of construction waste.

Keywords: Eco-concrete, Kyoto Protocol, Construction waste, demolition waste, incinerated steel plant waste, CO_2 emissions, blended cements

1. INTRODUCTION

Concrete is a hard composite material obtained by mixing fine aggregates (sand), coarse aggregates and cement with adequate quantity of water. Some other materials called admixtures also may be added to improve the properties of concrete. Concrete is strong, durable, aesthetic and rather not much expensive. This makes it the most viable option in the construction industry. The concrete finds its use in buildings, bridges, dams, airports, tunnels, etc.

2. CONCRETE – THE FIRST CHOICE:

Concrete is the first choice due to many reasons: viz. in buildings: it reduces the cost of maintenance, and use of energy consumption, in roads: reduce the fuel consumption by vehicles, reduced maintenance, in irrigation purposes: durable canals, dams, prevents infiltration, ground water contamination, etc. It has been in use for millennia and certainly is expected to continue for a long time in future.

3. CONCRETE PROPORTIONS:

Concrete's ingredient proportions may vary depending upon the strength required, but mostly the composition is in the range of about: 7%–15% cement, 15%–20% water, 0.5%–8% air, 25%–30% fine aggregates (sand), and 30%–50% coarse aggregates (gravel or crushed stone) by volume. Generally for a concrete mix, 1 metric ton of cement will yield about 3.4–3.8 m^3 of concrete and weigh about 7000 – 9000 kg having the density of about 2200 – 2400 kg/m^3. It is well known fact that the concrete consumption worldwide is seeing a sharp increase every year.

4. CARBON DIOXIDE EMISSIONS DUE TO CONCRETE:

Global concrete consumption in the year 2012 was about 31 billion tones. The cement consumption in that year stood at 3.78 billion tones with India at the second position after China. On an average, typically cements contain about 95% Portland clinker. The manufacturing process of cement releases about 0.9 tonnes of CO_2 per tonne of clinker. Thus, direct CO_2 emissions from clinker producing kilns are 3.23 billion tonnes/year (3.78x0.95x0.9). In the last several decades there has been an unusually high demand for cement and concrete. About fifty years ago, the world's concrete consumption was about 1 tonne per capita whereas today, it is 4.3 tonnes per capita. The manufacture of concrete brings about a great amount of CO_2 emissions, which is 0.1 to 0.2 Tonnes per Tonne of produced concrete. Thus, the CO_2 emissions from concrete were found to be about 4.65 billion tones in 2012. The Kyoto Protocol calls for the imperative need to reduce the CO_2 emissions in all the processes.

5. AGGREGATES AND SAND FOR CONCRETE:

The enormous demand for concrete world-wide had resulted in consumption of aggregates (sand and coarse aggregates) exceeding 40 billion tonnes, last year. The consumption of aggregates is almost double of the quantity of sediments carried by all the rivers of the world. The only easy option left to man to acquire the aggregates for concrete is through mining. The large scale mining of these naturally occurring raw materials has caused an impact on the environment. The apex court of India has noted that the removal of minerals from river beds due to mining has been posing a serious threat to the flow of rivers, survival of forests upon river banks and most seriously to the environment of river banks. It is observed that the extensive sand mining is destroying not only sensitive marine life but also the buffer between land and sea, forcing the saltwater to penetrate our groundwater table. The coconut trees at the banks of the rivers collapse due to loosening of the soil. The water turbidity in the rivers have increased and so also the CO_2 emissions due to transportation of these raw materials in vehicles.

6. DEPLETION OF NATURAL RESOURCES:

The National Green Tribunal has restricted the unabated mining and sale of sand. The same could transpire to coarse aggregate in due course of time. The building industry throughout the world is rapidly growing and a great amount of natural resources viz. sand and coarse aggregates are consumed every year. Also, in due course of time when the natural resources would be depleted, one will be forced to look at alternatives for construction materials.

7. ENVIRONMENT'S 3R'S:

The 3Rs of environment calls for a focus on Reduce, Reuse and Recycle. For the construction industry the 3R's applicable are as 1) Reduce the use of natural raw materials including aggregates, 2) Reuse the material as fine and coarse aggregates and 3) Recycle them as fine and coarse aggregates.

8. CEMENT:

The major component responsible for the production of carbon dioxide during the cement process is the $CaCO_3$ (limestone). The calcinations of limestone produces CaO and releases the carbon dioxide in the atmosphere. The reduction in use and consumption of clinker in producing cement can bring about a direct reduction in the production of carbon dioxide.

The solution obtained is by the use of blended cements such as Slag cement and the Fly Ash cement. These blended cements use the Supplementary Cementitious Materials (SCMs) like the fly ash and the granulated blast furnace slag in their production. The fly ash and the granulated blast furnace slag are the by-products of the coal burning power plant and steel industries respectively. The fly ash and the granulated blast furnace slag are often dumped as waste on dry lands. They create environmental hazards, viz.

1. They occupy lot of ground space which creates the disposal problems
2. The stacking space could be used for productive means,

3. These are carried over by the wind due to their lighter inherent density, thus creating dust problems in the neighbourhoods.

These materials by themselves though do not have any cementitious property, but they combine well with the other ingredients of Ordinary Portland Cement, and their reactions produce excellent results in concrete such as: the achieving of greater durability and increased crack resistance. Slag cements are produced by blending about 25 – 65% of granulated blast furnace slag along with OPC clinker and grinding together. It can be separately ground and mixed with OPC, too in the mixer during concreting also. Thus, the blended cements reduce the consumption of clinker by 25 to 65%.

The use of the fly ash and the granulated blast furnace slag brings about the advantages such as the

1. Use of industrial waste,
2. Reduction in the consumption of clinker and thereby reduction in the production of carbon dioxide,
3. Saving of huge amount of energy and
4. Giving longevity to the prestigious raw materials required to produce cement.

The carbon dioxide emissions are reduced by up to 60% by the blended cements. The energy consumption due to the use of blended cements also reduces to about 40%.

9. AGGREGATES

The aggregates (fine aggregates and coarse) are the inert materials in the concrete and do not react with the other ingredients. The carbon dioxide emissions with regards to aggregates are due to account of the burning of fuel for the transportation of aggregates to the site, the fuel burning for the mixing of ingredients of concrete and the explosives used for their mining. It is generally observed that during the construction, much of the sand is wasted as mortar, and also at the end of the day when the work stops and the mix which was prepared goes waste. Sand also gets wasted during the transportation at the site and in the concrete mixers. Care needs to be taken by providing plastic sheets at the lower level to recover the mortar falling off during masonary construction. Much of the sand can be recovered during the washing of the concrete mixer. Proper management ensures enough quantity of mixture compund to be prepared for the day to prevent wastage of mortar. The construction and demolition wastes (often termed as C & D wastes) are produced by very different processes and their quantities vary. Often, the demolition waste quantity is about 20 to 30 times the construction waste. All this waste finally finds a landfill as its resting place, since disposing this waste to a nearby landfill is found to be more often economical and viable. Some of the materials recovered from the demolition waste could be recycled as aggregates. A study was carried out with recycling of construction debris such as mosaic tiles, porcelain, vitrified tiles, Mangalore tiles being used partially as a substitute to coarse aggregates. Similarly, waste from the industry such as incinerated steel plant waste was replaced for sand in the concrete. Normal reference concrete using OPC in the proportion 1:1.5:3 was prepared. The compressive strengths after 7 days for each of the material so obtained by partially substituting was carried out. With same component materials and proportion, the demolition waste was substituted partially for coarse aggregates in the above mix by 33%, 50% and 75%. Compressive strengths were obtained after 7 days for the all the cubes.

10. RESULTS

1. Normal Reference Concrete:

Sr no	Concrete Mix	Strength after 7 days
1	1: 1.5: 3	70 Tonnes (311.11kg/cm^2)

2. Concrete by Replacement of coarse aggregates by using Mangalore Tiles:

Sr no	Concrete Mix	Strength after 7 days in Tonnes	Remarks
1	1: 1.5: 3	65 (288.88kg/cm^2)	33% replacement of coarse aggregates
2	1: 1.5: 3	60 (266.67kg/cm^2)	50% replacement of coarse aggregates
3	1: 1.5: 3	45(200.00kg/cm^2)	75% replacement of coarse aggregates

3. Concrete by Replacement of coarse aggregates by using Mosaic Tiles:

Sr no	Concrete Mix	Strength after 7 days in Tonnes	Remarks
1	1: 1.5: 3	68 (302.22kg/cm^2)	33% replacement of coarse aggregates
2	1: 1.5: 3	66 (293.33kg/cm^2)	50% replacement of coarse aggregates
3	1: 1.5: 3	66 (293.33kg/cm^2)	75% replacement of coarse aggregates

4. Concrete by Replacement of coarse aggregates by using Ceramic Tiles:

Sr no	Concrete Mix	Strength after 7 days in Tonnes	Remarks
1	1: 1.5: 3	56 (248.89kg/cm^2)	33% replacement of coarse aggregates
2	1: 1.5: 3	53 (235.56kg/cm^2)	50% replacement of coarse aggregates
3	1: 1.5: 3	52 (231.11kg/cm^2)	75% replacement of coarse aggregates

5. Concrete by Replacement of sand by using Incinerated Steel Plant Waste:

Sr no	Concrete Mix	Strength after 7 days in Tonnes	Remarks
1	1: 1.5: 3	71 (315.55kg/cm^2)	33% replacement of fine aggregates
2	1: 1.5: 3	78 (346.66kg/cm^2)	50% replacement of fine aggregates
3	1: 1.5: 3	82 (364.44kg/cm^2)	75% replacement of fine aggregates

It was observed that by partially replacing the aggregates with up to 50% of Mangalore Tiles, one could still achieve strength of about 85% of the original concrete. Similarly, by replacing the aggregates with Mosaic tiles, a better result was observed. The strength capability of about 95% of the original could be achieved by replacing the mosaic tile pieces for aggregates. Replacement by use of Ceramic tiles contributed to about 70 to 80% of the strength.

The incinerated waste of steel plant when used for sand partially, showed better results than the normal concrete. Further research would be undertaken in order to find the underlying reasons for the increase in strength and the effect of such incinerated waste and the other materials on properties of concrete.

In order that the steel plant waste be used in the process of slag cement, it was necessary that the steel plant waste be controlled-cooled, so that the blast furnace silica granules could be formed which could be used in the manufacture of slag cement. Many of the steel plants could not afford the controlled process and as such the waste from such plants could not be utilized in the manufacture of blended cements. And so, this waste from the incinerated steel industry was creating an environmental hazard as explained earlier. The above experiment, in which the incinerated steel plant waste which was not controlled-cooled was used for partial replacement of sand in concrete, showed that the strength achieved was better. This shows a good promise for the incinerated plant waste and environment.

11. ECO-CONCRETE

Eco-concrete is the concrete which is environment friendly and consumes less energy as compared to the conventional concrete. The eco-concrete creates the least environmental impact right from the usage of the raw materials, to the production, construction and the service life. This concrete has very small or negligible amount of carbon dioxide emissions, and consumes lesser energy. Use of recycled waste, reuse of the materials and reducing the wastage are the prime factors responsible for the eco-concrete. The eco-concrete thus enables in reducing the carbon dioxide emissions as per the Kyoto Protocol, reduce the use of fuel (energy) consumption, and increase the use of environmental wastes into useful products.

12. CONCLUSION

Eco-concrete is the solution for the present day. In this today's world, which is comprising of rising temperatures, green house gases, rising water levels, storms, drought, reduction in quality of food grains, it is imperative that one has to change from the conventional methods to a different process in order to reduce the carbon dioxide emissions. The per capita demand of concrete is rising and will continue to rise even faster in the next decade owing to the demand of population rise. The construction industry needs to have a paradigm shift by using the blended cements, the partial replacement for coarse aggregates as well as fine aggregates (sand). Environmental impact needs to be integrated at all levels of manufacture, production and service life.

Reducing the use of natural aggregates and supplementing them by usable environmental waste shall give the raw materials like Limestone, coarse aggregates and sand longevity. This will also help the environment by protecting the sensitive marine life, the prevention of salt water penetration in the ground water, collapse of the sand river banks, etc. Recycling the waste into the construction will help the environment by reducing the carbon footprint. Reusing the commodities by reducing the wastage improves the economics and increases the profitability. Finally, in order to come closer to the achievement of the target of 1990 levels as per the Kyoto Protocol, one has to face the challenges and understand that the eco-concrete is the one easy option one can freely choose as it gives us the opportunity and advantage now.

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