International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: http://dx.doi.org/10.7324/IJASRE.2017.32570 Vol.3 (11) December-2017

A Review Study on Green Concrete as Energy Efficient Building Material

Debanjan Mukherjee and Himanshu Tyagi

Electrical, Power and Energy Department,
College of Engineering Studies,
University of Petroleum and Energy Studies,
Bidholi, Dehradun-248007
Uttarakhand, India

ABSTRACT

The following paper describes the properties which are desirable in green concrete. The energy consumption study is being reviewed and the various methods are being described which are necessary for the production of green concrete. The following paper also shows a comparative study between conventional and green concrete; the future possibilities of green concrete in India as an energy efficient green building material and also focuses on the environmental goals which should be incorporated in order to ensure energy security in the long run.

Keywords: *Green Concrete, Energy Consumption, Green Building Material, Environmental Goals.*

I. INTRODUCTION

Green Concrete was first invented in the year 1998 in Denmark [2]. The concept of green concrete mainly revolves from raw materials manufacture over mixture design to structural design, construction, and service life. Green concrete is cheap to produce because waste products are normally utilised in place of conventional cement, disposal charges for the wastes are avoided, energy consumption in the production is comparatively lower, and the overall durability is greater. Green concrete is a type of concrete is a type of concrete which is similar to conventional concrete but the production or use of such concrete involves minimum amount of energy and envisages minimal harm to the environment.

The carbon dioxide emission during concrete production inclusive of cement production is between 0.1 and 0.2 tonne per tonne of produced concrete [18]. However, the total amount of concrete is very huge, hence the absolute figures for the environmental impact is prolific. Since, concrete is the second most consumed entity after water it accounts for 5% of world's total carbon-dioxide emission [7]. The solution to this environmental problem is not by replacing concrete by other materials but to reduce the effect of cement and concrete. [16]

The potential of building a society made from green concrete is enormous. It is possible to develop technology to use green concrete in the coming future thereby reducing the global carbon dioxide production by 1.5-2% . The residual products from several industries have the properties to produce concrete of high quality. And there is a large scope for investigation of these materials in the development of a high quality concrete. Well known residual products such as silica fume and fly-ash can be used for the same purpose.

The concrete industry has realised at a very early stage to document the environmental impacts of concrete production and has chalked out ways to mitigate the impact by implementing energy efficient measures instead of being forced by the government or other authorities to implement the same. Some companies have recognised that the reduction in production costs is directly related to the reduction in environmental impacts. Thus, environmental aspects are not only interesting from a holistic aspect but also from an economic aspect as well.

II. METHODS TO PRODUCE GREEN CONCRETE

A. Desirable Properties

The present day study shows that a super green type concrete can made without cement but with fly ash without any specification changes in the production equipment. But, this form of concrete will not develop strength and will not be durable. The concrete hence include certain performance characteristics as follows.

- Mechanical properties (strength, shrinkage, static behaviour etc.)
- Fire resistance (heat transfer, etc.)
- Workmanship (workability, curing, etc.)
- Durability (corrosion protection, frost etc.)
- Environmental impact (the intensity of carbon emissions etc.)

The above performance characteristics are hard to achieve and if not achieved the constructor would not recommend for building purposes. For e.g., a reduced service life will ensure the performance of concrete below normal, therefore it is necessary to develop technologies which makes the performance of green concrete as normal as possible with greater usage in the society.

B. **Energy Consumption During The Production.**

The environmental properties of cement mainly depend upon the type and amount of cement. An example of the above statement is shown in the figure below where the energy consumption in mega joules per kilogram of a concrete edge beam through all its life cycle phases is illustrated. The energy consumption of cement production make up more than 90% of the total energy consumption of all constituent materials and approximately one-third of the total life cycle energy consumption. One method of minimising the cement content in a concrete mix is by using packing calculations to determine the optimum composition of the aggregate. A high level of aggregate packing reduces the cavities between the aggregates and thereby the need for cement paste. The result is betterment of cement properties.

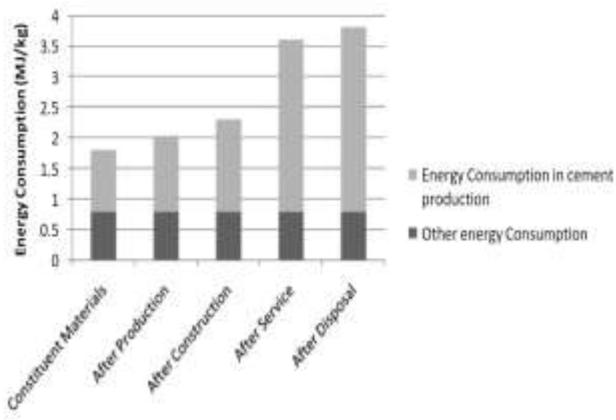

Figure. 1 Edge beam: total energy consumption through all the life cycle phases [15]

The other way of minimising the cement content in concrete is by replacing parts of the cement materials with pozzolanic materials. The residual products such as fly ash and/or micro silica are residual products and have pozzolanic properties. The Bureau of International Standards hasn't mentioned any guidelines in this regard, but Danish Standards has certainly laid certain specifications when it comes to the requirement of fly ash and micro silica in concrete [3].

C. **Evaluation Of Inorganic Wastes**

The following inorganic materials or inorganic residual products are selected from the concrete industry which produce a huge waste problem to the society and are in political focus.

- Stone Dust is formed during the crushing of aggregates. This inert material has a particle size of between that of cement and sand particles. Stone dust is an expected substitute for cement [16].
- Concrete slurry is a residue formed from concrete production specially from washing mixers and other equipment. The slurry can be a dry or wet substance and can be recycled with water or as a dry powder. For recycling it as a dry powder, pulverisation is very necessary. The concrete slurry possesses pozzolanic effect and therefore can be used as a replacement for fly ash [16].
- Combustion ash from water purifying plants has the same particle size and shapes that of fly ash. The heavy metal content in it is also similar to that of fly ash. And it is also a pozzolanic material [6].
- Smoke waste from waste combustion has pozzolanic effect. The heavy metal content is significantly higher than that of fly ash. Moreover the content of chlorides, fluorides and sulphates in it causes reinforcement corrosion, retardation and possible thaumastic reactions, hence further processing before use is a must criteria [4].

D. **Various Ways To Produce Concrete**

- To increase the use of conventional residual products, i.e., by replacing the cement with fly ash and micro silica in larger amounts than what is allowed in the present day.
- By producing new green cements and binding materials i.e., by increasing the use of alternate raw materials and fuels thereby developing cement with low energy consumption.
- Using inorganic residual products in concrete and cement stabilised foundation with waste incinerator slag, low quality fly ash or other inorganic residues. An information screening of the potential inorganic residual products is carried out where the products are described by origin, particle size and geometry, chemical composition and possible environmental impacts.

III. COMPARISON BETWEEN CONVENTIONAL AND GREEN CONCRETE

Test results show that, apart from having lesser environmental impact other properties like durability and resistance to fire are better bargain for green concrete than conventional cement.

Three green concrete columns defined as A, B and C are compared with a reference concrete column R designed for an environmental screening. The main purpose of the screening is to identify significant resource consumption and environmental effects of traditional concrete occurring during the entire service life mostly including the environmentally viewed most critical maintenance/ repair stage. The performed lifecycle tests quantify material usage as well as carbon-dioxide emissions generated at the involved stages during the lifecycle of the columns.

The environmental parameters related to the working environment have not been included. The results of the environmental screening for the 3 green concrete columns (A,B,C) and the traditional concrete column (R) is presented in Table-2 with regard to carbon-dioxide emission and in Table-3 with regard to the consumption of concrete.

TABLE1. A COMPARISON BETWEEN CONVENTIONAL AND GREEN CONCRETE [1].

Structural Element	Concrete Type	Design	Expected Service Life	Maintenance/ Repair
Bridge Deck	Green concrete	Waterproofing Membrane (traditional design)	25 years	Extensive, expensive
		Top layer of Density	Min. 30 years (may be 75years)	Limited, moderate
		Top layer of steel fibre reinforced concrete	Min. 30 years	Limited, moderate
Column	CRC[2]	None	Min. 75 years	Negligible, very cheap
	Green Concrete	Traditional design (column A)	50 years	Limited, moderate
		Stainless steel reinforcement (column B)	Min. 75 years	Negligible, very cheap
		Cladding of stainless steel (column C)	Min. 75 years	Negligible, very cheap

TABLE 2. COMPARISON OF COLUMNS AND RESPECTIVE CARBON-DIOXIDE EMISSIONS

	Column R	Column A	Column B	Column C
Design Solution	Traditional design + traditional concrete	Increased concrete+ Green concrete	Stainless steel reinforcement+ green concrete	Stainless steel cladding+ green concrete
Kg CO_2 per year	300	200	86	80

TABLE 3. Sources of CO_2 emissions for four types of columns

Design Solution	Column R	Column A	Column B	Column C
Concrete Construction (kg)	5102	5733	5102	5102
Concrete Maintenance (kg)	1533	2442	0	0
Total Kg concrete	6635	8175	5102	5102

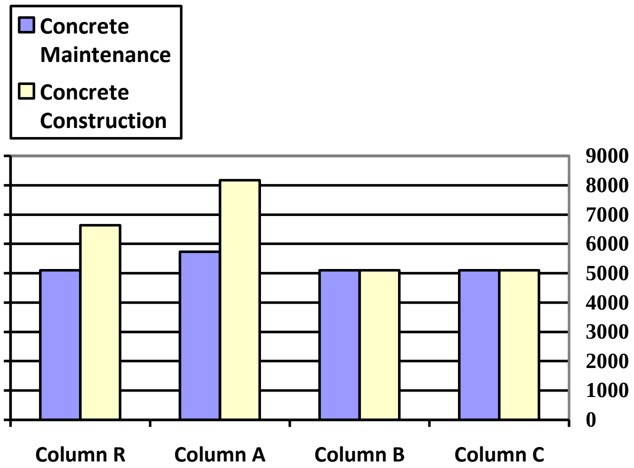

Fig. 2 Chart depicting the concrete consumption of the column. (Note: All units in the Y-axis are in kilograms) ***[1]***

The comparison demonstrates that column B (stainless steel reinforcement) and column C (stainless steel cladding) present the most environment friendly design solutions both with regard to the CO_2 emissions and also on the basis of consumption of concrete. If the selected concrete for column C is replaced by a more environmental friendly concrete type, then it would be much more energy efficient solution provided that the steel cladding assures the long term protection of the reinforced concrete.

IV. LIMITATIONS OF GREEN CONCRETE

Durability is one of the biggest concerns of the structures made by green concrete followed by the tension factor as it has been found that split tension of green concrete is much less than that of conventional concrete. Only when the properties of green concrete are at par with that of conventional concrete, only then it can take over the market of conventional concrete, until then it is unlikely to find customers.

Some researchers argue that stainless steel concrete has better durability than normal green concrete but the only disadvantage with stainless steel concrete is the increase in construction cost.

Thus, the limitations of green concrete can be summarized as below:

- Cost of stainless steel green concrete is high
- Durability is less compared to conventional concrete
- Split tension is lower than conventional concrete
- Less Life of green concrete structures as compared to that of conventional concrete

The above limitations attached with the urgent need to reduce greenhouse gas emissions have led the scientists to think over and increase the durability of green concrete.

V. SCOPE IN INDIA

India is the second largest producer of cement in the world and it would face an exponential growth in the concrete demand in the coming years [16]. Concrete is an indispensable commodity for the development of a country likes India and hence it needs a continuous infrastructure.

The concrete industry has a significant contribution to the carbon dioxide emissions. The net carbon dioxide emission from the concrete sector is greater than any other industry.

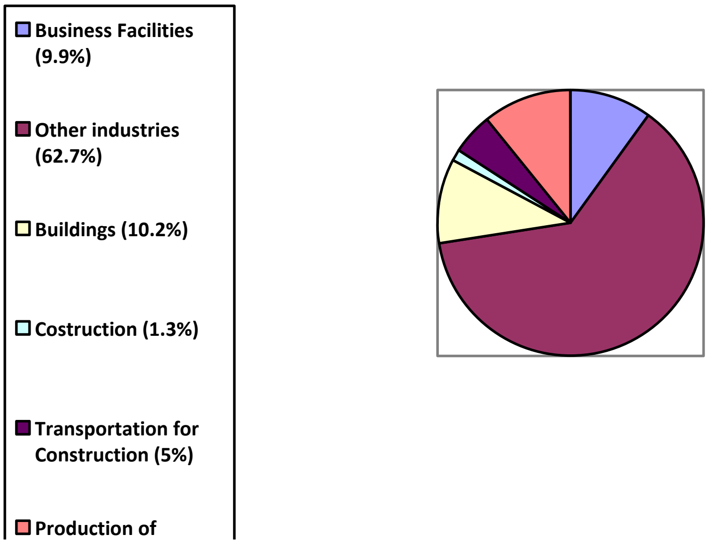

Figure3. Energy consumption of construction and building in India *[2]*.

Green concrete is an important tool for the sustainable development of the nation. Developing country like India produces a huge bulk of concrete which in turn releases epic volumes of carbon dioxide in the atmosphere. The total energy consumption during the manufacture of concrete is shown in table IV [17].

TABLE 4. FUEL CONSUMPTION IN THE INDIAN CEMENT INDUSTRY (1991-1993)

Fuel	Units	1991-92	1992-93	1993-94
Electricity	GWh	4800.52	6420.97	6754.60
Coal	Mt	10.8	11.7	11.1
Petroleum Products	Mt	0.293	0.296	0.291
Total Cement Production	Mt	53.6	54.1	58.0

The above statistics can be used as a guide line even though the values are old and technological advancements scarce. Considering the entire life cycle of concrete, green concrete is the only option that reduces the net carbon dioxide emissions. Apart from having energy efficient advantage, green concrete is much more economical as it is made from concrete wastes and recycled aggregates, which are cheaper than conventional substitutes. The waste disposal problem of most of the industries can be taken

care of substantially with the advent of the green concrete in the Indian scenario thus ensuring a greener and cleaner future for the country's energy requirements.
Pervious concrete is another form of green concrete which can be utilised for storm water management and rain water harvesting. Pervious concrete can be used to control the run off and can be harnessed for future uses in relatively dry areas which would have otherwise drained away. Pervious concrete can be a utilitarian tool to control the droughts in certain areas of the country [8].
The above mentioned facts and figures enhance the future scopes of green concrete in India which definitely looks promising!

VI. ENVIRONMENTAL GOALS

The following environmental obligations are expected to be fulfilled by the advent of green concrete.

- Reduction in carbon dioxide emissions by 21% in accordance with the Kyoto protocol.
- Increase in the use of inorganic residual products from industries other than the concrete industry by 20%.
- Increasing the use of waste derived fuels by reducing the use of fossil fuels in the cement and concrete industry.
- The capacity of recycling for green concrete must not be less as compared to the existing conventional concrete types.
- There should not be any deterioration in the environment during the production and usage of green concrete.
- Considering the entire service life, the green concrete structures must not possess any harm to the environment.

VII. ADVANTAGES OF GREEN CONCRETE

Since green concrete uses recycled aggregates and materials, it minimises the extra load in landfills and mitigates the wastage of aggregates. Hence, the net carbon dioxide emissions are reduced. Reuse of residual aggregates like silica and fly ash from a nearby power plant coupled with low transportation costs with enhance the economy of the state in the long run.
Green concrete is very much instrumental in ensuring sustainable development since it is eco-friendly and "green" in nature. Use of fly-ash in the concrete not only enhances the workability but also durability to an appreciable extent. Reduction of cement use in the cement mix by substituting it with residual products like fly ash is an energy efficient practice and reduces the overall consumption of cement and also reduces the load of disposal of wastes by industries. Green concrete is widely used as an energy efficient green building practice and has helped buildings to achieve LEED and Golden Globe certifications [13].
Other advantages of green concrete include:

- Reduced carbon dioxide emissions
- Production costs are low as mostly waste residual products are used
- Saves energy, emissions and waste water
- Recycling of industrial wastes
- Reduction in the overall consumption of cement
- Better workability
- Sustainable development
- Greater strength and durability than conventional concrete
- Compressive strength and flexural behaviour is fairly equal to conventional concrete

VIII CONCLUSIONS

The Danish and European environmental policies have motivated the concrete industry to react to the global concerns of CO_2 emissions and would continue to motivate them further for further development in production and use of concrete with reduced environmental impact. There is an increasing need to develop a specific technology for the development and use of green concrete. Technological goals must be set and must be reviewed in order to achieve the objective to developing a low emissive concrete, i.e. green concrete.

The year 1994 saw the cement industry consuming 6.6EJ of primary energy corresponding to 2% of total energy consumption. 1126 Mt of CO_2 or 5% of the CO_2 emission occurs from the cement and concrete industry [7]. The carbon intensity of cement making amounts to 0.81 kg of CO_2/ kg of cement. India, North America and China have 10% higher carbon intensity than the average. Specific carbon emissions range from 0.36 kg to1.09 kg of CO_2/ per kg of cement mainly depending on the type of processes, clinker/ cement ratio and fuel used [7].

A "green concrete" society is very much potent in the coming future. A technology to produce a concrete with low CO_2 emissions is very much possible. Seeing the modern trends and increase in the consumption patterns of green concrete, this will not only halve the carbon dioxide emissions but will reduce the CO_2 by 2% [15].

Seventeen different energy efficiency improvement options are identified as of now which ranges from a small percentage to a change as large as 25% per option depending on the reference case and local situation. The use of waste residues will reduce the

CO_2 emissions by 0.1 to 0.5 kg/ kg of cement. And end of pipe technology to reduce carbon emissions can be CO_2 removal. Probably the main technique is combustion under oxygen while recycling CO_2 [7]. However, considerable researches are yet to be performed in this particular technique.

It is important to keep a holistic approach and a broad perspective when it comes to the use of a material. Occupant energy use accounts for 99% of the life cycle energy use of a single family home. The contribution of cement and concrete to the life cycle energy use of the home is less than 1%. The global cement and concrete sector contributes to 5% of the total CO_2 emissions [4]. If someone focuses on the concrete production alone, the carbon dioxide emission is comparatively low, but that should not refrain ourselves from reducing the carbon dioxide emissions as the carbon dioxide emission reduction in concrete production will reduce the global emission by 2% [7].

ACKNOWLEDGMENT

We wish to acknowledge the significant contributions of the department of Electrical, Power and Energy of University of Petroleum and Energy Studies to provide us a platform to perform the review study on such an important and useful topic to aware and let other people know regarding the carbon emissions related to the most common construction material i.e., cement and concrete.

The study would not have been feasible if our respected Head of the department has not come forward to address us the global energy crisis which the world is facing as of now, and the need to put our best feet forward in dealing with the growing energy demand of the nation and the world in the whole by applying "green" energy efficient techniques which would help us to build a sustainable future.

REFERENCES

[1] Au Youn Thean Seng *http://www.madisonvelocity.blogspot.com/*

[2] Carbon dioxide Information Analysis Centre, *http://cdiac.ornl.gov/*

[3] Concrete Materials, DS 481: 1998 [in Danish]

[4] Gajda, J. VanGeem, Martha G., Marceau, Mdgar L., "*Environmental Life Cycle Inventory of Single Family Housing*", SN2582a, Portland Cement Association, Skokie, IL, PCA, 2002, *www.cement.org*

[5] Green Concrete in Denmark", Structural Concrete, 1(1), March 2000.

[6] Green Globes, The Green Building Initiative, Portland, Oregon, *http://www.thegbi.org/*

[7] Hendriks, C.A, Worrell, E., de Jager, D., Blok, and Riemer P., "Emission Reduction of Greenhouse Gases from the Cement Industry", Conference Paper-Cement, 2004, *http://www.ieagreen.org.uk/*

[8] *http://en.wikipaedia.org/Pervious_Concrete*

[9] *http://www.enercon.com*

[10] *http://www.epa.gov/nrmrl/news/news102008.html*

[11] *http://www.greenconcretedenmark.dk/*

[12] *http://www.perviousblog.com*

[13] Leadership in Energy and Environmental Design (LEED), U.S. Green Building Council, Washington, DC, *http://www.usgbc.org/*

[14] Medgar L. Marceau,Michael A. Nisbet, and Martha G. Vangeeem,"*Life Cycle Inventory of Portland Cement Concrete*", SN3011, Portland Cement Association ,Stokie, ICL, PCA, 2002, *www.cement.org*

[15] Obla, K.H., "*What is Green Concrete?*" Point of View, The Indian Concrete Journal, 24(4):26-28, April 2009.

[16] Pravin K., Kaushik S.K. "*SCC with crusher sludge, fly ash and micro silica.*" The Indian Concrete Journal, 79(8):32-37, August 2005.

[17] TERI, 1996: *Teri Energy Data Directory and Yearbook 1996/97*, Tata Energy Research Institute, New Delhi, India: Pauls Press.

[18] Shumacher, K, and Sathaiye J., "*India's Cement Industry: Productivity, Energy Efficiency and Carbon Emissions*", Energy Analysis Program, Environmental Energy Technologies Division, Lawrence Berkely National Laboratory, Berkely, July 2009.