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Green Concrete: An Efficient and Eco-Friendly Sustainable Building Material

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Abstract: Green concrete 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. Green concrete is a type of concrete which resembles the conventional concrete but the production or usage of such concrete requires minimum amount of energy and causes least harm to the environment. Since it uses the recycled aggregates and materials, it reduces the extra load in landfills and mitigates the wastage of aggregates. Thus, the net CO_2 emissions are reduced. The reuse of materials also contributes intensively to economy. Green concrete can be considered elemental to sustainable development since it is eco-friendly itself. One of the practices to manufacture green concrete involves reduction of amount of cement in the mix, which helps in reducing the overall cement consumption. The use of waste materials also solves the problem of disposing the excessive amount of industrial wastes. This paper discuses the importance of Green Concrete in the present day context and highlights its merits over conventional concrete which otherwise posing a serious threat to the environment through global warming.

1. INTRODUCTION

Concrete is the second most consumed entity after water and accounts for 5% of the world's total CO_2 emission (Worrell, 2001). The solution to this environmental problem is not to substitute concrete for other materials but to reduce the environmental impact of concrete and cement. The increasing awareness and activity to conserve the environment and the realization that concrete production too releases a considerable amount of CO_2 in the atmosphere are strong initiatives to catalyze the genesis of Green Concrete. It was first invented in Denmark in the year 1998. Green concrete has nothing to do with color. 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. Green concrete is also cheap to produce because the waste products are used as a partial substitute for cement, charges for the disposal of waste are avoided, energy consumption in production is lower, and durability is greater. It is a type of concrete which resembles the conventional concrete but the production or usage of such concrete requires minimum amount of energy and causes least harm to the environment. Green Concrete is expected to fulfill certain environmental obligations. It reduces the CO_2 emissions by 21 %, in accordance with the Kyoto Protocol of 1997. It increases the use of inorganic residual products from industries other than the concrete industry by approx. 20%. It also reduces the use of fossil fuels by increasing the use of waste derived fuels in the cement industry. The recycling capacity of the green concrete must not be less compared to existing concrete types. The production and the use of green concrete must not deteriorate the working environment. The structures do not impose much harm to the environment during their service life. Every 1 ton of cement produced leads to about 0.9 tons of CO_2 emissions and a typical cubic yard (0.7643 m^3) of concrete contains about 10% by weight of cement. Since a cubic yard of concrete weighs about 2 tons, CO_2 emissions from 1 ton of concrete varies between 0.05 to 0.13 tons. Approximately 95% of all CO_2 emissions from a cubic yard of concrete are from cement manufacturing only.

2. PRODUCTION OF GREEN CONCRETE

2.1. DESIRABLE PROPERTIES IN GREEN CONCRETE

Today, it is already possible to produce and cast very green concrete. Even a super green type of concrete without cement but with, for example, 300 kg of fly ash instead can be produced and cast without any changes in the production equipment. But this concrete will not develop strength, and it will of course not be durable. Therefore, the concrete must include aspects of performance like:

a) Mechanical properties (strength, shrinkage, creep, static behaviour etc.)
b) Fire resistance (heat transfer, etc.)
c) Workmanship (workability, strength development, curing, etc.)

d) Durability (corrosion protection, frost, new deterioration mechanisms, etc.)
e) Environmental impact (how green is the new concrete?).

Meeting these requirements is not an easy task, and all must be reached at the same time if constructors are to be tempted to prescribe green concrete. A constructor would not normally prescribe green concrete if the performance is lower than normal, for example, a reduced service life. The new technology will therefore need to develop concretes with all properties as near normal as possible.

2.2. ENERGY CONSUMPTION DURING THE PRODUCTION

2.2.1. Energy consumption in concrete mix design

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. By selecting a cement type with reduced environmental impact, and by minimizing the amount of cement, the environmental properties of the concrete are drastically changed. This must, however, be done while still taking account of the technical requirements of the concrete for the type and amount of cement. One method of minimizing 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. This results in better concrete properties.
Another way of minimizing the cement content in a concrete is to substitute parts of the cement with other pozzolanic materials. It is common to produce concrete with fly ash and/or micro silica. Both of these materials are residual products (from production of electricity and production of silicon, respectively) and both have a pozzolanic effect. Thus, a material with large environmental impact, i.e. the cement, is substituted with materials with reduced environmental impacts.

2.2.2. Energy consumption during cement and concrete production

It is also possible to reduce the environmental impact of concrete by reducing the environmental impact of cement and concrete production. As regards concrete production, experience with the reduction of primarily water consumption, energy consumption and waste production is available. Even though the contribution of concrete production to the environmental profile of concrete is minor, it does contribute, and is important environmentally and economically to the single concrete producer. By selecting a cement type with reduced environmental impacts and by minimising the amount of cement the concrete's environmental properties are drastically changed. This must, however, be done whilst still taking account of the technical requirements of the concrete for the type and amount of cement.

2.3. EVALUATION OF INORGANIC WASTES

Inorganic residual products from the concrete industry (e.g. stone dust and concrete slurry) and products which pose a huge waste problem to society and which are in political focus (e.g. combustion ash from water-purifying plants, smoke waste from waste combustion and fly ash from sugar production) have been given highest priority.
Stone dust is a residual product from the crushing of aggregates. It is an inert material with a particle size between that of cement and sand particles. Stone dust is expected to substitute part of the sand.
Concrete slurry is a residual product from concrete production, i.e. washing mixers and other equipment. The concrete slurry is can be either a dry or wet substance, and can be recycled either as a dry powder or with water. In the case of recycling of the dry material, it is necessary to process it to powder. The concrete slurry can have some pozzolanic effect, and might therefore be used as a substitute for part of the cement or for other types of pozzolanic materials such as fly ash.
Combustion ash from water-purifying plants has the same particle size and shape as fly ash particles. The content of heavy metals in the slurry is expected to be approximately at the same level as for fly ash. The slurry can also have some pozzolanic effect. Smoke waste from waste combustion has some pozzolanic effect. The content of heavy metals is significantly higher than that of ordinary fly ash. Furthermore, the content of chlorides, fluorides and sulphates can result in negative effects in connection with reinforcement corrosion, retardation and possible thaumasite reactions. Further processing will be necessary before its use in concrete.

2.4. WAYS TO PRODUCE GREEN CONCRETE

(i) To increase the use of conventional residual products and to minimise the clinker content, i.e. by replacing cement with fly ash, micro silica in larger amounts than are allowed .

(ii) By developing new green cements and binding materials, i.e. by increasing the use of alternative raw materials and alternative fuels, and by developing/improving cement with low energy consumption

(iii) Concrete with inorganic residual products i.e. stone dust, crushed concrete as aggregate in quantities are used along with cement stabilised foundation with waste incinerator slag, low quality fly ash or other inorganic residual products. Firstly, an information-screening of potential inorganic residual products is carried out. The products are described by origin, amounts, particle size and geometry, chemical composition and possible environmental impacts.

2.5 GREEN CONCRETE CONTAINING MARBLE SLUDGE POWDER AND QUARRY ROCK DUST

2.5.1 Raw materials Ordinary Portland Cement (43 Grade) with 28 percent normal consistency with specific surface 3300 cm^2/g conforming to IS: 8112-1989 is used. Marble sludge powder, obtained in wet form directly taken from deposits of marble factories has a high specific surface area and more cohesiveness to mortars and concrete. Specific gravity of the marble sludge powder is 2.212. Quarry rock dust has the specific gravity of 2.677. Moisture content and bulk density of waste are less than the sand properties. Medium size sand with a modulus of fineness of 2.20; Specific gravity 2.677, normal grading with the silt content 0.8% may be used as Fine aggregate. Crushed stone with a size of 5-20 mm and normal continuous grading is used as Coarse aggregate. The content of flaky and elongated particles is <3%, the crushing index ≤6% and the specific gravity 2.738. The qualities of water samples are uniform and potable. A superplasticizer based on refined lingo Sulphonates, 'Roff Superplast 320' is used to get and preserve the designed workability.

2.5.2 Mix proportion of concrete:
For durability studies the Indian standard mix proportion (by weight) use in the mixes of conventional concrete and green concrete are fixed as (Cement: River sand/marble sludge + stone dust: coarse agg.) 1:1.81:2.04, 1:1.73:2.04 after several trials. Based on properties of raw materials, two different mix proportions are taken. Mix A is the controlled concrete using river sand and Mix B is the green concrete using industrial waste (50% quarry rock dust and 50% marble sludge powder) as fine aggregate. The water/cement ratio for both two mixes is 0.55% by weight. Water reducing admixture is used to improve the workability and its dose is fixed as 250 ml/50kg of cement.

2.5.3 Results:
The comparison of two mixes of concrete is given in Table 1.

Table 1: Workability comparisons

Mix	Slump in mm	Slump flow in mm	V-funnel time in sec
Mix A	210	420	23
Mix B	255	657	14

The 150 mm size concrete cubes, concrete cylinder of size 150 mm diameter and 300 mm height are used as test specimens to determine the compressive strength and split tensile strength respectively. The results of standard cubes and cylinders are compiled:

Table 2: Avg. Compressive and Split tensile strength of concrete

Mix	Average Compressive Strength in N/mm^2			Split Tensile Strength in N/mm^2		
	3 Days	7 days	28 days	3 days	7 days	28 days
Mix A	15.45	18.33	36.85	2.40	2.60	4.62
Mix B	13.54	19.52	40.35	2.15	2.98	5.02

The details of Durability and Resistance to Sulphate attack are presented in Table 3.

Table 3: Percentage of weight loss

Mix	% of water absorption after 28 days	Percentage of weight loss					
		28 days		90 days		150 days	
		Na_2SO_4 and $MgSO_4$	H_2SO_4	Na_2SO_4 and $MgSO_4$	H_2SO_4	Na_2SO_4 and $MgSO_4$	H_2SO_4
Mix A	2.85	1.65	2.10	2.20	2.65	2.95	3.15
Mix B	3.74	1.15	0.80	1.95	1.10	2.10	1.80

The resistance to sulphate attack is studied by storage of standard prism specimens ire immersed in standard condition for 28 and 90 days and 150 days in testing baths (containing 7.5 percent $MgSO_4$ and 7.5 percent Na_2SO_4 by weight of water). From the above table it can be deduced that the durability of Green concrete under sulphate is higher to that of conventional concrete. This is due to that the active SiO_2 in marble powder and quarry rock dust can react with the Ca $(OH)_2$ in concrete to form secondary calcium silicate hydrate and make it chemically stable and structurally dense, the impermeability of concrete is enhanced as well. In addition, the marble powder can reduce the content of calcium aluminates in cementitious material, leading to increase of sulphate resistance of concrete.

2.5.4 Discussion:

All the experimental data shows that the addition of the industrial wastes improves the physical and mechanical properties. These results are of great importance because this kind of innovative concrete requires large amounts of fine particles. Due to its high fineness of the marble sludge powder it provided to be very effective in assuring very good cohesiveness of concrete. From the above study, it is concluded that the quarry rock dust and marble sludge powder may be used as a replacement material for fine aggregate.

- The chemical compositions of quarry rock dust and marble sludge powder are comparable with that of cement.
- The replacement of fine aggregate with 50% marble sludge powder and 50% Quarry rock dust (Green concrete) gives an excellent result in strength aspect and quality aspect. The results showed that the M4 mix induced higher compressive strength, higher splitting tensile strength. Increase the marble sludge powder content by more than 50% improves the workability but affects the compressive and split tensile strength of concrete.
- Green concrete induced higher workability and it satisfy the self compacting concrete performance which is the slump flow is 657mm without affecting the strength of concrete. Slump flow increases with the increase of marble sludge powder content. V-funnel time decreases with the increase of marble sludge powder content
- Test results show that these industrial wastes are capable of improving hardened concrete performance.
- Green concrete enhancing fresh concrete behaviour and can be used in architectural concrete mixtures containing white cement.
- The water absorption of green concrete is slightly higher than conventional concrete.
- The durability of green concrete under sulphate is higher to that of conventional concrete. From the results after 90-day immersion, the mortar specimens with green concrete in 7.5% sulphate solution have similar effect with those immersed for 28 days, but for those in 7.5% magnesium sulphate, the influence of addition on anti corrosion factor is not obvious.

The combined use of quarry rock dust and marble sludge powder exhibited excellent performance due to efficient micro filling ability and pozzolanic activity. Therefore, the results of this study provide a strong recommendation for the use of quarry rock dust and marble sludge powder as fine aggregate in concrete manufacturing.

3. CONCLUSION

Green concrete has manifold advantages over the conventional concrete. Since it uses the recycled aggregates and materials, it reduces the extra load in landfills and mitigates the wastage of aggregates. Thus, the net CO_2 emissions are reduced. The reuse of materials also contributes intensively to economy. Since the waste materials like aggregates from a nearby area and fly ash from a nearby power plant are not much expensive and also transport costs are minimal. It helps in recycling industry wastes. It reduces the consumption of cement overall and has better workability, greater strength and durability than normal concrete. Compressive strength and Flexural behaviour is fairly equal to that of the conventional concrete. Thus, it may be concluded that the green Concrete is a futuristic building material for Green Buildings.

4. REFERENCES

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