APPLICATION OF FLY ASH CONCRETE MIX AS A COSTRUCTION MATERIAL - PERSPECTIVE AND CHALLENGES

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ABSTRACT

Flyash enriched with bacteria is mixed in concrete that improves the durability, compressive strength, workability, mechanical properties. Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. The bacteria to be used as self-healing agent in concrete should be suitable for that purpose i.e. they should be able to perform long-term effective crack sealing, preferably during the total construction life time .the principle mechanism of bacterial crack healing is the bacteria themselves act largely as a catalyst, and transform a precursor compound to a suitable filler material. The newly produced compound such as calcium carbonate-based mineral precipitates should than act as a type of bio cement what effectively seals newly formed cracks. Fly ash is a coal combustion product composed of fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler, it is known as coal ash. Bacteria are used for the reduction of cracks in concrete. As bacterial concrete is called as self-healing concrete, thus the cement is replaced by the fly ash enriched with bacteria.

KEYWORDS

Fly ash, Concrete, Cement, Construction & Bacteria etc.

INTRODUCTION

Cement can be described as a material with adhesive and cohesive properties which make it capable of bonding mineral fragments into a compact mass. For constructional purposes cement is restricted to the bonding material which is used with stones, sand, bricks, blocks etc. It is the most important material in construction of structures because it is used at different stages of construction in the form of various forms viz mortar, concrete, cement slurry etc. With nearly 420 million tones of cement production capacity, India is the second largest cement producer in the world and accounts for 6.9 per cent world’s cement output. The cement production capacity is estimated to touch 550 million tonnes by financial year 2020. Of the total capacity, 98 per cent lies with the private sector and the rest with the public sector. The top 20 companies account for around 70 per cent of the total production. A total of 188 large cement plants together account for 97 per cent of the total installed capacity in the country, while 365 small plants make up the rest. Of the total 188 large cement plants in India, 77 are located in the states of Andhra Pradesh, Rajasthan and Tamil Nadu. Cement production in India increased from 230 million tonnes in financial year 2012 to 280 million tonnes in financial year 2017. Dalmia Cement Ltd has become the first cement company in India to commit itself to 100 per cent renewable power. The company plans to increase its capacity from existing 2.4 to 15-20 million tonnes by 2021 by investing US$ 1.27 billion.

The Government of India is strongly focused on infrastructure development to boost economic growth and is aiming for 100 smart cities. It plans to increase investment in infrastructure to US$ 1 trillion in the 12th Five Year Plan (2012–17). The government also intends to expand the capacity of the railways and the facilities for handling and storage to ease the transportation of cement and reduce transportation costs. These measures would lead to increased construction activity thereby boosting cement demand. The production of cement releases greenhouse gas emissions both directly and indirectly: the heating of limestone releases CO_2 directly, while the burning of fossil fuels to heat the kiln indirectly results in CO_2 emissions. The direct emissions of cement occur through a chemical process called calcination. Calcination occurs when limestone, which is made of calcium carbonate, is heated, breaking down into calcium oxide and CO_2. In this project efforts are being made to reduce the cement content by using flyash enriched with bacteria.

LITERATURE REVIEW

Murthy, (2013) studied Bacillus sp.CT-5,isolated from cement ,was used to study compressive strength and water absorption test . The highest compressive strength was obtained with mortar cubes prepared with Bacillus sp. CT-5 that were incubated for 28 days(31MPa) as compared to those with water(23 Mpa) and NBU medium(24 Mpa).There was about 36.15% increase in the compressive strength of mortar specimens at 28 days, prepared with bacterial cells compared to control . The deposition of a layer of calcium carbonate crystal on the surface resulted in a decrease of the permeation properties. As a consequence the ingress of harmful substances may be limited.

Tittelboom, et al (2010),studied the Use of bacteria to repair cracks in concrete, ,examined the objective of this present investigation is to study the potential application of bacterial species that is B.sphericus to improve the strength of cement concrete. The compressive strength and split tensile test were carried both on conventional and concrete specimen. It was observed that there was a considerable gain in the yield strength of cement paste. The application of bacteria will improve the strength and durability of cement concrete therefore it appears a promising field in the near future.

Navneet Chahal, et al (2011),influence of bacteria on the compressive strength, water absorption and rapid chloride permeability of flyash concrete, concluded *Sporoscarcina Pasteurii*in flyash concrete enhanced the compressive strength, reduced the porosity and permeability of flyash concrete. Inclusion of bacteria, chloride ingress capacity of flyash concretes decreased with increase in bacteria concentration.

J.Y.Wang,et al (2009), studied Application of hydro gel encapsulated carbonate precipitating bacteria for approaching a realistic self-healing in concrete2014 studied maximum healed crack was about 0.5mm width. Water permeability was decreased by 68% in average. Nonbacterial specimens have maximum healed crack width of (0-0.3mm). Water permeability of nonbacterial specimens was decreased by 15-55% only.

Chung Ho Huang, et al (2013) Mix proportions and mechanical properties of concrete containing very high volume of class F flyash, studied the Compressive and flexural strength of HVFA concrete mixtures demonstrated continuous and significant improvement at late ages of 95 and 365 days. Mixture containing low –LOI flyash exhibited superior mechanical properties as compared to high-LOI flyash.

F. Pacheco-Torgal, et al (2013)evaluated that the deterioration of reinforced concrete structures is a very common problem due to the fact that this material has a high permeability which allows water and other aggressive media to enter, thus leading to corrosion problems. The use of sealers is a common way of contributing to concrete durability. However, the most common ones are based on organic polymers which have some degree of toxicity. The Regulation (EU) 305/2011 related to the Construction Products Regulation emphasizes the need to reduce hazardous substances. Therefore, new low toxicity forms to increase concrete durability are needed. Recent investigations in the field of biotechnology show the potential of bioinspired materials in the development of low toxic solutions. This paper reviews current knowledge on the use of bacteria for concrete with enhanced durability. It covers the use of bacteria in concrete mix and also bio mineralization in concrete surface treatments. Investigation gaps are described. Results from practical applications in which there is exposure to environmental conditions are still needed in order to confirm the importance of this new approach.

RuotingPei, Jun Liu, et al (2013) examined**,** this research presents the role of bacterial cell walls of Bacillus subtilis as a concrete admixture to improve the mechanical performance of concrete. The bacterial cell walls are known to mediate microbial induced carbonate precipitation, a process in which CaCO3 is formed from Ca2+ ions and dissolved CO2. Consistent with such knowledge, incorporation of bacterial cell walls increased carbonation of Ca(OH)2 and formation of CaCO3 in concrete. Furthermore, the bacterial cell walls significantly increased compressive strengths of concrete by 15% while also decreased porosity at 28 days of curing. Assay for CaCO3 precipitation in vitro indicated that bacterial cell walls, but not dead cells, accelerated carbonation of Ca2+ ions in Ca(OH)2 solution. Since CaCO3formed can fill up the void, decrease the porosity and increase the compressive strength in concrete, bacterial cell walls could act as a promising concrete admixture with benefits in enhancing mechanical performance and improving other carbonation-related properties.

Navneet Chahal., Rafat Siddiqui, et al (2013) Permeation properties of concrete made with flyash and silica fume observed *Sporoscarcina Pasteurii*in flyash concrete enhanced the compressive strength, reduced the porosity and permeability of flyash concrete.

Kim Van Tittleboom, et al (2009) studied the use of bacteria to repair cracks in concrete, studied Pure bacteria culture were not able to fill the cracks. Bacteria when protected with silica gel were able to fill the cracks completely.

VarenyamAchal, et al. (2010) in the present study Bacillus sp.CT-5, isolated from cement, was used to study compressive strength and water absorption test. The highest compressive strength was obtained with mortar cubes prepared with Bacillus sp. CT-5 that were incubated for 28 days(31MPa) as compared to those with water(23 Mpa) and NBU medium(24 Mpa).There was about 36.15% increase in the compressive strength of mortar specimens at 28 days, prepared with bacterial cells compared to control . The deposition of a layer of calcium carbonate crystal on the surface resulted in a decrease of the permeation properties. As a consequence the ingress of harmful substances may be limited.

Studies on Bacterial Concrete

Bio-mineralization has been used for many years in several engineering applications. One encouraging bio-mimetic process in nature is the conversion of sand to sandstone by soil thriving bacteria [Dick *et al.* 2006]. Later it was found that this conversion was done by *Bacillus pasteurii*, which precipitate calcite that acts as a binding material for the limestone. Introducing a calcite precipitating bacteria can thus meet the need to improve the strength. The improvement of soil bearing capacity by microbial calcite precipitation is reported by [Whiff in *et al.* 2007]. Microbial mineral precipitation using ureolytic bacteria was reported to improve the overall behavior of concrete including strength and durability [Bachmeier *et al.* 2002; Muynck *et al.* 2008; Achal *et al.* 2009; Sung-Jin *et al.* 2010; Siddique and Chahal 2011; Majumdar *et al.* 2012; Grabiec *et al.* 2012; Pacheco-Torgal and Labrincha 2013; Vekariya *et al.* 2013; Achal *et al.* 2013; Sujatha *et al.* 2014]. Bacteria can be used externally as a healing agent on hardened concrete for sulphate treatment [Wiktor *et al.* 2011]. The microbially induced precipitation can resist the carbonation and chloride ingress in concrete [Muynck *et al.* 2008, Pacheco-Torgal *et al.* 2015]. Bio-mineralization has also been used as an alternative and environmental friendly crack repair technique [Bang *et al.* 2001; Muynck *et al.* 2007; Achal *et al.* 2011 and Xu *et al.* 2014]. *Bacillus subtilis* bacteria can precipitate $CaCO_3$ through urease activity [Siddique and Chahal. 2011; Pei *et al.* 2013 and Pacheco-Torgal and Labrincha 2013] which catalyses the hydrolysis of urea into ammonium and carbonate. Fig. 2.1 shows the schematic diagram of the mechanism of calcite precipitation. A brief discussions on the mechanism of bio-mineralization is described in Appendix A (Section A.2)

OBJECTIVE OF THE STUDY

- To indentify major perspectives of fly ash use in concrete mix as a resources.
- To indentify challenges associated with use of fly ash in concrete mixes .
- To work out the appropriate ratio of concrete cement fly ash for construction mix .
- To evaluate the strength of material prepared from the construction mix containing various proportion of fly ash..
- To mix bacteria with construction mix containing fly ash for self healing properties of creaks.
- To examine the economic and environmental viability of fly ash application in construction mix for pavement and buildings.

SCOPE OF THE PROJECT

- Make mix design for M40 concrete.
- Casting the specimens for durability characteristics and testing the concrete specimens for a period of 180 days.
- Comparing the bacterial concrete with control concrete.
- Tests to be conducted are RCPT, Acid Resistance, Air and Water Permeability, SEM and XRD
- Comparing the cost raw materials, electricity, water, release of carbon dioxide in atmosphere with normal concrete and concrete made with flyash enriched with bacteria.

MATERIALS USED

Following materials are used for study and experiment

- Ordinary Portland Cement (Grade 53)
- Fine aggregate
- Coarse aggregate
- Water
- Fly ash
- Bacteria Bacillus Sphaericus

WORKABILITY TEST

Slump Cone Test

The test is done for the determination of the consistency and workability of fresh concrete. The apparatus consists of a slump cone and a base made of galvanized steel.

Compaction Factor Test

The specimen of cement is set in the upper container up to the overflow. The trap-entryway is opened so that the solid falls into the lower container. The trap-entryway of the lower container is opened and the solid is permitted to fall into the chamber. The abundance concrete staying over the top level of the chamber is then cut off with the assistance of plane edges. The solid in the chamber is weighed. This is known as weight of somewhat compacted concrete. The chamber is loaded with a new specimen of cement and vibrated to acquire full compaction. The solid in the chamber is weighed once more. This weight is known as the heaviness of completely compacted concrete.

Compacting factor = (Weight of partially compacted concrete)/ (Weight of fully compacted concrete)

Compressive Strength

The compressive strength of specimens is determined after 7 and 28 days of curing respectively with surface dried condition as per Indian Standard IS: 516-1959. Both moulds size 150*150*150mm and 100*100*100mm are used for evaluation of compressive strength. Three specimens are tested for typical category, and the mean compressive strength of three specimens is considered as the compressive strength of the specified category

Tensile Splitting Strength

Tensile splitting strength of concrete is found out as per IS: 516-1959. Cylinders of size 300*150mm and 200*100mm are used for getting tensile splitting strength of concrete throughout experiment

Flexural Strength

Flexural strength of concrete is found out as per IS: 516-1959. Prisms of size 500*100*100mm were taken for the experiment

Capillary Water Absorption

In the present study, capillary action through the concrete is found out by mass method using the concrete cubes of size in mm. After casting and successive 28 days curing, the cubes are allowed to dry in an oven at 1050C until a gain of constant weight. One dimensional water flow is maintained for the measurement of capillary action by coating the cube with epoxy resins, except the top and bottom surfaces. The cubes are immersed in the water, and a minimum depth of immersion of 5 mm above the base of the cube is maintained. A gap of approximately 2 mm is maintained between the immersed face and the bottom of the water for good contact with water. The duration of immersions is 0.5, 1, 2, 4, 6, 24, 48, 72, and 96 hours respectively. The capillary water absorption is measured by recording the respective weights of the cubes after successive immersion. Capillary action is calculated using the following relation as a function of time.

= (2.1) W □t S □

where, Δis the cumulative amount of water absorbed per unit area (gm/mm2) during the time of immersion ( ) and *S* is the coefficient of capillary water absorption W t

Drying Shrinkage

Drying shrinkage test is used to measure the shrinkage of concrete by determining the change in length of concrete specimens due to changes in moisture content. Initial drying shrinkage for the RCA concrete is measured as per Indian Standard IS: 1199-1959. The concrete prism is de-moulded after 24 hrs and left in the moist air for seven days. At the end of moist curing, the specimens are put in a water tank at 270C for 20 days. After the completion of curing, the length of the specimen is measured (to an accuracy of 0.005mm) in wet condition. This length is termed as the original wet measurement. Then the specimens are kept in the oven at 500C for a period of 44 hrs. After this period of heating, it is allowed to cool for at least four hours. The reading which is taken after cooling is taken as dry measurements. Dry shrinkage is measured as the difference between the original wet measurement and final dry measurement.

Air Content

Pressure method is used for measuring air content in freshly mixed concrete as per Indian Standard IS: 1199-1959. Freshly mixed concrete is kept inside the bowl after successive tamping. Required test pressure which is slightly more than 0.02 kg/cm2 is applied through hand pump after adding water. At this instant, the corresponding initial height of water is measured on the graduated precision bore tube or gauge glass of the standpipe. Then test pressure is released gradually, and final water height is measured. where A is the apparent air content in percentage by volume of concrete, and it is equal to the difference between initial water height and final water height. 'G' represents the aggregate correction factor, in percentage by volume of concrete which is obtained as per IS: 1199-1959.

SEM and EDX

In order to understand the effect of bacteria in the microstructure of mortar various techniques such as spectroscopy, X-ray powder diffraction (XRD), Field Emission Scanning Electron Microscope (FESEM) and Scanning Electron Microscope (SEM) are used in the present study**.**

XRD Spectroscopy

Ultimate X-ray diffract meter with a Cu anode (40 kV and 30 mA) and scanning from 200 to 800 is used for XRD spectra. The samples are taken from the inner core area, well crushed and ground before mounting on a glass fibre filter using a tubular aerosol suspension chamber (TASC). The components of the sample are identified by comparing them with standards established by the international centre for diffraction data

MIX DESIGN

Concrete mix design is economically proportioning of concrete ingredients for better strength and durability based on construction site. While the nominal concrete mix may have higher amount of cement, when it is designed mix, the cement requirement may be low for the same grade of concrete for a given site. The proportions resulting from concrete mix design are tested for their strength with the help of compressive strength test on concrete cubes and cylinders. The concrete mix design proves to provide better quality economically.

PRELIMINARY CONCLUSIONS

- Culture of Bacillus Sphaericus .
- Enhancing the fly ash with Bacillus Sphaericus .
- Casting of specimenCubes, cylinders, beams with controlled concrete, concrete with cement and fly ash, Bacterial Concrete.
- Testing of specimen for RCPT, Air and Water Permeability, Acid Resistance, XRD and SEM
- Result analysis
- Graphs will be plotted using test results and conclusions are to be made based on test results.

Future scope of study

- The different species of the bacteria can be tried with different grades of concrete. Concrete can also be tested with different proportion of fly ash.
- The promising results on the use of microorganisms for the improvement of the durability of building materials have drawn the attention of research groups all over the world but until now, work on such bioremediation was mainly confined in some countries
- It indicates that the time taken for the water to rise by capillary action in microbial concrete are longer and thus proved that these concrete are less porous compared to the normal concrete. However, detail study of permeation properties and the extent of permeability reduction must be studied in detail.
- The fly as which is replaced by 30% can be reduced and mix of metakolin and alccofine with different ratios can be tried.
- The study of strength properties for different ratios of metakaolin and alccofine by reducing the fly ash percentage can be made.
- The replacement of cement only by the combination of metakolin and alccofine can be experimented and their strength properties can be studied.
- As the use of water is reduced by using curing compound this can be applied in future when there is a scarcity of water.

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