Performance Analysis of Ultra High Strength Concrete With Photocatalytic Process

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Abstract* — Ultra-high-performance concrete (UHPC) is a type of cement-based composite for new construction and/or restoration of existing structures to extend service life. UHPC features superior workability, mechanical properties, very high strength, elastic modulus, ductility and brilliant durability properties compared with conventional concrete. The main thing that makes it different from conventional concrete is the use of Steel Fibre Reinforcement, and some super plasticizers which give superior resistance to cracking and crack propagation. The reported results are in the range of: compressive strength > 150 MPa, flexural tensile strength > 25 MPa, modulus of elasticity > 50 GPa. But, cement production releases high amounts of carbon dioxide (CO2) to the atmosphere that leads to increase in global warming. Thus, another, environmentally friendly construction material such as photocatalyst concrete has been developed. Photocatalytic concrete applies greener alternative binder, which is a modern-day construction material that replaces the Conventional cement. This technology presented nano particles such as nano clay into the cement paste in order to improve their mechanical properties. The concrete materials also have been developed to be performed as self-cleaning construction materials. The self-cleaning properties of the concrete are induced with the help of photocatalytic materials such as titanium Di-oxide (TiO2). Self-cleaning concrete that contains those photocatalytic will be energized by ultraviolet (UV) radiation and quickens the decomposition of organic particulates. Thus, the spotlessness of the building surfaces can be maintained and the air surrounding air pollution can be reduced. So, we have chosen this topic to bring together the use of Ultra-high-performance concrete (UHPC) and Photocatalytic concrete for the structure which needs a longer span, high strength and exposed to external conditions such as Bridges, Railway Stations, Bus Stations, Metro Bridges.

Keywords — Ultra-high-performance concrete (UHPC), workability, very high strength, durability, compressive strength, flexural tensile strength, Photocatalytic concrete, self-cleaning properties, photocatalytic materials.

I. INTRODUCTION

Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. Its success lies in its versatility as can be designed to withstand harshest environments while taking on the most inspirational forms. Concrete structures that have been built around the world are subject to a wide range of different conditions of use and acquaintance to environmental conditions comprising erosion, weather, and pollution. The definition of Ultra-High-Performance Concrete (UHPC) may be broadly defined as a cementitious, composite material that has enhanced strength, durability and tensile ductility compared to High Performance Concretes (HPC). UHPC frequently uses fibres for post-cracking ductility, have specified compressive strength of at least 120 MPa at 28 days, and are formulated with a modified multi-scale particle packing of inorganic materials of less than 0.6 mm diameter (larger sizes can be used).

- Ultra-high-performance concrete (UHPC) is a modern composite material with extremely good mechanical characteristics.
- UHPC is more homogeneous than NSC due to optimized packing density and limited use of coarse aggregates. The size and strength difference between the matrix and the fine aggregates are so small that under external action
- UHPC displays ductile material behaviour and its tensile performance can be significantly improved
- Nanomaterial in UHPC accelerates the hydration of cement, densifies the microstructure, improves strength, and thus contributes to its durability
- HPC matrix has very low permeability

Many cities around the world struggle with increasing car exhaust fumes, industrial smog and other forms of air pollution. Together they produce a mix of nitrogen oxides (NOx), volatile organic compounds (VOC's), carbon monoxide (CO), sulphur oxides (SOx), and particulate matter (PM). Air pollution poses a serious threat to human health and the environment. Pollutants from exhaust systems can cause unsightly blackening and costly degradation of walls and building facades. Photocatalysts accelerate the chemical reaction whereby strong sunlight or ultraviolet light decomposes organic materials in a slow, natural process. When used on or in a concrete structure, photocatalysts decompose organic materials, biological organisms, and airborne pollutants. Dirt, soot, mould, bacteria and chemicals that cause odours are among the many substances that are decomposed by photocatalytic concrete. These compounds break down to have a minimal impact on the environment.

Titanium dioxide (TiO2), a white pigment, is the primary catalytic ingredient, and can be incorporated in the cement manufacturing process. When activated by the energy in light, the white pigment creates a charge that disperses on the surface of the photocatalyst, and reacts with external substances to decompose organic compounds.

II. LITERATURE REVIEW

A. Study on Strength Characteristics of High Strength Rice Husk Ash Concrete (**Ravande Kishori, V. Bhikshma and P. Jeevana Prakash**) **(2006)** The objective of the study is to investigate the mechanical properties of high strength concrete with different replacement levels of ordinary Portland cement by Rice Husk Ash. The standard cubes (150mmX150mmX150mm), cylinders (150mm diaX300mm height) and prisms (100mmX100mmX500mm) were caste. In all 144 specimens with M40 and M50 grade mix cases were caste and tested the strength effect of High-strength concrete of various amounts of replacement of cement viz., 0%, 5%, 10%, 15% with Rice Husk Ash of both the grades were compared with that of the high-strength concrete without Rice Husk Ash.

B. **Cwirzen et al. (2009)**, studied the basis of mechanical properties, frost durability and the bond strength with normal strength concrete of the ultra-high strength mortars and concretes. The produced mixes had plastic or fluid-like consistency. The 28-day compressive strength varied between 170 and 202 MPa for the heart-treated specimen's and between 130 and 150 MPa for the non-heart-treated specimens. The shrinkage value was two times higher for the UHS mortar in comparison with UHS concrete. After the initial shrinkage, swelling was noticed in the UHS mortars. The lowest creep values were measured for the non-heat-treated UHS concretes. The frost-deicing salts durability of the UHS mortars and concrete appeared to be very good even despite the increased water uptake of the UHS concretes. The study of the hybrid concrete beams indicated the formation of low strength transition zone between the UHS mortar and normal strength concrete.

C. Study on Photocatalytic Cement as Solution for Pollution Control by **Kotresh K.M, Dr. B. Sairam pattnaik, Mahaboob patel.** The major objective of this project was to review of the available results of existing research on the use of photocatalysts for reduction of air pollutants. Finally, based on best available information, a recommendation was to be provided whether to consider incorporating TiO2 into exterior and interior construction material. Materials used were Ordinary Portland Cement, FA(sand), CA, TIO_2. Normal mix design according to the grade of concrete. Tests conducted were Workability, Compressive strength, flexural strength. By this experiment they concluded that Application of TiO2 photocatalysis to cement and concrete provides an efficient strategy to simultaneously obtain: self-cleaning of building facades, retardation of natural surface ageing as well as air pollution mitigation, simply with the support of sunlight, atmospheric oxygen and water present as humidity and/or rain water.

D. Photocatalytic Self-cleaning Concrete by **Ranjit K. Odedra, K.A. Parmar and Dr. N. K. Arora.** In this experiment they have studied the photocatalytic activity by adding drops of rhodamine dye at surface. The materials used here are OPC, FA, CA, TIO_2 and The percentage of TIO_2 replaced with cement is 3.5%**.** From the above experiment we can conclude that the effect of Rhodamine dye is decreases between different time interval. And also Reduces levels of several environmental pollutants. NOx, SOx, VOC's etc.

E. Performance of Photocatalytic Concrete Blended with Artificial Sand and Iron Shavings by **D. Satyanarayana and R. Padma Priya.** In this experiment they have used Manufactured fine aggregate of size less than 4.75mm, Coarse aggregate held on 4.75mm strainer, Iron shavings from nailing of iron rods and Titanium Dioxide of 0%, 2%, 4%, 6%, 8%, 10%, 12%. Replacement of cement. The grade of concrete is M_{20} and the mix design ratio adopted was 1:1.77:2.89 and Water-cement ratio is 0.54. The tests conducted are compressive strength, split tensile strength test and the results found out till 10% TIO_2 its strength increases and after 10% it decreases again.

III. MATERIAL INVESTIGATION

A. CEMENT: The Ordinary Portland cement of 53-grade was used in this study conforming to IS: 12269-1987. The specific gravity of cement is 3.15. The initial and final setting times were found as 30 minutes and 580 minutes respectively. Standard consistency of cement was 31%.

B. FINE AGGREGATES: The river sand is used as fine aggregate conforming to the requirements of IS: 383-1970. Coarse aggregates:

C. COARSE AGGREGATE: obtained from local quarry units has been used for this study, conforming to IS: 383-1970 is used. Maximum size of aggregate used is 20mm with specific gravity of 2.74.and fineness modulus of 2.86 has been used as fine aggregate for this study.

D. FLY ASH: Fly ash is a by-product of the thermal power plants. Fly ash normally produced from burning anthracite or bituminous coal. Class F fly ash was used have a lower content of Cao and exhibit Pozzolanic properties. Specific gravity of fly ash is 2.2 as per Specific gravity Test, IS: 2386 Part III, 1963, (ASTM C 618).

E. SILICA FUMES: Very fine pozzolanic material, composed mostly of amorphous silica produced by electric arc furnaces as a byproduct of the production of elemental silicon or ferro-silicon alloys. Conforming to IS 15388: 2003

F. TITANIUM DIOXIDE: Titanium dioxide, also called titania, (TiO2), a white, opaque, naturally occurring mineral existing in a number of crystalline forms, the most important of which are rutile and anatase. These naturally occurring oxide forms can be mined and serve as a source for commercial titanium. Titanium dioxide is odourless and absorbent

IV. EXPERIMENTAL PROCEDURE & RESULTS

A. Mix Proportions:

In the below tables awarded as different type of mixes as well indifferent proportions of constituent materials. which are shown in Table below.

TABLE 1

DETAILS OF MIX PROPORTION OFCONCRETE

% of mix	Cement (Kg/m^3)	CA (Kg/m^3)	FA (Kg/m^3)	Fly ash	Silica fumes	TIO_2
5%	402.14	1160.45	645	80	27	27
10%	321.42	1151.18	639.55	107.14	53.57	53.57

B. Compressive strength test:

The compressive strength test is used to determine the strength of concrete. The sample dimensions are 150mm×150mm×150mm. Generally compressive strength conducted on samples of concrete at 3days, 7days, 14days, 28days, 56days and 90days. In this project, the compressive strength test performed at 7days and 28days. The procedure of compressive strength followed in this project according to IS-516:1959. The compressive strength conducted on 3 samples for each temperature condition cured of concrete. The values of every sample cube cured under different temperatures were noted. The average values of 3 samples of concrete taken as final value of strength.

Compressive Strength (N/mm^2) = Failure load/cross sectional area.

$$\sigma = P/A$$

Where, P=Applied load, A= Cross-sectional Area

FIGURE 1: COMPRESSIVE STRENGTH TESTING MACHINE

The results of compressive strength are given below

SL.NO	Percentage	7th day compression value	28th day compression value
1	5%	20.58 N/mm^2	34.88 N/mm^2
2	10%	18.36 N/mm^2	31.25 N/mm^2

TABLE 2: RESULTS OF COMPRESSIVE STRENGTH TEST

Discussion:

The compressive strength of concrete is found to decrease with the replacement of cement with Fly ash, Silica fumes & Titanium dioxide. The increase in ratio from 5% of Tio_2 to 10% Tio_2 leads to decrease in compressive strength.

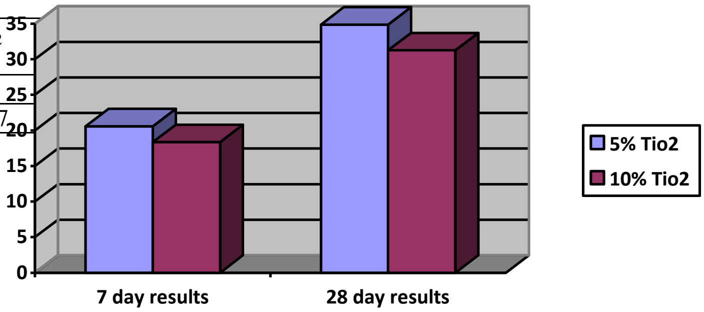

FIGURE 2: COMPRESSIVE STRENGTH OF 7&28 DAYS OF CUBES

C. Split tensile strength:

Split tensile strength is applying a diametric compressive load along the entire length until failure occurs. This loading induces tensile stresses on the plane containing the applied load and compressive stresses in the area around the applied load. In this experiment, split tensile strength test is performed for 7&28 days on the cylinders. The procedure for split tensile strength is followed according to IS 5816:1999. \

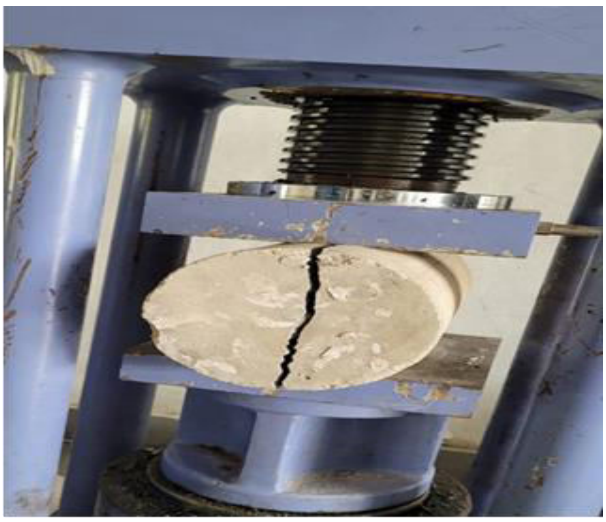

FIGURE 3: SPLIT TENSILE STRENGTH TEST

The results of split tensile strength are given below

SL.NO	Percentage	7th day Split value	28th day split value
1	5%	2.73 N/mm^2	3.25 N/mm^2
2	10%	2.45 N/mm^2	2.82 N/mm^2

TABLE 3: RESULTS OF SPLIT TENSILE STRENGTH TEST

Split rigidity was determined by conducting split tensile strength test.

$$S = 2P/\pi DL$$

Where, P = Failure Load (KN), D = Diameter of Specimen (150 mm), L = Length of Specimen (300 mm)

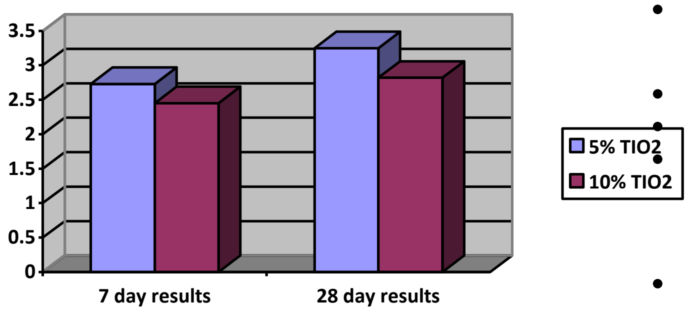

FIGURE 3: SPLIT TENSILE STRENGTH OF 7&28 DAYS OF CYLINDERS

Discussion: The split tensile strength of concrete is found to decrease with the replacement of cement with Fly ash, Silica fumes & Titanium dioxide. The increase in ratio from 5% of Tio_2 to 10% Tio_2 leads to decrease in compressive strength.

CONCLUSIONS

- The compressive strength decreases when there is an increase in partial replacement of cement by fly ash, silica fume and titanium dioxide (TIO_2).
- The split tensile strength also decreases when there is an increase in partial replacement of cement by fly ash, silica fume and titanium dioxide (TIO_2)
- The increase of TIO_2 from 5% to 10% leads to decrease in strength of the concrete.
- TIO_2 is the only chemical which exhibits photocatalytic properties
- Less percentage of TIO_2 leads to more strength
- Ultra-High-Performance Concrete (UHPC) is a material that is attracting attention in the construction industry due to the high mechanical strength and durability, leading to structures having low maintenance requirements.
- The construction industry is expected to push the concrete industry to new altitudes, which, in turn, will help the construction market achieve greater revenues and volumes in the near future, which will drive the demand for UHPC at a significant pace.
- In short, it can be concluded that UHPC can be a sustainable material due to its improved mechanical and durability properties, ecological factors, economic benefits and its recycling ability in various applications.

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