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Effect of Fiber Pattern in Strength of Light Transmitting Concrete

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Abstract: *Light transmitting concrete is a latest advancement in modern construction world. The development of a light transmitting concrete using plastic optical fiber (POF) is makes concrete sensible, sustainable and energy efficient by utilization of natural sunlight. But strength properties of light transmitting concrete are yet to be improved. It is important to focus on the problems related to the mechanical strength of the light transmitting concrete and to develop a high strength concrete with increased performance in terms of transparency, sensitivity, thermal conductivity and self-health monitoring. Our aim is to improve the strength properties of light transmitting concrete by optimizing the fiber arrangement pattern. This research focused its attention on finding solution to reduce the crack in light transmitting concrete by optimizing the area of fiber to the area of concrete and also by changing the pattern of fiber alignment in the concrete. Root cause for cracking is reduced by eliminating fibers from crack initiation points and there by enhances the strength of light transmitting concrete wall panels.*

Keywords - Light Transmitting Concrete, Plastic optic fiber, Strength, Crack.

I. INTRODUCTION

Large scale civil engineering structures and landmark buildings are built around the world with advanced development in science and technology. Even then, civil engineering structures always suffer from external environmental effects, high energy consumption, economic growth loss and casualties are serious once damaged. Global construction industry focused its attention on building energy saving and safe evaluation for engineering structures. Development of new kind of functional building materials can integrate energy saving with self-sensing properties of building. Based on the light transmitting properties and elasto-optic effect of optical fiber, a smart light transmitting concrete is researched by arranging the optical fibers into the concrete.

II. LIGHT TRANSMITTING CONCRETE

High rise building and sky scrapers are built in metropolitan areas due to economic development and space utilization requirements, especially in those countries with great populations. The closely located high rise building and sky scrapers depend mainly on man-made lights to maintain people's optical activities even in day time. There is no much research in the area of illumination and intrinsic characteristics of the optical identity in construction materials.

Concept of light transmitting concrete is first put forward by Hungarian architect Aron Losonzi in 2001. Later, in 2003, the first light transmitting concrete (LiTraCon) block is successfully produced by mixing large amount of glass fiber into concrete by Joel S. and Sergio O.G. They developed a transparent concrete material, which can allow 80% light through and only 30% of weight of common concrete. Later, in 2010, Italian Pavilion in Shanghai Expo 2010 shows a kind of transparent concrete developed by mixing glass into concrete. The light transmitting concrete mainly focuses on "transparency" and its application object are art design. There is no research on mechanics and long-term durability of light transmitting concrete.

III. STRENGTH OF LIGHT TRANSMITTING CONCRETE

Generally, concrete material fails gradually and it is a multi-scale process. When concrete is loaded, initially short and discontinuous micro cracks are developed in a distributed manner. Many micro cracks coalesce to form large macroscopic cracks, known as macro cracks. In light transmitting concrete, many optic fibers are used and hence the point of crack initiation is enormous. Crack will reduce the strength of concrete in many ways and in order to make an effective light transmitting concrete for practical application, crack should be avoided. It is very much important to reduce the crack at micro scale itself as the micro cracks are root cause for micro cracks which may result in concrete to loss its strength completely. Hence this study plays a major role in modern concrete technology.

IV. METHODOLOGY

A. Selection of Materials for Concrete

Ordinary Portland cement, 53 Grade, with specific gravity 3.1 is used for concrete. Fine Aggregate is selected from locally available river sand of grading zone II and specific gravity 2.5. Coarse aggregate is selected from locally available crushed blue granite stones of nominal size 12mm and specific gravity is 2.9. Water with pH value of 7.2 is used for concreting. PoF of size 1cm diameter and 1mm thickness is used.

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B. Mix Proportion

M20 grade of concrete is proposed for this work. Mix ratio of 1:1.5:3 is adopted for cement, fine aggregate and coarse aggregate. Water cement ratio of 0.5 is adopted at medium level of exposure. 15% area of concrete is replaced with PoF.

C. Making of mould for casting LiTraCon

150mm x 150mm x 150mm size cube mold are made with plywood. 10mm diameter holes are made in the end plates so that the PoF fibers can be inserted from one end and taken from the other end.

Fig.1 Mold and End Plate

D. Arrangement of PoF in LiTtaCon

Fibers are inserted from one end and tightened at the other end. The distance between the fibers decides the nominal size of coarse aggregate. Fibers can be made tight at both the ends but should not be over stressed.

Fig.2 Test Specimen at Collapse

E. Casting of Concrete Specimens

Control specimen for normal concrete is cased for M20 mix. With the same material used for control specimen, LiTraCon cubes are casted. Various shapes of PoF arrangement are selected and cubes are casted. Concrete cubes casted for various pattern of fiber arrangement are shown in Fig.3 (Zig-zag pattern), Fig.4 (Concentric circle pattern) and Fig.5 (Cluster pattern). For each pattern, three concrete cubes are casted. De-molding of cubes is made after 48 hours and the concrete cubes are kept in curing tank for a period of 28 days. After curing, concrete cubes are tested in universal testing machine for its compressive strength.

Fig.3 Test Specimen at Collapse

Fig.4 Test Specimen at Collapse

Fig.5 Test Specimen at Collapse

V. RESULTS AND DISCUSSION

A. Compressive Strength Test Results of Concrete

Hardened concrete specimens are tested at 3 days, 7 days, 14 days and 28 days of water curing period. Compressive strength values are recorded. Also the compressive strength of various pattern of LiTraCon cubes are tested at 28 days and the results are given on Table.1.

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Table.1 Compressive strength results for different pattern of fiber arrangement in light transmitting concrete cube specimens

Sl.No	Ageing	Pattern	Average compressive strength N/mm2
1	28 days	Zig-Zag	5.33
2	28 days	Concentric Circles	13.78
3	28 days	Cluster	9.77

From the cube strength values, it is observed that concentric circles patter yields maximum strength. Also cluster pattern yields comparatively better strength. Zig-zag pattern yields very low cube strength and hence this pattern shall be discarded in making light transmitting concrete wall panels.

B. Failure at Cracking and Collapse State

Failure of the cube specimens under compression loading is analyzed at cracking state and collapse state. The development of crack from the failure state to collapse state is also recorded and the patterns of cracking for various specimens are shown in Fig.7.

In Zig-Zag pattern cracks are initiated from the edges and propagate towards the center. In Concentric circle pattern cracks are initiated from the corners and propagate towards other corner. In Cluster Patter cracks are initiated from the center and propagate towards the edges. Thus, different pattern of arrangement of PoF shows variation in cracking pattern and hence it is required to optimize the fiber arrangement in the LiTraCon panel.

Based on the crack pattern of various specimens, cracks initiation points are identified and in next trial, PoF at crack initiations are removed. Specimens are casted for modified fiber pattern. After curing period the specimens are tested for its compressive strength at various ageing. Modified concentric circle patter is shown in Fig.9 and modified cluster pattern is shown in Fig.10. Test results shows considerable increase in strength. If we remove central fiber, concentric circle pattern shows considerable increase in strength. Among the selected pattern, concentric circle pattern yields maximum strength.

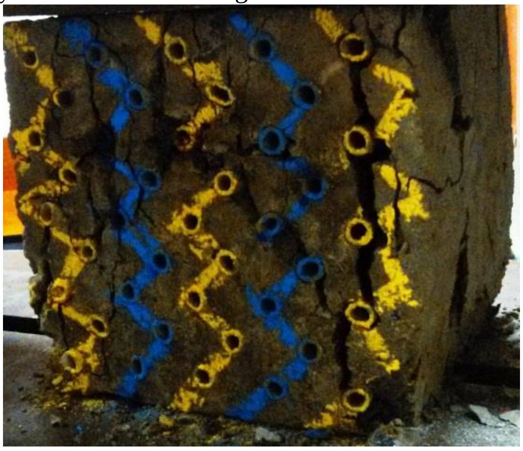

Fig.6 Cracking of zig-zag pattern test Specimen

Fig.7 Cracking of concentric circle pattern test Specimen

Fig.8 Cracking of cluster pattern test Specimen

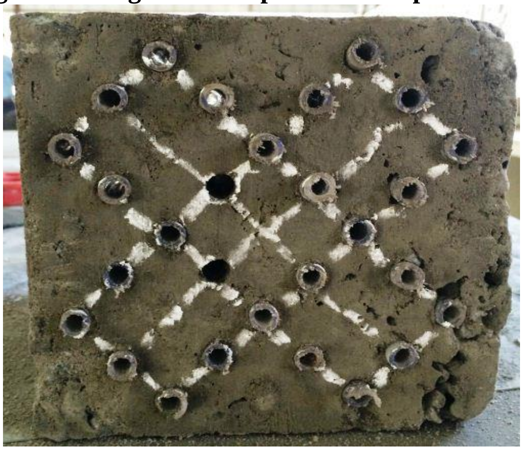

Fig.9 Cube casted with modified cluster Pattern

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Fig.10 Cube casted with modified Concentric Circle Pattern

VI. CONCLUSION

The compressive strength of LiTraCon cubes is less than that of control specimen cubes. Maximum compressive strength of 13.78MPa is obtained for concentric circle pattern of arrangement of PoF. Minimum compressive strength of 5.33 MPa is obtained for Zig-Zag pattern of arrangement of PoF. Variation in fiber pattern shows considerable variation in compressive strength results. The quantity of POF has greatly influenced the compressive strength of the light transmitting concrete. From the result it is observed that the intermittent and uneven arrangement of holes and the fibers which are flexible increases the porous of concrete. Hence by reducing the number of holes and by altering the arrangement of holes, it compressive strength of light transmitting concrete is improved.

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