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TRANSLUCENT CONCRETE

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Abstract- The concrete currently used in the construction industry generally consists of at least cement, water and aggregates (fine or coarse). As is well known, traditional concrete has a greyish colour, and its high density prevents the passage of light through it, which means that it is also impossible to distinguish bodies, colours and shapes through it. As can be imagined, concrete with the characteristic of being translucent will permit a better interaction between the construction and its environment, thereby creating ambiences that are better and more naturally lit, at the same time as significantly reducing the expenses of laying and maintenance of the concrete. Along with the translucent characteristics, the paper confines its area towards the reinforcement method of this type of concrete such that they can be practically implemented as a load bearing structure. This new kind of building material can integrate the concept of green energy saving with the usage self-sensing properties of functional materials.

Index Terms- Translucent, Reinforcement, load-bearing
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I. Introduction

Today we are living in a world where energy expenditure and environmental problems have escalated to global scale. In today's developed world our built environment takes energy; energy to make the materials that go into the buildings, energy to construct them (Embodied energy) and energy to heat, cool & light them (Operating energy). Our project of casting translucent concrete aims at reducing this operating energy by exploiting vast amount of potential energy in the form of sunlight. Another additional feature is its pleasing aesthetics that can change the image of the concrete which is generally perceived as dull, pale, opaque grey material.

II. Objective

To cast a special type of concrete with light transmitting properties, to study their characteristics and to develop a functioning material which is not only energy saving but gives out artistic finish.

III. Formulation for Obtaining a Translucent Concrete Mixture

The invention relates to a formulation for obtaining a translucent concrete mixture comprising a mixture of polycarbonate and epoxy matrices as well as glass fibers, optical fibers, colloidal silica, silica and diethylentriamine (DETA) and Portland cement. This invention has greater mechanical strength properties than those of a standard concrete, with lower density and mechanical characteristics that enable same to be used in both a structural and architectonic manner. The inventive formulation used to obtain the translucent concrete mixture comprises a type of concrete that is different from those currently available, which combines the advantages of existing concretes with translucency.

IV. Description

The concrete generally used in construction generally consist of at least cement, water and aggregates (fine or coarse). As is known, traditional concrete has a greyish colour, and its high density prevents the passage of light through it, which means that it is also impossible to distinguish bodies, colours and shapes through it. As can be imagined, concrete with the characteristic of being translucent will permit a better interaction between the construction and its environment, thereby creating ambiences that are better and more naturally lit, at the same time as significantly reducing the expenses of laying and maintenance of the concrete.
With the aim of eliminating these and other drawbacks, thought has been given to the development of a translucent concrete, which concerns a formulation of concrete which, as well as permitting the passage of light through it, also works more efficiently in the mechanical sense than traditional concrete.

V. INGREDIENT CHARACTERISTICS

The characteristic details of this novel concrete are studied under the following description and following the same reference signs for indicating it.

A polymeric matrix is expected to be provided to enhance the binding capacity and also the mechanical strength.

Preferable two polymeric mixture as per our studies are required. One, epoxy and the other is polycarbonate matrix. These together with their respective catalyst shall form a good binding strength.

The aggregates used in the manufacture and formulation were fiberglass, silica, colloidal silica sol and optical fibers. Optionally, rocky elements can be used as aggregates, for example, gravels, sands, etc.

The setting agent used is diethylenetriamine (DETA), which has to be dehydrated on molecular sieves prior to use.

The optical fibers used in the formulation of this concrete are basically fine glass or plastic threads that guide the light. The communication system arises from the union between the light sources that is sufficiently pure for not being altered. The types of fibers used are monomode and virgin fibers, in other words, those in the pure state and without any coatings, the aim of which is so that the light can pass through the concrete. Used as additives are: pigments; bridging agents for favouring the attachment to the matrix, giving resistance and protection against aging; lubricant agents for giving surface protection and filmogenic gluing agents for giving integrity, rigidity, protection and impregnation, metal salts, thixotropic agents (flakes of inorganic materials, glass microspheres, calcium carbonates, silicon dioxide, etc.), flame retardant agents (elements containing chlorine, bromine, phosphorus, etc.) and UV protection agents (stabilisers). Silica sol, also known as silica hydrosol, is a colloidal solution with a high molecular hydration of silica particles dispersed in water. It can be used as a binding agent. Silica of between 0.5 and 10% by weight of resin has to be used so that, once set, the silica used provides greater resistance and hardness to the concrete. According to the study the mechanical characteristics such as compressive resistance of a translucent concrete with epoxy matrix is up to 220 Mpa.

The mechanical characteristics such as compressive resistance of a translucent concrete with polycarbonate matrix is up to 202 MPa, as well as allowing light to pass through without any distortion at all. The good dispersion of the aggregates, additives and, above all, of the matrix, can be appreciated. The direction of the layers is parallel to the direction of the moulding. It has a laminar drying in the same direction in which it is cast. It displays good crystallisation in the highest parts, and decreases a little when approaching the lower end.

The manufacturing process of this concrete consists of the mixture of two processes, one where the cement is mixed with water, and the other where the matrices are mixed.

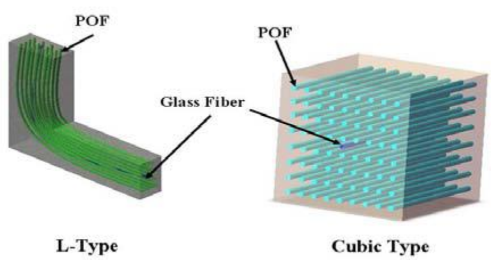

Fig: 01. Integrated model of translucent concrete cube

Fig: 02. Form-work of wood and thermocol

VI. EXPERIMENTS ON TRANSLUCENT CONCRETE

1. *LIGHT GUIDING PROPERTY ON TRANSLUCENT CONCRETE.*

The following are the factors to be considered for the performance of the transparency of the concrete:

a. Transmittance
b. Haze
c. Bi-fringence
d. Refractive index.
e. Dispersion.

The transmittance can be directly calculated by the ratio of the incident energy and transmission energy of light expressed as following equation:

(1) $\rho=\xi\times (J_1/J_0)\times 100\%$

Where ρ, ξ, J_1 and J_2 are transmittance, correction coefficient of measurement equipment, transmission energy and incident energy, respectively. While the translucent concrete studied by us is heterogeneous, its transmittance cannot be obtained by equation (1), because the number of POFs in unit area is different at different area, that is, the transmittance in unit is related to the arrangement of POF in translucent concrete.

Improvement in the calculation method for transmittance are as follows.

a) Incident light energy per unit area (ρ_0):

(2) $\rho_0 = W_0/A_0$

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Where W_0 and A_0 are light energy of incident probe and area of incident probe.
b) Incident total energy of concrete section at the side of light (J^s_0):

(3) $J^s_0 = \rho_0 \text{ x } A_{1=} (W_0/A_0) \text{x } A_1$

Where A_1 is the cross-section area of translucent concrete.
c) Transmitted light energy of single POF (ρ_1):

(4) $\rho_1 = (W_1/n_1)$

Where W_1 and n_1 are light energy of transmission probe and the number of POFs covered by transmission probe.
d) Transmitted light energy of translucent concrete (J^s_1):

(5) $J^s_1 = \rho_1 \text{ x } N = (W_1/ n_1) \text{ x } N$

Here N is the total number of POFs in the translucent concrete.
Then based on equation (3) and (5), we can obtain the transmittance (ρ^s) of the translucent concrete.

$$\rho^s = \xi\times(J^s_1/J^s_0)\text{x } 100 \% = [(\xi \text{ x } N \text{ x } W_1 \text{ x } A_0)/(W_0 \text{ x } A_1 \text{ x } n)] \text{ X } 100 \%$$

2. LIGHT GUIDING EXPERIMENT ON TRANSLUCENT CONCRETE.

In order to study the light guiding property of translucent concrete, six units of translucent concrete is fabricated with different POF volume ratios of 1%, 2%, 3%, 4%, 5% and 6%, and the diameters of POF is 1mm. The transmittance is measured by the Optical Power Meter and its wavelength range is 400-1100nm. The incandescent lamp with 200W and halogen lamp with 500W are chosen to provide light. To eliminate the measuring dispersion of transmittance caused by the discrepancy of POFs' position and the material, three areas (denoted as 1, 2 and 3) in the middle part of translucent concrete are chosen to test shown as figure below, and the number of POFs in each chosen area shall be equal. The number of the POFs is covered by transmission probe or integral sphere are 2 for 1% POF volume ratio, 4 for 2% POF volume ratio, 5 for 3% POF volume ratio, 7 for 4% POF volume ratio, 3 for 5% POF volume ratio and 9 for 6% POF volume ratio respectively. The incident light energy and transmission light energy are read simultaneously at each step.

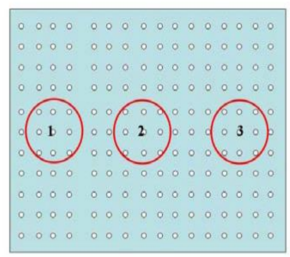


Fig: 03. Optical Power Meter Fig: 04. Measuring area of the optical fibers

3. SELF-SENSING PROPERTY OF TRANSLUCENT CONCRETE BASED ON STRESS ELASTO-OPTIC EFFECT.

Glass fiber is a kind of photoelastic material, which is isotropic under normal circumstances. Once be applied load, glass fiber becomes anisotropic, and light birefringence phenomena in it is generated. Commonly, if the optical constants and thickness of glass fiber, the isochromatics and isoclinics are known, the stress state of the glass fiber can be obtained based on the shear difference method. Based on this phenomenon, glass fiber is layout into the cube to monitor the stress state of structures, and the glass fiber can be considered as a sensing element and an optical transmission material. In order to study the self-sensing property of translucent concrete cube, we simultaneously layout a glass fiber with 15mm diameter and numbers of POFs into the concrete with the size of 100mmx100mmx100mm. In the test, the isochromatics and the isoclinics of the samples are gotten by using the plane polarized light and circularly polarized light equipments respectively. Figure below shows the experimental setup including a glass fiber or a translucent concrete, a loading device and a photoelasticity experimental equipment. The circularly polarized optical field is obtained by adding two 1/4λ wave plates in the plane polarized optical field. The strain applied on the samples is recorded by the strain gauge pressure transducer.

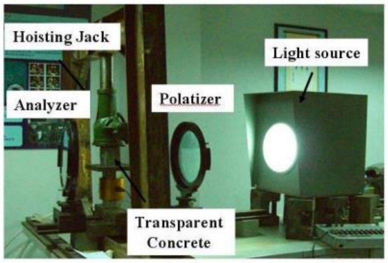


Fig 05: Experimental Setup

4. *TEST OF GLASS FIBER'S STRESS ELASTO-OPTIC EFFECT.*

Glass fiber with 15mm diameter is chosen to test its elasto-optic property under radial stress. Before test, the cross-section of glass fiber is polished to ensure the surface smooth. Under the plane polarized optical field, the glass fiber is applied radial load of 0.4kN and 0.8kN respectively. Keeping the polarizer and the analyser mirror orthogonal, the series of isoclinic of glass fiber at 0-90 degree with the step of 10 degree are obtained by synchronously rotation of the corresponding orthogonal polarization axis. To separate the isochromatic from the colour coupled photo elastic patterns, the series of isochromatic of fiber glass are obtained under the circularly polarized optical field, where the glass fiber is applied 0.2-1.6kN with step of 0.2kN.

5. *TEST OF SELF SENSING PROPERTY OF TRANSLUCENT CONCRETE BASED ON STRESS ELASTO-OPTIC EFFECT.*

Figure below shows the translucent concrete with size of 100mm×100mm×100mm by combining with glass fiber and POFs. The diameters of glass fiber and POF are 15mm and 2mm respectively. The glass fiber is considered as stress-sensing element in the concrete. Like the test described in the 3.2.1, the isochromatic and the isoclinic of the glass fiber are monitored under plane/ circularly polarized optical field, which can reflect the stress state of the concrete. In order to test the self-sensing properties of the translucent concrete, the elasto-optic effect of the translucent concrete under different damage modes are studied. Figure 7b shows the damage modes of concrete, where a crack with size of 0.5mm is produced. Figure 8 gives three loading modes:

- Un-damage mode (I)
- "Longitudinal" damage mode (II)
- "Lateral" damage mode (III).

The "longitudinal" damage mode is that the crack is parallel to the loading direction, and the "lateral" damage mode is that the crack is vertical to the loading direction.

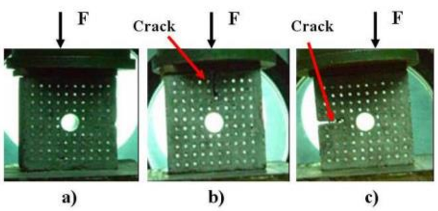


Fig 06: Loading Modes

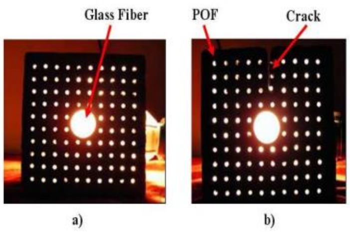


Fig 07: Undamaged and Damaged block

6. *TEST OF MECHANICAL PROPERTY OF TRANSLUCENT CONCRETE BY FREEZING TEST.*

In this paper, the POF volume ratios of translucent concretes chosen for test are 0% (or plain concrete), 1%, 2%, 3%, 4%, 5% and 6%. After 25 freeze-thaw cycle test, the mechanical properties of translucent concrete are evaluated by the compressive strength loss rate (ρ_f), expressed as follow.

(7) $\rho_f = [(f_{c0}-f_{cn})/f_{c0}]\times 100$

Where f_{c0} and f_{cn} are compressive strength before and after freeze-thawing test.

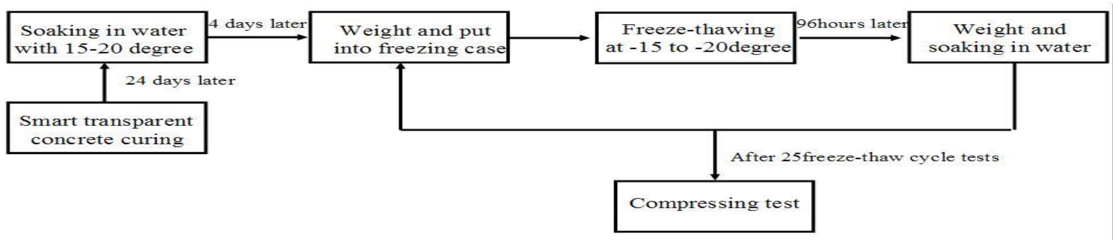
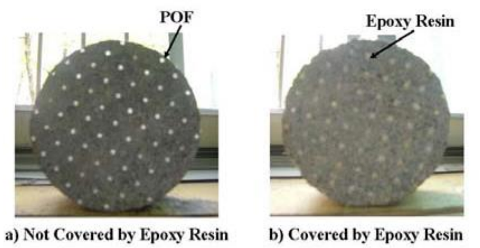


Fig. 08: Methodology for Freezing – Thaw test.

7. *PERMEABLITY TEST FOR TRANSLUCENT CONCRETE.*

For the concrete cubes, the interfacial bonding of the POFs and concrete is a crucial factor in determining ultimate impermeability properties. The chloride diffusion coefficient method (or electric flux method) is used to test the impermeability property of translucent concrete, which can rapidly evaluate the permeability of concrete by measuring the electric energy through concrete. In this paper, concrete cubes with 0%, 3% and 6% POF volume ratio are chosen for the test. The electric energy is recorded by the electric flux detector and cylindrical concrete specimens with 100mm diameter and 50mm height are fabricated from the prefabricated concretes by core-drilling method, shown as figure below. Moreover, in order to evaluate the effect of interface bonding on the impermeability property, each model of specimen has been divided two types. One is that the border of POF and concrete is covered by epoxy resin, the other one is not covered by epoxy resin, as shown in figure below.



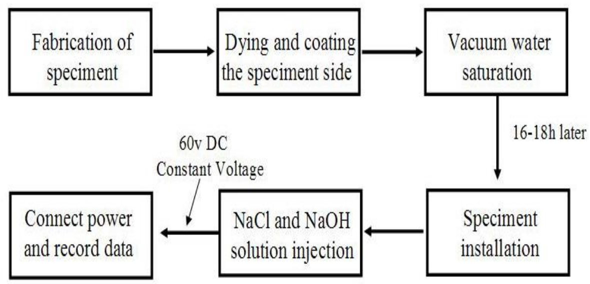


Fig 09: cylindrical concrete setup for Permeability Test Fig 10: Methodology for Permeability Test.

VII. EXPERIMENTS RESULTS AND ANALYSIS

1. *LIGHT GUIDING PROPERTY:*

Figure 11 and figure 12 show the light guiding property of translucent concrete with the POF volume ratio of 1%, 2%, 3%, 4%, 5% and 6% by using the halogen lamp and incandescent lamp, respectively. It can be seen that the transmittance of each type of translucent concrete almost keeps stable at whole wavelength, and the linear relationship between the POF volume ratio and its transmittance is good.

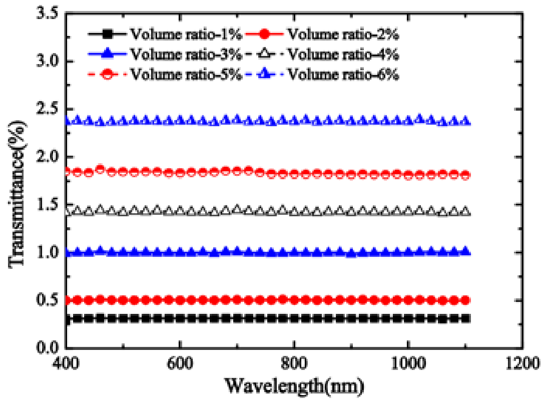


Fig 11(a): Transmittance

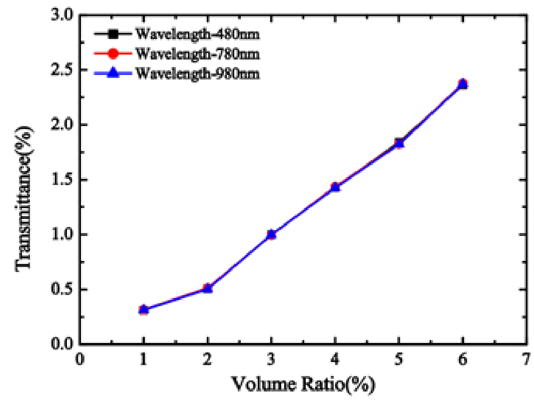


Fig 11(b): Relationship b/w POF volume and Transmittance

Fig 11: Light guiding test by Halogen Lamp

For the halogen lamp, the transmittances of the six ratio translucent concrete are 0.29%、0.59%、0.98%、1.41%、1.83% and 2.36%; for the incandescent lamp, the corresponding transmittances are 0.41%、0.82%、1.22%、1.72%、2.15% and 2.59%, respectively. The discrepancy of transmittance induced by different lamp is that the light scattering's angle of the chosen lamp is different, and the POFs absorb much light scattered by incandescent lamp than that by halogen lamp.

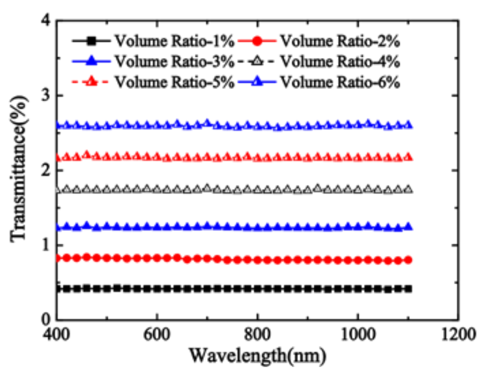


Fig 12(a): Transmittance

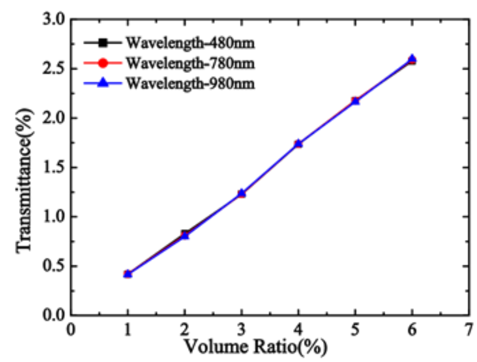


Fig 12(b): Relationship b/w POF volume and Transmittance

Furthermore, it is worthily of note that the large the POF volume ratio is, the large the transmittance is. In fact, the POF volume ratio and the corresponding transmittance are just like a sword with both edges. We cannot only pay attention to the high transmittance, for the POF inevitable affects the concrete strength. In the following experimental results, it can be seen that POF will reduce the concrete strength.

2. *PHOTOELASTIC EFFECT OF GLASS FIBER ON GLASS FIBER:*

Figure 13 shows the results of photoelastic effect of glass fiber applied radial load of 0.4kN under plane polarized optical field. Both the isochromatics and the isoclinics are figured out in the figure. The isoclinics, described as black lines in the figure, are changed along with the angle of the rotation of the corresponding orthogonal polarization axis, while the isochromatics remain unchanged at the same load. The isoclinics denote the direction of principle stress of the glass fiber, and the isochromatics are the difference.

Figure 14 shows the isochromatics at different load by adding two 1/4λ wave plates in the plane polarized optical field. It can be seen that the isochromatics are changed with loading change, which hints that the isochromatics of glass fiber are sensitive to the external load. In photoelasticity experiment, it is difficult to measure the series of isochromatic precisely due to various factors such as the accuracy or resolution of the measuring equipment. From the test's results, it can be seen that the glass fiber has a good photoelastic effect which is sensitive to the external force applied on it.

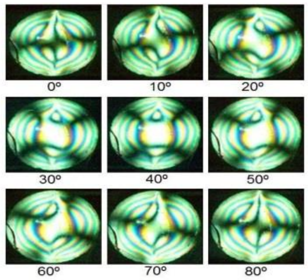


Fig 13: Photo-Elastic effect of glass Fiber

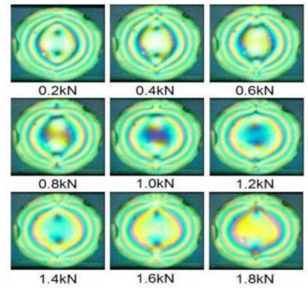


Fig 14: Isochromatic effect on Glass fiber

3. *IMPERMEABILITY PROPERTY OF TRANSLUCENT CONCRETE.*

Figure 15 show the results of photoelastic effect of translucent concrete at three conditions above mentioned under the plane polarized optical field. It can be seen that the isochromatics of glass fiber at the three conditions are different from each other at the same load due to the damage and different loading conditions. Comparison with that of the undamaged concrete, the isochromatics of glass fiber changes larger at "III" condition than that at "II" condition.

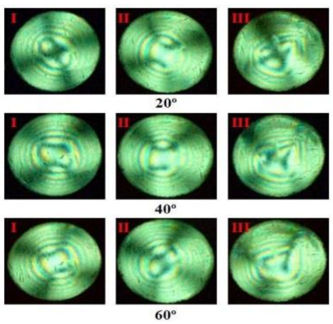


Fig 15(a): Photoelastic fringe at diff angle with 12KN

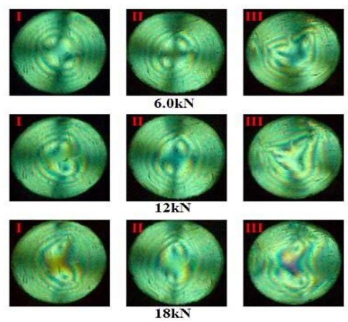


Fig 15(b): Photoelastic Fringe at diff level load

Figure 16 shows Photo elastic fringe of glass fiber at different angle under plane polarized optical field, where the concrete is applied 12kN load which is vertical to the crack. Figure 17 illustrates the series of isochromatics of glass fiber at 2.5-15kN with the step of 2.5kN under the circularly polarized optical field. It is obviously seen that the stress state of concrete with damage is more complicate than that with non-damage from figure 15 and figure 16. Based on the photo elastic fringe or stress state of glass fiber in the concrete, the stress state of corresponding concrete can be figured out.

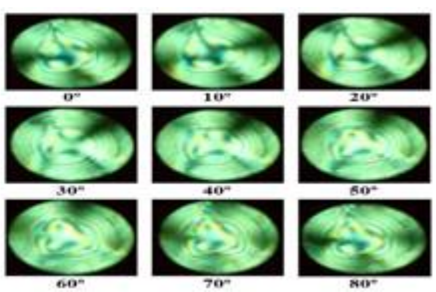


Fig 16: Photo elastic fringe of glass fiber at diff angle

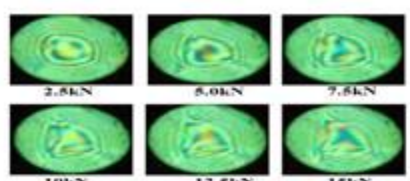
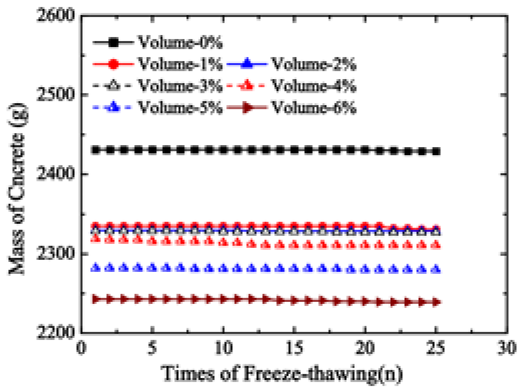


Fig 17: The series of isochromatic of glass fiber at diff loads

4. *MECHANICAL PROPERTY OF TRANSLUCENT CONCRETE AT FREEZE-THAW*

From figure 18, it can be seen that the mass of translucent concretes almost are unchanged in 25times freezing and thawing cycle and the maximum loss rate of mass is about 0.4%. Figure 19 shows the compressive strengthen of translucent concretes with freeze-thaw or not. It can be seen that the compressive strength of each type of translucent concrete have greatly decreased after 25times freeze-thaw cycle, and the maximum loss rate of compressive strength is about 42% comparison with that without bearing the function of freeze-thaw for the same type of concrete. It can be seen that the larger the POF volume ratio is, the smaller the compressive strengthen of the translucent concrete is. So we cannot endless increase the transmittance by way of increasing the POF volume ratio.
One point to be mention, the compressive strengthen of the plain concrete (or the translucent concrete with 0% POF volume ratio) is smaller than that of the accustomed plain concrete. The reason is that we consider the fabrication method of the translucent concrete

and ignore the normal mix proportion of cement mortar at pre-test. To improve the compressive strength of the translucent concrete, one solution is that the translucent concrete can be produced by some special high strength concrete, which can reduce the impact of the POF to the concrete's compressive strength.



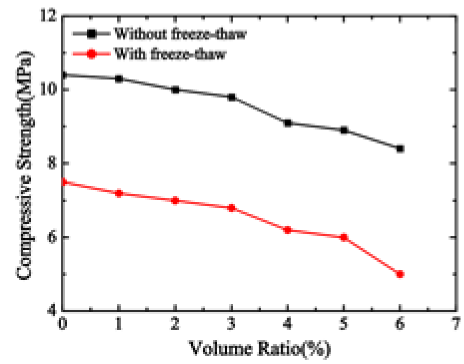
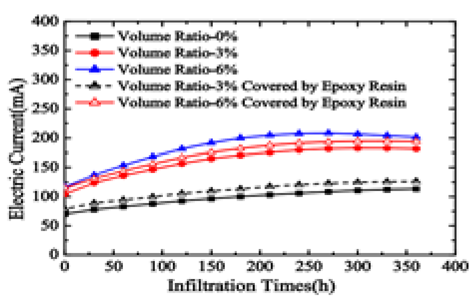


Fig 18: Loss rate of concrete mass at each freeze thawing   Fig 19: Compressive strength of concrete block with freeze-thaw

5. *IMPERMEABILITY PROPERTY OF TRANSLUCENT CONCRETE.*

Figure 20 shows the relationship of current strength over time. After the vacuum water saturation, the initial current strength of the plain concrete, the translucent concrete with 3% POF volume ratio, the translucent concrete with 3% POF volume ratio and POF covered by epoxy resin, the translucent concrete with 6% POF volume ratio and the translucent concrete with 6% POF volume ratio and POF covered by epoxy resin are 70.4mA, 104.5mA, 79mA, 117mA and 114.9mA, respectively. After six hours conduction time, the corresponding current strengths of the above six concretes increase to 113.6mA, 181.7mA, 126.4mA, 201.6mA and 1944.2mA, respectively.



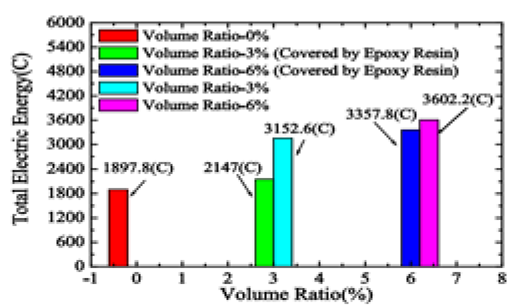


Fig 20: Relationship of strength over time   Fig 21: Comparison of total electrical energy traversing the block

The total electric energy of the plain concrete, the translucent concrete with 3% POF volume ratio and that with 6% POF volume ratio are 1897.8C, 3152.6C and 3602.2C, that is, there are some minor gaps between the POFs and concrete which cause the decrease of the anti-permeability shown in figure 24. It also can be seen that the anti-permeability is greatly improved by using the epoxy resin to cover the boundary of the POFs and concrete, and the total electric energy of the translucent concrete with 3% and 6% POF volume ratio covered by epoxy resin are reduced to 2147C and 3357.8C. In field application, the anti-permeability index of translucent concrete is very important for the long-term service. We can improve the anti-permeability by two methods: one is to seal the boundary of POFs and concrete with translucent waterproof material such as epoxy resin; the other one is to make the POF's coating rough to increase the compactness of interface between the POF and concrete.

VIII. CHARACTERESTICAL OVERVIEW OF THE PRODUCT

1. Formulation for obtaining a translucent concrete mixture, comprising a mixture of epoxy and polycarbonate matrices, plus fiberglass, optical fibers, colloidal silica sol, silica and diethylenetriamine (DETA) and Portland cement.
2. Formulation for obtaining a translucent concrete mixture, wherein the content of the components is: epoxy matrix from 0% to 90%, and the polycarbonate matrix from 0% to 60%, fiberglass from 0% to 10%, colloidal silica sol from 0.5% to 5%, silica from 0.5% to 10%, diethylenetriamine (DETA)

3. The ratio of the polymer matrices and the mortar is at least 1.5:1, and the mixing is done manually or mechanically.
4. According to study maximum water absorption range is within 0.35%.
5. s mechanical and optical characteristics, can be used for purposes that are both architectural and aesthetic, and also structural and under conditions of service equal to and even different from those of a traditional concrete.

In accordance with the above description, it is possible to affirm that the light refraction characteristics, or translucidity, as well as the mechanical resistance to compression of the formulation of the concrete of the present invention, have not been achieved by any other concrete, thereby meeting the optical and mechanical characteristics for calling it translucent concrete.

Other unique characteristics of the formulation of the concrete forming the object of this invention are that it can be used for structural purposes at the same time as being translucent; in other words it can be used in any kind of construction permitting colours, shapes and outlines to be seen through it.

IX. APPLICATIONS

Thanks to new features this material presents innovative technical solutions, semi-natural and ecological, for the traditional construction problems allowing a wide area of applications in construction, architecture, decoration and even furniture.

Some of the possible applications for this new material are spread over several areas creating new possibilities to various products such as:

1. Translucent concrete blocks suitable for floors, pavements and load-bearing walls.
2. Facades, interior wall cladding and dividing walls based on thin panels.
3. Partitions wall and it can be used where the sunlight does not reach properly.
4. In furniture for the decorative and aesthetic purpose.
5. Light fixtures.
6. Light sidewalks at night.
7. Increasing visibility in dark subway stations.
8. Lighting indoor fire escapes in the event of a power failure.
9. Illuminating speed bumps on roadways at night.

X. ADVANTAGES AND DISADVANTAGES

The main advantage of these products is that on large scale objects the texture is still visible - while the texture of finer translucent concrete becomes indistinct at distance.

- When a solid wall is imbued with the ability to transmit light, it means that a home can use fewer lights in their house during daylight hours.
- It has very good architectural properties for giving good aesthetical view to the building.
- Where light is not able to come properly at that place translucent concrete can be used.
- Energy saving can be done by utilization of translucent concrete in building.
- Totally environment friendly because of its light transmitting characteristics, so energy consumption can be reduced.
- The main disadvantage is these concrete is very costly because of the optical fibers.
- Casting of translucent concrete block is difficult for the labour so special skilled person is required.

XI. CONCLUSION

A novel architectural material called translucent concrete can be developed by adding optical fiber or large diameter glass fiber in the concrete mixture. The translucent concrete has good light guiding property and the ratio of optical fiber volume to concrete is proportion to transmission. The translucent concrete not loses the strength parameter when compared to regular concrete and also it has very vital property for the aesthetical point of view. It can be used for the best architectural appearance of the building. Also used where the light cannot reach with appropriate intensity. This new kind of building material can integrate the concept of green energy saving with the usage self-sensing properties of functional materials.

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