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Translucent Concrete by Plastics Fibre Optics as A Sustainable Material That Benefit to Residential Building

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ABSTRACT

Concrete regarded as a fundamental construction material that currently applied in construction development since Roman times whereby the basic composition of concrete consists of at least cement, aggregates (fine or course) and water. As usual, the normal concrete has a greyish colour and high-density characteristic which basically prevents the light from transmitting through the concrete itself. Currently, a newly developed translucent concrete has been fabricated with their transparency that may allow permission of light. From the research, the current issues and problems are a high usage of household electricity, low architecture level design and low compressive strength of the translucent panel. Furthermore, the objective presented in this research explores the differences between the translucent concrete and the conventional concrete in term of the compressive strength and light transmittance behavior whereby the curing ages of concrete block is after 7 days and 28 days respectively. Throughout the research, there is two testing method such as compressive strength test and light transmitting properties. Meanwhile, the different optics fiber amount varies from 0.25%, 0.75% and 1.25% were studied. As a result, the compressive strength and light transmitting are seen to increase with increasing of fiber content and 1.25% showed ideal results compared with others. For future research, the translucent concrete may replace the conventional brick wall in term of compressive strength and sustainability.

Keywords:
Translucent concrete, compressive strength, plastic optical fiber, energy saving, light transmitting properties

1. Introduction

Translucent concrete is a sustainable concrete which is different from normal concrete whereby conventional concrete made up of cement, water, and aggregates (fine or coarse) and prevents the light passing through the interior building while translucent concrete is combination of fiber optic wrapped in bundle and concrete whereby it applies the natural sunlight as a source of light instead of electrical energy which may be transmitted from one side to the other side of concrete [1]. Therefore, a breakthrough of translucent concrete will function as an energy collector and convey the daylight into the building to reduce pollution [2]. By comparing with the conventional building

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lighting application, illumination toward the interior of building with daylight also provide a more appealing and healthy environment of occupants [3].

A fiber optic is a transparent fiber with high adaptability which made up of glass or plastic where the size is almost the same as human hair. Furthermore, optical fiber works as a waveguide where the light flows from one end to another end. An optical fiber consists of a transparent core which coated by the cladding material with a low refraction index. Through the total internal reflection process, the light is a capable store in the core which claims the fiber as a waveguide [4].

Light Transmitting Concrete also is known as LiTraCon, was discovered in 2001 by the Hungarian architect AronLosonczi at the Technical University of Budapest who successfully produce a large number of mixes between fiber optic and concrete in 2003. This building material nowadays was firstly applicable in the Italian Pavilion at Shanghai World Expo 2010 [4].

2. Methodology

2.1 Raw Material

The materials used in this research are grade 43 cement, 2.36mm size of fine aggregate, 0%-1.25 % of plastic optics fibre and water. The mix proportions ratio of concrete is divided into 22.3% of cement, 67.7% of fine aggregates and water contribute 10.0% [5]. Moreover, the percentage of plastic fiber optics such as 0.25%. 0.75% and 1.25 % are used in this research and the number of plastic optic fiber in each specimen is obtained through the calculation below.

The volume of each optic fiber $= V = \pi r^2 h$

$= \pi(\frac{1x10^{-3}m}{2})^2(0.1m)$

$=7.854x10^{-8}m^3$

Table 1
Calculation for Number of Fiber Optics Used [6]

Percentage of fiber optic by volume	The total volume of fiber optics	No. Of optic fiber in each specimen
0.25%	$\frac{0.25}{100}x(0.1x0.1x0.1)m = 2.5x10^{-6}$	$\frac{2.5x10^{-6}}{7.854x10^{-8}} = 32$
0.75%	$\frac{0.75}{100}x(0.1x0.1x0.1)m = 7.5x10^{-6}$	$\frac{7.5x10^{-6}}{7.854x10^{-8}} = 96$
1.25%	$\frac{1.25}{100}x(0.1x0.1x0.1)m = 12.5x10^{-6}$	$\frac{12.5x10^{-6}}{7.854x10^{-8}} = 160$

2.2 Mix Design and Process

The manufacturing process of transparent concrete is almost the same as regular concrete. Only optical fibres are spread throughout the aggregate and cement mix. Small layers of the concrete are poured on top of each other and infused with the fibers and are then connected. Thousands of strands of optical fibers are cast into concrete to transmit light, either natural or artificial. Light-transmitting concrete is produced by adding 0.25% to 1.25% optical fibers by volume into the concrete mixture. The concrete mixture is made from fine materials only it does not contain a coarse

aggregate. The thickness of the plastic optical fibers can be varied between 1mm and 2mm to suit the particular requirements of light transmission. After that, the flexible clay is shaped into the desired shape with 10mm depth and leave it for 1 day in order to allow it to become harder. Fibers are then inserted into the clay layer in organic distribution where the clay has an ability to hold the fibers in the proper location. Once the fibers are fixed completely, the wood mold is then placed upon the layer of the clay.

For the concrete mixing process; the materials such as Ordinary Portland Cement and fine aggregate were mixed first. Then, the water will be added to the dry mixture. The mix was then mixed to ensure full mixing of the constituents. The calculation of proportions for each type of material is referred to [5]. After that, the mixture will be placed in preparation wood of concrete and compacted through vibration machine. Then, the cubes of concrete were cured in the water until the testing day for 7 and 28 days. The performance of translucent concrete is compared with the control concrete in term of compressive strength and light transmittance.

2.3 Testing and Analyzing

The compressive strength of a material is that the value of uniaxial compressive stress reached when the material fails completely. The compressive strength is usually obtained experimentally by means of a compressive test. The compressive strength of the concrete is determined by cast the cubes of size 100mm x 100mm x 100mm [7].

The light transmittance through the sample can be measured by measuring the current corresponding to the light which can be measured by a photodiode or a Light Dependent Resistors (LDR). The use of photodiode would require a separate sensor which would increase the cost of the project. The aptest choice would be LDR. The LDR is soldered onto a PCB board. The LDR measures the light transmitted through the sample and converts it into the current, which in this case is measured in mili amperes (mA). So two readings are taken, one without sample (A1) and one with the sample (A2). The source of light here is taken as 100 w incandescent bulbs, a resistance of 100 Ω is applied in the circuit and a uniform DC voltage of 2.5 V is kept between the circuits. To ensure no light escapes throughout the test, a box made up of plywood is made. The light source is fixed at the top of the box and LDR is placed at the bottom. The sample is placed between source and LDR and the test is carried out [8].

Light transmittance = 100 – (A1−A2/A1) x100 [8]
where
A1= light transmitted without sample
A2= light transmitted with sample

3. Results

3.1 Compressive Strength

As the ages of concrete increases, there is a steady improved in the compression strength of all mixtures 0, 0.25, 0.75, 1.25 % of POF due to hydration of cement will increase the interfacial transition zone between the structural matrix and POF. Besides, the results also indicate that the increasing POF percentage will also led the compressive strength increases. Thus, the maximum compressive strength obtained among LTC and also conventional concrete was 44.2 N/mm2 at 28 days which increased from 32.4 N/ mm2 during 7 days and it lies on 1.25% of POF where it is higher than the normal concrete. For the rest of the samples with respect %POF, they basically also beyond

the normal concrete in term of the compressive strength. This probably due to the numerous strand of plastic fiber optics might pretend like one of the prestressed components once it located in the correct manner, thus it will eventually slightly contribute extra strength towards the concrete itself [6]. On the other hand, the results also demonstrate that despite the improvement in POF percentage from 0.25% to 0.75%, the sample with 0.75 % POF has a lower compressive strength during both of the ages of 7 days and 28 days compared to the mix with 0.25% which is 29.6 N/mm2 and 41.8 N/mm2 respectively. Thus, this possibly due to inappropriate arrangements of POF whereby the smaller spacing between one another of POF will produce the poor strength concrete cube due to the smaller interconnecting extent when propagation of macro cracks under compressive load. This situation will be further explored in future research. In particular, these results able to prove that the POF basically have their significant influences on the compression strength. Thus, this is a positively satisfactory outcome for the strengthening of concrete structures in term of compressive strength aspect.

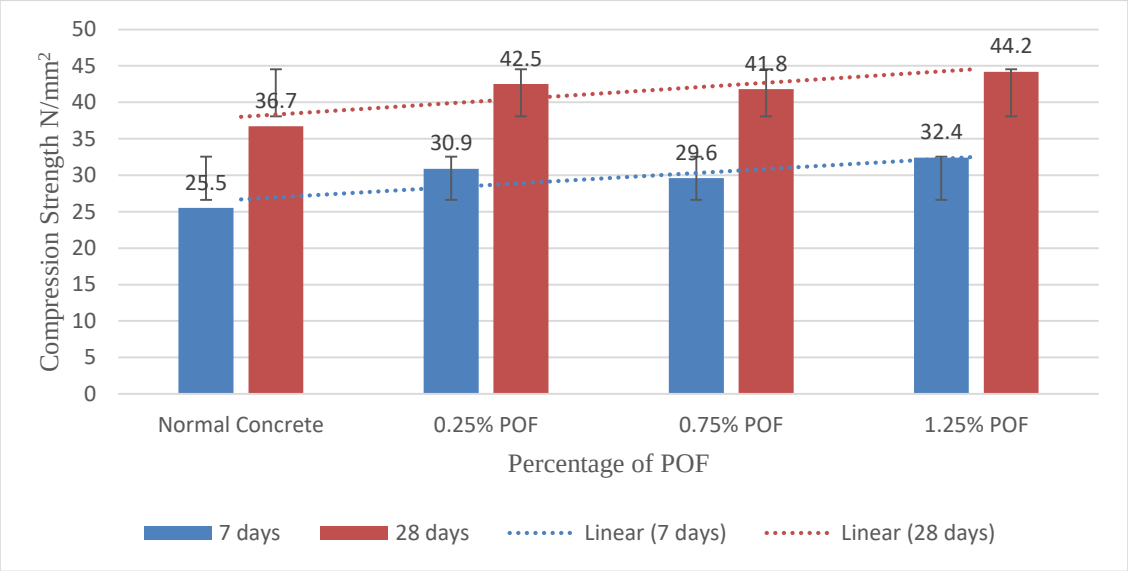

Fig. 1. The Bar Graph of Compression Strength vs Percentage of POF

3.2 Light Transmittance

Based on Figure 2, the amount of light transmitting through the concrete sample actually depends on the percentage of plastic fiber optic used on the concrete surface. As the percentage of optical fibers increases, the transmission of light will also increase [9]. The maximum intensity of light propagating through the sample is 1.25% POF which having 2.33% and 3.15% of light transmittance while the lowest intensity of light transmittance is 0.25% of POF due to its lowest consumption of fiber optic. From the result, also indicate that the light transmitting intensity will not be influenced by the increasing of curing age of 7 days until 28 days. Unfortunately, the transmission of light at 1.25% POF shows that despite the similar usage in the percentage of fiber optics, the light transmitting intensity at 28 days had significantly lowest than 7 days curing ages. This might be due to various factors such as the inconsistency spacing arrangement, the failure of light transmitting plastic optics fiber, and the influence of the natural environment during experiment test and so on. After completing the experiment test, it's found that the average value of light passed through the blocks will reduce the consumption of daily electricity in long term period.

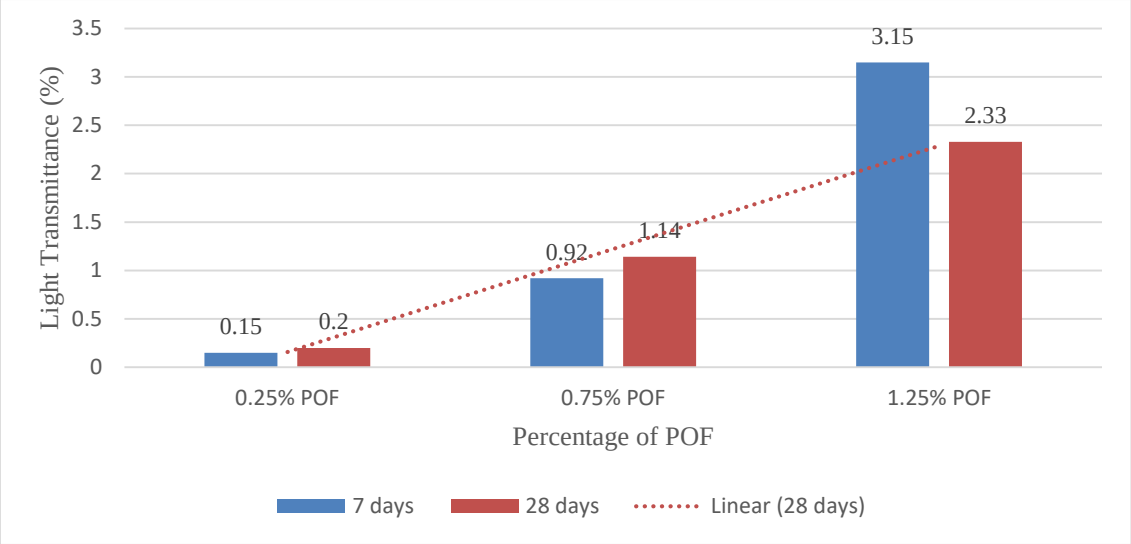

Fig. 2. The Bar Graph of Compression Strength vs Percentage of POF

4. Conclusions

In conclusion, it was found that the greatest compressive strength is 44.2 N/mm2 accomplished with 1.25% POF which is higher than the conventional concrete with 36.7 N/ mm2 in the similar curing age of 28 days. At the same time, the previous researchers also revealed that the reinforcing of optical fiber will transmit light without affecting the strength of concrete [10]. Also, the result concerning the mechanical impact of concrete with plastics optical fiber shows that the compressive strength of translucent concrete increase with increasing number of fiber optic [11]. Furthermore, the highest percentage of 1.25% POF reflect the highest amount of light transmittance value which is 3.15% compared with others. Also, the increasing percentage of POF will led the light transmittance percentage also increases. This result may be related to the previous researchers who studied the light guiding properties and effectiveness of optical fiber, they concluded that the translucent concrete has well light transmittance property and the amount of light transmittance is directly proportional to the POF volume ratio [12]. Also, translucent concrete could be regarded as a decorative material which could be applied in buildings [13]. Thus, there is possible to allow the concrete to become translucent without affecting its compressive strength. By the comparison between translucent concrete with normal concrete, the translucent concrete is much applicable than normal concrete.

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