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Experimental study on Luminescent Concrete

Prof. S. Sundari[1], A. Shriswarnambigai[2]

[1]S. Sundari, Associate Professor, Department of Civil Engineering, Government College of Engineering, Salem-11, Tamil Nadu, India.
[2]A. Shriswarnambigai, Dept. of Civil Engineering, Government College of Engineering, Salem-11, Tamil Nadu, India.

Abstract - *The traditional concrete currently used in the construction industry has a greyish color and high density. The high density of the concrete prevents the passage of light through it. Therefore, the concrete couldn't illuminate itself.*

On the context, it has been identified that the concrete can be provided with the property of luminance by varying the property of cement. The cement will be induced with luminance property by adding certain photo luminescent chemical substances to it. This project presents an investigation of the luminescent property of the concrete by modifying the property of the cement. The photoluminescent pigments used in the project is a sulphide powder which belongs to a rare alkaline earth element from lanthanide series. These elements are also proven to be inert and causes minimal harm to the environment. From the results it is also found that the luminescent concrete also possesses considerable compressive strength as like traditional concrete. The emergence of photoluminescent concrete has the ability to create a spectacular change in the field of construction and architecture. In many nations, the illumination of highways and rural households are still a biggest challenge. Lack of light in the night leads to many social issues and accidents. In these circumstances the photoluminescent concrete can play a drastic role. It is not only meant for these instances it can also be used to improve the ambience thereby reducing the cost of electricity used for decorations. This project builds on two existing areas of research in order to investigate new concrete materials. These materials have extensional applications to concrete exterior building walls, pedestrian safety infrastructure, and any number of other design applications where light emission is desired. In the future, a material like this could have the potential to reduce artificial light inside buildings, while also adding an aesthetic design appeal to interior fixtures and building elements. Therefore, the concept of photo luminescent concrete can pave a great way to an enormous change in the construction industry.

Key Words: **Photoluminescent, Chemical pigments, strontium aluminate, Glow-in-dark concrete (GID), Resins, Phosphoresce, Compressive strength.**

1.INTRODUCTION

Luminescent concrete is the one which has the ability to trap the solar or artificial light energy during daytime and convert it into visible light in nighttime. Luminescent concrete is otherwise known as light emitting concrete or Glow-in -the-dark concrete (GID). Luminescence is generally defined as the emission of light, caused when light is absorbed in the form of photons and causes the electrons to jump from their energy levels. The photoluminescent material can be charged by either natural or by artificial means. The naturally available sunlight can be used to obtain brighter glow in the photo luminescent material. Though the initial cost is high, it will prove to be cost effective in terms of operational and maintenance cost.

Luminescent concrete is relatively a new and little-researched variation. It has the potential for applications in a variety of civil, structural, and design areas. In addition to its potential for aesthetic and creative use, this concrete has its applications in coating buildings, bike lanes, highways, interiors, and even swimming pools in order to improve vehicular and pedestrian safety, as well as in reducing the need for energy intensive street and building lighting.

2. REVIEW OF LITERATURES

Hadi Barghlame, Hojjat Hashempour Gavgani published a journal on Light Emitting Concrete Composition and Method of Synthesizing Light Emitting Concrete Structure, Publication of US20170029696A1.

This paper provides the various embodiments of light emitting concrete composition and a method of synthesizing a light emitting concrete structure. The light emitting concrete composition comprises light emitting pigments. The light emitting pigments include a titanium powder, a sulfide powder and resins, cement, sand, gravel, and water. The method of synthesizing a light emitting concrete structure comprises preparing slurry. The slurry is prepared by mixing sand, gravel, cement, and water. Further, a light emitting pigment mixture is prepared by mixing a titanium powder, resins, and a sulphide powder. The light emitting pigment mixture is added to slurry. The slurry is molded by adding the slurry in molds. The molds are further kept for at least 12-14 hours. One of the objectives of the embodiments herein is to provide light emitting concrete structures that are environment friendly, cheap, emit ample of light by absorbing ambient light after removing the ambient light source.

Inference: Method of synthesizing the luminescent concrete.

Andrew Wiese, Taylor Washington, Bernie Tao & William Jason Weiss, Assessing the performance of Glow in the Dark Concrete, Transportation Research Record Journal of the Transportation Research Board (2508).

This study reports about the enhancement of luminance by adopting a soy-based luminescent sealant for use on concrete surfaces. The luminescent sealant used was soy methyl ester polystyrene and strontium aluminate, a phosphorescent powder. In this study a test procedure was developed to quantify the magnitude and duration of the luminance of the coated concrete surface; quantifying the luminance was key in evaluating the performance of the luminescent sealant. Results of the tests indicated that the luminescent surface emitted light. Larger particles of strontium aluminate were found to luminesce for a longer time than did smaller particles.

Inference: Larger particles of strontium aluminate illuminate for longer time than smaller particles.

Saleem, Muhammad, Blaisi, Nawaf Isam Ahmed, Luminescent concrete composition and product, Imam Abdulrahman Bin Faisal University (Damman, SA).

This paper reports the luminescent concrete compositions containing cement, fine aggregates such as sand, and a phosphor such as strontium aluminate. Glow-in-the-Dark concrete products made therefrom and methods of producing such concrete products are also specified. The glow-in-the-dark concrete products demonstrate good mechanical strength (e.g., compressive strength) and skid resistance. The addition of phosphorescent strontium aluminate provides luminance that persists for up to 10 hours to the concrete products.

Inference: Glow in the dark concrete also exhibits good mechanical strength and the use of Strontium aluminate hinders the illumination for a longer time.

Dipika G, Kaaviya S, Kavitha Karthikeyan S, Indhumathi Exploratory Study on photoluminescence induced concrete, International Journal of Civil Engineering and Technology (IJCIET).

This study reveals the illumination of highways and roads. On that context, cement being an omnipresent material, can be made photoluminescent. Photo luminescence is the light emission from any form of matter, initiated by photo excitation. This project presents an investigation on the introduction of photo luminescent property on concrete. The proposed concept is to induce light emitting pigments in glass so as to produce glow in the dark concrete. Photo luminescence pigments incorporated in the concrete, consist of rare alkaline earth elements from the lanthanide series and hence are proven to be inert, ensuring minimal harm to the environment. The resulting concrete material is found to have considerable compressive strength and possess light emitting properties. Implementing photo luminescence induced concrete has a high potential to make a valuable contribution to sustainable development in the future.

Inference: The incorporation of photoluminescence pigment in the concrete are proven to be inert, ensures minimal harm to the environment and possess considerable compressive strength.

3. METHOD OF PREPARATION

The luminescent concrete can be prepared by the following three methods.

1)Method of mixing the luminous component

2)Method of modifying the microstructure of cement

3)Method of coating the surface with luminous compounds.

Out of these three methods, the method of mixing the luminous component and the method of coating the surface with luminous compounds were adopted in this project.

4. COMPOSITIONS OF LUMINESCENT CONCRETE

The composition of the luminescent concrete is similar to that of the normal conventional concrete. It also comprises the components as the conventional concrete. In addition to the conventional concrete, it is added with the light emitting pigments. Therefore, the luminescent concrete consists of

1)Cement
2)Coarse Aggregate
3)Fine Aggregate
4)Water
5)Light emitting pigments

Light emitting pigments consists of a titanium powder, a sulphide powder, and resins. Since luminescent concrete can also be described as a special type of concrete in which additional property of luminance was induced in the concrete by adding the light emitting pigments.

5. MATERIALS USED

Cement - OPC 53 Grade
Coarse aggregate - Size of 20mm and below
Fine aggregate - M-Sand
Light emitting pigments
1)Titanium-di-oxide
2)Strontium Aluminate
3)Polyester

6. STUDY OF MATERIALS

The properties of the cement, coarse aggregate, fine aggregate, and light emitting pigments were studied in the project.

6.1. Ordinary Portland Cement (OPC)

As specified by IS 1489:1991, there are different grades of cement available. The grade of the cement indicates the characteristic compressive strength of the cement after 28 days test as per BIS specification. OPC 53 grade cement is used in the manufacturing process of luminescent concrete. All the tests on cement were conducted according to IS 4031 and IS 2720.The test conducted are.

Consistency test - IS 4031 Part 4

Initial setting time test - IS 4031 Part 5

Specific Gravity test - IS 2720 Part 3

6.2. Coarse aggregate

Coarse aggregates act as filler material in the concrete. It increases the volume of the concrete. The tests performed in the project are listed below.

Fineness modulus test - IS 383 (1970)

Crushing test - IS 2386 Part 4

Impact test - IS 2386 Part 4

Flakiness test - IS 2586 Part 1

Elongation test - IS 2586 Part 1

Specific Gravity test - IS 383 (1970)

6.3. Fine aggregate

Fine aggregate in concrete fills void between the aggregates. It provides resistance against shrinking and cracking of the concrete. There are many types of fine aggregate available based on their mode of origin, composition, and grain size. Due to the insufficient resource of river sand, manufacturing sand is adopted everywhere. Even in our project manufacturing sand (M-Sand) is employed. These were the tests conducted in the project.

Fineness modulus test - IS 383 (1970)

Specific Gravity test - IS 383 (1970)

6.4. Light emitting pigments

The light emitting pigments will induce the property of luminance in the concrete. It is the additional material added to the conventional concrete. The light emitting pigments are a titanium powder, a sulphide powder, and resins.

6.4.1. Titanium- di- oxide

Titanium is one of the most common elements in the Earth's crust which is commonly found in plants and animals. Titanium naturally interacts with oxygen to form titanium oxides and found in ores, indigenous dusts, sands, and soils. It is a fine, white pigment. It has been used for a century in a range of industrial and consumer products, including paints, coatings, adhesives, ceramics. It also exhibits good photo catalytic properties in many environmental and energy applications due to its efficient

photoactivity, high stability, low cost and safety to the environment and humans. In luminescent concrete about 3-6% of titanium-di-oxide is added. In this project about 3% of titanium-di-oxide is added.

6.4.2. Strontium Aluminate

The chemical formula of Strontium Aluminate is $SrAl_2O_4$. It is an aluminate compound which is pale yellow, crystalline powder, odorless and non-flammable. It is when activated with a suitable dopant, acts as a photoluminescent phosphor with long persistence of phosphoresce. It is being 10 times brighter and 10 times longer glowing. It is frequently used in the dark toys. About 3-6% of strontium aluminate is added in luminescent concrete. Strontium Aluminate of about 3% is added in this project.

6.4.3. Polyester

Polyester resins are synthetic resins formed by the reaction of dibasic organic acids and polyhydric alcohols. Maleic Anhydride is a commonly used raw material with diacid functionality in unsaturated polyester resins. It has adequate resistance to water and variety of chemicals. It also possesses adequate resistance to weathering and ageing. Usually a resin of about 6-7% is added in luminescent concrete. In our case resin of about 6% is added.

7. MIX DESIGN

The calculations of mix design were done according to IS 10262 – 1982.

Grade designation	- M 25
Data of materials collected from tests:	
Specific Gravity of cement	= 3.15
Specific Gravity of fine aggregate	= 2.31
Specific Gravity of Coarse aggregate	=2.96
Water cement ratio	= 0.48

Final Mix Ratio = 1: 1.63: 3.188; 0.48

7.1 Final quantity of materials

For casting 9 cubes (100 x 100 x 100mm) of conventional concrete, the following quantity of materials were calculated.

Cement	= 2.7 kg
Fine Aggregate	= 4.4 Kg
Coarse aggregate	= 8.6 kg
Water	= 1.3 l

For casting 12 cubes (100 x 100 x 100mm) of luminescent concrete, the following quantity of materials were calculated.

Cement	=4.3 Kg
Fine Aggregate	= 7.009 Kg
Coarse Aggregate	= 13.70 Kg
Water	= 2 l
Titanium dioxide	= 130g
Strontium aluminate	= 130 g
Polyester resin	= 300g

8. CASTING OF CUBES

Concrete cubes are casted in the mould of size 100x100x100mm. In this project, casting is done for both conventional and luminescent concrete. Initially the conventional concrete was casted with three mix design by varying the water cement ratios. For every water cement ratio, a set of 9 cubes were casted and tested for every 7,14 and 28 days. Their respective compressive strengths were calculated. Out of these three varying conventional concrete cubes, the mix design with the maximum strength is considered for the casting of luminescent concrete.

The casting of luminescent concrete involves two phases. The first phase consists of mixing the cement, coarse aggregate and fine aggregate with their respective water cement ratios. The second phase is the preparation of slurry of light emitting pigments (i.e., Titanium-di-oxide, strontium aluminate and polyester resin are mixed). Then the slurry is mixed with the first phase elements. The whole mix is now regarded as the mix of luminescent concrete.

Fig -1: Mixing of conventional concrete.

Fig -2: Casted cubes kept for vibration.

Fig-3: Setting of concrete cubes.

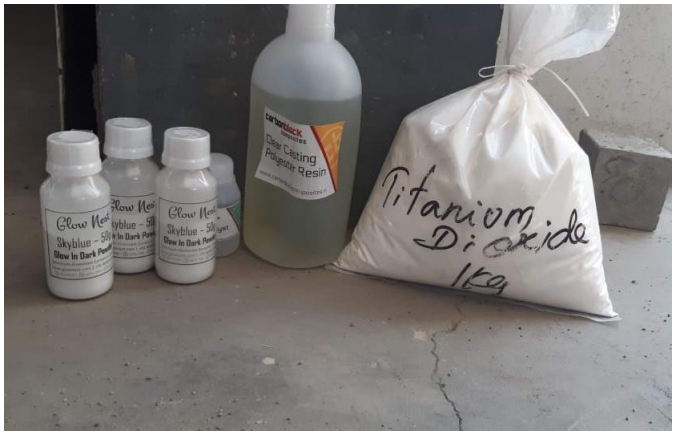

Fig-4: Light Emitting pigments.

Fig-5: Mixing of luminescent concrete.

Fig-6: Setting of luminescent concrete.

9. COMPRESSIVE TEST RESULTS

Cubes are tested at 7th,14th and 28th day. The average compressive strength of the cube are as follows.

9.1. Conventional Concrete

Average compressive strength obtained at 7th day= 17.658 N/mm^2.

Average compressive strength obtained at 14th day= 22.5 N/mm^2.

Average compressive strength obtained at 28th day= 28.449 N/mm^2.

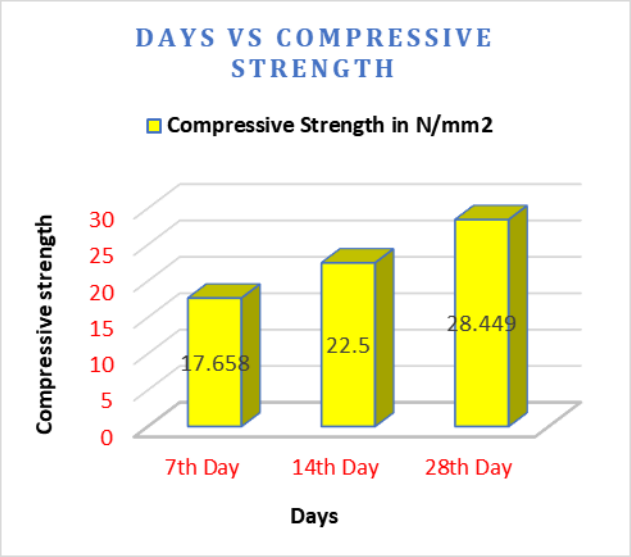

Chart-1 Compressive strength of Conventional concrete.

Fig-7: Compression testing of conventional concrete cubes.

9.2. Luminescent Concrete

Average compressive strength obtained at 7th day= 15.042 N/mm^2.

Average compressive strength obtained at 14th day= 20.601 N/mm^2.

Average compressive strength obtained at 28th day= 23.217 N/mm^2.

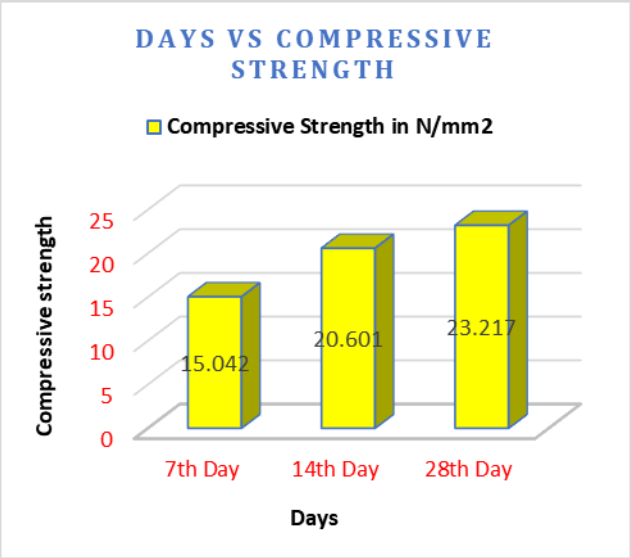

Chart-2 Compressive strength of Luminescent concrete.

Fig-8: Compression testing of luminescent concrete cubes.

On comparing the compressive strengths of both the conventional and luminescent concrete, it is found that the compressive strength of luminescent concrete varies slightly with the conventional concrete.

10. LUMINANCE TEST RESULTS

Before testing for luminance, the luminescent concrete cubes are needed to be excited by a light source. The test is performed by leaving the concrete cube in the daylight for 24 hours and then kept in a dark room and checked for luminance. This was the basic test for observing luminance in the concrete. The luminance produced is checked in terms of hours.

After keeping the concrete cube for 24 hours in daylight, the concrete cube was observed to emit the light for about nearly nine hours.

From the test it is observed that to get the maximum illumination, the percentage addition of the light emitting pigments has to be increased. More particularly the increased addition of Strontium Aluminate will end in better results of luminescent concrete.

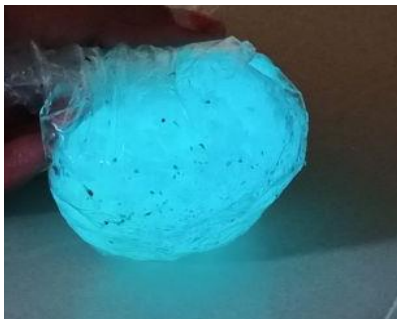

Fig-10: Glow of Strontium Aluminate

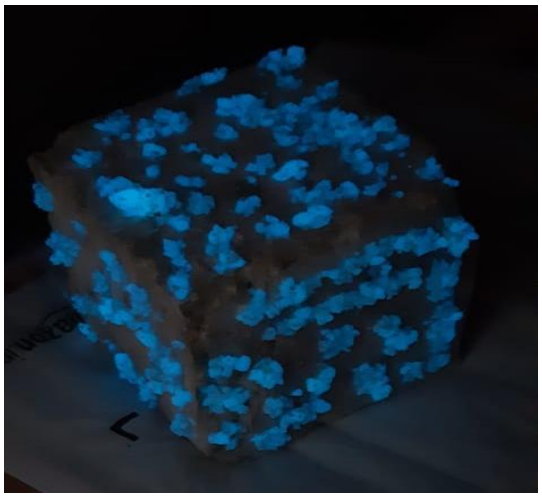

Fig-11: Glow of Luminescent concrete

11. CONCLUSIONS

This experiment will act as an initiative to look closely a newly and emerging advanced construction in future. It also adds a novel utility to life cycle sustainability. On the contrast it also has its own disadvantages. On our study we found that the setting time of the luminescent concrete was delayed by one day when compared with conventional concrete. The material i.e., the light emitting pigments used for luminescent concrete is very expensive and were unable to purchase locally. The materials must be ordered priorly. However, our project's aim is to create samples of photo luminescent concrete which gives rise to the idea that concrete can provide functions beyond structure, and as such, can be used in a wider array of applications.

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