Luminescent Cement

Engineering Materials ENGR 220

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Table of Contents

Table of Figures

Table of Tables

Abstract

Luminescent cement composite material (LCCM) is formed using a percentage of reflective powder (RP) and luminescent powder (LP) with White Portland Cement [1]. This composite cement has the potential to add energy free lighting to areas that are difficult to light using electricity, yet where safety can be improved with light. This composite material has displayed increased compressive and flexural strength over the standard control material of White Portland Cement without additives[1]. The 28-day curing time of the composite had a maximum compressive strength of 45.6 MPa over the control material with a standard value of 42.5 MPa [1]. Similarly, the maximum flexural strength of the composite compared to the standard control material was 11.8 MPa and 6.5 MPa respectively [1]. The afterglow of the LCCM material has a visible brightness in the range of 0.02-0.2 cd/m^2 at 8 hours [1].

Introduction

This report highlights the similarities of standard White Portland Cement with that of doped luminescent cement emphasizing the luminescent properties of luminescent composite material. Long afterglow luminescent materials have been increasingly applied in many fields because of its advantages of diverse luminescent colors, long afterglow time, high luminescent brightness, stable chemical properties, environmentally friendly and energy saving without radiation [1, 2]. Obtaining luminescent cement-based pavement materials would be a promising technology to save energy, reduce ecological light pollution and improve the safety of road and foot traffic in low lighting environment, and provide a good direction to improve the performance of smart road materials [2].

Motivation

Phosphorescent cement was considered for a safety material while navigating several unlit stairs and a path after returning home after dark. Many homes are situated away from well-lit main roads that can be poorly luminated if outdoor electric lighting has not been turned on or

becomes inoperable during power outages. By using phosphorescent cement in construction of these areas, safety can be increased adding value to property owners.

Applications

Results of luminescent cement-based composite material (LCCM) shows feasibility in fields of architecture, civil engineering, and textiles industries [1,2]. Possible applications would be to reduce light pollution, improve safety through traffic or signage applications, as well as decorative and architectural designs [1,2].

1. Definition

Luminescent cement-based composite materials (LCCM) prepared by doping luminescent powder (LP) and reflective powder (RP) into cement-based materials [2].

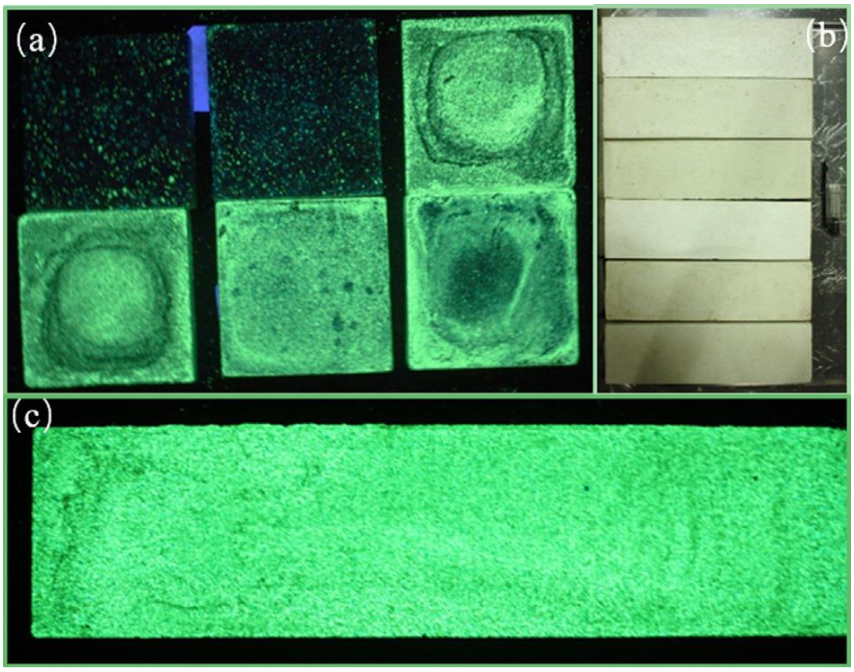

Figure 1 Luminous effect of the LCCM specimen (a) luminous specimen with self-made molds at night (b) LCCM specimen in the daytime (c) LCCM specimen at night.[2]

1.1. The Class of Material

This is a composite material comprised of White Portland Cement, luminescent powder, and reflective powder [1].

2. Properties

2.1. Physical Properties

The composite material included various percentages of White Portland Cement (P.W.42.5), luminescent powder (LP) consisting of SP type alkaline earth aluminosilicate, and reflective powder which was a white powder with a high refractive index [1]. Their physical properties can be seen in tables 1, 2, and 3.

Table 1.
Basic physical properties indexes of the white cement [1].

Indexes	Bulk Density (kg/m^3)	Fineness (%)	Specific Area (m^2/kg)	Initial Setting Time (h)	Final Setting Time (h)	Whiteness	Flexural Strength (MPa)		Compression Strength (MPa)	
							3d	28d	3d	28d
Standard Value	--	1.0-10.0	300-400	≥1.5	≤10	≥87	3.5	6.5	17	42.5
Measured Value	1320	1.2	400	1.6	5	89	5.9	8.7	25.2	47.8

Table 2.
Main indexes of the luminescent material [1].

Material	Excitation Wavelength Range (nm)	Emission Wavelength Peak (nm)	Central Particle Size Range (μm)	Afterglow Luminance Range (mcd/m^2)	Afterglow Time (h)	Light Permanency (h)	Specific Gravity (g/cm^3)
Luminescent Powder (LP)	200-450	520	1-100	40-400	≥10	≥1000	3.6

Table 3.
Main indexes of the reflective powder [1].

Material	Refractive Index	Size Range (μm)	Roundness Rate (%)	Permeability Rate (%)	Density (g/cm^3)
Reflective Powder (LP)	200-450	1-100	40-400	≥10	≥1000

3. Mechanical Properties

3.1. Compressive Strength

The composite of Portland Cement with the luminescent powder (LP) and reflective powder (RP) showed an improvement in compressive strength compared to the control group of Portland Cement without LP or RP added [1]. Figure 2 shows the increase in compressive strength after curing for 7 days vs 28 days. The 7-day curing compressive strength decreases as the reflective powder percentage increases; however, the 28-day curing compressive strength increased for all samples [1]. The optimum compressive strength was found in the composite of 30%LP with a 7-day and 28-day strength of 29.8-34.7MPa, and 38.6-45.6MPa respectively [1]. Figure 2 displays a graph of the various compositions compared to standard White Portland Cement from 7 days to 28 days.

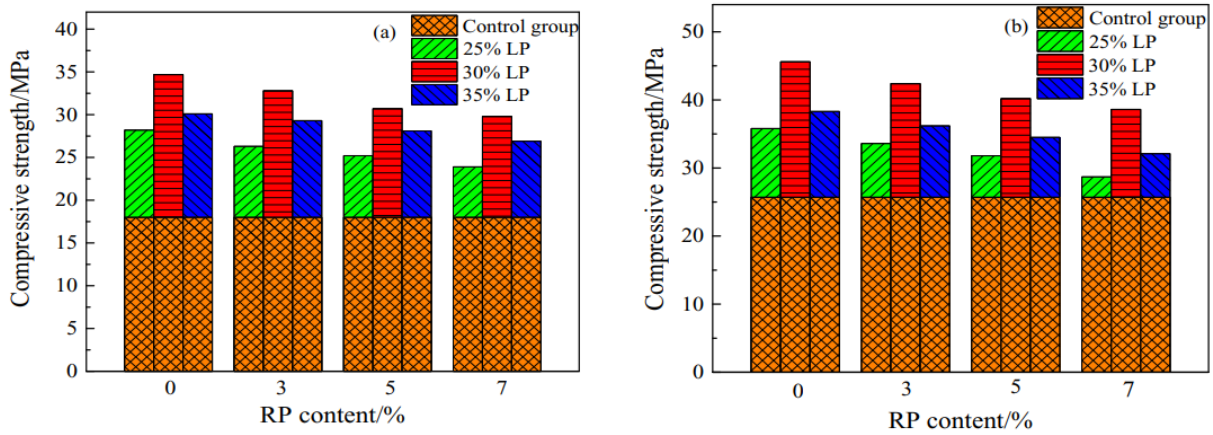

Figure 2. The compressive strength of the SCCM specimens: (a) 7 d; (b) 28 d [1].

3.2. Flexural Strength

The luminescent composite experienced an improvement of flexural strength over the control group of Portland Cement without the LP or RP added. The flexural strength greatly improved from the 7-day curing time compared to the 28-day curing time [1]. As seen in figure 3, the 28-day curing time for the composite of 7% RP and 30% LP showed the greatest flexural strength of 11.8 MPa [1].

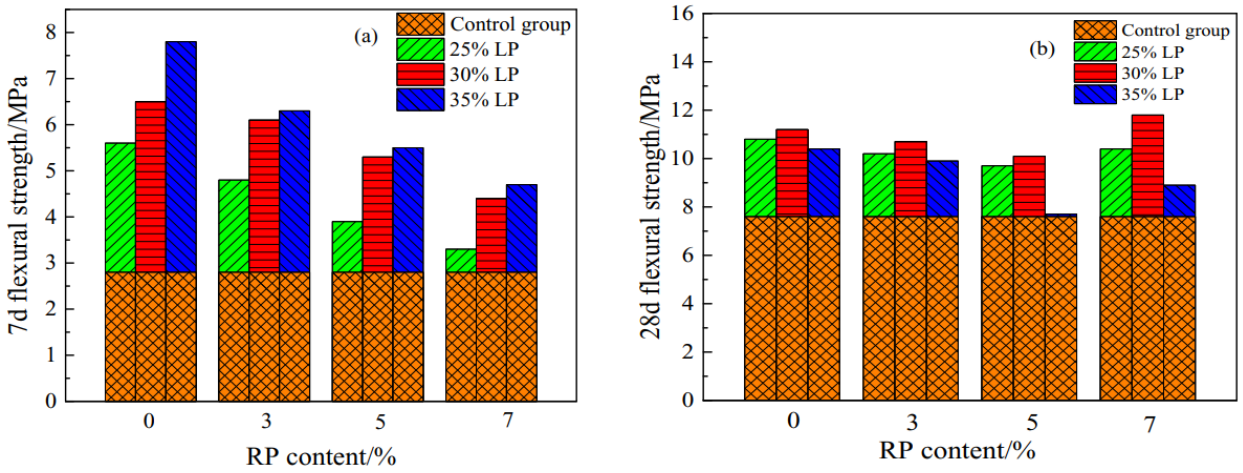

Figure 3. The flexural strength of the SCCM specimens: (a) 7 d; (b) 28 d [1].

4. Luminous Properties

During the experiment various combinations of luminescent powder (LP) and reflective powder (RP) concentrations were tested [1]. The combination with the highest luminescent property was 7% RP and 35% LP [1]. This sample displayed an initial and ten-minute brightness of 10.51 cd/m^2 and .89 cd/m^2 respectively [1]. The intensity of the initial brightness of all samples was between approximately 8 cd/m^2 and 10 cd/m^2 that declined to as low as less than 0.5 cd/m^2 [1]. Figure 4 compares the initial brightness to the 10 minute brightness of the various mixtures.

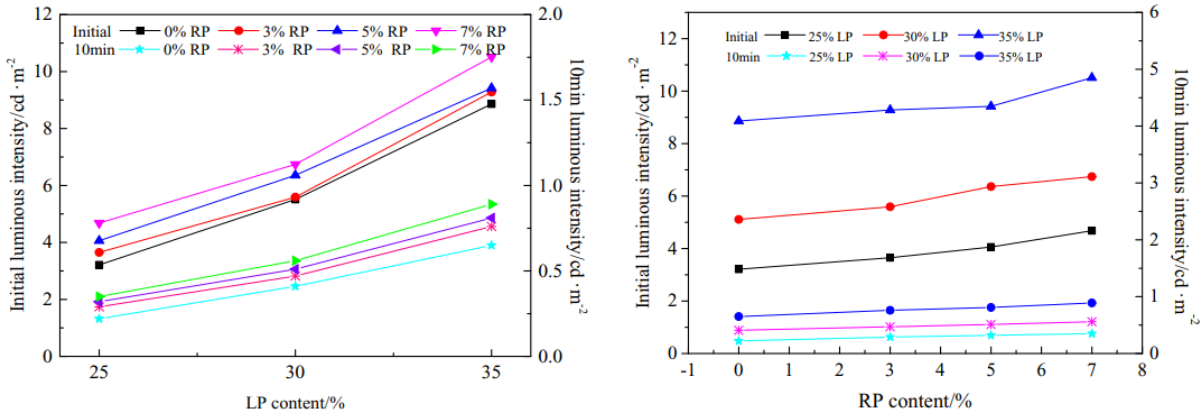

Figure 4. Effects of luminescent powder and reflective powder on luminous intensity of the SCCM specimens [1].

From approximately 30 minutes, the samples experienced a slow, constant decrease in intensity until they were barely visible at approximately eight hours [1]. The brightness of the samples at eight hours was between 0.02 and 0.2 cd/m^2 [1]. The samples were unmeasurable at 12 hours [1]. The minimal brightness visible to the human eye is understood to be 3.2 10^{-4} cd/m^2 [1]. Figure 5 graphs the initial brightness to the final 12 hour brightness.

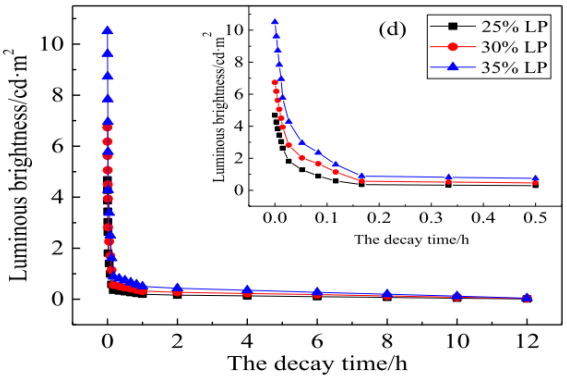

Figure 5. Effects of different content of luminescent powder and 7%RP reflective powder on afterglow time of the SCCM specimens [1].

Summary

This experiment showed that the composition of 7% RP with a range of 30-35% LP provided the optimal mechanical and luminescent properties [1]. With an increase in compressive strength as well as flexural strength this luminescent composite is suitable as a substitution in applications where standard cement material would be used. The long afterglow under optimal conditions makes this product attractive in applications that would desire the glow to sustain most or all the nighttime hours for outdoor applications. This experiment focused on fine luminescent powder of less than 100μm and reflective powder of less than 120μm [1]. Additional experiments could be conducted on LP and RP of increases size to determine if the mechanical or luminescent properties would be affected.

References

[1] He, B., Gao, Y., Qu, L., Duan, K., Zhou, W., & Pei, G. (2019). Characteristics analysis of self-luminescent cement-based composite materials with self-cleaning effect. *Journal of Cleaner Production, 225*, 1169-1183. doi:https://doi-org.proxy-sru.klnpa.org/10.1016/j.jclepro.2019.03.291

[2] Wang, W., Sha, A., Lu, Z., Jia, M., Jiang, W., Liu, Z., & Yuan, D. (2021). Self-luminescent cement-based composite materials: Properties and mechanisms. *Construction and Building Materials, 269*, 121267. doi:https://doi-org.proxy-sru.klnpa.org/10.1016/j.conbuildmat.2020.121267