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Research on the light transmitting cement mortar

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Key words: cement mortar, optical fiber, light transmitting ratio, compressive strength.

Abstract. The light transmitting cement mortar is to rely on a large number of optical fiber embedded in the block transferring light from the light side surface to the dark side. In this article, the preparation method of light transmitting cement mortar (LTCM) was introduced and the strength and light transmitting properties of LTCM were tested too. The results show that the LTCM can get higher light transmitting ratio and can also achieve, even exceed the light transmitting ratio of the 70g A4 print paper in the light wavelength range of 520~630nm.

Introduction

The light transmitting cement concrete is a new type light transmittance material whose permeability principle of light transmission is to rely on a large number of optical fiber embedded in the block transferring light from the light side surface to the dark side, which is totally different from traditional light transmission materials such as glass [1, 2]. When light sources are placed before these cement concrete blocks, the blocks will be light and an object on the bright side will be appear with a distinctive profile in the dark side. Wall made of light transmitting cement concrete just like a screen or a fluorescent display, special effects give the impression that the heavy thick concrete has become crystal clear, wall thickness and weight are gone [3 ,4].Therefore, the translucent concrete is an innovation for human's understanding of cement concrete. At the same time, LTCM greatly enhances the lighting effects, reduces the lighting energy consumption, and promotes the energy conservation of buildings. It also has very important scientific significance and application value [5, 6].

However, the composition, preparation and properties of LTCM have been rarely reported except for some commercial reports. The author has studied the preparation of light transmitting cement paste with optical fiber embedded by the means of parallel arrange, but those samples shrink largely which will decrease the durability and light transmitting stability. Therefore, cement mortar are used as the matix and the LTCM is prepared with optical fiber embedded by the means of parallel arrange. The effects of different optical fibers types and different optical fiber contents in volume on the property of light transmission and on the compressive strength are studied.

Materials and Testing Methods

1.1 Materials

Portland cement: ordinary Portland cement whose compressive strength are 18.5MPa on the 3rd day and 37MPa on the 28th day. Aggregate: Chinese standard sand meeting with GB/T17671-1999. 70g A4 print paper is used as the control material for light transmitting ratio testing.

Optical fiber: two kinds of glassy multimode optical fiber with the models of 50μ m/125μ m and 62.5μ m/ 125μ m, and here are separately named optical fiber (1) and optical fiber (2). In addition, ten items of fiber were glued as bunchy fibers, and the original fibers unglued are called filamentous fiber.

1.2 Testing methods

The mix design of cement mortar by weight is: cement/water/sand is 1/0.4/2, and the consistency is 13±2cm.

The cement mortar was poured into the 2cm × 2cm × 10cm cuboid mold, and each pouring height is around 1 / 7 of the mold height. Fiber length is about 95% of the mold length which can ensure them be placed in the mold completely. Gently vibrate the cement mortar containing the fibers. The above procedures are repeated until the mold is filled with fiber and cement mortar. Plain cement paste without fibers was also prepared for contrasting.

The samples were demolded after 1d curing, and then were cured for 27 days in standard condition. Each hardened cement mortar was cut into a cube of 2cm×2cm×2cm for compressive strength testing. At the same time, LTCM was cut into a thin slice whose cross section is 2x2cm and thicknesses is around 5mm, and then polish the cross sections of the slices for measuring light transmitting ratio. The cross section is perpendicular to fiber bundle when the blocks are cut.

UV765 UV-visible spectrophotometer was used to measure the light transmitting ratio, and the micro-structure of LTCM was analyzed by SEM.

Results and Discussions

2.1 Mix proportions and compressive strength testing results of LTCM.

Table 1: Mix proportions and compressive strength testing results of LTCM.

Sample	Optical fiber types	Content of optical fiber in volume /(%)	Optical fiber forms	28d comp. strength/(MPa)	Comp. strength ratio of LTCM to control cement mortar/(%)
(1)10F	(1)	10	Filamentous	23.4	94.4
(1)10B			Bunchy	11.9	48.0
(1)20F		20	Filamentous	16.3	65.7
(1)20B			Bunchy	11.7	47.2
(2)10F	(2)	10	Filamentous	15.2	61.3
(2)10B			Bunchy	13.1	52.8
(2)20F		20	Filamentous	19.3	77.8
(2)20B			Bunchy	12.1	48.8

Table 1 shows that, ①: The compressive strength of control mortar is markedly higher than that of LTCM. ②:The influences of optical fiber volume on the compressive strength are as follows: For filamentous optical fibers, the compressive strength decreases with the increase of optical fiber (1), while the strength increases for optical fiber (2); for bunchy optical fiber, the compressive strength basically unchanged with the increase of optical fiber (1), while the strength decreases slightly for optical fiber (2). The above phenomena maybe due to the size of testing samples are 2cm cube that is too small to ensure the results accuracy. Therefore, the larger size test blocks should be used in the future. ③:When the fiber contents are the same, the compressive strength of bunchy optical fiber is significantly lower than that of filamentous type, which is due to the bunchy optical fiber includes more extra bonding gel than filamentous fiber although their fiber volumes are same. Moreover, filamentous optical fiber is distributed more evenly than bunchy optical fiber.

2.2 Light transmitting ratio

When light launches into LTCM, part of the light will pass through, and part of the light will be reflected from the surface of LTCM, and the rest of the light will be absorbed by LTCM. The relationship of the three is as Eq. 1:

$$\tau + R + K = 1. \tag{1}$$

Where, τ—light transmitting ratio, R—light reflection ratio, K—light absorption ratio

The intensity ratio of the passed light to the irradiating light is marked as light transmitting ratio as Eq. 2:

$$\tau = I / I_0 \times 100\ \%. \tag{2}$$

Light in different wavelengths and their corresponding light transmitting ratio curve is called the spectral curve of transmission[7]. Since visible light wavelength range is 380~780nm, the 370~800nm light was used to study the spectral curves of transmission of LTCMs and 70g A4 print paper. The results are shown in Fig. 1 to 12.

1) Comparison between filamentous and bunchy optical fiber

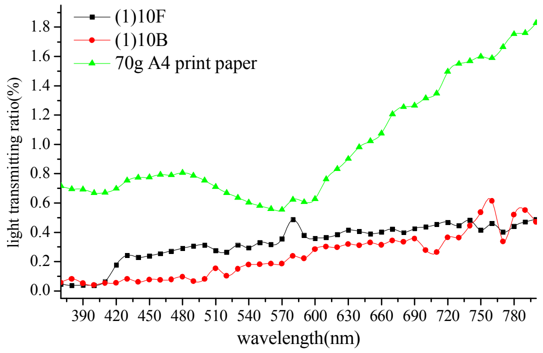

Fig. 1 light transmitting ratio contrast chart between (1)10F and (1)10B

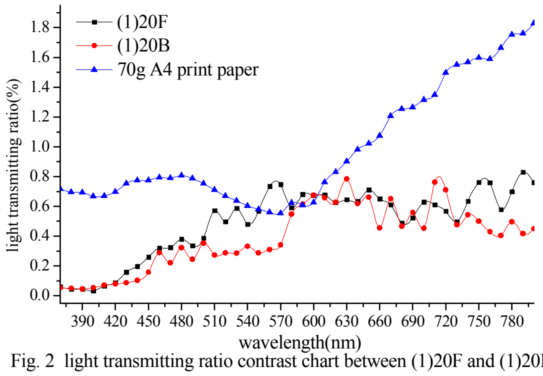

Fig. 2 light transmitting ratio contrast chart between (1)20F and (1)20B

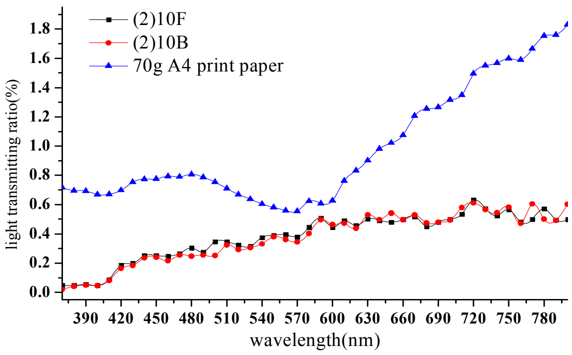

Fig. 3 light transmitting ratio contrast chart between (2)10F and (2)10B

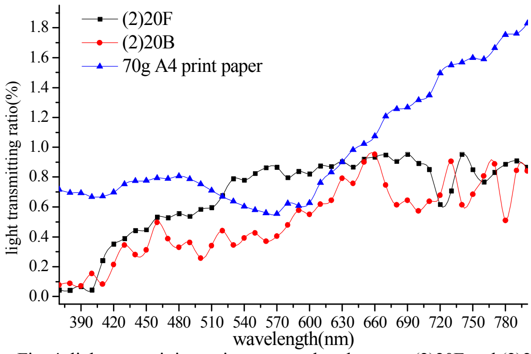

Fig. 4 light transmitting ratio contrast chart between (2)20F and (2)20B

It can been seen from Fig. 1 to 4 that, regardless of the optical fiber content is 10% or 20%, the light transmitting ratio of the filamentous optical fiber samples is generally larger than that of the bunchy optical fiber samples under the same circumstances. The main reason is as follows: the fibers are not evenly distributed in the test blocks, there is a big difference of optical fiber content in the UV-visible spectrophotometer measuring area. The distribution of filamentous optical fiber is more evenly than that of bunchy optical fiber in the samples. In addition, the light transmitting ratio of the prepared LTCM has a gradually increasing trend as the wavelength increases.

2) Comparison between optical fiber (1) and (2)

It can be seen that from Fig. 5 to 8, the light transmitting effect of optical fiber (2) is generally better than that of optical fiber (1). That is because although the outer skin diameters of the two

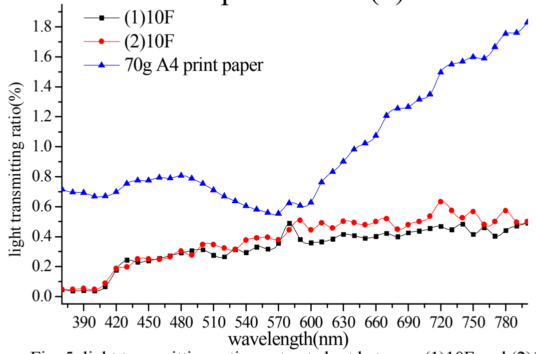

Fig. 5 light transmitting ratio contrast chart between (1)10F and (2)10F

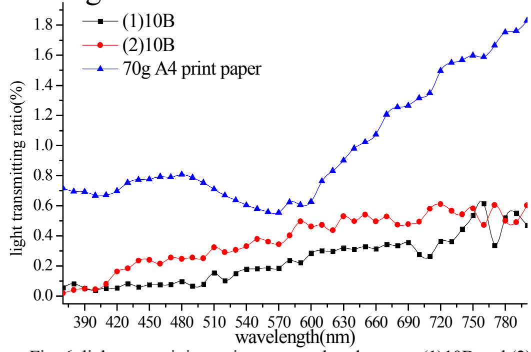

Fig. 6 light transmitting ratio contrast chart between (1)10B and (2)10B

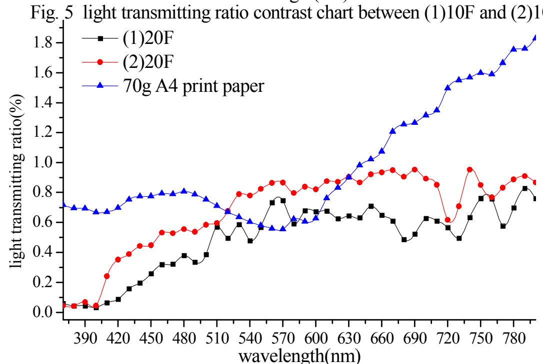

Fig. 7 light transmitting ratio contrast chart between (1)20F and (2)20F

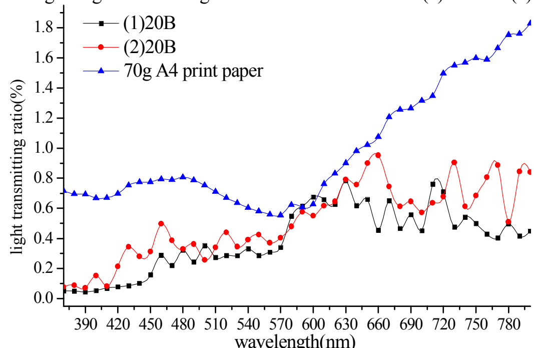

Fig. 8 light transmitting ratio contrast chart between (1)20B and (2)20B

kinds of optical fiber are both 125μm, but the outer skin is only used to protect the inner core that is the role of transmitting light. The inner core diameter of optical fiber (1) is 50μm, while the inner core diameter of optical fiber (2) is 62.5μm, which cause the property of transmitting light of optical fiber (2) is better than that of optical fiber (1).

3) Comparison between 10% content and 20% content

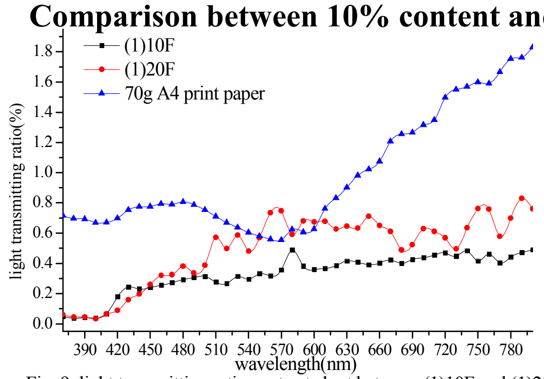

Fig. 9 light transmitting ratio contrast chart between (1)10F and (1)20F

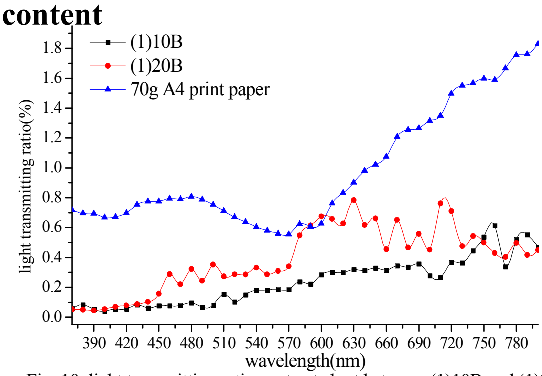

Fig. 10 light transmitting ratio contrast chart between (1)10B and (1)20B

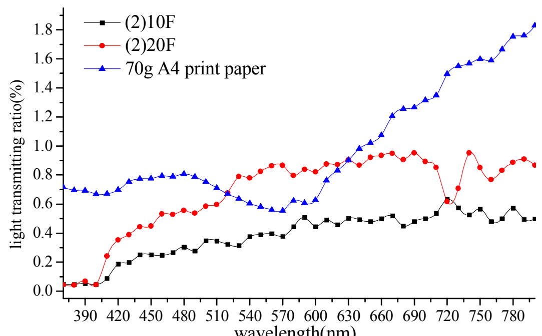

Fig. 11 light transmitting ratio contrast chart between (2)10F and (2)20F

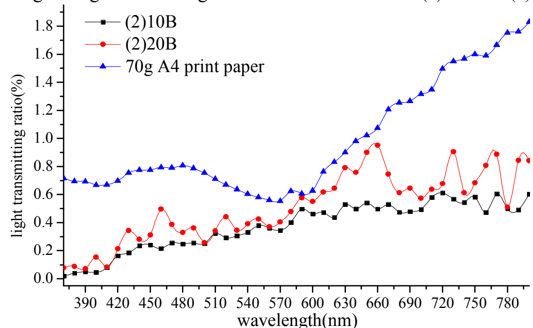

Fig. 12 light transmitting ratio contrast chart between (2)10B and (2)20B

It can be seen from Fig. 9 to 12 that, the light transmitting effect of the 20% fiber content samples is overall better than that of 10% fiber content samples, whose reason is also that the optical fiber inner core to assume the role of transmitting light increases.

In addition, Fig. 1~12 show that 70g A4 print paper has a markedly better light transmitting effect than that of the LTCM. But the LTCM sometimes has a better light transmitting effect and can achieve, even exceed the light transmitting ratio of the 70g A4 print paper in the wavelength range of 520~630nm.

2.3 Microstructures of different LTCMs.

Two samples "(1)20B" and "(1)20F" in table 1 are analyzed by SEM, as is shown respectively in Fig. 13 and Fig. 14. It can be seen that, ①:The brittle glass fiber has round rough cross section, and outer skin is used to protect the inner core (Fig. 13, 14). ②:Gaps exist in the interior of bunchy optical fibers even if they are glued by 502 glue, and the interface between the fibers and the cement mortar is also not firm (Fig. 13). ③:The interface between the filamentous optical fibers and the cement mortar are firm, and the optical fibers are evenly distributed in the blocks (Fig. 14). The above microstructure differences of the two samples explained the reason that why the compressive strength and light transmitting ratio of the samples with filamentous optical fibers and bunchy optical fibers embedded are different.

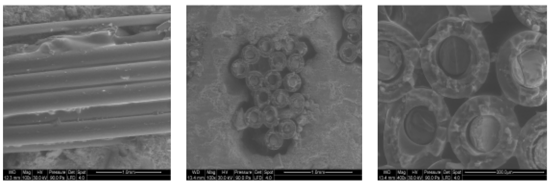

Fig. 13 SEM images of sample " (1)20B"

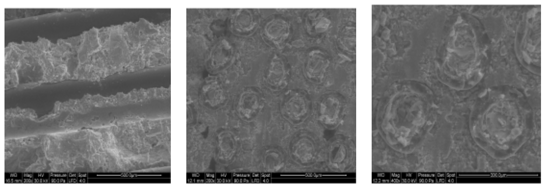

Fig. 14 SEM images of sample "(1)20F"

Conclusions

①: The prepared LTCM can transmit light. The light transmitting ratio is higher when parallel arranging optical fibers with bigger inner core diameter in filamentous form along the light direction, and it increases with the increase of optical fiber volume content. This kind of LTCM can achieve, even exceed the light transmitting ratio of the 70g A4 print paper in the wavelength range of 520~630nm.

②: The compressive strength of the prepared LTCM is lower than that of control cement mortar without optical fiber. The compressive strength of the samples with bunchy optical fiber embedded is significantly lower than that of samples with filamentous, whose reason is owe to that the interface between the filamentous optical fibers and the cement mortar are firm and the fibers are more evenly distributed in the blocks.

Acknowledgements

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