Translucent Concrete as the Building Material of the 21St Century

Jacek Halbiniak, Paulina Sroka

Cathedral of the Building and Material Processing Technologies,
Czestochowa University of Technology, Faculty of Civil Engineering
ul. Akademicka 3, 42-201 Częstochowa, halbiniak@wp.pl

Received February 09.2015; accepted February 19.2015

Summary. The article presents the research and consideration effects in relation to translucent concrete being the material, which gains recognition in the construction field. For research purposes a compression resistance research was carried out and concrete specimens containing plastic optical fibers were made. There was characterized an plastic optical fiber influence on the concrete resistance features and was presented concrete exploitation up to now as well as exploitation possibilities in the future.

Key words: translucent concrete, concrete modified by plastic optical fibers, concrete transmitting the light.

INTRODUCTION

The Hungarian architect Aron Lasonczi was a pioneer and an author of the translucent concrete. He tried to create an architectural material allowing forming new, untypical arrangements by changing the concrete structure. The aim was juxtaposition of the two opposing concrete features: big mass and transparency – what creates concrete transmitting the light. Thanks to connecting concrete with properly placed plastic optical fibers it is possible to create a possible to overexpose wall, through which person and object contours from the other side can be seen. The new material was called LiTraCon from the English words Light Transmitting Concrete (the concrete transmitting the light). Shortly after that the idea of a translucent concrete was known not only in Hungary but also in many European countries like Germany, Italy and outside Europe – in China and India. Aiming at learning how the new material works, numerous experimentations were launched. Some modification attempts were made, not losing at the same time the most important concrete feature – transparency [1].

The translucent concrete had raised the most interest among the Indian engineers who by carrying out the experimentations were aiming at estimation of the transparency level and at the basic concrete experimentation which is compression resistance.

Soumyaji Paul and Avik Dutta from the University of Technology in Kattankulathr started exploring the subject of the translucent concrete. The subject of the research was bending and compression resistence of beams made of translucent concrete, because till now the research was made only on small-sized objects. As a result of the research it was stated that the resistance features of the said material depend highly on the plastic optical fiber density in the concrete element. It was estimated that the plastic optical fiber share in the concrete, which will not worsen its resistance, amounts to 0.8% by applying the plastic optical fibers of the 1,5mm in diameter and of 0.4% steel fibers. What is more, plastic optical fibers can be easily connected with the concrete and they meet the conditions of bending and compression resistance [19].

The engineers Neha R. Nagdive and Shekar B. Bhole from the University of Technology in Maharashrta (India) also tried to estimate the attributes of the translucent concrete. They carried out a research concerning the use of this innovative material as the concrete transmitting the light, aiming at building the objects, in which it would be possible to reduce the use of energy coming from the artificial lighting. As a result of the research it was stated that the ratio of the volume of the plastic optical fibers to the concrete is proportional to the amount of the light transmitted through the specimen. Also the thickness of the elements is not very important on condition that the direction of placing the plastic optical fibers does not highly run off of an angle of 90 degrees. It is important to remember that the plastic optical fibers cannot refract in any point, because then they lose the ability to transmit the light [12].

Momin A.A., Dr. Kadiranaikar R.B., M.A. Inamdar A.A. from the University of Technology in Karnataka (India) also strted to examine the translucent concrete, using the specimens made in technology with the plastic optical fibers and alternative material which were glass tubes. During the research the engineers were concentrated mainly on the light transmission of the translucent concrete and compression resistance what helped by estimating basic parameters of the said concrete. The specimen were created together with the use of forms, where it was possible to adjust the density level of the plastic optical fibers or glass tubes. Thanks to it there were made a couple of specimen lines. Light transmission was measured by a light-depended resistor device called photoresistor, which changes its electrical resistance under the influence of radiation, in principle current flow. The device measures the amount of light transmitted through the specimen and converts it to current measured in milliamperes. A 100W bulb was used as a source of light. The examined object was placed in the wooden box to prevent unnecessary light coming out. The research showed that the greatest light transmission was achieved in specimens with the biggest plastic optical fibers density and the worst light transmission has been noticed in specimens with the smallest glass density of the glass tubes. The light transmission was greater in the case of plastic optical fiber concrete than glass tube concrete at the same time. The compression resistance results made on the specimens modified by the plastic optical fibers depending on their density amounted to 24,57-25,27 MPa. The resistance of the glass tubes using the cement to the concrete – class 52.5 – amounted to 20,7-22,2 MPa. Those results prove that various plastic optical fibers density has little influence on the resistance differences of the translucent concrete elements [11].

Similar experimentations aimed at creating a new development way of the discussed subject were carried out by Zhi Zhou, Ge Ou, Ying Hang, Genda Hen and Jinping Ou from the Universities of Technolgy in the USA and China. Concrete mixture used to make translucent concrete specimens was modified and cement was replaced by the epoxy, achieving resinous concrete. The epoxy is transparent and that is why a dye in form of an iron oxide was added to get the desired colour of the specimens. The transparency effect was achieved thanks to inserting the plastic optical fibers. The experimentations confirmed also the thesis of the Indian engineers that light transmission in concrete is completely determinated by the content of the plastic optical fibers and their density in relation to the area of the whole specimen. It was noticed that the result of the compression resistance research depends on the amount of the plastic optical fibers. It was also proved that by the density at the level of 5% of the plastic optical fibers the compression resistance reduction is about 10% in relation to the specimens not containing the plastic optical fibers. An additional research which has not been carried out is an analysis of the translucent concrete with the use of infrared rays. It was noticed that the coefficient of light transmission and infrared rays amounts to 0,529% – 0,535%, in relation to the level of the translucent concrete. It proves that the translucent concrete blocks conduct not only the light but also the thermal power [20].

In Poland it was M. Kurpińska who started research on translucent concrete production technologies with the use of the plastic optical fibers. She made translucent concrete specimens which contained plastic optical fibers having the 2.5% density and being 0,7-1,2mm in diameter. She also noticed that the said density enables good light conductance, where the element thickness does not matter. Furthermore, resistance of the translucent concrete blocks fits the boundaries 50–80 MPa [10].

The carried out translucent concrete experimentations allow to get to know better this innovative material which is about to revolutionize construction industry. Thanks to the most important feature which is ability of light transmission, it will be reliable as to reduce the energy consumption allowing more exposure with a natural sunlight. Moreover, this material will contribute to environmental protection and this is one of the most essential aspects concerning modern technologies not only in construction industry but also in other fields of knowledge.

PRODUCTION TECHNOLOGIES OF THE TRANSLUCENT CONCRETE DONE UP TO HOW AND ITS APPLICATION

Nowadays there are two production technologies of the translucent concrete. One of them relates to using plastic optical fibers as a transparent matrix which plays the role of the light transmitter. Light propagation occurs thanks to the phenomenon of total internal reflection. An optical impulse inserted into the plastic optical fibers breaks into a number of modes which are sent along the fiber axis. However, applying the plastic optical fibers the way Lasonczi suggested it to do, is connected with enormous translucent concrete production costs. It was the reason why a German engineer Andre Roye modified previously used technology and thanks to the pultrusion technology he created a transparent fabric which successfully replaced the previously used plastic optical fiber matrix. The new product's name is LUCEM. The production machine, material and its structure were presented in the figures 1 and 2 [14, 18].

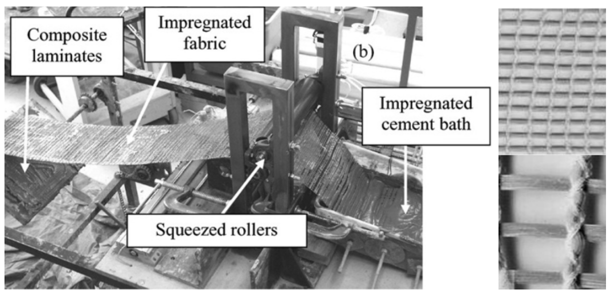

Fig. 1. Machine to the fabric production and the structure od the created material [14, 16]

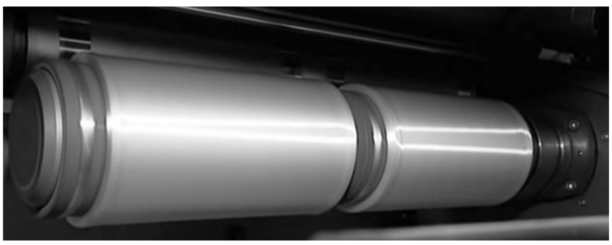

Fig. 2. Transparent fabric made by means of pultrusion [23]

This step allowed to considerably reduce production costs and enabled to produce the concrete on a larger scale at the same time. There were made elements in form of panels of 120x50 cm and thickness of 2 cm (Fig. 3), which were illuminated by LED panels to achieve the transparency effect. Unfortunately, the LUCEM panels are treated only as a decorative element which is installed on a removable construction. In view of that the main assumption of the translucent concrete concerning the object building where transparent walls allow more exposure and save energy was not fulfilled [16, 17].

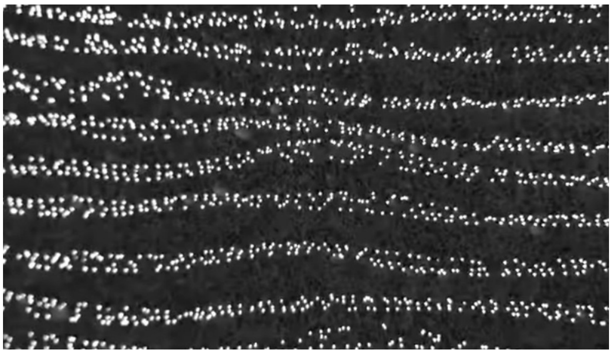

Fig. 3. Panel overexpose effect which was made of the translucent concrete LUCEM [22]

The second method of the translucent concrete production takes place with the use of transparent polymer plates PMMA which also has an ability of light transmission and are considerably cheaper from the plastic optical fibers. The structure of the created concrete was presented in the figure 4. This method was worked out by the Italian company Italcementi Group. In this technology the production of transparent and "light" panels being of 100x50 cm and thickness of 5 cm and weight of 50 kg, was launched [5].

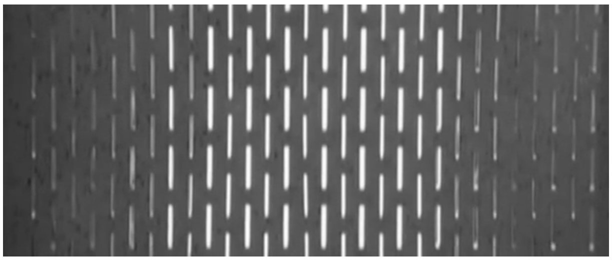

Fig. 4. Panel and "light" structure made of the translucent concrete [5]

Unfortunately, those panels are not used as removable elements to create construction walls of the buildings despite the fact, that their resistance is about 7.7 MPa. The pavilion World Expo 2010 in Shanghai was, indeed, built with the use of transparent panels but they lean against the steel removable construction. The biggest advantage of this technology is the possibility of achieving more exposure of the inside of the object using the daylight, what reduces energy consumption at the same time [5].

Nowadays the translucent concrete works well in lots of architecture and decoration areas by creating new architectural forms. One of them is furniture which become very effective in the connection with the discussed concrete. The translucent concrete can replace for example glass top of the table which is an impractical solution because it can easily break. Translucent concrete can be also successfully used as fragile ceramics or as finish material to the walls and floors. Partition walls made of the translucent concrete also create a fantastic effect what is presented in the figure 5 [2].

Fig. 5. Wall made of the translucent concrete Litracon [21]

Continual experimentations aim at the possibility of using this innovative material not only for decorative purposes but also as a construction concrete. Building even a few meter high wall should not be a problem in the coming years. The discussed material can be a good solution in the places where lots of objects were planned to be built near each other on a small area. The sunlight supply is straitened and thanks to the translucent concrete the amount of sunlight coming into objects can increase. Also in the later exploitation the use of an electrical energy with the purpose of more exposure for the rooms will be reduced. It can become a future material in the connection with the passive or energy-saving house building technology [6, 2].

Thanks to the translucent concrete will be also possible the thermal comfort improvement of the buildings. In the case of windscreen, the infiltration coefficient, which informs about the amount of light energy going through the windscreen to the room in form of warmth, is a very problematic parameter. It is hard to match such a factor so that the rooms do not overheat in summer and that the suitable amount of natural sunlight could come into the rooms in winter. This situation gets more and more complicated in places where there are high temperatures on the day and almost zero temperature at night. Translucent concrete resolves this problem in some way because it allows more exposure of the rooms and, thanks to its structure, protects them from overheating. It is also a material which cannot be easily broken, what cannot be said about glass. When it comes to our privacy, the translucent concrete is not fully transparent so it can be applied in the rooms where plastering the windows cannot be done [9, 4].

Thanks to the translucent concrete heavy, grey, concrete and unfriendly for the inhabitants buildings are a thing of the past. The panels or prefabricated elements made of the translucent concrete are new opportunities for architects, and an innovative attitude to the light, concrete and space creation have already gained lots of recognition. The innovative concrete can give lightness to the buildings, make them lose the sturdiness andartificiality, and cause, that they will better compose with the nature. Even the insides, especially the minimalist ones, can gain new glamour and enjoy unknown up to now visual effects. The concrete transmitting the light has already revolutionized the construction industry, replacing 20th century glass bricks, and it is only the beginning of its application. It is a new building material to which lots of people were skeptically oriented, but as time goes by, the opponents will become convinced that innovative attitude is a good solution.

COMPRESSION RESISTANCE RESEARCH OF THE TRANSLUCENT CONCRETE

The white concrete CEM I 52,5R was used to make a concrete mixture what enabled the exact and even concrete tinge with the black dye, which was added during one of the production stages of the concrete mixture.

In relation to the characteristics of the concrete mixture and its later application it was necessary to use fine-grained aggregate of the graining of 4mm and of the sand content of PP=86%. To get the appropriate concrete mixture consistency it turned out to be necessary to add superplasticizer. It caused the better workability what was very important considering the concrete arranging characteristics. Concrete was designed by the experimental method [3, 7, 8, 13]. Concrete composition was presented in the table 1.

Table 1. The amount of components in 1m³ of concrete

Components	kg/m³
concrete	453,0
water	216,6
fine-grained aggregate	1666,0
plasticizer	4,27
die	27,2

From the designed concrete there were specimens in form of tubes of 40x40x160mm. the specimens were made with and without adding plastic optical fibers. There were used polymer and unimode plastic optical fibers, which shine of their ends of 1.5mm in diameter. The plastic optical fiber density was 3.2% and the distance between the fibers was 5mm.

To make the translucent concrete specimens it was necessary to design new forms which would enable applying the plastic optical fibers (fig. 6). There were used traditional, standard tube forms of 40x40x160mm, where the dividers were replaced by the styrodur elements. Thanks to such solution it was possible to apply durably the plastic optical fibers. Also the stage of disbanding the specimens was not a problem what was presented in the figure 7.

The compression resistance research was carried out after 28 days of specimens' ripening in laboratory conditions based on PN-EN 206-1 [15]. The following specimens were examined:

– fine-grained concrete specimens which were not modified by application of the plastic optical fibers – series B
– fine-grained concrete specimens where the plastic optical fiber density in relation to the side area of the specimen was 3.2% – series A_1 and A_2. The compression resistance research on the specimens containing plastic optical fibers was carried out in two ways. One of them was such specimen arranging so that the compression power works parallel to the direction of plastic optical fibers placing in the balks (series A_1). The second method was to place the specimens in such way that the compression power works perpendicularly to the direction of plastic optical fibers placing (series A_2). The results were presented in the table 2 and graphically illustrated in the figure 8.

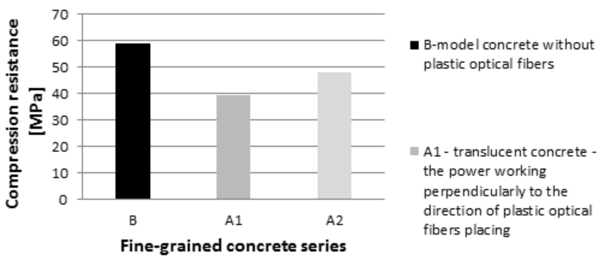

Fig. 8. Average concrete compression resistance

A control concrete – series B, obtained average compression resistance of f_{cm}=59.2 MPa. Series A_1 where the compression power worked parallel to the direction of plastic optical fibers placing, obtained average compression resistance of f_{cm}= 36,5 MPa. However in series A_2, where where the compression power worked perpendicularly to the direction of plastic optical fibers placing, obtained average compression resistance of f_{cm}= 48,0 MPa. In both cases there was drop of the average compression resistance of the translucent concrete in relation to the analogous concrete

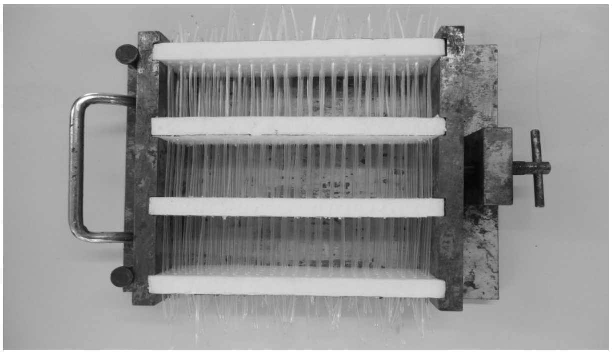

Fig. 6. Modified forms to make the translucent concrete specimens

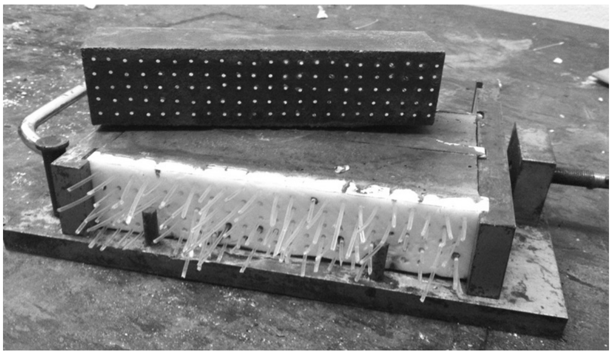

Fig. 7. Concrete specimen after disbanding

Table 2. Results of the compression resistance research

Series		A_1- the power working parallel to the direction of plastic optical fibers placing	A_2-the power working perpendicularly to the direction of plastic optical fibers placing	B
Compression resistance [MPa]	I	37,3	49,4	59,4
	II	34,0	47,5	57,5
	III	35,8	52,3	59,4
	IV	38,9	40,6	60,6
	V	37,6	49,6	59,4
	VI	35,5	48,7	58,7
Average value		**36,5**	**48,0**	**59,2**

without adding plastic optical fibers. What decides about this drop is the application direction of the compression power in relation to fiber placing. The feature of the destruction of the translucent concrete specimens was presented in the figure 9.

The average compression resistance of the concrete of the series A_1 (the compression power working parallel to the direction of plastic optical fibers placing) decreased by 38.3% in relation to the concrete without plastic optical fibers. Analogously for the concrete of series A_2 (the compression power working perpendicularly to the direction of plastic optical fibers placing), the average compression resistance of the concrete decreased by 18.9%.

USING THE TRANSLUCENT CONCRETE AS A DECORATIVE ELEMENT IN FORM OF THE LAMP

As it was said earlier, the discussed concrete can have various application, it can be also used to make objects of everyday use. To prove this statement, there was build such a decorative element in form of the lamp (fig. 11). It consists of transparent concrete blocks made in the technology with the use of plastic optical fibers. There were designed special forms entirely made of styrodur. Thanks to such solution it was possible to apply durably the plastic optical fibers. Also the stage of disbanding the specimens was not a problem what was presented in the figure 10.

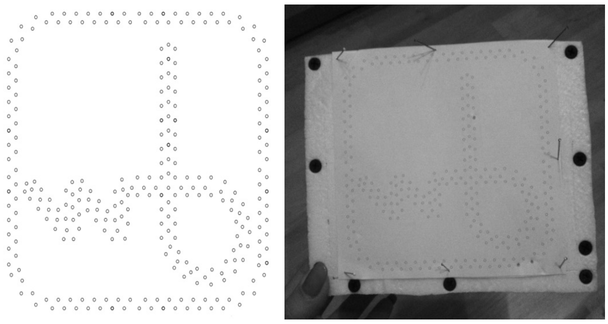

Fig. 10. Project of the plastic optical fibers placing made to create the logo of the faculty of Civil Engineering of Czestochowa University of Technology

The blocks forming the lamp were connected with polymer, transparent concrete glue. To achieve the overexposure effect and present the transparency ability of concrete elements, there was applied electrical system. Is consisted of LED belt, adapter and wires, which enable to connect the lamp with the current source. The lamp is controlled with the help of a remote control, thanks to which there is a possibility to choose any light sequences. The discussed material can be successfully joined with wood, metal or ceramics, enhancing the spectacular light effect of the translucent concrete at the same time.

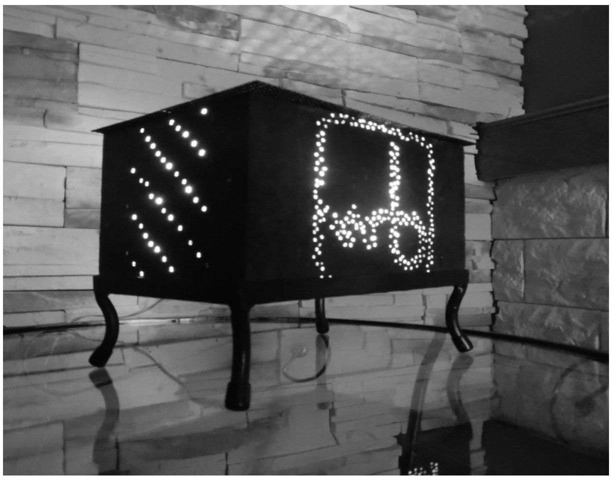

Fig. 11. decorative element in form of the lamp made of the translucent concrete

a) b)

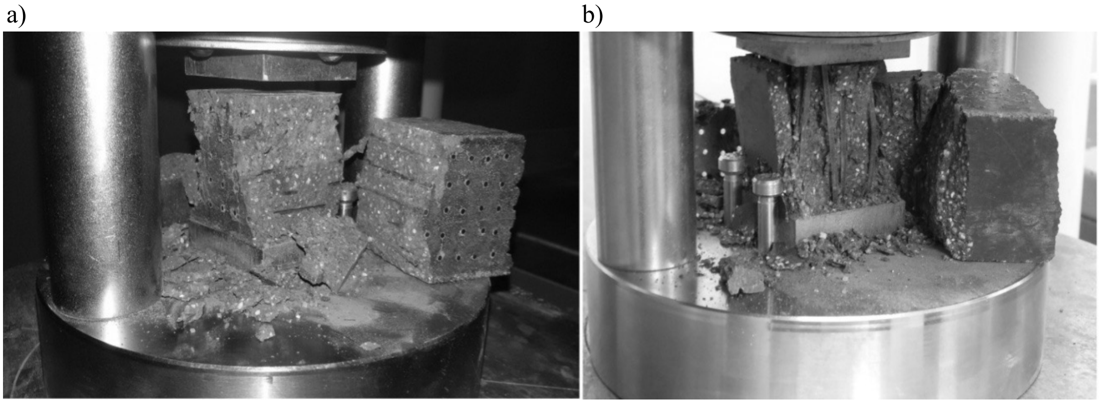

Fig. 9. Destruction of the translucent concrete specimens: a) the compression power working perpendicularly to the direction of plastic optical fibers placing, b) the compression power working parallel to the direction of plastic optical fibers placing

CONCLUSIONS

On the basis of this analysis it can be concluded that:

1) The compression resistance research carried out on the translucent concrete specimens proved that it is highly important, how are the plastic optical fibers placed in the compressed element.
Despite of lowering the compression resistance of the translucent concrete in relation to the model specimens, it has such a good resistance, which enables to use the said concrete as a construction material.
2) Nowadays translucent concrete is used as a material to create elements of everyday use or decorative objects. The example is a decorative element in form of the lamp.
3) The discussed material is not widespread in the country, the cause mostly being economic reasons, and precisely – the high prices, what makes it impossible to apply the translucent concrete on a larger scale. However, the modification of the one of the production technologies and reducing the costs can solve this problem.

REFERENCES

1. **Bhavin K., Raina V., Pitroda J., Shah B., 2013:** A study on Transparent Concrete: A Novel Architectural Material to Explore Construction Section. International Journal of Engineering and Innovative Technology, Gudźarad (Indie).
2. **Bosh C**., **2008:** Beton in vollig neuen Licht. Die Baustellen, Niemcy.
3. **Halbiniak J., Langier B, Rajczyk J., 2012:** Technologia kompozytów betonowych laboratorium i w praktyce. Wyd. Pol. Częst., Częstochowa.
4. **Frei J.,2008**: Lichtblicke. Weekend Magazin Vorarlberg, Berlin.
5. **Giovanni Mainini A., Poli T., Zinzi M., Cangiano S.,2012**: Spectral light transmission measure and radiance model validation of innovative transparent concrete panel for facades. Energy Procedia, Mediolan.
6. **Heidrun J., 2007:** Gelungener Licht – Streich. Echo nr 10, Berlin.
7. **Jamroży Z., 2005**: Beton i jego technologie. Wydawnictwo Naukowe PWN, Warszawa.
8. **Johnson D., Prasanthi K, Pasha A., Bhushan P., 2013:** Optical Fibres In the Modeling of Translucent Concrete Blocks. Vaddesvaram (Indie).
9. **Kamdi A., 2013**: Transparent concrete as a green material for building. Hajdarabad (Indie).
10. **Kurpińska M., 2013:** Możliwości wykorzystania betonu. Politechnika Gdańska, Wydział Inżynierii Lądowej i Środowiska, Gdańsk.
11. **Momin A. A., Kadiranaikar R. B., Jagirdar V.S., Inamdar A.A., 2014:** Study on Light transmittance of concrete using optical fibers and glass rods. Karnataka (Indie).
12. **Nagdive N., Bhole S., 2013:** To evaluate properties of translucent concrete. International Journal of Engineering and Innovative Technology, Gudźarad (Indie).
13. **Neville A.M., 2012:** Właściwości betonu. Polski Cement, Kraków.
14. **Peled A., Cohen Z., Pasder Y., Roye A., Gries T., 2007:** Influences of textile characteristic on the properties of warp knitted cement based composites. Cement&Concrete Composites, Aachen.
15. **PN-EN 206-1:** Beton. Wymagania, właściwości, produkcja i zgodność.
16. **Roye A., 2012**: Der Charme der Transparenz. Forschung 4/2012, Weinheim.
17. **Roye A., Barle M., 2011:** Luccem Lichtbeton, Aachen.
18. **Roye A., Barlé M., Gries T.,2009:** Faser- und Textilbasierte Lichtleitung in Betonbauteilen. Schaker Verlag, Aachen.
19. **Soumyaji P., Avik D., 2013**: Transculent concrete. Departament of Civil Engineering, SRM University, Kattankulathur (Indie).
20. **Zhou Z., Ou G., Y. Hang, G. Chen, J. O, 2009:** Research and Development of Plastic Optical Fiber Based Smart Transparent Concrete. Gudźarad (Indie).
21. http://journal.pl/architektura/74/litracon-beton-transparentny/zdjecie/9.
22. http://lucem.de.
23. https://www.youtube.com/watch?v=Zf45wS_JxO0.

BETON TRANSPARENTNY JAKO MATERIAŁ BUDOWLANY XXI WIEKU

Streszczenie. Artykuł przedstawia efekty badań i rozważań nad zdobywającym coraz szersze uznanie w dziedzinie budownictwa materiałem, jakim jest beton transparentny. W celach badawczych wykonano próbki z betonu zawierającego włókna światłowodowe oraz przeprowadzono badanie wytrzymałości na ściskanie. Określono wpływ światłowodów na cechy wytrzymałościowe betonu. Przedstawiono dotychczasowe wykorzystanie betonu transparentnego oraz możliwości jego zastosowania w przyszłości.

Słowa kluczowe: beton transparentny, beton modyfikowany włóknami światłowodowymi, beton przepuszczający promienie świetlne.