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Analysis of Transparent Concrete as an Innovative Material Used in Civil Engineering

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Abstract. Since the dawn of history concrete has been, right behind stone and brick, one of the oldest building materials. The ancient Romans took advantage of its opportunities. They constructed amazing architectural objects, which survived centuries as whole buildings or parts of them. Concrete is so ubiquitous, that when we are walking in a newer districts of cities we are virtually surrounded by concrete from everywhere. Sometimes we do not realize in how many cases and various ways concrete is used in towns and cities. As we know, human curiosity and quest for newer and newer solutions and capabilities does not leave such amazing material as concrete alone. There are many varieties of concrete, depending on what people want to achieve. By changing its chemical composition, technological process and adding various other materials, we receive various types of concrete. We use them to create durable supporting structures, a variety of concrete which is resistant to constant moisture or different chemical types. Additionally, some aspects of aesthetics in architecture are made with the help of concrete.

1. Introduction

The aim of this paper is to analyze and describe one of the particular types of architectural concrete – translucent concrete. This material is becoming more popular due to its unusual properties. Its high strength and transparent character are related with aesthetic value of concrete. Several examples of applications of this material are shown in the paper. The origin, properties and problems of using this material are broadly described.

Architecture is much more than just erecting buildings. It is about creating spaces through the proper shaping of the forms and the relationships between them. Architects express both feelings and emotions through their projects. Architecture is certainly one of the oldest types of art departments. Since people left caves, they have started building shelters. Later on they began to take care of appearance of their places of living, transforming ordinary buildings into works of art. Construction technologies and building materials have been developing for a very long time and very quickly. A construction material which is constantly being modified in order to improve its properties is concrete. Tendencies shaping its quality and development are described in numerous scientific papers [1-3]. The strength of concrete, its durability and usability are systematically modified so that the buildings made in this technology can be higher, with larger span, and prolonged period of their use. Although it seems that theoretically everything that a man could build has already been invented, yet new possibilities are still emerging. One of the ideas is to create a material with a bearing capacity of concrete and translucency of glass. The composition and technology of such a material and possibilities of its usage were created by a Hungarian designer Aron Losonczi. His purpose was to obtain a construction material with transparent properties of glass. The combination of conventional concrete with a very expensive and technologically advanced fibre-optic material resulted in an amazing effect. The only one, but unfortunately very big disadvantage of this material is the price, which has limited its spread and narrowed the field of applications which are available only for the richest.

2. Origin and development of Litracon

Concrete is a composite made from aggregate, water and binding agent which is cement. By using certain additives concrete parameters can be changed in order to obtain a specific texture, desired weight, bearing capacity or colour. Currently concrete is the most popular building material. Annually about 5 thousand Articles [4] on concrete are published every year. This is primarily due to the possibility of developing different forms. In addition, concrete as a building material has very good load-bearing parameters which affect the variety of applications in different structures. The first use of concrete dates back to Roman times. One of the largest ancient structures made from concrete is the Pantheon's dome which is over 43 meters in diameter, weighing more than 5,000 tons. The history of concrete development as a building material and types of structures which can be created from concrete shows Figure 1.

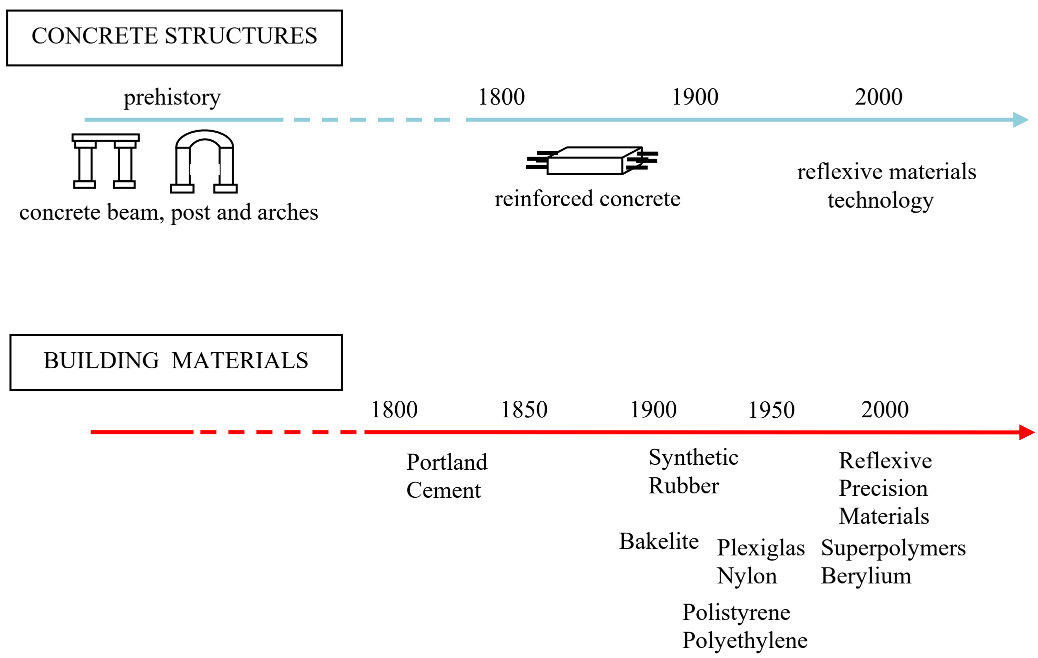

Figure. 1. Scheme of development of concrete structures and building materials [1]

In order to cover buildings with significant spans and to increase the pressure resistance, concrete reinforcement bars were added to concrete structures. These bars are intended to transfer tensile forces.The combination of both materials allows to create structural components that are resistant to compression, stretching and bending (Figure 2). Waterproof concrete is a type of concrete which is resistant to temporary or constant influence of water. There are several classes of these concretes depending on their waterproofness. It is important that the mixture of these concretes is as dense as

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possible and that the aggregate is fine and uniform.Waterproofness itself depends on the porosity of the concrete. Abrasion resistant concrete as the name suggests is the concrete resistant to abrasion. There are two types of this concrete: resistant to abrasion with flat surfaces (cars, pedestrians) and resistant to abrasive materials (any small particles of hard materials, sand). Another type of concrete is hydrotechnical concrete. It can be said that hydrotechnical concrete is a combination of two types mentioned above. It must be resistant to both water and abrasion. Mixes of these concrete are prepared individually depending on the environment in which they are supposed to be used. Fireproof concrete is mainly used for the construction of flue chimneys, central heating boilers, escape staircases in objects particularly exposed to fires. Standard concrete loses its bearing properties at temperatures over 200-300 degrees, which is a relatively low temperature during fires. Fireproof concretes can withstand temperatures up to 700 degrees, but they must be made of high-quality materials, which significantly raises their costs. Shielding concrete is used to separate the areas with radioactive radiation. It is used at nuclear power plants and in laboratories, where radiation experiments are carried out. These material is created for specific situations and the type of radiation for properly select the components and methods of production this type of concrete should be known.

Figure 2.Example of reinforced concrete construction

One of the more modern types of concrete is translucent concrete. This concrete is made from a combination of transparent materials and concrete. Light transmitting elements must be located over the full thickness of the finished concrete element. Special layouts can create different light areas, depending on your needs.Translucent concrete has been invented recently. New versions of this material are constantly being developed. Various types of translucent materials such as plastic, glass or even fibre optics are used.

The creator and originator of transparent concrete is Aron Losoncz, a Hungarian architect, graduated from Royal College of Fine Arts in Stockholm. While studying, he experimented with two fundamentally different materials: concrete and glass. He tried to obtain a material that would combine the characteristics of the two components: glass transparency and the load bearing capacity and structural properties of concrete. In this way, transparent concrete was created. The main inspiration were artistic works Aron found during his studies. There were drawings which showed objects with characteristics similar to that of today's transparent concrete. In 2001 the young architect patented his work as a new building material called "Litracon" (short for "light-transmitting concrete"), [5].

3.Characteristics of Litracon

It would seem that creating material with properties like Litracon could revolutionize modern architecture.Of the same opinion was the young creator who was fully convinced that his invention would have a significant impact on the world of architecture. But he was wrong.The high cost of materials made its usage very limited. Nowadays, few objects have been made in this technology and it is old enough to be known in the whole world.In 2006 the architect got one of the most important awards in the field of design - the RedDot Design Award. After this event it was almost obvious that the material would be applicable but had encountered several obstacles in its path.

Table 1. The pros and cons of Litracon

ADVANTAGES	DISADVANTAGES
• resistant of compression - 50 N/mm^{2}and bending - 7 N/mm^2 • blocks may have different dimensions (even 30 x 60 cm) • may be construction material which allows to build several meter high walls with light transmitting • changes in the intensity of light, referred as "light information", are transferred from the brighter side of the wall to darker side without major changes (including colour), due to the parallel arrangement of the fibres • reduction of energy due to the penetration of daily light into the object	• compressive strength is classification as standard • square meter thickness of 2.5 cm costs about 750 euro • available only in the form of ready, it can't be made on the building site

The biggest disadvantage of the new material was its cost. Producing a square meter which is only 2.5 cm thick costs about 800 euros. Apart from the price, the problem was a crisis that could be observed in the economy in the years when material was invented and developed. But that was only the beginning; some time later Aron created a concrete called Litraconp XL whose composition and manufacturing process allowed for significant cost reduction. There is a chance that translucent concrete will replace luxfer tiles used in architecture today. Transparent concrete can be used as a structural element and it contains between 2.5% and 4% of fibre optics in its volume [5].In this case, using standard concrete mix was obtainconcrete with a density of 2100-2400kg/m^3, compressive strength and tensile strength of 50-80MPa and bending strength of 7MPa [6].

4. Optical fibres used in blocks of Litracon

Optical fibre is a closed fibreglass structure that is capable of transmitting light information within its structure at a speed of light for huge distances. Fibre optics are used in many areas of life, in medicine, communication, decorative techniques, lasers, etc. The fibre, in which information is transmitted, slightly exceeds the diameter of a human hair. The essential feature of the fibre is that no matter how it is arranged, how many bends and changes of direction there are, it does not lose any amount of energy that has been applied to one of its ends. In short, the amount of energy coming into one end goes out from the other one. When creating translucent concrete, no translucent plastics or glass are a real match to the fibre since they lose light energy at every curvature and bend. Fibre optics proved unrivalled as far as quality is concerned. However, the price has verified this material. It can be wonder why in telecommunications there is no problem using so expensive material but in case of creating Litracon it is. When it comes to building entire communication installations, the cost of using fibre optics is marginal because the installations themselves are so expensive that the use of optical fibre does not constitute a high price increase and greatly improves the efficiency of the installation. However, in building materials, the combination of cheap concrete with expensive fibre makes the price increase several times.

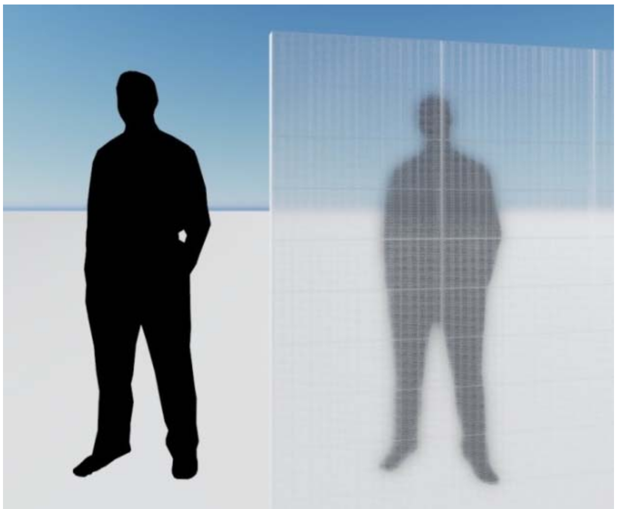

Figure 3. Transparency scheme of Litracon.

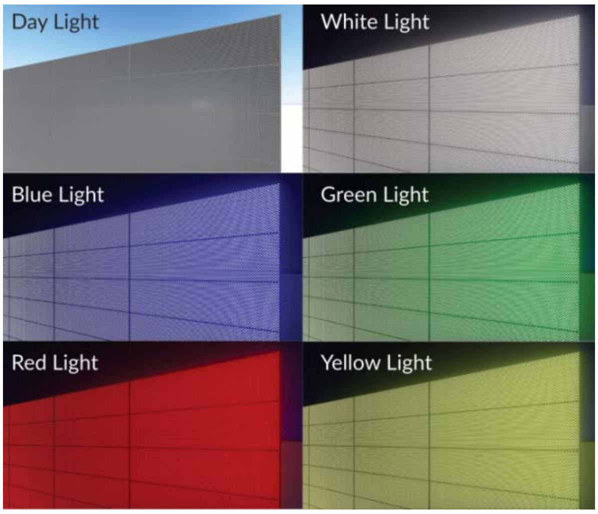

Figure 4. Lighting scheme of Litracon.

The fibre optic construction is shown in Figure 5-6. Single fibre consists of core - this is the internal and most important part of the fibre, it transfers all the information from the transmitter to the receiver. The diameter of this element is very small (5 to 100 microns). Cladding is the material that surrounds the core. Its light reflecting capacity is lower which allows the light to stay in the core and flow freely over the length of the connection. Buffer coating is a plastic rubber sheath which protects the fibre from mechanical damage[7-8]. The totalthickness of the fibre is between 250 and 300 microns.

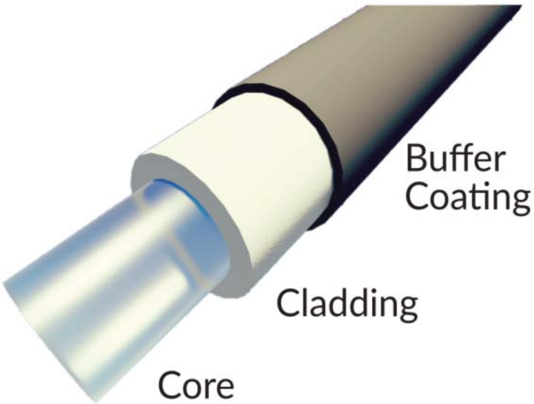

Figure 5. Scheme of the fibre optic construction

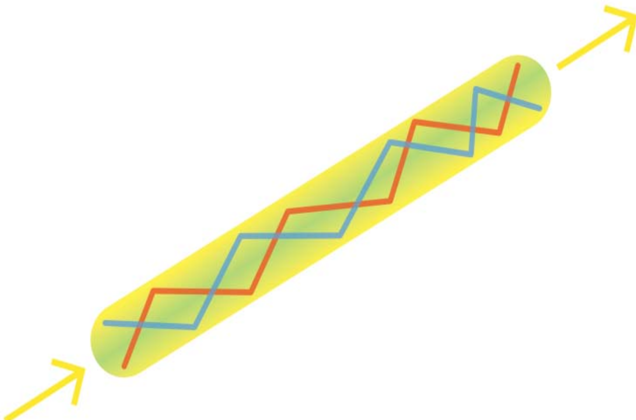

Figure 6. Diagram of optical signal transmission in fibre optics

5. Examples of using Litracon

Transparent concrete is used in elements on which the light has specific influence.It is used in eg. partition walls, shower cabins, stairs, floors between tiers (with good illumination of the building) and in smaller objects such as lamps, garden benches, garden walls or small architectural elements.The effect of transparent concrete can be compared to the partition walls using rice paper in Japanese architecture.You do not see exactly what or who is on the other side, but you can see the black outline of an object or a character (Figure 3) .The thickness of the concrete does not play any role here apart from its bearing capacity. Optical fibres will pass the light through the concrete with the same intensity no matter whether the thickness is 500mm or 25mm.Additionally, because it is concrete,ornaments or building elements in various shapes on their own discretion could be modelled.

a) b) c)

Figure 7. Examples of using Litracon: a) Italian Pavilon at the Shanghai Expo in 2010 [9], b) Litracon lamp [10], c) Europe Gate in Hungary [10]

One of the most interesting Architectural Exhibitions with Litracon is the Italian Pavilion at the Shanghai Expo in 2010 (Figure 7a). The facility covers an area of about 3,600 square meters and is 18 meters high. The interior is divided into irregular sections of different dimensions.Only in certain places (as seen in the picture above) transparent concrete was used. The rest of the structure is made of ordinary concrete blocks of the same color as transparent concrete. By day the building is not outstanding in any way (except for the form),however, after dark shows its second face.Much smaller implementation is the Europe Gate of 2004, which symbolizes the accession of Hungary to the European Union (Figure 7c).A manufacturer of Litracon has in its offer lamps made with this material (Figure 7b).

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6. Conclusions

Concrete could give countless creative possibilities. Several millennia ago people knew this and are constantly developing their knowledge in this scientific field. Concrete is a great material not only for construction purposes, but also has great artistic potential. The simplicity of its construction, relatively low price (unless we talk about the concrete with expensive additives), the possibility of giving the mould any desired shape, gives concrete a great advantage over other building materials. So why not delve deeper into the subject and look for new solutions and possibilities. As far as Litracon itself is concerned, the impression is that the world is not yet ready for the Hungarian product. This material can be used in many ways, in many variants, despite its high price. It gives the possibility to illuminate the interior while preserving privacy which cannot be obtained with conventional glass. Additionally, it can be used as a constructional element. So far the only solution for Litracon is to try to change its properties, mainly by replacing fibre optics with glass (plastic did not give such a great effect). So architects and constructors need to focus mainly on creating a quality alternative to a fibre optic with a lower price or to try to find a solution for cheaper fibre optic production. Otherwise, such a great product can go away into oblivion.

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