

## **Application of Transparent Concrete in the interior design of smart houses**

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### **Abstract:**

Just a few decades ago, concrete was often misunderstood, and captured by its image fixed due to the rapid urbanization of the 1960s. However, since that time, scientists have made considerable progress on concrete, not only in technical terms, but also in aesthetic terms. It is no longer the heavy, cold and grey material of the past; it has become beautiful, colored, more resistant and lively.

In 2001, the architect Aron Losonzi first put the concept of transparent concrete forward, and the first transparent concrete block successfully produced by mixing large amount of glass fiber into concrete in 2003, which can allow 80% light through and only 30% of weight of common concrete. While the transparent concrete mainly focuses on transparency and its objective of application pertains to green technology and artistic finish. Lower energy is commonly associated with buildings whose forms are directly determined from local climatic conditions while those buildings with sophisticated and complex systems are routinely seen as energy hogs, Smart materials are presumed to be direct and discrete substitutes to deliver the elusive solution to the intractable problem of ever increasing energy use by building systems.

This research will highlight the transparent concrete development, and using it in the smart houses interior design, rather than restricting their use to external architecture, to enhance the functional, technical, environmental and aesthetic side as well; it will discuss the relationship between the environment and this new material.

### **Keywords:**

Transparent Concrete – Optical Fiber – Smart materials – Interior design – Smart house – Energy – Environment – Eco-friendly – Decorative elements – Light transmission.

### **Statement of the problem:**

- 1- Consuming huge amounts of energy in houses because of using traditional materials instead of using smart alternative materials.
- 2- The need to use materials with an increasing range of applications to solve energy problems, provide an opportunity for new wealth creating products and investigate the important role in interior design sustainability.

### **The research objective:**

- 1- Focusing on transparent concrete as a smart material that combines the characteristics between flexibility, form and function in terms of practical and environmental, and not only using it as an architectural material but also using it in smart homes interior design.

- 2- Linking the use of smart materials and the possibility of energy conversion for introducing better interior design to modern homes that makes them more convenient and comfortable and energy saving.
- 3- Using a special type of concrete with light transmitting properties, to study its characteristics and to develop a functioning material which is not only energy saving but gives out artistic finish.

### ملخص البحث: Abstract

على مر العقود السابقة اعتبرت الخرسانة خامة جافة مكروهة وغير جمالية، وذلك نظرا للتوسع الحضاري الكبير في نهايات القرن الماضي، إلا أنه منذ عام 1960 بدأ العلماء في إجراء بعض التطورات على الخرسانة، لكي تتحول الخرسانة من تلك الخامة الرمادية الثقيلة الباردة، إلى خامة حيوية مستدامة ذات ألوان متعددة.

في عام 2001 كان المعماري "أرون لوسونزي" أول من طرح مفهوم الخرسانة الشفافة، ثم تم إنتاج أول كتلة خرسانية شفافة بنجاح عن طريق خلط كمية كبيرة من الألياف الزجاجية إلى الخرسانة عام 2003، وزن تلك الكتلة كان 30% فقط من وزن الخرسانة العادية، كما كانت تسمح بمرور 80% من الضوء، وقد اهتمت الخرسانة الشفافة في الأساس بتحقيق مبدأ الشفافية بهدف تحقيق جانبي الشكل من خلال الحصول على تصميمات جمالية، والوظيفة من خلال تطبيق التكنولوجيا الخضراء بهدف توفير الطاقة وحماية البيئة، حيث يرتبط انخفاض استهلاك المباني للطاقة بتوافقها تصميميا مع الظروف المناخية والبيئية المحلية، على عكس المباني ذات النظم المعقدة غير المتوافقة مع البيئة والتي تعتبر مصدراً سلبياً لهدر الطاقة، ويفترض أن تكون المواد الذكية بديلاً مباشراً ومتبائناً لتقديم الحل بعيد المنال للمشكلة المستعصية المتمثلة في الاستخدام المتزايد للطاقة من خلال أنظمة البناء.

وسيتناول البحث بالدراسة تطور الخرسانة الشفافة، واستخدامها في التصميم الداخلي للمنازل الذكية بدلا من اقتصار استخدامها على العمارة الخارجية فقط، وذلك بهدف تعزيز الجانب الوظيفي والتقني والبيئي والجمالي، بالإضافة إلى مناقشة العلاقة بين البيئة وهذه الخامة الجديدة.

### الكلمات الدالة

الخرسانة الشفافة - الألياف البصرية - الخامات الذكية - التصميم الداخلي - المنزل الذكي - الطاقة - البيئة

### مشكلة البحث:

ارتفاع استهلاك المباني للطاقة، مع عدم الوعي بخامات ذكية بديلة يمكن استخدامها في التصميم الداخلي للمنزل عوضا عن الخامات التقليدية.

### أهداف البحث:

- 1- التركيز على خامة ذكية تجمع في خصائصها بين المرونة وتحقيق الشكل والوظيفة من الناحية العملية والبيئية وهي الخرسانة الشفافة، والخروج من نطاق استخدامها في العمارة والبناء إلى مجال التصميم الداخلي في المنازل الذكية.
- 2- ربط استخدام المواد الذكية بتوفير الطاقة بهدف الحصول على تصميم داخلي في المنازل الحديثة يجعلها أكثر ملاءمة وراحة وتوفيرا للطاقة.

وقد خلص البحث إلى أن الخرسانة الشفافة كمادة ذكية يمكن تطبيقها على نطاق واسع في مجال التصميم الداخلي، مما يمكنها من حل مشاكل الطاقة وتوفير فرص لابتكار أفكار جديدة مستدامة.

**The research Postulation:**

The research assumes that it is possible to use the translucent concrete in the interior design of the smart houses, to take the advantages of this durable, sustainable, versatile and economical material to enhance its functional, technical, environmental and aesthetic side.

**The research importance**

Transparent Concrete is used in fine architecture as a facade material. In this research, to integrate the merits of concrete and optical fiber, for developing transparent concrete.

To use it in:

- 1- The smart homes' interior design, as a light semi-transparent material for interior walls cladding and partitions. In order to use sunlight as a light source to reduce the power consumption of illumination
- 2- The smart home furniture and decorative elements as a lightweight sustainable material for good aesthetical view of the house, and in sustainable purposes.
- 3- Solving the energy problems and providing an opportunity for new wealth creating products and could have an important role in interior design sustainability.

**Research Axes****First Axis: Theoretical Framework****Introduction:**

An important part of interior design is recognizing the specification of suitable materials for the various components that make up a particular interior space.

Using a sustainable, durable, environmental and cheap interior material is an important issue, to reduce the flow of non-renewable resources into interior materials and pollutants from interior materials throughout life cycle of interior materials. To improve indoor air quality and achieve human comfort. <sup>(4)</sup>

Smart materials will help in achieving these objectives, provide an opportunity for new wealth creating products and could have an important role in sustainability architecture and interior design. This research will discuss the development of the new sustainable material “transparent concrete” to use it in different interior design applications. In order to improve existing technology, add new functionality to products and develop the house aesthetics. <sup>(3)</sup>

**1- Research Terms**

**Concrete:** is a material from construction field, which is one of the most important civil engineering materials with the advantages of rich raw materials, low cost and simple production process. <sup>(6)</sup> consists essentially of a binding medium, such as a mixture of Portland cement and water, within which are embedded particles or fragments of aggregate, usually a combination of fine and coarse aggregate. <sup>(7)</sup> The figure (1) shows these components.



Figure 1 Concrete components.

**Optical Fiber:** is a material from sensing field, has a good light guiding property which can be arranged to transmit the sun light or the artificial light according to pre-design road without light-heat, light-electrical or photochemical process, and photo elastic effect.<sup>(6)</sup> Fiber optics are long, thin strands of very pure glass, about the size of a human hair. They are arranged in bundles – figure (2) – called optical cables. In addition, used to transmit signals over long distances.<sup>(22)</sup>

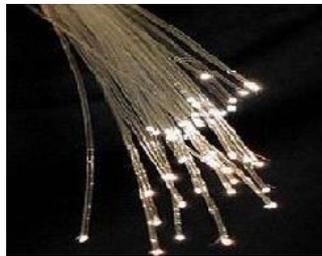


Figure 2 optical fiber bundles

Optical fibers have three main parts as shown in figure (3):

- **Core:** is a thin glass center of the fiber in which the light travels.
- **Cladding:** is the outer optical material surrounding the core, which reflects the light back into the core.
- **Coating:** is a plastic coating protecting the fibers from damage and moisture.<sup>(11)</sup>

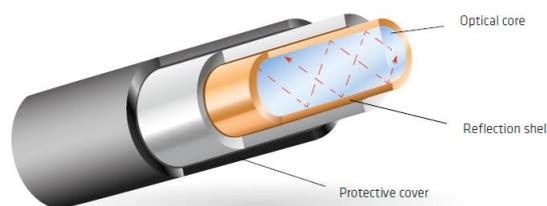


Figure 3 shows the different parts of optical fibers

**Smart materials:** are designed materials that undergo changes in one or more of their properties (chemical, electrical, magnetic, mechanical, or thermal) in a direct response to change in external stimuli in the surrounding environment<sup>(18)</sup>. In order to affect the internal energy of the material by altering the material's microstructure and the input results in a property change of the material, this process does not alter the material, but the energy undergoes a change.<sup>(4)</sup>

**Interior design:** is the creation of interior space enclosed by walls, ceilings, and floors with such openings as windows and doors — it often reflects how people work and live in their

spaces, by supporting the function, aesthetics, and cultures of those who work, inhabit, live, and thrive in interior spaces.<sup>(21)</sup>

**Smart house:** is a residence place equipped with smart materials, multi-functional furniture, computing and information technology, which anticipates and responds to the needs of the occupants, working to promote sustainability, comfort, convenience, security and entertainment.<sup>(4)</sup>

**Environment:** is the circumstances, objects, or conditions by which one is surrounded, and it is the complex of physical, chemical, and biotic factors (such as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determine its form and survival.<sup>(9)</sup>

**Transparent Concrete:** is a concrete-based material with light properties due to embedded Optical fibers, light is conducted through the stone from one end to the other. Therefore, the fibers have to go through the whole object. Transparent concrete is also known as the translucent concrete and light transmitting concrete because of its properties.<sup>(6)</sup>

## 2- Transparent concrete Composition:

There are several potential types of mixtures to compose translucent concrete.

- **The first approach** is to exchange the traditional ingredients with transparent or translucent alternatives. Pieces of plastic or glass can be used as aggregates, and the binding agent can be switched with a type of transparent glue.
- **The second approach** is the combination of fine concrete and optical fibers that allow light to transmit from one side of a block to the other.<sup>(16)</sup> Combining the advantages of the concrete and optical fiber, developing a new functional material called transparent concrete has an important value in different fields.<sup>(6)</sup>

## 3- How transparent concrete works:

Transparent concrete is working Based on “Nano-Optics”. Optical fibres passes as much light when tiny slits are placed directly on top of each other as when they are staggered. Principal can carry because optical fibers in the concrete act like the slits and carry the light across throughout the concrete.<sup>(6)</sup>

## 4- Transparent concrete characteristic

- Translucent concrete is a waterproof material; it can be installed in both outdoor and in damp indoor environments<sup>(1)</sup>.
- A material with heat insulating properties; it has a High freeze-thaw resistance that protects against outdoor extreme temperatures, so it'll be very effective in cold countries, thereby minimizing energy and saving lots of money in both the cases<sup>(1) (8) (16)</sup>.
- Environmental impact and energy saving: when a solid wall is imbued with the ability to transmit light, it means that a home can use fewer lights during daylight hours. Since the insulating capacity of the wall is unchanged, the result is a net energy gain.<sup>(12)</sup>

- It can light roads from the bottom where traffic signs can be made, more efficient and solar cells can be used with them to increase their efficiency and economy, as well as lighting bumps in the streets as they will light the fall of the beam of car lights on them.
- It is a high-durable material; strength and durability are equal to ordinary concrete slabs.
- It has an aesthetical properties, attractive artistic view and Innovative design options, that optical fibres incorporated into concrete let the stone appear massive and transparent equally, making light, shadows and colors visible, figure (4) <sup>(1)</sup>.



**Figure 4 translucent concrete aesthetical properties**

- Security aspect, it can provide more control in places such as schools, museums, prisons, etc. where people can be monitored without seeing the full picture of them, to provide the privacy to them. <sup>(17)</sup>
- Harsh-climates material, it can shut out heat or cold without shutting the building off from daylight.
- Sustainable material; Translucent concrete combines the fluid potential of concrete, with glass ability to admit light.
- Translucent concrete could provide safety applications such as speed bumps that could be lit from below to make them more visible at night, or to light indoor fire escapes in case of a power failure. <sup>(16)</sup>
- It can be obtained in the concrete standard colors (white, black and gray), or any other preferred colors, with different surface shapes (grinded, blasted, brushed, scorched, satined, factory-impregnated, grinding, drilling, polishing, sawing and blasting) figure (5) <sup>(1)</sup>



**Figure 5 transparent concrete colors and shapes**

## 5- Transparent Concrete disadvantages:

- The cost: Create load-bearing structures out of translucent concrete would be very expensive due to the rarity of the product and its experimental nature. However, it is going up in availability, down in price and getting ever more versatile. <sup>(16) (20)</sup>
- Translucent concrete creation process needs careful, attention and skilled work crews. If the fiber is cut, the concrete loses its ability to pass the light. <sup>(17)</sup>

## 6- Using a new material in smart homes:

One of the most important designers' strategies for mitigating the environmental and health effects of the interior space is choosing the appropriate materials for the specific needs of the interior space, based on its durable performance, and the materials proportion to the way a space actually is used. For instance, a harder, more cleanable surface makes sense in an entryway area that is subject to heavy foot traffic and mud, water and detritus from the outdoors. In some cases, a designer may consider combining surfaces for increased sustainability and durability.

Translucent concrete has been used primarily as a building material; the second axis in the research will highlight the idea of using it in smart homes' interior design, to get benefits from its characteristics, by presenting the translucent concrete applications in interior design field and analyzing them. <sup>(4)</sup>

## Second Axis Practical Framework:

### Applications of Translucent concrete in interior design field:

The possible uses for the translucent concrete are nearly endless that the translucent concrete blocks can be produced in different sizes, which can give designers a wide variety of options when working with the material. The blocks can be used in many applications, from interior and exterior walls to lamps and outdoor memorial, and even may be used in the construction of energy-smart homes to reduce electricity costs, by allowing more daylight to penetrate the structure. <sup>(12)</sup>

### 1- Walls structure:

The wall made of transparent concrete has the strength of traditional concrete, however using the embedded arrays of optical glass fibers lets in the view of the outside world, such as the shadow of trees, or passers-by, that can be displayed inside the building, Figure (6) <sup>(13)</sup>. One of the major advantages of using this concrete in walls that it is eco-friendly, aesthetic and saves energy too, White or colorful illumination elements can be utilized to create special light and color effects. <sup>(5)</sup>



Figure 6 using the translucent concrete in Walls

Figure (7) shows the application of transparent concrete panels in form of a partition wall in “Europe Point” – Millenáris Park – Budapest – Hungary. <sup>(2)</sup>



Figure 7 the application of transparent concrete panels in form of a partition wall in “Europe Point”

The figure (8) shows two shots of the Garden Pavilion, Zurich, Switzerland. This idea was to create a simple structure, which would sit quietly in the garden; the designer wanted the pavilion to create a shelter. This pavilion has a space defined by five translucent precast concrete panels connecting floor, walls and roof, but at the same time allow a subtle perception of the garden and the sunlight, and it allowed the surrounding colors, shapes, movements and shadows to be perceived from the interior. Therefore, the translucent concrete allows the pavilion to be alive too. As the light conditions change in time, the surfaces change and vary from heavy to light, from solid to translucent. <sup>(2)</sup>

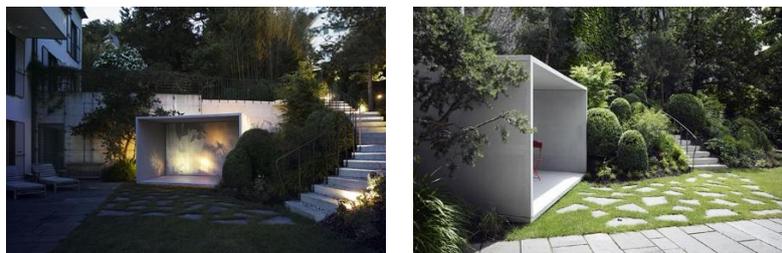


Figure 8 Garden Pavilion, Zurich, Switzerland

## 2- Wall cladding:

The transparent concrete panels can be used for wall cladding that embedded optical fibers transport the light from the backlight to the surface without loss. This creates a translucent look and the light concrete begins to shine fascinatingly from the inside out. Figure (9).

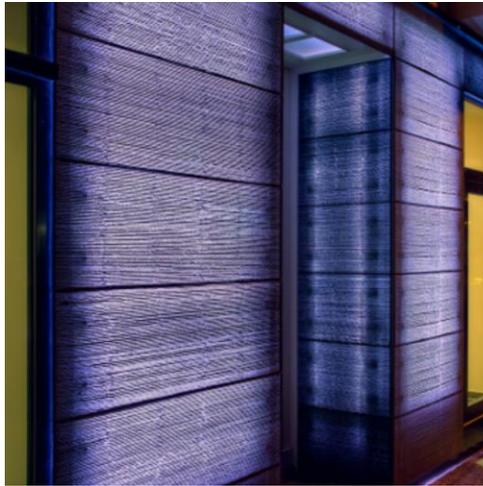


Figure 9 transparent concrete panels uses in wall cladding

The figure (10) shows the application of black transparent concrete blocks in form of a thin wall made of 25mm thick is located in the lobby of the studio Hibiya, in Tokyo, Japan. There is a projection room behind; in this manner, one can see videos, moving images on the wall.



Figure 10 transparent concrete wall cladding, located in the lobby of the studio Hibiya, in Tokyo, Japan

## 3- Floors:

The new flooring made of transparent concrete produces a special effect, without light, the floor panels appear as elegant natural stone panels, or any chosen texture, but illuminated, the panels seem to glow and due to the conical shaped light effect of each fiber, the light seems to be brighter the more the viewer is above the single panel. It seems as if there is a spotlight following the viewer. In comparison to the wall cladding, the floor application required greater load bearing capacity from each panel.

The figure (11) shows the difference between the illuminated panels and dark panels, and the figure (12) shows the first time to use transparent concrete in flooring in London & Oriental's London offices - features. <sup>(20)</sup>

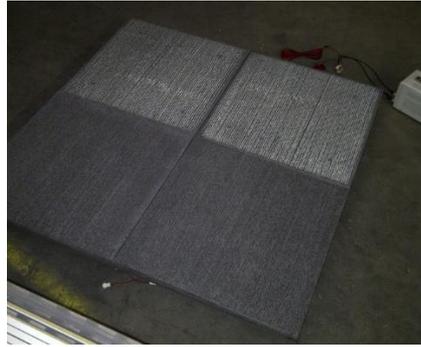


Figure 11 the difference between the illuminated panels and dark panels

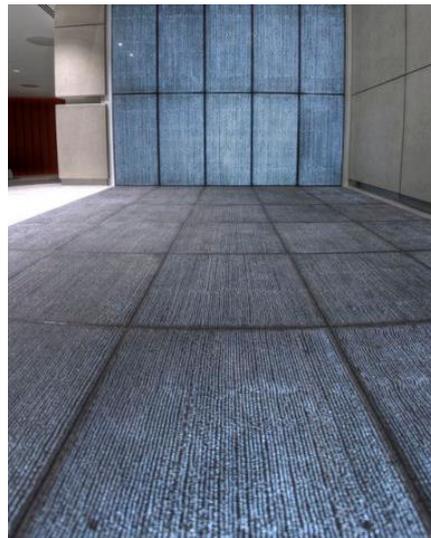


Figure 12 the first time to use transparent concrete in flooring in London & Oriental's London offices – features

#### 4- Ceiling:

Light transmitting concrete can be used in ceiling design to create various effects, for example a starry sky by using the concrete panels where the optic fibres are laid into the concrete in such a way they depict stars when lit, or for creating silhouette forms. Panels also come in different textures, colors and finishes. <sup>(20)</sup>

#### 5- Stairs:

Translucent concrete blocks incorporated in staircases help during times of power cuts at night leading to a great deal of safety. Light transmitting concrete can be used in the stairs illuminated from below, figure (14) or with linear LED fixtures, figure (15) shows an Impressive staircase with illuminated abutting faces. <sup>(8) (15)</sup>



Figure 13 the stairs illuminated from bellow



Figure 14 the stairs with linear LED fixtures

## 6- Furniture:

The furniture made of translucent concrete can be lit from the front and the side, to give aesthetic view. The figure (15) shows a bed with a head part made of translucent concrete with changing colors, and the figure (16) shows a living room with illuminated fireplace and bar for relaxed evenings. <sup>(1)</sup>



Figure 15 a bed with a head part made of translucent concrete with changing colors

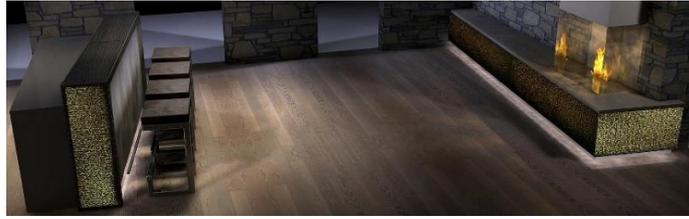


Figure 16 a living room with illuminated fireplace and bar

## 7- Decoration supplements:

Translucent concrete blocks can be made in desired shapes; they can be used in decorative supplements design like bookshelves and sunshades, tables and statues. <sup>(8)</sup> The decoration supplements made of translucent concrete can be an interior decoration and light source at the same time. <sup>(16)</sup> The following are examples of decoration supplements.

### - Partitions, figure (17)



Figure 17 Translucent Concrete partition

### - Light fixtures and lamps

Lamps using translucent concrete blocks with a light source would add a great deal of aesthetic look. <sup>(8)</sup> The figure (18) shows an exclusive ambient lamp – litracube lamp – made out of translucent concrete, designed by Aron Losonczi, with the size of 221x175x175mm. <sup>(2)</sup>



Figure 18 an exclusive ambient lamp – litracube lamp – made out of translucent concrete

### - SHOWER

The figures (19 – 20) show the game of light and water drops in the washing basin and the shower basin.



Figure 19 washing basin

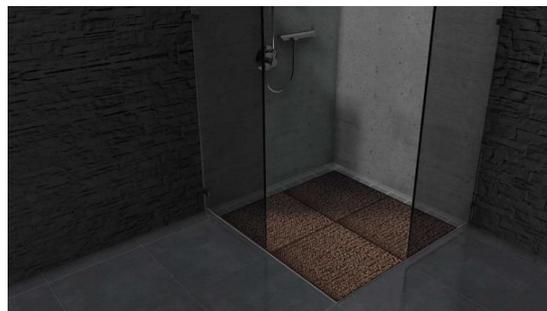


Figure 20 shower basin

### - Transparent panels

Contrary to the classic translucent concrete, in LiTraCon pXL<sup>1</sup>® there are no optical fibers for light transmission but a specially formed and patented plastic unit. This and the industrialized way of manufacturing bring the new pXL® material into a more affordable price range. The panels are reinforced and can make installation easier. The light dots appear with regular distribution on the surface of the pXL® panels just like pixels on an LCD screen, figure (21).  
(2)

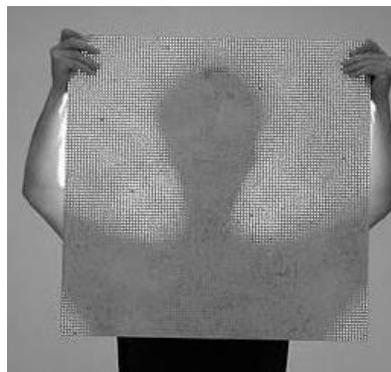


Figure 21 Transparent panels

<sup>1</sup> LiTraCon is a trademark for a translucent concrete building material. The name is short for "light-transmitting concrete"... As of 2006, all LiTraCon products have been produced by LiTraCon Bt. The concrete comes in precast blocks of different sizes.

### **Third axis: Results and conclusion:**

#### **Results:**

- 1- Transparent concrete as a smart material have an increasing range of applications in the interior design field, and it can solve energy problems and provide an opportunity for new wealth creating products and could have an important role in Sustainability interior design.
- 2- Transparent concrete combines the characteristics between flexibility, form and function in terms of practical and environmental, and it can be used in smart homes' interior design.
- 3- Linking the use of smart materials and the possibility of energy conversion for introducing better interior design to modern homes that makes them more convenient and comfortable and energy saving.
- 4- Translucent concrete has aesthetical properties so it can be used for artistic purposes and Innovative design options.

#### **Conclusion:**

A new architectural material called transparent concrete can be developed by adding optical fibers to the concrete mixture to get innumerable uses. In the next few years, it is sure to be employed in a variety of interesting ways that will change the opacity of architecture and interior design. The translucent concrete has very vital property for the aesthetical point of view, because of its lighting properties, besides it can integrate the concept of green energy and energy saving. Yet, the only drawback would be its high cost due to the rarity of the product. However, it is going up in availability, down in price and getting ever more versatile. To sum up, translucent concrete is the smart way of optimizing and utilizing light, it is a smart material, in a smart home in order to create a smart way of living.

#### **References**

- 1- (n.d.). Retrieved from lucon: <http://www.lucon.com/en/references/>
- 2- (n.d.). Retrieved from litracon: <http://www.litracon.hu/en>
- 3- Aggour, D. M. (n.d.). SMART MATERIALS – TOWARD A NEW ARCHITECTURE. Paper's No. BUE-FISC – 13.
- 4- Al-Baldawi, M. T. (2015). Application of Smart Materials in the Interior Design of Smart Houses. ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online), Vol.7, No.2. Retrieved from [www.iiste.org](http://www.iiste.org)
- 5- Bajpai, R. (2014, February). Application of transparent concrete in construction world. i-manager's Journal on Civil Engineering, Vol. 4.
- 6- Bhavin K. Kashiyani, V. R. (2015, August 23). A Study on Transparent Concrete: A Novel Architectural Material to Explore Construction Sector . researchgate, 83. Retrieved from [https://www.researchgate.net/publication/281178537\\_A\\_Study\\_on\\_Transparent\\_Concrete\\_A\\_Novel\\_Architectural\\_Material\\_to\\_Explore\\_Construction\\_Sector](https://www.researchgate.net/publication/281178537_A_Study_on_Transparent_Concrete_A_Novel_Architectural_Material_to_Explore_Construction_Sector)
- 7- Concrete. (2017). Retrieved from columbia: [www.columbia.edu/cu/civileng/meyer/publications/publications/93%20Concrete.pdf](http://www.columbia.edu/cu/civileng/meyer/publications/publications/93%20Concrete.pdf)

- 8- Dhonchak, A. (2016, May). A Glowing furniture – transparent concrete. IJARIE-ISSN, 2. Retrieved from [www.ijarie.com](http://www.ijarie.com)
- 9- environment. (n.d.). Retrieved from merriam-webster: <https://www.merriam-webster.com/dictionary/environment>
- 10- Furuto, A. (2012, April). Illuminated Translucent Concrete for Interior Design / Architectural Group & Partners. Retrieved from [archdaily](http://archdaily.com): <https://www.archdaily.com/228934/new-headquarters-of-bank-of-georgia-illuminated-translucent-concrete-for-interior-design-architectural-group-partners>
- 11- Hudson, L. (n.d.). transparent-concrete. Retrieved from [dreamplanbuilder](http://dreamplanbuilder.com): <http://dreamplanbuilder.com/transparent-concrete.html>
- 12- Kamdi, A. B. (2013, August 3). TRANSPARENT CONCRETE AS A GREEN. International journal of structural and civil engineering research, 2. Retrieved from [www.ijscer.com](http://www.ijscer.com)
- 13- Khater, Y. (2011). transparent-concrete. Retrieved from [egy-arch.blogspot](http://egy-arch.blogspot.com): <http://egy-arch.blogspot.com/2011/04/transparent-concrete.html>
- 14- Lichtbeton - translucent concrete (2016). [Motion Picture]. Retrieved from <https://www.youtube.com/watch?v=Tzd8Ix5a6Y>
- 15- light transmission concrete - seminar report 2015. (n.d.). Retrieved from [slideshare](http://www.slideshare.net): <https://www.slideshare.net/SahlaFathima/seminar-report-53878460>
- 16- McGillivray, S. (2017, December 1). Translucent-concrete-an-emerging-material. [illumin](http://illumin.usc.edu). Retrieved from <http://illumin.usc.edu/245/translucent-concrete-an-emerging-material/>
- 17- Shaker, Q. M. (n.d.). Translucent(Transparent) concrete. Faculty of engineering, Kufa University. Retrieved from <http://www.eng.uokufa.edu.iq/index.php/2012-07-20-18-23-02/2015-04-26-11-09-03/1029-translucent-transparent-concrete-15-1-2017>
- 18- smart-materials. (n.d.). Retrieved from [slideshare](http://www.slideshare.net): [https://www.slideshare.net/Biswajit\\_A/smart-materials-34678533](https://www.slideshare.net/Biswajit_A/smart-materials-34678533)
- 19- Soumyajit Paul, A. D. (2013, October 10). Translucent concrete. International Journal of Scientific and Research Publications, 3. Retrieved from [www.ijsrp.org](http://www.ijsrp.org)
- 20- Taylor, G. (2013, Dec 9). A look at the lighter side of concrete. [worldarchitecturenews](http://worldarchitecturenews.com). Retrieved from <http://www.worldarchitecturenews.com/project/2013/23661/lucem/tech-focus-lucem.html>
- 21- The Goodheart-Willcox Co., Inc. (n.d.). Retrieved from [https://www.g-w.com/pdf/sampchap/9781619602427\\_ch01.pdf](https://www.g-w.com/pdf/sampchap/9781619602427_ch01.pdf)
- 22- Torlak, M. (n.d.). Fiber optics communications. Retrieved from <https://www.utdallas.edu/~torlak/courses/ee4367/lectures/FIBEROPTICS.pdf>
- 23- Translucent insulated Concrete Panel (2013). [Motion Picture]. Retrieved from <https://www.youtube.com/watch?v=f3oVZ3STC2c>