Translucent Bricks

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***Abstract*—Expenses on energy and environmental impacts have grown globally. All current developments in our man made environment consumes energy--to produce materials, to construct them and further energy for thermal comfort & illumination systems. Walls made using translucent bricks installed near staircases and inner walls can help during times of power failures and serve for a great deal of safety. For subways and airports these bricks would add to visibility. Blocks can be made into desired forms and can be used as decorative materials for bookshelves, sunshades, tables, lampshades and even statues. They can also be designed as security walls which enhance security by giving a hazy image of the perimeter. In schools, museums and prisons, translucent walls are useful to add safety and security, as well as for surveillance. Lamps made using this technique combined with a powerful light source can highlight desired surfaces.**

This research paper explores the advantages of using translucent bricks and examines the scope of using this as a substitute for jalli system. The function of a translucent brick has been analyzed by measuring features like temperature, intensity of light and safety. The research also probes for a cost effective way to construct translucent bricks in the Indian market by using alternative raw materials. Use of recycled optical fibers from e-waste and use of traditional mud have been deeply considered as alternative materials. The research aimed towards producing a detailed report regarding the same using standard brick tests in a lab. Until now, concrete structures alone were considered as structural members, but in the recent years this idea has been undergoing a massive change with concrete being used for aesthetic considerations too. The research concludes by identifying a combination of high grade concrete with optical filaments that can be used as an add-on material for the beautification of the buildings by making it light emitting.

***Keywords*—Thermal comfort, Illumination system, E-waste, Optical fiber, Optical cable**

I. INTRODUCTION

In today's fast moving world, with a population that grows exponentially every year, the need for energy increases subsequently. We are continuously insisted to save our resources and to utilize them wisely. Methods to save energy are therefore primary in the construction sector.

In fact, for a green building certification, one of the prime categories is the maximized use of incident daylight. While a lot of research and innovative solutions are being discovered and applied, most of them involve movable infrastructure, lighting installation technology and motion sensing fixtures among many other similar ideas.

While we hunt for a solution to minimize energy by technological innovations, there exists a perfectly viable solution to save energy from illumination and thermal comfort, which also uses recycled e-waste as a major constituent. This innovation exists in the domain of construction with the use of translucent brick, or light transmitting brick, but yet remains to be deeply discovered in its use.

Living up to its name, the translucent brick is on the verge of being transparent. When light is permitted to pass through translucent brick walls, objects on the other side of the separation are seen as vague silhouettes. This could completely revolutionize the illumination requirements of any structure in which it is used. Daylight entry can be maximized without removing separations, and the amount of luminaires can be reduced tremendously.

The face of a brick could now be changed from an aesthetically unappealing solid to a semi-transparent, energy efficient element of construction. Giving an ambient lighting with modifiable shadow pattern could make it an elegant choice for any interiors. The translucent brick can also be used as perimeter walls serving the dual purpose of maintaining security and privacy as well as adequate vision.

This translucent property or the light passage property attributed to this modified brick is gained by the addition of light optical elements to the mix. Usually optical fibers are used for the purpose. The importance of using optical fibers can be extended to the fact that they being one of the most used means of data transmission and medical solutions, it could present itself as a potential future waste due to its use in large quantities.

Another remarkable advantage of the Translucent brick is that it also acts as an insulating material that can prove to be useful in extreme climatic conditions. It can conserve the heat present inside the building thereby reducing the energy required for heating purposes in cold conditions. It can also act as a barrier that prevents the cooler inner temperature to be lost to the outside heat in case of hot conditions. This makes it a perfect material for buildings in extreme climates that need to be protected from harsh climatic contexts without blocking the building off completely from daylight.

Probably the only drawback of transparent brick today is it being too expensive. Even with the cost disadvantage, the material is still being preferred and used by several architects. This is due to the iconic translucent factor that stays unique to this brick variant. It also stands as a great sign of attraction and artistic evolution. Any structure with translucent brick possesses not only remarkable beauty but also provides for safety and security with its semi see-through walls. A major percentage of human beings find comfort in open spaces as it provides them with a sense of security. But residential spaces have always been restricted in its use of open spaces due to issues of security. The use of translucent bricks can negate the problem by creating open spaces that aren't open, and closed spaces that aren't closed. It can also affect our sensory stimulations with the indirect illumination and semi transparency. Walls would start to act dually as mediums that separate people and also unite them. Mutual lookout element between family members in residences can be enhanced by the use of these functionally dynamic as well as structurally stable walls. Surveillance of public buildings could also benefit from the same.

Translucent brick is therefore a product derived from a combination of applied science, architecture and engineering, thus giving us the most as an efficient energy saver. With this, walls, ceilings and flooring cease to be separating elements or simple surfaces, rather they become energy savers. It is easily the smartest way of optimizing and utilizing light energy in today's world. Therefore, this is a material of tomorrow and holds an immense deal of potential for research and subsequent future developments and innovations.

II. CURRENT SCENARIO

Illumination and thermal comfort amount to one of the basic necessities according to today's living standards. The amount of energy that we consume on a daily basis, has a major percentage of it owed to electricity and primarily to illumination. We are urged for increased conservation of light energy and more technology is being researched up on, for the same using movable infrastructure, lighting installation technology, motion sensing fixtures and similar other new technologies.

Transparent brick is a brick based building material with light transmissive properties due to the light optical elements embedded in them, which are usually optical fibers. Through these blocks, light is conducted from one stone to the other, making it necessary for the fibers to go through the whole object. This creates interesting patterns on the close by surfaces depending on the fiber structure. There is a partial visibility to what's happening on the other side of the wall as well. Silhouettes or shadows remain visible. This amazing material consists of 95% fine grain mortar and only a 5% of light conducting elements. Apart from the fine fiber patterns that are usually created, variants are available with the use of textile and optical fibers which create coarser light patterns.

Just a few decades ago, concrete was often disliked and misunderstood due to the rapid urbanization of the 1960s. Since then concrete has made a lot of progress and one was an attempt to become aesthetically appealing. This aesthetically appealing form is the translucent brick variety.

The core use of translucent brick continues to be an energy saver that is further adorned as an aesthetically pleasing one, with the uses being varied and advantages innumerable. Making use of its properties and being true to its name, Translucent brick walls installed near staircases and inner walls help during times of power failures, thus providing a great deal of safety while conserving energy. For subways and airports these blocks would add to the visible connectivity and also add to the character of the space. Translucent brick blocks can be made into desired forms and used as a decorative material for bookshelves, sunshades, tables and even statues. They can also be designed to act as boundary walls which enhance security giving a hazy image of the perimeter. Lamps using translucent brick with a powerful source would have detailed light and shadow effect. In schools, museums and prisons, translucent walls are useful to add safety as well as security and also increase the ease of surveillance.

Translucent brick creates some other aesthetic advantages such as the texture being visible on a large scale. And sensibly when a home has transparent walls it can have fewer amounts of light in it. If a room appears to be dim and unlit, it can employ the use of this material to get a better feel to it. A façade made of this gives a good aesthetic advantage to the building.

There are only two major difficulties faced-- the need for skilled labor and the high initial cost due to the lack of availability of optical fibers.

Translucent brick is a revolutionary building material which has the potential to break the conventional systems of lighting schemes and the process followed for recycling e-waste. It would in the future reduce the accumulation of such wastes by providing a practical solution. The issue of safety isn't affected either, as translucent brick is just as strong as the opaque one.

The primary aim of this research is to analyze the use of optically reinforced brick in the construction of spaces. The dynamic advantage it holds is the fact that it maximizes daylight entry and reduces the amount of illumination required to provide for multiple rooms in close proximity, thus reducing power consumption but by continuing to maintain privacy and safety unlike any other material. It is easy to get a high green rating for a building that utilizes transparent brick. When a solid wall gets the property to transmit light, it decreases the amount of light needed during daytime too by the use of the incident daylight on the walls. The insulating capacity of the wall is altered, and thus the result is a net energy gain. Simultaneously, transparent brick can act as a building material as well as its light source. It separates, connects and illuminates walls &floors with ambient lighting or other light installations. Translucent brick also acts as an insulating material which can prove to be useful in extreme climatic conditions. It can conserve the heat present inside the building reducing the energy required for heating purposes in cold conditions, and can act as a barrier that prevents the cooler inner temperature from being lost to the outside heat in case of hot conditions. This makes it a perfect material for buildings in such climatic conditions where it protects from the harsh climatic contexts without blocking the building off from daylight. It can be used to light up underground buildings and levels, such as subways and parking lots. Translucent brick can be used as a safety application on roads as speed bumps that can be highlighted from below to make them more visible in dark environments, or to light fire escapes during power failure. It also possesses the sustainability quality as it is eco-friendly, by reducing the waste and not polluting nature.

III. E-WASTE IN INDIA

The development in the field of science and technology during 18^{th} century was a turning point in life style of humans, termed as industrial revolution. The impact of advancement in technology brought many changes in the economy and ecology of our system. This era was followed by the development of communication system during 20^{th} century which in turn completely re-organized the structural system of our economy, education, industry and health. Undoubtedly these marvelous advancements and inventions improved the quality of our life. Meanwhile it has also led to a manifold of problems including the production of hazardous waste and other wastes from electronic goods. These wastes pose threats to both humans and the environment. The lack of proper waste management system is a threat to life and environment.

Just like hazardous waste, e-waste is also a prime concern to our society due to its uncontrolled accumulation and non-scientific treatment leading to huge environmental and health issues. The advancement in technology has given a facelift in our life style, work and communication, bringing the country a stable economic background. The updated technology and globalization resulted in large production of electronic goods which has ultimately resulted in the heavy and uncontrolled usage of these goods. The people have taken to heart the concept of "use and throw" as these goods have become easily affordable to a majority of the population. These new products are a part of our life, providing us comfort, safety and faster availability of information, while at the same time leads to unrestricted resource utilization and alarming flow of waste due to outdated equipment.

IV. CONCRETE DESIGN MIX

The samples are made using cement and varying optical fiber composition in a standard testing mould of 15cm x 15cm x 15cm under lab conditions. A standard ration of 1:2 for the mixture is fixed for the test. The optical fiber is cut into small filaments of 15.2cm from the large spool.

A. The Mix

The quantity of cement, fine aggregate and water required to prepare a concrete mix of proportion 1:x by weight with water cement ratio "k" for casting 3 cubes 15cm x 15cm x 15cm is calculated. The materials are collected and kept ready. The measured quantity of cement and fine aggregate is mixed dry until the mixture is thoroughly blended and is uniform in color. The water is added and the entire batch is mixed until concrete appears to be homogeneous and has the desired consistency.

Desired quantity of optical filaments of size 15.2cm is weighed and kept aside.

B. Procedure

The cast iron cubes of size 15cm x 15cm x 15cm is assembled and a layer of oil is applied in the inner surface (to help in de-moulding). The prepared mixture of cement and sand is poured as the first layer and leveled with the measured amount of optical fiber placed on top of the mortar as another layer. The process is continued and the cube is filled.

The mixture is left to set for 32 hours and is then de-moulded and left for curing. The cubes are cured for 28 days and finally the surface of the cubes are finished using a sandpaper.

Fig.1 Weighing of cement and sand

C. Calculation of the quantity of ingredients

Mix proportion = 1:2

total volume of the test cube = 15 x 15 x 15 x 0.93 (safe ratio)= 3144cm^3

Specific gravity of cement = 3.15

Specific gravity of fine aggregate = 2.65

Yield of 1gm cement = 1/ Specific gravity of cement + 1/ Specific gravity of fine aggregate + k

Weight of cement required = V / yield of cement

Weight of fine aggregate required = 2 x weight of cement

Weight of water required = (0.7 x weight of cement) / density

D. Specimens

1) *Specimen 1 (N1)*:

Mix proportion = 1:2

total volume of the test cube = 15 x 15 x 15 x 0.93 (safe ratio) = 3144cm^3

Specific gravity of cement = 3.15

Specific gravity of fine aggregate = 2.65

Yield of 1gm cement = 1.772

Weight of cement required = 2.075kg

Weight of fine aggregate required = 4.150kg

Weight of water required = 1.45 l

Weight of optical fiber = 0gm

2) *Specimen 2 (O1)*:

Mix proportion = 1:2

total volume of the test cube = 15 x 15 x 15 x 0.93 (safe ratio) = 3144cm^3

Specific gravity of cement = 3.15

Specific gravity of fine aggregate = 2.65

Yield of 1gm cement = 1.772

Weight of cement required = 2.075kg

Weight of fine aggregate required = 4.150kg

Weight of water required = 1.45 l

Weight of optical fiber = 35gm

3) *Specimen 3 (O2)*:

Mix proportion = 1:2

total volume of the test cube = 15 x 15 x 15 x 0.93 (safe ratio) = 3144cm^3

Specific gravity of cement = 3.15

Specific gravity of fine aggregate = 2.65

Yield of 1gm cement = 1.772

Weight of cement required = 2.075kg

Weight of fine aggregate required = 4.150kg

Weight of water required = 1.45 l

Weight of optical fiber = 55gm

4) *Specimen 4 (O3)*:

Mix proportion = 1:2

total volume of the test cube = 15 x 15 x 15 x 0.93 (safe ratio) = 3144cm^3

Specific gravity of cement = 3.15

Specific gravity of fine aggregate = 2.65

Yield of 1gm cement = 1.772

Weight of cement required = 2.075kg

Weight of fine aggregate required = 4.150kg

Weight of water required = 1.45 l

Weight of optical fiber = 90gm

5) *Specimen 5 (O4)*:

Mix proportion = 1:2

total volume of the test cube = 15 x 15 x 15 x 0.93 (safe ratio) = 3144cm^3

Specific gravity of cement = 3.15

Specific gravity of fine aggregate = 2.65

Yield of 1gm cement = 1.772

Weight of cement required = 2.075kg

Weight of fine aggregate required = 4.150kg

Weight of water required = 1.45 l

Weight of optical fiber = 180gm

V. TESTING OF SPECIMENS

A. Thermal Performance Test

The amount of heat absorbed and transmitted by the brick is a key factor for its performance in cost effective energy utilization. Therefore, the thermal properties of the specimens are tested under normal temperature. The main source of heat is considered to be emitted from the specimens that are placed under direct sun light on a raised platform. The temperature on the surfaces are measured using an infrared thermometer. The thermometer is calibrated using a glass of ice. The outer temperature and the inner temperature is measured in a time interval of 1 hour from 7am to 7pm.

Fig.2 Calibration of thermometer

Fig.3 Specimen placed on a raised platform

Fig.4 Measuring surface temperature

B. *Light Reflection Test*

The amount of light absorbed and transmitted by the brick determines the efficiency of the bricks. Hence the properties of the specimens are tested under normal temperature on a sunny day, considering sun as the main source of light. A plywood box is made to measure the efficiency of the specimens by checking the intensity of reflected light through different bricks with varying fiber density using a lux meter.

Fig.5Box to measure light intensity

Fig.6specimens placed inside box for testing

VI. RESULT ANALYSIS

The results obtained from testing of conventional concrete brick and translucent brick is tabulated. Two tests i.e., thermal performance test and light reflection are carried out on 5 specimens. The optical fiber density in each bricks vary from 0.005% to0.023% of the total weight of the bricks.

A. *Thermal Performance*

The bricks were tested using IR thermometer after a curing period of 28 days and the temperature was measured throughout a day in an interval of one hour. The results obtained are tabulated in table 1.

TABLE I

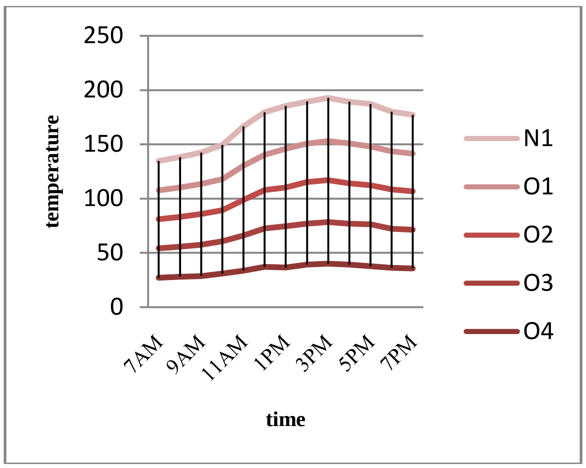
TEMPERATURE VARIATION EXTERNAL-INTERNAL

Time	O1	O2	O3	O4	N1
7AM	27.6-27.1	27.2-27	27.2-27	27.2-26.3	27.8-27.2
8AM	28.5-28.1	28.0-27.6	28.1-27.5	28.1-27	28.8-27.9
9AM	29.6-28.7	29.4-28.8	28.5-28.2	28.3-27.5	29.5-29
10AM	37.9-30.9	37.2-29.6	37.8-28.7	35.5-28.6	35.7-31.5
11AM	39.9-33.5	40.7-32.5	39.32-32.7	38.4-31.5	40.5-36.3
12PM	43.7-37	43.6-35.5	39.8-35.5	39-32.2	43.5-39.3
1PM	45.3-38.6	45.1-37.8	41.1-35.8	40.6-35.6	45.6-39.6

2PM	43.9-39.1	43.7-37.7	40.1-38.3	40.1-35.5	42.4-38.8
3PM	45.1-40	50-38.4	43.1-38.6	42.56-36	45-39.8
4PM	41-39.1	41.3-37.7	38.7-37.3	38-36.8	41.6-38.3
5PM	37.7-37.7	38.7-38.7	35.8-35.8	36-35.8	39.6-39.1
6PM	35.8-36.3	36-36	35.6-36.1	35-35.2	36.2-36.4
7PM	34.2-35.5	35.6-35.8	34.8-35.3	34-35	35.2-35.4

CHART I

INTERNAL TEMPERATURE OF SPECIMENS



B. *Intensity of Reflected Light*

The intensity of light passing through the blocks was measured throughout a day in an interval of one hour. The results obtained are tabulated in table 2.

TABLE II

INTENSITY OF REFLECTED LIGHT IN SPECIFIC HOURS

Time	O1	O2	O3	O4	External intensity
7AM	0	0	0.7	1	10
8AM	0.15	0.1	0.5	1.1	80
9AM	0.47	0.5	1.2	1.6	246
10AM	0.75	0.9	1.4	1.9	390
11AM	1.89	1.9	2.2	2.4	980
12PM	1.61	1.7	1.8	2.6	1126
1PM	1.94	2	2.4	2.9	1360
2PM	1.4	1.6	1.9	2.1	992
3PM	1.3	1.4	1.7	1.8	950
4PM	0.7	0.8	1.1	1.6	527
5PM	0.4	0.6	0.7	1.8	345
6PM	0.1	0.1	0.3	1.3	76
7PM	0	0.1	0.2	0.4	8

VII. CONCLUSION

After considering the tests done during the manufacturing of translucent bricks, the results of thermal performance, light reflection draws the following conclusions:

A. *Conclusions regarding Thermal Performance*

The thermal capacity can be lowered by addition of fibers and it will also help in keeping the interior temperature low. This is clear from table 1. Maximum temperature on the outer surface is recorded during 1pm and minimum during 7am. The interior temperature rises till 3pm and latter drops, but the dropping rate is higher on the outer surface such that the inner temperature will be slightly more than the exterior after 4pm.Hence it is proved that addition of fibers will save energy in HVAC systems.

B. *Conclusions regarding Light Performance*

The intensity of light transmitted through the brick depends on the density of optical fibers in the brick. This property can be used to control privacy, as the transmission of light increases with the increase in the percentage of optical fibers. The maximum intensity of light pass through the block is during 1pm. The intensity may also vary with the natural factors like overcast and shadows due to vegetation. It is clear from the table that it is possible to achieve the required amount of light for various works by increasing the fiber density (according to standards 300lux for office and 80lux for store rooms) hence it can replace glass and even can be used for jalli works. It will much safer in the case of jalli as the holes are tiny and it will eliminate the problem of insects and dust.

C. *Conclusions regarding Cost*

Although the initial cost of the brick is 6.2 times that of normal concrete solid bricks the invested money can be returned by saving energy in lighting and HVAC. It will take years for the complete payback of invested money. In addition to that the product has a finished surface when compared with a normal concrete block and hence can save money in plastering and the energy wasted in man power. It will also reduce the carbon foot print which is dangerous for the nature, as it can reduce at least 5% of total waste produced in the field of network and communication systems by reusing the optical filaments. Therefore, this can be considered as a high performance building material which is beneficial for protecting mother nature.

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