

# SEVEN FUTURISTIC CONSTRUCTION MATERIALS FOR ENVIRONMENTAL SUSTAINABILITY

## Abstract

Environmental protection and a determination of the state of both the health of the earth planet and human living on the earth planet has become a major concern and becoming important topic for the societal development. Studies and Reports are showing alarming realities through climate change and human activities around the globe that is producing too much polluting emissions leading to rapid deterioration of mother nature and the climate of the earth. This situation has asked the mankind to re-examine and re-think on the exploration of earth materials and their relationship of final product to use it as raw and finished goods by considering sustainability in general and environmental sustainability in particular. Further the seventh goal of Millennium Development Goals is related to environmental sustainability. As it is noted that according to Paris agreement on climate change, annual emission of CO<sub>2</sub> from cement is needed to be fallen by at least 15% by the year 2030, it is the time and need to conduct an explorative research on identifying the environmentally sustainable building materials and futuristic construction materials. Therefore objective of this paper is to provide explorative description and insights on some selected seven futuristic construction materials. It indicates the importance of analyzing and integrating applications of nano and biotechnology into the civil engineering field by also addressing the implications of CO<sub>2</sub>.

**Keywords:** Campaigning environmentally sustainable materials, Environmental sustainability, Futuristic construction materials, Net-zero carbon pro materials, Seventh Millennium Development Goal.

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## I. INTRODUCTION

In September 2000, 189 UN member states signed the Millennium Development Goals (MDG), in which the seventh goal is related to environmental sustainability. Major transformations have not been taken place to change the instable conditions of human civilization and human sustainability. Peace, security, stability and good governance are prerequisites to achieve sustainable economic development. Construction can be referred to be presented as an economic activity that involves the three stages of construction process viz., producing raw and manufactured building materials, design and project management and execution of the physical work on the site. Thus, Project management for construction, architecture and engineering activities and manufacturing building materials can be classified under management of construction economic activities. Durability requirement and complexity nature are the main reasons of construction of civil engineering works. The diversified requirements of customers and construction site conditions result in dealing with the complexity of wide range of construction materials, technology, design solutions and construction methods. Further, Building materials makeup major components of total construction costs. Durability is the characteristics of a material and it is the maintenance of its properties over time, so that it can continue to become useful for longer period.

Morelli (2011) [6] concluded the definition of environmental sustainability as “meeting the resources and services needs of current and future generations without compromising the health of the ecosystem that provide them”. The construction industry sector consumes up to 60% of all the raw materials extracted from the earth. When these raw materials are transformed into construction materials, approximately 50% of the atmospheric emissions of CO<sub>2</sub> is generated. Therefore, the construction engineering profession is expected to integrate environmental protection mechanism in their construction works in view of achieving environmental sustainability contributing by construction industry. Fundamental definition of sustainability considers environmental, social and economical aspects. It is difficult to achieve top results in all three aspects of sustainability. However a balance of the three can be thought of considering while formulating the criteria. Some of the criteria can mutually reinforce each other, while trade-off must be made among other criteria. Some of the research works are done on trade-off between economic sustainability and environmental sustainability at measurement level discussion level etc.

Building with zero carbon foot print are classified under net-zero carbon buildings and may be called as climate neutral buildings. The carbon emission reduction can be achieved through considering the knowledge domains of energy, materials and waste, transportation and water. Life Cycle Assessment (LCA) of a building is a method that evaluates the environmental impact assessment (EIA) during the whole building construction life cycle. Some of the factors that become part of it are: carbon emissions, energy demand etc.

From the definition of environmental sustainability given by Morelli (2011) [6], a correlation between Green Building rating system health and well-being can be observed, which indicates the adoption of sustainability criteria called WELL. Environmental sustainability criteria aspect when considered, the following are some of the green building rating methodologies that can be mainly focused. They are: Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), German Sustainable Building Council (DGNB) and SBToolCZ- A

building performance assessment tool designed based on life cycle phases of building construction.

## II. RESEARCH OBJECTIVE AND ITS SCOPE

Objective of this research is limited to the brief discussion of sustainability and environmental sustainability and tradeoff aspects on three sustainability pillars viz., environmental sustainability, social sustainability and economic sustainability. Further on conducting explorative research on some seven environmentally sustainable pro-futuristic construction materials in civil engineering.

**1. Using environmentally sustainable materials campaign:** As per the campaign and appeal made by the AIA-The Blueprint [11] for Better, construction industry can minimize embodied carbon by focusing on reducing the use of top three worst offenders viz., concrete, steel and aluminum, which account for about 22% of all the embodied carbon. Therefore, initiating green building strategy encourages the adoption of green building materials, which can halt the climate change. It is also important to show that the materials made with little or net zero embodied carbon can be cheaper and healthier than the traditional products that are being in use.

For this purpose, the following Objectives of Selecting Environmentally Sustainable Materials are listed:

- Support human health by eliminating the use of hazardous substances.
- Support health and equity by preferring from those manufacturers who produce products with environmental consciousness and protecting human rights throughout the supply chain.
- Support ecosystem health by preferring products that regenerate and support the natural, ecological and biological cycles throughout the supply chain.
- Support the health of climate and weather by preferring products that reduce carbon emissions.
- Support circular economy having zero-waste goal for global construction activities.

**2. Seven environmentally sustainable building materials of the future:** The following seven environmental sustainable building materials are selected for the description and discussion.

**Zero-Carbon Cement:** The cement industry contributes about 5%-8% to global CO<sub>2</sub> emission, asking the cement industry to thrive for CO<sub>2</sub> emission mitigation strategies. Emission CO<sub>2</sub> is due to the calcination process of limestone, due to combustion of fuels in the kiln and from power generation [13] [14] [15]. As per the discussion held by cement industry leaders in Poland for UN's climate change conference COP24 and according to Paris agreement on climate change, annual emission from cement is needed to be fallen by at least 15% by the year 2030 [15]. Therefore, there is an urge towards using CO<sub>2</sub> free concreting and construction by the year 2050 based on United Nations declarations of Millennium Development Goals DB group of UK for example, has created zero-cement concrete called CemFree that can save up to 88% in embodied CO<sub>2</sub> as compared to conventional mix and also created called Concrete Canvas when mixed with water forms

a thin, durable, water and fire resistant concrete layer. Anglia Water in the UK became the first water company to use Cemfree in the year 2017. Concrete Canvas has been used to create storm drains and building for emergency and natural disaster situations.

**Self-Healing concrete:** Crack formation is a common phenomenon in concrete structures. Cracks when developed, they reduce the durability and strength of the structure and also affect the reinforcement. Repairing cracks require regular maintenance and may adopt the use of special type of treatments by using techniques like grouting and guniting, which could be expensive [18]. Cement has the natural ability of self-healing with long-term hydration phenomenon. Humidity can spontaneously close some initial cracks, however repairing major cracks require self-healing strategy. Search for more sustainable and durable concrete, less prone to cracking has lead to focus on bringing up the self-healing concrete concept. Further, Jonker [19] described the sealing of crack mechanism where initially added water allows the conversion of calcium lactate to calcium carbonate (i.e. limestone) that can result in crack sealing with water-activated bacteria after lowering the PH value of water.

In India, Professor Nemkumar Banthia's self-repairing road used 60% fly-ash, which is a by-product from burning pulverized coal and 40% of cement for experimenting a road construction in Karnataka State. The fibres used is having a hydrophobic nano-coating that helps in storing the water during rain fall. When a crack appears on the road, this water gives hydration capability to un-hydrated cement to produces more silicate and help with bonding capacity. Correspondingly it enables to close the cracks before it further become larger crack [20]. The possible sizes of crack that can be self-healed are: 0.87mm, 5 to 10 $\mu$ m, 100 $\mu$ m, 200 $\mu$ m, 200 $\mu$ m and 300 $\mu$ m as mentioned in [18]. In cinch, this study shows that crack healing of bacterial concrete based on expanded porous soil particles be loaded with bacteria and calcium lactate. Non-hydrated cement particles exposed at the crack surface of concrete then will undergo through secondary hydration to generate bacterial concrete. The self healing process in bacterial concrete is much more efficient due to the active metabolic conversion of calcium lactate in passing [21]. Adoption and implementation of self-healing concrete helps in reducing the infrastructure maintenance requirements and cost as well as cut the greenhouse gases (GHG).

**Light-generating concrete:** The first commercially available light transmitting cement-based material (LTCM) is invented by a Hungarian Architect Aron Losonczi naming it as LiTraCon [22]. LiTraCon has optical fibers, that are arranged in the required patterns before the self compacted mortar is casted [23] [24]. These optical properties of LiTraCon depend on parameters such as fiber type, diameter, and volumetric fraction as well as on the specific spatial arrangement pattern. Optical effects can be generated by adjusting these optical parameters and by using different composition and texture of self compacting mortar (SCM).LTCM is a new type of structural material that allows light transmission without the need to limit the thickness of the wall or pavement thickness [23] [24]. Mexican research professor Dr. Jose Carlos Rubio created a cement additive that absorbs solar energy during the day and then emits light after dark for up to 12 hours. When this kind of the cement is used in pavement and building construction scenarios, it provides basic light needed to light highways and buildings.



**Figure 1a & b: Light Transmitting Concrete (Google Search Source: (a) [28] b) [29])**

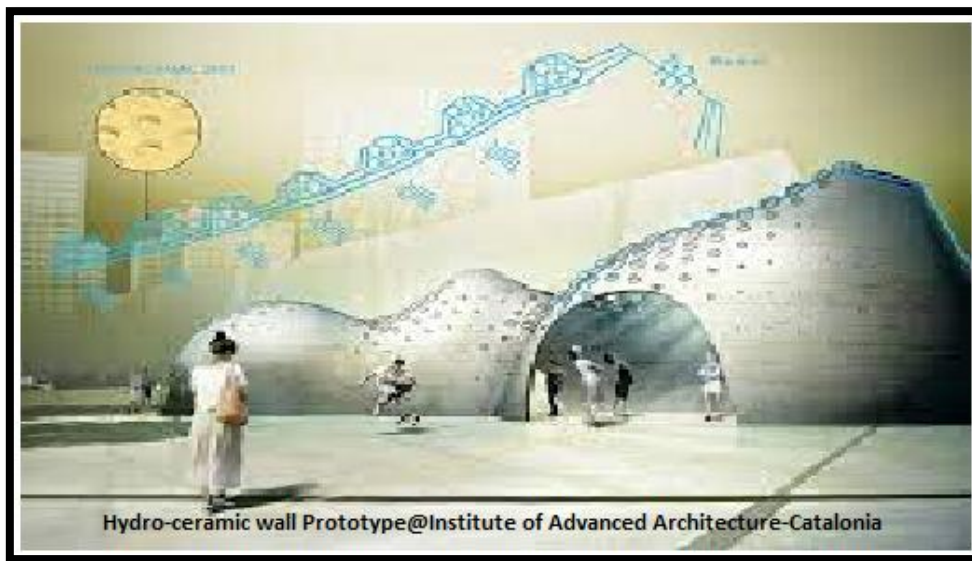
According to Rubio, modification of micro-structure of the cement is required by allowing the concrete to absorb solar energy during the day and re-emit it as light. The intensity of blue and green colors can also be adjusted as per the user's needs and this kind of material can last up to 100 years [27].

Lighting is also possible with Translucent concrete by embedding tiny glassy balls in the materials to reflect light in order create signage, underground lighting and warning signs [30] [31]. Potential uses of this kind of materials used when made into panels can be used in ceilings of residential buildings to reduce the lighting costs and enhance building safety, commercial buildings like restaurants, office buildings and shops, monumental entrance tower of Hindu temples (Gopuram), Churches, Masjids etc. to attract more spiritual customers. However the factor of cost effectiveness is a topic of further research.

**Pollution-absorbing bricks:** Air pollution has become one of the important concerns with respect to climate change. It has severe effects on health of public. Carbon emission releasing in to the atmospheric air is causing the surface of the earth subjected to global warming. Pollution Absorbing Bricks (PABs) become an alternative to traditional/conventionally used bricks to curtail the air pollution [33]. PABS were developed by Ar. Carmen Trudell, an assistant professor at School of Architecture of California Polytechnic State University, USA. These bricks absorb pollution, based on the principle of air filtration. They filter air from outside the wall provide filtered air to the inside of the wall (e.g. rooms of a house). Thus they separate dust particles and pollutants from the air leaving the rooms clean and safe for breathing [34]. After the testing, it was inferred that 30% of the particles spanning up to 2.5 micros or smaller in diameter and filters 100% of coarse particles with diameter  $\geq 10$  microns. Therefore these bricks are also called 'Breath Bricks'. These breath bricks function similar to a vacuum cleaner [35]. Breath brick can be used in load bearing structures up to 1-2 storey height. It can be best useful in regions where there the air quality is poor. One of the disadvantages of using this brick is that the exterior wall thickness becomes double the conventional size brick thickness leading to reduce the interior spaces of rooms [33].

**Hydro ceramics:** Hydroceramic is a concrete made by curing a mixture of inorganic waste, calcined clay, vermiculite,  $\text{Na}_2\text{S}$ ,  $\text{NaOH}$  added with water under hydrothermal

conditions, thus form into hydrated calcium silicate. It contains the pozzolanic substrata of Metakaolin. It chemically behaves like cancrinite. It has the unconfined compressive strength ranging between 5-14 Mpa. Hydro-ceramic concrete is thermodynamically stable (or durable) than glass under realistic geological disposable conditions [36]. According to Markopoulou, the academic director and project head at Institute of Advanced Architecture of Catalonia, Hydro-ceramic is a combination of a hydro-gel with support materials such as ceramic material, which responds to moisture and heat. It can serve as an evaporative cooling device that reduces temperature of 5 to 6 degrees and increases the humidity [37]. The cooling effect of Hydro-ceramic is due the presence of hydro-gel in its structure that can absorb water up to 500 times its weight. This absorbed water is released during the hot temperature days to reduce the temperature.



**Figure 2: Hydro-ceramic wall Prototype (Google Search Source: [37])**

Correspondingly bricks and tiles can be manufactured to reduce the heat coming into the building. It helps in reducing the cost of HVAC (Heat, Ventilation and Air Conditioning) aspects of a building services

**Nano crystal:** Recently nano-technology is creating better materials with enhanced properties for its use and offering a range of possibilities with various application areas or fields including in the construction domain [39]. A nanocrystal is a crystalline nanoparticle and is smaller than 100 nanometers (a nanoparticle). It is composed of atoms in either a single or poly-crystalline arrangement [40]. The atoms within nanoparticles are perfectly ordered. When the dimensions of a material are condensed from macro size to micro size (or nano size), there is a substantial change in the properties of the material can be occurred. Some of the applications of nano materials in construction materials are: Rapid hydration can be seen with the presence of silica nano particles in concrete; Effect of self-cleaning can be seen with the presence of titania nano particles in concrete, Increase in durability and crack prevention can be seen with the presence of carbon nanotubes in concrete; increase compressive strength can be seen with presence of clay nanoparticles in brick mortar; Corrosion resistance can be seen with the presence of copper nanoparticles in steel [39].

**Transparent wood:** Translucent wood or transparent wood is an eco-friendly construction material first invented by Siegfried Fink in the year 1992 after having done research by his teams at both Swedish KTH Royal Institute of Technology and University of Maryland during the years 2015 and 2016. The property of transparency is found obtained by replacing the modules of lignin by polymers. The process of obtaining transparent wood is two steps. In the first step, as the lignin is found responsible for giving the color to wood, it has to be replaced. In the second step, the polymers having transparency with refractive index is subjected to the repeated vacuum and de-vacuum process and is done in the second step in order to obtain the transparent wood. Transparent wood optical properties become more attractive with acetylating. Compared to glass, transparent wood facades require less material and less costly to save more money. It brings architectural beauty when using it for load bearing structures for I-beams, girders etc.

### III. CONCLUSION

The reality of climate change and global warming in all its implications including its effects on environmental sustainability is realized by many nations. Therefore it is essential to react immediately at the international level to define and respond appropriately to the stated needs of Millennium Development Goals (MDG) in the year 2000 and to the Paris agreement in the year 2015. Since concrete is the most used construction material on the Earth till date along with its 5-8% of the world's total CO<sub>2</sub> emission it would merit more nanotech research efforts thus helping to fulfill the 7th MDG. It is expected that the futuristic construction materials to be highly durable and will be able to incorporate different technologies to capture energy while removing pollution and be able to sustain to serve for longer periods by lowering the environmental cost as compared to natural materials. However balancing the trade-off between three aspects of sustainability i.e. social sustainability, economical sustainability and environmental sustainability for obtaining its optimal value is a great challenge to the nations.

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