Eco-friendly Cellular Concrete : A Review

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Abstract

Several materials are employed in the process of construction of a building. One of the most important ones, cement is bound to produce a lot of carbon footprint. Also, there are several other materials, whose production and transportation is not environment friendly. With this research, our aim is to reduce that footprint and fabricate a structure with the help of more sustainable materials. The concept of embodied energy has been discussed in this research. Embodied energy of a material plays an important role as it determines the total energy required for producing or manufacturing a material. Therefore, by replacing important secondary materials such as cement plastering by gypsum plastering, the embodied energy is reduced by almost 2500 MJ/cu.m. Several comparisons between conventional and unconventional materials are made to point out the impact of embodied energy of a material with respect to construction. Also, using cradle-to-cradle materials will ensure a better, more recyclable process that will not only ensure environment safety but will also promote healthy space for people to live.

Keywords : **Eco-friendly, cellular, concrete, lightweight, sustainable**

I. INTRODUCTION

Sustainable building materials are materials related to resource and energy efficiency in the manufacturing process [1]. Sustainable construction material not only fulfils the environmental criteria but also leaves a drastic change in the quality, performance, scope, and cost of a project positively. These materials also increase the durability of a project giving us a stronger, durable and long-lasting structure. Construction materials are more durable when these materials are recycled and such materials can be found where recycling of similar products takes place, for example, plastic is a greater source of a variety of materials used in all aspects of structure right from using it for construction of roads to using it for roof tiles, insulation, fence etc. [2]. This entire process saves cost while keeping the environment clean by reducing waste and using recycled materials. Sustainable construction materials also result in advanced framing techniques that reduce labour cost and increase the life of projects. Sustainable materials are the future because they conserve energy as these last a long time and less resources are required for their production. Their production process emits less waste and these are equivalently more efficient [3]. The current scenario has made us aware of the importance of material selection, and manufacturing materials with low energy usage than structures' operating energy. Building technology and manufacturing processes have reduced the energy consumption of building materials that result in drastic reduction of energy consumption per unit usage of production. Most of the sustainable materials are natural materials with low energy consumption and low maintenance that should be convenient, can be easily dismantled, and are feasible for any project irrespective of structure and design. These should have zero impact on the environment.

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II. NEED FOR SUSTAINABLE CONSTRUCTION MATERIAL

Embodied energy or embodied carbon of building material is the total impact of greenhouse gas emissions during its extraction, manufacturing, maintenance, transportation, construction, and disposal [4]. For instance, although materials like steel and concrete represent a minimal part of the ultimate cost in the building as a whole, a large amount of energy is required for their manufacturing, transportation, and installation process. Even if there is a small amount of embodied carbon in one ton of concrete, when it is multiplied by the amount of concrete used in a building, it indicates that concrete contains the largest amount of carbon in the world [5]. Since cement production is extremely energy and fuel intensive, it makes concrete a ranking producer of carbon dioxide emissions contributing to global warming [5]. In the manufacturing process of cement, for instance, cement dust, waste concrete, scrap block, and brick constitute solid waste [6]. Therefore, different types of building materials have been identified as sources of hazardous substances and processes, the most significant of which is the carbon footprint that is left behind when fossil fuels are burned for energy generation and throughout the life cycle of the building material. Finding proper replacements for the materials which have a big proportion in contributing carbon dioxide to the environment is necessary to reduce the amount of its emission to prevent the increase in global temperature. The life cycle cost of a structure is directly related to materials, long-lasting materials give us fewer repair costs reducing the life cycle cost of a project. Higher greenhouse emissions are a result of high energy usage in the initial stages of construction, replacing regular materials with sustainable energy materials that will resolve various factors in our industry. A construction material's chemical-physical properties and appropriate design are responsible for the material's strength, but these high strength materials are responsible for the emissions of harmful greenhouse gases and energy consumption causing adverse effects on the environment [7]. These harmful conditions are not only applicable to the environment but also to human beings working under that roof that is strangled in that hazardous environment. Many types of researches have been carried out with modifying durable materials, with high strength and eco-friendly properties regarding the latest comfort standards. There is an urgent need for reducing the impact of building materials and their negative application by the implementation of advance technology and sustainable way to tackle it. This shows us the importance of energy efficient buildings and net-zero energy buildings in today's era. However, complete net-zero energy consumption is not possible but nearly zero is what we should aim for. The main objective of creating sustainable materials is to discover a material that has a lesser impact on environmental degradation and create healthy buildings. Within the scope of sustainability, emphasis should be given to fundamentals, application, and impact of a material. These sustainable materials falls under the concept of eco-friendly sustainable development (ESD) that focuses on accomplishing the current and future needs keeping the environment in a safer zone.

III. ECO-FRIENDLY CELLULAR CONCRETE

Eco-friendly cellular concrete is a concrete made with hydraulic cement, water and preformed foam. After hardening it gives a concrete block that is usually used in building as well as construction applications such as roof decks and geotechnical applications such as annular space-filling in slip lining and void fill abandonment having an oven-dry density of 50lb/cubic foot or less. The composition of cellular concrete distinguishes itself from other types of concrete. Aggregates play a major role where the ones used in cellular concrete are extremely fine making them highly suitable for re-shaping or pre-casting purposes. A major difference between standard and cellular concrete is in the aggregates that are used during mixing. In standard concrete along with cement and sand, gravel is used as an aggregate [8]. On the other hand, in cellular concrete industrial waste material-fly ash and preformed foam are used. As a result, cellular concrete is very light in weight compared to standard concrete. Cellular concrete has a low-density range, between 400-1600 kg/m^3 compared to normal concrete which has a relatively high density because of the coarse aggregates used [8].

They also differ in their uses. Cellular concrete is mainly used in making partition walls, concrete slabs for roofing, vessels, and roof decks. It is also used as loose-fill insulation in construction where it is used to enhance fire rating, reduce noise transmission, and is termite resistant. Applications of normal concrete on the other hand include

dams, bridges, swimming pools, patios basements etc. [8].

IV. COMPOSITION

Eco-friendly cellular concrete is also known as foam concrete or lightweight concrete. The foam that is created during the process helps to maintain the lightweight and durability of the material. Various chemical reactions are responsible for the lightweight property of this concrete. One is when Aluminium particles react with $Ca(OH)_2$ (Calcium Hydroxide) and H_2O (water) to form H (Hydrogen) [9]. This formation of hydrogen doubles the volume of the mixture and creates bubbles. After the foaming process is completed, this hydrogen escapes from the mixture and is replaced by air (Fig. 1). The foam is generated by using a suitable agent while the air is maintained at 40% to 80% of the absolute volume. The prime agents used can be gentile or any organic substance. Fly ash helps make this concrete eco-friendly. Fly ash is easily disposable and is a waste product of industries. It helps in improving the workability of concrete along with strength and durability, and for cementitious properties a mixture of cement pozzolana, lime pozzolana, cement silica, lime silica, and Portland cement paste.

To make cellular concrete more eco-friendly, filler material can be replaced by plastic fibres, wood fibres, paper powder, rice husk ash, sugar bagasse ash, coconut coir ash, groundnut shell powder, crop harvest ash, etc., and chemical foaming agent can be replaced by using water in which soapberries are soaked for 12 hours.

V. ADVANTAGES

A major component of cellular concrete is fly ash, which is considered industrial waste and is easy to dispose of [8]. Since it is the key ingredient in cellular concrete, it resolves the issue of its disposal and it is also very economical. Thus, cellular concrete is considered eco-friendly. Its density is relatively low. Thus, it has a positive impact on the weight management of building materials. Since it is light in weight, the transportation cost is reduced considerably. By using cellular concrete, the overall dead load of a structure is decreased which results in less use of supporting members in high rise structures [10]. Therefore, there is a reduced construction costs less money than that spent on materials like steel and cement. It acts as a perfect thermal insulator at low density [8]. Also, along with thermal insulation, it provides sound protection as there is air embedded in cellular concrete which helps in absorbing sound and reduces its intensity. The air embedded in cellular concrete also makes it a good fire-resistant material as its walls are made from this material and it can endure fire breakout for hours [8]. Cellular concrete is a self-compacting material that naturally fills voids, cavities etc. within the pouring area [10]. With these advantages, it is evident that cellular concrete is an efficient and cost-effective solution because of its durability, less maintenance cost and it also

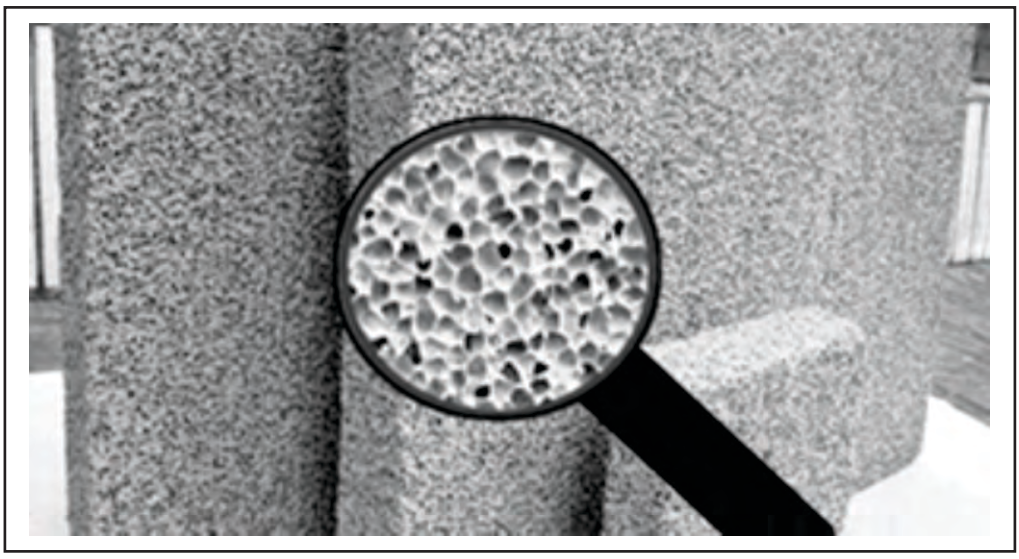

Fig. 1. Cellular Concrete

requires less labour force. These concrete blocks offer great fire and heat protection. It avoids transmission of fumes during fire with thickness of just 10 mm and a density of 1000 kg/m^3. Therefore, it provides a better fire rating than a brick wall.

VI. LIMITATIONS

Cellular concrete takes a longer time to dry and if not dried properly, it can also result in the formation of cracks [11,12]. This makes it difficult for civil contractors as they have to wait longer after installing cellular concrete as flooring. This makes the work hectic during rainy seasons as it increases the formation of cracks after installation which can be reduced to any extent by ensuring that the drying process is fully completed and the strength of the mortar is reduced. These concrete blocks are brittle and easily breakable when direct pressure is applied [12]. These blocks need more care than bricks. Due to the brittle nature, attention needs to be paid to the drilling and hammering process. This is also needed where longer and thinner screws are preferred as attachments and hammers of greater diameter, these materials usually end up increasing the overall cost. However, to satisfy the present rules and regulations to realize thicker walls, contractors usually find themselves applying an extra layer of plaster/insulation.

VII. APPLICATIONS

Cellular concrete is used for bulk filling by applying relatively low strength material for old pipes, unused cellars and basements, wells, deep excavations, storage tanks, and tunnels and is used for trench fill that helps prevent later soil settlement and subsequent dips in the road [12, 13]. Potential damage to geogrid can be reduced to a great extent during the backfill process using cellular concrete. They are a great alternative to building interior walls that are light in weight. It is used for soil water drainage purposes and the production of heat-insulated light wall pane [13]. It is an excellent option for building foundations on weak grounds. It is also used for insulation and heating purposes.

VIII. CONCLUSION

Among the most important and largest consumers of natural resources in the construction industry, construction materials use about 60% of the world's natural resources directly or indirectly in the development of infrastructures and buildings [14]. Several problems are caused due to the extraction, disposal, and manufacturing processes of unsustainable building materials. In the mining industry, the major issue is that solid waste appears in the form of overburden and gangue. Solid waste piles can lead to some waste runoff into the near water bodies which in turn can cause stream sedimentation [6]. For instance, in coal mining, the most significant liquid waste is acid mine drainage and acid runoff from relocated overburden, while the major gaseous waste from the same is methane in underground mines. On the other hand, waste from equipment wash off, accidental spill washdown, and aggregate moisture control forms a part of miscellaneous wastes [6]. Another example is from iron and steel industries, where the by-product of the manufacturing process of steel, namely slag, poses a special solid-waste disposal problem. Severe hydrogen sulphide and dust-related air problems have been observed near the steel mills where the slag has been dumped in huge piles [6]. Deriving from the above-mentioned statements, there is an urgent need for sustainable materials having lesser impact on the environment and surroundings, and leaving a better place for the upcoming generations. Eco-friendly cellular concrete is not only environment friendly but also durable, lightweight, disposable fire-resistant, and easy to handle. These concrete blocks have a great impact on the cost of the project as they are made at cheaper prices and due to the lightweight, labour cost is also reduced. With a greater fire-resistance rating when compared to other materials, cellular concrete is indeed a sustainable construction material.

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