REDUCTION OF CARBON FOOTPRINTS OF MUMBAI CITY- USING CIVIL ENGINEERING TECHNOLOGY

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Abstract - *India is one of the major contributors of greenhouses gases in the world and construction industry is one of the major source of pollution. Encroachment of pioneering technology in the industry will create a tremendous positive impact on the environment.*

As the carbon footprint of Mumbai city has reached to an average of 1.76 tonnes CO2/ capita, and the construction industry is thriving with new projects to expand the city it is time to integrate the technological advancements in order to mitigate the greenhouse gases.

Using Timbercrete, 3D Construction Printing, Moss covered benches and onsite turning of the excavation waste into building material will take the edge off the carbon footprint of the city by manifolds.

Key Words: **Carbon Footprint, Timbercrete, Moss benches, 3D Structural Printer, Green house gases, Excavation waste**

1.INTRODUCTION

A **carbon footprint** is the total greenhouse gas (GHG) emissions caused by an individual, event, organization, service, place or product, expressed as carbon dioxide equivalent. The increasing levels of Co2 in atmosphere is leading to climate change impacting the health and lives of many species of this planet. India is the third-largest emitter of greenhouse gases and accounts for 2.46 billion metric tonnes of carbon or 6.8% of the total global emissions. While the average carbon footprint of every person in India was estimated at 0.56 tonnes per year but the distribution varies greatly between the metropolitan cities and the other parts of India. The carbon footprint of every person in Mumbai is more than 3 times the average of the country. Study shows that Mumbai has an average of 1.76 tonnes CO2/ capita. This is an alarming value.

Our construction industry is one of the highest contributors to the country's CO2 emissions accounting to 22% of total annual CO2 emissions. As Maharashtra is accounting for 25% investment in real estate and Mumbai being the hotspot for industrial advancement, it is a witness to proliferating population. Thus, the need for construction of amenities and floor space is escalating. As the city is continuously expanding, the increasing CO2 emissions is alarming.

In infrastructure projects, on-site handling and hauling of excavated soil and rock and construction material from quarries generate significant amount of CO2. The advancements in construction technology can reduce the carbon emissions and aim for sustainable living and greener environment. Smart solutions for absorbing CO2 from the atmosphere can be implemented by the civil engineers to reduce the existing carbon footprint of the city.

2. METHODOLOGY

2.1 CONSTRUCTION 3D PRINTING

3D printing (sometimes referred to as Additive Manufacturing (AM)) is the computer-controlled sequential layering of materials to create three-dimensional shapes. It is particularly useful for prototyping and for the manufacture of geometrically complex components.

Construction 3D printing may allow, faster and more accurate construction of complex or bespoke items as well as lowering labour costs and producing less waste. A recent paper from researchers at Delft University of Technology predicts that additive manufacturing could reduce global energy usage by 25% by 2050.

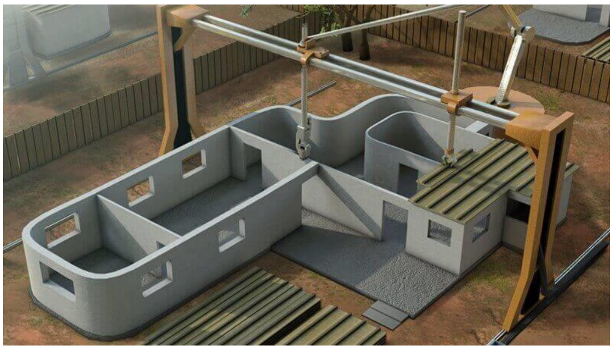

Fig.1. Working of 3D Structural Printer

This advancement in technology addresses the three major facets of construction industry's carbon footprint i.e. Materials, Manufacturing and Transportation.

2.1.1 Materials

3D printing can reduce the materials component of the carbon footprint is by enabling energy-efficient geometries that use much less material than traditional manufacturing processes. Thus, demineralization will effectively reduce the material waste.

2.1.2. Manufacturing

The traditional construction techniques generally take months or years to build a house but 3D printers can complete the work in a few days or weeks. The speedy process ensures less pollution of the environment and also limited use of resources. Moreover, many metal components used in the construction can be replaced by high performance polymers created using 3D printers. The reduction in use of metals impacts the reduction of carbon footprints by manifolds.

2.1.3. Transportation

The biggest impact of 3D printing on the transportation component of carbon footprint. This involves the transport, storage, and handling of the product to the construction site. A lot of machinery and materials are required to be transported at construction site which burns a lot of fuel and cause a lot of pollution. As 3D printing is the computer-controlled sequential layering of materials to create three-dimensional shapes, the need for the transportation of various machines and materials is eliminated.

Three-dimensional concrete printing is an up-and-coming technology that is being adopted globally due to its diverse set of advantages: reduced costs, saved time, and decreased labor requirements, enhances safety on-site, increases design flexibility, and reduces environmental impact. Thus it is a great innovation to balance the growing construction demand and the carbon footprint of the city.

Fig.2. Piping of concrete on the construction site

2.2. TIMBERCRETE

Timbercrete is made of a unique blend of cellulose (timber waste) i.e. sawdust or recycled timber, cement, sand, binders, and other materials. Its main ingredient sawdust is often used for producing fertilizers, as floor cover in horse stables, or is simply discarded or burnt. All of these uses have a negative impact on our environment, because as the product breaks down, it releases carbon dioxide gas into the atmosphere. This is referred to as "greenhouse gases". When used for Timbercrete however, this vicious cycle is stopped because Timbercrete acts as a carbon trap, when the cellulose waste is preserved within a concrete tomb and never breaks down.

It has lower Embodied Energy Due To:

• No Kiln Firing – Timbercrete does not need to use artificial or man-made drying processes. Conventional clay bricks require firing for strength and durability. This process consumes a large amount of energy and the toxic by-product is a poisonous cocktail of sulphuric, carbon monoxide and carbon dioxide gases.

• Energy use during manufacturing - To manufacture 1m2 of wall area, Timbercrete uses far less equipment and energy than other traditional brick and block making systems in its production process.

• Energy to attain raw materials - Wherever practically possible Timbercrete utilizes locally sourced raw materials.

Fig.3. Timbercrete Brick

It is an environmentally sensitive building material that has many advantages over clay and concrete bricks. Whether used as bricks, blocks, panels or pavers, its comprehensive performance and benefits to the environment are impressive. This unique product can be moulded or pressed into a vast range of sizes, shapes, colours and textures. It can be used for residential, industrial and commercial construction, as well as landscaping and a range of other applications. The advantages of Timbercrete in building construction are :

• Timbercrete is a structural brick or block product that traps carbon which would normally end up as greenhouse gases in our atmosphere.

• It has substantially lower embodied energy compared to clay fired bricks.

• It has a higher insulation value (R) in comparison with traditional solid masonry bricks blocks and panels.

• It has a workable thermal mass which is the ability to store thermal energy and release it lowly.

• It boasts unique and in some situations improved engineering qualities such as better resilience and improved breaking load resistance compared to unreinforced clay and concrete products (as tested).

• Lighter weight (up to 2.5 X lighter than concrete or clay).

• Unique workability, it can be nailed and screwed into just like timber, but retains all the advantages of conventional masonry.

• Higher fire resistance – at 190 mm thick, outperforming typical concrete blocks, clay, timber and steel construction. It has the highest possible fire rating exceeding FRL240/240/240.

Timbercrete is very environmentally friendly all the way from its raw ingredients through to its everyday use. Its main ingredient is recycled timber waste (cellulose). It has significantly lower embodied energy, and acts as a carbon trap. On top of all this, its improved insulation qualities mean Timbercrete homes are more energy efficient throughout the year.

Fig.4. Timbercrete house

India is one of the ten most forest-rich countries of the world. As India is blessed with 70.7 million hectares (23.8%) of forested land, this technology can be economical as well as sustainable. Thus, Timbercrete will be proved very effective considering the continuous expansion of Mumbai city and the growing need of floor space for the increasing population. Its CO_2 absorbing capacity will prove beneficial for reducing the high carbon footprint of the city.

2.3. MOSS COVERED BENCHES

A moss covered bench is a city bench with the ability to absorb as much pollution as a small forest. Using a vertical installation of moss, the bench can absorb as much pollution as 275 trees in 1 percent of the space.

It has already been installed by GreenTech Solutions in cities across Europe and Asia, including Berlin, Oslo, Paris, Amsterdam, Brussels, Drammen, Newcastle, and Hong Kong.

The bench is about 13 feet high and can hold up to 1,682 pots of moss, planted in the vertical garden. The moss acts to filter out particulate matter, absorb CO_2 and remove soot, dirt, and other pollutants. The use of moss, which hosts bacteria, both work to absorb particulate matter in the range of 0.1 microns to 10 microns.

Laboratory tests to determine the efficiency of the CityTree were done by Proambiente Institute, a partner of Climate-KIC. As for trees themselves, each adult tree can absorb about 0.022 metric tons of carbon dioxide per year, meaning a grove, which is a small clustering of trees could absorb around 2.2 metric tons of carbon dioxide per year, estimating a grove at about a hundred trees. Each CityTree removes 240 metric tons of CO_2 from the atmosphere per year and 250 grams of particulate matter per day. A trial wall went up off Piccadilly Circus in London and it indicated that a single CityTree could remove the particulate pollution of 42 diesel cars every month.

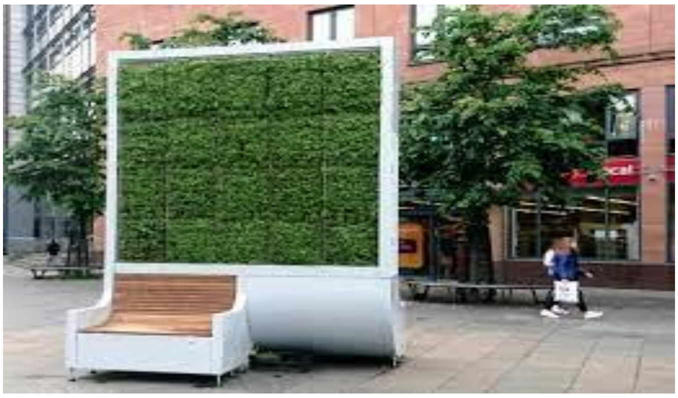

Fig.5. Moss bench installed at Berlin

The ability of certain moss cultures to filter out and absorb air pollutants such as particulates and nitrogen dioxide makes them ideal air purifiers but in towns and cities air pollution presents the greatest challenge making mosses impossible to survive as they need constant water and shade. But CityTree uses protective, shade-giving plants to create an environment where the specially cultivated mosses can thrive in the urban conditions. Powered by solar panels, the living structure also collects rainwater and automatically redistributes it using an inbuilt irrigation system.

Integrated into a wall is:

- Solar panels to power fans for a controllable ventilation technology that allows airflow to be intensified (meaning that the filter effect can be increased as required.)
- A rainwater catchment system to supply a fully automated irrigation system for watering the moss.

- IoT technology which delivers comprehensive information on performance and status as well as environmental data on the CityTree's surroundings.
- It can provide power for Wi-Fi hotspots, e-bike charging stations, or transport or tourist information.

Fig.6. Moss planted on the wall

These 4-meter tall slabs can improve human health by consuming ultra-fine airborne particles that can travel deep into the lungs and pass into the bloodstream, posing a serious risk to health. Research suggests that particulate pollution is linked to higher death rates from respiratory illnesses and there are numerous studies that link dirty air to higher risk of mental disorders such as dementia, bipolar disorder, severe depression, and schizophrenia.

Regardless, the mossy walls create a very pleasant ambiance and they also provide a pleasant cooling effect. Mosses store large quantities of moisture. That, combined with the considerably increased evaporation surface of the wall creates an immense cooling effect for the people around it.

These city trees can be installed at bus stands on the highway where the traffic and pollution is unbearable in Mumbai. While the city trees cost is very high it can be redeveloped using Indian technology and skills and also it can display marketing advertisements so the cost can be recovered gradually.

2.4. TURNING EXCAVATION WASTE INTO BUILDING MATERIAL

Construction in urban areas implies use of construction materials from quarries and excavation of soil and rock. From a resource perspective, there could be benefits from using excavated soil and rock as a construction material. Depending on local geological conditions and anthropogenic activities, excavated material can be rock, stones, gravel, sand, clay, organic material and materials from previous constructions or industrial activities. The quantities of excavated soil and rock can be considerably big and hauling and handling costs high. In infrastructure projects, on-site handling and hauling of excavated soil and rock and construction material from quarries, i.e. quarry material, can be up to 30% of the total project cost and generate significant amounts of CO_2 emissions.

A US-based company has developed a new technology that repurposes excavated waste on building sites into building material, eliminating the problem of waste disposal. To make way for new buildings, truckloads of excavated waste are removed from site in a noisy, time-consuming and gas-guzzling process. Exploring a more sustainable solution, the California-based company Watershed Materials have developed an onsite pop-up plant which repurposes excavated material right at the job site to create concrete masonry units (CMUs) used in the development. By eliminating truck traffic, reusing waste and reducing imported materials, the result is a win for the environment. The pop-up plant itself works by applying ultra-high compression to loose excavation spoils, transforming it into a sustainable CMU. The pressure turns the mineral grains into a sort of sedimentary rock, mimicking the natural geological process of lithification. According to the founder of the company David Easton, "what is new and absolutely ground breaking is that with upgraded technology and improved material science, a construction waste product the developer had to pay to dispose of can now become an asset and provides environmental benefits as well."

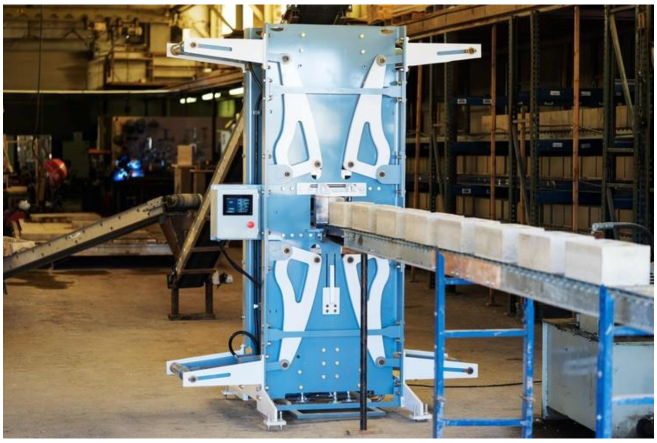

Fig.7. Machine used at Watershed Materials

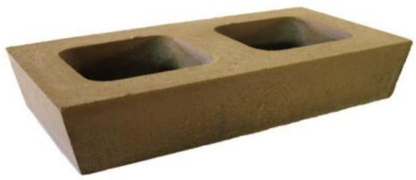

Fig.8. Brick made using excavation waste

The compelling advantages of the onsite process and product are that reduced truck traffic will reduce cost, diesel emissions and impact on neighbours. Also, the pop-up plant itself is no louder than typical construction equipment and only onsite for a limited period of time. Taking into account the amount of construction waste produced yearly and the fuel usage during the construction this technology is revolutionary in exercising sustainable construction in the city.

3. CONCLUSIONS

The use of the mentioned advanced technology will ameliorate the highly alarming carbon footprint of the city. It is required to supplant the traditional construction methods with 3D structural printing and implementing onsite turning of excavation waste to building materials.

Moreover, Timbercrete and Moss-covered benches are a revolutionary development in terms of sustainable construction as it acts as a carbon trap. Therefore, the pollution of the unremitting city of Mumbai can be redressed.

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