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NEED OF CARBON NEGATIVE CONSTRUCTION MATERIALS TO SEQUESTER GHG EMISSION AND GLOBAL WARMING.

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Abstract – Concrete is the key element for construction of buildings after its introduction in construction industry, it was supposed to be a gift for construction industry but its excessive use has become a threat with the amount of CO2 emitted each year during its production. Concrete contributes to green house gas emission and its production alone contributes to 102 mega tones of global CO2 production. Advancement in construction technologies like Tunnel formwork and Aluminium formwork has bought significant changes over conventional construction process. These technologies and advancement have replaced all the building elements with concrete, which eventually will result in growing demand for concrete production and CO2 emitted along with it. Before introduction of concrete, load bearing structures were built with masonry width 450mm and above but after its introduction only frame structure of the building were built in concrete except facade and internal walls, which were built with mud bricks, but in later stage with such an advancement in construction trends and technologies all the components of buildings are built in concrete including external and internal walls. If all the components of buildings are made in concrete, it will ultimately lead to excess concrete production and thus emitting maximum green house gas which will reflect in rising global temperature thus causing sea level rise up due to conversion of ice glaciers into water. This research paper emphasis on using carbon negative building blocks i.e Hempcrete blocks to absorb carbon from the atmosphere thus decreasing the global temperature and to have control over the disasters caused such as floods due to rising sea level. To mitigate ever increasing green house gases, use of sustainable material which is carbon negative is mandatory for building low rise as well as high rise towers. Carbon absorbing bio composite material which is hempcrete is advised to be used to sequester existing CO2 from the environment.

Keywords *– Hempcrete, GHG, Sea level rise, Flood, CO2, Negative carbon footprint.*

I. INTRODUCTION.

Concrete is widely produced man made material around the globe with production of 4 billion tones each year [1]. Its production results in 8% global carbon dioxide emission[1]. The rate at which cement is produced, if it continues to be the same then in coming 50 years sea level will rise due to unstable Antarctic ice sheet melting and it will result in annual flooding in continents with low terrain. China is the largest producer of cement world wide. China alone produces concrete which is almost double as compared to concrete produced by addition of all the countries, which is estimated 2.2 billion metric tons in year 2020. Global cement production in year 2010 was 3.27 billion metric tones and analyzing the past growth in cement production it is expected to rise to 4.83 billion metric tones in 2030 [15]. 900 kg CO2 is produced with each tone of cement produced thus many researchers around the world are paving a path towards discovering cellulose aggregate concrete (CAC),Such bio based concrete are made by using straw, hemp, agricultural waste or animal hair. Out of which Hemp is the only material which practically shows negative carbon footprint. Thus its use in building blocks along with lime offers many indoor and outdoor advantages .

II. FACTORS FUELING CONTINUOUS CONSTRUCTION.

Migration of people from suburbs to cities in search of job opportunities and better standard of living are the core factors which contribute to infinite construction activities. According to the studies conducted in 2015 about 247 million people live in a country not of their birth as most of the population gravitate to foreign lands in search of new job opportunities. Majority of the population migrating are in the age group of 18 to 60 years and around 80% of migration hails from developing countries. India Mexico and China are the leading countries for the origin of migrants. Developing Latin America accounts for 18% , Eastern Europe and central Asia accounts for 16 % while North Africa accounts for 14 % of migrants gravitating to developed countries. People migrate from remote countries but their concentration is in developed nations which leads to rising demand for residential apartments and improved infrastructure.

III. ADVANCEMENT IN CONSTRUCTION INDUSTRY ACCELERATED THE USE OF CONCRETE.

New construction technology such as Alu-formwork and tunnel formwork accelerated the use of concrete as it has replaced conventional construction process where the brick walls are replaced with shear walls and along with it internal walls are also replaced with shear walls. These advancement in construction technology replaced each and every building component with concrete. In conventional method of building construction only frame structure which includes foundation, columns, beams and slabs were constructed with concrete. External walls were constructed 230mm thick and internal walls were 150 mm thick brick walls. In later stage, external walls were constructed of 150mm and internal walls 75mm thick brick. But these recent construction trends and techniques replaced external and internal walls with shear walls which are casted in concrete.

IV. CEMENT PRODUCTION PROCESS.

Carbon dioxide is a by product of cement produced. CO2 is released during production of a clinker which is a component of a cement. It is produced when clay and lime i.e calcium carbonate (CaCo3) is heated in a rotating kiln at

600 to 900 degree celsius to obtain cement sediments. Carbon-dioxide is a by product of calcination process which is obtained in production of cement. The direct CO2 emission from cement manufacturing arises from de-carbonation of the limestone and combustion of the fuels in the kiln.

V. CEMENT CONTRIBUTES TO GREEN HOUSE GAS EMISSION.

Construction industry is completely dependent on concrete for infrastructure and residential development. Concrete is the most widely used man made material so far in existence. It is second most consumed resource in the world after water, which emits 8% carbon dioxide in to the atmosphere. It is a vital construction material for the construction of housing sector and infrastructure activities and is a key to economic growth of any country. Every year cement contributes to mega ton of GHG emission. The way to estimate CO2 produced is to start from the specific gross CO2 emissions i.e kg of CO2 emitted per ton of cement produced and multiply it by the total cement production which gives us an exact number (e.g. kg of CO2 emitted). IEA indicates that 0.5-0.6 ton of CO2 is emitted per ton of cement [5], reports from cement companies rather indicate a value around 0.6-0.7 tone CO2 per ton of cement (GNR average of 0.654 t CO2/t cement). By multiplying the average value (0.6) by the total cement production (4.1 Gt) we obtain total CO2 emission from the cement industry (2.5 Gt) which is about 8% of the total CO2 emission in the world. Each ton of cement production dissipates 900 kg CO2 in to the atmosphere. .

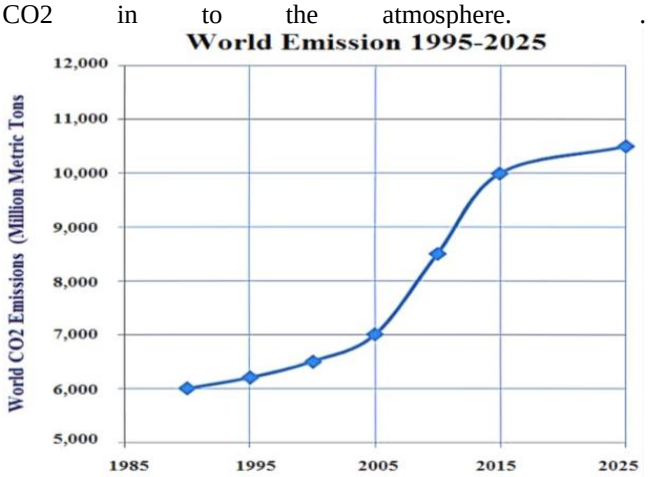

Figure 1. CO2 emisson in million metric tons from 1995-2025.
(source - https://www.researchgate.net/publication/319292238)

Reffering to the graph it can be seen that global CO2 emission after 1985 was 6000 million metric tons which gradually increased with the start of 1995 when it crossed the previous CO2 emission level and it can be seen rising continuously. spikedup to 10000 million metric tons in 2015.A study conducted in 2014 states that manufacturing of cement alone produces 102 mega tones od CO2 in India, which forms 4.4 % of total 2.3 giga tones of CO2. Major industry for greenhouse gas emission around the globe is cement industry, which contributes almost 6% of the world global warming and anthropogenic conservatory gases emanations [3]. The demand of cement is directly linked with the economic growth of any country [6]. Many developing countries are concentrating on the development of infrastructure which results in the growing demand for cement in the global market. Although cement industry benefits the economic development of a country, its production emits more carbon dioxide contributing to GHG than Aviation industry of any country.

VI. RISE IN SEA LEVEL DUE TO GHG EMISSION.

Global mean sea level is rise has accelerated due to rise in temperature due to green house gas emission and will further more continue to rise until all the habitable land available to reside submerses. Global mean sea level from 1993 to 2021 is rising at the rate of 3.4 mm per year as hundreds of megatons of ice glaciers are melting due to heat that is trapped in Earths atmosphere due to GHG[14]. Warmer atmosphere temperature is responsible for the melting of the ice sheets while warm ocean waves are responsible for eating up the ice glaciers from the bottom. Dark ocean colour contributes to absorb more heat which is generated by GHG emission, thus warming the ocean waters which then reflects in melting of ice glaciers from the bottom. Ice sheets alone is responsible for sea level rise by 1.2mm per year out of 3.4 mm sea level rise. Scientists calculated this by collecting the data from GRACE FO and GRACE satellites which studied Greenland ice mass change for last 18 years[14].

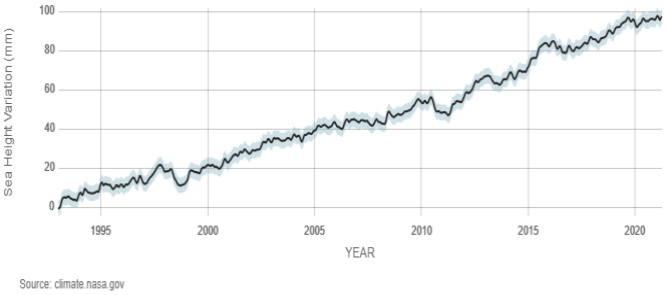

Figure 2. Sea height variation from 1995 – 2020.
(Source – climate.nasa.gov)

This graph indicates the global sea level rise i.e is 3.4mm per year from 1993 to 2021. Since 1993, four generations of satellite altimeters have measured the height of the oceans and seas through out the world. Sea level has risen globally by about 4 inches (93 millimeters) and as much as 6 inches (150 millimeters) in some places [14]. A study was conducted with (DEM) Digital Elevation Model which makes a survey of global population living on land and which are exposed to extreme costal water levels in up coming years. Two models were taken in to consideration , one with probabilistic model which is closely aligned to IPCC findings which was named K14. The other was named K17 which was also a probabilistic model but emphasized on rising sea level due to unstable ice sheet dynamics. In case of Antarctic ice glaciers instability, total of 300 million people residing on land are considered vulnerable which is expected to rise to 480 million by the start of 2100. That means around 360 million people across the globe are going to be threatened by Annual flood events in 2100. Recent work has suggested that, even in the US, sea-level rise this century may induce large-scale migration

away from unprotected coastlines, redistributing population density across the country and putting great pressure on core urban fabric i.e inland areas [9]. Majority of the people living on flood prone land are in developing countries across Asia due to low terrain. Chronic coastal flooding or permanent inundation will threaten areas occupied by more than 10% of the current populations of nations including Bangladesh, Vietnam, and many Small Island developing nations by 2100 [6]. For the present day, Coastal Digital Elevation model estimates a total of 110Million people on land below the current high tide line and 250Million on land below annual flood levels, in contrast with corresponding SRTM-based estimates of 28M and 65M. These mentioned values serves as a platform to differentiate between total and marginal exposure estimates. Sea levels projected by 2050 are high enough to threaten land which is currently a home to a total of 150 million people to a future permanently below the high tide line. Total and marginal exposure each rise by another 50 million across the globe. Considering the findings coastal communities worldwide must prepare themselves for much more difficult future to come due to rising ocean level than may be currently anticipated.

VII. GLACIAL REBOUND IS THE ANOTHER CAUSE FOR SEALEVEL RISE.

Solid earth dynamics and glacial rebound dynamics is another reason for some countries to already suffer effects of rising sea level while some countries are facing no issue of rising sea level. This is because, when ice glaciers are accumulated in a large quantities on a particular continent, earths crust below that glacier gets suppressed due to its heavy weight. Over the time when these glaciers starts melting the weight it exerted before on earths crust slowly releases which helps to regain its original state. Due to this phenomena, some countries on the opposite side of the same continent becomes a victim of rising water level while some countries suffer no adverse effects of sea level rise. e.g there was much ice accumulated during ice age in Canada and Scandinavia, on the contrary countries on the other end of same continent i.e US was gradually high in terrain but over the years as the ice glaciers in Canada melted, the land which was suppressed by weight of ice glaciers got free and did regain its original state and this will eventually result in rise of seal levels in US by the start of 2100 if adequate measure are not taken to stop emitting green house gases.

VIII. HOW RISING TEMPERATURE CAUSES FLOODING.

Global glacier melting is currently affecting human society by increasing the rate of sea-level rise, changing seasonal discharge in glacier fed rivers, and increasing geo-hazard potential [7] .Globally rising heat causes more water to evaporate in to the air which leads to an increase in amount of annual rainfall and snow. In coastal areas warmer atmosphere holds excess moisture which also increases the intensity of rainfall. A research conducted states that global sea level is is expected to rise 20 to 30 cm by the end of 2050 [5]. Ice glaciers in green land melted seven times with 34 billion tones per year between 1992 to 2001 and 247 billion tones from 2012 to 2016. Antarctic ice loss from 1992 to 2001 is 51 billion tones and 199 billion tones from 2012 to 2016 [13]. Scientists say government must make an effort to cut down carbon emission which is fueling extreme disaster events. Even northern hemisphere suffered record breaking heat wave which took many lives. World has already gone through a shift of 1.2degree Celsius after the industrial era began and is expected to rise in next 50 years [2]. Even a sharp cut in GHG emission around the globe yet sea level is likely to rise 0.5 m this century. Due to rising global temperature, intensity of heavy rains has increased in recent times.

IX. NATURAL CALAMITIES IN 2021 DUE TO INCREASED GHG.

Pasific northwest areas of US and Canada experienced heatwave like never previously observed with temperature hike of 46.9 degree celcius in the villagae of lytton which broke previous record and soon after it was a victim of wildfire. This heat wave was predicted to occur once in 1000 years but with continue increase in temperature due to GHG emission now it is ought to happen once on 5 to 10 years. This exceptionally rise in temperature lead to spike in death rate [21]. River running through swiss capital bern bursted its bank which was flowing at a record rate of 560 cu m per second [2]. Kastamonu province in Turkey suffered major loss when Ezine river bursted its bank. Bozkurt town is washed out with collapsing of many residential buildings and reports say that 70 people are found dead while many others are still missing. On July 16th more than 100 residents lost their life in western Europe and more than 22 deaths have been reported in Belgium. All this happened due to swollen rivers bursted its banks causing water to rush inland [2]. On 21st july China did suffer from heavy flood, total of 25 people were reported dead in Heina province. Out of which 12 people died due to heavy rain that flooded underground railway tunnels and more than 500 prople were rescued from the railway tunnels. Above ground roads were turned in to high current rivers which swept away cars and other debris. Costal regions in India suffered major flood as water clogged and was forced back into the towns as sea level has increased and back waters rushed through rivers causing floods in to the remote villages. Reports state that over 110 people have lost their lives due to floods and heavy rain causing landslide [3]. Experts say that global warming is the main reason for climate change which resulted in heavy rainfall. A land slide in taliye, Maharashtra, India encapsulated a whole village causing 42 deaths [3].Due to flood crossing its highest flood level, residents were asked to move to rooftops so that helicopter can spot them and rescue them. In Mumbai a building collapsed due to flood causing 2 deaths and leaving 10 injured [3].

X. NEED OF CARBON NEGATIVE BUILDING BLOCKS.

Hempcrete blocks are bio composite construction blocks which are made of hemp shives, lime and water. Hempcrete has showcases the ability to lock CO2 within its fibres unlike any other bio composite materials. One of the greatest advantage of using hempcrete blocks in constructing a wall is that these walls can breath and absorb carbon from environment unlike cement or any plastered

wall. One kg hemp shivs absorbs about 1.6 to 1.8 kg carbon from environment [22]. Hemp is the only plant which absorbs carbon when its alive and as well as when its composite is used in building blocks.Hemp blocks are termed carbon negative due to the physical properties it offers along with absorbing carbon. These blocks has potential to absorb CO2 emitted during its manufacturing process and still continue to absorb CO2 throughout its lifespan. These blocks can be used in residential or commercial apartments as insulation on interior surface of walls also these hempcrete blocks can be used on external walls due of its properties like water permeability and damp resistance.

Figure 3. Hemp blocks for interior and exterior wall.

Figure 4. Detail for door opening.

(Source- https://www.isohemp.com/sites/default/files/styles/x-large/public/galerie/isohemp-)

1 hectar hemp field	
Hemp from 1 hectar = 8 ton hemp	Shiv from 1 hectar = 4 to 8 ton
Hemp from 1 hectar = 18 ton CO2 absorbed	Shiv from 1 hectar = 10 ton CO2 absorbed.
1 m3 hempcrete wall	
110 kg hemp shiv	202 kg CO2 absorbed
220 kg lime binder	94 kg CO2 emitted
1 m3 Hempcrete wall	108 kg CO2 absorbed

Table 1. Hempcrete's CO2 absorbing data. [17] [19]

Substitution of traditional brick wall by hempcrete wall for area of 1sqm emits 100 kg/sqm and hempcrete wall of thickness 300mm absorbs 40 kg/sqm CO2. Thus nett benefit per sqm is140 kg of CO2.

XI. PROPERTIES OF OF HEMPCRETE BUILDING BLOCKS.

Talking about its mechanical properties, it cannot be used in construction of load bearing structures but can be used in RCC structures for external walls and internal walls. Density of hempcrete blocks ranges from 300 to 900 kg/m3 but hempcrete has never lost its lightweight properties and have always been less than 1000 kg/m3 [17]. Compaction of these blocks increases the density of hempcrete blocks, as air pockets in between are removed in the process of compression. Many researchers state that thermal conductivity increases with increase in density. Researchers around the world has worked with different samples of hempcrete with varied density and stated that hempcrete's compressive strength ranges from 0.2 to 6.94 mpa. Which again depends upon its casting process [8]. Density and compressive strength is related in a way i.e as density increases thermal conductivity increases thus increased compressive strength. Thus it states that thermal conductivity and compressive strength varies with its density. Hempcrete blocks maintains thermal comfort very well according to change in seasons. During extreme cold it maintains warm temperature inside the room and during hot climate, it maintains cool temperature inside the room with sound absorbing properties.

	Hempcrete	Mud Brick	Concrete block Siporex (AAC)	Straw Bale
Carbon footprint	Absorbs CO2	Low	High	Moderate
Thermal comfort	0.065 [w/mk]	0.137 [w/mk]	0.16 [w/mk]	0.052 [w/mk]
Pest	Pest proof	Pest proof	Pest proof	Required
Fire resistance	Fire proof	Fire proof	3 - 6 hours	15 - 30 mins
Density	275 kg/m3	800 kg/m3	551 - 650 kg/m3	90-120 kg/m3
Workability	Fast & Easy	skills required	Fast & easy	Easy & fast
Recycling	Completely recycled at low cost	Recycled at Moderate cost	Recycled at high cost	Used as mulch
Damp & rot	Damp resistant	Depends on plaster	Damp resistant	Not resistant.
Sound reduction	37 - 45 dB	45-50 dB	37 - 49 dB	40 - 59.4 dB

Table 2. Properties of Hempcrete compared to other materials [17] [18] [19].

Hempcrete offers many advantages over other construction materials such as mud brick, concrete blocks and straw bale blocks. Hempcrete has a negative carbon foot print as hemp shiv from which it is made absorbs more CO2 in its life span than the amount of CO2 emitted during its production process. No other building material is capable of absorbing CO2 produced during its manufacturing but hempcrete does. It is one of the best thermal insulating material and also provides sound insulation which ranges between 37 to 45 dB. Since hempcrete blocks are admixtures of Lime, hemp shiv and water, it offers fire resistance unlike any other building blocks. These blocks are easy to handle, light weight and are easy to cast on site. These blocks can be completely recycled with minimum cost and can be reused or can be used as fertilizers.

XII. CONCLUSION.

Hempcrete blocks are of utmost importance as it helps sequester CO2 from the atmosphere. These blocks with hemp shiv absorbs carbon due to its natural properties even after binding with lime. Professionals in construction industry must spread awareness regarding use of carbon negative hempcrete blocks. Architects must propose hempcrete blocks for external as well as for internal walls in project specifications. Hemp cultivating countries must promote the use of hempcrete blocks in construction activities. With its observed advantages and impact on surrounding it is ought to set an example for other countries to follow it. Countries where hemp cultivation is illegal can understand the importance of hempcrete to take a step towards its cultivation and use it for construction activities. Use of building blocks with negative carbon foot print will help to control the intensity global warming and other natural calamities like floods, land slides due to excess rain, forest fires etc. which are observed in 2021. Production of hempcrete blocks are done at low cost also the extent to which the harm is done to the environment is negligible. Because the production of hempcrete blocks emits low CO2, it will further more add less CO2 into the environment. With the properties of hempcrete blocks to sequester CO2 produced during its manufacturing process, it has properties to absorb CO2 throughout its life span thus making it a Carbon negative bio composite building material. Considering all the mentioned factors, hempcrete blocks are of vital importance in maintaining balanced

ecology and having control over rising sea level due to green house gas emission. Use Carbon negative hempcrete blocks are suggested in construction of low rise and well as high rise towers to sequester GHG emission and thus achieving control over Global warming.

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