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Assessment of Carbon Footprint in Building Construction

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Abstract— **Global warming, which is generally and widely considered to be predominately caused by greenhouse gases as a result of human activities, has been one of the most critical and strategic environmental challenges. Carbon footprint is a term commonly used to describe the total amount of carbon dioxide and other greenhouse gas emissions. For example, in the paper making industry, the carbon footprint of paper is the amount of greenhouse gases released into the environment during the full life cycle of paper making. Carbon dioxide emissions from transportation of raw materials, as well as methane emissions from landfill sites can sometimes also be important contributors. Globally, the calculation/evaluation and reduction of carbon footprint of the contributing industries is an urgent and strategic task. In order to achieve sustainable and environmentally friendly future for the all industries, strategically effective measures (such as energy efficiency improvement of the manufacturing processes, energy self-sufficiency, use of non-fossil/carbon-neutral fuel energy and bio-based and biodegradable chemicals, practicing of sustainable forestry, development of integrated forest products biorefinery technology, efficient use of wood and non-wood fibers, more local sourcing of materials, can be implemented to reduce its carbon footprint. It goes without saying that ensuring a carbon-neutral economy of construction is one of the ultimate goals of green and sustainable development. In this paper, an attempt has been made to estimate the carbon footprint in correction with the building of an five storied building in a mega city of Kolkata, West Bengal.**

Index Terms— **Carbon footprint, Global warming, Greenhouse gases, Life cycle.**

I. INTRODUCTION

Carbon is the essential ingredient of all fossil fuels. When these fuels are burnt to provide energy, carbon dioxide (CO_2), a "greenhouse gas (GHG)", is released to the Earth's atmosphere. As material improvements are becoming more dependent on carbon-based fuels, a rapid increase in the atmospheric concentration of CO_2 has occurred. If current trend of fossil fuel use continues, the resulting concentration of CO_2 may results in more frequent severe weather conditions and damage to many natural ecosystems. To avoid such disastrous situation it is essential to promote actions that ensure stabilization of atmospheric CO_2 concentrations not more than limiting value.

Environment protection, in context of Global warming and climate change is one of important concern for all nation of today and this reducing carbon foot prints is the topmost concern. The mitigation of greenhouse gas emissions and the reduction of the consumption of fossil natural resources are now on the agenda of all countries throughout the world and for all sectors of human activity. Building carbon footprint is the total amount of greenhouse gases produced throughout the life cycle of a building, from energy use and materials. It includes building carbon emission from all life cycle stages such as material manufacturing (i.e. embodied carbon, capital carbon) and operating emissions (operational carbon).

Role of construction industry in climate change

Though generally unknown to common persons, the construction industry is one of the major sources of pollution. Construction-related activities account for quite a large portion of CO_2 emissions. Contribution of the building industry to global warming can no longer be ignored. Modern buildings consume energy in a number of ways. Energy consumption in buildings occurs in five phases. The first phase corresponds to the manufacturing of building materials and components, which is termed as embodied energy. The second and third phases correspond to the energy used to transport materials from production plants to the building site and the energy used in the actual construction of the building, which is respectively referred to as grey energy and induced energy. Fourthly, energy is consumed at the operational phase, which corresponds to the running of the building when it is occupied. Finally, energy is consumed in the demolition process of buildings as well as in the recycling of their parts, when this is promoted. In this respect, the cost-effective alternate construction technologies, which apart from reducing cost of construction by reduction of quantity of building made of alternate low-energy consuming materials, can play a great role in reduction of CO_2 emission and thus help in the protection of the environment.

CO_2 emission during production of construction materials

Production of ordinary and readily available construction materials requires huge amounts of energy through burning of wood or coal and oil, which in turn emit a large volume of GHGs. Reduction in this emission through alternate technologies/ practices will be beneficial to the reduction of global warming. To deal with this situation, it is important to accurately quantify the CO_2 emissions per unit of such materials. In India, the main ingredients of durable and 'pucca' building construction are steel, cement, sand and brick. Emission from crude steel production in sophisticated plants is about 2.75 tonne carbon / tonne crude steel. Cement production is another high energy consuming process and it has been found that about 0.9 tonne of CO_2 is produced for 1 tonne of cement. Sand is a natural product obtained from river beds, which does not consume any energy, except during transport. The energy thus consumed has not been considered in this article.

Brick is one of the principal construction materials and the brick production industry is large in most Asian countries. It is also an important industry from the point of view of source of GHG emissions as indicated from the very high coal consumption and the large scope that exists for increasing energy efficiencies of brick kilns.
Greenhouse gas emission is a key environmental factor and an integral component of building life cycle assessment (LCA). It is used in all green building certification schemes. Carbon footprint can also be used to track yearly optional emissions of a building.

II. PROPOSED INVESTIGATION

BUILDING SPECIFICATION

A newly five storied residential building under K.M.C., Kolkata- 700014 has been chosen. Frame structure with strap foundation. Height of the building is 15.5 mts. Total covered area = 780 sq.m. Marble, granite slab, vitrified tiles are used for flooring, toilet's wall and cooking platform. It consists one lift of 4KW. There are one staircase in the building. Glass windows are used in the building. Ground floor is partly used for two shops, one tenement and car parking space. First to fourth floor is used in residential use.

ENERGY AND MATERIALS CONSUMPTION

In Civil Engineering Building CO_2 emission is the parameter of the electrical energy consumption and the amount of material consumption. The amount of energy consumption is assessed by calculating the total wastage of the electrical components of the building and the total energy consumption per month for that building. From the energy consumption data one can calculate the amount of CO_2 emission per month from that building.
Materials used in the construction of a building have a huge impact on the emission of CO_2. Transportation of those materials is also a big factor for CO_2 emission.

[1] Quarried materials like stone and soil emit CO_2 during quarry. On the other hand materials like brick emit CO_2 during burning.

[2] Timber and wood work emit CO_2 during cutting and preparing it for various uses.

[3] Metals, cement and plastic or fiber emit CO_2 during manufacturing.

[4] Mortar emit CO_2 during mixing process.

All these materials emit large amount of CO_2 during transportation to site from source.

III. CALCULATION OF EMBODIED CO_2 EMISSION

1. QUARRIED MATERIALS
Soil
Earth work is filling = 4.3 m^3
Earth work in foundation = 221.5 m^3
Total earth work = 225.8 m^3
Weight of the earth work = 225.8 x 1.9 = 429.02 ton
Assuming 0.022 tons CO_2 emitted from 1 ton material.
Amount of CO_2 emitted = (429.02x0.022)=9.438 tons

2. ARTIFICIAL STONE
Artificial stone used in each floor is shown in Table 1.

Table 1: Amount of stone used in the Building.

FLOOR	Artificial stone in m^2	Porcelain tiles in m^2	Marble tiles in m^2
GROUND	95	2.5	75
1st	20	11.5	250
2nd	20	11.5	250
3rd	20	11.5	250
4th	20	11.5	250
Total	= 175	48.5	48.5

Total Volume of artificial stone = 175x35/1000=6.125 m^3
Total Weight = (6.125x2)= 12.25 tons.
Assuming 0.056 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission = 12.25x0.056=0.686 tons

3. PORCELAIN TILES
Porcelain tiles used in each floor
Total Volume = 48.5 x 25/1000=1.213 m^3
Total Weight =1.213 x1.8= 2.183 tons
Assuming 0.04 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =2.183 x 0.04=0.09 tons.

4. MARBLE TILES
Marble tiles used in each floor
Volume of Marble tiles = 17.2 m^3
Total weight of marble = 17.2x2.7 = 46.44 tons
Assuming 0.03 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission = 46.44x0.03=1.4 tons
CO_2 emission during transportation of this material
Distance from Rajasthan = 2000 km.
Mode of transportation = Road
Amount of CO_2 emission = 14.6 tons.

5. GRANITE SLAB
Granite slab Area = 19.2 m^2
Total Volume of granite = 19.2x0.25/1000=0.005 m^3
Total Weight of granite = 0.005x2.8= 0.014 tons
Assuming 0.03 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =0.014x0.03= 0.0004 tons
CO_2 emission during transportation of this material
Distance from Pankur = 400km
Mode of transportation =Road
Amount of CO_2 emission =3.8 tons.

6. BRICKS
Brick work used in each floor is shown in Table 2.

Table 2: Amount of brick work in the Building.

FLOOR	250mm thick brick work in m^3 (1:6)	125 thick brick work in m^2 (1:4)
GROUND	10.4	50.45
1st	35.775	158.6
2nd	35.775	158.6
3rd	35.775	158.6
4th	35.775	158.6
Total =	153.5	684.85

Volume of 125 thick brick work = 684.85x125/1000=85.6 m^3

Volume of 250 thick brick work = 153.5 m^3
Total weight = (85.6+153.5)x2.4=573.84 tons
Assuming 0.22 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =573.84x0.22=126.245 tons.

7. SAND
The total amount of sand used = 140.95 tons.
Assuming 0.005 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =140.95x0.005=0.705 tons
CO_2 emission during transportation of this material
Distance from kolaghat = 80 km
Mode of transportation = Road
Amount of CO_2 emission =16.242 tons.

8. STONE AGGREGATE
The total amount of stone aggregate used = 185.4 tons
Assuming 0.017 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =185.4x0.017=3.15 tons
CO_2 emission during transportation of this material
Distance from Pankur = 400 km
Mode of transportation = Road
Amount of CO_2 emission =94.271 tons

9. TIMBER
Number of windows and doors used is shown in Table 3.

Table 3: No of windows and doors used in the Building.

Item	WINDOWS	DOORS
GROUND	6	6
1^{st}	16	14
2^{nd}	16	14
3^{rd}	16	14
4^{th}	16	14
Total =	70	62

Volume of windows taken as =0.055x70=3.85 m^3
Volume of doors taken as =0.088x62=5.47 m^3
Total volume of wood used= 9.32 m^3
Total wood work =9.32 m^3 =4.66 tons
Assuming 0.46 tons CO_2 emitted from 1 ton material
Total Amount of CO_2 emission =4.66x0.46=2.144 tons.

10. METALS Reinforcement
Amount of reinforcement & grill used is shown in Table 4.

Table 4: Amount of reinforcement & grill used.

Floor	Reinforcement in tones	Grill (kg)
Foundation	5.5	-
Ground floor	5.25	190
1^{st}	5.25	2027.6
2^{nd}	5.10	2027.6
3^{rd}	4.95	2027.6
4^{th}	4.85	2027.6
Total =	30.9 tons	8300.4 kg

Assuming 1.71 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =30.9x1.71=52.839 tons

CO_2 emission during transportation of this material
Distance from Durgapur = 200 km
Mode of transport = Road
Amount of CO_2 emission =11.975 tons.

11. GRILL
Grill used in each floor
Total weight = 8300.4kg =8.3 tons
Assuming 1.77 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =8.3 x1.77=14.691 tons.

12. G.I.PIPES
Use of G.I.pipes of different diameter is shown in Table 5.
Table 5: G.I.pipes of different diameter used in the Building.

Diameter in mm	Length in m	Unit weight per m (kg/m)	Weight in kg
15	34.6	1.22	42.212
20	10.6	1.57	16.642
25	26.45	2.43	64.274
40	13.85	3.6	49.86
50	14.5	5.1	73.95

Total weight of G.I. pipes = 246.938 kg =0.247 tons
Assuming 2.7 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =0.246x2.7=0.667 tons.

13. CEMENT
Total amount of cement used = 43.67 tons.
Assuming 0.88 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission = 43.67x0.88 =38.43 tons
CO_2 emission during transportation of this material
Material came in three parts from three different places equally. Mode of transport =Road
Distance from Durgapur =200 km
CO_2 emission =4.028 tons.

14. MORTAR
Amount of plaster required is shown in Table 6.
Table 6: Amount of plaster required in the Building.

FLOOR	4:1 cement mortar plaster 10mm thick in m^2	6:1 cement plaster20mm thick in m^2	6:1 cement plaster 15mm thick in m^2
Ground	12.5	19.85	16.48
1^{st}	84.9	184.45	107.9
2^{nd}	84.9	184.45	107.9
3^{rd}	84.9	184.45	107.9
4^{th}	84.9	184.45	107.9
Total =	352.1	757.65	448.08

Volume of 4:1 cement mortar plaster 10mm thick =352.1x10/1000=3.521 m^3
Total weight = 3.521x2.2= 7.75 tons.
Assuming 0.18 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =7.75x0.18=1.395 tons.
Volume of 6:1 cement plaster =(757.65x20/1000)+(448.08x15/1000)=21.874 m^3
Total weight = 21.874x2.2=48.123 tons
Assuming 0.16 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =48.123x0.16=7.699 tons.

15. CEMENT CONCRETE
a. Volume of cement concrete with graded ghama khoa (1:4) =2.85 m^3
Weight = 2.85x2.2=6.27 tons
Assuming 0.18 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =6.27x0.18=1.129 tons
b. Volume of cement concrete [M20](1:3) =5.19 m^3
Weight = 5.19x2.2=11.418 tons
Assuming 0.21 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =11.418x0.21=2.398 tons.
c. Volume of cement concrete [M25](1:2) =27.83 m^3
Weight = 27.83x2.2=61.226 tons
Assuming 0.23 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =61.226x0.23=14.08 tons.
Plastic
Plastic Poly Ethylene: Material Used = 1.9 m^2
Weight = 1.9x0.0009=0.0017 tons.
Assuming 1.9 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =0.0017x1.9=0.003 tons.
Fiber Reinforced Polymer: Material Used = 1.85 m^3
Total Weight =1.85x0.005=0.009 tons
Assuming 0.005 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =0.009x0.005=0.00005 tons.

16. DAMP PROOF COARSE / MEMBRANE
Total weight of D.P.C. = 19.82 x0.9 =17.838 tons
Assuming 4.2 tons CO_2 emitted from 1 ton material
Amount of CO_2 emission =17.838x4.2= 74.92 tons.

TOTAL CARBON FOOT PRINT
Total wattage = 65130 watt.
We assume 25 % usage of total wattage in 24 hours according to California energy commission for domestic use.
Power consumption in one Month = 65130X24X0.25X30=11723400 Watt.

Power consumption for lift
No of lift = 1 no. Wattage = 5 KW
So, power consumption per month =5000x1x24x30=3600000 watt hour

Power consumption for pump
No of tank: 1 tank of 6000 litres at 15.5 mts. Height.
Total energy used
M_{gh}=(6000x1x9.807x15.5)=912051 joules
Tanks filled 30 times per month
So, power consumption per month =(912051x30)/(30x24)=38002 watt hour

Total power consumption=3600000+38002+11723400=15361402 watt hour = 15361.402 KW hour
Assuming 0.0007 tonnes Co_2 emitted for 1KW hour
So, Co_2 emission per month=(15361.402x0.0007) =10.753 tonnes (6).
The amount of embodied CO_2 emission in the Building is shown in Table 7.

Table 7: Amount of embodied CO_2 emission in the Building.

Construction materials	Embodied CO_2 per ton of materials	Quantity (tones)	Embodied CO_2 emission
Soil	0.022	429.02	9.438
Artificial stone	0.056	12.25	0.686
Porcelain	0.04	2.183	0.09
Marble tiles	0.03	46.44	1.4
Granite Slab	0.03	0.014	0.004
Bricks	0.22	573.84	126.245
Sand	0.005	140.95	0.705
Stone aggregate	0.017	185.4	3.15
Normal Wood	0.46	4.66	2.144
Reinforcement	1.71	30.9	52.839
Grill	1.77	8.3	14.691
G.I. Pipes	2.7	0.247	0.667
Cement from Durgapur	0.88	43.67	38.43
Mortar Plaster (4:1) 10mm	0.18	7.75	1.395
Plaster (6:1) 20mm	0.16	33.34	5.33
Plaster (6:1) 15mm	0.16	14.783	2.365
Cement concrete M20	0.21	11.418	2.398
Cement concrete M25	0.23	61.226	14.08
Cement conc. ghama koha	0.18	6.27	1.129
Plastic poly ethylene	1.9	0.0017	0.003
Fiber reinforced polymer	0.005	0.09	0.00005
Damp proof coarse	4.2	17.838	79.92

Amount of power consumption of different items is shown in Table 8.

Table 8: Amount of power consumption in the Building.

Item	Total no. required	Wattage/ no.	Total Wattage
Tube light	90	40	3600
LED lamp	51	25	1275
Fan	36	50	1800
Calling bell	9	40	360
T.V.	9	150	1350
Computer Point	9	120	1080
Water heater	9	1125	10125
Exhaust fan point	9	50	450
Chimney point	9	60	540
Electrical iron point	9	1000	9000
Micro oven point	9	1000	9000
Vacuum cleaner point	9	1000	9000
Refrigerator point	9	450	4050
AC (1.5 T)	9	1000	9000
Washing machine point	9	500	4500
		Total =	65130

IV. Conclusion

The global demand for reduction of energy consumption and reduced emission of climate related gases like CO_2 and CH_4 are big challenges for the construction industry. Economical and ecological advantages based on cost savings and dramatical redcution of handling of soil masses or "green" solutions by using construction methods with geosynthetics are already well know. A next step to demonstrate ecological advantages is given by comparing two infrastructure construction examples which document that the geosynthetic alternatives have a lower environmental impact due to much less cumulated energy demand (CED) and CO2 emissions. These results are site, product and construction specific. But there is a good chance that the comparison of other construction solutions will show the same advantages. For the future it is recommended to consider the costs of CO2 emission certificates when comparing different offers for a construction job to identify the most suitable solution for the environment.

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