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Towards Sustainable Building Construction Materials for Smart Cities

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Abstract: *It shows the environmental impact of a building with change of material which changes the consumption of energy and carbon dioxide (CO_2) emission. The world today has met with global warming and climate transformation. As Investment in infrastructure and innovation are crucial drivers of economic growth and development. Therefore technological progress is also key to finding lasting solutions to both economic and environmental challenges.Here an emission of carbon dioxide (CO_2) is taken into consideration. The Country like India surrounded by river suffers adversely due to the impact of global warming. It prefers the use of stone and brick chips production and find out overall impact of that material in construction. This paper recount how much a typical building is contributing to global warming by liberating the carbon dioxide emission. This research also focuses on the comparison of carbon dioxide (CO_2)emission from different construction materials from the same quantity and comes out with a conclusion that use of bricks produces three times more emission than stones.*

Keywords: *Global warming, Carbon-Dioxide (CO_2), EnergyConsumption, Cost analysis, Brick chips, Stone chips.*

I. Introduction

The most largely consumed construction material worldwide is Concrete and almost seventy percent of concrete volume is aggregate Brick chips are man-made coarse aggregate and Stone, especially Granite, is extensively used in building construction as coarse aggregate. Manufacturing of bricks is an energy-intensive activity. Manufacturing processes have shifted from traditional low- efficiency manufacturing tomodern high-efficiency ones in all developed countries and some developing ones. They have also become a significant building material in the rural areas. High prices or scarcity of alternative building materials, such as stones, iron sheets, wood, bamboo, and straw are very rapidly increasing the demand for bricks. To demonstrate, a typical building is selected and estimated its Co_2 emission. For this study, concrete building in humid climatic environment is selected. All the materials used in building construction are assessed. Embodied energy of each material is considered in its lifecycle. Finally, the Co emission has been estimated to find the amount of sustainability of the building and its effect on global warming.

1.1 Objectives

The estimation of the amount of carbon dioxide (CO_2) emission for three storeys's building in Lakheri town for its entire life cycle in construction phase is the objective of this thesis. Here three storey building in Lakheri have been analyzed.

- Estimation of unit carbon dioxide (CO_2) emission and energy consumption for different types of building materials.
- Evaluate critical component of carbon dioxide (CO_2) emission for a building and suggest ways to reduce it.
- Comparison of carbon dioxide (CO_2) and environmental impact between the building materials like stone &brick chips.

II. Building & Building Materials

Three stories reinforced concrete residential building is selected for the study. The total building area is 95 mm2. RC frames structure is made with brick masonry infill. Wood work issued for wardrobes inside bedrooms and kitchen. Aluminum is used as the frame for windows and the bathroom doors. Table1shows the quantities of each material used in the building.

Figure1. Elevation and Plan of Residential Building

2.1. Comparison between Stone and Brick Chips Building

From times immemorial, stone has been used both for residential as well as public buildings. Historical buildings that stand today are the living examples of the strength, durability and the excellent weather resisting qualities of stone masonry. Brick on the other hand has much less strength, durability and weather resisting qualities.

- On account of its high crushing strength stone is used in the construction of peers, docks, dams and other marine structures. Brick on the other hand, is not considered suitable in all such places.
- Shining texture of good class of stone masonry requires no treatment to enhance its appearance. On the other hand, plastering is necessary to conceal the defects in brick masonry.
- In buildings of monumental nature where architecture requires heavy mouldings with large projections, stone is best suited, brick being suitable for light ornamental work.
- Bricks when exposed are liable to get damp. Dampness may ultimately head to the disintegration of the masonry. Stone work on the other hand suffers from no such danger.
- On account of the high cost of stone masonry, its usage is generally restricted to hilly areas or stone districts, bricks on the other hand are easily available in almost at all places and the masonry constructed with bricks costs much less.
- First class bricks possess all such qualities which are required for a good construction and hence brick masonry has now practically replaced stone masonry.
- On account of their regular shape and size, bricks afford great facility in maintaining proper bond in the masonry. It also results in quick construction. On the other hand, in stone masonry, the process of dressing and placing stones requires a great deal of time and extra labour.
- For the construction of jambs of and windows and for the walls meeting at obtuse or acute angle, bricks offer greater facility than stone.
- Bricks can be conveniently moulded into any desired shape at reasonable cost while the expense of the moulding of stone work is far more than that of brick.
- On account of their convenient size and light weight, bricks require no lifting tackle while in stone masonry the large blocks of stone have to be kept in position with the aid of some lifting device.
- Brickwork is more fire resisting than stone work.

2.2. Methodology

For research, detail construction data are collected and analyzed from two different residential building projects situated in Lakheri, India.For the simplicity of comparison the buildings are so selected that the building plan area and number of floors remain same. The life cycle analysis (LCA) of building materials show that the energy requirement and CO_2 emission is mainly by two ways: active & passive. Table 1 shows the summary of LCA of building materials with the reasons of CO_2 emission & energy consumption from the preparation, transportation to the site and use of these materials.

Table 1. Summary of LCA of building material

Serial No.	Description of construction item	Sources of CO_2 emission and energy consumption				
		Wood cutting	Burning of wood/ coal/gas	Electricity for machine operation	Plant operation	Fuel burning for transportation
1	Cement		Y	Y	Y	Y
2	Brick					
2.1)	Cutting, caring and mixing of earth			Y		Y
2.2)	Moulding work				Y	
2.3)	Burning sources:					
a)	Wood	Y	Y			
b)	Gas		Y			
c)	Coal		Y			
2.4)	Kiln operations and maintenance				Y	
2.5)	Brick transportation to construction site					Y
3	Stone					
3.1)	Collection of boulder					Y
3.2)	Crushing of boulder			Y		
3.3)	Transportation to construction site					Y
4	Sand				Y	Y
5	Rebar		Y	Y	Y	Y
6	Glass		Y	Y	Y	Y

2.3. Embodied Energy Analysis Method

In order to comprehend the total CO_2 emission from a building, it is necessary to access the emission from each material individually. Initially all the quantities of the building evaluated using center line method. And later volume of CO_2 emission from each material isassessed by using the formula given below:

Amount of CO_2 emission (Kg)=VxDxC

Where, V= Volume of Building Material Used (m3)
D=Density of Building Materials (kg/m3)
C= Embodied Carbon Emission (kg CO_2 /kg)
Table 3 describes the amount of carbon dioxide emitted by various materials used in the building. It can be seen that the highest amount of carbon dioxide is releasing from Steel, Aluminum, Stone, Glass and Concrete. The CO_2 emission of Brick and Timber wood almost are same. Between all of the used materials just ceramic tile and cement mortar have the least level of carbon dioxide emission. Having a look at the total CO_2 released gas, it will be perceived that a considerable amount of carbon dioxide is releasing from this building during its construction period, 442175 ton which is a noticeable amount.

Table 2. Quantities of materials

Materials	Quantity	Unit
Wood & Timber Framing	185.3	M^3
Steel	12827	Kg
Brick(baked clay)	38.9	M^3
Tiles & Ceramics	0.17	M^3
Mosaics	0.28863	M^3
Aluminum	396	Kg
Glass	53.1	M^2
Moisture Insulation	125.2	M^2
Painting(Water-based)	1215.5	M^2
Stone(Local)	49.14	M^2
Concrete	170.4	M^3
gypsum plaster	60.9	M^3
Cement Mortar	1	M^3

Table 3. Embodied Energy of Materials of Case Study

Materials	Quantity	Unit	Energy Intensity /Unit	Embodied Energy (GJ)
Wood & Timber Framing	2.5	M^3	3400 MJ/m^3	25.296
Steel	12827	Kg	42 MJ/Kg	538.734
Brick(baked clay)	105030	Kg	1.60 MJ/kg	168.048
Tiles & Ceramics	340	M^2	285 MJ/m^2	96.9
Mosaics	144.3	M^2	250 MJ/m^2	36.075
Aluminum	396	Kg	236.8 MJ/Kg	93.773
Glass (4mm)	15.7	Kg	25.8 MJ/Kg	0.451
Moisture Insulation	125.2	M^2	53.7 MJ/Kg	28.91
Painting(Water-based)	70	Kg	76.8 MJ/Kg	5.376
Stone(Local)	1.5	M^3	2030 MJ/Kg	7825.65
Concrete	170.4	M^3	2346 MJ/m^3	399.758
gypsum plaster	60.9	M^3	2.9 MJ/Kg	407.616
Cement Mortar (1:6)	1	M^3	1226 MJ/m^3	1.226
Total				9627.813 GJ

III. Impact of Construction on Global Warming

Any development project plan to advance the worth of life has some built-in positive and negative impacts. The development project should be prearranged in such a manner that it has maximum positive impacts and minimum negative impacts on the environment. It is expected that construction damages the fragile environment because of adverse impacts of building construction. Technology development paves way to all-round growth. The danger which these technologies are producing in terms of carbon emissions is in leaps and bounds.

India predominantly lives in rural areas. Materials used for house roofing during 1990's clearly displays that the usage of natural materials is very high and on the contrary the percentage of cement usage is around 12% only.

However, as in one decade i.e., during 2000's usage of cement has almost doubled. This trend is seen both in rural as well as urban areas.

Table 4. Alternative Materials Used

Used materials	Total(CO_2)Emission (Kg)	Alternative materials	CO_2 Emission Reduction (%)	Total CO_2 Emission
Steel	414976026	Recycled Steel (40%)	-35	261434896.4
Aluminum	26234208	Recycled Aluminum	-9.8	23663255
Stone	762865.95	Lime Stone	-37	430605.55
Glass	103192.96	Cullet Glass (100%)	-50	51596.48
Total	442076292.9			285630353.4

IV. Discussion & Suggestion

Table 4 describes some alternative materials in place of frequently used material. As largeamount of carbon dioxide is coming out of steel and aluminum, they can be substituted by other materials with low carbon footprint. It can be seen that CO_2 emission can be reduced up to 35%. And by using cullet glass 50 % of CO_2 emission can be reduced. Therefore, the best options for cutting down the carbon dioxide emission in the building construction are

1. Use recyclable materials as much as possible
2. Use locally available materials for decreasing the fuel used for transporting of materials in order to reduce CO_2 gas emission
3. Using eco-friendly building materials
4. Designing the buildings with respect to the nature for having better ventilation and natural day light.

V. Conclusions

A huge number of concrete buildings are constructed in the world every year, every month. Impact of emission of carbon dioxide is threatened on environment. The total aggregate used in the world is 9 billion tones and it is about 70 % of concrete volume. Hence concrete production and transportation will emit carbon dioxide and consume fuel. The crying need is for sustainable development which aims at development which does not have a negative impact on the environment. So by using energy saving material, not sacrificing strength is important and locally available materials induce in concrete will help by the course. The paper only focuses on the building materials used in construction and not on the functions of the building. Embodied energy and CO_2 emission in a reinforced concrete building as a case study has beendiscussed in this paper. It is observed that stone, steel, concrete and Gypsum plaster are the highest energy consumer materials among the all materials used for construction. Careful use of the resources and maximum use of non-conventional energy sources will enable us to attain sustainable development.

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