11th International Conference (CITC-11)
September 9-11, 2019, London, UK

Embodied Carbon Footprint Assessment of a conventional Commercial Building using BIM

[1]Daud Khan, [1]Ehsan Ahmed Khan, [1]Muhammad Sheharyar Tara, and [1]Syed Shujaa Safdar Gardezi

[1]Capital University of Science and Technology,Islamabad, Pakistan.
dr.shujaasafdar@cust.edu.pk

Abstract. Materials are one of the major sources of carbon emissions for the construction sector. The current research aimed to assess the environmental potential contribution of a ground plus three storey commercial building in Pakistan. Life cycle assessment (LCA) along with BIM helped to develop the material inventory of conventional materials used and achieve their emissions. With a total contribution of more than 80%, steel (33.51%), concrete (19.98%), brick (14.75%), aluminum (12.10%), and paint (3.22%) were the top contributing materials. A thorough embodied carbon emission assessment at the stage of planning and design would help to adopt proper sustainable development strategy.

Keywords: Carbon emissions, Life cycle assessment, BIM, Sustainable

1 Introduction

Construction is the major activity to fulfil the basic needs of development. Pakistan is a developing country presently striving for growth in construction activities. Although it has a good impact on economy but on the other hand it is directly affecting the environment. The increase in human population can cause increase in the demand of built structures. With increase in construction activities, there be a continuous pressure on natural resources to meet these demands. However, the construction activities are one of the major concerns for generation of GHGs. Gases that entrap heat within the atmosphere are referred as greenhouse gases. Carbon dioxide is a naturally-occurring gas, which play basic role in the emission of GHG [1].A large quantity of CO_2 is emitted due to the construction. Construction completely depends upon natural resources. The consumption of those resource discharge a particular quantity of CO_2 into atmosphere which is the major source causing increase in global warming. In construction industry, buildings are one amongst the important parts for the fundamental residential, education, industrial and health facilities requirements of human beings. Carbon dioxide is not only emitted while construction of building but also during its operation.. Scientist are worried about the rapid change in climate and they are finding the way to stop the emission of GHG. Therefore, a concept of carbon footprint assessment come into being. Carbon footprint can be defined as the amount of carbon emission cause by the human activities like utilization and manufacturing of product in form of equivalent factor of CO_2. Due to lack of control environment it is difficult to calculate the exact amount of CO_2 therefore the building construction is divided into various stages to calculate the approximate amount of CO2 emission. To study these effects and calculation of CO_2 a method was introduce known as life cycle assessment[2]. Life Cycle Assessment (LCA) is a tool to review the environmental impact of products throughout their entire life cycle – (from cradle to Cradle). In order to make this analysis a suitable set of data is required. To estimate the CO_2 emission of material concept of embodied carbon come into being. It is the emission of CO_2 in the extraction of raw material, transportation manufacturing and assembling of that material. In term of life cycle assessment is the cradle to site stage of construction. This thing will help to develop a sustainable development.

2 Literature Review

Climatic change and its social, environmental, monetary and moral consequences are well known due to the fact the major set of interconnected issues facing human societies. Human activities directly affecting the globe temperature. Due to this change scientist start working in early 1980s to control the built environment to fight the consequences of temperature Variations on earth. Building is one of the major sources of CO_2 emission. It contributes in both construction and operational phase. According to IPCC [1] the building consumes the 40 % of natural resources in construction which 40-50% GHGs emission world widely. Due this rapid emission scientists are predicting that building sector of construction industry emit about 50% CO_2 all around world by 2050. Different researchers have evaluated the environmental effects of building around the world table 1 show details of some.

Table 1: Environmental effect evaluation of different case study

Author	Country	Findings
Nasir Shafiq, Muhd. Fadhil Nurrudin, Syed Shujaa Safdar Gardezi & Azwan Bin Kamaruzzaman [3]	Malaysia (2015)	Different classes of construction material can considerably reduce carbon amount.
Georgios Syngros, Constantinos A. Balaras And Dimitrios G. Koubogiannisa [4]	Greece (2017)	Concrete cause more emission because of its quantity and mass. Steel also plays its role in embodied carbon footprint.
F.H. Abanda, A.H. Oti, J.H.M. Tah [5]	UK (2017)	Assessed environmental impacts using BIM

C.M. Lu, J.Y. Chen, C.A. Pan, T.S. Jeng[6]	Taiwan (2015)	Reveals significant difference in the immediate Carbon Footprint computation and the localized value-input while processing
Afaf Azzouz, Meike Borchers, Juliana Moreira, Anna Mavrogianni[2]	UK (2016)	Optimizing strategies can significantly save life cycle carbon and energy as well.
Z. Alwan, P Jones [7]	UK (2014)	Highlighted the impact of embodied energy of construction materials.
Zhixing Luo, Liu Yang, Jiaping Liu[8]	China (2015)	During construction materialization stage steel, concrete and walls as variables predicate CO_2 emissions.
Ya Hong Dong, S. Thomas Ng[9]	Hong Kong (2015)	An analytical tool EMOC has been developed to estimate the environmental performance of building construction
Wahidul K. Biswas[10]	Australia (2014)	Revision of cement formulations and recycled aluminum and steel can reduce emission

Sustainable development is a monetary development and performed without depletion of natural sources. The design directly affects the amount of CO_2 released and it can be controlled in this phase by efficient design and achieving sustainable development. To promote sustainable designs, new process is introduced which is known as BIM (Building Information Modeling). BIM can also help in calculating the quantities of different material to be used in building accurately which increases the accuracy of environmental effect estimation.

3 Objectives Of Study

To assess the impact of construction activity on environment, estimation of CO_2 is necessary which will be generated from various material used in building construction. The target of our study is to develop 3D parametric model of a conventional commercial building using BIM (Building Informational Modeling) and its carbon footprint assessment. After the analysis, it is possible to see the contribution of each material in carbon emissions which have potential to affect the climate of Pakistan.

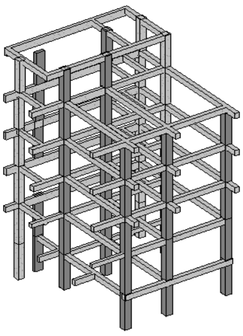
4 Case Study

For the evaluation of environmental effect of building on Pakistan climate, a commercial building is selected as case study. This building is located in DHA 2, Islamabad, Pakistan, Fig 1.This study is only limited to embodied part of CO_2 emission of material use in commercial building.

Fig. 1: Commercial building on site

5 Methodology

This study includes the embodied carbon footprint assessment of commercial building. Building information modeling (BIM) process was adopted to develop a virtual model of building, Fig 2. By the help of BIM, different material were extracted and quantity database was formed. By the help of this data base, carbon footprint assessment was performed using ICE (Inventory of carbon and energy). LCA evaluation method is applied by restricting the to ‘cradle to site’. This methodology has been restricted to the carbon inventory assessment of construction materials. The characteristics of material chosen for the models was according to site. Carbon emission of every material was calculating by opting CO_{2e} per kg coefficient given in ICE. The overall embodied carbon emissions for each material has been calculated in kg-CO_{2e}.



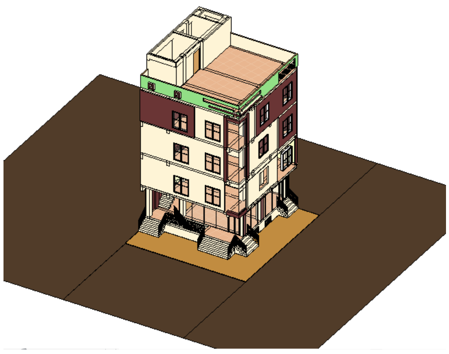


Fig. 2:Virtual 3D model of case study

6 Result Analysis

Table 2 provides the details of materials quantities for the case study building. The quantities were cross- checked with the actual bill of quantities to observe any major difference.

Table 2. Quantities of materials extracted from virtual model

S. No	Description of Material	Unit	Quantities
1	Steel Rebar	Kgs	34496.20542
2	Concrete	Cft	6724.24
3	Brick	Cft	3093.25
4	Plaster	Sft	20644.29333
5	Aluminum	Kgs	3768.413025
6	Glass	Sft	3681.369863
7	Timber	Sft	591.12
8	Hygrip	Sft	900
9	False Ceiling	Sft	2838.6
10	Percaline Tile	Sft	5266.08
11	Paint	Sft	23272.5
12	Steel chrome	Kgs	486.938093
13	Motor	Sft	6346.08

The extracted quantities were multiplied with emission factor from Inventory of Carbon and energy (ICE) to achieve the embodied carbon footprint contributions, table 3. A total carbon footprint of 285189.87 kg- CO_{2e} have been extracted from case study with a graphical percentage contribution detailed in figure 3.

Table 3: Embodied CO_2 emissions from materials

S. No	Materials	CO_{2e}/kg	CO_{2e} Emission (kg-CO_{2e})
1	Steel Rebar	2.77	95565
2	Concrete	0.124	56978.23911
3	Brick	0.24	42055.59829
4	Plaster	0.13	8836.980439
5	Aluminum	9.16	34518.66331
6	Glass	0.91	8658.671717

7	Wood	0.2	590.4386554
8	Hi grip	1.93	2460.012885
9	False Ceiling	0.47	1334.142
10	Percaline Tile	0.7	7395.894875
11	Paint	0.87	9186.513158
12	Steel chrome	2.87	8554.724479
13	Motor	0.13	9054.993862

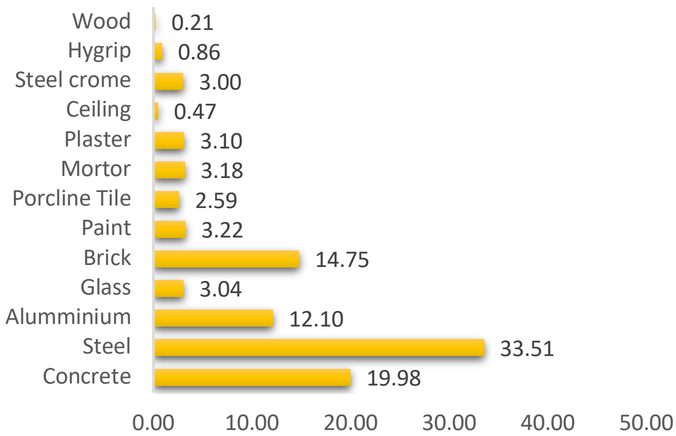


Fig. 3: Percentage contribution of material in carbon footprint content.

In order to observe the contributions on individual basis, material ranking was performed, table 4. The major materials were steel, concrete, brick, aluminum and paint with a contribution of 33.51%, 19.98%, 14.75%, 12.10% and 3.22% respectively. The study revealed that top five contributing material made a share of more than 80%.

Table 4: Material ranking which contributes more in carbon emissions.

S.No	Material	Percentage contribution	Ranking
1	Steel	33.51	Rank 1
2	Concrete	19.98	Rank 2
3	Brick	14.75	Rank 3
4	Aluminum	12.10	Rank 4
5	Paint	3.22	Rank 5

7 Conclusions

The study explored the carbon footprint potential of conventional commercial building in Pakistan. Building Information Modelling (BIM) along with ICE inventory have assessed a total CO_2 emissions equivalent to 285.189 tons- CO_2. Thus, per unit area contributions worked out to 54.26. Thirteen (13) construction materials were taken under consideration. The top five (05) materials included steel, concrete, brick, aluminum and paint contributed 33.51%, 19.98%, 14.75%, 12.10% and 3.22% respectively. The contribution from these five materials was more than 80% of the total embodied CO_2 in the study. From the research, it was observed that if the embodied carbon emissions from the five materials could be managed somehow, a noticeable reduction in such emissions is possible from conventional commercial buildings for future.

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