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Life Cycle Environmental Assessment of an Office and Residential Building in Northern India

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Abstract*— Now a day's every one using the passwords for user authentication Structures require utmost effectiveness and strength in their entire life cycle apt from its development to obliteration. To recognize the specific predominant phases of most prevalent and huge energy consumption to establish stratagems for its decline a study is essential on every usage of the energy throughout its life cycle. This project purposes to signify the environmental hazards of a residential and an educational construction positioned in the state of Uttar Pradesh, India. Life cycle assessment has been used to determine which life cycle phase (construction, operation, maintenance, and demolition) contributes the most to the total impacts. It has been found that operational phase alone adds more than 80% to GHG emissions and is topmost energy consumer. Around 90% of total life cycle energy is consumed by residential building and 88% of total life cycle energy is consumed by an educational building in their anticipated reliability in terms of 50 years of service life. This scholastic work also projects that RCC framework and Red brick masonry are the greatest contributors in GHG radiant emissions for both the buildings. Energy consumed in the construction phase is the second highest that contributes significantly. The results obtained from this study has been compared with other studies done on similar basis, it is found that a building being situated in a region where climatic conditions vary greatly the operational energy accounts for more as compared to the buildings situated in places where climatic conditions are generally constant keeping this in mind there is a demand for some substitute to design buildings for sustainablility..

***Index Terms*— Ecology, Embodied energy, GHG emissions, LCA, Buildings**

1. INTRODUCTION

Construction of buildings is mainly for residential, office and commercial purposes. This contributes to parameters of a nation's expansion which consumes a significant amount of natural resources in the process of synthesizing the energy needed for satisfying the global demand. Around 30-40% of the primary energy is the cause of 40-50% of GHG emissions worldwide [1]. Sustainable development is very essential for the building and construction sector. It helps the present age to address their issues without bargaining the capacity without bounds ages to meet theirs [2]. Sustainability is estimated as far as three basic parts: economy, condition and society [3].

As of late, building and development segment has been observed to be in charge of an expansive piece of the ecological effect of human exercises (United Nations Environment Program 2003). The percussions of operation and construction of a building are plentiful. The most pertinent compelling effects are the climatic variation caused by the energy consumption in this process of utilization. Emergence of climate change is due to the increased consumption of fossil fuels. Subsequently the affiliation amid greenhouse gases and their repercussion on overall temperature prevailing globally was revealed. The warmer climate is considered due to the Greenhouse gases, which can increase the melting of glaciers. Likewise, discharges bother hydrological cycles, brought about factor environmental change with extraordinary wind impacts and engulfing. One result may be the uprooting of populace alongside huge practical impacts. According to a study, the effective segment is utmost demanding, foundation, masonry , structure, and coating layer pertaining to the the highest environmental influential with respect to materials, such as concrete, ceramic tiles and steel has become the largest contributions across the globe [4].

Buildings and industries related to it exemplify a momentous probable for mediation to reduce GHG emissions through reduction of material and energy consumption [5]. Data centers deplete immense amount of energy to power the IT equipment operating within them. [6]

LCA embodies an extensive strategy for the investigation of the ecological effects of items at all phases throughout their life cycle, from support to grave. The concept of LCA varies from a single customer or commercial products to building materials and its allied components. Life Cycle examinations of prevailing entire structures are basic to recognize and assess how its key plan frameworks (establishment, structure, dividers, floors, rooftops) will impact a building's ecological execution. A parametric inquiry revealed that employment of insulating materials without straining considerably its total exemplified energy [7].

The essentiality of this research is to evaluate and measure the environmental influences instigated by a residential structure and an educational structure throughout a service life of 50 years. The investigation concludes the life cycle stages that add most to these environmental impacts. So for this study Nadeem Tarin Hall and Department of Civil Engineering of Aligarh Muslim University (AMU) Aligarh (Uttar Pradesh, India) has been selected. LCA is used to investigate the essential energy utilization and GHG radiation contributed by each of these buildings.

II. LIFE CYCLE ASSESSMENT

LCA as it is called is a process of assessment and analysis of materials and energy flow of a system. Initially the extraction, production, transportation and construction, then use and followed by deconstruction and disposal of a product or service system are examined first. Later, the sustainable planning and policy making decisions require an assessment of the energy demand and environmental performance of buildings at large scales [8]. According to international

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15O\organization for standardisation LCA can be used for an estimation of influences of different processes and life cycle stages on the environment. [9], LCA studies generally subsist of four phases: goal and scope definition, life cycle inventory (LCI), impact evaluation and perception of results. Purposes, system boundaries and audiences taken into account in defined by goal and scope. The LCI collection of data and calculations to measure material and embodied energy of a system, and the impact quantification evaluates the implication of probable environmental impacts based on the LCI. Structures devour energy straightforwardly or in an ambiguous way in all periods of their life cycle suitable from the crib to the grave and there is transaction between periods of energy utilization (inherent and working energy). Henceforth, they should be investigated from life cycle perspective. Building obliteration waste presents a huge test because of its expansive scale. Particularly, the treatment of waste (i.e. obliteration, gathering, arranging, transportation, reusing and landfill) has natural ramifications, e.g. carbon discharges because of vitality devoured by gear and vehicles [10]. It is achieved since working energy of the structures has biggest share in life cycle energy dissemination, diminishing it has all the earmarks of being the most essential part for the outline of structures which request less vitality for the duration of their life cycle. Governments can accomplish the reduction in carbon emanations by focusing on the operational period of structures. Be that as it may, the opportunity to obsolete stages ought not to be overlooked on the grounds that the normal carbon emanations per working zone every time of obsolete stages is far more prominent than those of the utilization stage [11]. Typified energy should then be tended to in second occasion. In spite of the qualification regarding the measure of embodied energy between elevated structures and low-ascent counter parts, nil reasonable connection is found amidst the building stature and encapsulated energy intensity [12]. Although encapsulated energy comprises just 10– 20% to life cycle energy, open door for its diminishment ought not to be disregarded. There is a possibility for lessening epitomized vitality necessities through utilization of materials in the development that requires less vitality amid assembling [13]. The significance of assessment and change of life cycle execution of structures in early plan stages is broadly recognized; the wide utilization of Life Cycle Assessment (LCA) in any case, is controlled by huge vulnerability in outline and material choices at this stage [14]. Building Information Model (BIM) should be taken into the picture in the design and pre-construction stages as a inclusive simulation method that can be used to create circumstances to assess and enhance the performances of buildings. Life cycle inventory can be reduced by the incorporation of BIM and Life cycle assessment which is called as LCA, and significantly mend the characteristic of the LCA outcomes for explicit building design and exploration [15].

III. ELECTRICITY GENERATION IN INDIA

India is at the sixth position in terms of electricity generation and consumption in the world and accounts for 4% of electricity generated annually in world. India's demand for power is increasing at an inordinate rate; electricity generated and consumed annually in India has increased by about 64% in the past ten years, and is projected to increase as much as 8-10% annually, through the year 2020. A brief summary of current generation in India is illustrated in the Table 1 (Ministry of Power, 2018; [16]).

IV. METHODOLOGY

Energy used in the operational phase of both the buildings is presumed to be constant throughout their entire life span. Operating energy might not remain constant due to the climatic changes all around the world, but this is not considered in our investigational analysis .and the energy required in demolition processes of the buildings is negligible and so not taken into consideration [17] to cause any significant impact. The operational phase of NT Hall and Department of Civil Engineering is taken to be 50 years. It is assumed that no re-construction and extension are made in these buildings during the 50 years life cycle. Electrical energy usage impacts the environment during this phase. While in maintenance phase, only subsequent process like re-painting is considered and only 2% is used in construction phase as per standard practice.

Calculation of inventory data of material is the first step to perform LCA in this study. The quantity of the construction material used in the building was compiled from the plan and visual inspection of the building. The plan of the buildings are as shown in Fig. 3 and Fig. 4 was obtained from Building Department, AMU, and was drafted using AutoCAD. The other plans of first and second floors of the buildings are similar to the ground floor plan. The elements which are the extensive provider in the emission from the structure were contemplated. The equivalent personified energies of all three floors were determined autonomously.

Embodied energy is defined as the total utilization spent in extraction, conversion, transmission, manufacturing, utility and transportation of a particular product. The embodied energy parametric coefficients are presented in Table 2 has been taken from the paper [18]. The total embodied energy is procured by the summation of all embodied energy utilized in the construction process.

The GHG radiant emissions were calculated using the present Electricity generation in India. Electricity from the national grid all activities of the buildings such as running air-conditions, desert coolers, heaters, computers, heavy machineries, lighting etc. conversed from Primary thermal energy into electricity is taken as 1 **MJpri =0.111 kWh** [18]. The average thermal energy to electrical energy efficiency coefficient has been taken as 0.40. The electrical energy is evaluated from the electricity bills for past 2-3 years for both the buildings separately and according to these bills the consumption of NT Hall and Department of Civil Engineering for 50 years is 8.3 GWh and 5.06 GWh respectively.

V. CASE STUDY

A. Description of building

Nadeem Tarin Hall and Department of Civil Engineering at Aligarh Muslim University consists of three floors. The climatic residual reminants moderate throughout the entire year. Electricity is utilized mainly by the use of ceiling fans, lighting, computer systems and machineries in the laboratory, cooling/heating during working hours of the department in seminar halls and faculty rooms. Fig. 1 shows the pictorial view of NT Hall and Fig. 2 shows pictorial view of Department of Civil Engineering. The main construction elements used in the buildings considered were: Cement

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motar, Reinforced cement concrete (RCC) framework, Red brick masonry, Plain cement concrete, Glass, Timber, and Mild Steel.

The specification of buildings is:

- Structure is made up of RCC frame work
- All the outer and inner walls are made of brick masonry.
- Flooring: All laboratories, class rooms, faculty rooms, seminar hall, at Department of Civil Engineering. and all the rooms dining hall, common room, toilets, have plain cement concrete flooring
- Door and windows: All the doors are made up of Timber and window panes are made up of glass. Mild steel is used in the frames of door, windows and vents.

Table 1 Electricity Generation In India

Fuel	Set Up capacity (MW)	Percentage (%)	Combined GHG emissions
			(g CO_2eq/kWh)
Total Thermal	2,22,907	64.8	950
Coal	1,97,172	57.3	1004
Gas	24,897	7.2	543
Oil	838	0.2	650
Hydro (Renewable)	45,293	13.2	41
Nuclear	6,780	2.0	25
RES*	69,022	20.1	35
Total	**344,002**	**100**	**629.3**

Table 2 Construction Materials Taken And Their Equivalent Embodied Energies.

S. No.	Materials Used	Embodied energy
1	Cement Mortar	1268 MJ/m^3
2	RCC frame work	730 MJ/m^3
3	Red Brick Masonry	2141 MJ/m^3
4	Mild Steel	42 MJ/m^3
5	Glass	25.8 MJ/kg
6	Timber	10.8 MJ/kg
7	PCC	6.70MJ/kg

B. Functional unit

A functional unit has to be chosen to calculate the environmental impact. According to ISO, ISO 14040, functional unit is defined as unit of reference that is used to compute the systematic variable performance in LCA techniqology [19]. It is provided to give an account of the inputs and outputs of a system. In this work, the functional parametric unit "m2 usable floor area" has been chosen. The usable floor area is the classrooms cum faculty rooms, hostel rooms, labs, stair cases, seminar hall, toilets, dining room etc.

C. Limitations

For estimating the environmental impacts certain simplification has been made. In the case where manufacture's definitive information was not given data for similar products has been used. The impact on human beings such as work environment, odor and noise has not been taken into consideration. The machineries in laboratory and furniture in respective rooms, seminars, class rooms are neglected in this study.

Fig. 1 Pictorial view of NT Hall

VI. RESULTS AND DISCUSSION

Life cycle assessment has been carried out for the NT Hall and Department of Civil Engineering at AMU. All the three floors of both the residential and office building were separately assessed and the GHG emissions associated with each floor have been evaluated. The three life cycle phases of the buildings include construction, operation (use) and maintenance phase.

A. Energy Usage

The total energy usage in construction phase for the selected buildings is shown in Tables 3 & Table 4. The construction phase of NT Hall consumes about 79, 99,074.4 MJ of primary energy while that Department of Civil Engineering consumes 67, 36,339.01 MJ which is around 9.68% and 12.86% respectively of the total energy requirement. The energy used in the operation phase was estimated to be maximum and it is 90.31% for NT Hall and 86.88% for Department of Civil Engineering. In maintenance phase the energy usage is lesser than 1% for both the buildings.

Total life cycle energy has been calculated from the energy usage during construction phase, maintenance energy is taken as 2% of the constructional and operational energy is evaluated from the electricity consumption for 50 years of the buildings life cycle. The total life cycle energy usage for the buildings is provided in Table 5 and Table 6.

B. *GHG emissions*

The complete life cycle, GHG emission from both the buildings is shown in Table 7 & 8. The GHG radiant emissions of total life that is subsidized by NT Hall are 5698.13 ton CO_2eq while that of Department of Civil Engineering is 3594.78 ton CO_2eq. The operational phase of both the buildings consumes maximum total life cycle GHG emissions accounting to 91.7% and 88.6% for NT Hall and Department of Civil Engineering respectively.

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RCC framework and Red Brick Masonry and GHG emissions per unit area are around 1.00 ton CO2eq/m2 50 years for NT Hall and 0.47 ton CO2eq/m2 50 years for Department of Civil Engineering.

C. Comparison and analysis

Table 9 shows the correlation of GHG emissions of the present study with other previous studies. The values of Table 9 suggest that residential buildings have lesser impact on environment in contrast to commercial buildings. Also, with an increase in floor area of a building the GHG emissions per unit area are decreased. There is a significant contribution in Global Warming with the impact from this high GHG emission from commercial buildings. Whereas in our case study residential building proves to be a major contributor as compared to the educational building primarily because of the variations in the operational hours of both the buildings. There is a dire requirement to develop some new methods by which GHG emissions from the buildings can be curtailed and the problem of Global Warming can be decreased.

The total energy consumption of electricity varies according to the type of building. Generally commercial building consumes more amount of energy as compared to residential buildings; however some commercial buildings even consume lesser energy in contrast to residential buildings. Some commercial buildings operate 24 hours in a day while others may operate for just around 8–10 hours per day this decreases their energy requirement even to around 50%, operated for 24 hours. Climatic contribution of a region depends on the type of structural unit and accessibility of energy that is sourced.

Fig. 2 Pictorial view of Department of Civil Engineering

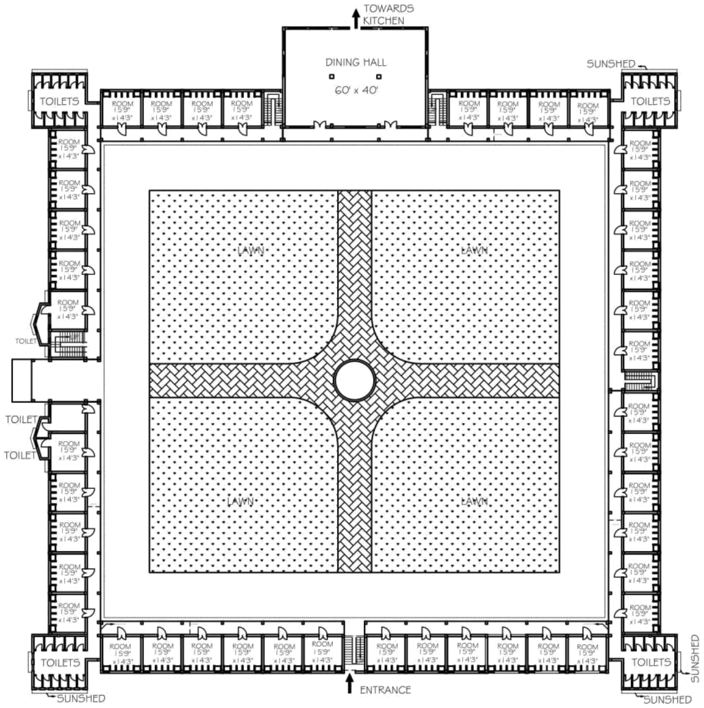

Fig. 3 Ground Floor Plan (NT Hall)

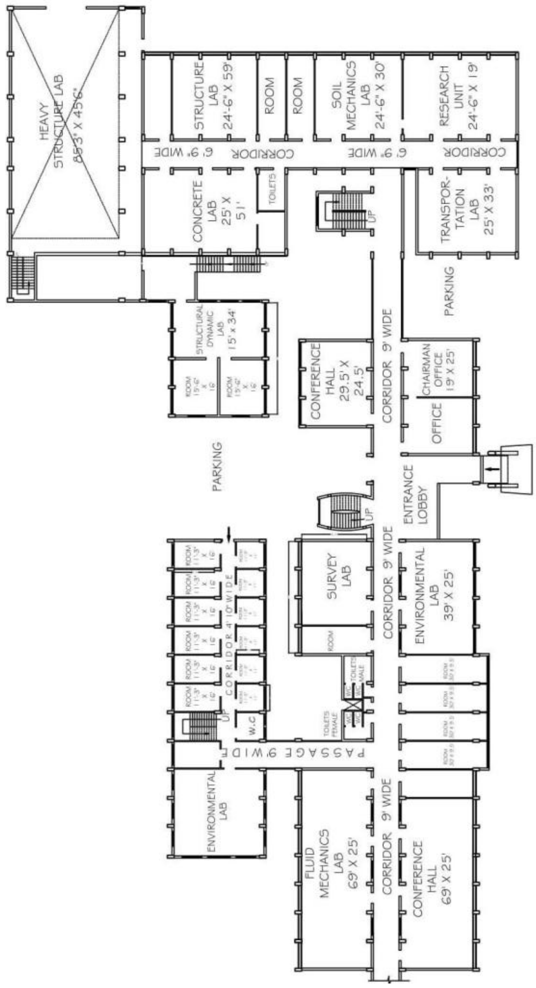

Fig. 4 Ground Floor Plan (Department of Civil Engineering)

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VII. CONCLUSION

In this study, LCA approach has been used for the estimation of GHG emission for all the three floors of NT hall and Civil engineering department at AMU Aligarh. RCC frame work and Red brick masonry were discovered to be the greatest contributor of life cycle GHG emissions in construction phase. It was also found that most of the energy was utilized during the operational phase of the buildings due to electrical appliances such as AC, coolers, pump, heating devices, laboratory machinery, computers etc. Since the operational phase of a building is the highest and there is an inter-relation between the energy use and the environmental impact during life cycle. Hence it is important to design the buildings that are energy- efficient during their operation.

To lessen CO2 outflows for the duration of the life of structures, it is expected to think about the embodied energy of construction materials and embodied CO2 emissions at the material production stage, and in addition at the activity and upkeep stage. There should be an in-depth study on carbon-reduction methods of construction materials. The carbon-reduction technologies for construction materials include: Recycled materials or industrial by products can be used to reduce resource consumption (manufacture phase); Shortening the production processes or changing fuels to reduce CO2 emissions; the decrease in consumption of resources throughout the life of buildings by decreasing the consumption of materials used for repair and using construction materials that reduce energy consumption and have a longer lifespan (operation and maintenance phase).

In this case study it can be concluded that although Department of Civil Engineering being an educational building is projected to have lesser environmental impact as compared to the residential building viz. NT Hall. The difference arises due to the operational phase as the maximum total GHG emissions for NT Hall is 91.7% as compared to 88.6% for Department of Civil Engineering.

Engineers and Architects need to find alternative approach of building construction, operation and maintenance so that issue of high energy consumption and GHG emissions can be brought down significantly. Life cycle analysis (LCA) needs to end up a standard piece of material determination on the off chance that we are to effectively decrease the indirect effects of material utilization for structures, particularly considering that structures as of now create over half of worldwide waste. This adjustment in thought for materials can significantly affect CO2 outflow lessening that would somehow, or another be neglected. The CO2 emanations from structures should likewise be assessed as a standard piece of the design process. We should utilize our innovative advances and best accessible practices to quickly change the present circumstance where structures are the biggest single segment creating CO2 emanations. The solutions are available. We should just exhibit their possibility and extend their application. This will produce an extraordinary stride toward negating emissions from structures.

Table 3 Total Energy For Nt Hall During Constructional Phase

Ground floor					
S.No.	**Name of Item**	**Volume (m3)**	**Density (kg/m3)**	**Weight (kg)**	**Total Embodied Energy (Mega Joule)**
1.	Cement mortar	78.61	-	-	85,273
2.	PCC	70.5	1600	1,12,800	7,55,760
3	RCC Frame Work	445.13	-	-	3,22,024.9
4.	Red Brick Masonry	485.3	-	-	10,39,209.1
5.	Glass	0.86	2500	2150	55,470
6.	Timber	12.22	750	9165	98,982
7.	Mild Steel	-	-	2053.68	86,254.56
					Total = 24,42,965.56
First floor					
1.	Cement mortar	88.89	-	-	1,12,712.52
2.	PCC	70.5	1600	1,12,800	7,55,760
3.	RCC Frame Work	447.54	-	-	3,26,704.2
4.	Red Brick Masonry	577.38	-	-	12,36,170.58
5.	Glass	0.86	2500	2150	55,470
6.	Timber	12.22	750	9165	98,982
7.	Mild Steel	-	-	2053.68	86,254.56
					Total = 26,72,053.86
Second floor					
1.	Cement mortar	98.89	-	-	1,25,392.52
2.	PCC	70.5	1600	1,12,800	7,55,760
3	RCC Frame Work	445.13	-	-	3,22,024.9
4.	Red Brick Masonry	672	-	-	14,38,752
5.	Glass	0.882	2500	2205	56,889
6.	Timber	12.22	750	9165	98,982
7.	Mild Steel	-	-	2053.68	86,254.56
					Total = 28,84,054.98
Grand Total = 79,99,074.4					

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Table 4 Total Energy For Department Of Civil Engineering During Constructional Phase

Ground floor					
S.No.	Name of item	Volume (m^3)	Density (kg/m^3)	Weight (kg)	Total Embodied Energy (Mega Joule
1.	Cement mortar	65.43	-	-	82,965.24
2.	PCC	92.78	1,600	1,48	9,94,601.6
3.	RCC framework	678.96	-	-	4,95,640.8
4.	Red Brick Masonry	379.87	-	-	8,13,301.67
5.	Glass	1.78	2,500	4,450	1,14,810
6.	Timber	2.96	750	2,220	23,976
7.	Mild Steel	-	-	5,342.8	2,24,397
					Total = 27,26,715.31
First floor					
1.	Cement mortar	51.12	-	-	64,820.16
2.	PCC	76.37	1,600	1,22,192	8,18,686.4
3.	RCC framework	647.04	-	-	4,72,339.2
4.	Red Brick Masonry	325.49	-	-	6,949.3596,847.09
5.	Glass	1.04	2,500	2600	67,080
6.	Timber	2.79	750	2092.5	22,599
7.	Mild Steel	-	-	3742.2	1,57,172.4
					Total = 22,99,544.25
Second floor					
1.	Cement mortar	33.95	-	-	43,048.6
2.	PCC	67.74	1,600	1,08,384	7,26,172.8
3.	RCC framework	521.35	-	-	3,80,585.5
4.	Red Brick Masonry	200.35	-	-	4,28,949.35
5.	Glass	0.564	2,500	1,410	36,378
6.	Timber	1.82	750	1,365	14,742
7.	Mild Steel	-	-	1,909.6	80,203.2
					Total = 17,10,079.45
Grand Total = 67,36,339.01					

Table 5 Complete Life Cycle Energy Usage For Nt Hall

S.No.	Energy usage	MJ	Percentage (%)
1.	Construction	80,19,665	9.68
2.	Maintenance	1,60,393.3	0.20
3.	Operation	74,783,783.78	90.31
	Total	**82,798,856.26**	**100**

Table 6 Complete Life Cycle Energy Usage For Department Of Civil Engineering

S. No.	Energy usage	MJ	Percentage (%)
1.	Construction	67,59,316	12.86
2.	Maintenance	1,35,186.32	0.25
3.	Operation	45,659,409.91	86.88
	Total	**52,553,912.23**	**100**

Table 7 Complete Life Cycle Ghg Emissions For Nt Hall

S.No.	Materials Used	Life cycle GHG emissions (Kg-CO_{2eq})		
		G Floor	1st floor	2nd floor
1.	Cement Mortar	6,681.85	7,555.65	8,405.65
2.	PCC	18273.6	18273.6	18273.6
3.	RCC frame work	21,366.24	21,481.92	21,366.24
4.	Red brick masonry	69,397.9	82,565.34	96,096
5.	Glass	3698	3698	3992.6
6.	Timber	15,122.25	15,122.25	15,122.25
7.	Mild Steel	5,750.30	5,750.30	5,750.30
	Total	1,40,290.14	1,54,447.06	1,69,006.64
	Total Construction of all floors (Mg-CO_{2eq})	463.74		
	Operation (Mg-CO_{2eq})	5223.19		
	Maintenance (Mg-CO_{2eq})	11.20		
	Grand Total (Mg-CO_{2eq})	**5698.13**		

Table 8 Complete Life Cycle Ghg Emissions For Department Of Civil Engineering

S. No.	Materials Used	Life cycle GHG emissions (Kg-CO_{2eq})		
		G floor	1st floor	2nd floor
1.	Cement Mortar	5561.55	4345.2	2885.75
2.	PCC	24048.6	19,795	17558.2
3.	RCC frame work	32590.08	31057.92	25024.8
4.	Red brick masonry	54321.41	46545.07	28650.05
5.	Glass	7654	4472	2425.2
6.	Timber	3663	3452.62	2252.25
7.	Mild steel	14959.84	10478.16	5346.88
	Total construction	142798.48	120145.97	138143.13
	Total Construction of all floors (Mg-CO_{2eq})	401.08		
	Operation (Mg-CO_{2eq})	3184.26		
	Maintenance (Mg-CO_{2eq})	9.44		
	Grand Total (Mg-CO_{2eq})	**3594.78**		

Table 9 Correlation Of Life Cycle Ghg Emissions With Previous Studies

S. No.	Year	Specification of building	Place	Type	Life time (year)	Floor area (m^2	GHG emissions (ton CO_{2eq}/m^2 50 year)
1.	2001 (Adalberth, Almgren, & Peterson, 2001)	Malmo	Sweden	R	50	700	1.30
2.	2001 (Adalberth et al., 2001)	Helsingborg	Sweden	R	50	1160	1.35
3.	2001 (Adalberth et al., 2001)	Vaxjo	Sweden	R	50	1190	1.51
4.	2001 (Adalberth et al., 2001)	Stockholm	Sweden	R	50	1520	1.40
5.	2003 (Arena & Rosa, 2003)	School building	Mendoza, Argentina	C	50	-	34000
6.	2003 (Scheuer et al., 2003)	University of Michigan	Michigan, USA	C	75	7300	18.49
7.	2005 (Guggemos & Horvath, 2005)	Steel framed	Midwestern US	R	50	4400	-
8.	2005 (Guggemos & Horvath, 2005)	Concrete framed	Midwestern US	R	50	4400	-
9.	2006 (Norman, MacLean, & Kennedy, 2006)	Low-density bulding	Toronto, Canda	R	50	-	3,365
10.	2006 (Norman et al., 2006)	High-density building	Toronto, Canada	R	50	-	3885
11.	2006 (Junnila, Horvath, & Guggemos, 2006)	High-end	South, Finaland, Europe	C	50	4400	3.01
12.	2008 (Kofoworola & 6110Gheewala, -2008)	Office building	Thailand	C	50	60,000	0.93
13.	2009 (Blengini, 2009)	Via Garrone building	Turin, Italy	R	-	6110	3.34
14.	2012 (Varun et al., 2012)	NIT Hamirpur	India	C	50	3960	0.45
15.	Current	Residential and Educational building	India	R and C	50	5664 and 7682	**1.00 and 0.47**

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