Life Cycle Assessment of a commercial Building

Submitted in partial fulfilment of the requirements

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in

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by

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DECLARATION

I Saiyad Ameen.J (41400018), hereby declare that this thesis report entitled **"Life Cycle Assessment of a commercial Building "**recommended in the partial fulfilment about the requisition for the approval of degree of Masters of Civil Engineering, in the School of Civil Engineering, Lovely Professional University, Phagwara, is my own work. This report is not presented anywhere in partial or complete to any university or other institution for the passage of approval.

Date: **Saiyad Ameen.J**

Place:

CERTIFICATE

Certified that this project report entitled **"Life Cycle Assessment of a commercial Building"** submitted independent by student of School of Civil Engineering, Lovely Professional University, Phagwara carried out the work under my supervision for the Award of Degree. This report has not been submitted to any university or institution for the award of any degree.

Signature of Supervisor

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ABSTRACT

This study quantifies the Green House Gas (GHG) emissions of Khanduja's located at Banga road, Phagwara, Punjab. The methodology involves quantifying both primary energy consumption as well as GHG emissions in construction phase. A comprehensive Life Cycle Assessment is intended to carry manually to determine environmental effects of the structure. LCA is a very important tool to support civil, structural and environmental engineers realize how they can be a part to reduce the GHG emissions and embodied energy of any building. It provides us with huge potential of improving and lessons learned from LCA are significant. Construction materials like steel are highly recyclable but come with high energy requirements. In this study, the materials contributing to the overall GHG emissions have been estimated and productive alternative solutions have been prepared. The replaceable materials have been identified and a comparative analysis has been conducted to understand the materials that can reduce the overall GHG emissions in Khanduja's. Further, the scope of this thesis lies in discussing Energy saving techniques for reduction of Carbon Footprint during both Operation and maintenance phase along with Construction phase.

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LIST OF ABBREVIATIONS

LCA	Life Cycle Assessment
GHG	Green House Gas
LCCE	Life Cycle Carbon Emissions
GA	Globally Adopted
GBI	Index for Green Building
GEO	Green Energy Office
ECEB	Embodied Carbon & Energy of Buildings
BMS	Building Management System
SC	Smart City
ERM	Efficient Retrofits Measures
EE	Energy Efficient
SERT	Sustainable Energy Research Team
ICE	Inventory of carbon and energy

Chapter 1

Introduction

1.1 Introduction

As the Construction sector is developing at a faster rate, environmental impacts related to buildings such as global warming, GHG emissions, ozone layer depletion, etc. are also increasing rapidly. Research from the past years indicates that these changes in global climate are increasing rapidly and will continue with time (Hulme et al., 2002; Intergovernmental Panel on Climate Change, 2011). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) derived that between 1970 and 2004, global greenhouse gas emissions due to human activities increased by 70 percent (IPCC, 2007).

Construction sector has now become a major source of Global GHG emissions and therefore a reduction in these emissions are required so as to minimize overall global GHG emissions. Hence there is an absolute need to change and revise the construction materials and processes for reducing the impact on environment. The building sector consumes 40% of the primary energy and 36% of the energy related to CO_2 emissions in the countries with more industries (IPCC, 2011b).

Building utilizes the energy throughout its construction phase and operation phase. Therefore, while selecting the materials in construction phase, comparison can be done on various available materials and the materials that tend to contribute to less use of energy can be chosen. The concepts of embodied energy and LCA (Life Cycle assessment) can be the useful tools in decision making when it comes to selection of materials.

1.2 The concept of Life Cycle assessment (LCA)

Due to the Urbanization and rapid development of countries in the world, the resources are becoming insufficient for the demand and in addition to that, it is giving rise to environmental issues. Hence it has become very important to generate new ideas to tackle and reduce these issues. LCA is therefore a useful tool to analyze buildings from the point of view of the environment (Baumann et al., 2004).

The knowledge that is produced from these studies can assist the architects and civil engineers to make choice for the most appropriate constructive ideas from the point of sustainability (Antonio Garcia Martinez et al., 2011).

1.3 Objective of the project-

- To calculate Green House Gas emissions throughout the construction phase of the building.
- To find out impact of each material on the overall carbon footprint of the building.
- To reduce the carbon footprint of the structure by using more environmental friendly materials and suggesting some renewable energy techniques that can be used to reduce environmental impact of buildings that would be constructed in future

1.4 Scope of the project -

The scope of this project lies in helping civil, structural and environmental engineers understand how they can contribute to lowering the embodied energy of any building.

It provides us with huge potential of improving and lessons learned from LCA are significant. Construction materials like steel are highly recyclable but come with high energy requirements. Construction materials such as concrete, masonry and bricks are more difficult to recycle and contribute largely to total material consumption.

Chapter 2

Literature review

The information collected on life cycle assessment, emission quantification during construction from research journals, e-resources is presented below:

Reddy et al., (2004), addressed certain ideas regarding embodied energy in buildings and its effect on environment with current methods of construction. Construction industry contributes 22% of the total GHG into the atmosphere. Currently adopted energy-oriented materials and building methods have a huge burden of future demand. The need is to begin the use of concept of energy efficient construction materials and technology and invent new techniques to utilize industrial wastes. Recycle and reuse of building wastes for the preparation of building materials and similar products for the efficient construction practices should be promoted.

Liu & Yang, (2010), discussed the importance of sustainable technologies for sustainable low carbon buildings. The study relates natural technology with building technique to create a type of sustainable low carbon building which is cheap and convenient related to a situation in China. The study highlighted factors that affect the emissions after building is used i.e. dimensions, style, function and life of the building. Amongst materials, locally available materials were given preference and use of solar energy chimney and passive solar housing was encouraged. Economizing the air conditioning by studying the plan and space design is also an important factor and can help reduce emissions up to a great extent.

Yan et al., (2011) discussed the ideas to construct and come up with the Low-carbon building during its time of planning and design, construction, and operation phase, so as to control and decrease carbon footprint of the building. The study talks about the development of low-carbon building is a organized project and the material with less carbon and energy saving instruments are of vital importance for controlling the main segment of carbon emission and to make sure low-carbon quality.

Frazoni et al., (2011), explained the role of selection of building materials in achieving “green” tag for the building both at early design stage as well as at working plan stage. Working plan stage is more important but engineers and architects at this stage usually lack evaluation strategies that can help them to select best materials. In this study, the critical aspects of defining “green building materials” are discussed and overviewed with attention particularly on the working plan stage and the application of such tools are discussed relating to Italian market. It is observed that the architects and engineers presently are alone while selecting commercially available environmental friendly building materials. The issues of environmental impact and importance o f indoor air quality has to be considered and also the evaluation tools should be modified.

Tang et al., (2011), presented a report on growth of low carbon buildings based on life cycle assessment and researched about the scenario of low carbon technologies in building describing the need and importance of decreasing carbon emissions throughout the life time of the building. A low-carbon assessment model was prepared and the problems and challenges faced in its growth were found, effective ways were applied and made a theoretical idea for the sustainable and fast growth of low-carbon buildings. The key carbon decreasing policies should be based on the actual scenario and should include the different properties and factors such as public awareness regarding carbon emissions.

Bo WU & Wei-hua ZENG, (2011), brought forward the research about carbon footprint to organise the development of low carbon planning of city in an appropriate way. By computing method of carbon footprint, all types of carbon footprint and the ability of carbon sink of a city, in Beijing Shijingshan District, were calculated and analyzed. The results show clearly that the carbon footprint of the city was comparatively more, specifically the production carbon footprint reached 17,008,722 tons and that of life reached 2144.33 tons. To minimize carbon footprint, the industrial structure has to be modified and improved, the carbon sink resource has to be expanded, new energy conservation technology must be developed and the existing sources of renewable energy has to be encouraged and low carbon buildings, transport with low footprint should be developed in future.

Bei et al., (2011), discussed the importance of low carbon structures and buildings at a time when the bad impact of environment and climate has raised threats to the survival of human . The architectural design should be aimed at controlling and improving the bad impacts of climate and environment by proper design methods and new technologies that can generate an environment with less energy consumption with economic circumstances along healthy living. Developing the less carbon building would become a point of focus attention to the whole society.

Bignozzi et al., (2011), conducted a study on sustainable cements for green buildings by partially changing clinker substances with non-harmful waste. It is important that the waste has been selected should possess uniformity in composition and should be available in large quantity throughout the territory. Various physical, mechanical and chemical properties were tested. Loss on ignition, Insoluble residue, sulphate and chloride content were checked and all results were within Italian specifications. Electrical and heat efficiency of cement manufacturing unit has to be improved taking into account the aim of avoiding energy losses and more consumption of fossil fuels.

Guardigli et al., (2011) compared the environmental impact of wooden and reinforced concrete structures by Life Cycle assessment methods and inferred that the calculated impact of buildings made by wood on human health, ecosystem and resource quality is normally lesser than a general concrete structure but at the same time more use of wood hampers the ecosystem's quality. LCA can be utilized effectively for decision making as far as sustainable building construction and design is concerned.

The cost analysis was done and found out that the wood buildings could save 17 percent more money than the concrete structures and also wooden structures can be constructed faster than concrete ones. LCA approach stated that the wood structures are environmentally less harmful than concrete structures.

Patle et al., (2011), presented energy minimization and cost minimization techniques ultimately leading to reduction in overall impact of the building on environment and pushing it towards green building category.

The study revealed that fly ash bricks are 2.86% cheaper than clay bricks and PPC provides 11.43 percent less cost than OPC and both of above said products have appropriate quantity of fly ash making it a good solution to solid waste management problem along with serving cost reducing technique.

Hu et al., (2011), analyzed a residential building in china for carbon emissions throughout its life . The research introduces Life Cycle Carbon Emissions (LCCE) Model to predict carbon dioxide emissions of urban building system which is based on the methodology of LCA. It was observed that GHG emissions in residential buildings are due to more energy usage and land footprint. Buildings made up of masonry-concrete structure produces more GHG emissions than the steel-concrete structures having the same area. The results show that steel-concrete structural building contributes 315.79 tonnes equivalent carbon dioxide per 100 square meters and masonry- concrete architectural style contributes 329.61 tons per 100 square meters. Most emissions resulted from energy usage and land footprint, accounting for 78–83 percent and 13–20 percent of the total emissions. This further can be reduced by promoting the recycling of construction materials, changing of patterns of user's consumption and efficient use of natural energy .

Varun et al., (2012), quantified the significant environmental effects of mechanical engineering block of NIT, Hamirpur which is a three storey building. The building has a floor area of 3960 m^2 and a projected service life of 50 years. The total energy usage for different phases i.e. construction, operation and maintenance is calculated. The construction phase consumes about 10,512,410.8 MJ of primary energy which is around

40% of the total energy requirement. The energy usage for operation phase was calculated to be maximum and it has been found out to be around 59% of total energy usage. Most of the use energy is required for heating/cooling, computer usage and operating of heavy machineries in the building. During the operational phase almost all the life-cycle elements cause significant impacts. In maintenance phase the energy usage is around 210,248.22 MJ which is less than 1% of total energy usage. The total life cycle GHG emissions contributed by the MED building are 1764.82 ton CO_2 eq. The operation phase consume maximum about 59% of total GHG emissions. The total GHG emissions per unit area are around 0.45 ton CO_2 eq/m^2 50 year. Construction of second floor has the biggest share in the GHG emissions i.e. about 25% of total GHG emissions. This is due to high large amount of steel and aluminum used in the construction. During the construction phase, RCC framework and steel are the highest contributor of total GHG emissions for all three floors. Two life cycle phases viz. construction and operation seem to be more significant in all impact categories (energy and emissions).

Vatalis et al., (2013), researched about the sustainability fractions that affect the decisions for green building projects. 32 participants were surveyed based on a questionnaire that assessed nine sustainability components. Energy efficient constructions and renewable energy methods are considered first with more priority followed by the decrease of toxic materials, indoor contamination and water saving related to which the results showed that the people should and want to achieve an environment that is designed and adopted for energy efficient construction and renewable energy.

Yiing et al., (2013), conducted a study to check the approachability of green buildings in Malaysia. Malaysia has both Globally Adopted (GA) and Design of Green Building Design (GBD) and Index for Green Building (GBI) is a way to further reinforcement of agenda of GBD although is not mandatory. For more than forty years, SD has dominated the global environmental discourse and guiding ecosystem protection. The accessibility was checked using creating similar situations as persons with disability (e.g. blindfold). Kettha office of LOW ENERGY in Putrajaya and PTM Office of Green Energy Office (GEO) in Bangiare are two certified government office green buildings, located in commercial existing building category and commercial new construction (NRNC) category, correspondingly and The Ministry of Women, Family and Community Development (KPKWM) in Putrajayais a non-green certified building, were chosen according to the consideration of GA and accessibility of PWD during preconstruction.

The results showed that KPWKM building (score of 65 of 90) provides better accessibility to building users, followed by LEO(score of 51 of 90)and GEO (score of 44 of 90).This means, the majority of the facilities provided in the KPWKM meets 75% of the requirements while less than 50% for the facilities in GEO building. Future studies were recommended to perform a qualitative research using case studies by interviewing disabled persons including those with sensory impairment in terms of using green- certified buildings, from the perspective of employment

Dulal et al., (2013), suggested GHG emission reduction techniques in cities with a wider perspective of finding out the coincidences of common priority locally adopted and alleviation policy for climatic change. Strong urban policy and its implementation have become necessity and still most of policies urban areas are feeble and disjointed.

Joshi and Pathak, (2013), found the profits and obstacles to the energy efficient buildings and decentralized energy in India. It was found that building sector has a huge ability to act as India's secondary power source. Reforms of Architecture and advanced energy efficient technology usage can help to reduce the demand. Renewable Decentralized Energy can be utilize to for on-site use in order to produce energy which has lower cost of installation contrasted to usual centralized power plants and transmission losses are reduced significantly. Energy crisis is a major obstacle to sustainable growth.

Moncaster et al., (2013), described the method used by a new design decision tool, Embodied Carbon & Energy of Buildings (ECEB), to compute the embodied energy for the whole life and carbon for the buildings as recommended by UK government. The method described provides an estimate of the whole life. ECEB includes the carbon and energy impacts and the carbon of the material. The study has further shown the analysis of embodied energy for whole life and carbon of buildings within the United Kingdom which is significantly restricted by the lack of data and it is now the responsibility of industries to complete the relevant data with standardization.

Bakisi et al., (2013), in a study on the city of Barcelona analyses the transformations from a usual accumulation to a twenty-first century metropolitan city. The reason for choosing Barcelona for the study was due to its obvious need, reflected by its present policies concerning urban planning making it one of the leading metropolitan city in Europe.The result by the analysis of case study states that Barcelona has been effectually incorporated the Smart City approach with a goal to be an Elegant City model for the world.

Kanagaraj et al., (2014), in this it provides a means for refining decision making pertaining to energy of the structure during designing phase. To bridge the gap between architects, environmentalists and engineers, a elaborative design process titled 'Combined Energy Effectual Building Design Process' is suggested. It also provides an outline based on Philosophy that enables the combination of various different parameters.

Weibenberger et al., (2014),in this, past development and background Assessment of Life cycle was made (LCA)In this ecological improvement of construction and removal of buildings of zero energy is the important next step. In order to oppose the main confront of the building sector, controlled resources as well as the energy-efficiency and a maintainable building stock, a life cycle view is required .The current applied assessment methodology began in the 1970s in the packaging industry.Around the turn of the millennium this calculation method was standardized into an international series of standards. Today the ISO 14040 and ISO 14044 are the only internationally standardized methods for evaluating potential effects on environment.

Buyle et al., (2014), presented LCA screening of an apartment in Belgium rendering to Attributional (ALCA) as well as Consequential (CLCA) approach. The main objective was to perform the comparative analysis of the result of both the approaches rather than doing detailed LCA. The main difference in both approaches is data collection. ALCA uses regular data at certain point of time and assumption was made that all the process are not linked. CLCA looks at the bordering variations i.e. it only focus on the the processes that are actually disturbed by the system. The overall results show that there is impactial shifts per building stage. At use phase, CLCA assigns a very less impact (8%) to consumption pertaining to electricity and rewards recycling and it generates adverse impact for the end of the life. Finally, to improve a maintainable society it is needed that policy is concentrate on the entire life cycle of buildings instead on energy efficiency only.

Biswas, (2014), employed 'mining to use' approach to conduct assessment of life cycle and analysis of energy for the Engineering Pavilion (building 216) at Curtin University Western Australia. The life cycle pertaining to emission of GHG and EE of building 216 e are 14,229 CarbonDioxide and 172 T J respectively. The usage stage production 63% less GHG emissions than the University's average, due to implementation of an energy efficient Building Management System (BMS). The study identifies the stages in production and operational process of building 216 that pays heavily in GHG emissions. Introduction of BMS reduced the embodied energy consumption of life cycle of building by 20% less than the university's average. The research estimates that there is a potential for saving around 60% carbon footprint associated with Building 216. However, use of revised cement formulations and recycled aluminum and steel use wherever possible can further reduce GHG emissions by around 7%.

Kapure et al., (2014), discussion was made on the different parameters for upgrading existing building into green building. Energy efficiency upgrades signifies the most cost effective way to meet growing demands of energy. The numerous studies have shown that the energy-efficient and certified green buildings gives a higher market values, huge rents and higher residences. After understanding the dynamics, cost factor is also considered and cost benefit analysis is done for understanding the increase in capital cost, payback period and benefits of green buildings. A ten point program is primarily focused on the decision maker activities among various property owner whereby which this is used as for greening the existing building. Long term investment act as cheap or economic drivers when done in energy efficiency.

Mangano et al., (2014), provides with a complete interpretation of the concept of Smart City (SC) through relevant domains namely: natural available resources and energies, economy, people, transport and mobility, living and buildings. This study explores the possibility of role that various economic, urban, demographic and geographical variables might have in influence the planning approach to create a smarter city and explores current trends in shaping smarter cities. The results exposed that there is no exclusive global definition of SC, and the trends any individual SC depend on the local context factors.

Kamal et al., (2014), conducted a study of achieving environmental sustainability through renewable energy technologies in tall building structures. The hunt for checking the availability of various renewable energy sources, various technologies to utilize them. The rising pressure globally for the reduction for the footprints of Carbon and pointing to sustainable habitats, which became a developing trend in tall building designs. Approx 35% of the renewable energy involvement is from wind energy, which is the plus point of tall building and high level of wind speeds in the mainstream of atmospheric boundary layer can benefit tall buildings.

Bull et al., (2014), gave carbon life cycle and also provide with the life cycle assessment pertaining to the cost of energy efficient retrofit measures (ERMs) to the building envelope and heating system of four existing schools which represent school archetypes built in the UK between the year 1870-1995. The basis of energy efficiency assessment was energy simulation models of the existing structures. The regression equation formulated with the help of energy models has a coefficient of determination of 95–97%. This equation can be used in predicting life cycle carbon saving within the tested range of ERMs , and also within the range of the other building features included as independent variables. The regression equation calculated carbon savings will be close to energy model simulated savings.

The study also shows that it is vital to create scenarios to understand the energy-use implications of different design interventions and retrofit measures in combination. This a an easy and simple approach for each retrofit measure individually but is inadequate for multiple retrofits together.

Biswal et al., (2014), suggested innovations to reduce carbon footprint that is interfering with the climate and causing climate chain in Indian context. Availability of suitable technologies and various effective processes for decision making among multiple investors limit the capacity for mitigation of climate change. Schools should act as a bridge between public and the knowledge producers. Various approaches such as Food Prints Reduction, Energy Movement protection,Enhancing Awareness programmes through social media network, All Coordinated Projects/Publications in India, School Level Encouraging Science Communication, which are proposed to be implemented in India as strategy of action for future carbon emissions and economic development encouragement discussion was also made.

Ali et al., (2015), conducted environmental life cycle impact assessment of a residential building in Egypt using Simapro v8.1 and using ISO 14040 standards for the analysis. The final results and analysis indicate that the use stage, which has the highest share of energy, is also the main contributor to all the other environmental impacts and contribute 71.9% to total effect. The main categories which have the biggest share are respiratory inorganics, global warming and non-renewable energy. Solutions were suggested to minimize the adverse environmental impacts of buildings such as reducing operating energy consumption, selecting sustainable building materials and increasing use of renewable energy during operating phase.

Praseeda et al., (2015), investigated in embodied energy (EE) of different materials for the building from standpoint life cycle and numerous methods for their measurements were identified. EE assessment can be carried out by using analysis pertaining to Input Output (I/O), analysis of process and cross analysis. Undependable data, lack of data specifically of product, high variability of energy tariffs of and commodities are salient drawbacks of Input/output method. Input/Output method is claimed as an inappropriate method for the assessment of embodied energy in perspective of Indians. Therefore a new framework based upon the process was finally adopted for Embodied energy assessment. Aluminium coils were found to have the highest EE amongst basic materials trailed after steel, glass and cement. EE for the blocks made from concrete is delicate content in cement used in the block manufacture.

Chapter 3

Material and methodology

3.1 Description of Building

3.1.1 Location:

The building that has been chosen for the study is a relatively new building known as 'Khanduja's' which is located in Banga road, opposite to old vegetable market, Phagwara. The building was planned as well as built in single phase and the structure has a floor area of nearly 175 m2. It is a three storey commercial building with a semi-basement. The semi-basement and the first storey is being utilized for selling garments and accessories. The second storey is kept vacant to let for renting and the third storey is still under construction.

3.1.2 Structural Features

The structure is aesthetically appealing due to vitrified tile floor work along with marble and granite stone tiling at some minor places. The main construction components used are considered and it is evident that cement mortar, reinforced concrete cement framework, glass, timber, brick masonry, aluminum, steel, anti-skid tiles, gypsum ceiling and vitrified tiles are main components employed in the construction.

Other significant specifications of building are: Structure: Reinforced Cement Concrete Framework Masonry: Brick masonry

Flooring: Cement concrete flooring with vitrified tiles (mainly), marble and anti-skid tiles used at various locations. Door and Windows: Aluminum shutters have been used for doors (washroom) and Glazed doors have been used for main entry since it is a garment showroom. The interior portion is mainly constructed of commercial plywood, teak wood, and timber for stacking garments and for furniture.

Fig 3.1 Front View of Khanduja's

Fig 3.2 View of Floor

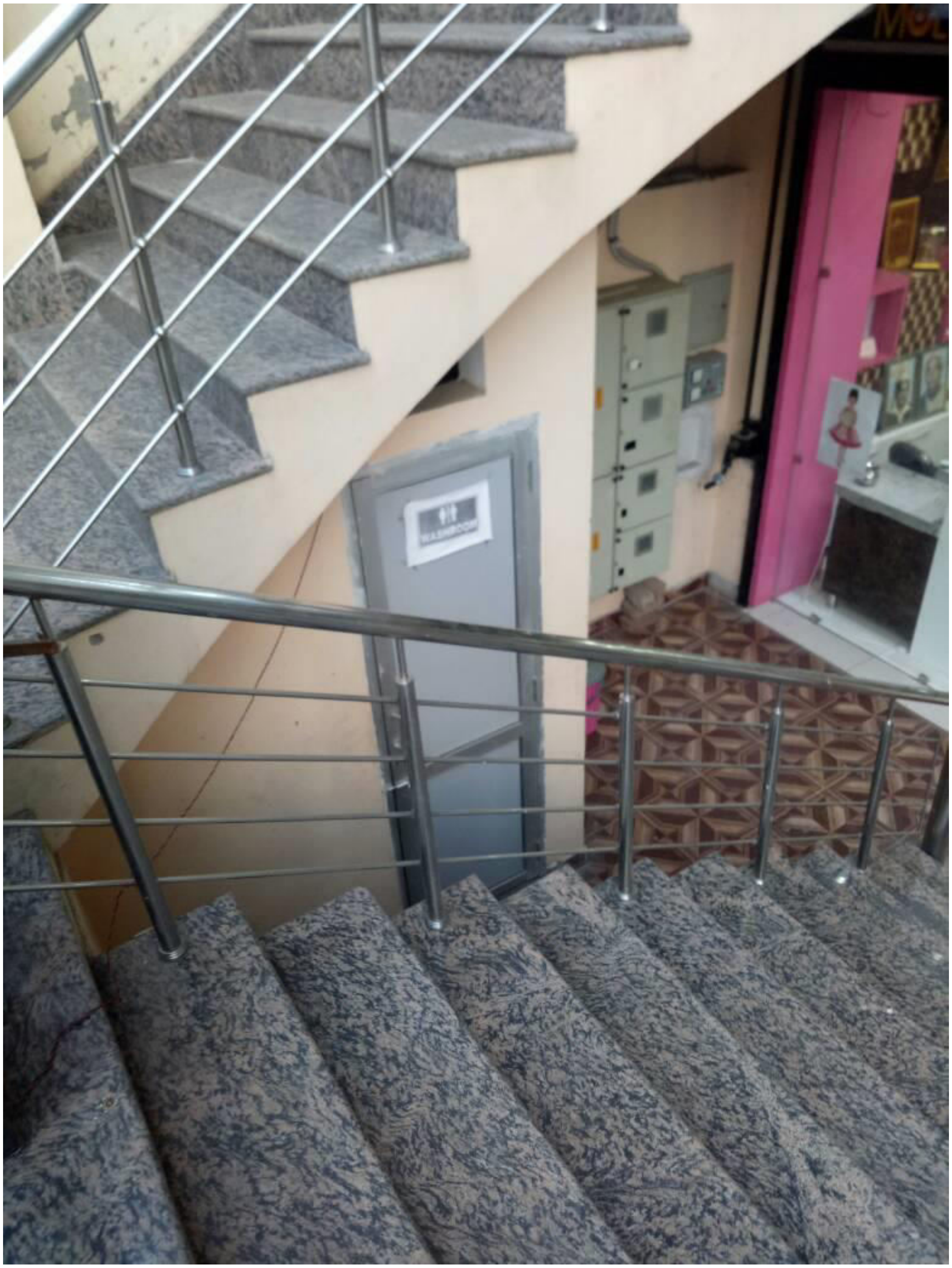


Fig 3.3 Stairs of Khanduja's

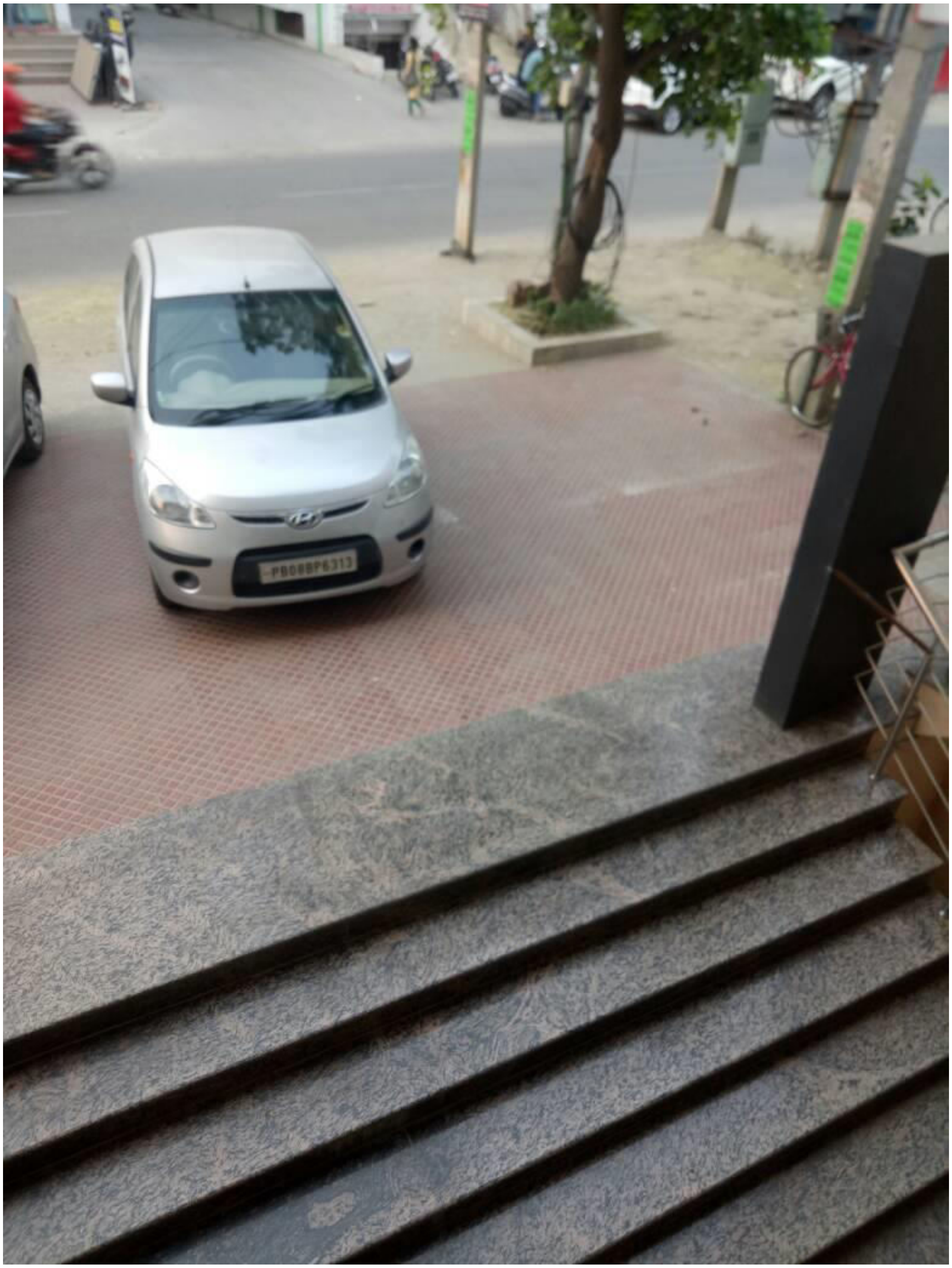


Fig 3.4 Stairs at main entry

Fig 3.5 Khanduja’s third storey (under construction)

Fig3.6 Wooden work of Khanduja's

3.2 Life Cycle Assessment

LCA is one of the most reliable tools used for the quantitative assessment of any material and environmental impacts caused by it. It follows a step by step method to determine the impact of each material.

LCA is the most suitable framework for the determination and evaluation of the inputs, outputs and the possible environmental impacts throughout its life cycle. Basically there are three types of LCA methodology that is LCA based on process, LCA based on input–output and hybrid LCA (Bullard & Herendeen, 1975; Facanha & Horvath, 2006; Guinea, 2002; Heijungs & Suh, 2002; Kofoworola & Gheewala, 2008; Suh & Huppes, 2005). In LCA based on process, the user highlights all processes associated with all life-cycle phases of a product, and relates inputs and outputs with each process, by which total environmental load energy can be determined. There are four stages of Life Cycle Assessment. The methodology of the study is illustrated in Figure3.7

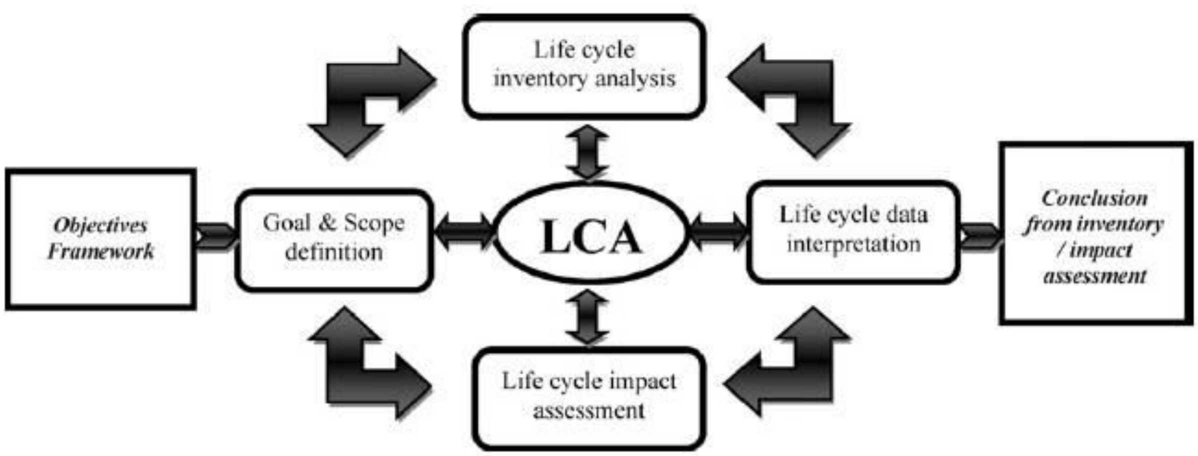


Fig 3.7: Methodology of LCA analysis (Source: Varun et al., 2012)

3.2.1 Goal and Scope of LCA

The scope and goal of and LCA determines the significance of the study. System boundaries are defined and a quality criterion for inventory analysis is set up. Life Cycle assessment deals with the building life cycle and materials used during construction. Indoor air quality data, furniture details and individual emissions due to people entering and leaving the building are out of the system boundaries.

The life span of the building consists of three phases: Construction, Operation and maintenance. It is assumed that no structural modifications are done to the structure. The life span of the building is considered as 50 years.

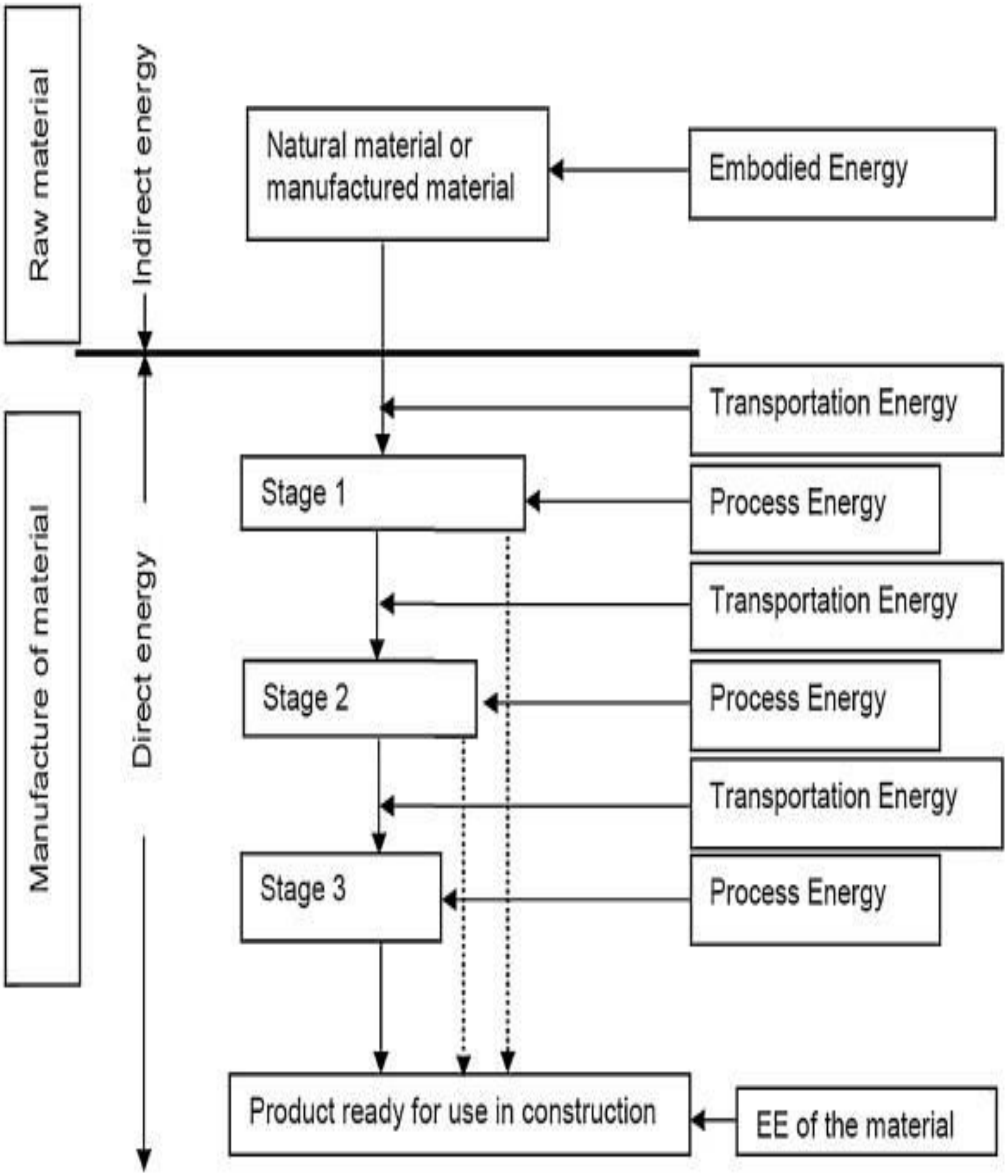
3.2.2 Life Cycle Inventory Analysis (LCI)

For Buildings and structures, the plan of the building and visual inspection helps to collect the raw data and inventory analysis is done during all three phases of life span of building. Using the consumption chart and abstract of quantities, a list of number of materials and their quantities is prepared. The data is then compiled using embodied energy coefficients of all different types of materials and primary energy of the structure during the construction phase is established. The values of coefficients are taken from Indian Literature, Inventory of carbon emissions (ICE) database published by University of Bath UK and other standardized databases.

3.2.2.1 Embodied Energy

Embodied energy (EE) of building materials comprises of the total energy spent for production of building materials including that for extraction of raw materials and related transportation. EE assessment of building material shows the extent of energy utilized and associated greenhouse gas emissions in their manufacture.

In the present study, process based LCA is followed all over the process whether it is 22-embodied energy assessment or impact assessment due to other factors. The methodology of process based assessment of embodied energies is shown in fig 3.8



3.8 Methodology of process based assessment of embodied energy (Source Praseeda et al., 2015)

3.2.3 Life Cycle Impact Analysis (LCIA)

The Life Cycle Impact Assessment (LCIA) stage of an LCA is the judgment of possible environmental impacts of the environmental resources and discharges during the LCI. A life cycle impact assessment tries to establish a bond between the product or process and its budding environment. An LCIA provides a step by step procedure for categorizing and characterizing these kinds of environmental effects.

.3.2.4 Life Cycle Data Interpretation

Life cycle data interpretation is a systematic procedure to present and analyze information from the results of the LCI and the LCIA, and communicate them effectively. Life cycle interpretation is the last stage of the LCA process.

ISO has defined the following two objectives of life cycle interpretation:

1. To analyze the results and provide conclusions explaining the limitations. Along with this, suggest recommendations based on the findings of the stages of the LCA, and to present the results of the life cycle interpretation in a transparent manner.

2. To supply a readily understandable, overall, and consistent presentation of the results of the LCA study, with respect to the goal and scope of the study. (ISO 1998b). This step mainly involves comparing the suggested alternatives by interpreting the results.

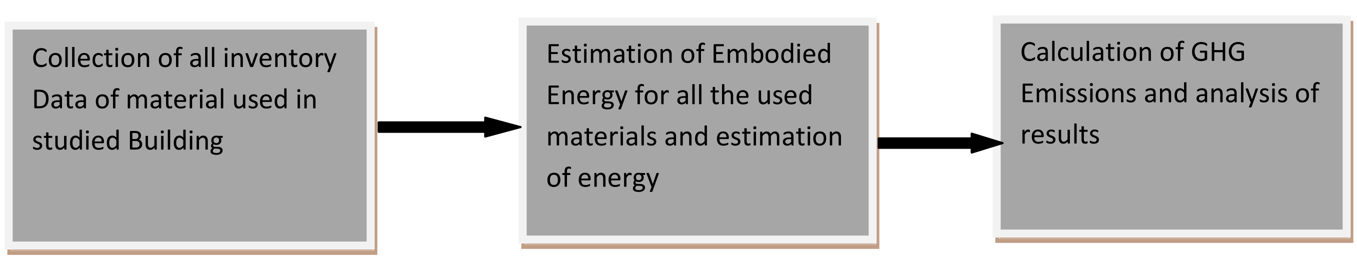


Fig 3.9: Methodology followed for Khanduja's

3.3 Embodied Energy Assessment (for Databases)

The Inventory of carbon and energy (ICE V2.0) database is a widely accepted database which is possible due to efforts of Sustainable Energy Research Team (SERT), Bath University U.K

The database follows "Cradle to Gate" approach for Embodied Energy calculations and precision is maintained throughout EE assessment. Material profiling is done in order to maintain the standards of results. Material profiling usually consists of four sections that is Database Statistics, Best values of Embodied energy and carbon, Scatter graph and fuel split and embodied carbon split and Material properties.

The database is improvised and modified over the years with changing construction practices. All possible energy inputs are taken into consideration to ensure accuracy in embodied energy values.

3.3.1 Material Profiling

This section contains the step by step procedure followed to obtain the values in Inventory of carbon emissions version 2.0 – a database used for the study. The database has been developed by Sustainable Energy research team of University of Bath, UK.

Section 3.4.1.1 Database Statistics

The materials are divided into sub categories, which reflect the way the data is stored within the database. Some materials have a General for, and are divided into more specific categories, for example Iron general, Iron Extrusion. Each of the sub categories are further broken into

Recycled/virgin content of the metal

These are simple statistics from database. These include no of records which represent the sample size that was used to select this data. Additional statistics include maximum and minimum values of EE and Standard deviation to maintain openness in the inventory. The boundaries are predefined as seem in the previous section

Material Profile: Example						
Embodied Energy(EE) ICE- Database statistics MJ/Kg						
Main Materials	No of Record	Average EE	Standard Deviation	Minimum EE	Maximum EE	Comments on
Material						
Sub Material						
100% Recycled						
50% Recycled						
Other						
Unspecified						
Virgin						

Section 3.3.1.2: Selected (or 'best') values of embodied energy and carbon

The values of embodied energy are presented here, although this example is only for products that are recyclable which are mostly metals. General values can be used if unsure what to apply. Primary is mainly for virgin material and secondary for recycled materials

Embodied carbon is shown her. Again the same distinguish between primary and secondary materials have been used

The low to high range of EE is written here and hence an idea can be drawn about the range in which the value might exist

Selected Embodied Energy and Carbon Coefficients and Associated Data

Materials	**Embodied Energy- MJ/Kg**			Embodied Carbon- MJ/Kg			Boundaries	Best EE Range- MJ/Kg	
	UK Typical	Primary	Secondary	UK Typical	Primary	Secondary		Low EE	High EE
General Material									
Cast Products									
Extruded									
Rolled									
Comments									

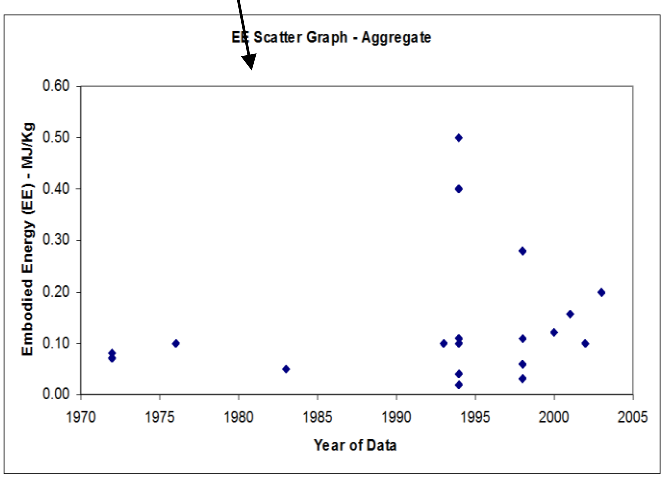
3.3.1.3 Scatter Graph And Fuel Split and embodied carbon split

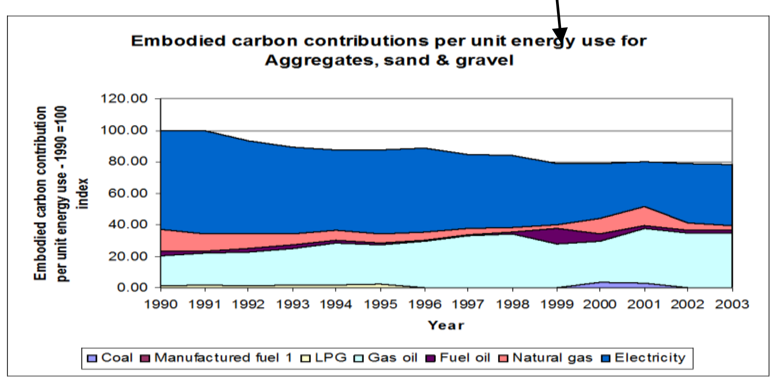
There is a scatter graph for each materials. The scatter graph plots the year of data versus the value of embodied energy for each point in the database. This maintains the transparency of inventory data and it can be seen that whether the real value is affected by one or two values

Where possible the historical embodied carbon per unit fuel was calculated as an index of 1990 data. This section does not appear on all profiles

The fuel split is shown here along with the fraction of embodied energy used from source. In cases where it was not possible to get a fuel breakdown

Scatter graph and fuel split and Embodied Carbon Split			
Material Scatter Graph	**Embodied Energy and Embodied Carbon Split**		
	Energy Source	**% of embodied energy from energy source**	**% of Embodied carbonfrom source**
	Coal		
	LPG		
	Oil		
	Natural Glass		
	Electricity		
	Others		
	Total		
	Fuel Split and Embodied Carbon Comments:		





Section 3.3.1.4: Material Properties (CIBSE Data)

Data extracted from the most recent CIBSE guide is presented here.

Material	Condition	Thermal Conductivity	Density	Specific Heat	Thermal Diffusivity
Material		230	2700	880	9.68013E-05
Material Galvanized		45	7680	420	1.39509E-05

Chapter 4

Results and Discussion

This Chapter deals with the analysis carried out and the results obtained during the analysis of Khanduja's situated in Phagwara.

4. 1 Carbon Footprint Calculations

Table 4.1.1 Quantities of Materials Used for Construction

1.	**Basic Materials used for various construction purposes**	Quantity of Material	Unit S	Conversion Factor	Conversion Factor(KG)	**Final Value**
	Bricks	120000	Nos	NA	2.9	348000
	Cement	3333	Bag s	NA	50	166650
	Sand(fine	236.389	cum	NA	1800	425500.2
	Bajri(coarse aggregate)(20M	271	cum	NA	2240	607040
2.	**Stone usage and Tile Work**					
	P.O.P covering(10mm)	357.9	sqm	0.01	2500	8947.5
	Bitumen on Roofs	Nil	Kg	NA		Nil
	parking Tiles 25mm thick	39.76	sqm	0.025	2360	2345.84

	Colored Granite stone tiles(20mm)	36.105	sqm	0.02	2750	1985.775
	Vitrified floor tiles of Size 600 x 600 mm	357.9	sqm	0.01	2000	7158
	Anti-skid tiles10 mm	59.56	sqm	0.01	2200	1310.32
	Gypsum/lafarz false	357.9	sqm	0.0125	2500	11184.37
	Marble stone flooring with 18 mm thick marble	48.2	sqm	0.018	2700	2342.52

3.	**Metal & other material used**					
	Aluminum	2.658	sqm	.025	2700	179.41
	Steel (reinforcement)	20035	KG	NA	NA	20035
	Glass sheets	37.81	sqm	0.055	2500	5198.875
	Glass (toughened)	1655.532	KG	NA	NA	1655.532
	Steel (railing and shutters)	1301.815	KG	NA	NA	1301.815
	Total Steel	21336.815	KG	NA	NA	21336.815
4.	Acrylic [illegible]	2666.6	sqm	NA	NA	266.6(per 10 sqm 1 kg of [illegible]
	Plastic emulsion [illegible]	2226.78	sqm	NA	NA	222.6(per 10 sqm 1 kg of [illegible]
5.	**Wood used**					
	12 mm commercial	179.34	sqm	0.012	900	1936.872
	Teak wood	116.36	sqm	0.003	900	314.172
	3mm plywood	63.08	sqm	0.003	900	3710.016
	Additional wood	112	kg	NA		112

Table 4.1.2 Primary Embodied Energy of commercial building (khanduja's)

(LCIA results)

1.	**Basic Materials used for various construction**	**Final Value**	**Embodied Energy Coefficient (MJ/kg)**	**Embodied Energy(MJ)**
	Bricks	348000	**3.00**	1044000
	Cement	166650	**5.5**	916575
	Sand(fine aggregate)	425500.2	**0.081**	34465.5162
	Bajri(coarse aggregate)(20MM)	607040	**0.083**	50384.32
2.	**Stone usage and Tile Work**			
	P.O.P covering(10mm) to	8947.5	**1.8**	16105.5
	Bitumen on roofs	Nil	**51**	Nil
	parking Tiles25mm thick	2345.84		2345.84
	Coloured Granite	1985.77	**7.5**	14893.275
	Vitrified floor tiles of Size 600 x 600 mm	7158	**9.00**	64422
	Anti-skid tiles	1310.32	**4.2**	5503.344
	Gypsum/lafarz false ceiling(12.5mm)	11184.37	**1.95**	21809.5215
	Marble stone flooring with 18 mm	2342.52	**2.5**	5856.3

3.	**Metal & other material used for**			
	Aluminium	179.41	**218**	39112.47
	Steel (reinforcement)	20035	**35.40**	709239
	Glass sheets	5198.87	**15.00**	77983.05
	Glass(toughened)	1655.5	**23.50**	38904.25
	Steel (railing and shutters)	1301.81	**35.40**	46084.074
	Total Steel	21336.81	**35.40**	755323.074
4.	**Paints(Sqm)**			
	Acrylic	266.6	**65.1**	17355.66
	Plastic emulsion paint(interior)	222.6	**77.2**	17184.72
5.	**Wood used**			
	12 mm commercial Plywood	1936.87	**14.4**	27890.928
	Teak wood	314.17	**27.00**	8482.59
	3mm plywood	3710.016	**15.00**	55650.24
	Additional wood	112	**12.00**	1344

4.2 GHG Emissions during Construction Phase

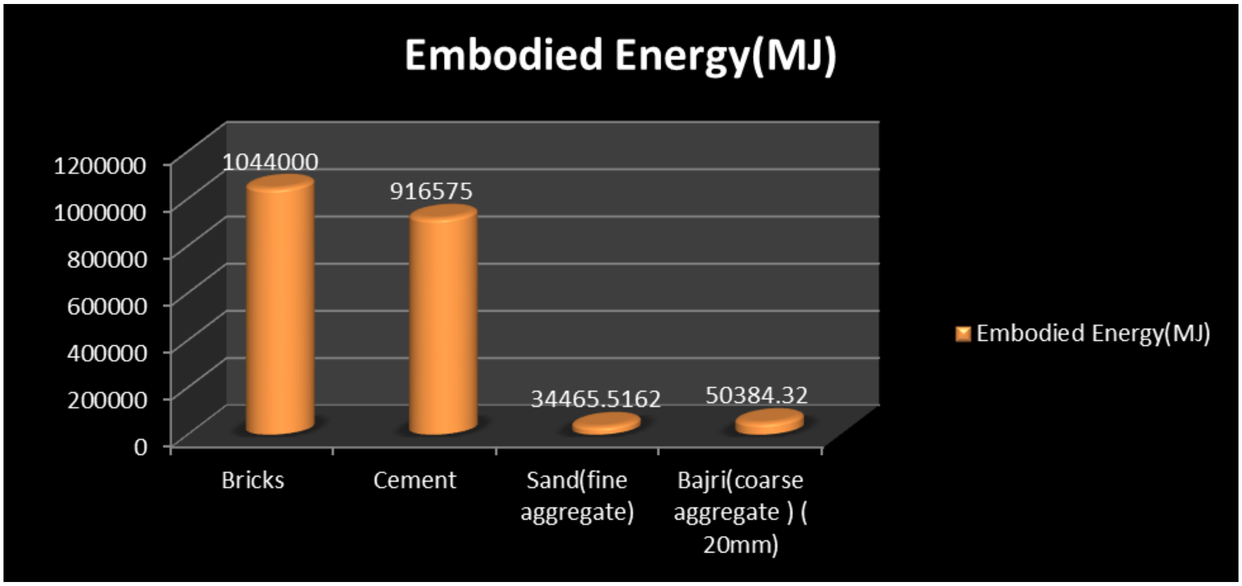
Table 4.2.1 GHG emissions from Construction Phase

1.	**Basic Materials used for various construction**	**Final Value**	**GHG emissions Coefficient (Kg CO_2 equivalents/ Kg)**	**GHG Emissions (Kg CO_2 equivalents)**
	Bricks	348000	**0.24**	83520
	Cement	166650	**0.95**	158317.5
	Sand(fine aggregate)	425500.2	**0.0051**	2170.05102
	Bajri(coarse aggregate)(20MM)	607040	**0.0052**	3156.608
2.	**Stone usage and Tile Work**			
	P.O.P covering(10mm) to protect tiles	8947.5	**0.12**	1073.7
	Bitumen on roofs	Nil	**0.55**	Nil
	parking Tiles25mm thick	2345.84		2345.84
	Coloured Granite stone tiles(20mm)	1985.77	**0.48**	953.1696
	Vitrified floor tiles of Size 600 x 600 mm	7158	**0.55**	3936.9
	Anti-skid tiles10 mm	1310.32	**0.32**	419.3024
	Gypsum/lafarz false ceiling(12.5mm)	11184.37	**0.13**	1453.9681
	Marble stone flooring with 18 mm	2342.52	**0.187**	438.05124

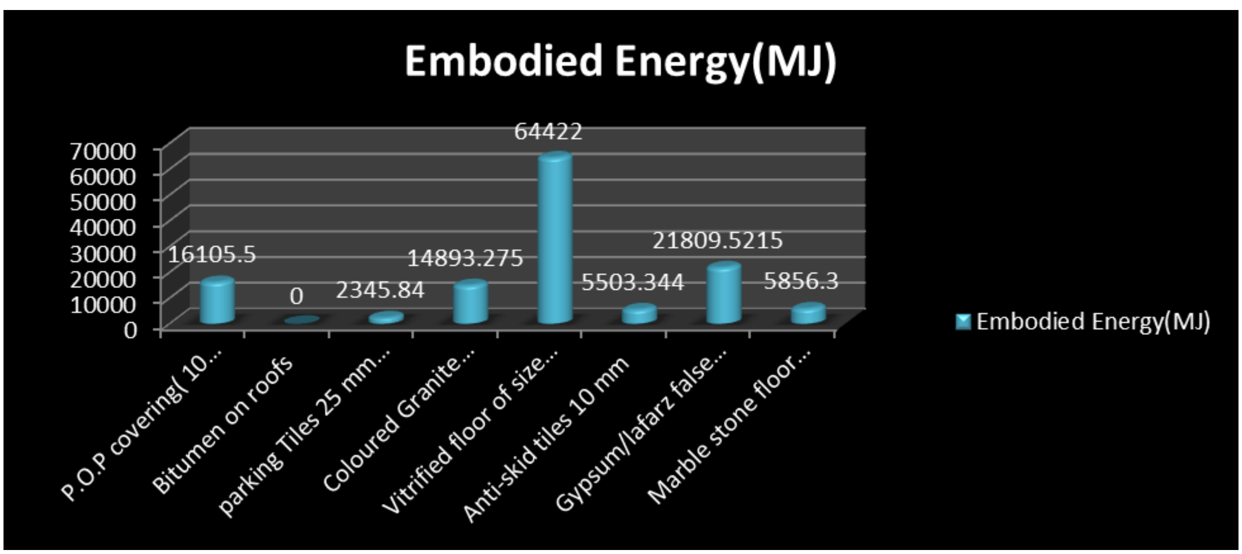
3.	**Metal & other material used for**			
	Aluminum	179.41	**12.79**	2294.65
	Steel (reinforcement)	20035	**2.89**	57901.15
	Glass sheets	5198.87	**0.91**	4730.972
	Glass(toughened)	1655.5	**0.91**	1506.505
	Steel (railing and shutters)	1301.81	**2.89**	3762.231
	Total Steel	21336.81	**2.89**	61663.38
4.	**Paints(Sqm)**			
	Acrylic	266.6	**2.1**	559.86
	Plastic emulsion	222.6	**2.3**	511.98
5.	**Wood used**			
	12 mm commercial	1936.87	**1.0788**	2089.495356
	Teak wood	314.17	**1.56**	490.1052
	3mm plywood	3710.016	**1.08**	4006.81728
	Additional wood	112	**0.75**	84

4.3 Graphical analysis for EMBODIED ENERGY:

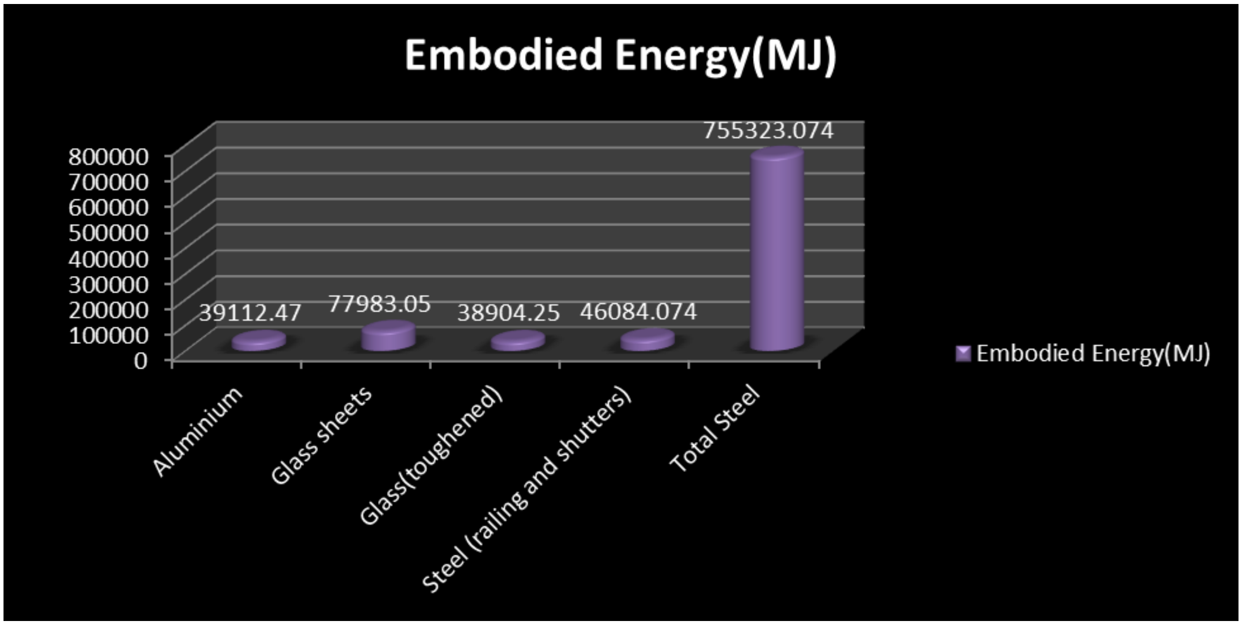
4.3.1 Graphical Analysis of Embodied Energy (MJ) for **Basic Materials used for various construction**



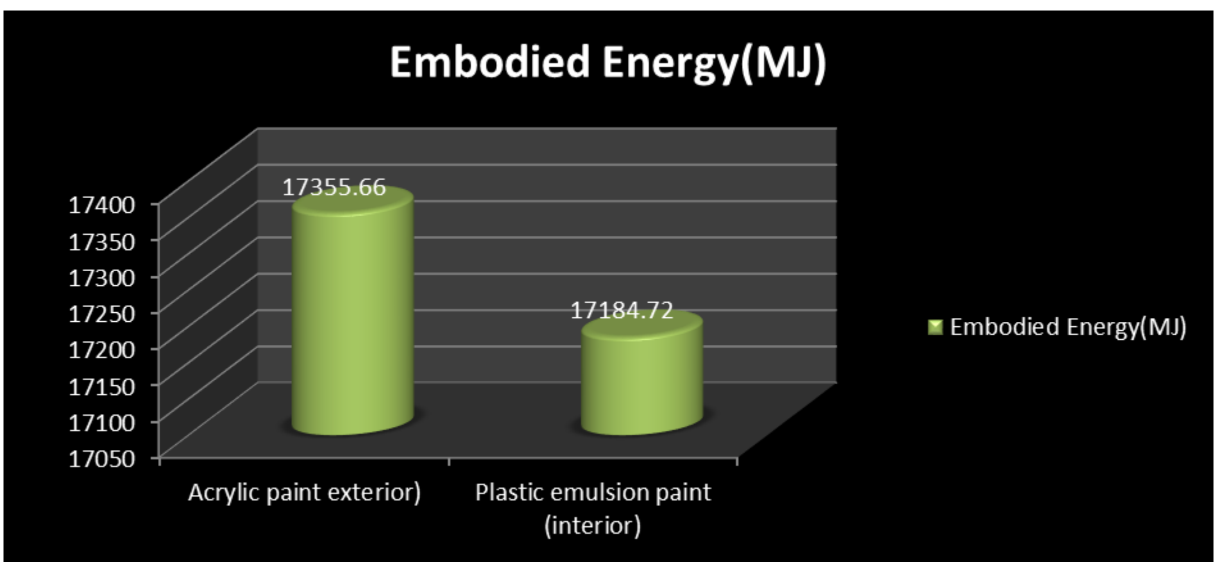
4.3.2 Graphical Analysis of Embodied Energy (MJ) for **Stone usage and Tile Work**



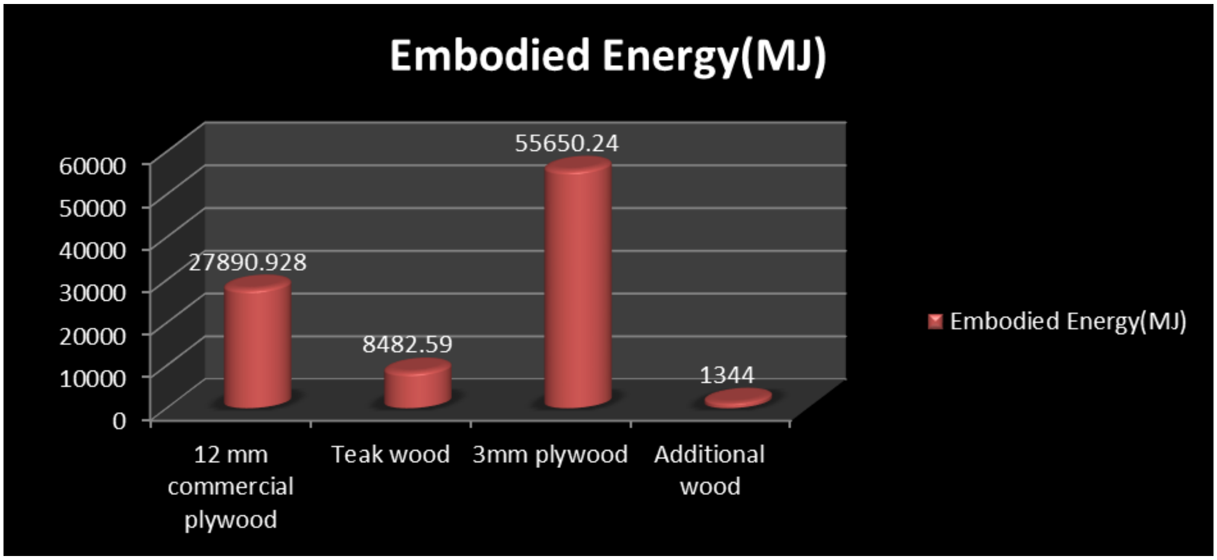
4.3.3 Graphical Analysis of Embodied Energy (MJ) for **Metal & other material used for construction**



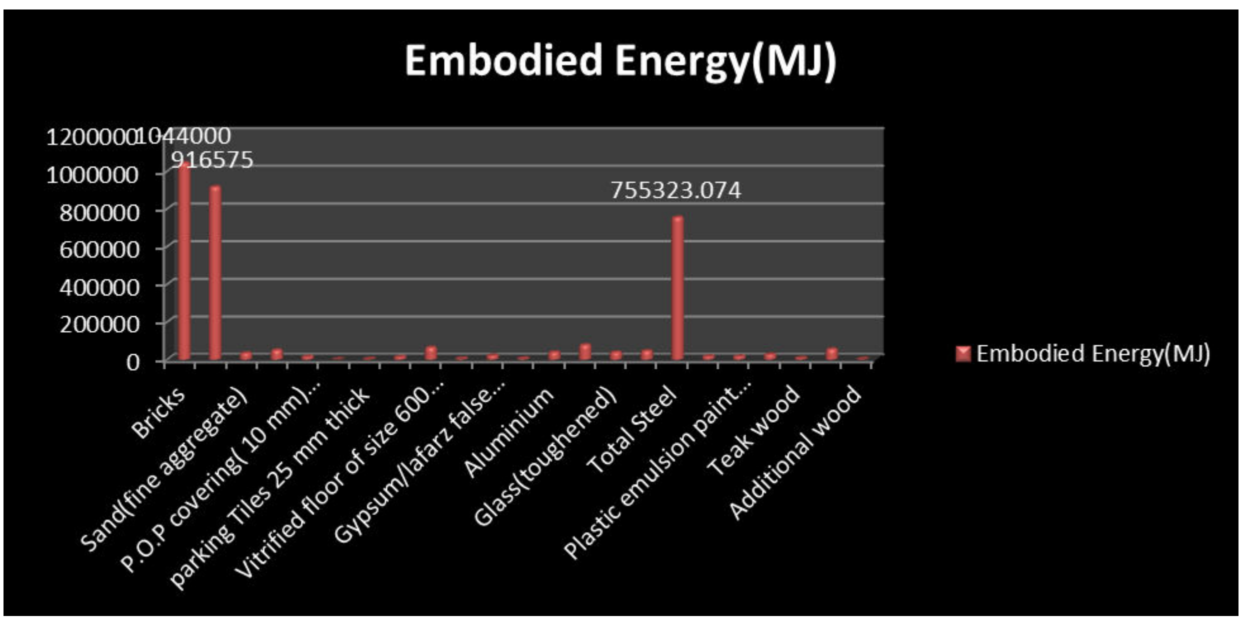
4.3.4 Graphical Analysis of Embodied Energy (MJ) for **Paints (Sqm)**



4.3.5 Graphical Analysis of Embodied Energy (MJ) for **Wood Used**

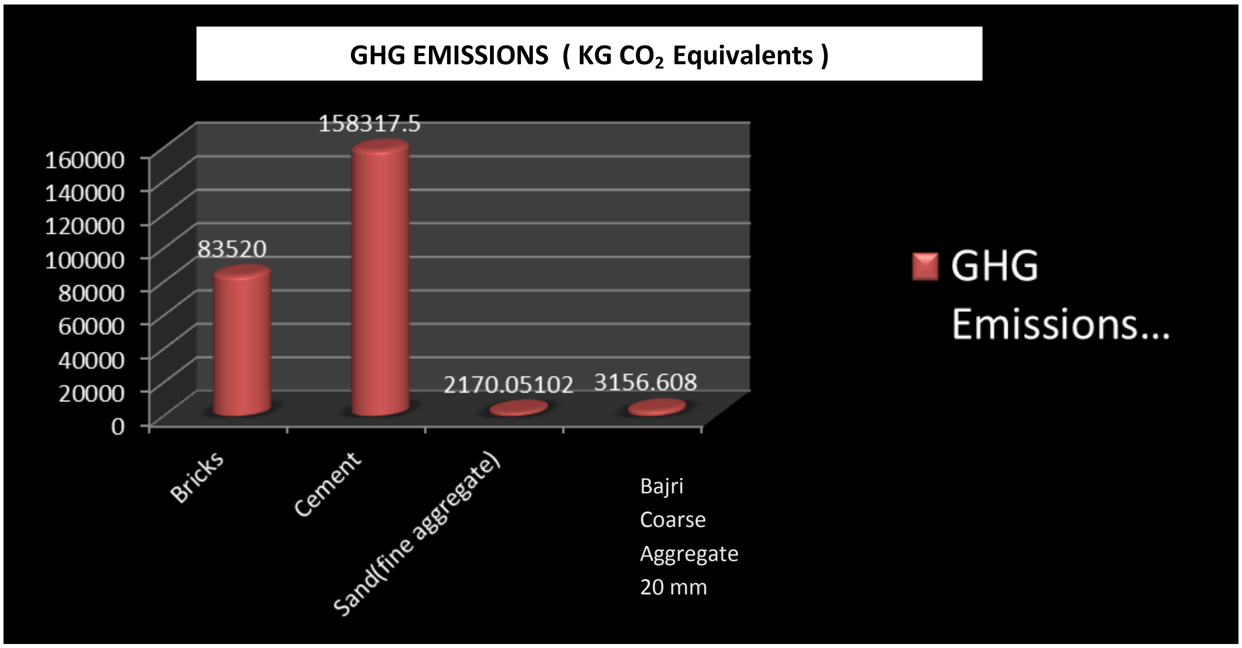


4.3.6 Overall Graphical Analysis of **Embodied Energy (MJ) for Khanduja's**

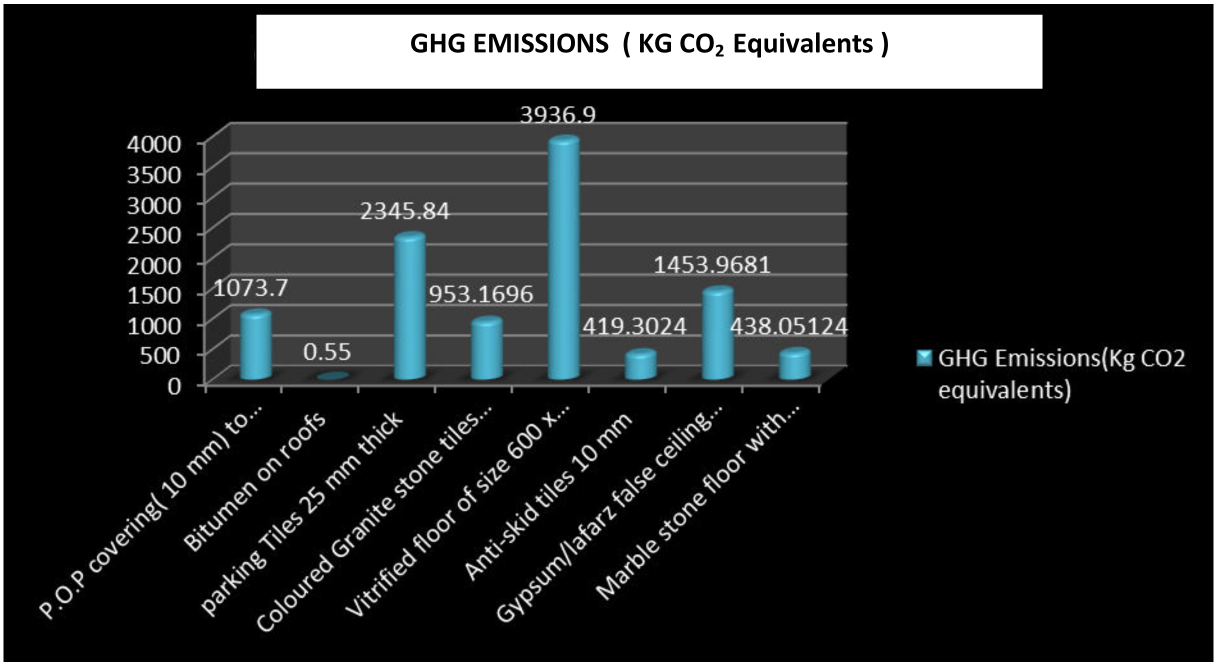


4.4 Graphical Analysis for GHG EMISSIONS

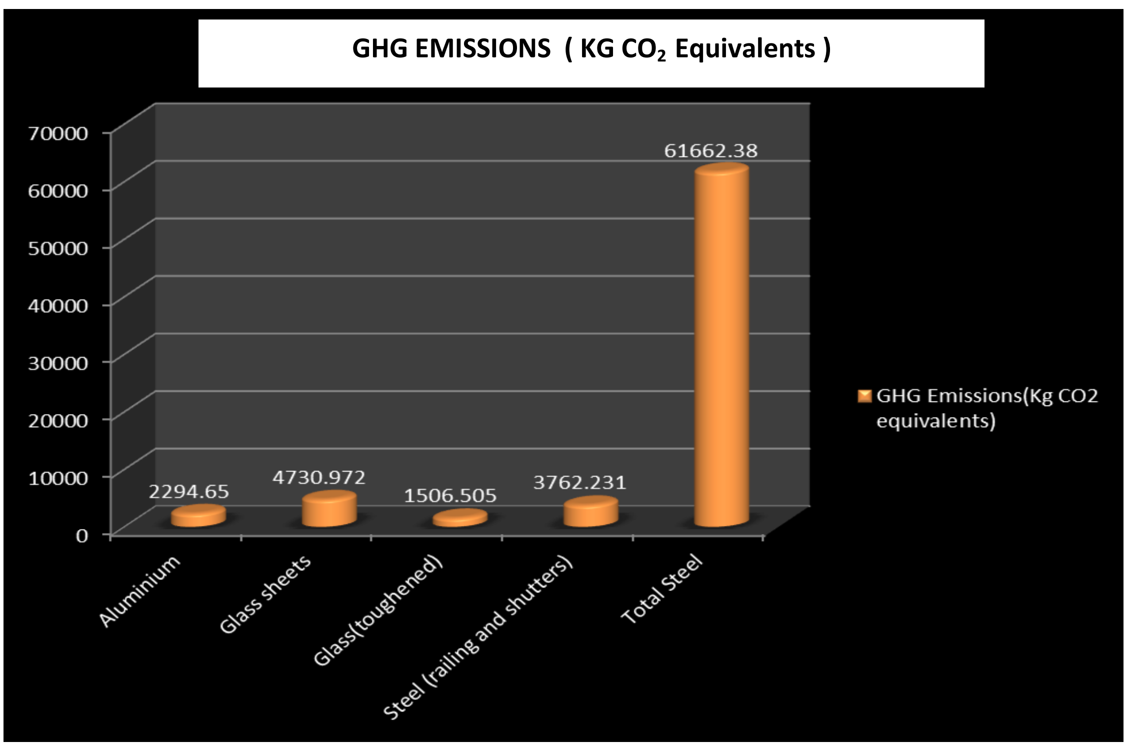
4.4.1 Graphical Analysis of GHG Emissions for **Basic Materials used for various construction**



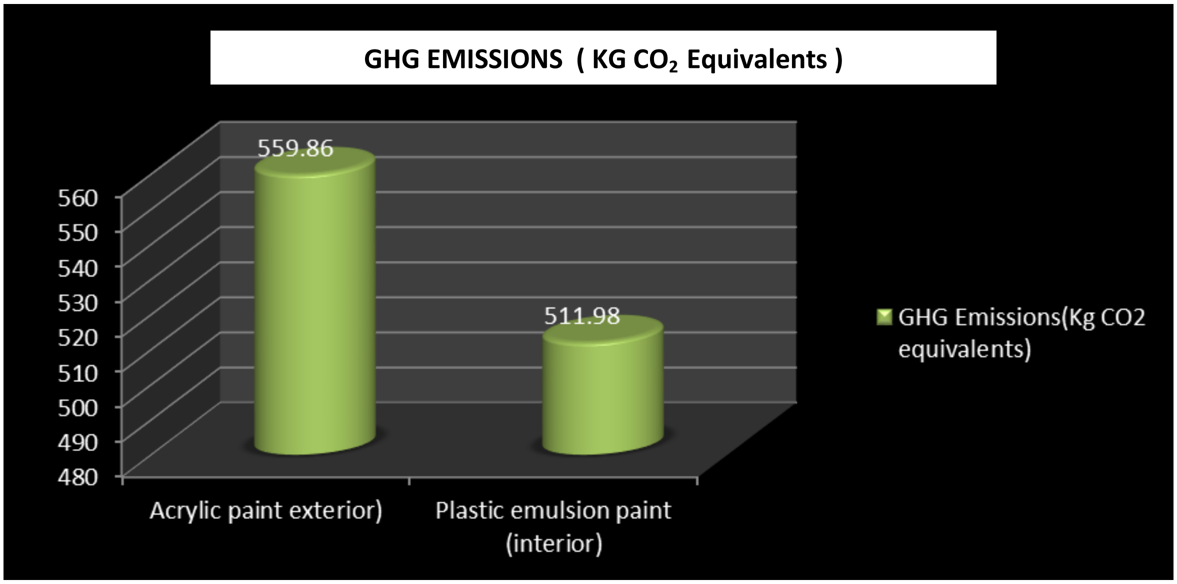
4.4.2 Graphical Analysis of GHG Emissions for **Stone usage and Tile work**



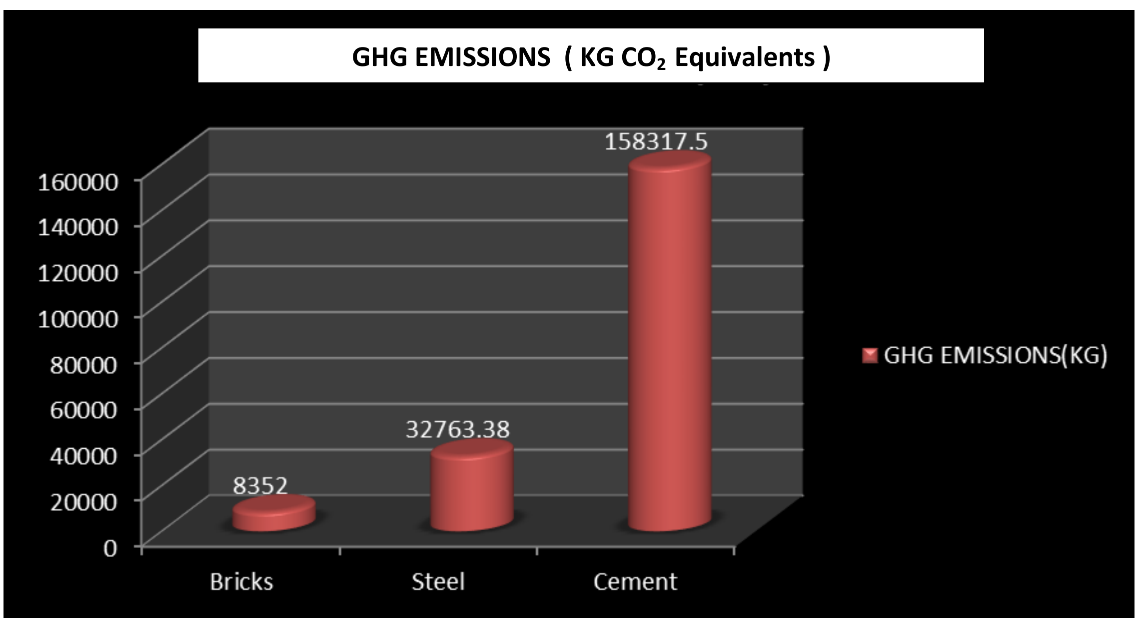
4.4.3 Graphical Analysis of GHG Emissions for **Metal and other material used for construction**



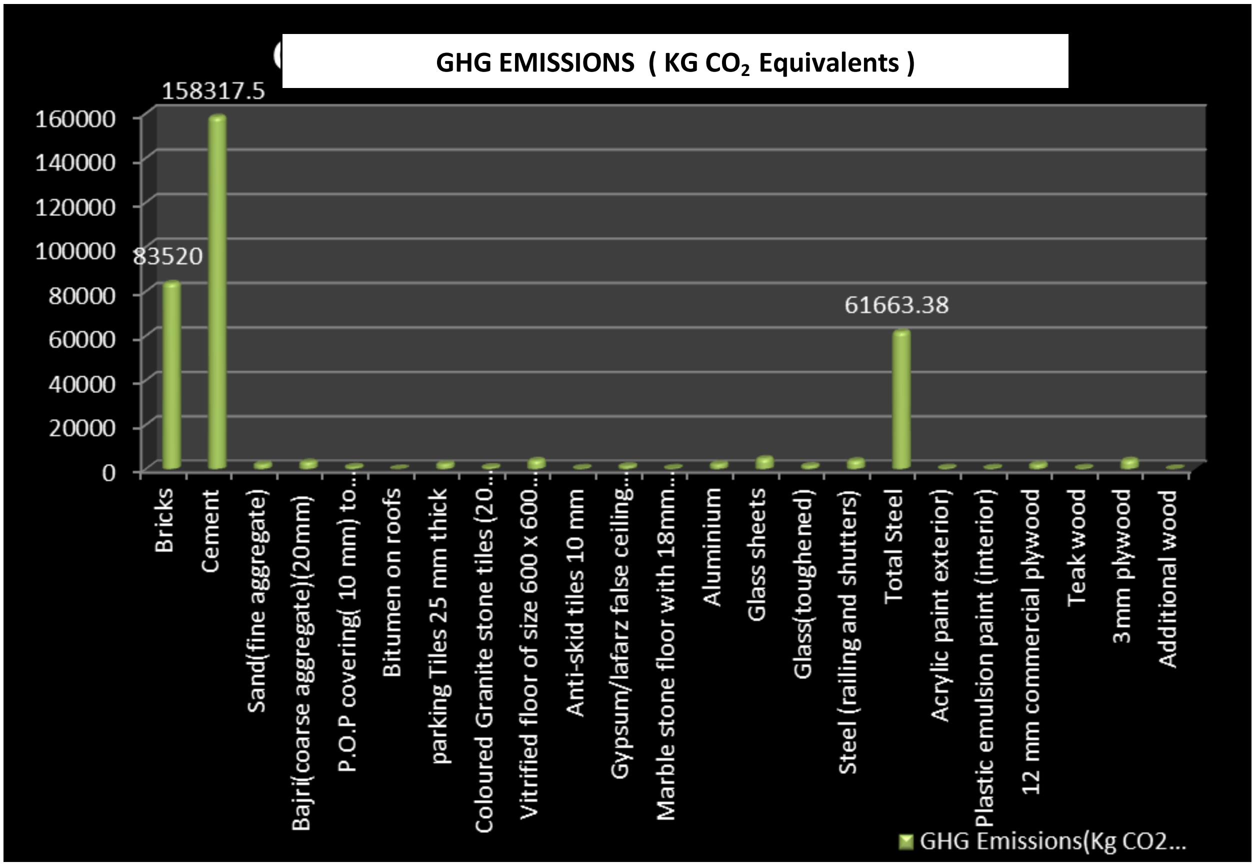
4.4.4 Graphical Analysis of GHG Emissions for **Paints**



4.4.5 Graphical Analysis of GHG Emissions for **Wood used**



4.4.6 Overall Graphical Analysis of **GHG Emissions(Kg CO_2 equivalents) for Khanduja's**

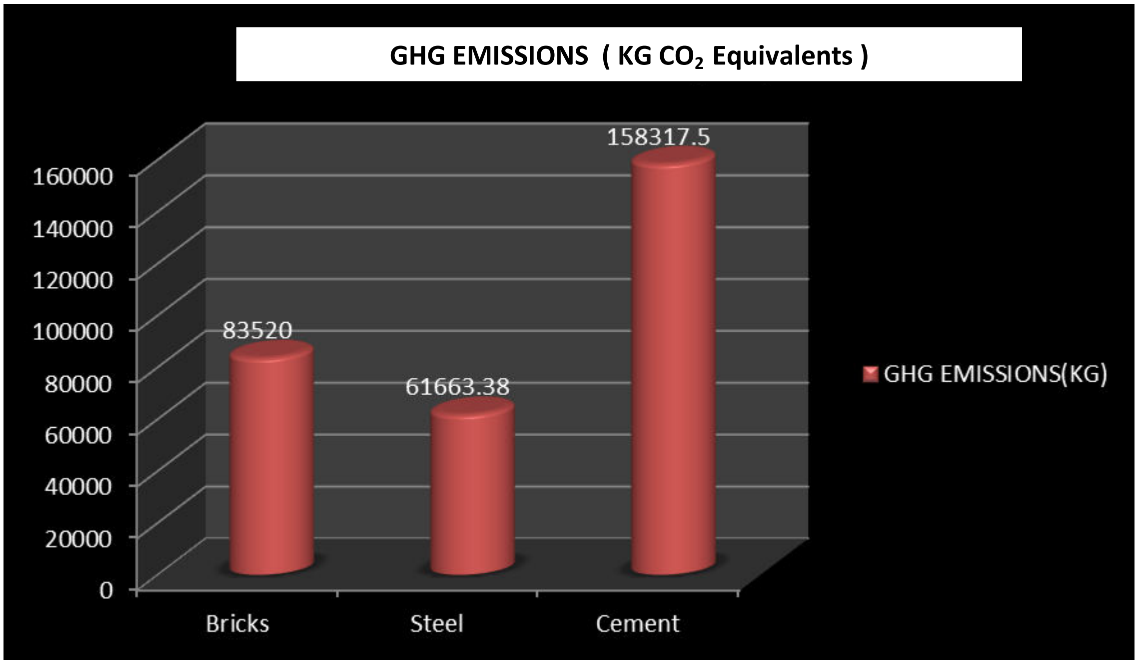


4.5 POTENTIAL REDUCTIONS

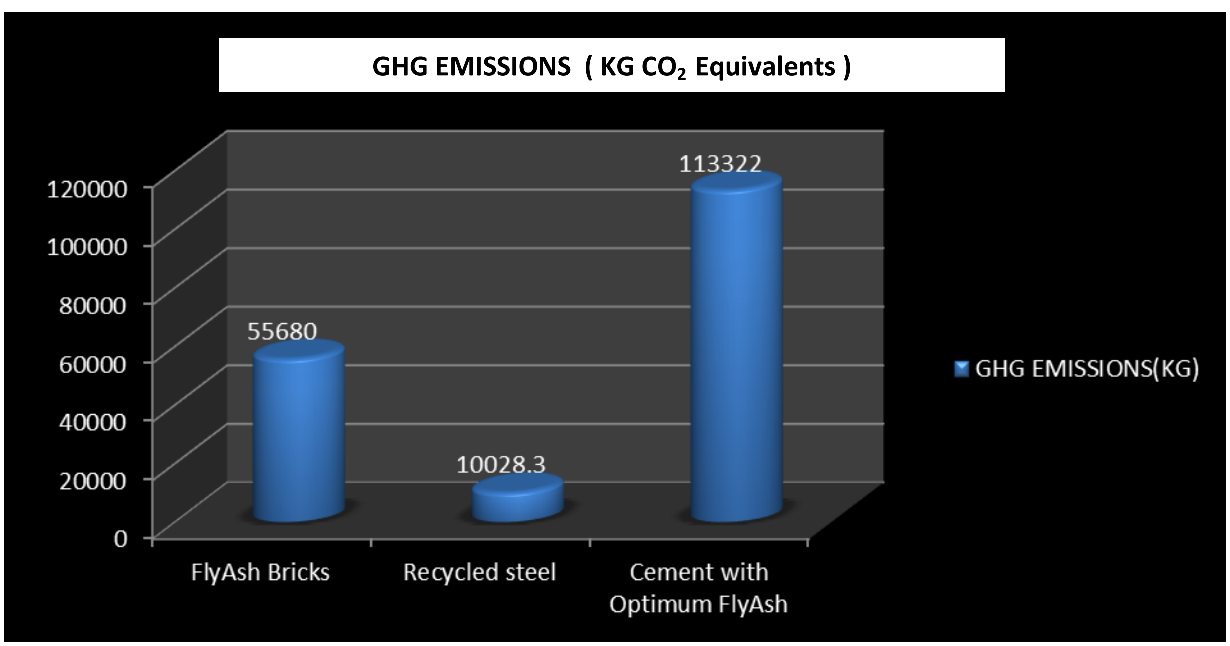
4.5.1 Table for potential reductions

S.No.	1	2	3
Material Used	Bricks	Steel	Cement
GHG	83520	61663.38	158317.5
Material Replaced	Fly Ash bricks	Recycled Steel	Cement with Optimum Fly ash
GHG	55680	10028.30	113322
% Reduction	**33.33%**	**83.73%**	**28.42%**

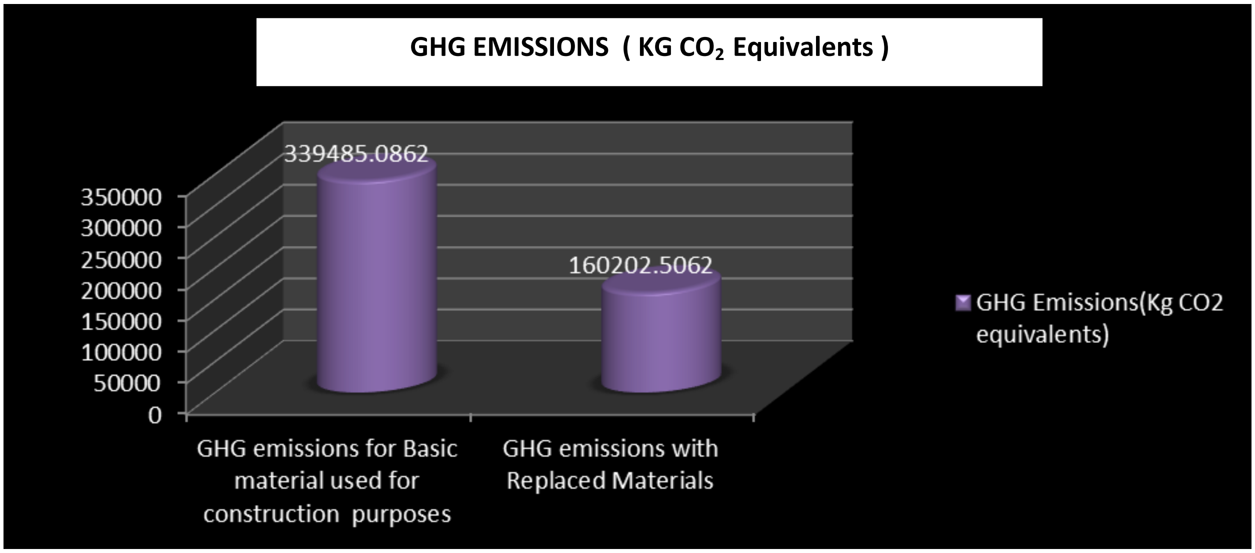
4.5.2-Graphical Analysis of GHG Emissions for **Existing major GHG contributors**



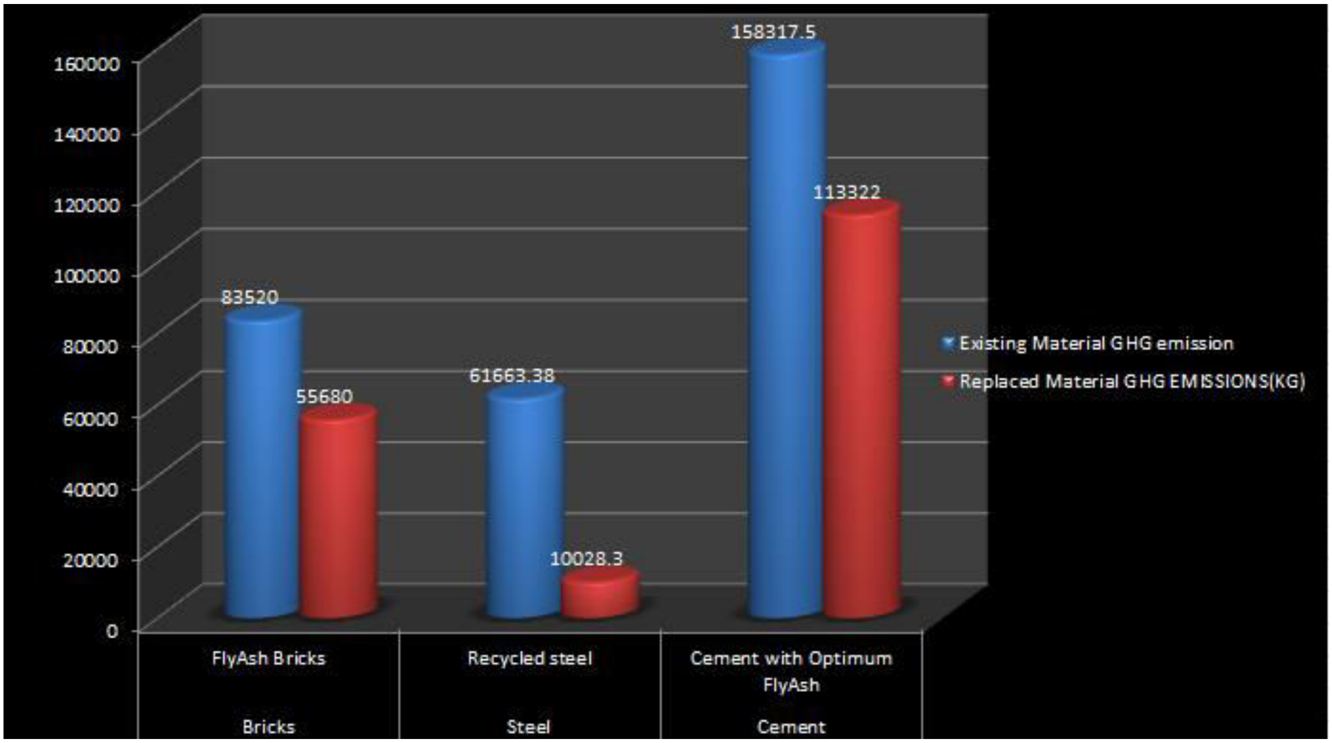
4.5.3-Graphical Analysis of GHG Emissions for **proposed Replaced materials**



4.5.4-Graphical Analysis showing overall **reduction in GHG emissions for Khanduja's after the replaced materials are put instead of normal conventional materials**



4.5.5-Graphical Analysis of GHG Emissions for **Existing Vs Replaced Materials**



4.5.3 Potential Savings

Recycled steel, Fly ash bricks and Cement containing fly ash can be used to minimize construction phase GHG Emissions up to 52.8%.therefore, such materials can be replaced in existing Khanduja's for reducing the GHG emissions.

4.5.4 Material Recommendations for Khanduja's, Phagwara:

<u>Fly ash brick instead of normal brick</u>

By using Fly ash bricks instead of normal conventional bricks a reduction of 33.33% of GHG emissions can be achieved. Not only that, a considerable amount of cost reduction is also possible. The tentative calculations for the same is shown in 4.5.6

Fig 4.6(Fly ash bricks)

Fig 4.7 Cement vs Flyash

4.5.5 Comparison between normal bricks and Fly ash bricks

According to (ICE)

Normal bricks	Per brick	Fly Ash bricks
0.36 kg	CO_2 emission	0.05 kg
6.5 MJ	Embodied energy	1.25 MJ
10 N/mm^2	Strength	15 N/mm^2
4 days (1200 ^0C)	Firing	Overnight (100 ^0C)
3.2 kg	Weight	2.6 kg

4.5.6 Cost analysis of normal bricks Vs Fly ash bricks

Normal bricks	Fly ash bricks
Required Bricks per m^3 $1m^3$ = 500 bricks = 500 * 7 (price per brick) = Rs. 3500 [Source : BB bricks , Phagwara(Hoshiyarpur road]	Required Bricks per m^3 $1m^3$ = 500 bricks = 500 * 5 (price per brick) = Rs. 2500 [Source : Shree bala ji green bricks ,khamona (Ludhiana)]
Save Rs. 3500-2500= Rs. 1000 per m^3	

4.5.7: Fly ash Concrete instead of normal concrete

The fly ash concrete could have been preferred over the normal concrete for the construction of

Khanduja's since the embodied energy for Fly ash concrete is relatively lower than that of normal concrete and also it would minimize the GHG emissions. Moreover the cost could also be reduced. The comparison of normal concrete and Fly ash concrete is given below

4.5.8: Comparison of Normal concrete Vs fly ash concrete.

According to inventory of carbon & energy (ICE)

Normal concrete	Fly ash concrete
1) Making 1 m^3 of concrete releases about 400 kg of Co_2 into the atmosphere. 2) Embodied energy of 4GJ/m^3 concrete.	1) Making 1 m^3 of concrete releases about 300 kg of Co_2 into the atmosphere. (reduce 25 %) 2) The Embodied energy of 3.16GJ/m^3 concrete.

4.5.9: Cost analysis of Normal Concrete & Fly ash concrete

Normal concrete	Fly ash concrete
$1m^3$ = Rs. 6000/ m^3 Cement = 398 kg Sand =14.6 cft Aggregate =29.25 cft [Source : ACC RMC plant in front of lpu gate]	$1m^3$ = Rs. 6000 = 6000- (7 * 100) + (0.18 *100) =Rs. 5318 / m^3 Rate of cement = Rs. 7 per kg Rate of fly ash = Rs. 0.18 per Kg [Note : if we replace 25% cement with Fly ash]
Save Rs. 6000-5318=682 per m^3	

Recycled steel instead of normal steel

By using Recycled steel instead of normal conventional steel a reduction of 83.73% of GHG emissions can be achieved when it comes to GHG emissions through steel. In Khanduja's the steel contributes to 61633.38 Kg CO2 equivalents of GHG emissions but recycled steel for the same would contribute to only 10028.80 Kg CO2 equivalents.

Optimum fly ash cement instead of normal cement

By using Optimum fly ash cement (20-25% fly ash) instead of normal cement a reduction of 28.42% of GHG emissions can be achieved when it comes to GHG emissions through cement. In Khanduja's the normal cement contributes to 158317.5 Kg CO2 equivalents of GHG emissions but optimum fly ash cement for the same would contribute to only 113322 Kg CO2 equivalents.

Low-E-Glass instead of normal glass

Low-E-Glass could be preferred instead of normal glass. It is an energy efficient glass which helps in reducing the heat escape during winters and entry of heat during summers. After replacing the existing glass with low-e glass, one can improve the energy efficiency of the building, reduce the monthly bills and decrease the size of the carbon footprint.

Fig 4.8 (Double glazed unit)

Following pictures explains how does low-e-glass work

Cooler in the daytime in summer:

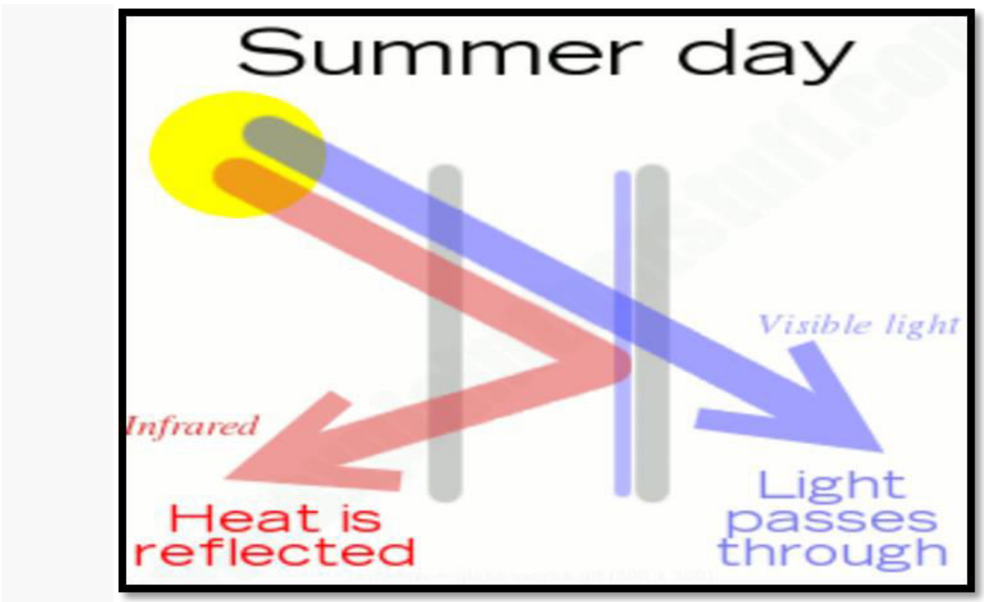


Fig 4.9 Cooler in the daytime in summer

Warmer at night in winter:

Fig 4.10 Warmer at night in winter:

Future Scope of the Study

- Furniture and indoor air quality can be taken into account for future studies.

- HVAC and other requirements can be further reduced.

- Operation and maintenance phase of the building can be taken into account for future studies

A comparison with Previous Similar Studies Conducted

S.No	Year	Specification of Building	Place	Type	Life Time	Floor Area	GHG Emissions (CO_2eq Tons/sqm
1	2001	Malmo	Sweden	R	50	700	1.30
2	2001	Helsingborg	Sweden	R	50	1160	1.35
3	2001	Vaxjo	Sweden	R	50	1190	1.51
4	2001	Stockholm	Sweden	R	50	1520	1.40
5	2003	School	Mendoza,	C	50	NA	34,000 *PE
6	2003	University Of	Michigan,	C	75	7300	18.49
7	2005	Steel Framed	Midwestern	R	50	4400	NA
9	2006	Low density	Toronto,	R	50	NA	5.365
10	2006	High density	Toronto,	R	50	NA	3.885
11	2006	High-End	South Finland,	C	50	4400	3.01
12	2008	Office	Thailand	C	50	60,0	0.93
13	2009	Via Garrone	Turin, Italy	R	50	6110	3.34
14	2012	NIT, Hamirpur	India	C	50	3960	0.45

CONCLUSION

- It is clear from the study that steel, cement and Brickwork are the main contributors to GHG emissions during construction phase with glass and tiles playing a minor role
- The GHG emissions can be reduced up to 52.8% during construction phase by replacing certain materials by more environmental friendly materials
- The environmental friendly materials for Khanduja's could have been Fly ash bricks, Recycled steel and optimum fly ash bricks instead of normal conventional materials.
- Further Low-e-glass can be preferred over normal glass to reduce electricity bill and the overall carbon footprint.
- There is also a scope to minimize the carbon foot print in operation and maintenance phase for Khanduja's

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