

A Review on Elements of Construction Industry Contributing to Carbon Footprint and How to reduce them?

Tanushree Shenwai ¹

U.G. Student, Department of Civil Engineering, Indian Institute of Technology, Bhubaneswar, India¹

ABSTRACT: The immensely growing construction industry accounts for a major factor that contributes to the substantial development of an economy. But it also imparts a major threat to humankind. This is because the buildings consume about 40% of the world's energy and account for 36% of global greenhouse gas emissions. Inefficient use of energy and natural resources will have devastating effects on the environmental aspects globally if serious actions are not taken. Different elements contributing to the carbon footprint of a building and some aspects of civil engineering that can be implemented to significantly reduce the carbon footprint has been discussed. This review paper majorly focuses on what is the carbon footprint and the leading contributing material in construction industry to the carbon footprint of a building.

KEYWORDS: Carbon Footprint, Greenhouse gas emissions, Construction Industry.

I. INTRODUCTION

Climate Change and Green House Gas emissions have become a matter of unprecedented concern among humankind. And yet, human activities are the main cause of greenhouse gas emissions, the major contributors being deforestation, the use of fossil fuels, and change in land use. The industrialization has led to the occurrence of climate change. Carbon dioxide emissions have increased from 2 billion tonnes in 1990 to over 36 billion tonnes 115 years later. Data from the Global Carbon Project reported that there has been an annual increase of 2.7% in 2018. At present, the buildings consume about 40% of the world's energy and account for around 36% of total global carbon dioxide emissions. The building sector imparts a serious threat to humankind because of the immense use of energy and exploitation of natural resources. Emissions of greenhouse gas will have devastating environmental impacts if serious actions are not taken. Therefore, there is a need for processes that help in sustainable construction and reduces greenhouse gas emissions.

II. RELATED WORK

The work in this paper mainly reviews several pieces of research on the major constituents of construction contributing to the carbon footprint of a building. At present, there are several approaches associated with determining the environmental impacts of building construction. One of the most efficient methods is known to be is the determination of the carbon footprint of the constructed building. This review paper mainly explains two important things, first being the elements contributing to the carbon footprint and second on the approaches to reduce the carbon footprint being followed by various countries.

WHAT IS CARBON FOOTPRINT?

Carbon footprint is the total amount of Green House Gas (GREENHOUSE GAS) emitted into the atmosphere as a result of activities performed by an individual or an entity, expressed as carbon dioxide equivalent. A building's carbon footprint is defined as the total amount of CO₂ emissions due to its operations and activities are undertaken throughout its life cycle. The carbon footprint is extensively being used as a tool to understand the environmental impacts of building construction by the Life Cycle Assessment (LCA) methodology. Earlier, in the ecological footprint concept, the carbon footprint was expressed through the area assimilating the CO₂ emissions generated during the life cycle of manufactured products. However, as the global warming problem became a priority on the international agenda, the concept and method of carbon footprint have changed over the years as global warming became a problem of prime concern globally. Now carbon footprint is the amount of greenhouse gas (greenhouse gas) associated with a product or service throughout its life cycle, limited to the emissions that affect climate change.

ELEMENTS CONTRIBUTING TO GREENHOUSE GAS EMISSIONS:

In emerging economies, the construction industries contribute a major factor towards substantial development, and yet, it is one of the main sources for greenhouse gas emissions because of the resources used. The most widely used building material is concrete which results from the proportionate mixing of cement, aggregates, and water. Cement is the most important supplement used in the production of concrete. It binds the aggregates together when mixed with water, forming a durable mass that can be used for the construction of buildings. As much cement is important, it also contributes to environmental degradation significantly.

Cement industries are energy-intensive. It is the third-largest energy consumer in the world. Energy consumption leads to more carbon dioxide emission which in turn increases the greenhouse gas emissions into the atmosphere. Concrete, aluminium, and steel are among the materials with the highest contained energy content and they are also responsible for large quantities of CO₂ emissions. It is, therefore, no wonder that cement industries are the second-largest industrial emitter of carbon dioxide. It alone accounts for 7 percent of global carbon dioxide emissions. Since energy consumption contributes to an increase of greenhouse gas percentage into the atmosphere, the contained energy is considered as an indicator of the overall environmental impact of building materials and its systems. Regardless of efforts being made in this sector to implement new technologies for the reduction of carbon dioxide emissions, these emissions are likely to increase by 4% globally by 2050. This is because it is extremely difficult to find a material that can substitute cement completely and gives the same properties when mixed with aggregates and water.

With the substantial development of an economy, the demand for construction industries has heightened. More and more natural resources are being consumed to meet the demands of the immensely growing industry. The construction industries not only degrade the environment by contributing to the greenhouse gas emissions, but it also contributes to the exploitation of the natural resources extracted to sustain the demand of the growing industry. Inefficient use of energy and natural resources will eventually deteriorate the environmental quality globally.

III. METHODOLOGY

CARBON FOOTPRINT OF A BUILDING PROJECT:

The energy released from the life cycle of the building leads to greenhouse gas emissions. However, some studies exclude important aspects of greenhouse gas emissions e.g. building operation, renovation, and end of life phases. It is extremely important to consider the entire life cycle of a building while calculating the building's carbon footprint, starting from the production stage, construction phase, operational phase, and the demolition phase/the end of the building. Energy consumption produces carbon dioxide, which contributes to greenhouse gas emissions, so the contained energy is considered as an indicator of the overall environmental impact of building materials and systems. Greenhouse gas emissions of a building can be accessed to evaluate the environmental impacts by the life cycle assessment (LCA)

The project life cycle of a building involves the following phases:

1. Project Conceptualisation and planning
2. Project Construction
3. Project Operation and Maintenance
4. End of life of project/Demolition

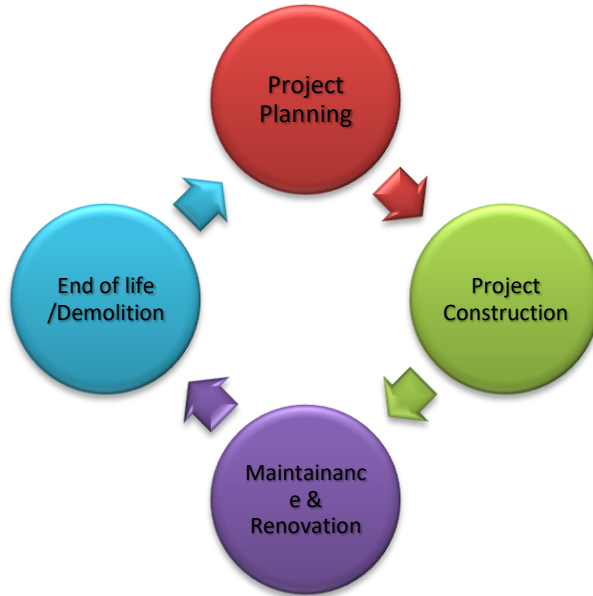


Fig.1 Cyclic representation of the life-cycle of a project

Project conceptualization and planning contribute almost negligible to greenhouse gas emissions. Several studies show that building operations, services, and tenants impact the environment the most by contributing around 85.82% of the emissions. The materials consumed during the construction phase emits considerably more greenhouse gas in the operation phase than in the construction phase, contributing about 12.69 percent of the building’s carbon footprint. The remaining aspects, including the renovation, transportation of materials, and the disposal of the block accounts for 1.14%, 0.07%, and 0.28%, respectively, of total life cycle emission. Therefore, this report pays more attention to the construction and operation phase of a project life cycle. Contribution of different phases of project life cycle to the construction’s carbon footprint can be visualized in the chart representation below:

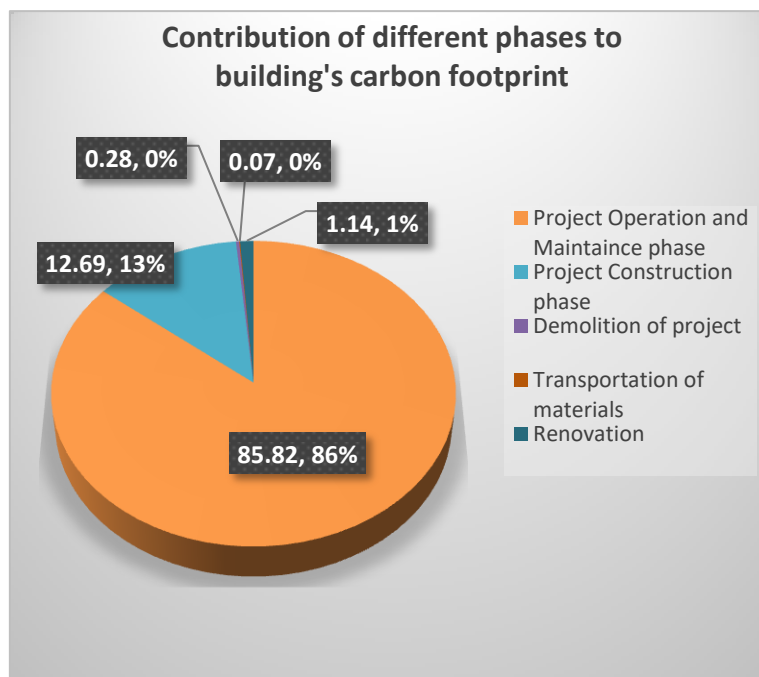


Fig.2 Contribution of different life-cycle phases of a project to building’s carbon footprint

IV. EXPERIMENTAL RESULTS

Construction and Demolition Phase:

Concrete is the dominantly used building material during the construction of a building. Concrete embodies a large quantity of carbon. A study has revealed that a building consuming 28,600 m³ of concrete, emits about 12 million kg of carbon dioxide into the atmosphere. Therefore, it is very important to reduce the carbon content of concrete through the manufacturing process, which can be achieved by:

- Increasing the proportion of off-site manufacturing of components.
- Selecting recycled materials or materials with low carbon content. For instance, the amount of cement being used as a binding material can be significantly reduced by using alternative materials (e.g., pulverized fuel ash, ground granulated blast furnace slag, and silica fume) which produces cementitious material while manufacturing concrete. This reduces the amount of cement used in the concrete mix which in turn reduces carbon dioxide emissions.
- In addition to this, low carbon cement-like eco-glass cement or Portland fly-ash cement can be used to considerably reduce the carbon dioxide emissions.

Concrete has harmful environmental impacts because the wastes generated by construction and demolition of concrete-based structures produce a major component of wastes produced by the construction industry. Demolition waste consists of about 65% of concrete based waste, bricks and tiles constitute about 25% while wood, metals, plastic, and other constitutes around 5%, 2%, 1%, and 2% respectively. This imparts long term environmental damage. The manufacturing concrete mix requires aggregates that are obtained by the consumption of natural resources. The exploitation of these resources results in a reduction of the reserves because of insufficient time for resource replenishment.



Fig.3 Waste from Demolition of building

(Source: <https://blog.capterra.com/5-tips-for-recycling-your-construction-waste/>)

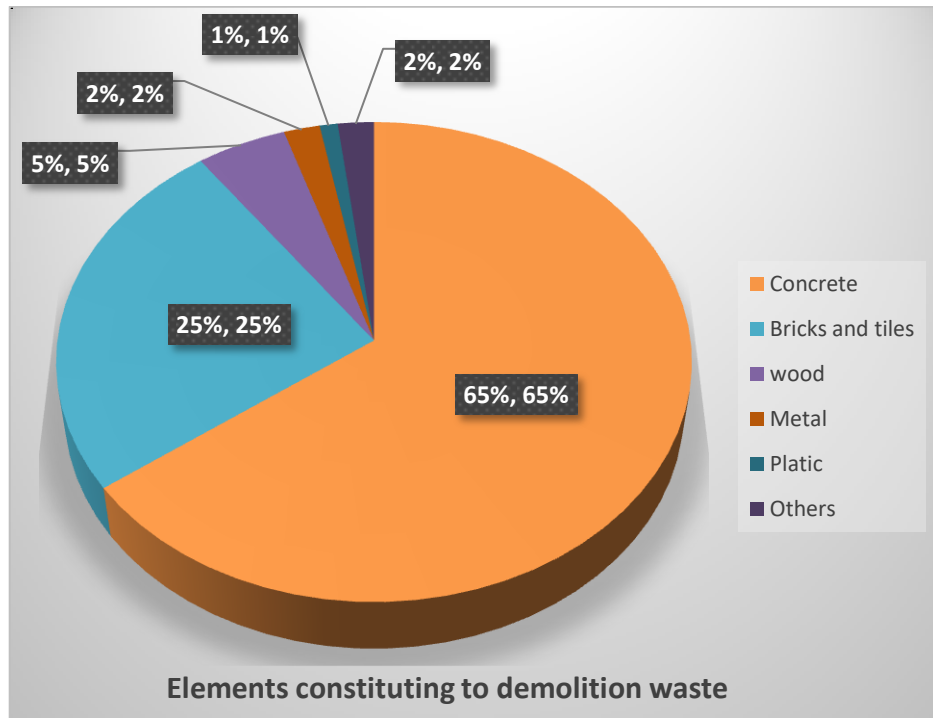


Fig.4 Elements constituting waste from demolition

There is a need to reduce the consumption of natural resources which is being achieved in some of the following ways:

- **Eliminating Wastes** - During the construction process, it is important to eliminate wastes that can be eliminated. Waste elimination is considered beneficial as it reduces the damages incurred to the environment and human health. For example, Wood waste associated with the framework of lumber and plywood can be eliminated by using durable modular metal to form the systems to be used in concrete construction.
- **Minimizing Waste** - One of the best practices in construction is to minimize the waste generated. For example, using recyclable materials is often considered beneficial as it minimizes the waste generated. The selection of construction products based on its design and manufacturing process involved to be shipped with minimal packaging.
- **Use of Recycled Aggregates** - Instead of using usual aggregates obtained from the crushing of virgin limestone, aggregates can be obtained by recycling the concrete debris which are wastes resulted from the construction or demolition of concrete-based structures. Opting use of recycled aggregates is promising since 75 percent of the concrete is made of aggregates. Using recycled aggregated offers more economic advantage when compared to normal aggregates as they save almost 4 USD (26%) per m3 of aggregate and almost 6 USD (9%) per m3 of concrete can be obtained.

Many countries have successfully carried out the application of recycled aggregates in the various construction process. Some of them are listed below:

1. In Taiwan, results obtained after evaluation of pavements rehabilitated using recycled materials such as crushed stone (67%), sand (50%), and asphalt cement (70%) revealed greenhouse gas reductions of 16 to 23%.
2. A study developed in Hong Kong revealed reductions in greenhouse gas emissions ranging from 6 to 17% in the construction of concrete buildings when the conventional materials were replaced by recycled materials such as recovered stone aggregates, bricks, and concrete blocks, plastics, asphalts, and galvanized steels, and others.

- In Australia, the use of geopolymers in place of ordinary Portland concrete (OPC) during the manufacture of concrete reported a reduction in greenhouse gases by 10%.

Operation Phase:

The building operation and services used for operating the building during its life cycle contributes the most to the building’s carbon footprint. Most of the greenhouse gas emissions are associated with the energy consumption of tenants and building services equipment, especially heavy equipment vehicles that consume fossil-derived oil. Elements including communal lighting and lifts, the energy consumed by tenants for hot water, space conditioning, refrigeration, and several such types of equipment emits significantly more greenhouse gas. This reflects that the carbon footprint of a building is not only dependent on the building and occupancy factors such as ventilation and efficiency of appliances, but also the source of energy. Optimizing the use of energy and heavy equipment to reduce greenhouse gas emissions is therefore very crucial. Certain methods that should be considered are stated as below:

- Installation of energy-efficient building service equipment and initiative taken by tenants to use energy-efficient appliances to reduce energy consumption and emission of greenhouse gas is highly encouraged. Apart from reducing energy consumption and embodied energy in buildings, switching to low carbon fuels and utilizing renewable energy or obtaining operational energy from environmentally friendly sources are considered effective in tackling the climate change problem e.g. use of solar energy reduces the greenhouse gas emissions significantly.

The United Arab Emirates has taken a very important step by building the world’s first nuclear power station. With just 1 gram of uranium, energy equivalent to 3 tonnes of coal or 600 gallons of fuel oil can be generated. This power station consists of four APR-1400 nuclear reactors of total capacity 5,600 MW which are intended to generate energy to meet the needs of about 25% of UAE's population. Energy generation using nuclear power stations is far safer than the use of oils for energy generation. The mortality rate due to nuclear energy is extremely less when compared to that of coal and oils.

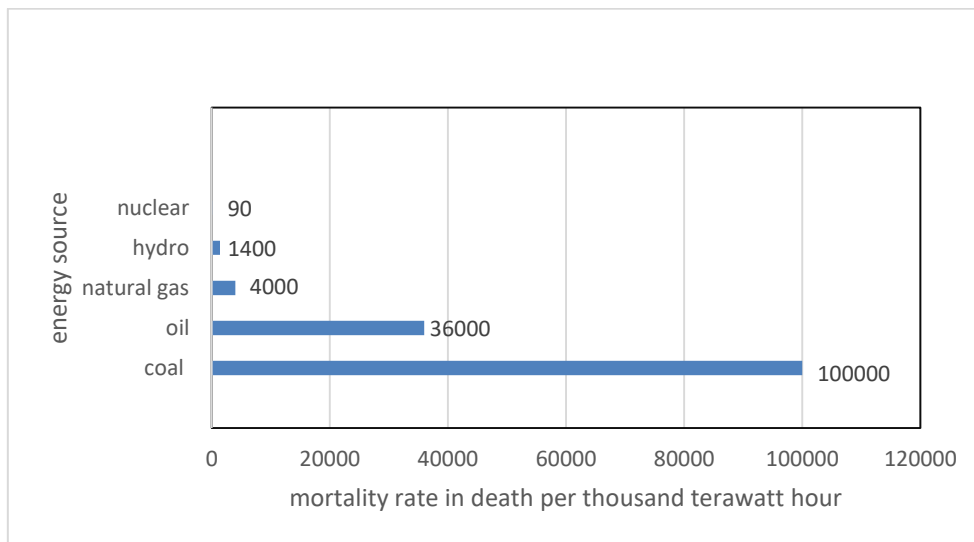


Fig.5 Mortality Rate caused by different Energy Source

- Building architecture to allow more ventilation and natural light, reducing the dependency on the conventional sources of energy.
- Materials (including their production and transportation) emit about 13% of the total emissions. However, it is possible to reduce greenhouse gas emissions by sourcing sustainable materials and using low carbon materials.

3. Rainwater harvesting methods can be adapted to make use of locally available rainwater to meet the demands for domestic, industrial, and irrigation purposes.
4. Waste management is a critical task as the wastes generated during the construction phase, operation cycle, and at the end of the life cycle of a building may affect the environment directly or indirectly e.g. combustion of carbon-based wastes releases carbon dioxide directly affecting the atmosphere whereas other wastes transported to landfills indirectly impact the environment. Several pieces of research show that more than 50% of the waste generated by the construction industry is dumped into landfills. Nearly 26% of landfill sites are occupied by waste materials generated by the construction industry.

V. CONCLUSION

The construction industry is highly energy-intensive. The buildings consume about 40% of the world's energy and account for around 36% of total global carbon dioxide emissions. High energy consumption produces carbon dioxide which adds to the greenhouse gas emissions. The building sector, therefore, contributes to climate change imparting a serious threat to humankind. Emissions of greenhouse gas have devastating environmental impacts.

The carbon footprint of a building is defined as the total amount of CO₂ emissions due to its operations and activities are undertaken throughout its life cycle. Greenhouse gas emissions of a building can be accessed to evaluate the environmental impacts of the life cycle assessment (LCA). The materials consumed during the construction phase emits considerably more greenhouse gas in the operation phase than in the construction phase, contributing about 12.69 percent of the building's carbon footprint. The carbon content of the building can be reduced during the construction phase by effective and efficient use of tools, labor, capital, and other resources, use of recyclable materials during construction, and minimizing the waste generation. Several studies have reported that the operation phase of a building contributes about 85.82% of the total greenhouse gas emissions throughout its life cycle. Use of environmentally friendly energy and is highly encouraged. Therefore, it is very important to optimize the use of heavy equipment and energy to reduce the carbon footprint of the building.

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