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ENVIRONMENTAL IMPACTS OF DIFFERENT SLAB SYSTEMS

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Abstract: During the construction process of different types of slabs systems in buildings different construction materials have been used in excessive quantities.Due to this the environmental impacts of construction of such slabs cannot be ignored. This has put a pressure on designer to develop improved construction process to reduce environmental impacts. The present study aims to assess and compare the environmental impacts of conventional slabs, Flat slabs and Waffle slabs during construction stage of multistoried buildings or structures. A quantitative model based on process has been developed which reveals that the conventional slabs show maximum environmental impacts and Waffle slabs show minimum impacts on environment. This is because of consumption of constructional material is highest in conventional slab and waffle slabs consume least material during its construction.
Keywords: environmental performance; conventional slab;flat slab; waffle slab system.

Introduction: In civil engineering era, the increasing demands of buildings and various structures has put a load on civil engineers to construct various types of modern and advanced structures. These structures need construction of slabs. **Roh et al. [1]** analysed the embodiedenvironmental impacts of apartment buildings by major construction tasks to identify the major source ofenvironmental impact. Moreover, **Gorobets [2]** suggested solutions to achieve sustainable development,such as technological aspects as well as political approaches.In old times ordinary and conventional slabs have been constructed which not only require huge amount of construction materials. Now a days there are new trends of growing interests in the reduction of impacts on environment due to various activities including civil construction also. **Basbagll et al.** [8] suggested that the early design stage would be one of the critical stages for reduction in embodied environmental impact through utilisation of Building InformationModelling (BIM). In addition, **Na and Paik** [9] examined the greenhouse gas emissions of alternativestructural systems with a combination of construction costs. **Kumar et al.** [10] evaluated the relationshipbetween the energy consumption and the greenhouse gas emissions over the variables of life cycle inCanadian cases.It has been considered that larger buildings, apartments, structures etc. are the major sources of environmental impacts. In order to reduce such environmental impacts, technological aspects and legislative approaches have come into action. The larger construction companies have enacted strict environmental regulations and spend large money for research work related to reduce the consumption of energy as well as related materials. In India it has been reported from the study that the annual consumption of energy byconstruction industry is about 30% of the total global energy demand. This causes emission of carbon dioxide. Various studies have been carried out to minimise the environmental loads in the construction industry,which not only consumes enormous energy but also emits greenhouse gases, including carbondioxide.It has been revealed from the studies that early design stage would help better to reduce such environmental impacts.
Sandanayake et al. [5] indicate that the energy consumed in this operation and maintenance stagephase is about 70% of the total energy consumption during the overall life of a building.
The construction industry has unique features that need to be considered when the reduction in environmental impact is addressed. Constructing a building consists of many phases from building material production, their transportation, and utilising equipment and machinery duringconstruction work. Moreover, the whole life cycle of a building has more than 30 years for the

operationand maintenance phase, compared to other products or services. Throughout the longer life cycleof a building, the building not only consumes a large amount of energy, but also releases a considerableamount of Greenhouse Gases during the operation and maintenance phase. Due to the longer life cycle of a building, the majority of studies regarding environmental impact have focused on theoperation and maintenance stage.

Due to thehuge energy consumption in this stage, there are a number of newly developed technologies andefforts to decrease the energy consumption and emissions of greenhouse gases during operation andmaintenance. **Edwards et al.** [21] compared different machine

learning techniques to predict accurate energy consumption for residential homes in the USAFor example, zero-energy housing would make it possible to reduce a significant amountof energy consumption of residential buildings from heating, ventilation, and air-conditioning.Moreover, highly advanced computing technologies, and newly emerging techniques, such as ArtificialIntelligence (AI), big data, and machine learning, could make it possible to accurately predict theamount of energy consumption as well as Green House Gasesemissions during this period, as a means of precautionalapproaches for mitigating environmental impact.

Although the construction phase, which consists of several phases, is relatively shorter than theoperation and maintenance phase, its environmental impact should be considered, since large amountsof building materials are used to construct a building in this stage. A number of studies haverevealed that one of the main sources of environmental impact during the construction stage isthe manufacture of building materials, the reduction in environmental impact frombuilding materials would be the most effective approach to mitigate the environmental impact andgreenhouse gases emissions.

The replacement of traditionalbuilding materials, such as concrete, rebars, or bricks, by low embodied carbon ones would lower theenvironmental impact by almost 50%. Moreover, the application of high-strength materials, such ashigh-strength reinforcing bars, and reinforced concrete might achieve lower environmental impact,since the amount of utilised building materials is reduced. With the use of high-strengthmaterials, applying recycled materials and by-products from the demolition stage is also suggested asan effective approach to alleviate the environmental burdens from construction work. Moreover,the optimal structural design of a building would be an important stage to determine the constructionmethods and building materials that lower the environmental impacts.

As discussed above, the mitigation of environmental impacts that occur from the construction

phase is mainly focused on the replacement of low environmental impact materials, the optimalstructural design of a building, and increasing the use of recycled materials or by-products. However,studies on the improvement of construction techniques or the application of newly developedconstruction methods for reducing the environmental impact are relatively scant, compared to otherresearch topics. In particular, slabs are one of the significant elements for a building; they provideflat surfaces for occupants, as well as transferring various loads through beams, girders, and columnsto the ground. While the main focus of research on slabs is to verify the structural performance,including stability against flexural, shear, or seismic loads, and structural design optimisation.

There are few studies on the evaluation of the environmental impact of different slab systems

For example, **Ferreiro-Cabello** et al. evaluated the carbon dioxide emissions from slabs of differentthickness and suggested optimal structural design for environmental performance and structuralreliability. In order to fill the gap in research, the purpose of this study is to assess and compare theenvironmental impact of the conventional Slab, the Flat Slab, and the Waffle

Slab System during the construction phase.The potential of minimising embodied carbon in reinforced concrete flat slabs by parametrically varying the slab thickness, grade of concrete, column

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spacing, column size, and reinforcement details. A parametric design algorithm was developed to generate a range of one storey structural frames with flat slabs
In this study, the construction phase includes themanufacture of building materials, transportation of the building materials to the construction site,and the utilisation of construction equipment.

Research Methodology:
In this study Life Cycle Assessment methodology has been used that comprises of three analysis namely Process-based analysis, Economic input–output analysis and Hybrid analysis.
Process-based analysis is a bottom-up approach to evaluate environmental performance in consideration of all the processes and activities that are involved in producing a product or service.
Economic input–output analysis is a top-down method that considers both direct and indirect environmental impacts during the life cycle of a product or service. This approach evaluates the directenvironmental impacts of a project or service, as well as the indirect ones associated with the supplychain of the product or service.
Hybrid analysis is a combination of above-mentioned approaches to calculate the environmentalimpacts. It would make it possible to enhance the accuracy of the environmental performance evaluationcomplementary to insufficient data from either process-based or economic input–output analysis.
Slab systems,which are the Conventional Slab, the Flat slab and the Waffle slabs for apartment buildings in India. Slabs are one of thesignificant structural components for buildings. They not only transfer various loads through beams,girders, and columns to the ground, but also provide flat surfaces for building occupants. Sinceconstructing high-rise commercial or residential buildings is common in urban areas around theworld, the role of slabs has grown to facilitate more storeys. When the construction of slabs is carriedout during the construction phase, a vast amount of concrete and reinforcing bars is required. Due to this the load on manufacturing of such building material gets increased to a considerable amount. This leads to consumption of energy as well as raw materials which cause an impact in negative sense on the nearby environment. So emphasis should be laid in the beginning stage of the construction of buildings to minimise the use of such materials. Similarly the use of waste materials may also help in reducing pollution.
Conventionally, slabs would require a large number of beams and girders to secure the structuralstability of buildings or facilities. While the conventional method of constructing slabs would requirevast amounts of building materials, such as concrete and reinforcing bars.
In this study, the system boundary for assessing the environmental impact is the construction phase for the three slab systems. This includes embodied emissions fromthe production of building materials, emissions due to transportation of the manufactured materials.

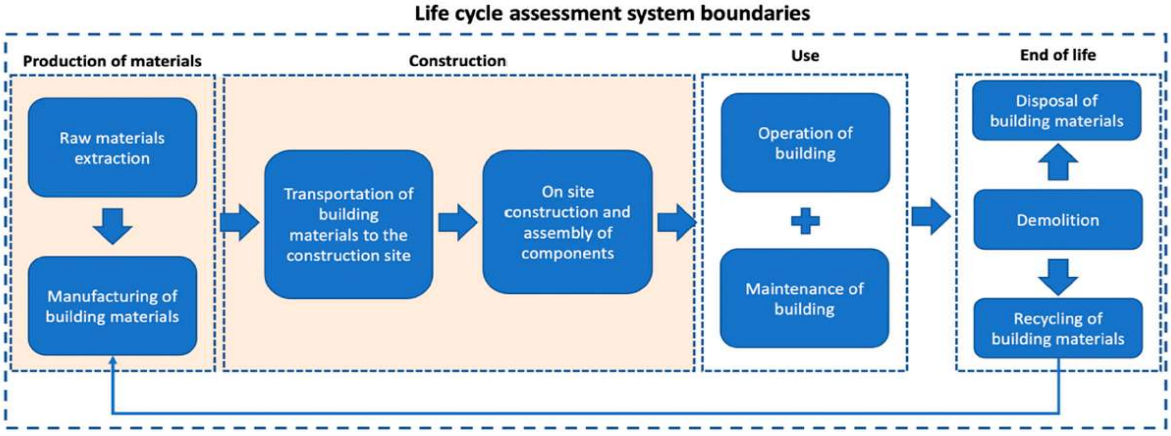

Fig. Life Cycle Assessment

The environmental Impact assessment is a quantitative approach that gives a numerical value which is the sum of numerical ratings of various fixed and well – defined related parameters. These parameters are Global Warming Potential,Acidification Potential, Eutrophication Potential, Ozone Layer Depletion Potentialand Abiotic Depletion Potential.

Global Warming Potential refers to the average temperaturerise level of the surface of the Earth, which is a parameter of the climate changes causing the ecosystemchanges in soil and water. Acidification Potential indicates the fate and deposition caused by acidifying substances, such asSO_2, NH_3, and NO_x on soil, water, organisms, ecosystems, and materials. This is mainly affectedby the circulation of pollutants and would threaten the survival of living organisms on the Earth.

Eutrophication Potential is the polluted state of aquatic ecosystem, such as algal growth and red tides, since the biomass inthe water is grown by over-fertilisation of water and soil. Ozone Layer Depletion Potential is a measure of the density decreasein the ozone layer that is located in the stratosphere as a result of trichlorofluoromethane.

These parameters have been assessed at various construction sites in India particularly at important and large structures e.g.Airports, Bust terminals, Malls and quantitative data have been observed. Based on the data the following conclusions have been interpreted.

Conclusions:

(1) In this study, the construction phase was divided into the manufacture of building materials, transportation of the building materials, and usage of construction machinery. The total environmental impacts from all the environmental indicators were the highest in the manufactureof building materials, followed by the transportation of building materials, and the use ofconstruction machinery.

(2) The assessment results show that among the three slab systems, the environmental impacts fromthe conventional slabs are the highest, while those of the Waffle slabs are the lowest. Along with the assessment of totalenvironmental impacts, the variation of the environmental impacts by replacing the Conventional slabs with the Flat Slabs and the Waffle Slabshas been examined.

(3) As the slab system of the studied building was replaced, the environmental impact indicatorsshowed a decreasing tendency.

(4) Replacing the Conventional slabs with the Waffle slabs showed the highest reduction ratio for all of the environmentalimpact indicators. This study also considered the environmental impact assessment results fromeach building material for the three different slab systems.

The assessment results of this study should be used to conduct further research regarding the comparison of the environmental impacts of the whole life stage of a building, including construction,operation and maintenance, and demolition. Moreover, only major building materials for theconstruction of slab systems were dealt with in this study. Further research that takes into account allof the building materials would be useful to assess and compare the potential benefits from selectingamong the alternative slab systems.

References:

1. Roh, S.; Tae, S.; Suk, S.J.; Ford, G. Evaluating the embodied environmental impacts of major building tasksand materials of apartment buildings in Korea. Renew. Sust. Energy Rev. **2017**, 73, 135–144.
2. Gorobets, A. Eco-centric policy for sustainable development. J. Clean. Prod. **2014**, 64, 654–655.
3. Paik, I.; Na, S. Evaluation of Carbon Dioxide Emissions amongst Alternative Slab Systems during theConstruction Phase in a Building Project. Appl. Sci. **2019**, 9, 4333.
4. Asdrubali, F.; Baldassarri, C.; Fthenakis, V. Life cycle analysis in the construction sector: Guiding theoptimization of conventional Italian buildings. Energy Build. **2013**, 64, 73–89.

5. Sandanayake, M.; Zhang, G.; Setunge, S. Environmental emissions at foundation construction stage ofbuildings—Two case studies. Build. Environ. **2016**, 95, 189–198.
6. Guggemos, A.A.; Horvath, A. Comparison of Environmental Effects of Steel- and Concrete-Framed Buildings.J. Infrastruct. Syst. **2005**, 11, 93–101.
7. Sartori, I.; Hestnes, A. Energy use in the life cycle of conventional and low-energy buildings: A review article.Energy Build. **2007**, 39, 249–257.
8. Basbagill, J.; Flager, F.; Lepech, M.; Fischer, M. Application of life-cycle assessment to early stage buildingdesign for reduced embodied environmental impacts. Build. Environ. **2013**, 60, 81–92.
9. Na, S.; Paik, I. Reducing Greenhouse Gas Emissions and Costs with the Alternative Structural System forSlab: A Comparative Analysis of South Korea Cases. Sustainability **2019**, 11, 5238.
10. Kumar, V.; Hewage, K.; Sadiq, R. Life cycle assessment of residential buildings: A case study in Canada.Int. J. Energy Environ. Eng. **2015**, 9, 1017–1025.
11. Mao, C.; Shen, Q.; Shen, L.; Tang, L. Comparative study of greenhouse gas emissions between off-siteprefabrication and conventional construction methods: Two case studies of residential projects. Energy Build.**2013**, 66, 165–176.
12. Cabeza, L.F.; Barreneche, C.; Miró, L.; Morera, J.M.; Bartolí, E.; Fernández, A.I. Low carbon and low embodiedenergy materials in buildings: A review. Renew. Sust. Energy Rev. **2013**, 23, 536–542.
13. Sentman, S.D.; Del Percio, S.T.; Koerner, P. A Climate for Change: Green Building Policies, Programs, andIncentives. J. Green Build. **2008**, 3, 46–63.
14. Hong, J.; Shen, G.Q.; Feng, Y.; Lau,W.S.-T.; Mao, C. Greenhouse gas emissions during the construction phaseof a building: A case study in China. J. Clean. Prod. **2015**, 103, 249–259.
15. Pacca, S.; Horvath, A. Greenhouse Gas Emissions from Building and Operating Electric Power Plants in theUpper Colorado River Basin. Environ. Sci. Technol. **2002**, 36, 3194–3200.
16. Wang, T.; Seo, S.; Liao, P.-C.; Fang, D. GHG emission reduction performance of state-of-the-art greenbuildings: Review of two case studies. Renew. Sust. Energy Rev. **2016**, 56, 484–493. Appl. Sci. **2020**, 10, 7278 14 of 15
17. Hong, T.; Koo, C.; Kim, J.; Lee, M.; Jeong, K. A review on sustainable construction management strategiesfor monitoring, diagnosing, and retrofitting the building's dynamic energy performance: Focused on theoperation and maintenance phase. Appl. Energy **2015**, 155, 671–707.
18. Mlecnik, E. Defining nearly zero-energy housing in Belgium and the Netherlands. Energy Effc. **2011**, 5,411–431.
19. Moore, T.; Morrissey, J. Lifecycle costing sensitivities for zero energy housing in Melbourne, Australia.Energy Build. **2014**, 79, 1–11.
20. Ferrante, A.; Cascella, M. Zero energy balance and zero on-site CO2 emission housing development in theMediterranean climate. Energy Build. **2011**, 43, 2002–2010. [CrossRef]
21. Edwards, R.E.; New, J.; Parker, L.E. Predicting future hourly residential electrical consumption: A machinelearning case study. Energy Build. **2012**, 49, 591–603. [CrossRef]