International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A Review on Life Cycle Analysis of RCC Building and Assessment of Carbon Emissions

A. Tejaswini Reddy [a], Ch. Srinivas [b], B. Vinay Kumar [c], A. Purana Chandra Rao [d], D. Teja [e]

[a,b,c,d,e] UG Students, Department of civil Engineering, GMR Institute of Technology, Vizianagaram District, A.P, India

ABSTRACT:

Concrete is the material that is used most frequently worldwide, second only to water. Additionally, it is one of the substances that pollutes the environment the most. Concrete, a common construction material, is known to emit large amounts of environmentally hazardous waste during the processes related to its production, construction, maintenance, and demolition. For every ton of Portland cement produced, 0.84 tones of carbon dioxide are released into the atmosphere. The amount of greenhouse gas (GHG) emissions by the product is specified in a ready-mixed concrete report whenever concrete is sold commercially. Hence, there have been many studies addressing the quantitative evaluation and reduction of the environmental effects of concrete. This study aims to introduce a method for assessing the amount of carbon dioxide emission from the processes of producing concrete. In order to advance, we used the REVIT software to model and design an RC building. We developed a results of CO_2 emissions of materials from the developed model via spreadsheets. Finding a substitute for this will lead to an interesting conclusion.

Keywords: CO_2 emission, Design, Revit, Life cycle Analysis

INTRODUCTION:

Since the 1800s, regular Portland Cement Concrete has been utilised extensively. According to research, each tonne of cement produced emits around 0.84 tonnes of carbon dioxide into the atmosphere, both directly during decomposition and indirectly due to the energy required for manufacturing. The sum of all contribution between 5 and 8% of the world's carbon dioxide emissions are attributed to cement. Currently, 4.2 billion tonnes of cement are produced annually, with a 2.5% annual increase rate predicted. The seven major building materials accounting for more than 90% of building greenhouse gas (GHG) emissions include concrete, a reinforcing rod, and section steel. Among the CO2 emissions generated by these major building materials, concrete accounts for 70%. In the Republic of Korea, in particular, the concrete mix design significantly differs Sustainability whether the concrete is used inland or in a coastal area for prevention of chloride-induced corrosion. Therefore, an assessment of CO2 emission and an analysis of their characteristics against the concrete used in diverse construction sites is needed.

Therefore, the assessment of CO2 emission is very important for achieving the national-level CO2 reduction objective.

The concrete production was divided into the following stages: Raw material and transportation.

The input materials, transportation distance, and energy usage data of each stage were used for assessing CO2 emission.

The CO2 emission levels calculated via spreadsheet as such were divided and based on material characteristics and transportation characterstics.

LITERATURE REVIEW:

1) **Tae hyoung kim[1] , chang u chae[2] , gil hwan kim[3] , and hyoung jae jang[4] , MPDI in sustainability journal.** Here the research is done on 10 under construction projects, including office buildings, apartment buildings, and high rise residential buildings in south korea. The materials used here are cement , coarse and fine aggregate. A system boundary was established for the life cycle co_2 emission evaluation of concrete. The system boundary was selected as the product stage of concrete (cradle to gate) based on iso 14044. Here the author concluded with the statement i.e the LCA method and program for various environmental load is needed.

2) **Tankshila kumari[1], Udayan gani kulathungu [2] , thatsarani hewavitharana and nandun madusanka. Taylor and Francis journal** . It is revealed that, the author mainly focused on efficient selection and use of low energy and low carbon materials , and transportation minimization , efficient construction process , reuse and recycling of carbon intensive materials. And also the author concerned about the four main stages. They are design stage; construction stage; operational stage ; end of building life .the author concluded that BIM can optimize the building design incorporating green techonology features to reduce the embodies carbon.

3) **Keun-hyeok yang [1], jin-kyu-song[2], keum-11 song [3]. Elseveir.** The materials used in this research are granulated blast furnance slag(ggbs) cement is replaced with AA-GGBS binder. Although alakli-activated (AA) concrete is generally regarded as one of the most effective concrete technologies for reducing co_2 emissions. Here the author focused on material, production, curing, transportation . The material used here is $Ca(OH)_2$ based AA-GGBS . The author observed that the emissions of co_2 2.4 times lower than that of opc concrete. The manual calculations are done by using the formulas derived from a data set.

4) **Chang U Chae, Gil Hwan Kim and Hyoung Jae Jang.Elsevier** This study aims to introduce a method for assessing the amount of carbon dioxide emission from the processes of producing concrete. Moreover, we measured the quantities of CO2 emission of about 10 under-construction projects, including office buildings, apartment buildings, and high-rise residential buildings in South Korea. Using the assessment result, we analyzed the CO2 reduction performance of an office building in South Korea and drew conclusions about measures for reducing CO2 emission. Using the proposed concrete CO2 emission assessment method, the characteristics of construction projects in terms of area and purpose were analyzed for the causes of differences in CO2 emission based on concrete strength, structure type, and structure area. This was accomplished by assessing each stage of construction, i.e., material procurement, transportation, and manufacturing. In the analysis according to building types, CO2 emission was found to decrease, from highest to lowest, apartment buildings, office buildings, and multipurpose buildings.

5) **Mohamad Monkiz Khasreen,Phillip F.G. Banfill,Gillian F. Menzies. Sustainability.** In this paper they discuss LCA methodologies and applications within the building sector, reviewing some of the life-cycle studies applied to buildings or building materials and component combinations within the last fifteen years in Europe and the United States.1)dentify the purpose of the study, and determine the questions to be answered.2)LCA is inventory analysis(data collection and calculation procedures).By use these methodologies determine the LCA OF the particular building.Hear the author concluded with statement i.e Despite the limitations and criticisms LCA is a powerful tool for the evaluation of environmental impacts of buildings. It has the potential to make a strong contribution tothe goal of sustainable development.

6) **Mehrdad Rabani,Habtamu Bayera Madessa,Malin Ljungström,Lene Aamodt,Sandra Løvvold, Natasa. Science Direct.** In this study, the LCA method was adopted and for calculation the functional unit was considered as one square meter of heated floor area(m^2)over a service lifetime of 60 years.the CO2-eq emissions from different stages of building life cycle for the reference building are elaborated.They concluded that Analysis of the reference building showed that around 77%, 1021.4 kg CO2-eq/m2, of the total GHG emissions were due to building energy use and the 23% were attributed to the embodied emissions of building materials and components, of which 16%, 213 kg CO2-eq/m2.

7) **Jianzhou You,Yaozhi Luo,Yafeng Wang,Xian Xu. Science Direct.** In this tje analysis of c02 is done by process based method("bottom-up" calculation method").E(pro)=EF*Q where E(pro) is the life-cycle carbon emissions,EF and Q are the carbon emission factor and activity data of production process i, respectively.Hear the author concluded with statement i.e that the carbon emissions in the component production phase account for 70%–80% of the whole life cycle carbon emissions.

8) **C.k chau , w.k.hui , w.y.ng.g powell. Elsevier.** The research is done on 13 high rise building by using applied monte carlo method. Diverting construction waste to recycling can reduce the co_2 foot print by 5.9%. resuing resources and importing regional materials can each only reduce the co_2 foot print by 3.2 and 3.1% respectively . 5% of co_2 will reduced by fabricated materials are used in facades , slabs and partition walls.

9) **Taehyoung Kim and Chang U. Chae. Elsevier.** Korea has set a greenhouse gas (GHG) emission reduction target of 37% (851 million tonnes) of the business as usual (BAU) rate by 2030 in order to conform with current worldwide trends and efforts and to contribute to sustainable development. Demands for the evaluation of CO2 emissions throughout the life cycle in compliance with ISO (International Standardization Organization's Standard) 14040 are also growing in relation to environmentally-focused standards like the IGCC (International Green Construction Code). Precast concrete (PC) engineering research now focus mostly on structural and construction issues, such as enhancing structural performance in joints, implementing pre-stressed concrete, and developing half PC. Steam curing is mostly employed in the early-strength development of concrete in the production of PC.

10) **Unghoon Parka, Sungho Taea, Taehyung Kima. Elsevier.** The development of technologies that can quantitatively analyse the LCCO2 emissions of a building at the level of the construction materials is crucial because research on the reduction of the life cycle carbon dioxide (LCCO2) emissions of buildings has become more and more relevant. A quantitative assessment of CO2 basic units for these new materials is required because concrete of diverse compositions, including high-performance concrete blended with fly ash and blast boiler slag and ecoconcrete, has become widely accessible. Nevertheless, the National Life Cycle Inventory Database (LCI DB) in Korea does not include fundamental units for different varieties of concrete. Thus, it has become very vital to do in-depth study on these materials.

Methodology of CO2 Life Cycle Assessment for Concrete:

A system boundary was established for the life cycle CO2 emission evaluation of concrete. The system boundary was selected as the product stage of concrete (cradle to gate) based on ISO 14044 and ISO 21930 . The product stage of concrete is divided into the raw material stage, the transportation stage, and the manufacturing stage. The raw material stage refers to CO2 emission during the production of major components of concrete such as cement, aggregate, and water. The transportation stage's CO2 emission occurs during the transportation of raw materials to the ready-mixed concrete manufacturing plant.

1. Raw materials

CO2 emission from concrete production was calculated as the sum of the quantity of each ingredient used for producing 1 m3 of concrete and the CO2 emission factor. The CO2 emission factor for cement, aggregate, and water were based on the some references.

$$CO2M = \Sigma(M(i) * CO2 \text{ emission factor } M)$$

(i = 1 : cement, 2 : aggregate, 3 : admixture, 4 : water)

CO2M is the CO2 emission quantity at the raw material stage for the production of a unit of concrete [kg-CO2/m3], M(i) is the amount of material used [kg/m3] of concrete, and CO2 emission factor M is the CO2 emission factor [kg-CO2/kg] for each material.

The emission factors of some different types of cement are mentioned in given below table:

Sr No	Cement	Embodied Carbon - Kg CO2/Kg	Density - kg per m3
1	**Cement I - Portland cement**	0.91	1440.00
2	**Cement II - Portland-slag cement**	0.67	1440.00
3	**Cement III - - Pozzolanic cement**	0.50	1440.00

The emission factors of some of other building materials are in given below table:

Materials	Embodied Carbon - KgCO2/Kg
Cement, OPC	0.912
Aggregates	0.00747
Admixture	1.67
GGBS	0.0416
Fly ash	0.004
Water	0.00034

2. Transportation

For assessing the CO2 emission due to transportation, the total quantity used and the load for each component were measured to calculate the number of vehicles required for transportation. The calculated number of vehicles, the distance, and the fuel efficiency of each vehicle were used for assessing the CO2 emission. In this study, the truck's speed and traffic were not considered. Equation (2) is used for calculating the CO2 emission during the transportation process.

$$CO2T = \Sigma[(M(i)/Lt) * (d/e) * CO2 \text{ emission factor } T]$$

Here, CO2T is the quantity of CO2 emitted during the transportation of a unit of produced concrete [kg-CO2/m3], M(i) is the amount of material used [kg/m3] in the concrete, Lt is the transportation load [tons], d is the transportation distance [km], e is the fuel efficiency [km/L], and CO2 emission factor T is the CO2 emission factor [kg-CO2/kg] of the energy resource.

The CO2 factors of transportation:

Item	Carbon - kgCO2e
Transport, 33t articulated per tonne.km	0.1033
Transport, per 50 KM trip	0.005177334

Analysis of C02 Emission for concrete

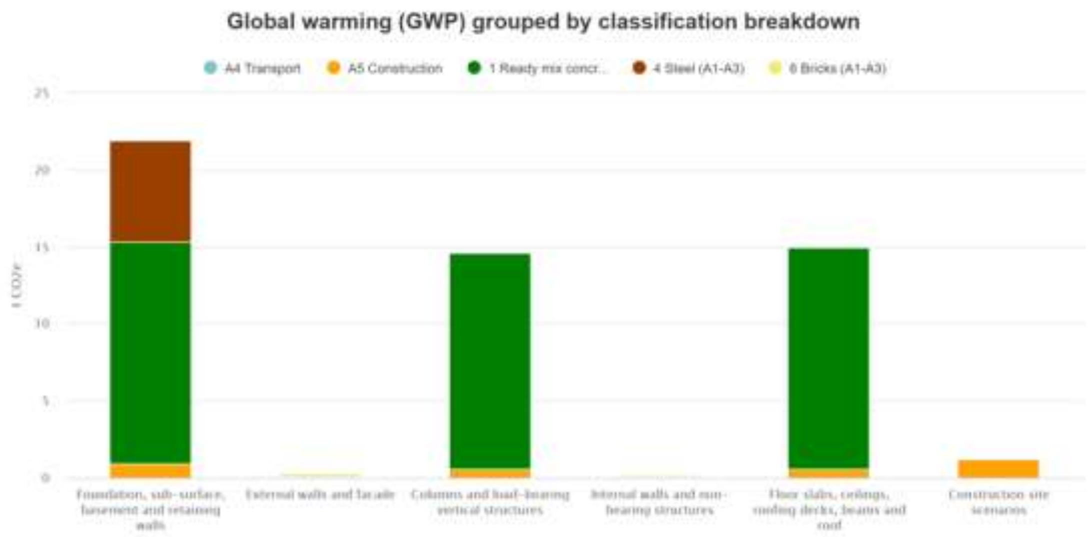
The analyzed buildings was constructed in Rajam town of Srikakulam in the state of Andhra Pradesh. This building includes 4 floors, 10 class rooms and 3 office rooms. Moreover, the CO2 emission of concrete using construction projects was evaluated by the methodology of CO2 life cycle assessment for concrete. The analysis of CO2 emission was divided into the structure part and basis part. This is because much of the cement is substituted with blast-furnace slag for reducing heat generation during hydration to ensure that the CO2 emission is very low.

DISCUSSIONS AND LIMITATIONS:

This study aimed to assess and analyze the CO2 emission of concrete, which is used according to building type and region. Then, it proposed a method to reduce CO2 emission in the use of concrete in building.

First, this study examined concrete only among diverse construction materials. Therefore, it is limited in assessing the CO2 emission of buildings. Among the construction materials used during a construction stage, the following seven materials accounted for 95% of total CO2 emission: ready- mixed concrete, reinforced rod, steel frame, paint, glass, concrete mix, and insulating material. Therefore, there should be further studies on the construction materials with high CO2 emission to assess the CO2 emission of building and propose their reduction technology.

However, this study analyzed a construction stage (required) only in the LCA, without considering the use, maintenance, and destruction/disposal stages. A reliability test on the proposed CO2 emission reduction technology is not enough because only one case was analyzed. Therefore, there should be further verifications through diverse case studies.



CONCLUSION:

Life-cycle assessment of buildings is less advanced than in other industries, but researchers are working to enhance the possibilities of adopting LCA as a decision making support tool within the design stage. It is clear that LCA is well explained, and its methodologies are well established and accessible to users, but there are still many impediments to its use for buildings, and these set the research agenda for the future.

The CO2 emission reduction method at the construction stage can be summarized as the application of high-strength concrete, the standardization of reduction mix design using blast-furnace slag, and the selection of RMC companies with low CO2 emission.

The most effective option is to maintain the existing structural and non-structural building elements over the life of a building. The amount of emissions reduction greatly depends on the quantities of materials to be maintained or reused for the existing materials.

REFERENCES:

1. Tae hyoung kim , chang u chae, gil hwan kim and hyoung jae jang. Analysis of CO2 Emission Characteristics of Concrete Used at Construction Sites, *MPDI in sustainability journal*. 2016, 8,348.
2. Tankshila kumari, Udayan gani kulathungu, thatsarani hewavitharana and nandun madusanka. Embodied carbon reduction strategies for highrise buildings in Sri Lanka, *Taylor and Francis journal.* 2020.
3. Keun-hyeok ya2ng, jin-kyu-song, keum-song. Assessment of CO2 reduction of alkali-activated concrete, *Elsevier*.2013, 39, 265-272.
4. Mohamad Monkiz Khasreen,Phillip F.G. Banfill,Gillian F. Menzies. Life-Cycle Assessment and the Environmental Impact of Buildings, *Sustainability*. 2009, 1, 674-701.
5. Mehrdad Rabani,Habtamu Bayera Madessa,Malin Ljungström,Lene Aamodt,Sandra Løvvold, Natasa. Life cycle analysis of GHG emissions from the building retrofitting: The case of a Norwegian office building, *Elsevier*. 2021, 204.

6. Jianzhou You,Yaozhi Luo,Yafeng Wang,Xian Xu. Analysis and assessment of life-cycle carbon emissions of space frame structures, *Elsevier*. 2023, 385.

7. Taehyoung Kim and Chang U. Chae. Evaluation Analysis of the CO2 Emission and Absorption Life Cycle for Precast Concrete in Korea, *Sustainability*. 2016, 8, 663.

8. C.k chau , w.k.hui , w.y.ng.g powell. Assessment of CO2 emissions reduction in high-rise concrete office buildings using different material use options, *Elsevier*. 2012, 61, 22-34.

9. Ali Alsalman, Lateef N. Assi, Rahman S. Kareem, Kealy Carter, Paul Ziehl. Energy and CO2 emission assessments of alkali-activated concrete and Ordinary Portland Cement concrete: A comparative analysis of different grades of concrete, *Elsevier*.2021, 3.

10. Xian Xu, Jianzhou You, Yafeng Wang, Yaozhi Luo. Analysis and assessment of life-cycle carbon emissions of space frame structures, *Elsevier*. 20323,385.

11. Junghoon Parka, Sungho Taea, Taehyung Kima. Life cycle CO2 assessment of concrete by compressive strength on construction site in Korea, *Elsevier*. 2012, 16, 2940-2946.

12. K. Naga Rajesh, R Srinivasa Rao. Effect on Replacement of Conventional Sand with Used Foundry Sand in Flyash Bricks, *Research gate*. 2017, 5, 2321-9653.

13. K. NagaRajesh, B. Girish Kumar, G. Jagadeesh, R. Srinivasa Rao. A study on Asphalt pavements by using Rap, Sand and UFS mixtures as replacements, *Research gate*. 2019.

14. Jayaraju Raja Murugadoss, Nachimuthu Balasubramaniam, Ravindiran Gokulan, Kanta Naga Rajesh, Gurusamy Pandian Sreelal, Pupalwad Arti Sudam , Dhaleelur Rahman Zunaithur Rahman, Razack Nasar Ali. Optimization of River Sand with Spent Garnet Sand in Concrete Using RSM and R Programming Packages. *Research gate*. 2022.

15. Naga rajesh kanta, Marakandeya Raju ponnada, Kapileswar Mishra. Application of response surface method for optimization of alkali activated slag concrete mix with used foundry sand as partial replacement of sand, *Research gate*. 2022, 47, 269.

16. Kanta Naga Rajesh. A review on sustainable concrete mix proportions, *Research gate*. 2021.

17. K. Naga Rajesh, Manoj Kumar Rath, P. Markandeya Raju. A Research on Sustainable Micro-Concrete. *Research gate*. 2019, 2277-3878.

18. K. Naga Rajesh, P. Markandaya Raju, Kapileswar Mishra, P. Srinivas Rao. Performance of cement mix plus and Styrene Butadiene Rubber Polymers in slag based concrete, *Research gate*. 2020, 2249-6890.