International Journal of Engineering and Science Invention (IJESI)
ISSN (Online): 2319-6734, ISSN (Print): 2319-6726
www.ijesi.org ||Volume 15 Issue 7 July 2026 || PP 01-04

Embodied Carbon Analysis of Self-Compacting Concrete Containing Marble Waste Powder, Manufactured Sand, and Polypropylene Fibers

Oggu Ankamma Raju[1], Dr T V S Vara Lakshmi[2]
[1](*Civil Engineering, Acharya Nagarjuna College of Engineering and Technology/ Acharya Nagarjuna University, India)*
[2](*Civil Engineering, Acharya Nagarjuna College of Engineering and Technology/ Acharya Nagarjuna University, India)*

ABSTRACT: *The construction industry is one of the major contributors to global carbon emissions due to the extensive use of cement and natural river sand in concrete production. This study investigates the development of sustainable Self-Compacting Concrete (SCC) incorporating marble waste powder (MWP) as a partial cement replacement, M-sand as a fine aggregate replacement, and polypropylene fibers as reinforcement. Marble waste powder was utilized to reduce cement consumption and minimize industrial waste disposal problems, thereby lowering the carbon footprint of SCC. M-sand was adopted as an eco-friendly alternative to natural river sand to conserve natural resources and reduce environmental degradation. Polypropylene fibers were added to improve the tensile strength. The results indicated that the incorporation of MWP and M-sand significantly reduced cement-related carbon emissions while maintaining satisfactory workability and mechanical performance. Overall, the developed SCC mixture demonstrated improved sustainability, reduced environmental impact, and suitable engineering performance for modern construction applications.*

KEYWORDS - *Carbon Emissions, Carbon Footprint, Marble Waste Powder (MWP), M-sand, Polypropylene Fibers, Sustainable Concrete, Cement Replacement, Eco-friendly Construction Materials, Mechanical Properties, Workability, Green Concrete..*

Date of Submission: 08-07-2026 | Date of acceptance: 20-07-2026

I.INTRODUCTION

The construction industry is one of the largest contributors to global carbon emissions due to the extensive use of cement and natural resources in concrete production. Cement manufacturing alone accounts for a significant percentage of worldwide CO_2 emissions because of the calcination process and high energy consumption involved during production. In addition, excessive mining of natural river sand for concrete causes environmental degradation, depletion of riverbeds, and ecological imbalance. Therefore, reducing the carbon footprint of concrete has become an important objective in sustainable construction practices.Self-Compacting Concrete (SCC) is a highly flowable concrete that can compact under its own weight without the need for external vibration. SCC provides several advantages such as improved workability, reduced labor requirements, enhanced surface finish, and better durability. However, SCC generally contains a higher quantity of cement and fine materials compared to conventional concrete, which may increase its environmental impact and carbon emissions. Hence, the use of alternative sustainable materials in SCC is necessary to develop environmentally friendly concrete. Marble Waste Powder (MWP) is an industrial by-product generated during the cutting and polishing of marble stones. Large quantities of marble waste are disposed into landfills, causing environmental pollution and disposal issues. Utilizing MWP as a partial replacement for cement in SCC helps reduce cement consumption and lowers the associated carbon emissions. Due to its fine particle size and filler characteristics, MWP also improves the packing density and enhances the fresh properties of SCC.Manufactured sand (M-sand) is considered an effective alternative to natural river sand in concrete production. The use of M-sand helps conserve natural river resources and minimizes environmental damage caused by sand mining activities. M-sand possesses better grading and angular particle characteristics, which contribute to improved cohesiveness and stability in SCC mixes. The replacement of river sand with M-sand also supports sustainable construction by reducing dependence on natural materials.The combined use of Marble Waste Powder and M-sand in Self-Compacting Concrete offers an eco-friendly solution for reducing the carbon footprint of construction materials. By partially replacing cement and natural sand with industrial waste and manufactured materials, the overall environmental impact of SCC can be significantly minimized. This study focuses on evaluating the carbon footprint reduction and performance characteristics of SCC containing Marble Waste Powder and M-sand, aiming to promote sustainable and green concrete technology for future construction applications.

II.LITERATURE REVIEW

Topçu et al., [1] developed eco-efficient SCC by replacing cement with waste marble powder and evaluated fresh and hardened properties. The study reported that marble powder improved flowability and reduced cement consumption, thereby lowering CO_2 emissions associated with concrete production. The authors concluded that utilization of marble waste in SCC is an effective sustainable solution for reducing carbon footprint in the construction industry. Masoud Ahmadi et al.,[2] conducted a life-cycle assessment on SCC containing waste marble powder as cement replacement and marble aggregates as fine aggregate replacement. The study observed nearly 20% reduction in carbon footprint compared to conventional SCC while maintaining satisfactory mechanical performance. The research highlighted that optimum replacement levels significantly improve sustainability and environmental performance of SCC. M. Arun Kumar et al.,[3] investigated SCC prepared with marble waste as partial fine aggregate replacement and polypropylene fibers as reinforcement. The results showed improved tensile and flexural strength with 0.4% polypropylene fiber addition, while 20% marble waste replacement produced optimum compressive strength. The study emphasized that using marble waste in SCC minimizes environmental pollution and contributes to low-carbon sustainable concrete productionYamuna Bhagwat et al.,[4] studied the performance of SCC containing M-sand and polypropylene fibers at different volume fractions. The investigation reported improved durability, reduced permeability, and enhanced crack resistance due to fiber reinforcement in M-sand SCC. The authors concluded that replacing river sand with M-sand significantly reduces environmental degradation and supports sustainable construction practices with lower embodied carbon. Amit Kumar Tomar and Ankit Kumaret al.,[5] evaluated SCC with waste marble powder replacing fine aggregate at various percentages. The study found that the workability of SCC improved with increasing marble powder content while maintaining acceptable strength characteristics. The researchers concluded that marble waste utilization decreases landfill disposal problems and reduces the environmental impact associated with conventional concrete materials.Valdez et al.,[6]This research investigated SCC containing marble sludge powder and polypropylene fibers to improve mechanical performance. The study showed enhancement in compressive, split tensile, and flexural strengths due to fiber reinforcement and marble sludge incorporation. The authors highlighted that replacing cementitious materials with industrial marble waste contributes to sustainable concrete technology and reduction of carbon emissions.arel et al.,[7]The review summarized previous research on SCC containing waste marble powder and supplementary cementitious materials. The authors stated that marble powder improves particle packing density, workability, and sustainability of SCC while reducing cement demand. The paper emphasized that industrial waste incorporation in SCC is an effective method for lowering the carbon footprint of concrete production. Dhanalakshmi and Shahul Hameed et al.,[8]investigated the use of marble-sludge powder and M-sand in high-strength SCC. The study observed improved cohesiveness and satisfactory mechanical properties with partial replacement of natural fine aggregate. The researchers concluded that the replacement of river sand with alternative materials reduces environmental degradation and promotes sustainable SCC production. And some Global warming potential factors are considers from previous literatures according to NSW 2000 department climate change.

III.METHODOLOGY

Methodology Use the following steps of approach to calculate the carbon impact of a concrete mix:

1. Identify the quantities of each ingredient in line with the concrete mix design
2. Select the suitable carbon intensity factor for each the constituent material from literature review
3. To obtain the equivalent carbon impact of each ingredient, multiply the quantity of each constituent (e.g. cement) with the carbon factor for that constituent (in this example the cement carbon factor). This will give you the carbon impact of each constituent of the mix.
4. To obtain the carbon impact of the concrete mix, add the calculated carbon impact of each ingredient from The carbon impact of concrete mix =∑ quantity of constituent (kg/m^3)* Global Warming Potential Factor
5. Calculate the carbon reduction between mixes by comparing them to a baseline concrete.
6. Carbon Reduction (%)={[1-(carbon impact of reduced carbon mix/carbon impact of base line mix)]

IV. CALCULATIONS

Table 1: Mix Design Details and equivalent embodied carbon emission for M30 pp fibers

	CM- Mix kg/m3	M0 Mix kg/m3	M4- Mix kg/m3	**GWP (kg co2e/kg)**	C Mix-GWP (kg co2e/kg)	M0 Mix-GWP (kg co2e/kg)	M4 Mix-GWP (kg co2e/kg)
Cement	395.8	316.8	316.8	0.97	383.96	307.29	307.29
Marble Waste Powder	0	79.2	79.2	0.65	0	51.48	51.48
Fine Aggregate	1052.5	842	842	0.004	4.21	3.368	3.368
M Sand	0	210.5	210.5	0.01	0	2.10	2.10
Coarse Aggregate	731.3	731.3	731.3	0.01	7.313	7.313	7.313
Water	190	190	190	0.0004	0.076	0.076	0.076
Chemical Ad Mixture	2.37	2.37	2.37	2.2	5.2	5.2	5.2
Poly Propylene Fibers	0	0	7.9	3.57	0	0	28.20
				Total	400.7	376.8	405

- Carbon Reduction (%) for **CM Mix and M0 Mix**={[1-(carbon impact of reduced carbon mix/carbon impact of base line mix)]

  - CM Mix and M0 Mix = [1− (376.8/400.7] ×100

    =[1−0.9403] ×100 =5.97%

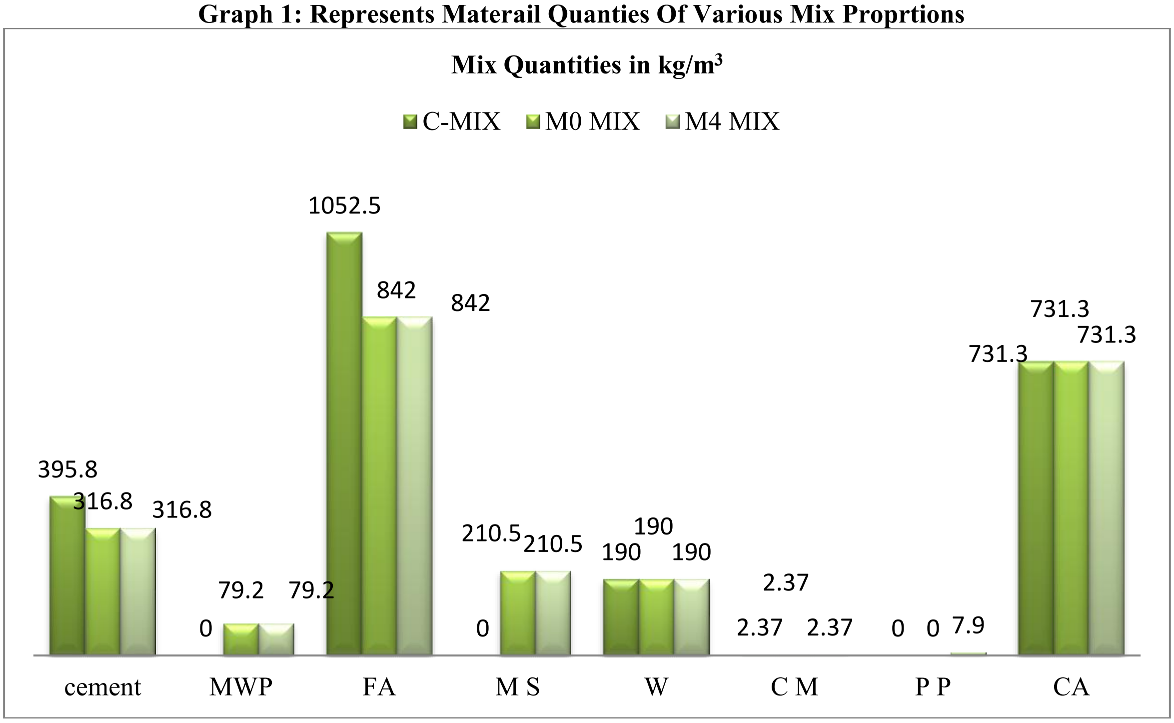
  - M0 Mix and M4 Mix = [1− (376.8/405] ×100

    = [1−0.9304] ×100=6.96%

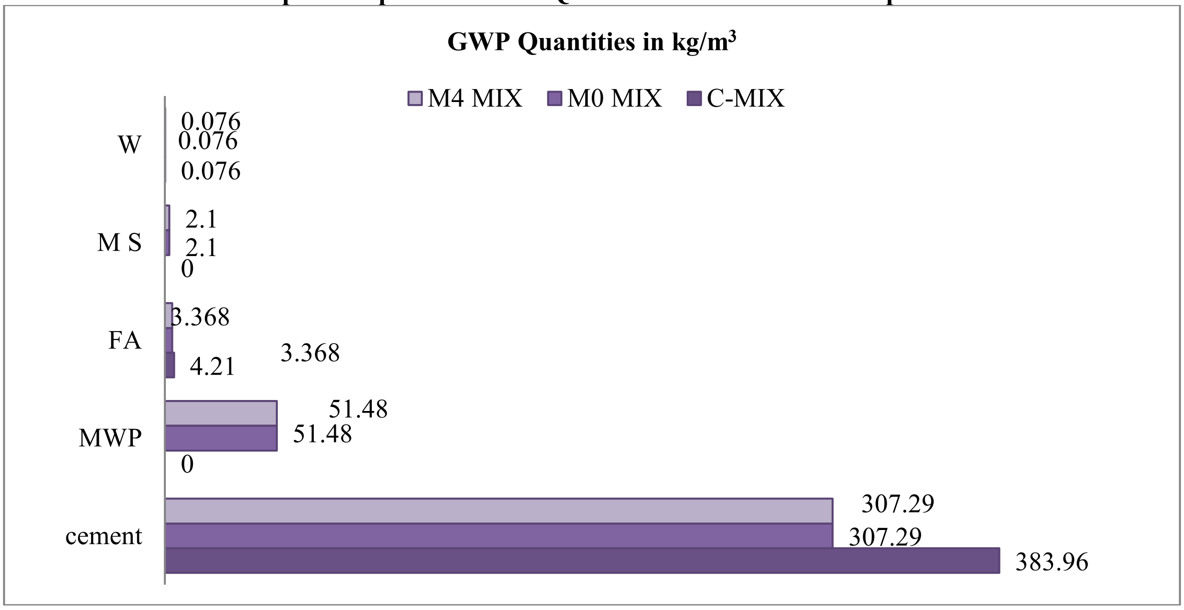
  - M4 Mix and CM Mix = [1− (405/400.7] ×100

    = [1−1.01] ×100= -1.0 %(increase)

Graph 1: Represents Materail Quanties Of Various Mix Proprtions



Graph 2: Represents GWP Quanties Of Various Mix Proprtions



V.CONCLUSION

The carbon reduction percentage determines how much "greener" a modified mix is compared to a baseline.**M0 Mix vs. CM Mix 5.97% Reduction** The substitution of cement with marble waste powder successfully lowered the total carbon footprint. This confirms that marble waste is effective eco-friendly filler.**M4 Mix vs. CM Mix -1.07% Increase** The M4 mix is slightly more carbon-intensive than the control mix. Despite the 20% cement reduction, the high embodied carbon of **Polypropylene Fibers** outweighed the environmental gains.**M0 Mix vs. M4 Mix 6.96% Difference** Comparing the two modified mixes shows that the inclusion of fibers increases the GWP of the concrete by nearly 7% relative to the non-fibrous modified mix. In all mixes, cement remains the primary contributor to GWP, accounting for over 75% of the total carbon impact. The M4 mix demonstrates a classic engineering trade-off. While PP fibers are added to improve mechanical properties (like tensile strength and crack control), they impose a "carbon penalty" that makes the concrete less sustainable than the control. The use of **Marble Waste Powder** and **M-Sand** (Manufactured Sand) shows a dual benefit it reduces the need for carbon-heavy cement and preserves natural river sand resources.

Acknowledgements

The authors greatly acknowledge the full-fledged support by the Acharya Nagarjuna University College of Engineering and Technology Acharya Nagarjuna University, Guntur Andhra Pradesh, India. The complete literature works were carried out in the laboratory of the Civil Engineering Department, Acharya Nagarjuna University. The great support of the University Management Team and Researchers were extremely acknowledged here with thank fullness.

REFERENCES

[1]. K. E. Alyamaç, E. Ghafari, and R. İnce, "Development of eco-efficient self-compacting concrete with waste marble powder using the response surface method," *Journal of Cleaner Production*, vol. 144, pp. 192–202, 2017.

[2]. M. Ahmadi, E. Abdollahzadeh, M. Kashfi, B. Khataei, and M. Razavi, "Life cycle assessment and performance evaluation of self-compacting concrete incorporating waste marble powder and aggregates," *Materials*, vol. 18, no. 13, p. 2982, 2025.

[3]. A. K. Tomar and A. Kumar, "Strength characteristics of self-compacting concrete partially replaced with waste marble powder," *Journal of Environmental Nanotechnology*, vol. 7, no. 4, pp. 46–50, 2018.

[4]. J. Ahmad, Z. Zhou, and A. F. Deifalla, "Self-compacting concrete with partially substitution of waste marble: A review," *International Journal of Concrete Structures and Materials*, vol. 17, p. 25, 2023.

[5]. A. Iqbal, H. Ashfaq, K. Ullah, W. Mushtaq, U. U. Rehman, and M. U. Rehman, "Use of waste material for sustainable self compacting concrete," *Pakistan Journal of Engineering and Technology*, vol. 3, no. 1, 2020.

[6]. P. Valdez, B. Barragán, I. Girbes, N. Shuttleworth, and A. Cockburn, "Use of waste from the marble industry as filler for the production of self-compacting concretes," *Materiales de Construcción*, vol. 60, no. 299, pp. 61–74, 2010.

[7]. H. Ş. Arel, "Recyclability of waste marble in concrete production," *Journal of Cleaner Production*, vol. 131, pp. 179–188, 2016.

[8]. D. K. Ashish, "Concrete made with waste marble powder and supplementary cementitious material for sustainable development," *Journal of Cleaner Production*, vol. 211, pp. 716–729, 2019.

[9]. A. Alsabri, F. Tahir, and S. G. Al-Ghamdi, "Environmental impacts of polypropylene (PP) production and prospects of its recycling in the GCC region," *Materials Today: Proceedings*, 2022.

[10]. Arup Australia and Department of Climate Change, Energy, the Environment and Water (DCCEEW), NSW Treasury, *How to Calculate Embodied Carbon of a Concrete*, Sydney, NSW, Australia, 2021.