IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

FEASIBILITY STUDY OF PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH PLASTIC IN CONCRETE

[1]Aniruddha U Ghorpade, [2]Shripad B Kore
[1]P.G. Student of Civil Engineering Department of Sanjay Ghodawat university, Kolhapur, India
[2] Assistant Professor of Civil Engineering Department Sanjay Ghodawat university, Kolhapur, India

Abstract: Plastic being a diverse group of materials known as polymers, exhibit a multitude of useful and versatile properties. which compiles information on the most used plastic materials and their mechanical properties at room temperature. Two particularly advantageous characteristics of plastics are their durability and resilience, enabling the creation of long-lasting products with minimal maintenance requirements. This longevity contributes to the cost-effectiveness of plastic-based products over their lifespan Consequently, individuals encounter plastic in various forms daily, given its widespread use compared to other materials. The intrinsic benefits of plastics, coupled with a growing global population, forecast a doubling of production within the next ten to twenty years, with Asia, North America, and Europe anticipated to be the major contributors, accounting for 50%, 10%, and 16% of the future supply, respectively.

Keywords – Durability, Resilience Encounter plastic

1.0 INTRODUCTION

Plastic waste has emerged as a critical global issue, with its pervasive presence posing significant environmental, economic, and health challenges. Rapid production and consumption, coupled with inadequate waste management practices, have led to the accumulation of vast quantities of plastic debris in landfills, waterways, and ecosystems worldwide. Plastic waste figures underscore the magnitude of the global crisis. Over 300 million tons of plastic are produced annually, with a staggering 8 million tons entering the oceans each year. By 2050, it is estimated that there will be more plastic than fish in the ocean by weight if current trends continue. Alarmingly, only about 9% of all plastic ever produced has been recycled, while the remainder persists in the environment for centuries, polluting ecosystems and harming wildlife. Single-use plastics exacerbate the problem, with approximately 50% of plastic items designed for single use. Plastic waste in India presents a significant environmental and social challenge. With a population exceeding 1.3 billion and rapid urbanization, the country generates an estimated 26,000 tons of plastic waste daily. However, inadequate waste management infrastructure, coupled with limited recycling facilities and widespread single-use plastic consumption, exacerbates the problem. It is estimated that only about 60% of plastic waste is collected for recycling, with the remainder often ending up in landfills, water bodies, or being openly burned, contributing to air and water pollution. Plastic pollution affects ecosystems, wildlife, and public health, with microplastics entering food chains and posing risks to human well-being.

2.0 SCOPE OF THE STUDY

The scope of utilizing waste materials, particularly plastic aggregates, in construction presents a promising avenue to address various challenges associated with traditional natural aggregates. Natural aggregates are essential materials in construction and are indicative of a country's economic activity. However, factors such as quarry distances from demand points, environmental regulations, and societal concerns near populated areas influence their availability and cost. As quarries move away from demand areas, longer transportation distances lead to economic, environmental, and safety issues. To alleviate these challenges, this work focuses on the utilization of waste materials, which not only reduces the reliance on natural aggregates but also addresses environmental concerns. Materials like iron slag and crusher dust are already being used, while others are under research. Incorporating these waste materials into concrete serves a dual purpose of minimizing raw material usage and mitigating environmental impacts. In summary, the scope of utilizing waste materials, particularly plastic aggregates, offers a sustainable solution to the challenges associated with traditional natural aggregates.

3.0 METHODOLOGY

3.1 Material used:

Cement: Conforming to Specification as per IS 1489:1991. Grade-43 OPC Density-1440Kg/m3, Specific gravity- 3.15
Fine aggregate: Conforming to specification as per IS 383:1970 Density-1600Kg/m3 Specific gravity- 2.6 Type-Dry River sand
Coarse aggregate and Plastic aggregate: Conforming to specification as per IS Standards IS 383:1970
Water: Regular potable water is utilized for mixing and curing.

3.2 M-20 Concrete mix design

The chosen grade of concrete for this project is M20, which is the minimum grade commonly used in RCC construction. This decision was made after consulting online resources to ensure originality and to compare with previous studies on the topic. The project avoids the use of admixtures or other binder materials to keep costs down and simplify the mix design. While admixtures could potentially improve results, their interaction with plastic aggregate is not well understood, so only cement is used as the cementitious material in the mix. The mix design involves determining the proportions of various ingredients such as cement, sand, coarse aggregates, and water to achieve the desired properties of the concrete. The amount of plastic aggregate needed can be determined by multiplying the volume of coarse aggregate obtained through mix design by the desired replacement volume and the density of the plastic aggregate.

3.3 Casting of test specimen

Concrete cube testing conducted on-site serves as a pivotal quality control measure aimed at verifying that the concrete attains the specified minimum strength requirements. This validation is imperative to ensure structural integrity and safety in construction projects. It necessitates meticulous adherence to standardized procedures encompassing casting, curing, and testing methodologies. Each stage of the process demands precise execution to obviate discrepancies that might lead to erroneous estimations of compressive strength. Even minor deviations from established protocols can significantly impact the accuracy of the results obtained. The deployment of specialized equipment such as sample trays, moulds for cube casting, spanners, scoops, steel trowels, compacting bars, and vibrating tables underscores the meticulousness requisite in this endeavour.

The preparation of moulds assumes paramount importance, necessitating meticulous cleaning to remove any residual mortar or contaminants that could impede the proper assembly of mould sections. Application of mould oil serves to prevent concrete adhesion, facilitating seamless demoulding post-casting. Bolting the mould sections securely and ensuring their stability on base plates are imperative steps to uphold the integrity of the casting process. Concrete pouring into the moulds demands a representative sample, meticulously obtained either during discharge from the mixer or from a heap of mixed concrete. Compaction, whether performed manually or through vibrating tables, warrants thorough removal of entrapped air, as its presence can substantially undermine cube strength. However, caution must be exercised to prevent over-compaction, which may lead to segregation of aggregates and cement paste, thereby compromising the final compressive strength. The demoulding phase, occurring typically after 16 to 24 hours, necessitates careful handling to prevent damage to the cube edges, as any such impairment could adversely affect compressive strength readings. Subsequent curing of the cubes is imperative prior to testing, involving immersion in a curing tank or exposure to controlled humidity levels in a mist room. Maintaining optimal curing conditions, including water temperature and humidity levels, is essential to facilitate proper concrete hydration and ensure accurate test results. For this project, a variety of moulds were utilized, including cube moulds of 150 x 150 x 150 mm size, cylindrical moulds of 150 x 300 mm size, and prism moulds of 100 x 100 x 500 mm size. These moulds were carefully placed on a level surface to ensure uniformity and stability during the casting process. The concrete materials were thoroughly mixed using a mixer machine to ensure a homogenous mixture. The mixing process began with the addition of coarse aggregate and fine aggregate, which were mixed thoroughly in their dry state to achieve an even distribution. Following this, cement and water were added to the mixture to form fresh concrete. Simultaneously, powdered plastics were integrated into the mix to ensure they were properly combined with the other materials.

4.0 Experimental Investigation

The casted specimens were carefully demoulded to assess their mechanical properties, including compressive strength, split tensile strength, and flexural strength. These evaluations were conducted after specific curing periods of 7 days, 14 days, and 28 days to observe the progression and development of the concrete's strength over time. The results from these tests were meticulously recorded and compared with the strength characteristics of conventional concrete to identify any improvements or deviations. This comparative analysis provided valuable insights into the performance of the tested concrete mix relative to standard concrete formulations. Detailed procedures were followed during the testing phase to ensure accuracy and reliability of the results. The test setups for each type of strength assessment were prepared according to standardized protocols. During the compressive strength test, the specimens were subjected to axial loads until failure, and the maximum load sustained was recorded. For the split tensile strength test, the specimens were loaded diametrically until failure, and the stress at which splitting occurred was noted. Similarly, in the flexural strength test, the specimens were loaded at their mid-span until failure, and the corresponding flexural strength was calculated. The compressive strength test is performed to determine the compressive strengths of conventional concrete and plastic-partially replaced cube specimens using a compression testing machine. This test measures the ability of the material to withstand axial loads that tend to reduce size. The results of the compression test for specimens at 7 days, 14 days, and 28 days are presented, highlighting the strength development over time for both types of specimens. These results provide valuable insights into the early-age and long-term performance of the materials under compressive loads.

4.1 Fresh Properties

Fresh Properties Test Results for Concrete with Waste Plastic Replacement In the study, fresh properties of concrete mixes were evaluated across different replacement levels of waste plastic. The test results are summarized in Table 4.1One critical test conducted was the slump cone test (SCT), which measures the workability of fresh concrete. The varying replacement levels (ranging from 0% to 25%) of waste plastic were considered, following the guidelines specified in IS:1199-1959. Slump Value Decrease as the proportion of waste plastic replacement increased, there was a noticeable decrease in the slump value of the concrete. Slump value reflects the consistency and flowability of the fresh concrete. A lower slump indicates reduced workability. Cohesiveness and Adhesiveness: At 0% and 5% waste plastic replacement levels, the concrete mix remained cohesive. However, as the dosage of waste plastic increased (10%, 15%, and 20%), the concrete became more adhesive. The test results for slump and compaction factor of M20 grade concrete with varying levels of waste plastic replacement exhibit a mixed trend. While the slump values fluctuate, there is no clear pattern of increase or decrease with increasing plastic content. It ranges between 91mm for the control concrete to 105mm for 20% replacement, with some overlap between mixtures.

4.2 Mechanical Properties:

4.2.1 Compressive Strength Test:

In the compression test conducted on M20 grade concrete, which was partially mixed with waste plastic at varying replacement levels (ranging from 0% to 25%), the compressive strength was evaluated.

4.2.2 Split Tensile Test

In the split tensile test conducted on M20 grade concrete, which was partially mixed with waste plastic at varying replacement levels (ranging from 0% to 25%), the tensile strength was evaluated. As the percentage of waste plastic increased, the tensile strength of the concrete exhibited fluctuations. This study provides valuable insights into how waste plastic affects the structural behaviour of the concrete mix under tensile forces.

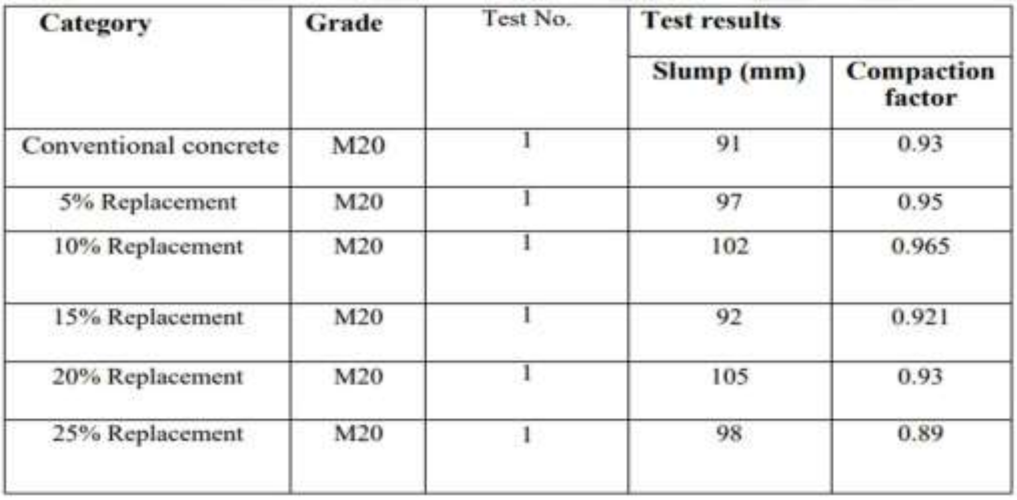
4.2.3 Flexural Strength Test

In the flexural strength test conducted on M20 grade concrete, which was partially mixed with waste plastic at varying replacement levels (ranging from 0% to 25%), the ability of the concrete to withstand bending forces was evaluated. As the percentage of waste plastic increased, the flexural strength of the concrete exhibited changes. This study sheds light on how waste plastic influences the structural behaviour of the concrete under bending loads.

5.0 RESULTS AND DISCUSSION

5.1 Fresh Properties of Concrete

Table No.5. 1- Test results of all categories of concrete mixes



Category	Grade	Test No.	Test results	
			Slump (mm)	Compaction factor
Conventional concrete	M20	1	91	0.93
5% Replacement	M20	1	97	0.95
10% Replacement	M20	1	102	0.965
15% Replacement	M20	1	92	0.921
20% Replacement	M20	1	105	0.93
25% Replacement	M20	1	98	0.89

The test results for slump and compaction factor of M20 grade concrete with varying levels of waste plastic replacement exhibit a mixed trend. While the slump values fluctuate, there is no clear pattern of increase or decrease with increasing plastic content. It ranges between 91mm for the control concrete to 105mm for 20% replacement, with some overlap between mixtures. The compaction factor shows a similar trend, with values ranging from 0.93 to 0.965 for most mixtures and dropping to 0.89 for 25% replacement. This suggests that incorporating waste plastic up to a certain level may not significantly affect the workability of the concrete as measured by slump and compaction factor. However, further investigation is needed to determine the optimal replacement level and its impact on other fresh and hardened properties of the concrete.

5.2.1 Compressive Strength Test:

Table No.5.2 Compressive Strength Test results of all categories of concrete mixes

Sr. No	Category	Grade	% Replacement	Average Compressive Strength Test in MPa		
				7 (days)	14 (days)	28 (days)
1	Conventional concrete	M20	0	12.5	17.23	21.23
2	Waste Plastic Mix Concrete	M20	5	13	18.22	21.50
3			10	13.9	18.60	21.80
4			15	14.3	19.23	23.40
5			20	14.1	17.40	21.90
6			25	13.5	16.90	19.40

An investigation into the influence of waste plastic replacement on the compressive strength of M20 grade concrete yielded interesting results. Conventional concrete, without any waste plastic (0% replacement), exhibited a steady increase in compressive strength over the curing period, reaching 21.23 MPa at 28 days.

Figure 5.1: CS test results of M20 grade all concrete mixes

However, the introduction of waste plastic in measured quantities appears to have an even more positive effect. Concrete mixes containing 5% waste plastic replacement by weight demonstrated a slight but consistent improvement in compressive strength at all curing times tested. At 7 and 14 days, these mixes displayed a marginal increase of 0.5 MPa and 0.99 MPa respectively compared to the conventional mix. Notably, at the crucial 28-day mark, the 5% waste plastic mix surpassed the conventional concrete by 0.27 MPa, achieving a compressive strength of 21.50 MPa. This trend suggests a potential benefit in incorporating a low percentage of waste plastic into the concrete matrix. While data for earlier curing times (7 and 14 days) is not available for replacement levels beyond 5%, the trend of increasing compressive strength continues up to 15% replacement at 28 days, reaching 14.3 MPa. While data for earlier curing times (7 and 14 days) is not available for replacement levels beyond 5%, the trend of increasing compressive strength continues up to 15% replacement at 28 days, reaching 14.3 MPa. This indicates that the optimal range for waste plastic replacement to enhance compressive strength might lie between 5% and 15%. Further investigation into the performance of concrete mixes with replacement levels exceeding 15%, along with data for earlier curing times, would be necessary to definitively establish the impact of waste plastic on M20 concrete's strength development.

5.2.2 Split Tensile Test:

Table 5.3 CS test results

Sr. No	Category	Grade	% Replacement	7 days (MPa)	14 days (MPa)	28 days (MPa)
1	Conventional Concrete	M20	0	1.54	1.88	1.9
2	Waste Plastic Mix Concrete	M20	5	1.63	1.9	2.03
3			10	1.65	1.89	2.1
4			15	1.71	1.97	2.21
5			20	1.72	1.94	2.20
6			25	1.78	1.96	2.10

An evaluation of M20 grade concrete's split tensile strength with varying waste plastic content (0% to 25% replacement) reveals some interesting trends. Standard concrete (0% replacement) exhibited a gradual increase in tensile strength over the curing period, reaching 1.90 MPa at 28 days.

Figure No. 5. 2 Split Tensile Test results of M20 grade all concrete mixes

However, the incorporation of waste plastic appears to have a positive impact on tensile strength, particularly at later stages of curing. Concrete mixes with a 5% waste plastic replacement displayed a consistent improvement in tensile strength at all curing times tested. They achieved a slight increase of 0.09 MPa at 7 days and 0.12 MPa at 14 days compared to the conventional mix. Notably, at the critical 28-day mark, the 5% waste plastic mix surpassed the standard concrete by 0.13 MPa, reaching a tensile strength of 2.03 MPa. This trend continues with increasing replacement levels up to 25%. There is a clear improvement in tensile strength as the waste plastic content rises, with 25% replacement concrete reaching 1.78 MPa at 28 days, exceeding the strength of standard concrete by 0.12 MPa. These findings suggest that incorporating a measured amount of waste plastic into the concrete mix can potentially enhance its resistance to tensile forces.

5.2.3 Flexural Strength Test

Table No.5.4 Flexural Strength Test results of all categories of concrete mixes

Sr. No	Category	Grade	% Replacement	7 days (MPa)	14 days (MPa)	28 days (MPa)
1	Conventional Concrete	M20	0	1.5	1.65	2.11
2	Waste Plastic Mix Concrete	M20	5	1.54	1.72	2.22
3			10	1.62	1.82	2.3
4			15	1.66	1.8	2.44
5			20	1.65	1.75	2.35
6			25	1.62	1.70	2.30

Examining the flexural strength test results of M20 concrete with varying waste plastic content (0% to 25% replacement) sheds light on how waste plastic influences the concrete's ability to resist bending. Standard concrete (0% replacement) demonstrated a steady increase in flexural strength over the curing period, reaching 2.11 MPa at 28 days. Interestingly, the introduction of waste plastic in controlled amounts appears to have a beneficial effect on flexural strength, particularly at later curing stages.

Figure No. 5.3 Flexural Strength Test results of M20 grade all concrete mixes

Concrete mixes containing a 5% waste plastic replacement exhibited a slight but consistent improvement in flexural strength at all curing times. They achieved a marginal increase of 0.04 MPa at 7 days and 0.07 MPa at 14 days compared to the conventional mix. Notably, at the crucial 28-day mark, the 5% waste plastic mix surpassed the standard concrete by 0.11 MPa, reaching a flexural strength of 2.22 MPa. This trend continues with a gradual rise in flexural strength as the waste plastic content increases up to 25%. Concrete with 25% replacement reached 1.88 MPa at 28 days, exceeding the strength of standard concrete by 0.27 MPa.

6.0 CONCLUSION

The study's conclusion comprehensively aligns with its initial objectives, demonstrating a meticulous investigation into the use of waste plastics in concrete from both environmental and performance perspectives. Firstly, the study addresses the environmental perspective by showcasing the significant benefits of converting waste plastics into recycled plastic aggregates. It elucidates how the inclusion of waste plastics in concrete can effectively divert plastic waste from landfills, thus mitigating environmental pollution and promoting sustainability. This aligns with the objective of analysing the environmental impact of this conversion process, presenting a strong case for the sustainable management of plastic waste through its integration into construction materials.

In comparing the mechanical properties of concrete with partial waste plastic replacement to those of conventional concrete, the study reveals that concrete incorporating waste plastic can achieve comparable or even superior mechanical properties. For instance, the split tensile strength tests showed that conventional concrete reached 1.90 MPa at 28 days, while concrete with up to 25% waste plastic replacement achieved 1.78 MPa, surpassing the conventional mix.

Furthermore, the study identifies an optimal range for waste plastic replacement, suggesting that a replacement level between 5% and 15% offers a balanced approach that enhances mechanical properties while providing substantial environmental benefits. The conclusion highlights that concrete mixes with a 5% waste plastic replacement show consistent improvements in compressive, tensile, and flexural strengths, suggesting this level as a potential sweet spot.REFERENCES

1) Abdulaziz Ibrahim Almohana, Mohanad Yaseen Abdulwahid, Isaac Galobardes, Jasir Mushtaq, Sattam Fahad Almojil. (2022).

“Producing sustainable concrete with plastic waste: A review.” Environmental Challenges, Volume 9.

2) A. K. Poonia and P. Verma, "A study of use of plastic waste as aggregate in concrete," International Journal of Engineering and Technical Research (IJETR), vol. 5, no. 5, pp. 43–46, 2016.

3) A. Khan, "Sustainable concrete using recycled plastic as partial coarse aggregate replacement," Ph.D. dissertation, Jamia Millia Islamia, Delhi, India, 2019.

4) A. P. M. Shende, "Performance of plastic waste as partial replacement of coarse aggregate in concrete," M.Tech Thesis, NIT Raipur, India, 2020.

5) Al-Manaseer, A.A., & Dalal, T.R. (1997). "Concrete containing plastic aggregates." Concrete International, vol. 19, no. 8, pp. 47–52.

6) B. Rai, S.T. Rushad, Bhavesh Kr, & S.K. Duggal. (2012). "Study of Waste Plastic Mix Concrete with Plasticizer." International Scholarly Research Notices, vol. 2012, Article ID 469272.

7) Bureau of Indian Standards (BIS), IS 456: 2000 – Plain and Reinforced Concrete – Code of Practice, BIS, New Delhi, 2000.

8) Gérard-Philippe Zéhil, Joseph J. Assaad. (2020). “Feasibility of concrete mixtures containing cross-linked polyethylene waste materials.” Construction and Building Materials, Volume 226, Pages 1–10.

9) Gu, L., & Ozbakkaloglu, T. (2016). "Use of recycled plastics in concrete: A critical review." Waste Management, vol. 51, pp. 19–42.

10) Hannawi, K., Kamali-Bernard, S., & Prince, W. (2010). "Physical and mechanical properties of mortars containing PET and PC waste aggregates." Waste Management, vol. 30, no. 11, pp. 2312–2320.

11) Hazha Mohammed, Monower Sadique, Andy Shaw, Ana Bras. (2020). “The influence of incorporating plastic within concrete and the potential use of microwave curing; A review.” Journal of Building Engineering, Volume 32, 101824.

12) H. Singh, "Study of concrete properties using plastic aggregates," M.Tech Thesis, Thapar Institute of Engineering and Technology, Punjab, India, 2021.

13) Ibrahim Almeshal, Bassam A. Tayeh, Rayed Alyousef, Hisham Alabduljabbar, Abdeliazim Mustafa Mohamed. (2020). “Eco-friendly concrete containing recycled plastic as partial replacement for sand.” Journal of Materials Research and Technology, Volume 9, Issue 3, Pages 4631–4643.

14) Ismail, Z.Z., & Al-Hashmi, E.A. (2008). "Use of waste plastic in concrete mixture as aggregate replacement." Waste Management, vol. 28, no. 11, pp. 2041–2047.

15) Kore, S. B., Patil, S. S., Patil, D. M., Madekar, A. A., & Hadimani, S. S. (2018). *Use of waste plastic aggregate as partial replacement of natural aggregate in concrete mix*. International Journal for Research in Applied Science & Engineering Technology (IJRASET), 6(3).

16) K. Rahmani, M. Dehestani, M. Beygi et al., "On the mechanical properties of concrete containing waste PET particles," Construction and Building Materials, vol. 47, pp. 1302–1308, 2013.

17) Kou, S.C., & Lee, G. (2011). "Using recycled plastic waste as a partial replacement of coarse aggregate in concrete blocks." Waste Management & Research, vol. 29, no. 6, pp. 633–640.

18) Kore, S. B., Dhemare, L. S., Balam, S. V., & Bodake, S. N. (2017). *Use of solid waste material in construction*. International Journal for Scientific Research & Development (IJSRD), 5(2), 493–495.

19) M. A. Elzafraney, S. M. Soroushian and G. Balaguru, "Thermal properties of sustainable concrete materials incorporating granulated plastics," Construction and Building Materials, vol. 20, no. 10, pp. 777–783, 2006.

20) M. Frigione, "Recycling of PET bottles as fine aggregate in concrete," Waste Management, vol. 30, no. 6, pp. 1101–1106, 2010.

21) Maher Al-Tayeb Mustafa, Ismail Hanafi, Rade Mahmoud, B.A. Tayeh. (2019). “Effect of partial replacement of sand by plastic waste on impact resistance of concrete: experiment and simulation.” Structures, Volume 20, Pages 519–526.

22) N. A. Mangi, A. Jamaluddin, M. F. Nuruddin and T. S. Shafiq, "Utilization of polyethylene terephthalate (PET) plastic waste as partial replacement of coarse aggregates in concrete," Construction and Building Materials, vol. 213, pp. 318–324, 2019.

23) N. Marzouk, R. Dheilly and M. Queneudec, "Valorization of post-consumer waste plastic in cementitious concrete composites," Waste Management, vol. 27, no. 2, pp. 310–318, 2007.

24) N. Singh, D. Hui, R. Singh, I.P.S. Ahuja, L. Feo, F. Fraternali. (2017). "Recycling of plastic solid waste: A state of art review and future applications." Compos. Part B Eng., 115, 409–422.

25) P. Choi, R. Almansour and F. Aslani, "Recycled plastic as coarse aggregates in concrete: A comprehensive review," Journal of Building Engineering, vol. 36, p. 102136, 2021.

26) P. Limbachiya, J. Koulouris, A. N. F. Roberts and A. Fried, "Performance of recycled aggregate concrete containing plastic waste," Waste Management, vol. 30, no. 6, pp. 1231–1238, 2010.

27) Raigandhi, S. D., Mane, S. S., & Kore, S. B. (2015). *Use of recycled concrete aggregates*. International Journal for Research in Applied Science & Engineering Technology (IJRASET), 3(7), 218–221.

28) R. Islam, M. M. Rahman and M. A. B. Bhuiyan, "Waste plastic as partial replacement of coarse aggregate in concrete," International Journal of Structural and Civil Engineering Research, vol. 2, no. 1, pp. 10–13, 2013.

29) R. Siddique, P. Khatib and A. Kaur, "Use of recycled plastic in concrete: A review," *Waste Management*, vol. 28, no. 10, pp. 1835–1852, 2008.