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Recycled Coarse Aggregate Treatment Processes for a Sustainable Environment: A Review

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India's demand for infrastructure projects is increasing, putting serious pressure on our existing natural resources. Construction and demolition waste from construction sites, industries, and research laboratories necessitates significant landfill space for disposal. Managing this waste effectively is crucial to mitigate environmental impacts and optimize resource utilization. A lot of energy is also required to transfer this waste to the landfill. To fill the gap and make the environment sustainable, the use of recycled coarse aggregate is a great initiative. The recycled concrete coarse aggregate is attached to the adhered mortar. This attached mortar reduces the physical properties of concrete. It also diminishes its mechanical strength. So, several treatment techniques are available. Surface modification, chemical treatment, mechanical treatment, and more have been invented over the years. Mechanical and thermal treatment with different combinations of steel balls improves the properties of recycled coarse aggregate. This review paper will give an insight into the treatment techniques and some different processes to choose for recycled concrete coarse aggregate in a sustainable environment.

Keywords: Recycled Coarse Aggregate, Adhered mortar, Interfacial transition zone, sustainable material.

1. Introduction

There has been a shift in the times since the year 2000, with a significant increase in urbanization and industrialization worldwide. This has resulted in heightened demand from the construction industry for natural resources (Wang et al., 2020). The waste generated from urban areas consists predominantly of aggregates (47%), addition to materials like brick and plaster (32%), concrete (7%), metal (6%), timber (3%), and other things (5%) (Ojha et al., 2023). On an annual basis, around thirty million tons of construction- and demolition-related debris are produced in India, accounting for around 25% of the total municipal solid waste (MSW) produced (MHUAG 2023). Large-scale construction projects, infrastructure initiatives, and redevelopment activities throughout the country are major contributors to the generation of construction and demolition (C&D) waste (BMTPC 2017). Untreated recycled concrete coarse aggregate (RCCA) has an adverse impact on concrete's characteristics; water absorption increases up to 50 %, and the specific gravity and density of coarse aggregate decrease (Hansen et al., 1992). The presence of adhered mortar (AM) also negatively affects the properties of concrete. The study shows the treated RCCA can be used up to 100% instead of aggregates found in nature, depending on the treatment technique. The non-treated RCCA can be used up to 40% (Ojha et al., 2023). Chen j et al. (2022) and Dawood et al. (2022) show the effect of RCCA on the characteristics of concrete by test and analysis, as shown in Table 1.

Table 1: The Effect of Recycled Concrete Aggregate (RCA) on Concrete Characteristics

Factors	**Effect**	**References**
Modulus of Elasticity	Decreases	Chen j et al.(2022)
Compressive Strength	Decreases up to 25%	Vu x et al.(2021) Dawood et al.(2022)
Splitting and Flexural Tensile Strength	Decreases up to 10%	Dawood et al.(2022)
Water Absorption	Increases up to 50%	Ding et al.(2023)
Bulk Density	Decreases	Wang et al.(2024)
Specific Gravity	Decreases	Suryadi et al.(2022)

2. Methodology

The research execution pathway for the study on Recycled Coarse Aggregate (RCA) involves several key steps in Figure 1. First, comprehensive information is gathered from sources like Science Direct, Google Scholar, and others, using relevant keywords. Next, the study focuses on understanding RCA, analyzing treatment methods, and examining the effects of RCA on concrete properties. A total of 200 publications were searched, with 145 selected after screening. Finally, 50 papers were used for the review, leading to the study's conclusion

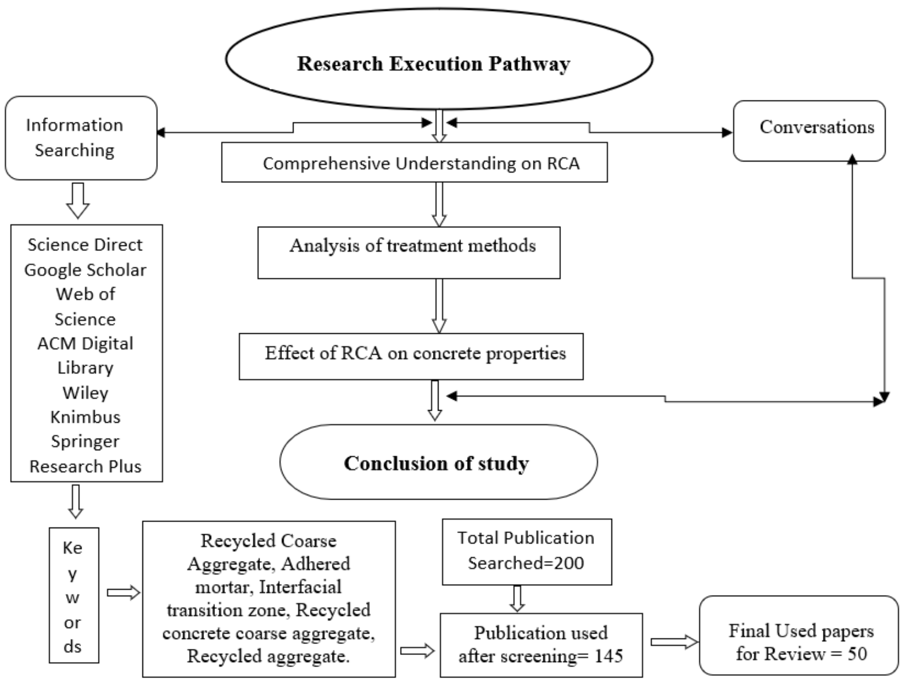

Figure 1: Research execution pathway of the study Recycled coarse aggregate concrete

Figure 2 provides an overview of research conducted on Recycled coarse aggregate concrete with and without treatment across various countries, highlighting the distribution of research activities. India emerges as a prominent contributor with 18 research studies, followed by China with 10 studies and Iraq with 6. Several countries, including Poland, Japan, Canada, Vietnam, and Australia, each have 2 research studies. Other countries such as London, Singapore, Egypt, the United States, Saudi Arabia, Bhutan, Oman, and Finland are represented with 1 research study each. This diverse distribution underscores the global scope of research endeavors across different nations, reflecting their varied contributions to the academic and scientific landscape.

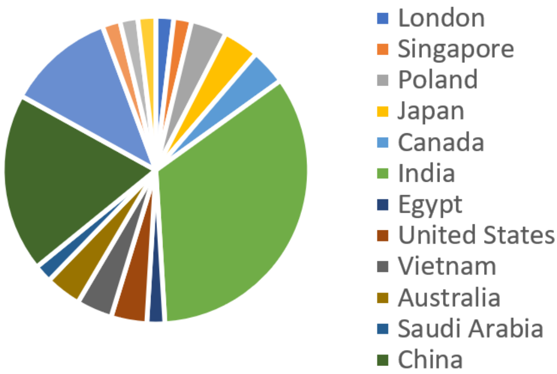

Figure: 2 Overview of Research conducted country-wise

Table 2: Critical Evaluation of RCA Treatment Methods

S.No	Treatment Method	Limitation	References
1	Addition of fiber	Slump get reduced if basalt fiber is used, but not in the case of silica fume and polypropylene fiber.	Ahmed et al. (2020)
2	Surface treatment technique	It does not delve into the long-term effectiveness and strength of concrete made with modified recycled coarse aggregate, which could be crucial for real-world applications.	Merin et al. (2022)
3	Thermal Treatment & Chemical Treatment	While the treatment was carried out at a variety of temperatures (between 250 and 750 °C), it was unclear which particular temperature was most effective in increasing the characteristics of CRCA.Presoaking techniques using strong and weak acids on the durability and performance of CRCA require further investigation.	Bayati et al. (2016)
4	Mechanical treatment	If RCA is treated to reduce water absorption by up to 1%, this will have an impact on the crushing and impact value.	Kim j (2022)
5	Addition of fiber	A hybrid fiber system demonstrates superior performance compared to individual fibers.	Teng et al. (2018)
6	Mixing Approaches	During different mixing processes, it is typical to achieve the required slump and hydration. Requires more time than conventional processes.	Merin et al. (2022)
7	Nanomaterial surface treatment	More study is required to know the quantity of nanomaterial for durability.	Younis et al. (2018)

8	Thermal- mechanical	The bond strength in the case of RAC was reduced by 7 %.	Pandurangan et al. (2016)
9	Thermal treatment	Alone thermal treatment is not cost effective, if RCA is completely made of adhered mortar.	Pawluczuk et al. (2019)
10	Addition of fiber	Long-length fibers enhance post-crack.	Kasagani et al. (2018)
11	Mixing Approaches	More voids and cracks between mortar and RCA generate.	Merin et al. (2022) Tam et al. (2005)
12	Chemo - mechanical treatment	A Large amount of water is required to wash the strong acids used in treatment.	Bayati et al. (2016)

3. FINDINGS & DISCUSSIONS:

Table 2 represents a critical evaluation of a number of recycled concrete aggregate (RCA) treatment methods, highlighting their shortcomings and signifying areas for more study. It highlights the necessity for enriched techniques to deal with problems such as including fiber to reduce slump values, being unsure of the best thermal and chemical treatments, and the complicated consequences of mixing methods on concrete performance.

Researchers and industry practitioners employ several treatment techniques to eliminate AM from waste, hence enhancing the qualities of RCCA. Wang et al.'s results showed that adding calcium silicate hydrate (C-S-H) to recycled coarse aggregate (RCA) greatly improved its performance. The mechanical qualities of recycled aggregate concrete (RAC) were improved, density was raised, and the qualities of the old and new interfacial transition zones (OITZ) were improved (Wang et al. 2021). OITZ mechanical, thermal, chemical, and double treatment methods are exhibiting positive effects on the qualities of newly produced concrete from construction and demolition waste (C&D).

A. Thermal treatment

The thermal treatment is a process where the adhered mortar is removed. This is achieved by heating the recycled coarse aggregate to a specific temperature. It is done in two ways: traditional heating and microwave heating. The AM was detached from the aggregate by the difference in thermal expansion coefficient (Shaban et al., 2019). Above 500 0C the heat treatment shows negative results, and 350 °C heat treatment, followed by a quick mechanical treatment, produces the best outcomes. (Bayati et al., 2016).

B. Mechanical treatment

Mechanical treatment is done by the Los Angeles machine but the recycled concrete aggregate has different charges and varying numbers of revolutions. The colliding of RCA with charges removes the AM from it and improves its properties. This study aims to investigate the impact of several influencing parameters with four replacement levels of recycled aggregate (0%, 33%, 67%, and 100%). There are two maximum aggregate sizes: 10 mm and 20 mm. The treatment methods include cement-silica fume slurry treatment, sodium silicate solution treatment, and Los Angeles (LA) abrasion treatment. According to Alqami et al. (2021), the Los Angeles abrasion treatment of RCA was the most effective of the three treatment techniques. The treated RCA had higher tensile and compressive strengths and less water absorption.

C. Thermal- mechanical treatment

The study focuses on exploring the efficacy of thermal-mechanical treatment as a method to enhance recycled concrete aggregates (RCAs). This treatment involves a sequential process where RCA samples undergo initial mechanical and chemical treatments to facilitate the removal of adhering mortar. Subsequently, the treated aggregates are subjected to high temperatures, specifically heated for two hours at 400 °C. This controlled thermal exposure aims to further cleanse the RCA surfaces and modify their chemical and physical properties. The overarching goal is to improve bonding characteristics and reduce any residual contaminants that might affect the RCA's performance in concrete applications.

By gradually adjusting both temperature and exposure duration during the thermal phase, researchers sought to achieve optimal results in removing adhering mortar from the RCA. This dual treatment approach not only cleanses the aggregates but also alters their surface to potentially enhance bonding with cementitious materials. The study emphasizes the importance of precise thermal-mechanical treatments in maximizing the quality and performance of recycled concrete aggregates, offering insights into sustainable practices for enhancing the properties of concrete mixes in construction applications (Yunusa et al., 2022).

D. Chemical treatment

A Micro-Deval device was applied during the brief mechanical treatment, whereas the presoaking procedure used both strong acid (HCl) and weak acid ($C2H4O2$). Since weak acid is safer and less dangerous to use, it is preferable to strong acid. (Et al., Bayati, 2016). So chemical treatment is also good for removing the adhered mortar but can be used for research purposes.

E. Chemical mechanical treatment

This treatment technique combines chemical presoaking with mechanical processes to enhance recycled concrete aggregates (RCA). The study involved preparing and testing six series of concrete mixtures after subjecting the RCA to scrubbing and heat treatment with hydrochloric acid (HCl) and sulfuric acid ($H2SO4$). The findings indicate that heating the aggregates and treating them with $H2SO4$ prior to scrubbing results in aggregates with reduced water absorption. These modified aggregates exhibit characteristics similar to natural aggregates, suggesting improved performance when used in concrete mixes.

Concrete produced with these modified aggregates demonstrates qualities comparable to those made with natural aggregates. The study highlights the potential of this combined chemical and mechanical treatment approach to enhance the properties of recycled concrete aggregates, aiming to achieve similar performance standards as conventional concrete. The research underscores the importance of effective treatment methods in the recycling process, offering insights into sustainable practices that could contribute to the broader adoption of recycled materials in construction applications (Purushothaman et al., 2015).

F. Mixing approach differently

Novel mixing techniques are created to lower RCA's absorption of water and enhance its characteristics. The compressive strength of recycled aggregate concrete (RAC) was improved by utilizing two different materials in three separate surface preparation processes and three different mixing methodologies. Experimental results showed that the quality of RAC can be significantly improved by using the right surface pretreatments and mixing techniques. The water-to-cement ratio of the pretreated materials proved to be critical. Furthermore, optimized RAC with 100% recycled coarse aggregate achieved a remarkable compressive strength at 28 days attaining 43.3 mega Pascal (6,277 psi) (Liang et al., 2015).

G. Surface treatment with nanomaterials

Nanomaterials containing slurries improve the properties of RCA by improving the ITZ in recycled aggregate concrete. Nanoindentation analysis confirmed strengthened old mortars and overall macroscopic improvements in RA and RAC post-treatment (Zhang et al., 2016). This study proposed two optimization methods focusing on enhancing "carbonation" and "slurry wrapping" treatments. These methods aim to elevate the quality of recycled aggregate and enhance the performance of recycled concrete (Wang et al., 2020). This study investigates the

enhanced bonding effect achieved by applying surface treatment agents to recycled aggregates. Both medium-quality and poor-quality recycled aggregates were used in material experiments. There were two different kinds of agents used: silane-based and oil-based. Results indicate that aggregates treated with the silane-based agent showed significant improvement in recovery rate but exhibited reduced strength. Conversely, aggregates treated with the oil-based agent demonstrated slightly higher recovery rates compared to untreated aggregates and also exhibited improved hardening properties (Tsujino et al, .2007).

H. Use of fibres

The use of fibers in the RCCA mix enhances its properties and durability. This study examined the use of recycled coarse aggregates and fibers in sustainable concrete. The tensile strength improved by increasing the fiber content, and at the fiber-paste interface, the crack width is comparatively much less. Mixes made of 20% RCA containing either 1% ST fibers or 1% PP fibers, or a combination of 0.75% ST fibers and 0.25% PP fibers, were recommended. This recommendation considers both economic performance and improved properties. (Mohseni et al.,2017).

4. OBJECTIVE OF THE REVIEW

This paper's goal is to thoroughly examine and evaluate several methods of treating recycled concrete coarse aggregate (RCCA). Its objective is to assess the extent to which these methods may improve the surface, chemical, physical, and mineralogical characteristics of RCA while also successfully removing adhering mortar. The goal of the paper is to offer insights into the best treatment approaches for promoting the long-term use of RCCA in real applications by combining the results of current investigations. The ultimate objective is to help the construction sector minimize its negative environmental effects and maximize its use of resources.

5. ANALYSIS OF FINDINGS

The table offers a critical assessment of the several ways that recycled coarse aggregate (RCA), which is used to make concrete, is treated. Every technique is evaluated according to its constraints and relevant references, offering an understanding of the difficulties and possible advancements in augmenting the characteristics of RCA. The research reveals several motives, including First, aggregate strength characteristics may be impacted by mechanical treatments like crushing and impact value modifications, which are sensitive to decreases in water absorption. Second, chemical treatments such as chemo-mechanical and thermal processes draw attention to the need for acid washing and temperature variability, implying that it can be difficult to optimize treatment conditions consistently for improved performance. Thirdly, the inclusion of fibers—both synthetic and natural—shows promise for enhancing durability and crack resistance, however further investigation is required to determine the ideal combinations and kinds of fiber. The use of nonmaterial or conventional methods for surface treatments suggests that accurate dosage and long-term performance assessments are necessary to determine their efficacy in practical applications. Overall, the table shows for the purpose to effectively progress the use of RCA in sustainable concrete practices, extensive studies incorporating durability, long-term performance, and realistic application situations are necessary. The shortcomings of each technique and potential study topics are pointed out in detail, directing future efforts to optimize RCA treatments for wider application in the building sector.

Table: 3 Physical and mechanical properties analysis of tests done on the mix

Source	**Year**	**Compressive strength**	**Split Tensile**	**Flexural strength**	**Density**	**Water absorption**	**Non-Destructive test**	**workability**
Dhaheer et al.	2024	yes	yes	yes	yes	yes	yes	no
Karthikeyan et al.	2023	yes	no	no	no	yes	yes	no
Yang et al.	2023	no	no	no	yes	yes	no	no
Tenzin et al.	2023	yes	yes	no	no	no	no	no
Rizwan et al.	2022	yes	no	yes	no	no	no	no
Merin et al.	2022	yes				yes	no	no
Alyaseen et al.	2021	yes	yes	yes	yes	no	no	no
Nagaraja et al.	2022	yes	no	yes	yes	no	no	yes
Deepak et al.	2022	yes	no	yes	yes	yes	yes	no
Makul et al.	2021	yes	yes	yes		yes	no	no
Gunasekara et al.	2020	yes	no	no	no	no	no	no
Meddah et al.	2020	yes	no	no	no	no	no	no
Suryawanshi et al.	2020	yes	yes	yes	yes	yes	no	no
Raman et al.	2023	yes	yes	yes		yes	no	no
Detterborn et al.	2017	yes	no	no	yes	yes	no	no
Atamajayanti et al.	2018	yes	yes	no	no	yes	no	no
Albayati et al.	2016	no	no	no	no	no	no	yes

The table 3 presents a comprehensive analysis of physical and mechanical properties testing conducted on various mixes by different researchers between 2016 and 2024. Key properties evaluated include compressive strength, split tensile strength, flexural strength, density, water absorption, non-destructive testing, and workability, revealing diverse research findings and methodologies across the studies. This compilation underscores the breadth of research efforts aimed at understanding and enhancing the performance characteristics of different mix compositions in construction and materials science.

6. Conclusion

It is analysed by investigating the different mechanisms of treatment of RCA that the method of treatment of the recycled coarse aggregate specifically depends upon the source of recycled coarse aggregate such as type of RCA, the location of origin of RCA, the amount of mortar and shape of the aggregate. All these above-mentioned parameters are responsible for the efficacy of the method of treatment. From the reviewed publications it is clear that as compared to the untreated RCA, the rationally chosen method used for the treatment improves their mechanical, physical and durability properties. If the aggregate surface physical property is improved by detaching the adhered mortar to the recycled aggregate will require a less water-cement ratio which will enhance the quality of the Recycled coarse aggregate properties, thus bringing their quality closer to that of the virgin aggregate. While choosing the appropriate method for the treatment of RCA, sustainability and cost-effectiveness needs to be taken care of. The researchers have used various methods and techniques for the quality enhancement of the concrete with RCA such as mechanical methods, which are effective in the removal of the adhered mortar by varying the number of drum revolution & steel balls; chemical methods improve the quality of RCA by using different strength of acids with a limitation the higher strength acid improves the surface property which reducing the crushing value of the aggregate, thermal methods at temperature 400 degree Celsius are also effective in removing the adhered mortar and thermally treated along with mechanical process also .Different mixing approaches by use of fibres, admixture and nanomaterial for quality improvement of concrete with RCA can be applicable. After reviewing 50 different research articles involving different mechanisms, it can be concluded that the thermal-mechanical treatment method gives the best results in terms of quality improvement of the concrete formed by RCA subjected to the source of recycled aggregate. This review will give insight into the treatment methods to research personnel and the construction industry for rationally opting the method of treatment of RCA to obtain a higher quality recycled coarse aggregate concrete.

References

1. Ahmed, T.W., Ali, A.A.M. and Zidan, R.S., 2020. Properties of high strength polypropylene fiber concrete containing recycled aggregate. Construction and Building Materials, 241, p.118010.
2. Alqarni, A.S., Abbas, H., Al-Shwikh, K.M. and Al-Salloum, Y.A., 2021. Treatment of recycled concrete aggregate to enhance concrete performance. Construction and Building Materials, 307, p.124960.
3. Al-Bayati, H.K.A., Das, P.K., Tighe, S.L. and Baaj, H., 2016. Evaluation of various treatment methods for enhancing the physical and morphological properties of coarse recycled concrete

aggregate. Construction and Building Materials, 112, pp.284-298.
4. Al-Bayati, H.K.A., Tighe, S.L. and Baaj, H., 2016. Effect of different treatment methods on the interfacial transition zone microstructure to coarse recycled concrete aggregate. In TAC 2016: Efficient Transportation-Managing the Demand-2016 Conference and Exhibition of the Transportation Association of Canada.
5. Alyaseen, A., Shah, S., Solanki, R., Daxini, B., Alwani, Y.K. and Alahmad, H., 2021, April. Reuse of improved recycled concrete aggregates (RCA) for sustainable and environmental-friendly construction materials. In IOP Conference Series: Materials Science and Engineering (Vol. 1145, No. 1, p. 012024). IOP Publishing.
6. Al-Bayati, H.K.A., Tighe, S.L. and Baaj, H., 2016. Effect of different treatment methods on the interfacial transition zone microstructure to coarse recycled concrete aggregate. In TAC 2016: Efficient Transportation-Managing the Demand-2016 Conference and Exhibition of the Transportation Association of Canada.
7. Atmajayanti, A.T. and Haryanto, Y., 2018. The effect of recycled coarse aggregate (RCA) with surface treatment on concrete mechanical properties. In MATEC Web of Conferences (Vol. 195, p. 01017). Edp Sciences.
8. Building Materials & Technology Promotion Council (2017), Ministry of Housing & Urban Poverty Alleviation. “Guidelines for Utilization of C&D Waste”.
9. Chen, J., Zhou, Y. and Yin, F., 2022. A Practical Equation for the Elastic Modulus of Recycled Aggregate Concrete. Buildings, 12(2), p.187.
10. Dawood, M.H. and Al-Asadi, A.K., 2022. Mechanical properties and flexural behaviour of reinforced concrete beams containing recycled concrete aggregate. Przegląd Naukowy. Inżynieria i Kształtowanie Środowiska, 31(4).
11. Dhaher, M.A., Nahhab, A.H. and Nasr, M.S., 2024. Development of treated coarse recycled aggregate-based sustainable fibrous high-strength concrete with fine recycled aggregates. Materials Science-Poland, 42(2), pp.1-15
12. Ding, Y., She, A. and Yao, W., 2023. Investigation of Water Absorption Behavior of Recycled Aggregates and Its Effect on Concrete Strength. Materials, 16(13), p.4505.
13. Deepak, O.P., Krishnakumar, R., Krishnagopal, M. and Vishnu, P., Reuse of Coarse Aggregate as Recycled Aggregate in Concrete. Materials Research Proceedings, 23.
14. Detterborn, T. and Korkiala-Tanttu, L., 2017. Environmentally sustainable use of recycled crushed concrete aggregate in earthworks. Proc. 19th ICSMGE.
15. Gunasekara, C., Seneviratne, C., Law, D.W. and Setunge, S., 2020. Feasibility of developing sustainable concrete using environmentally friendly coarse aggregate. Applied Sciences, 10(15), p.5207.
16. Hansen, T.C., 1992. Recycling of demolished concrete and masonry. CRC Press.
17. Kim, J., 2022. Influence of quality of recycled aggregates on the mechanical properties of recycled aggregate concretes: An overview. Construction and Building Materials, 328, p.127071.
18. Kasagani, H. and Rao, C.B.K., 2018. Effect of graded fibers on stress strain behaviour of Glass Fiber Reinforced Concrete in tension. Construction and Building Materials, 183, pp.592-604.
19. Karthikeyan, S., Neelakantan, T.R. and Jagan, S., 2023. Microbial technique to treat recycled aggregates from construction waste for its effective reutilization in concrete. Global NEST Journal, 25, pp.1-8.
20. Liang, Y.C., Ye, Z.M., Vernerey, F. and Xi, Y., 2015. Development of processing methods to improve strength of concrete with 100% recycled coarse aggregate. Journal of Materials in Civil Engineering, 27(5), p.04014163.
21. Ministry of Housing and Urban Affairs Government of India. (2021). “Draft on Circular Economy in construction and demolition waste”.
22. Mohseni, E., Saadati, R., Kordbacheh, N., Parpinchi, Z.S. and Tang, W., 2017. Engineering and

microstructural assessment of fibre-reinforced self-compacting concrete containing recycled coarse aggregate. Journal of Cleaner Production, 168, pp.605-613.

23. Merin, M., Girija, K. and Sreedevi, A.R., 2022, December. Strengthening of Recycled Coarse Aggregate using Different Surface Treatment Techniques. In ASPS Conference Proceedings (Vol. 1, No. 1, pp. 165-169).
24. Merin, M., Girija, K. and Sreedevi, A.R., 2022, December. Strengthening of Recycled Coarse Aggregate using Different Surface Treatment Techniques. In ASPS Conference Proceedings (Vol. 1, No. 1, pp. 165-169).
25. Merin, M., Girija, K. and Sreedevi, A.R., 2022, December. Strengthening of Recycled Coarse Aggregate using Different Surface Treatment Techniques. In ASPS Conference Proceedings (Vol. 1, No. 1, pp. 165-169).
26. Makul, N. and Makul, N., 2021. Principles of Tailor-Made Recycled Aggregate Concrete. Principles of Cement and Concrete Composites, pp.115-148.
27. Meddah, M.S., Al-Harthy, A. and A. Ismail, M., 2020. Recycled concrete aggregates and their influences on performances of low and normal strength concretes. Buildings, 10(9), p.167.
28. Nagaraja, K., PraveenGannavaram, V., Kavali, M., Naidu, K.N. and Sadhvika, P., 2022, September. Comprehensive Study for Engineering usage of Sustainable Concrete using Recycled Coarse Aggregates, Crumb Rubber and Steel Fibers. In IOP Conference Series: Earth and Environmental Science (Vol. 1086, No. 1, p. 012055). IOP Publishing.
29. Ojha, P.N., Mohapatra, B.N., Puneet, K. and Singh, B., 2023. MANAGEMENT AND CLASSIFICATION OF CONSTRUCTION AND DEMOLITION WASTE IN INDIA. Sustainable Structures and Materials, An International Journal, 6(1), pp.13-25.
30. Ojha, B., Kaura, P.N. and Singh, P., 2023. Studies on mechanical performance of treated and non-treated coarse recycled concrete aggregate and its performance in concrete-an Indian case study. Res Eng Struct Mater, 10, pp.341-362.
31. Purushothaman, R., Amirthavalli, R.R. and Karan, L., 2015. Influence of treatment methods on the strength and performance characteristics of recycled aggregate concrete. Journal of Materials in Civil Engineering, 27(5), p.04014168.
32. Pandurangan, K., Dayanithy, A. and Prakash, S.O., 2016. Influence of treatment methods on the bond strength of recycled aggregate concrete. Construction and Building Materials, 120, pp.212-221.
33. Pawluczuk, E., Kalinowska-Wichrowska, K., Bołtryk, M., Jiménez, J.R. and Fernández, J.M., 2019. The influence of heat and mechanical treatment of concrete rubble on the properties of recycled aggregate concrete. Materials, 12(3), p.367.
34. Rizwan, S.A., Irfan-ul-Hassan, M., Rahim, A., Ali, S., Sultan, A., Syamsunur, D. and Md Yusoff, N.I., 2022. Recycled Coarse Aggregate for Sustainable Self-Compacting Concrete and Mortar. Advances in Materials Science and Engineering, 2022(1), p.4566531
35. Raman, J.V.M. and Ramasamy, V., 2023. Dissimilar surface treated recycled coarse aggregate in concrete. Cement-Wapno-Beton= Cement Lime Concrete, 28(3), pp.146-168.
36. Shaban, W.M., Yang, J., Su, H., Mo, K.H., Li, L. and Xie, J., 2019. Quality improvement techniques for recycled concrete aggregate: A review. Journal of Advanced Concrete Technology, 17(4), pp.151-167.
37. Suryadi, A., Qomariah, Q. and Susilo, S.H., 2022. The Effect of the Use of Recycled Coarse Aggregate on the Performance of Self-Compacting Concrete (SCC) and Its Application. Eastern-European Journal of Enterprise Technologies, 2(6), p.116.
38. Suryawanshi, P.S. and Patwari, V.G., 2020. STANDARD RECYCLED AGGREGATE CONCRETE INCORPORATE WITH MICRO SILICA.
39. Tsujino, M., Noguchi, T., Tamura, M., Kanematsu, M. and Maruyama, I., 2007. Application of

conventionally recycled coarse aggregate to concrete structure by surface modification treatment. Journal of Advanced Concrete Technology, 5(1), pp.13-25.
40. Tam, V.W., Gao, X.F. and Tam, C.M., 2005. Microstructural analysis of recycled aggregate concrete produced from two-stage mixing approach. Cement and concrete research, 35(6), pp.1195-1203.
41. Teng, S., Afroughsabet, V. and Ostertag, C.P., 2018. Flexural behavior and durability properties of high performance hybrid-fiber-reinforced concrete. Construction and Building Materials, 182, pp.504-515.
42. Tenzin, R.Y., Drakpa, L., Deki, T., Subba, S., Norbu, C. and Kuenchap, P., 2023. Recycled aggregate concrete (rac): A viable solution for sustainable construction. Journal of Applied Engineering, Technology and Management, 3(1), pp.63-69.
43. Vu, X.H., Vo, T.C. and Phan, V.T., 2021. Study of the compressive strength of concrete with partial replacement of recycled coarse aggregates. Engineering, Technology & Applied Science Research, 11(3), pp.7191-7194.
44. Wang, C.Q., Cheng, L.X., Ying, Y. and Yang, F.H., 2024. Utilization of all components of waste concrete: Recycled aggregate strengthening, recycled fine powder activity, composite recycled concrete and life cycle assessment. Journal of Building Engineering, 82, p.108255.
45. Wang, J., Zhang, J., Cao, D., Dang, H. and Ding, B., 2020. Comparison of recycled aggregate treatment methods on the performance for recycled concrete. Construction and Building Materials, 234, p.117366.
46. Wang, R., Yu, N. and Li, Y., 2020. Methods for improving the microstructure of recycled concrete aggregate: A review. Construction and Building Materials, 242, p.118164.
47. Wang, X., Yang, X., Ren, J., Han, N. and Xing, F., 2021. A novel treatment method for recycled aggregate and the mechanical properties of recycled aggregate concrete. Journal of Materials Research and Technology, 10, pp.1389-1401.
48. Younis, K.H. and Mustafa, S.M., 2018. Feasibility of using nanoparticles of SiO2 to improve the performance of recycled aggregate concrete. Advances in Materials Science and Engineering, 2018(1), p.1512830.
49. Yunusa, M., Zhang, X., Cui, P. and Tian, X., 2022. Durability of Recycled Concrete Aggregates Prepared with Mechanochemical and Thermal Treatment. Materials 2022, 15, 5792.
50. Yang, S., Gu, M., Lin, H. and Gong, Y., 2023. Property improvement of recycled coarse aggregate by accelerated carbonation treatment under different curing conditions. Sustainability, 15(6), p.4908.
51. Zhang, H., Zhao, Y., Meng, T. and Shah, S.P., 2016. Surface treatment on recycled coarse aggregates with nanomaterials. Journal of Materials in Civil Engineering, 28(2), p.04015094