World Journal of Engineering Research and Technology
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BASIC PROPERTIES OF RECYCLED COARSE AGGREGATES FROM DEMOLISHING WASTE: A REVIEW

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Article Received on 28/12/2021 Article Revised on 18/01/2022 Article Accepted on 08/02/2022

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ABSTRACT

Use of demolishing waste in new concrete as coarse aggregates not only solves the waste management issue to some extent, protect the environment from bad impacts of the waste and associated problems but also provide an alternative material in place of conventional ingredients of concrete. However, its basic properties and properties of concrete utilizing it must be checked to ensure serviceability of concrete without compromising on key parameters, i.e., strength. The influence of the basic properties of the material on final strength of the product is evident. Therefore, this article presents a comprehensive review of the basic properties of the recycled coarse aggregates from demolishing waste determined by several scholars around the world. It is believed that the outcome will not only enrich the literature on the topic but also will help the future researchers of the field in comparison and analysis of the properties.

KEYWORDS: Demolishing waste, recycled aggregates, water absorption, moisture content, specific gravity, density, unit weight, dry rodded density, flakiness, elongation, abrasion, soundness, sustainable development.

1. INTRODUCTION

With time development of social trends, technology, and materials led the governments and associated institutions to adopt new aspects of development. Same is the case with construction industry. Above aspects and growing population in developed regions have forced the industry to meet the demand of shelter and associated facilities by adopting vertical expansion in place of short height structures. Vertical expansion has also become important for almost all the countries to remain in line with socioeconomic trends of the globe. New construction is also unavoidable as with time deterioration of existing structures make them less usable. Both factors need demolishing of old or small height structures. It generates the demolishing waste in large quantum. Originally it was used as filling material in no load areas and the remaining was dumped in landfills. With time shortage of space for such a purpose particularly in metropolitan and cosmopolitan areas have posed serious problem of the waste. The disposal of the waste is now done by throwing it in or near by useful agricultural lands, transported to far distances or left unattained. All the options create additional problems of destruction of useful land, economy, and environmental problems. Aesthetic view of the area is an additional problem if the waste is not properly disposed.

New construction and its boom on other hand require large amounts of conventional ingredients of concrete. To meet the demand, associated industry runs for more time resulting in emission of dangerous gases to the extent that the environmental issues become prominent. Also, this consumption eradicates the natural deposits posing future issues of availability of such material. The factor in turn requires finding of the indigenous / alternative materials as substitute of conventional ingredients. Among several solutions for the issues, one of the best options is the use of this waste on site particularly in new concrete as aggregates. The idea require good research thus has become the active area of research among scholar around the globe.

Several indigenous materials have been attempted in concrete as replacement of its constituent ingredients. Demolishing waste have also been used in new concrete as replacement of fine and coarse aggregates; partially or completely. But major focus is on use of the waste as coarse aggregates as it consumes more quantity of the waste. The properties of the waste as coarse aggregates and the properties of concrete using it have also been studied by several researchers. However, the scatter in results is probably one of the major hurdles in setting up the standards for the material. Therefore, this research work attempts to review the basic properties of the waste as coarse aggregates from available state of art. It is believed that the outcome of the work will not only summarize the properties but will help the future researchers in the field with ready source for comparison and analysis.

2. LITERATURE REVIEW

This section provides the summary of available state-of-art on the use of demolishing waste in preparation of new concrete. The waste obtained from demolishing of the structures has been researched by several scholars around the world for processing it in required size and shape, problems and hurdles associated with it, its properties, properties of concrete utilizing it in fresh and hardened state. Taboada et. al.[7] reviewed the quality of waste as aggregate with reference to its compressive strength. The authors prepared data database of existing work and compared with results published by several scholars in the field. The authors observed prosperous use of the material with scatter in obtained results. Sellakkannu and Subramani.[13] also reviewed the literature for properties of the demolishing waste. Based on the findings authors argued that the compressive strength of concrete using recycled aggregates is much affected when it is used as coarse aggregates than when it is used as fine aggregates. The recycled coarse aggregates also influence modulus of elasticity. They suggest blending it with conventional aggregates, removing attached mortar at processing plant, saturating the aggregates before use may solve the problem to some extent. Nuruzzaman and Salauddin.[15] reviewed the literature with reference to increase in population, demand of the infrastructure and generation of the waste and argues that the use of the material leads towards better sustainability of the construction industry and has several positive effects on various aspects of construction and environment. Fonteboa et. al.[17] reviewed the state-of-art on use of recycled aggregate properties. The authors attempted to predict the performance of the waste in concrete based on the published results. The research attempted to develop the numerical equations to predict the performance of recycled concrete in terms of strength, modulus of elasticity, creep, shrinkage, and stress-strain. Xiao and Li.[23] are reviewed the literature on subject matter published during 15 years in China. The focus of the article was on the properties of aggregate, failure mechanism of micro and meso structures, durability for chloride diffusion and seismic performance. The findings of the article were that although scatter in results is present yet with proper design and construction recycled aggregate can be successfully used in structure works. Review of 163 publications over the period of 26 years (1992 – 2018) was done by dos-Reis et. al.[27] The article not only reviewed the use of the waste in concrete production but also its use as water decontamination agent and found the material suitable for both aspects. However, authors argued that the physical, chemical, and mechanical properties of the aggregates play an important role in deciding its use for proper application. Gagan and Agam[52] reviewed the literature for flexural behavior of the recycled aggregate concrete. The study focused on the central deflection and peak load for reinforced recycled aggregate concrete beams and found that central deflection is higher and peak load is lower when compared with conventional reinforced concrete beams, however both the parameter values were higher than theoretical values of the parameters. Therefore, they proposed use of fibers to improve the parameters.

2.1 Fineness modulus: It is index number representing the average size of the particles in sieved lot of the aggregates. It mainly depends on the size of the aggregates for a volume of aggregates with maximum 20mm size aggregates it ranges between 6.0 – 6.9. Different scholars of research community have evaluated the fineness modulus of both recycled and conventional aggregates. The results obtained by ten different scholars are compared in Figure 1. Comparing the maximum values of the parameter it is observed that the fineness modulus of RCA is lower compared to conventional aggregates by about 14%. Whereas the comparison for minimum recorded values it may be noted that fineness modulus of recycled aggregates was recorded 55% higher than the fineness modulus of conventional aggregates. The standard deviation of quoted results for conventional aggregates is 1.57 whereas the same for recycled aggregates is 0.65. This shows that deviation of the sizes of recycled aggregates from its mean value is less compared to conventional aggregates. The highest value of the parameter reported in article[4] is higher than allowable maximum value of the parameter. Therefore, recycling of the aggregates should carefully be done, also, the sieving of the aggregates should also be done in the way to ensure proper gradation of the aggregates resulting in control of the fine ness modulus. Which in turn will ensure minimum effect on the hardened properties of the concrete using the aggregates.

2.2 Water absorption: It is amount of water absorbed by the material when exposed to water and is represented as percentage. The factor is highly important with respect to concrete mix as it may violate the water quantity required for the mix. In case of recycled aggregates old mortar attached with the aggregates absorbs more water than conventional aggregates. A solution to it is that recycled aggregates may be used in saturated surface dry state or use of the water reducing admixture. But in field it is not practiced therefore the water demand of recycled aggregates must be adjusted in water-cement ratio of the mix for proper workability of the mix. The method of recycling the waste into aggregates may influence greatly the quantum of the mortar attached. Therefore, determination of this parameter is one of the key parameters for proper utilization of the recycled aggregates. Lot of research studies have performed tests to evaluate the water absorption of the aggregates. Water absorption results of both recycled and conventional aggregates published in 39 different articles are plotted as bar graph in Figure 2. It may be observed that for minimum water absorption recoded for recycled aggregates is 0.32% and the maximum value is observed equal to 9% with standard deviation of 2.18. The same for conventional aggregates is in the range of 0.3 – 2.69. The percentile increase in water absorption of recycled aggregates is about 335% then maximum recorded value of the parameter for conventional aggregates. Although the deviation in the result of parameter is evident for both conventional and recycled aggregates, but the deviation of conventional aggregates is marginal whereas the deviation in the observed values of the parameter for recycled aggregates is high. This requires careful consideration of the same while designing the water-cement ratio of the concrete mix to avoid segregation and honey combing in hardened state.

2.3 Specific gravity: It is ratio of volume of aggregates to an equal volume of water. The parameter is important as it affects the torque and power of the mixer resulting in improper mixing of the concrete ingredients. For aggregates used in construction it normally ranges between 2.5 – 3.0 with average value of 2.68. Specific gravity of recycled aggregates is normally less than the specific gravity of the conventional aggregates due to old mortar adhered with the waste. Literature reports test results of specific gravity of recycled aggregates and its comparison with conventional aggregates by different scholars. Test results of specific gravity of both recycled and conventional aggregates reported by 25 scholars are plotted in Figure 3. It may be observed that test results are as low as 1.17 and as high as 2.65, whereas the same for conventional aggregates is reported in the range of 2.35 – 2.96. The test results of conventional aggregates fall in the specified range whereas the maximum reported result of specific gravity for recycled aggregates is even less than the average allowable value (2.68) of the parameter. It is further observed from the comparison of the maximum values of specific gravity reported that specific gravity of recycled aggregates is 10.47% less than the maximum value of specific gravity of conventional aggregates. It is also observed that the standard deviation of specific gravity of recycled aggregates (0.32) is almost double than the standard deviation of the parameter of conventional aggregates (0.15). This shows that the density of the aggregates is affected due to old mortar adhered with the aggregates. Therefore, this factor must be given due consideration while designing the concrete mix with recycled aggregates.

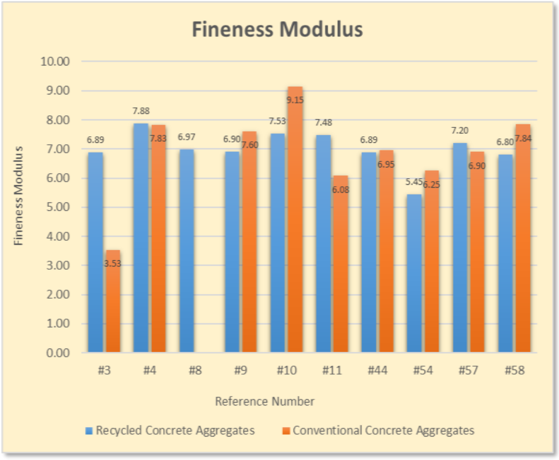

Figure 1: Fineness modulus.

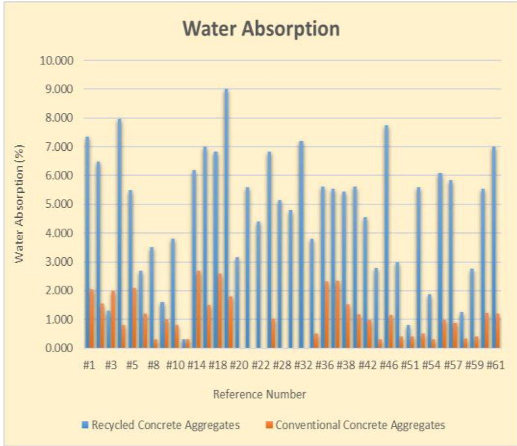

Figure 2: Water absorption.

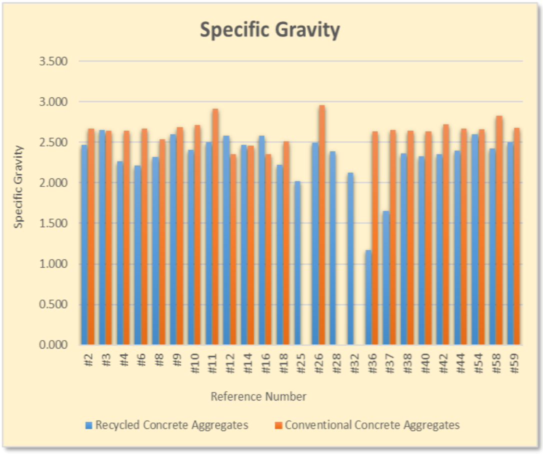

Figure 3: Specific gravity.

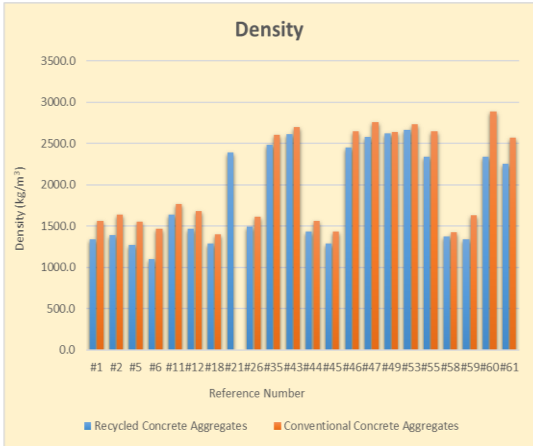

Figure 4: Density.

2.4 Density: Mass or weight per unit volume is defined as density. It is quantitative measure of mass contained per unit volume. 1450 – 2082 kg/m^3 is the range of the density of the aggregates used for construction. Density of the aggregates recycled from demolishing waste is not same as those of virgin aggregates due to age, usage during previous service life, old mortar attached with them. It is also evident from the literature that the density of the recycled aggregates is less compared to conventional aggregates. Test results of the parameter from available state-of-art (22 articles) are plotted in Figure 4 along with the density results of conventional aggregates. It may be observed that the density of recycled aggregates is in the range of 1103 – 1403 kg/m^3 whereas 2660 – 2885 kg/m^3. On the other hand, while checking the standard deviation for both recycled and conventional aggregates is same. It may also be observed that percentile decrease in the parameter value is 7.8 in comparison to that of conventional aggregates. The observation further reveals that the density of conventional aggregates is even higher than the maximum allowable limit of the parameter, whereas the maximum reported value of density of recycled aggregates is little lower than the lowest allowable limit of the aggregates. The scatter in the observed results of the parameter is also evident. Therefore, due consideration must be given to this parameter for proper workability and strength of the concrete using it.

2.5 Unit weight: Unit weight or bulk density is another property of the aggregates to determine its quality. It is weight in compact form of aggregates to fill unit volume. It is also helpful in determining the voids. The parameter is a necessary measure used for mix design by absolute volume method. 1200-1750 kg/m^3 is taken as the range of the aggregates used in normal weight concrete. However, deviation in the readings of the parameter for recycled aggregates is evident from the literature. Several scholars evaluated the parameter for recycled aggregates and compared it with that of the conventional aggregates. Dhaqane.[25] in his research programs to check the quality of recycled aggregates from Mogadishu observed unit weight of aggregates equal to 1095 kg/m^3 whereas Arezoumandi et. al.[42] in their research program on evaluation of flexural strength of recycled concrete beams cast with 100% recycled aggregates observed 1440 kg/m^3 as the unit weight of the recycled aggregates. The first reported value is even less than the lower value of the range of unit weight of conventional aggregates. Whereas the second report values fall within the allowable range of the parameter for conventional aggregates. This shows that quality of recycled aggregates even varies from place to place and is dependent on several factors. Thus, determination of the basic properties is essential to ensure proper performance of the material.

2.5 Abrasion: It is resistance of aggregates against crushing, degradation, and disintegration. Also known as measure of toughness of aggregates. ASTM C131 provides the test procedure to determine the abrasion of the aggregates along with the maximum permissible values for different sized aggregates. The tougher the aggregates higher will be the strength of the product using it. Thus, evaluation of this property gives the idea of the strength of the concrete at hardened state. Figure 5 shows the bar graph of the test results abrasion resistance of recycled aggregates of 14 scholars along with comparison with the results of conventional aggregates. It may be observed that the degradation of the recycled aggregates was in the range of 24% - 52% whereas the range of the degradation of the conventional aggregates was in the range of 8% - 49%. The maximum values of both aggregates differ by +7% for recycled aggregates. It may also be observed that standard deviation of recycled aggregates was about 3% lower than standard deviation of the conventional aggregates. From the reported results it may also be observed that variation in the outcome of the test results for conventional aggregates was more compared to the recycled aggregates.

2.6 Impact value: Resistance to suddenly applied or shock loads is known as impact value. Sudden or impact load although are seldom but their possibility can not be neglected during service life of concrete structures. Therefore, the concrete thus the aggregates used in it, should be strong enough for these loads to ensure the proper serviceability of the structure. Impact value less than 20% represent exceptionally strong aggregates, 10% - 20% is treated as strong, 20% - 30% is considered satisfactory but should not be less than 35%. For cement concrete value of 30% is treated as satisfactory. Impact value of recycled aggregates has been evaluated by different scholars around the globe. The test results published by 12 researchers are plotted in Figure 6 along with the same for conventional aggregates. The lowest result reported is 9% whereas the maximum result reported is 35.0% for recycled aggregates. The same for conventional aggregates was recorded in the range of 3.6% - 30%. Although the minimum values of the parameter differed much but the maximum reported values differed only by 17%. The standard deviation of the parameter for recycled and conventional aggregates was observed 9% and 8% respectively. It is again clear from the test results of this value that the age and old mortar attached result in higher disintegration. It must be considered properly before making final decision of using the aggregates in new concrete.

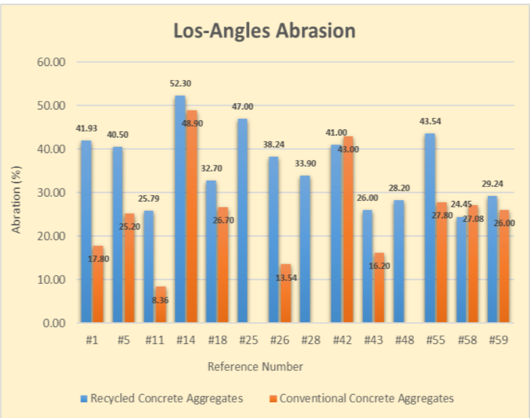

Figure 5: Abrasion.

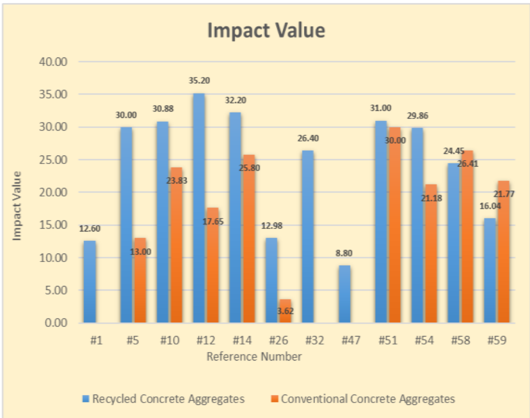

Figure 6: Impact value.

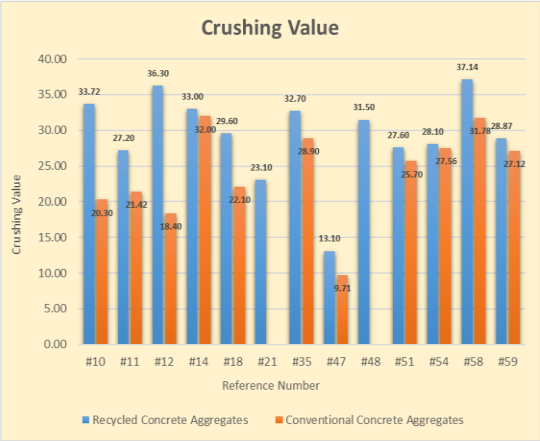

Figure 7: Crushing value.

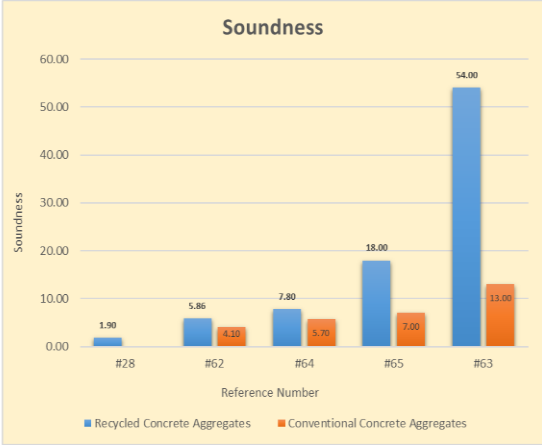

Figure 8: Soundness (Sodium Sulfate).

2.7 Crushing value: It is percentage loss of weight of aggregates under specified load. It is also known as numerical index of strength of the aggregates. Generally, it is used in pavement design, however it is also an important measure for hardened strength of the concrete using the aggregates. For different conditions of the pavement the range of the parameter is 30% – 50% with crushing value for cement-concrete equal to 30%. Although the crushing value of recycled aggregates from demolished concrete should be less than that of conventional aggregates due to attached mortar with it, but its knowledge is essential to have rough estimate of the strength loss of concrete in hardened state. This parameter of recycled aggregates has also been evaluated by several scholars while using it in road and building construction. From the cited literature test results of the parameter by 13 investigators are plotted in Figure 7 along with the test results of conventional aggregates. It may be observed that crushing value of conventional aggregates is in the range of 9% - 32% whereas the range for recycled aggregates is 13% - 37%. Comparing the maximum reported values, the percentile increase in the value of parameter for recycled aggregates is 16%. It may also be observed that the standard deviation of the parameter for both types of aggregates is almost same (6.6 and 6.3). These results show that crushing value for both aggregates do not differ much thus the performance of recycled aggregates under specified crushing load is in good agreement with those of conventional aggregates.

2.8 Porosity: The property is defined as the weight percentage of fully water saturated voids to dry rock. It is related to permeability and water absorption also. The voids present in the aggregates affects bond between aggregates and bonding cement paste, chemical stability, and specific mass of concrete. It also affects the water demand of the concrete mix resulting in changed behavior of workability and final strength of the concrete. The porosity of recycled aggregate is different from the conventional aggregates. The reasons for it are same as mentioned before. Therefore, its estimation helps in proper decisions about the water demand and other related issues of the concrete mix. The research community have worked on this issue and evaluated the porosity of recycled aggregates from demolishing waste. Zheng et. al.[6] observed 11% higher results in comparison to the conventional aggregates whereas Ramadevi et. al.[51] observed 14% higher results. Although the difference between the results of two researchers is not much but deviation from the results of conventional aggregates is evident. Also, it is anticipated that if more evaluations are made will result in more deviation due to different in source of aggregates, age of concrete and quantum of mortar attached. It is therefore necessary to address this deviation of the parameter while designing the concrete mix.

2.9 Soundness: It is durability of the aggregates to resist weathering action. In laboratory it is performed using sodium sulfate and magnesium sulfate. The outcome by former is less than that by later chemical. The range of soundness by sodium sulfate is 0 – 15% for conventional aggregates. It is believed and estimated by different scholars of research community that the soundness of the recycled aggregates is less compared to that of conventional aggregates. From the cited research articles in this review results of soundness obtained by five scholars are plotted in Figure 8. It may be observed that lowest results of soundness of recycled aggregates reported is 1.9% and the maximum equal to 54% with standard deviation equal to 6.86. The same for conventional aggregates are equal to 4.1%, 13% and 3.89 and the values of minimum, maximum soundness, and standard deviation. The results reported by Kolay and Akentuna.[63] for recycled aggregates are far higher than the results reported by other scholars, it might be due to very poor-quality aggregates used in the research. The percentage difference of these results is 315% higher than the soundness of conventional aggregates. Whereas the results of other scholars are in good agreement with each other. Excluding the results reported in reference,[63] the range of values for recycled aggregates is 1.9% - 18% and for conventional aggregates is equal to 4.1% - 7%. The results of conventional aggregates fall with in allowable range. The lowest values of recycled aggregates are also within allowable range of the soundness, but the highest values reported is 20% higher than the maximum allowable value of soundness of aggregates by sodium sulfate. Therefore, the weakness of the aggregates is evident and require careful consideration before taking final decision of using the same in new concrete.

2.10 Clay content: Presence of clay in aggregates adversely affects the compressive strength and shrinkage of concrete using the aggregates. The phenomenon is well understood for conventional concrete. Elahi and Ali [66] observed 12% reduction in compressive strength of concrete with clay particles in addition to adverse effect on permeability and acid attack with increase in clay content. In a similar approach Desire and Leopold[67] observed 18% reduction in compressive strength and concluded that the compressive strength is inversely proportional to the clay contents. Therefore, for proper strength of concrete aggregates should be free from clay particles. Same is the case for recycled aggregates, but as it is recycled from the waste therefore presence of the clay in the aggregates in unavoidable. The solution of it is by washing the aggregates before using in concrete but in field work it is almost impossible to ensure washing of all the coarse aggregates therefore determination of the amount of clay in the aggregates give rough idea of decrease in the final strength of the concrete. In research program conducted by Al-Zahraa et. al.[1] authors observed 0.53% clay content in recycled aggregates in comparison to 2.4% clay content in conventional aggregates. Another article by Sagoe-Crentsil et. al.[21] reported 0.6% clay content in recycled aggregates.

2.11 Loss on ignition: It is reduction in weight due to burning of organic matter present in the aggregates. Although presence of organic matter in the aggregates but its presence is not neglected. As recycled aggregates are obtained from demolishing waste therefore possibility of presence of organic matter in the aggregates is more compared to conventional aggregates. To this end Sagoe-Crentsil et. al.[21] determined the loss on ignition of recycled aggregates and found 4.9% weight loss. The results show that if these aggregates are used in concrete without removing organic impurities will result in 5% less quantity of the required quantum of the aggregates in concrete. Therefore, the parameter must be checked and ensured its removal before using it in the concrete.

3. CONCLUSION

This research article presents the review of the basic properties of recycled aggregates obtained from the demolishing waste. The properties reviewed are fineness modulus, water absorption, specific gravity, density, unit weight, abrasion impact value, crushing value, porosity, soundness, clay content and loss on ignition. The reported results of the properties are plotted and discussed. It is observed that all these properties of recycled aggregates differ from the same of conventional aggregates. Also, within the results of the property scatter and deviation is observed. This show that the quality of the aggregates is different for different sources. Also, recycling method impact a lot on the properties of the recycled aggregates. Hence it is evident that more work is required to reach at suitable consensus. However, the results collected in one place will help the future researchers in the field.

4. REFERENCES

1. Al-Zahraa F. I., El-Mihilmy M. T., and Bahaa T. M., “Flexural Strength of Concrete Beams with Recycled Concrete Aggregates”, Journal of Engineering and Applied Science, 2010; 57(5).
2. Abhiram K., and Kumar S. P., “Properties of Recycled Aggregate Concrete Containing Hydrochloric Acid Treated Recycled Aggregates”, International Journal of Chem Tech Research, 2015; 8: 1.
3. Frank S. S, Chockalingam M. P., and Bebitta R., “Recycled Aggregate Concrete Flexural Behavior using Fly Ash”, Journal of Critical Reviews, 2020; 7(8).
4. Sharma J., and Singla S., “Influence of Recycled Concrete Aggregates on Strength Parameters of Concrete”, SSRG International Journal of Civil Engineering, 2014; 1(4).
5. Wagih A. M., El-Karmoty H. Z., Ebid M., and Okba S. H., “Recycled Construction and Demolition Concrete Waste as Aggregate for Structural Concrete”, HBRC Journal (Housing and Building National Research Center), 2013; 9.
6. Zheng C. C., Lou C., Du G., Li X. Z., Liu Z. W., and Li L. Q., “Mechanical Properties of Recycled Concrete with Demolished Waste Concrete Aggregate and Clay Brick Aggregate”, Results in Physics, 2018; 9.
7. Taboada I. G., Fonteboa B. G., Abella F. M., and Lopez C., “Study of Recycled Concrete Aggregate Quality and its Relationship with Recycled Concrete Compressive Strength using Database Analysis”, Materiales de Construction, 2016; 66: 323.
8. Silva F. A. N., Delgado J. M. P. Q., Azevedo A. C., and Lima A. G. B., “Preliminary Analysis of the Use of Construction Waste to Replace Conventional Aggregates in Concrete”, Buildings (MDPI), 2021; 11: 81.
9. Malik P., “Effect of Recycled Aggregate on Compressive Strength of Concrete”, International Journal of Engineering Research & Technology, 2014; 3: 11.
10. Nandhini K. U., Jayakumar S., and Kothandaraman S., “Flexural Strength Properties of Recycled Aggregate Concrete”, International Journal of Application or Innovation in Engineering & Management, 2016; 5(5).

11. Kori P. S., and Bashetty R., "Methods of Enhancing the Performance of Recycled Aggregate Concrete through the use of supplementary Cementitious Materials", International Journal of Emerging Technologies (Special Issue on NCRIET-2015), 2015.
12. Sonawane T. R., and Pimplikar S. S., "Use of Recycled Aggregate Concrete", IOSR Journal of Mechanical and Civil Engineering (Second International Conference on Emerging Trends), 2013.
13. Sellakkannu N., and Subramani V., "Study on Properties of Recycled Aggregate – A Review", Imperial Journal of Interdisciplinary Research, 2016; 2(3).
14. Abmdas M. S. A., and Saeid H.S. O., "Recycling Building Demolition Waste as an Asphalt Binder Course in Road Pavements: A Case Study in Benghazi", Alhabit Journal of Applied Science, 2020; 1(1).
15. Nuruzzaman M., and Salauddin M., "Application of Recycled Aggregate in Concrete – A Review", Proceedings of 3rd International Conference on Advances in Civil Engineering, 21-23 December 2016.
16. Rajkumar M. R., and Krishna R. R. M., "Recycling of Construction and Demolition Waste for the Use of Recycled Aggregates in Concrete: A Review", International Research Journal of Multidisciplinary Science and Technology, 2017; 2(9).
17. Fonteboa B. G., Paz S. S., de-Brito J., Taboada I. G., Abella F. M., and Silva R. V., "Recycled Concrete with Coarse Recycled Aggregates. An Overview and Analysis", Materials de Construction, 2018; 68: 330.
18. Qasrawi H., "The Use of Recycled Building Rubble in the Reconstruction of Demolished Buildings", JEA Conference, 2017.
19. Nakhi A. B., and Alhumoud J. M., "Effects of Recycled Aggregate on Concrete Mix and Exposure to Chloride", Advances in Materials Science and Engineering (HINDAWI), 2019.
20. Altera A. Z. A., Bayraktar O. Y., Bodur B., and Kaplan G., "Investigation of Properties of Concrete Produced with Recycled Aggregates", Journal of Cement Based Composites, 2020; 2.
21. Sagoe-Crentsil K. K., Brown T., and Taylor A. H., "Durability and Performance Characteristics of Recycled Aggregate Concrete", 9th International Conference on Durability of Building Materials and Components, 2002.
22. Velerie S. Tegguer A. D., "Treatment of Recycled Concrete Aggregates by Si-Based Polymers", International Journal of Science, Engineering and Technology, 2013; 7(1).

23. Xiao J. Z., and Li L., "Review on Recycled Aggregate Concrete in the Past 15 Years in China", 3rd International Conference on Sustainable Construction Materials and Technologies, 2019.
24. Shinde M. G., Vyawahare M. R., and Modani P. O., "Effect of Physical Properties of Recycled Aggregate on the Strength of Concrete", International Journal of Engineering, Research and Technology, 2013; 2(4).
25. Dhaqane A. I., "An Experimental Study on Recycling of Demolished Concrete in Mogadishu City", Mogadishu University Journal, 2018; 4.
26. Aquib M. and Mamilwar B. M., "Building Future with Recycled Aggregate", International Journal of Engineering Research and Application, 2017; 7: 10.
27. Dos-Reis G. S., Qautrone M., Ambros W. M., Cazaciu B. G., and Sampaio C. H., "Current Applications of Recycled Aggregates from Construction and Demolition: A Review", Materials (MDPI), 2021; 14.
28. Al-Swaidani A. M., and al-Hajeh T., "Production of Greener Recycled Aggregate Concretes using Local Supplementary Cementing Materials", MOJ Civil Engineering, 2017; 2(1).
29. Rampit R., Smith J., and Ray I., "A Review of Recycled Concrete Aggregates as a Sustainable Construction Material", The International Conference on Emerging Trends in Engineering and Technology, 2020; 5.
30. Dardis J. M., "Recycling Concrete for Sustainable Construction", Master of Science in Civil Engineering, Cleveland State University, 2012.
31. Yehia S., Helal K., Abusharkh A., Zaher A., and Istaitiyeh H., "Strength and Durability Evaluation of Recycled Aggregate Concrete", International Journal of Concrete Structures and Materials, 2015 9(2).
32. Ranpise R. B., and Salunkhe M. S., "Recycling of Demolished Concrete and Mortar in Manufacturing of Aggregate", International Journal of Science and Research, 2015; 4(7).
33. Malesv M., Radonjanin V., and Marinkovic S., "Recycled Concrete as Aggregate for Structural Concrete Production", Sustainability, 2020; 2.
34. Huda S. B., "Mechanical and Durability Properties of Recycled and Repeated Recycled Coarse Aggregates Concrete", Master of Applied Science, University of British Columbia, 2014.
35. Ignjatovic I. S., Marinkovi S. B., Miskovic S. M., and Savic A. R., "Flexural Behavior of Reinforced Recycled Aggregate Concrete Beams under Short-Term Loading", Materials and Structures, 2013; 46(6).

36. Oad M., and Memon B. A., "Compressive Strength of Concrete Cylinders using Coarse Aggregates from Old Concrete", Proceedings of 1st National Conference on Civil Engineering, 2014; 28 – 29.
37. Memon B. A., and Bhatti G. S., "Flexural Behavior of Beams made by Partial Replacement of Natural Aggregates with Coarse Aggregates from Old Concrete", International Journal of Engineering Sciences and Research Technology, 2014; 3(5).
38. Bhatti A. A., and Memon B. A., "Strength, Deflection and Cracking Behavior of Concrete Slab using Demolished Concrete as Coarse Aggregates", International Journal of Engineering Sciences and Research Technology, 2014; 3(6).
39. Memon B. A., "Recent Development on Use of Demolished Concrete as Coarse Aggregates", International Journal of Emerging Technology and Innovative Engineering, 2016; 2(1).
40. Raza A., Memon B. A., and Oad M., "Effect of Curing Types on Compressive Strength of Recycled Aggregate Concrete", QUEST Research Journal, 2019; 17(2).
41. Razzak, Memon B. A., Oad M., and Raza A., "Effects of Height to Diameter Ratio on Compressive Strength of Recycled Aggregate Concrete", QUEST Research Journal, 2019; 18(1).
42. Arezoumandi M., Smith A., Volz J. S., and Khayat K. H., "An Experimental Study on Flexural Strength of Reinforced Concrete Beams with 100% Recycled Concrete Aggregate", Engineering Structures, 2015; 88.
43. Konin A., and Kouadio D. M., "Influence of Cement Content on Recycled Aggregates Concrete Properties", Modern Applied Science, 2011; 5(1).
44. Jain N., Garg M., and Minocha A. K., "Green Concrete from Sustainable Recycled Coarse Aggregates: Mechanical and Durability Properties", Journal of Waste Management, 2015.
45. Kang M., and Li W. B., "Effect of Aggregate Size on Strength Properties of Recycled Aggregate Concrete", Advances in Materials Science and Engineering, 2018.
46. Tang W. C., Ryan P. C., Cui H. Z., and Liao W., "Properties of Self-Compacting Concrete with Recycled Coarse Aggregates", Advances in Materials Science and Engineering, 2016.
47. Ye T. P., Cao W. L., Zhang Y. X., and Yang Z. W., "Flexural Behavior of Corroded Reinforced Aggregate Concrete Beams", Advances in Materials Science and Engineering, 2018.

48. Reddy G. J., and Mastan S. A., "Experimental Study on Green Concrete", International Journal for Technological Research in Engineering, 2017; 5(3).
49. Xiao J. Z., Li L., Sen L. M., and Poon C. S., "Compressive Behavior of Recycled Aggregate Concrete under Impact Loading", Cement and Concrete Research, 2015; 71.
50. Al-Ajmani H., Suleiman F., Abuzayed I., and Tamini A., "Evaluation of Concrete Strength made with Recycled Aggregate", Buildings, 2019; 9(56).
51. Ramadevi K., Juhi M., and Shalini H., "Flexural Behavior of RC Beams with Recycled Aggregates", International Journal of Engineering and Advanced Technology, 2019; 8: 653.
52. Gagan and Agam, "Flexural Behavior of Reinforced Recycled Concrete Beams: A Review", International Journal of Research in Engineering and Technology, 2014; 4(1).
53. Yanya Y., "Blending Ratio of Recycled Aggregate on the Performance of Pervious Concrete", Fracttura ed Integrita Structturale, 2018; 46.
54. Govindagowda G., Rao B. S., and Naik S. M., "Behavior of Recycled Aggregate Concrete on Exposed to Elevated Temperature", International Journal of Civil Engineering, 2017; 4(6).
55. Domingo A., Lazaro C., Gayaree F. L., Serrano M. A., and Colina C. L., "Long-Term Deformations by Creep and Shrinkage in Recycled Aggregate Concrete", Materials and Structures, 2010; 43.
56. Buraczewska B. S., Hunek D. B., and Szafraniec M., "Influence of Recycled High-Performance Aggregate on Deformation and Load-Carrying Capacity of Reinforced Concrete Beams", Materials, 2020; 13.
57. Jose M. V., and Soberon G., "Porosity of Recycled Concrete with Substitution of Recycled Concrete Aggregate an Experimental Study", Cement and Concrete Research, 2002; 20(69).
58. Panda K. C., and Bal P. K., "Properties of Self-Compacting Concrete using Recycled Coarse Aggregate", Procedia Engineering (Chemical, Civil and Mechanical Engineering Tracks of 3rd Nirma University International Conference), 2013; 51.
59. Surya M., Kanta-Rao V. V. L., Lakshamy P., "Recycled Aggregate Concrete for Transportation Infrastructure", Procedia Social and Behavioral Sciences, 2013; 104.
60. Sala M. A., Oseafiana O. J. and Oyegoke T. O., "Effects of Temperature on Concrete with Recycled Coarse Aggregates", 2nd International Conference on Innovative Materials, Structures and Technologies – IOP Conference Series: Materials and Engineering, 2015; 96.

61. Manzi S., Mazzotti C., and Bignozzi M. C., “Short and Long-Term Behavior of Structural Concrete with Recycled Concrete Aggregate”, Cement and Concrete Composites, 2013; 37.
62. Dahri S. A., Memon B. A., Oad M., Bhambhro R., and Rahu I. A., “Quality of Recycled Aggregates and Compressive Strength of No-fines Recycled Aggregate Concrete”, Engineering Technology and Applied Science Research, 2021; 11(5).
63. Kolay P. K., and Akentuna M., “Characterization and Utilization of Recycled Concrete Aggregate from Illinois as Construction Material”, Geo-Congress, Technical Papers, ASCE, 2014.
64. Tran D. V. P., Allawi A., Alhayati A., Cao T. N., El-Sohairy A., and Nguyen Y. T. H., “Recycled Concrete Aggregate for Medium-Quality Structural Concrete”, Materials (MDPI), 2021.
65. Reza F., “Evaluation of Recycled Aggregates Test Section Performance”, Technical Report, Department of Transportation, Minnesota State University, Mankato, 2017.
66. Elahi A., and Ali Aitzaz, “Effects of Clay on Properties of Concrete”, Proceedings of Resilient Structures and Sustainable Construction, 2017.
67. Desire T. J., Leopold M., “Impact of Clay Particles on Concrete Compressive Strength”, International Research Journal of Engineering, 2013; 1(2).