Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X
Volume 3, Issue 10, 2025

EFFECT OF ELONGATED CURING, RECYCLED AGGREGATES FROM DIFFERENT STRUCTURAL MEMBERS AND FLY ASH ON FLEXURAL BEHAVIOR OF GREEN CONCRETE

Ghulam Shabir Bhatti[1], Bashir Ahmed Memon[2], Mahboob Oad[*3], Kamran Memon[4], Faizyab Latif[5]

[1]Post graduate student, Civil Engineering Department QUEST, Nawabshah
[2]Professor, Civil Engineering Department QUEST, Nawabshah
[*3]Assistant professor, Civil Engineering Department QUEST, Nawabshah
[4]Civil Engineering student, Civil Engineering Department QUEST, Nawabshah
[5]Lecturer Civil Engineering Department QUEST, Nawabshah

bhatti.shabir@gmail.com[1], bashir_m@ hotmail.com[2], engrmahboob04@gmail.com[*3], kamranmemon1827@gmail.com[4], faizyablatif@gmail.com[5]

DOI: https://doi.org/10.5281/zenodo.17627887

Keywords
Green Concrete, Recycled Aggregates, Fly Ash, Flexural Strength, Deflection, Flexural Behavior, Sustainable Development, Indigenous Material

Article History
Received: 11 September 2025
Accepted: 21 October 2025
Published: 04 November 2025

Corresponding Author: *
Mahboob Oad

Abstract
In this research study laboratory investigation to check the effect of fly ash and recycled aggregates from different structural member is presented. 35% recycled aggregates and 10% fly ash were used as replacement of conventional coarse aggregates and cement respectively. Seven batches of concrete were prepared with 1:2:4 mix ratio and 0.5 water-cement ratio. Fifteen beams of (900 x 150 x 300) mm size was prepared for each batch in standard fashion. Equal number of specimens were cured for 7-, 28-, and 90 days. All beams were tested under central point loading with gradually increasing load. Load and deflections were recorded at regular interval till failure. From recorded load flexural strength was computed. Results showed better performance of recycled aggregates from column concrete than other counter parts. Maximum deflection in all beams were well within allowable range by ACI318. Deflection performance of binary blended concrete was better than conventional concrete. Elongated curing showed improvement in flexural strength, but increase was less than 5%. In all specimen failure mode observed was flexural failure.

INTRODUCTION

Primary industrial processes generate output for necessity and problem solution. But it also generates waste material which with every passing day is increase at large scale and have become the major concern with respect to environmental protection and human health. Same is the case with construction industry it has given beautiful, eye catching, fascinating, and accommodating infrastructure to the world in a way that modern world has changed remarkably. But several problems are also associated with it. For example, cement industry is running for more time than usual thus carbon dioxide emission is large compared to normal working of the industry. To meet the mega boom of the construction aggregates consumption has also increased. To meet the demand quarrying of the aggregates has increased posing the same problems as in case of cement. Also, it has posed the serious problem of depletion of the natural sources of aggregates.

On other hand, construction of mega structures require space, which is already very less in the city centers around the world. The demand is generally met by demolishing the old, deteriorated, or short height building. This aids up to the construction waste resulting in large volumes of the waste to be treated properly. This waste is increasing day by day, if world is considered it is generated in millions of tons every year. Earlier this waste was used in floor and plinth fills to some extent and remaining was dumped in dumping areas. But with time the availability of space has become the problem. High transportation cost also does not allow the transportation of the waste to far areas as it puts financial embargo on the project. Leaving the waste unattained is not only not permitted by law but is also very harmful for human health and environment. Dumping it in nearby areas of valuable/agricultural land negatively impact the economy of the country as in case of Pakistan. Therefore, a solution of the multi-fold problem is to recycle the waste in useful product. Even if partially, it will reduce this multi-fold problem to some extent.

Recycling is the process of converting waste material into useful product. It will not only end the life cycle of the old material but also help in developing new indigenous material. Demolishing waste is composed of multiple items, i.e., bricks, steel, glass, wood, marble, tiles, ceramics, aluminum, concrete, etc. Recycling of almost all have been attempted. The volume of concrete in the waste is large compared to other. The old concrete has good strength to be used as the alternative of the conventional ingredients of new concrete. Research community has attempted this waste as replacement of cement, fine and coarse aggregates. But as the volume of coarse aggregates is more compared to cement and fine aggregates thus using the waste as coarse aggregates will consume the waste more and help in saving the conventional aggregates more. Also, it will help in less quarrying of the aggregates thus will reduce carbon dioxide effect on environment and human health. Additionally, it will also help in reduced waste management of the waste.

Good number of publications shows that different recycling techniques including double recycling process have been developed for the purpose. Reasonably high number of publications present in literature shows the need of the material, interest of the research community in the development and use of the recycled coarse aggregates from demolishing concrete. But yet several problems associated with the old concrete probably did not allow the research community to reach a reasonable conclusion. Recycling of the material, dosage of the aggregates, properties of the aggregates, and properties of the concrete still differ. Although several countries have developed rules and regulation in this regard and implemented them but yet industry is reluctant in use of the material. Hence it is advised by several scholars to give incentives and implement the regulation in true sprit to make use of the material wherever it is possible [1].

Improvement of the properties of recycled aggregate concrete have been attempted by using various materials as additive. Fly ash is one among them. It is byproduct of coal burning and is available in large volumes around the world. It is also available in large volumes in various cities of Pakistan, with maximum in Lakhra coal plants and mines. It is a waste material which need proper treatment and disposal to safeguard environment and inhabitants. Its proper disposal is also one of the major issues worldwide. Therefore, if used in concrete may reduce the waste management to some extent. Fly ash is a pozzolanic material having good bonding properties such that it may even be used as cement replacement. Therefore, the material is aimed to use in concrete as partial replacement of cement in this research study.

Although use of recycled aggregates from demolished concrete and fly ash in new concrete is not new but generally mixed aggregates are used. The effect of recycled aggregates processed from different structural members particularly on flexural strength is either seldom or absent. Therefore, this research study aims at evaluating the flexural behavior of recycled aggregate concrete binary blended with recycled aggregates from five different structural members and fly ash. To achieve the aim of the study standard (7- and 28-day) and elongated (90-day) curing was used.

Literature review

Literature review summarizes the already done work in the field of research and highlights the outcome along with gaps of the studies. Therefore, in the following review of available state-of-art relevant to proposed topic of research is given.

As stated earlier the use of demolished waste in new concrete as replacement of conventional ingredients of concrete particularly coarse aggregates is not new. Reasonably large number of publications are published in past few decades. The work in the area has been reviewed by many researchers [1][2]. These reviews discussed the need, processing techniques, properties of aggregates, properties of concrete at fresh and hardened state but the scatter in the results is quite clear [3]. The reviews also emphasis on the implementation of rules and regulation along with incentives for the concerned to adopt the material in new concrete properly.

Compressive strength is the key property of concrete to ensure its durability and serviceability during service life. It has been studied by Oad and Memon [4] among many other using recycled aggregates in various proportions as replacement of conventional coarse aggregates. Compressive strength results of 378 cylinders revealed 26% loss of strength in 28-day cured samples with 50% recycled aggregates. Therefore, authors concluded 50% dosage of recycled aggregates as optimum. In another research study Jin et.al. [5] used recycled aggregates and bricks separately to check and compare their effect on compressive strength. Pre wetting of recycled aggregate was used whereas bricks were used in dry state. Test results showed the author good improvement in compressive strength with pre wetting of RCA than brick aggregates and RCA in dry state. Emad et. al. [6] also used recycled aggregates in their research study but they also used crushed ceramics and bricks to compare the effect on high-strength concrete. The aggregates were used in the replacement level of 25%, 50%, 75%, and 100%. The test results of 7-, 28-, and 56-day cured samples showed the increase in strength from 13.1% - 67.2%. Katar et. al. [7] on other observed 40% increase in strength at 75% dosage of recycled aggregates, 0.38 water cement ratio and super plasticizer for 28-day cured samples.

In a study on checking the effect of different replacement levels of recycled aggregates on compressive strength of M30 concrete Li et. al. [8] prepared and cured samples for 3-, 7-, and 28 days. Test results showed slow decrease of the strength at early age but was more for later curing age. The authors also observed that there was no obvious declined trend of strength with increase in percentage replacement of the aggregates. From the observations authors concluded that although the decrease in the strength of recycled aggregate concrete is obvious yet requirements of M30 concrete can be achieved with minimal loss of strength. Motlagh [9] on other hand recorded compressive strength up to 7200 psi at 100% replacement level of conventional aggregates with recycled aggregates from demolished waste for 7-, 14-, 28-, and 90-day cured samples. Jun et. al. [10] in another research study concluded that accelerated carbonation with lime water improves the strength properties of recycled aggregate concrete to great extent.

It may be observed that compressive strength of recycled aggregate concrete reported by different scholars at different replacement levels and techniques is different from case to case. Even reported results shows difference in outcome for same replacement level and technique. A beam is one of the important structural members used abundantly in infrastructures. It has to face transverse loading during service life. Its flexural performance is highly important towards safety and serviceability of the structure. Hence evaluation of flexural strength and understanding flexural behavior of recycled aggregate concrete is also important. Towards it Nandhini et. al. [11] designed a research program to study deflection and strain of the reinforced recycled aggregate concrete beams under two-point loading. For 100% dosage of recycled aggregates authors observed 3.57% increase in deflection and 13.7% increase in strain. They attributed this deviation to the inferior properties of the aggregates. Prajapati et. al. [12] on other hand used glass powder as additive to study the flexural strength of recycled aggregate concrete. The authors used RCA in the dosage of 5%, 10%, 15%, and 20% with glass powder in the dosage of 5%, 10%, and 15%. Test results of beams under central point loading revealed 6.6% increase with 5% glass powder and decrease of 2.5% with 10% glass powder. The results of both dosages of glass powder were observed at 20% replacement level of RCA. Hence authors concluded 20% recycled aggregates with 5% glass powder as optimum for better flexural strength and better flexural behavior of the recycled aggregate concrete beams.

The desire for improved flexural performance of recycled aggregate concrete continued and the waste as partial replacement of fine aggregates was attempted by Evangelista and de-Brito [13]. For varying dosages of the waste and testing of beams under central point load showed the authors substantial increase in displacement and plastic deformation. Also, the authors did not find any meaning full difference in average crack distance and flexural performance. But ductility thus the energy dissipation capacity at plastic state was note higher than conventional concrete beams. Vinayak et. aal. [14] in separate attempt developed M25 and M30 concrete using 20%, 40%, 70% and 100% demolished waste as recycled coarse aggregates. Test results of central point loading on beams showed 10.66% and 4.72% decrease in flexural strength for M25 and M30 concrete respectively at the RCA dosage of 20%. Therefore, the authors concluded 20% as the optimum dosage for best residual flexural strength. Yaba et. al. [15] attempted metakaolin as additive in recycled aggregate concrete for improvement of flexural strength and observed 20% as optimum for similar flexural strength in comparison to conventional concrete. Sindy et. al. [16] on other hand used 0%, 20%, 50%, and 100% replacement levels of conventional coarse aggregates with recycled aggregates from demolished waste to check the flexural strength. Using 0.5 and 0.65 water cement ratio in casting and testing of the beams, authors observed 50% dosage as optimum for least loss of flexural strength of the beams. Oad et. al. in two separate studies used 1:2:4 mix [17] and 1:1.5:3 mix [18] to study the flexural capacity of reinforced recycled aggregate concrete beams. 2#4 bars were used in both tension and compression zones along with #3 stirrups at 6-inch center to center to reinforce the beams. Both mixes were prepared with 0.54 water to cement ratio. One point loading at center revealed 5.25% and 11.68% reduction in flexural strength of normal and rich mix concrete beams. Alsabbagh [19] on other hand observed similar flexural strength with 5% significance for recycled aggregate concrete beams. Whereas, almost under similar conditions Ramadevi and Shalini [20] observed 14% higher results for flexural strength. Chaboki et. al. [21] also used recycled aggregates equal to 50% and 100% in development of concrete beams. The comparison of the flexural strength results with control concrete, ACI318, and EuroCode2 provisions, authors found increase in flexural strength and argued that with careful considerations even 100% recycled aggregates can be used in new concrete without any loss of flexural capacity of the beams. Yang et. al. [22] in their study also compared the results with ACI318 and EC2 provisions. They tested concrete beams cast with 30%, 50%, and 100% recycled aggregates but varied the rebar ratio equal to 0.5%, 0.79% , and 1.14%. Observations of the results revealed similar crack pattern, smaller crack space, less flexural strength than conventional concrete beams. They further observed that both ACI318 and EC2 provisions predicted flexural strength of recycled aggregate concrete beams conservatively. Rashid and Mohammed [23] also used similar dosage of RCA as of Yang et. al. [22] but they observed that deflection reduced by 15% at 75% dosage and 43% at 100% replacement level. The authors also observed that at 100% replacement of conventional coarse aggregates ductility, stiffness, toughness was reduced by 24%, 10%, and 34% respectively.

Fly ash having pozzolanic properties have been used in conventional and recycled aggregate concrete as cement replacement and as additive. It was used as cement replacement in green concrete by Chandio et. al. [24] in the dosage of 2.5%, 5.0%, 7.5%, and 10.0% with 50% recycled aggregates from demolished concrete. Compressive strength results showed that authors improvement in the parameter with fly ash with 11% reduction than conventional concrete. Niu et. al. [25] also used fly ash as cement replacement but they also used ballast furnace slag, glass fibers, and polypropylene fibers to check the flexural strength of the concrete. From the test results authors observed 11% reduction in flexural strength with fly ash and slag. But it was increased when fibers were used. It increased 8% and 19% with glass and polypropylene fibers respectively. Whereas 22.6% increase in flexural strength was recorded when both fibers were used together in the concrete along with fly ash and the slag. Therefore, authors concluded that use of fly ash has positive impact on the flexural strength but if it is combined with fibers results increase even beyond the flexural strength results of conventional concrete. Also, the fibers help in arresting the cracks resulting in lesser crack width and higher first crack load. Pramod et. al. [26] developed M25 concrete with varying percentages of recycled aggregates, fly ash, and GGBS. Both fly ash and GGBS were used as cement replacement. Results showed the authors that at 50% dosage of RCA 85% residual flexural strength can be obtained.

Above discussion of available literature relevant to the topic of research shows the need, interest, and attempts of the research community but the scatter of the results, diversification of the techniques in use of the material demands more work in the area to reach a suitable conclusion. Particularly the effect of recycled aggregates from different structural members, fly ash and elongated curing. It is the main aim of the proposed research of this article.

Material and Testing

The constituent materials of concrete used in this research work are ordinary Portland cement, fly ash, hill sand, coarse aggregates (crush), recycled aggregates, and potable water. The ordinary Portland cement sold under brand name Lucky cement was dry and smooth in feel and grey in color. Its fineness was checked using #100 sieve. Percentage retained was less than 20% confirming its quality with respect to ASTM C150/C150M-18 [27].

Fly ash used in this work was obtained from Lakhra coal mines. In physical appearance it was a bit coarser than cement, dry, and greyish black in color (Figure 1). Its fineness was checked using #100 sieve. The percentage retained was less than 30%. Other physical and chemical properties of the material are used from the separate work of author [31]. Comparing the physical and chemical properties with provisions of ASTM C618 [28], the fly ash was class C-fly ash.

Figure 1: Fly ash

Figure 3: Waste

Figure 4: Recycled aggregates

Fine aggregates opted for this research work was hill sand purchased from government approved source for the material. Sieve analysis of the material revealed fineness modulus equal to 3.3 confirming its quality as coarse sand in accordance with ASTM C136/C136M-14 [29]. Conventional coarse aggregates were also obtained from same source as of fine aggregates. Maximum size of the aggregates was ensured equal to 25 mm, followed by sorting for unwanted substances, washing and drying in closed environment at room temperature. Sieve analysis of the material was done. The fineness modulus obtained was equal to 5.1. Percentage passing on various sieves is shown in Figure 2. It was observed that percentage passing on various sieves was in the specified ranges of relevant ASTM standards. The water used for washing and mixing of the concrete ingredients was potable water with pH value equal to 6.9.

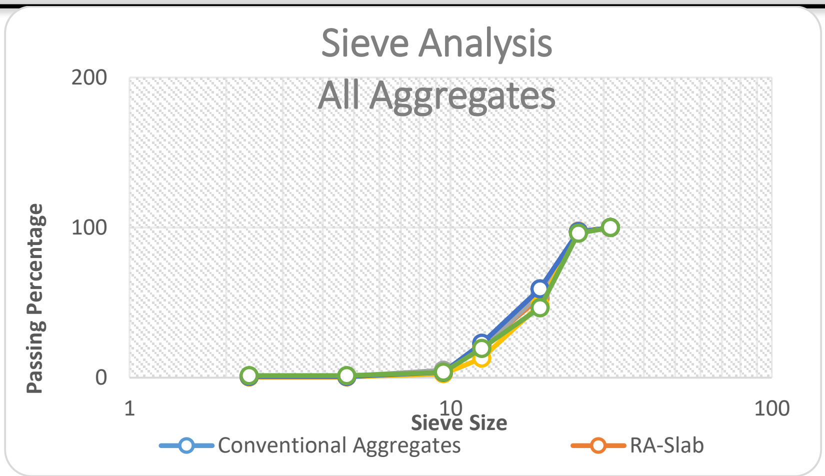

Figure 2: Sieve analysis of coarse aggregates

For recycled aggregates demolished waste was collected from different locations. The waste was of five different structural members, i.e., roof slab (RA-Slab), beam (RA-Beam), Column (RA-Col), Footing (RA-Fot), and lintel (RA-Lnt). Large blocks of the waste (Figure 3) were hammered down to maximum of 25 mm separately for each source. Aggregates from each source were sorted for impurities, cracked particles etc. followed by washing and drying at room temperature in the laboratory. Sieve analysis of the aggregates from all sources was done in line with conventional aggregates. Percentage passing of the aggregates is shown in Figure 2. It may be observed that the percentage passing for all aggregates falls within allowable ranges of relevant ASTM standards. The fineness modulus of the aggregates was equal to 5.23, 5.21, 5.37, 5.09, and 5.3 for all five sources respectively.

Mix details

To prepare the concrete mix 1:2:4 ratio with 0.5 water cement ratio were used. 35% conventional coarse aggregates were replaced with recycled aggregates from demolished waste. The dosage was opted following the recommendations of Bhatti et. al. [31]. Also, the recommendations of same author were adopted for the dosage of fly ash equal to 10%. Therefore, 10% by weight cement was replaced by fly ash. The details of mixes using recycled aggregates from different structural members is given in Table 1. The quantities shown are for 5 beam specimens.

Table 1: Details of mix and quantities for one specimen

No.	Batch	Cement (kg)	Fly Ash (kg)	FA (kg)	NCA (kg)	RCA (kg)	No. of Specimens	Slump (mm)
1	CC	14.0	0.0	28	56.0	0.0	15	48
2	RCA (mix)	12.6	1.4	28	36.4	19.6	15	40
3	B1RASlab	12.6	1.4	28	36.4	19.6	15	32
4	B2RABeam	12.6	1.4	28	36.4	19.6	15	30
5	B3RACol	12.6	1.4	28	36.4	19.6	15	32
6	B4RAFot	12.6	1.4	28	36.4	19.6	15	29
7	B5RALnt	12.6	1.4	28	36.4	19.6	15	26

Workability

Using above mentioned mix and water-cement ratio concrete mix for all batches mentioned in Table 1 were prepared to check the workability of the concrete in turn. The workability was checked using slump cone test (Figure 5) as per the provisions of

ASTM C1743 [30]. Obtained results of slump are shown in last column of Table 1.

Figure 5: Slump test

Figure 6: Beam specimens

Figure 7: Specimen curing

Sample preparation

Using above mentioned details fifteen beam specimens of size 900 mm x 150 mm x300 mm were prepared in each batch. Beam molds were prepared by lubricating the inner surface. Concrete ingredients along with required quantity of water were mixed in concrete mixer till formation of uniform paste. Molds were filled in layers and compacted in standard fashion. Figure 6 shows few samples. After 24 hours the specimens were de-molded and allowed to air dry for 24-hours. Equal number of specimens (5) were cured each for 7-, 28-, and 90-days (Figure 7).

Sample testing

After the completion of respective curing age specimens were taken out of water, wiped, and allowed to air dry for one day in the laboratory. The specimens were then tested in universal testing machine under gradually increasing central point load. The loading rate of the machine was 0.5 kN/sec. The load and deflection were monitored and recorded at regular interval till crushing of the beam. Few specimens during testing are shown in Figure 8.

Figure 8: Specimen testing

Results and Discussion

The sieve analysis of the coarse aggregates used in this work revealed good agreement between the groups of aggregates, also, the percentage passing, and fineness modulus was with the relevant ASTM ranges. It showed well grading of the aggregates in concrete mix.

Slump test performed on all mixes and the results reported earlier are plotted in Figure 9 for comparison. It may be observed that highest recorded slump was of conventional concrete. Addition of recycled aggregates affected the slump by 16.67%. The reduction in slump further increased due to addition of fly ash by 33.33%, 37.5, 33.33%, 39.6%, 45.8% for batches B1 to B5 respectively. This shows that water demand of the mix increases with addition of RCA and gets further increase with addition of the fly ash. It should be considered while calculating the water cement ratio of the mix. Otherwise, the resulting mix will be stiff as was the case during slump test and demand use of plasticizer for proper workability. The increased demand of water was considered for sample preparation in this study.

During testing of the specimen load and central point deflection were recorded at regular intervals till complete failure of the beams. The obtained results of 7-day cured samples are plotted in Figure 10 to Figure 16 for all five groups of aggregates. Good agreement between the samples may be observed with minor variations. Similar trend was also observed for 28-day and 90-day cured samples. The deflection results of five samples within batch were averaged. The averaged values for 7-, 28-, and 90-day cured samples are plotted in Figure 17 to Figure 19. It may be observed that recycled aggregate concrete showed lesser deflection than conventional concrete leading to better control of the deflection. Further improvement was observed due to addition of fly ash. The maximum decrease in the deflection was up to 44% in 7-day cured specimens. This shows that both recycled aggregates and fly ash has good deflection resistance and when combine the net effect on the deflection is noticeable. Further observation revealed that for all curing ages the maximum deflection observed by the beams was less than the allowable deflection by ACI318 under the loading conditions used in this work.

From the recorded maximum sustained load by each specimen flexural strength was computed in accordance with ASTM C293 [32]. The obtained results were average over all five specimens in each batch and each curing age. The same are plotted in Figure 20 to Figure 22 for comparison. It may be observed from the figures that due to addition of recycled aggregates flexural strength dropped than conventional concrete, but addition of fly ash showed improvement. The maximum flexural strength recoded was equal to 4.2 MPa at 28-day curing in comparison to 4.4 MPa of conventional concrete at same curing age. Further observation revealed better performance of recycled aggregates from demolished waste of column than other four counterparts. Lintel concrete showed least results whereas other three sourced showed more or less similar results. For recycled aggregates from column concrete, 7-day cured samples observed 7% reduction in average flexural strength. 28-, and 90-day cured samples observed 2% and 1% reduction in the strength. For other sources the reduction in the strength was in the range of 10% - 44%.

Comparison of the effect of curing age revealed that elongated curing (90-days) has good impact on the flexural strength of recycled aggregate members except conventional concrete where 28-day strength was recorded maximum with minimal reduction in strength at 90-day curing. Figure 23 shows the average flexural strength at different curing ages. It may be observed that in all samples of recycled aggregate concrete 90-day curing showed improved performance with maximum increase for sample cast with recycled aggregates from column concrete. Further comparison of the percentage change of flexural strength for different curing ages with respect to conventional concrete (Figure 24) and with respect to mixed recycled aggregate concrete (Figure 25) maximum improvement is again with samples prepared from column concrete. The error is evaluated with respect to 28-day cured sample being standard curing age used in the field. Although elongated curing showed improvement in the strength, but the increase is only 3%. The increase being less than 5% may be ignored to save the curing time and 28-day curing commonly used may the continued. However, the improvement with elongated curing should be considered wherever necessary.

The failure of the specimens at peak load was monitored as flexural failure (Figure 26) which confirms with the theoretical failure of plain concrete prisms. Few prisms observed minor cracks at little offset from center but in all samples, failure was dominantly the flexural failure. This also confirms the usability of recycled aggregates as coarse aggregates in concrete beams with respect to failure mode.

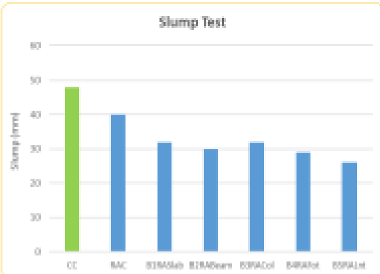

Figure 9: Slump values

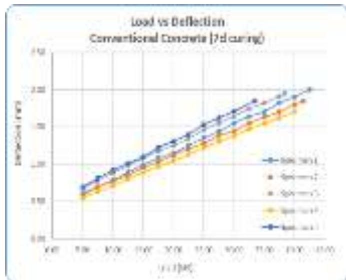

Figure 10: P-Δ (CC)

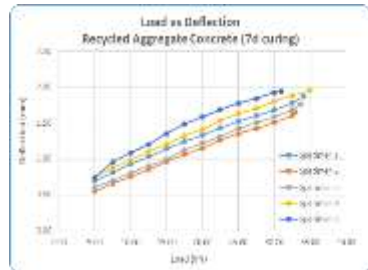

Figure 11: P-Δ (RAC-mix)

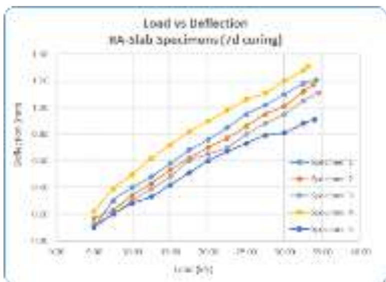

Figure 12: P-Δ (B1)

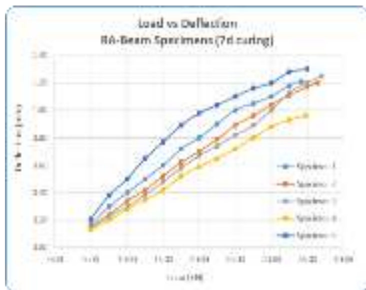

Figure 13: P-Δ (B2)

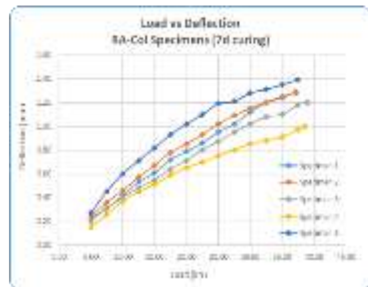

Figure 14: P-Δ (B3)

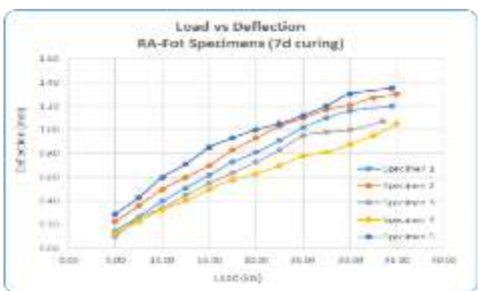

Figure 15: P-Δ (B4)

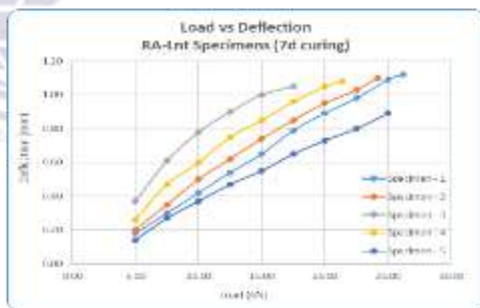

Figure 16: P-Δ (B5)

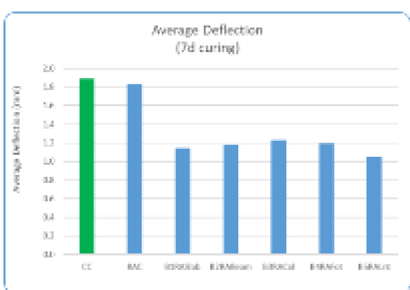

Figure 17: Avg. deflection (7d)

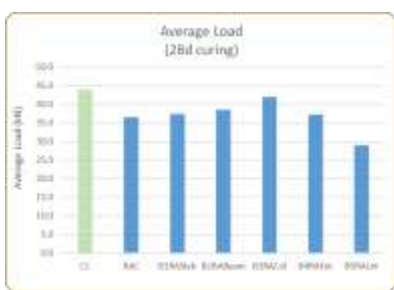

Figure 18: Avg. deflection (28d)

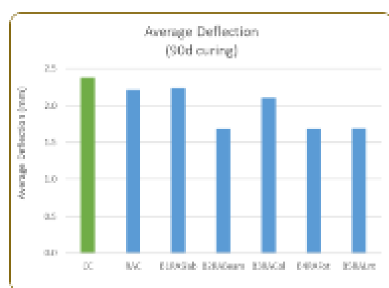

Figure 19: Avg. deflection (90d)

Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X Volume 3, Issue 10, 2025

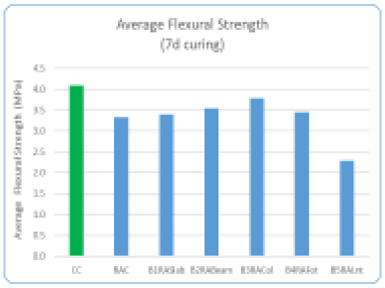

Figure 20: Avg. FS (7d)

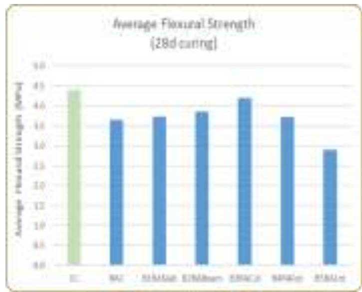

Figure21Avg.FS(28d)

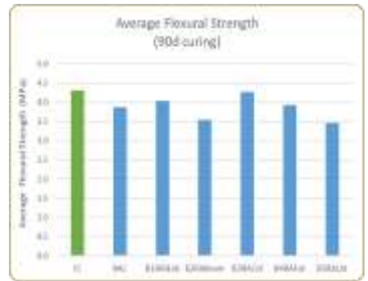

Figure 22: Avg. FS (9

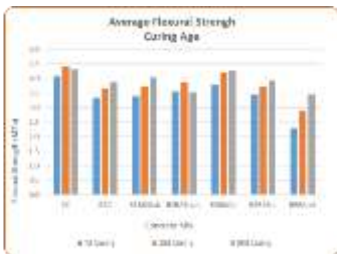

Figure 23: Avg. FS (curing)

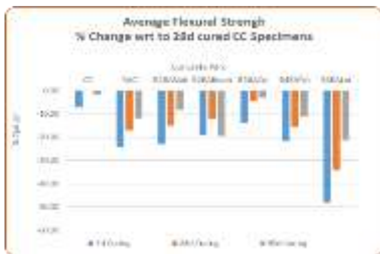

Figure 24:Error (28d-CC)

Figure 25: Error (28d-RAC)


Figure 26: Failure of specimens

Conclusion

Based on the outcome of the research presented in this article, following are concluded

Induction of demolished waste as recycled coarse aggregate negatively impact the flexural strength.

Addition of fly ash in recycled aggregate concrete improves the flexural strength of concrete than recycled aggregate concrete alone.

Out of different structural members recycled aggregates from column concrete performs better than recycled aggregates from other structural members.

7-day cured specimens cast with recycled aggregates from column concrete observed 14% reduction in flexural strength.

28-day cured specimens cast with recycled aggregates from column concrete observed 4.6% reduction in flexural strength.

90-day cured specimens cast with recycled aggregates from column concrete observed 3% reduction in flexural strength.

Deflection in the beams was observed less compared to conventional concrete, thus showed improved deflection resistance of binary blended concrete with recycled aggregates and fly ash.

Deflection in all beams was less than the maximum allowed deflection by ACI-318 for simply supported beams loaded at center.

Although elongated curing (90-days) showed improvement but less than 5%. Therefor, 28-day curing is good enough except when necessary.

Failure mode of all specimens considered in this research work was dominantly flexural failure confirming with theoretical failure mode of plain concrete beams.

REFERENCES

Memon B. A., “Recent Development on Use of Demolished Concrete as Coarse Aggregates”, International Journal of Emerging Technology and Innovative Engineering, Vol. 2, No. 1, 2016.

Kilani A., Fapohunda C., Adeleke O., and Metiboba C., “Evaluating the Effects of Agricultural Wastes on Concrete and Composite Mechanical Properties: A Review”, Research on Engineering Structures and Materials, Vol. 8, No. 2, 2022.

Memon B. A., Oad M., Buller A. H., and Bhutto A. H., “Basic Properties of Recycled Coarse Aggregates from Demolishing Waste: A – Review”, World Journal of Engineering Research and Technology, Vol. 8, Issue 3, 2022, pp: 01 – 17.

Oad M., and Memon B. A., “Compressive Strength of Concrete Cylinders using Coarse Aggregates from Old Concrete”, 1st National Conference on Civil Engineering (NCCE 2013-14) - (Modern Trends and Advancements), April 28th – 29th, 2014.

Jin R., Li B., and Elamin A., “Experimental Investigation of Properties of Concrete Containing Recycled Construction Wastes”, International Journal of Civil Engineering, Vol. 16, No. 11, 2018.

Emad M., Soliman N. M., and Bashandy A. A., “Recycled Aggregate High-Strength Concrete”, International Journal of Civil Engineering and Technology, Vol. 10, No. 9, 2019.

Katar I., Ibrahim Y., Malik M. A., and Khahro S. H., “Mechanical Properties of Concrete with Recycled Concrete Aggregate and Fly ash”, Recycling, Vol. 23, No. 6, 2021.

Li C. G., Zhao H. K., Wu J. F., Li X. G., and Zhang Y., “Experimental Study on the Influence of Recycled Aggregates on the Mechanical Properties of Concrete”, E3S Web of Conferences., Vol. 283, 2021.

Motlagh M. H., "Mechanical Properties of Concrete with 100 Percent Coarse Recycled Concrete Aggregate (RCA)", Theses and Dissertations 2960, Rowan University, 2022.

Jun W., Ding Y. H., Xu P., Zhang M. X., Guo M., and Guo S. Q., “Effects of Carbonated Recycled Concrete Aggregates on the Mechanical Properties of Concrete and the Micro-Properties of the Interfacial Transition Zone”, Ceramics-Silikáty, Vol. 66, No. 1, (2022.

Nandhini U., Jayakumar S., and Kothandaraman S., “Flexural Strength Properties of Recycled Aggregate Concrete”, International journal of Application or Innovation in Engineering & Management, Vol. 5, No. 5, 2016.

Prajapati R., and Mishra C., “Effect of Replacement of Cement & Aggregate by Glass Powder & Recycled Aggregate on Flexural Strength of Concrete”, International Journal of Science and Research, Vol. 5, No. 1, 2016.

Evangelista L. and de-Brito J., “Flexural Behavior of Reinforced Concrete Beams made with Fine Recycled Concrete Aggregates”, KSCE Journal of Civil Engineering, Vol. 21, No. 1, 2017.

Vinayak R., Garg V., and Maan S., “Relationship between Flexural Strength of Plane Recycled Aggregate Concrete and Plane Natural Aggregate Concrete”, International Research Journal of Engineering and Technology, Vol. 4, No. 7, 2017.

Yaba H. K., Nail H. S., Younis K. H., and Ibrahim T. K., “Compressive and Flexural Strengths of

Recycled Aggregate Concrete: Effect of Different Contents of Metakaolin", Materials today, Vol. 45, No. 6, 2017.

Sindy S. P., Belen G. F., Fernando M. A., Javier E. L., "Flexural Performance of Reinforced Concrete Beams made with Recycled Concrete Coarse Aggregates", Engineering Structures, Vol. 156, 2018.

Oad M., Buller A. H., Memon B. A., and Memon N. A., "Flexural Stress-Strain Behavior of RC Beams made with Partial Replacement of Coarse Aggregates with Coarse Aggregates from Old Concrete Part-1(124 Ratio)", Engineering Technology and Applied Science, Vol. 8, No. 3, 2018.

Oad M., Buller A. H., Memon B. A., Memon N. A., and Sohu S., "Flexural Stress-Strain Behavior of RC Beams made with Partial Replacement of Recyclable Concrete Aggregates, Part-2: Rich Mix", Engineering Technology and Applied Science Research, Vol. 8, No.5, 2018.

Alsabbagh N., "The Flexural and Compressive Strength of Recycled Concrete", 4th Asia International Conference, Asia Proceedings of Social Sciences, Vol. 2, No. 1, 2018.

Ramadevi K. and Shalini M. J. H., "Flexural Behavior of RC Beams with Recycled Aggregates", International Journal of Engineering and Advanced Technology, Vol. 8, No. 8: 6S3, 2019.

Chaboki H. R., Ghalehnovi M., and Karimipour A., "Study of the Flexural Behavior of Recycled Aggregate Concrete Beams", Journal of Concrete Research, Vol. 12, No. 3, 2019.

Yang I. H., Park J., Kim K. C., and Lee H., "Structural Behavior of Concrete Beams Containing Recycled Coarse Aggregates under Flexure", Advances in Materials Sciences and Engineering, Volume 2020.

Rashid H. M., and Mohammed H. J., "Flexural Behavior of Recycled Demolition Waste Reinforced Concrete Beams", International Multi-Disciplinary Conference, September 07-09m Sakarya, Turkey, 2021.

Chandio S. A., Memon B. A., Oad M., Chandio F. A., and Memon M. U., "Effect of Fly Ash on the Compressive Strength of Green Concrete", Engineering, Technology & Applied Science Research Vol. 10, No. 3, 2020.

Niu H. C., Tariq J., Na H., Wang X. G., Zhang X. G., and Hui C., "Residual compressive and flexural strength of a high strength recycled aggregate concrete", International Journal of Scientific Development and Research, Vol. 6, No. 6, 2021.

Pramod A. V., Parshivamurthy P., Yoganada M. R., and Srishaila J. M., "Mechanical Properties of Recycled Coarse Aggregate Concrete with Mineral Admixture", SSRG International Journal of Civil Engineering, Vol. 6, No. 2, 2019.

ASTM C150/150M-18, "Standard Specifications for Portland Cement", ASTM International, West Conshohocken, PA, 2019, www.astm.org

ASTM C618 – 17, "Standard Specifications for Coal Fly Ash and Raw or Calcined Natural Pozzolan for use in Concrete", ASTM International, West Conshohocken, PA, 2019, www.astm.org

ASTM C136/C136M-14, "Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates", American Society for Testing and Materials (ASTM), Philadelphia, PA. USA, www.astm.org

ASTM C143, "Slump of Hydraulic Cement Concrete", American Society for Testing and Materials (ASTM), Philadelphia, PA. USA, www.astm.org

Bhatti G. S., "Effect of Fly Ash and Source of Demolished Aggregate on Flexural Behavior of Plain Green Concrete", PhD Project, Department of Civil Engineering, Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah.

ASTM C293, "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Central Point Loading)", American Society for Testing and Materials (ASTM), Philadelphia, PA. USA, www.astm.org