COMPARISON OF COMPRESSIVE STRENGTH OF CONCRETE MADE WITH VARIOUS PERCENTAGE OF RECYCLE AGGREGATE

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A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering

Department of Civil Engineering

Sonargaon University

147/I, Green Road, Dhaka-1215, Bangladesh

Section: 15C

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ABSTRACT

Demolition of old structures to make way for new and modern ones is common features in metropolitan areas due to rapid urbanization. Due to strict environmental laws and lack of dumping sites in urban areas, demolished waste disposal is a great problem. The study is a part of comprehensive program wherein experimental investigations have been carried out to assess the effect of partial replacement of coarse aggregate by demolished waste on compressive strength of recycle aggregate for the period of 7, 14 and 28 days. The compressive strength thus observed on has been compared with strength of conventional concrete. In fact, none of the results showed that recycled aggregates are unsuitable for structural use. However, some hypothetical problems related to durability aspects resulted in recycled aggregates being employed practically only as base filler for road construction. This paper focuses on the possibility of the use of recycled aggregate concrete as a structural material. For that purpose an experimental study of the shear behavior and strength of beams made with recycled aggregate concrete was studied.

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CHAPTER 1
Introduction

1.1 Background and Motivations

A great deal of research has been undertaken to find ways of using recycled aggregate in the manufacture of concrete and, in particular, in the use of recycled aggregates from concrete (Poon & Chan, 2007).

The increasing awareness on environmental protection by the public has resulted in having most reclamation projects either been deferred or much reduced in scale. This in turn results in a substantial reduction of the public filling capacity to accommodate the surplus of Construction and demolition (C&D) materials. If these materials are not managed properly, it will also accelerate the depletion of the already limited precious landfill spaces (Poon & Chan, 2007).

C&D waste is one of the largest waste flows in the world. Several research investigate that C&D waste has reached 30–40% of the total solid waste because of the large scale construction and demolition activities resulting from the accelerated urbanization and city rebuilding(Poon & Chan, 2007).

1.2 Research Objectives and Overview

The objectives of research work are:

- To observe and compare the compressive strength of cylinders casted with different percentage of recycled aggregate and normal aggregate.

- To evaluate prospect of using recycled aggregate concrete (RAC) as coarse aggregate.

1.3 Organization of the thesis

Chapter 1: Introduction and Objective. This chapter provides the background and motivations of the research. The overall objectives and expected outcomes are also described in this chapter.

Chapter 2: Literature Review. This chapter reviews the related works in the Recycle Aggregate Concrete with a special focus on varying percentage.

Chapter 3: Methodology. This chapter describes the methodology adopted to carry out the research.

Chapter 4: Results and Discussion. This chapter describes the results of compressive strength of recycle aggregate concrete with various percentage

Chapter 5: Conclusions and Future Work. This chapter summarizes the conclusions and major contributions of this study and provides recommendations for future studies.

CHAPTER 2

Literature Review

A work reports the results of an experimental study on some of the mechanical properties of recycled aggregate concrete (RAC) as compared to those of the conventional normal aggregate concrete (NAC). Ten mixes of concrete with target compressive cube strength ranging from 20 to 50 MPa were cast using normal or recycled coarse aggregates. The development of the cube compressive strength and the indirect shear strength at ages of 1, 3, 7, 14, 28 and 56 days, the compressive strength, the strains at maximum comp ressive stress and the modulus of elasticity tested by using concrete cylinders at 28 days are reported. The results show that the 28-day cube and cylinder compressive strength, and the indirect shear strength of recycled aggregate concrete were on the average 90% of those of natural aggregate concrete with the same mix proportions. For concrete with cylinder compressive strengths between 25 and 30MPa, the modulus of elasticity of RAC was only 3% lower than that of NAC. The trends in the development of compressive and shear strength and the strain at peak stress in recycled aggregate concrete were similar to those in natural aggregate concrete (Ahmed et al., 2020)

Another work reports on comparison of normal and recycled aggregate concrete. Each Series includes a reference concrete prepared with natural crushed stone and two RAC prepared with two coarse aggregates obtained by crushing a normal strength and a high strength concrete. Flexural tests on notched beams and uniaxial compression tests on standard cylinders were performed. In addition, the characteristics of the fracture surfaces were analysed in order to determine the amount of broken aggregates. RAC present lightly lower strengths (1–15%), lower modulus of elasticity (13–18%) and significant reductions in the energy of fracture (27–45%) and, consequently on the fracture zone size, when it is compared with a concrete prepared with natural coarse aggregates. (Casuccio et al., 2008)

Durability of recycled aggregates (RAs) used in concrete production was studied in (Olukunle Bamigboye et al., 2022). In carrying out this assessment, a host of properties ranging from water permeability up to chemical resistance has been taken into account, considering work that has been carried out by researchers on the durability characteristics of RAs. The RAs under each topic are compared with the natural aggregates (NA). The need to assess them is pivotal as it will help provide suitable standpoints for their utilization in construction works of greater magnitude and significance. Results showed that recycled aggregates concrete (RAC) has high water absorption due to its porosity compared to the conventional NA. A mortar fluidity of 135±2.5 mm also exhibited a better permeation performance in contradiction to the synergetic effects of water–binder ratio and the quality of the RA mortar where the result showed that the water sorptivity of the RAC and the quantity of the aggregates are directly related at a constant curing age. The creep of the concrete made from RA is 50% greater than equivalent control concretes made with the conventional aggregates. The RCAs were used as a complete replacement of natural aggregate (100%), and the shrinkage was determined to increase up to 33%. From this comparison, it is well established that RAs possess lesser strength than conventional aggregates. On the other hand, the performance of the RA can be greatly improved with materials like metakaolin, silica fumes, and fly ash, among others.

The objective of (Tabsh & Abdelfatah, 2009) study was to investigate the strength of concrete made with recycled concrete coarse aggregate. The variables that are considered in the study include the source of the recycled concrete and target concrete strength. The toughness and soundness test results on the recycled coarse aggregate showed higher percentage loss than natural aggregate, but remained within the acceptable limits. The compressive and splitting tensile strengths of concrete made with recycled coarse aggregate depend on the mix proportions. In general, the strength of recycled concrete can be 10–25% lower than that of conventional concrete made with natural coarse aggregate.

CHAPTER 3

Methodology

3.1 Introduction

First, we collected materials. We were looking for an old building, got some broken concrete from there and then went to the university. The university lab took it into small pieces with the help of a hammer.

3.2 Methodology Overview

At first collected materials, and tested from materials properly. In this study, five materials are used to produce desired concrete mixture. The materials are cement, fine aggregate, natural coarse aggregate, recycled coarse aggregate and potable water.

3.2.1 Collection of materials

We collected Sylhet sand from construction site of Gabtoli. We collected Cement from green road store.

Figure 1. Sylhet sand, collected from gabtoli

Figure 2 OPC collected from green road store

We collected Stone from construction site of Gabtoli.

Figure 3. Stone collected from Gaptoli

We collected recycle aggregate from construction site of Farmgate.

Figure 4 collected from Farmgate site

3.2.2 Sieve analysis of aggregates (fine aggregate and coarse aggregate)

At first, we separated the fine aggregates. We took no. ¾", 3/8",4" sieve for fine aggregate sieve analysis. Then we sieved it and made a chart of residual.

For particle size distribution for both coarse and fine aggregate sieve analysis method were used according to ASTM C136

3.2.3 Determination of specific gravity of aggregates (fine and coarse aggregate)

It is the aggregate most of which passes through No.4 (4.75m) sieve and contain only that much coarser material as is permitted by the specifications. Same type of sand was used as the fine aggregate for both NAC and RAC in this study as shown in the figure. The sand was oven dried before being use to obtain SSD.

3.2.4 Mix design

A smooth, watertight surface was selected as platform and it were washed before mixing of concrete. Sand was measured for each mixing batches and was spread evenly to the platform. The required quantity of cement was dumped on the sand and spread evenly. Sand and cement were mixed properly until the mixture became uniform in color. Sand and cement mixture was spread evenly and required amount of coarse aggregate was spread on the mixture. When preparing recycled aggregate concrete recycled aggregate was replaced with natural aggregate at desired percentage. After spreading coarse aggregate, whole mass was mixed with shovel properly until the mixture was uniform. Mixing ratio 1:1.5:3.

Figure 5. mixing material

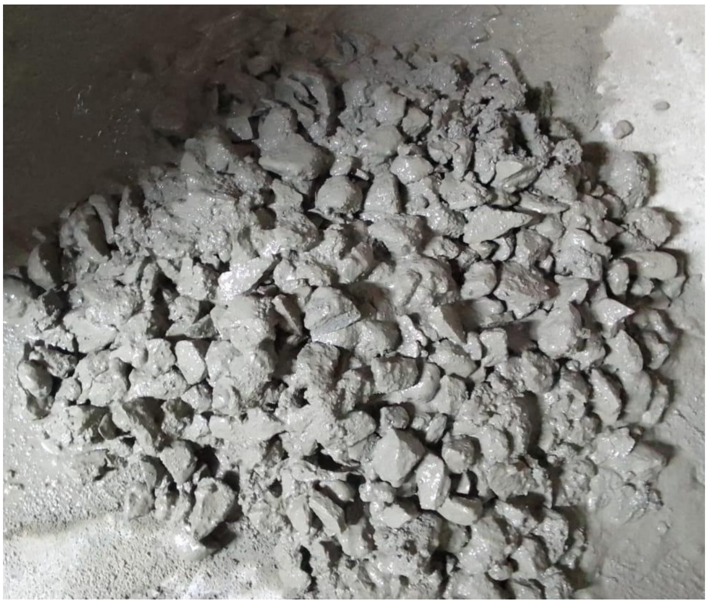


Figure 6. Mixing of concrete

3.2.4.1 ***Water cement ratio***

The water to cement ratio is calculated by dividing the water in one cubic yard of the mix (in pounds) by the cement in the mix (in pounds). So, if one cubic yard of the mix has 235 pounds of water and 470 pounds of cement- the mix is a 0.55 water to cement ratio.

Figure 7. Weighing of Cement

3.2.4.2 *Material ratio*

Quantities of materials for concrete such as cement, sand, and aggregates for production of required quantity of concrete of given mix proportions such as 1:1.5: 3 (M20), can be calculated by absolute volume method.

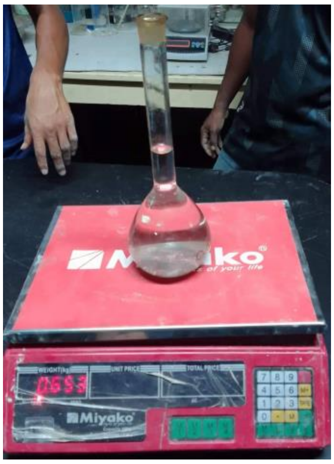


Figure 8. Water

3.2.5 Casting cylinder

Concrete cylinders cast for acceptance testing are typically 4 x 8in or (100 x 200mm diameter by length. A wide variety of single-use or reusable concrete cylinder molds meeting ASTM C470/AASHTO M 205 is available in those sizes. Concrete mixes with larger aggregate sizes must be wet-sieved to remove material coarser than 2” (50 mm). The smaller size and lighter weight of 4 x 8in cylinders make them a popular choice when test methods and project specifications allow.

Figure 9. Cylinder

3.2.6 Curing for specified days

After demolding, the specimens were placed under water up to 7 days 14 days and 28 days. The specimens were fully immersed under water. Figure 5 (7 days) Figure 6 (14 days) Figure 7 (28 days) shows curing of cylinder concrete specimens.

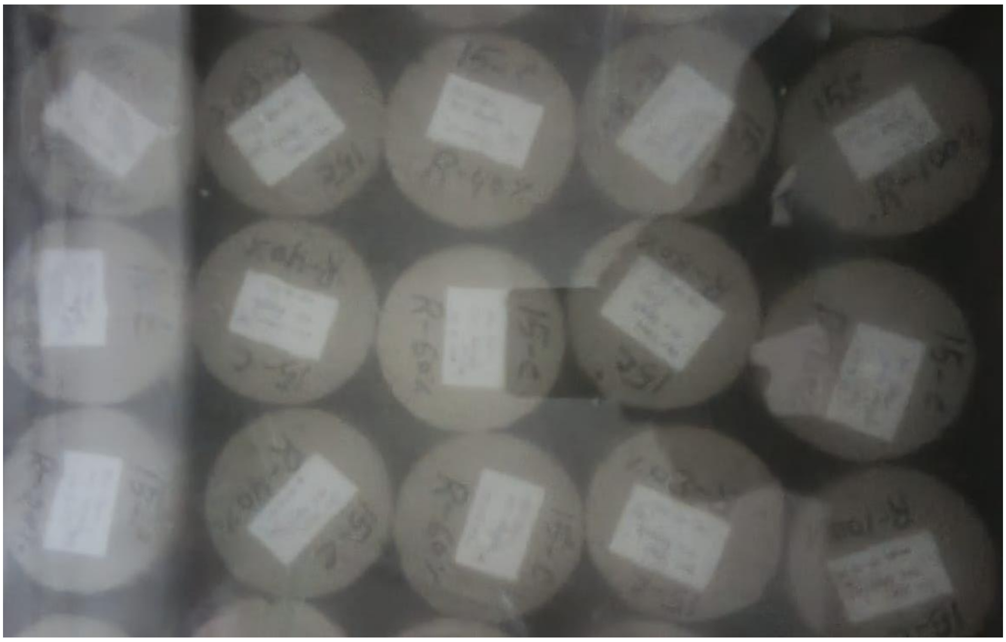


Figure 10. Curing of cylinder

3.2.7 Compressive strength test of cylinder

The aggregate crushing value test is an important test aggregate. Its gives numerical Index of the strength of the aggregate and it is used for concrete in construction of road.

The aggregate has minimum crushing value are a recommended for a roads and pavements as it indicates a lower crushed factions under load and would give a longer service life and a mor economic performance.

Figure 13 Crushing 7 days

Figure 12 Crushing 14 days

Figure 11 Crushing 28 days

CHAPTER 4

Results and Discussion

4.1 Introduction

This chapter presents the findings of the compressive strength test of cylinder with varying percentage of normal aggregate and recycle aggregate.

4.2 Sieve Analysis for fine aggregate

Table 1. Sieve analysis of fine aggregate

Sieve Aperture	Retained(g)	Retained %	Cumulative Retained (%)	Cumulative Passing %
4	0	0	0	100
8	76	7.28	7.28	92.72
16	330	31.91	39.19	60.81
30	366	35.39	74.98	25.02
50	224	21.66	96.24	3.76
100	40	3.86	100	0
Pan	7			

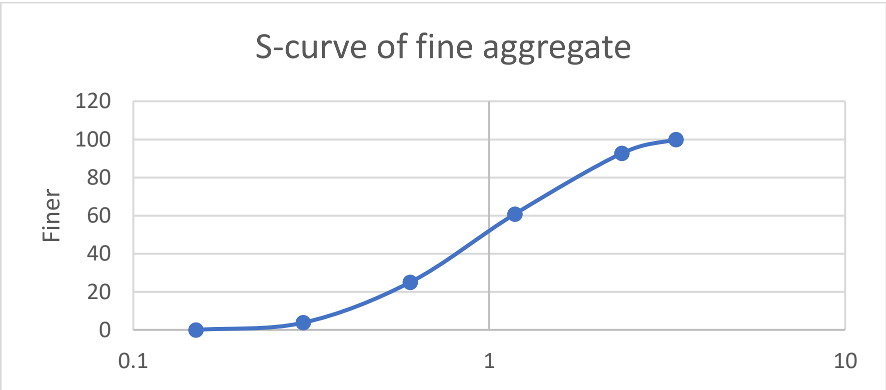


Figure 14. S-curve from sieve analysis of fine aggregate

From the table 1 and figure 11, it is observed that, the collected sylhet sand, as a fine aggregate is a well graded mixture.

4.3 Sieve Analysis for coarse aggregate (Normal stone aggregate)

Table 2. Sieve analysis of normal stone aggregate

Sieve Aperture	**Retained(g)**	**Retained %**	**Cumulative Retained(%)**	**Cumulative Passing %**
3/4’’	675	38.57	38.57	61.42
3/8”	1053	60.17	98.92	39.83
0.19”	22	1.25	100	0

From table 2 and figure 12, the sieve analysis of normal stone aggregate gives a result of uniform graded mixture.

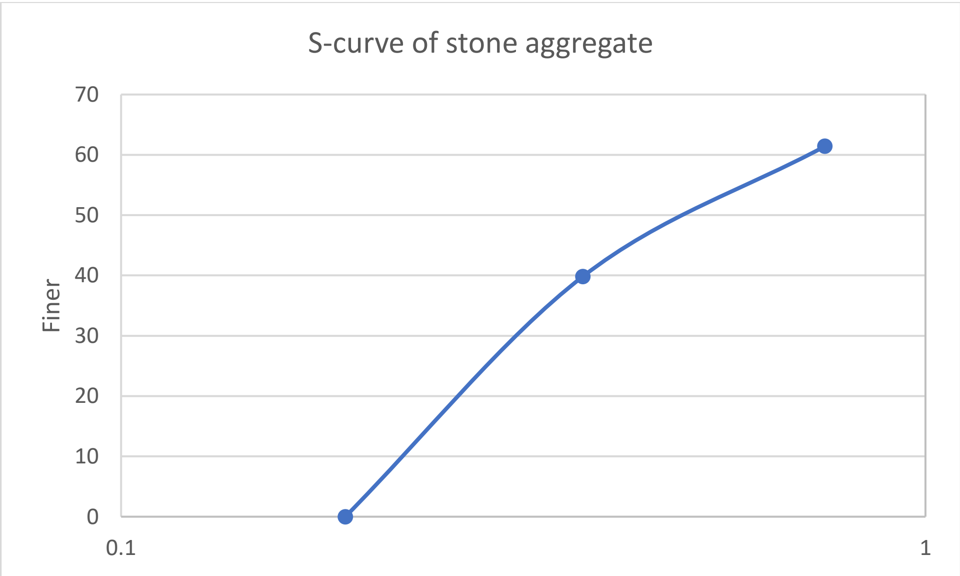


Figure 15. S curve of normal stone aggregate from sieve analysis

4.4 Sieve Analysis for course aggregate (Recycle aggregate)

Table 3. Sieve analysis of recycle aggregate

Sieve Aperture	Retained(g)	Retained %	Cumulative Retained (%)	Cumulative Passing %
3/4''	602	37.16	37.16	62.84
3/8"	957	59.07	96.23	3.77
0.19"	61	3.76	100	0

From table 3 and figure 13, the sieve analysis of recycle aggregate gives a result of non-uniform graded mixture.

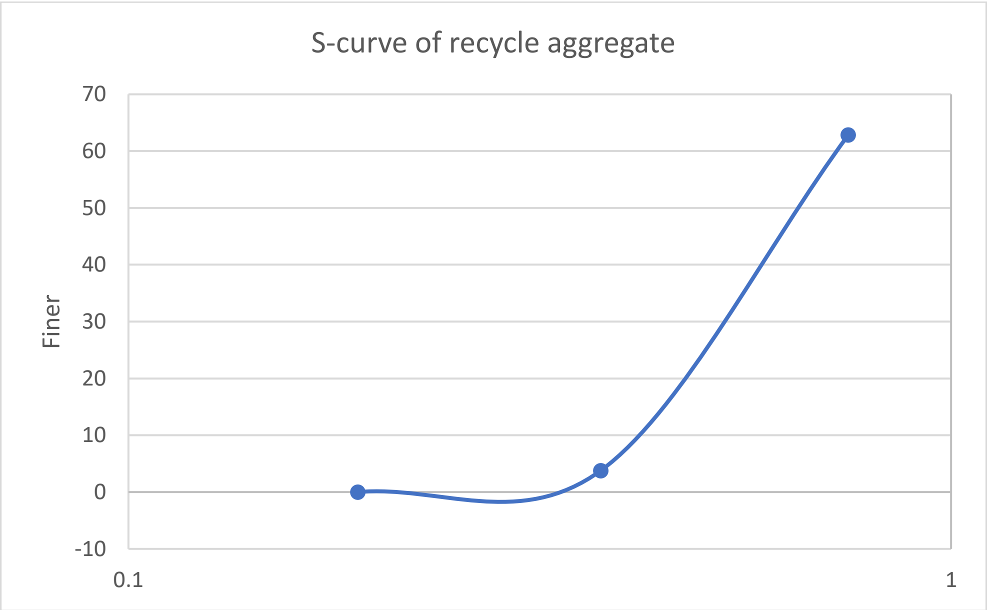


Figure 16. S curve of recycle aggregate

4.5 Specific gravity for coarse aggregate (Normal stone)

Table 4. Data sheet for specific gravity of stone aggregate

Wt. of pycnometer Filled with water to Calibration, B gm	Oven Dry Wt. in air, A gm	Wt. of pycnometer with Specimen and water to Calibration mark, C gm
1465 gm	2435 gm	2465 gm

Table 5. Specific gravity of stone aggregate

Test	Formula	Calculation	Result
Apparent Specific Gravity	$\frac{A}{B+A-C}$	$\frac{2435}{1465+2435-2465}$	1.69
Bulk Specific Gravity (Oven Dry Basic)	$\frac{B}{B-C}$	$\frac{1465}{1465-2465}$	1.46
Absorption Capacity, D%	$\frac{A}{B-C}$	$\frac{2453}{1465-2465}$	2.435
Bulk Specific Gravity (S.S.D. Basic),G	$\frac{(B-A)*100}{A}$	$\frac{(2495-2435)*100}{2435}$	2.43

The specific gravity of the normal stone coarse aggregate after oven drying was found 1.46 Specific gravity for coarse aggregate. We found the specific gravity of the apparatus to be 1.69 and bulk specific gravity oven dry ac obtained from 1.46 Apparent capacity redaction received 2.435 And bulk SSD received 39.83.

4.6 Specific gravity for fine aggregate.

Table 6. Data sheet for specific gravity of fine aggregate

Wt. of pycnometer Filled with water to Calibration, B gm	Oven Dry Wt. in air A gm	Wt. of pycnometer with Specimen and water to Calibration mark, C gm	Wt. of S.S.D. sample in Air, S gm
653 gm	291 gm	834 gm	300 gm

Table 7. Specific gravity of fine aggregate

Test	**Formula**	**Calculation**	**Result**
Apparent Specific Gravity	$\frac{A}{B+A-C}$	$\frac{291}{653+291-834}$	2.645
Bulk SG (Oven Dry Basic)	$\frac{A}{B+S-C}$	$\frac{291}{653+300-834}$	2.445
Absorption Capacity, D%	$\frac{S-A}{A}*100$	$\frac{300-291}{291}*100$	3.092
Bulk SG (S.S.D. Basic),G	$\frac{S}{B+S-C}$	$\frac{300}{653+300-834}$	2.521

The specific gravity of the sylhet sand as fine aggregate after oven drying was found 2.44. Specific gravity for fine aggregate We found the specific gravity of the apparatus to be 2.645. and bulk specific gravity oven dry ac obtained from 2.445 Apparent capacity redaction received3.092 And bulk SSD received 2.221

4.7 Specific gravity for recycle aggregate

Table 8. Data sheet of recycle aggregate

Wt. of pycnometer Filled with water to Calibration B gm	Oven Dry Wt. in air A gm	Wt. of pycnometer with Specimen and water to Calibration mark, C gm
900 gm	860 gm	600 gm

Table 9. Specific gravity of recycle aggregate

Test	Formula	Calculation	Result
Apparent Specific Gravity	$\frac{A}{A-C}$	$\frac{860}{860-600}$	3.30
Bulk Specific Gravity (Oven Dry Basic)	$\frac{B}{B-C}$	$\frac{900}{900-600}$	3.00
Absorption Capacity, D%	$\frac{A}{B-C}$	$\frac{860}{900-600}$	2.86
Bulk Specific Gravity (S.S.D. Basic),G	$\frac{(B-A)*100}{A}$	$\frac{(900-860)*100}{860}$	4.65

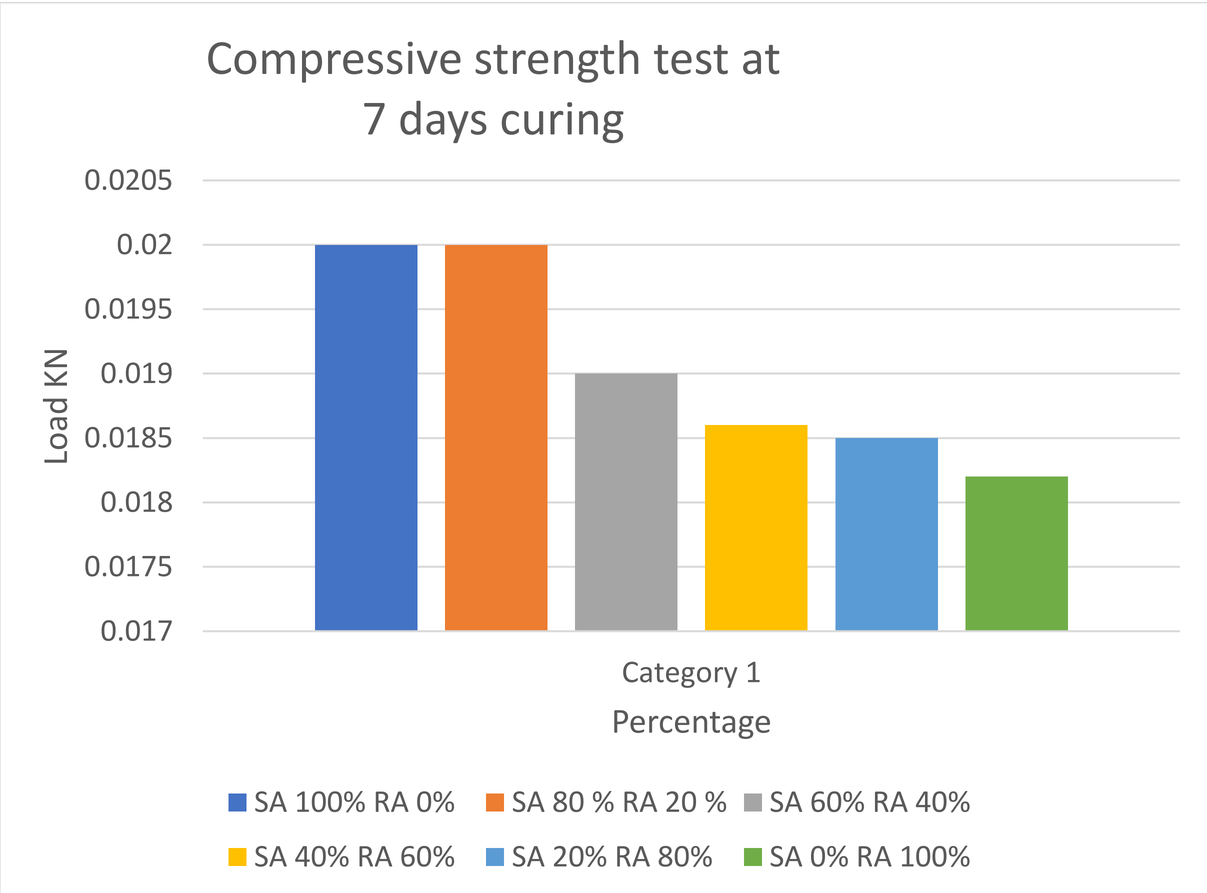
The specific gravity of the recycle aggregate after oven drying was found 1.46 Specific gravity for fine aggregate We found the specific gravity of the apparatus to be 3.30 and bulk specific gravity oven dry ac obtained from 3.00 Apparent capacity redaction received 2.86 And bulk SSD received 4.65

4.8 Recycle aggregate concrete cylinder compressive loading test at 7 days curing

Serial No	Aggregate %		Día		Dia av $(mm)^2$	H $(mm)^2$	Area (mm^2)	Load KN	Compressive strength (KN/mm^2)	Comment
	Stone	Recycle	D_1	D_2						
1	100	0	101.14	101.94	101.54	207	8097.74	170	0.02	
2	80	20	100.75	101.81	101.28	207	8056.33	165	0.020	
3	60	40	102.25	192.92	102.98	206	8264.47	162	0.019	
4	40	60	102.63	102.98	102.80	208	8299.96	155	0.0186	
5	20	80	102.98	102.52	102.75	200	8291.89	154	0.0185	
6	0	100	102.10	101.69	101.89	207.5	8153.66	149	0.0182	

In case of 7days curing.

When we use 100% stone the comprehensive strength is 0.02 KN/mm^2. When the stone decreases, the comprehensive strength decreases. If the stone is 0%, the comprehensive strength is 0.0182 KN/mm^2

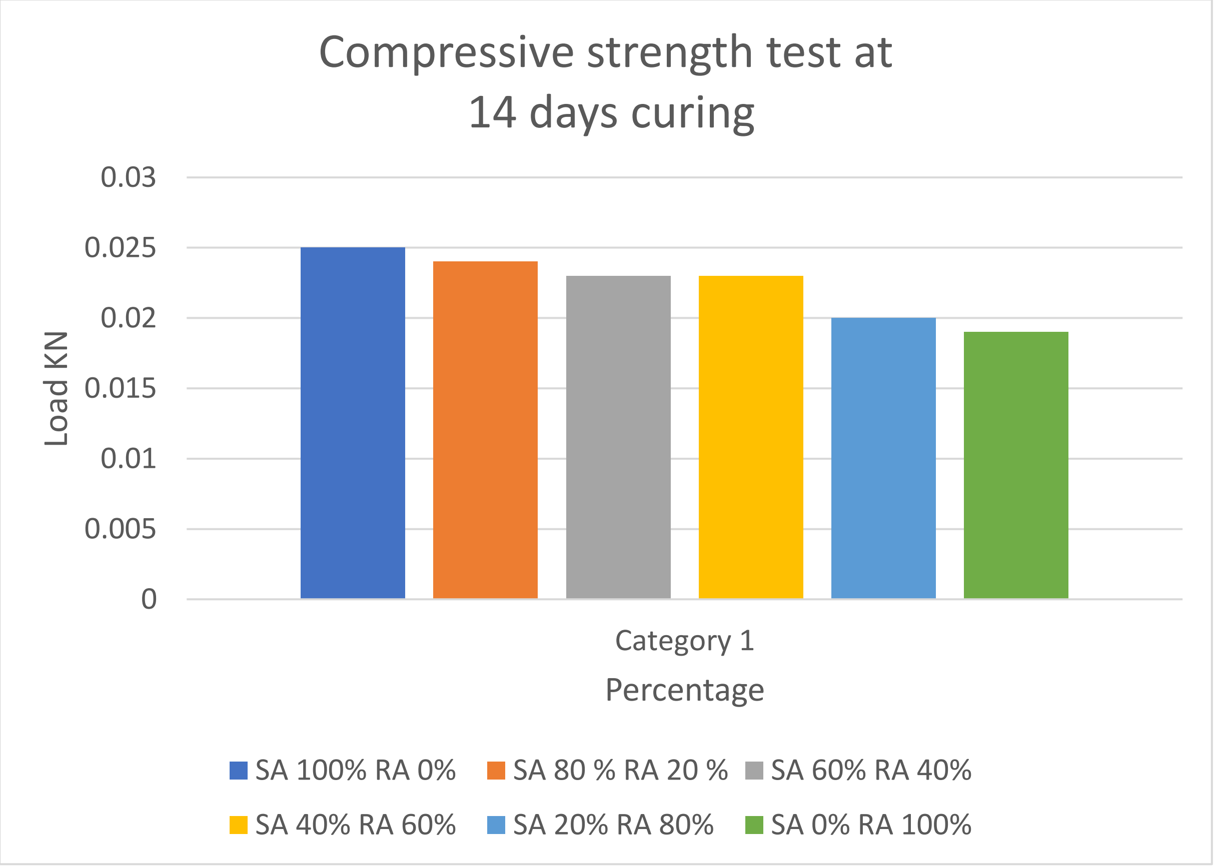


4.9 Recycle aggregate concrete cylinder compressive loading test at 14 days curing

Serial No	Aggregate %		Dia		Dia av (mm)	H (mm)	Area (mm^2)	Load KN	Compressive strength (KN/ mm^2)	Comment
	Stone	Recycle	D1	D2						
1	100	0	101.13	101.95	101.45	205	8097.74	202	0.025	
2	80	20	100.75	101.81	101.28	207	8056.33	198	0.024	
3	60	40	102.26	192.93	102.60	208	8267.70	190	0.023	
4	40	60	102.65	102.95	102.95	207	8299.96	185	0.023	
5	20	80	102.98	102.48	102.73	206	8288.67	170	0.020	
6	0	100	102.35	101.67	102.16	206.5	8196.94	158	0.019	

In case of 14 days curing.

When we use 100% stone the comprehensive strength is 0.025 KN/mm^2. When the stone decreases, the comprehensive strength decreases. If the stone is 0%, the comprehensive strength is 0.019 KN/mm^2

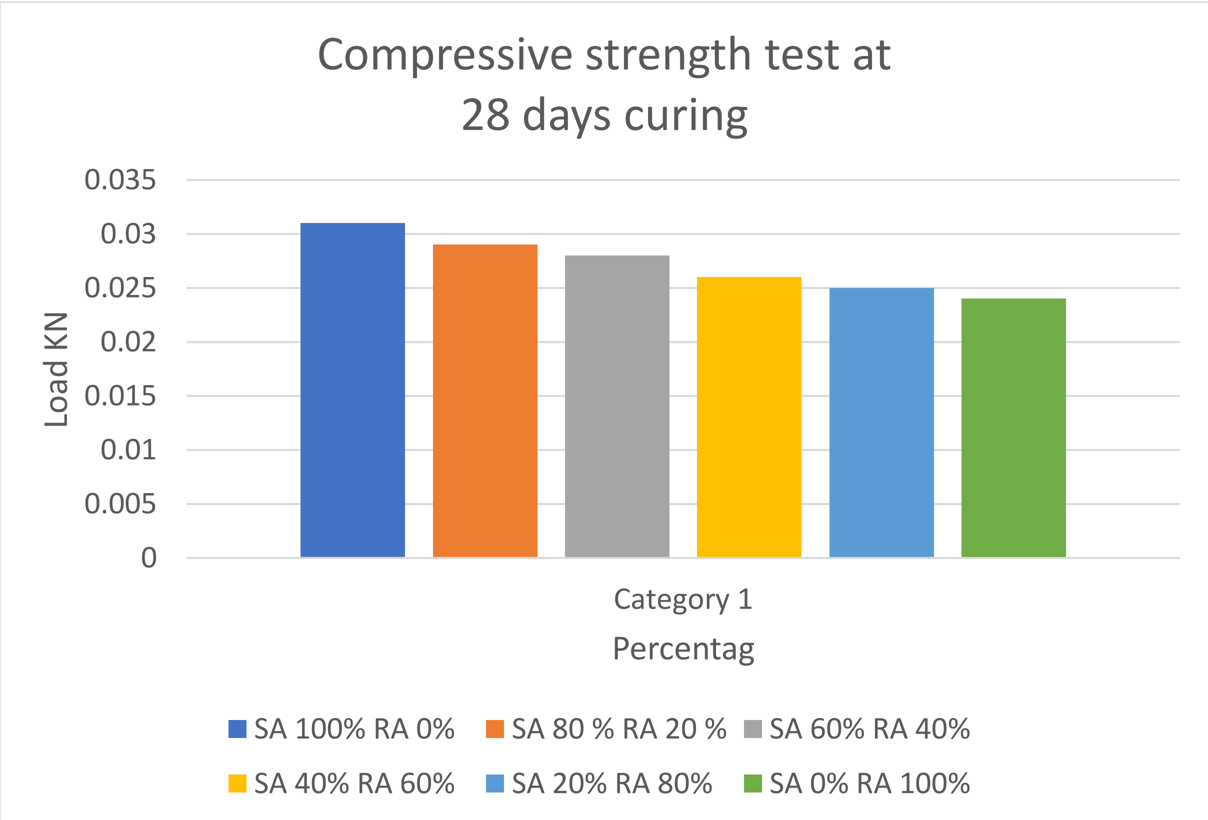


4.10 Concrete cylinder compressive loading test at 28 days curing.

Serial No	Aggregate %		Dia		Dia av (mm)^2	H (mm)	Area (mm)^2	Load KN	Compressive strength (KN/mm)^2	
	Stone	Recycle	D1	D2						
1	100	0	101.49	101.76	101.62	205	8110.51	255	0.031	
2	80	20	101.40	101.80	101.6	205	8107.31	240	0.029	
3	60	40	102.40	102.45	102.42	207	8238.71	235	0.028	
4	40	60	100.80	100.99	100.89	208	7994.40	228	0.026	
5	20	80	102.76	102.62	102.69	206.5	8282.20	213	0.025	
6	0	100	102.93	102.95	102.94	205	8322.58	203	0.024	

In case of 28 days curing.

When we use 100% stone the comprehensive strength is 0.031 KN/mm^2. When the stone decreases, the comprehensive strength decreases. If the stone is 0%, the comprehensive strength is 0.024 KN/mm^2



CHAPTER 5

Conclusions and Future Works

5.1 General

This study gives scenario of strength development characteristics of concrete for different percentage of coarse aggregate. It can be expected that these findings will be useful for construction of concrete structure

5.2 Conclusions

The study is a part of comprehensive program wherein experimental investigations have been carried out to assess the effect of partial replacement of coarse aggregate by recycle aggregate at different percentages in concrete on tensile and compressive strength of recycled concrete for the period of 7 days, 14 days and 28 days. Test results indicate that recycled aggregate, an industrial by-product, is a suitable substitute of natural aggregate in concrete.

1) The compressive strength of concrete with 0% recycled coarse aggregate and 100% stone aggregate of 7 days is 0.02 Mpa , 14 days is 0.025 Mpa 28 days 0.031Mpa that is maximum.

2) The compressive strength of concrete with 20% recycled coarse aggregate and 80% stone aggregate of 7 days is 0.020 Mpa , 14 days is 0.024 Mpa 28 days 0.029 Mpa that is maximum.

3) The compressive strength of concrete with 40% recycled coarse aggregate and 60% stone aggregate of 7 days is 0.019 Mpa , 14 days is 0.023 Mpa 28 days 0.028 Mpa that is maximum.

4) The compressive strength of concrete with 60% recycled coarse aggregate and 40% stone aggregate of 7 days is 0.0186 Mpa , 14 days is 0.023 Mpa 28 days 0.026 Mpa that is maximum.

The compressive strength of concrete with 80% recycled coarse aggregate and 20% stone aggregate of 7 days is 0.0185 MPa , 14 days is 0.020 MPa 28 days 0.025 MPa that is maximum.

The compressive strength of concrete with 100% recycled coarse aggregate and 0% stone aggregate of 7 days is 0.0182 MPa , 14 days is 0.019 MPa 28 days 0.024 MPa that is maximum.

5.3 Limitations and Recommendations for Future Works

This is a short scale research considering only percent replacement of recycle aggregate with stone one due to the limitation of time and resource. To get the more accurate result large scale research should conduct changing various parameters. Such as

- To find the appropriate percent of recycle aggregate to satisfy the required strength
- To estimate the cost reduction for using recycle aggregate
- To determine the environmental impact while using recycle aggregate

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