

Effect of Bio-enzyme on Compressive Strength of Recycled Aggregate Concrete

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ABSTRACT: Degradation of environment is one of the major problems the Earth is facing from the last half century. To reduce some part of environmental pollution, we can use of recycled aggregate in any construction work. This reduces the C&D waste which is produced by demolition of a structure. But use of this recycled aggregate in concrete reduces its compressive strength by 10% to 15%. So, to increase its compressive strength, we have used Bio-enzyme alongwith other basic materials in concrete. By adding different dosages of Bio-enzyme to samples, we get compressive strength of every sample. By plotting a graph of Dosage of Bio-enzyme v/s Compressive strength, we can determine the maximum compressive strength of recycled aggregate concrete having optimum dosage of Bio-enzyme. The results would clear whether the use of bio-enzyme increases the compressive strength of Recycled aggregate concrete or not.

An increase in compressive strength of recycled aggregate concrete has been found with the use optimum dosage of bio-enzyme.

KEYWORDS: Bio-enzyme, enzyme, recycled aggregate, recycled aggregate concrete, compressive strength, C&D waste, Construction and Demolition waste

ABBREVIATIONS: RAC – Recycled Aggregate Concrete, SSD – Saturated Surface Dry, w-c – water to cement

I. INTRODUCTION

A. General

Every structure has a particular life span after which it has to be either repaired, reconstructed or demolished. The act of demolition always results in generation of demolition waste. This demolition waste consists of different components like hardened concrete, wood products, clay tile and brick, sanitary and steel. General practice of handling this demolition waste is land filling which has adverse effects on soil, ground water, etc. Thus, to avoid land filling, we can recycle the aggregates and reuse them in construction.

Recycled aggregate can be obtained by a simple process that involves breaking, removing, crushing, cleaning and sizing of hardened concrete from an acceptable source.

The Bio-waste generated in our day-to-day life is actually not a waste as everything can be reused, transformed and utilized in one or the other form. One of which is bio-enzyme, a bio-product that is obtained by fermentation of bio-waste. It has various characteristics that help in modifying any undergoing reaction in many ways.

In India, every year 165-175 million tonnes of C&D waste is generated [16]. If proper actions are not taken with time, this waste will increase rapidly. In financial year 2018-19, Indian government has increased its expenditure towards infrastructure by 20.9%, due to which more structures will be constructed, and the general practice is by demolishing the old ones and this will eventually increase demolition waste at one point of time. According to a report by NKG infrastructure, there will be shortage of 26.53 million houses in the coming years. There is an act under RERA, which gives permission to undergo re-development of a building after 30 years of its construction. But, a civil engineer designs a structure for life span of 50-60 years. This would not help in decreasing the concrete waste, rather it would increase the generation of concrete waste which is not sustainable for the environment.

With the advances in cement and concrete industry, many admixtures are used in concrete mix to improve, modify or alter different properties of concrete. Admixtures are classified as mineral and chemical admixtures. Some of the admixtures which are used in industry are retarders/ accelerators- to increase/decrease setting time of concrete, plasticizers and super plasticizers- to improve workability of mix, water reducing plasticizers- improve workability by reducing water content, air entraining admixtures- to cause small bubbles of air throughout the concrete mix.

A bio-enzyme is a bio-product prepared by fermentation of bio-waste such as fruit peels, vegetable waste, etc. for a definite period. A bio-enzyme has the ability to breakdown, create, change or catalyze any reaction. The bio-waste contains a wide range of organic compounds which can be used to alter/improve various properties of concrete and in many researches it is found that the use of these bio-enzyme help to increase the compressive strength of concrete, reduce or increase the setting time, etc.

Some uses of bio-enzyme are

- To reduce the use of chemical fertilizer.
- To fertilize the soil for vegetable growing.
- To stabilize the soil.
- To alter properties of concrete and cement.
- Cleaning agent in various household activities.
- Clean dirty and impure water in the farm.

B. Problem Statement

For sustainable development, recycled aggregate concrete can be used in construction works but as the aggregate used in making of recycled aggregate has been already used earlier, RAC shows different values of characteristic properties when compared with normal aggregate concrete.

Table 1. Comparison of Properties

Recycled aggregate concrete property	Change w.r.t. normal aggregate concrete
compressive strength	10% -15%
bulk density	10% -15%
air content	0.5% -1%
specific gravity	15% -20%

The major property of concrete is compressive strength which decreases by 10%-15%. The problem which is addressed is "Low Compressive Strength of Recycled Aggregate Concrete".

For increasing the compressive strength of RAC, trials are to be taken with different dosages of bio-enzyme and results obtained would clear whether the use of bio-enzyme in making of RAC helps to increase the compressive strength or not.

II. LITERATURE SURVEY

A. REVIEW OF LITERATURE

Tony Hartono Bagio, MaknoBasoeki, Julistyana T. and Sofyan Ali Pradana, Optimum Concrete Compressive Strength Using Bio-enzyme in 2017 [1]

They carried out compressive test on normal aggregate concrete with 6 different dosages of bio-enzyme. It was found out that with the addition of bio-enzyme 200 ml/m³, there is an increase of 3.15 % to normal concrete ; addition of bio-enzyme 400 ml/m³, there is an increase of 17.5 % to normal concrete ; addition of bio-enzyme 600 ml/m³, there is an increase of 18.2 % to normal concrete ; addition of bio-enzyme 800 ml/m³, there is an increase of 15.4 % to normal concrete ; addition of bio-enzyme 1000 ml/m³, there is an increase of 16.6 % to normal concrete. On the practical basis, optimum dosage of bio-enzyme was 600 ml/m³.

The optimum dosage based on regression analysis turned out to be 509 ml/m³.

Dr. Wasan I. Khalil, Using Citric Acid as an Admixture and its Influence on some Properties of Concrete in 2009 [2]

They found citric acid to be one of the effective retarders. The optimum dosage of citric acid was 0.02% by weight which caused reduction in water-cement ratio by 13%. They also believed that it is possible to use citric acid as a chemical admixture as it can be classified according to ASTM-C494 as water reducing and retarding agent.



Dr. K. Ramadevi, Dr. R. Chitra, Concrete Using Recycled Aggregates in 2017 [3]

Their theory turned out to be a controversy to the previous works because they concluded an increase in the compressive strength of recycled aggregate concrete in comparison to normal aggregate concrete. It was found that there is not much variation in the strength of concrete replaced with 30 % R.A. but when amount of R.A. increased by 60 % and 100 %, there was a constant increase in the Compressive strength.

Prashant Motwani, Rajendhiran, Santhi A.S., AnandElemalai, High Strength Concrete Using Recycled Aggregate in 2013 [4]

They carried out various tests on recycled aggregate concrete and normal aggregate concrete and compared the results.

Table 2. Comparison of Results (literature survey)

Sr. No.	Test performed	Normal aggregate concrete	Recycled aggregate concrete (100% replacement)
1	Specific gravity	2.74	2.247
2	Water absorption	1%(11% for light weight concrete)	6.2 %
3	Deflection of reinforcement	5.7 mm	4.8 mm
4	Cracking load	40 kN	55 kN
5	Stress-strain curve(elastic region)	Comparatively steeper	Comparatively less steep
6	Modulus of elasticity	X	0.8 X
7	Ultrasonic pulse velocity (>3.5 kmph)	acceptable	Acceptable
8	Cost saving	normal	20%

M. Charitha, CH. Sravani, K. Priyanka, An Experimental Investigation of using Recycled Aggregate in Concrete in 2017 [5]

Their work comprised of investigation of workability and compressive strength of recycled coarse aggregate mix. They prepared 4 mixes with 0%, 20%, 40%, 60% replacement by recycled coarse aggregate in M20 mix. The results were

Table 3. Slump Values (literature survey)

Mix no.	Percentage of recycled aggregate	Slump(mm)
1	0	130
2	20	127
3	40	132
4	60	113

Table 4. Compressive Strength Results (literature survey)

Sr. no.	Mix	Average Compressive Strength (N/mm ²)		
		3 days	7 days	28 days
1	Mix1	16.11	23.11	27.59
2	Mix2	13.3	18.5	23.4
3	Mix3	15.4	21.8	25.6
4	Mix4	15.8	18	21.6

According to their results they concluded that mix2, mix3, mix4 gains compressive strength slowly when compared to mix1. The values of compressive strength and slump test for mix3 (40% replacement) were observed nearer to mix1 (0% replacement)

A. Sathya, P. Bhuvaneshwari, G. Niranjana, M. Vishveswaran, Influence of BioAdmixture on Mechanical Properties of Cement and Concrete in 2014 [6]

Their study revealed that addition of bio admixture- hydro extract and bio powder of Water Hyacinth influence the compressive strength and setting time of concrete. The setting time was delayed, the compressive strength and workability were increased with increasing amount of bio admixture.

Jitendar Sharma, Sandeep Singla, Study of Recycled Concrete Aggregates in 2014 [7]

Their study was related to recycled aggregate properties and its comparison with normal natural aggregate. They found improvement in tensile strength and modulus of elasticity in recycled aggregate mix when the water cement ratio was reduced. The water absorption and porosity of recycled concrete aggregates in higher comparatively but are in permissible limits. They also found low workability of recycled concrete aggregate mixes and further mentioned that replacing the normal concrete aggregate fully may affect on chloride ions resistance. With their experimental results, they concluded that recycled concrete aggregate are of lower quality than normal concrete aggregate.

Nelson, Shing Chai NGO, High- Strength Concrete with Recycled Aggregates in 2004 [8]

Their research focused on sustainable development and their aim was to determine the strength characteristics of recycled aggregate to find out their application in high strength structural concrete. When the w-c ratio was reduced. They found out a 48 MPa compressive strength, improved tensile strength and modulus of elasticity. But they also mentioned the problem faced of low workability with reduced water content. As the achieved compressive strength is good, it can be applied in high strength structure.

Tomas U. Ganiron Jr, Recycling Debris from Construction and Demolition Waste in 2015 [21]

By performing tests on concrete having recycled aggregate, they found the following:

The proportions of concrete debris affect cement and water because it absorbs most of the water in the mixture.

After seven days of curing, the mixture of concrete debris obtained low compressive strength.

The consistency of mortar is affected by the amount of water in mixture.

G. Murali et al, Experimental Study on Recycled Aggregate concrete in 2012 [22]

They performed experiment on recycled aggregate concrete and the test results showed that the RAC was having low flexural, compressive and split tensile strength compared to natural aggregate. They also added that on addition of water and acid treatment, the strength of RAC improved. They treated RA with nitric acid, hydrochloric acid and sulphuric acid and the results of aggregates treated with nitric acid were better than the other two.

Geetha Saramanda, Jyothi Kaparapu, Antimicrobial Activity of Fermented Citrus Fruit Peel Extract in 2017 [9]

Their aim was to evaluate the antimicrobial potency of fermented citrus fruit peels extract. They found activity of garbage enzyme in terms of microbial activity on most of the clinically isolated micro-organism and fungi when compared to standard drugs. They mentioned the need of further studies for better and effective understanding of citrus peel extract as the antimicrobial agent.

Bahiru Bewket Mitikie, Tai Sik Lee, and ByungChul Chang, Application of Enzyme to Clay Brick and its Effect on Mechanical Properties in 2017 [10]

They performed compressive strength test on earthen clay brick for 7th, 14th, 21st and 28th day by adding enzymes to it and they have concluded that the strength of each brick was above requirement i.e. above 5 MPa and the brick which had clay/silt ratio as 85/15 gained maximum compressive strength of 6.89 MPa after 28 days. The compressive strength of common building bricks lies in between 3.5 MPa to 5 MPa and 6.89 MPa is 96% more w.r.t. 3.5 MPa and 37% more w.r.t. 5 MPa.

Pradeep Singh Sodhi, Ocean, Yogesh Kumar, Stabilization of Soil Using Acidic Bio-enzyme (Terrazyme) in 2018 [11]

By conducting different studies and geotechnical tests on the soil sample with and without Terrazyme, they saw proper improvement in consistency limit, dry density, UCS and CBR values.

The results were as follows:

Increase in dosage of terrazyme decreased liquid limit and plastic index from 0.06 ml/kg.

In comparison to day 0 of virgin soil, Terrazyme dosage of 0.2 ml/kg increased UCS and CBR of virgin soil by 375 % & 185.32 % respectively.

M.V. Sravan, H.B. Nagaraj, Preliminary study on use of Terrazyme as a Bio Stabilizer along with cement and lime in Compressed stabilized Earth Blocks in 2015 [13]

Their study showed clear improvement in the soil properties with the use of terrazyme as a stabilizer. The liquid limit decreased with time and plastic limit increased with time on addition of terrazyme. With appropriate dosage of

terrazyme, the soil can be transformed to less compressible soil with ageing which indicates that the soil becomes relatively more volumetrically stable.

Sanjeet Sahoo, G. Sridevi, Soil Stabilization using Bio-enzyme in 2018 [12]

They found a significant improvement in soaked CBR test, unconfined compressive strength of black cotton soil. The UCS for soil having 0 ml dosage was found to be 120 KN/m². On addition of 0.05 ml/kg dosage, the results for 1 day and 7 days were 122.5 KN/m² and 151 KN/m² respectively. When the dosage was increased to 0.1 ml/kg, the results for 1 day and 7 days were 135.5 KN/m² and 173 KN/m² respectively. They also conducted CBR test and the values for unsoaked and soaked condition with 0 dosage of terrazyme was found to be 3.79% and 2.286% respectively. With addition of 0.05% and 0.1% of terrazyme, the CBR values for 4 days soaked condition were 5.3% and 6.6% respectively.

B. Godrej | Construction, Recycled Concrete Blocks & Pavers [15]

Godrej | Construction have started creating innovative products and rebuilding infrastructure in concern for the environment which includes three step process (Integrity, reliability and Care) leading to sustainability and building a greener world. They have come up with different products with the use of following steps:

- a. Collecting debris of size less than 20 mm from limited trusted sources. The debris should be free from all the impurities (i.e. steel, bricks, etc.) other than cement and aggregates.
- b. Crushing these debris in jaw crusher and producing R.A. of size less than 10 mm.
- c. Use of these R.A. in making of various products according to their mix design.

C. Research Gap

There have been many researches done to increase the compressive strength of normal aggregate concrete and earthen bricks, stabilize soil using bio-enzymes but there is a lack of research in improvement of compressive strength of recycled aggregate concrete using Bio-enzymes.

III. METHODOLOGY

A. Material

- a. Aggregate
 - i. The aggregates should conform the properties according to IS 383 : 2016.
 - ii. The aggregates should be in saturated surface dry (SSD) condition.
 - iii. The Coarse aggregate to be used in our experiment are according to IS 383: 2016 obtained from Navdeep Constructions.
10 mm and 20 mm size aggregate are to be used in 40-60 proportion.
 - iv. The fine aggregates are to be fully replaced by recycled fine aggregate obtained from Godrej plant.
- b. Cementitious material
 - i. Type and grade of cement used is OPC- 53 (75%)
 - ii. Fly ash (25%)
- c. Admixture
 - i. The use of admixture is only to increase the flow/ workability for easy handling of concrete. The results of the experiment would not be affected by the use of admixture as it has been used in equal amounts for all trials.
 - ii. The admixture used is SikaPlast®-5201 NS.
- d. Bio-enzyme
Along with other components of the mix, bio-enzyme is also added to different trials according to the dosage.

B. Preparation of Bio-enzyme

The bio-enzyme used is lemon bio-enzyme. The period of fermentation in our case is 3 months i.e. from October, 2019 to January, 2020.

C. Mix design calculation for M30 Concrete (according to IS 10262:2019) [18][19][20]



Table 5. Quantity of Material (according to mix design)

Sr. No.	Material		Quantity for 1 m ³
1	Cementious content	Cement	427 kg
		Fly ash	107 kg
2	Water		192litres
3	Coarse aggregate		1144 kg
4	Fine aggregate (recycled)		650 kg

D. Casting and testing of concrete cubes according to different dosage of bio-enzyme.

a. Casting of cubes

i. Calculation of material according to batch size.

- (1) The proportion of different materials in the mix design are computed according to batch size of 1m³.
- (2) In practical means, one trail will comprise of only 9 cubes (i.e. very less than 1 m³) that has dosage of bio-enzyme according to previous plan.
- (3) Therefore, calculation of material according to the batch size is necessary for easy handling of materials, maintaining records and avoiding mistakes.

ii. Weigh the material accordingly and gather them in a place near to the mixer.

Important: We need aggregate to be in SSD condition. The fine aggregates used are recycled having greater water absorption.

Generally, on site the water absorption values of fine and coarse aggregate are found out experimentally and changes in proportion are made accordingly to meet the SSD condition.

Recycled aggregate has frequent variation in their properties as their source varies.

In our case, to meet SSD condition;

- (1) Small amount of water is sprinkled on fine aggregate.
- (2) Material is mixed properly.
- (3) The above two steps are to be repeated until a stage is received when the aggregates look wet enough but does not stick to hands.

This method is to be followed every time before casting any batch.

iii. Mixing of material is to be done using rotatory mixer.

- (1) Firstly, the internal surface of mixer is buttered with cement paste or simply water to avoid sticking / accumulation of mix material on surface.
- (2) The next step is addition of coarse and fine aggregate to the mixer and mixing them for a while, then cement is to be added and mixed and water is poured into the mixture in next step.
- (3) Later, admixture SikaPlast®-5201 NS is added and mixed to increase workability and lastly bio-enzyme needs to be poured and mixed according to the dosage.

iv. Concrete is then poured in the mould (oiled / greased) and after a while batch name is scratched on its cube for its identification.

b. Compressive test is to be performed on 7th, 14th and 28th day.

c. The dosages planned are according to the following table

Table 6. Trials

Trial no.	1	2	3
Dosage(ml)	0	200	400

E. Comparison of Results

After one or two trials, the results of compression test help us to decide the next dosage of bio-enzyme. If the results are satisfactory, we can continue with the designed procedure, if not we can accordingly decide the next dosage for improved results.



F. Computation of results and getting a generalized optimum result

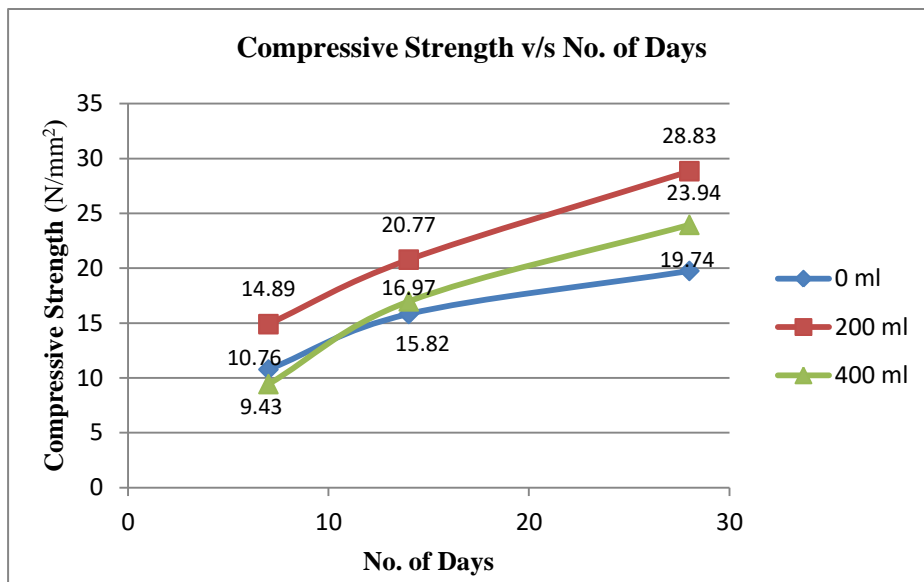
After all the trials are completed, the next step is to obtain a optimum dosage that has the maximum compressive strength. For that, a graph of compressive strength v/s dosage (dependent v/s independent quantity) is to be plotted. The dosage having maximum compressive strength at 28th day is the optimum dosage (ml/m³).

IV. EXPERIMENTAL RESULTS

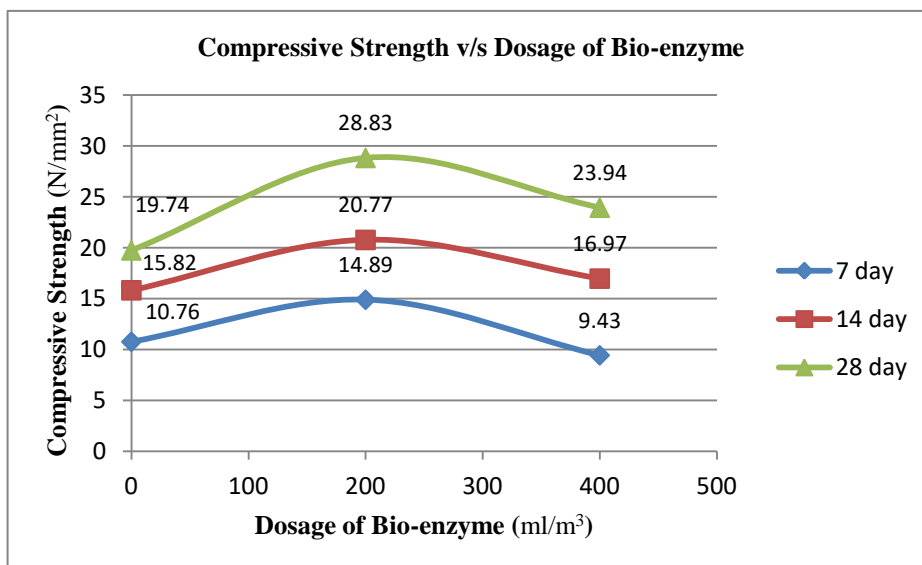
A. The compressive strength test results according to different dosages of bio-enzyme are as follows:

Table 7. Compression test results- 0 ml, 200 ml, 400 ml dosage of bio-enzyme

Dosage (ml/m ³)	Compression test results (N/mm ²)		
	7 th day	14 th day	28 th day
0 ml	10.76	15.82	19.74
200 ml	14.89	20.77	28.83
400 ml	9.43	16.97	23.94



Graph 1. Compressive Strength v/s No. of Days



Graph 2. Compressive Strength v/s Dosage of Bio-enzyme

B. Discussions

- a. It can be seen in Graph 1 that at every stage the compressive strength of concrete having 200 ml dosage is higher than the other two dosages.
- b. When we have a closer look at Graph 1 and Graph 2, it can be seen that the compressive strength of 400 ml dosage at 7th day is 9.43 N/mm^2 which is lower than the compressive strength corresponding to 0 ml dosage having 10.76 N/mm^2 .
- c. But later, at 14th and 28th day, the compressive strength of 400 ml dosage is having values of 16.97 N/mm^2 and 23.94 N/mm^2 respectively which is higher than the compressive strength of concrete with 0 ml bio-enzyme dosage having 15.82 N/mm^2 strength at 14th day and 19.74 N/mm^2 strength at 28th day.
- d. From the above points, we can say that the enzyme helps in improving the compressive strength of RAC.

V. CONCLUSION

Based on the experimental work done in the project,

We get the maximum Compressive Strength of 28.83 N/mm^2 (96.1% of 30 N/mm^2) corresponding to RAC having 200 ml/m^3 bio-enzyme dosage which therefore turns out to be the optimum dosage. Also, from the other dosages, it is clear that the bio-enzyme used surely helps to improve the Compressive Strength of Recycled Aggregate Concrete. The compressive strength of RAC having 0 ml/m^3 dosage is 19.74 N/mm^2 which is only 65.8% of 30 N/mm^2 . The increase in strength due to use of bio-enzyme is good and commendable. As the compressive strength achieved with the optimum dosage of bio-enzyme is good enough, it can be used in many construction works when the results of other required tests performed on concrete are satisfactory.

By the simple usage of bio-extracts, a major chunk of national waste can be reduced thus bringing about a paradigm shift in the way demolition waste is treated, ultimately leading to sustainable development.

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