Feasibility of Recycled Concrete in Pavements with Demolished Building Waste in UAE

Priyanka Sunil Sabhnan, Vidya P Mohanan

Abstract—The growing population has increased the demand for residential and commercial buildings. As a result of demolition of these buildings, lot of construction waste is generated. Most of these waste are non-biodegradable. When put into landfills, these waste pollute the land and harm the environment. Therefore, need of recycling these materials and using them is necessary. Concrete aggregates from demolished buildings can be reused to make concrete. However, its strength is immensely affected due to cement paste and mortar attached to it. Experimental research was carried out to determine how strengths of concrete made of natural aggregate, rejected concrete batch aggregate, aggregate from 8 years and 16 years old demolished buildings vary and also the feasibility of each. Different ratios of each type of recycled aggregates were taken along with the natural aggregates to determine how strength varies with change in ratio.

Keywords—recycled concrete aggregate; compressive strength; moisture content; porosity; specific gravity; void ratio

I. INTRODUCTION

A. Concrete

The need to build has been there since pre-historic times. The ideology and methods of past has helped us shape our present.

Previously, wood and stones were the materials used for construction. Slowly, methods and techniques evolved. People began using mud and clay to build houses. As time passed, it was understood by people that the material and the way it is used are key factors in order to get a structure which is strong and has a greater lifespan.

Romans were the first ones to use concrete as a construction material [5]. Its main advantage is its workability. Its ability to remain workable and strong has made it an incredible versatile material with room for innovation.

Today, concrete is produced in large quantities. Technology has helped us decrease time and cost for construction as large amount of concrete can be produced and placed at once without compromising the strength of the structure.

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B. *Constituents of concrete*

Concrete is a composite mixture of four main ingredients: Portland cement, water, fine aggregate and coarse aggregate. The ratio of these four ingredients can be varied to get desired properties of concrete and can be used for construction. (Table 1)

TABLE I: MIX DESIGN FOR DIFFERENT COMPRESSIVE STRENGTHS

Designation	Mix design	Characteristic compressive strength in n/mm^2	Group (as per is:456-2000)
M5	1:05:10	5	Lean mix
M7.5	1:04:08	7.5	
M10	1:03:06	10	Ordinary concrete
M15	1:02:04	15	
M20	1:1 ½:3	20	
M25	1:01:02	25	Standard concrete
M30	Designed	30	
M35		35	
M40		40	
M45		45	
M50		50	
M55		55	
M60		60	High strength concrete

C. Quality parameter of fresh concrete

Fresh concrete is a freshly mixed composite material which can be placed and molded into any shape. The amount of aggregates, water and cement used in the mixture control the properties of wet concrete. Table 2 shows the factors need to be taken into consideration as they affect wet concrete.

TABLE II: FACTORS AND QUALITY PARAMETERS OF FRESH CONCRETE

Factors	Quality Parameter
Colour of concrete	Grey colour due to cement
Workability	Try to reduce water cement ratio and use admixtures to improve workability so that strength is not compromised. Use the right mix proportion. Use bigger size of aggregate that is well graded and cubical in shape.
Bleeding	For concrete to be of good quality, water should not come out to the surface.

Segregation	Constituent materials of concrete should not separate in the mix. Mix the concrete properly and use vibrators appropriately for compaction to avoid segregation.
Temperature	Temperature of wet concrete should be between *25 to 30 °c.*

D. Recycled concrete aggregate

Concrete is most widely used since it is available easily and at affordable cost. However, demolition of buildings can produce lot of concrete waste. Concrete is a non-biodegradable material which harms the environment to large extent. Studies are been done to find out how this concrete waste can be used economically in construction to reduce waste accumulation and waste pollution. One such material that can be reused from these demolished waste is recycled concrete aggregate.

Recycled concrete aggregate are aggregates taken from demolished structures. They can be reused as aggregates to prepare fresh concrete and can be used. This will help in reducing the cost of aggregates and also help to reduce the accumulation of waste due to demolished or waste concrete.

Objectives

- To find out how strength varies with different proportions of recycled aggregate and natural aggregate.
- To find out how various aggregate properties vary when compared to natural aggregate.

II. LITERATURE REVIEW

A. Research paper reference: A study on recycled aggregate as a substitute to natural aggregate for sustainable development in India [4]

The use of recycled aggregates for concrete can help reduce the environmental impact of constructional waste.

The uses of RCA is limited since its properties are not up to the mark as that of NCA. However, up to some proportion of NCA with RCA can be used for construction.

The properties of RCA as compared to NCA show that there are lots of problems when it comes to using RCA. Therefore, high quality of RCA needs to be used to get better results.

In this experimental analysis,M65 concrete mixture was prepared with water to binder ratio of 0.45 with cement content of 400 kg/m^3 having recycled concrete aggregate content of 0%, 20%, 50% and 100%. These were tested for compressive strengths after 1 day, 4 days, 7 days, 28 days and 90 days.

It was noted that as the amount of RCA in the concrete mix increases the compressive strength of the concrete decreases. It was concluded that up to 20 % RCA can be utilized for economical and sustainable development of concrete.

B. Research paper reference: Recycled concrete as aggregate for structural concrete production [2]

An experimental analysis was done with different ratios of natural concrete aggregate (NCA) with recycled concrete aggregate (RCA). Samples having 100% NCA(R0), 50% NCA and 50% RCA(R50) and 100% RCA(R100) were considered. 99 specimens were prepared and tested.

When concrete is crushed to make RCA, certain amount of cement paste and mortar from the original concrete is stuck to stones which result in low quality of RCA compared to NA. In order to get a better quality of RCA this cement paste and mortar paste has to be separated from the stones.

Since this mortar that is attached to the recycled aggregate cannot be completely removed, the water absorption of RCA is higher than that of NA. Therefore, to obtain the desired workability certain amount of water needs to be added to saturate recycled concrete before or during mixing if no water reducing admixtures are used. Either the aggregate could be "water saturated surface dry" ie the state where no more water absorption can take place in the aggregate or by drying the aggregate completely and adding the required amount of water during mixing.

The Recycled concrete aggregate was prepared from old concrete cubes used for compressive strength testing and one from precast reinforced concrete column. Primary crushing was performed by a pneumatic hammer and secondary crushing was done by a rotating crusher.

Certain tests were performed on natural aggregate and recycled aggregate to check their quality. Natural aggregate meet all required quality standards. However, Recycled aggregate did not meet all required quality standards. It had high percentage of content of weak grains and high mass loss percentage of crushing resistance.

Slump test was performed immediately after batching and after 30 minutes. After 30 minutes it was noted that almost same workability was achieved by R0, R50 and R100. Additional water was used in R50 and R100 to get the required workability. Also, the difference in air content was insignificant. The bulk density of R0 was the highest and R100 was the lowest.

R100 had highest compressive strength followed by R50 and R0 at the end of 28 days. Drying shrinkage tests were done on R0, R50 and R100 which clearly showed that the amount of shrinkage in R100 was more since it absorbed more water.

Tests were also performed to check the bonding of concrete with reinforcement.

The results for compressive strengths showed insignificant different. The author of the journal compares his results to other authors and concludes that same strength of concrete can be produced as of NA if RCA of high quality is used contradicting the results of other authors that claim RCA gives weak compressive concrete strengths has the percentage of RCA used increases.

Modulus of elasticity is low for R100. Also water absorption and material loss is high for R100.

On testing of reinforced beams having concrete R0, R50 and R100 it was noted that upto some load that was added the difference in the deflection was negligible. However as the load increased it was noted that R100 had the maximum deflection followed by R50 and R0. This also showed that as the quantity of RCA used increases the deflection in the beam increased which is also the same reason for R100 having low modulus of elasticity.

Concrete compressive strengths increases with the amount of RCA used.

The experiments proved that concrete having recycled aggregate had a satisfactory performance as compared to natural aggregate.

However, it is not advisable to use recycled aggregate for structural elements as modulus of elasticity and shrinkage deformation of Recycled concrete aggregate is lower than that of natural aggregate. Also this concrete should not be used for structures exposed to aggressive environment conditions without appropriate previous testing.

C. Research paper reference: Use of recycled aggregate as an alternative of natural coarse aggregate for structural construction [1]

The increased pollution due to construction waste has led to become a concern for the environment, therefore the use of recycled concrete aggregate is being done to have a sustainable environment in which they have compared Bangladeshi standard and ASTM.

For the following research Natural coarse aggregate, recycled coarse aggregate, fine aggregate, cement is being used. To analyze the compressive strength of concrete, cylinder of size 6 inch diameter and 12 inch height were prepared. The ratio of cement: sand: aggregate was taken 1:2:4 and constant water-cement ratio of 0.48 was used in all the samples.

Ratios which they considered or performed was (80%NA-20%RA), (60%NA-40%RA), (40%NA-60%RA) and (20%NA-80%RA). The observation they got shows that the bulk density of NA is higher than all the samples, all the samples possessed value above the minimum standard of 90lb/ft3. From their first experiment they observed that the compressive stress of RA was more than NA.

From the physical properties and compressive strength of RA, NA and percentile mixing samples of RA and NA was investigated. From the experimental physical property analysis, it is clear that all the samples confirm to the standard value for bulk density. For specific gravity and % void determination, RA and 20%NA-80%RA combination failed to meet the standard rate. Only the NA and 80%NA-20%RA combinations exhibit the absorption capacity value within the standard range. The NA, RA and all other mixing combinations confirm 28 days compressive stress value above BNBC minimum standard for structural use.

III. METHODLOGY

A. Sample collection

In order to conduct our experiment samples had to be collected. Natural aggregate and recycled aggregate samples were collected from concrete mixing company. 8 years old recycled aggregate (Figure 1) and 16 years old recycled aggregate (Figure 2) samples was collected from demolition sites.

Fig 1: Demolition site from where 8 year old aggregate sample was collected

Fig 2: Demolition site from where 16 year old aggregate sample was collected

B. *Sample treatment*

Once the samples were collected (Figure 3) they had to be treated before concrete could be made. Recycled aggregate obtained from batching plant had to be washed and dried properly as it had cement attached to it.

8 years old aggregate had glass pieces in them as they were collected from demolition sites. Therefore, it was manually removed.

Fig 3: natural aggregate, recycled aggregate from batching plant, 8 year old aggregate and 16 year old aggregate (left to right)

16 years old aggregate had wood pieces and tiles in it and were big in size. Therefore, they had to be broken down into smaller pieces using a hammer.

C. Experiments conducted

Experiments were done to determine the specific gravity, void ratio, porosity, bulk density, fineness modulus and moisture content of sample aggregates.

After performing test for these aggregates, concrete will be prepared (Figure 4) with different ratios of aggregate (Table 3) and compression tests will be performed on them. [3]

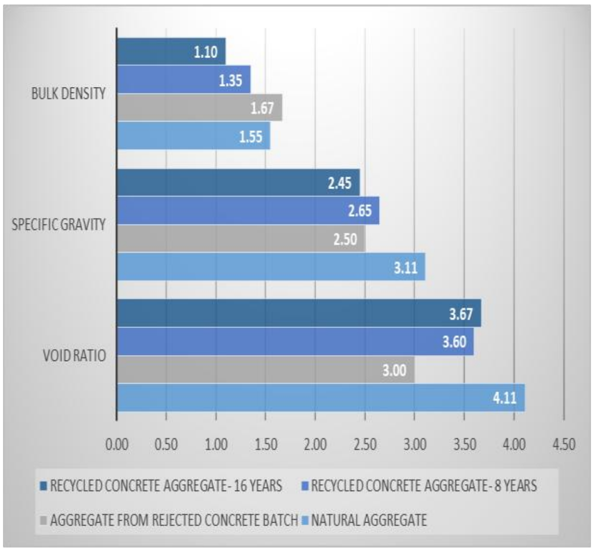
TABLE III: RATIO OF AGGREGATE TAKEN FOR COMPRESSION TEST

Aggregate	Percentage aggregate
Natural aggregate	100%
Recycled aggregate (batching plant)	100%
Recycled aggregate (batching plant)	50%
Recycled Aggregate (8 years)	100%
Recycled Aggregate (8 years)	50%
Recycled Aggregate (16 years)	100%
Recycled Aggregate (16 years)	50%

Fig 4: Freshly prepared concrete

IV. Data Analysis and Observation

The above experiments were performed and the following observations were made:



Graph 1: Representation of bulk density, specific gravity and void ratio for different types of aggregates

Bulk density depends upon how densely the aggregate is packed. Higher bulk density means the voids present in the aggregate are less. Graph 1 shows aggregate from the rejected concrete batch has high bulk density means the voids are less. Therefore, less cement and water will be required to fill the voids. On the other hand, recycled concrete aggregate of 16 years has low bulk density means the more voids are present so more cement and water will be required to fill the voids.

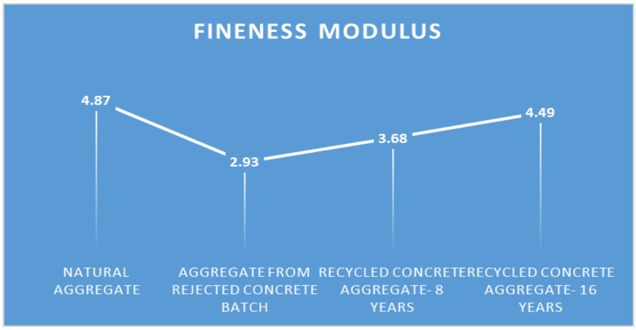
Specific Gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. Graph 1 shows recycled concrete aggregate of 16 years has low specific gravity which means its weak and natural aggregate has high specific gravity which means it's stronger.

Void ratio is the gap between different particles. Graph 1 shows that the void ratio of natural aggregate is the highest.

Table 4 shows that the highest porosity was of Recycled concrete aggregate of 16 years meaning that as more water will be needed for concrete, once it dries up many pores will be formed as water will evaporate, reducing the overall strength of concrete.

TABLE IV: Porosity for different types of aggregates

	Porosity
Natural aggregate	50.00%
Aggregate from rejected concrete batch	33.33%
Recycled concrete aggregate- 8 years	48.89%
Recycled concrete aggregate- 16 years	55.07%



Graph 2: Representation of fineness modulus for different types of aggregates

Higher the fineness modulus, coarser in the aggregate. Graph 2 and figure 5 shows that natural aggregate has a higher fineness modulus meaning it is coarser compared to other aggregates.

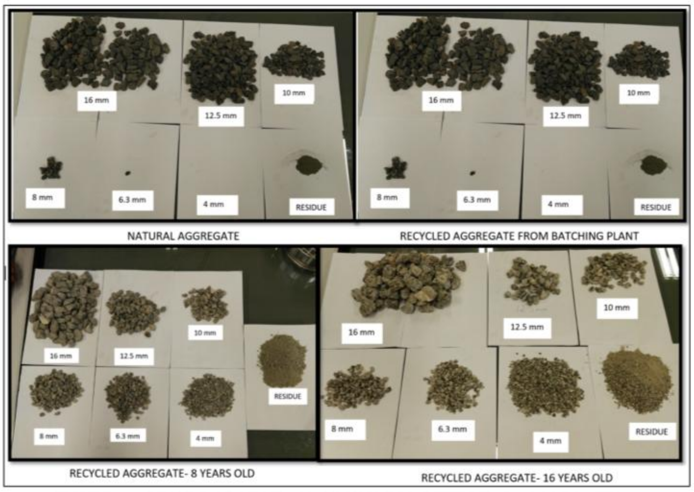
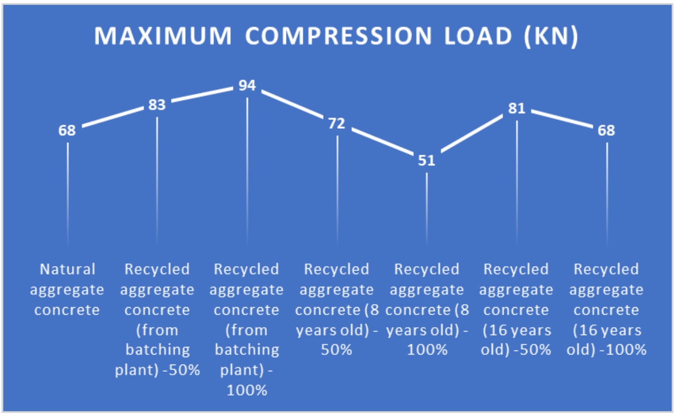


Fig 5: Result of sieve analysis for different aggregates

Table 5 shows that the moisture content for recycled concrete aggregate of 8 years has highest moisture content means it has high absorption rate.

TABLE V: Moisture content for different types of aggregates

	Moisture content
Natural aggregate	1.83%
Aggregate from rejected concrete batch	6.08%
Recycled concrete aggregate- 8 years	10.71%
Recycled concrete aggregate- 16 years	7.75%



Graph 3: Representation of maximum compression load for different concrete ratio

TABLE VI: MAXIMUM COMPRESSION LOAD FOR DIFFERENT CONCRETE RATIOS

Concrete type	Maximum compression load (kn)
Natural aggregate concrete	68
Recycled aggregate concrete (from batching plant) -50%	83
Recycled aggregate concrete (from batching plant) -100%	94
Recycled aggregate concrete (8 years old) -50%	72
Recycled aggregate concrete (8 years old) -100%	51
Recycled aggregate concrete (16 years old) -50%	81
Recycled aggregate concrete (16 years old) -100%	68

The same mix proportion of 1:2:4 was taken for all of the above samples as per the table 6. Graph 3 shows that recycled aggregate concrete from the batching plant (100%) could take maximum compressive load.

V. CONCLUSION

The strength of natural aggregate is less as compared to other aggregates which contradicts our assumption before the test that it will be able to take maximum compression. The reason for concrete made up of natural aggregate to have such low strength is that it had a high void ratio. Also, it had many aggregates of one size i.e. 10mm because of which the concrete could only give a maximum strength of 68 kN. The probable reason that recycled aggregates from batching plant that had 100% recycled content showed maximum strength could be because of cement attached to the aggregate from the batching plant.

With such high and unexpected variations in the compressive strengths it can also be concluded that the age of aggregates used may not be a significant factor in the compressive strength of recycled concrete. However, the place, the type and mix of proportion of the aggregates can greatly influence the strength of recycled concrete.

VI. CHALLENGES

The main challenges that were faced initial in this experiment was arranging the samples. Various companies were contacted to get samples.

Later on the problems faced were of transporting the sample to the laboratory.

Fig 6: Hammering big pieces of aggregate to smaller pieces

The aggregates from batching plant had to be washed and dried before using as it had some cement attached to it. The 8 year old aggregates had glass pieces in it and had to be separated. The 16 year old aggregate were big in size and had to be broken to smaller pieces which was done by a hammer (Figure 6). It also had wooden pieces that had to be removed before further use.

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