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# Usage of Recycled Brick as Coarse Aggregate in Concrete

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**Abstract:** This paper presents the comparative analysis of different properties of both the Recycled Brick Aggregate (RBA) and Granite Aggregate (GA). The results indicate that the crushed clay bricks are suitable to replace the granite aggregate in concrete production. Trial mixes of RBA concrete were prepared by replacing the GA with 25%, 50%, 75% and 100% crushed clay bricks by volume. M20 grade of both GA and RBA concretes were prepared and tested to compare the compressive strength. The test results showed that it is possible to produce RBA concrete with characteristics similar to those of GA concrete with 25% replacement.

**Key Words:** Granite Aggregate, Recycled Brick Aggregate, replacements, concrete.

## 1. INTRODUCTION

Concrete is second widely used construction material in the world. It mainly consists of Coarse Aggregate, Fine Aggregate, Cement and Water. The Coarse Aggregate consumes 70-80% of the volume of the concrete[1], hence dictating the strength and density relationship. Due to the rapid growth in construction industry, the demand for the natural resources like gravel which is used as a coarse aggregate and sand were increased from recent past.

The primary sources of coarse aggregate are getting diminished due to various reasons such as excessive consumption, technological and industrial development, erosion, excessive mining, etc. On the other hand, the waste from construction industry is generating at a rapid rate and is being disposed as landfills.

These wastes are being accumulated at certain places which cause the environmental and land fill problems.The most efficient method of managing the construction and demolition waste is recycling and reusing of these products in an effective and economic way. The total quantum of waste from construction industry is estimated to be 12 to 14.7million tons per annum out of which 7-8 million tons are concrete and brick waste[1].

The objective of this paper is to investigate the feasible use of recycled bricks as a substitute for natural coarse aggregate (Granite) in concrete. To achieve this objective the physical and mechanical properties of Recycled Brick Aggregate (RBA) are studied and results are compared with the Granite Aggregate (GA). The properties of concrete such as slump, density, compressive strength are studied by replacing the granite aggregate with recycled brick aggregate.

## 2. REVIEW OF LITERATURE

Farid Debib and Said Kenai[2] studied the effect by partially replacing the fine and coarse aggregate with crushed clay brick in concrete. The compressive, flexure and split tensile tests were conducted on concrete at the replacement levels of 25, 50, 75 and 100%. The authors reported a relatively low density for crushed brick concrete than normal concrete. The substitution levels of 25% for coarse aggregate and 50% for fine aggregate were reported from the test results.

Cachim .P .B[3] investigated the mechanical properties of fresh and hardened concrete made with crushed bricks at replacement levels of 15 and 30%with the water cement ratios of 0.45 and 0.5. The author concluded that the crushed brick can be replaced upto 15% without any strength reduction and upto 30% with a strength reduction. Yang .Jet al. [4]investigated the physical and mechanical properties of concrete after replacing the natural aggregate with recycled concrete aggregate and crushed clay brick. The authors observed that with the increased Crushed Clay Brick substitution levels the compressive strength decreased. The reduction in compressive strength was observed more significantly in recycled concrete made with 50% CCB replacement. The author concluded that the compressive strength and cylindrical splitting strength were crucially effected when the replacement levels of CCB was varying between 0 to 50% and no predominant change was observed in flexural strength.

Khalaf .F .M and Devenny .A .S[5] carried out a study to evaluate the physical and mechanical properties of new and recycled crushed clay brick as aggregate for use in Portland cement concrete. The author stated that the impact value of brick aggregate increases as the

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compressive strength of the parent brick decreases. The results showed that the crushed clay brick aggregates can be used for producing concrete for low level civil engineering applications.

## 3. MATERIALS USED

**3.1. Cement:** The cement used was Portland Pozzolana cement with 28 days compressive strength of 62.4 MPa[6]. The same cement was used to study the performance of both RBA and GA concretes.

**3.2. Fine Aggregate:** Locally available natural sand is used as fine aggregate. The sieve analysis carried out in accordance with IS 2386 (Part 1)-1963[7].

**3.3. Granite and Brick Aggregates:** Natural crushed 20 mm single sized granite aggregate was used in the investigation so that comparisons could be made with the crushed clay brick aggregate. The collected recycled brick are crushed to 20 mm and 10mm aggregate manually.

The RBA is then coated with cement slurry to reduce its water absorption before using them in concrete. The GA and RBA are used in SSD condition. The aggregate used in investigation are shown in Figure.1.


Figure.1. Aggregate used in concrete

## 4. CONCRETE MIX USED IN INVESTIGATION

M20 Concrete mix was designed in accordance with IS 10262:2009[9]. Both the granite and recycled brick aggregate were used in SSD condition by soaking the aggregates in water tillthe aggregate is saturated.

In order to investigate the mechanical properties, RBA concrete was produced by replacing GA with 25%,50%,75% and 100%volume of RBA.

The mix proportion 1:1.25:2.80 and water cement ratio 0.55 were kept constant for all the mixes. The designations for different mixes are presented in Table.1. The compressive strength of all the mixes were determined in accordance with IS 516-1959 [9].

Table.1. Designation of Various Mixes

| Type of Aggregate | Percentage Replacement | | | | |
|---|---|---|---|---|---|
| GA | 100% | 75% | 50% | 25% | 0% |
| RBA | 0% | 25% | 50% | 75% | 100% |
| Mix Designation | RBA 0 | RBA 25 | RBA 50 | RBA 75 | RBA 100 |

## 5. RESULTS AND DISCUSSIONS

The physical and mechanical properties of granite and coated recycled brick aggregate were studied and compared. The results were given in Table. 2. The discussions on various properties were presented in this section.

### 5.1. Physical and Mechanical Properties of Granite and Recycled Brick Aggregate

#### 5.1.1. Specific Gravity

The specific gravities of Sand, GA and RBA were determined in accordance with IS 2386 (Part III)–1963[7].The specific gravity of sand and GA are used in the design calculations of concrete mix. The specific gravities of both the GA and RBA were shownin Table.2.

The specific gravity of sand is 2.65. RBA however, had a low specific gravity of 2.20 probably due to the low strength and density of the parent brick from which it is produced. Apebo N[13]et al. and Bhattacharjee[14] et al.also reported low values of specific gravity for brick aggregate.

#### 5.1.2. Sieve Analysis of Aggregates

Sieve analysis was carried out on sand, granite and recycled brick aggregate before using them in concrete.The set of sieves used for the analysis was in accordance with IS: 2386 (Part I) – 1963[7]for grading the aggregate.

Figure.2 shows the particle size distribution of sand and Figure.3 shows the particle size distribution of GA &RBA together with the corresponding grading limits set out in IS 383-1970[10] for natural aggregates of same size.

The fineness modulii were found to be 3.07, 7.10 and 7.06 for sand, granite aggregate and recycled brick aggregate respectively. Figure.2 indicates that the Sand used in this investigation confirms with the grading limits of Zone II.Figure.3 indicates that both the aggregates used have gradingvalues within the limits for 20-mm single-sized aggregate.

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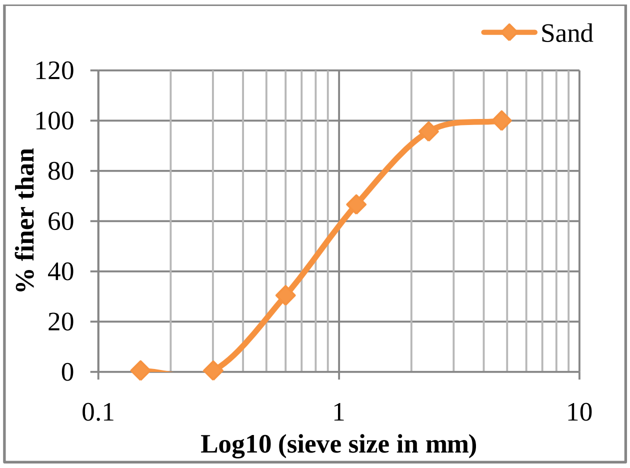


Figure.2. Grading Curve of Fine Aggregate

Table.2. Comparison of the Properties of Natural and Recycled Brick Aggregate

| Property | Specific Gravity | Fineness modulus | Bulk Density ($kg/m^3$) | Impact Value (%) | Crushing value (%) | Water absorption (%) | Flakiness Index (%) | Elongation Index (%) |
|---|---|---|---|---|---|---|---|---|
| Granite Aggregate | 2.72 | 7.10 | 1992 | 18.29 | 26.33 | 0.25 | 13.10 | 17.33 |
| Coated Recycled Brick Aggregate | 2.20 | 7.06 | 1192 | 43.02 | 44.30 | 12.85 | 1.10 | 5.17 |

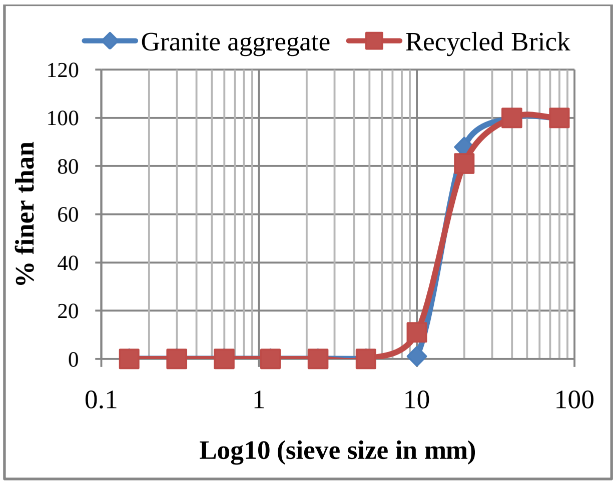


Figure.3. Grading Curve of Coarse Aggregate (Granite and RBA)

**5.1.3. Aggregate Impact Value**

Aggregate impact value gives a relative measure of the resistance ofan aggregate to sudden shock or impact. The impact values were determine by using IS 2386 (Part 4) – 1963[7]for both granite aggregate and recycled brick aggregate. The impact value is found by allowing a standard hammer to fall freely on to the sample of aggregate and measuring the weight of the fines resulting from the impact.Theratio of the weight of fines formed to the total sample weight is expressed as a percentage. The aggregate impact values of both GA and RBA were shown in Table.2. These results are compared with the standards set out in IS 383: 1970[10].
The result of aggregate impact value test forrecycled brick aggregate is 43.02%. Table 2 also shows that the recycled brick aggregates, in general, are not as strong as granite aggregate because of low crushing strength of brick compared to granite. The impact value of RBA falls within the acceptable limits of IS 383-1970[10] which prescribes

maximum value of 45% for aggregate tobe used for concrete other than for wearing surfaces.

### 5.1.4. Aggregate Crushing Value

The aggregate crushing values of both the aggregates were determined as per IS: 2386 (Part IV) – 1963[8]. The crushing value is found by allowing a standard hammer to fall gradually onto a sample of aggregate and measuring the weight of the fines resulting from gradual load application. The results shown in Table 2illustrates that the crushing values of both GA and RBA are in allowable limits set out by IS 383: 1970[10].The crushing value of RBA is 44.3%. The value is within maximum prescribed value of 45% for concrete other than for wearing surfaces.

### 5.1.5. Bulk Density of Aggregate

The bulk density of the RBA and GA were determined in accordance with IS 2386 (Part 3) – 1963[7].The net weight of the compacted aggregatesis measured for calculating the bulk density.

These results of bulk densities for the aggregates used in this investigation are shown in Table.2. The results indicate that recycled brick aggregates used in this investigation have a lower density than the granite aggregate. These results are in agreement with the findings of Khalaf F .M[5] et al .The RBA can be classified as a lightweight aggregate due to its low density. Hence it can be concluded that the recycled brick aggregate concrete can be used where concrete of low density is required.

### 5.1.6. Water Absorption

The water absorption test was carried out for both RBA and GA in accordance with IS 2386 (Part3) – 1963[7]. The water absorption of aggregate is determined by measuring the increase in mass of an oven-dried sample when immersed in water for 24 hours. The ratio of the increase in mass to the mass of the dry sample, expressed as a percentage, is termed as absorption[7]. The water absorption results were shown in Table.2.

The water absorption in RBA was found to be 12.85%. This value was much higher than that of GA, of which absorption wasonly 0.25%. The higher water absorptionwas due to the presence of more pores in RBA.It can also be attributed to theporous characteristics of theold mortar adhered to the recycled brick.The brick aggregate was precoated with cement slurry to limit the water absorption before using it in the concrete.

### 5.1.7. Flakiness and Elongation Index

The flakiness index of an aggregate is the percentage by weight of particles in it whosethicknessis less than three-fifth of their mean dimension. The elongation index of an aggregate is the percentage by weightof particles whose lengthis greater than one and four-fifths times their mean dimension. The flakiness and elongation index tests were conducted in accordance with IS 2386 (Part I) -1963[7]on thickness gauge and length gauge respectively. Table 2 gives the results of flakiness and elongation indices of both the aggregates.

The Flakiness and Elongation Indices of both GA and RBA are well within the values reported by Santha Kumar[15]. RBA however, had exhibited very low values of Flakiness and Elongation Indices than the granite aggregate. This may be due to the formation of smaller sizes of particles having similar sizes in all directions during crushing. Further, the presence of new mortar coat formed on the surface of the particles of RBA due to the soaking will make these particles less flaky.

## 5.2. Recycled Brick Aggregate Concrete

The properties of concrete such as slump, densityand compressive strength are measured on M15 and M20 grades coated recycled brick aggregate concrete with different percentage replacements.

### 5.2.1. Slump Test

The slump test was conducted to determine the workability of fresh concreteproduced with both RBA and GA. Different RBA concrete mixes were prepared by replacing GA with 25%, 50%,75% and 100% volume of RBA to assess the effect of percentage replacement of RBA on workability. The slump was determined with the help of slump cone apparatus in accordance with IS1199-1959[11]. The variation of slump of all the above mixes was shown in Figure.4.

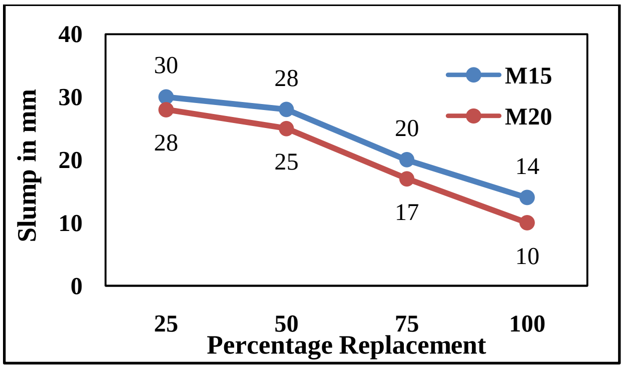


Figure.4. Variation of slump of M15 and M20 grades of concrete with different replacements

The increase in replacement of RBA in M15 concrete has led to the loss of slump, the percentage loss being 6.66%, 33.33%, 53.33% and 66.66% of original slump value (zero percent replacement) where as the percentage loss in M20 concrete being 10.71%, 39.25%, 64.28% and 78.57% of original slump value (zero percent replacement) for 25, 50, 75 and 100% replacements respectively. The lower workability of concrete at higher replacements of GA with RBA may be attributed to the higher water absorption of RBA.

It can be concluded from Figure.4 that the slump of RBA concrete decreases with the increase in the percentage replacement in both the gardes of concrete. It can ce also concluded that the percentage slump loss increases with the increase in grade of concrete. the higher slump loss in higher grade concrete may be attributed to the lower W/C ratio.

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### 5.2.2. Density of Concrete

Density of concrete is determined by dividing the weight of fully compacted concrete in the measure by the capacity of measure and shall be recorded in kg/m$^3$. Density test was performed on GA concrete and RBA concrete mixes using IS 1199-1959[11].The variation of density of concrete with the percentage replacement of RBA was presented in Figure.5.

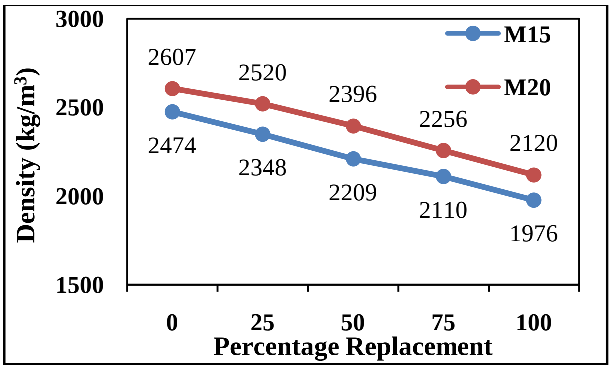


Figure.5Variation of Density of M15 and M20 grades of concrete with different replacements

The increase in percentage substitution of RBA in M15 and M20 concretes has led to the loss of density. This decrease in density is probably due to the less weight of recycled brick particle and porous mortar surrounding the RBA.

Hence RBA concrete can be used to produce concrete with lower weight resulting in lower dead loads.The lower density of concrete at higher replacement may be attributed to the lower specific gravity and lower density of recycled brick aggregate in both the grades of concrete.

The percentage loss in M15 concrete is being 5.09%, 10.71%, 14.71% and 20.13% of original density value (zero percent replacement) whereas the same in M20 concrete is being 3.35%, 9.09%, 13.17% and 18.66% of for 25, 50, 75 and 100% substitutions respectively. It can be concluded that the recycled brick aggregate concrete with 25% replacement exhibited slightly lighter density than that of the GA concrete in both the grades.
It can also be concluded that the higher is the grade of concrete,lower is the percentage loss of density. The lower percentage loss of density in M20 grade concrete may be attributed to lesser volume of aggregate.

### 5.2.3. Compressive strength

The compressive strength of concrete was tested at the age of 28 days, on 150 X 150 X150 mm cube specimens using a 2000kN compression testing machine in accordance with IS 516-1959[10]. The results of the compressive strength of both Granite Aggregate Concrete (GAC) and Recycled Brick Aggregate Concrete (RBAC) produced with replacement of granite aggregate by RBA in different percentages of 25, 50,75 and 100 were presented in Table.3.

Table.3. Compressive Strengths of M15 and M20 grades of concrete at various replacements

| Mix | Compressive strength at 28 days (N/mm$^2$) | | | | |
|---|---|---|---|---|---|
| | RBA 0 | RBA 25 | RBA 50 | RBA 75 | RBA 100 |
| M15 | 21.33 | 21.18 | 14.28 | 8.65 | 5.46 |
| M20 | 25.25 | 25.15 | 17.35 | 10.82 | 7.25 |

From Table. 3 it can be observed that the compressive strength decreases with the increase in peracentage replacement in both the grades of concrete.

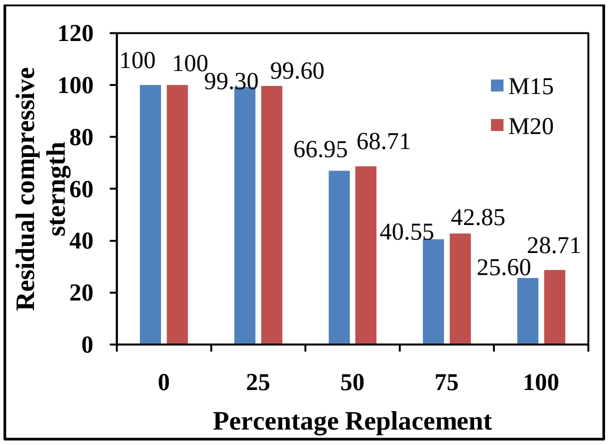


Figure.5. Variation of residual of compressive strength of M15 and M20 grades of concrete with different percentage replacements

The variation of residual compressive strength of both the grades of recycled brick aggregate concrete with percentage replacement is shown in Figure.5. From the Figure. 5. it is clear that the higher is the percentage replacement, lower is the compressive strength.This strength loss may be attributed to the lower compressive strength of brick.

It can also be observed that the higher is the grade of concrete higher is the residual compressive strength. It was further observed thatRBA 25 exhibited similar strength as that of GAC.Hence it can be concluded that within the experimental limitations the granite aggregate can be replaced by 25% with RBA to achieve the strength of GAC.

## 6. CONCLUSIONS

- The similar procedure of mixing GA concrete can be adopted for the production of RBAC. Howeverthe RBA is coated with cement slurry before it is used in the concrete. Both the aggregates shall be used in the SSD condition.
- The impact and crushing values of RBA are higher than the GA but within the acceptable limits as prescribed by IS 383-1972.

- The relative density of RBA is less than that of GA and hence it can be classified as lightweight aggregate. The recycled brick aggregate concrete produced with this RBA can be used where concrete of low density is required.
- The water absorption of recycled brick aggregate is very high when compared to granite aggregate. The recycled brick was pre coated with cement slurry to limit the water absorption.
- RBA had exhibited very low values of Flakiness and Elongation Indices than the granite aggregate.
- The slump, density and compressive strength of RBA concrete decreased with the increase in the percentage replacement.
- The slump, density and compressive strength showed an optimum value at 25% replacement in both the gardes of concrete.
- Standard concrete can be produced using recycled brick aggregate as the coarse aggregate. The results show that the strength of standard concrete was reached with the replacement of 25% of GA with RBA.

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