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Utilization of Demolished Concrete Waste for New Construction

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***Abstract*—**In recent years demolished concrete waste handling and management is the new primary challenging issue faced by the countries all over the world. It is very challenging and hectic problem that has to be tackled in an indigenous manner, it is desirable to completely recycle demolished concrete waste in order to protect natural resources and reduce environmental pollution. In this research paper an experimental study is carried out to investigate the feasibility and recycling of demolished waste concrete for new construction. The present investigation to be focused on recycling demolished waste materials in order to reduce construction cost and resolving housing problems faced by the low income communities of the world. The crushed demolished concrete wastes is segregated by sieving to obtain required sizes of aggregate, several tests were conducted to determine the aggregate properties before recycling it into new concrete. This research shows that the recycled aggregate that are obtained from site make good quality concrete. The compressive strength test results of partial replacement and full recycled aggregate concrete and are found to be higher than the compressive strength of normal concrete with new aggregate.

***Keywords*—**Demolished, concrete waste, recycle, new concrete, fresh coarse aggregate.

I. Introduction

INCREASED concern for environmental protection and for promotion of the principles of sustainable development has led some governments to introduce legislation to encourage the use of recycled aggregates. A favored method is to lower the selling price of recycled aggregates in relation to natural aggregate, and this is largely achieved by increasing landfill costs. Demolition sites and restoration schemes are sources of large amounts of solid waste, which today is being used as mere landfill. On the other hand, building practices are such that reusable materials also become mixed with rubble, stone and soil, reducing their value and making recycling difficult or uneconomical. This waste material too, is rendered suitable only as infill for construction work, or as landfill. A Building waste recycling as aggregates is a modern approach for preventing environmental pollution through both reducing the stocks of waste and decreasing the use of natural aggregates. The reuse of building waste is a relatively new issue for the world despite the existing considerable quantity of building waste and the significant changes in the environmental rules applied.

When buildings are demolished as a result of disasters, their rubble contains fragmented building components, furnishings and organic matter that are difficult to separate. On the other hand, it is possible to selectively demolish a building if it is an intentional act; in which case, it is possible to reuse most of the building materials and components, and recycle much of the rubble. According to [1] investigations on the composition of demolition waste in the Netherlands revealed that 20% of the wood, 90% of the steel and 100% of other metals like zinc, lead and copper are being removed from the structure, leaving behind building waste, which on the average is composed of:

Brickwork	62%	Concrete rubble	24%
Brick rubble	6.1%	Tiles	2.3%
Bituminous materials	0.2%	Wood	4.7%
Scrap steel	0.1%	Other	0.6%
			Total 100%

Although the volume of demolition waste is huge, much of it is inert, allowing it to be crushed, processed, and reused as aggregate in building works. Nevertheless, large amounts still end up as landfill rather than being recycled. Waste containing half-used paint pots, discarded solutions, solvents and chemicals are potentially hazardous, and building waste likely to be contaminated with asbestos must also be treated as dangerous [2].

It has been established that materials and components recovered from demolished buildings are being reused for new construction works as well as renovation projects, especially by low-income communities in developing countries. It has also been noted that material, which was not considered worthy of re-use a few years ago, has appeared in the market after the recent global economic crisis. For example, steel reinforcement from demolished buildings used to be recycled back into steel; however, it is now considered worthwhile to adopt measures to facilitate its reuse as a building material. Meanwhile, demolition contractors have also become increasingly aware of the feasibility of recovering as much material as possible, for new construction works. Consequently, they are giving considerable importance to the proper sorting, storing and display of their wares. Rapid industrial development causes serious problems all over the world such as depletion of natural aggregates and creates enormous amount of waste materials from construction and demolition activities. One of the ways to reduce these problems is to utilize recycled aggregate in the new construction concrete components [3].

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A. Literature Surve

The state of art reports indicate that concrete demolished every year in European countries and United States is about 50-60 million tons respectively [4, 5]. Very little demolished concrete is currently recycled in the country. Demolished concrete not even used as stabilized base or sub base in the highway construction. It is being dumped off as fill. It is right time to seriously think of reusing demolished concrete for the production of recycled concrete in our country (India) [6]. Recycling would not only conserve the resources but would also promote safe and economic use of such concrete which is the need of the hour for a country like India, Saudi Arabia etc.

Research work indicates a positive result of rising recycled concrete for pavement construction. However, there are certain limitations for using it in structure. Comprehensive research study is in progress to rectify these limitations and thereby advocates the safe and economical use of recycled concrete in future after establishing certain guidelines. Some experimental work has been carried out in the 80's to investigate the properties of recycled aggregate concrete by [7, 8] and several other researchers. United States of America [8] currently used the 2.7 billion metric tons of aggregate approximately, the pavements account for 10–15%, whereas other road construction and maintenance work consumes another 20–30%, and the bulk of about 60–70% aggregates are used in structural concrete. Recycled aggregate in the US is produced by natural aggregate producers, contractors and debris recycling centers, which have a share of 50%, 36% and 14%, respectively.

In some countries, many technologies for recycling concrete wastes have been developed and some recycling specifications have been established as well [8, 9, 10]. In the process of the practical reutilization to recycle waste concrete requires further breaking and crushing of demolished concrete. Generally, two typical grades of crushed concrete aggregates can be produced and classified by size gradation. One is coarse recycled concrete aggregates, part of which can be used in new concrete or road base materials. Other is fine recycled concrete aggregates or recycled mortar from crushed concrete waste whose sizes are smaller than 5 mm; recycling, evaluation and application of both parts are discussed in different researches [11, 12, 13, 14, 15].

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B. Experimental Techniques

Concrete waste has been procured from the demolished site. The demolished waste was transported, crushed and segregated. Several tests on segregated concretes were conducted in the laboratory such as water absorption, sieve analysis, crushing value test, impact value test, and abrasion test, workability and crushing strength of natural & demolished waste by making cubes. The demolished waste was sieved through a set of IS sieves to obtain a fitness of fine aggregate which was also replaced.

To study the partial replacement of demolished waste in fresh (new) concrete, effect of demolished waste has been observed on the strength of concrete, by casting more than 180 cubes of size 150mm in the laboratory using two nominal mixes M15 & M20 (1:2:4 & 1:1.5:3). An effect of partial replacement of demolished waste has been made here to compare the strength of concrete. The same quality and required quantity of cement and fine aggregate have been used for both the nominal mixes, replacing fresh coarse aggregate by 0%, 25%, 50%, 75% and 100% demolished waste aggregate concrete for both mixes have been prepared and cubes were caste. Seven days and 28 days compressive strength of the cubes have been obtained. Ordinary Portland cement (53 grades) has been used in both the mixes. Locally available coarse sand has been used as fine aggregate. Locally available crushed stone aggregate has been used of size from 4.75 to 20 mm throughout the experimental study. Potable water is used for concrete mix and curing. Water cement ratios 0.60, 0.625 and 0.65 have been used throughout the experiments.

1. Water Absorption

Table I shows the results of absorption capacity of aggregate at different percentage respectively, indicate the recycled aggregate showed higher water absorption than conventional concretes. It may be concluded that the water absorption of coarse recycled aggregates is much higher than the water absorption of original aggregates. This is due to higher water absorption of old mortar attached to original aggregate particles. The porosity of the adhered mortar causes the water to penetrate into the accessible pores and leads to an increase in the water absorption capacity in comparison with crushed aggregate.

TABLE I
WATER ABSORPTION OF DIFFERENT PERCENTAGE OF RECYCLED & FRESH AGGREGATES

S. No.	Material	Observed value (%)
1.	0% Recycled Aggregate	1.50
2.	25% Recycled Aggregate	2.05
3.	50% Recycled Aggregate	2.87
4.	75% Recycled Aggregate	3.40
5.	100% Recycled Aggregate	4.60

2. Sieve Analysis Test of Aggregates

From the sieve analysis test, the particle size distribution of coarse and fine aggregate has been determined. The test is performed by using different size of sieves as standardized by IS (Indian Standard) code and then pass aggregate through them and collect different size of particles left over different sieve (Fig. 1).

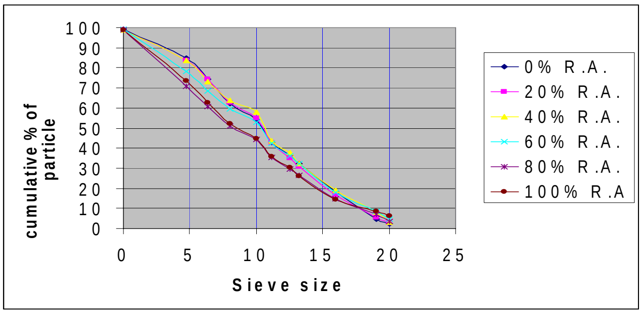

Fig. 1 Average sieve analysis test of aggregates

3. Aggregate Crushing Value Test

The crushing strength of stone may be determined either on aggregates or on cylindrical specimens cut out of rocks. Aggregate is used in road construction should be strong enough to resist crushing under traffic wheel load. If the aggregate are weak, the stability of the pavement structure. Fig. 2 shows the mean crushing value of aggregate with different percentage of recycled aggregates.

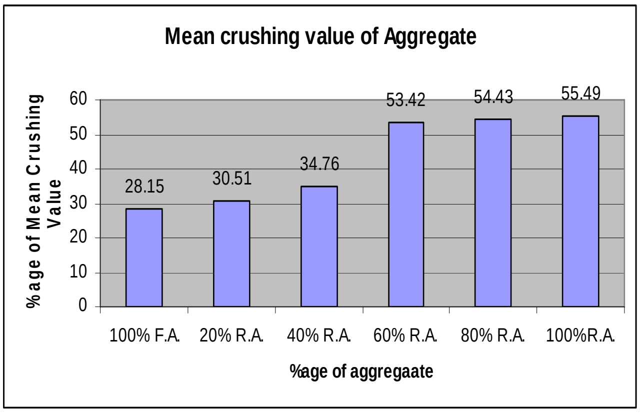

Fig. 2 Mean crushing value of aggregate for different %age of R.A.

4. Aggregate Impact Test (Toughness of Aggregate)

Toughness is the property of a aggregate to resist impact. Due to traffic loads, the road stone are subjected to the pounding action or impact and there is a possibility of stones breaking into smaller pieces. The resistance of the stones to fractures under repeated impacts may be called an impact test for road stones. The aggregate impact value indicates resistance of aggregate to a sudden shock or an impact. Table II shows the Impact value of different percentage of recycle & fresh aggregates.

TABLE II
IMPACT VALUE OF DIFFERENT PERCENTAGE OF RECYCLE & FRESH AGGREGATES

S. No.	Aggregates	Impact Value (%)
1.	100% F.A.	24.67
2.	20% R.A.	31.41
3.	40% R.A.	34.74
4.	60% R.A.	36.46
5.	80% R.A.	38.74
6.	100%R.A.	41.17

5. Los Angeles Abrasion Test

The principle of Los Angeles abrasion test is to find the percentage wear due to the relative rubbing action between aggregates & steel balls, and aggregate which are used as abrasion resistance. The Los Angeles abrasion value are shown in Table III.

TABLE III
ABRASION VALUE OF DIFFERENT FRESH AND RECYCLED AGGREGATE

S. No.	Aggregates	Abrasion Value (%)
1.	100% F.A.	27.02
2.	20% R.A.	28.40
3.	40% R.A.	29.76
4.	60% R.A.	31.20
5.	80% R.A.	34.28
6.	100%R.A.	35.72

6. Workability

While casting specimens, slump test were carried out to determine the workability of different mixes. The Fig. 3 - 5 show the variation of slump with water cement ratio of different percentage of recycled concrete mixes of 1:2:4 and 1:1.5:3. From the Fig. 3 - 5 the scenario of slump observed the fresh concrete has the great slump value. In addition, increasing partial replacement of demolished waste in concrete decreasing the slump value which is due to the large amount of old mortar adhered over the recycled concrete which absorbs the greater amount of water. For producing the same slump, higher water cement ratio has to be maintained for sample with high percentage of demolished waste.

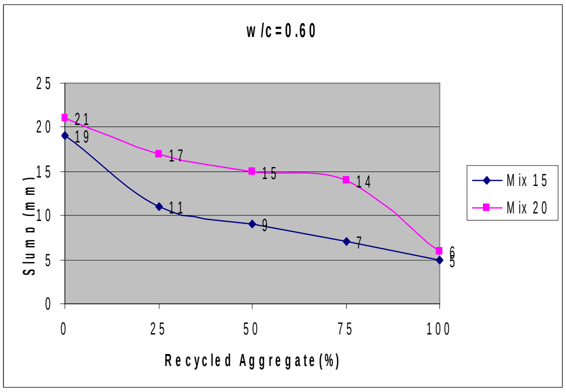

Fig. 3 Slump value of M15 & M20 concrete with w/c=0.60

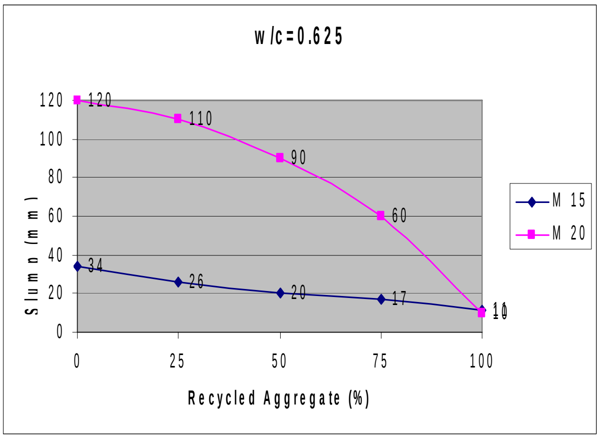

Fig. 4 Slump value of M15 & M20 concrete with w/c=0.625

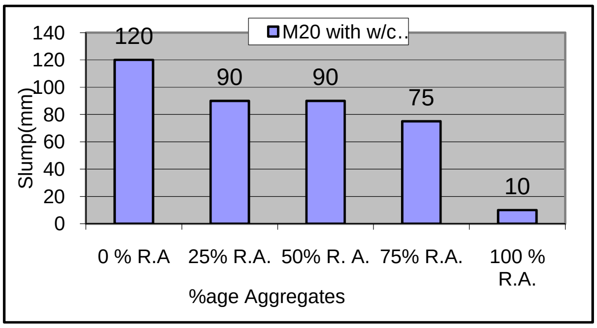

Fig. 5 Slump value of M20 concrete with w/c=0.650

II. Compressive Strength of Concrete

The concrete was mixed in high capacity tilting drum mixer. The minimum 30 specimens were cast for each w/c ratio i.e. 0.60, 0.625 and 0.65 for the two mixes (M15 & M20), thereby making more than 180 specimens. Five sets of cubes were cast replacing fresh aggregate by coarse aggregate from demolished waste @ 0%, 25%, 50%, 75% and 100% by weight. 0% demolished waste means only fresh concrete has been used in both the mixes. All the specimens were remoulded after 24 hours and cured by putting in water. Compressive strength of cubes has been determined using the compression testing machine as shown in (Fig. 6 – Fig. 9).

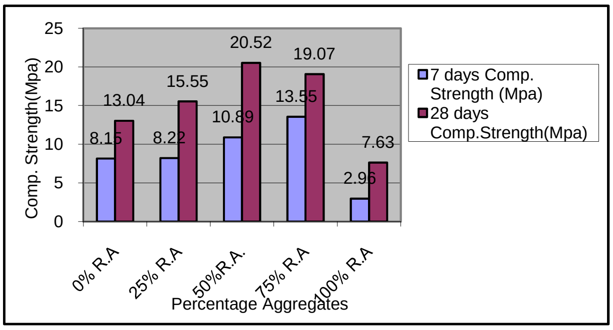

Fig. 6 Compressive strength at 7days & 28 days of M15 concrete with w/c=0.60

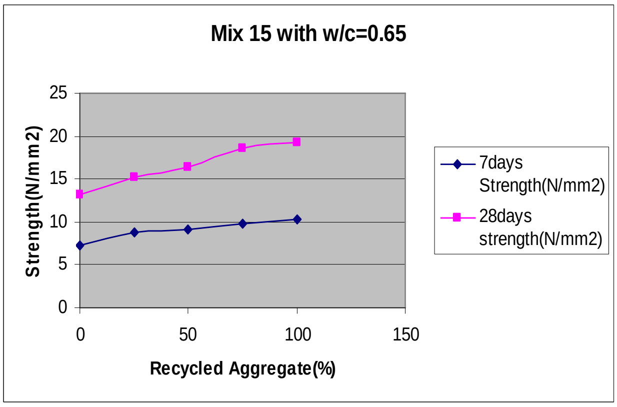

Fig. 7 Compressive strength at 7days & 28 days of M15 concrete with w/c=0.65

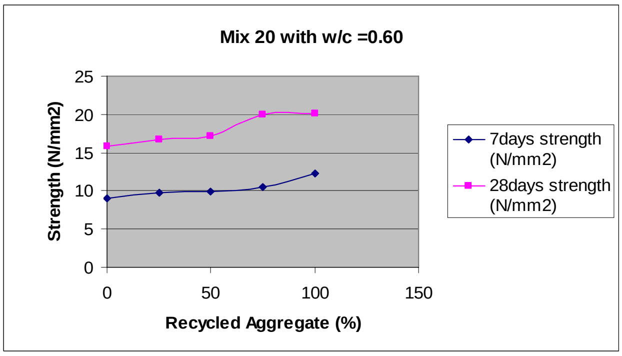

Fig. 8 Compressive strength at 7days & 28 days of M20 concrete with w/c=0.60

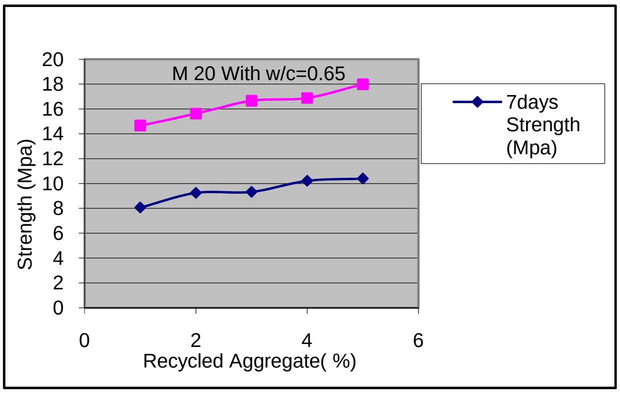

Fig. 9 Compressive strength at 7days & 28 days of M20 concrete with w/c=0.65

III. Concluding Remarks

Concrete recycling will become one of the most important elements for construction sustainability. Concrete in which binders, additives and aggregates are all made of cement or materials of cement, and all of these materials can be used as raw materials of cement after hardening. Concrete which contains waste products as aggregate is called ‘Green’ concrete. This paper focuses on the feasibility of construction waste aggregate to making new green concrete. Various standard tests were carried out using recycled aggregate such as water absorption, sieve analysis, impact value, abrasion value, crushing value, workability and compressive strength of the mixes using 150mm standard cubes. The study suggested the use of alternative material (demolished or recycled waste) for new construction which is beleaguered with normal waste in terms of debris, dust, rubbish etc. in place of conventional material. Tests were conducted by using 0%, 25%, 50%, 75%, 100% replacement of fresh aggregate with recycled aggregate to determine the physical and mechanical properties.

The following conclusions are drawn on the basis of this study:

1. Water absorption increases from 1.5% (for 100% fresh new aggregate) to 4.6% (for 100% dismantled aggregate) which shows (Table I) more requirement of water that is higher w/c ratio for making concrete mix, while large percentage of dismantled coarse aggregate is to be used, which is supplemented by slump observations for the mixes as shown in (Fig. 3 - 4).

2. The higher percentage of recycled aggregate increases the crushing value of the aggregates (Fig. 2).In Saudi Arabia the general specifications for roads and bridges are mentioned in the fifth section (Nov. 1998), Indian Roads Congress and ISI have specified that the aggregate crushing value of the coarse aggregates used for cement concrete pavement at surface should not exceed 30%. For aggregates used for concrete other than for wearing surfaces, the aggregate crushing value shall not exceed 45%, according to the IS (Indian Standard) code.

3. Impact value tests on aggregates allow only 20% of dismantled aggregate **(**Table II). This implies that roller compaction of concrete to be employed in cement concrete pavement construction having more than 20% recycled aggregate of total coarse aggregate should not be used. Abrasion values obtained, permits 30% replacement of aggregate by dismantled aggregate for concrete to be used in roller compacted concrete pavement construction as shown in Table III.

4. With different w/c ratio as recommended in IS456-2000 compressive strength of mix increases by 26.75% when fresh aggregate is replaced by 75% dismantled aggregate, however slump decreases to $2/3^{rd}$ value. Increasing w/c ratio from 0.60 to 0.625 i.e. by 4.16%, slump increases from 21mm to 60mm when fresh aggregate is replaced by 75% dismantled with 12.68% increase of compressive strength of the mix (Fig. 6 & 7).

5. For 0.65 w/c ratio (IS 456-2000) compressive strength of M15 & M20mix replacing fresh aggregate by 75% dismantled aggregate (Fig. 8 & 9), increases up to 40%, however slump decreases to half (20mm to 10mm) (Fig. 3-5).

6. The use of dismantled aggregate in making fresh concrete will also help in reduction of solid waste dumping on existing landfill sites.

7. The reuse of dismantled concrete will help in improvement of overall environment of the region. Firstly by reduction in mining and secondly reduction in air pollution resulting from production of aggregates (dust pollution) and transportation of aggregate from mining to consumption point (vehicular pollution).

8. Thus, study shows that dismantled concrete is not solid waste but useful material to be recycled to prepare fresh concrete, which saves the cement and make the concrete economical.

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