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RECYCLING OF CONSTRUCTION AND DEMOLITION WASTE FOR THE USE OF RECYCLED AGGREGATES IN CONCRETE: A REVIEW

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Abstract - *The waste generated during the construction and demolition (C&D) activities are sand, gravel, concrete, bricks, metal, plastic, glass etc. Out of 48million tones of solid waste generated in India, C&D Wastes makes up to 25% of overall waste annually. These wastes are bulky and heavy and are mostly unsuitable for disposal by incineration or composting. Hence recycling can be preferred if possible. The cost of recycled sand and aggregates is lower than conventional aggregates and sand, resulting in reduction of overall construction cost. Recycling and reuse of this waste will result in preservation of natural resources, effective In this rapid industrialized world, recycling construction material plays a vital role to preserve the natural resources. Recycling of concrete is important because it helps to promote sustainable development in the protection of natural resources, and reduces the disposal of C&D waste. RILEM Committee 121-DRG [1] has published recommendations for the use of recycled aggregates, classifying them into three groups:*

Group I: aggregates that stem mainly from masonry rubble. utilization of growing waste stream, saving landfill space. Some of the studies have suggested that, first the basic properties of virgin concrete is studied. Then, the recycled aggregate properties have been determined and compared to those of virgin aggregates. This paper deals with the review of the existing literature work for the use of recycled concrete as aggregates in concrete in respect of mainly the properties of recycled concrete aggregates.

Key words: Demolition waste, recycled coarse aggregate, properties of aggregates, concrete debris.

1.INTRODUCTION

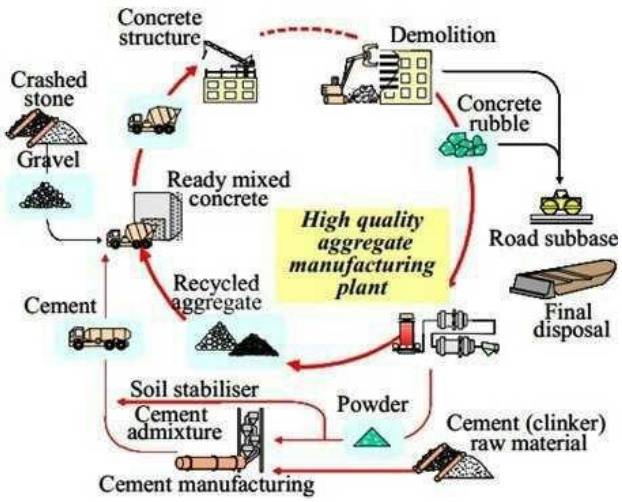
Group II: aggregates obtained mainly from concrete rubble.

Group III: a mixture of natural aggregates (>80%) and rubble from the other two groups (with up to10% of Group I). Group III can be used for the production of all types of concrete, whereas restrictions limit the applications of the other two groups. In highway replacement for example[2], a uniform source of recycled aggregate is guaranteed (from the demolition of the old pavement).However, when the aggregate source is a center for recycling of construction waste, the rubble is collected from various origins and the properties of the aggregate are not uniform. This leads to difficulties in the application of the resulting aggregates for the production of new concrete [3,4]. Buck [5] and Frondistion-Yannas [6] have shown that it is possible to produce new concrete from crushed concrete, but that recycled concrete may be expected to have lower strength than the virgin concrete.De Juanand Gutiérrez [7] studied the effect of attached mortar content on

2. LITERATURE REVIEW

Recycling of waste concrete is to reuse the concrete rubble as aggregates in concrete [9, 10]. The recycled aggregate have less crushing strength, impact resistance, specific gravity and has more water absorption value as compared to fresh aggregates. Millions tons of waste concrete rubbles are generated every year around the world due to following reasons [11,12]: (a) Demolition of old structure for renovation (b)Destruction of buildings and structures during earthquakes and wars. (c) Removal of useless the properties of recycled concrete aggregate. It was observed that the properties of recycled concrete aggregate adversely affected by attached mortar content are the density, water absorption and Los Angeles abrasion. Khatib [8] examined the effect of fine recycled aggregate on the properties of concrete. The results showed that there is strength reduction of 15 – 30% for concrete containing fine recycled aggregate and that more shrinkage and expansion occur in these concretes. the properties of recycled concrete aggregate. It was observed that the properties of recycledconcrete aggregate adversely affected by attached mortar content are the density, water absorption and Los Angeles abrasion. Khatib [8] examined the effect of fine recycled aggregate on the properties of concrete. The results showed that there is strength reduction of 15 – 30% for concrete containing fine recycled aggregate and that more shrinkage and expansion occur in these concretes.

concrete from structures, buildings, road pavements *etc*. (d) Waste concrete generated due to concrete cube and cylinder testing, destructive methods of testing of existing structures *etc*.German researchers demonstrated that recycled aggregate does not affect most performance characteristics of concrete, although it tends to increase drying shrinkage and creep, and reduce modulus of elasticity [13, 14].



Process of recycling of waste concrete to aggregate The strength of recycled aggregate concrete is about 10 to 15 per cent less as compared to concrete with fresh aggregate. The mix requires slightly higher quantity of cement or using admixtures to reduce water requirement. Recycled aggregate concrete can be safely used as plain concrete. With proper corrections in mix design, it can be used for R.C.C. works. Basic changes in all aggregate properties are determined and their effects on concreting work are discussed at length. Similarly the properties of recycled aggregate concrete are also determined. Basic concrete properties like compressive strength, flexural strength, workability etc. are explained here for different combinations of recycled aggregate with natural aggregate. Codal guidelines of recycled aggregates concrete in various countries are stated here with their effects, on concreting work. In general, present status of recycled aggregate in India along with its future need and its successful utilization are discussed here. (IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN: 2278-1684,

PP: 52-59) Recycled aggregates to be produced from aged concrete that has been demolished and removed from foundations, pavements, bridges or buildings, is crushed and processed into various size fractions. Reinforcing steel and other embedded items, if any, are removed and care is taken to prevent contamination by dirt or other waste building materials such as plaster or gypsum. It is prudent to store old concrete separately to other demolition materials to help avoid contamination

3.PROPERTIES OF RECYCLED AGGREGATE

The use of recycled aggregate obtained from the waste concrete, as a component of the new concrete mixture. The study implies that the basic properties of recycled aggregates differs from the properties of aggregates obtained natural resources. It primarily depend on the quantity and quality of cement mortar, which is attached to the grains of recycled aggregate. Since the recycled aggregates has the potential to replace natural resources and in the process address the issue of sustainability and environmental degradation many countries outside India have been using the product satisfactorily. However this requires upgrading the waste material to normal standards and reducing it to proper size to attain the desirable properties. Works have shown that aggregates from different sources, exhibit different engineering properties. Aggregates also are the key ingredients in concrete making up 70-80 % of volume in concrete and dictating the strength and density relationship. Hence using recycled concrete as aggregate will require checking the quality of the aggregates, since they are collected from different sources, grades of concrete and age. Works on recycled concrete have emphasized that the basic material properties, such as shape, texture, specific gravity, absorption, moisture content, permeability, strength characteristics, deleterious substance, resistance to freeze–thaw, etc., need to be thoroughly evaluated before it is used to produce concrete [15] . Aggregate's properties greatly affect the properties of a concrete. It would also be necessary to assess the effect of recycled material on final concrete and work out optimum composition of recycled aggregate to produce concrete of desirable quality [16].

Grading of Aggregates

"Grading of recycled coarse aggregate normally satisfies the standards for natural aggregate, while in the case of recycled fine aggregate, composition corrections are often necessary, because, according to many practical experiences, it was found that there was often a certain amount of grains larger than what is required by standards for natural aggregate.

Shape and Surface Texture of Aggregate particles In terms of morphological characteristics, the recycled aggregates are less favorable than natural aggregates. The grains are irregular, mostly with angular shape, rough and with cracked surface and porous. These grain characteristics significantly affect the workability of fresh concrete, as well as the permeability of liquids and gases in the hardened state.

WATER ABSORPTION

Water absorption of recycled aggregate is a characteristic by which this aggregate differs most from the aggregate obtained from natural resources. According to all available research in this area, it has been shown that recycled concrete aggregate has a significantly higher absorption level compared to natural aggregates. The reason for that is that the original cement mortar, which is an integral part of the recycled aggregate, has a significantly more porous structure in comparison to natural aggregate, whereby its porosity primarily depends on the water cement ratio of the original (old) concrete. Thus, the absorption of water of recycled aggregate is even bigger, as the quantity of mortar, which is attached grains of the original recycled aggregate,

increases. It has been shown in practice that the stated amount of cement mortar in recycled aggregate ranges from 25% to 65% (in volume percentage), and that it differs in certain fractions –the smaller the fraction, the greater the amount of cement mortar, as well as the level of water absorption.

Bulk Density of Aggregate

The bulk density of the recycled aggregate, due to a higher porosity of mortar layer, has a lower value than the bulk density of natural aggregates and their mutual difference decreases if recycling is conducted by an advanced technology, which can remove a significant portion of the old cement mortar. Also, the smaller the fraction, the greater the amount of cement mortar in the total mass of aggregates, so the bulk density is accordingly lower. According to practical experience, it was shown that the bulk density of recycled aggregate was on the average by10% lower compared to the bulk density of natural aggregates.

Crushing and Abrasion Resistance

Mechanical properties of recycled aggregate are primarily dependent on the quality of the original cement mortar present in the aggregate, and also, as in the case with natural aggregates, depend on a number of factors - the type of the original aggregate, structure, shape and size of grains, aggregate grading and so on. The resistance to crushing and abrasion of recycled aggregate is less than the respective resistance of natural aggregate, which is a consequence of easier separation and crushing of the mortar layer around the recycled aggregate grains. In addition, recycled aggregate, in most cases, meets standard requirements in terms of the resistance to crushing and abrasion, which are prescribed for aggregates from natural resources. Their differences may widely range - from 0% up to 70%, which, as already pointed out, primarily depends on the quality, original concrete compressive strength, as well as the methods of crushing of recycled aggregate.

PRESENCE OF HARMFUL SUBSTANCES

Harmful substances, which may be present in recycled aggregate These substances can be found in the following forms: lumps of clay, humus, gypsum, various organic substances (bitumen, wood, paper, cardboard, plastic, coal, plant materials, and various colors), steel and other metals, glass, lightweight concrete, brick, etc. The presence of the stated components negatively affects the characteristics of the new concrete, and the studies show that they can cause a reduction in compressive strength by up to 15%.

4.PROPERTIES OF FRESH RECYCLED AGGREGATE CONCRETE

Entrapped Air content

The application of recycled coarse aggregate has no effect on the amount of entrapped air in fresh concrete. Some research have found that about 1**%** of entrapped air is present in the concrete - which can be considered as negligible.

Bulk Density

An increase in a share of recycled aggregate in total mass of the component aggregate reduces the bulk density of fresh concrete, where it was shown that the bulk density of the recycled aggregate concrete was 5% to 10% lower than in the comparable natural aggregate concrete, while concretes made with the recycled coarse aggregate and natural fine aggregates had densities of 1% up to 5% lower than in the comparable natural aggregate concrete. In general, the values of bulk densities of the fresh concrete based on recycled aggregates range from2280 kg/m3 to 2360 kg m3.

Consistency

The use of recycled aggregate affects the consistency, in the sense that due to a usually higher absorption of recycled aggregate grains, as well as the less favorable grain shape and texture, the flowability of the concrete mixture is reduced.

5. COMPRESSIVE STRENGTH TO BE ACHIEVED USING RECYCLED AGGREGATES

Recycled aggregates to occupy a role in high strength concrete it is necessary that the composition in the first place provides the necessary compressive strength. Various research works carried out on recycled aggregates have pointed the following parameters to be addressed to achieve the required strength.

Adhered Mortar

Research has concluded that more than 50% of recycled aggregate have adhered mortar paste. Inalmost all the cases this paste is identified to be of poorer quality than the new paste. On account of this poor quality, (highly porous mortar) the recycled aggregates are of inferior quality. M.S D.Juan [17] has reported, that percentage of adhered mortar depends on the size of aggregate. The literature which suggests that this may vary from 25-65% and will also depend upon the method adopted to evaluate the mortar content. This factor contributes to a large amount of water absorption in recycled aggregates that varies from 4 to 12%.

Los Angeles Abrasion

Abrasion is linked to the inherent strength of the aggregates. As the % abrasion increases, the compressive strength decreases and this depends on the strength of parent concrete as well as on the size of aggregate. Work by Sami [18] has reported low abrasion in higher parent strength concrete. Since fine aggregates have larger specific surface, the adhered mortar on these aggregates is high thus more is the abrasion. More abrasive aggregates mean lesser parent strength. A. K. Padmini [19] has reported that recycled aggregates can have abrasion up to 48%in case of fine aggregates and this may lead to a loss in strength in the range of 20-35%.The loss of compressive strength as the abrasion percentage increases [17].

Size of Aggregates

Larger size recycled aggregates may replace normal aggregates without reducing compressive strength. Incorporations of fines (10mm) in concrete have more impact on strength and work by A.K. Padmini et.al [19] has reported strength deterioration by 20-35% even if parent concrete is of high strength. The compressive strength reduces to a 12.5% and 8% respectively in comparison with 20mm and 40 mm size aggregates for a w/c ratio of 0.4.

Parent concrete Strength

Work by Sami [18] has stressed that parent high strength concrete only will produce high quality second generation concrete. M.S D.Juan [23] has reported that in order to attain a comparable strength of concrete with recycled aggregates, the minimum strength of parent concrete should be at least 25 MPa. Research has identified parent concrete strength on fresh concrete and works have suggested that higher the parent strength concrete more is the adhered mortar (bond between mortar and aggregate is more) and this may have a detrimental effect on concrete strength. Sami [18] has reported a loss in strength up to 16% with 30Mpa concrete and with 50Mpa to be around 30%. The reduction in compressive strength also takes place with size of aggregates is altered in making fresh concrete from concrete of known strength [19].

Interfacial Transition Zone

The interfacial transition zone formation is related to moisture movement and chemical reaction in the recycled aggregate concrete. Stronger the bond developed at the interfacial zone between the matrix and the coarse aggregate greater is the strength. Works on high performance concrete byC.S. Poon [20] has proven this fact. A stronger bond between the cement and recycled coarse aggregate may be able to compensate to some degree the negative effect due to the use of weaker aggregate. Work by Sami [18] has concluded that in comparison with normal concrete, recycled aggregate concrete results in15% reduction in strength.

Age and Ratio of Recycled Aggregates (RA) to Normal Aggregates

The experimental work carried out by Limbachiya [16] at 28 days, compared with control concrete the compressive strength of the three types of recycled concrete were reduced by 16.7, 21.7 and 18.8 resp. The reduction however decreased as the curing age increased and for all ratios of recycled to normal aggregates. After 5 yrs. The reduction was reduced to 10.5, 6.3 and 8.9 resp. Experimental results have proven in that comparison with control concrete,100% crushed old concrete as recycled had the highest strength gain of more than 60% between28 days and 5 years.

6. RESULTS

Specific Gravity

The specific gravity in saturated surface dry condition of recycled concrete aggregate was found from **2.35 to 2.58** which are less but satisfying the results. If specific gravity is less than 2.4, it may cause segregation; honeycombing & also yield of concrete may get reduced [24].

Water Absorption

The RCA from demolished concrete consist of crushed stone aggregate with old mortar adhering to it, the water absorption ranges from **1.5% to 7.0%,** which is relatively higher than that of the natural aggregates. Thus the water absorption results are satisfactory [24].

Bulk Density

The bulk density of recycled aggregate is lower than that of natural aggregate, thus results are not satisfactory; due to less Bulk Density the mix proportion gets affected [24].

Crushing and Impact Values

The recycled aggregate is relatively weaker than the natural aggregate against different mechanical actions. As per IS 2386 part (IV), the crushing and impact values for concrete wearing surfaces should not exceed 30% & for other than wearing surfaces 45% respectively. The crushing & impact values of recycled aggregate satisfy the BIS specifications limit. From crushing & impact test it is found that use of recycled aggregate is possible for application other than wearing surfaces [24].

Compressive test on cubes

The average compressive strengths of cubes cast are determined as per IS 516 using recycled aggregate (RAC) and natural aggregate concrete (NAC) at the age 3, 7, & 28days. The reduction in strength of RAC as compare to NAC is in order of 8-14% and 10-16%for M-30 & M-40 concretes respectively [24].

Flexural Strength

The average flexural strength of recycled aggregate are determined at the age 7, & 28 days varies from 3.30 N/mm2-5.637 N/mm2 respectively. The reduction in flexural strength of recycled aggregate as compared to NAC is 3 -16% respectively, so it is satisfactory [24].

Water-Cement ratio

With increase in water/cement ratio from

1. 0.5 to 0.55, there is an increase in compressive strength of both concretes.
2. 0.55 to 0.60, NAC shows reduction in compressive strength whereas RAC shows increase in compressive strength
3. 0.60 to 0.65, there was a reduction in compressive strength of both concretes.

7. CONCLUSION

The following main conclusions are drawn from the study:

1. Recycled aggregate has lower specific gravity, higher water absorption and higher aggregate crushing value than is typical of similar conventional aggregate.
2. Recycled concrete generally required about 7% more water for the same workability as a corresponding concrete produced with natural aggregate.
3. The strength of recycled concrete is equal to or lower than the strength of the original concrete from which the recycled aggregate is derived.
4. It is possible to produce recycled concrete of strength equal that made from similar natural aggregate, but the target strength of the new concrete may have to be lower than the strength of the old concrete from which the recycled aggregate is derived.
5. On the basis of this investigation, it is apparent that recycling of aggregate is feasible and may become a viable and routine process for the generation of aggregate for middle and low strength concrete.
6. The use of recycled aggregate usually ranges from 20% to 45% of the total coarse fraction mass.

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