

A Review on Recycled Aggregates for the Construction Industry

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Abstract The essence of modern development is closely linked with conservation of natural resources by preventing environmental degradation as construction materials are increasingly judged by their ecological characteristics. Concrete, the most versatile material for construction, is playing a significant role in the growth of infrastructural and industrial segments but it has been claimed that concrete is not an environmentally-friendly material due to its destructive resource consuming nature and the possibly severe environmental impact after its use. It will, however, remain the major construction material being used worldwide. In order to study closely and in brief related studies in the field of recycling of hardened concrete or the use of recycled aggregates this literature review was carried out. Recycled aggregates are still not conventionally used in the construction industry but still a lot of work has been done on recycling of hardened concrete and continuous improvements are required to optimize this. Some of the research studies on the properties, uses, shortcomings and behavior of recycled aggregate have also been highlighted.

Keywords: *Construction and Domestic waste, industrial segments, recycled coarse and fine aggregate sand, hardened concrete, Portland Pozzolana Cement*

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1. Introduction

Conservation of natural resource and prevention of environmental hazards is the essential task of any modern development. Construction materials are increasingly judged by their ecological characteristics but concrete has become the most versatile material for construction work in the growth of infrastructural and industrial segments in spite of the fact that concrete is not an environmentally-friendly material due to its destructive resource-consuming nature and severe environmental impact after its use. It would seem, however, that it will remain the major construction material being used worldwide.

2. Aims And Objectives

The environmental impact of production of the raw ingredients of concrete (such as cement, coarse and fine aggregate) warrants close consideration. The scale of the problem makes it prudent to investigate other sources of raw materials in order to reduce the consumption of energy and available natural resources. Minimizing the environmental impact, energy and CO₂ intensity of concrete used for construction is increasingly important as resources are declining and the impact of greenhouse emissions becoming more evident. Thus, it is logical to

use life cycle as well as sustainable engineering approaches to concrete mix design and uses. This requires several elements namely maximizing concrete durability, conservation of materials, use of waste and supplementary cementing materials such as fly ash, blast furnace slag, silica fume, rice husk ash and metakaolin as partial replacements for Portland cement. These materials can improve concrete durability, reduce the risk of thermal cracking in mass concrete and are less energy and CO₂ intensive than cement. Use of aggregate obtained from crushed concrete is an example of recycling and conservation of raw materials.

In general aggregate occupy 55-80% of concrete volume. Without a proper alternative and assuming continued use of aggregates, the concrete industry globally will consume 8 to 12 billion tons annually of natural aggregate after the year 2010. In connection with the above, the use of Construction and Demolition Waste (C & DW) as coarse recycled aggregate and fine aggregate has increased at a rapid rate in the entire world. In large developing countries like India, China and Japan there is a large amount of Construction and Demolition Waste generation due to new zoning by laws, modified settlement patterns, increased population, in urban areas due to industrial development, modernization of old road bridges for present as well as for future growing traffic and so on.

In India, the Central Pollution Control Board has estimated that solid waste generation is about 48 million

tons per annum, of which 25% are from the construction industry. Also, the eighth five-year-plan envisaged that there was a shortage of coarse aggregates in the housing sector. Further, to achieve the target for road development up to 2010, an estimated 750 million cubic meters of coarse aggregate as sub base material will be required. The use of Recycled Coarse Aggregate (RCA) can fill this gap in part. Therefore, the recycling of waste concrete is beneficial, necessary for the environmental preservation and effective utilization of natural resources. The use of recycled coarse aggregate obtained from C & DW in new concrete is a solution for effective utilization of construction and demolition waste.

3. Material and Methods

3.1. Fly Ash as an Environmental Pollutant

Fly ash, generated during the combustion of coal for energy production is an industrial byproduct and is recognized as an environmental pollutant. Due to the environmental problems presented by it, considerable research has been undertaken worldwide, in search of reliable ways for the utilization of fly ash. Due to its pozzolanic nature use of fly ash appears technically feasible in cement related works and industry.

Researchers have suggested that the use of fly ash as a partial replacement of cement in concrete production due to its beneficial effects such as lower water demand for similar workability; reduced bleeding and lower evolution of heat. It has been used partially with cement in mass concrete applications and large volume placement to control expansion due to the heat of hydration.

Due to the presence of cementitious compounds of Calcium and a reactive glass, high Calcium fly ash has been used successfully in Portland cement products. The use of fly ash in concrete enhances its workability, reduces the cost of construction, provides a much stronger and more stable protective cover to steel against natural weathering action.

The setting and hardening rates of fly ash concrete at early ages are slower but in general the long term ultimate mechanical properties of fly ash concrete are higher than those of plain Portland cement concrete. Silica fume, also known as micro silica is very fine non crystalline silica produced in electric arc furnaces as a byproduct of the production of elemental silicon or alloys containing silicon. It has particles approximately 100 times smaller than average cement particles and exhibits effective pozzolanic properties. Before the mid 1970's nearly all silica fume was discharged into the atmosphere. After environmental concerns necessitated the collection and land filling of silica fume which again become a considerable problem very quickly, other areas for its disposal were sought.

Because of its extreme fineness and high silica content it has been successfully used with cement and cement concrete. When used with cementitious compounds it works on two levels. During its pozzolanic reaction it chemically reacts with the Calcium hydroxide, Ca(OH)_2 , (produced during the hydration of cement) and produces Calcium silicate hydrates (also shown as C-S-H), (Calcium silicate hydrate is known to be the source of the

strength of concrete). The formation of additional Calcium silicate hydrates improves the compressive strength of the resulting concrete. On the other hand, it fills the voids created by free water in the matrix. This reaction typically is expressed as:



3.2. Recycling of Concrete

Recently, the rapid rate of industrialization has made recycling of construction material play an important role in the preservation of natural resources. Basically, in order to ensure sustainable development recycling of concrete has become increasingly important. The various advantages of the recycling of concrete are as follows:

- 1) Conserves natural resources.
- 2) Reduces the impact on dwindling land fill spaces.
- 3) Reduces disposal costs.
- 4) May also reduce the overall project cost.

3.3. Characteristics of Recycled Aggregate (RA)

Strength characteristics of recycled aggregate from hardened concrete are influenced by key factors such as:

- 1) Strength of original concrete.
- 2) Ratio of coarse to fine aggregate in original concrete.
- 3) The ratio of maximum aggregate size in original concrete to that of recycled aggregate.

4. Traditional and Recent Views

The benefits and weaknesses of using Recycled Aggregate (RA) in concrete have been widely studied. It was found that use of RA generally increases the drying shrinkage, creep and decreases the compressive strength, modulus of elasticity of concrete compared to those of natural aggregate.

Experimental works were performed to determine the compressive, splitting tensile and flexural strength of RAC and compared with those of concrete made from natural aggregate. Fine aggregate used in both cases were 100 % natural sand [1].

Test samples were prepared by using different values of control factor & were evaluated for various mechanical properties [2]. Overall assessment on both slump and compressive strength of concrete indicated that to achieve a concrete of compressive strength of 30.17 MPa at 28 days the optimum properties are as w/c ratio 0.5; value ratio of coarse aggregate 42%, natural river sand 100% crushed brick 0% and the remaining part as recycled aggregate.

While investigating the durability of RA aggregate concrete for a safe way to sustainable development, the researchers utilized fine and coarse RA recovered from demolished masonry, concrete structures for production of new concrete. New concrete was evaluated for water absorption, total pores volume and carbonation [3]. It was found that the concrete with highest pore volume and with the same compressive strength did not always correspond to the concrete with the highest degree of carbonation.

When the mechanical properties of RA concrete under uniaxial loading are evaluated, the researchers used RA

from concrete waste and prepared the test samples with varying percentages (0%, 30%, 50%, 70% and 100%) of RA [4]. It was found from experiment that the compressive strength of recycled aggregate concrete decreases with any increase in the percentage of RA and the failure pattern of such concrete is largely in shear mode.

Related work was carried out on micro structural analysis of recycled aggregate concrete produced from two-stage mixing approach. The researchers studied the performance of concrete samples after 7, 14, 28 and 56 days of its production [5]. The samples were made with a varying proportion (0% to 30%) of recycled aggregate with normal mixing approach and two stage mixing approach. The study indicated that the two stages mixing improve the compressive strength in general for all samples.

The work [6] demonstrates the suitability of coarse RCA for use in high strength concrete production. Up to 30% coarse RCA can be used in high strength applications with engineering and durability properties similar to natural aggregate concrete. An adjustment in the w/c ratio has been suggested a mix with high proportions of RCA which is both simple and can be integrated with existing mix design procedures. The result of durability related properties shows satisfactory performance. Encourages engineers to adopt a more relaxed and rational attitude towards the use of RCA in concrete production.

While examining the properties of HPC with recycled aggregates, the researchers [7] examined recycled aggregate generated from demolition construction waste and the same were used in production of HPC. It was found that specific gravity, water absorption capacity, gradation, soundness and wear resistance of recycled aggregate were worse than natural aggregate due to the presence of residual mortar and impurities. There was a reduction of 20%-30% in compressive strength of HPC was noticed due to the addition of recycled aggregate.

Evaluating the mechanical properties of concrete made from recycled coarse aggregate using a specimen of ten mixes of concrete with target compressive cube strength ranging from 20 to 50 MPa using normal and RCA was also undertaken. The cube compressive strength and the indirect shear strength at ages of 1, 3, 7, 14, 28 and 56 days were developed. The compressive strength, the strains at maximum compressive stress and the modulus of elasticity tested by using concrete cylinders at 28 days were reported [8]. It was found that the 28 days cube and cylinder compressive strength and the indirect shear strength of recycled aggregate concrete were on average 90% of those of natural aggregate concrete with the same mix proportions. For concrete with cylinder compressive strengths between 25 and 30 MPa, the modulus of elasticity of recycled aggregate concrete was only 3% lower than that of normal aggregate concrete. The trends in the development of compressive and shear strength and the strain at peak stress in RA concrete were similar to those in natural aggregate concrete.

The feasibility of using stone slurry in production of high performance concrete as a substitute for fine aggregate at Portugal was carried out. The stone slurry from the stone industry was collected, dried and converted into a powdery form to produce a total of 8 concrete sample blocks with 0, 10, 15, 20, 34, 67, and 100%

replacement of fine aggregate with stone dust. The researchers [9] concluded that with substitution of 5% of sand cement by stone slurry the performance of the resulting concrete increases and this substitution can be carried up to 20% without much loss of strength.

For optimization of the proportion of RA in concrete using a two-stage mixing approach, researchers used a general regression neural network to find the optimum percentage of RA in concrete by using two stages mixing approach. It was found that a RA replacement of 25 - 40% is optimal [10].

Optimization on proportion for recycled aggregate in concrete using a two-stage mixing approach by exploring RA substitutions ranging from 0 to 100% was worked on and their performance compared with the traditional mixing procedure. Based upon the experimental works, improvements on strength and rigidity of RAC using two-stage mixing approach (TSMA) were compared with those of the traditional mixing procedure based on different percentages of RA replacements. The results were then optimized using general regression neural networks (GRNN) and RA replacements of 25- 40 % and 50 - 70% were found to be optimal when TSMA was adopted [10].

It is noticed that as regards the properties of concrete made with aggregate obtained from demolition waste and using silica fume, researchers used 50% RCA for the production of concrete samples of recycled concrete and recycled concrete with silica fume [11]. It was observed that the presence of RA seemed to produce lower performance levels in terms of sustained load, both the concretes in fresh and hardened state presented lower density as well as higher water absorption.

To evaluate the mechanical properties of brick aggregate concrete two types of ceramic bricks were used for investigation [14]. The bricks were crushed in order to obtain a usable aggregate. The properties investigated were workability and the density of fresh concrete, compressive strength, tensile splitting strength, modulus of elasticity and stress-strain behaviour of hardened concrete. Replacement ratios of natural aggregate by 15 to 30% were investigated with a water/cement ratio of 0.45 to 0.5. Strength indexes were used to assess the effectiveness of aggregate replacement. The results of concrete produced with RA were compared with a reference concrete produced with natural limestone aggregate. Observed results indicate that ceramic residuals could be used as partial replacement of natural aggregate in concrete without reduction of concrete properties for 15% replacement and with reductions of up to 20% the replacement up to 30%.

Studying the influence of silica fume on high strength light weight concrete prepared by concrete mixes with varying percentage of silica fume (0, 5, 10, 15, 20 and 25%) as partial replacement to cement the study of split tensile, compressive and flexure strength after 28 days indicated that strength increases with silica fume incorporation but that the optimum replacement percentage finally depends upon the water cementitious material ratio of the matrix [14].

Investigation of the properties of sustainable concrete containing fly ash, slag and recycled concrete aggregate is carried out using five basic concrete mixes:

- 1) Conventional mix with no material substitutions.
- 2) 50% replacement of cement with fly ash.

- 3) 50% replacement of cement with blast furnace slag.
- 4) 70% replacement of cement with blast furnace slag.
- 5) 25% replacement of cement with fly ash and 25% replacement with blast furnace slag.

Site tested concrete specimens (i.e., 28 days concrete cubes after a compression test from a local construction site) were used for preparing RA. It was found that RAC had more than 28 days compressive strength and split tensile strength. It was suggested that RCA should be in Saturated Surface Dry (SSD) condition before casting in order to satisfy the workability criteria [15].

Assessment of the optimal mixture for concrete made with RCA with five main control factors such as:

- 1) Water cement ratio.
- 2) Volume ratio of recycled coarse aggregate.
- 3) Replacement by river sand.
- 4) Content of crushed brick.
- 5) Cleanness of aggregate.

Properties investigated included compressive strength, tensile strength, elastic modulus, coefficient of permeability and durability in chloride and sulphate solutions [17]. It was determined that the mixes containing 50% slag gave the best overall performance. Slag was particularly beneficial for concrete with RA and could reduce strength losses. Durability tests indicated slight increases in coefficient of permeability and chloride diffusion coefficient when using recycled concrete aggregate. However, values remained acceptable for durable concrete and the chloride diffusion coefficient was improved by incorporation of slag into the mixture by adding the concrete up to 50% fly ash had relatively poor performance for the materials and mix properties used in this study. The study of split tensile, compressive and flexure strength after 28 days indicated that above strength increase with silica fume incorporation but the optimum replacement percentage finally depends upon the water cementitious material ratio of the mix.

For diversification of the two-stage mixing approach (TSMA) for recycled aggregate concrete: Two-Stage Mixing Approach(silica fume) (TSMAs) and Two-Stage Mixing Approach(silica fume and cement) (TSMAsc) during the work one approach was to coat the RCA with silica fume (TSMAs) and the other was to coat the RCA with mixture of silica fume and cement. Concrete samples for both cases were prepared for the study of compressive, flexure & split tensile strength. It was reported that two stage mixing of RCA with application of silica fume (TSMAs) as well as two stage mixing of RCA with mixture of silica fume and cement (TSMAsc) develop a stronger interfacial layer around aggregate and hence helped in improvement of strength of the concrete [12].

A new approach in measuring water absorption of recycled aggregates has also been presented. The researchers concerned (i) investigated the current BSI methodology in measuring the water absorption of aggregate (ii) examined the problem presented in measuring this property for RA (iii) developed an alternative methodology to examine water absorption of RA named real-time assessment of water absorption (RAWA) in giving a more accurate [13] and reliable measure; and (iv) explored the experimental works for RAWA with recycled aggregates and virgin aggregates.

The properties of concrete prepared with crushed fine stone, furnace bottom ash and fine recycled aggregate as fine aggregates have been studied. The samples were prepared with the use of river sand, crushed fine stone (CFS), furnace bottom ash (FBA), and fine recycled aggregate (FRA) as fine aggregates. Two methods were used to design the concrete mixes: (i) fixed water - cement ratio (W/C) and (ii) fixed slump ranges. The investigation included testing of compressive strength, drying shrinkage and resistance to chloride-ion penetration of the concretes. The test results showed that, at fixed water-cement ratios, the compressive strength and the drying shrinkage decreased with the increase in the FBA content [21]. FRA decreased the compressive strength and increased the drying shrinkage of the concrete. However, when designing the concrete mixes with a fixed slump value, at all test ages, when FBA was used as the fine aggregates to replace natural aggregates, the concrete had higher compressive strength, lower drying shrinkage and higher resistance to the chloride-ion penetration. The use of FRA however led to a reduction in compressive strength but increase in shrinkage values. The results suggest that both FBA and FRA can be used as fine aggregates for concrete production.

The properties of RA derived from parent concrete (PC) of three strengths were studied, each of them made with three maximum sizes of aggregates. Using these nine recycled aggregates, three strengths of RAC were made and studied. The typical relationship between water-cement ratio, compressive strength, aggregate-cement ratio, cement content have been formulated for RAC and compared with those of PC. RAC requires relatively lower water-cement ratio as compared to PC to achieve a particular compressive strength. The difference in strength between PC and RAC increases with the strength of the concrete [22]. The relative evaluation of tensile and flexural strengths and modulus of elasticity has also been made.

The strength of concrete made with recycled concrete coarse aggregate has been investigated. The variables that were considered in the study included the source of the recycled concrete and target concrete strength. The toughness and soundness test results on the recycled coarse aggregate showed higher percentage loss than natural aggregate, but remained within acceptable limits. The compressive and splitting tensile strength of concrete made with recycled coarse aggregate depend on the mix proportions [18]. In general, the strength of recycled concrete can be 10-25% lower than that of conventional concrete made with natural coarse aggregate.

The failure mechanism of RA concrete tested by three series of concretes prepared with different compressive strength levels was examined. Each series included a reference concrete prepared with natural crushed stone, two RAC prepared with two coarse aggregates obtained by crushing a normal strength and a high strength concrete [19]. Flexural tests on notched beams and uniaxial compression tests on standard cylinders were performed. In addition, the characteristics of the fracture surfaces were analysed in order to determine the amount of broken aggregates. RAC present slightly lower strength (1-15%), lower modulus of elasticity (13-18%), significant reductions in the energy of fracture (27-45%) and consequently on the fracture zone size when it is

compared with a concrete prepared with natural coarse aggregates.

The influence of coating RA surface with pozzolanic powder on properties of recycled aggregate concrete was studied. The compressive strength, flexural strength of samples after 7 and 28 days was compared with the values of samples prepared with a normal mixing approach [20]. It was noted that a surface coating with pozzolanic powder (fly ash and silica fume) improves the strength of concrete which results in stronger and denser inter facial transition zone.

The research has carried out mechanical properties modelling of RAC. The researches carried out the work with varying water/cement ratio and substitution percent of natural aggregate by recycled aggregate. The experimental program used the samples of construction and demolition waste containing concrete, mortar, red ceramic brick as well as tiles [23]. Results of concrete compressive strength, elastic modulus were statistically analyzed and modeled. The study shows that for both concrete properties, recycled coarse aggregate was more influential than recycled fine aggregate. However, the use of fine recycled red ceramic increased concrete strength. Coarse recycled red ceramic aggregate, fine recycled concrete aggregate exercised the greatest and the smallest influence respectively, in concrete properties.

Researchers also have found the effect and mechanism of surface - coating pozzalanic materials around aggregate on properties. Interfacial Transition Zone (ITZ) microstructure of recycled aggregate concrete by using some additional pozzalanic material such as commercially available fly ash and fine ground slag along with OPC for concrete production with recycled aggregate. The effect of mixing methods and coating of recycled aggregate by various admixtures was also studied. It was found that the strength and durability of recycled aggregate concrete increases by choosing a suitable coating method of recycled aggregate with pozzalanic material [24]

In a review of the utilization of fly ash revealed after critically reviewing the literature, the researcher concluded that fly ash produced as waste from energy and industrial activity has become an important raw material for various applications. The use of fly ash in cement and concrete production has great potential. It has been successfully used as a 50% replacement of cement during concrete production [25].

This study has investigated the feasibility of using ceramic waste, fly ash to produce mortar and concrete. Ceramic waste fragments obtained from local industry were crushed and sieved to produce fine aggregate. The measured concrete properties demonstrated that while workability was reduced with increasing ceramic waste content for Portland cement concrete and fly ash concrete, the workability of the fly ash concrete with 100% ceramic waste as fine aggregate remained sufficient, in contrast to the Portland cement control concrete with 100% ceramic waste where close to zero slump was measured. The compressive strength of ceramic waste concrete was found to increase with ceramic waste content and was optimum at 50% for the control concrete, dropping when the ceramic waste content was increased beyond 50%. This was a direct consequence of having a less workable concrete. However, the compressive strength in the fly ash

concrete increased with increasing ceramic waste content up to 100% [26].

This study has also investigated the potential for using recycled demolition aggregate in the manufacture of precast concrete building blocks in the UK. The researchers used the RA derived from construction and demolition waste. The experimental work was carried out upon sample blocks made with recycled coarse aggregate and masonry derived aggregate [27]. It has been concluded that for desirable compressive strength maximum replacement levels for RCA is 60% for coarse fraction and maximum replacement levels for masonry derived aggregate is 20% for coarse fraction.

Also, evaluated has been the mechanical and durability property of concrete using contaminated recycled aggregates. The researchers cured the natural aggregate concrete slabs in water, sea water, chloride solution and sulphate solution. The slab was then crushed to obtained virgin and contaminated RA. These aggregates were used to produce RCA. It was found that contamination of recycled aggregate does not seem to have a significant [28] effect on mechanical properties up to 28 days of age, but mechanical properties of recycled concrete were found to be lower by up to 40% as compared to the natural concrete.

Attention has also been paid to the behavior of recycled aggregate concrete under drop weight impact load. The researchers prepared beams (in accordance with BIS) of RA concrete by using different amounts of RCA and applied low velocity impact upon it. It was observed that a 25% addition of RCA does not influence the strength of concrete [29].

The scope for recycling of crushed demolished concrete in structures in Egypt revealed that using all the samples as per ASTM Standards C 192-81 is successful and suggested that recycled concrete mixes produce lower strength than ordinary concrete but with the addition of other cementing material up to 50% the strength of the same recycled concrete prepared with RCA improves to satisfies the requirement of the code of practice in Egypt [30].

It was suggested that the weakness of using RA can be mitigated by incorporating a certain amount of fly ash into the concrete mixture. Further it was suggested that the strength of RAC can be improved by water and acid treatment. RA was treated with water, nitric acid, sulphuric acid and the effect studied. It was found that RAC made from such RA showed increased compressive strength when compared with the natural aggregate concrete [31].

Working for the development of high-performance Green concrete using demolition and industrial wastes for sustainable construction, a study was conducted to investigate the feasibility of recycling of air cooled slag (ACS) as a substitute of natural coarse aggregate during production of high performance concrete [32]. The use of RCA along with ACS as coarse aggregate was also studied. It was suggested that use of ACS is particularly beneficial for concrete containing RCA as it attenuated the negative impacts of RCA on concrete strength and durability without the need to increase the cement demand.

To predict the beneficial use of recycled materials in concrete mixtures during study the cement was replaced with ground granulated blast furnace slag (GGBFS), coarse and fine aggregate were replaced by RCA along

with crushed waste glass respectively. The concrete mixtures with 25% to 100% replacement were prepared and tested. It was suggested that 100% recycled materials concrete had very low permeability and lower compressive strength as compared with normal concrete [33]. It was also suggested that use of recycled material becomes beneficial with regard to strength and durability up to 50% when compared with a normal concrete made with virgin materials.

To determine the influence of the amount of recycled coarse aggregate in concrete design and durability properties, the concrete samples using RA were prepared for a study of compressive strength, ultrasonic plus velocity, shrinkage, water absorption and permeability. It was suggested that the samples produced as per mix design methods proposed by the Department of Environment, United Kingdom were able to achieve the target strength even when 80% of the total coarse aggregates were replaced with RCA [35].

A work undertaken by Luis R., Evangelista and Jorge C, de Brito envisages the use of recycled fine aggregate. In a current research programme concrete with different ratios of natural sand with fine RCA was used and it was found that the replacement of fine natural aggregate with fine RCA is feasible. Therefore, it is concluded that, safe to replace natural sand with fine recycled aggregate with the same grading curve up to a substitution ratio of 30%.

5. Conclusions

In order to reduce the consumption of energy and available natural resources. Minimizing the environmental impact, energy and CO₂ intensity of concrete used for construction is increasingly important as resources are declining. The impact of greenhouse emissions becoming more evident. Thus, it is logical to use life cycle and sustainable engineering approaches. rapid rate of industrialization has made recycling of construction material play an important role in the preservation of natural resources. Basically, in order to ensure sustainable development recycling of concrete has become increasingly important.

For the benefit of our future generations, we need to set up recycling of hardened concrete or RA for the construction industry and issuance of specifications in order to encourage the adoption of RA for construction activities have been exercised. The following conclusions are drawn on the basis of the thorough review for future research work:

- 1) Recycled fine aggregate (RFA) has not been used.
- 2) RFA have not been used along with Recycled coarse aggregate.
- 3) Grading of aggregates both coarse and fine has not been suggested.
- 4) Effect of using stone dust along with RA has not been studied.
- 5) Codes of practice have not been considered.
- 6) Optimization of use of Recycled coarse aggregate (RCA) and RFA has not been suggested.
- 7) Effect of PPC cement on the use of RA has not been studied.
- 8) Percentage of micro silica and fly ash when used together has not been suggested.

9) Use of aggregates obtained from construction and demolition waste along with fly ash and micro silica for concrete production has not been suggested.

10) Use of PPC (Portland Pozzolana Cement) along with micro silica, RCA and stone dust has not been studied

11) Optimization of admixtures in concrete containing PPC, micro silica, stone dust and RCA obtained from demolition waste has not been discussed.

12) A vast number of combinations of concrete mix have not been studied.

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