Microstructural Analysis of Recycled Aggregate Concrete

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Abstract: This paper highlights the microstructure analysis of recycled aggregate concrete(RAC) using electro dispersive spectrometer (EDX) and scanning microscope (SEM). Roll of calcium silicate hydrate in RAC is well discussed during this paper. Quantification of quicklime (CaO) and silica (SiO2) has been done evaluated. Which justifies the role of recycled aggregate in fresh concrete.

To obtain good quality concrete using recycled aggregate its necessary to follow the minimum requirements defined by the respective Building Standards. Acceptable properties of aggregates are an elemental base for concrete quality; however adequate mix proportions and concrete production methods are highly important in concrete quality too. Recycled aggregates composed of original aggregates and adhered mortar. The use of recycled concrete aggregates as an alternate aggregate material in concrete has been studied over the past 20 yrs. it's now recognized that recycled aggregate concrete (RAC), where natural aggregates are replaced by recycled concrete aggregates, is also a technology for conserving natural resources and reducing the environmental impact of the concrete. This paper presents a study on mechanical properties of concretes manufactured with recycled aggregates sizes and contents of 14 batches of RACs were manufactured. Tests were undertaken the compressive strength, strength, durability, workability, drying shrinkage, and water absorption of batch. Test parameters comprised the recycled aggregate replacement ratio, size of coarse aggregates, and mixing method within the preparation of concrete. The results indicate that the compressive strength isn't determine on mechanical and durability-related properties of RACs.

Keywords

Scanning electron microscopic (SEM), reinforced aggregate concrete (RAC), EDX. : Concrete recycling; crushing process; recycled aggregate; sustainable concrete; durability; benefits and uses

1. Introduction

Construction and demolition waste comprises of sand, gravel, concrete rubbles, stones, bricks, wood, metal, plastic etc. Concrete rubbles waste recycled and recycled aggregates extracted for effective utilization in fresh concrete eventually reduce the demand of virgin natural aggregates in new construction. Effective utilization reduce landfill space. With expansion of construction activity, construction and demolition waste increasing day by day. So its use recycled aggregates effectively in fresh concrete production which protect environment and also reduce the exploitation of natural resources with in production of virgin aggregates. Residential projects Imperial Heights and building near Tatibandh was taken for detailed estimate and material quantities are published during this paper. Research paper clearly states composition of materials like concrete, mortar, bricks, plastic, tiles, wood, reinforcement/steel and glass. Concrete rubbles generated from construction and demolition waste comprises of sand,gravel,concrete,stone,bricks,wood,metals,glass,plastic,paper etc; Recycling and reusing the waste (Recycled Aggregates) may save landfill space and also may reduce the natural resources (Virgin Aggregates) for the assembly of fresh concrete. Recently lot of research work is dispensed on recycling and reuse of recycled aggregates as a part of waste management. Waste arising out of construction and demolition structures are increasing day by day and approximately 50% of this waste comprises of concrete rubble which may be the grate source of recycled aggregates. So there's an urgent must establish a technology to reuse recycled aggregates as a substitute to virgin aggregates in production of fresh concrete. Recycled aggregates were collected from different sources and also the mixes were varied by replacement of virgin aggregates with recycled aggregates up to 100% by weight with or without admixture, Micro Silica. Results projects that the replacement of virgin aggregate by coarse recycled aggregate with Micro Silica up to 50% has better compressive strength as compared to the standard concrete but higher levels of replacement reduces the compressive strength.

Fig.1 Recycled aggregates

The construction industry contributes substantially to the generation of solid waste in most the countries. In North America the event and demolition waste contributes around 25 – 40% of the overall waste generated depending upon the region (Tabsh and Abdelfatah 2009). The event Materials Recycling Association (CMRA) has conducted a study on construction and demolition waste, associated with the buildings and it had been estimated to be around 136 million tonnes of waste. Also, It absolutely was reported that expert of the building waste, a various tonnes of waste is coming from road, bridge, and airport construction and renovation. In developed countries the annual per capita building and construction waste generation were 500 – 1000 kg and within the eu countries the building and construction waste was estimated to be around 175 million tonnes each year (Nitivattananon and Borongan 2007) .the development and demolition waste generation scenario in Asian countries is additionally within the identical trend.it had been reported that Asia alone generates about 760 million tonnes of construction and demolition waste once a year (World Bank 1999).in keeping with the annual report of Dubai municipality's Waste Management Department, there was about 27.7 million tonnes of construction waste, generated from various construction sites within town in 2007 (Shrivastava and Chini 2009). This was recording growth in construction waste generation of 163% as compared to the waste generated in 2006.

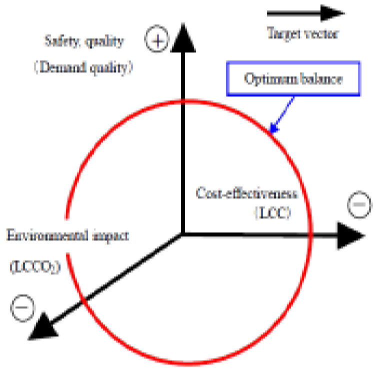

Figure.2 - Evaluation of recycling

The construction industry contributes substantially to the generation of solid waste in most the countries. In North America the event and demolition waste contributes around 25 – 40% of the complete the total waste generated depending upon the region (Tabsh and Abdelfatah 2009). The event Materials Recycling Association (CMRA) has conducted a study on construction and demolition waste, related to the buildings and it absolutely was estimated to be around 136 million tonnes of waste matter. Also, it absolutely was reported that apart from the building waste, a uncountable tonnes of waste is coming from road, bridge, and airport construction and renovation. In developed countries the annual per capita building and construction waste generation were 500 – 1000 kg and within the ecu countries the building and construction waste was estimated to be around 175 million tonnes p.a. (Nitivattananon and Borongan 2007). 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The utilization figures have shown steady increase from 14.6 million in 1995 to 31.46 million in 2005. The event industry in India significantly affects the economical process of the country. During 2004 – 2005, over US$ 100 billion has been invested during this sector. Dueto government of India's (GOI) recent initiative to permit 100% foreign direct investment in realty development projects, the event the event sector likely to still record higher growth within the within the approaching years (Market Research 2006). The contribution of the event industry in total gross domestic product (GDP) has risen from 6.4% in 2000 – 2001 to 7.2% in 2004 – 2005 (TIFAC Ed 2005). Technology Information, Forecasting and Assessment Council (TIFAC) indicate that the complete construction work is appreciate $847 billion during the number 2006 – 2011 (TIFAC Ed 2005). Per the tenth five year plans the materials cost was around 40 – 60% of the project cost. And demolition waste in India was estimated to be approximately 14.5 million tonnes (Pappu et al. 2007). The Central Pollution (CPCB) had estimate solid waste generation as 48 million tonne for the year 2001 and out of which 12 – 14.7 million tonnes from industry alone and by 2010, this was expected to be around 24 million tonnes (TIFAC Ed 2005). Recycling of aggregate material from the event and demolition waste may reduce the demand-supply gap in both these sectors. Construction material across the planet so the foremost the employ of all reasonably bailiwick works. As aggregate represents about 70-80% of concrete components so it'll be beneficial to recycle the mixture for construction works and also to unravel the environmental problems. To minimize the matter of more than west product its an honest step to utilize the recycled aggregates provide that the specified final product will meet the standards. The value of Recycled Concrete Aggregate is additionally but 20 to half hour but natural aggregate in some regions[1]. By using the recycled aggregate the consumption of natural aggregate is reduced. Indian housing industry today is amongst the five largest within the earth and at the present rate of growth, its slated to be amongst the easiest two within the next century. With the shortage as likely seen today the long run seems to be in dark for the event sector. The of natural aggregates aren't only required to satisfy the demand for the upcoming projects, but the requirements of the extensive repairs or replacements required for the prevailing infrastructure and dilapidated buildings built few decades back. Construction and demolition disposal has also emerged as a controversy in India. India is presently generating construction and demolition waste to the tune of 23.75 million tons annually as per the Hindu online of March 2007[2], which is love style of the developed nations and these figures are likely to double fold within the next 7 years. The management of construction and demolition waste can be a significant concern because of increased quantity of demolition rubble, continuing shortage of dumping sites, increase in cost of disposal and transportation and specifically of the priority about environment degradation. The increasing problems associated with construction and demolition waste have led to a rethinking in developed countries and thus many countries have started viewing this waste as resource and presently have fulfilled a component of their demand for stuff. Maybe since concrete composes 35% of the waste as per the survey conducted by Municipal Corporation of Delhi [3], India should seriously consider reusing demolished rubble and concrete for production of recycled construction material. Work on recycled concrete has been despenced at few places in India but waste and quality of fabric produced being site specific, tremendous inputs are necessary if recycled material should be utilized construction for producing high grade concrete. Formerly, most the materials which are being utilized within the construction activity are obtained naturally and every one the wastes which are obtained from the demolished buildings were disposed in large unauthorized open places. Over 20 years the usage of RCA's which are acquired from demolition wastes of construction activity encompasses a greater importance because the availability of natural aggregates is reducing drastically year by year and thus the damage caused by the disposal waste is increasing. thanks to advance techniques which are being employed within the crushing industry and advancement within the equipment & recycling process, it became very easy to pulverise demolish waste larger boulders in to tiny pieces so as to provide recycled aggregates at reasonable cost. Now a days the standard of recycled aggregates has been drastically increased thanks to good demolition practices and advancement within the crushing machinery. As a results of this the recycled aggregates of easiest quality are available at the rates adequate that of natural aggregates and giving a troublesome completion to the natural aggregates. Though these aggregates are available at reasonable rates, the usage is \limited due to using low strength cement and poor quality aggregates and also the constraints of the standards. So by using latest technologies in concrete technology and material production the negative impact on the recycled aggregates must be removed and usage of RCA's should be increased in construction activity.

Fig.3. Recycled aggregate crusher

The usage of construction and demolition wastes as an aggregate for the manufacture of concrete is taken into account in new research studies. The usage of construction and demolition waste aggregates helps in reducing the depletion of natural aggregates and problems associated with mining the aggregates. It is found that the standard of natural aggregates is healthier compared to the development and demolition waste aggregates. Thus, demolition waste aggregates have limited usage. But the reduced cost of manufacture of concrete with the assistance of construction and demolition waste aggregates must be gained appreciation. The rule over the reduction of disposal of demolition waste has prompted the usage of CDW as construction aggregates. The life cycle of construction materials is made more performing with the assistance of recycled construction demolition waste. There's government laws and regulation that are advises to extend the employment of recycled construction demolition material. This has made the recycling amount of construction and demolition material by an amount of 90%.

Standardization of Construction Demolition Waste Aggregate

The incorporation of demolition waste material as an aggregate in the concrete mix requires standardization similar to that compared to the natural aggregates. This is because the concrete mix almost composes 75% of the aggregates.

The construction and demolition waste aggregates are classified by BS 8500 (2002).

Classifies this into two types as:

- Recycled Concrete Aggregates (RCA)
- Recycled Aggregates (RA)
- Recycled Concrete Aggregates (RCA)

The concrete aggregate that contains 95% of crushed concrete is named as recycled concrete aggregates. And if the mixture employed in the concrete is 100% crushed, it's called as recycled aggregates. Recycled concrete aggregate (RCA) is that the designation utilized in BS 8500-2 for recycled aggregate principally comprising crushed concrete. Designations of recycled aggregate apart from RCA are of lower quality and will contain significant quantities of masonry which might preclude or limit their use in structural concrete. The results of a test programme to check the utilization of recycled concrete aggregate (RCA) in high-strength, 50 N/mm2 or greater, concrete are described. The consequences of coarse RCA content on the ceiling strength, bulk engineering and sturdiness properties of such concretes are established. The results showed that up to 30% coarse RCA had no effect on concrete strength, but thereafter there was a gradual reduction because the RCA content increased. A way of accommodating the results of high RCA content, involving simple adjustment to water/cement ratio of the combination is given. It's shown that high-strength RCA concrete will have equivalent engineering and sturdiness performance to concrete made with natural aggregates, for corresponding 28-day design strengths.

The construction and demolition waste in its original state consists of wood, gypsum, plastics and plenty of contaminating materials, that must be removed thanks to its usage in concrete manufacture.

Construction industry generates huge amounts of debris that has to be recycled and reused as recycled aggregates (RAs) for partial or total substitution of natural aggregates. Recycling reduces waste and reduces energy consumption and hence contributes to a more sustainable industry. During this chapter the necessity for recycling and also the current situation worldwide are highlighted. RA properties are discussed. RAs have a density below that of virgin materials and better water absorption. A state of the art RA concrete performance at the fresh and hardened state is summarized. RA concrete presents lower compressive and flexural strengths additionally as lower modulus of elasticity and lower fracture due to the porous nature of the RA and therefore the old adhered cement mortar on the surface of the aggregates. Bond strength and abrasion resistance are little affected. Shrinkage, water permeability and water absorption by capillary increase with increase in RA content. However, the lower performance is mitigated by an honest mix design using supplementary cementitious materials.

Performance of concrete made with commercially produced coarse recycled concrete aggregate

Performance tests are meted out for fresh and hardened properties of concrete made with commercially produced coarse recycled concrete aggregate and natural fine sand. Test results indicate that the difference between the characteristics of fresh and hardened recycled aggregate concrete and natural aggregate concrete is maybe relatively narrower than reported for laboratory-crushed recycled aggregate concrete mixtures. For concrete without furnace slag having similar volumetric mixture proportions and workability, there was no difference at the five hundred significance level in concrete compressive and tensile strengths of recycled concrete and control normal concrete made of natural basalt aggregate and fine sand. Water absorption rates and carbonation of recycled concrete and reference concrete were comparable for many applications. However, the abrasion loss of recycled aggregate concrete made with ordinary hydraulic cement increased by about 12% compared to normal concrete, while the corresponding drying shrinkage was about 25% higher at 1 year. The ratio of splitting strength to compressive strength was found to be in good agreement with established values derived for equivalent grade concretes made with normal-weight natural aggregates. One-year test results indicate that incremental improvements in durability characteristics can further be achieved with the utilization of furnace slag cement. Enhanced fresh and hardened concrete properties of the investigated recycled concrete aggregate as compared to aggregate derived from laboratory-crushed concrete arise primarily from improved aggregate grading and quality achievable in plant crushing operations.

Preparation of Construction and Demolition Waste Aggregates

The CDW aggregates are recycled and produced in many countries. The mixture preparation is completed by breaking the CDW into small pieces that of natural aggregates mechanically. The pieces are later crushed by means crushers into further smaller pieces. Next, just like the grading of conventional aggregates, these are screened by means of sieve analysis and hence used as standard aggregates. As mentioned before the waste from demolition is contaminated by many waste materials that are utilized in construction. So, the removal of those materials will affect the performance of the aggregates. The rubbles employed in the development, after demolition, are covered by a mortar that too must removed for the usage as aggregates. Two typical plants that represent the recycling of recycled aggregates are shown in figure-1 and figure2.

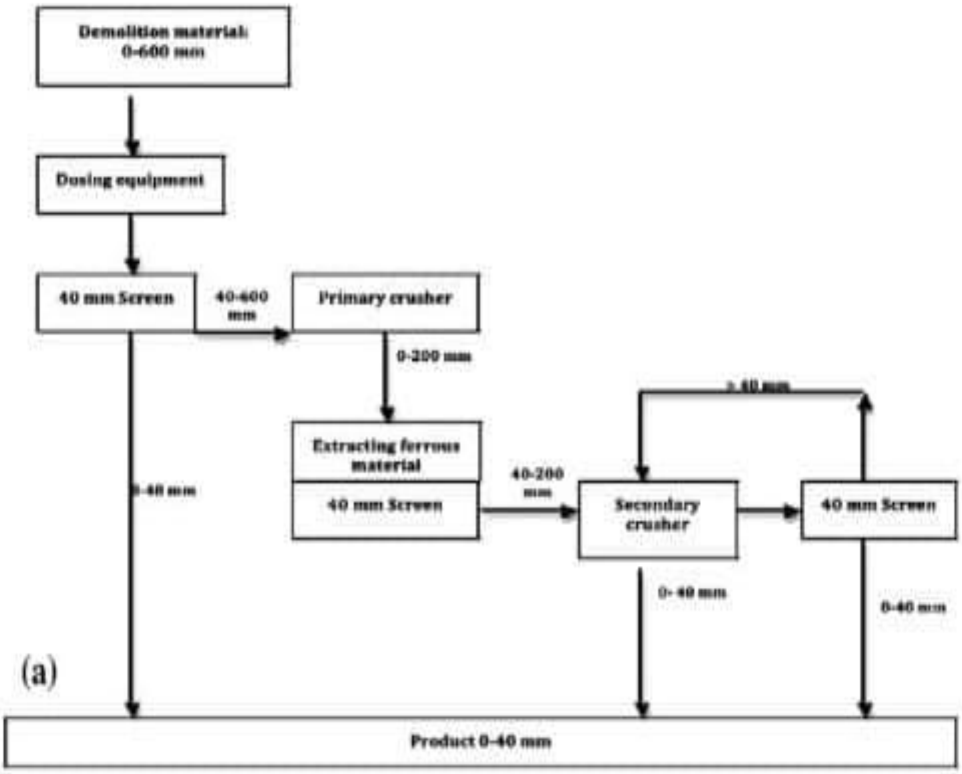

Fig.1: A Construction and Demolition Waste Plant, As per Gonzalez – Fonteboa (2008)

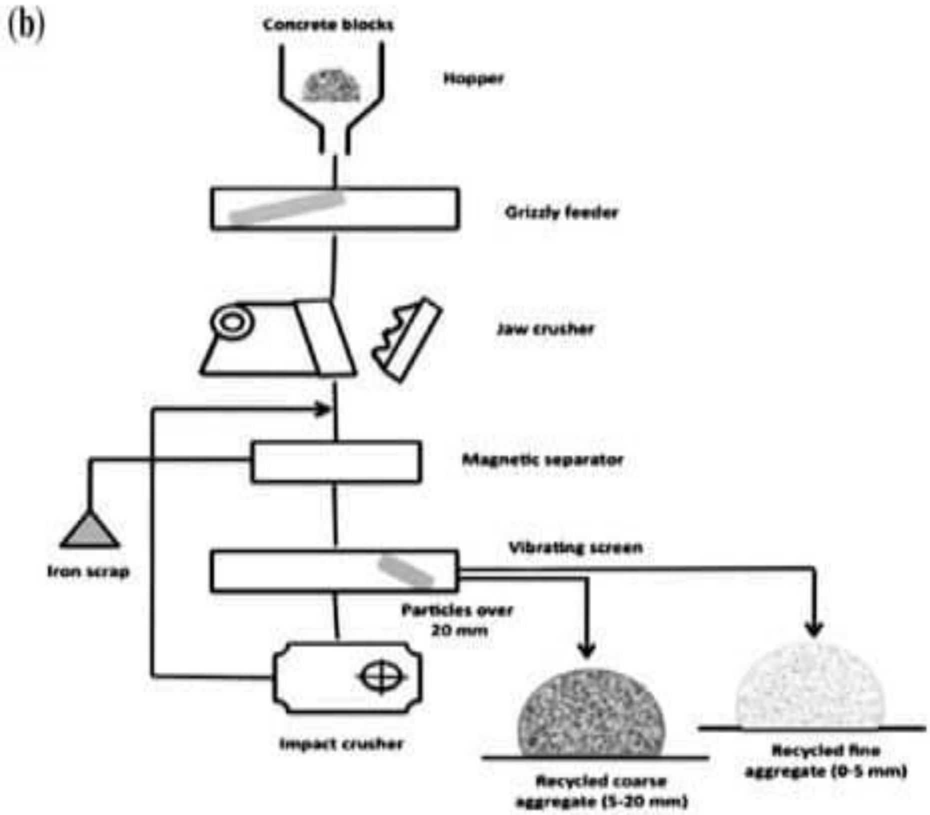

Fig.2: Construction and Demolition Waste Plant as per Eguchi et.al (2007)

The production of CDW aggregates are factors that would determine the quality and the material composition. The good processing of concrete helps in a better quality of aggregates.

Composition of Construction and Demolition Aggregates

The production of CDW aggregates are factors that will determine the standard and also the material composition. The nice processing of concrete helps in an exceedingly better quality of aggregates. Composition of Construction and Demolition Aggregates. It was reported that the CDW contains some amount of some natural aggregates that have adhered mortar. These have the origin from the precast concrete and test specimens. The CDW composition depends upon the sort of demolition waste further because the form of aggregate used for that construction. A typical construction and demolition waste aggregate is claimed to possess 65-70% of major coarse furthermore as fine aggregates, with 30-35% of cement paste.

Table-1: Composition of different materials in construction wastes as per Coelho and de Brito 2011

Materials	Pereira (2002)	Costa and Ursella (2003)	Reixach et al. (2000)	Franklin Associates (1998)
	Amount in %			
Concrete and ceramics	58.3	84.3	85.0	24.0
Metals	8.3	0.08	1.8	2.0
Wood	8.3		11.2	42.0
Plastics	0.83		0.20	32.0
Bituminous concrete	10.0	6.9		
Other waste	14.2	8.8	1.8	
Total	100	100	100	100

Different Classification of Recycled Aggregates from the construction and demolition waste

The aggregate recycled from Construction demolition waste must satisfy certain requirement of particle size furthermore because the minimum presence of contaminants. These parameters stand along the necessity of durability and stability of those materials. Waste, usually mixed, which can be composed of different origin materials, most of them catalogued as non-hazardous. The European Union targets for this waste for 2020 have been already achieved by the UK, but it is mainly developed in downcycling processes (backfilling) whereas upcycling (such as recycle in new concrete batches) still keeps at a low percentage. The aim of this paper is to explore further within the use of recycled aggregates from construction and demolition waste (CDW) in concrete mixes so as to improve upcycling. A review of most up-to-date research and legislation applied in the UK is developed regarding the assembly of concrete blocks. As a case study, initial tests were developed with a CDW recycled aggregate sample from a CDW plant in Swansea. Composition by visual inspection and sieving tests of two samples were developed and compared to original aggregates. Over 70% was formed by soil waste from excavation, and also the rest was a mix of waste from mortar, concrete, and ceramics with small traces of plaster, glass and organic matter. Two concrete mixes were made with 80% replacement of recycled aggregates and different water/cement ratio. Tests were carried out for slump, absorption, density and compression strength. The results were compared to a reference sample and showed a considerable reduction of quality in both mixes. Despite that, the discussion brings to identify different aspects to solve, like heterogeneity or composition, and analyze them for the successful use of these recycled aggregates in the production of concrete blocks. The conclusions obtained can help increase upcycling processes ratio with mixed CDW as recycled aggregates in concrete waste, usually mixed, which can be composed of different origin materials, most of them catalogued as non-hazardous. The European Union targets for this waste for 2020 have been already achieved by the UK, but it is mainly developed in downcycling processes (backfilling) whereas upcycling (such as recycle in new concrete batches) still keeps at a low percentage. The aim of this paper is to explore further within the use of recycled aggregates from construction and demolition waste (CDW) in concrete mixes so as to improve upcycling. A review of most up-to-date research and legislation applied in the UK is developed regarding the assembly of concrete blocks. As a case study, initial tests were developed with a CDW recycled aggregate sample from a CDW plant in Swansea. 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No reasonably unexpected or depletion- causing reactions must be taken place by the aggregates, with the cement or the armor. It should possess perfect shape plus particle size that may help in acceptable workability for the concrete.

The various classification of recycled aggregates from the development demolition waste by different institution in several countries. A number of them are: classified RA into four main categories. These are described as follows:

- Recycled concrete aggregate (RCA): aggregate derived from crushed concrete made with NA.

- Recycled masonry aggregate (RMA): aggregate derived from masonry rubble such as ceramics bricks and sand–lime bricks.

- Mixed recycled aggregate (MRA): aggregate consisting mainly of RCA and RMA.

- Construction and demolition recycled aggregate (CDRA):

Classification based on Water absorption and Loss in Weight

Table-2: Classification of Recycled Aggregates from Construction demolition waste as per Ministry of Construction Japan (As per Kawana, 2000)

Coarse aggregate				Fine aggregate		
Class	Water absorption		Loss in weight	Class	Water absorption	Loss in weight
I	<3%		<12%	I	<5%	<10%
II	<3%	and	<40%	II	<10%	–
		or				
	<5%	and	<12%			
III	<7%		–			

Classification based on Origin

This type of classification was put forward by Rilem (1994) for aggregates that are recycled from the major material in construction as,

- Type I – Masonry Waste originated Aggregates
- Type II – Concrete Waste originated Aggregates
- Type III- Natural aggregates + recycled aggregates; This type will be having a range of 80% of natural aggregate and 10 % type I aggregates.

Fig.3. Recycled Aggregates from Masonry Construction Demolition

Classification Based on Constituents

This classification is advance by the eu standard, EN 12620. Here an in depth sorting of recycled aggregates supported its individual constituents is formed as shown in table-3. One example to point out what precisely the code wishes to convey is, the names RCU90, RB10, RA5 implies that an aggregate containing concrete 90% by mass, 10 % lesser masonry, bituminous material by 5 try to so on.

Fig.4: Recycled Waste Aggregates from Concrete Waste

Table-3: Different Categories of Recycled Aggregates based on Constituent Present

Constituent	Content (wt %)	Category
R_c	≥ 90	R_c 90
	≥ 70	R_c 70
	< 70	R_c D
	no requirement	R_c SR
$R_c + R_u$	≥ 90	R_{cu} 90
	≥ 70	R_{cu} 70
	≥ 50	R_{cu} 50
	< 50	R_{cu} D
	no requirement	R_{cu} SR
R_B	< 10	R_B 10
	< 30	R_B 30
	< 50	R_B 50
	> 50	R_B D
	no requirement	R_B SR
R_A	< 1	R_A 1–
	< 5	R_A 5–
	< 10	R_A 10–
$FL_S + FL_{NS}$	< 1	FL_{total}1
	< 3	FL_{total}3
FL_{NS}	< 0.01	FL_{NS}0.01
	< 0.05	FL_{NS}0.05
	< 0.1	FL_{NS}0.1
$X+R_G$	< 0.2	XR_G0.2
	< 0.5	XR_G0.5
	< 1	XR_G1

Table-4: The Constituents present in Construction Waste Demolition, as mentioned to table 3

Constituent	Description
R_C	Concrete, concrete products, mortar, concrete brick
R_U	Natural stone, recycled aggregate clean (without mortar)
R_B	Bricks, tiles, masonry units, calcium silicate, non-floating aerated concrete
R_A	Bituminous material
R_G	Glass
FL_S	Floating stone material (< 1 mg/m^3)
FL_{NS}	Floating non-stone material (< 1 mg/m^3)
X	Others: cohesive materials (soils and clays), metals, non-floating wood, plastic, rubber

Key Characteristics of Recycled Aggregates from Construction Demolition Waste

- **Elongated aggregates-**

  When the length of aggregate is larger than the opposite two dimensions then it's called elongated aggregate or the length of aggregate is bigger than 180% of its mean dimension.

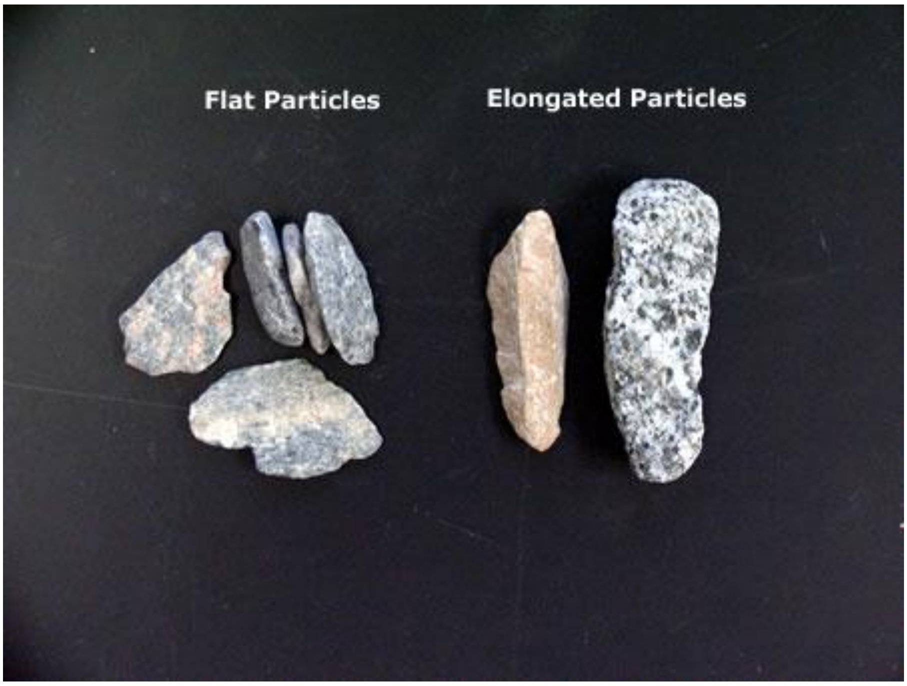

Figure 5 : Flat particles (left) and elongated particles (right)

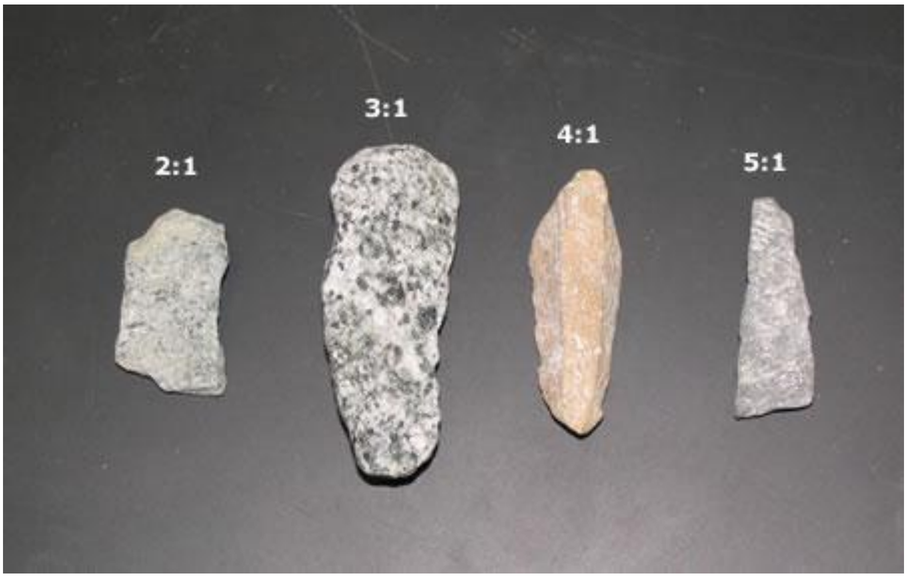

Figure6 Range of flat and elongated particle ratios. The 5:1 particle is very flat, giving a length: height ration of 5:1. The height: width dimensions seen in the photo are about 4:1.

- **Irregular –**

These are shaped by attrition, but aren't fully rounded. These include small stones and gravel, and offer reduced workability to rounded aggregates. The mixture with irregular shape has higher percentage of voids starting from 35 to 37%. It gives lesser work-ability than rounded aggregate for the given water content. Water requirement is higher and hence more cement is required for constant water cement ratio. The interlocking between aggregate particles is best than rounded aggregate but not up to be used for top strength concrete and pavements subjected to tension.

- **Rough Texture –**

The shape and surface texture affect the properties of fresh concrete quite the properties of hardened concrete.

Rough-texture, and angular particles require more water to provide workable concrete than do smooth, rounded and compact particles. For both crushed or noncrushed aggregate, proper gradation gives the identical strength for the identical cement factor.

Bond between cement paste and a given aggregate generally increases the particles surfaces change from smooth and rounded to rough and angular. The rise in bond is vital for choosing aggregates for concrete where strength at early age is vital.

Aggregate should be freed from flat or elongated particles. Because they require a rise in mixing water and thus may affect the strength of concrete particularly in flexure. Aggregate particle shape and surface texture are important for correct compaction, deformation resistance, and workability. ... In HMA, since aggregates are relied upon to produce stiffness and strength by interlocking with each other, cubic angular-shaped particles with a rough surface texture are best.

The durability of the concrete is severely littered with increasing the scale of the combination. On increasing the most grain size to 120–180 mm, the reduction in enduringness is 30–50% as compared with concretes with maximum aggregate size 20 mm. there's also a discount within the elongation limit.

Increasing the granular composition of the mixture increases the efficiency utilization of cement in concretes working in compression. At the identical time, there's a discount in deformation and a rise in coefficient of elasticity and unit weight of the concrete. The enduringness of the concrete is severely tormented by increasing the dimensions of the mixture.

On increasing the most grain size to 120–180 mm, the reduction in enduringness is 30–50% as compared with concretes with maximum aggregate size 20 mm. there's also a discount within the elongation limit.

On increasing the combination size, homogeneity of the concrete deteriorates, and therefore the values Rp and Rpb approach one another, even on specimens of the identical cross-sectional dimensions.

When designing concretes for given strength and deformation properties, the coarseness of the mixture is one amongst the foremost important technological parameters.

Aggregate Type	Particle Shape Classification	Surface Texture Classification
Natural	Rounded or irregular: shaped by a combination of attrition and crushing 	Smooth or rough: combination of river stone and crushed gravel 
RCA-1	Angular or irregular: shows fairly well-defined edges at the intersection of plane surfaces 	Rough: noticeable roughened fracture surfaces resembling crushed limestone 
RCA-2	Irregular: resembles crusher run gravel but with a large amount of adhered mortar; particles are not angular like the RCA-1 	Granular: because of large amount of adhered mortar, more brittle surface, loose adhered rounded mortar particles 
RCA-3	Irregular or rounded: resembles crusher run gravel but with significant amounts of adhered mortar	Granular: adhered mortar is quite brittle resulting in large amount of adhered surface fines

- **High Porosity-**

The internal pore characteristics are important properties of aggregates. The size, the number, and therefore the continuity of the pores through an aggregate particle may affect the strength of the mixture, abrasion resistance, surface texture, relative density, bonding capabilities, and resistance to freezing and thawing action. Absorption relates to the particle's ability to require in an exceedingly liquid. Porosity may be a ratio of the amount of the pores to the entire volume of the particle. Permeability refers to the particle's ability to permit liquids to meet up with. If the rock pores don't seem to be connected, a rock may have high porosity and low permeability.

• **Fissured Surface** –A long fine crack within the surface of something is named a fissure. If you see a fissure within the ice on a frozen lake, you will need to require off your skates and head back to the car. Fissure has its roots within the Latin word fissura, meaning a cleft or crack.

• **Higher Water Requirement** –Two of the foremost commonly specified requirements for concrete employed in the manufactured concrete products industry are the look compressive strength (f' c) and therefore the maximum water-to-cement ratio (w/c). These two values are inversely related, which implies that because the water-to-cement ratio increases, the compressive strength decreases. Not only does the w/c ratio have a powerful influence on compressive strength, but it also affects the permeability and ultimately the sturdiness of the concrete. Both of those properties become extremely important when the precast product are going to be subjected to a corrosive environment or freeze-thaw conditions, or when it's required to supply a watertight structure. Concrete is intended to resist a specific maximum load per area before failing, called compressive strength variety of things influence the concrete's ability to resist the force from an applied load, like the dimensions, type, quantity and gradation of aggregates, the sort and quantity of cement and/or supplementary cementitious materials, the number of mix water, the age or maturity of the concrete, and also the production practices utilized in placing, consolidating and curing the concrete. Small changes in any of those variables can have a profound effect on the concrete's compressive strength, permeability and sturdiness. To account for such variables, mixes are designed to satisfy a median or required compressive strength (f' cr), which is larger than the planning strength. Procedures for determining the common or required compressive strength are addressed in chapter 5 of ACI 318 and are covered within the May/June 2004 MC article titled "Standard Deviation" (available at www.precast.org). Once general requirements like the desired compressive strength, air content and slump are established, initial mix designs is also developed following the rules in ACI 211.1, "Standard Practice for choosing Proportions for Normal, Heavyweight and Mass Concrete."

Water-to-cement ratio- The maximum water-to-cement ratio is also established by the customer or authority having jurisdiction supported anticipated exposure conditions. The target w/c ratio may be selected from available data on the particular materials which will be used. If no such data is offered the w/c ratio are often selected from table 6.3.4(a) of ACI 211.1 supported the specified compressive strength. The lower of the 2 w/c ratios should be used for the combo design. The water-to-cement ratio is that the weight of water provided during a mix divided by the burden of cementitious materials. The overall weight of water includes all batch water and free water from the surface of aggregates. If the number of water is provided in gallons, it can easily be converted to pounds by multiplying the overall gallons by 8.34 pounds per gallon. Cementitious materials include cement, blended cements and supplementary cementitious materials like ash, silica fume and slag. Thanks to this, the water-to-cement ratio is also noted because the water-to-cementitious materials ratio (w/cm). When calculating the w/c ratio, the full weight of all cementitious materials is employed within the denominator.

1 gallon of water = 8.34 pounds of water

$$w/c = \frac{weight\_water}{weight\_cementitious\_materials} = w/cm$$

2. Literature review:

Use of recycled aggregate in concrete is helpful for environmental protection. Recycled aggregates are the materials for the long term. The applying of recycled aggregate has been started in an exceedingly sizable amount of construction projects of the various European, American, Russian and Asian countries. Many countries are giving infrastructural laws relaxation for increasing the employment of recycled aggregate. This paper reports the elemental properties of recycled fine aggregate and recycled coarse aggregate & also compares these properties with natural aggregates. 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 various combinations of recycled aggregate with natural aggregate.

Recycled Concrete Aggregate (RCA)

Base on some research, it's been reported that the concrete made with recycled coarse aggregates (RCA) has similar properties to it produced fromNA. Meanwhile the utilization of RCA needs caution thanks to its higher water absorption tendency compared to NCA. The RCA may include the Mixed aggregate that come from construction and demolition waste treatment and include concrete waste, unbound aggregates and ceramic products as the additional mixture. 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.

Selected international experience has been outlined here which has relevance for the Indian situation:

A) Scotland – About 63% material has been recycled in 2000, remaining 37% material being disposed in landfill and exempt sites. a) The govt is functioning out on specifications of recycling and code of practice. b) Attempts are being made for establishing links with the design system, computerizing transfer note system to facilitate data analysis and facilitating dialogue between agencies for adoption of secondary aggregates by consultants and contractors.

B) Denmark – consistent with the Danish Environmental Protection Agency (DEPA), in 2003, 30% of the overall waste generated was Construction & Demolition waste.
a) Consistent with DEPA around 70-75% waste is generated from demolition activity, 20-25% from renovation and also the remaining 5-10% from new building developments.
b) Thanks to constraints of landfill site, recycling could be a key issue for the country.
c) Statutory orders, action plan and voluntary agreements are administered, e.g., reuse of asphalt (1985), sorting of Construction & Demolition waste (1995) etc.

C) Netherlands – over 40 million Construction & Demolition waste is being generated out of which 80% is brick and concrete.

a) variety of initiatives taken about recycling material since 1993, like prevention of waste, stimulate recycling, promoting building materials which have a extended life, products which might be easily disassembled, separation at source and prohibition of Construction & Demolition waste at landfills.

D) USA – Construction & Demolition waste accounts for about 22% of the entire waste generated within the USA.

a) Reuse and recycling of Construction & Demolition waste is one component of larger holistic practices called sustainable or green building practice.

b) Green building construction practices may include salvaging dimensional number, using reclaimed aggregates from crushed concrete, grinding drywall scraps, to use as soil amendment at the location.

c) Promoting „„deconstruction"" in situ of „demolition".

d) Deconstruction means planned breaking of a building with reuse being the most motive.

E) Japan – Much of the R&D in Japan is concentrated on materials which might withstand earthquake and prefabrication a) 85 million a lot of Construction & Demolition waste has been generated in 2000, out of which 95% of concrete is crushed and reused as road bed and backfilling material, 98% of asphalt + concrete and 35% sludge is recycled.

F) Singapore – Construction & Demolition waste is separately collected and recycled. A personal company has built an automatic facility with 3, 00,000 ton every year capacity.

G) Urban center – Concrete bricks and paving blocks are successfully produced impregnation of photo catalyst for controlling Nox in ambient air.

H) India – Use for embankment purpose in bridges, roads etc. up to three to 4% of total production. Akmal, Sami1 (2011) insist that the available resources should be used appropriately & whenever recycled it should be done at the national level with the assistance of GULF COOPERATION COUNCIL (GCC) & ENVIRONMENT PROTECTION INDUSTRIAL CO (EPIC). They observe that GCC countries produce quite 120 million plenty of waste once a year out of which 18.5% is expounded to solid construction waste. Results from Dubai municipality indicate that out of 75% of 10,000 a lot of general waste produced, 70% is of concrete demolition waste. The author strongly advocates that a powerful commitment & investment by government bodies additionally as private bodies make this necessary for sustainability. Some materials are reused for recycling like plastic, glass etc. within the same way concrete also can be used continuously as long because the specification is true. Recycling solid waste materials for construction purposes becomes an increasingly important waste management option, because it can result in environmental and economic benefits. Conservation of natural resources, saving of energy in production and transportation, and reduction of pollution are the benefits of recycling. Particularly, concrete could be a perfect construction material for recycling. In gulf countries natural resources are imported from different locations for fulfilling the necessity of construction. Small sources available in gulf countries in Arabian Peninsula are limited. For construction work, demand of desalinated water & sand locally available exits. Conservation of natural sources, saving natural resources, energy transportation & reduction of pollution are advantage. Guide for Cement & Concrete Association of latest Zealand (CCANZ) 8 has show that the costs applying $10/ton onto land fill dumping often make recycling concrete aggregate (RCA) a preferred option. The utilization of RCA to conserves natural aggregate & the associated environmental cost of exploration & transportation waste minimization & reducing the burden on landfills may be a global issue. Extensive research has been meted out worldwide on the utilization of recycled aggregate in concrete. It also shows that globally the concrete construction industry has taken a responsible attitude to confirm that its natural resources don't seem to be over exploited. Thanks to issues referring to sustainability and limited natural resources, it's clear that the utilization of recycled and secondary aggregates (RSA), for instance, crushed concrete and asphalt and industrial byproducts like ash and furnace slag, will grow. However, currently, it's only within the USA, Japan, parts of Western regulations are sufficiently put within the place that the utilization of RSA exceeds 10% of the overall aggregate usage. Consequently, worldwide the utilization of RSA stands at approximately 750 million tones, it's less 3% out of total aggregates use in world. They also insist that sustainability is mostly recognized as a foundation for resource and energy – saving technological developments in many fields including that of construction. Parekh, Modhera5 (2011) discuss the problems referring to sustainability and limited natural resources. They also suggest use of recycled and secondary aggregates (RSA), for instance crushed concrete and asphalt and industrial byproducts like ash and furnace slag. Then products now reused in several material production. There are many studies that prove that concrete made with this kind of coarse aggregates can have mechanical properties like those of conventional concretes and even high-strength concrete is nowadays a possible goal for this environmentally sound practice. Mirjana Malešev4 et al insiste that the number of recycled aggregate varies with river aggregate by the point of 0,50,100 respectively. The properties of workability (slump test) immediately after mixing and half-hour after mixing, bulk density of fresh concrete, air content, bulk density of hardened concrete, water absorption (at age of 28 days), wear resistance (at age of 28 days), compressive strength (at age of two, 7 and 28 days), splitting enduringness (at age of 28 days), flexural strength (at age of 28 days), modulus of elasticity (at age of 28 days), drying shrinkage (at age of three, 4, 7, 14, 21 and 28 days), bond between ribbed and mild reinforcement and concrete are tested. Ninety nine specimens were made for testing of the listed properties of hardened concrete. It's been found that workability of concrete with natural and recycled aggregate is nearly the identical if water saturated surface dry recycled aggregate is employed. Also, if dried recycled aggregate is employed and extra water quantity is added during mixing, the identical workability are often achieved after a prescribed time. Bulk density of fresh concrete is slightly decreased with increase within the quantity of recycled aggregate. The authors also insist that for concrete, compressive strength mainly depends on the standard of recycled aggregate. If good quality aggregate is employed for the assembly of latest concrete, the recycled aggregate has no influence on the compressive strength, irrespective of the replacement ratio of natural coarse aggregate with recycled aggregate. The identical findings are found for concrete enduringness (splitting and flexural). The modulus of elasticity of concrete also decreases with increasing recycled aggregate content as a consequence of lower modulus of elasticity of recycled aggregate compared to natural aggregate. Shrinkage of concrete depends on the quantity of recycled concrete aggregate. Concrete with quite 50% of recycled coarse aggregate has significantly more shrinkage compared to concrete with natural aggregate. Increased shrinkage may be a results of the attached mortar and cement paste within the recycled aggregate grains. Brett et al2 (2010) insist that the employment of recycled aggregates in concrete is both economically viable & technically feasible. Additionally to demolition waste sources, RA also can be composed of excess Concrete materials returned to the plant. Mirza and Saif3 have studied the effect of silica fume on recycled aggregate concrete characteristics. The odds of recycled aggregate replacements of natural aggregate employed by weight were 0, 50, and 100%, whereas the chances of silica fume replacements of cement utilized by weight were 5, 10, and 15%. The results show that the compressive and tensile strengths values of the recycled concrete aggregate increase because the recycled aggregate and also the silica fume contents increase. The study also indicates that so as to accommodate 50% of recycled aggregate in structural concrete, the combo has to incorporate 5% of silica fume. Gupta7 discusses that normally coarse aggregate is that the fractured stone obtained from rocks in hills or pebbles from river bed, and since of depletion of excellent conventional aggregate in certain regions, the requirement for development of Recycled Aggregate technology should be preoccupied commercially. It's like ash, which is offered from electrostatic precipitators of assorted super thermal power stations which is an industrial waste product. It's chemically reactive when, mixed with cement to be used in concrete. This can be also useful as partial replacement of cement, because it gives concrete having better impermeability. Thus, it's a wider use in industry. He also notifies large scale recycling of demolished waste will offer, not only the answer of growing waste disposal problem and energy requirement, but will help housing industry in getting aggregates locally. Such demolition waste is crushed to required size, depending upon the place of its application and crushed material is screened so as to provide recycled aggregate of appropriate sizes. An aggregate produced by demolished buildings are going to be called Recycled Aggregates. Sankarnarayanan10 et al see the scenario in India presence of Construction & Demolition waste and other inert material (e.g. drain silt, dust and grit from road sweeping) and observes the following:

i) The potential to save lots of natural resources (stone, river sand, soil etc.) and energy, exits in these wastes

ii) Its occupying significant space at landfill sites.

iii) Its presence spoils processing of bio-degradable likewise recyclable waste, Construction & Demolition waste has potential use after processing and grading, Utilization of Construction & Demolition waste is sort of common in industrialized countries but in India up to now no organized effort has been made. The author suggests the following:- Hierarchy -The principle of „3R" – reduction, reuse and recycle is applicable for C&D waste PLAN-With an honest plan during construction or demolition, it's possible to attenuate waste generation by reducing wastage (reduction), followed by reuse or salvage of the materials of things like door/window frame, panes and shutters etc.

The last within the list of priority recycle is feasible by way of segregation of the components, crushing the massive aggregates and using the various size grades.

Working Sub-Group on construction and demolition waste Presence of Construction & Demolition waste and other inert material (e.g. drain silt, dust and grit from road sweeping) is critical a couple of third of the full municipal solid waste generated. Construction & Demolition waste has to be focused upon seeable of:

(i) The potential to save lots of natural resources (stone, river sand, soil etc.) and energy.

(ii) Its bulk which is carried over long distances for just dumping.

(iii) Its occupying significant space at landfill sites.

(iv) Its presence spoiling processing of bio-degradable in addition recyclable waste. Construction & Demolition waste has potential use after processing and grading. Utilization of Construction & Demolition waste is sort of common in industrialized countries but in India to date no organized effort has been made.

Government and ULB (Urban Services Ltd.) Initiatives

1. The Solid Waste Management (SWM)Cell of the government. Of Maharashtra has given a prominent place to C&D waste in their action plan. Action point 1 state that „„Separate collection of debris and bulk waste. Each city has to have its own mechanism for collection and disposal of waste from bulk waste producers and construction debris"" (prescribed time – 30th November, 2006).

2. Municipal Corporation of Mumbai has notified Construction and Demolition and Desilting Waste (Management and Handling) Rules, 2006"".Construction & Demolition waste together with silt was used as cover material within the closure project of old dump-site at Gorai in Mumbai. The bulk of Construction & Demolition waste generated in Delhi doesn't get into the municipal solid waste stream as Management of construction and demolition waste (MCD) has certain intermediate points for Construction & Demolition waste but proper disposal may be a problem because the debris is dumped within the existing landfills, eating into their space. MCD was instrumental in getting a feasibility study worn out collaboration with IL&FS. The study "Feasibility study on use of Construction & Demolition waste in road works" was dole out by CRRI. The study found potential feasibility for application in

(a) Embankment and sub-grade construction,

(b) Sub-base construction,

(c) Stabilized base course construction and

(d) Rigid pavement construction.

MCD has allocated a DBOT project for correct storage and collection of 500 TPD Construction & Demolition waste from 3 MCD zones, transportation to an identified site where the fabric would be processed and utilized. The rejects would be land filled at the identical site. The DBOT partner – IL&FS Waste Management and concrete Services Ltd. would also build a „test" road using processed C&D waste with technical assistance of CRRI which might then be monitored for quite a year.

3. Efforts would be made for market development of processed C&D waste. Relevant rules and guidelines C&D is briefly included within the „Municipal Solid Waste (Management and Handling) Rules, 2000" but there's no detail information, except a quick mention in Schedule II of the rule for its separate collection. This brief mention doesn't appear to be sufficient seeable of its growing quantum and also the way it affects the general management of municipal solid waste. Greater details and more teeth are required

(a) Controlling the situation and

(b) Management of C&D waste in a comprehensive manner which is likely to have significantly positive impact on the overall scenario of waste management and cleanliness.

3. LOGISTICS OF RECYCLED AGGREGATE PRODUCTION

For use of leftover concrete aggregate, the best situation is where the concrete plant and aggregate plant are on the identical site thus minimizing the cartage of the leftover concrete to the crushing plant. The employment of mobile crushing plants strategically located can reduce the demolition concrete and recycled aggregate cartage distances and might be justified on larger projects.

3.1 Production of Concrete Aggregate from Demolition Material:-

Recycled aggregates to be produced from aged concrete that has been demolished and far 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 forestall contamination by dirt or other waste building materials like plaster or gypsum. It's prudent to store old concrete separately to other demolition materials to assist avoid contamination. Records of the history of the demolition concrete – strength, mix designs etc. – would seldom be available, but if available these are useful in determining the potential of the recycled aggregate concrete.

Aggregate crushing plant

Working Sequence of Aggregate crushing plant

3.2 Processing

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3.4 Recycled Wash Water and Aggregate Recovery

Trucks coming back from site to be washed out discharge into a „concrete reclaimed" where the coarse aggregate and coarse sand are recovered from the „liquid" fines for reuse. Coarse aggregate recovered from fresh concrete will be recycled and thought of as love virgin aggregate, provided the mortar is sufficiently washed out.

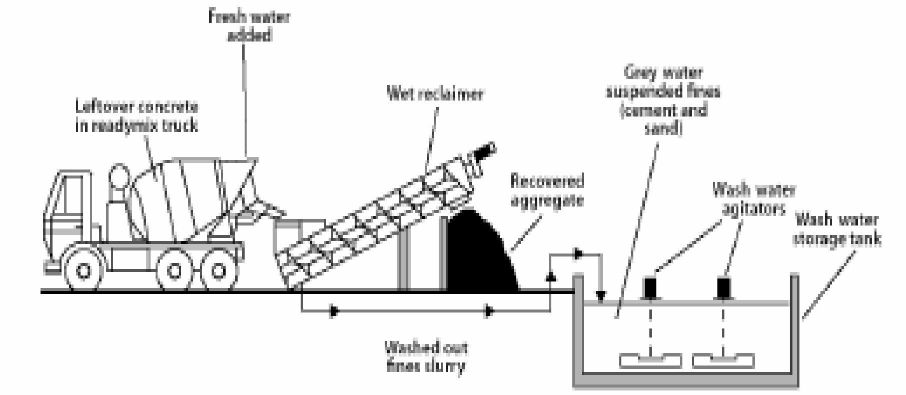


Figure2: Typical system for recycling wash water/aggregate recovery

Typical rural low volume ready mixed plants operate a recycling system that settles the solids from the fines out of suspension so allows reuse of the clear wash water. The solids that have settled are periodically removed and allowed to dry, before disposal to landfill. For larger plants the number of solid material to be disposed of is prohibitive, and a recycled wash water system (see Figure) is often used.

3.5 Quality Control

The flow of internal control is from investigation of the initial concrete to application of the recycled coarse aggregate concrete. Internal control is meted out in keeping with the development specification & manufacturing guidelines for recycled coarse aggregate concrete. Internal control covers the three respective processes for the

a) Original concrete

b) Recycled coarse aggregate

c) Recycled coarse aggregate concrete.

As a results of examination, any material that doesn't adapt the standard requirements of the development specification and/or manufacturing guidelines at any of three processes is restricted from use.

4. TESTS ON RECYCLED AGGREGATE

Demolished material of reinforced cement concrete (RCC) & PCC is employed for recycling in foundation. The lifetime of RCC demolish material is 25 yrs. Such mated crushing, sieving & separation process are done by manual crushing method. On demolish material, aggregate tests are conducted which are mentioned in Indian Standard code for natural aggregate & check feasibility.

4.1 Properties of Recycled Concrete Aggregate:-

4.1.1Particle Size Distribution:-

Sieve analysis is dispensed as per IS 2386 for crushed recycled concrete aggregate and natural aggregates. It's found that recycled coarse aggregate are reduced to numerous sizes during the method of crushing and sieving, which provides the simplest particle size distribution. The amounts of fine particles but 4.75mm after recycling of demolished waste were within the order of 5-20% depending upon the initial grade of demolished concrete. the most effective quality natural aggregate may be obtained by primary, secondary & tertiary crushing, whereas the identical is obtained after primary & secondary crushing in case of recycled aggregate. The only crushing process is additionally effective within the case of recycled aggregate. The particle shape analysis of recycled aggregate indicates similar particle shape of natural aggregate obtained from gravel. The recycled aggregate generally meets all the quality requirements of aggregate employed in concrete.

4.1.2 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 relative density is a smaller amount than 2.4, it should cause segregation, honeycombing & also yield of concrete may get reduced.

4.1.3 Water Absorption:-

The RCA from demolished concrete include crushed stone aggregate with old mortar adhering thereto, the water absorption ranges from 1.5% to 7.0%, which is comparatively above that of the natural aggregates. Thus the water absorption results are satisfactory.

4.1.4 Bulk Density

The majority density of recycled aggregate is under that of natural aggregate, thus results aren't satisfactory; thanks to less Bulk Density the combination proportion gets affected.

4.1.5 Crushing and Impact Values

The recycled aggregate is comparatively weaker than the natural aggregate against different mechanical actions. As per IS 2386 part (IV), the crushing and impact values for concrete wearing surfaces mustn't exceed 30% & for apart from wearing surfaces 45% respectively. The crushing & impact values of recycled aggregate satisfy the BIS specifications limit. From crushing & impact test it's found that use of recycled aggregate is feasible for application aside from wearing surfaces.

4.2 Compressive test on cubes

The typical compressive strengths of cubes cast are determined as per IS 516 using RCA and natural aggregate at the age 3, 7, & 28days and reported in Table2. Of course, the compressive strength of RAC is slightly below the traditional concrete made up of similar mix proportions. The reduction in strength compare to NAC is so as of 8-14% and 10-16%for M-30 & M-40 concretes respectively. The number of reduction in strength depends on parameters like grade of demolished concrete, replacement ratio, w/c ratio, processing of recycled aggregate etc. As per test results the strength of recycled aggregate cube is over target strength, so RCA are often used for construction purpose.

5: Flexural Strength

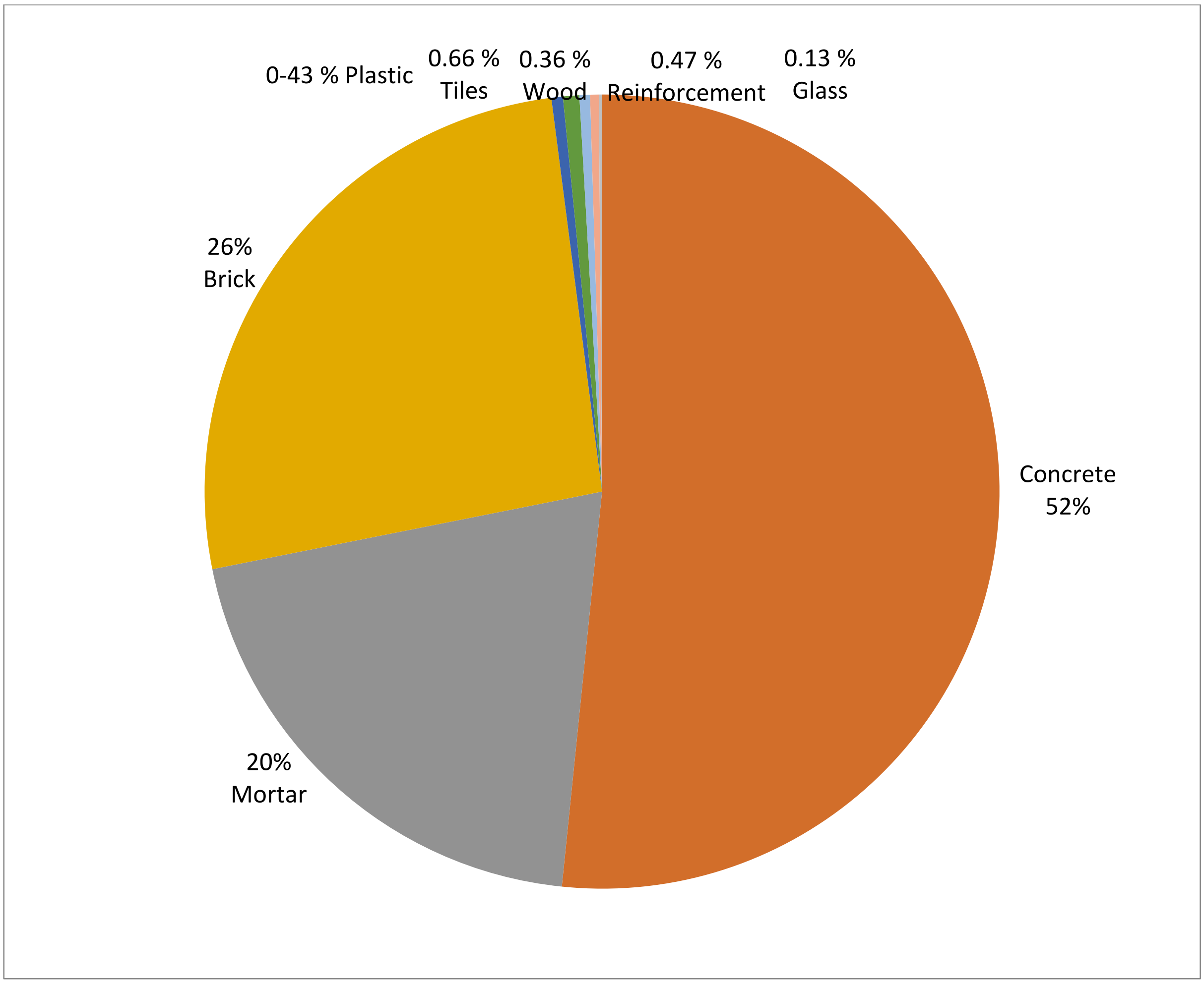
Flexural Strength Replacement Of Natural Aggregate 0% 10% 20% 30% M30-7 Days 3.58 N/mm2 3.04 N/mm2 3.52 N/mm2 3.30 N/mm2 M30-28 Days 4.98 N/mm2 4.71 N/mm2 4.805 N/mm2 4.601 N/mm2 M40-7 Days 4.69 N/mm2 4.57 N/mm2 4.48 N/mm2 4.396 N/mm2 M40-28 Days 5.818 N/mm2 5.637 N/mm2 5.436 N/mm2 5.334 N/mm2 Inferences from table nos. 2 & 3:- From table no. 2 & 3 it's observed that the M30 grade & M 40 grade of concrete satisfy the results for 10%, 20%, and 30%. As compared M 30 grade of concrete the strength reduction in M 40 grade of concrete is more as per results.

Methodology/Analysis:

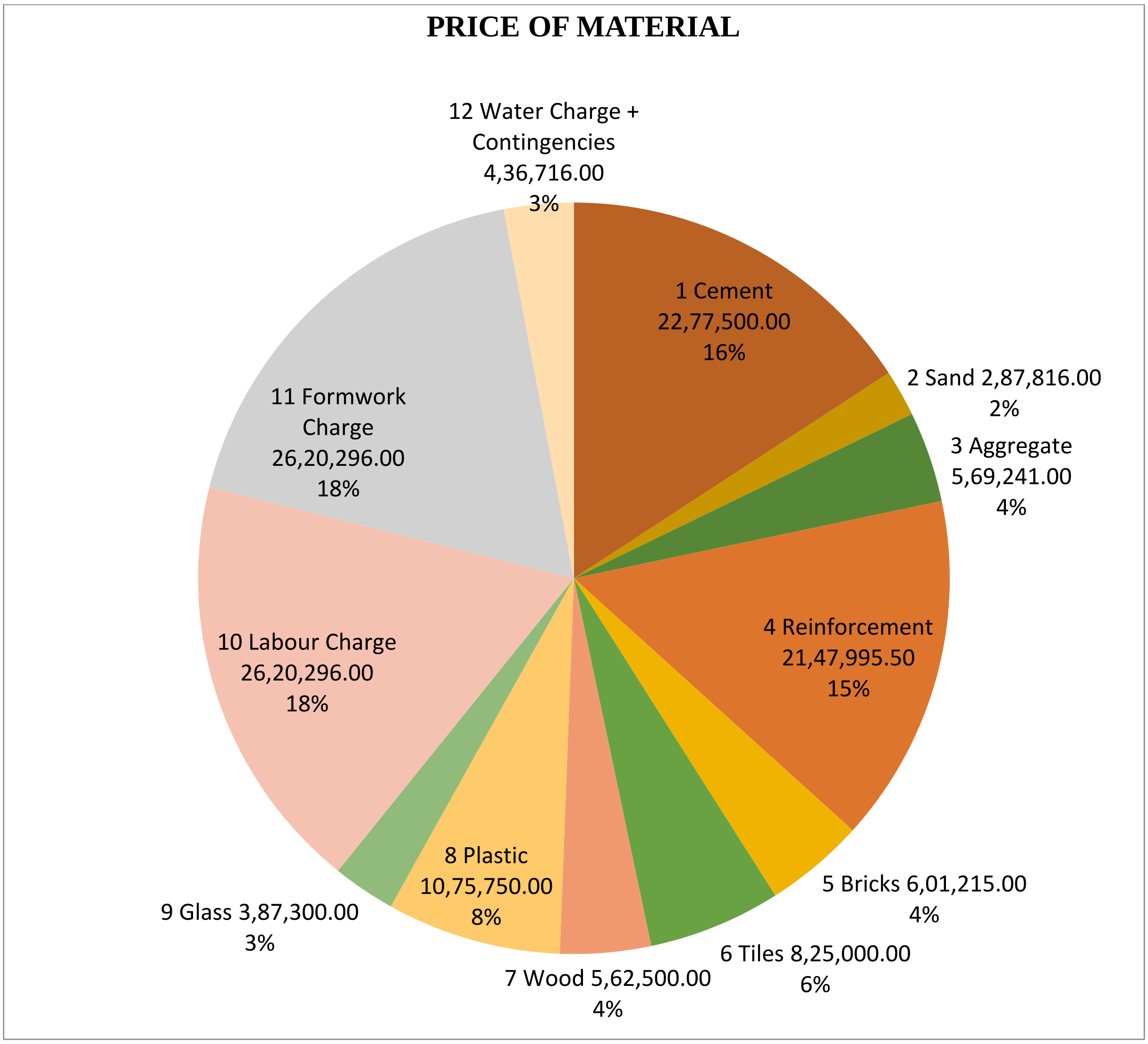
Method of microstructural analysis of recycled concrete is described as follows. Architectural and structural drawings are accustomed evaluate the quantities for the project Imperial Heights and quantities are tabulated below:

S.No.	Materials	Quantity (Cu.m.)	Percentage (%)
1	Concrete	720.75	51.61
2	Mortar	282.83	20.25
3	Brick	364.37	26.09
4	Reinforcement	6.515	0.47
5	Tiles	9.25	0.66
6	Plastic	6	0.43
7	Wood	4.92	0.36
8	Glass	1.8	0.13

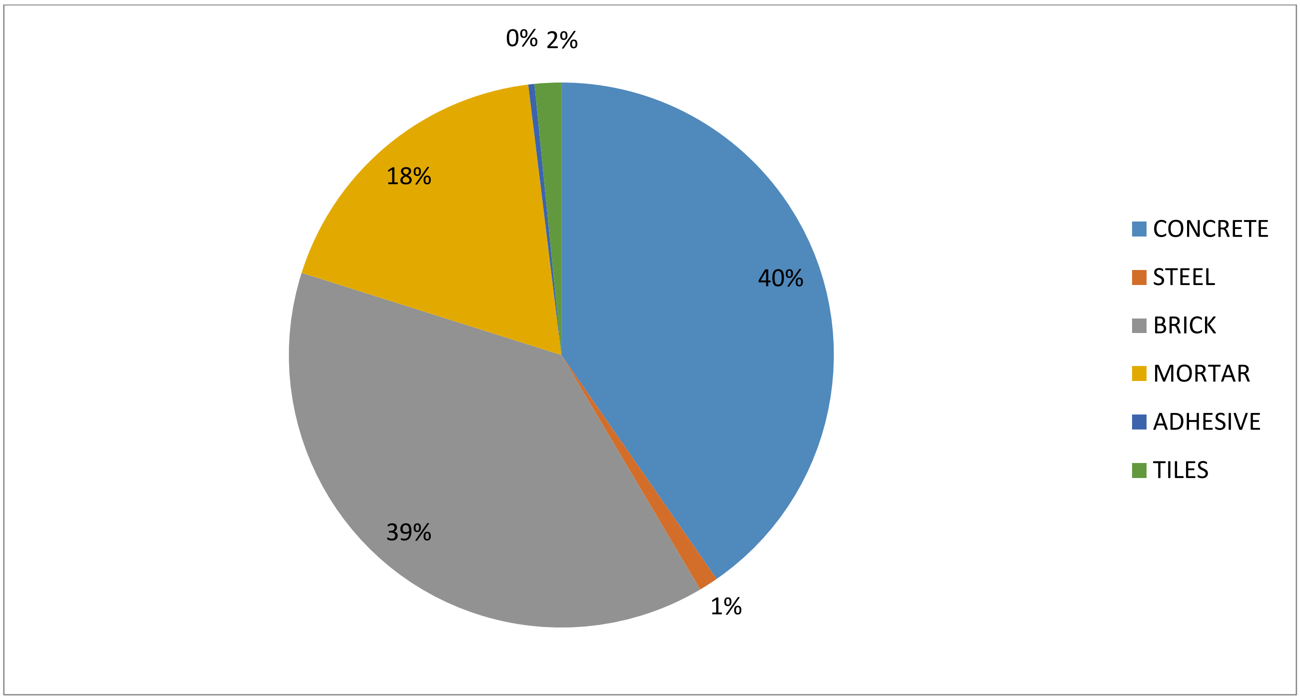
Quantities in percentage are shown below in Pi-Chart:

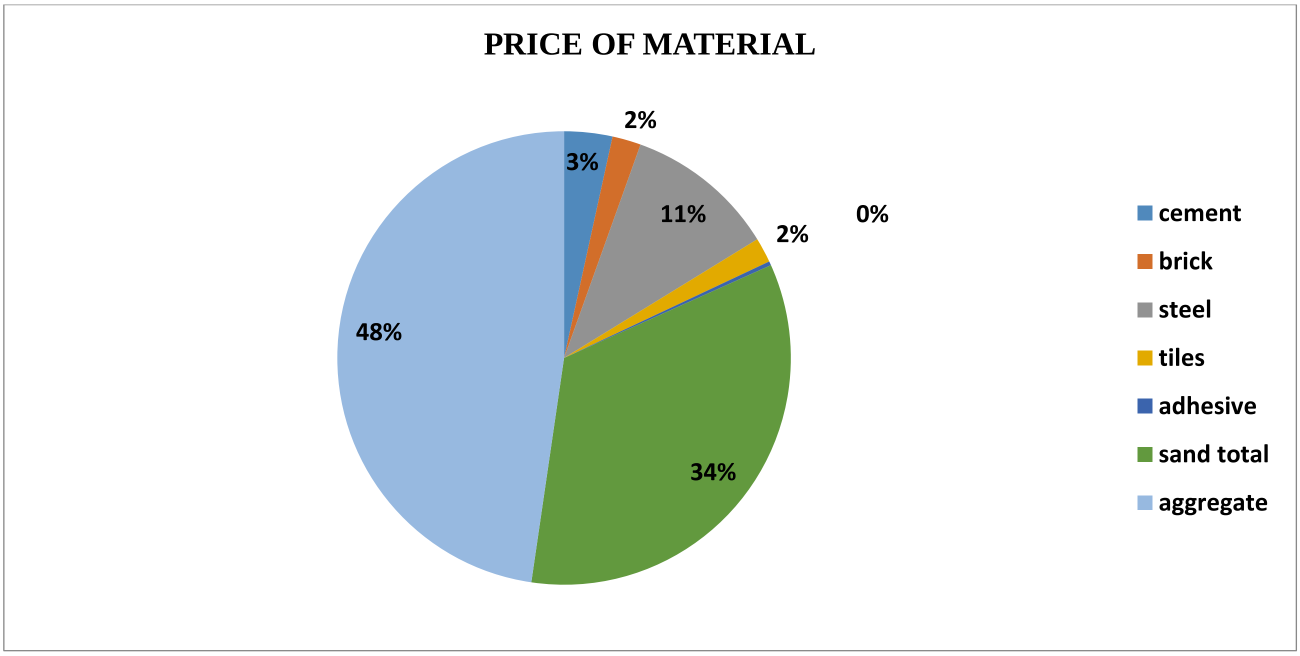


S.No	Material	Quantity (Cu.m)
1	Concrete	1339.156
2	Steel	37.819
3	Bricks	1274
4	Mortar	603.44
5	Adhesive	12.21
6	Tiles	52.23



Same study is carried out for residential project near Tatibandh in Raipur city and percentage quantities calculated are tabulated and shown in Pi-Chart below.





It is well observed from the calculated quantities that the percentage of concrete rubbles in both the residential projects is 51.6% and 40% .These concrete rubbles after crushing can fetch recycled aggregates which has good potential to be used in fresh concrete. Rest other materials quantified can also be reused. Scope of this paper is restricted to recycled aggregates only and in every residential projects approximately 50 % of concrete rubbles exists which can be good source of recycled aggregates.

6. Recycled Aggregate Concrete observation:

As revealed from previous studies, the standard of aggregate is usually classified in line with the absorption rates. High absorption indicates high level of cement mortar attachment, which generally ends up in concrete with inferior strength, durability and deformation and shrinkage properties. Accordingly, the utmost allowable design strength and therefore the members and portions to which such concrete is also applied are limited. From the research, three sorts of RA are classified: Type C1, C2 and C3 for recycled coarse aggregate and sort 3 F1 and F2 for recycled fine aggregate. For the recycled coarse aggregate, Type C1 has the most effective quality with rock bottom water absorption rate of three or less and sulfate soundness of 12% or less, while recycled coarse aggregate Type C3 is intended to own 7% or less of water absorption. For the recycled fine aggregate, Type F1 and F2 are designed to possess 5% or less and 10% or less of water absorption respectively. The physical properties of recycled aggregates rely on both adhered mortar quality and therefore the amount of adhered mortar. The adhered mortar could be a porous material; its porosity depends upon the w/c ratio of the recycled concrete employed. When structures manufactured from concrete are demolished or renovated, concrete recycling is an increasingly common method of utilizing the rubble. Concrete was once routinely trucked to landfills for disposal, but recycling features a number of advantages that have made it a more attractive option during this age of greater environmental awareness and therefore the desire to stay construction costs down. Recycled aggregates (RA) were sourced from a site of the demolished building structure of around 20 years in Ho ChiMinh City, the demolished concrete collected was further crushed employing a small jaw crusher to get aggregates in its unscreened and ungraded state and experience mechanical sieves. Minor impurities were removed and fine RCA of particle size passing through sieve 4.75 mm and coarse RCA of particle sizes starting from 4.75 to 25 mm was obtained. This experimental study didn't consider the employment of fine recycled aggregates. For the natural aggregates, coarse aggregates of crushed granite aggregates of carbonaceous mineral type with particle size starting from 4.75 to 25 mm were sourced from the quarry, while river sand was used as fine

TESTS ON RECYCLED AGGREGATE

- Water absorption test
- Compaction factor test
- specific gravity test
- sieve analysis test
- mix design
- slump test
- compressive strength test

For all the most important test are computed. The slump of recycled aggregate concrete is quite the conventional concrete. At the tip it are often said that the RCA may be used for obtaining good quality concrete. Demolished material of reinforced cement concrete (RCC) & PCC is employed for recycling in foundation. The lifetime of RCC demolish material is 25 yrs. Such mated crushing, sieving & separation process are done by manual crushing method. On demolish material, aggregate tests are conducted which are mentioned in Indian Standard code for natural aggregate & check feasibility.

- **Water absorption test**

With the rise within the use of recycled aggregate concrete, the demand on recycled aggregate (RA) is escalating. As such, the behaviour and characteristics of RA must be clearly understood. In practice, the testing procedures of aggregates in city follow those laid down in British Standard Institution (BSI) (BS: 812), which give a decent foundation for assessing properties of natural aggregates. As RA may have cement paste attached which will detach from the mass during sample preparation when repetitive soaking in water and drying are employed. Thus, the standard testing approach for water absorption cannot give accurate results for RA, based upon which, errors in concrete mix designs may result.

Procedure for Aggregate Coarser Than 6.3mm:

1. About 2 kg of aggregate sample is taken, washed to get rid of fines so placed within the wire basket. The wire basket is then immersed in water, which is at a temperature of 220C to 320C.

2. Immediately after immersion the entrapped air is far from the sample by lifting the basket 25 mm above the bottom of the tank and allowing it to drop, 25 times at a rate of about one drop per second.

3. The basket, with aggregate are kept completely immersed in water for a period of 24 ± 0.5 hour.

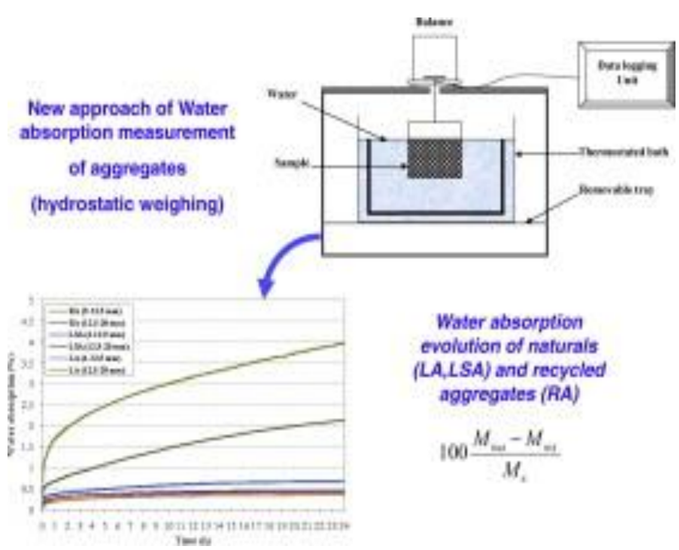
4. The basket and aggregate are weighed while suspended in water, which is at a temperature of 220C to 320C.

5. The basket and aggregates are aloof from water and dried with dry absorbent cloth.

6. The surface dried aggregates are weighed.

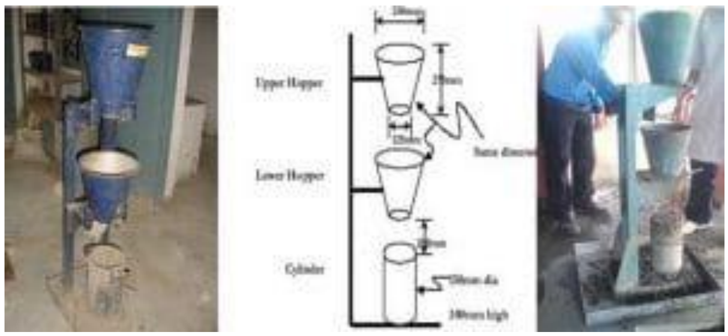
7. The combination is placed in an exceedingly shallow tray and heated to 100 to 1100C within the oven for twenty-four ± 0.5 hours. Later, it's cooled in an airtight container and weighed. 5.

Weight of saturated aggregates in air: W1 g = 2. Weight of oven dry aggregates in air: W2 g = Water Absorption (%) = [(W1-W2)*100]/W2 =



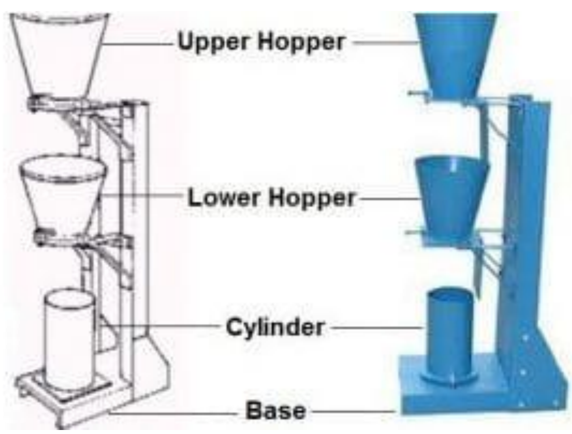
COMPACTION FACTOR TEST

The compaction factor test is employed to calculate the degree of workability of fresh concrete with relevance the interior energy required for computing the concrete perfectly. Compaction factor tests were developed and also the degree of compaction is measure by it. This test will give the reasonably reliable assessment of the workability of concrete and therefore the test require measurement of the load of the partially and fully compacted concrete and also the ratio the partially compacted weight to the fully compacted weight The compacting factor lies between 0.8 to 0.92 for the conventional range of concrete. For concrete which has low workability that slump test isn't suitable then the compaction factor test is employed and this test is conducted within the laboratory.



APPARATUS FOR COMPACTION FACTOR TEST:

1. Compaction Factor Machine
2. Weighing Machine & Compacting Rod
3. Mechanical Vibrator or Steel Trowel.



The apparatus consists of trowels, hand scoop which is 15.2 cm long, balance, and a rod of steel which is 1.6 cm diameter, 61 cm long rounded at one end. In the laboratory, the concrete mix is ready as per design.

THE PROCEDURE OF COMPACTION FACTOR TEST:

There are the subsequent steps within the procedure as given below;

1. By using the hand scoop, place the concrete sample gently within the upper hopper to its brim and level it and so cover the cylinder.

2. At the underside of the upper hopper, open the trapdoor so concrete falls into the lower hopper and with the rod, push the concrete sticking on its sides gently.

3. To constitute the cylinder below, open the trapdoor of the lower hopper and permit the concrete to fall.

4. By using trowels, bring to a halt the surplus of concrete above the highest level of the cylinder and level it, then clean the surface of the cylinder.

5. To the closest 10g weight the cylinder with concrete and this weight is named the burden of partially compacted concrete as W1.

6. Empty the cylinder so with the identical concrete mix in layers approximately 5 cm deep refill it and to get full compaction, each layer has got to be heavily rammed.

7. Level the highest surface then weigh the cylinder with fully compacted which is thought because the weight of fully compacted concrete as W2.

8. Then as W, find the burden of the empty cylinder.

9. From 0.7 to 0.95 is that the range of compaction factor values.

Compaction Factor Value	Standard of Workability
0.95	Good
0.92	Medium
0.85	Low

ADVANTAGES OF COMPACTION FACTOR TEST:

There are the subsequent advantages of compaction factor test such as;

1. In laboratories, suitable for testing workability.

2. For concrete of low workability, this test is suitable.

3. Over a large range, it's suitable to detect the variation in workability.

4. As compared to the slump test, the compaction factor test gives more information that's about compatibility.

5. This test is more appropriate than static tests for highly thixotropic concrete mixtures and may be a dynamic test.

6. More precise and sensitive results.

DISADVANTAGES OF COMPACTION FACTOR TEST:

There are the subsequent disadvantages of this test;

1. Reduces its usefulness within the field because of the massive and ponderous nature of the device.
2. To live the mass of the concrete within the cylinder, the test method requires a balance.
3. This test method doesn't use vibration and although the test is commercially available and used rarely.

specific gravity test

The coarse aggregate relative density test measures coarse aggregate weight under three different sample conditions:

• Oven-dry (no water in sample).

• Saturated surface-dry (SSD, water fills the combination pores).

• Submerged in water (underwater).

Using these three weights and their relationships, a sample's apparent relative density, bulk relative density and bulk SSD relative density additionally as absorption are often calculated. Aggregate relative density is required to see weight-to-volume relationships and to calculate various volume-related quantities like voids in mineral aggregate (VMA), and voids filled by asphalt (VFA). Absorption are often used as an indicator of aggregate durability yet because the volume of asphalt binder it's likely to soak up. The standard coarse aggregate relative density and absorption test is: Specific gravity may be a measure of a material's density (mass per unit volume) as compared to the density of water at 73.4°F (23°C). Therefore, by definition, water at a temperature of 73.4°F (23°C) includes a relative density of 1. Absorption, which is additionally determined by the identical test procedure, could be a measure of the number of water that an aggregate can absorb into its pore structure. Pores that absorb water are remarked as "water permeable voids". Specific Gravity Use Aggregate relative density is employed in an exceedingly number of applications including Superpave mix design, deleterious particle indentification and separation, and material property change identification.

Superpave Mix Design

Superpave mix design could be a volumetric process; it relies on mixing constituent materials on the premise of their volume. However, aggregate and asphalt binder volumes are diffucult to live directly, therefore a material's weight is usually measured so converted to a volume supported its relative density. Correct and accurate material relative density determinations are vital to proper mix design. An incorrect relative density value will end in incorrect calculated volumes and ultimately lead to an incorrect mix design. Aggregate Absorption Use Aggregate absorption is that the increase in mass thanks to water within the pores of the fabric. Aggregate absorption may be a useful quality because: 1. High values can indicate non-durable aggregate. 2. Absorption can indicate the quantity of asphalt binder the combination will absorb. It is generally desirable to avoid highly absorptive aggregate in HMA. This can be because asphalt binder that's absorbed by the combination isn't available to coat the mixture particle surface and is therefore not available for bonding. Therefore, highly absorptive aggregates (often specified as over 5 percent absorption) require more asphalt binder to develop the identical film thickness as less absorptive aggregates making the resulting HMA costlier. Aggregate relative density Types Several differing types of relative density are commonly used depending upon how the amount of water permeable voids (or pores) within the mixture are addressed • Apparent relative density, Gsa. The amount measurement only includes the degree of the mixture particle; it doesn't include the quantity of any water permeable voids. The mass measurement only includes the mixture particle. Apparent relative density is meant to only measure the particular gravity of the solid volume, therefore it'll be the best of the combination specific gravities. It's formally defined because the ratio of the mass of a unit volume of the impermeable portion of aggregate (does not include the permeable pores in aggregate) to the mass of an equal volume of gas-free H2O at the stated temperature.

• Bulk relative density (Bulk Dry Specific Gravity), Gsb. the degree measurement includes the general volume of the combination particle additionally because the volume of the water permeable voids. The mass measurement only includes the mixture particle. Since it includes the water permeable void volume, bulk relative density are but apparent relative density. It's formally defined because the ratio of the mass of a unit volume of aggregate, including the water permeable voids, at a stated temperature to the mass of an equal volume of gas-free water at the stated temperature.

• Bulk Saturated Surface Dry (SSD) relative density. Volume measurement includes the volume of the combination particle additionally because the volume of the water permeable voids. The mass measurement includes the combination particle moreover because the water within the water permeable voids. It's formally defined because the ratio of the mass of a unit volume of aggregate, including the load of water within the voids filled to the extent achieved by submerging in water for roughly 15 hours, to the mass of an equal volume of gas-free H2O at the stated temperature.

• Effective relative density, Gse. Volume measurement includes the quantity of the mixture particle plus the void volume that becomes stuffed with water during the test soak period minus the amount of the voids that absorb asphalt. Effective relative density lies between apparent and bulk relative density. It's formally defined because the ratio of the mass in air of a unit volume of a permeable material (excluding voids permeable to asphalt) at a stated temperature to the mass in air (of equal density) of an equal volume of gas-free H2O at a stated temperature. Effective relative density is set by a distinct procedure and isn't covered during this section. Relationship with Other Specific Gravities

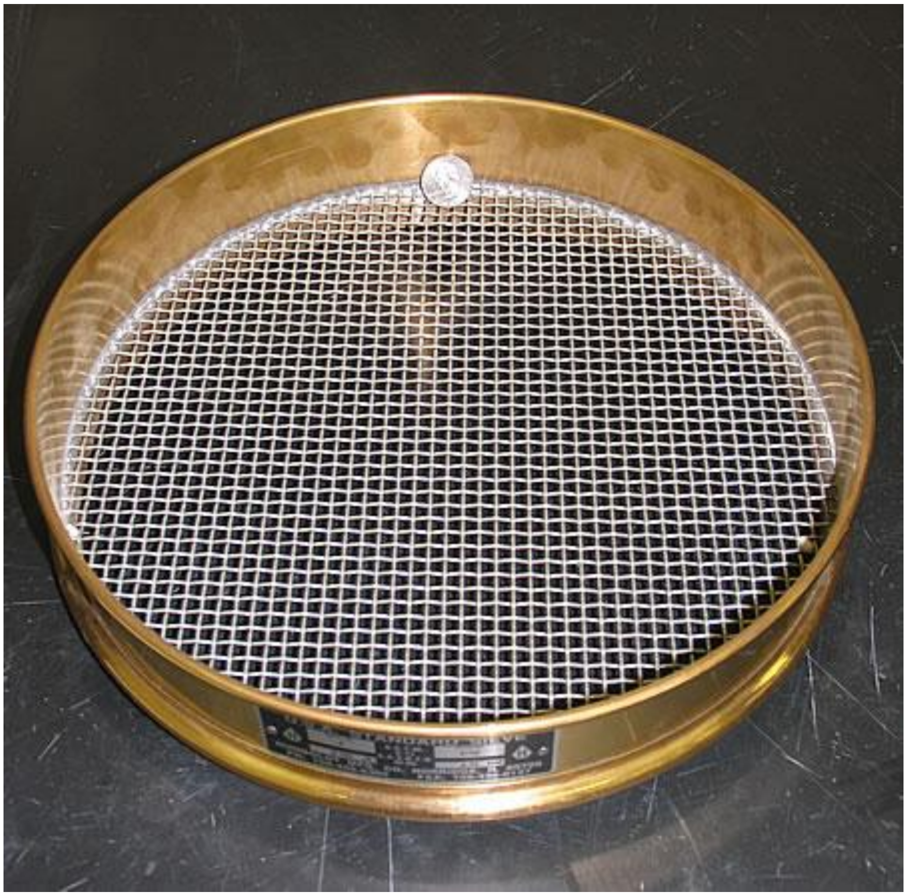
• The difference between Gsa and Gsb is that the volume of aggregate employed in the calculations. The difference between these volumes is that the volume of absorbed water within the aggregate's permeable voids. Both use the aggregate's oven dry weight.

• The difference between Gsb and bulk (SSD) relative density is that the weight of aggregate employed in the calculations. The difference between these weights is that the weight of absorbed water within the aggregate's permeable voids. Both use the identical aggregate volume.
• The difference between Gsa, Gse and Gsb is that the volume of aggregate employed in the calculations. All three use the aggregate's oven dry weight.
• The following relationships are always true:

1. Gsa ≥ Gse ≥ Gsb
2. Bulk (SSD) specific gravity ≥ Gsb
3. Aggregate specific gravities (Gsb, Gsa,Gse and bulk SSD specific gravity) are all ≥ Gmm(because Gmm includes the asphalt binder, which has a lower specific gravity than the aggregate)

Basic Procedure

1. Obtain a sample of coarse aggregate material retained on the No. 4 (4.75 mm) sieve (Figure 6). This sample size is based on nominal maximum aggregate size (NMAS). Sample sizes range from 2000 g for a 0.5 inch (12.5 mm) NMAS to 5000 g for a 1.5 inch (37.5 mm) NMAS.



(4.75 mm) sieve.

2. Prepare the material.

- Wash the aggregate retained on the No. 4 (4.75 mm) sieve. This discards small aggregate particles clinging to the retained large particles.
- Dry the material until it maintains a constant mass. This indicates that all the water has left the sample. Drying should occur in an oven regulated at 230°F (110°C).
- Cool the aggregate to a comfortable handling temperature.
- Immerse the aggregate in water at room temperature for a period of 15 to 19 hours (Figure 7).

7: Soaking the sample.

If the combination isn't oven-dried before soaking, relative density values is also significantly higher. This can be because within the normal procedure the water might not be able to penetrate the pores to the middle of the mixture particle during the soaking time. If the mixture isn't oven-dry to start out, the prevailing water within the aggregate pore structure is also ready to penetrate further into the pores (AASHTO, 2000c[1]).

3. Dry the sample to a saturated surface dry (SSD) condition. Rolling up the mixture into the towel and so shaking and rolling the mixture from side to side is sometimes effective in reducing the sample to a SSD condition (Video 1). It should be necessary to wipe the larger particles separately. Once there are not any visible signs of water film on the mixture particle surfaces, determine the sample mass. Make sure to use cloth and not paper towels. Paper towels may absorb water within the aggregate pores.

4. Place the complete sample in a very basket (Figure 8) and weigh it underwater (Figure 9). The basket should be pre-conditioned to the water bath temperature. Shake the container to release any entrapped air before weighing. The container overflow must work properly to atone for the water displaced by the sample.

5. Remove the mixture from the water and dry it until it maintains a relentless mass. This means that each one the water has left the sample. Drying should occur in an oven regulated at 230°F (110°C).
6. Cool the mixture in air at temperature for 1 to three hours then determine the mass.

Sieve analysis test

Sieve analysis helps to work out the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (Part I) – 1963. during this we use different sieves as standardized by the IS code so pass aggregates through them and thus collect different sized particles left over different sieves.

Theapparatus used are –

i) a collection of IS Sieves of sizes – 80mm, 63mm, 50mm, 40mm,31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm,4.75mm, 3.35mm, 2.36mm, 1.18mm, 600μm, 300μm, 150μm and 75μm.
ii) Balance or scale with an accuracy to live 0.1 percent of the load of the test sample.

The weight of sample available should not be less than the weight given below:-

Maximum size present in substantial proportions (mm)	Minimum weight of sample despatched for testing (kg)
63	100
50	100
40	50
25	50
20	25
16	25
12.5	12
10.0	6
6.3	3

The sample for sieving should be prepared from the larger sample either by quartering or by means of a sample divider.

Procedure to work out particle size distribution of Aggregates.

i) The test sample is dried to a continuing weight at a temperature of 110 + 5oC and weighed.

ii) The sample is sieved by employing a set of IS Sieves.

iii) On completion of sieving, the fabric on each sieve is weighed.

iv) Cumulative weight passing through each sieve is calculated as a percentage of the entire sample weight.

v) Fineness modulus is obtained by adding cumulative percentage of aggregates retained on each sieve and dividing the sum by 100.

Slump test

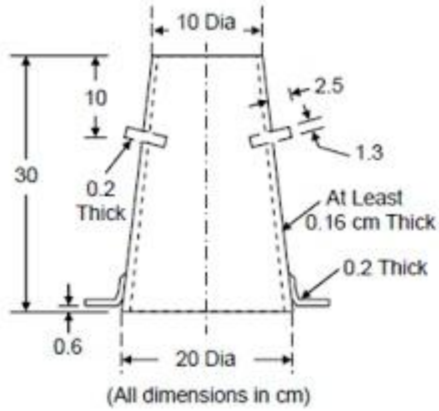
The slump value of concrete is simply a principle of gravity flow of surface of the concrete cone that indicates the quantity of water added to that, which suggests what proportion this concrete mix is in workable condition.

Apparatus for Slump test

Followings apparatus are employed in the slump test of concrete:

• Metallic mould within the shape of a frustum of cone having bottom diameter 20 cm (8 in), top diameter 10 cm (4 in) and height 30 cm (12in).

• Steel tamping rod having 16 mm (5/8 in) diameter, 0.6 m (2 ft.) long with bullet end.



Procedure of Slump test

During Slump test following steps are followed:

• First of all, the inner surface of the mould is cleaned and free from moisture and free from other old sets of concrete.

• Then place the mould on the sleek horizontal, rigid, and non-absorbant surface.
• The mould is then stuffed with fresh concrete in four layers with taping each layer 25 times by taping rod, and level the highest surface with a trowel.
• Then the mould is slowly pulled in vertical and far from concrete, so as to not disturb the concrete cone.
• This free concrete deform all the surface to subside thanks to the effect of gravity.
• That subsidence of concrete within the periphery may be a SLUMP of concrete.
• The height difference between the peak of subsidence concrete and mildew cone in mm is 'slump value of concrete'.

Recorded slump value of a sample is = ……… mm Compressive strength test Compressive strength is that the capacity of fabric or structure to resist or withstand under compression. The Compressive strength of a cloth is decided by the power of the fabric to resist failure within the form cracks and fissure. In this test, the push force applied on the both faces of concrete specimen and also the maximum compression that concrete bears without failure is noted.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 12 | Dec 2020 www.irjet.net p-ISSN: 2395-0072

Concrete testing helps us to majorly target the Compressive strength of concrete because it helps us to quantify the flexibility of concrete to resists Compressive stresses among structures where-as other stresses like axial stresses and tensile stresses are catered by reinforcement and other means. In technical point of view, Compressive Strength of concrete is defined because the Characteristic strength of 150mm size concrete cubes @28 days.

Compressive strength of Concrete and its importance:-
As we all know that concrete could be a mixture of sand, cement, and aggregate. The strength of the concrete depends upon many factors like individual compressive strength of its constituents (Cement, Sand, aggregate), quality of materials used, air entrainment mix proportions, water-cement ratio, curing methods and temperature effects. Compressive strength gives a concept of the strength and above-mentioned factors. Through conducting this test, one can easily judge the concrete strength psi and quality of concrete produced.

Factors affecting compressive strength of concrete:-

Coarse aggregate:-

Concrete is formed homogenous by combining aggregates, cement, sand, water and various other admixtures. But even with proper mixing, there may arise some microcracks because of differences in thermal and mechanical properties of coarse aggregates and cement matrix, which ends up in failure of concrete. Concrete technologists came up with theoretical concepts regarding size of aggregates, which because the size of aggregate being the main contributor of compressive strength. So if the dimensions of aggregate is increased, then it'd lead increased compressive strength. This theory was later discarded, as experiments proved that greater size of aggregates showed increased strength in initial phases but reduced exponentially. The sole reason for this strength drop was because of the reduced area for bond strength between cement matrix and aggregates and weaker transition zone.

Air-entrainment:-

Air entrainment in concrete was one in all the concepts developed by cold countries so as to forestall damages because of freezing and thawing. Later on, as experimentation's proved multidimensional benefits of air entrainment together with improved the workability of concrete at lower

water/cement ratio.

As the achievement of the specified workability at lower water content helped one to attain concrete with the greater compressive strength which successively, results in light concrete with greater compressive strength.

Water/Cement ratio:-

We are all very tuned in to how excess water are often harmful to the strength of concrete. Cement being the key binding material in concrete needs water for hydration process, but that's only limited to about (0.20 to 0.25) you look after cement content. the surplus water seems to be beneficial in contributing to workability and finishing of concrete. The very aspect where excess water is taken into account harmful because because the water within the concrete matrix dries, it leaves large interstitial spaces among aggregate and cement grains. This interstitial space becomes primary cracks during compressive strength testing of concrete.

Compressive strength testing of concrete:-

The test is carried out using 150mm concrete cubes on a Universal testing machine or compressive testing machine.

Apparatus

As per IS: 516-1959 Compressive testing machine (2000Kn),15cm×15cm×15cm steel cube molds or Cylinder having Dia 15cm and length 30cm are used.

Steel Cube 150mm x 150mm x 150mm

Preparing of material for Cube test*:*

All the fabric must be brought and stored to an approximate temperature of 27 ±3 degree Celsius. Cement must be uniformly mixed with a trowel so as there exist no lumps. Mixing of concrete: Machine mixing: The ingredient must not be rotated for over 2 minutes and therefore the following pattern must be followed 1>Calculated water,2>50% coarse aggregates,3>fine aggregates,4>cement,5>50% coarse aggregates. Hand mixing: the method must be done on the oblong pan until a regular mix is obtained. Dry mixing of fine aggregates and cement>addition of coarse aggregate with the even distribution>addition of calculated water in batch till consistency is achieved. Preparing of fabric for Cube test: All the fabric must be brought and stored to an approximate temperature of 27 ±3 degree. Cement must be uniformly mixed with a trowel so as there exist no lumps.

Mixing of concrete: Machine mixing: The ingredient must not be rotated for quite 2 minutes and also the following pattern must be followed 1>Calculated water,2>50% coarse aggregates,3>fine aggregates,4>cement,5>50% coarse aggregates Hand mixing: the method must be done on the oblong pan until a standardized mix is obtained. Dry mixing of fine aggregates and cement>addition of coarse aggregate with the even distribution>addition of calculated water in batch till consistency is achieved.

Universal testing Machine (UTM)

Procedure for Compressive strength of concrete or Cube test:-

1. Place the prepared concrete mix within the steel cube mould for casting.

2. Once it sets, after 24 hours remove the concrete cube from the mould.

3. Keep the test specimens submerged underwater for stipulated time.

4. As mentioned the specimen must be kept in water for 7 or 14 or 28 days and for each 7 days the water is modified.

5. make sure that concrete specimen must be dried before placing it on the UTM.

6. Weight of samples is noted so as to proceed with testing and it must not be but 8.1Kg.

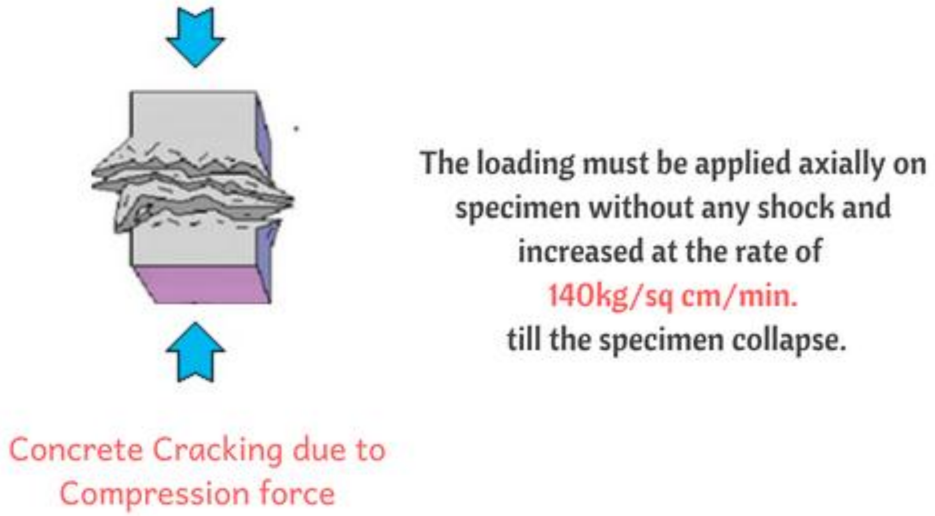
7. Testing specimens are placed within the space between bearing surfaces.

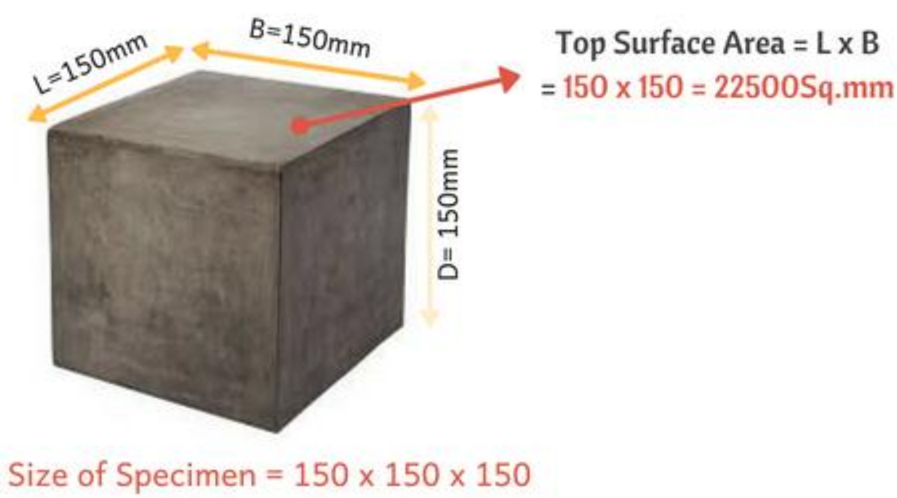
8. Care must be taken to stop the existence of any loose material or grit on the metal plates of machine or specimen block.

9. The concrete cubes are placed on bearing plate and aligned properly with the middle of thrust within the testing machine plates.

10. The loading must be applied axially on specimen with none shock and increased at the speed of 140kg/sq cm/min. till the specimen collapse.

11. Thanks to the constant application of load, the specimen starts cracking at a degree & final breakdown of the specimen must be noted.





Effects of Recycled Aggregate on Concrete Mix:

Construction and demolition (C&D) waste is one in every of the most important waste flows within the world. Disposal of C&D waste isn't only an environmental concern but also includes a major influence on the conservation of natural resources by avoiding excavation of material. Most of this waste goes into landfills, increasing the burden on landfill loading and operations. Some noninert waste materials in C&D waste (such as lead, tar, asbestos, paint, and preservative residues) may introduce environmental hazards over time [1].

Instead, recycling presents a chance to lose concrete and other nonhazardous waste. Recycling is one amongst the strategies toward minimizing waste and offers many benefits—

reducing the demand for brand spanking new resources, lowering on transport and production energy costs, using waste which might preferably be lost to landfill sites [2],preserving areas of land for future urban development, improving the final state of the environment [3], and sustaining more jobs than would be available by treating the identical amount of materials at traditional landfills [1]. According to Kartam et al. [4], there are four factors affecting C&D waste recycling. First is that the purity of recycled material. Choosing between recycling and other appropriate disposal methods is set by the concentrations of harmful substances in recycled C&D materials. Second is that the cost of collection and transport. Third is that the cost of sorting, transformation into reusable material, and therefore the disposal costs of any residual material to landfills or incineration. Finally, it's necessary that recycled materials meet the pertinent required specifications and standards. Recycled aggregate is important due to the high consumption of raw materials needed to create concrete and since of this high level of worldwide construction activities. By recycling concrete waste aggregates and using them as a source for producing new concrete, an alternate source of aggregate production is offered. The environmental impact of the assembly of coarse aggregate led Kuwait's local Environment Public Authority in 1997 to ban its production from local quarries [5].

The volume of construction waste in Kuwait was estimated at 4.1 million tons at a rate of 11,000 tons per day in 2010, which is taken into account high compared to international figures, probably thanks to the high level of construction activities after the Gulf war and to poor materials management by the Kuwaiti industry. C&D waste in Kuwait is produced from the subsequent activities: demolition of old buildings, material left over from new construction, building maintenance, and manufacturing debris [4].Thomas et al. [6]found that because the water absorption of recycled aggregate is beyond that of natural aggregate, especially when the recycled aggregate is dry before mixing, the number of water required to combine the concrete properly must be increased. Abdel-Hay [7] studied three groups of mixes containing different water to cement ratios (w/c), and every of those groups involved five mixes with different amounts of recycled aggregate. The authors found that each one the concrete mixes had low workability, and also the workability decreased with increasing percentage of recycled aggregate content due to the high-water absorption of the recycled aggregate and its rough surface texture.
Poon et al. [8] studied four groups of concrete mixes: 100% natural aggregate, 20% recycled aggregate, 50% recycled aggregate, and 100% recycled aggregate. Each group used three mixes: the primary with air-dried (AD) aggregate, the second with oven-dried (OD) aggregate, and therefore the last with saturated surface dry (SSD) aggregate. This study was wont to test the slump and also the strength of the recycled aggregate concrete mixes. The authors concluded that the number of recycled aggregate within the concrete mix had a coffee effect on initial slump for the mixes containing recycled aggregate within the SSD condition, while the mixes containing an oversized amount of AD and OD recycled aggregate would require an outsized amount of water, which resulted in high initial slump [9].

Muduli and Mukharjee [10] found that recycled aggregate concrete mix has higher air content than natural aggregate concrete mix. Falek et al. [11] concluded that the connection between the density and also the amount of fine recycled aggregate in concrete mixes is an inverse relationship; when the proportion of fine recycled aggregate increases, the density of the concrete mix decreases. this is often due to the denseness of the fine recycled aggregate compared to the density of the crushed fine stone and since the mixture to cement ratio has an insignificant effect on concrete density.
Lovato et al. [12] found that a rise of the recycled aggregate content (fine (FRA), or coarse (CRA)), tends to scale back the concrete's resistance, which isn't desirable. the very best resistances are exhibited by concretes without recycled aggregates. When 100% FRA or CRA are added to the mixture, the concrete's resistance is reduced by 18% and 24%, respectively. When working with 100% substitution of natural aggregates by recycled ones, a resistance reduction of roughly 20% was found for low w/c ratios (0.45) in concretes with 100% FRA or 100% CRA.
According to Thomas et al. [6], concrete with 100% coarse recycled aggregate showed a discount in compressive strength between 9% and 45%. Puthussery et al [13] concluded that the compressive strength decreased with the rise of fresh concrete waste (FCW) aggregate content in both series of concrete mixes that were evaluated. Maslehuddin et al. [13] concluded that the compressive strength

decreased with the rise of fresh concrete waste (FCW) aggregate content in both series of concrete mixes that were evaluated. Maslehuddin et al. [14] confirmed that Type I concrete (concrete with normal cement) is more proof against chloride diffusion than Type V (concrete with high sulfate resistance) and demonstrated that adding silica fume improves the performance of concrete. They also found that the chloride concentration accelerates reinforcement corrosion, and as chloride concentration increases, the corrosion current density () increases, leading to higher weight loss of the fabric because of corrosion. Verian et al. [15] observed that the diffusion coefficient decreases with time until it eventually reaches a stable value. Zhang and Gjorv [16] concluded that chloride diffusivity is inversely proportional to the root of the chloride source concentration in an exceedingly diluted solution, whereas both conductivity and diffusivity are inversely proportional to the cubic root of the chloride source concentration during a concentrated solution (general solution). Moreover, the diffusion of chloride was more enthusiastic about the concentration at lower concentration levels. Puthussery et al. [13] observed that the utilization of FCW aggregate decreased the resistance to chloride ion penetration by the concrete. this might even be associated with FCW aggregate having higher porosity than natural granite aggregate. Olorunsogo and Padayachee [17] presented a large range of experimental results on acid soluble chloride diffusion for various mixes of concrete. They showed that the effective chloride transport coefficient is strongly passionate about the amount of exposure of concrete to a chloride environment. Neves et al. [18] and Buhamad [19] found that chloride conductivity increased with increases within the replacement levels of RA for a given curing duration of concrete mixes. However, longer curing duration decreased the conductivity of the concrete mix for any given RA level. Xiao et al. [20] found that the chloride diffusion process is additionally influenced by the RA shape to some extent. the upper the amount of equilateral polygons of RA, the lower the effective chloride diffusion (Deff) is, meaning regulation of RA can reduce the Deff of the RAC model. additionally, the variation of chloride concentration on concrete boundaries may affect the diffusion process and diffusivity of chloride. Diffusion involving larger chloride concentrations on the boundary within the middle is more favorable than on either end for the identical chloride concentration [21].

7.Experimental program

7.1. Material

The materials used for this experimental program for the assembly of recycled aggregate concrete are binder (OPC and GGBS and FA), recycled coarse aggregate, natural fine and coarse aggregates, water, and superplasticizer.

7.1.1. Binder material

Binder consists of ordinary hydraulic cement (OPC) Type I Portland cement general-purpose cement supported BS 12 [26] classification and sort F Waste ash conforming to ASTM C 618 [27], and with Blaine's fineness of 4000 g/cm2, fineness in terms of specific expanse between 250 and 550 m2/kg and relative density of two.3 g/cm3. GGBS was obtained from Ho Chi Minh, Vietnam. Table 1 gives the chemical and physical properties of the cementitious replacement materials. A Sulphonated Naphthalene formaldehyde type superplasticizer (CERAPLAST 300) was used for the combination.

Table 1. Chemical composition and physical properties of FA and GBFS.

Chemical composition (%)	FA type F	GBFS
SiO_2	53	17.8
Al_2O_3	25.8	11.6
Fe_2O_3	6.5	25.8
CaO	9.5	33.5

Chemical composition (%)	FA type F	GBFS
MgO	0.7	4
Na_2O	0.3	0.1
K_2O	3.8	–
SO_3	0.4	0.3
TiO_2	–	0.4
Physical composition		
Fineness (blaine) m^2/kg	295	400
Loose dry unit weight kg/m^3	650	
Specific gravity	2.3	
Retaining on 45 μm sieve (%)	8.2	

7.1.2. Aggregates

Recycled aggregates (RA) were sourced from a site of the demolished building structure of around 20 years in Ho Chi Minh City, the demolished concrete collected was further crushed employing a small jaw crusher to get aggregates in its unscreened and ungraded state and go through mechanical sieves. Minor impurities were removed and fine RCA of particle size passing through sieve 4.75 mm and coarse RCA of particle sizes starting from 4.75 to 25 mm was obtained. This experimental study failed to consider the employment of fine recycled aggregates. For the natural aggregates, coarse aggregates of crushed granite aggregates of carbonaceous mineral type with particle size starting from 4.75 to 25 mm were sourced from the quarry, while river sand was used as fine aggregates. Fig. 1 shows the sieve analysis curve for the fine aggregate, while the characterization testing of the physical properties of aggregates is presented in Table 2.

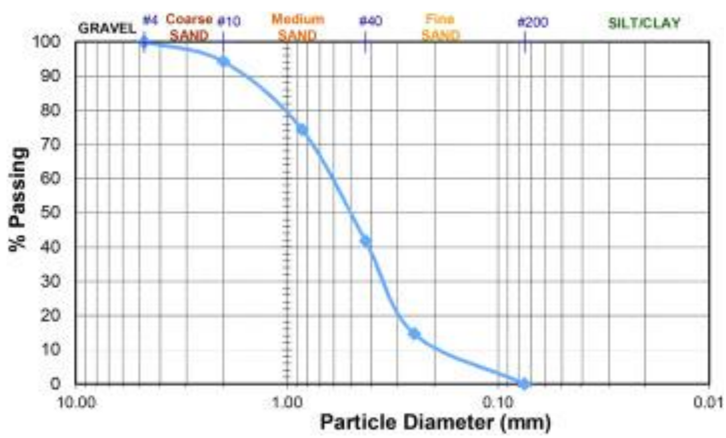


Fig. 1. Particle size distribution of river sand used in this study.

Table 2. Physical properties for coarse and fine aggregates.

Aggregate	Absorption capacity (%)	Porosity (%)	Specific gravity	Los abrasion value (%)	Bulk density (kg/m^3)
RCA	5.2	12.75	2.35	34	1490

Aggregate	Absorption capacity (%)	Porosity (%)	Specific gravity	Los abrasion value (%)	Bulk density (kg/m^3)
NCA	1.25	4.25	2.6	22.3	1515
River Sand	0.9		2.65		1550

7.2. Mix proportions and testing of variables

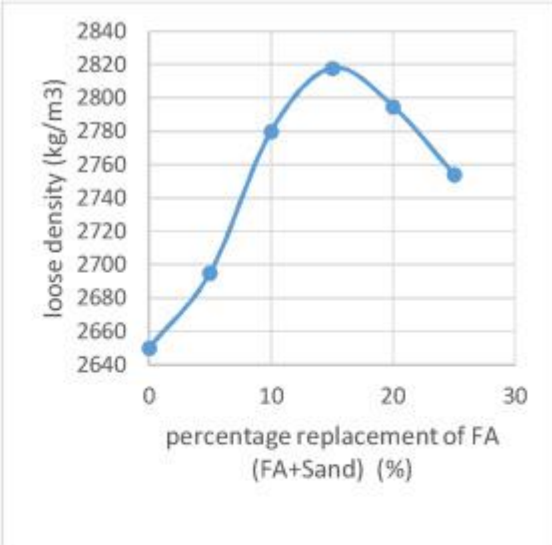
The mix proportion was tired two groups. a combination proportion was made to supply normal concrete (NC), while the DMDA was adopted for recycled aggregate concrete (RAC) mix with the ternary binding system. FA was used as filler for natural sand at optimum loose packing density followed by a combination of (Sand + FA) with RA to get optimum packing density (Fig. 2a and b). In other to analyze the influence of mix proportions and supplementary materials on RAC properties, this experimental work considered two concrete mix batch group, batch I and batch II. GGBS was wont to replace OPC at varying percentage level from 0%, 10%, 20%, 30% 40% and 50% at constant cement w/b ratio in batch I concrete mix while for batch II concrete mix, aggregates constituent remains constant with GGBS replacement level fixed at 30% and ranging w/b ratio range of 0.3, 0.35. 0.4, 0.45, and 0.5 were adopted. The most idea of the DMDA was to confirm that enhanced performance RAC when the majority density of the concrete mixture is highest. The binder paste volume was fixed at N = 1.2 and constant water reductant of 1.4% was used for all concrete mix. Mix nomenclature and proportion used is as presented in Table 3. the tactic followed Hwang's [25] findings, as summarized here: an approach to optimizing mix design for properties of RAC was supported the properties of basic materials constituents of RAC employing a densified mix design approach (DMDA) suggested by Chang [21]. The optimal amount of ash to fill aggregate voids is determined; then, the coarse aggregate was added to the mixture in proportion to the obtained optimum packing density of (sand + Flt ash) + RCA. The ratio of ash to both fine and coarse aggregates of the most unit weight was accustomed calculate the void volume (Vv). When cement paste content equals to void volume Vp = NVv, where N is magnification factor for paste volume taking as constant of 1.2 during this experiment, with this all the void space is entirely stuffed with cement paste. Summary of the procedure is given as:

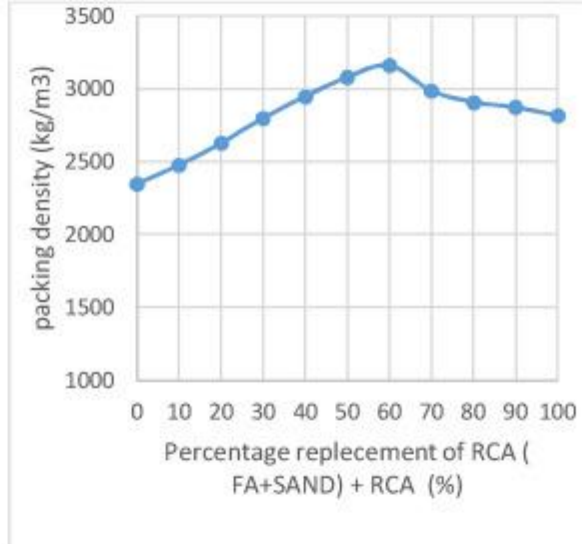
(i)Different trials of mix prepared by filling the fine aggregate with varying percentage of ash (FA + GBFS) to obtain the optimum amount of ash + fine aggregates as shown in Fig. 2(a);

(ii)Different trial mixes of mixture for (Fly ash + Fine aggregate) amount to fill the voids in coarse aggregates to achieved optimum packing density and porosity ratio as shown in Fig. 2(b);

(iii)Constant 'α', 'β' through optimum weights of materials obtained during laboratory experiments was determined with Eqs. (1), (2).

(1)α=WflyWfly+Ws,(2)β=Ws+Wfly(Ws+Wfly)+Wca,(3)ξ=WslagWslag+C,where W_{fly}: weight of fly ash (kg/m^3 of concrete); W_s: weight of fine aggregate (kg/m^3 of concrete); W_{ca}: weight of coarse aggregate (kg/m^3 of concrete); W_{slag}: weight of blast-furnace slag (kg/m^3 of concrete); and C: weight of cement (kg/m^3 of concrete).





8. CONCLUSION

Testing programme was carried out replacing virgin aggregates by recycled ones with replacement percentages of 25%,50%,75% and 100% along with admixture MicroSilica.Concrete cubes were casted in moulds with machined faces of 15cmx15cmx15cm.Cubes were tested after 7 and 28 days. Various concrete mixes (Cement:Sand:Aggregates) in proportion 1:2.36:3.2 were taken with water cement ratio 0.55 . CR0 -Normal concrete.

Table 1. Results of cube compressive strength with 15% Silica

Sr. No.	Symbol	CF	Weight (Kg.)			Curing Period (Days)	Average Compressive Strength (MPa)
1	CR0	0.94	9.416	9.372	9.24	28	**28.67**
2	CR25	0.95	8.866	9.317	9.152		23.177
3	CR50	0.96	8.646	9.053	8.844		20.284
4	CR75	0.96	8.47	8.338	8.459		16.038
5	CR100	0.96	7.876	7.931	7.92		14.168
6	CR0S10	0.95	8.822	8.767	7.880		29.81
7	CR25S10	0.95	9.163	9.229	9.185		**24.761**
8	CR50S10	0.95	8.789	8.987	8.767		26.075
9	CR75S10	0.97	8.305	7.887	8.008		17.424
10	CR100S10	0.95	8.69	8.514	8.459		14.663

Aggregates. CRA0S10-Normal concrete with 0% replacement by recycled aggregate and 15% addition of silica .CF-Compaction Factor. It is observed that the strength achieved with the addition of silica (15%) by weight of cement is less than the strength of normal grade concrete (CR0) and further study is carried out with same design mix with replacement of Silica to 15%. Replacement ratio of recycled aggregates with virgin Aggregates is maintained same and cube strength is tested after 7 and 28 days of curing at room temperature.

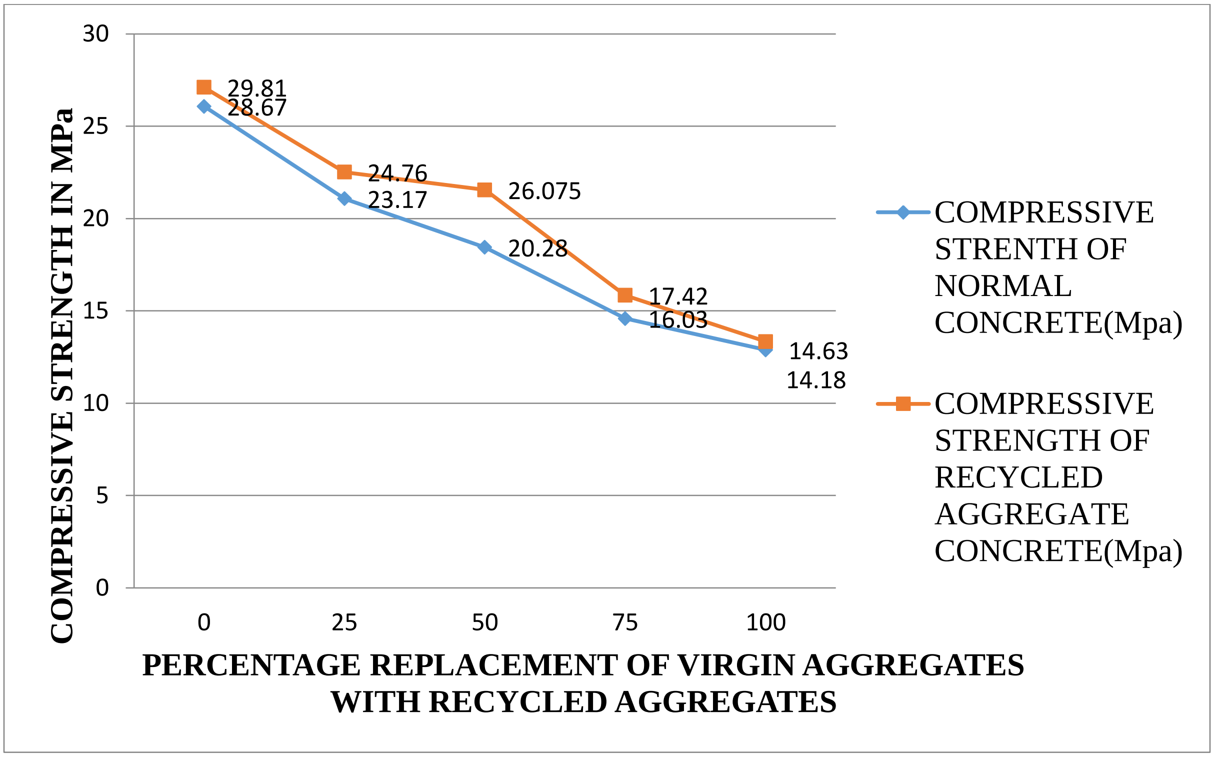


Figure 1.1. Relative 28 days compressive strength for Normal Concrete and Recycled Aggregate Concrete with 20% Silica

Table 2. Results of cube compressive strength with 20% Silica

Sr. No.	Designation	CF	Weight (Kg.)			Curing Period (Days)	Average Compressive Strength (MPa)
1	CR0	0.945	9.159	9.116	8.988	28	**27.89**
2	CR25	0.95	8.624	9.062 9	8.902		22.54
3	CR50	0.96	8.41	8.806	8.602		19.73
4	CR75	0.96	8.239	8.11	8.22		15.60
5	CR100	0.96	7.661	7.714	7.70		13.78
6	CR0S15	0.95	8.613	8.56	8.506		**29.9**
7	CR25S15	0.945	8.388	8.485	8.506		**29.71**
8	CR50S15	0.93	8.399	8.538	8.474		**28.29**
9	CR75S15	0.947	7.629	7.661	7.564		18.30
10	CR100S15	0.952	8.763	8.699	8.549		15.92

Average compressive strength after 7 days of curing with 50% replacement of virgin aggregate by recycled ones is quiet greater than the normal grade of concrete CR0.

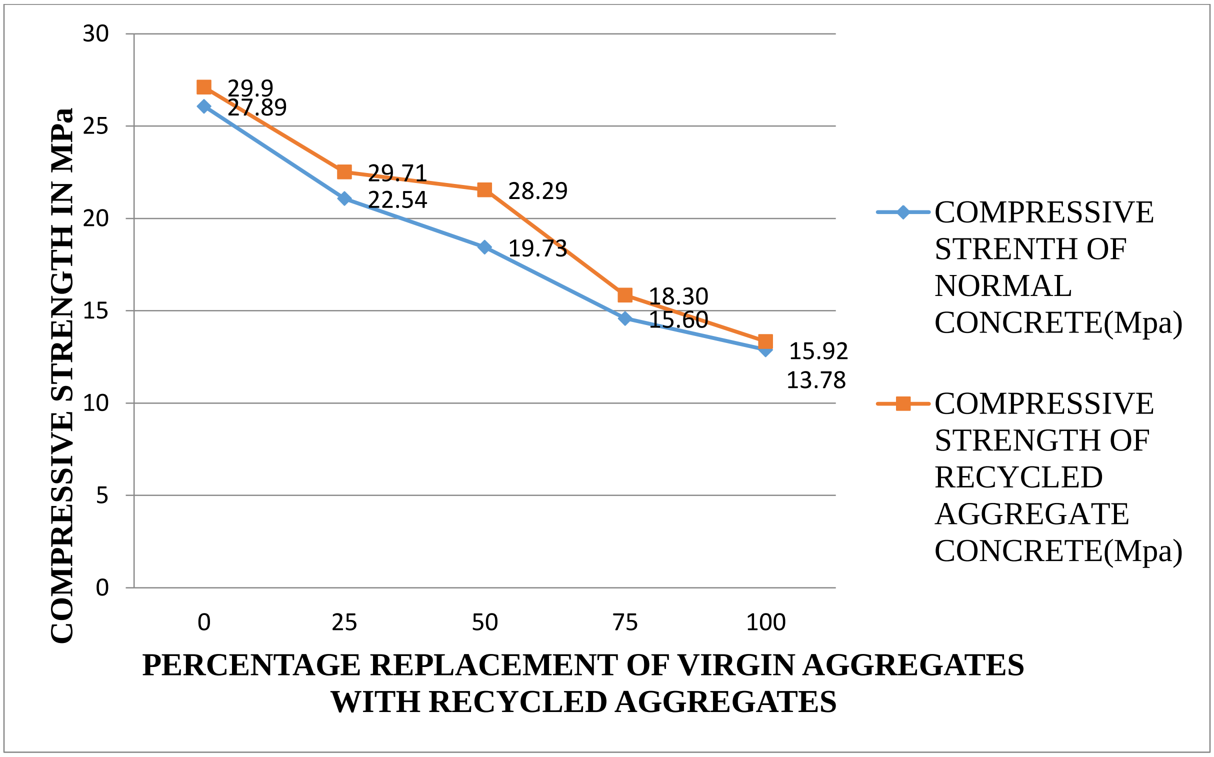


Figure2.1. Relative 28 days compressive strength for Normal Concrete and Recycled Aggregate Concrete with 20% Silica

Based on test results, recycled aggregate concrete with admixture Silica is giving better compressive strength as compared to fresh concrete with replacement percentages of 25% and 50%.Recycled aggregate concrete mixes is giving bigger compressive strength as compared to fresh concrete at replacement percentages of 25% and 50% due to gel formation because of admixture Silica. Workability decreases with percentage increase of recycled aggregates because of water absorption by the adhered mortar. Recycled aggregates can be termed as raw material which can be economic assets in future for the construction industry. Results are awesome and recycled aggregates can be utilized for sustainable infrastructural development.

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