A STUDY ON STRENGTH AND DURABILITY OF RECYCLED AGGREGATE CONCRETE

A

THESIS

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Under the supervision

of

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by

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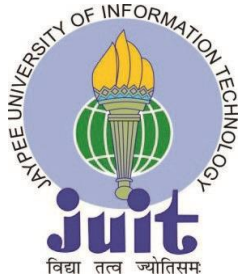
to



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CERTIFICATE

The certificate claims that the experiment which are represented in this thesis **"A STUDY ON STRENGTH AND DURABILITY OF RECYCLED AGGREGATE CONCRETE"** to fulfil the requirement in order to receive the degree of Master of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is a unique experimentation presented by **Swaran dhar (182605)** in the time period from January, 2020 to December 2020 and was carried out under the guidance of **Mr. Kaushal kumar (Asst. Professor)** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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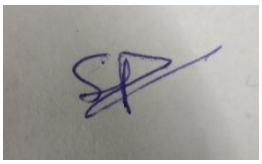
Swaran dhar	182605	

ABSTRACT

It is very evident in today's time to introduce the use of recycled aggregates in the construction business as demolition waste is increasing and the resources are depleting day by day which is leading towards huge amount of environmental degradation. The three main aspects of this are the conservation of natural resources, the increasing of demolition waste and the economical aspects. Though some countries have started using the waste for highway construction, it hasn't been used otherwise because of the sufficient supply of good quality unused material. There are some parts of the world that use crushed concrete but it's only because of the poor quality of local material and there Is now a push within the Indian cement and concrete sector to improve the industry efficiency, one aspect of which is the use of recycled materials.

Most of the researches deal with the strength of the recycled aggregate concrete and very little attention has been paid to the behaviour in service. In general, this research emphasizes on the Durability of concrete containing RCA . As the most common failure occurs in reinforced structures the aim of the project is to focus on durability and compressive strength. This research consists of samples of concrete and focuses on the following:

- To check the compressive strength of M 30 grade of concrete incorporating use of RA.
- To analyse the durability of incorporated RA concrete by chloride penetration test.

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(Swaran dhar)

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ABBREVIATIONS

RA	Recycled aggregate
RAC	Recycled aggregate concrete
UEPG	The European aggregates association
EFTA	European free trade association
CPT	Chloride permeability test
CDW	Construction demolition waste
EU	European
ITZ	Interfacial transition zone
HSRA	High strength recycled aggregate
LSRA	Low strength recycled aggregate
LCD	Liquid crystal display
RCA	Recycled coarse aggregates
NCA	Natural coarse aggregates

SEM Scanning electron microscope

PPO Particle packing optimization

LWA Light weight aggregate

CHAPTER 1: INTRODUCTION

1.1 General

According to the global Statistics the need of using recycled materials is increasing due to the amount of demolished waste which is being dumped into the landfills[2]. The main reason which is making it happen is the construction business[3]. So, it has become necessary for the industry of construction to get aware of it and start working sensibly towards this topic by recycling the demolished waste that is being generated.

Concrete as we know is the material being vastly used in the construction process[4], The purpose of research should be to replace the material which consumes 80% volume of concrete[5], known as aggregates. The consumption of aggregates which are rising day by day in the urban areas. This leads to an increase in the transportation of these things as they have to be taken to the cities where most of the construction takes place. The adverse environmental issues and the increase in the awareness of public has forced the need of introducing recycled products in today's time[6.]

The purpose of the thesis is to provide an overview of the strength and durability of the recycled aggregates also known as RA, for the concrete to be produced. In general, the motive behind the thesis is to check the strength and durability of the blocks made of concrete which are made by the help of RAC. The purpose of the research is to identity the characteristics of RAC in comparison with the natural aggregates that help in achieving the suitable strength which is required for the construction to take place.

All in all, the thesis provides a perspective on how it has become important to replace the natural aggregates with RA in order to improve the environmental effects, the scarcity of aggregates is having on the nature. It has become an urgent need in today's time to reduce the amount of the consumption of natural aggregates and replace it with the recycled

aggregates for the sake of future generations as environmental degradation is increasing rapidly these days.

1.2 Scope of study

The construction sector has evolved so much these days that depletion of natural aggregate resources is becoming a big concern and measures need to be taken. Globally speaking the consumption of natural aggregates has been raised by a huge quantity (48.3 billion metric ton) by the year of 2015 which can be seen in Fig. 1.1 (The Freedonia Group 2012). So, this in return is also responsible for the construction waste that is being produced. As you can see the construction waste being produced by the European countries every year consists of 31%. In the same way, waste generated by Hongkong was 20 million tons by 2011. This makes up for almost 50% waste that appeared by demolition. Dumping the demolished waste into the landfills is the method which is used to take care of the waste, leading to environmental damage.[33]

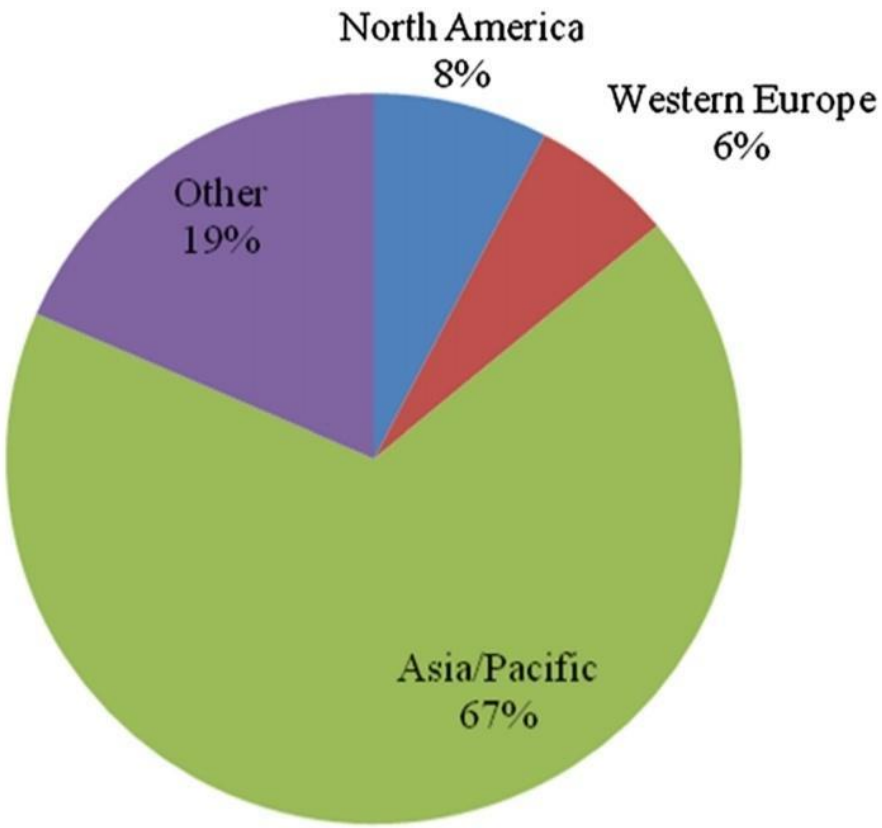

Fig 1.1 The freedonia group 2012

So all the above studies indicate an urgent need of introducing the recycled aggregate concrete in the construction industry to minimize all the adverse effects the waste generated from demolition of concrete has on our environment. Thus, the use of RAC has become very crucial and important at the same time in the construction industry in today's time. Conducting experiments on RAC need to be rapidly increased for the benefit of humankind and sustainability of the environment.

1.3 Goal of the study

This project mainly deals with the study on strength and durability for RAC. Most of the researches which have been done on recycled aggregates are usually done for achieving high compressive strength, but here we are trying to find out how to achieve suitable strength for low grade of concrete with the help of recycled aggregates. The grade of concrete used in this research is M 30. The main goal is to find out how to start using recycled aggregates for low grades without having significant amount of variation in it's strength and durability.

1.4 Objectives of the study

The mechanical properties of concrete are distinctively affected by the presence of RAC present in it. The effort made by the research focuses on using RA. The use of recycled aggregates is a very important initiative that needs to be taken.

The replacement of RA is also very useful in context of developing the sustenance and management in the modern construction industry. The preservation of the environment can be hugely impacted by replacing RA with natural coarse aggregates.

So the main objectives are following:

1. To understand the importance of RAC in the construction industry.
2. To determine the amount of recycled aggregates required to achieve suitable compressive strength for M 30 grade of concrete.
3. To check the compressive strength gained by using RA.
4. Determining the life of RAC by conducting durability test.
5. Observing the affect of recycled aggregates on concrete.

1.5 Aggregates

The constituents of aggregates are granular materials which are inert, like rock which is crushed,gravel,sand etc,acting as one unit and is used in concrete,plaster etc[1]. UEPG claims that the aggregate industry is so far the world's biggest industry which is having efficiency in non energy extraction in context of large amount of production,companies that are being operated and employment it's giving to people[7]. Aggregates are not just an alternative which will help in making the economy more feasible, The role it play is very important in the different characteristics of concrete because cement can't itself handle the duties required by construction. Hence, it can definitely be claimed that without the use of aggregates, the structures can't be made stable.

The main source for the extraction of aggregates are dependent on a variety of resources that are natural for obtaining them. The extraction of materials such as sand and gravel are done by digging deep into the bottom surface of rivers,lake etc. The collection of crushed stone is done by excavating the bedrocks[5]. According to UEPG at least 400 tonnes of concrete is used for the construction of one house. If we calculate these statistics, the amount of aggregates required for the construction of one kilometre highway will be 30000 tonnes. As the transportation is very expensive, it is very obvious that the aggregates are obtained through the local sources to avoid the increment in the cost of manufacturing concrete which can further affect the development of certain areas. According to the survey done by EUPG, the amount of trade going on between the 28 countries in the EU is not much and most of the extraction of aggregates is done by the small and medium firms present out there[7].

Many researchers have established the fact that the use of aggregates is variant depending on the particularity of a certain project. The relation of these needs mainly associate with

mechanical properties such as durability, abrasion, workability etc. [8.] As concrete constitutes 80% volume of aggregates[5], it is very necessary to consider the aggregates to be chosen with the right kind of expertise as it may later have a very huge influence on the different kind of properties concrete has in itself.

Figure 1.2 shows the ranking of production per capita amongst EU countries with 16 tonnes per inhabitant. [7.]

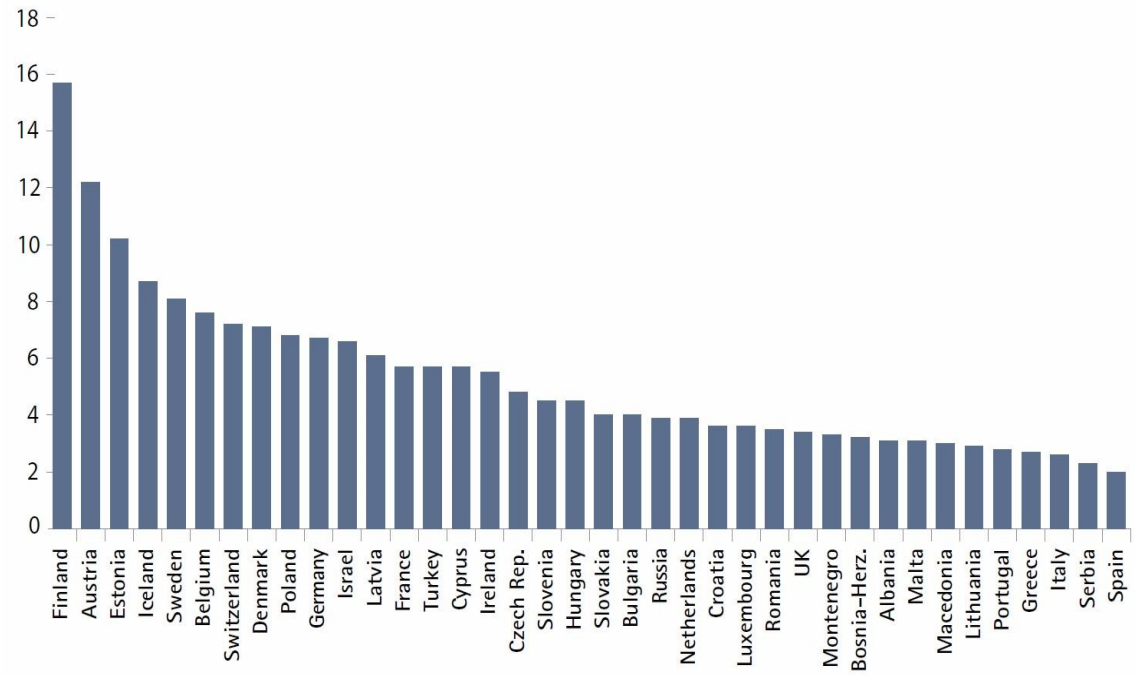

Figure 1.2 Tonnes of aggregate produced per capita by country [7]

The development of a certain kind of area is proportional to the production of aggregates in that area. For example if a post office is to be constructed in Agra, there will be a significant amount of rise in the production of aggregates only around Agra. This means that the extraction of aggregates won't increase in any other area because of the construction done in Agra.

In a global context it means that the increase in production of aggregates is inevitable in a country that is going through a massive construction development. On the other hand a fall down in economy may further push the companies out of business. The EUPG states a fact to prove this which says that the countries involved in European free trade association[EFTA] generated 3.65 billion tonnes of aggregates by 2007, which as a result show a significant amount of decrease by the year 2013 which was 2.65 billion. It occurred due to recession and

a very clear amount of 29% decrease was observed. All in all it just clearly shows that amount of development affects the production of aggregates.

It is very difficult to judge the amount of aggregate production of the whole world as developing countries do not have proper records of consumption. There are many different sources having different kind of analysis on the amount of aggregate production which range from 16.5 to 30 billion tonnes up to 2005 [9-10]. The numbers in this case don't really matter as it is clear that the consequences are going to be severe if this kind of exploitation of resources continue.

Habert and Roussel claim that the worse fear the construction industry has is the fact that resources are diminishing in the developed areas only and it is not a worldwide concern. The research done by them states that the transportation cost of RA doubles for every 30km[11]. As we all know aggregates are very heavy and dense material which in turn makes the vehicle produce carbon emissions which affects the environment.

The environmental affects can clearly be noticed which are caused by the extraction of aggregates. The work conducted with the help of drills,machinery which is heavy create a very disturbing sound and huge waves of dust. To pile it up the process of extraction causes the visual of local landscape to look like a dust storm all the time as trees have to be cut to obtain them. Flora and fauna is very adversely affected by the cutting down of trees, the view is not the only problem.

Aggregates are not only extracted this way but also from other resources such as the bottom surface of ocean, rivers and lake, a study carried out by Messieh et al. [13] found out the disastrous exploitation of the life that is evolved in the sea in the region of eastern portion of canada. Research done by them show the analysis of damage that has been caused due to the dredged aggregates.

It can now even be seen by different governments around the world, the kind of damage been done as awareness about the topic is spreading. Hence, strict laws need to be made for the conservation of environment. In Norway, the Ministry of the Environment has changed the Environmental Protection Act (86/2000) in different situations to resist the exploitation of resources that are natural and to regulate the process of recycling for waste[14].

1.6 Recycled aggregate concrete (RAC)

There are numerous reasons for concrete being the most prioritized material for the purpose of construction throughout the world[4]. The most distinctive qualities of concrete such as: comparatively low price, abundance of availability of it's elements, workability, durability, ability of shaping it according to convenience and its fire resisting ability makes it very accessible. The thing we ignore is the negative impact it has on the environment as manufacturing of cement is responsible for the abundance of pollution caused by it[15].

An initiative to reduce this is urgently required in today's time, infusion of demolition waste in concrete can be a very helpful solution. Maximum amount of research and studies that have been done involve waste material in the form of RA ,which usually is destruction waste of structures involving fine and coarse debris. There are many other materials as well which researchers have researched on such as plastic, fly ash, glass, coal, ash from volcanos and laundry sand[16-20]. The involvement of RA as an element in concrete mix is what we call recycled aggregate concrete.

Areas that are fully developed usually face the problem of aggregate shortage and besides, the degradation of environment that occurs because of the extraction process, the use of RA at an intense level can be seen very clearly. Though this is not what's happening. Statistics shown by UEPG shows that the quantity of aggregates that were consumed in 2013 only consisted of only 1% amount of sources that were recycled (crushed concrete which was old) [7].

550 and 431 million tonnes of aggregates were consumed by Russia and turkey, respectively, and no recycled materials were involved in it. Some of the countries located in EU too follow the same kind of path i.e. zero use of RA. Whereas, according to UEPG Netherlands is a country which consisted of 25% of recycled material among all the aggregates that were produced over there.21% of all the aggregates produced in UK also consisted of the material that was recycled. In addition to which, this amount for Belgium is 18% and for Germany is 12%. If we calculate an average amount of recycled materials which are used among the 28 members of EU countries, it is 7%[7].

The research established by Tam [21] clearly depicted a comparison in the context of economy by differentiating RAC and regular concrete with debris of old concrete in the form of RA. The conclusion of the study displayed vast amount of economical difference that was created by using RAC instead of conventional concrete. RAC is not only just a great way of reducing the environmental hazards that are increasing everyday, it is also a great way of increasing the cost reduction efficiency in a construction project[21].

As concrete majorly consists of aggregates, and is a prioritized material throughout the world, this report gives an insight on the concrete which is replaced by coarse recycled aggregates, commonly known as recycled aggregate concrete (RAC). What we are trying to achieve here is to confirm the behaviour of RAC and the results obtained have to be compared with the characteristics of regular concrete, i.e. concrete manufactured without the infusion of recycled materials.

1.7 Tests to be conducted to find out the strength and durability of RAC

- **Compressive strength test**
- **RCPT (Rapid chloride permeability test)**

- The test which is done to check the load bearing capacity of concrete is undertaken by compressive strength test. To estimate different properties of concrete, the

compression can be checked by casting cubes of concrete. This test alone can help us in verifying that is the concrete having enough strength to be used or not. The compressive strength for the structures usually fluctuates between 15 to 30Mpa for residential structures and the criteria for commercial is usually higher[12].

There are many different aspects of concrete which affect it's compressive strength which are the strength of cement ,water-cement ratio, quality of material used for concrete, the quality considered during manufacturing etc. There are two ways of conducting the test, either by cube or by cylinder. There are many different codes that suggest using cylinder and cubes as standard apparatus for the test. The potential of bearing loads and deflection present in the structures define the compressive strength. The size tends to reduce under compression, whereas it stretches under tension. The formulae to calculate the compressive strength can be found out by dividing the load by the cross- sectional area of the specimen[12].

Compressive Strength = Load / Cross-sectional Area

- Chloride Permeability Test Equipment (CPT) is a kind of equipment having amenities with various ports which can be used to check samples having a diameter of 100mm and a thickness of 50mm for testing the ion permeability of concrete for research purposes. The connections which are easy are usually used as chloride ion permeability test equipment for the testing of Portland concrete of different grades. The most common environmental hazard which causes a lot of negative effect on the concrete structures is corrosion of reinforced steel. Regular concrete which is used is not as durable as the concrete which contains silica fumes and fly ash. All the loss that occurs due to corrosion in different kind of marine structures and bridge decks results in huge revenue which has to be invested in repairs, this is a kind of problem which has started occurring very frequently in structures and is becoming a very major concern as the cost of repairs due to this durability problem is very high. There are different kinds of reactions which cause permeability such as capillary absorption etc. The phenomena of diffusion mainly takes place when the chloride concentration of concrete is more on the outer layer than the inner layer. This reaction

causes the ions of chloride in concrete to shift to the level of rebar. The cycle combinations of wetting and drying while oxygen is present creates condition for the perfect reinforcement corrosion. The internal pore structures of concrete primarily depend on the presence of chloride ions in it. Conditions of curing, hydration degree, design used for mix etc are some other factors which relate to the internal pore structure. So from this we can clearly say that whenever there is a chance of corrosion occurred due to induced chloride, the checking of permeability becomes necessary. The Chloride-ion Permeability Test (CPT) is a test which is established to check how much ability does the concrete have to bear the chloride ions, specifying it's permeability. The main aim we are trying to achieve here is to consider the quality control and find a method for testing which takes minimum amount of time.The chloride permeability test [CPT} meets these goals. As the name itself proves that, this test is performed to check the Concrete's Ability to Resist Chloride Ion Penetration**.** This test is an Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration. This test enables to predict the service life of concrete structures. It can also be used for durability-based quality control purposes. In this test, the constant voltage (V) is applied on a concrete specimen for 6 hours and the current (i) passing through the concrete is recorded to find the coulombs[23].

Apparatus:

The testing can be conducted with the help of an equipment which is called the chloride permeability test equipment, it consists of two types of holder. Out of these two holders one holds 3%Nacl and the other has 0.3M NaOH solution. The samples of concrete are usually having thickness of 50 mm and dia of about 100mm.

Chloride test procedure:

1. Samples having dia of 90-100mm and thickness of 50mm are casted.
2. The concrete specimen is located between the holders(known as a single cell) which hold both the solutions between them.

3. The holders are then attached to DC supply and concrete samples at both ends undergo a voltage of 60V.
4. The current passing through the samples are then noted according to the duration of time.
5. A device called LCD connected to the cell is then used to estimate the current passing through the sample[23].

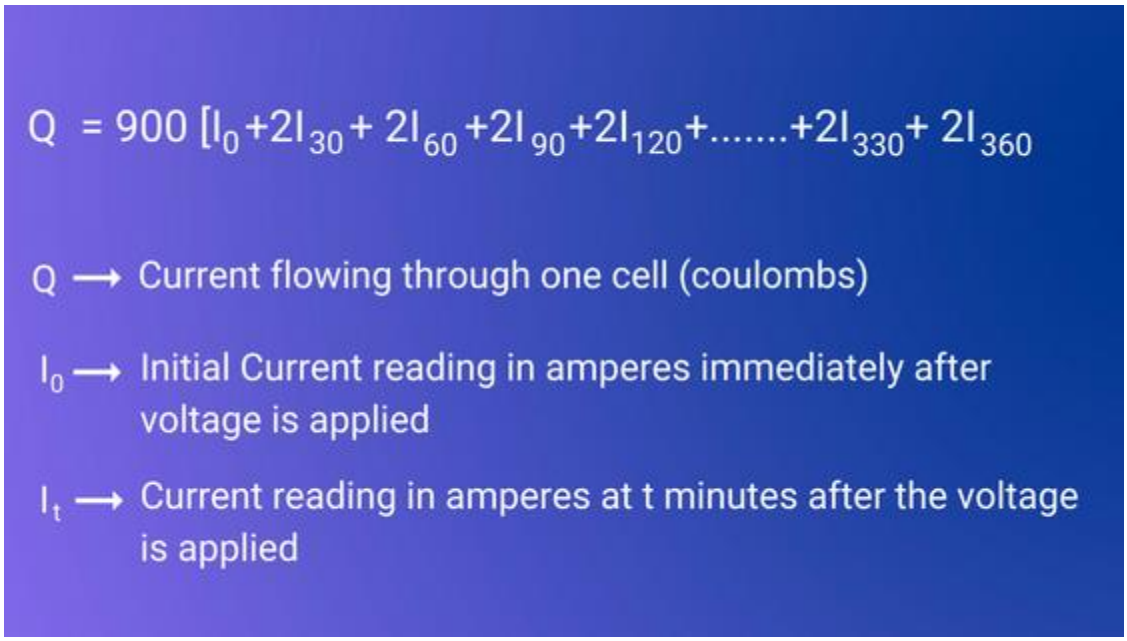

Fig 1.3 Formula for CPT Test

To estimate the amount of permeability in concrete 2-3 samples are tested from the same set of samples, the final result is the mean value of the above. LCD meter can have 2-3 cells connected to the permeability equipment to check those samples.

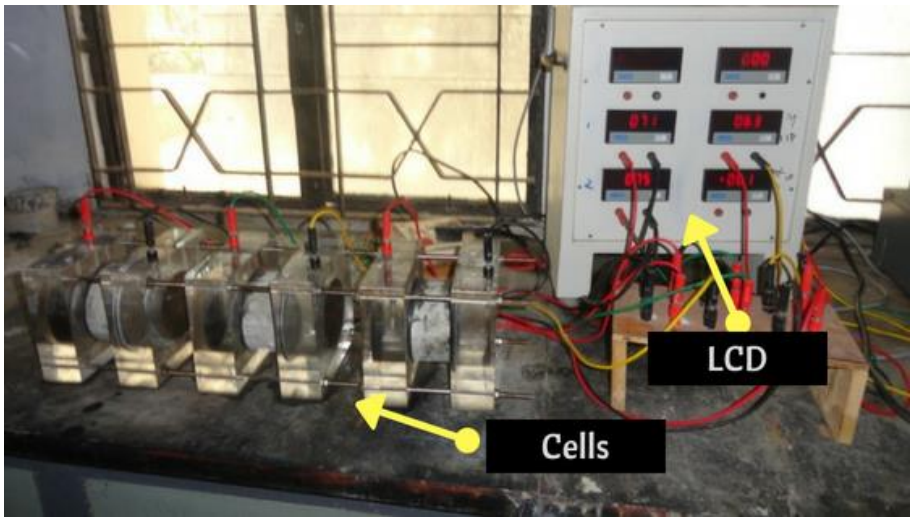

Fig 1.4 Permeameter[23]

Table to interpret CPT test Results:

The determination of the current can be done by the above given formula and can be rated according to the table given below.[23]

Charge (Coulombs)	Chloride Permeability
>4000	High Permeable Concrete
2000 - 4000	Moderate
1000 - 2000	Low
100 - 1000	Very Low
<100	Negligible

Table 1.1 Table used to interpret CPT results

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CHAPTER 2: LITERATURE REVIEW

2.1 General

Concrete possesses different kind of properties such as water absorption and penetration, modulus of elasticity, water permeability, collapsing under excess load etc. All in all these characteristics help in knowing deeply about concrete's strength, the values of it are still related to the compressive strength which is the major concern in context of concrete[22]. Bearing loads is one of the duty which has to be fulfilled but other than that it's compulsory to check the compressive strength of concrete. So what we are trying to conclude in this research is focusing on compressive strength and durability of concrete specifically rather than checking every property separately.

The review of the literature done here presents and explains all the different kind of researches that have been done regarding the compressive strength of concrete with the help of replacing RA with natural coarse aggregates. Different studies show different conclusions, although the curing time used in most of them was 28 days. The main thing that has been noticed in most of the cases is that the compressive strength increases with time; perhaps, it can be claimed that the initial values are not final values. The manufacturing of the concrete was done according to the country codes that are used in their respective countries and no amends were made in the quality of cement when the concrete was casted with RA and natural aggregates.

Many researches have been done till today which have induced RA to conduct experiments on concrete to check the compressive strength. All the waste that is used in these experiments are used are collected from the sites where demolition takes place.

2.2 RA: Recycled Aggregate

The construction sector is responsible for the waste that's produced. Generation of this kind of waste usually happens at demolition sites after the structures gets demolished and the idea

of recycling it is totally ignored by people[24]. It’s not only concrete that produces waste other things like shingles, gypsum board, metals, glass, insulation component, paper, etc are also responsible[25]. 47% amount accounts for demolished waste in Europe. [26.]

Introducing RA that’s produced from demolition can be very useful for reducing the impact on environment caused by disposing waste into the landfills. It can be helpful in many other aspects as well such as reduction of energy, decrease in transportation cost and most importantly recycling the demolition waste in cities where this problem has started becoming critical. In addition to this, this can also help in raising the employment in developing countries as a lot of demolition waste is generated over there.

A survey done estimates the amount of construction waste produced in EU countries add up to 821 million tonnes by the end of 2013[26]; so it’s very obvious that the use of RA in the form of demolition waste has to be used in the construction sector and it’s not very surprising anymore[27-32]. It is noticed every time that the results obtained by different researchers are different, these results are totally dependent on the quality of concrete waste that is used for recycling. This means that if the concrete which was used as RA was constructed with proper specification will be better than the one constructed incorrectly.

2.3Different findings on RAC

Mortar and aggregates are the two main constituents of concrete. Slowly and gradually it’s use is becoming common these days. The RA extracted from demolition is highly porous which makes it’s interfacial transition zone(ITZ) weak. The modulus of elasticity of RA is lower than natural aggregates and the reason for this is usually the porosity that the demolished aggregates are having. Uddin Ahmed[34] researched about the dividing strength which is possessed by concrete containing recycled aggregates. 192 concrete cylinders (100ϕ×200 mm) and 192 mortar cubes (50×50×50 mm) were studied by him and the values of NAC and RAC that were obtained after conducting the compressive strength test were compared. When NAC is used the linear relationship between mortar and concrete's strength is observed. Anyhow, when RAC is used, the relationship observed in mortar and concrete strength is a two stage relationship which proves the existence of dividing strength in the concrete that’s tested. His research clearly shows how important is it to emphasize on

researching more about the dividing strength of RAC as it varies according to the contents present in the material used.[34].

Research done by him also shows that the E values of rock are affected by the porosity and cracks that are induced inside the rock. Perhaps, the E value RCA has is supposedly less than NCA ,and this happens because of the porosity being high in RA and there are some micro cracks which are already present. The RCA plays a small role in context of compressive strength as it's E value is low. In light weight aggregate (LWA) concrete, the LWA is obviously a material that doesn't contribute much for compressive strength because of it's low E-value[34].

There's a research done by five people which elaborates about the use of 100% recycled aggregates in concrete to check different kind of effects it has on strength and durability. Concrete possesses many physical and mechanical properties which include shape, texture, absorption, specific gravity etc and all of these properties play a vital role in defining compressive strength. Generally, the recycled aggregates which are extracted from demolished sites are dependent on the quality of structures. A series of experiments were conducted in this research to identify affects the physical and mechanical properties recycled aggregates have on concrete. Moreover, the properties associated with fine and coarse aggregates are calculated. Number of mixes of concrete samples were casted with 100% RCA to check the results. A process called SEM was undertaken to check the microstructure of the mixes that were selected. The output was surprising as it concluded that if the packing density is extremely high expected results can be achieved[33].

The studies also shows the affects it has on the final concrete samples. The calculation of properties showed a variation between them because of using 100% RA in the testing process. The studies demonstrates that how the quality of recycled aggregates affect the results obtained from the research. The calculation of different mechanical and physical properties of concrete showed an acceptable variation in results when the samples were collected from different locations at an interval of six months . Anyhow some of the limitations that occur can be controlled during proportioning in order to achieve high packing density . In addition to this it can be conclude that flexural tensile strength, modulus of elasticity and other characteristics

obtained by utilising the concrete waste collected from different sources in a time phrase of six months. [33].

A huge disadvantage of using recycled materials is that inspire of being sustainable, it might ruin the life of the concrete. A very useful tool to avoid the performance issues caused in the concrete can be rectified by using superplasticizers which help in improving the overall strength given by concrete. Experiments were conducted on standard and high quality plasticisers to find the impact it has on durability(immersion helping in water absorption shrinkage and action of capillarity, chloride penetration resistance and carbonation)of samples made with fluctuating levels of coarse aggregate that is obtained in concrete that was crushed and comparison need to be done with the performance of regular concrete. All in all we can conclude that the recycled concrete is more likely to deteriorate as the environment is getting degraded but this doesn't happen in the case of regular concrete that is used in the construction sector. Anyhow, the conclusion of the whole thing is that by using the superplasticizers, the performance of the concrete can be enhanced as it helps in increasing the durability of recycled concrete[35].

The work carried out in this study shows the following conclusion:[35]

1. The superplasticizers have no effect whatsoever on water absorption and capillarity action of concrete when it's immersed in water.

2. The density of aggregate decides about the specific gravity of the concrete i . e. Recycled aggregates with higher specific gravity should be preferred.

3. The water absorption caused in aggregates is mainly caused because of the highly porous properties the RA has.

4. Even the superplasticizers are not efficient when it comes to support recycled concrete, thus reducing the amount of recycled aggregates might help superplasticizers.

5. By inducing RA in concrete it's strength decreases but superplasticizers can help it in managing it if limited amount of RA is used.

6. The shrinkage stains were noticed in concrete with induced RA and superplasticizers can be a very helpful solution to avoid this problem.

7. Superplasticisers also help in reducing the carbonation depth of RA compared to RA at an early age. With the passage of time the efficiency of superplasticizers get low , in spite of using high quality plasticisers, as the time passes the effect reduces which is major concern for the construction sector.

8.The chloride penetration in the mixtures of plasticisers an aggregates are more resistant than RC. By the addition of superplasticizers the cement paste gets compacted, which has an effect on the penetration of chloride; anyhow, there were some mistakes made while conducting the test which makes further experimenting necessary[35].

A study done by Abraham and ramnath claimed a method of packing concrete with high packing density consisting of RA, and this can be achieved by soaking the aggregates before experimenting and by PPO(particle packing optimization) methods. A total of 300 specimen of concrete were checked with inducing 100% RA in the concrete and these were tested for 7,14 and 28 days. Water absorption in the aggregates is time dependent is a fact that was noticed when the comparison of soaked and unsoaked recycled aggregates was done, this in turn does have an affect on performance of fresh concrete which is having W/C ratio with low water-cement ratio. Anyhow, later it was investigated that if soaking was done earlier the reaction of absorption occurred immediately. The study also concluded the fact that if the recycled aggregates are soaked before the production of concrete, it will definitely give better compressive strength. The mean value of the strength that was obtained by conducting these experiments was 83.0MPa. If we look at the statistics the literature tells us about strength achieved by using RA with 100% volume, this might be the highest value that has been recorded[36].

Formidable results were obtained regarding the compressive strength of concrete. The results were recorded by the normal procedure of 7,14 and 28 days. The strength achieved by natural aggregates was highest, strength achieved by HS-RA was ranked second and LS-RA was last and the values were 106.9,83.7 and 76.7Mpa respectively. The conclusion of the study was way better comparatively as no research ever concluded the kind of results this research

showed. Micro silica and low water cement ratio are the factors that help in inducing high compressive strength. Micro silica acts like a material which is pozzolanic , and then the size of crystalline compounds start reducing, mainly calcium hydroxide; it later on results in decrement of ITZ zone in concrete with high compressive strength. The depth of the interfacial transition zone makes the load transfer efficient between the coarse aggregates and the cement mortar, which supports the strength of the concrete. For the concrete having high strength, even a small variation can have a huge affect. The specimen used didn't show any relationship that could've existed between packing density and compressive strength. the highest compressive strength of 106.22 MPa was obtained by packing density of 70.4, whereas compressive strength of 85.56 MPa was achieved with highest packing density of 86.7. So this shows that soaking RA before using it can help us in achieving higher compressive strength. The logic behind it is that the soaked aggregates provide internal moisture which assists the curing of cement paste that's new, which results in stronger bonds between the particles[36].

CHAPTER 3: METHODOLOGY

3.1 General

The main aim of the experimentation is to study about the strength and durability of the RAC. Compressive strength test has been performed to check the strength of RAC at 7 and 28 days. A total of six samples of concrete were casted to check the compressive strength. The 15×15×15 cm standard size moulds were used. Out of all these six samples, three were tested after 7 days of curing and the other three were tested after 28 days of curing. The RCPT (Rapid chloride permeability test) has not yet been performed.

3.2 Materials used for the study

The RCA used in the experiment was collected from the old samples which had already been tested in the university laboratory. The samples from which the RCA was collected were of the same grade as the one being used in this study i.e.M30 grade. The fine aggregates used in this study were not the recycled ones, perhaps the quality of the fine aggregates used was much more superior than the coarse aggregates and lastly the most extensively used cement i.e. Ordinary Portland cement was used to cast the samples in this study.

3.3 Methodology followed

1. In this study, the recycled aggregate concrete were obtained from the concrete blocks which were previously tested in the university lab.
2. The blocks were crushed with use of hammer to a size of 40 mm or less.
3. To obtain the desirable size i.e.10 mm – 20mm, the aggregates were crushed further with the help of crusher.
4. The moisture content from the aggregates was removed by keeping them in oven for 24 hours.
5. Mix design of M 30 grade of concrete was used with the help of IS 10262-2009.
6. Compression test was then conducted to check the strength of RAC.

3.4 Procedure for compression test

Basically there are two types of samples that can be casted for cube and dimension for them are either 15×15×15 cm or 10×10×10cm and it usually depends on the size of aggregates. The ones which are often used are 15×15×15cm molds.
The pouring of concrete is done and to avoid the voids, it's made sure that tampering is done properly. The molds are deformed after 24 hours and water is used for curing. It is important for the topmost surface of the sample to be smooth. To carry out this process the cement is very carefully used to make the layer smooth.

The samples that are casted are checked with the help of compression machine. While applying the load we have to make sure it's gradual and should be applied at a rate of 140 kg/cm2. This procedure helps us in estimating the compressive strength.

Following are the steps for testing the Compressive strength of Concrete Cubes:

Apparatus for Concrete Cube Test:

Machine for testing compression

Preparation of Concrete Cube Specimen

The aggregates used in the test were obtained from previous lab tests.

Specimen

15 cm cubes (6)Mix. M30 or above

Mixing of Concrete for Cube Test

Concrete should be mixed thoroughly.

Hand Mixing

1. A waterlight clean setup should be used until and mixture should be created properly in order to gain efficiency.
2. The cement and fine aggregates have to be mixed with recycled aggregated and it should be done till a proper Mix is not achieved.
3. Then water has to be added to it and it has to be mixed thoroughly.

Sampling of Cubes for Test

1. Moulds have to be cleaned and the oil has to be applied.
2. The layers of filled concrete should at least be having a thickness of 5 cm.
3. Each layer has to be compacted with the help of tamping it 35 times(steel bar 16mm diameter and 60cm long, bullet-pointed at lower end).
4. Top surface has to be levelled and Smoothening of it should be done.

Curing of Cubes

Samples are kept in moist air for 24 hrs and when this time passes, the samples have to be separated from the molds and then these have to be kept in freshwater before conducting any kind of experiment on it.

Precautions for Tests

After every 7 days, the water should be tested and it should be having a temperature of about 27 -29 deg. Celsius.

Procedure for Concrete Cube Test

1. The excess water has to be wiped out after taking it out of the curing circumstances it was in.
2. Dimension of sample should not be 0.2 m
3. The bearing surface of the testing machine has to be cleaned.
4. The positioning of samples have to be done in a way that the load is applied from both sides of the cube.
5. The alignment should be proper and at the centre of the base plate.
6. The process has to be carried out gently in order to obtain the maximum output from the experiment.
7. The load at the rate of 140/kg/cm2 has to applied very gradually to neatly carry out the experiment.
8. Unusual features should be noted and values have to be recorded.

CHAPTER4: RESULTS AND DISCUSSION

4.1 General

The results of the study were not as expected. Experimentation on RAC is a very wide research topic with a number of outcomes. The use of RAC has become an urgent requirement in today's time, so continuous research needs to be done on this topic. Moreover, the effect of CDW on the environment is very adverse as we all know. There are many different factors that affect the mechanical properties of RAC, so in order to establish the proper amount of RA which can be used for the manufacturing of concrete, studies on mechanical properties of RAC too need to be done.

4.2 Compression strength test results

Three samples were tested after 7 days of curing and three were tested after 28 days of curing

So the results are as follows:

For seven days testing:

S. No.	Load(KN)	Compressive Strength (N/mm2)
1.	230	10.2
2.	232	10.3
3.	222	9.8

Table 1.2 Compressive test results after 7 days.

Therefore, average compressive strength after 7 days is equal to 10.1 N/mm2

For 28 days testing:

S. No.	Load(KN)	Compressive strength (N/mm2)
1.	456	20.3
2.	462	20.5
3.	452	20.2

Table 1.3 Compressive test results after 28 days

So the average strength achieved after 28 days is equal to 20.3 N/mm2

4.3 Observations made from the above results

65% strength is achieved within 7 days but the strength achieved here is not desirable as M30 grade should be giving 20 N/mm2 of strength after seven days and only 50% of it has been achieved. So, it is very clear that desirable strength cannot be achieved by using 100% RA for M30 grade therefore, experiments with different amount of quantities should be conducted in order to achieve the desirable strength. Experiments also show that the strength achieved after 28 days was doubled. Though it is a good amount of strength achieved by RAC but still it can not be used in the industry. Hence experiments with different proportions need to be necessarily be done.

4.4- Chloride penetration test results

In order to apply the solution indicator method of silver nitrate, R4 (from the NC-RCA)Concretes and C4 (from the OC-RCA concretes) we're exposed to saturated salt solution after it was broken after at an interval of 160 days. The 0.1 N silver nitrate solution which damaged the surface of broken blocks gave the results that indicated 30 and 20 mm Depth of chloride penetration into NC-RCA and OC-RCA concrete, and this can be seen in Figures 4.1 and 4.2.

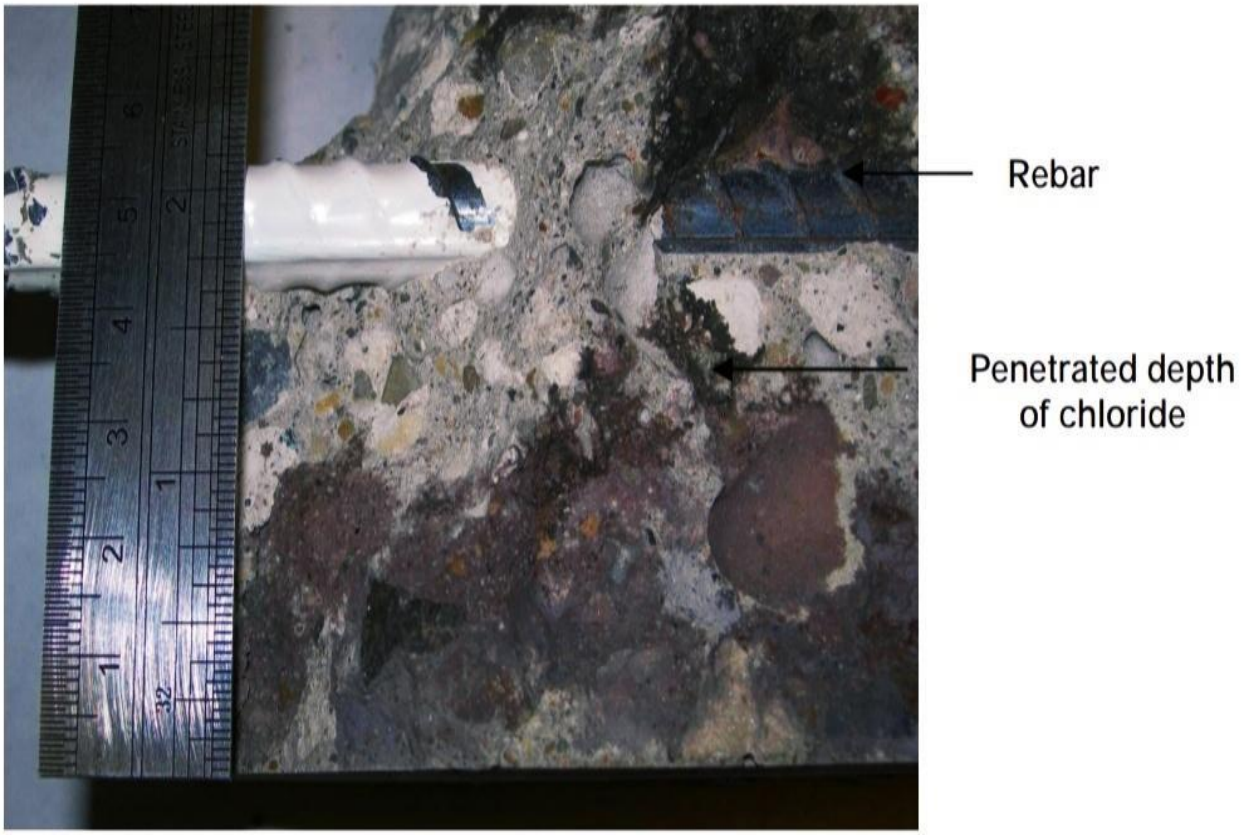

Fig. 4.1 Chloride depth of penetration in NC-RCA after 160 days

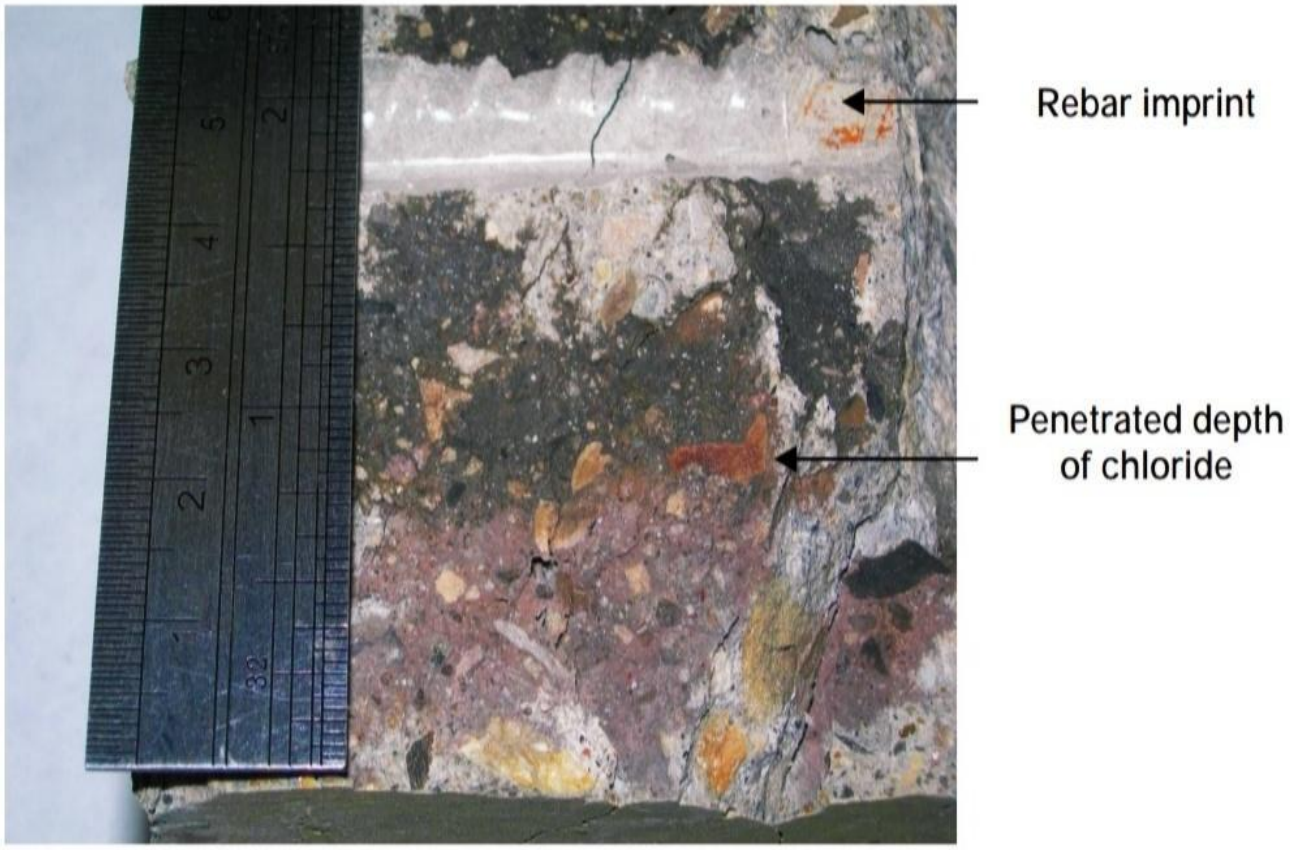

Fig 4.2 Chloride depth of penetration of OC- RCA after 160 days

One specimen from each set of blocks was chosen for concrete profile grinding(O1, R1 and C1) to find the chloride content after 370 days passed to conduct the experiment. Weight percent of concrete) which entered the concrete accordingly. It was a difficult task for the grinder to pulverize it beyond 25 mm, the top layer of concrete showed significant changes and was also grounded after cutting the blocks. Different analysis were made to estimate the amount of chloride content at the rebar. Figure 4.3, depicts the chloride fusion trend in the depth of concrete specimen.

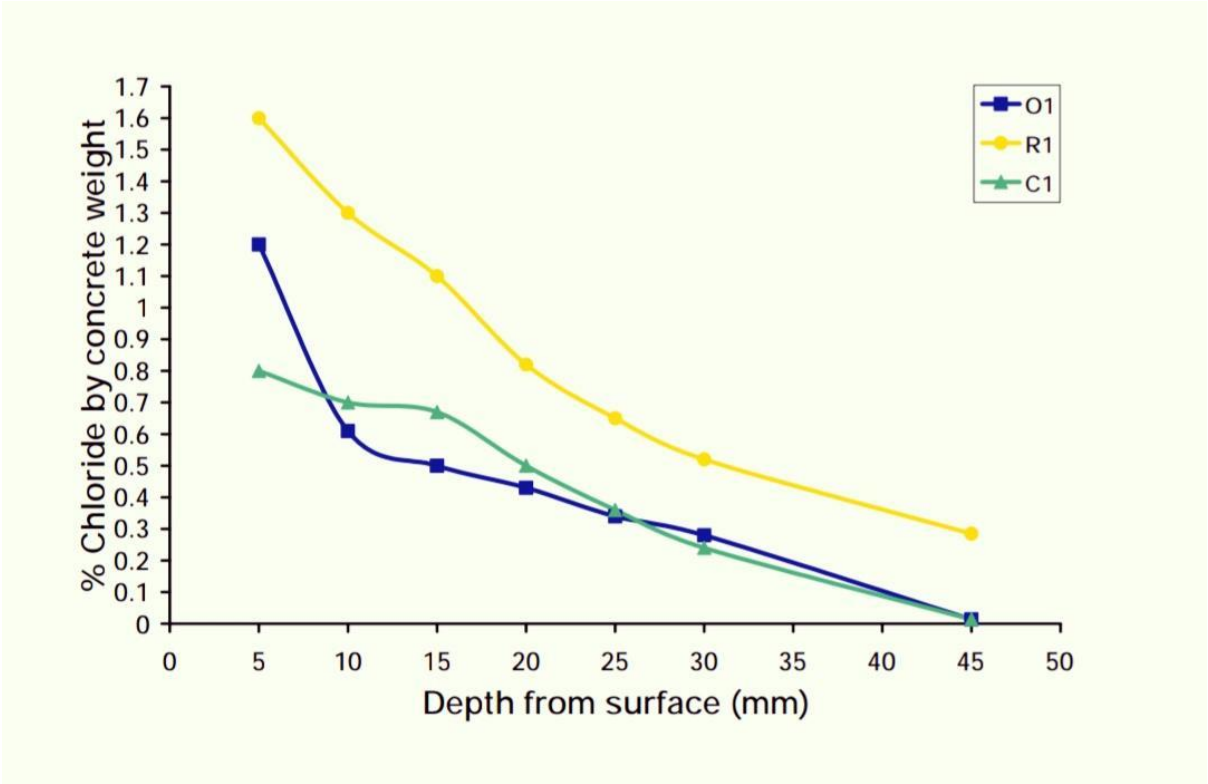

Fig 4.3 Trend of chloride diffusion

Fick's 2nd law and linear curve fitting were used to calculate the chloride diffusion and the values were 15.3, 16.7 and 14.2× 10-11 m2 /s for O1, R1 and C1 concrete blocks respectively. Towards the concrete surface and the rebar, it was seen that there was decrement of values in these areas. Whereas, the content of chloride near the rebar's surface(40 mm from the surface of the concrete) was nearly the same for these two samples, 0.013% by concrete's weight, this result in the R1 concrete block was 0.275% concrete's weight. Rebar concrete interface had high value and the chloride diffusion curve showing downward slope in R1 sample block clearly show that OC-RCA and NA were not permeable as NC-RCA. The steel rebars were detached and the concrete blocks were sliced to check the chloride permeability. Though the downside part of the reinforced steel in the R1 Concrete block, just with the surface casted, was rusted (Figure 4.4), no signs of corrosion or rusting were found in the OC-RCA and NA samples that were tested.

Fig 4.4 Condition of steel rebar

LPR is a device used to measure the corrosion of the rebar, many different kind of techniques were used to re calculate the amount of corrosion in context of samples (about 0.1374 cm2) of block consisted of reinforced steel. Figures 4.5, 4.6and 4.7, depicts the condition of the surface after using the silver nitrate solution to estimate the amount of chloride penetration that occured inside the specimen.

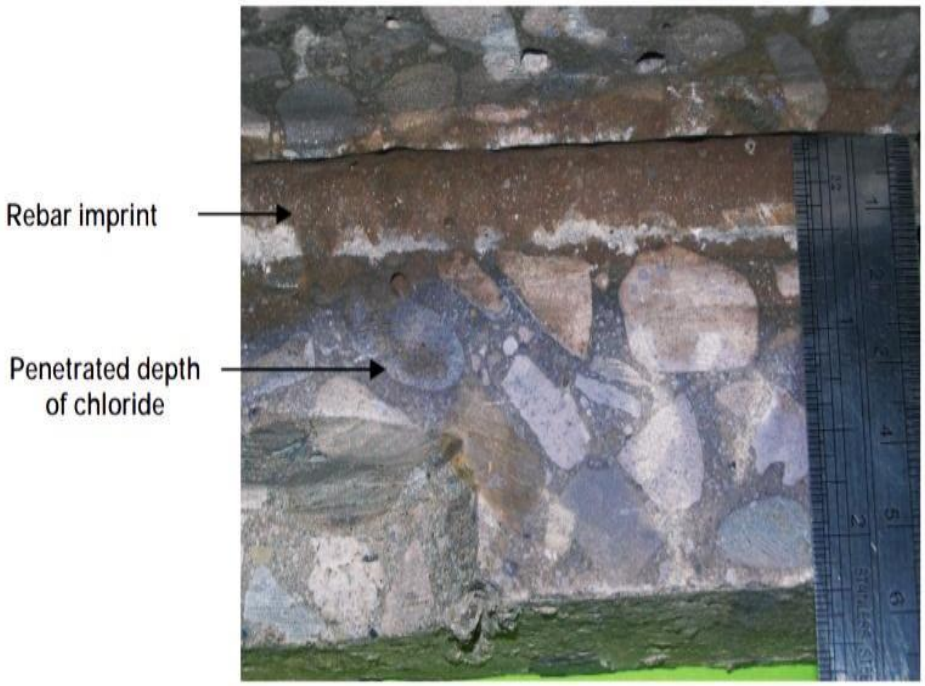

Fig 4.5 Chloride depth in NA after 360 days

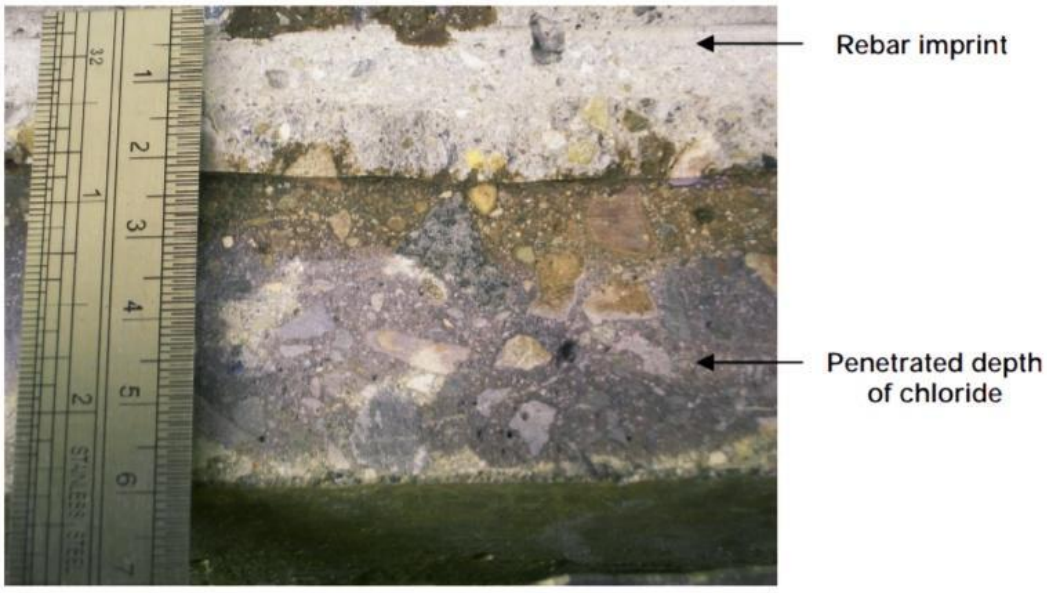

Fig 4.6 Chloride depth in NC- RCA after 360 days

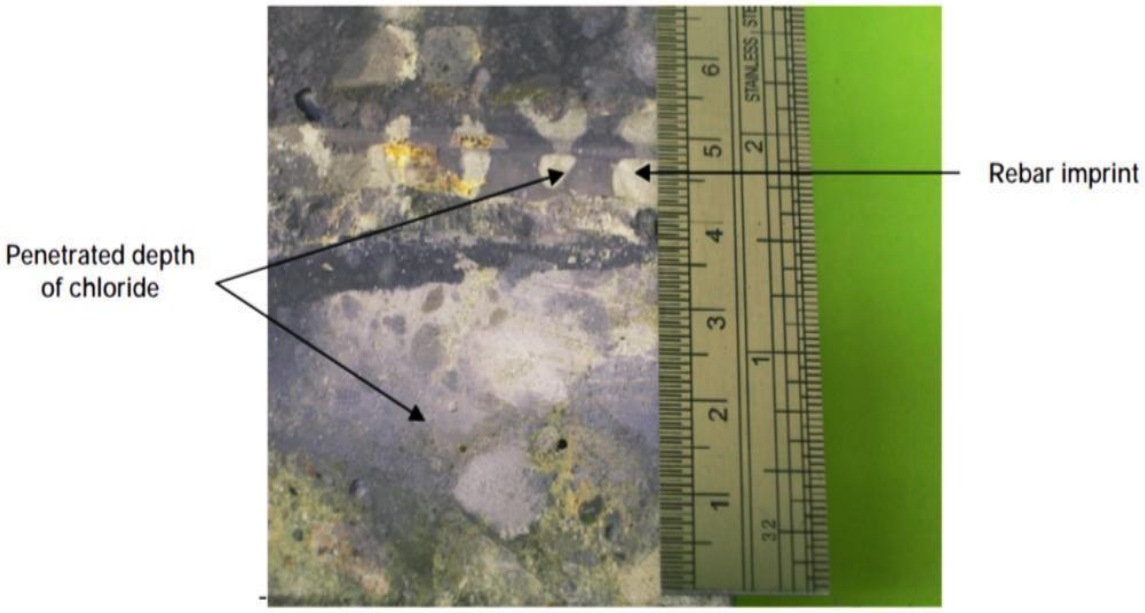

Fig 4.7 Chloride depth in OC-RCA after 360 days

The amount of Coloured area define the measurement with respect to the surface of concrete and it clearly shows that amount of chloride that's penetrated in O1 and C1 concrete blocks was about 35mm and 20mm.After passing through 40mm concrete cover the rebar of the concrete didn't allow any chloride penetration. Interface was holding the content of chloride with the separated rebar in O1 and C1 Concrete block and the value of this was about 0.013% by concrete's weight and a good condition was attained by the surface of rebar in context of both concretes, so it can be clearly noticed that the OC-RCA is having lower permeability (and more useful than the regular concrete)for the purpose of resisting the chloride and corrosion for reinforcing steel has to be avoided even though the beginning concentration of chloride was 0.022% by concrete's weight.

CONCLUSION

65% strength is achieved within 7 days but the strength achieved here is not desirable as M30 grade should be giving 20 N/mm2 of strength after seven days and only 50% of it has been achieved. So, it is very clear that desirable strength cannot be achieved by using 100% RA for M30 grade therefore, experiments with different amount of quantities should be conducted in order to achieve the desirable strength. Experiments also show that the strength achieved after 28 days was doubled. Though it is a good amount of strength achieved by RAC but still it can not be used in the industry. Hence experiments with different proportions necessarily be done.

The results which were seen by conducting these experiments done on different kind of characteristics which are permeability, strength in context of age and their impact on concrete durability, the conclusions And recommendations are given below:

The age limit of RAC totally depends on the durability of these aggregates. The involvement of recycled concrete which is old and hard is used as coarse Aggregate with 16 mm nominal maximum size which is accompanied by sand that's natural. If we want the structural concrete to be more efficient the characteristics such as chloride penetration, reinforcing steel corrosion resistance and salt scaling of RCA concrete should be able to fulfil the requirements that are expected from natural aggregates. Comparatively the strength displayed by the OC- RCA was strong enough and very close to the natural materials.

REFERENCES

1 Davies N, Jokiniemi E. Dictionary of Architecture and Building Construction. Burlington, MA, USA: Architectural Press; 2008.

2 Francis AA. Non-Isothermal Crystallization Kinetics of a Blast Furnace Slag. Journal of the American Ceramic Society 2015:88(7);1859–1863.

3 Gavilan R, Bernold L. Source Evaluation of Solid Waste in Building Construction. Journal of Construction Engineering and Management 1994;120(3):536-552.

4 Crow JM. The Concrete Conundrum. Chemistry World. March 2008, pp.62-66.

5 Edward GN. Concrete Construction Engineering Handbook. 2nd ed. USA: Taylor & Francis Group; 2009.

6 Haberta G, Bouzidib Y, Chena C, Jullienc A. Development of a depletion indicator for natural resources used in concrete. Resources, Conservation and Recycling 2010:54(6);364-376.

7 UEPG - European Aggregates Association. Annual Review 2014-2015. Belgium: Publisher unknown; 2015.

8 Domone P, Illson J. Construction Materials: Their nature and behaviour. 4th ed. USA and Canada: Spon Press; 2010.

9 William HL, Lawrence JD, Janet S S. Aggregate and the Environment. Alexandria, VA, USA: American Geological Institute; 2005.

10 Concrete Construction. Global Demand for Construction Aggregates to Exceed 48 Billion Metric Tons in 2015 [online]. URL:http://www.concreteconstruction.net/aggregates/global-demand-for-construction-aggregates-to-exceed-48-billion-metric-tons-in-2015.aspx

11 Habert G, Roussel N. Study of two concrete mix-design strategies to reach carbon mitigation objectives. Cement and Concrete Composites 2009;31(6):397402.

12 https://theconstructor.org/concrete/compressive-strength-concrete-cube-test/1561/

13 Messieh SN, Rowell TW, Peer DL, Cranford PJ. Proceedings of the Canadian Continental Shelf Seabed Symposium. Continental Shelf Research 1991:11(810);1237-1263.

14 Ministry of Environment. Environmental Protection Act. Finland; 2011.

15 Calkins M. Materials for Sustainable Sites: A Complete Guide to the Evaluation, Selection, and Use of Sustainable Construction Materials. USA and Canada; John Wiley: 2008.

16 Pandey P, Harison A,Srivastava V. Utilization of Waste Foundry Sand as Partial Replacement of Fine Aggregate for Low Cost Concrete. International Journal of Current Engineering and Technology 2015;5(6):3535-3538.

17 Kaushal M, Gupta A, Verma V, Singh B. To Examine the Strength Characteristics of Concrete with the Replacement of Sand by Foundry Sand. Manish Kaushal al. International Journal of Recent Research Aspects 2014;1(3):129-132.

18 Amritkar SS, Chandak SN, Patil SS, Jadhav RA. Effect of Waste Foundry Sand (WFS) on the Mechanical properties of concrete with artificial sand as Fine Aggregate. International Journal of Engineering Research & Technology 2015;4(4):390-393.

19 Bang JW, Prabhu GG, Lee BJ, Hyun HJ, Kim YY. Mechanical and Durability Properties of Concrete Made with Used Foundry Sand as Fine Aggregate 2015;2015(1):Article ID 161753.

20 Prabhu GG, Hyun JH, Kim YY. Effects of foundry sand as a fine aggregate in concrete production. Construction and Building Materials 2014;70(1):514-521.

21 Tam VWY. Economic comparison of concrete recycling: A case study approach. Resources, Conservation and Recycling 2008;52(5):821-828.

22 Ondova M, Stevulova N. Benefits of fly ash utilization in concrete road cover. Theoretical Foundations of Chemical Engineering 2014;46(6):713-718.

23 https://civilread.com/concrete-permeability/

24 Brito J, Silva RV, Dhir RK. Performance of cementitious renderings and masonry mortars containing recycled aggregates from construction and demolition wastes. Construction and Building Materials 2016;105(1):400-415.

25 Jeffrey C. Construction and Demolition Waste Recycling, a literature review. Dalhousie, USA: Dalhousie University's Office of Sustainability; 2011.

26 Eurostat. File:Waste generation by economic activity and households, 2012 (1000 tonnes) [online].

27 Arezoumandi M, Drury J, Volz SJ, Khayat HK. Effect of Recycled Concrete Aggregate Replacement Level on Shear Strength of Reinforced Concrete Beams. ACI Materials Journal 2015;112(4).

28 Manzi S, Mazzotti C, Bignozzi MC. Short and long-term behaviour of structural concrete with recycled concrete aggregate. Cement & Concrete Composites 2013;37(1):312-318.

29 Gonzalez-Fonteboa B, Martınez-Abella F. Concretes with aggregates from demolition waste and silica fume; Materials and mechanical properties. Building and Environment 2008;43(1):429–437.

30 Ramli M, Ismail S. Engineering properties of treated recycled concrete aggregate (RCA) for structural applications. Construction and Building Materials 2013;44(1):464–476.

31 Rahal K. Mechanical properties of concrete with recycled coarse aggregate. Building and Environment 2007;42(1):407–415.

32 Khoshkenari AG, Shafigh P, Moghimi M, Mahmudb HB. The role of 0–2 mm fine recycled concrete aggregate on the compressive and splitting tensile strengths of recycled concrete aggregate concrete. Materials and Design 2014;64(1):345– 354.

33 Strength and Durability Evaluation of Recycled Aggregate Concrete: Sherif Yehia*, Kareem Helal,, Anaam Abusharkh,, Amani Zaher, and Hiba Istaitiyeh, International Journal of Concrete Structures and Materials Vol.9, No.2, pp.219–239, June 2015 DOI 10.1007/s40069-015-0100-0 ISSN 1976-0485 / eISSN 2234-1315.

34 Existence of Dividing Strength in Concrete Containing Recycled Coarse Aggregate, Shaikh Faiz Uddin Ahmed , DOI: 10.1061/(ASCE)MT.1943-5533.0000864. © 2014 American Society of Civil Engineers.

35 Durability of Concrete with Recycled Coarse Aggregates:Influence of Superplasticizers: Daniel Matias, Jorge de Brito,Alexandra Rosa and Diogo Pedro, DOI: 10.1061/(ASCE)MT.1943-5533.0000961. © 2014 American Society of Civil Engineers.

36 Manufacturing Concrete with High Compressive Strength Using Recycled Aggregates: Abrahams Mwasha, M.ASCE and Rakesh Ramnath, DOI: 10.1061/(ASCE)MT.1943-5533.0002398. © 2018 American Society of Civil Engineers.

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