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Behaviour of Recycled Concrete in M30 and M35 Grades with Nanosilica

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Abstract

The use of recycled concrete aggregate (RCA) in concrete as partial and full replacements of natural coarse aggregate is growing interest in the construction industry, as it reduces the demand for virgin aggregate. In addition, the use of RCA leads to a possible solution to the environmental problem caused by concrete waste and reduces the negative environmental impact of the aggregate extraction from natural resources. This paper presents a comprehensive review on the use of RCA in concrete based on the experimental data. The most important physical, mechanical, and chemical properties of RCA are discussed in this paper. However, more emphasis has been given to discuss the effects of RCA on the fresh and hardened properties and durability of concrete.

This project, however, shows that the recycled aggregates that are obtained from concrete specimen make good quality concrete. Concrete waste from demolished cubes has been collected and coarse aggregate of20% natural and 60% recycled aggregate is used for preparing fresh concrete of M35. In this study, for the 28th day cube compressive strength using PPC; the strength for 60% RCA mixes were 16%, 21.% 75%, and 100% results, FOR 3 days, 7days and 28 days respectively.

In this work mechanical properties of recycled coarse aggregate were studied and Nanosilica is used as partial replacement to Portland Pozzolana cement by 1.5% of total cement weight and M-Sand as a fine aggregate. Strength studies such as compression strength, split tensile strength and flexural strength were conducted on M35 grades of concrete with 60% RAC. Durability studies such as permeability test and acid attack on concrete cubes. To study the microstructure of the concrete XRD analysis and SEM analysis were conducted. This paper also identifies the gaps existing in the present state of knowledge on RCA and RCA concrete and provides some recommendations for future research.

1. Introduction

1.1 General:

Demolition of old and deteriorated buildings and traffic infrastructure, and their substitution with new ones, is a frequent phenomenon today in a large part of the world. The main reasons for this situation are changes of purpose, structural deterioration, rearrangement of a city, expansion of traffic directions and increasing traffic load, natural disasters (earthquake, fire and flood), *etc.* The most common method of managing this material has been through its disposal in landfills. In this way, huge deposits of construction waste are created, consequently becoming a special problem of human environment pollution.

A possible solution to these problems is to recycle demolished concrete and produce an alternative aggregate for structural concrete in this way. Recycled concrete aggregate (RCA) is generally produced by two-stage crushing of demolished concrete, and screening and removal of contaminants such as reinforcement, paper, wood, plastics and gypsum. Concrete made with such recycled concrete aggregate is called recycled aggregate concrete (RAC). The main purpose of this work is to determine the basic properties of RAC depending on the coarse recycled aggregate content, and to compare them to the properties of concrete made with natural aggregate (NAC)—control concrete. Fine recycled aggregate was not considered for RAC production because its application in structural concrete is generally not recommended.

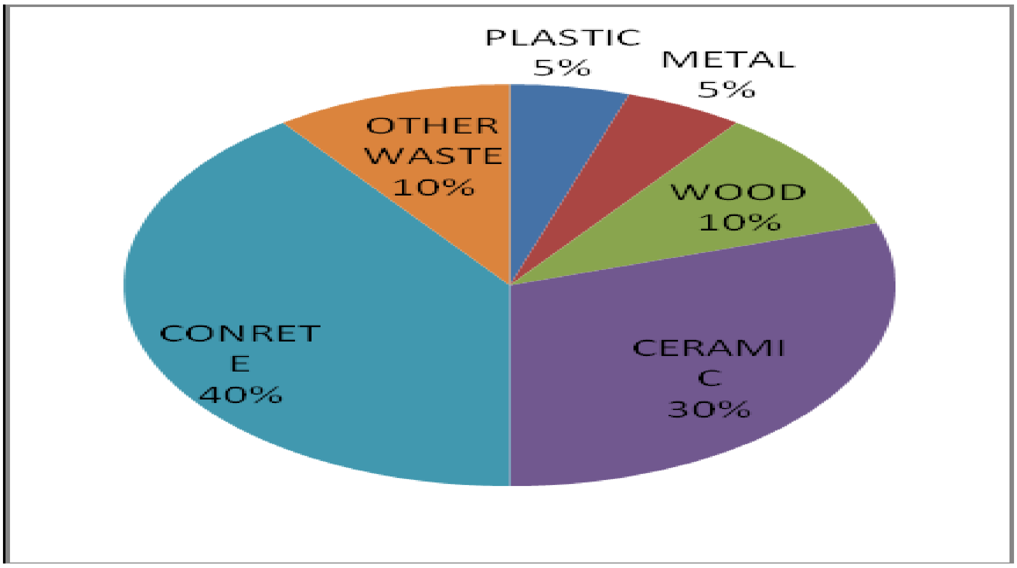


Figure1: Pie chart for solid waste

Concrete is globally the most widely used material in the construction industry. Basically, concrete is a harden product consisting of cement, aggregates, water and admixture. The composition of aggregates forms a major portion of the mixture consisting of sand, crushed stones and gravel which are inert granular materials. Construction aggregates make up more than 80 percent of the total aggregate market and are used mainly for building constructions and pavements.

1.2 CEMENT:

Concrete is the material of present as well as future. The wide use of it in structures, from buildings to factories, from bridges to airports, makes it one of the most investigated materials of the 21st century. Due to the rapid population explosion and the technology boom to cater to these needs, there is an urgent need to improve the strength and durability of concrete. Out of the various materials used in the production of concrete, cement plays a major role due its size and adhesive property. So, to produce concrete with improved properties, the mechanism of cement hydration has to be studied properly and better substitutes to it have to be suggested.

Composition and hydration:

Cement can be described as a crystalline compound of calcium silicates and other calcium compounds having hydraulic properties. The four major compounds that constitute cement are Tri-calcium silicate (C_3S), Di-calcium silicate (C_2S), Tri-calcium aluminate (C_3A), Tetra-calcium alumina-ferrite (C_4AF) where C stands for CaO, S stands for SiO_2, A stands for Al_2O_3 and F for Fe_2O_3. Tri-calcium silicate and Di-calcium silicate are the major contributors to the strength of cement, together constituting about 70 % of cement. Dry or anhydrous cement does not have adhesive property and hence cannot bind the raw materials together to form concrete. When mixed with water chemical reaction takes place and is referred to as 'hydration of cement'. The products of this exothermic reaction are C-S-H gel and $Ca(OH)_2$. Calcium hydroxide has lower surface area and hence does not contribute much to the strength of concrete. On hydration of cement aluminates a product is formed known as ettringite, which has needle like morphology and contributes to some early strength of concrete. C-S-H gel refers to calcium silicate hydrates, making up about 60 % of the volume of solids in a completely hydrated cement paste. It has a structure of short fibers which vary from crystalline to amorphous form. Owing to its gelatinous structure it can bound various inert materials by virtue of Vander Waal forces. It is the primary strength giving phase in cement concrete

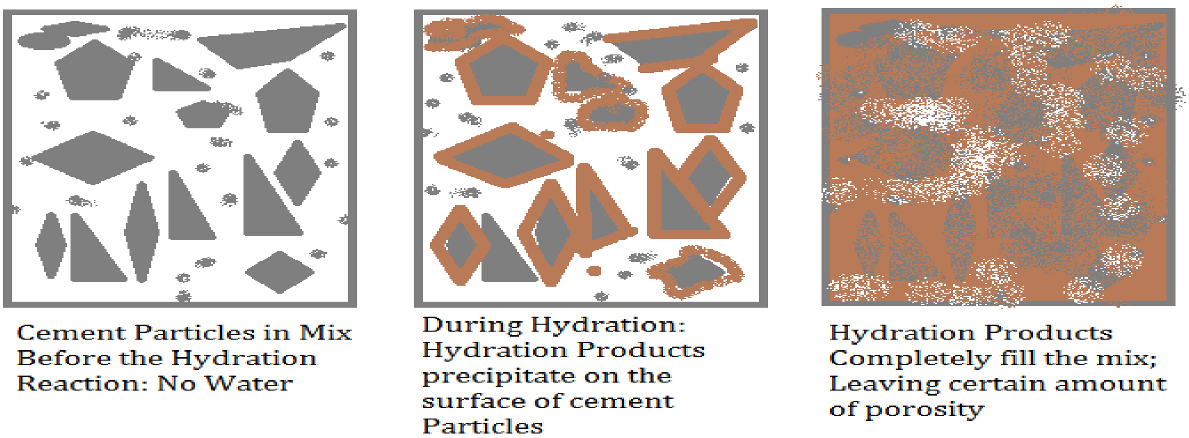


Figure1.1: Hydration of Cement

1.3 NANOTECHNOLOGY IN CONCRETE:

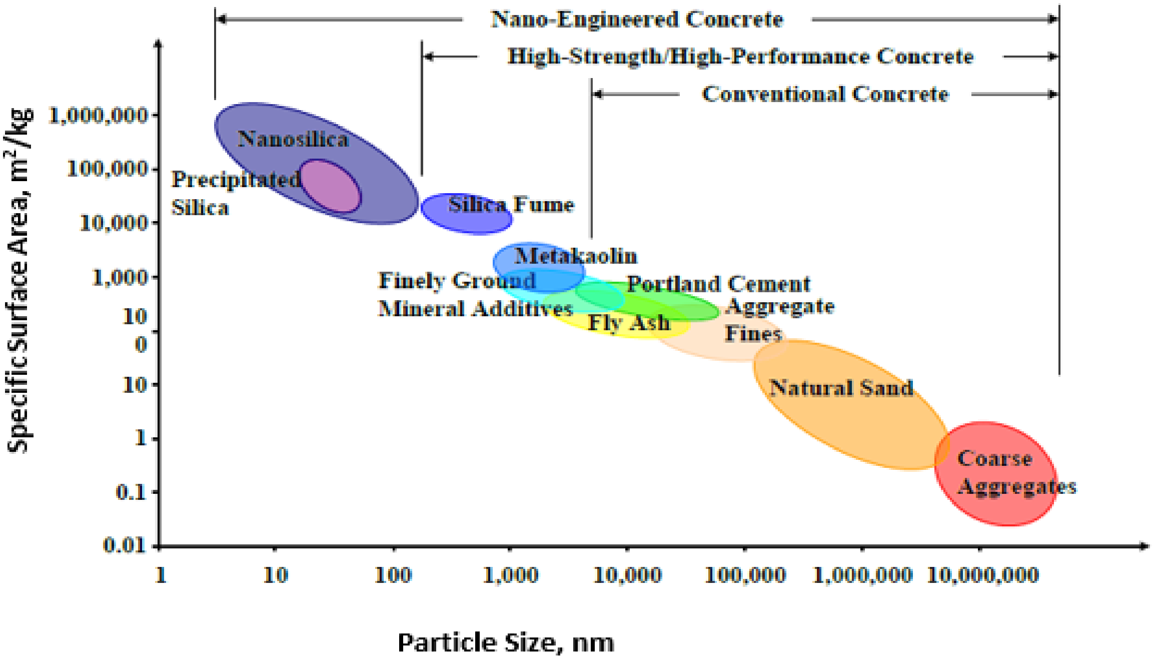
Nanotechnology is an emerging field of science of related to the understanding and control of matter at the nano scale, i.e., at dimensions between approximate 1 and 100nm. Nanotechnology is not simply working at ever – smaller dimension rather, working at the nano scale enables scientists to utilize the unique physical, chemical, mechanical, and optical properties of material that naturally occurs at that scale. Nanotechnology has a significant impact in the construction sector. Several applications have been developed for this specific sector to improve the durability and enhanced performance of construction components, energy efficiency and safety of the building, facilitating the ease of maintenance and living comfort.

Basic construction materials cement, concrete and steel will also benefit from nanotechnology. Addition of Nanoparticles will lead to stronger, more durable; air purifying, easy to clean and quick compacting concrete.

1.4 NANOSILICA:

Recently Nanotechnology has been introducing in civil engineering application. One of the most used nano materials is Nanosilica (NS). This is the first product that replaced micro silica. The advancement made by study of concrete at nano scale is much better than silica fume use in conventional concrete. Nanosilica possess more Pozzolanic nature, it has the capability to react with the free lime during the cement hydration and forms additional C-S-H gel which gives strength, impermeability and durability to concrete.

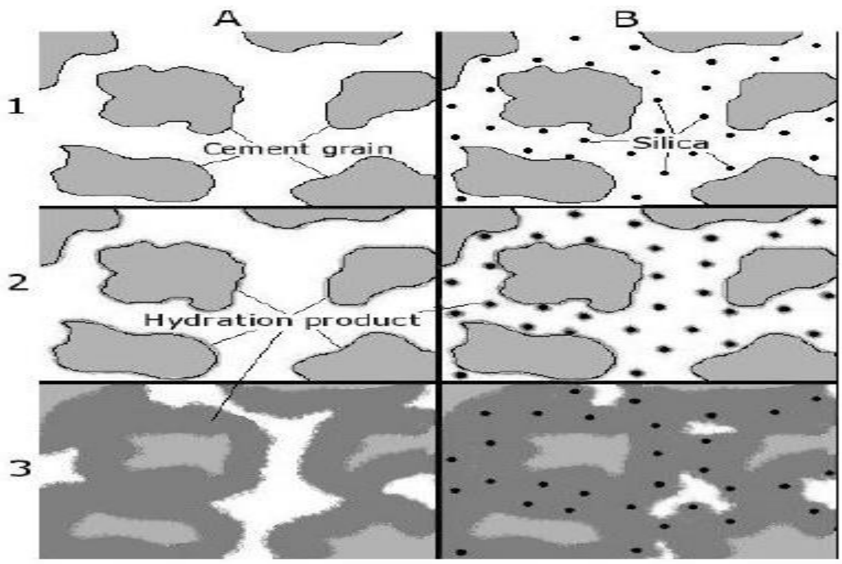
The implementation of nanotechnology in concrete has led to an active incorporation of Nanosilica in concrete in a global level. Different method of Nanosilica production is available and varies from expansive to cost-effective routes. Nanosilica particles sizes and their chemical and physical nature depend on method of production. Several types of dispersed Nanosilica are recommended to be used in concrete. However, the dry powders of Nanosilica particles are difficult to be dispersed in concrete and require special types or family of nano super plasticizer. The effective addition of NS leads to C-S-H with improved cementations properties.



Particle size and SSA related to concrete partilces [Sobolev et al. 2005]

Figure 1.2: Particle sizes and Specific surface area related to concrete particles

As concrete is most usable material in construction industry it is required to improve its quality. Concrete is a highly heterogeneous material produced by mixture of finely powdered cement, aggregates of various sizes and water with inherent physical, chemical and mechanical properties. Cement can be partially replaced by a number of mineral admixtures such as fly ash, silica fume, metakaoline etc., which have certain properties related to that of cement. By adding the Nano materials, concrete composites with superior properties can be produced. Nanotechnology applied to concrete includes the use of Nano materials like Nanosilica. If Nanoparticles are integrated with cement-based building materials, the new material possesses some outstanding properties. Nanosilica improves the microstructure and reduces the water permeability of concrete thus making it more dense and durable. Use of Nanosilica in HPC improves the cohesiveness between the particles of concrete and reduces segregation and bleeding. Certain problems like longer setting time, lower compressive strength at higher percentages can be overcome by adding Nanosilica. The addition of supplementary cementations materials in the concrete will not only improve the mechanical properties of concrete, but also its workability, alteration in setting times and durability. The pozzolanic activity of Nanosilica is more obvious than that of silica fume. Nanosilica can react with Calcium hydroxide ($Ca\ (OH_2)$) crystals, which are arrayed in the Interfacial Transition Zone (ITZ) between hardened cement paste and aggregates, and produce C-S-H gel. Thus, the size and the amount of calcium hydroxide crystals are significantly decreased, and the early age strength of the hardened cement paste is increased. Nanosilica can behave as a nucleus to tightly bond with cement hydrates. The stable gel structures can be formed and the mechanical properties of hardened cement paste can be improved when a smaller amount of Nanosilica is added. Nanosilica can improve the pressure-sensitive properties of cement mortar. Fly ash concrete with Nanosilica has the higher density and strength also indicating that high strength concrete with Nanosilica has higher flexural strength.



hydration of pure cement (A) and with addition of nanosilica (B) after mixing (1-3) [Land et al. 2011]

Figure1. 3: Hydration of pure cement and hydration of cement with Nanosilica cement

The Nanoparticles of silica act as fillers in the voids or empty spaces. The well dispersed Nanosilica acts as a nucleation or crystallization centers of the hydrated products, thereby increasing the hydration rate, that is, Nanosilica assists towards the formation of smaller size CH crystals and homogeneous clusters of C-S-H composition. Moreover, it was found that Nanosilica improved the strength of the structure.

1.5 RECYCLED AGGREGATES:

Recycled aggregates are aggregates derived from the processing of materials previously used in construction. Examples include recycled concrete from construction and demolition waste material (C&D), reclaimed aggregate from asphalt pavement and scrap types. Coarse *R*ecycled *C*oncrete *A*ggregate (RCA) is produced by crushing sound, clean demolition waste.

The main reasons for increase of volume of demolition concrete / masonry waste are as follows:-

i. Many old buildings, concrete pavements, bridges and other structures have overcome their age and limit of use due to structural deterioration beyond repairs and need to be demolished;
ii. The structures, even adequate to use are under demolition because they are not serving the needs in present scenario;
iii. New construction for better economic growth;
iv. Structures are turned into debris resulting from natural disasters like earthquake, cyclone and floods etc.
v. Creation of building waste resulting from manmade disaster/war.

The aim of the project is to determine the strength and durability characteristics of normal and recycled aggregate concrete with nano-silica for application in structural concrete, which will give a better understanding of the properties of concrete with recycled aggregates, as an alternative material to coarse aggregate in structural concrete.

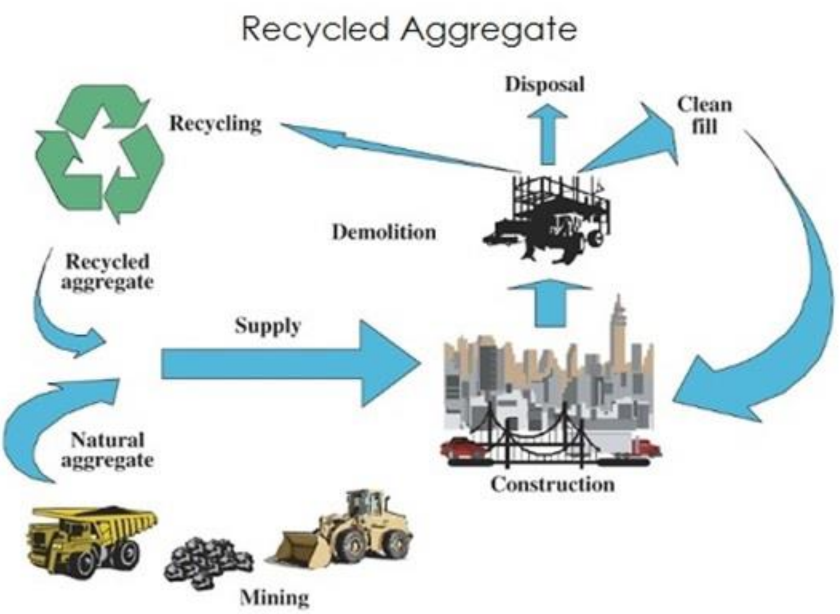


Figure1.4: Recycling process of RCA

Recycling is the act of processing the used material for use in creating a new material. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of normal aggregates, recycled aggregates can be used as the replacement materials. These materials are generally from buildings, roads, bridges and sometimes even from catastrophes, such as wars and earthquakes. Due to the critical shortage of natural aggregates, the availability of demolished concrete for use as recycled concrete (RCA) is increasing. Recycled aggregates are the materials for the future. The application of recycled aggregates has been started and increased in many countries for construction projects.

Applications of Recycled Aggregates

Traditionally, the application of recycled aggregates is used as landfill. Nowadays, the application of recycled aggregates in construction areas is wide. The applications are different from country to country.

- Concrete kerbs
- Granular Base course
- Embankment fill materials
- Paving blocks
- Backfill materials
- Building blocks

Advantages of Recycled Aggregates

There are many advantages using the recycled aggregates. The advantages that occur through usage of recycled aggregates are listed below:

- Environmental gain:

The major advantage is based on the environmental gain. According to CSIRO, construction and demolition waste makes around 40% of the total waste produced each year (estimated around 14million tons) going to landfill. By recycling these materials, it can keep diminishing the resources of urban aggregates. Therefore, natural aggregates can be used in higher grade applications.

- Save energy:

The recycling process can be done on site. According to Kajima technical research institute (2002), Kajima, is developing a method of recycling crushed aggregate that was used in construction, known as the within site recycling system. Everything can be done on the construction site through this system, from the process of recycled aggregate, manufacture and use them. This can save energy to transport recycled materials to the recycling plants.

- Cost :

Secondly, it is based on the cost. The cost of the recycled aggregate and virgin aggregate. According to According to the PATH Technology Inventory, the costs of recycled aggregate are sold around $3.50 to $7.00 per cubic yard. It depends on the aggregate size limitation and local availability. This is just around half of the cost for natural aggregate used that is used in the construction works. The transportation cost for the recycled aggregate is reduced due to the weight of recycled aggregate is lighter than virgin aggregate. Concrete network stated that recycling concrete from the demolition projects can save the cost of transporting the concrete to landfill (around $0.25 per ton/mile), and the cost of disposal (around $100.00 per ton). Besides that, aggregate advisory service also stated that the recycling site may accept the aggregate materials at lower cost than landfill without tax levy and recycled aggregate can be used at a lower price than primary aggregates in the construction works

- Sustainability:

The amount of waste materials used for landfill will be reducing through usage of recycled aggregate. This will reduce the amount of quarrying. Therefore this will extend the lives of natural resources also extend the lives of sites that area using for landfill.

Disadvantages of Recycled Coarse Aggregates

- Lack of specifications and guidelines:

There is no specification or guidelines when using recycled concrete aggregate in the constructions. In many cases, strength characteristics will not meet the requirement when using recycled concrete aggregate. Therefore, more testing should be considered when using recycled concrete aggregate.

- Water pollution:

The recycled process will cause water pollution. Morris of National Ready Mix Concrete Association had mentioned that the wash out water with high pH is a serious environmental issue. According to Building Green (1993). The alkalinity level of wash water from the recycling plants is OW. This water is toxic to the fish and other aquatic life.

1.6 MANUFACTURED SAND (M-sand):

Manufactured sand (M-Sand) is a substitute of river sand for concrete construction. Manufactured sand is produced from hard granite stone by crushing. The crushed sand is of cubical shape with grounded edges, washed and graded to as a construction material. The size of manufactured sand (M-Sand) is less than 4.75mm.

Why Manufactured Sand is used?

Manufactured sand is an alternative for river sand. Due to fast growing construction industry, the demand for sand has increased tremendously, causing deficiency of suitable river sand in most part of the word.

Due to the depletion of good quality river sand for the use of construction, the use of manufactured sand has been increased. Another reason for use of M-Sand is its availability and transportation cost.

Since manufactured sand can be crushed from hard granite rocks, it can be readily available at the nearby place, reducing the cost of transportation from far-off river sand bed.

Thus, the cost of construction can be controlled by the use of manufactured sand as an alternative material for construction. The other advantage of using M-Sand is, it can be dust free, the sizes of m-sand can be controlled easily so that it meets the required grading for the given construction.

Advantages of Manufactured Sand (M-Sand)

It is well graded in the required proportion.

It does not contain organic and soluble compound that affects the setting time and properties of cement, thus the required strength of concrete can be maintained.

It does not have the presence of impurities such as clay, dust and silt coatings, increase water requirement as in the case of river sand which impair bond between cement paste and aggregate. Thus, increased quality and durability of concrete.

M-sand is obtained from specific hard rock (granite) using the state-of-the-art International technology, thus the required property of sand is obtained.

M-Sand is cubical in shape and is manufactured using technology like High Carbon steel hit rock and then ROCK ON ROCK process which is synonymous to that of natural process undergoing in river sand information.

Modern and imported machines are used to produce M-Sand to ensure required grading zone for the sand.

Properties of Manufactured Sand for Concrete Construction

- Higher Strength of concrete

The manufactured sand has required gradation of fines, physical properties such as shape, smooth surface textures and consistency which make it the best sand suitable for construction. These physical properties of sand provide greater strength to the concrete by reducing segregation, bleeding, honeycombing, voids and capillary.

Thus required grade of sand for the given purpose helps the concrete fill voids between coarse aggregates and makes concrete more compact and dense, thus increasing the strength of concrete.

- Durability of concrete

Since manufactured sand (M-Sand) is processed from selected quality of granite, it has the balanced physical and chemical properties for construction of concrete structures.

This property of M-Sand helps the concrete structures withstand extreme environmental conditions and prevents the corrosion of reinforcement steel by reducing permeability, moisture ingress, and freeze-thaw effect increasing the durability of concrete structures.

- Workability of concrete

Size, shape, texture play an important role in workability of concrete. With more surface area of sand, the demand for cement and water increases to bond the sand with coarse aggregates.

The control over these physical properties of manufacturing sand make the concrete require less amount of water and provide higher workable concrete. The less use of water also helps in increasing the strength of concrete, less effort for mixing and placement of concrete, and thus increases productivity of construction activities at site.

- Less Construction Defects

Construction defects during placement and post-concreting such as segregation, bleeding, honeycombing, voids and capillarity in concrete gets reduced by the use of M-Sand as it has optimum initial and final setting time as well as excellent fineness.

- Economy

As discussed above, since usage of M-Sand has increased durability, higher strength, reduction in segregation, permeability, increased workability, decreased post-concrete defects, it proves to be economical as a construction material replacing river sand.

It can also save transportation cost of river sand in many cases.

- Eco-Friendly

Usage of manufactured sand prevents dredging of river beds to get river sand which may lead to environmental disaster like ground water depletion, water scarcity, threat to the safety of bridges, dams etc. to make M-Sands more eco-friendly than river sand.

1.7 NECESSITY OF PRESENT STUDY

This study aims to reduce the environmental problems which are generated from dumping the construction and demolition wastes. This can be achieved by recycling the construction and demolition wastes to produce concrete mixes for structural elements with high performance as natural aggregate.

Concrete is mixture of cement, sand and aggregates. Properties of aggregate affect the durability and performance of concrete, so coarse aggregate is an essential component of concrete. It is therefore, important to obtain right type and good quality aggregate at site, because the aggregate forms the main matrix of concrete or mortar.

The increased use of cement is essential in attaining a higher compressive strength. But, cement is a major source of pollution. The use of nano materials by replacement of a proportion of cement can lead to a rise in the compressive strength of the concrete as well as a check to pollution. Since the use of a very small proportion of nano-silica can affect the properties of concrete largely, a proper study of its microstructure is essential in understanding the reactions and the effect of the Nanoparticles.

Recycling is the act of processing the used material for use in creating a new material. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of normal aggregates, recycled aggregates can be used as the replacement materials. These materials are generally from buildings, roads, bridges and sometimes even from catastrophes, such as wars and earthquakes. Due to the critical shortage of natural aggregates, the availability of demolished concrete for use as recycled concrete is increasing.

Recycled aggregates are the materials for the future. The application of recycled aggregates has been started and increased in many countries for construction projects.

Manufactured sand is an alternative for river sand. Due to fast growing construction industry, the demand for sand has increased tremendously, causing deficiency of suitable river sand in most part of the word.

Due to the depletion of good quality river sand for the use of construction, the use of manufactured sand has been increased. Another reason for use of M-Sand is its availability and transportation cost.

The recycling of Construction and Demolition Wastes has long been recognized to have the potential to conserve natural resources and to reduce energy used in production.

1.8 OBJECTIVES

- To Study the physical and mechanical performance of recycled aggregate used in concrete.
- To check the possibility of using recycled aggregate in concrete mixes.
- The bonding strength can be investigated between reinforcement bars and concrete from recycled aggregate.
- To optimize the ratio of recycled aggregate to natural aggregate which produce better result of concrete mix.
- To investigate the response of recycled concrete aggregate in M35 grade of concrete and by using 1.5% Nanosilica by weight of cement and studying the mechanical and physical of concrete in compression, tension and flexure.
- To evaluate the compressive strengths at 3, 7 and 28 days for all the mixes used in the investigation.
- To evaluate the split tensile strengths at 3, 7 and 28 days for all the mixes used in the investigation.
- To evaluate the flexural strengths at 3, 7 and 28 days for all the mixes used in the investigation.
- To study the microstructure of the concrete using SEM (Scanning Electron Microscopy) and XRD (X-ray Diffraction).
- To evaluate the workability characteristics in terms of slump cone test for all the different types of mixes used in the investigation
- To study the durability test like acid exposure and permeability test.

1.9 ORGANISATION OF THE DISSERTATION

- The Chapter 1 presents the general introduction to concrete, necessity of Nano- silica and recycled aggregates, advantages of recycled aggregates, alternative use of sand i.e. M-sand, necessity of the project, objectives and finally organization of the study.
- The Chapter 2 deals with the review of literatures i.e. the work done by various researchers in the field of recycled concrete using nanomaterials.
- The Chapter 3 discusses about the methodology and experimental investigation.

2. LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter the works of various authors on the use of nano materials and recycled coarse aggregate in concrete has been discussed in brief. A great number of researches have been performed to understand the nature of nano materials and their effect on the properties of concrete. A number of Research & Development works dealing with the use of nano materials like nano-silica, colloidal nano-silica (CNS), Al2O3, TiO2, ZrO2, Fe2O3, carbon nanotubes (CNT) in cement based materials are discussed in the literature. Various research & development works dealing with the strength, durability and microstructure of nano- silica were studied. The Pozzolanic activity of the material is essential in forming the C-S-H gel and hence the CH crystals are prevented from growing and their number reduces. Thus the early age strength of hardened cement paste is increased. This chapter which will highlight the significances of each work. Out of the numerous works done in the field only a few relevant works have been highlighted in the next section.

2.2 LITERATURE REVIEW:

1) Haider A Ibrahim*, Mohammed B Mahdi, Basim J Abbas. (2020)

This research investigates on the performance Evaluation of Fiber and Silica fume on Pervious Concrete Pavements Containing Waste Recycled Concrete Aggregate. The employment of Recycled Coarse Aggregates (RCA) from site of construction and destruction wastes to product green concrete as a sustainable solve with varied environmental interests.

The test results shows that the use of RCA slightly affect hydraulic conductivity and little effect on compressive, tensile, and flexural strengths where the use of silica fume and glass fibers more strong effect on the hydraulic conductivity and positive effect on pervious concrete flexural, splitting tensile strengths.

2) Rajeeb Kumar1,Shilpa Pal2, Neelesh Jadaun3, Rohit3 . (2019)

PERFORMANCE OF POLYMER TREATED RECYCLED CONCRETE AGGREGATE UNDER DIFFERENT CURING CONDITION OF CONCRETE. This study has been conducted to evaluate its applications in structural concrete. Study has been carried out to enhance the performance of recycled aggregate by improving its water absorption by treatment with polymer. Hardened concrete properties of recycled concrete aggregates for M35 grade under different types of curing i.e. Normal curing, Open-air curing and Polythene curing has been done. Experimental investigation has been carried out at various replacements (i.e. 100% natural coarse aggregate, 100% recycled concrete coarse aggregate, and 100% Polymer treated recycled concrete coarse aggregate). Also, the durability studies such as water absorption and water permeability of the recycled concrete aggregate specimens has been carried out.

This study concludes that the hardened concrete properties, water absorption and water permeability improves after the treatment of RCA which makes the TRCA concrete more durable and also improve the strength as compared to RCA concrete.

3) QuanminPenga,b,⇑, Li Wang a, Qun Lu a,c (2018)
To investigate the influence of recycled coarse aggregate (RCA) content on the fatigue performance of recycled aggregate concrete (RAC), an experiment about compressive fatigue residual strength on RAC with different replacement percentages was conducted. The results show that fatigue life, residual strength, and residual stiffness all decrease with an increase in RCA replacement percentage, with the smallest effect on stiffness. The residual strength and stiffness degradation curves of RAC were obtained by regression analysis and the replacement percentage effect on degradation laws was discussed. The fatigue life, residual strength, and residual secant modulus all decrease with an increase in RCA replacement percentage, but to differing degrees.

4) Sidam Gangaram1 Vankadothu Bhikshma2 Maganti Janardhana3 (2018):
The recycled aggregate concrete (RAC) is very much required to preserve the natural resources for future generation. Study on recycled aggregate is having high significance as the concrete contains 60 to 80% with coarse aggregates.. Strength and durability studies pertaining to Recycled Aggregate Concrete (RAC) of M20 and M30 grades made by replacing 100 % virgin aggregates with recycled aggregates are presented. The results of compressive strength test, split tensile strength, flexural strength and permeability tests are presented . The study shows that 100% replacement of natural aggregate with recycled coarse aggregates gives satisfactory results for M20&M30. So the replacement is of much benefit and shall be encouraged to achieve higher grades of concrete.

5) Nagaraja Ba, Vinay K V a, KeerthiGowda B S a, Karisiddappa b.(2017)
In the present study crushed concrete cube debris of size 20 mm sieve passed and 10 mm sieve retained) are used as coarse aggregates for the production of cement concrete in economical way. Here compressive strength of conventional concrete is compared with crushed concrete debris embedded plain cement concrete. Percentage of replacement of debris is varied from 10, 20, 25, 30, 35, 40, 50 and 100 to compare the compressive strength results among them. 30 % replacement of debris for conventional coarse aggregate recorded the highest compressive strength of 31.11 MPa. Compressive strength of debris embedded concrete showed higher compressive strength compared to conventional concrete. Also, a plain cement concrete embedded with debris and 10 mm long raw Banana fibers (1% of cementitious material) recorded highest compressive strength compared to other concrete.The experiment results showed high values of water absorption and moisture content for all the recycledaggregates concrete. Here the mortar adhered it is more porous, thus absorbs more water is the mainfactor contributing towards decrease of compressive strength.

6) MarcoPepe a, Romildo Dias Toledo Filho b, Eduardus A.B. Koenders c, Enzo Martinelli (2016)
This paper proposes a conceptual formulation for predicting and controlling the compressive strength of Recycled Aggregate Concrete (RAC) mixtures, by explicitly taking into account the specific features of Recycled Concrete Aggregates (RCAs).Therefore, the formulation proposed herein is intended at generalizing the aforementioned rules with the aim to take into account the higher porosity of RCAs. Although being a mainly conceptual methodology, the proposed formulation is supported by a wide set of experimental results: they unveil the influence of several aspects and parameters (such as source and processing procedures of RCAs, aggregate replacement ratio, water-to-cement ratio, water absorption capacity and initial moisture condition of aggregates) on the resulting compressive strength of RAC. Finally, the proposed mix design methodology demonstrates that the resulting compressive strength of RACs can be predicted by taking into account only one parameter (i.e., water absorption capacity) identifying the ‘‘quality” of RCAs. Further generalizations intended at controlling other physical and mechanical parameters of RAC are among the future development of this research..

7) Shi-cong Kou a,b, Chi-sun Poon a,⇑(2015)
This paper presents the experimental results of a study on the effect of the quality of parent concrete (PC) on the properties of recycled aggregates (RAs) that are derived from them, and on the mechanical and durability properties of normal strength and high performance recycled aggregate concrete (NSRAC and HPRAC). PC with strength grades ranging from 30 to 100 MPa was crushed to the size of coarse aggregates (<20 mm), and then used to produce new NSRAC and HPRAC mixes. The results indicated that the compressive strength of the NSRAC and HPRAC prepared with RA derived from 80 and 100 MPa PCs was similar or slightly higher than that of natural aggregate concrete. Moreover, the concrete mixtures made with RA are derived from parent concrete with higher strength had lower drying shrinkage and higher resistance to chloride ion penetration. The RA derived from 80 and 100 MPa PCs can be used to replace 100% natural aggregates for the production of high performance concrete.

8) Mukharjee and Barai (2014) studied the compressive strength and characteristics of Interfacial Transition Zone (ITZ) of concrete containing recycled aggregates and nano- silica. An improvement in the compressive strength and microstructure of concrete was observed with the incorporation of nano-silica.

9) Dr.s.elavenil (2013)
In this paper Scarcity of good quality Natural River sand due to depletion of resources and restriction due to environmental consideration has made concrete manufactures to look for suitable alternative fine aggregate. One such alternative is “Manufactured sand” A durable concrete covers and bears the responsibility of sustaining the entire R.C.C. structure throughout it service life. A well processed manufactured sand as partial or full replacement to river sand is the need of the hour as a long term solution in Indian concrete industry until other suitable alternative fine aggregate are developed. This contributed to the better binding effect with the available cement paste and improved the compressive strength.

10) Surya Abdul Rashid et al. (2011) worked on the effect of nano-silica particle on both mechanical properties (compressive, split tensile and flexural strength) and physical properties (water permeability, workability and setting time) of concrete which shows that binary blended concrete with nano-silica particles up to 2% has significantly higher compressive, split tensile and flexural strength compared to normal concrete. Another inference drawn was that partial replacement of nano-silica particles decreases the workability and setting time of green concrete for samples cured in lime solution.

11) Mahdi Koushkbaghia, PedramAlipourb, BehzadTahmouresic, EhsanMohsenid,⇑, AshkanSaradarc,Prabir Kumar Sarkere. (2019)

Influence of different monomer ratios and recycled concrete aggregate on mechanical properties and durability of geopolymer concretes.

Properties of geopolymer concrete using metakaoline (MK) as the alumino silicate source and recycled concrete aggregate (RCA) as partial replacement of natural aggregate is presented in this paper. The probability of occurrence of corrosion of specimens with a monomer ratio of 2 was in the range of low to medium and that with increasing the proportion of sodium silicate to sodium hydroxide was in the low range. Images of electron microscopy of hardened geopolymer paste confirmed the significant increase in density and uniformity of polymer products in the presence of suitable monomer ratios. It was confirmed that the geopolymer concretes incorporating RCA indicated a reduction in compressive strength of around8%–28%, in comparison to the mixtures with the same monomer ratio. It is noteworthy to mention that the compressive strength achieved was still high enough for structural applications

12) Lee and Ryou (2014)

The focus of the study was on characterizing recycled coarse aggregate (RCA) using a surface coating method. When RCA was utilized in concrete, the high porosity of the recycled aggregate required the addition of water, which led to a decrease in workability during transportation. Consequently, the workability of recycled aggregate concrete (RAC) was found to be lower compared to other materials. The results demonstrated that as the replacement percentage of crushed recycled coarse aggregate (CRCA) increased, the changes in slump values became less pronounced. In terms of mechanical properties, all the concrete mixes, except for the control using 100% natural aggregates (RCA), exhibited comparable or higher compressive and tensile strengths. This suggests that incorporating CRCA in concrete did not significantly compromise the overall strength performance. The findings highlight the potential of utilizing recycled coarse aggregates in concrete production, as the modified surface coating method helped improve the workability and maintain or enhance the mechanical properties of the RAC. This research contributes to advancing sustainable construction practices by promoting the use of recycled materials, reducing waste, and minimizing the environmental impact associated with concrete production.

13) Adday et al.(2018)

This research involved conducting experimental investigations on four types of concrete mixtures to assess the production of high-early strength concrete pavement using recycled coarse aggregates (RCA) with the addition of virgin silica. The objective of the study was to examine the impact of incorporating virgin silica into recycled concrete pavement aggregate on concrete properties and determine the maximum percentage that can be used in concrete. The investigations focused on evaluating the mechanical and physical properties of recycled concrete aggregate with and without silica, comparing them to natural aggregate concrete. Based on the obtained density of 24 kN/m3, the concrete was classified as dense concrete. Compressive strength and split tensile strength tests were performed on the materials, and the results were recorded at 7, 14, and 28 days of curing. The use of RCA and natural aggregate (NA) mixed with virgin silica resulted in an early strength of 37.5 MPa after 7 days of curing. For road construction, slump values ranging from 25 to 50 mm were recommended. The results showed variations in slump values between 38 and 47 mm for concrete mixtures with different compositions of RCA ranging from 0 to 75%. Overall, the findings of the study demonstrated the influence of incorporating virgin silica into recycled concrete pavement aggregate on the mechanical properties of the resulting concrete. The past tense of the research findings indicates that the experiments and analyses have already been conducted and the results have been obtained.

14) Kien et al.(2018)

This study aimed to enhance the quality of 100% coarse recycled concrete aggregate (RCA) by introducing new treatment solutions involving pozzolanic materials and sodium silicate solution. The performance of the treated RCA was evaluated using a new mixing procedure, and its mechanical properties were assessed under various conditions. The study focused on investigating the impact of the new treatment solutions on the mechanical abilities of the RCA. The results of the study revealed significant improvements in the mechanical properties of the 100% coarse RCA when treated with a combination of sodium silicate and pozzolanic materials. By utilizing a 20% concentration of sodium silicate and silica fume, the compressive strength of the treated RCA increased by up to 36%. These findings highlight the effectiveness of the approach in enhancing the strength of RAC and suggest its potential application in treating RCA for concrete production in the future. Overall, this study provides valuable insights into the use of novel treatment solutions and a modified mixing procedure to enhance the mechanical properties of 100% coarse RCA. The results indicate the feasibility of implementing this approach to improve the quality and performance of recycled concrete aggregates, offering promising prospects for the utilization of RCA in concrete applications.

15) Sahu et al.(2021)

In this experimental study, the focus was on enhancing the mechanical and microstructural properties of recycled aggregate concrete (RAC) by incorporating a colloidal nano-silica (CNS) admixture. CNS particles are highly reactive and can generate C-S-H gel when ombined with hydrated cement. This gel effectively fills microvoids and cracks in RAC, leading to an improved interfacial transition zone (ITZ). The experimental investigation involved 100% replacement of natural coarse aggregate (NCA) with recycled coarse aggregate (RCA) and partial replacement of cement with CNS at varying percentages (0%, 1%, 2%, and 4% by weight). Through detailed analysis of the experimental results, it was observed that the substitution of cement with CNS, both in NAC and RAC mixes, had a positive impact on the mechanical and microstructural characteristics of the concrete. Significant improvements were observed, including a reduction in voids and enhancement of the ITZ. Even with 100% RCA and partial replacement of cement with CNS, the concrete mixes met the design requirements for construction industry applications.

16) Tam et al.(2021)

This paper presented an overview of various methods employed in the past to enhance the properties of recycled aggregate. These methods included autogenous healing, autonomous healing, bacterial and micro-encapsulation techniques, as well as two-stage mixing approaches. The aim of these methods was to improve the permeability, durability, and nano mechanical properties of the recycled aggregate. Different strategies were explored to reduce voids and the calcium hydroxide (Ca(OH)2) content in the recycled aggregate. Mechanical grinding, heat grinding, pre-soaking in water or acid, and microwave-assisted mortar removal were some of the techniques used to remove or strengthen weak parts and mortar layers in the recycled aggregate. Furthermore, the utilization of mineral admixtures such as fly ash, silica fume, metakaolin, and ground granulated blast furnace slag was investigated to enhance the properties of the recycled aggregate. These admixtures were found to contribute to improved interfacial transition zones and nano mechanical properties. Each method had its own set of advantages and disadvantages, and their effectiveness varied depending on the specific application. The research provided insights into the potential of these methods in the past for improving the performance of recycled aggregate.

17) Wang et al.(2021)

This study presented a comprehensive review of recycled aggregate (RA) and recycled aggregate concrete (RAC), focusing on their historical background, recycling and reuse processes, manufacturing methods, as well as inherent defects such as the presence of additional interfacial transition zones in RAC. The review also examined the properties of RAC, including its workability in fresh concrete, physical and chemical characteristics such as density, carbonation depth, and chloride ion penetration, mechanical properties including compressive, flexural, and splitting tensile strength, as well as elastic modulus, and long-term performance factors such as resistance to freezing-thawing, alkali-silica reaction, creep, and dry shrinkage. Through the review, various aspects of RAC and RA were evaluated based on past research and findings. The study discussed the challenges and limitations associated with these materials, as well as their potential benefits in sustainable construction practices. By analyzing the properties and performance of RAC, the review aimed to provide a comprehensive understanding of the material and its suitability for different applications in the construction industry.

18) Yan et al.(2022)

In this study, the aim was to enhance the surface properties of recycled aggregates by treating them with a nano-silica slurry and applying them to concrete beam specimens. The self-healing performance of cracks and the resistance to chloride ingress in recycled concrete beams were investigated under the influence of cracks caused by continuous loading and drying-wetting cycles. The study examined the effects of different levels of recycled aggregate additions, nano-silica contents, and crack widths on the self-healing capability of cracks and the resistance to chloride ingress. It was observed that the self-healing rate of cracks initially increased and then decreased as the nano-silica content increased, with the maximum rate achieved at a content of 0.4%. Higher amounts of additive in the recycled aggregate led to increased concentrations of free chloride ions in cracks. However, this concentration was found to be mitigated in the case of nano-reinforced aggregate. Taking a comprehensive perspective, controlling the crack width to be smaller than 0.12 mm and utilizing improved recycled aggregates treated with 0.2% nano-silica material proved to be effective in reducing the relative chloride ion concentration. These findings highlight the potential of nano-silica treatment in enhancing the self-healing properties and chloride resistance of recycled concrete, offering insights for future applications and design considerations.

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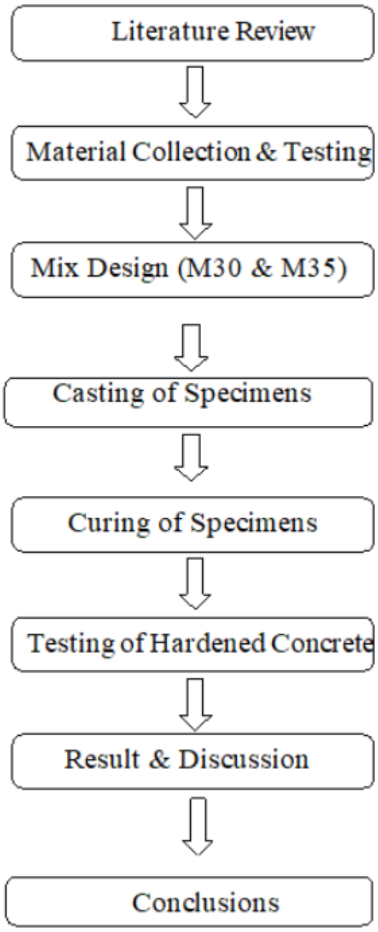
3. METHODOLOGY AND EXPERIMENTAL INVESTIGATION

3.1 GENERAL

In this chapter, methodology of the project is discussed



Experimental investigation was planned to provide sufficient knowledge about the strength and durability characteristics on 40% use of recycled aggregate concrete with 1.5% of Nanosilica to cement weight and M-sand as fine aggregate. Tests were conducted on materials to know their physical properties. Results were analyzed to derive useful conclusions regarding the strength behaviour of the recycled aggregates with nano-silica and M-sand as a fine aggregate replacement. M30 and M35 design mixes were adopted. The design mixes are presented in Appendix.

Two different grades of similar mixes were employed to examine the influence of recycled coarse aggregate with Nanosilica and M-sand

The two mixes are as follows:

1. RAC M30 grade concrete
2. RAC M35 grade concrete

The above two mixes were conventionally cured. The water binder ratio for the mixes is considered as 0.43, 0.395 for RAC M30, M35 respectively. Several trail mixes were done in order to achieve the required target mean strength for the above mixes.

Fresh concrete tests such as Slump flow value, Compaction factor value are investigated. Hardened concrete tests such as compressive strength for cubes (150mm x 150mm x 150mm); Split tensile strength for cylinders (150mm x 300mm), flexural strength for prisms (500mm x 100mm x 100 mm), were done at 3,7 & 28 days. And permeability test on concrete cylinders (100mm x100mm), after 28days curing was conducted. In addition to this bond strength tests of cubes were tested after 28 days of curing of 150mm x 150mm x 150mm cubes. For acid attack, cubes (100mm x 100mm x 100mm), were cured for 28 days and then exposed to 0.1% and 0.3% of acidic solution. The cubes are then tested for weight loss and Residual compressive strength. And microstructure studies like SEM and XRD test were done on powdered concrete.

Table 3.1 Specimens cast for strength and durability tests

Name of the Test	**RAC M30**	**RAC M35**
Number of cubes cast for compressive strength	9	9
Number of cylinders cast for split tensile strength	9	9
Number of prisms cast for flexural strength	9	9
Number of cylinder for permeability	3	3
Number of cubes cast for acid attack	24	24
Total number of sample cast	54	54

Total number of samples cast for the present work: 108

3.2 MATERIALS USED AND TEST

Cement

Ramco PPC was used. Physical Properties of Cement are shown in Table 3.2

Fine Aggregate

M-sand of Zone-II was used. The properties of normal sand is shown in Table 3.3

Coarse Aggregate

40% of recycled coarse aggregate of demolished structures of 20mm passing and retained on 10mm sieve were used and Crushed granite metal were subdivided into another 40% of passing 20 mm and retained on 10 mm sieve and 60 % passing 10mm and retained on 4.75 mm sieve was used. The details of both recycled and crushed aggregate and their properties are shown in Tables- 3.5to 3.8

Water

Potable fresh water, which is free from acid or organic substances, was used for mixing the concrete.

Admixture

Nanosilica CEM SYN XLP type is used. The properties of Nanosilica were shown in Table 3.9

3.2.1 CEMENT

Cement is the binding material in cement concrete .Cement is produced by intimate mixing of calcareous, siliceous and aluminous substances at high temperatures and crushing the resultant clinkers to a fine powder. Cement is the most expensive ingredient in concrete and is available in a variety of different forms. The properties of cement depend upon the chemical composition, the process of manufacture and the degree of fineness to which they are ground. When cement is mixed with water, a chemical reaction takes place as a result of which the cement paste first sets and then hardens to a stone like mass. Depending upon their chemical composition, setting and hardening properties, cements can be broadly divided in the following two categories:

1. Portland Cement
2. Special Cement

Portland cement

This is a most widely used type of cement and is so named because of the resemblance of its properties with a well-known natural stone quarried at Portland (U.K). Joseph Aspdin, a Yorkshire is regarded as the discoverer of Portland cement.

Composition of Portland cement

Lime, silica and alumina are considered to be the three principal constituents of cement. In addition most of the cement contains iron oxide, magnesia, sulphur trioxide and alkalis in small proportions. Cement is manufactured by burning to white heat an intimate mixture of the above ingredients and then grinding the resulting clinkers with gypsum to an extremely fine powder. The magnitudes of the different constituents in the comparison of cement are:

Lime (Ca0)	---	60 to 67%
Silica ($Si0_2$)	---	17 to 25%
Alumina (Al_2O_3)	---	3 to 8%
Iron oxide (Fe_2O)	---	0.5 to 6%
Magnesia (Mg0)	---	0.1 to 4%
Sulphur trioxide (SO_3)	---	1 to 2.75%
Alkalis (Soda and Potash)	---	0.5

Pozzolanic materials like fly ash is waste materials emitted from industries to control the pollution to environment these effluents from industries are trapped and they are ground granulated and mixed with Ordinary Portland Cement to form a Special type of cement called Portland Pozzolana Cement. By production of Ordinary Portland Cement large amount of pollutants are released from cement industries to reduce this we add Pozzolanic material and produce Portland Pozzolanic Cement which is finer than OPC and have a good durability properties.

Types of Portland cement

Portland cement can be further sub-divided in to the following types. The difference in the properties of the various types of cement is basically on account of variance in the proportions of its ingredients and degree of fineness to which the clinkers are ground.

- **i.** Ordinary Portland cement
- **ii.** Portland Pozzolana cement
- **iii.** Rapid hardening Portland cement
- **iv.** Low-heat Portland cement
- **v.** White or colored Portland cement
- **vi.** Sulphate resisting Portland cement
- **vii.** Water-repellent Portland cement
- **viii.** Portland blast furnace cement

Portland Pozzolana cements (IS: 1489-Part-1: 1991).

This cement is the combination of OPC and Pozzolanic material (fly ash), which is produced by partial replacement of fly ash emitted industries. Which is finer than OPC, Setting time of PPC is more than OPC. Specifications of Portland Pozzolana Cement was given in IS: 1489(Part-1): 1991.

Specific Gravity Test (IS: 2720 - Part III: 1980).

Specific gravity is the ratio of the density of a substance compared to the density (mass of the substance per unit volume) of a reference substance. Apparent specific gravity is the ratio of the weight of a volume of the substance to the weight of an equal volume of the reference substance.

Fineness Test (IS: 4031-1968).

Fineness is the ratio of residual cement on the sieve per initial weight of the sample, Retained sample on the sieve should not be more than 10% of the total weight.

Importance of cement fineness;

1. The fineness of cement affects hydration rate, and in turn, the strength. Increasing fineness causes an increased rate of hydration, high strength, and high heat generation.
2. Bleeding can be reduced by increasing fineness. However, increased fineness can also lead to the requirement of more water for workability, resulting in a higher possibility of dry shrinkage.

3. The increased surface area-to-volume ratio will ensure a more available area for water-cement interaction per unit volume.

Fineness of cement can be determined by two methods.

1. By sieving.

2. by determination of specific surface (total surface area of all particles in gm of cement) by air permeability apparatus.

Standard consistency Test (IS: 4031- 1988 Part IV)

The standard consistency of a cement paste is defined as that consistency which will permit the Vicat plunger to penetrate to a depth of 5mm to 7mm from the bottom of the mould. The standard consistency of a cement paste is also called normal consistency. The parameter standard consistency is used to find out the initial setting time, final setting time and soundness of cement.

Initial Setting and Final Testing Time Test: (IS: 4031-1988 Part V)

Initial setting time of concrete is the time period between additions of water to cement till the time at 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5mm to 7mm from the bottom of the mould. Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould.

Initial setting time of should not be less than 30min and final setting time of cement should not be greater than 600min.

Compressive strength of cement: (IS: 1489 Part II – 1991)

Compressive strength of cement is determined from mortar cubes of size (7.07x7.07x 7.07) cm and cement to M- sand ratio 1:3. The strength is obtained after 3, 7 and 28 days. The strength obtained on 28th day is called compressive strength of cement.

3.3 AGGREGATES

Aggregates are those chemically inert materials which when bonded by cement paste form concrete. Aggregates constitute the bulk of the total volume of concrete and hence they influence the strength of concrete to a great extent. Aggregate is derived from igneous, sedimentary and metamorphic rocks or is manufactured from clays, slag etc. The properties of concrete are directly related to those of its constituents and as such aggregate used, in a concrete mix should be hard, strong, dense, and durable. And free from injurious amounts of clay, loam, vegetable and other such foreign matter. The presence of deleterious substances such as coal, lignite, clay lumps. Soft fragment of foreign materials and other deleterious materials prevent proper adhesion of cement on the surface of aggregates and thus affect the properties of concrete adversely.

Depending upon their size, the aggregates are classified as:

i. Fine aggregate
ii. Coarse aggregate

FINE AGGREGATE

The material below 4.75mm size is termed as fine aggregate. The sum of percentage of all types of deleterious materials in fine aggregate should not exceed 5% Natural sand or crushed stone dust is the fine aggregate chiefly used in concrete mix. Manufactured sand (M-Sand) is a substitute of river sand for concrete construction. Manufactured sand is produced from hard granite stone by crushing. The crushed sand is of cubical shape with grounded edges, washed and graded to as a construction material. The size of manufactured sand (M-Sand) is less than 4.75mm

Manufactured sand is an alternative for river sand. Due to fast growing construction industry, the demand for sand has increased tremendously, causing deficiency of suitable river sand in most part of the word.

Due to the depletion of good quality river sand for the use of construction, the use of manufactured sand has been increased. Another reason for use of M-Sand is its availability and transportation cost.

Since manufactured sand can be crushed from hard granite rocks, it can be readily available at the nearby place, reducing the cost of transportation from far-off river sand bed.

Thus, the cost of construction can be controlled by the use of manufactured sand as an alternative material for construction. The other advantage of using M-Sand is, it can be dust free, the sizes of m-sand can be controlled easily so that it meets the required grading for the given construction.

COARSE AGCREGATE

The material whose particles are of such size as are retained on I.S. sieve No 480(4.75 mm) is termed as coarse aggregate. The size of the coarse aggregate depends upon the nature of work. The maximum size may be 20mm for mass concrete, such as in dams etc. and 30mm for plain concrete work. For R.C.C construction aggregate having a nominal size of 20mm are generally considered satisfactory Crushed hard stone and gravel are the common materials used as aggregates for structural concrete Coarse aggregates are usually obtained by crushing granite, gneiss, crystalline limestone and good variety of sand stone etc. as far as possible flaky and elongated pieces of stone should be avoided. Broken brick is cheap aggregate for plain concrete but it renders the mix weak in strength. It is not used in R.C.C work on account of the possibility of the reinforcement getting rusted due to the high porosity of the aggregate. Clinker slag, coal ashes and coke-breeze are also used as aggregate for light weight and insulating concrete where great strength not desired. Gravel (as obtained from pit or river) or crushed stone contain high percentage of fine material and in this state it is only used for un-reinforced work. However, the sum of percentage of all type of deleterious substances in coarse aggregate should not exceed 5%.

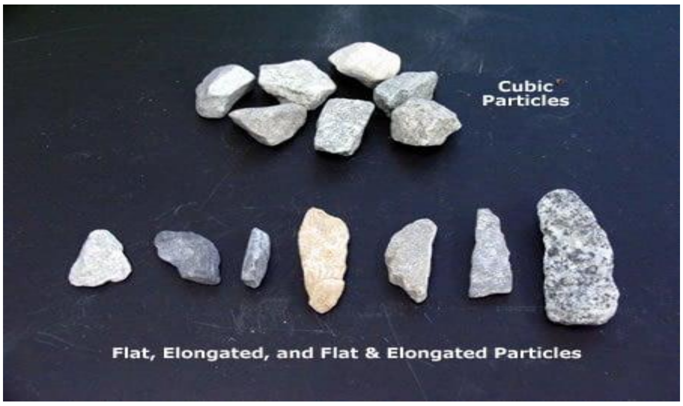
Grading Of Aggregates

This is one of the factors which will have maximum influence on workability. A well-graded aggregate is the one which has the least amount of voids in a given volume. Other factors being constant, when the total voids are less, the excess paste is available to give a better lubricating effect. With an excess amount of paste, the mixture becomes cohesive and fatty which prevents segregation of particles. Aggregate particles will slide past each other with the least amount of compacting efforts. The better the grading, the less is the void content and the higher the workability.

To make a strong, dense, Workable and impervious concrete the mixing of its ingredients has to be such that cement used is sufficient to fill the voids in the fine aggregate (sand) and mortar thus produced is sufficient to fill the voids in the coarse aggregates To achieve this, the fine aggregates as well as the coarse aggregate should be graded suitably so that the smaller particles can occupy the voids between the Large particles and hence the percentage voids is reduced considerably. The reduction in void, results in corresponding reduction in the quantity of mortar required filling the void in the coarse aggregates and hence there is reduction in the quantity of cement required to make the concrete. Thus grading of aggregates is also necessary to have the economy in the production of concrete.

The shape of Aggregates:

The shape of aggregates influences workability in good measures. Angular, elongated or flaky aggregates makes the concrete very harsh when compared to rounded aggregates or cubical shaped aggregates. Contribution to better workability of rounded aggregate will come from the fact that for the given volume or weight, it will have less surface area and fewer voids than the angular of flaky aggregate. Not only that, being round in shape, the frictional resistance is also greatly reduced. This explains the reason why river sand and gravel provide greater workability to concrete than crushed sand and aggregate.



Size of Aggregates:

The bigger the size of the aggregate, the less is the surface area and hence less amount of water is required for wetting the surface and less matrix or paste is required for lubricating the surface to reduce internal friction. For a given quantity of water and paste, the bigger size of aggregates will give higher workability.

Recycled Aggregate

Recycled aggregates are comprised of crushed, graded inorganic particles processed from the materials that have been used in the construction and demolition debris. The aim of the project is to determine the strength and durability characteristics of recycled aggregate with nano-silica for application in structural concrete, which will give a better understanding in the properties of concrete with recycled aggregates, as an alternative material to coarse aggregate in structural concrete.

Recycling is the act of processing the used material for use in creating a new material. The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of normal aggregates, recycled aggregates can be used as the replacement materials.

These materials are generally from buildings, roads, bridges and sometimes even from catastrophes, such as wars and earthquakes. Due to the critical shortage of natural aggregates, the availability of demolished concrete for use as recycled concrete (RCA) is increasing. Recycled aggregates are the materials for the future. The application of recycled aggregates has been started and increased in many countries for construction projects.

Applications of Recycled Aggregates

Traditionally, the application of recycled aggregates is used as landfill. Nowadays, the application of recycled aggregates in construction areas is wide. The applications are different from country to country.

- Concrete kerbs
- Granular Base course
- Embankment fill materials
- Paving blocks
- Backfill materials
- Building blocks

In this investigation normal coarse aggregate was replaced by recycled aggregates by 40% by total weight of normal coarse aggregates.

Water Content:

Water content in a given volume of concrete will have significant influences on the workability. The higher the water content per cubic meter of concrete, the higher will be the fluidity of concrete, which is one of the important factors affecting workability. At the work site, supervisors who are not well versed with the practice of making good concrete, resort to adding more water for increasing workability. During mixing of concrete one cannot arbitrarily increase the water content.

Here is a table showing minimum water content, maximum water cement ratio and minimum grade of concrete for different exposures conditions.

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Table 5 Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(Clauses 6.1.2, 8.2.4.1 and 9.1.2)

Sl No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	-	300	0.55	M 20
iii)	Moderate	240	0.60	M 15	300	0.50	M 25
iii)	Severe	250	0.50	M 20	320	0.45	M 30
iv)	Very severe	260	0.45	M 20	340	0.45	M 35
v)	Extreme	280	0.40	M 25	360	0.40	M 40

NOTES

1 Cement content prescribed in this table is irrespective of the grades of cement and it is inclusive of additions mentioned in 5.2. The additions such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and water-cement ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit of pozzolona and slag specified in IS 1489 (Part 1) and IS 455 respectively.

2 Minimum grade for plain concrete under mild exposure condition is not specified.

Mix Proportions:

Water/cement ratio is an important factor influencing workability. The higher the water/cement ratio, the leaner is the concrete. In lean concrete, less quantity of paste is available for providing lubrication, per unit surface area or aggregate and hence the mobility of aggregate is restrained. On the other hand, in case of rich concrete with lower aggregate/cement ratio, more paste is available to make the mix cohesive and fatty to give better workability.

3.3.1 TESTS CONDUCTED ON AGGREGATES

Sieve analysis (IS: 383- 1970)

A sieve analysis (or gradation test) is a practice or procedure used (commonly used in civil engineering) to assess the particle size distribution (also called gradation) of a granular material. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of inorganic or organic granular materials including sands, crushed rock, clays, granite, feldspars coal and soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing it is probably the most common method.

Fineness modulus

Fineness modulus (FM) is used in determining the degree of uniformity of the aggregate gradation. Fineness modulus is generally used to get an idea of how coarse or fine the aggregate is. It is an empirical number relating to the fineness of the aggregate. More fineness modulus value indicates that the aggregate is coarser and small value of fineness modulus indicates that the aggregate is finer.

FINE AGREGATE	FINENESS MODULUS
Fine sand	2.2-2.6
Medium sand	2.6-2.9
Coarse sand	2.9-3.2

Generally sand having fineness modulus more than 3.2 is not used for making good concrete. The higher the FM is the coarser the aggregate.

Bulk Density (IS: 2386 Part III – 1963)

When dealing with aggregates it is important to know the voids that presents between the aggregate particles, so that we decide whether to fill them with finer aggregate or with cement paste. We all know that the Density we often deal with equal the mass divided by volume, when using this law to measure the density of aggregates the volume we use is the volume of aggregate + the volume of the voids, and, in this case we get a new quantity called the Bulk Density.

Specific Gravity (IS: 2386 Part- III – 1963)

The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. The specific gravity test helps in the identification of stone.

Bulking of Sand (IS 2386 Part-III – 1963)

When dry sand comes in contact with moisture, thin film is formed around the particles, which causes them to get apart from each other. This results in increasing the volume of sand. This phenomenon is known as bulking of sand.

Table -3.2 Physical properties of cement (PPC) (IS 1489 Part-1 - 1991)

S.NO	PROPERTY	VALUE
1.	Specific gravity	2.94
2.	Fineness of cement by sieving	2%
3.	Normal consistency	30
4.	Setting time Initial setting time Final setting time	 168 min 284 min
5.	Compressive strength i. 3days ii. 7days iii. 28days	 16.00 MPa 26.00 MPa 42.01 MPa

Table 3.3 Physical properties of fine aggregate: M-sand

S.NO	PROPERTY	Value
1	Grading of sand	Zone II as per IS 383
2	Specific gravity	2.57
3	Bulk density Loose state Compacted state	 1.77 g/cc 2.00 g/cc
4	Fineness modulus	2.80

Table 3.4 Sieve analysis of Fine aggregate: M-sand

Weight of sample taken = 1000gms

Sl. No	IS Sieve	Weight Retained (g)	% Weight retained	Cumulative % Weight retained	% Passing
1	10mm	0	0	0	100
2	4.75mm	2.1	0.21	0.21	99.79
3	2.36mm	126.5	12.65	12.86	87.14
4	1.18mm	240	24	36.86	63.14
5	600 µm	238.2	23.82	60.68	39.32
6	300 µm	266	26.6	87.28	12.72
7	150 µm	127.2	12.72	100	100
Fineness modulus = 2.98					

With Reference to IS 383-1970 this M-sand confirms to Zone – II

Table 3.5 Sieve Analysis of Recycled Coarse Aggregate

Sl. No	IS Sieve	Weight Retained (Kg)	% Weight Retained	Cumulative % Weight Retained	% Passing
1	80 mm	0.00	0.00	0.00	100.00
2	40 mm	0.00	0.00	0.00	100.00
3	20 mm	292	14.6	14.6	85.4
4	10 mm	1704	85.2	99.8	0.2
5	4.75 mm	2	0.1	99.9	0.1
6	2.36 mm	0.23	0.1	100.00	0.00
7	1.18 mm	0.00	0.00	100.00	0.00
8	600 µm	0.00	0.00	100.00	0.00
9	300 µm	0.00	0.00	100.00	0.00
10	150 µm	0.00	0.00	100.00	0.00
Fineness Modulus = 7.14					

Table 3.6 Physical properties of Recycled Coarse Aggregate

Sl. No	PROPERTY	VALUE
1	Specific gravity	2.74
2	Bulk density Loose state Compacted state	 1.45 g/cc 1.60 g/cc
3	Fineness modulus	6.62
4	Water absorption 1. 20mm	 1.02%

Table 3.7 Sieve Analysis of Coarse Aggregate

S.No.	IS Sieve	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative % Weight Retained	% Passing
1	80mm	0	0	0	100
2	40mm	0	0	0	100
3	20mm	118.5	5.925	5.925	94.075
4	10mm	1881.5	94.075	100	0
5	4.75mm	0	0	100	0
6	2.36mm	0	0	100	0
7	1.18mm	0	0	100	0
8	0.6mm	0	0	100	0
9	0.3mm	0	0	100	0
10	0.15mm	0	0	100	0

Fineness modulus = 7.05925

Table 3.8 Physical properties of Coarse Aggregate

Sl. No	PROPERTY	VALUE
1	Specific gravity	2.82
2	Bulk density Loose state Compacted state	 1.45 g/cc 1.60 g/cc
3	Fineness modulus	6.62
4	Water absorption 1. 20mm 2. 10mm	 0.81% 0.78%

3.4 WATER

Water plays a vital role during the life of concrete. First, water is always a component of fresh concrete ---sometimes an excessive component. Second, water can be retained by concrete (dams, pipes) or restrained by its (walls).and third; water can go into concrete but generally not through it. The water is used in concrete plays an important part in the mixing, laying, compaction setting and hardening of concrete. The strength of concrete directly depends on the quantity and quality of water used in the mix. Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely.

Clean portable water is used for mixing concrete. Water used for mixing and curing should be clean and free from injurious amounts of oils ,acids , alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete and steel.

Water is measured by volume and specified as number of liters per bag of cement. For a given quantity of water to be mixed in concrete, adjustment should be made for the amount water present in fine and coarse aggregate. The strength and workability of concrete depends on the amount of water used.

Water to be used in concrete work should have the following properties:-

1. It should be free from injuries amounts of oils.
2. It should be free from injurious amounts of acids or alkalis or other such organic or inorganic impurities
3. It should be free from iron, vegetable matter or any other substances which is likely to have adverse effect on concrete and reinforcement.
4. It should be fit for drinking purposes

The functions of water in the concrete mix may be summarized as below:

1. It acts as lubricant for the fine and coarse aggregates.
2. It reacts chemically with cement to form the binding paste for the coarse aggregate and reinforcement.
3. It is necessary to flux the cementing material over the surface of the aggregate.
4. It is employed to damp the aggregate in order to prevent them from absorbing water vitally necessary for chemical action.
5. It enables the concrete mix to flow into mould.

Water Cement Ratio

The ratio of weight of cement to volume of water used in concrete mix is termed as water cement ratio. As a result of experiments it is observed that for a given proportion of ingredients in a concrete mix, there is almost a fixed amount of water (optimum) which gives maximum strength. A small variation in the quantity of water causes much wider variation in the strength of concrete. In case the water used is less, the resultant concrete will be comparatively dry, difficult to place in position and may pose problems in compaction. Moreover, with less water complete setting of cement cannot be ensured and hence the strength of concrete gets reduced appreciably. On the other hand, in case the water used is more; it would result in formation of excessive voids and honey-combing in the set concrete, thereby reducing its density, strength and durability. Thus, water cement ratio serves as a yard stick for obtaining concrete of desired strength. The lower the water cement ratio greater is the strength of the mix. A rich mix of concrete gives a higher strength than a lean mix, not because of more cement but it is on account of the fact that concrete can be used with a lower water cement ratio.

3.5 NANOSILICA

There are three different types of suspended Nanosilica gel containing different percentage of active Nanosilica with 99.99% pure SiO_2 . Specific gravity of each material varies from 1.08 to 1.32. Particle size of Nanosilica varies between 5-40 nm. The pH of the solution is between 9.3 and 10. The properties of different Nanosilica provided by the manufacturer are given in Table 3.7.

Table 3.9 Properties of Nanosilica

Notation of Nanosilica gel	XLP	XTX	XFX
Active nano content (%wt/wt)	14.0-16.0	30.0-32.0	40.0-41.5
Ph	9.3-9.6	9.0-10.0	9.4-10.4
Specific gravity	1.08-1.11	1.20-1.22	1.30-1.32

1. CemSynXLP is the smallest particle grade and is used to give good strength to concrete and admixtures and faster setting.
2. CemSynXTX is medium particle Nanosilica which can be used as very good additive for all kind of cementing and construction grouts and admixture. It is extensively used for strengthening of study soil, for tunnels, dams, bridges, heavy construction etc..
3. CemSynXFX is large particle Nanosilica used specially for chlorides and sulphate resistance and offering other properties related to CemSynXTX grade. This is used for area and underground constructions which are exposed to chloride and sulphate or acid environment which can be reduce the life of RCC.

In this present study, particle packing method has been use for mix design of RAC M35 grade of normal strength concrete and nano modified concrete to optimize the mix design. Here we are using NANOSILICA CEMSYNXLP. It is observed that the effect of nano material in filling can’t be depicted correctly using the particle packing method. To know the optimum quantity of nano material, more trail experimental have to be carried out. In the present study, trail experiments conduct are very limited and further investigations will be carried out future to arrive at a precise mix design procedure for nano modified concrete. However, the steps followed for addition of Nanosilica gel in normal concrete are given in the following section:

Figure 3.1 Nanosilica

1. For filling the pores, Nanosilica has to be in solid form. Hence for calculation of silica content only solid Nanosilica is taken while remaining liquid gel is subtracted from water to be used in concrete.
2. Replaced solid Nanosilica is by 15% and 85% of water.
3. Remove the solid Nanosilica (NS) content from cement and liquid gel from water for balancing mix.

The material has been produced from Bee chems, Kanpur, India

4. TESTS ON CONCRETE

4.1 TESTS ON FRESH CONCRETE

4.1.1 WORKABILITY

Workability is one of the physical parameter of concrete which affects the strength and durability as well as the cost of labor and appearance of the finished product. It is the property of concrete which determines the amount of useful internal work; necessary to produce full compaction i.e. workability is the amount of energy to overcome Friction while compacting. Also defined as the relative ease with which concrete can be mixed, transported, moulded and compacted.

Concrete is said to be workable when it is easily placed and compacted homogeneously i.e., without bleeding or Segregation. Unworkable concrete needs more work or effort to be compacted in place, also honeycombs or pockets may also be visible in finished concrete.

Definition of Workability

The property of fresh concrete which is indicated by the amount of useful internal work required to fully compact the concrete without bleeding or segregation in the finished product.

4.1.2 SLUMP CONE TEST

A Slump test is a method used to determine the consistency of concrete. The consistency, or stiffness, indicates how much water has been used in the mix. The stiffness of the concrete mix should be matched to the requirements for the finished product quality.

The concrete slump test is used for the measurement of a property of fresh concrete. The test is an empirical test that measures the workability of fresh concrete more specifically, it measures consistency between batches. The test is popular due to the simplicity of apparatus used and simple procedure. The apparatus consists of frustum of a cone and is hollow at top and bottom.

This test is carried out with a metallic mould called slump cone whose top diameter is 10cm, bottom diameter is 20cm and height is 30cm. before conducting test the internal surface of the mould is thoroughly cleaned. Then mould is placed on a smooth, horizontal rigid non-absorbent surface. The mould is then filled in three equal layers with prepared concrete. Each layer is tamped 25 times by tamping rod. After the top layer has been rodded, the concrete is struck off level with a trowel and tamping rod. The mould is removed from the concrete immediately by raising it slowly and carefully in vertical direction. This allows the concrete to subside. The subsidence is referred as slump of concrete. The difference in level between height of the mould and that of the highest point of subsided concrete is measured, this difference is measured in millimeter (mm) is taken as slump of concrete.

Figure 4.1 Slump cone test

4.1.3 COMPACTION FACTOR TEST

Compacting factor of fresh concrete is done to determine the workability of fresh concrete by compacting factor test as per IS: 1199 – 1959. The compacting factor test works on the principle of determining degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. The degree of compaction called the compacting factor is measured by the density ration. The ratio of the density actually achieved in the test to density of same concrete fully compacted.

The sample of concrete to be tested is placed in the upper hopper up to the brim. The trap door is opened so that concrete falls into lower hopper. Then the trap door of the lower hopper is opened and the concrete is allowed to fall in the cylinder. Then measure the weight of the cylinder which is known as "weight of partially compacted concrete". The cylinder is emptied and then refilled with the concrete from the same sample in three equal layers. The layers are heavily rammed to obtain full compaction. This weight is known as “weight of partially compacted concrete”. Compacting factor is the ratio of “weight of partially compacted concrete” to “weight of partially compacted concrete”.

$$\text{Compaction factor} = \frac{(\text{Weight of partially compacted concrete})}{(\text{Weight of fully compacted concrete})}$$

Table 4.1 slump cone and compaction factor values

S.no	Grade of concrete	Slump cone value (mm)	Compaction factor
1	RAC M30	28	0.80
2	RAC M35	30	0.80

4.1.4 MIXING OF CONCRETE

Concrete was mixed in a tilting type concrete mixer. The mixer was hand loaded with coarse aggregate first, then with fine aggregate and with cement. During the rotation of the mixer, water and admixture were added to the ingredients inside. The rotation was continued up to minutes. The mixer was tilted and the concrete was unloaded one clean platform.

4.1.5 CASTING OF SPECIMENS

Casting is a manufacturing process by which concrete material is usually poured into a mould, which contains a hollow cavity of the desired shape, and the allowed to solidify. Each mould is provided with a metal base plate having a plane surface. The base plate is of such dimension as to support the mould during the filling without leakage and it is preferably attached to the mould by springs or screws. In assembling the mould for use, the joints between the sections of the mould are thinly coated with lubricating oil and a similar coating is applied between the contact surface of the bottom of the mould and the base plate in order to ensure that no water escapes during the filling. The interior surface of the assembled mould is also required to be thinly coated with oil to prevent adhesion of concrete

Figure 4.2 Casting of specimens

In the present research, the compressive strength, split tensile strength and flexural strength of the test specimens were evaluated. Ingredients for the design mix M30,M40 was mixed. The cement used was

Portland Pozzolana Cement (PPC). The coarse aggregate used was crushed stone passing IS 20mm sieve, retained on IS 10mm sieve and passing IS 10mm sieve, retained on IS 4.75mm sieve and recycled aggregates of passing IS 20mm sieve, retained on IS 10mm.is also used The fine aggregate used was M-sand conforming to zone II of IS 383-1970. The mould is placed on a level platform. The well mixed concrete is filled in to the mould by vibration with table vibrator. Excess concrete was removed with trowel and top surface is finished level and smooth as per IS: 516-1959. The casting of test specimens is shown in Figure 4.2.

CASTING OF CUBES

To study the compressive strength of concrete, 9 cubes of (150mm x 150mm x 150mm) size were cast for each batch of concrete mix. Oil was applied to the cube mould and is filled with concrete. The concrete filled cube moulds was placed on table vibrator and are vibrated for 1 minute. After the compaction was completed, excess concrete was removed with trowel and the top surface is leveled.

Figure 4.3 Casting of cubes

CASTING OF CYLINDERS

To study the split tensile strength of concrete, 9 cylinders of 150mm (diameter and 300mm height) size were cast for each batch of concrete mix. Oil was applied to the cylinder mould and is filled with concrete. The concrete filled cylinder mould was placed on table vibrator and is vibrated for 1 minute. After the compaction was completed, excess concrete was removed with trowel and the top surface is leveled.

Figure 4.4 Casting of cylinders

CASTING OF PRISMS

To study the split tensile strength of concrete, 9 prisms of (500mm x 100mm x 100mm) size were cast for each batch of concrete mix. Oil was applied to the prism mould and filled concrete. The concrete filled prism moulds was placed on table vibrator and are vibrated for 1 minute. After the compaction was completed, excess concrete was removed with trowel and the top surface is leveled.

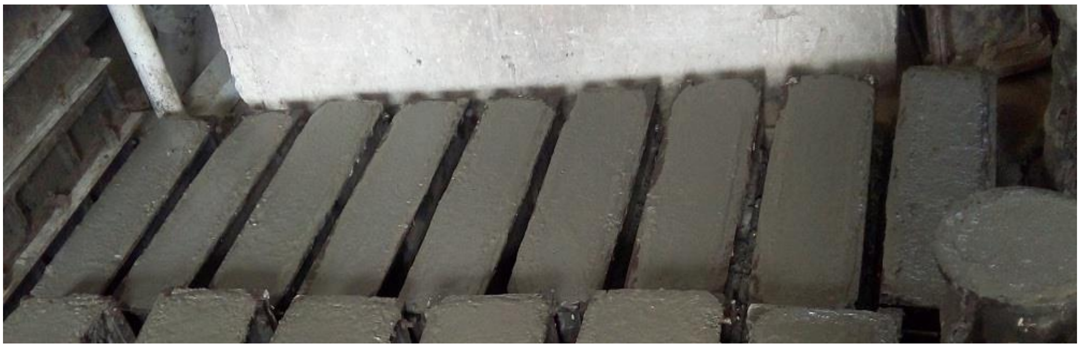

Figure 4.5 Casting of prisms

4.1.6 CURING OF SPECIMENS

Curing is the process of controlling the rate and extent of moisture loss from concrete to ensure and uninterrupted hydration of Portland cement after concrete has been placed and finished in its final position. Curing also ensures to maintain an adequate temperature of concrete in its early ages, as this directly affects the rate of hydration of cement. Curing of concrete must begin as soon as possible after placement & finishing and must continue for reasonable period of time as per the relevant standards, for the concrete to achieve its desired strength and durability. Uniform temperature should also be maintained throughout the concrete depth to avoid thermal shrinkage cracks. Also measures to control moisture loss from the concrete surface are essential to prevent plastic shrinkage cracks.

STANDARD CURING

The specimens are left in the mould undisturbed at room temperature for about 24 hours after casting. The specimens are then removed from the mould and immediately transferred to the curing pond containing clean and fresh water and cured for required period as per IS:516-1959.

The cubes, cylinders and prisms were demolded after 24 hours of casting. These specimens were cured in a water tank. After curing of the specimens in water for a period of 3,7,28 days the specimens were taken out and allowed to dry under shade.

4.2 TESTS ON HARDENED CONCRETE

4.2.1 COMPRESSIVE STRENGTH: (IS: 516-1959)

Figure 4.6 Compressive strength on cube

The test set up for conducting cube compressive strength test is depicted in Figure 4.6. Compressive test on the cubes is conducted on the 300T compressive testing machine. The cube was placed in the compression testing machine and the load on the cube is applied at a rate of 140kg/cm^2/min up to the failure of the specimen and the ultimate load is noted. The cube compressive strength of the concrete mix is then computed. A sample calculation for determination of cube compressive strength is presented in appendix. This test has been carried out on the cube specimens at 3,7,28 Days age.

$$\text{Compressive strength} = \frac{P}{A}$$

Where, P = Compressive load at failure in kn.

A = cross sectional area of the cube (150mm x 150mm).

4.2.2 SPLIT TENSILE STRENGTH: (IS: 5816-1999)

This test is conducted on 300T compression testing machine as shown in Figure 4.7. The cylinders prepared for testing are 150mm in diameter and 300mm height. Diametrical lines are drawn on the two ends, such that they are in the same axial plane. Then the cylinder is placed on the bottom compressive plate of the testing machine and is aligned such that the lines marked on the ends of the specimen are vertical. Then the top compression plate is brought into contact at the top of the cylinder. The load is applied at uniform rate, until the cylinder fails and the load is recorded. From this load, the splitting tensile strength is calculated for each specimen. A sample calculation for computation of split tensile strength is presented in appendix. In the present work this test has been conducted on cylinder specimens after 3,7,28 days of curing.

$$f_{cr} = \frac{2P}{\Pi DL}$$

Where P = Split tensile load

D = Diameter of the specimen (150 mm)

L = Length of the specimen (300 mm)

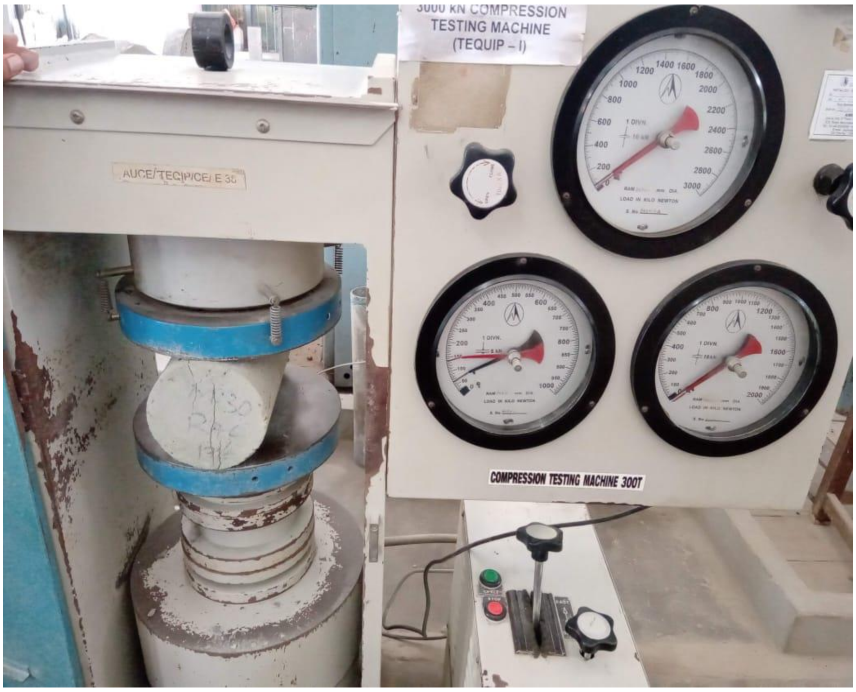

Figure 4.7 Split Tensile Strength on cylindrical specimen

4.2.3 FLEXURAL STRENGTH TEST: (IS 516-1959).

This test is conducted on 10T Universal Testing Machine (UTM). The loading arrangement to test the concrete beam specimens for flexure is shown in Figure 4.8. The beam element is simply supported on two steel rollers of 38mm in diameter these rollers should be so mounted that the distance from center to center is 400mm for 10cm specimens. The load is divided equally between the two loading rollers and all rollers are mounted in such a manner that the load is applied to the upper most surface as cast in the mould, along two lines spaced 13.3cm apart. The axis of the specimen is carefully aligned with the axis of the loading device. No packing is used between the bearing surfaces of the specimen and the rollers. The load is applied without shock and increasing continuously at a rate such that the extreme fiber stress increase at a rate of 180kg/min for the 10 cm specimens. The load is increased until the specimen fails, and the maximum load applied to the specimen during the test is recorded. Also the distance between the line of fracture and the nearer support is measured. The sample calculation for computing flexural strength is presented in Appendix-III(C). In the present investigation this test has been conducted on beam specimens after 3, 7, 28 days of curing.

$$f_b = \frac{PL}{bd^2} \text{ (when crack length is greater than 13.33cm)}$$

$$f_b = \frac{3Pa}{bd^2} \text{ (when crack length is between 13.33 and 11.0cm)}$$

Where P = Flexural load

L = Support length of the specimen

b = Measured width of the specimen

d = Measured depth of the specimen

a = distance from support to tensile crack

Figure 4.8 Flexural strength on prism

4.3 TESTS FOR DURABILITY OF CONCRETE

4.3.1. ACID ATTACK

After proper water curing the specimens (cubes, cylinders and beams) were exposed to dilute Sulphuric acid of 0.1% and 0.3% concentrations. The strength of acid was measured at regular intervals and the depleted acid was replenished. For measuring the strength of acid volumetric analysis was used.

4.3.1.1 Procedure for volumetric analysis

To estimate the strength of H_2SO_4 acid present in the sample, Sodium hydroxide (NaOH) was used as a base in the analysis. Methyl Orange was used as an indicator, which changes from pink in acid medium to pale yellow color in alkaline medium. The strength of Sodium hydroxide selected was approximately in the order of the strength of the H_2SO_4 acid. The strength of hydroxide was determined by using the standard Sulphuric acid (for H_2SO_4) and methyl orange as an indicator.

Let the normality of base be N_1. 20ml of Sulphuric acid was taken into a conical flask and two drops of indicator was added. Sodium hydroxide was added to this solution drop by drop till the pale yellow color just formed. Let sodium hydroxide consumed is V_b ml. Then

$$\text{Normality of Sulphuric Acid } (N_2) = N_1 \text{ x } V_b / 20$$

4.3.2 Permeability Test on Concrete (IS 3085:1965)

Permeability characteristic of concrete plays an important role for the durability. The test was performed to evaluate the Permeability characteristics of normal concrete and concrete with nano silica.

Figure 4.9 Permeability apparatus

4.3.2.1 Test Specimens

Test specimens for Permeability test were 100mm × 100mm cylinders of recycled concrete and concrete with Nanosilica. 3 specimens for each mix were prepared and test was conducted on Permeability test apparatus.

4.3.2.2 Test Procedure

Already cast Cylinders of size (Radius 50mm and height 100mm) were placed in the permeability moulds and sides of the mould were sealed with the sealant and top plate was fixed and the reservoir was filled with water up to of its height. Then the pressure was applied by means of a pressure pump. Water pressure of $10kg/cm^2$for the duration of 100h is applied and when study flow is attained, discharge water from outlet was collected and measured for the duration of test.

$$K = Q/\{A.T.(H/L)$$

K = coefficient of permeability in cm/sec

Q = quantity of water in milliliters percolating over the entire period of test after the steady state has been reached.

A = Area of the specimen face in cm^2

T = time in seconds over which Q is measured

H/L = ratio of the pressure head to thickness of specimen, both expressed in the same units.

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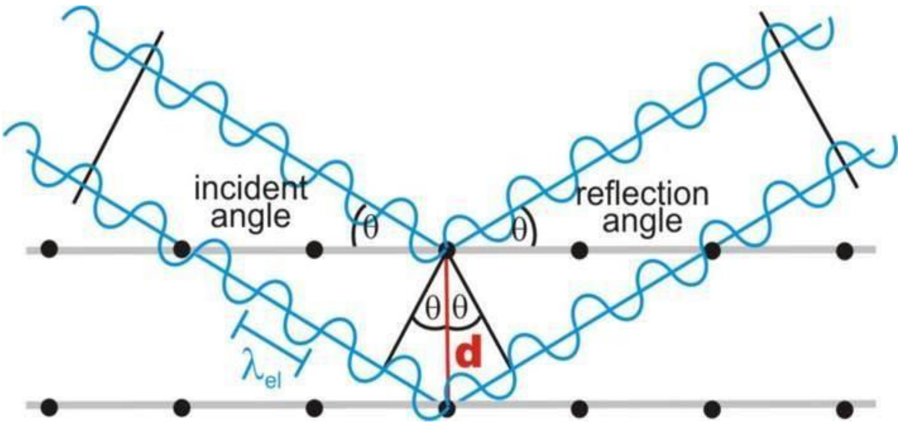
4.4 X-ray Diffraction Test (XRD)

X-ray powder diffraction (XRD) is a rapid analytical technique primarily used for phase identification of a crystalline material and can provide information on unit cell dimensions. This is now a common technique for the study of crystal structures and atomic spacing. X-ray diffraction is based on constructive interference of monochromatic X-rays passing through a crystalline sample. These X-rays are generated by a cathode ray tube, filtered to produce monochromatic radiations, collimated to concentrate, and directed towards a sample. The diffraction of X-rays by crystal planes allows one to derive lattice spacing by using the Bragg's law shown in Figure 4.10

Figure 4.10 Bragg's Law

$$n\lambda = 2d\sin\theta$$

Where, *n* is an integer called the order of reflection, λ is the wavelength of X-rays, *d* is the characteristic spacing between the crystal planes of a given specimen and θ is the angle between incident beam and the normal to the reflecting lattice plane. By measuring the angles, θ, under which the constructively interfering X-rays leave the crystal, the inter planar spacing, of every single



crystallographic phase can be determined. This law relates the wavelength of electromagnetic radiation to the diffraction angle and the lattice spacing in a crystalline sample. These diffracted X-rays are then detected, processed and counted. By scanning the sample through a range of 2θangles, all possible diffraction directions of the lattice should be attained due to the random orientation of the powdered material. Conversion of the diffraction peaks to d- spacing allows identification of the mineral because each mineral has a set of unique d-spacing. Typically, this is achieved by comparison of d-spacing with standard reference patterns. In order to identify an unknown substance, the powder diffraction pattern is recorded with the help of camera or a diffractometer and a list of d values and the relative intensities of the diffraction lines is prepared. These data are compared with the standard line patterns available for the various compounds in the Powder Diffraction File (PDF) database. This file is released annually and is updated by the International Centre for Diffraction Data (ICDD). It contains line patterns of more than 60,000 different crystallographic phases.

Basic principle and working of the instrument:

A schematic diagram of an X-ray diffractometer used for qualitative and quantitative analysis of materials is shown in the Figure 4.11 From the figure it is evident that a diffractometer is primarily made up of a compact X-ray protected housing, called goniometer, a high voltage transformer for X-ray tubes with filters, a highly stable X- ray generator, a detector, and a data processing system.

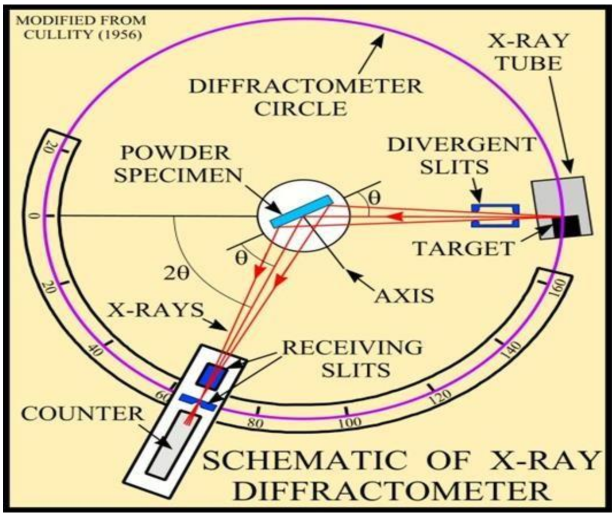


Figure 4.11 Schematic x-ray diffractometer

The X-ray tubes may have a different radiation targets like Mo, Cu, Co, Fe, Cr and W with different Kβ filters like Zr for Mo, Ni for Cu, Fe for Co, Mn for Fe and V for Cr. The tubes can be of normal, broad or long fine focus type. Depending on the target and nature of focus the maximum load of X-ray tubes generally varies from 1 to 3 kW while the tube voltage and current are mostly in the range of 0-60 kV and 0-80 mA, respectively. Primary beam monochromators made of quartz to remove undesirable radiations and secondary monochromators made up of LiF flat crystals, or more extensively bent graphite crystal adjusted for Cr, Co, Fe, Cu or Mo-Kα radiation in order to eliminate fluorescent radiations from the samples are used in the incident and diffracted beam paths, respectively, along with different slits (fixed, variable and roller types). X-ray diffractometers consist of three basic elements: an X-ray tube, a sample holder, and an X-ray detector.

X-rays are generated in a cathode ray tube by heating a filament to produce electrons, accelerating the electrons toward a target by applying a voltage, and bombarding the target material with electrons. When electrons have sufficient energy to dislodge inner shell electrons of the target material, characteristic X-ray spectra are produced. These spectra consist of several components, the most common being Kα and Kβ. Kα consists, in part, of Kα1 and Kα2. Kα1 has a slightly shorter wavelength and twice the intensity as Kα2. The specific wavelengths are characteristic of the target material (Cu, Fe, Mo, Cr). Filtering, by foils or crystal monochromators, is required to produce monochromatic X-rays needed for diffraction. Kα1 and Kα2 are sufficiently close in wavelength such that a weighted average of the two is used. Copper is the most common target material for single-crystal diffraction, with CuKα radiation = 1.5418Å. These X- rays are collimated and directed onto the sample. As the sample and detector are rotated, the intensity of the reflected X-rays is recorded. When the geometry of the incident X- rays impinging the sample satisfies the Bragg Equation, constructive interference occurs and a peak in intensity occurs. A detector records and processes this X-ray signal and converts the signal to a count rate which is then output to a device such as a printer or computer monitor.

The geometry of an X-ray diffractometer is such that the sample rotates in the path of the collimated X-ray beam at an angle θ while the X-ray detector is mounted on an arm to collect the diffracted X-rays and rotates at an angle of 2θ. The instrument used to maintain the angle and rotate the sample is termed a *goniometer*. For typical powder patterns, data is collected at 2θ from ~5° to 70°, angles that are preset in the X-ray scan.

4.4.1 Procedure of conducting the XRD Analysis:

The concrete sample which are to be tested are crushed by hammer and are sieved through 90 microns sieve. This powdered sample was taken for the test in Powdered XRD Laboratory in Department of chemistry, IIT Madras, Chennai. The sample is filled in the slit provided for the test. The green ”door open ” button on the right hand side of the XRD instrument was pressed. The handles were gently pulled and the doors were slide opened. The sample is then installed by holding it in place with one hand and with the other the stage is pressed up until it locks. The slits in the ‘anti-scattering’ and ‘detector’ positions are verified.

On computer ‘XRD commander’ is expanded and the power is raised if necessary. There were <shutter> and <X-ray> buttons to open and close the shutter or turn on and off the X-rays were present in the left hand side of the window in XRD commander. The indicator to the right of the buttons gives the status of the shutter and X-ray. When the shutter light is green , the shutter is closed and the enclosure doors can be opened.

In XRD commander the jobs tab at the bottom of the page is selected. ‘Create Job ‘ icon on the tool bar is selected. Then you have start scan. Scan is observed in the adjust tab. Data will be automatically saved. Sample is removed, when the scan is completed. Do not yank on, pull on or apply any force or torque to the sample stage pressure unit. Data can be found out in the ‘short-cut scans ‘file on the desktop when it is finished. Remember to remove the sample and close the doors when your scan has been completed.

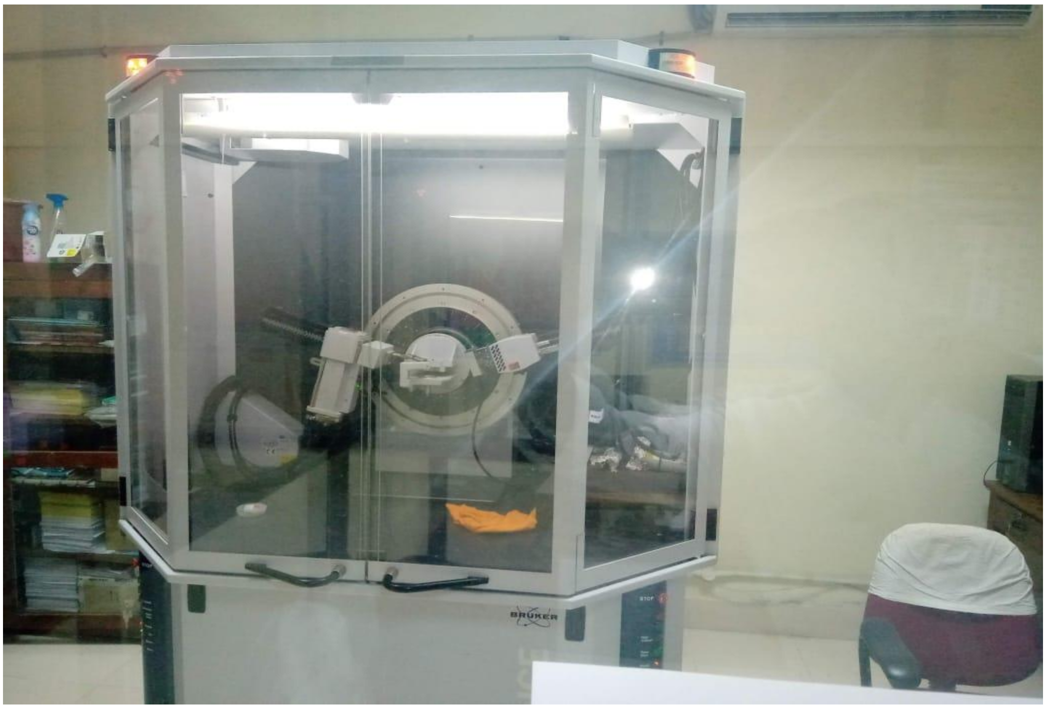


Figure 4.12 XRD instrument IIT Madras

Diffraction effects are observed when electromagnetic radiation impinges on periodic structures with geometrical variations on the length scale of the wavelength of the radiation. The interatomic distances in crystals and molecular amount to 0.15-0.4nm which corresponds in the electromagnetic spectrum with wavelength of X-rays having photon energies between 3 to 8keV. Accordingly, phenomena like constructive and destructive interference should become observable when crystalline and molecular

structures are exposed to the X-rays.
X-Rays are having wavelength between 0.01nm to 10nm. Hence X-Rays can penetrate inside the crystal structure of any material very easily; and tells us the properties of material while coming out from that material. Which is why X-Ray spectroscopy is very useful technique for characterization of different types of materials? We can easily calculate the size of particles from Scherrer formula given:

Scherrer Formula:

$$Dp = (0.94 \times \lambda) / (\beta \times \cos\theta)$$

Where, Dp = Average Crystallite size, β = Line broadening in radians(FWHM), θ = Bragg angle, λ = X-Ray wavelength

4.5 Scanning Electron Microscopy (SEM) Analysis:

The scanning electron microscopy (SEM) instrument shown in Figure 4.10, uses a focused beam of high energy electrons to generate a variety of signals at the surface of solid specimens. The signals that derive from electron-sample interaction reveal information about the sample including external morphology (texture), chemical composition, crystalline structure and orientation of materials making up the sample. In most applications, data are collected over a selected area of the surface of the sample and a 2-D image is generated that displays special variations in these properties. Areas ranging from approximately 1cm to 5 microns in width can be imaged in a scanning mode using conventional SEM techniques (magnification ranging from 20X to 30,000X, spatial resolution of 50 to 100nm). The SEM is also capable of performing analysis of selected point locations on the sample; this approach is especially useful in qualitatively or semi-qualitatively determining chemical compositions (using EDS). The design and function of SEM is very similar to the EPMA and considerable overlap in capabilities exists between the two instruments.

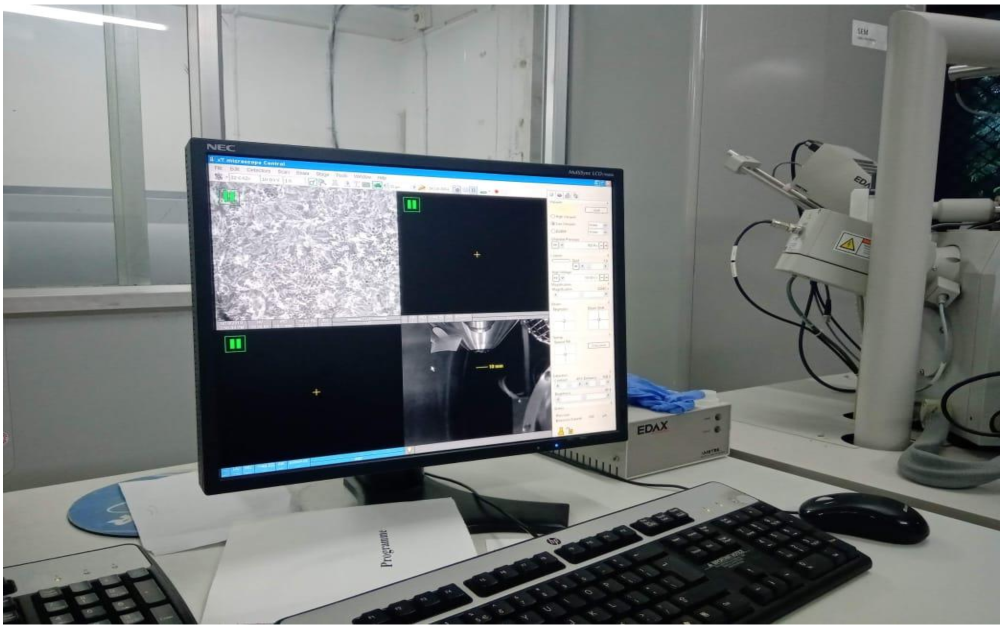


Figure 4.13 Scanning Electron Microscopy instrument ,IIT Madras

The concrete sample which are to be tested are crushed by hammer and are sieved through 90 microns sieve. The test was done in SEM Laboratory in Department of chemistry, IIT Madras, Chennai .The sample is mounted on one of a number of sample mounts. The simplest mount is the pin mount made of Aluminum. They have a "Hummer VI" sputter deposition system for coating the sample. It has a gold target and a sputter deposition rate of about 38 Angstroms/minute. Thus about 1.0-1.5 minutes of sputtering will apply enough metal to conduct the SEM electrons to ground and prevent charging without noticeably altering the topography of your substrate. The next few steps of preparing the SEM for sample loading and image acquisition require commands from the software.

The SEM user interface is spread across two monitors. The row of icons at the bottom of the screen has commands allowing us to measure or label things on the image. The SEM image appears in the large region in the center. Now that the sample is prepared and mounted on the SEM sample mount, there is a vent to load it. The stage table has a stainless steel disk at the center of the copper table that has a bevel on its rim that fits the reverse bevel over this disk until it docks against the cross bar on the top of the SEM stage table. After the sample is properly mounted on the SEM stage and inspected, gently close the chamber door.

The stage movement is controlled manually by a dual joystick desk console. Left joystick controls the Z-axis movement and the stage tilt angle, and the right joystick controls the X, Y motion and the stage rotation. The SEM keyboard has a number of knobs and buttons to give the operator analogue- like control of SEM parameters. The large kob on the left is magnification and the large knob on the right is for focus. The two knobs on the upper right are for brightness and contrast. And the two knobs on the upper left are stigmators.

To know information from the topography of a sample, you should consider the penetration depth of the probe electrons. As electrons enter the sample surface, they penetrate into the body of the material a distance depending on several parameters, chiefly the energy of the electron itself and the material. The deeper they penetrate, the less surface information is contained in the image and the more material parameter information they convey. The standard SEM image is generated by 'Secondary

Electron Emission from the substrate. These are low energy electrons (less than 50eV) produced both by the primary electron beam and backscattered electrons. However, while the primary electron beam can penetrate the substrate by several or many microns, the escape depth for the secondary electrons is only on the order of tens or hundreds of Angstroms.

TESTS CONDUCTED ON HARDENED CONCRETE

The tests conducted on the hardened concrete in this project are shown in the form of Flow chart.

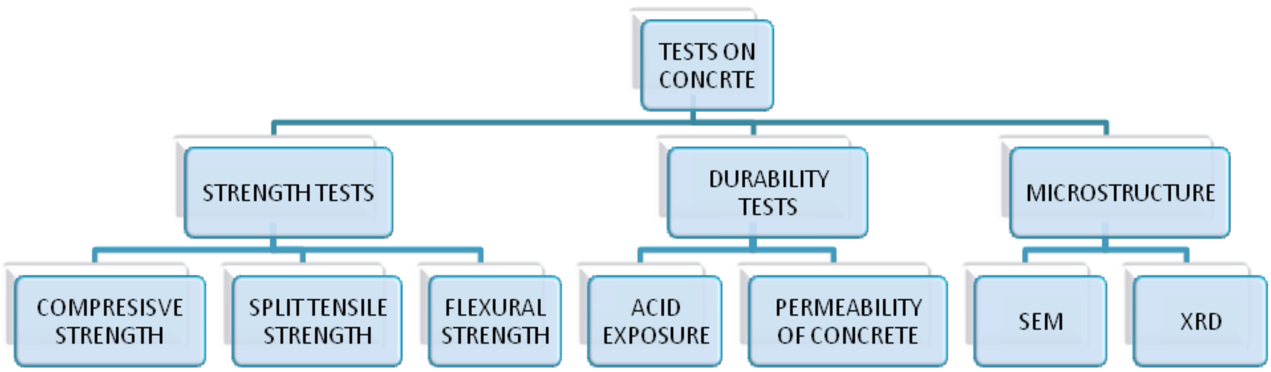


Figure 4.14 Diagrammatic representations of tests conducted on hardened concrete

CHAPTER 5

EXPERIMENTAL RESULTS

In this chapter results based on the experimental work are presented in the form of tables and graphs and are discussed. The results include compressive strength, split tensile strength, flexural strength, permeability, acid attack, SEM and XRD analysis.

5.1 COMPRESSIVE STRENGTH OF CONCRETE OF RAC M30

Table 5.1 Compressive Strength of Concrete of RAC M30

Average Compressive strength(N/mm^2) of RAC M30			
Sample No	**3 days**	**7 days**	**28 days**
1	25.3	25.3	40.8
2	22.2	23.5	43.1
3	20.8	26.2	36.4
Average	**22.7**	**25**	**40.1**

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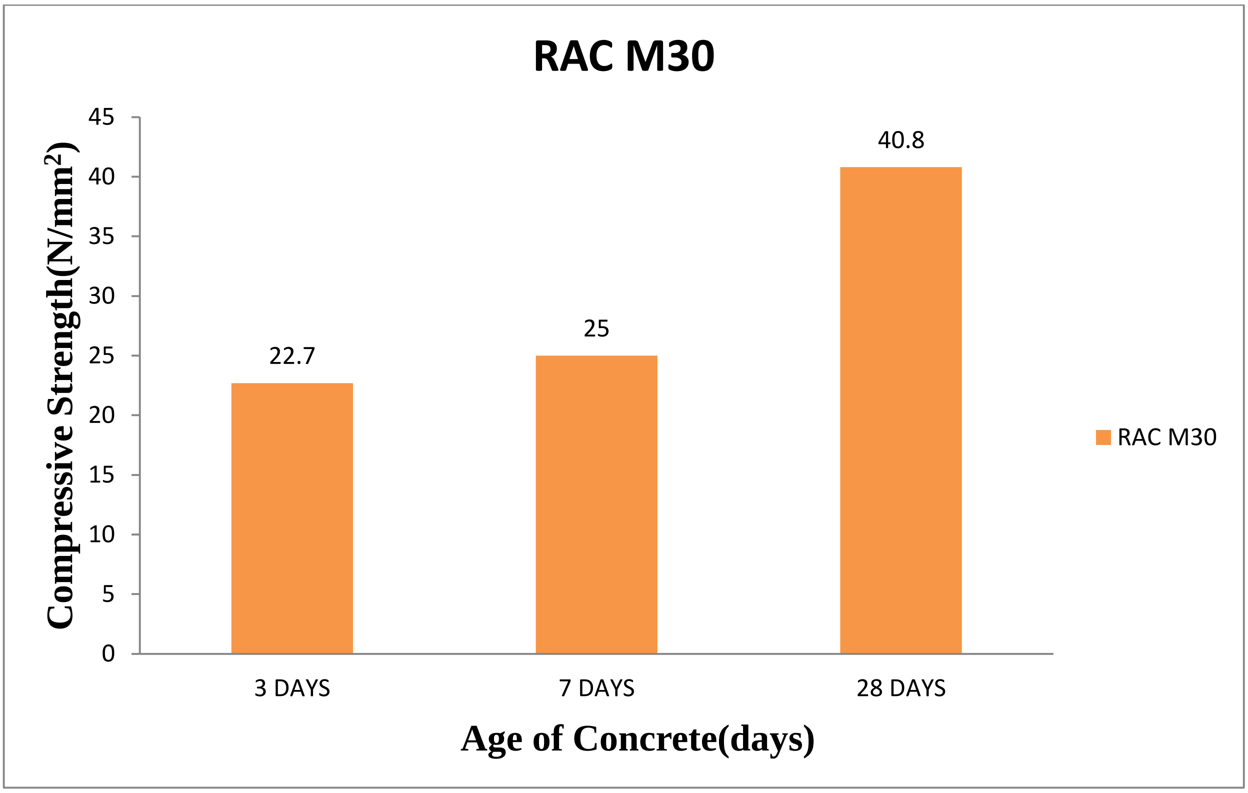

Figure 5.1 Compressive strength of RAC M30

5.2 SPLIT TENSILE STRENGTH OF CONCRETE OF RAC M30

Table 5.2 Split Tensile Strength of Concrete of RAC M30

Average Split Tensile Strength(N/mm^2)of RAC M30			
Sample No	**3 days**	**7 days**	**28 days**
1	1.5	2.2	2.5
2	1.4	1.8	2.4
3	2.2	1.9	2.1
Average	**1.7**	**1.9**	**2.3**

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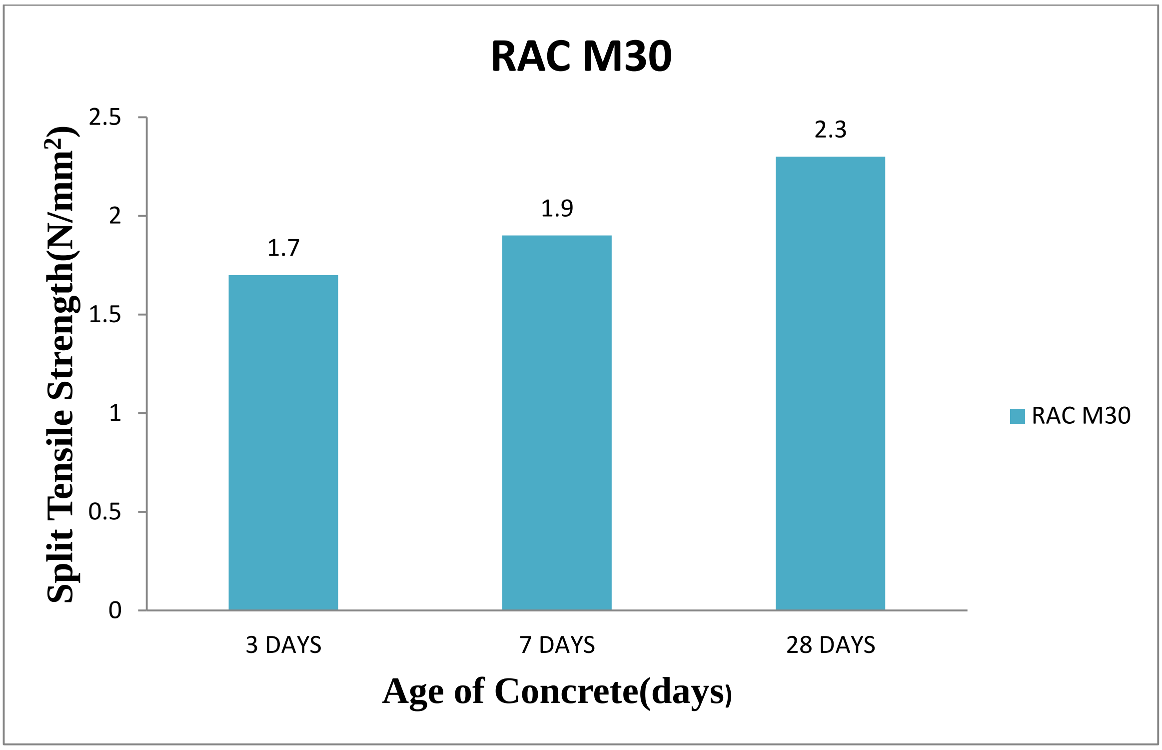

Figure 5.2 Split tensile strength of RAC M30

5.3 FLEXURAL STRENGTH OF CONCRETE OF RAC M30

Table 5.3 Flexural Strength of Concrete of RAC M30

Average Flexural Strength(N/mm²)of RAC M30			
Sample No	**3 days**	**7 days**	**28 days**
1	4.3	5.4	6.6
2	4.0	4.9	6.2
3	4.9	5.3	6.3
Average	**4.4**	**5.2**	**6.3**

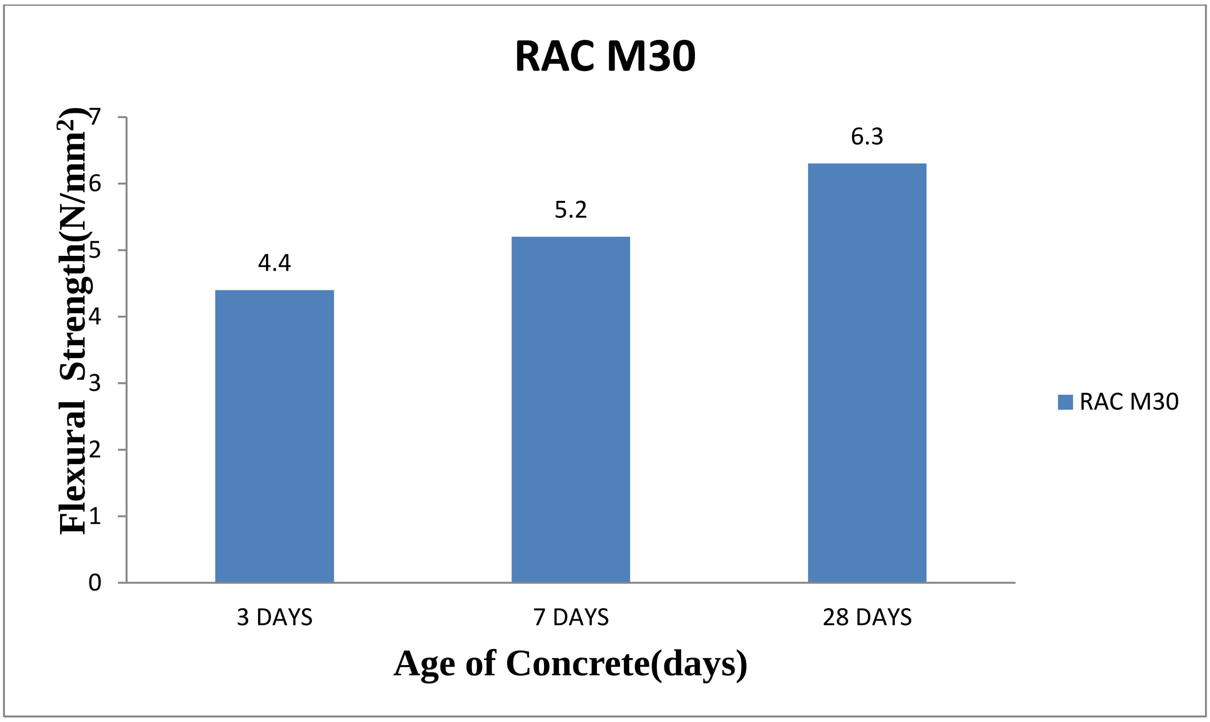

Figure 5.3 Flexural strength of RAC M30

RAC M35

5.4 COMPRESSIVE STRENGTH OF CONCRETE OF RAC M35

Table 5.4 Compressive Strength of Concrete

Average Compressive strength(N/mm^2) of RAC M35			
Sample No	**3 days**	**7 days**	**28 days**
1	24.8	31.5	51.1
2	22.2	31.1	41.7
3	20	32.8	41.7
Average	**22.3**	**31.8**	**44.8**

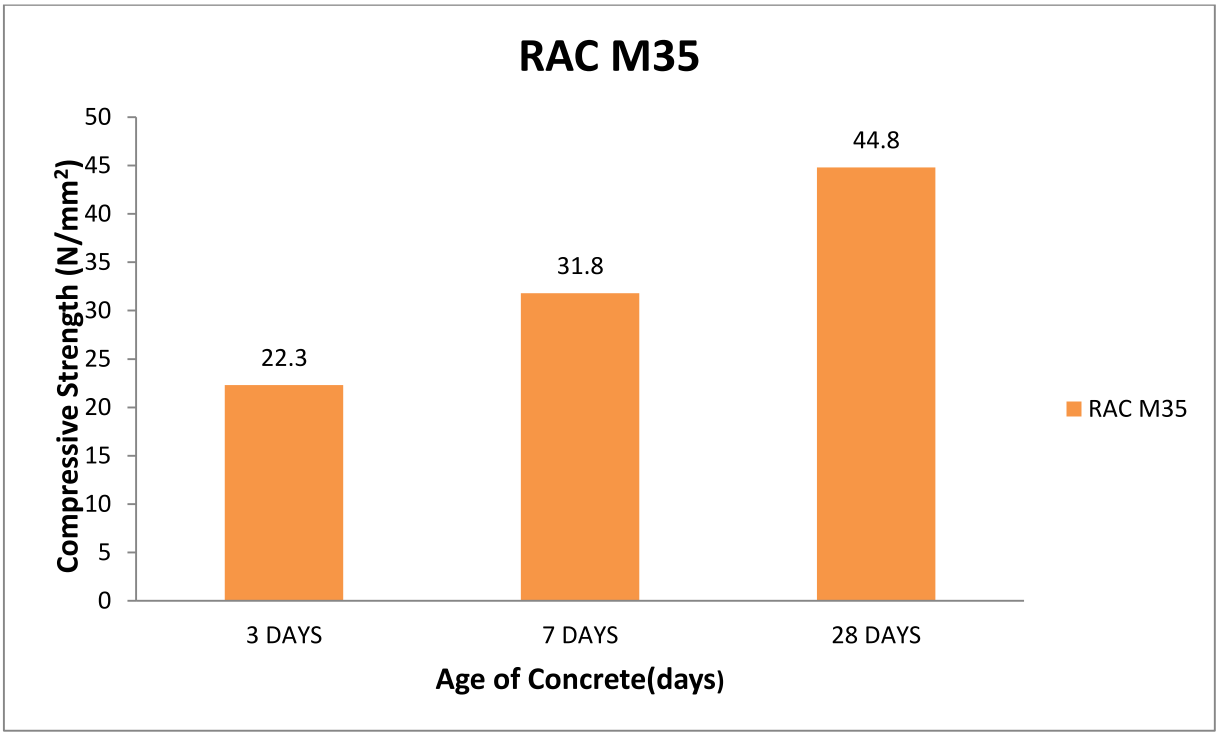

Figure 5.4 Compressive strength of RAC M35

5.5 SPLIT TENSILE STRENGTH OF CONCRETE OF RAC M35

Table 5.5 Split Tensile Strength of Concrete

Average Split Tensile Strength(N/mm²)of RAC M35			
Sample No	**3 days**	**7 days**	**28 days**
1	1.8	2.2	2.4
2	1.8	2.2	2.5
3	1.8	2.2	2.5
Average	**1.8**	**2.2**	**2.4**

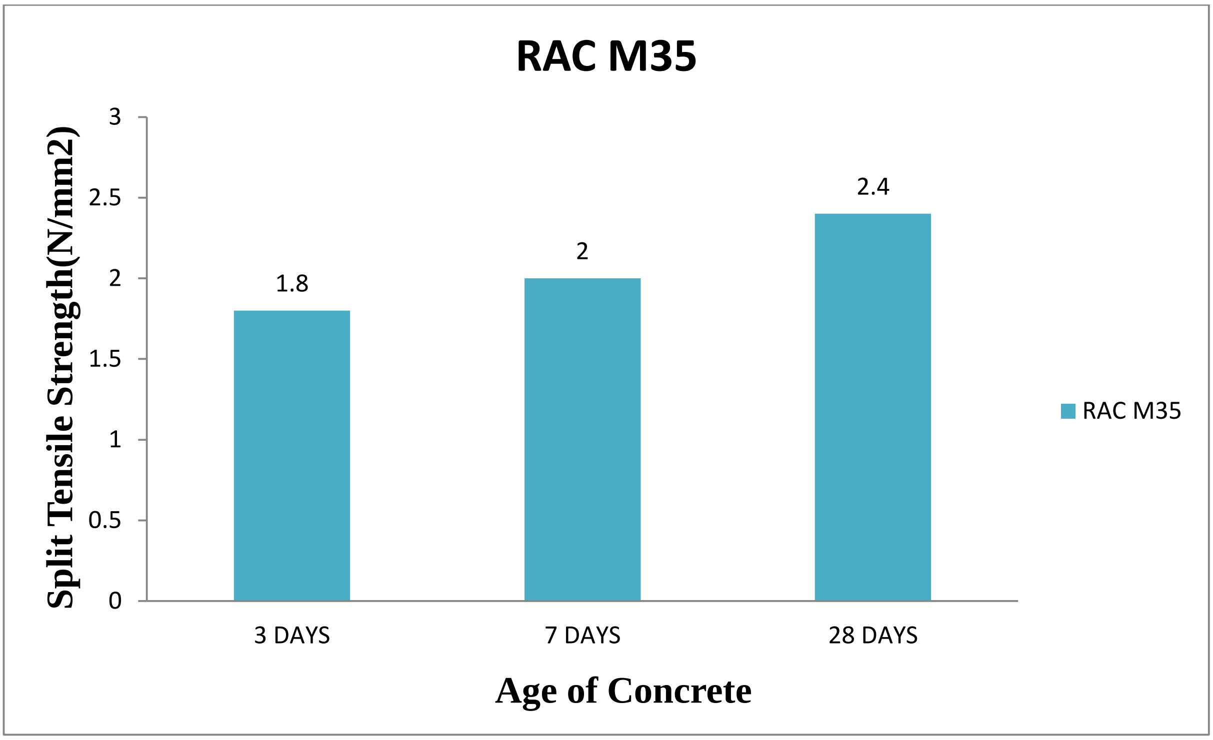

Figure 5.5 Split tensile strength of RAC M35

5.6 FLEXURAL STRENGTH OF CONCRETE OF RAC M35

Table 5.6 Flexural Strength of Concrete

Average Flexural Strength(N/mm^2)of RAC M35			
Sample No	**3 days**	**7 days**	**28 days**
1	4.4	5.8	8.2
2	4.4	5.1	7.6
3	4.5	5.9	6.1
Average	**4.4**	**5.6**	**7.3**

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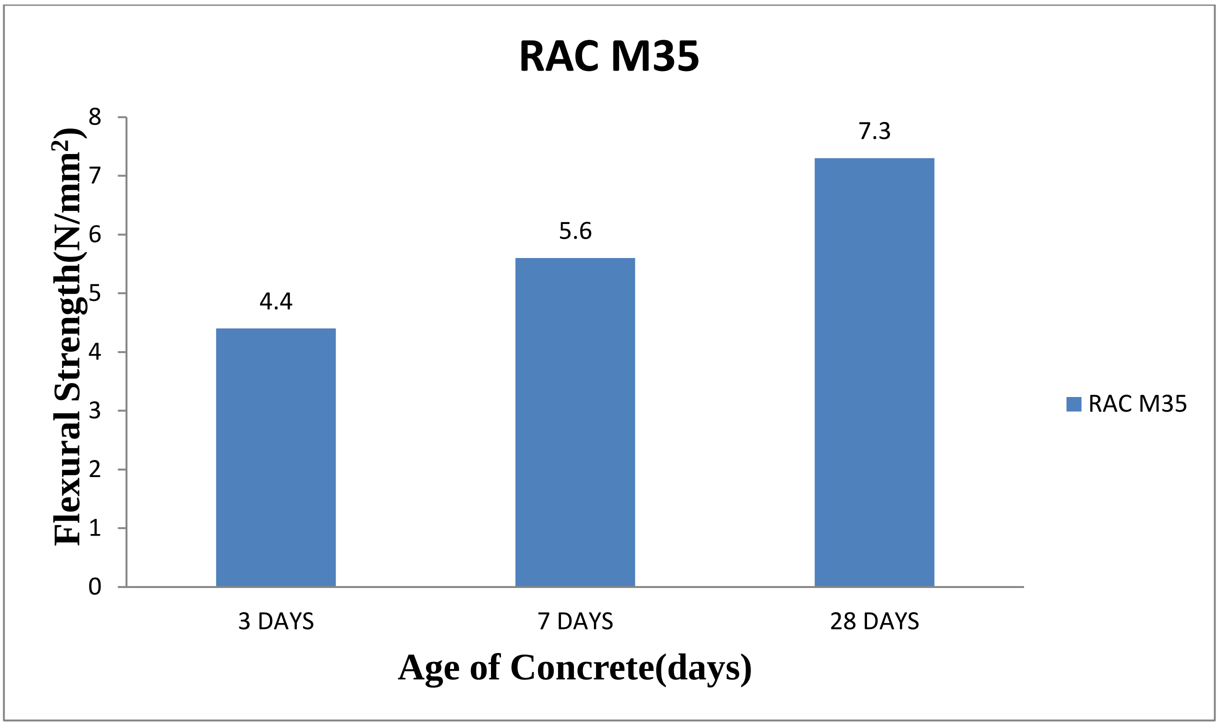

Figure 5.6 Flexural strength of RAC M35

5.7 ACID EXPOSURE

After proper water curing for 28 days the specimens (cubes 100mm x 100mm)were exposed to dilute Sulphuric acid of 0.1% and 0.3% concentrations. The strength of acid was measured at regular intervals and the depleted acid was replenished.

5.7.1 Acid attack of RAC M30 grade concrete of 0.1% H_2S0_4

Table 5.7 Acid attack of RAC M30 grade concrete of 0.1% H_2S0_4

Sl. NO	Age (days)	Weight of cube before immersion (g)	Weight of cube after removal from acid tank (0.1% of H_2SO_4) (g)	Weight reduction (%)	Average % weight reduction	Compressive strength (N/mm^2)	Average Age Compressive strength (N/mm^2)
1	14	2760	2746	0.51	0.52	40.00	39.33
2		2690	2676	0.52		39.00	
3		2746	2713	0.55		39.00	
4	28	2638	2620	0.68	0.55	39.50	37.50
5		2712	2701	0.41		36.00	
6		2732	2717	0.55		37.00	
7	42	2616	2590	0.99	0.96	36.500	35.13
8		2746	2722	0.87		35.00	

9		2702	2675	1.00		34.00	
10	56	2698	2622	2.82	2.60	32.00	32.13
11		2682	2612	2.61		31.89	
12		2704	2640	2.37		32.50	

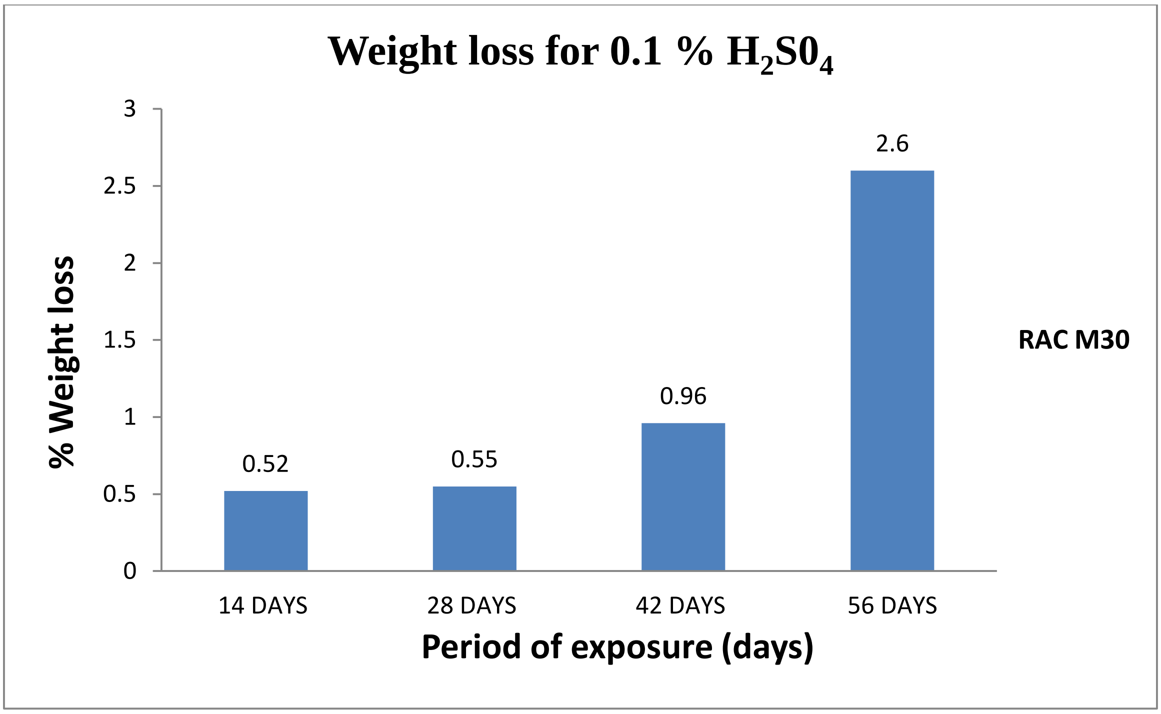

Figure 5.7 weight loss due to 0.1% of H_2SO_4 solution on RAC M30

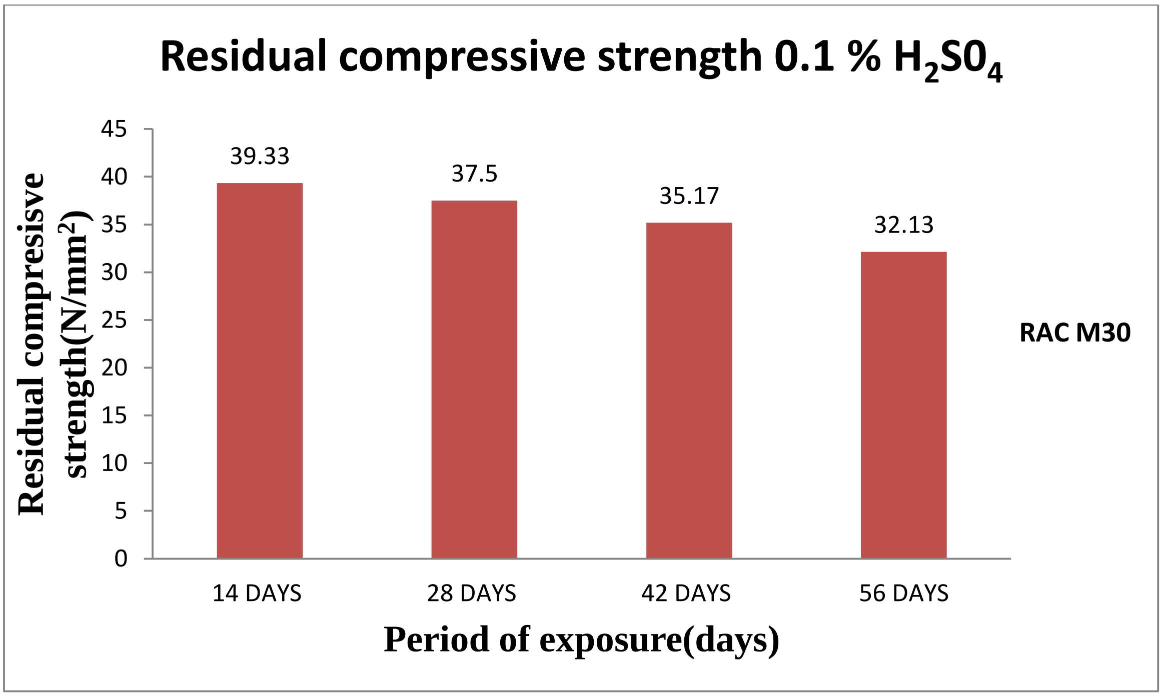

Figure 5.8 Residual compressive strength of 0.1% H_2SO_4 solution RAC M30

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5.7.2 Acid attack of RAC M30 grade concrete of 0.3% H_2SO_4

Table 5.7.1 Acid attack of RAC M30 grade concrete of 0.3% H_2SO_4

Sl. NO	Age (days)	Weight of cube before immersion (g)	Weight of cube after removal from acid tank (0.3% of H_2SO_4) (g)	Weight reduction (%)	Average % weight reduction	Compressive strength (N/mm^2)	Average Age Compressive strength (N/mm^2)
1	14	2690	2661	1.08	1.87	40.00	38.33
2		2672	2602	2.62		38.00	
3		2682	2631	1.90		37.00	
4	28	2766	2699	2.42	1.97	40.50	35.00
5		2758	2701	2.07		35.00	
6		2688	2650	1.41		35.00	
7	42	2688	2602	2.47	2.52	36.00	34.50
8		2688	2600	2.55		34.00	
9		2714	2645	2.54		33.50	
10	56	2646	2542	2.92	2.97	30.97	31.07
11		2722	2624	2.90		31.00	
12		2708	2632	2.81		31.25	

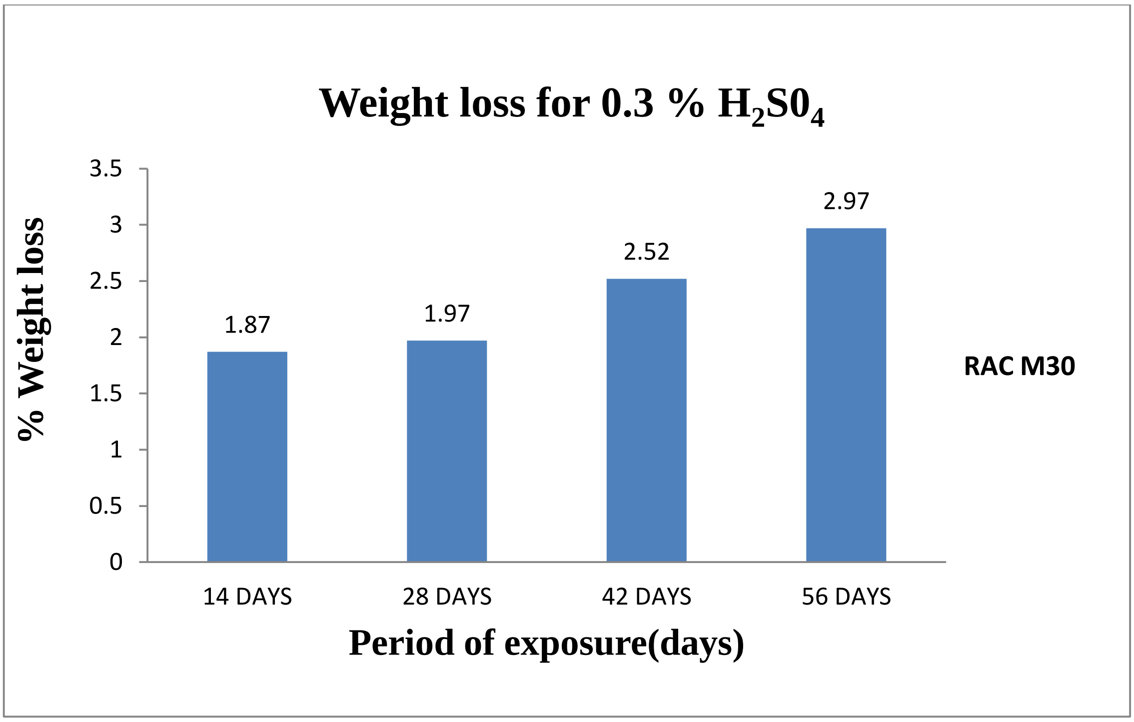

Figure 5.9 weight loss due to 0.3% of H_2SO_4 solution on RAC M30

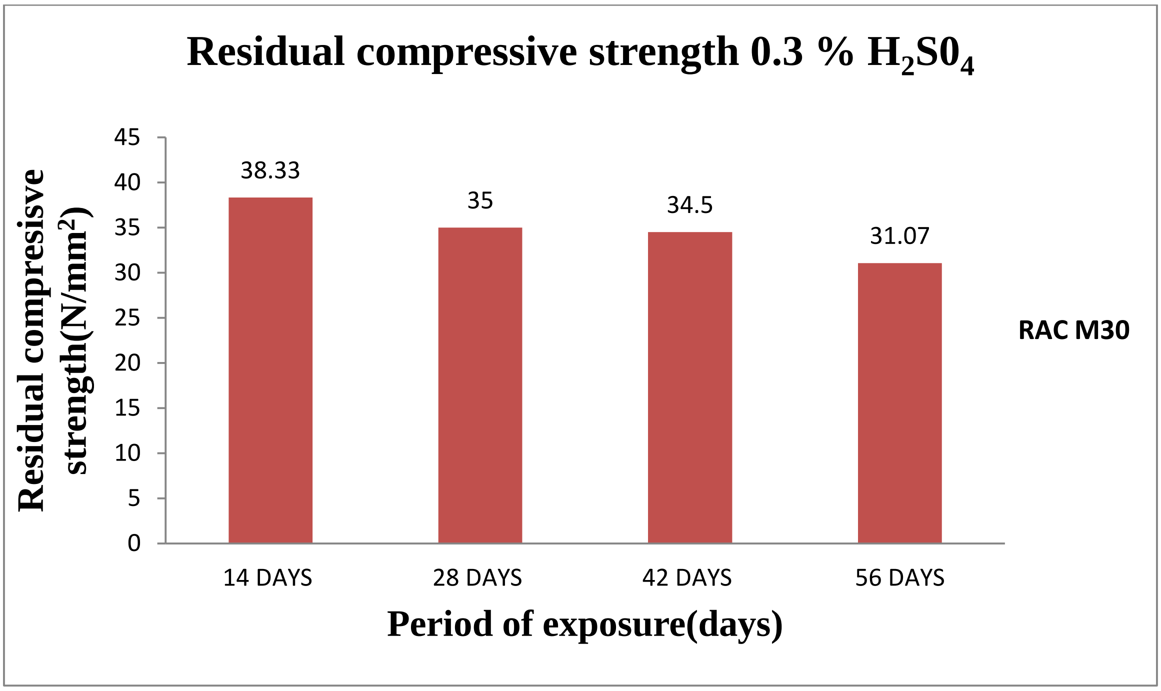

Figure 5.10 Residual compressive strength of 0.3% H_2SO_4 solution RAC M30

5.7.3 Acid attack of RAC M35 grade concrete of 0.1% H_2S0_4

Table 5.7.3 Acid attack of RAC M35 grade concrete of 0.1% H_2S0_4

Sl. NO	Age (days)	Weight of cube before immersion (g)	Weight of cube after removal from acid tank (0.1% of H_2SO_4) (g)	Weight reduction (%)	Average % weight reduction	Compressive strength (N/mm^2)	Average Age Compressive strength (N/mm^2)
1	14	2632	2605	1.03	1.15	40.00	40.67
2		2622	2599	0.88		41.00	
3		2672	2631	1.53		41.00	
4	28	2672	2636	1.35	2.06	41.50	39.50
5		2798	2736	2.22		39.50	
6		2684	2614	2.61		38.00	
7	42	2634	2588	1.75	2.22	36.00	36.00
8		2666	2600	2.48		37.00	
9		2732	2665	2.45		35.00	
10	56	2676	2600	2.84	2.72	35.00	34.50
11		2738	2674	2.34		33.50	
12		2622	2544	2.97		33.00	

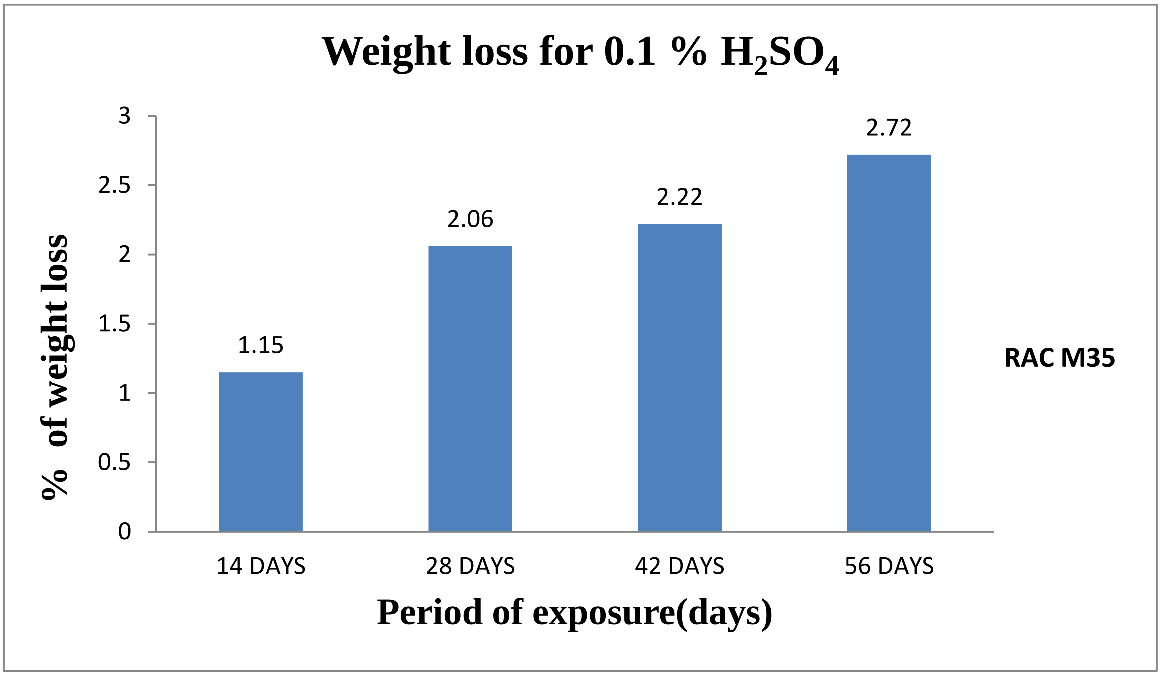

Figure 5.11 weight loss due to 0.1% of H_2SO_4 solution on RAC M35

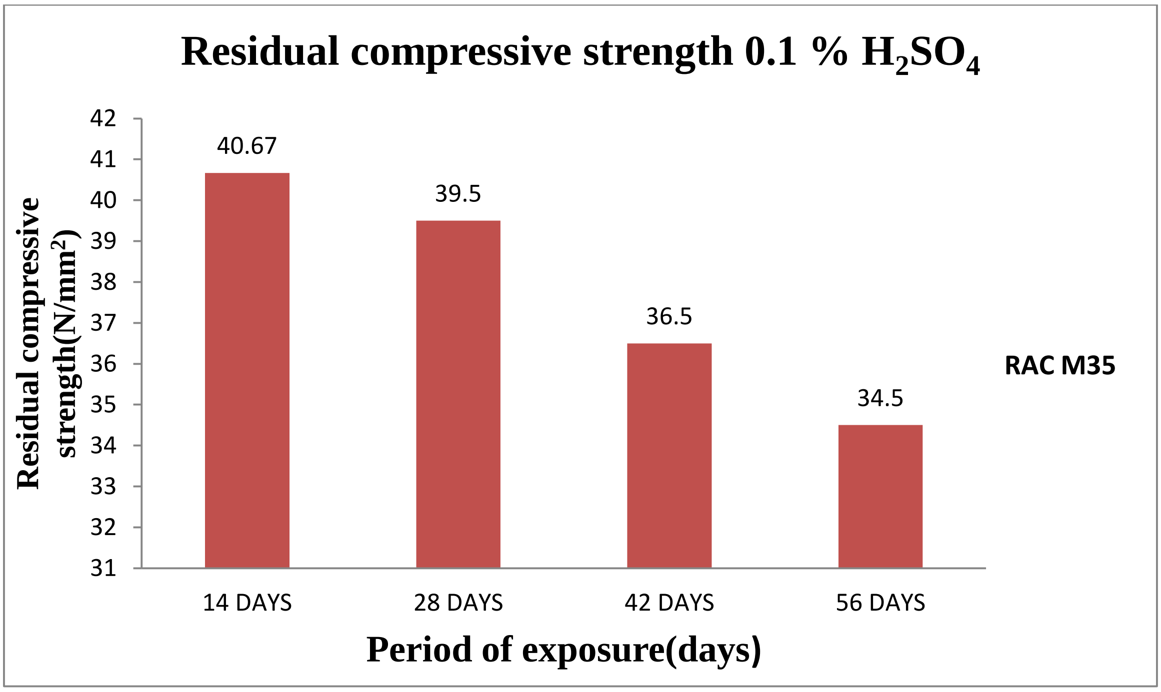

Figure 5.12 Residual compressive strength of 0.1% H_2SO_4 solution RAC M35

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5.7.4 Acid attack of RAC M35 grade concrete of 0.3% H_2S0_4

Table 5.7.4 Acid attack of RAC M35 grade concrete of 0.3% H_2S0_4

Sl. NO	Age (days)	Weight of cube before immersion (g)	Weight of cube after removal from acid tank (0.3% of H_2SO_4) (g)	Weight reduction (%)	Average % weight reduction	Compressive strength (N/mm^2)	Average Age Compressive strength (N/mm^2)
1	14	2718	2685	1.21	1.23	39.50	39.50
2		2730	2709	0.77		40.00	
3		2656	2611	1.69		39.00	
4	28	2618	2586	1.22	1.93	38.00	37.17
5		2716	2656	2.21		37.00	
6		2718	2654	2.35		36.50	
7	42	2718	2600	2.40	2.58	35.00	35.00
8		2664	2604	2.54		36.00	
9		2672	2615	2.79		34.00	
10	56	2676	2588	3.29	3.1	34.00	32.50
11		2738	2624	4.16		32.50	
12		2622	2569	2.02		31.00	

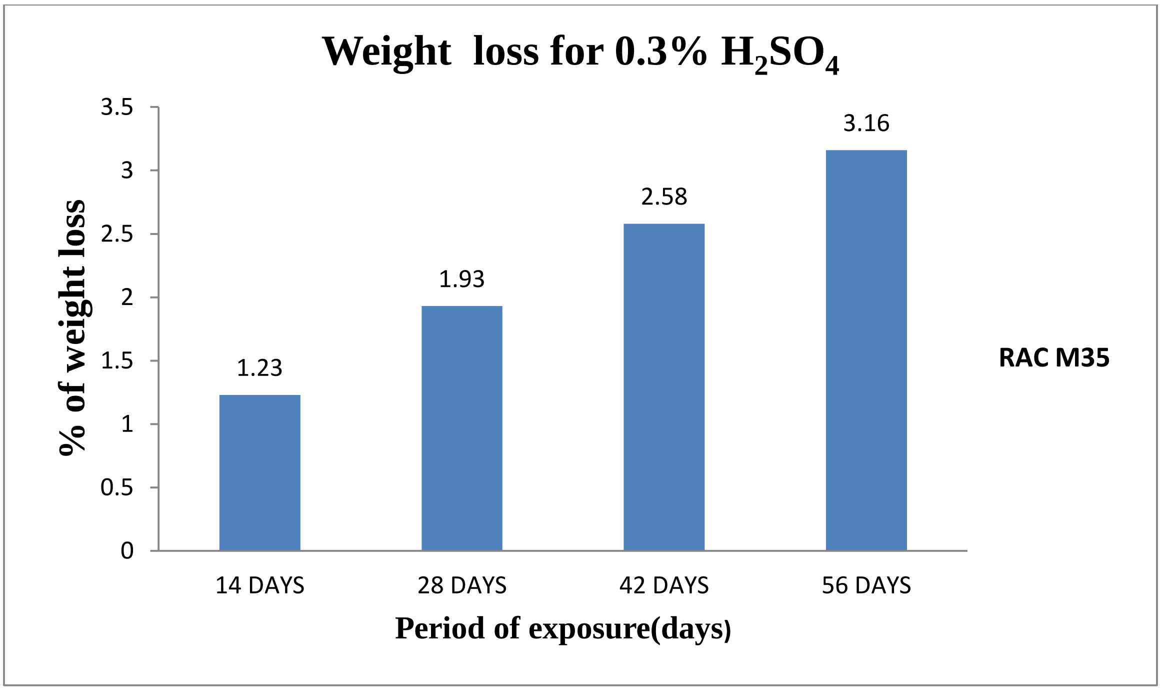

Figure 5.13 weight loss due to 0.3% of H_2SO_4 solution on RAC M35

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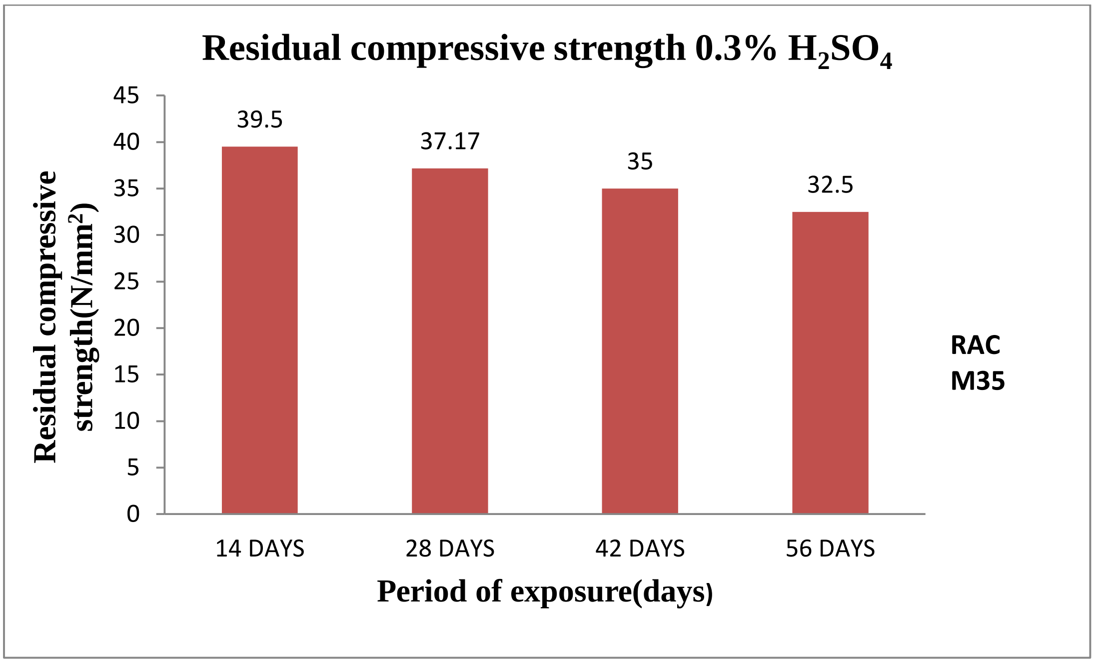

Figure 5.14 Residual compressive strength of 0.3% H_2SO_4 solution RAC M35

5.8 PERMEABILITY TEST ON CONCRETE OF RAC M30

Table 5.8 Permeability of Concrete: (RAC M30)

Grade of concrete RAC M30	Drained water (ml)	Coefficient of Permeability (cm/sec)
Sample 1	27	$9.55x10^{-7}$
Sample 2	28	$9.90x10^{-7}$
Sample 3	26	$9.02x10^{-7}$
Average	**27**	**$9.55x10^{-7}$**

5.8.1 PERMEABILITY TEST ON CONCRETE OF RAC M35

Table 5.8.1 Permeability of Concrete: (RAC M35)

Grade of concrete RAC M35	Drained water (ml)	Coefficient of Permeability (cm/sec)
Sample 1	26	$9.2x10^{-7}$
Sample 2	25	$8.84x10^{-7}$
Sample 3	24	$8.49x10^{-7}$
Average	**25**	**$8.84x10^{-7}$**

To determine the quality of concrete, comparing with standard classification of concrete according to Instruction and Maintenance Manual of GWT

Table 5.8.2.Standard classification of concrete (GWT):

Coefficient of permeability (mm/sec)	Quality of concrete
$0\text{-}1x10^{-3}$	High permeable concrete
$1x10^{-3} – 1x10^{-5}$	Average permeable concrete
$1x10^{-5} – 1x10^{-6}$	Low permeable concrete
$1x10^{-6} – 1x10^{-7}$	High impermeable concrete
$1x10^{-7} – 1x10^{-9}$	Higher impermeable concrete

RAC M30

$9.55x10^{-7}$ cm/sec i.e. multiplied by 10 for mm/sec = $9.55x10^{-6}$

RAC M35

$8.84x10^{-7}$ cm/sec i.e. multiplied by 10 for mm/sec = $8.84x10^{-6}$

The permeability of RAC M30 and RACM35 concrete comes under the low permeable concrete due to involvement of Nanosilica in concrete improved the concrete by filling pores and voids.

5.9 X-RAY DIFFRACTION ANALYSIS

5.9.1X-ray diffraction for RAC M30

After the analysis done the obtained raw data file is converted into xrdml format by PowDLL software and the file was analyzed in Xpert high score software

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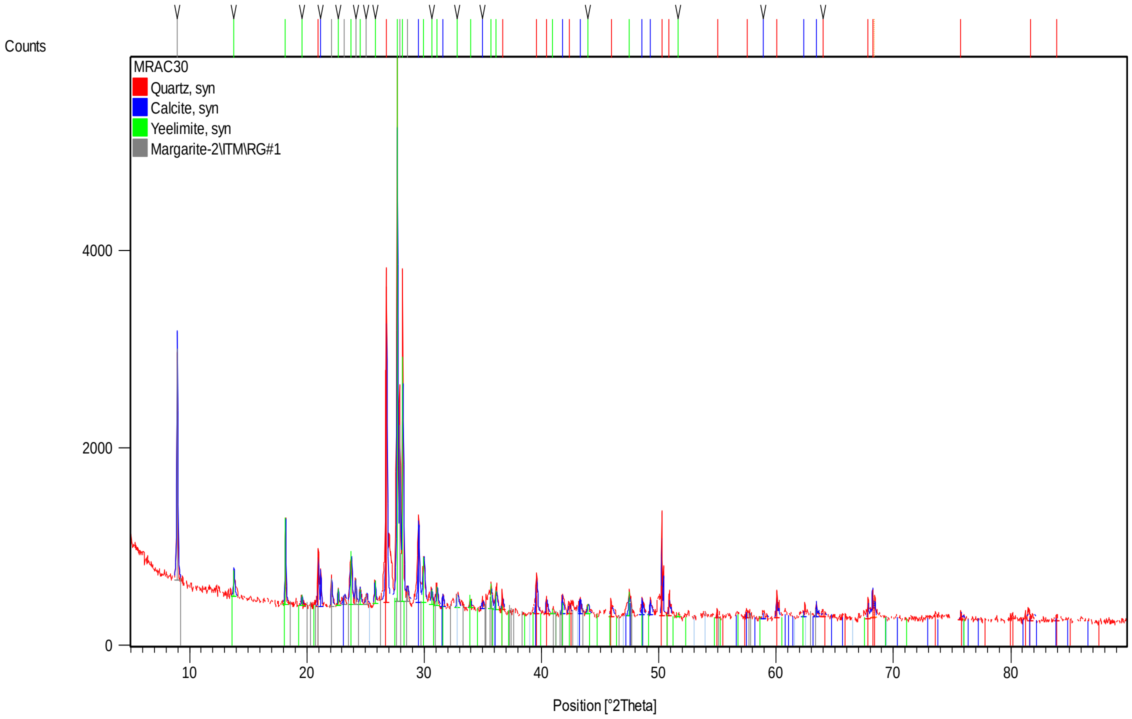

Figure 5.15 Graph obtained from Xpert high score software for RAC M30

Matched chemical compounds in Xpert high score

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	00-046-1045	56	Quartz, syn	0.099	0.395	SiO_2
*	00-005-0586	44	Calcite, syn	0.079	0.133	$CaCO_3$
*	00-033-0256	32	Yeelimite, syn	0.102	0.091	$Ca_4\ Al_6\ O_{12}\ SO_4$
*	00-018-0276	28	Margarite-2\ITM\RG#1	-0.028	0.084	$Ca\ Al_2\ (\ Si_2\ Al_2\ )\ O_{10}\ (\ O\ H\ )_2$

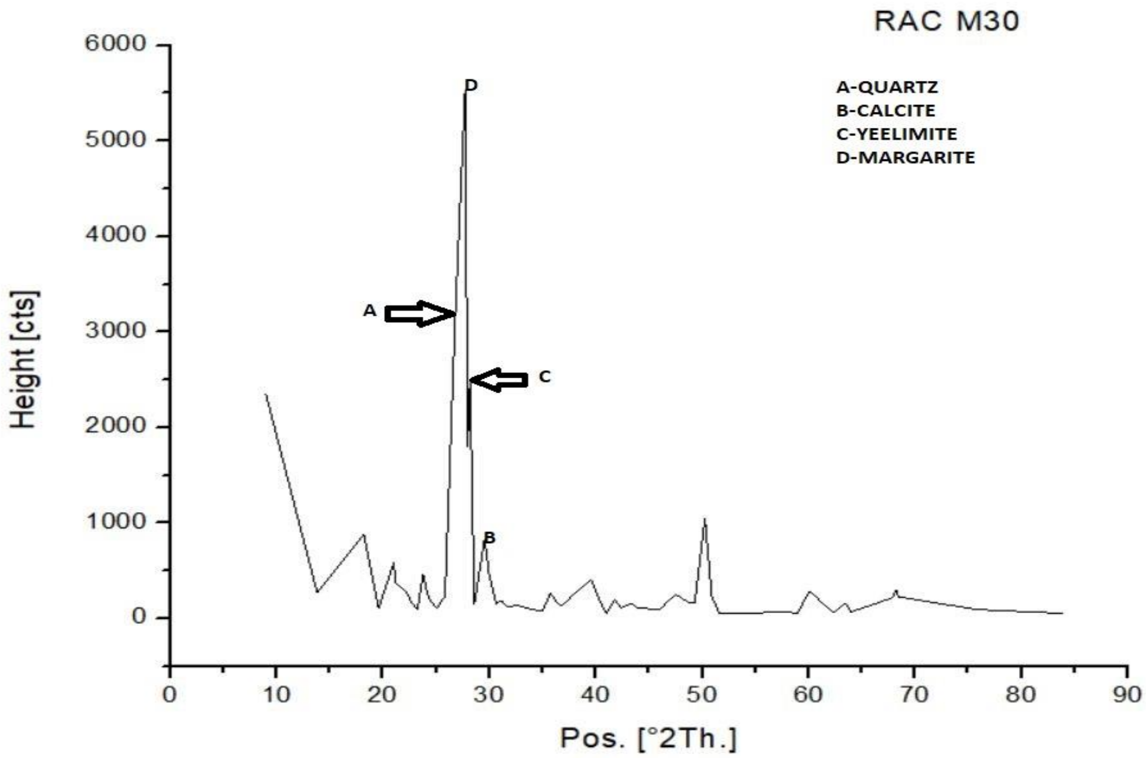

Figure 5.16 Graph 2θ degree vs. heights RAC M30

Table 5.9 compounds and its 2θ degree for RAC M30

Compound Name	**Pos.[°2h]**	**Height (Counts)**
Quartz (SiO_2)	26.7858	3204.32
Calcite ($CaCO_3$)	29.5335	833.47
Yeelimite ($Ca_4 Al_6 O_{12}SO_4$)	28.1762	2487.19
Margarite($Ca Al_2(Si_2Al_2)O_{10} (OH)_2$)	27.7113	5504.97

Crystallite Size Determination:

Crystallite size generally corresponds to the coherent volume in the material for the respective diffraction peak. Sometimes, it also corresponds to the size of the grains of a powder sample, or thickness of polycrystalline thin film or bulk material. The Scherrer's equation is used for determination of size of particles of crystals in the form of powder, which can be represented as follows

Scherrer's Formula:

Dp = (0.94 X λ) / (β X Cosθ)

Where, Dp = Average Crystallite size, β = Line broadening in radians, θ = Bragg angle, λ = X-Ray wavelength

Table 5.9.1 compounds and its crystallite size for RCA 30

Compound Name	Pos.[°2h]	FWHM [°2h]	Crystallite size (nm) Dp
Quartz (SiO_2)	26.7858	0.1004	84.99
Calcite ($CaCO_3$)	29.5335	0.1338	64.16
Ye'elimite ($Ca_4\ Al_6\ O_{12}SO_4$)	28.1762	0.1004	85.15
Margarite($Ca\ Al_2(\ Si_2Al_2\ )O_{10}\ (OH\ )_2$)	27.7113	0.1004	85.24

5.9.2 X-ray diffraction for RAC M35

After the powder analysis done the obtained raw data file is converted into xrdml format by PowDLL software and the file was analyzed in Xpert high score software

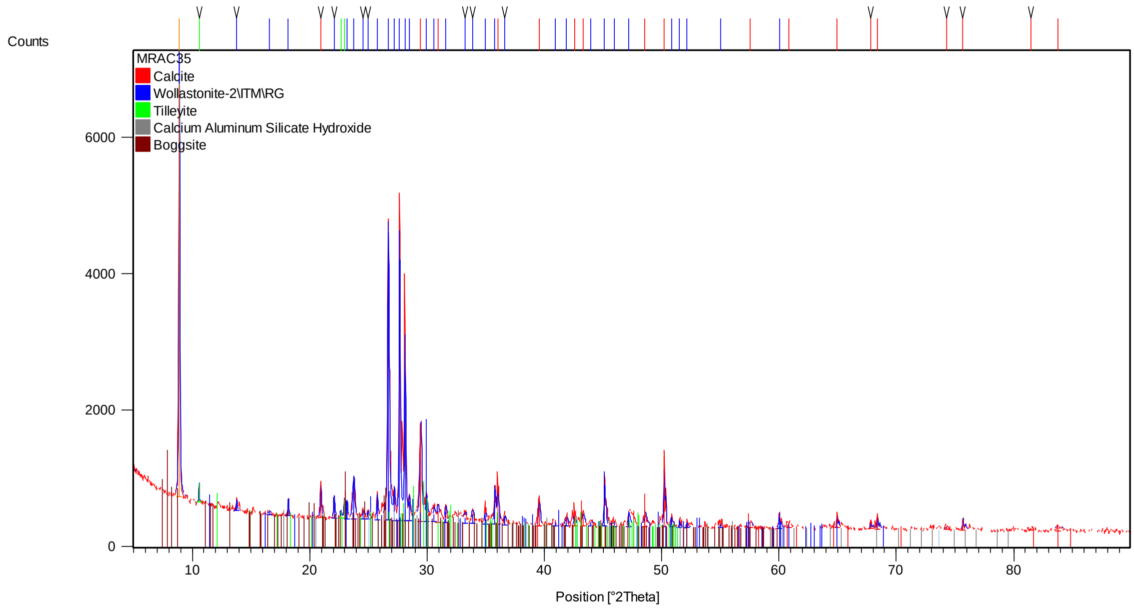

Figure 5.17 Graph obtained from Xpert high score software for RAC M35

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Matched chemical compounds in Xpert high score

Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	00-024-0027	40	Calcite	-0.001	0.196	$Ca\ CO_3$
*	00-027-0088	27	Wollastonite-2\ITM\RG	-0.070	0.208	$Ca\ SiO_3$
*	00-025-0159	24	Tilleyite	-0.015	0.082	$Ca_5\ Si_2\ O_7\ (\ C\ O_3\ )_2$
*	00-032-0151	12	Calcium Aluminum Silicate Hydroxide	0.091	0.027	$Ca_3\ Al_2\ (\ Si\ O_4\ )\ (\ O\ H\ )_8$
*	00-042-1379	14	Boggsite	0.042	0.095	$Na_{3.7}\ Ca_{7.4}\ Al_{18.5}\ Si_{77.5}\ O_{192}$!74 $H_2\ O$

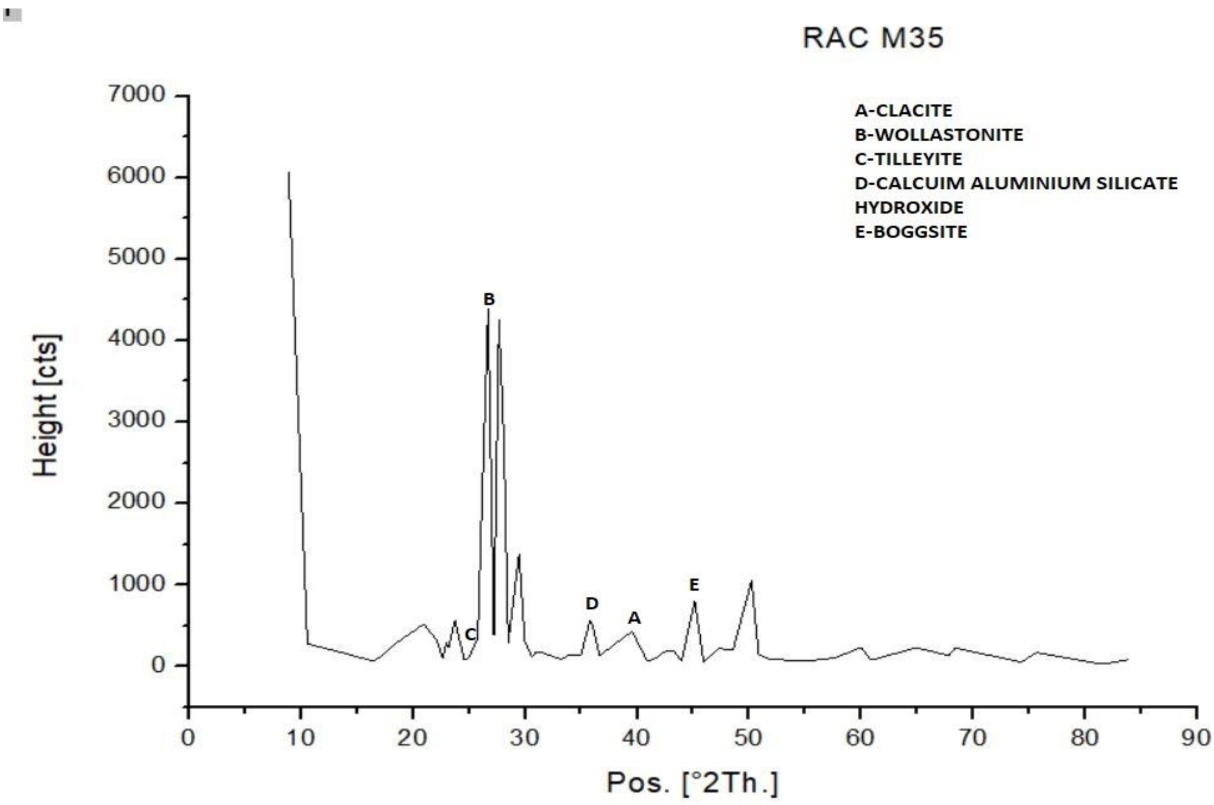

Figure 5.18 Graph 2θ degree vs. heights RAC M35

Table 5.9.2 compounds and its 2θ degree for RAC M35

Compound Name	Pos.[°2h]	Height (Counts)
Calcite (($CaCO_3$))	39.5449	432.94
Wollastonite (($Ca\ SiO_3$))	26.7022	4383.09
Tilleyite (($Ca_5Si_2O_7$ (CO_3))	25.7658	349.54
Calcium Aluminum Silicate Hydroxide (($Ca_3\ Al_2$($Si\ O_4$) ($O\ H$)$_8$)	35.7899	560.56
Boggsite(($Na_{3.7}\ Ca_{7.4}\ Al_{18.5}\ Si_{77.5}\ O_{192}$!74H_2O))	39.5449	432.94

Crystallite Size Determination:

Crystallite size generally corresponds to the coherent volume in the material for the respective diffraction peak. Sometimes, it also corresponds to the size of the grains of a powder sample, or thickness of polycrystalline thin film or bulk material. The Scherrer's equation is used for determination of size of particles of crystals in the form of powder, which can be represented as follows

Scherrer's Formula:

$Dp = (0.94 \times \lambda) / (\beta \times \cos\theta)$

Where, Dp = Average Crystallite size, β = Line broadening in radians, θ = Bragg angle, λ = X-Ray wavelength

Table 5.9.3 compound and its crystallite size RAC M35

Compound Name	Pos.[°2h]	FWHM [°2h]	Crystallite size(nm) Dp
Calcite (($CaCO_3$))	39.5449	0.1004	87.86
Wollastonite (($Ca\ SiO_3$))	26.7022	0.1338	63.76
Tilleyite (($Ca_5Si_2O_7$ (CO_3))	25.7658	0.1004	84.81
Calcium Aluminum Silicate Hydroxide (($Ca_3\ Al_2$($Si\ O_4$) ($O\ H$)$_8$)	35.7899	0.1004	86.88
Boggsite(($Na_{3.7}\ Ca_{7.4}\ Al_{18.5}\ Si_{77.5}\ O_{192}$!74H_2O))	39.5449	0.1338	65.93

Table 5.9.4 Compound matrix for RAC M30 and RACM35

Compound name	RAC M30	RAC M35
Quartz (SiO_2)	✓	…………
Calcite ($CaCO_3$)	✓	✓
Ye'elimite ($Ca_4 Al_6 O_{12}SO_4$)	✓	…………
Margarite($Ca Al_2(Si_2Al_2)O_{10} (OH)_2$)	✓	…………
Wollastonite (($Ca SiO_3$))	…………	✓
Tilleyite (($Ca_5Si_2O_7 (CO_3)$))	…………	✓
Calcium Aluminum Silicate Hydroxide (($Ca_3 Al_2(Si O_4) (O H)_8$)	…………	✓
Boggsite(($Na_{3.7} Ca_{7.4} Al_{18.5} Si_{77.5} O_{192}$!74H_2O))	…………	✓

Quartz:

Less soluble but still a major component of space filling hydrate

Calcite:

The late or delayed ettringite formation from monosulfate under the combined action of CO_2 and water. the monosulfate is decomposed by carbonation to form $CaCO_3$

Tilleyite:

Anhydrous mineral (–silicate –carbonate mineral) occurs in the presence of nano silica

Ye'elimite:

it is naturally occurring form of calcium sulfoaluminate, $Ca_4(AlO_2)_6SO_3$.On hydration in the presence of calcium and sulfate ions, it forms the insoluble, fibrous mineral ettringite, which provides the strength in sulfoaluminate concretes, and/or monosulfoaluminate, and aluminium hydroxide.

Margarite:

It is clay mineral rarely belongs to mica group it occurs due to special compositional or physical condition of formation.

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Boggsite:

it is a zeolite group which belongs to Pozzolanic in nature it delivers the better performance in mechanical properties of concrete

Calcium Aluminum Silicate Hydroxide:

It is formed due to C-S-H reaction in concrete paste or cement paste.

Wollastonite:

Wollastonite is a naturally occurring mineral known as calcium metasilicate (CaSio3). It contains silica which reacts with water to form calcium-silicate-hydrate (CSH). CSH is also responsible for imparting strength to cemented material when Portland cement hydrates.

5.10 SCANNING ELECTRON MICROSCOPE- IMAGES

5.10.1 SEM RAC M30

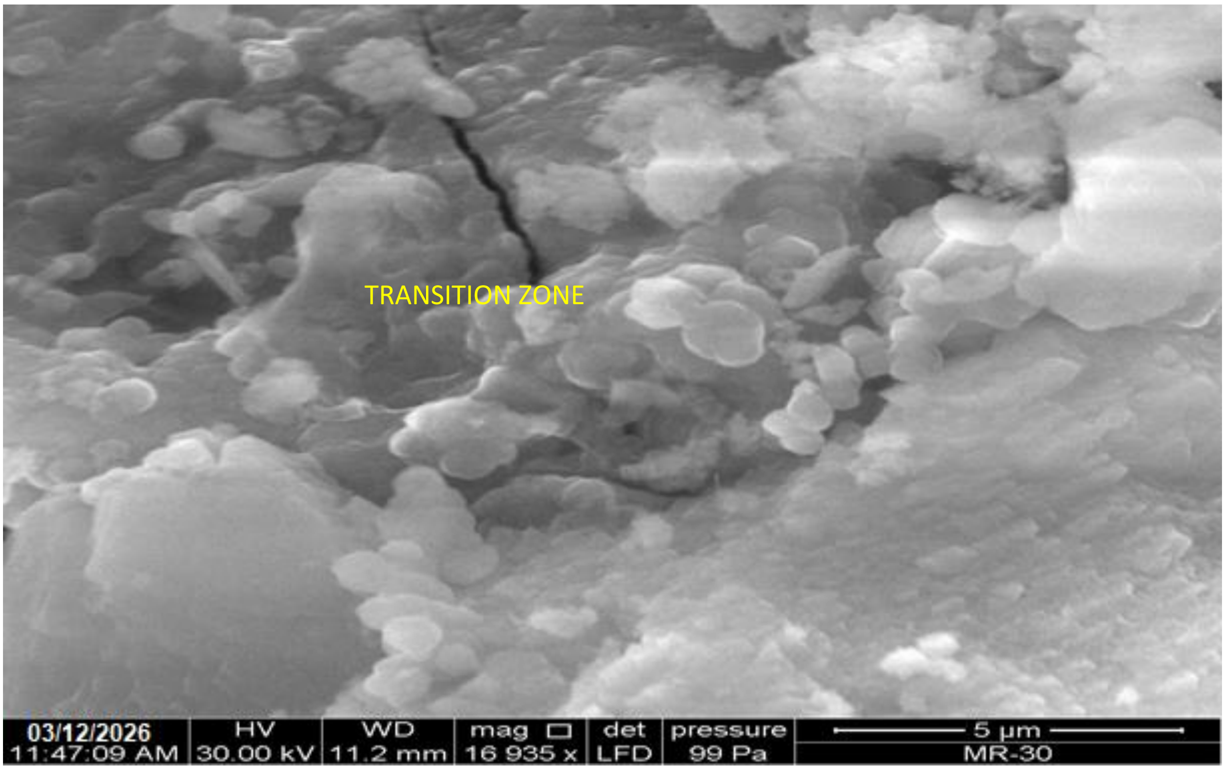

Figure 5.19 Scanning electron microscopy of RAC M30 at 5 µm

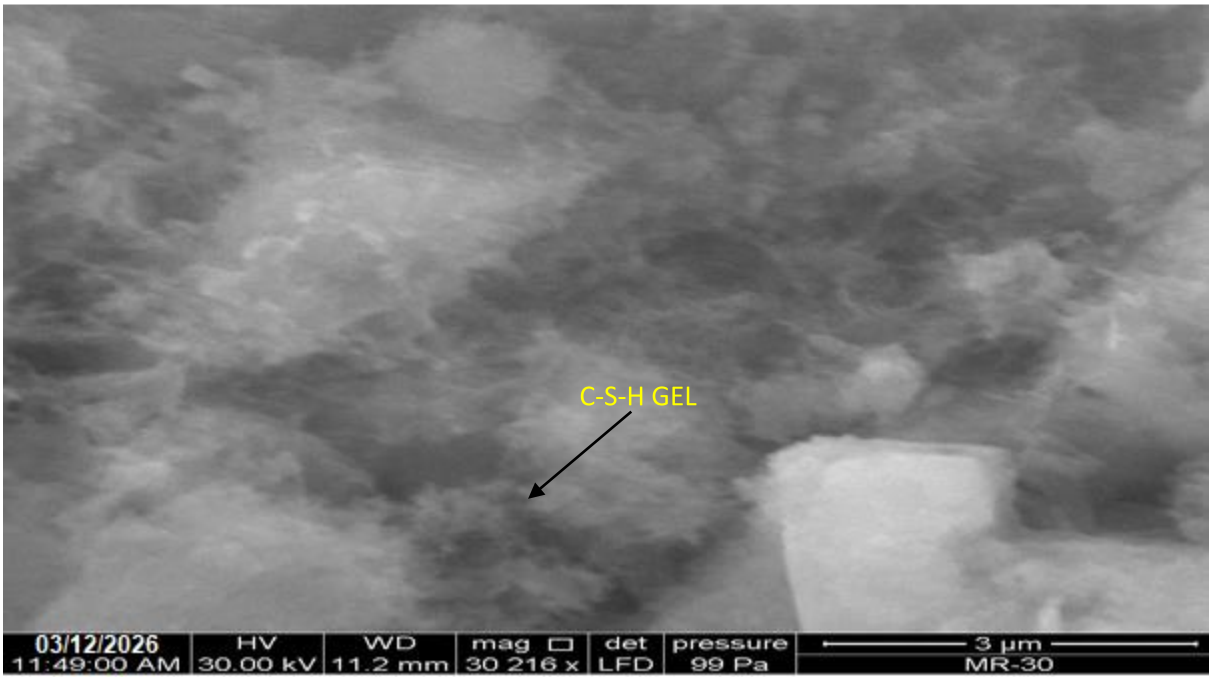

Figure 5.20 Scanning electron microscopy of RAC M30 at 3 µm

5.10.2 SEM RAC 35

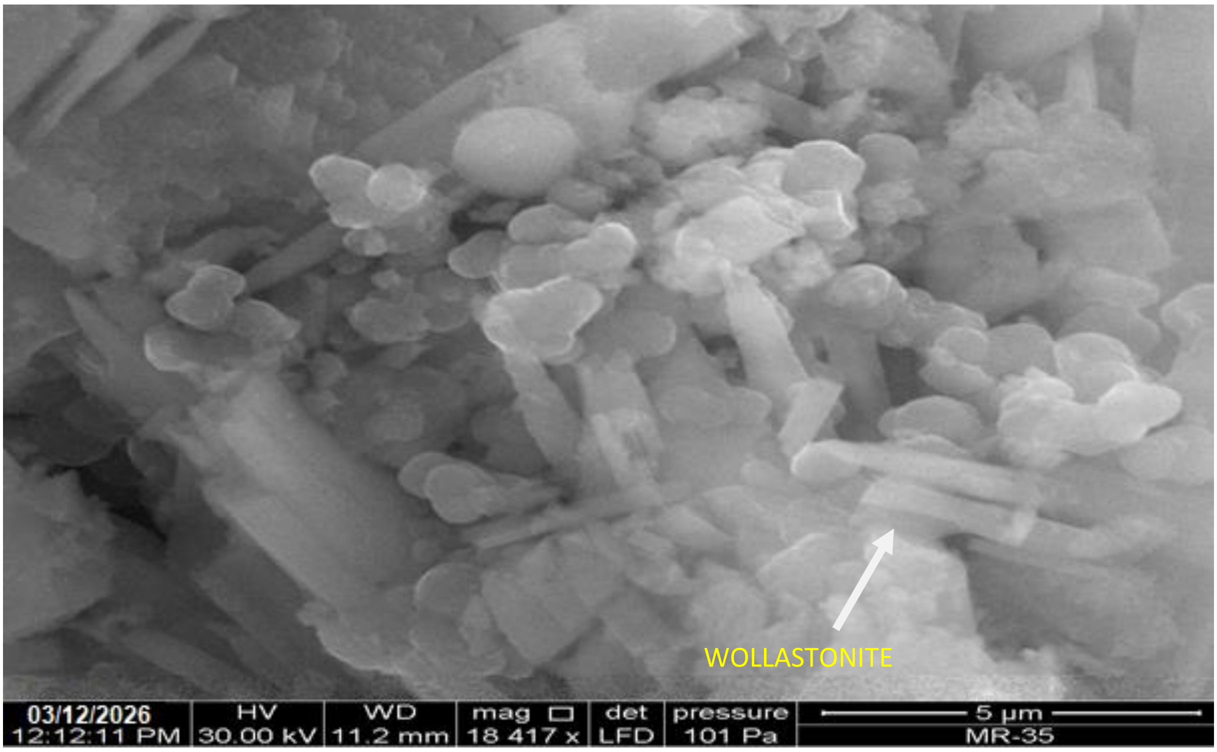

Figure 5.20 Scanning electron microscopy of RAC M35 at 5 µm

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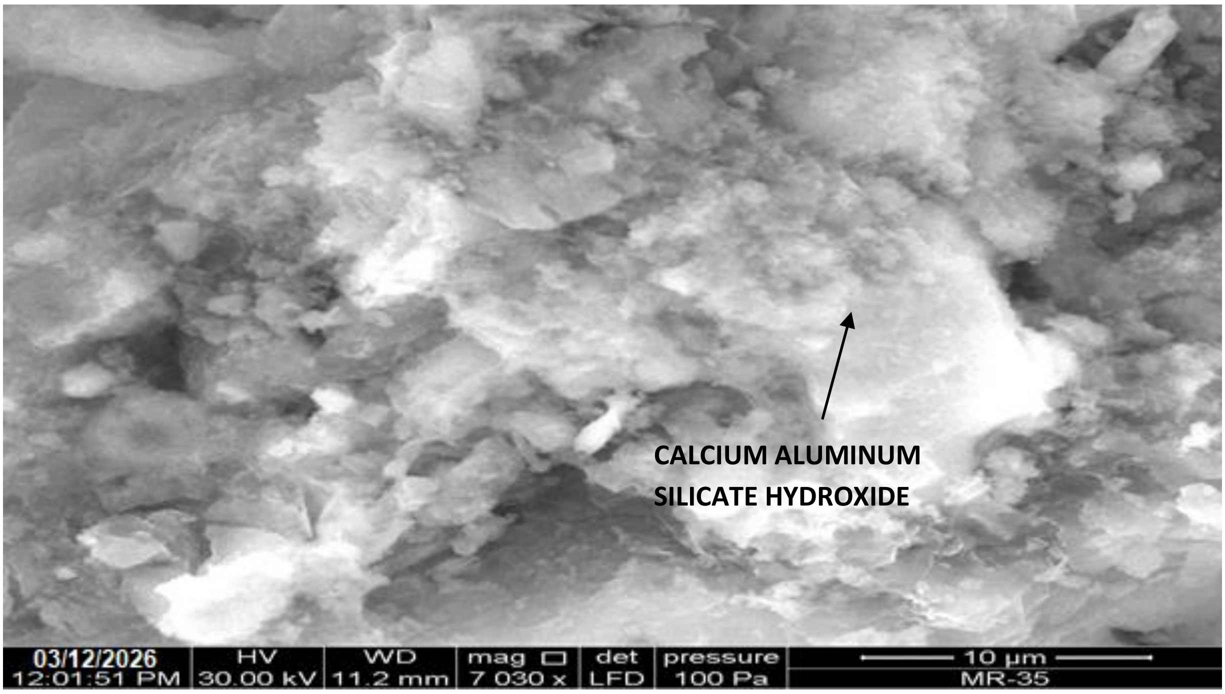

Figure 5.21 Scanning electron microscopy of RAC M35 10 µm

6. CONCLUSIONS

6.1CONCLUSIONS

A study was done on 40% use of recycled concrete with 1.5% partial replacement of Nanosilica by weight of cement, Compressive strength, Split tensile strength, Flexural strength, effect of acid on concrete, Permeability test, SEM images and XRD analysis were conducted.

Based on the test results, the following conclusions were drawn:

1. Compressive strength at the age of 28 days was increased by 5% and 3% to its target strength of RAC M30 and RAC M35 grades respectively due to influence of Nanosilica
2. There is a lean variation in split tensile strength and flexural strength of RAC M30 and RAC M35 at 3, 7 and 28 days curing.
3. There is weight loss due to acid exposure for 14, 28, 42 and 56 days for both the grades in 0.1% and 0.3 % of H_2SO_4
4. There is gradual reduction of compressive strength in 42 and 56 days of acid exposure of 0.1% and 0.3 % of H_2SO_4 in both the grades.
5. Coefficient of permeability obtained of RAC M30 and RAC M35 and comparing it to standard quality of concrete (GWT) was found low permeable concrete were Nanosilica reduced the flow of water in the concrete.
6. Under the scanning electron microscopy the voids and pores were filled by Nanosilica to some extent is shown and transition zone is also observed.

7. In xrd analysis two theta values was found for matched compounds and its crystallite size was derived. Concrete exposure to aggressive environment condition and cyclic loading effect the crystal growth and leads to cracks and deterioration of concrete starts.

APPENDIX - I

MIX DESIGN PROCEDURE

The mix design for M35 grade of concrete is described below in accordance with Indian Standard Code IS: 10262-1982.

Grade : M35-RAC35

Cement : PPC

Size of the aggregate : 20mm &10mm

Min content of cement : 400kgs

Exposure condition : Moderate

Workability of concrete : 50

Degree of super position : Good

Max water cement ratio : 0.395

TARGET STRENGTH FOR MIX PROPORTIONING:

Characteristic compressive strength at 28 days: f_{ck} = 35 MPa

Assumed standard deviation (Table 1 of IS 10262:1982): sd = 5 MPa

Target average compressive strength at 28 days: $f_{target} = f_{ck} + 1.65sd = 43.25$ MPa

1. SELECTION OF WATER-CEMENT RATIO:

From Table 5 of IS: 456-2000, maximum water-cement ratio = 0.60

From Table 2, maximum water content =186

2. SELECTION OF WATER CONTENT:

Maximum water content per cubic meter of concrete (refer Table 2 of IS: 10262-1982)

W_{max} = 186L (for 50 mm slump).

Water content taken = 158 liters

3. CALCULATION OF CEMENT CONTENT:

Mass of water selected per cubic meter of concrete = 158 kg.

Mass of cement per cubic meter of concrete = 158/0.395 = 400 kg.

Minimum cement content = 300 kg/m^3 (for moderate exposure condition, Table 5 of IS 456:2000)

Maximum cement content = 450 kg/m^3 (Cl. 8.2.4.2 of IS 456:2000)

So, the selected cement content is alright.

4. PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT:

Volume of coarse aggregate per unit volume of total aggregate (Table 3 of IS: 10262-1982) = 0.62

(This is corresponding to 20 mm size aggregate and Zone II fine aggregate for Water-cement ratio of 0.47)

As the water-cement ratio is lowered by 0.05, the proportion of volume of coarse aggregate is increased by 0.01 (ref. Table 3 of IS: 10262-1982)

Corrected volume of coarse aggregate per unit volume of total aggregate = (0.60+0.02) = 0.62

Volume of fine aggregate per unit volume of total aggregate = 1-0.62 =0.338

5. MIX CALCULATIONS

i. Volume of concrete = 1 m^3

ii. Volume of cement = 400 / (2.9×1000) = 0.1379 m^3

iii. Volume of water = 158/1000 = 0.158 m^3

iv. Volume of all aggregates = 1-(0.1379+0.158) = 0.7041 m^3

v. Mass of fine aggregate = 0.7041×0.38×2.57×1000 = 687.62kg

vi. Mass of Recycled coarse aggregate = 0.7041x0.4x2.74x0.62x1000=478.45kg

vii. Mass of Crushed aggregate=0.7041x0.6x2.82x0.62x1000=738.6kg

viii. Mass of 20mm crushed aggregate= 0.40x738.6= 295.45 kg.

ix. Mass of 10mm crushed aggregate= 0.60x738.6= 443.1kg.

x. volume of Nanosilica=1.5x400/100=6.0

Water : cement : fine aggregate : course aggregate (RCA+NCA)

158 : 400 : 687.62 :1217 (478.45: 738)

1 : 1.719 :3.042

Table a: Mix design contents

Components	RACM30 grade	RACM35 grade
W/C Ratio	0.43	0.395
Cement (Kg)	368	400
Water (Kg)	182	181
Fine aggregate (Kg)	698	687
Coarse aggregate (Kg) 1. 20mm RCA 2. 20mm NCA 3. 10mm NCA	 486. 300 450	 478 295 443
Nanosilica (Kg)	5.15	6.0

Nanosilica calculation:

Nanosilica : 1.5% of cement = 1.5x400/100

= 6.00 Kg

Given Solid content : 15%

Liquid content : 85%

Solid content: (15/100) x 6.00 = 0.90Kg

Liquid content: (85/100) x 6.00 = 5.1 Kg

Subtracting solid and liquid content:

The required quantities of cement and water added are:

Cement = 400 – 0.90 = 399.12 Kg

Water = 186 – 5.07 =180.0 Kg

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APPENDIX - II

SAMPLE CALCULATIONS

Sample calculations of the quantities required for the mix with water-cement ratio 0.47 for the basic mix design with normal sand as fine aggregate.

Volume required:

For 9 cubes = $9 \times 0.15 \times 0.15 \times 0.15$ $= 0.030\ m^3$

For 9 cylinders = $9 \times \frac{\pi}{4} \times 0.15^2 \times 0.3$ $= 0.047\ m^3$

For 9 cubes = $9 \times 0.50 \times 0.10 \times 0.10$ $= 0.045\ m^3$

Add 25% extra to the total considering wastage = $0.122\ m^3$

Total quantity $= 0.244\ m^3$

Quantity of cement required for $0.244\ m^3$ of concrete = 0.244x 400

=97.6 kg

Quantity of fine aggregate required for $0.244\ m^3$ of concrete =0.244 x 687

= 167.62 kg

Quantity of total coarse aggregate required for $0.244\ m^3$ =0.244 x 1217

of concrete =296.9kg

Quantity of recycled aggregate for $0.224\ m^3$ of concrete (20mm) ==0.4x295

=118.0kg.

Quantity of crushed aggregate for $0.224\ m^3$ of concrete =0.224x738

(40% 20mm+60%10mm) =165.31(66.08+99.2)

Quantity of water required for $0.244\ m^3$ of concrete =0.244 x 158

= 38.524 liters

Quantity of admixture required for $0.244\ m^3$ of concrete

(Nanosilica) =97.6 x (1.5/100)

=1.464

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APPENDIX – III

STRENGTH CALCULATIONS

A. Compressive strength of Cube:

Maximum load applied on the specimen (P), in Newton = 1150kN

Cross sectional area of cube (A), in mm^2 = 150 x $150mm^2$

Compressive strength of cube $= \frac{P}{A}$

$= \frac{1150 \text{ x } 1000}{150 \text{ x } 150}$

$= 51.11 \text{ N/mm}^2$

B. Split tensile strength of Cylinder:

Maximum load applied on the specimen (P), in Newton = 200 kN

Area of cylinder (A), in mm^2 $= \frac{\pi}{4} \text{ x } 150^2 \text{ mm}^2$

Compressive strength of cube $= \frac{2 \text{ x } P}{\pi \text{ x } d \text{ x } l}$

$= \frac{2 \text{ x } 200 \text{ x } 1000}{\pi \text{ x } 300 \text{ x } 150}$

$= 2.83 \text{ N/mm}^2$

C. Flexural strength of Prism:

i. When the tensile crack is between 11.00 cm and 13.33 cm,

Maximum load applied on the specimen (P), in kgs = 1260 kg

Volume of prism (l, b, d) = 500 x 100 x 100 mm^3

Flexural strength of the beam $= \frac{3xPxa}{bxdxd}$

$= \frac{3 \text{ x } 1260 \text{ x } 9.81 \text{ x } 131}{100 \text{ x } 100 \text{ x } 100}$

$= 4.85 \text{ N/mm}^2$

ii. When the tensile crack is greater than 13.33 cm,

Maximum load applied on the specimen (p), in kg = 1260 kg

Volume of prism (l, b, d) = 500 X 100 X 100 mm^3

Flexural strength of the beam $= \frac{P \text{ x } l}{b \text{ x } d \text{ x } d}$

$$= \frac{1260 \times 9.81 \times 400}{100 \times 100 \times 100}$$

$$= 4.94 \text{ N/mm}^2$$

APPENDIX – IV

Sample calculation for 0.1% H_2SO4 solution:

Say, Normality of sodium hydroxide is 1N, Sodium hydroxide consumed by 20ml of sulphuric acid is 2.2 ml.

$$N_2 = \frac{N_1 \times 1}{V_b} = \frac{1 \times 2.2}{20} = 0.11N$$

Sample calculation for 0.3% H_2SO4 solution:

Say, Normality of sodium hydroxide is 1N; Sodium hydroxide consumed by 20ml of sulphuric acid is 3.3 ml.

$$N_2 = \frac{N_1 \times 1}{V_b} = \frac{1 \times 3.3}{20} = 0.166N$$

Sample calculation for 0.3% H_2SO_4 Solution

0.136 liters of Sulphuric acid was added to 25 liters of water. To neutralize 20ml of this solution 3.3ml of Sodium hydroxide was consumed. Concrete specimens were exposed in this solution, after 3 days, a sample of solution was collected. This time 2.2of sodium hydroxide was required to neutral 20ml of the solution.

Calculation for the amount of acid consumed by the concrete are

$$\text{ANo.} = \frac{N_2 \times M_{(NaHCO3)} \times V_b}{V_s}$$

$$= \frac{(1 \times 83 \times 2.2)}{20}$$

$$= 9.3$$

$H_2SO_4 + 2NaOH ==> Na_2SO_4 + 2H_2O$

Each mole of H_2SO_4 needs 2 moles of $NaHCO_3$ for neutralization.

Moles of H_2SO_4 present in one liter of solution

$$C_o = \frac{18.816}{(40 \times 2)}$$

$$= 0.2352 \text{ moles of } H_2SO_4/\text{lt}$$

Where the subscript of AN and C refers to the age in days at which the sample is analyzed.

$$AN_3 = \frac{0.98 \times 40 \times 1.8}{5}$$

$$= 14.112$$

$$C_3 = \frac{14.112}{(40 \times 2)}$$

$$= 0.1764 \text{ moles of } H_2SO_4/\text{lt}$$

$$\text{Acid consumed in three days} = \frac{(c_o - c_t) \times v_0}{c_o}$$

$$= \frac{(0.166 - 0.11) \times 136}{0.166}$$

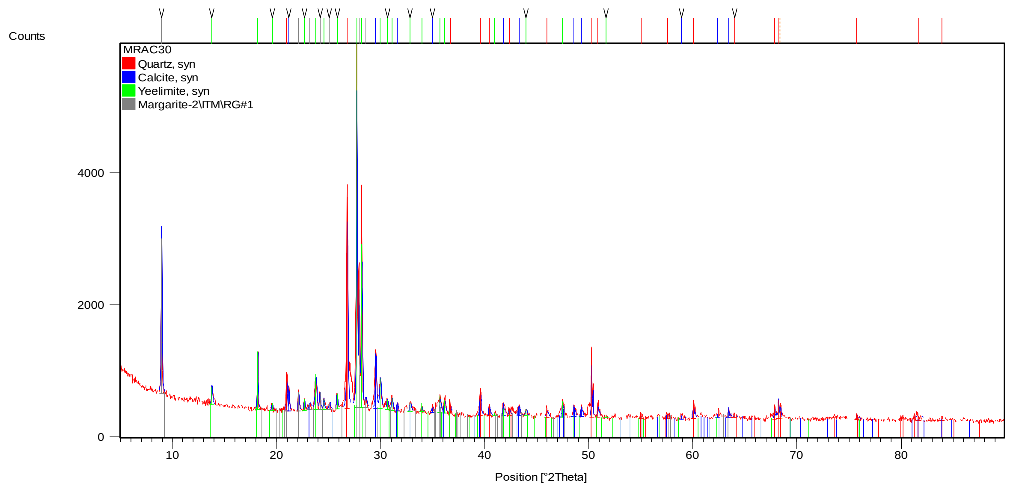
$$= 42.5\text{ml}$$

Therefore approximately 42.5ml of acid was added to the solution and thoroughly mixed to get a uniform solution. Similar procedure was employed for all the samples and at all ages.

APPENDIX – V

XRD DATA:

RAC M30



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DATA OBTAINED FROM XPERT HIGH SCORE

Pos. [°2Th.]	Height [cts]	FWHM [°2Th.]	d-spacing [Å]	Rel. Int. [%]
8.9662	2352.85	0.1004	9.86295	42.46
13.8041	268.74	0.1338	6.41525	4.85
18.1838	883.80	0.1004	4.87878	15.95
19.5844	107.92	0.1004	4.53291	1.95
20.9812	581.33	0.0669	4.23420	10.49
21.1874	375.10	0.0669	4.19345	6.77
22.1217	288.37	0.1004	4.01841	5.20
22.6806	169.79	0.1004	3.92064	3.06
23.2085	92.96	0.2676	3.83263	1.68
23.7662	463.62	0.2007	3.74394	8.37
24.1560	264.18	0.1004	3.68441	4.77
24.5285	168.99	0.1338	3.62930	3.05
25.0849	107.49	0.2007	3.55004	1.94
25.8129	234.31	0.1338	3.45154	4.23
26.7868	3204.32	0.1004	3.32823	57.83
27.7113	5540.97	0.1004	3.21926	100.00
27.9368	1793.63	0.0669	3.19379	32.37
28.1762	2487.19	0.1004	3.16719	44.89
28.5778	145.78	0.1338	3.12359	2.63
29.5335	833.47	0.1338	3.02465	15.04
29.9647	473.60	0.1673	2.98210	8.55
30.6271	149.34	0.1338	2.91910	2.70
31.0986	187.78	0.1338	2.87591	3.39
31.5964	129.30	0.1338	2.83173	2.33
32.8394	132.90	0.2007	2.72733	2.40
33.9381	95.14	0.1338	2.64151	1.72
34.9690	75.06	0.2007	2.56596	1.35
35.7091	264.88	0.1004	2.51446	4.78
36.1508	197.16	0.1338	2.48475	3.56
36.6800	129.48	0.1338	2.45010	2.34
39.5659	408.74	0.1338	2.27779	7.38
40.4356	169.52	0.1338	2.23079	3.06
40.9680	52.79	0.2676	2.20302	0.95
41.7876	194.97	0.1004	2.16168	3.52
42.3553	109.44	0.1338	2.13402	1.98
43.2767	158.87	0.1673	2.09069	2.87
43.9596	109.27	0.1673	2.05979	1.97
45.9783	95.00	0.2676	1.97394	1.71
47.4766	254.39	0.1338	1.91509	4.59

48.5810	176.75	0.1338	1.87410	3.19
49.2770	161.06	0.1338	1.84925	2.91
50.2482	1044.53	0.0669	1.81576	18.85
50.8805	229.05	0.1004	1.79467	4.13
51.6290	47.48	0.2007	1.77040	0.86
55.0475	57.67	0.2007	1.66827	1.04
57.5522	71.01	0.2007	1.60149	1.28
58.9352	54.50	0.4015	1.56717	0.98
60.0652	283.22	0.1004	1.54036	5.11
62.3662	61.96	0.5353	1.48894	1.12
63.4261	161.57	0.1004	1.46659	2.92
63.9798	68.32	0.2007	1.45523	1.23
67.8454	215.87	0.1004	1.38143	3.90
68.2287	296.16	0.1224	1.37346	5.34
68.4207	227.98	0.0816	1.37348	4.11
75.7485	93.91	0.1224	1.25470	1.69
81.6533	64.91	0.6528	1.17824	1.17
83.9365	53.94	0.4896	1.15190	0.97

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