Recycling of Concrete using Chemical Admixtures

Submitted in partial fulfilment of the requirements

of the degree of

Bachelor of Engineering

by

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CERTIFICATE

This is to certify that **following students** has satisfactorily completed and delivered a Project-A seminar report entitled **“RECYCLING OF CONCRETE USING CHEMICAL ADMIXTURE”** submitted in partial fulfilment of the requirements for the award of the degree of **bachelor of Engineering** in **Civil Engineering** course conducted by university of Mumbai in Anjuman-I-Islam’s Kalsekar Technical Campus, Navi-Mumbai.

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Project Report Approval for B.E.

This project report entitled ***Recycling of Concrete using Chemical Admixturess*** by ***Shaikh Ramjan Mustak, Shafi Abdul Basit and Khan Abdul Karim*** is approved for the degree of ***Bachelor of Engineering in Civil Engineering.***

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2. --

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Chairman/Director

Date: 29/04/2016

Place: New Panvel, Navi Mumbai

Declaration

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Abstract

The development in the construction industry all over the world is progressing day by day. High-tech and modernized designs are being built and old buildings are being demolished or renovated. One of the things builders, developers and contractors must consider during construction, renovation or demolition is where to put all the debris. When structures made of concrete are to be demolished, concrete recycling is an increasingly common method of disposing of the rubble. Concrete debris was once routinely shipped to landfills for disposal, but recycling has a number of benefits that has made it more attractive option in this age of greater environmental awareness, more environmental laws, and the desire to keep construction costs down. In this study, we are aiming to design a concrete debris mixture as mortar mix that will meet the IS requirements, in order to help contribute to the industry in saving the environment, to encourage the government to find solutions regarding the disposal to landfills of waste materials and save the environment, to provide new knowledge to the contractors and developers on how to improve the construction industry methods and services by using recycled concrete debris, and to sustain good product performance and meet recycling goals. The objectives of this project are to prepare a mix design of M20 grade concrete using concrete rubble from demolition site and admixture (super-plasticizer), to prepare a mix design of M25 grade concrete using concrete rubble from demolition site and admixture (super-plasticizer), to carry out Slump Cone Test on the above mentioned concrete mixes, to carry out Compressive Strength Test on the above mentioned concrete mixes, to carry out different tests on recycled aggregates & natural aggregates & compare their results and to finally conclude the effectiveness of concrete recycling based on the above test results

Keywords: Concrete, recycling, debris, slump cone test, compressive strength

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Chapter 1

Introduction

1.1. General

As time goes by, the development in the construction industry all over the world is progressing. Many structures are being built, both residential and non residential, as well as roads and bridges. Just like many countries, the demand for new structures in the India is highly increasing. High-tech and modernized designs are built and old buildings are demolished or renovated. The resulting non-hazardous and uncontaminated materials are called debris. These include asphalt, bricks, concrete and other masonry materials, soil, rock, wall coverings, drywalls, plumbing fixtures, insulation, roofing, shingles, steel plates, glass, metal, wood waste, carpet and electrical wires. These materials can be separated and salvaged prior to disposal.

One of the things builders, developers and contractors must consider during construction, renovation or demolition is where to put all the debris. As what most people do in the preservation of the environment and for economic purposes, studies, researches and experiments are being done to find solution considering where else to put debris and what can be done to lessen its disposal landfill to disposal and since, there is an increasing environmental problem regarding the waste disposal to landfills, it is necessary to think of possible ways on how to avoid these problems and at the same time secure safety and convenience, and that is, to recycle.

When structures made of concrete are to be demolished, concrete recycling is an increasingly common method of disposing of the rubble. Concrete debris was once routinely shipped to landfills for disposal, but recycling has a number of benefits that has made it more attractive option in this age of greater environmental awareness, more environmental laws, and the desire to keep construction costs down. Major motivators include the realization that using recycled materials can achieve cost savings, qualify for tax savings, improve product performance and meet recycling goals. It is beneficial in two ways: it reduces the inputs (energy and raw materials) to a production system and reduces the amount of water produced for disposal.

In this study, we are aiming to design a concrete debris mixture as mortar mix that will meet the IS requirements, in order to help contribute to the industry in saving the environment, to encourage the government to find solutions regarding the disposal to landfills of waste materials and save the environment, to provide new knowledge to the contractors and developers on how to improve the construction industry methods and services by using recycled concrete debris, and to sustain good product performance and meet recycling goals.

1.2. Background:

The construction of buildings, bridges and roadways continues to increase in the twenty-first century, especially in areas with ever-growing populations. Existing structures and highways require repair or replacement as they reach the end of their service life or simply no longer satisfy their intended purpose due to the growing population. As modern construction continues, two pressing issues will become more apparent to societies: an increasing demand for construction materials, especially concrete and asphalt aggregates and an increasing production of construction and demolition waste. Already, it has been estimated that two billion tons of new aggregate are produced each year in India. This demand is anticipated to increase to two and a half billion tons each year by 2020. With such a high demand for new aggregates, the concern arises of the depletion of the current sources of natural aggregates and the availability of new sources. Similarly, the construction waste produced is also expected to increase. From building demolition alone, the annual production of construction waste is estimated to be 123 million tons. Currently, this waste is most commonly disposed of in landfills. To address both the concern of increasing demand for new aggregates and increasing production of waste, many states have begun to recognize that a more sustainable solution exists in recycling waste concrete for use as aggregate in new concrete, or recycled concrete aggregates (RCA). The solution helps address the question of how to sustain modern construction demands for aggregates as well as helps to reduce the amount of waste that enters already over-burdened landfills. There are many studies that prove that concrete made with this type of coarse aggregates can have mechanical properties similar to those of conventional concretes and even high-strength concrete is nowadays a possible goal for this environmentally sound practice. Some researchers insist that the quantity of recycled aggregate varies with river aggregate by % of 0, 50 and 100 respectively. Compressive strength mainly depends on the quality of recycled aggregate. If good quality aggregate is used for the production of new concrete, the recycled aggregate has no influence on the compressive strength, regardless of the replacement ratio of natural coarse aggregate with recycled aggregate. The modulus of elasticity of concrete also decreases with increasing recycled aggregate content as a consequence of lower modulus of elasticity of recycled aggregate compared to natural aggregate. Some researchers have concluded that the use of recycled aggregates in concrete is both economically viable & technically feasible. In addition to demolition waste sources, RA can also be composed of excess concrete materials returned to the plant. Large scale recycling of demolished waste will offer, not only the solution of growing waste disposal problem and energy requirement, but will also help construction industry in getting aggregates locally. Such demolition waste can be crushed to required size, depending upon the place of its application and crushed material is screened in order to produce recycled aggregate of appropriate sizes. Utilization of construction & demolition waste is quite common in industrialized countries but in India so far no organized effort has been made.

1.3. Problem

The environmental impact of concrete, its manufacture and applications, is complex. Some effects are harmful; others welcome. Many depend on circumstances. A major component of concrete is cement, which has its own environmental and social impacts and contributes largely to those of concrete. In spite of the harm that badly planned use of concrete can do, well-planned concrete construction can have many sustainable benefits. The cement industry is one of the primary producers of carbon dioxide, a major greenhouse gas. Concrete is used to create hard surfaces which contribute to surface runoff that may cause soil erosion, water pollution and flooding. Conversely, concrete is one of the most powerful tools for proper flood control, by means of damming, diversion, and deflection of flood waters, mud flows, and the like. Concrete is a primary contributor to the urban heat island effect, but is less so than asphalt. Concrete dust released by building demolition and natural disasters can be a major source of dangerous air pollution. The presence of some substances in concrete, including useful and unwanted additives, can cause health concerns due to toxicity and radioactivity. Wet concrete is highly alkaline and should always be handled with proper protective equipment. Concrete recycling is increasing in response to improved environmental awareness, legislation, and economic considerations.

1.4. Solution:

The solution to the above problem lies in recycling of concrete. There are many good reasons for a business or individual to take the time to recycle concrete instead of having it dumped in a concrete disposal. First of all, recycling concrete benefits the environment. While some pollution is generated when a concrete recycling plant crushes the used concrete, this pollution is negligible compared to the pollution produced by trucks transporting concrete to and from a quarry. Anyone who is concerned about air pollution should do everything possible to promote concrete recycling.

The fact that crushed concrete can be used in place of granite also helps to preserve the environment. Mining granite not only produces air pollution but also water pollution. It has been estimated that every ton of recycled concrete saves 1,360 gallons of water that would otherwise be used to mine granite.

As the concept of recycling concrete has started gaining in popularity, more and more companies have found ways to use this form of concrete. Small pieces of recycled concrete are often used in place of gravel for new building projects. This is commonly done when a new road is built. After the broken, recycled concrete has been laid down, fresh concrete or asphalt is poured over it to form the road surface.

If the recycled concrete does not have any contaminants, it can be used as dry aggregate and mixed in with fresh concrete. Large pieces of concrete are commonly used for erosion control. Crushed concrete blocks can also be placed in wire cages known as gabions and then used to build cheap yet durable retaining wall or even outer property walls.

Whether or not the recycled concrete can be used for a particular project depends on the quality standards set by the recycling plant that handles the used concrete. If the plant has a high quality control system, then the crushed concrete can in some cases be used in place of mulch or traditional landscaping stones.

There are numerous advantages to recycling concrete. While this form of recycling was not common until recently, it is starting to become more and more popular. Recycling concrete helps to protect the environment, reduce landfill space and prevent water and air pollution. Concrete recycling also provides job opportunities in the local area and reduces costs for construction companies and those who are hiring such companies to build a particular structure. There are numerous uses for recycled concrete, so any individual involved in the construction business will want to take advantage of recycled concrete to not only reduce operating costs but even more importantly preserve the earth for future generations.

1.5. Objectives of the project:

The objectives of this project are as follows:

i) To prepare a mix design of M20 grade concrete using concrete rubble from demolition site and admixture (super-plasticizer)
ii) To prepare a mix design of M25 grade concrete using concrete rubble from demolition site and admixture (super-plasticizer)
iii) To carry out Slump Cone Test on the above mentioned concrete mix
iv) To carry out Compressive Strength Test on the above mentioned concrete mix
v) To carry out different tests on recycled aggregates & natural aggregates & compare their results.
vi) To conclude the effectiveness of Concrete Recycling based on the above test results

1.6. Organization of the project:

In the first chapter "Introduction", the background, problem, proposed solution, objectives of the project and its expected outcomes are mention. In the second chapter, namely "Review of Literature", various technical papers related to the subject are summarized in order to understand the nature of work that has already been carried out in this field. The third chapter is called "Methodology" and in this chapter, the various tests carried out in this project are discussed. In the fourth chapter "Results", the results of the above test are presented. In the fifth chapter called "Conclusion", based on the above results, the effectiveness of using recycled concrete is commented upon.

Chapter 2

Review of Literature

2.1. Introduction:

Technical papers from various well-known journals from all over the world are studied in this section and each relevant paper is summarised and presented in this chapter in chronological order so as to understand the existing work available on this topic.

2.2. Summaries of relevant technical papers:

Shi Cong Kou, Chi Sun Poon et al (2002) have shown that the use of high percentages of recycled aggregates in concrete would usually worsen the concrete properties. This paper tries to address the deficiency of the use of recycled aggregates by systematically presenting results on the influence of incorporating Class F fly ash on concrete properties. In this study, two series of concrete mixtures were prepared with water-to-binder (W/B) ratios of 0.45 and 0.55. The recycled aggregate was used as 0, 20, 50, and 100% by weight replacements of natural aggregate. In addition, fly ash was used as 0, 25, and 35% by weight replacements of cement. The results showed that the compressive strengths, tensile strengths, and static modulus of elasticity values of the concrete at all ages decreased as the recycled aggregate and the fly ash contents increased. Further, an increase in the recycled aggregate content decreased the resistance to chloride ion penetration and increased the drying shrinkage and creep of concrete. Nevertheless, the use of fly ash as a substitute for cement improved the resistance to chloride ion penetration and decreased the drying shrinkage and creep of the recycled aggregate concrete. The results showed that one of the practical ways to utilize a high percentage of recycled aggregate in structural concrete is by incorporating 25–35% of fly ash as some of the drawbacks induced by the use of recycled aggregates in concrete could be minimized.

W. H. Wang, H. L. Lin et al. (2010) have concluded that there are an Interfacial Transition Zone (ITZ) between the recycled aggregate and the new mortar matrix body. The ITZ is still the weakest position in the recycled aggregate concrete. In this paper, the micro-hardness of the ITZ and the interface between the old cement paste of recycled aggregate and new mortar matrix body of recycled aggregate concrete in different strength grade are tested by using digital micro-hardness meter. The testing results indicate the micro-hardness value of the recycled aggregate is much higher than that of the ITZ of the recycled aggregate concrete and the micro-hardness of the interface between the old cement paste of recycled aggregate and the new mortar matrix body is the lowest. The testing result also shows the value of micro-hardness increase gradually with the testing distance growth from the interface to the new mortar matrix body and it keeps constant when the testing distance from the interface to the new mortar matrix reaches 100um. The micro-hardness of the old cement paste and new mortar matrix in the ITZ grows with the strength grade growth of the recycled aggregate concrete.It is concluded from the experiment that the mineral admixtures can improve the performance of ITZ and enhance the micro-hardness of recycled aggregate concrete.The micro-hardness can reflect the interfacial strength of recycled aggregate concrete well and the testing results would provide important references for explosion the failure mechanism of recycled aggregates concrete.

Yijin Li and Xinpeng Sun et al. (2010) have investigated that the cement-stabilized recycled aggregate base course material was prepared with lower quantities of ordinary Portland cement (only 4% and 5% by weight) and recycled aggregate replacing 30%,40%,50%,60%,75%,80%,90% and 100% of crushed stone. Compaction, un-confined compressive strength and dry shrinkage of mixture were tested. The effects of recycled aggregate replacing levels and cement dosage were analyzed based on compaction test. The results showed that the use of 100% recycled concrete aggregates increased the optimum moisture content and decreased the maximum dry density of base course materials compared to those of natural base materials. The effect of recycled aggregate replacement on un-confined compressive strength was discussed at 7, 28 and 90 days. The relational model between recycled aggregate replacement and un-confined compressive strength were established. The results of dry shrinkage tests showed that the ratio of dry shrinkage of the base materials prepared with recycled concrete aggregates increased with the increase of replacement levels of recycled concrete aggregates. The primary mix proportion parameters were determined with maximum replacement of recycled aggregates, meeting the requirements of base course road performance and lower costs

Claudio Javier Zega and Angel Antonio Di Maio (2010) have shown that using waste materials for new products is a global trend undergoing rapid development. Recycling materials allows for a more efficient life cycle and contributes to environmental protection. In the construction field, this trend has gained importance because of the shortage of natural resources and because of environmental problems caused by storing building-demolition wastes. This situation has led to the search for new applications for these wastes, and their use as aggregates in concrete is an interesting alternative. In this paper, some characteristics of recycled coarse aggregates obtained by crushing waste ready-mix concrete, as well as the mechanical and durability properties of recycled concretes made by using 25, 50, and 75% of these aggregates, are presented. Recycled concretes show lower compressive strength than conventional concrete for the higher strength level, whereas the durability properties of the two are similar.

Ignjatovic et al. (2012) studied nine full scale beams with 0%, 50%, and 100% recycled coarse aggregate and 0.28%, 1.46%, and 2.54% longitudinal reinforcement ratios. They reported no noticeable difference between load-deflection behaviour, service load deflection, and ultimate flexural strength of RCA and CC beams, but they observed that the beams with a higher range of recycled aggregate showed higher levels of concrete destruction at failure.

J. D. Thompsonand H. and H. Bashford(2012) have investigated that Construction is the largest contributor to landfill waste and concrete accounts for a significant portion of that waste. In turn, concrete waste can easily be recycled and reused as aggregate base course under roadway pavements and building slabs. Using recycled concrete in this manner reduces the environmental impact of construction by diverting waste and limiting the amount of virgin aggregate required for construction. Since aggregate is a finite resource, recycling and using recycled concrete limits the quantity of natural resources needed to support construction activity.

This research identified barriers and drivers associated with recycling concrete and using the recycled material in new construction in the Phoenix metropolitan area. Data was collected through interviews with general contractors, demolition contractors, concrete recyclers, and engineers, as well as observation of jobsite activities. The results of this research revealed that the infrastructure for recycling and reusing concrete material is in place but there is a need to establish that recycled concrete is an acceptable material for use as base material in the Phoenix area, and there is a need for education and awareness among the stakeholders. Factors impacting the decision to recycle versus sending concrete debris to a landfill were not cost and proximity as expected but were the result of existing relationships contractors have with disposal locations. The factors impacting whether or not to utilize recycled material were lack of enabling standard specifications, perception of risk, and the regulatory environment of the municipality where the construction takes place.

Weerachart Tangchirapat, Rak Buranasing et al. (2012) have investigated that the effects of fineness and replacement of fly ash on the fresh and hardened properties of recycled aggregate concrete. Two groups of recycled aggregate concretes were studied and compared with that of conventional concrete (CON) in which crushed limestone and local river sand were used as aggregates. The first group was prepared using 100% coarse recycled concrete aggregate and local river sand. For the second group, crushed limestone and local river sand were fully replaced by both coarse and fine recycled concrete aggregates. The results indicate that the slump loss of the recycled aggregate concrete with fly ash was reduced to lower than that of the recycled aggregate concrete without fly ash when the fineness of the fly ash was increased, which increased the slump loss of the fresh concrete. Fly ash can be used to increase the compressive strength of recycled aggregate concrete, depending on its fineness and the degree of fly ash replacement. The addition of fly ash with different fineness in recycled aggregate concrete had no significant effect on the splitting tensile strength and the modulus of elasticity of the recycled aggregate concrete, which are related to its compressive strength.

Matais (2014) has shown that the use of recycled aggregates in concrete production can significantly contribute to its sustainability, but it may also jeopardize its durability. The use of superplasticizers may compensate for this performance handicap by contributing to the improvement of the inner structure of this type of concrete. The main goal of this study is to evaluate the effect of standard and high-performance superplasticizers on the key durability-related properties (shrinkage, water absorption by immersion and by capillarity, carbonation and chloride penetration resistance) of concrete made with different percentages of recycled coarse aggregates (RCA) from crushed concrete and compare the findings with the corresponding effect on conventional concrete. The overall conclusion is that recycled aggregate concrete is more susceptible to deterioration because of environmental conditions affecting this concrete's durability performance more than that of conventional concrete. However, introducing superplasticizers in recycled aggregate concrete can help to enhance the concrete's performance and offset this higher susceptibility.

Ali Soleimanbeigi and Tuncer B. Edil et al.(2015) have concluded that the Compressibility of recycled materials including bottom ash (BA), foundry slag (FSG), foundry sand (FSD), recycled asphalt pavement (RAP), recycled pavement material (RPM), recycled concrete aggregate (RCA), and recycled asphalt shingle (RAS) mixed with glacial outwash sand (GOS) was evaluated using one-dimensional (1D) compression tests. Results showed that except RCA, compressibility of all the compacted recycled materials is higher than that of the compacted GOS. Different compression mechanisms were attributed to each recycled material depending on the type, composition, and morphological characteristics of the particles. Bituminous recycled materials including RAP, RPM, and RAS-GOS mixtures exhibited relatively higher compressibility compared with nonbituminous recycled materials. At a constant vertical effective stress ($\sigma'v$), compression of the recycled materials increased over time with strain rates that are higher for bituminous recycled materials compared to nonbituminous recycled materials. The vertical strain rates ($\dot{\varepsilon}v$) of all the recycled materials log-linearly increased with increasing $\sigma'v$. The slope of the $\log\dot{\varepsilon}v - \log\sigma'v$ curves, termed stress coefficient of compression, is independent of the elapsed time after loading. The stress coefficient of compression indicates degree of stress dependency for compression and is different for each recycled material. Secondary compression ratio is a power function of $\sigma'v$indicating that an embankment constructed with recycled materials settles at different rates along the embankment height. Temperature rises increased compressibility of the compacted RAP and RAS-GOS mixtures. On the other hand, thermal preloading significantly reduced the compressibility of the compacted RAP and RAS-GOS mixtures. Construction of embankments containing bituminous materials such as RAP, RPM, or RAS is recommended during summer to induce thermal preloading and reduce long-term settlement. Long-term settlements of typical highway embankments constructed with the recycled materials used in this study were below the allowable limit.

M. M. Y. Ali and A. Arulrajah (2012) have concluded that the recycling industry continues to grow as a means of utilizing waste materials in today's world and as such more markets must be urgently established for recycled products. Currently in the state of Victoria, Australia, 186,000 tonnes of recycled glass are stockpiled annually and these stockpiles are growing. However, there is little known reuse application for recycled glass in pavement sub-base applications due to limited knowledge of its geotechnical properties. The reuse of recycled glass in road pavement applications will provide the opportunity not only to get rid of the waste glass stockpiled and minimize the use of virgin materials in pavement applications but also to minimize the valuable land being used for stockpiles. This paper presents a preliminary laboratory evaluation of select geotechnical properties of recycled glass when used in blends of up to 50% with recycled crushed concrete in pavement sub-base applications. Laboratory tests discussed in this paper include modified compaction, Los Angeles abrasion loss, consolidated drained tri-axial compression test and California Bearing Ratio (CBR) test. The findings of this laboratory evaluation indicate that potentially up to 30% recycled crushed glass of particle size less than 4.75 mm could be safely added to Class 3 recycled crushed concrete in pavement sub-base applications.

Revathi Purushothamanand, Ramesh RuthirapathyAmirthavalli et al **(2012)** have investigated that with the rise in the adoption of recycled aggregate for construction, investigation on ways to improve its quality has been wide spread. The major factor that affects the quality of recycled aggregate is the large amount of cement mortar that remains on the surface of the recycled aggregate. This attached mortar results in higher porosity, higher water absorption rates, and thus a weaker interfacial zone between new cement mortar and aggregates, weakening the strength and mechanical performance of concrete made from recycled aggregate. This paper attempts to compare the effect of chemical as well as mechanical treatment approaches in reducing the mortar attached to aggregate. Six series of concrete mixtures are prepared using natural aggregate, recycled aggregate, recycled aggregate treated with HCl and H2SO4, recycled aggregate obtained after scrubbing treatment, and heating and scrubbing treatment. The physical and mechanical properties of these aggregates, and their strength and performance of recycled aggregate concrete are determined. The results show that treatment with H_2SO_4, and heating and scrubbing yield, aggregate with reduced water absorption and other desired properties of natural aggregate. The concrete made out of these treated aggregates are able to achieve strength and performance characteristics on par with natural aggregate concrete.

2.3. Conclusion:

By studying the above technical papers, a lot of knowledge has been gained regarding the recycling of concrete using chemical admixtures. It can also be noted that super-plasticizers are the kind of chemical admixtures that work the best in giving the recycled concrete its desirable properties. However significant work has also been found to be published on the effect of superplasticizer on recycled concrete. Therefore, we have chosen to work on its effect on recycling of concrete. We also hope to publish our findings in reputed journals.

Chapter 3

Methodology

3.1. Introduction:

Based on the knowledge gained from the review of literature available on the topic, methodologies various tests on recycled concrete and its related materials are discussed below citing reference of relevant codes when and where required.

3.2. Collection of debris:

Concrete aggregate collected from demolition sites is put through a crushing machine. Crushing facilities accept only uncontaminated concrete, which must be free of trash, wood, paper and other such materials. Metals such as rebar are accepted, since they can be removed with magnets and other sorting devices and melted down for recycling elsewhere. The remaining aggregate chunks are sorted by size. Larger chunks may go through the crusher again. After crushing has taken place, other particulates are filtered out through a variety of methods including hand-picking and water flotation.

3.3. Procurement of material:

3.3.1. Cement:

Ambuja Cement Pvt. Ltd has been kind enough to provide us with required amount of 53 grade OPC cement.

Fig. 3.1: 53 grade OPC (`Brand: Ambuja Cement)

3.3.2. Aggregates:

Fine as well as course aggregates were replaced by concrete debris taken from site demolished.

Fig 3.2: Crushing of debris

Fig. 3.3: Crushed debris

3.3. Batching of Concrete:

It is the process of measuring concrete mix ingredients either by volume or by mass and introducing them into the mixture. Traditionally batching is done by volume but most specifications require that batching be done by mass rather than volume. Percentage of accuracy for measurement of concrete materials is as follows:

3.3.1.Cement:

When the quantity of cement to be batched exceeds 30% of scale capacity, the measuring accuracy should be within 1% of required mass. If measuring quantity is less than 30% i.e. for smaller batches then the measuring accuracy should be within 4% of the required quantity.

3.3.2. Aggregates:

If the measurement is more than 30% of the scale capacity then the measuring accuracy should be within 1%. If measurement is less than 30% then the measuring accuracy should be within less than 3%.

3.3.3. Water:

Water is measured in volumetric quantity as 1 liter = 1kg. In case of water, the measuring accuracy should be within 1%.

3.3.4. Admixtures:

For mineral admixtures same accuracy as that required for cement. For chemical admixtures same accuracy as that required for water. Mineral admixtures accuracy is same as that of cement because it is used as partial replacement of cement. As chemical admixtures are liquid or added to water therefore its accuracy is same as that of water.

The mixing operation consists of rotation or stirring, the objective being to coat the surface the all aggregate particles with cement paste, and to blind all the ingredients of the concrete into a uniform mass; this uniformity must not be disturbed by the process of discharging from the mixer.

3.4. High Range Water Reducing and Retarding Superplasticiser for concrete

CAC-Super flow 65 is a super plasticising admixture to produce flowable or pumpable concrete for Higher grades, without bleeding and segregation when added to the concrete mix having slump of at least 25mm without admixture.

CAC-Super flow 65 is formulated from synthetic polymers specially designed to impart the cohesiveness to the concrete mix for easy pumping and placing. It considerably improves the properties of fresh and hardened concrete.

3.4.1. Area of Application:

i. Ready Mix Concrete upto grades of M50
ii. High Ultimate Strength Concrete
iii. Precast / Pre-stressed Concrete
iv. Casting in hot climates
v. Pumped concrete
vi. Primary uses to obtain-
vii. High workability for longer period
viii. Higher early & ultimate strengths
ix. With congested reinforcement
x. Increases durability & impermeability
xi. Lower pumping pressure

3.5. Concrete Mix Design:

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

3.5.1. Requirements of concrete mix design:

The requirements which form the basis of selection and proportioning of mix ingredients are:

i. The minimum compressive strength required from structural consideration

ii. The adequate workability necessary for full compaction with the compacting equipment available.
iii. Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions
iv. Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

3.5.2. Procedure:

- Determine the mean target strength f_t from the specified characteristic compressive strength at 28-day f_{ck} and the level of quality control.
- $f_t = f_{ck} + 1.65\ S$
- where S is the standard deviation obtained from the Table of approximate contents given after the design mix.
- Obtain the water cement ratio for the desired mean target using the emperical relationship between compressive strength and water cement ratio so chosen is checked against the limiting water cement ratio. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in table and adopts the lower of the two values.
- Estimate the amount of entrapped air for maximum nominal size of the aggregate from the table.
- Select the water content, for the required workability and maximum size of aggregates (for aggregates in saturated surface dry condition) from table.
- Determine the percentage of fine aggregate in total aggregate by absolute volume from table for the concrete using crushed coarse aggregate.
- Adjust the values of water content and percentage of sand as provided in the table for any difference in workability, water cement ratio, grading of fine aggregate and for rounded aggregate the values are given in table.
- Calculate the cement content form the water-cement ratio and the final water content as arrived after adjustment. Check the cement against the minimum cement content from the requirements of the durability, and greater of the two values is adopted.
- From the quantities of water and cement per unit volume of concrete and the percentage of sand already determined in steps 6 and 7 above, calculate the content

of coarse and fine aggregates per unit volume of concrete from the following relations:

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p}\frac{f_a}{S_{fa}}\right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p}\frac{C_a}{S_{ca}}\right] \times \frac{1}{1000}$$

- where V = absolute volume of concrete
- = gross volume ($1m^3$) minus the volume of entrapped air
- S_c = specific gravity of cement
- W = Mass of water per cubic metre of concrete, kg
- C = mass of cement per cubic metre of concrete, kg
- p = ratio of fine aggregate to total aggregate by absolute volume
- f_a, C_a = total masses of fine and coarse aggregates, per cubic metre of concrete, respectively, kg, and
- S_{fa}, S_{ca} = specific gravities of saturated surface dry fine and coarse aggregates, respectively
- Determine the concrete mix proportions for the first trial mix.
- Prepare the concrete using the calculated proportions and cast three cubes of 150 mm size and test them wet after 28-days moist curing and check for the strength.
- Prepare trial mixes with suitable adjustments till the final mix proportions are arrived at.

3.5.3. Standards

Reference: IS 9103: 1999

a. Methods of Applications:

Add 70-80% water to the concrete based on Mix Design by weight. The correct quantity of CAC-Superflow 65 should be measured with recommended dispenser and should be added to the concrete with remaining mixing water. Allow to mix it for recommended mixing time. The addition of CAC-Superflow 65 to dry mixes or cement is not recommended.

b. Dosage:

As a starting point, a dosage range of 0.7kg to 1.2kg per 100kg of cementitious materials is recommended. Optimum dosage of CAC-Super flow 65 should be determined in trial mixes. Please consult CAC Pvt. Ltd. Technical staff for further information.

c. Batch mixer:

The usual type of mixer is a batch mixer, which means that one batch of concrete is mixed and discharged before any more materials are put into the mixer. There are four types of batch mixer.

d. Tilting drum mixer:

A tilting drum mixer is one whose drum in which mixing take place is tilted for discharging. The drum is conical or bowl shaped with internal vanes, and the discharge is rapid and unsegregated so that these mixers are suitable for mixes of low workability and for those containing large size aggregate.

e. Non tilting drum mixer:

A non tilting drum is one in which the axis of the mixer is always horizontal, and discharge take place by inserting a chute into the drum or by reversing the direction or rotation of drum. Because of slow rate of discharge, some segregation may occur.

f. Pan type mixer:

A pan type mixer is a forced–action mixer, as distinct from drum mixer which relies on the free fall of the concrete inside the drum. The pan mixer consist of a circular pan rotating about its axis with one or two stars paddles rotating about vertical axis of pan.

g. Dual drum mixer:

A dual drum is sometimes used in highway construction. Here there are two drums in series, concrete being mixed part of the time in one and then transferred to the other for the remainder of the mixing time before discharging.

h. Continuous mixers:

These are fed automatically by a continuous weigh-batching system.

i. Charging the mixer:

There are no general rules on the order of feeding the ingredients into the mixer as this depend on the properties of the mixer and mix. Usually a small quantity of water is fed first, followed by all the solids materials. If possible greater part of the water should also be fed during the same time, the remainder being added after the solids. However, when using very dry mixes in drum mixers it is necessary to feed the coarse aggregate just after the small initial water feed in order to ensure that the aggregate surface is sufficiently wetted.

j .Uniformity of Mixing

In any mixer, it is essential that a sufficient interchange of materials occurs between parts of the chamber, so that a uniform concrete is produced. The efficiency of the mixer can be measured by the variability of the samples from the mix. ASTM prescribes samples to be taken from about points 1/6 and 5/6 of the discharge of the batch and the difference in the properties of the two samples should not exceed any of the following:

a. Density of concrete 1 lb/ft^3
b. Air content 1%
c. Slump 1" when average is less than 4"
d. 1.5" when average is less than 4 to 6"
e. % of aggregate retained on 4 No. sieve 6%
f. Compressive strength 7 day, 3 cylinders 7.5%

k. Mixing time:

It is important to know the minimum mixing time necessary to produce a concrete of uniform composition, and of reliable strength. The mixing time or period should be measured from time all the cementing materials and aggregates are in mixer drum till taking out the concrete. Mixing time depends on the type and size of mixer, on the speed of rotation, and on the quality of blending of ingredients during charging of the mixer. Generally, a mixing time of less than 1 to 1.25 minutes produces appreciable non-uniformity in composition and a significant lower strength; mixing beyond 2 minutes causes no significant improvement in these properties.

Capacity of mixer (yd^3)	**Mixing time (Minutes)**
Up to 1	1
2	1.25
3	1.5
4	1.75
5	2
6	2.25
10	3.25

Table 3.1: Recommended minimum mixing times

l. Prolong mixing:

If mixing take place over a long period, evaporation of water from the mix can occur, with a consequent decrease in workability and an increase in strength. A secondary effect is that of grinding of the aggregate, particularly if soft; the grading thus becomes finer and the workability lower. In case of air entrained concrete, prolong mixing reduces the air content.

m. Ready mixed concrete:

If instead of being batched and mixed on site, concrete is delivered for placing from a central plant. It is referred to as ready-mixed or pre-mixed concrete. This type of concrete is used extensively abroad as it offers numerous advantages in comparison with other methods of manufacture:

- Close quality control of batching which reduces the variability of the desired properties of hardened concrete.

- Use on congested sites or in highway construction where there is little space for a mixing plant and aggregate stockpiles;
- Use of agitator trucks to ensure care in transportation of concrete, thus prevention segregation and maintaining workability
- Convenience when small quantities of concrete or intermittent placing is required.

There are two categories of ready-mixed concrete: central-mixed and transit mixed or truck mixed. In the first category, mixing is done in a central plant and then concrete is transported in an agitator truck. In the second category, the materials are batched at a central plant but are mixed in a truck.

3.7. Concrete Placing and Compaction of Concrete:

The operation of placing and compaction are interdependent and are carried out simultaneously. They are most important for the purpose of ensuring the requirements of strength, impermeability and durability of hardened concrete in the actual structure. As for as placing is concerned, the main objective is to deposit the concrete as close as possible to its final position so that segregation is avoided and the concrete can be fully compacted. The aim of good concrete placing can be stated quite simply.

Fig:3.4: Placing of Concrete.

Fig: 3.5: Placing of Concrete. Fig: 3.6: Compaction of Cubes.

To achieve proper placing following rules should be kept in mind:

- The concrete should be placed in uniform layers, not in large heaps or sloping layers.
- The thickness of the layer should be compatible with the method of vibration so that entrapped air can be removed from the bottom of each layer.
- The rate of placing and of compaction should be equal. If you proceed too slowly, the mix could stiffen so that it is no longer sufficiently workable. On no account should water ever be added to concrete that is setting. On the other hand, if you go too quickly, you might race ahead of the compacting gang, making it impossible for them to do their job properly.
- Each layer should be fully compacted before placing the next one, and each subsequent layer should be placed whilst the underlying layer is still plastic so that monolithic construction is achieved
- Collision between concrete and formwork or reinforcement should be avoided.
- For deep sections, a long down pipe ensures accuracy of location of concrete and minimum segregation.
- You must be able to see that the placing is proceeding correctly, so lighting should be available for large, deep sections, and thin walls and columns.
- Once the concrete has been placed, it is ready to be compacted. The purpose of compaction is to get rid of the air voids that are trapped in loose concrete.

3.7.1. Necessity of Compaction:

It is important to compact the concrete fully because:

- Air voids reduce the strength of the concrete. For every 1% of entrapped air, the strength falls by somewhere between 5 and 7%. This means that concrete containing a mere 5% air voids due to incomplete compaction can lose as much as one third of its strength.
- Air voids increase concrete's permeability. That in turn reduces its durability. If the concrete is not dense and impermeable, it will not be watertight. It will be less able to withstand aggressive liquids and its exposed surfaces will weather badly.
- Moisture and air are more likely to penetrate to the reinforcement causing it to rust.
- Air voids impair contact between the mix and reinforcement (and, indeed, any other embedded metals). The required bond will not be achieved and the reinforced member will not be as strong as it should be.
- Air voids produce blemishes on struck surfaces. For instance, blowholes and honeycombing might occur.

Summing up, fully compacted concrete is dense, strong and durable; badly compacted concrete will be porous, weak and prone to rapid deterioration. Sooner or later it will have to be repaired or replaced. It pays, therefore, to do the job properly in the first place. Stiff mixes contain far more air than workable ones. That is one of the reasons why a low-slump concrete requires more compactive effort than one with a higher slump - the compaction needs to continue for a longer time, or more equipment has to be used.

Even air-entrained concrete needs to be compacted to get rid of entrapped air voids. The difference between air voids and entrained air bubbles should be noted at this stage. The air bubbles that are entrained are relatively small and spherical in shape, increase the workability of the mix, reduce bleeding, and increase frost resistance. Entrapped air on the other hand tends to be irregular in shape and is detrimental to the strength of the mix. It is to remove this air that the concrete must be properly compacted. There is little danger that compaction will remove the minute air bubbles that have been deliberately entrained, since they are so stable.

3.7.2. Methods of Compaction of concrete

a. Vibration:

To compact concrete you apply energy to it so that the mix becomes more fluid. Air trapped in it can then rise to the top and escape. As a result, the concrete becomes consolidated, and you are left with a good dense material that will, after proper curing, develop its full strength and durability.

Vibration is the next and quickest method of supplying the energy. Manual techniques such as rodding are only suitable for smaller projects. Various types of vibrator are available for use on site.

b. Poker Vibrators

The poker, or immersion, vibrator is the most popular of the appliances used for compacting concrete. This is because it works directly in the concrete and can be moved around easily.

c. Sizes:

Pokers with diameters ranging from 25 to 75mm are readily available, and these are suitable for most reinforced concrete work. Larger pokers are available - with diameters up to 150mm - but these are for mass concrete in heavy civil engineering.

d. Radius of action:

When a poker vibrator is operating, it will be effective over a circle centered on the poker. The distance from the poker to the edge of the circle is known as the radius of action. However, the actual effectiveness of any poker depends on the workability of the concrete and the characteristics of the vibrator itself. As a general rule, the bigger the poker and the higher its amplitude, the greater will be the radius of action. It is better to judge from your own observations, as work proceeds on site, the effective radius of the poker you are operating on the concrete you are compacting. The length of time it takes for a poker vibrator to compact concrete fully depends on:

- The workability of the concrete: the less workable the mix, the longer it must be vibrated.
- The energy put in by the vibrator: bigger vibrators do the job faster.
- The depth of the concrete: thick sections take longer.

3.8. Curing of Concrete:

Definition:

Curing can be described as keeping the concrete moist and warm enough so that the hydration of cement can continue. More elaborately, it can be described as the process of maintaining satisfactory moisture content and a favorable temperature in concrete during the period immediately following placement, so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement of service.

If curing is neglected in the early period of hydration, the quality of concrete will experience a sort of irreparable loss. An efficient curing in the early period of hydration can be compared to a good and wholesome feeding given to a new born baby.

3.8.1. Methods of Curing Concrete:

Concrete curing methods may be divided broadly into four categories:

a. Water curing
b. Membrane curing
c. Application of heat
d. Miscellaneous

a. Water Curing:

This is by far the best method of curing as it satisfies all the requirements of curing, namely, promotion of hydration, elimination of shrinkage and absorption of the heat of hydration. It is pointed out that even if the membrane method is adopted, it is desirable that a certain extent of water curing is done before the concrete is covered with membranes. Water curing can be done in the following ways:

i. Ponding.
ii. Spraying or Fogging
iii. Wet Covering

The precast concrete items are normally immersed in curing tanks for certain duration. Pavement slabs, roof slab etc. are covered under water by making small ponds. Vertical retaining wall or plastered surfaces or concrete columns etc. are cured by spraying water. In some cases, wet coverings such as wet gunny bags, hessian cloth, jute matting, straw etc., are wrapped to vertical surface for keeping the concrete wet. For horizontal surfaces saw dust, earth or sand are used as wet covering to keep the concrete in wet condition for a longer time so that the concrete is not unduly dried to prevent hydration.

i. **Ponding:** This is the most common and inexpensive method of curing flat surfaces such as floor slabs, flat roofs, pavements and other horizontal surfaces. A dike around the edge of the slab, which may be sub-divided into smaller dikes, is erected and water is filled to create a shallow pond. Care must be taken to ensure that the water in the pond does not dry up, as it may lead to an alternate drying and wetting condition.
ii. **Sprinkling, fogging & mist curing**: Using a fine spray or fog or mist of water can be an efficient method of supplying water to the concrete surface especially during hot weather, which helps to reduce the temperature of concrete, eventually conserving moisture inside the body of concrete.
iii. **Wet coverings**: Water absorbent fabrics such as hessian, burlaps, cotton mats, rugs etc. may be used to maintain water on the concrete surface by completely covering the surface immediately after the concrete has set.

They must be continuously kept moist to prevent the fabric from absorbing water from the body of concrete, due to capillary action. In rural areas, straw sprinkled with water regularly can be used to cure concrete. Care must be taken when using straw, as dry straw can fly away if the wind velocity is very high and it can also cause fire hazards. Moist earth, sand or saw dust can be used to cure horizontal surfaces. However, staining of the surface can occur due to certain organic matter, if present.

b. Impermeable Membrane Curing:

- Formwork leaving the formwork in place during the early age of concrete is one of the most efficient methods of curing, especially for columns. The formwork reduces considerably.
- **Plastic sheeting** Plastic sheets form an effective barrier to control the moisture losses from the surface of the concrete, provided they are secured in place and are protected from damage. They must be placed immediately after the final set of concrete without causing any damage to the surface. On flat surfaces like slabs, pavements, etc they must be properly secured to the surface and must extend beyond the edges of the slab, so that they are not blown away by gusty winds. Also foot, machinery and vehicular traffic must be avoided over the plastic sheet, to prevent damage. For vertical surfaces, the member must be thoroughly wrapped and the edges taped to prevent loss of moisture from the concrete surface. Plastic sheet may be transparent or colored depending upon the ambient temperature prevailing during that particular season. The efficiency of this system can be enhanced by flooding the concrete surface of the slab with water, under the plastic sheet.
- **Membrane curing compounds** - Curing compounds are wax, acrylic and water based liquids which are sprayed over the freshly finished concrete to form an impermeable membrane that minimizes the loss of moisture from the concrete. These are cost effective methods of curing where standard curing procedures are difficult to adopt. When used to cure concrete the timing of the application is critical for maximum effectiveness. They must be applied when the free water on the surface has evaporated and there is no water sheen on the surface visible. Too early application dilutes the membrane, where as too late application results in being absorbed into the concrete. Care must be taken to avoid foot, machinery and

vehicular traffic over the concrete surface to prevent damage of the coating.

- For concretes with low w/c ratio, the use of curing compounds may not be suitable for curing. When hydration takes place the relative humidity of interior concrete drops leading to self-drying of concrete. Under such circumstances, wet curing provides an external source of water to replenish the water utilized in the hydration process. Curing compounds may also prevent the bond between the hardened and the freshly placed concrete overlay. For example Curing compounds should not be applied to two lift pavement construction. Similarly, curing compounds should not be applied to concrete surface which will be receiving plasters, decorative & protective paints, etc, as it affects the adhesion.

c. Steam Curing:

Steam curing is a process for accelerating the early hardening of concrete and mortars by exposing it to steam and humidity. This type of system is most commonly used for precast concrete products where standard products are manufactured in the factory and the turnaround time of the formwork is very quick. In the curing chamber, the control of temperature and humidity is of prime importance or else the concrete products are likely of fracture, crumble and develop other problems later in their service lives. This type of curing systems are generally adopted for railway sleepers, concrete blocks, pipes, manhole covers, poles, pipe culverts, prestressed precast concrete products, and so forth.
Curing in Hot and cold weather requires additional attention.

d. Hot weather:

During hot weather, concrete must be protected from excessive drying and from direct sun and wind. Curing materials which reflect sunlight to reduce concrete temperature must be used. Water curing is recommended and care should be taken to prevent excessive stress caused by alternative wetting and drying or by cold water on warm concrete. Framed enclosures of canvas tarpaulins or sun shades may be used to protect the concrete from direct sunlight.

e. Cold weather:

Some problems associated with temperature below 4o C are:

- Freezing of concrete before adequate strength is developed
- Slow development of concrete strength
- Thermal stresses induced by the cooling of warm concrete to cooler ambient temperatures.
- In cold weather, some procedures like heated enclosures, insulating blankets & curing compounds may be used. The temperature of fresh concrete must be kept above 100C by using heated raw materials and the curing shall be continued for a longer period of time till concrete gains the desired strength.

3.8.2. Necessity of Curing:

Often questions are asked whether water can be poured over the above concrete within two hours to prevent the drying. The associated problem is, if water is applied within say two hours, whether it will interfere with the water/cement ratio and cause harmful effects. In other words, question is how early water can be applied over concrete surface so that uninterrupted and continued hydration takes place, without causing interference with the water/cement ratio.

Fig: 3.7. Curing of Concrete

The answer is that first of all, concrete should not be allowed to dry fast in any situation. Concrete that are liable to quick drying is required to be covered with wet gunny bag or wet hessian cloth properly squeezed, so that the water does not drip and at the same time, does not allow the concrete to dry.

This condition should be maintained for 24 hours or at least till the final setting time of cement at which duration the concrete will have assumed the final volume. Even if water is poured, after this time, it is not going to interfere with the water/cement ratio.

However, the best practice is to keep the concrete under the wet gunny bag for 24 hours and then commence water curing by way of ponding or spraying. Of course, when curing compound is used immediately after bleeding water, if any, dries up, the question of when to start water curing does not arise at all.

Even on the next day they make arrangements and build bunds with mud or lean mortar to retain water. This further delays the curing. Such practice is followed for concrete road construction by municipal corporations also. It is a bad practice. It is difficult to set time frame how early water curing can be started.

It depends on, prevailing temperature, humidity, wind velocity, type of cement, fineness of cement, w/c used and size of member etc. The point to observe is that, the top surface of concrete should not be allowed to dry. Enough moisture must be present to promote hydration.

Regarding how long to cure, it is again difficult to set a limit. Since all the desirable properties of concrete are improved by curing, the curing period should be as long as practical. For general guidance, concrete must be cured till it attains about 70% of specified strength. At lower temperature curing period must be increased. Since the rate of hydration is influenced by cement composition and fineness, the curing period should be prolonged for concretes made with cements of slow strength gain characteristics.

3.8.3. Importance of Curing:

Curing is the process of controlling the rate and extent of moisture loss from concrete to ensure an 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 and eventually the strength gain of concrete or mortars.

Curing of concrete must begin as soon as possible after placement & finishing and must continue for a 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 protective measures to control moisture loss from the concrete surface are essential to prevent plastic shrinkage cracks.

3.8.4. Reasons to Cure Concrete

i. There are several important reasons why one should cure concrete: **1.Concrete strength gain** - Concrete strength increase with age as moisture and a favorable temperature is present for hydration of cement. An experimental investigation was conducted by "Cement, Concrete & Aggregates Australia" (CCAA) and the same was published in their data sheet on "Curing of Concrete," which has been included in this article for reference. Figure-1 illustrates a comparison of the strength of concrete at 180 days of moist curing with various periods of moist curing (0, 3, 7, 14 & 28 days) and then allowing it to dry out. From the graph below, it can be observed that concrete allowed to dry out immediately, achieves only 40% of the strength of the same concrete water cured for the full period of 180 days.

ii. **2. Improved durability of concrete** – The durability of concrete is affected by a number of factors including its permeability, porosity and absorptivity. Well cured concrete can minimize thermal, plastic & drying shrinkage cracks, making concrete more water tight, thus preventing moisture and water borne chemicals from entering into the concrete and thereby increasing its durability.

iii. **3. Enhanced serviceability** - Concrete that is allowed to dry out quickly undergoes considerable early age shrinkage. Inadequate curing contributes to weak and dusty surfaces having a poor abrasion resistance.

iv. **4. Improved microstructure** - Material properties are directly related to their microstructure. Curing assists the cement hydration reaction to progress steadily and develops calcium silicate hydrate gel, which binds the aggregates leading to a rock solid mass, makes the concrete denser, decreases the porosity and enhances the physical and mechanical properties of concrete.

$$2(CaO)_3(SiO_2) + 6H_2 \Longrightarrow (CaO)_3(SiO_2)\,3(H_2O) + 3Ca(OH)_2$$

C-S-H gel

$$2(CaO)_2(SiO_2) + 4H_2O \Longrightarrow (CaO)_3(SiO_2)\,3(H_2O) + Ca(OH)_2$$

C-S-H gel

3.8.5. Right Time to Cure Concrete

i. After concrete has been placed in its final position and during the initial set, bleed water rises to the concrete surface as plastic settlement occurs. During this period, if the rate of evaporation of bleed water is greater than the rising water, plastic shrinkage of the concrete occurs. Initial mist curing is necessary to keep the surface moist to prevent the surface from drying out.
ii. Between initial set and final set, intermediate curing would be needed if the finishing is complete prior to final set. This may be in the form of a barrier which prevents the loss of moisture from the concrete surface. e.g. covering the concrete surfaces with plastic sheets, waterproof paper, etc.
iii. After final set, meticulous curing will have to be done as per the procedures selected. e.g. water curing methods-Ponding, Misting, wet coverings with hessian cloth, Impermeable membrane curing, Curing compounds, etc.

3.8.6. Duration of Curing:

The duration of curing of concrete depends on the grade & type of cement, mix proportion, desired concrete strength, shape and size of the concrete member and environmental &exposure conditions. The duration may vary from few days to a month.

IS-456:2000 provisions for duration of Curing (Indian Standard-Plain & Reinforced concrete-Code of Practice, 4th revision, page 27)

Exposed surfaces of concrete shall be kept continuously damp or in a wet condition by ponding or by covering with sacks, canvas, hessian or other similar material and kept continuously wet for atleast 7 days from the date of placing, in case of Ordinary Portland Cement (OPC) and atleast 10 days when mineral admixtures or blended cements are used.

In case of concrete where mineral admixtures or blended cements are used, it is recommended that the above minimum periods may be extended to 14 days, for assisting the secondary reaction.

Secondary reaction in case of blended cement:

1. Portland Pozzolana cement (PPC)

   OPC+Water → C-S-H gel + $Ca(OH)_2$ (Primary gel)

   $Ca(OH)_2$ + SiO2 (Fly ash) → C-S-H gel (Secondary gel)

2. Portland Slag cement (PSC)

   OPC+Water → C-S-H gel + $Ca(OH)_2$ (Primary gel)

   GGBS + water **Activated by Alkali's** → C-S-H + SiO_2 (Primary gel) (Silicates)

   $Ca(OH)_2$ + SiO2 (Silicates) → C-S-H gel (Secondary gel)

3.9. Tests Required to be Performed:

The following 2 tests are required to be performed to achieve the objectives of this project:

i. Sieve Analysis.

ii. Penetration Test on Concrete.

iii. Specific Gravity and Water Absorption of Concrete.

iv. Slump Cone Test on Fresh Concrete.

v. Compressive Test on Hardened Concrete.

3.9.1. Sieve Analysis of Crushed Concrete Debris:

A gradation test is performed on a sample of aggregate in a laboratory. A typical sieve analysis involves a nested column of sieves with wire mesh. A representative weighed sample is poured into the top sieve which has the largest screen openings. Each lower sieve in the column has smaller openings than the one above. At the base is a round pan, called the receiver.

The column has been shaken typically by manual method by us. The shaker shakes the column, usually for some fixed amount of time. After the shaking is complete the material on each sieve is weighed. The weight of the sample of each sieve is then divided by the total weight to give a percentage retained on each sieve.

Fig: 3.8: Sieve analysis

The size of the average particle on each sieve is then analyzed to get a cut-off point or specific size range, which is then captured on a screen.

3.9.2. Penetration Test of Standard and Concrete Debris Mix:

3.9.2.1: Scope:

This standard covers the method for determining the setting time of concrete with slump greater than zero, by testing mortar sieved from the concrete mixture. 1.2 In this method of test, the initial setting time and the final setting time are the time intervals required for the mortar sieved from the concrete mixture to reach the prescribed penetration resistance after the initial. contact of cement and water.

3.9.2.2: Terminology:

For the purpose of this standard, the following definitions shall apply. 2.1 Initial Setting Time - The elapsed time, after initial contact of cement and water, required for the mortar (sieved from the concrete) to reach a penetration resistance of 3’43 N/mm2 (35 kg f/cm2). 2.2 Final Setting Time - The elapsed time, after initial contact of cement and water, required for the mortar (sieved from the concrete) to reach a penetration resistance of 26.97 N/mm2 (275 kg f/cm z).

3.9.2.3: Apparatus:

Containers for Mortar Specimens Rigid, watertight, non- absorptive, non-oiled containers, either cylindrical or rectangular in cross- *h: section, with minimum lateral dimension 150 mm and height at least 150 mm. NOTE -The container for the mortar from the concrete mixture a hall provide enough mortar surface for the undisturbed reading of penetration resistance. Penetration Resistance Apparatus Spring reaction-type apparatus, graduated from 50 N (5 kg f) to 600 N (60 kg f) in increments of 10 N (1 kg f) or less; or hydraulic reaction-type apparatus with pressure gauge of 700 to 900 N (70 to 90 kg f) capacity, graduated in increments of 10 N (1 kg f) or less. Indications of actual needle loads by these apparatus shall be accurate to 10 N (1 kg f). Removable needles of 645,323,161, 65, 32 and 16 mm2 bearing areas shall be provided. Each needle shank shall be scribed peripherally at a distance of 25 mm above the bearing face. The length of the 16 mm2 needle shall be not more than 90 mm to minimize bending. NOTE - The spring reaction-type apparatus shall be recalibrated periodically. Pipette from the pipette or suitable instrument for drawing off free water surface of the test specimens. Tamping Rod - Round, straight, steel rod 16 mm in diameter and approximately 609 mm in length, having the tamping end rounded to a hemispherical tip, of 16 mm diameter.

Fig: 3.9: Penetration testing Apparatus.

3.9.2.4: Preparation of Mortar Specimen:

From the concrete mixture under test, select a representative sample of concrete of sufficient volume to provide enough mortar to fill the test con- tainer, or containers, to a depth of at least 140 mm. 4.2 Remove essentially all of the mortar from the sample of concrete by sieving it through a 4.75-mm IS sieve onto a non-absorptive surface. 4.3 Thoroughly remix the mortar by hand on the non-absorptive surface and place it in the container, or containers in layers of 50 mm each, and compact by rodding each layer. Rod the specimen by means of the tamping rod held so as to penetrate the mortar with the round end. Rod the mortar once for each 6.5 cm2 of top surface area of the specimen and distribute the strokes uniformly over the cross-section of the specimen. After completion of the rodding, tap the sides of the containers lightly with the tamping rod to close voids left by the tamping rod and to further level the surface of the specimen. Upon completion of specimen preparation, the mortar surface shall be at least 13 mm below the top edge of the container to provide space for the collection and removal of bleeding water and to avoid contact between the mortar surface and the protective covering specified.

3.9.2.5: Storage of Mortar Specimen:

Store and maintain the specimens at the temperature, selected for testing the specimens. To prevent excessive evaporation of moisture, keep the specimens covered and protected with a suitable tight-fitting, water- impermeable cover for the duration of the test, except when bleeding water is being removed or penetration tests are being made. The specimens shall be shielded from the sun.

3.9.2.6: Procedure:

Remove bleeding water from 'the surface of the mortar specimens just prior to making a penetration test by means of a pipette or a suitable instrument. To facilitate collection of bleeding water, tilt the specimen carefully to an angle of about 12" from the horizontal by placing a block under one side 2 minutes prior to removal of the bleeding water. 7.2 Insert a needle of appropriate size, depending upon the state of hardening of the mortar, in the penetration resistance apparatus and bring the burning surface of the needle into contact with the mortar surface. Gradually and uniformly apply a vertical force downward on the apparatus until the needle penetrates the mortar to a depth of 25 mm as indicated by the scribe mark. The time required to penetrate to the 25 mm depth shall be approximately 10 seconds. Record the force required and the time of application, measured as elapsed time after initial contact of cement and water. In subsequent penetration tests take care to avoid areas where the mortar has been disturbed by previous tests. The clear distance between two needle impressions shall be at least two diameters of the needle being used, but not less than 13 mm. The clear distance between any needle impression and the side of the container shall be not less than 25 mm. 7.3 Make penetration tests at hourly intervals for normal mixtures and normal temperatures, the initial test being made after an elapsed time of 3 to 4 h. For accelerated mixtures or high temperatures, it may be advisable to make the initial test after an elapsed time of 1 or 2 h and subsequent tests at + h intervals. For low-temperature conditions or retarded concrete mixtures, the initial penetration test may be deferred for an elapsed time of 4 to 6 h, and perhaps longer. Subsequent tests may be made at intervals of 1 h, unless the rate of increase in penetration resistance indicates that shorter intervals are desirable. 7.4 Not less than six penetration resistance determinations shah be made in each rate of hardening test and the time intervals between penetration resistance determinations shall be such as to give a satisfactory rate of hardening curve, as indicated by equally spaced points. Continue the tests until one penetration resistance of at least 26.97 N/mm’ (275 kg f/cm z) is reached.

3.9.2.7: Calculation:

Calculate the penetration resistance, in N/mm2 (kg f/cm z), as the force required to cause a 25 mm depth of penetration of the needle divided by the area of the bearing face of the needle.

.3.9.3. Specific gravity and water absorption test of aggregates

(IS 2386 PART 3)

3.9.3.1. Introduction:

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

Water absorption gives an idea of strength of aggregate. Aggregates having more water absorption are more porous in nature and are generally considered unsuitable unless they are found to be acceptable based on strength impact and hardness test.

3.9.3.2.Object:

To determine the specific gravity and water absorption of aggregates by perforated basket.

3.9.3.3.Apparatus:

1. A wire basket of not more than 6.3 mm mesh or a perforate container of convenient size with thin wire hangers for suspending it from the balance.
2. Thermostatically control oven to maintain temperature of 100-110°c
3. A container for filling water and suspending the basket.
4. An airtight container of capacity similar to that of the basket.
5. A balance of capacity of about 5kg to the accurate to 0.5gm and of such a type and shape as to permit weighing of the sample container when suspended in water.
6. A shallow tray and two dry absorbent clothes is not less than 750×450 mm.

Fig: 3.10: Le Chatelier's Apparatus.

3.9.3.4.Procedure:

About 2 kg of aggregate sample is washed thoroughly to remove fines, drain and then placed in the wire basket immersed in distilled water at a temperature between 22-32°c with a cover of at least 50mm of water above the top of the basket. Immediately after immersion in trapped air is removed from the sample by lifting the basket containing it 25mm above the base of the tank and allowing it to draw 25 times at the rate of one drop per second. The basket and the aggregate should remain completely immersed in water for a period 24±0.5 hours afterwards.

The basket and the sample are then weighed while suspended in water at a temperature of 22-32 .In case it is necessary to transfer the basket and the sample of different tank for weighing, they should be jointed 25 ideas described above in new tanks to remove air before weighing. This weight is noted while suspended in water W1 gm. The basket and the aggregate are then removed from water and allowed to drain for few minutes after which the aggregate are transfer to one of the dry absorbent clothes. The empty basket is then returned to the tank of water jolted 25 times and weight in water W2 gm.

The aggregate placed in the absorbent clothes are surfaced driven till no further moisture to be removed by this cloth. Then the aggregate are transferred to the second dry clothes spread in a single layer covered and allowed to dry for at least 10 minutes until the aggregates are completely surface dry. Then 10-60 minutes drying may be needed. The aggregate should not be exposed to the atmosphere direct sunlight or any other source of the heat while surface drying. A gentle current of unheated air may be used during first 10 minutes to accelerate the drying of aggregate surface. A surface dry aggregate is then weighed W3gm. The aggregate is placed in shallow tray and kept in an oven maintained a temperature of 110°c for 24 hours. It is removed form the oven. Cooled in an airtight container of weighed W4 gm. Atleast two days should be carried out but not concurrently.

3.9.3.5. Calculations:

Weight of saturated aggregate suspended in water with the basket= W1 gm

Weight of basket suspended in water = W2 gm

Weight of saturated aggregate in water = (W1-W2) = WS gm

Weight of saturated surface dry aggregate in air = W4 gm

Weight of water equal to the volume of aggregate = (W3 – WS) gm

1. Specific gravity = $\frac{dry\ weight\ of\ aggregate}{Weight\ of\ equal\ volume\ of\ water}$

$$= \frac{W4}{W3-WS} = \frac{W4}{W3-(W1-W2)}$$

2. Apparent specific gravity =

$$\frac{dry\ weight\ of\ aggregate}{Weight\ of\ equal\ volume\ of\ water\ excluding\ air\ voids\ in\ aggregates}$$

$$= \frac{W4}{W4-WS} = \frac{W4}{W4-(W1-W2)}$$

3. Water Absorption = percent by weight of water absorbed in terms oven dried weight of

Aggregates.

$$= \frac{(W3-W4)100}{W4}$$

3.9.4. Slump Cone Tests on Fresh Concrete

This test is performed to measure consistency or workability of fresh concrete, where the nominal maximum size of aggregate does not exceed 38 mm using slump test apparatus.

Reference Code: IS: 1199 – 1959 – Method of sampling and analysis of concrete.

3.9.4.1. Equipments and Apparatus:

- Slump cone (Height = 30 cm, Base dia = 20 cm, Top dia = 10 cm)
- Tamping rod (Length = 60 cm, Dia = 16 mm)

Fig: 3.11: Slump Cone Test Apparatus

3.9.4.2. Procedure:

1. The internal surface of the mould is thoroughly cleaned and freed from superfluous moisture before commencing the test. And if the cone is in completely dry condition then dampen it using a damp cloth.
2. The mould is then placed on a smooth, horizontally levelled rigid and non-absorbent surface such as a rigid plate. It is held firmly in place during filling by the operator by standing on the two foot pieces provided in the slump cone.
3. The mould is filled by concrete in four layers, each approximately one-quarter of height of the mould, and each layer is tamped down with 25 strokes of tamping rod with pointed end in a uniform manner.

4. After tamping the top layer, the concrete is struck off level with a trowel and any mortar leaked out between the mould and base plate is cleaned away.
5. The mould is then removed from the concrete immediately by raising it slowly and carefully in a vertical direction.

3.9.4.3. Report: Report the slump in terms of millimeters to the nearest 5 mm of subsidence of the specimen during the test.

3.9.4.4. Notes to Remember:

- If concrete consists of aggregates of size larger than 38 mm, then that concrete should be first sieved on a 38 mm sieve. Concrete passing the 38 mm sieve is then tested for workability using the slump cone apparatus of above mentioned dimension.
- If the slump test shows shearing of the concrete mass or become completely collapsed, then the test results are invalid and the slump test is repeated. See Fig. 1.2.
- After completion of the slump test, to get an idea on cohesiveness of concrete, tap slightly the outer perimeter of the slumped concrete. If it subsides further, then it is an indication of good quality concrete having required cohesiveness. But if it gets collapsed or shears away then the concrete lacks cohesiveness and this is an indication of poor quality concrete.

3.9.4.5. Safety and Precautions:

- Use hand gloves & shoes while testing.
- Equipment should be cleaned thoroughly before testing & after testing.
- The apparatus should remain free from vibrations during the test.
- Petroleum jelly should be applied to the mould.

3.9.5. Compression Test on Concrete:

It is the most common test conducted on hardened concrete as it is an easy test to perform and also most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The compression test is carried out on specimens cubical in shape of the size 150 × 150 × 150 mm. The test was carried out in the following steps:

First of all the mould preferably of cast iron, is used to prepare the specimen of size 150 × 150 × 150 mm. During the placing of concrete in the moulds it is compacted with the tamping bar with not less than 35 strokes per layer. Then these moulds are placed on the vibrating table and are compacted until the specified condition is attained. After 24 hours the specimens are removed from the moulds and immediately submerged in clean fresh water. After 28 days the specimens are tested under the load in a compression testing machine.

3.9.5.1. Procedure:

1. Representative samples of concrete shall be taken and used for casting cubes 15 cm x 15 cm x 15 cm or cylindrical specimens of 15 cm dia x 30 cm long.
2. The concrete shall be filled into the moulds in layers approximately 5 cm deep. It would be distributed evenly and compacted either by vibration or by hand tamping. After the top layer has been compacted, the surface of concrete shall be finished level with the top of the mould using a trowel; and covered with a glass plate to prevent evaporation.
3. The specimen shall be stored at site for 24+ ½ h under damp matting or sack. After that, the samples shall be stored in clean water at $27+2^0$C; until the time of test. The ends of all cylindrical specimens that are not plane within 0.05 mm shall be capped.
4. Just prior to testing, the cylindrical specimen shall be capped with sulphur mixture comprising 3 parts sulphur to 1 part of inert filler such as fire clay.
5. Specimen shall be tested immediately on removal from water and while they are still in wet condition.
6. The bearing surface of the testing specimen shall be wiped clean and any loose material removed from the surface. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load cube as cast, that is, not to the top and bottom.
7. Align the axis of the specimen with the steel plate, do not use any packing.
8. The load shall be applied slowly without shock and increased continuously at a rate of approximately 140 kg/sq.cm/min until the resistance of the specimen to the increased load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall then be recorded and any unusual features noted at the time of failure brought out in the report.

Fig: 3.12: Compressive Strength Testing Machine

3.9.5.2. Safety and Precautions:

- Use hand gloves, safety shoes & apron at the time of test.
- After test switch off the machine.
- Keep all the exposed metal parts greased.
- Keep the guide rods firmly fixed to the base & top plate.
- Equipment should be cleaned thoroughly before testing & after test.

Chapter 4

Results and Discussions

4.1. Introduction:

Based on the methodologies discussed in the previous chapter, sieve analysis was carried out on aggregates larger than 10 mm and on aggregates smaller than 10 mm. Specific gravity and water absorption test is carried out on the aggregates and is checked for IS standards. Penetration test was also carried out on standard and debris concrete mix. The particle size distribution and mix design of the different mixes has also been presented in this chapter. And finally the workability by slump cone test and compressive strength results from compressive strength test are also added and discussed here. All the above are presented separately for M20 and M25 grades in the formats below.

4.2. Results of M25 Mix:

The results of the various tests carried out on M25 Grade of Concrete Mix are presented in the tables below and compared with the standard values as and when required.

4.2.1. Sieve Analysis:

Table 4.1: Sieve Analysis of Aggregate Larger than 10mm (as per IS 2386 Part 1) for M25 grade of concrete

IS Sieve Size (mm)	Test No 1		Test No 2		Mean of percent retained	Cumulative percent	
	Wt. retained	Percent retained	Wt. retained	Percent retained		Retained	Passing

	(gm)		(gm)				
40	0	0	0	0	0		100
25	241.4	11	257.3	13	12	12	88
20	266.6	12	329.1	16	14	26	74
12.5	368.2	17	91.6	5	11	37	63
10	128.4	59	1330.3	6.5	62	99	01
4.75	-	-	-	-	-	-	-
2.36	-	-	-	-	-	-	-
Pan	26.4	01	23.3	1	1	100	0
Total	2187	100	2031.6	100	100		

Table 4.2: Sieve Analysis of Aggregate Smaller than 10mm (as per IS 2386 Part 1) for M25 grade of concrete

IS Sieve Size mm	Test No 1		Test No 2		Mean of percent retained	Cumulative percent	
	Wt. retained (gm)	Percent retained	Wt. retained (gm)	Percent retained		Retained	Passing
10							100
4.75	495.5	55	379.8	42	49	49	51
2.36	135.4	15	135.2	15	15	64	36
1.18	132.6	15	165.8	19	17	81	19
0.6	59.1	07	88.5	10	09	90	10
0.3	37	04	65.2	07	05	95	05
0.15	15.4	02	25.2	03	02	97	03
Pan	20.9	02	33	04	03	100	00
Total	895.9	100	892.7	100	100		

Table 4.3: Penetration Test of Standard and Concrete Debris Mix for M25 grade of concrete

Standard mix	Penetration (mm)	Concrete Debris Mix	Penetration (mm)
1	3.8	1	4.0
2	5.0	2	5.5
3	4.5	3	5.9
4	5.0	4	5.0
5	4.0	5	4.0
Average	4.46	Average	4.88

The above table shows the different values of penetration of each five specimens of the M25 mix. The average difference of the penetration of the standard mix is 8.61% higher than the average penetration of the concrete debris mixture. However, the penetration must be read from the nearest ¼ in (6.4 mm). Hence, the penetration of the concrete debris mixture passed the allowed penetration for mortar.

Table 4.4: Design Stipulation for M25 Grade Concrete

Characteristic strength at 28 days (N/mm^2)	25
Workability, slump at placing point (mm)	100±20
Nominal maximum size of aggregate (mm)	40

Table 4.5: Mix Proportions for M25 Grade of Concrete

Data on Ingredients	Source	Specific Gravity	DLBD (kg/l)	Water Absorption (%)	Quantity (kg/cum)
Cement	Ambuja OPC 53	3.00	--	--	320
Fine aggregates	N.A	2.57	--	5.16	697
Coarse aggregates	N.A	2.54	--	5.36	1187
Water	Local	--			160

Admixture	CAC SF 65	1.23			3.20
Water/cementitious	0.50	Aggregate / Cementitious		5.89	-

Table 4.6: Particle Size Distribution of Fine and Coarse Aggregates for M25 grade of concrete

IS Sieve	NS	CS	10 mm	20 mm
40	100	--	--	95
25	100	--	--	95
20	100	--	--	29
12.5	100	--	--	22
10	100	--	--	19
4.75	95	--	--	10
2.36	81	--	--	7
1.18	60	--	--	4
0.6	45	--	--	3
0.3	23	--	--	2
0.15	5	--	--	1

Table 4.7: Workability (Slump Cone) for M25 Grade of Concrete

Initial reading (mm)	Final reading (mm)
100	80

Fig. 4.1: Slump Cone Test

Table 4.8: Compressive Strength of Concrete for M25 grade of Concrete

No. of Days	3	7	14	28
Average Compressive Strength (N/mm^2)	21	25.1	30	34.9

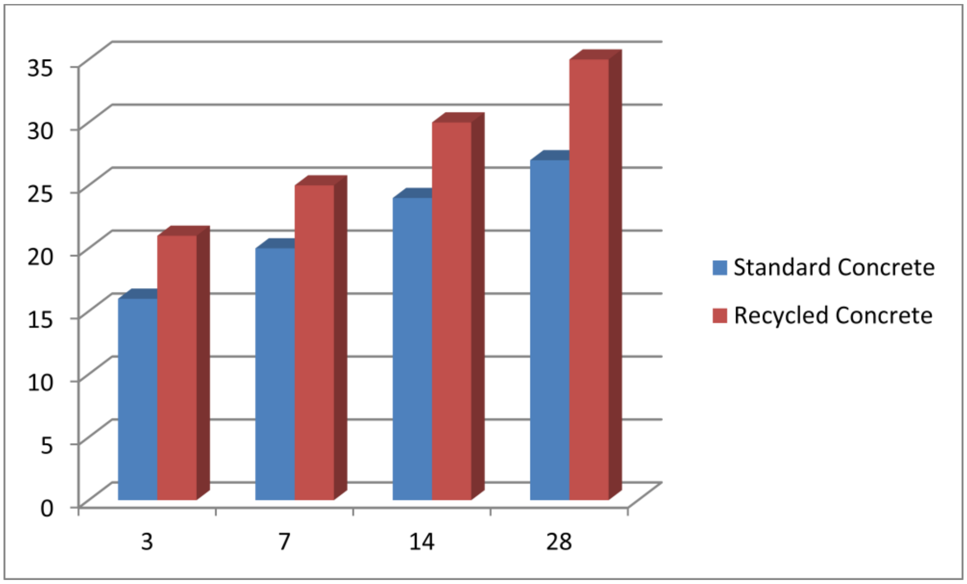

Fig. 4.2: Comparison of Compressive Strength of Standard and Recycled Concrete (N/mm^2) for M25 Grade of Concrete

From the above figure, it is evident that the compressive strength of recycled concrete is more than that of standard concrete.

4.3. Results of M20 Mix:

The results of the various tests carried out on M20 Grade of Concrete Mix are presented in the tables below and compared with the standard values as and when required.

4.3.1. Sieve Analysis:

Table 4.9: Sieve Analysis of Aggregate Larger than 10mm (as per IS 2386 Part 1) for M20 grade of Concrete

IS Sieve Size (mm)	Test No 1		Test No 2		Mean of percent retained	Cumulative percent	
	Wt. retained	Percent retained	Wt. retained	Percent retained		Retained	Passing

	(gm)		(gm)				
40	0	0	0	0	0		100
25	193.12	11	205.84	13	12	12	88
20	213.28	12	263.28	16	14	26	74
12.5	294.56	17	73.28	5	11	37	63
10	102.72	59	1064.24	6.5	62	99	01
4.75	-	-	-	-	-	-	-
2.36	-	-	-	-	-	-	-
Pan	21.12	01	18.64	1	1	100	0
Total	1749.6	100	1625.28	100	100		

Table 4.10: Sieve Analysis of Aggregate Smaller than 10mm (as per IS 2386 Part 1) for M20 grade of concrete

IS Sieve Size mm	Test No 1		Test No 2		Mean of percent retained	Cumulative percent	
	Wt. retained (gm)	Percent retained	Wt. retained (gm)	Percent retained		Retained	Passing
10	-	-	-	-	-	-	100
4.75	396.4	55	379.8	42	49	49	51
2.36	108.32	15	135.2	15	15	64	36
1.18	106.08	15	165.8	19	17	81	19
0.6	47.28	07	88.5	10	09	90	10
0.3	29.6	04	65.2	07	05	95	05
0.15	12.32	02	25.2	03	02	97	03
Pan	16.72	02	33	04	03	100	00
Total	716.72	100	892.7	100	100		

Table 4.11: Penetration Test of Standard and Concrete Debris Mix for M20 grade of Concrete

Standard mix	Penetration (mm)	Concrete Debris Mix	Penetration (mm)
1	4.75	1	4.5
2	6.25	2	5.2
3	5.625	3	6.1
4	6.25	4	5.3
5	5	5	4.4
Average	5.575	Average	5.1

The above table shows the different values of penetration of each five specimens of the M25 mix. The average difference of the penetration of the standard mix is 8.26% higher than the average penetration of the concrete debris mixture. However, the penetration must be read from the nearest ¼ in (6.4 mm). Hence, the penetration of the concrete debris mixture passed the allowed penetration for mortar.

Table 4.12: Design Stipulation for M20 Grade Concrete

Characteristic strength at 28 days (N/mm^2)	20
Workability, slump at placing point (mm)	100±20
Nominal maximum size of aggregate (mm)	40

Table 4.5: Mix Proportions for M25 Grade of Concrete

Data on Ingredients	Source	Specific Gravity	DLBD (kg/l)	Water Absorption (%)	Quantity (kg/cum)
Cement	Ambuja OPC 53	3.00	--	--	320
Fine aggregates	N.A	2.75	--	5.26	697
Coarse aggregates	N.A	2.45	--	5.46	1187
Water	Local	--			160

Admixture	CAC SF 65	1.23			4.00
Water/cementitious	0.45	Aggregate / Cementitious		4.70	-

Table 4.13: Particle Size Distribution of Fine and Coarse Aggregates for M20 grade of Concrete

IS Sieve	NS	CS	10 mm	20 mm
40	100	100	100	95
25	100	100	100	67
20	100	100	100	48
12.5	100	100	100	17
10	100	100	100	11
4.75	100	97	100	3
2.36	100	77	100	0
1.18	100	51	100	0
0.6	100	36	100	0
0.3	100	23	100	0
0.15	100	14	100	0

Table 4.14: Workability (Slump Cone) for M20 grade of Concrete

Initial reading (mm)	Final reading (mm)
95	85

Table 4.15: Compressive Strength of Concrete for M20 grade of Concrete

No. of Days	3	7	14	28
Average Compressive Strength (N/mm^2)	14.1	17.2	22.5	25

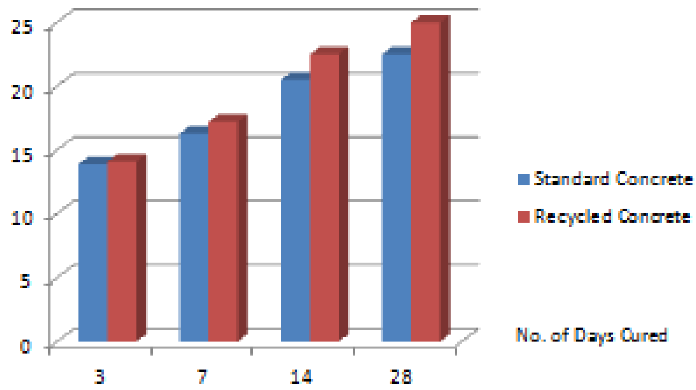

Fig. 4.3. Comparison of Compressive Strength of Standard and Recycled Concrete of M20 (N/mm^2)

Chapter 5

Conclusion

Mix designs are prepared for M25 and M20 grade of concrete with recycled concrete as aggregates. Sieve analysis, penetration test on concrete, specific gravity and water absorption test of aggregates, slump cone test and compressive test on concrete is carried out.

From the results of the above mentioned tests, as presented in the above it can be concluded that recycled concrete can be used as an aggregate as it meets all the Indian standards specified for aggregates for concrete.

Furthermore, the concrete made with it i.e. recycled concrete also passes the standards mentioned in the I.S. codes as far as workability is concerned. Also, the compressive strength of recycled concrete is also more than that of standard concrete.

Therefore, it is not only environmental-friendly but also beneficial from an engineering point of view too to use recycled concrete. It also proves to be economical than standard concrete.

In the future scope of the project, further tests like flexural test, split tensile test, vicat tests etc. may be performed on recycled concrete to get an in depth knowledge of the same.

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