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Comparative Study of M30 And M35 Grades of Concrete Using Bis, Aci, And Doe Method of Mix Design

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ABSTRACT

Mix design is a critical process in concrete production that determines the optimal combination of materials to produce concrete with desired properties. In this, we will discuss three commonly used methods for mix design: the American Concrete Institute (ACI) method, the Bureau of Indian Standards (BIS), and the Design of Experiments (DOE) method.

The cement, water, fine aggregate, and coarse aggregate ratios needed to produce the desired strength and workability are calculated using the commonly used ACI technique. The ACI technique uses experimental data and historical experience to arrive at an appropriate mix design. The BIS technique, which offers recommendations for the selection of materials, proportions, and testing processes to achieve the specified strength and durability of concrete, is comparable to the ACI method.

The DOE technique is a statistical strategy that entails developing a design matrix and doing tests to ascertain the impact of various elements on the characteristics of concrete. This approach makes it possible to evaluate the variables that affect mix design in a more systematic and thorough manner, producing a concrete mix that is more effective and optimized.

In conclusion, while the DOE method is a more challenging approach that may result in more effective and optimized mix designs, the ACI and BIS approaches are frequently utilized and offer helpful guidance for mix design. In the end, the strategy used will depend on the particular needs of the project and the resources that are available.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND: -

The process of figuring out the amounts of different ingredients that must be blended to create a concrete mix with the appropriate qualities for a particular application is known as mix design. Cement, water, aggregates (such sand, gravel, or crushed stone), and frequently extra elements like additives are included in the conventional component list. The process of creating the mix design takes into account the unique characteristics of the project site, environmental issues, and aspects like the strength, durability, workability, and economy of the concrete. To obtain a good quality product, precise mix design is necessary. High-quality, long-lasting, and reasonably priced concrete that satisfies the construction project's particular needs. This kind of study can help to clarify how each method differs from the others or demonstrate the validity of a strategy in other ways. The ACI, BIS, and DOE concrete mix designs will be compared and contrasted in the study. It is important to look into how the cement content and water cement ratio of these three procedures vary from one another. According to variations in these procedures, the anticipated change in concrete properties (whether fresh or hardened) will be investigated. In order to produce concrete with the appropriate qualities at the lowest cost, concrete mix design is therefore both a science and an art. Cost is a factor when evaluating various methods of designing concrete mixes, then. It should be taken into account in addition to other characteristics.

It should be clarified that design in the literal meaning of the word is not possible because many of the attributes of the materials used are variable and cannot be accurately quantified. On the basis of the links discovered in past investigations, we are really only speculating about the ideal combination of the substances. Therefore, it should come as no surprise that in order to produce a satisfactory mix, we must verify the predicted proportions of the mix through trial mixes and, if required, make the necessary adjustments to the proportions until a satisfactory mix has been obtained.

1.2 NEED OF MIX DESIGN: -

In the sphere of concrete technology and building, mix design is a crucial step. Utilizing diverse techniques, including those developed by the American Concrete Institute, the Bureau of Indian Standards, and the Design of Experiments, offers a number of benefits and meets certain demands. These are the main justifications for employing these techniques:

1. ACI Method: -

- **Industry Standard: -**

The ACI method is widely recognized and used internationally as a standard practice for concrete mix design. It provides guidelines and procedures that are well-established and accepted within the industry.

- **Experience-based approach: -**

The ACI method incorporates years of practical experience and empirical data, making it a reliable choice for designing conventional concrete mixes.

- **Flexibility: -**

The ACI method allows adjustments to accommodate specific project requirements, such as strength, workability, durability, and environmental factors.

2. BIS Method: -

- **Local Relevance: -**

The BIS method is developed by the Bureau of Indian Standards and is specially tailored to the local conditions, materials, and practices in India. It considers factors such as regional variations, availability of materials, and construction practices specific to the Indian context.

- **Regulatory Compliance: -**

In India, adherence to BIS codes and standards is often mandatory for construction projects. Using the BIS method ensures compliance with these regulations.

- **Consistency: -**

The BIS method provides a standardized approach, ensuring consistency in mix design across different projects within the country.

- **Proven Performance: -**

The BIS method has been used extensively in India, and its mix design have demonstrated satisfactory performance in a wide range of applications.

3. DOE Method: -

The DOE method is a statistical approach to mix design that involves conducting series of experiments to identify the optimal combination of ingredients.

- **Optimization and Efficiency: -**

The DOE method utilizes statistical techniques to systematically optimize mix proportions, considering multiple factors simultaneously. This approach can help achieve the desired performance with the least amount of trial and error, leading to efficient mix designs.

- **Material Characterization: -**

The evaluation of various materials, their interactions, and the discovery of crucial elements affecting concrete performance are all made possible by the DOE approach. Selecting the best materials for a particular application is made easier with the help of this information.

Engineers and researchers can take advantage of the collective knowledge of recognized standards (ACI and BIS), as well as the optimization capabilities and research-oriented approach provided by the DOE technique, by combining these methodologies. The approach selected is determined by the project specifications, regional laws, the resources at hand, and the required level of creativity and optimization.

1.3 SCOPE OF MIX DESIGN: -

- **Understanding the Properties of Materials: -**

Mix design study involves understanding materials that make up the concrete mixture, including aggregates, cement, water and admixture.

- **Developing a Suitable Concrete Mix: -**

The objective of mix design is to develop a concrete mix that meets the required strength, durability and workability requirements for a specific application. This involves selecting appropriate materials and proportions to achieve the desired properties.

- **Evaluating the Performance of Concrete: -**

In a mix design study, concrete performance is assessed using tests that measure its compressive strength, tensile strength, flexural strength, and other characteristics including shrinkage and durability.

- **Meeting Specifications: -**

Mix design study ensures that the concrete mix meets the specifications and standards set by the relevant regulatory authorities such as the American concrete institute (ACI), the British standards institution (BIS) or the European committee for standardization.

Overall mix design study is a critical process that enables engineers and contractors to design and produce concrete mixes that meet the required performance and durability standards. While optimizing the use of materials and minimizing costs.

- **Quality Control and Assurance: -**

The mix design process is crucial for maintaining consistency and quality in concrete production. It provides a basis for quality control and assurance by specifying target proportions and properties, enabling the evaluation and verification of the produced concrete against those specifications.

1.4 OBJECTIVES: -

The goal of concrete mix design is to guarantee that the component elements are combined in the best possible proportions to meet the needs of the structure being built.

➢ Comparing the M30 and M35 concrete grades for compressive strength.

- To assess the concrete grades M30 and M35's split tensile strength.
- To produce concrete as economically as possible.
- In order to obtain the desired workability during the plastic stage.

CHAPTER 2
LITERATURE REVIEW

- **Aginam CH, umenwaliri SN, nwakire C, "influence of the mixed design" methods for the compressive strength of concrete", ARPN engineering and applied science, vol.8, june6, 2013...** The American concrete institute (ACI), the department of environment, road sign 4 (rn4) and the CPIIO are among the organizations involved. The Ibeto brand research used Portland cement, and the first four hybrid design strategies were applied to create a characteristic strength of 20n/mm^2. The concrete components that were utilized were unique, gravity was determined, and moisture content and grading were confirmed to be suitable. Four combined designs were used to cast 4 groups of concrete cubes (150*150*150) mm compressive strength was rated at 7, 14, 21, and 28 days after curing, there were four distinct groups discovered for ACI, DOE, rn4 and CPIIO mixtures, the 28th day strength is 30.7n/mm^2,33.7n/mm^2, 33.0n/mm^2 and 30.01n/mm^2 respectively. The resistance has continued for the 28th day.

- **CK jeevendra and Mishra S.P, "comparison between is, British and ACI methods, concrete mix design and design based on function equations", IJCSEIERD, vol.2, issue 20-56 march 1, 2012…**the is, British mix and ACI techniques were used of m15, m20, m25, m35. Only hybrid designs have strength. This standard should be assessed regardless of durability requirements. At 7 and 28 days, the compressive strength was measured the UK mixture method, at least the is method, has the greatest water content in UK mixtures, the amount of cement used by is, is the most, while the amount of cement used by British mix is the least. The average strength of the combination prepared using the British mixing method did not meet the aim. The failure was caused by a high-water cement ratio, a lack of cement, and a high aggregate content. The mixes created by ACI and is met their desired average strength.

- **Abdul Aziz and A Rama Krishnaiah (2019)**
  This study investigates for determining the most suitable concrete mix in order to achieve the target strength. In this research work ordinary Portland cement, sand and aggregates were selected based on IS:456-2000 and IS 10262-2009 standard for determining quantities and proportions for concrete grades. The specimen having size 150mm*150mm*150mm was tested at the age of 7 and 28 days of curing period.

- **Kunal Bajaj and Sameer Malhotra (2018)**
  In this paper proportion of ingredients and comparison of various ratios, i.e., amount of cement, water-cement ratio, total aggregate content by using BIS, ACI and IS method were studied. The mixes designed by IS and ACI method achieved the target mean strength, which indicate that these methods were consistent.

- **Dr. S. A. Deepa et. al. (2014)**

Has out a comparison and concluded that the ACI method of concrete mix design has a higher fine aggregate concentration than the BIS method. He added that the coarse aggregate concentration is higher in the BIS approach of concrete mix design than in the ACI method. As a result, the ACI mix can be more practical than the BIS mix.

- **Singh Ravinder and Verma S. K. (2015)**

It is suggested that the BIS approach uses the most aggregate while the ACI method uses the least aggregates. For M25 grade, the BIS method achieved the maximum strength compared to the other methods, with a significant increase in split tensile strength above M20. Concrete's mechanical properties were discovered to behave generally significantly better under M20 than under M25. Even for the grade of concrete, the performance of concrete designed using the ACI method was excellent.

- **Historical Perspective: -**

For more than a century, mix design has been a part of the concrete industry. In 1904, Duff A. Abrams, a civil engineer for the US Bureau of Reclamation, created the first concrete mix design. In order to manufacture concrete with the desired strength, Abrams presented a method for calculating the proportions of the ingredients required. The parameters he used, such as specific gravity, water absorption, and surface area, formed the basis of his methodology.

- **Recent Advancements: -**

Concrete's sustainability and durability have been improved recently by innovations in mix design. Researchers have looked into using alternative ingredients including fly ash, slag, and recycled aggregates to lessen the negative effects of concrete production on the environment. Additionally, they have investigated how different admixtures, such as superplasticizers, affect the workability and strength of concrete.

CHAPTER 3
MATERIALS DESCRIPTION
3.1 CEMENT: -

Cement is a binding material used in construction to bind other materials together. It is a fine powder made from a mixture of calcined limestone, clay, and gypsum. When mixed with water, cement hardens and sets, forming a strong and durable material that is used to create concrete mortar and other building materials. The function of cement is first of all to bind the sand and stone together and second to fill up the voids in between sand and stone particles to form a compact mass. The most widely used cement is Portland cement. It is manufactured by grinding together calcareous (limestone, chalk, marl etc.) and argillaceous (shale or clay) materials in approximate proportion. The OPC is classified into 3 grades namely 33 Grade, 43 Grade, 53 Grade depending upon the strength of 28 days.

Fig 3.1 Cement

- **3.1.1 PROPERTIES: -**
- **Strength: -**It is strong and durable material that can withstand a lot of weight and pressure.
- **Adhesion: -**
  Cement has excellent adhesion properties which means that it can bond well with other materials.
- **Water Resistant: -**
  It is water resistant which makes it an ideal material for use in deep environments such as basements and bathrooms.
- **Workability: -**
  Cement can be easily molded into different shapes and sizes making it a versatile material for construction.
- Initial setting time not more than 30 minutes.
- Final setting time not less than 10 hours.
- Specific gravity 3.15.

3.2 AGGREGATES: -

Generally, aggregates occupy 70% to 80% of the volume of concrete and have an important influence on its properties. They are granular materials, derived for the most part from natural rock (crushed stone or natural gravels) and sands. In addition to their use as economical filler, aggregates generally provide concrete with better dimensional stability and wear resistance. In order to obtain a good concrete quality, aggregates should be hard and strong, free of undesirable impurities and chemically stable. Aggregates should also be free of impurities like slit, clay, dirt, or organic matter. If these materials coat the surface of the aggregate, they will isolate the aggregate particles from the surrounding concrete, causing a reduction in strength. Slit, clay and other fine materials will increase the water requirements of concrete and the organic matter may interfere with cement hydration.

3.2.1 FINE AGGREGATE: -

Aggregates that pass through an IS sieve with a 4.75mm opening. Fine aggregates, sometimes known as sand, are collections of mineral grains created by the breakdown of rocks. Typically, river banks or sand dunes that were first created by wind action are where commercial sand is found. Sand is a key ingredient in the production of mortar, concrete, and polish. In foundries, molds are created using sand that contains a little amount of clay. Clear sand is used as a water filter.

Fig 3.2 Fine Aggregates

3.2.1.1 PROPERTIES: -

- **Gradation: -**
  The distribution of particle sizes in the fine aggregate is important for achieving a dense and durable concrete mix.
- **Shape and Texture: -**
  The shape and texture of fine aggregate particles can influence the workability of the concrete mix.
- **Angular: -** Interlock and provide better stability.
- **Rounded: -** To provide better workability.
- **Specific Gravity: -**
  Specific gravity of fine aggregates= 2.54
  It affects the density and strength of concrete mix. A higher specific gravity will result in a denser and stronger concrete.
- **Surface Area: -**
  Surface area influences the amount of cement needed for the concrete mix. A larger surface area will require the desired strength and durability.

3.2.2 COARSE AGGREGATES: -

Fig 3.3 Coarse Aggregate

These are one of the main components used in the construction industry, typically used in the production of concrete and road materials. These are materials with a particle size greater than 4.75mm, and are typically sourced from natural deposits such as crushed rocks, gravels and sand.

3.2.2.1PROPERTIES: -

- **Size and Shape: -**

These are typically larger in size than fine aggregates with a range of sizes from 4.75mm to 80mm. The shape of particles can also affect the properties of the concrete, with round or smooth particles providing better workability, and angular or irregular providing better bonding between the aggregates and cement paste.

- **Density and Porosity: -**

Coarse aggregates have a lower density than cement paste which can affect the overall density of the concrete. The porosity of aggregates can also affect the permeability and durability of the concrete.

- **Strength: -**

The strength of coarse aggregates is important in determining the strength of concrete. Higher strength aggregates can result in higher compressive and tensile strengths in the concrete.

- **Abrasion Resistance: -**

Coarse aggregates with high abrasion resistance are preferred for used in the road materials to withstand the wear and tear caused by traffic.

- Specific gravity of coarse aggregates= 2.72
- Unit weight of coarse aggregates= 1450 kg/m^3

3.3 WATER: -

The water used for mixing and curing was free of harmful chemicals such as alkalies, acids, oils, salt, sugar, organic materials, vegetable growth and other substances that could harm aggregates or concrete. Concrete masonry was made with potable water. The pH of the water should not be less than 6.

3.4 ADMIXTURE: -

Admixture in concrete refers to the addition of chemicals or other materials to the concrete mix to enhance its properties or improves its performance. Admixtures are typically added during the mixing process and can alter the setting time, workability, strength, durability, and other characteristics of the concrete.

There are several types of admixtures used in construction, including:

- **Accelerating Admixtures: -**

These admixtures are used to speed up the setting time of the concrete, which is useful in cold weather conditions or for rapid construction projects were time is less.

- **Retarding Admixtures: -**

These admixtures are used to slow down the setting time of the concrete, which is useful in hot weather conditions or for large pours where the concrete needs more time to be placed and finished.

- **Superplasticizers: -**

These admixtures are used to increase the workability of the concrete mix to allow for easier placement and finishing. They can also be used to reduce the water-cement ratio, which can increase the strength and durability of the concrete.

- **Air-Entraining Admixtures: -**

These admixtures are used to introduce microscopic air bubbles into the concrete, which improves its freeze-thaw resistance and durability.

3.5 CONCRETE: -

Concrete is a building material made from a mixture of cement, water, and aggregates (such as sand, gravel, or crushed stone). When the water is added to the cement and aggregates, a chemical reaction called hydration occurs, which binds the ingredients together and hardens the mixture into a solid mass. Concrete is commonly used in construction for a wide variety of applications, including building foundations, walls, floors, bridges, dams, and roads. It is known for its durability, strength, and versatility, and is one of the most widely used building materials in the world.

3.5.1 PROPERTIES: -

For proper designing of concrete mix, designer should be aware of properties of concrete viz,

1. In fresh concrete.
2. In hardened concrete.

3.5.1.1 IN FRESH CONCRETE: -

In the fresh stage, concrete is a fluid mixture of cement, water and aggregates (such as sand, gravel, and crushed stone) and often admixture. The properties of concrete in its fresh stage are important because they can affect the workability, placement, and finishing of the concrete, as well as its final strength and durability. Some of the key properties in its fresh stage include:

- **Workability: -**

It describes how simple it is to mix, transport, pour, and finish concrete without segregation or bleeding. The amount of water to cement, the kind of aggregates, and the admixtures used to the mixture all play a role. When compared to less workable concrete, which may need more effort to compact and may be more prone to bleeding or segregation, highly workable concrete can be put and compacted with ease.

- **Consistency: -**

It speaks to how flexible or rigid the concrete mix is. Slump or flow tests, which show how the concrete deforms under its own weight, can be used to measure it.
High slump: simpler to put and more fluid.
Low slumps are harsher and could be harder to place.

- **Setting Time: -**

It describes the amount of time needed for concrete to transition from a liquid to a solid state. The type and quantity of cement used, as well as the ambient temperature and humidity, all play a role. It has an impact on the concrete's polish and workability.

- **Bleeding: -**

It refers to the tendency of water to rise to the surface of concrete mix, leaving voids or channels behind. It can be caused by the settlement of solid particles or by the buoyancy of water. Bleeding can affect the uniformity and strength of the concrete and it can also cause surface defects such as cracking or scaling

- **Air content: -**

It refers to the amount of air voids in the concrete mix. It can be controlled by adding air-entraining admixture, which create small bubbles in the mix. The air content can affect the workability, durability and freeze-thaw resistance of the hardened concrete.

- **Segregation: -**

It refers to the separation of the components of the mix such as coarse aggregates, fine aggregates, cement, and water during the period of pouring and consolidation of the concrete. It occurs due to variety of reasons, including improper mixing, over-vibration of concrete, use of aggregates with varying sizes and densities. In order to prevent segregation, it is important to properly mix the components, control the water content, and use appropriate methods of consolidation, such as vibration or self-compacting concrete.

- **Hydration: -**

It is a chemical process that occurs when water is mixed with cement and other ingredients to create a concrete mixture. During the hydration process, the cement particles react with water to form new compounds that bind the aggregates (sand and gravel) together and harden the concrete. The amount of water used in the mixture can significantly impact the strength and durability of the resulting concrete. Too little water can cause the mixture to be too dry, making it difficult to work, while too much water can weaken the concrete and make it prone to cracking.
Proper hydration is critical for the strength and durability of the concrete. If the concrete dries too quickly, the hydration process can be disrupted, resulting in weak and brittle concrete. On the other hand, if the concrete remains too wet for too long, it can also weaken the concrete and make it susceptible to cracking and other damage.

3.5.1.2 IN HARDENED CONCRETE: -

Concrete in its hardened stage is a strong durable material, with several important properties that make it suitable for use in a variety of construction applications. Some of the key properties of hardened concrete include:

- **Compressive Strength: –**

Concrete's ability to support loads is mostly determined by this characteristic. Depending on the mix design and curing circumstances, concrete can generate significant compressive strengths over time, ranging from 20 MPa to 100 MPA.

- **Tensile Strength: -**

Concrete is strong in compression but only moderately robust in tension. Depending on the mix design and reinforcing employed, the tensile strength of concrete can range from 1.5 MPa to 6 MPa.

- **Durability: -**

Concrete is a durable material that can withstand harsh environmental conditions including freeze-thaw cycles, chemical exposure, and abrasion. The durability of concrete depends on the quality or the constituent materials and the curing conditions.

- **Shrinkage: -**

As concrete dries and cures, it shrinks, which can lead to cracking and other deformation. The mix design, the ratio of water to cement, and the ambient temperature and humidity all affect how much shrinkage occurs.

- **Creep: -**

It is the gradual deformation of concrete under sustained load overtime. The creep of concrete depends on the type and quality of the constituent materials. The mix design and conditions of the environment.

- **Elastic Modulus: -**

The elastic modulus, which varies from 20 to 40 GPa depending on the design and curing circumstances, is a measure of the rigidity of concrete.

- **Density: -**

Concrete has a density ranging from 2200-2500kg/m^3.this makes it a good material for structural applications, and it can support heavy loads.

- **Thermal Conductivity: -**

Concrete is a good thermal insulator, with a thermal conductivity ranging from 0.8-1.7 w/mk depending on the mix design and environmental conditions.

- **Impermeability: -**

Concrete is generally impermeable to water and other liquids, which helps to prevent moisture damage and corrosion of reinforcing materials.

- **Dimensional Stability: -**

Concrete is relatively stable and does not shrink or expand significantly due to changes in temperature or humidity. This makes it good choice for structures that require a high degree of dimensional stability.

CHAPTER 4
MIX PROPORTION

Also known as concrete mix designs, are the specific ratios of different materials used in the production of concrete. The mix proportions may vary depending on the intended use of concrete such as strength requirements, durability, workability and environmental conditions. Here are some of the common types of mix proportions used in the concrete construction:

- **Nominal Mix: -**

In this type of proportion, the quantities of cement, sand and aggregate are not specified and are usually based on experience or local practices. Nominal mix proportions are commonly used in small scale construction projects where precise control over concrete quality is not critical.

- **Standard Mix: -**

Standard mix proportion are based on established guidelines or specifications provided by relevant organizations such as codes of practice or construction standards. These mix proportions are commonly used in medium to large scale construction projects and are designed to meet specific performance requirements.

- **Design Mix: -**

Design mix proportions are calculated based on the desired performance characteristics of the concrete, such as durability, and workability. These mix proportions are determined through laboratory testing and are tailored to meet the specific requirements of a project. Design mix proportions offer more control over the quality of concrete and are commonly used in critical structures such as high-rise buildings, bridges and infrastructure projects.

4.1 Factors Affecting the Mix Proportions: -Several factors can affect the mix proportions in construction including;

- **Desired Concrete Properties: -**

The properties required for the concrete such as durability, strength and workability are crucial in determining the mix proportion. E.g. Higher strength concrete typically requires a higher proportion of cement and lower water-cement ratio, while more workable concrete may require higher water content.

- **Aggregate Properties: -**

The form, size, gradation, and moisture content of the aggregates can all have an impact on the mix proportion. The volume of aggregate in concrete is a sizable percentage, and it affects the final project's workability, strength, and durability.

- **Cementitious Materials: -**

The proportion of the mix can be impacted by the type, quality, and quantity of cementitious materials employed, such as cement, fly ash, slag, and silica fume. Concrete's strength, durability, and other qualities are affected by cementitious elements, which also act as a binder. The mix percentage and general effectiveness of the concrete can be affected by the selection and proportion of cementitious elements.

- **Water Cement Ratio: -**

The water cement ratio is the ratio of water to cementitious materials in the mix and is a critical factor in determining the strength. Higher water cement ratio results in more workable but weaker concrete, while lower water cement ratios result in stronger but less workable concrete. The water content ratio needs to be carefully considered in mix proportions to achieve the desired properties.

- **Admixtures: -**

These are chemical additives that can be added to concrete to improve its properties. Admixtures, such as accelerators, water-reducers, retarders and plasticizers can affect the mix proportion by modifying the workability, setting time, and other properties of concrete.

- **Durability Requirements: -**

The durability of the final product is crucial in many applications. Factors such as exposure to harsh environments, chemical attack, or freeze-thaw cycles need to be considered when determining mix proportions. Certain additives or specific aggregate types may be incorporated to enhance durability.

- **Project Requirements: -**

The specific requirements of the construction project, including the structural design, construction schedule, and budget can affect the mix proportions. For example, a high-rise building may require higher strength concrete while a decorative application may require special mix proportions to achieve the desired aesthetic appearance. It plays a significant role in determining the mix proportion in construction.

- **Environmental Considerations: -**

Environmental factors like temperature and humidity can impact the curing and setting of mixtures. Mix proportions may need to be adjusted to accommodate variations in environmental conditions during mixing, placing, and curing.

- **Cost and Availability: -**

The cost and availability of materials can also influence mix proportions. Some materials may be more expensive, necessitating adjustments to the mix design to optimize cost or make use of locally available resources.

CHAPTER 5
METHODOLOGY

Concrete mix design is the process of determining the proportions of ingredients such as cement, aggregates, water and admixture that will result in a concrete mix with desired properties. There are several methods of concrete mix design, each with its own advantage and limitations. Some of the common are as;

- BIS method.
- ACI method.
- DOE/BRITISH method.

5.1 BIS (Bureau of Indian standards) Method of Concrete Mix Design: -

The previous BIS strategy was as follows (is 10262-1982):
based on conditions in the area. Bis recommends designing the mixture with cement and other elements. These requirements relate to typical mixed concrete designs (less than 45MPa). The use of differential admixtures, gap-graded aggregates, or volcanic ash is not covered by this specification.
The new BIS method (IS10262-2009) includes a few noteworthy characteristics. In order to illustrate the mixing ratio technique, the new code employed a typical mixed design challenge.
The new BIS 6 stipulates the specifications of durability, water-cement ratio limitations, and maximum cement content but only for regular and standard concrete grades. It was necessary to change the parameters for calculating the water-cement ratio, water content, and predicted amounts of coarse and fine aggregate. In terms of air content, ordinary concrete (non-aerated) is not particularly noteworthy. The air content has been eliminated as a result. Air content is likewise disregarded by IS 456-2000.

5.1.1 Steps involved in BIS Method of Concrete Mix Design: -

- ✓ **Design Requirements: -**
  Establish the design specifications, including the necessary compressive strength, workability, exposure circumstances, and kind of construction.
- ✓ **Selection of Target Strength: -**
  Based on design requirements and the type of structure, select the target strength of concrete that needs to be achieved at the end of 28 days.
- ✓ **Selection of Water-Cement ratio:**

Based on the type of exposure conditions and the type of cement being used, select an acceptable water-cement ratio. Based on the desired strength, the water-cement ratio is often chosen from the table using the 10260-2019 code.

- ✓ **Estimation of Cementitious content: -**
  Based on the chosen water-cement ratio, estimate the water content, and calculate the cementitious content. Typically, the cementitious component of the concrete mix is reported as a percentage of its overall weight.
- ✓ **Selection of Aggregate Proportions: -**
  Determine the proportion of coarse and fine aggregates based on the type of aggregate, grading requirements and workability of the mix. The aggregate proportions are generally expressed in terms of volume or mass.
- ✓ **Estimation of Admixtures: -**
  If any admixture such as water reducing agents, air entraining agents, or the chemical admixtures are used estimate their quantities based on the manufacturer's recommendation and desired properties of concrete
- ✓ **Mix Proportioning: -**
  To determine the final mix proportion through trial and error, use the predicted values for cementitious content, aggregate proportions, and additive quantities. Make that the mix proportion satisfies the design criteria for workability, durability, and strength.
- ✓ **Validation of Mix Proportions: -**
  To verify the effectiveness of the suggested mix proportions, test them in a lab setting. To make sure the mix has the appropriate qualities, run tests including compressive, slump, and other pertinent testing.

5.2 ACI (American Concrete Institute) Method of Concrete Mix Design: -

This proportional allocation method was first published by ACI committee 613 in 1954; it was later upgraded to incorporate, among other things, the usage of entrained air. The ACI hybrid design concept, which was given to the ACI committee 211 in 1970, has the benefit of simplicity because it can be applied to polymerization processes that round or chamfer edges using much the same technique. Ordinary light aggregate was used in concrete in 2002, whether it was aerated or not. ACI 211.1-91 was seen once more. These standard requirements outline the quantity and chemical admixture of hydraulic cement concrete produced with or without cementitious components. Concrete regularly uses chemical admixtures to speed up, slow down, improve, reduce the need for mixing water, increase strength, or alter other properties. Based on a balancing of the needs for density, economy, and durability, different proportions of the option are made. Two things to take into account are density and attractiveness. Based on a specified minimum strength, the American academy of concrete's hybrid design method calculates the average design strength.

5.2.1 Steps involved in ACI method: -

- ✓ **Determination of Concrete Requirements: -**
  This step involves specifying the desired properties of the concrete, such as target compressive strength, maximum aggregate ratio, exposure conditions and workability measurements.
- ✓ **Selection of Materials: -**

Materials like cement, aggregate, and water are chosen appropriately based on the desired characteristics of concrete. These are often chosen depending on their price and availability of properties.

- ✓ **Proportioning of Materials: -**
  Based on each material's unique characteristics and interactions, the ACI technique offers recommendations for calculating the quantities of each component in the mix.
- ✓ **Adjustment for Moisture Content: -**
  The ACI technique contains provisions for modifying the quantities of elements to account for their moisture content and ensure that the right amount of water is introduced to the mix because aggregates and other materials may contain moisture.
- ✓ **Testing and Evaluation: -**
  Following proportioning, the concrete mix is often tested in a lab or outdoors to ascertain its qualities, including slump, air content, and compressive strength. The outcomes of these experiments are used to assess the mix's performance and make any necessary changes to the mix's proportions.

5.3 DOE (Department of Energy) Method of Concrete Mix Design: -

It is the concrete mix design approach used in the UK, and it has a long history in both the UK and the rest of the world. The 1950 UK publication "Notes to Highway 4" served as its inspiration. In order to replace the notes, the DOE "ordinary Concrete Mixture Design" was introduced in 1975. 1988 saw the revision and alteration of the "Design of Common Concrete Mixture" document to reflect changes to various British standards. DOE regulations cover the vast majority of applications for concrete, including roadways. This method can be applied to concrete that has fly ash in it.

5.3.1 Steps involved in DOE Concrete mix design are as: -

- ✓ **Determination of Target Strength: -**
  Based on the project requirements and structural design considerations, the target strength of the concrete is determined. This is usually based on the expected load and exposure conditions
- ✓ **Selection of Appropriate Materials: -**
  Based on local availability and specifications, suitable materials such as cement, aggregate, water, and admixture are selected. The properties of these materials such as their specific gravity, fineness modulus is considered in the mix design proces
- ✓ **Estimation of Water-Cement Ratio: -**
  The water-cement ratio has a significant impact on the durability and strength of concrete. The DOE approach entails predicting the concrete's exposure circumstances, cement type, and water-cement ratio.
- ✓ **Determination of Aggregate Proportion: -**
  The intended workability, strength, and durability requirements are taken into account while determining the proportions of coarse and fine particles in the concrete mix. The DOE approach uses the idea of the maximum density curve to calculate the combined aggregate grading.
- ✓ **Selection of Admixture: -**
  Chemical additions known as mixes can change the strength, workability, and setting time of concrete. Utilizing the DOE approach, admixtures can be chosen and dosed according to their desired effects and compatibility with other mix proportions.

- ✓ **Mix Design Calculations: -**
  The weights of each material needed to obtain the appropriate mix proportion are calculated as part of the concrete mix design calculations based on the aforementioned factors. These calculations take into account elements including the material's unit weight, moisture content, and aggregate bulking.
- ✓ **Trial Batches and Testing: -**
  Trial batches of concrete are made and evaluated for fresh concrete properties including compressive strength and durability once the mix design has been decided upon. Depending on the outcomes of the tests, the mix proportions may need to be changed.

CHAPTER 6
CALCULATIONS
6.1 Design mix of M30 by using BIS method of: -

- Grade= M30
- Type of cement= OPC
- Maximum size of aggregates= 20mm
- Exposure condition= Severe
- Minimum cement content= 320kg/m^3 (IS-456, Table 5)
- Type of coarse aggregate= Crushed
- Maximum cement content= 450kg/m^3 (IS-456, Cl 8.2.4.2)
- Water-cement ratio=0.45 (IS-456, Table 5)
- **Step 1: Target mean strength: -**
  fm= fck+1.65s (IS-10262-2019)
  = 30+1.65×5
  = 38.25 MPa
- **Step 2: Water-Cement Ratio: -**

Table No. 6.1: - Different Exposure Conditions of Concrete with 20mm MSA.

Sl No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m^2	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content kg/m^2	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete
1	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	-	300	0.55	M20
ii)	Moderate	240	0.60	M15	300	0.50	M25
iii)	Severe	250	0.50	M20	320	0.45	M30
iv)	Very Severe	260	0.45	M20	340	0.45	M35
v)	Extreme	280	0.40	M25	360	0.40	M40

Exposure condition= Severe (IS-456-2000, Table 5)
W/C ratio= 0.45By using admixture water-cement ratio can be reduced. W/C ratio= 0.45-0.05
= 0.4

- **Step 3: Water Content:**

Table No. 6.2: -

Maximum water content per cubic meter of concrete for nominal maximum size of aggregate		
S. No	Nominal maximum size of aggregate	Maximum water content
1	10	208
2	20	186
3	40	165

As per IS 10262 Table 2
For 20mm aggregate= 186kg (for 25-50 Slump)
For 100 slump, for every 25mm add 3% (IS-10262, Cl.5.3)
186+6% of 186= 186+6÷100×186
= 197.16kg

- **Step 4: Calculation of Cement content: -**

W/C ratio= water content/cement content
As admixture is used water content can be reduced by 15% or above
= 197.16-15÷100×197.16 = 167.59kg
Cement content= water content/W/C ratio
= 167.59÷0.4
= 418 kg/m^3 > 320kg/m^3

- **Step 5: Aggregate Proportion between Coarse aggregate and Fine aggregate:**

Table No. 6.3: -

S.No.	NMSA (mm)	Volume of coarse aggregate per unit volume of total aggregate for different zones of fine aggregate			
		Zone IV	Zone III	Zone II	Zone I
1	10	0.50	0.48	0.46	0.44
2	20	0.66	0.64	0.62	0.60
3	40	0.75	0.73	0.71	0.69

As per IS 10262, Table 3 Cl.5.5.1
For Zone II= 0.62 (W/C-0.5)
For every 0.05 decrease, increase by 0.01,
= 0.62+0.01
= 0.63
Volume of Coarse Aggregates= 0.63
Volume of Fine Aggregates= 1-0.63= 0.37

- **Step 6: Mix Calculation: -**

Volume of Concrete= $1m^3$
Volume of Cement= Mass/specific gravity×1000
= 418÷3.16×1000
= $0.1322m^3$
Volume of water= Mass/specific gravity×1000
= 167.59÷1.0×1000
= $0.167m^3$
Volume of Admixture= (Mass/specific gravity) × (1×1000)
Mass= 1.2% of cement
(1.2÷100) × 418÷ (1.12×1000)
= $0.0044m^3$
Volume of entrapped air= 2%
= 2/100 = $0.02m^3$
Volume of all in aggregates= 1-(0.132+0.167+0.0044+0.02)
= $0.676m^3$
Mass of Coarse aggregates= Volume of all in aggregates×Volume of coarse aggregates×specific gravity
= 0.676×0.63×2.73×1000
= 1162kg
Mass of Fine aggregates= Volume of al in aggregates×Volume of fine aggregates×specific gravity
= 0.676×0.37×2.65×1000
= 662.8kg
Final Estimated Quantities are;
Cement= 418 kg/m^3
Water= 167.59 kg/m^3
Fine Aggregate= 662 kg/m^3
Coarse Aggregate= 1162 kg/m^3
Admixture= 5.016 kg/m^3

Final Ratio	Cement	F. A	C. A	Water-Cement Ratio
	1	**1.58**	**2.77**	**0.40**

6.2 Design Mix of M35 By using BIS Method: -

- **Step 1: Target Mean Strength**
  fm= fck+1.65s
  = 35+1.65×5
  = 43.25MPa
- **Step 2: Water-Cement Ratio: -**
  W/C ratio= 0.50
  Exposure Condition= Moderate
  While using admixture it can be reduced to=(W/C-0.05)

= (0.50-0.05)
= 0.45

- **Step 3: Water Content: -**
  From table-2 of IS 10262:2009
  Maximum water content for 20mm aggregate= 186 lit (for 25-50 Slump)
  As per IS 10262:2009 CL.4.2, we can increase 3% for every additional 25 slump
  Estimated water content for 100 slump= 186+6% of 186
  = 186+11.16
  = 197.16 lit
  As Admixture is used water content can be reduced by 15% or above
  = 197.16-5÷100×197.16
  = 167.59 lit
- **Step 4: Calculation of Cement Content: -**
  As per table 5
  IS 456:2000 For moderate Condition,
  Cement= 300 kg/m^3
  W/C ratio= 0.45
  Water content= 167.59 lit
  Cement Content= Water Content/ W/C ratio
  = 167.59÷0.45
  = 372.42>300 kg/m^3
- **Step 5: Calculation of Volume Coarse and Fine Aggregates: -**
  From table 3 of IS 10262:2009, Volume of Coarse aggregate corresponding to 20mm size aggregate and Fine aggregate zone III for water-cement ratio of 0.5= 0.64
  Actual W/C ratio= 0.45
  It is less by (0.5-0.45) = 0.05
  As the W/C ratio is reduced, it is desirable to increase the Coarse aggregate proportion to reduce the fine aggregate.
  Coarse aggregate is increased at the rate of 0.01 for every decrease in W/C ratio of 0.05.
  For every decrease of 0.05 W/C ratio= Coarse aggregate increased by 0.01.
  For every decrease of 1 W/C ratio= Coarse aggregate increased by 0.01/0.05.
  For decrease of every 0.05 W/C ratio= Coarse aggregate increased by 0.01/0.05×0.05= 0.01
  Corrected proportion of volume of aggregates= 0.64+0.01= 0.65
  Since it is angular aggregates, the coarse aggregate can be reduced by 10% (IS 10262:2009 Cl.4.4.1)
  By reducing 10%, we get= 0.65 (10÷100×0.65) = 0.585
  Volume of Coarse aggregates= 0.585
  Volume of Fine aggregates = 1-0.585
  = 0.415
- **Step 6: Mix Calculations: -**
  Volume of Concrete= $1m^3$
  Volume of Cement= Mass/Specific gravity×1000
  = 372.42÷3.16×1000
  = $0.1178m^3$

Volume of Water= Mass/Specific gravity×1000

= 167.59÷1×1000 = 0.167m^3

Volume of admixture= Mass of admixture/Specific gravity×1000

Assuming dosage of 1.2% by weight of cementitious material and assuming specific gravity at 1.21

= 102÷100×372.42÷1.12×1000

= 0.003m^3

Volume of entrapped air= 2% of 20mm Coarse aggregate

= 2÷100 = 0.02m^3

Volume of all aggregates= Volume of Concrete- (Volume of Cement+ Volume of water+ Volume of admixture+ Volume of entrapped air)

= 1- (0.1178+0.167+0.003+0.02)

= 0.693m^3

Mass of Coarse aggregate= Volume of all aggregates× volume of Coarse aggregate× specific gravity×1000

= 0.693×0.585×2.73×1000

= 1101.1kg/m^3

Mass of Fine aggregates= Volume of all aggregates× Volume of fine aggregates× specific gravity× 1000

= 0.693× 0.415× 2.65× 1000 = 758.8kg/m^3

Final Estimated Quantities are:

Cement= 372.42kg/m^3

Water= 167.59kg/m^3

Coarse aggregates= 1101.9kg/m^3

Fine aggregates= 758.8kg/m^3

Admixture= 4.46kg/m^3

Final Ratio	Cement	F. A	C. A	Water-Cement Ratio
	1	2.03	2.95	0.45

6.3 Design Mix of M30 By using ACI Method: -

- Target slump= 50mm
- Maximum size of aggregate= 20mm
- Specific gravity of Cement= 3.16
- Specific gravity of Fine aggregates= 2.65
- Specific gravity of Coarse aggregates= 2.75
- Bulk density= 1600kg/m^3
- Moisture content adjustment for aggregates
- Water absorption of Coarse aggregate= 1%
- Free moisture surface in Fine aggregates= 2%
- Non-air entrained concrete.

- **Step 1: Target Mean Strength: -**

  fcr= fc+8.5 (when fc= 21to 35 MPa)

  = 30+8.5 fc= Characteristic Strength of concrete

  = 38.5MPa fcr= Target strength of concrete

- **Step 2: Water content: -**

  Choice of Maximum size of aggregates, estimation of mixing water and air content.

  Maximum size of aggregates= 20mm

  Value of slump= 50mm

Table No. 6.4: Approx Mixing Water and Air Content Requirements for Slumps:

Slump	9.5 Mm	12.5 mm	19 mm	25 mm	37.5 mm	50 mm	75 mm	150 mm
25-50	207	199	190	179	166	154	130	113
75-100	228	216	205	193	181	169	145	124
150-175	243	228	216	202	190	178	160	-

Then, Water content= 189kg/m^3 (By Interpolation)

Volume of water in 1m^3 = Mass/Specific gravity×1000

= 189÷1×1000= 0.189m^3

Volume of air= 2%= 2/100= 0.02m^3

- **Step 3: Water-Cement ratio: -**

  Selection of water cement ratio, compressive strength at 28 days= 38MPa

Compressive strength at 28 days, MPa*	Water-cement ratio, by mass: Non-air-entrained concrete	Air-entrained concrete
40	0.42	—
35	0.47	0.39
30	0.54	0.45
25	0.61	0.52
20	0.69	0.60
15	0.79	0.70

Fig. 6.4

So, W/C ratio= 0.44 (By Interpolation)

Weight of Cement= Weight of water/W/C ratio

= 189÷0.44= 430kg/m^3

Volume of Cement= 430÷3.15×1000= 0.136m^3

- **Step 4: Estimation of Coarse Aggregate content: -**

Nominal maximum size of aggregate, mm	Volume of dry-rodded coarse aggregate* per unit volume of concrete for different fineness moduli† of fine aggregate			
	2.40	2.60	2.80	3.00
9.5	0.50	0.48	0.46	0.44
12.5	0.59	0.57	0.55	0.53
19	0.66	0.64	0.62	0.60
25	0.71	0.69	0.67	0.65
37.5	0.75	0.73	0.71	0.69
50	0.78	0.76	0.74	0.72
75	0.82	0.80	0.78	0.76
150	0.87	0.85	0.83	0.81

Fig. 6.5

Max. size of aggregates= 20mm
Then,
Volume of dry robbed Coarse aggregate= 0.62
Weight of Coarse aggregate= 0.62×1600 = 992kg/m^3 (Bulk density= Weight/Vol.)
Volume of Coarse aggregate in 1m^3= 992÷2.7×1000= 0.3674m^3

- **Step 5: Estimation of Fine Aggregates: -**

Volume of Fine aggregates= 1- (Volume of water+ volume of air+ Volume of Cement+ Volume of Coarse aggregate)
= 1- (0.189+0.02+0.136+0.367)
= 0.288m^3
Weight of Fine aggregate= 0.288×2.65×1000
= 763.2kg/m^3

- **Step 6: Moisture content adjustment for Coarse and Fine aggregates: -**

Water absorption of Coarse aggregate= 1% of 992
= 1÷100×992= 9.92kg
Free surface moisture content in sand= 2% of 763.2
= 2÷100×763.2= 15.27kg
Final Estimated Quantities are:
Cement= 430kg/m^3
Water content= 189+9.92-15.27= 183.65kg/m^3
Fine Aggregates= 763.2+15.27=778.47kg/m^3
Coarse Aggregates= 992kg/m^3

Final Ratio	Cement	F. A	C. A	Water-Cement Ratio
	1	**1.77**	**2.30**	**0.42**

6.4 Design Mix of M35 By using ACI Method: -

- **Step 1: Target Mean Strength: -**
  fcr= fc+8.5
  = 35+8.5
  = 43.5MPa
- **Step 2: Water content: -**
  Estimation of mixing water and air content
  Max. size of aggregate= 20mm
  Value of slump= 50mm
  Then,
  Water content= 189kg/m^3
  Volume of water in 1m^3= Weight/ specific gravity×1000
  = 189÷1×1000= 0.189m^3
  Volume of air= 2%= 2/100= 0.02m
- **Step 3: Selection of Water-Cement ratio: -**
  Target Compressive strength= 43.2MPa
  So, W/C ratio= 0.398=0.40 (By interpolation)
  Weight of Cement= 189/0.40
  = 472.5kg/m^3
  Volume of Cement= 472.5÷3.15×1000= 0.15m^3
- **Step 4: Estimation of Coarse Aggregate content: -**
  Max. size of aggregate= 20mm
  Volume of dry robbed Coarse aggregate= 0.62
  Weight of Coarse aggregate= 0.62×1600= 992kg/m^3
  Volume of Coarse aggregate in 1m^3= 992÷2.7×1000= 0.367m^3
- **Step 5: Estimation of Fine Aggregates: -**
  Volume of Fine aggregates= 1- (Volume of Water+ Volume of air+ Volume of Cement+ Volume of Coarse aggregate)
  = 1- (0.189+0.02+0.15+0.367)
  = 0.274m^3
  Weight of Fine aggregates= 0.274×2.65×1000= 726.1kg/m^3
- **Step 6: Moisture content adjustment for Coarse and Fine aggregates: -**
  Water absorption of Coarse aggregate= 1% of 992= 9.92kg
  Free surface moisture content in sand= 2% of 726.1= 0.02×726.1= 14.52kg
  Final Estimated Quantities are:
  Cement= 472.5kg/m^3
  Water content= 189+9.92-14.52= 184.4kg/m^3

Coarse aggregates= 992kg/m^3
Fine aggregates= 726.1+14.52= 740.62kg/m^3

Final Ratio	Cement	F. A	C. A	Water-Cement Ratio
	1	**1.56**	**2.09**	**0.40**

6.5 Design Mix of M30 By using DOE/BRITISH Method: -

- Exposure condition= Moderate
- Size of Aggregate= 20mm
- Bulk Specific gravity= 2.65
- Slump= 75mm
- Type of Aggregate= Uncrushed
- **Step 1: Target Mean Strength: -**
  fm= fck+1.65×s
  = 30+1.65×5
  = 38.2MPa
- **Step 2: Water-Cement ratio: -**

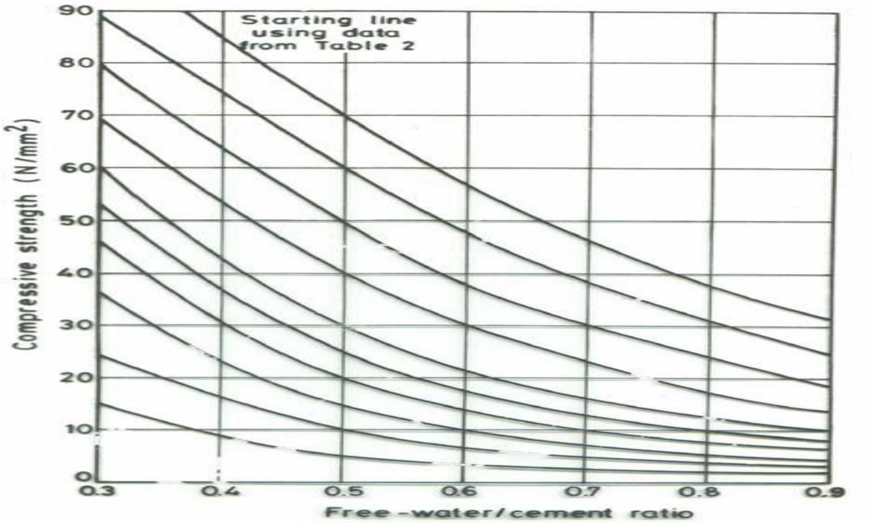

Fig. 6.6

From the curve, W/C ratio= 0.62
The Maximum W/C ratio permitted is= 0.50 (Adopt Minimum among two

- **Step 3: Water-Content: -**

Table No. 6.5: - Water Content Determination.

M.S. A	Type	Slump 0-10	Slump 10- 30	Slump 60-180
20 mm	Uncrushed	135	160	195
	Crushed	170	190	225

40 mm	Uncrushed	115	140	175
	Crushed	155	175	205

Water content for slump of 75mm and for 20mm uncrushed aggregate, water content= 195kg/m^3

- **Step 4: Cement Content: -**

  W/C= Water content/Cement content

  Cement Content= Water content/W/C ratio

  = 195÷0.5= 390kg/m^3

  Minimum Cement content for durability is 350kg/m^3, adopt greater of two

  Therefore, Cement Content= 390kg/m^3

- **Step 5: Wet Density of Concrete and Total Aggregate Content: -**

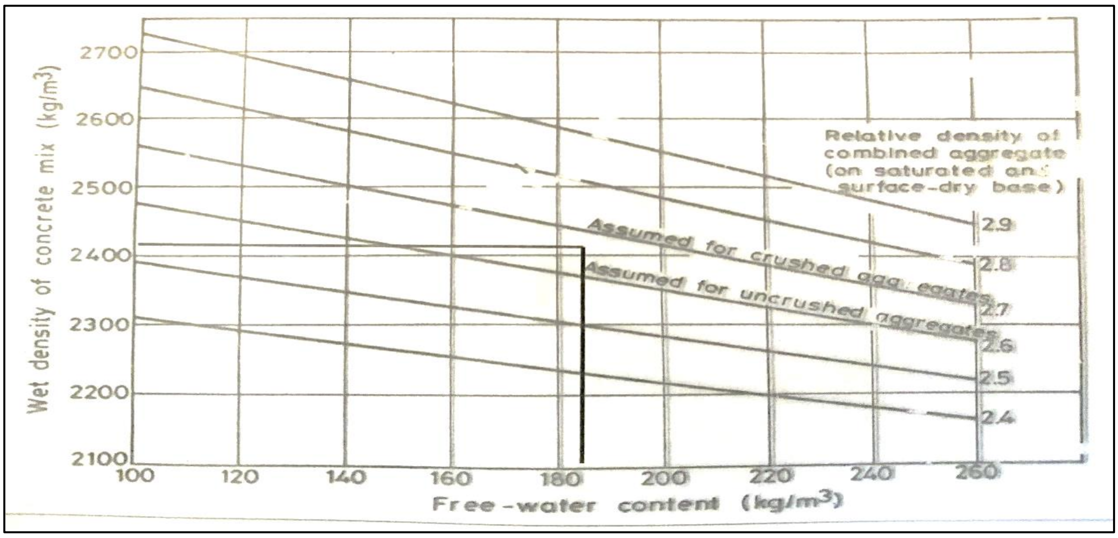

Fig. 6.7

Density of fresh concrete

For water-content of 195kg/m^3, 20mm uncrushed aggregate of specific gravity=2.65

Wet density= 2400kg/m^3

Therefore, Weight of total aggregate= 2400-(195+390)

= 1815kg/m^3

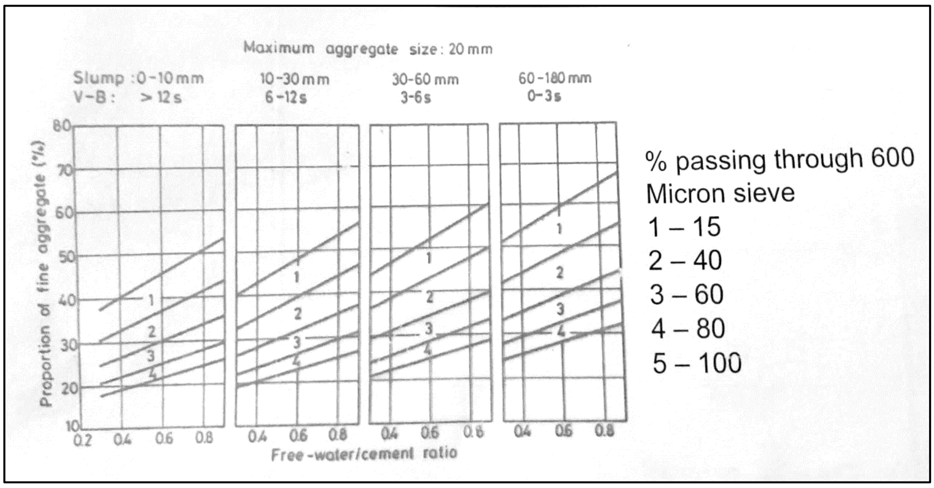

Fig. 6.8

Percentage of Fine aggregates:
For 20mm size of aggregates
W/C ratio of 0.50, slump 75mm, 50% passes through 600 microns
Therefore,
The percentage of Fine aggregates= 40%
Weight of Fine aggregates= 1815×40÷100
= 726kg/m^{3}Fine aggregate has surface moisture of 2%
Weight of F. A= 726+2÷100×726
= 740.52 kg/m^3
Therefore,
Weight of Coarse aggregates= 1815-740.52 =1074.48kg/m^3
Coarse aggregate absorbs 1% water
Weight of C. A= 1074.48-1÷100×1074.48 = 1063.73kg/m^3

Final Estimated Quantities are:
Cement= 390kg/m^3
Fine Aggregates= 740.5kg/m^3
Coarse Aggregates= 1063.7kg/m^3
Water Content= 195kg/m^3

Final Ratio	Cement	F. A	C. A	Water-Cement Ratio
	1	1.89	2.72	0.5

6.6 Mix of M35 By using DOE/BRITISH Method: -

- **Target Mean Strength: -**
  fm= fck+1.65s
  = 35+1.65×5
  = 43.25MPa
- **Water-Cement ratio: -**
  We are using OPC and uncrushed aggregates. So, Compressive strength at the age of 28 days is 49MPa. Since 43.2MPa is the target mean strength to that newly formed curve draw down the curve to get new W/C ratio which is equal to 0.58
  W/C ratio based on durability condition= 0.5
  Exposure condition= Moderate
  Adopting Minimum of two= 0.5
- **Step 3: Water- Content: -**
  Water content depends upon maximum size of aggregates which is equal to 20mm
  For 20mm crushed and slump range 75mm
  Water content= 225kg/m^3

- **Step 4: Cement Content: -**
  Cement content= Water content/W/C ratio
  = 225÷0.5 = 450kg/m^3
  From durability condition, cement content= 300kg/m^3
  Taking maximum among the two= 450kg/m^3
- **Step 5: Wet Density of Concrete and Total Aggregate Content: -**
  Weight density of concrete= 2400kg/m^3
  Therefore,
  Total aggregate density or aggregate content= Total weight density- Cement +water
  = 2400-(450+225)
  = 1725kg/m^3
- **Step 6: Percentage of Fine Aggregates: -**
  For 20mm aggregates, W/C ratio= 0.50
  Slump 50% passes through 600 microns, then the percentage of Fine aggregates= 45%
  Weight of Fine aggregates= 1725×45÷100
  = 776.25kg/m^3
  Fine aggregates have surface moisture of 2%
  Weight of F. A= 776.25+2÷100×776.25
  = 791.7 kg/m^3
  Weight of Coarse aggregates= 1725-791.7
  = 933.3kg/m^3
  Coarse aggregates absorbs 1% water
  Weight of C. A=933.3-1÷100×933.3
  = 924kg/m^3
  Final Estimated Quantities are:
  Cement= 450kg/m^3
  Fine Aggregates= 791.7kg/m^3
  Coarse Aggregates= 924kg/m^3
  Water Content= 225kg/m^3

Final Ratio	Cement	F. A	C. A	Water-Cement Ratio
	1	1.75	2.05	0.5

CHAPTER 7
MIXING AND CASTING

The ingredients were combined with a pan mixer. Continue mixing the ingredients until they are evenly distributed and the mass is homogeneous in both colour and consistency. After being removed from the mixer, if there is segregation, the concrete needs to be mixed again. The mixing process must last at least two minutes. It is advisable to heed the manufacturer's recommendations for other, more effective mixer kinds. To get the necessary sample size, all of the cubes, beams, and cylinders were vibrated after being cast in standard moulds. The moulds should be free of dust before pouring concrete, and oil should be coated on their surface to make it simpler to remove the specimen. Three equal layers of concrete were poured into the moulds, and then they were either set on a vibrating table or tamped with a tamping bar using 25 strokes for each layer of the round end. All of the mould's surface should be covered with strokes. Finally, a metal trowel was used to level, polish, and finish the concrete's surface.

Fig. 7.1 Mixing

7.2 CURING OF CONCRETE: -

It involves limiting moisture loss from the concrete while maintaining an acceptable temperature range. By extending the cement's hydration, especially in the cement's surface zone, suitable and adequate curing processes can be used to decrease the permeability of the concrete and increase its durability. Scaling compounds are also employed; however, water is typically used to cure concrete. It increases the concrete's strength, resilience, impermeability, durability, and resistance to frost and abrasion. Water can be sprayed on the surface or a moist cloth can be used to cure it. As soon as the concrete is sufficiently hard, curing typically begins. For regular concrete, an additional 14 days of cure are usually required. After the specimens were taken out of the casting moulds for this job, they were immersed in the curing tank to complete the curing process. At the time of testing, the samples are removed from the water after being cured for 7 and 28 days.

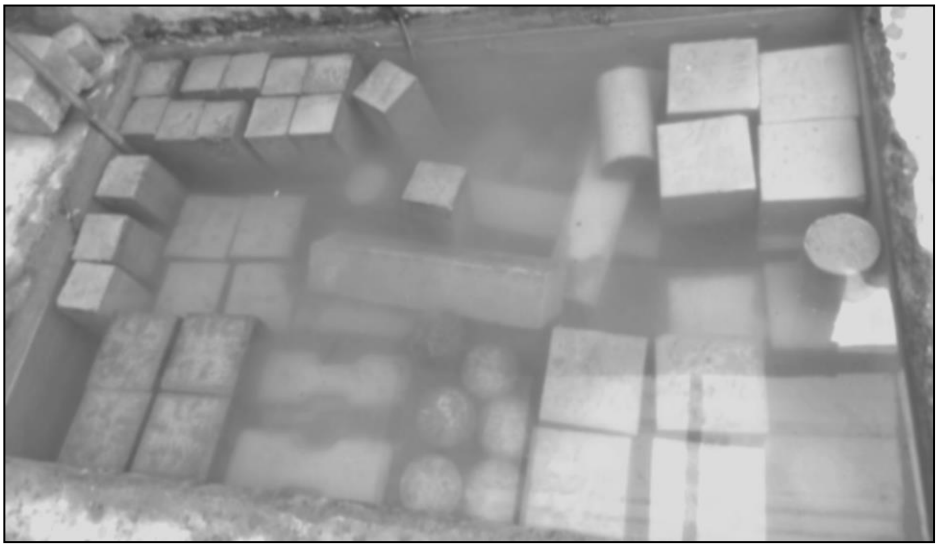

Fig. 7.2 Curing Tank

CHAPTER 8
TESTS ON CONCRETE

The following are the tests procedures which are conducted in order to compare the desired properties of concrete designed by different methods of mix design;

8.1 TESTS ON HARDENED CONCRETE: -

8.1.1 Compressive Strength Test: -

One of the most crucial tests for concrete is this one. It evaluates if a concrete mix has the necessary strength and measures how well concrete can endure compressive loads.

general procedures for carrying out a concrete compressive strength test;

- **Prepare the Concrete specimens: -**

After the designated curing period, remove the specimen from the water tank and wipe off any excess moisture.

- **Prepare the Testing machine: -**

Utilizing CTM, the compressive strength test is performed. Before testing, the device needs to be calibrated and its accuracy confirmed. cleaned the testing machine's bearing surface.

- **Test the specimen: -**

Insert the specimen into the compression testing device with the cylinder's axis upright and in the center of the compression platen. Apply a load at a rate of 140 kg per cubic centimeter per minute until the specimen breaks. Note the highest load.

- **Calculate the compressive strength: -**

The compressive strength of the concrete is calculated by dividing the maximum load by the cross-sectional area of the specimen. The result is typically reported in MPa.

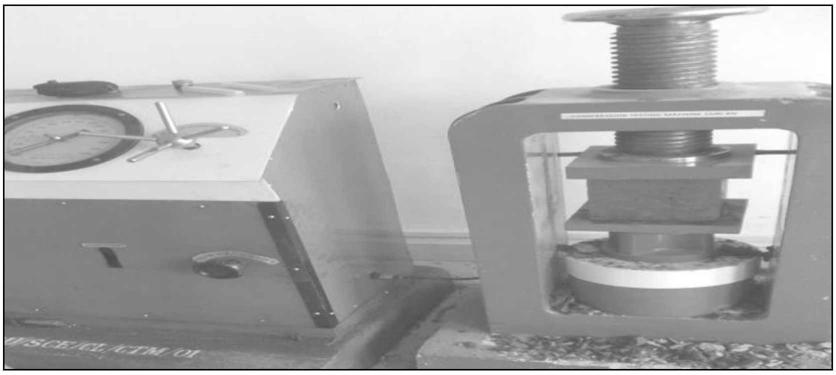

Fig. 8.1 Compressive Testing Machine

8.1.2 Split Tensile Strength Test: -

It is a standard technique for figuring out the tensile strength of concrete. A cylindrical or cubical specimen of concrete is compressed during the test, and the tensile strength of the specimen is then determined as the specimen splits along a plane perpendicular to the compressed force.

basic procedures for conducting a split tensile test on concrete;

- Creating concrete cylindrical examples. For cylinder specimens, the typical size is 150 mm x 300 mm, whereas for cubic specimens, it is 150 mm x 150 mm x 150 mm. Until the time of testing, the samples should be cured and kept in a controlled atmosphere.
- Mark a line around the circumference of the specimen at the mid-point of its height. This line will serve as a reference for the splitting force.
- Set up the specimen on the testing device, then apply a compressive load on it at a fixed rate of deformation. Usually, the loading is between 0.7 and 1.4 MPa/min.
- Insert the specimen into the machine for splitting. The force necessary to split the specimen along the reference line is measured as the tensile strength of the specimen, which is determined by applying a load perpendicular to the reference line.
- As per IS-456,
  Split Tensile Strength of Concrete= 0.7fck
  The split tensile strength can also be calculated by using the formula= 2P/Πdl
  Where,
  P= Splitting load
  D= Diameter of specimen
  L= Length of specimen.

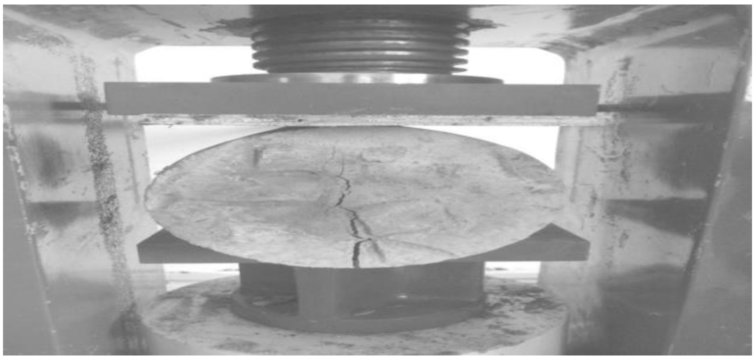

Fig. 8.2 Split Tensile Strength Test

8.2 TESTS ON FRESH CONCRETE: -

8.2.1 Slump Test: -

Through the slump test, the workability of each concrete mixture was evaluated. The IS 1199-1959 standard was followed in performing the slump tests.

Apparatus: - Frustum of cone, Tamping Rod.

Procedure: -

- Prior to starting the test, the interior surface of the mould must be well cleaned, dry, and devoid of any moisture or set concrete.
- The mould must be set down on a flat, smooth, rigid, and non-absorbent surface, such as a well levelled metal plate, and must be securely kept in place as it is filled.
- Four layers, each roughly one-quarter the height of the mould, must be poured into the mould.
- Twenty-five strokes of the rounded end of the tamping rod are required to tamp each layer.
- The strokes shall be distributed in a uniform manner over the cross-section of the mould and for the second and subsequent layers shall penetrate in the underlying layer.
- The concrete must be levelled with a trowel or tamping rod after the top layer has been rounded off to ensure that the mould is completely filled.
- The base plate and the mould must be thoroughly cleaned to remove any mortar that may have spilled out.
- As soon as possible, the mould must be withdrawn from the concrete by carefully and slowly raising it vertically.
- As a result, the concrete can settle, and the slump can then be determined right away by comparing the height of the mould to the highest point of the test specimen.

Table No. 8.1: - Workability, Slump of Concrete with 20mm MSA.

Degree of Workability	Slump(mm)
Very Low	—
Low	25-75
Medium	50-100
High	100-150

Fig. 8.3 Slump Cone

8.2.2 Compaction Factor Test: -

This test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. It is more precise and sensitive than the slump test.

Apparatus: -

Compaction factor apparatus.

Procedure: -

- Using the hand scoop, carefully deposit the concrete sample to be analyzed in the upper hopper.
- Once the hopper is full to the top, the trap door must be opened to allow concrete to fall into the lower hopper.
- Some mixtures have a propensity to stick in one or both hoppers. If this happens, gently pushing the rod into the concrete from the top may ease the concrete through.
- The bottom hopper's trap door was opened, allowing the concrete to fall into the cylinder. The excess concrete above the level of the top of the cylinder must then be removed by simultaneously moving one trowel from each side across the top of the cylinder while maintaining pressure on the top edge of the cylinder while holding a trowel in each hand with the plane of the blades horizontal.
- The aforementioned procedure must be performed in an area free from shock or vibration.
- Afterward, the weight of the concrete inside the cylinder must be calculated to the nearest 10 g.
- The weight of partially compacted concrete shall be referred to as this weight.
- The cylinder must be replaced with concrete from the same sample in layers
- about 5 cm deep, with the layers preferably vibrated or severely pushed to achieve complete compaction. Carefully levelling the top surface of the thoroughly compacted concrete is required. The cylinder's exterior must then be thoroughly cleaned.

Calculation: -

The compacting factor is defined as the ratio of the weight of partially compacted concrete to the weight of fully compacted concrete. It shall normally be stated to the nearest second decimal place.

Compaction Factor = $W_2 – W_1 \div W_3 – W_1$

Where,

W_1 = Weight of Empty Cylinder

W_2 = Weight of Partially Compacted Concrete

W_3 = Weight of Fully Compacted Concrete

Table No. 8.2: - Compacting Factor of Concrete

Degree of Workability	Compacting Factor
Very Low	0.78
Low	0.85
Medium	0.92
High	0.95

Fig. 8.4 Compaction Factor Apparatus

8.3 TESTS ON AGGREGATES: -

8.3.1 Sieve Analysis of Fine Aggregates: -

To determine the gradation of fine aggregates.

Apparatus: -

Sieves of the sieve 10mm, 4.75mm, 2.36mm, 1.18mm, 600micron, 300-micron, 150 micron and 75-micron, Balance and standard weights, Oven.

Sample: -

Fine aggregate

Procedure: -

- Gather 1000 g of sand.
- Air-dry the sample by placing it in a warm oven (between 100 and 110 degrees Celsius) or by leaving it at room temperature. The air-dry sample must be weighed and sieved on the proper sieves in succession.
- For no less than two minutes, each sieve must be shaken individually over a clean tray. The 150- and 75-micron sieves can be lightly brushed to avoid blinding the apertures.
- The material that was kept on each after sieving must be weighed.
- The cumulative percentage of the whole sample's weight that passes through each sieve, rounded up to the nearest whole number.
- The proportion of the whole sample's weight that passes through a sieve and is kept on a smaller sieve, to the closest 0.1%
- To determine the grading zone, compare it to the acceptable limits in Table 4 of IS-383 1972.
- The Fineness Modulus is determined by dividing the total cumulative percent maintained by 100.

Results: -

Fineness Modulus = (Sum of cumulative % retained)/100.

8.3.2 Sieve Analysis of Coarse Aggregate: -

To determine the gradation of coarse aggregates.

Apparatus: -

Sieves of sizes 25mm, 20mm, 10mm, 4.75mm & 2.36mm, Balance, Oven

Samples: - Coarse aggregates.

Procedure: -

- The sample coarse aggregate and trays must weigh a total of 25 kg before being divided or quartered. From the bigger sample, a sieve sample must be created by quartering it or using a sample divider. For each sieve analysis on aggregate with a 20 mm grade, the sample must weigh a minimum of 2.0 kg.
- The sample must reach an air-dry state before being weighed and sieved. Either drying at ambient temperature or heating to a temperature between 1000 C and 1100 C can accomplish this.
- Starting with the largest sieve, the air-dry sample must be weighed and sieved consecutively on the suitable scales. Before usage, care must be taken to make sure the sieves are clean.
- The shaking shall be done with a varied motion, back and forth, left to right, circular clockwise and anticlockwise, and with frequent jarring, so that the material is kept moving over the sieve surface in frequently changing directions. Each sieve shall be shaken separately over a clean tray until not more than a trace passes, but in any case, for a period of not less than two minutes.
- Material must not be manually pushed through a sieve; nevertheless, inserting particles into sieves with a grain size of greater than 20 mm is OK.
- If fine material clumps are present, they can be broken by applying little pressure with fingertips to the sieve's side. To clean the sieve apertures, lightly brush the underside of the sieve with a soft brush.
- To prevent powder accumulation and blinding of apertures, the IS sieve can be lightly brushed with a fine camel toothbrush. It is forbidden to use stiff or worn-out brushes for this task, and it is also forbidden to press down on the sieve's surface to push particles through the mesh.
- After sieving is complete, the material still in each sieve as well as any material that was removed from the mesh must be weighed.

Results

The weighted percentage of the entire sample that was retained on the next, smaller sieve after passing through one larger sieve. The chart may graphically display the sieve analysis results.

Fig. 8.5 Sieve Analysis Apparatus

CHAPTER 9
RESULTS AND DISCUSSION

Table No. 9.1: -Compressive strength of M30 grade of concrete after 7 and 28 days of curing:

Method	Cement Content in Kg	Water-Cement Ratio	Compressive strength at 7 days in N/mm^2	Compressive strength at 28 days in N/mm^2
BIS	418	0.45	28.46	36.12
ACI	394	0.47	26.99	38.84
DOE	390	0.50	23.1	32.30

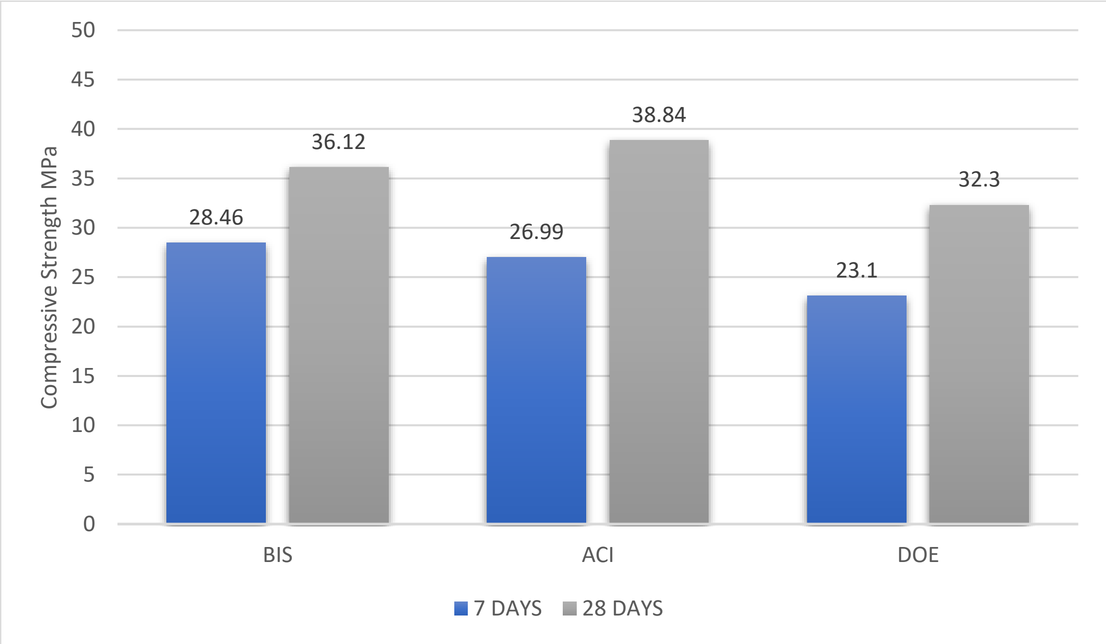

Fig. 9.1 Compressive Strength (vs) Curing Period of M30

According to experimental research, the compressive strength of concrete of the M30 grade improves after 7 and 28 days of curing for BIS, ACI, and DOE, respectively. But of the three techniques, ACI and BIS produce the best outcomes over DOE. ACI fills space holes fully because it uses more fine aggregate than the other two methods combined. More cement and fewer fine particles are included in BIS. Although the water-cement ratio in the DOE approach is higher than that in BIS and ACI, the cement content is nearly the same, resulting in a reduction in concrete strength.

Table No. 9.2: - Compressive strength of M35 grade of Concrete after 7 and 28 days of curing:

Method	Cement Content in Kg	Water-Cement Ratio	Compressive strength at 7 days in N/mm^2	Compressive strength at 28 days in N/mm^2

BIS	372.42	0.45	32.06	42.30
ACI	463	0.40	30.35	42.61
DOE	450	0.5	26	37.4

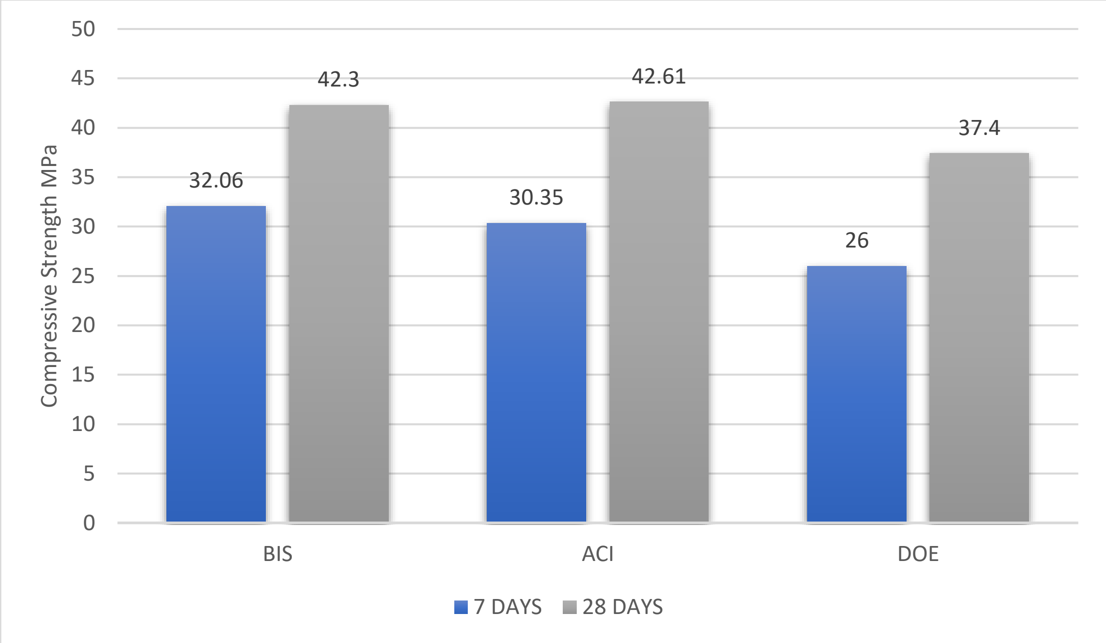

Fig. 9.2 Compressive Strength (vs) Curing Period of M35

After 7 and 28 days of curing, the compressive strength of concrete of the M35 grade rises using all three techniques. Due to the high cement content and high fine aggregate content in ACI, the strength gradually becomes more. The space voids are not entirely filled in BIS because there is less fine aggregate content and a lower cement content than in ACI. Even while DOE contains the same amount of cement as ACI, it has a higher water-to-cement ratio than ACI and BIS, respectively, which reduces the strength of the concrete. The target mean strength was attained by both the ACI and BIS.

Table No. 9.3: - Split Tensile strength of M30 Grade of concrete after 7 and 28 days of curing;

Method	Cement Content in Kg	Water-Cement Ratio	Split Tensile Strength at 7 days in N/mm^2	Split Tensile strength at 28 days in N/mm^2
BIS	418	0.45	2.52	3.58
ACI	394	0.47	2.61	3.75
DOE	390	0.50	2.15	3.10

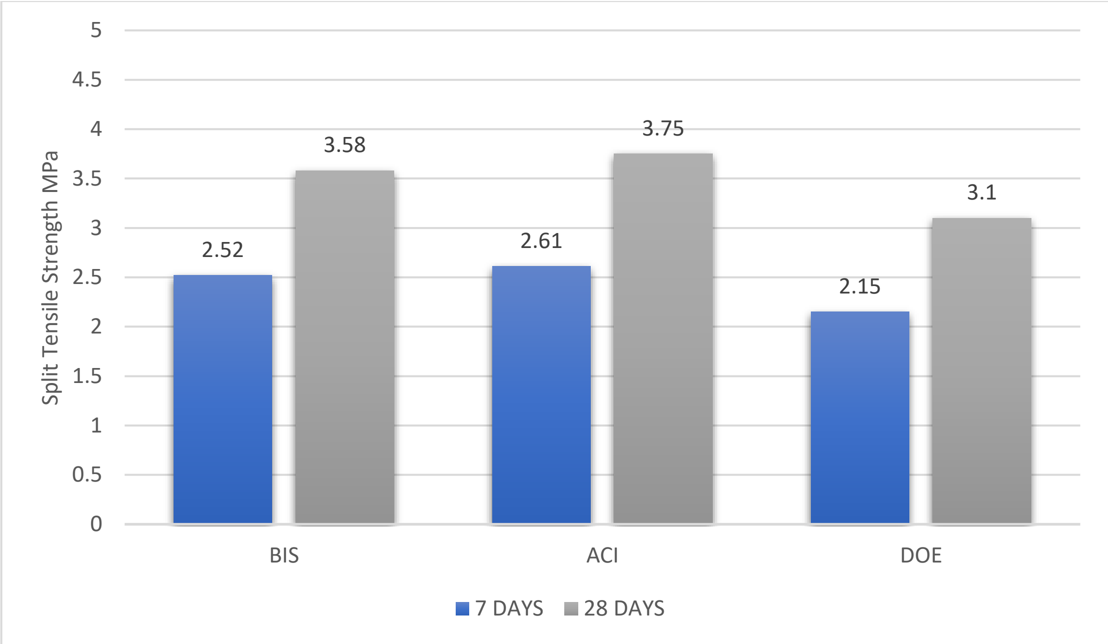

Fig. 9.3 Tensile Strength (vs) Curing Period of M30

According to experimental research, the high proportion of fine aggregate material in the M30 grade of concrete allows the ACI method to have a stronger split tensile strength than the BIS and DOE methods. Although the water-cement ratio is nearly identical between BIS and ACI, BIS has a higher cement content than DOE and ACI. In DOE, compared to the other two processes, the fine aggregate concentration is higher, but the water-cement ratio is higher, which over time has a negative impact on the strength of concrete.

Table No. 9.4: -Split Tensile Strength of M35 Grade of concrete after 7 and 28 days of curing:

Method	Cement Content in kg	Water- Cement Ratio	Split Tensile Strength at 7 days in N/mm^2	Split Tensile Strength at 28 days in N/mm^2
BIS	372.42	0.45	3.09	3.94
ACI	463	0.40	2.93	4.07
DOE	450	0.5	2.41	3.44

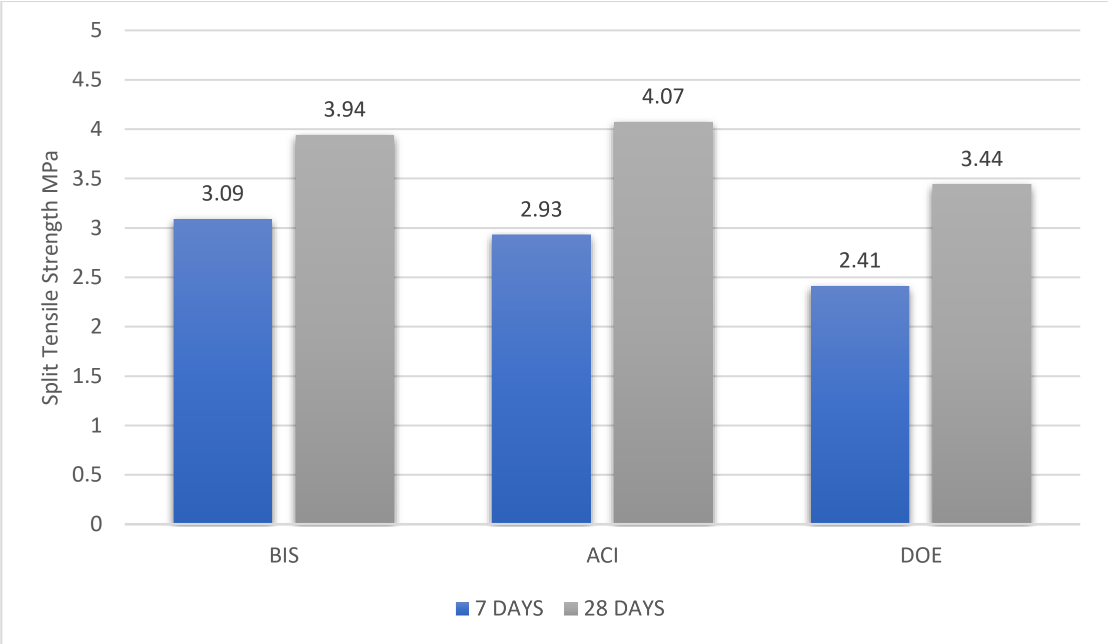

Fig. 9.4 Tensile Strength (vs) Curing Period of M35

The results show that ACI has the best tensile strength of M35 grade concrete among BIS, ACI, and DOE because ACI has a lower water-cement ratio than BIS and DOE, as water-cement ratio is inversely related to concrete strength. There are more coarse aggregates and fewer fine aggregates in BIS. As a result, the strength of the coarse aggregates is decreased since the blank spaces between them are not entirely filled. In comparison to the other two processes, DOE has a larger cement content and a higher water-to-cement ratio as compared to other two methods, which causes the strength of the concrete to deteriorate over time.

AGGREGATES

Fine Aggregates: -

Locally obtained sand that met Indian Standard Specifications IS: 383-1970 was used for the project. The outcomes are displayed in Table 12 below. Zone III of the grading system contained the fine aggregates.

Table No. 9.5: - Sieve Analysis of Fine Aggregates.

Weight of sample taken =1000 gm					
S. No	**IS-Sieve (mm)**	**Mass Retained (gm)**	**Cumulative mas Retained**	**Cumulative % mass Retained**	**Cumulative % passing through**
1	4.75	1	1	0.1	99.9
2	2.36	20	21	2.1	97.7
3	1.18	78	99	9.9	90.1
5	600µ	154	253	25.3	74.7
6	300µ	266	519	51.9	48.1
7	150 µ	423	942	94.2	5.8
8	Below150µ	58	1000	100	0
	Total	1000		**Σ283.5**	

Fineness Modulus of Fine Aggregates = 283.5÷100
= 2.835

Table No. 9.5(A): Physical Properties of Fine Aggregates

Parameters	Value
Type	Natural river sand
Specific Gravity	2.54
Water Absorption	1%
Fineness Modulus	2.83 (Zone III)
Unit Weight	1700kg/m^3
Surface Moisture	2.3%

Coarse Aggregates: -

In this investigation, coarse aggregate with a maximum size of 20mm that was readily available locally was used. According to IS: 383-1970, the aggregates underwent testing. The outcomes are displayed in Table 13 below.

Table No. 9.6: Sieve Analysis of Coarse Aggregates(20mm).

Weight of sample taken =2000 gm					
S. No	**IS-Sieve (mm)**	**Mass Retained (gm)**	**Cumulative mass retained**	**Cumulative %age mass Retained**	**Cumulative % mass passing through**
1	40	0	0	0	100
2	20	143	143	7.15	92.85
3	10	1730	1873	93.65	6.35
5	4.74	125	1998	99.9	0.1
6	2.36	0	1998	99.9	0.1
7	1.18	0	1998	99.9	0.1
8	600µ	0	1998	99.9	0.1
9	300µ	0	1998	99.9	0.1
10	150 µ	0	1998	99.9	0.1
11	Below150µ	2	2000	100	0
	Total			**Σ800.2**	

Fineness Modulus of Coarse Aggregate = 800.2÷100
= 8.002

Table No. 9.6(A): Physical Properties of Coarse Aggregates.

Parameters	Value
Type	Crushed
Color	Grey

Shape	Angular
Nominal Size	20 mm
Specific Gravity	2.62
Total Water Absorption	0.89
Fineness Modulus	8.00

Table No. 9.7: Workability, Slump Test of Concrete with 20mm MSA

Method	Slump Value (mm)
BIS	25
ACI	26
DOE	21

The Slump value vs mix design techniques was displayed with aggregates no larger than 20mm. Although the slump values for ACI and BIS are nearly identical, but the DOE technique has the lowest value among the 3 methods, which leads to very low degree of workability level and can be utilized as vibrated concrete for pavement-roads.

Table No. 9.8: Compaction Factor Test Results

Method	Compacting Factor
BIS	0.82
ACI	0.83
DOE	0.77

The compacting factor vs mix design techniques in the above table displays the outcomes of compaction factor test. Which shows that ACI method has a larger compacting factor than BIS and DOE, which are considered to have poor levels of workability and are frequently utilized in mass concreting.

Table No. 9.9: Cost Implication of ACI, DOE and BIS mix design proportion methods

Cost Implication for 1m^3 of Concrete					
Grade of Concrete	**Method**	**Materials**	**Kg**	**Rate/kg**	**Amount (Rs)**
M30	ACI	Cement	394	7.03	2769.8
		F.A	780	7.70	6006
		C.A	992	9	8928
					∑17,703.8
	BIS	Cement	418	7.03	2938.5
		F.A	662	7.70	5097.4
		C.A	1162	9	10458
					∑18,493.9

	DOE	Cement F.A C.A	390 726 1089	7.03 7.70 9	2741.7 5590.2 9801
					∑18,132.9
M35	ACI	Cement F.A CA	463 763 992	7.03 7.70 9	3254.8 5875 8928
					∑18,057.8
	BIS	Cement F.A C.A	373 758 1101	7.03 7.70 9	2622.2 5836.6 9909
					∑18,367.8
	DOE	Cement F.A C.A	450 776 950	7.03 7.70 9	3163.5 5975.2 8550
					∑17,661.7

NOTE: These estimates are based on data provided by the Public Works Department of the Government of Jammu and Kashmir (R&B), according to the schedule of rates for engineering departments (SOR-2022).

In table 16, prices for various mix designs are shown. The BIS approach, which used the maximum cement content in the concrete mix for the production of M30 and M35 grades of concrete, was shown to be the most expensive mix design method. For concrete of the M30 grade, the ACI approach was less expensive than the BIS and DOE methods. Compared to the BIS and DOE methods, the ACI method turned out to be the most affordable one. In the end, for concrete of the M35 grade, the ACI approach was marginally more expensive than the DOE method. The target mean strength for the grades M30 and M35 was not achieved by the DOE approach. However, it may still be used for proportioning concrete mix only if the required concrete strength is adequate for the structures to be built. In order to ensure the quality, durability and integrity of the concrete construction, concrete technology professionals always choose concrete that not only meets the needed strength but also the goal mean strength. It has been shown to be the most effective and cost-effective method of proportioning concrete when compared to the other two proportioning design approaches, this places the ACI method of mix design at the top of the food chain.

CHAPTER 10
CONCLUSION

- The results showed that the DOE approach did not achieve the target mean strength for the grades of the produced concrete, although the ACI and BIS methods did. The DOE methods failure to achieve the desired mean strength could be attributable to a number of factors, including its use of more water, a greater water-cement ratio, less cement content, a larger ratio of aggregate to cement ratio, and more air voids and porosity than the other two methods. Compared to the other two methods, the DOE method was inefficient.

- Due to the high cement percentage used in the concrete mixture, the cost implications for the various mix proportions revealed that the BIS approach was the most expensive mix design proportioning method. However, the ACI approach met the desired mean strengths for the grade of M30 and M35 of concrete, making it the most cost-effective method of proportioning the concrete when compared to the other two methods. In conclusion, compared to the other two methods, the ACI method was the most effective method to proportion concrete.
- The BIS approach is quite similar to the ACI approach on the basis of achieving target mean strengths. Only regular and standard grades of concrete as well as concrete in light and heavy weights are covered by this rule. The provisions of IS 456:2000 is applicable for durability requirements under all exposure scenarios.
- For the design of standard concrete, heavy concrete, and mass concrete mixes, with 28-day cylinder compressive strengths of 45 MPa and slump ranges of 25-100mm, the ACI method of mix design and mix proportioning is suitable.
- The fineness modulus of the sand and the coarse aggregate content are calculated using ACI method using the dry robbed coarse aggregate bulk density. Additionally, this approach provides separate tables for air-entrained concrete, sand and water content for aggregate sizes up to 150mm.
  ACI method needs a little more water than BIS method does. This results in ACI mixtures that are more cohesive and therefore more workable. The nominal maximum sizes of the aggregates and the necessary slump value are used to calculate the water content in BIS mixture. The water concentration in ACI mixes is determined by the nominal maximum aggregate size, air entrainment, and slump range.
- BIS mixes use more cement than other mixes, which may be because American cements are much finer than Indian cements. BIS technique is not cost-effective when using greater cement contents.
- With rising strength, the content of fine aggregates continues to decline. But compared to BIS, ACI technique employs more fine particles. This results in an ACI concrete mix that is denser than BIS and DOE concrete mixes, which increases strength.
- Because less water is used in the cement mix and there is a higher proportion of fine aggregate in ACI and BIS concrete than in DOE, the strength of the concrete is higher in these two methods than in DOE.
- Only if the desired concrete strength is adequate for the structures to be built, the DOE approach be used for proportioning concrete mixes. In comparison to the BIS and ACI methods of mix design, this method provides the least value for the M35 grade of concrete.
  The coarse aggregate content in ACI for M30 and M35 is nearly same, however it varies for BIS and DOE methods of concrete mix design; the higher the coarse aggregate content, the weaker the concrete will be. Because there are greater spaces between the particles, ACI meets this requirement by utilizing a higher proportion of fine aggregates in the mix, which produces a dense mixture and eventually increases the strength of concrete.

CHAPTER 11
FUTURE SCOPE

For a concrete mix to meet the desired strength, workability, and durability requirements for a particular application, the proportions of various constituent materials, such as cement, water, aggregates, and admixture must be determined. Mix design is an important process in the field of concrete technology. Different mix design methodologies have been evolved over time, and each methodology has strengths and weaknesses of its own.

With the development of technology and the rising need for sustainable and HPC, the breadth of mix design by various ways is anticipated to grow and change in the future. The following are some potential advances in mix design techniques in the future:

- **Incorporation of Nanotechnology: -**
  To improve the mechanical, chemical, and thermal qualities of concrete, nanoparticles like silica fume and fly ash can be added to the mix. In order to provide high performance and sustainable concrete, mix design techniques may eventually include the usage of nanoparticles.
- **Emphasis on Sustainability: -**
  In order to produce concrete with a lower environmental impact and greater durability, mix design methods will need to maximize the use of sustainable materials like recycled aggregates, alternative cementitious materials, and bio-based admixtures. As the demand for the sustainable construction practices rises, mix design methods are likely to incorporate these materials.
- **Standardization of mix design: -**
  Concrete performance and quality can vary due to the absence of standardization in mix design techniques. To guarantee consistent and dependable concrete quality, there may be a push for standardization of mix design techniques in the future. This can entail creating fresh testing procedures and mix design guidelines.
- **Self-Healing concrete: -**
  Concrete that can self-heal cracks has been the focus of research. Future mix designs could include self-healing substances or bacteria that can react with moisture to seal cracks, extending the lifespan of concrete structures and lowering maintenance expenses.
- **Resilient Infrastructure Materials: -**
  Mix designs may concentrate on producing and building materials that are more resilient to endure severe weather, seismic activity, and other testing conditions.

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