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Influence of METAKAOLIN and ROBO Sand on the Strength and Durability of Concrete

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ABSTRACT:

For concrete to come together, you need four things: water, fine aggregate, coarse aggregate, and cement. However, contemporary researchers are eager to improve concrete mixes for environmental sustainability by using a range of substitute chemicals and products from polluting industries. Metakaolin was used as a partial cement replacement in this research, with Robo-sand being the optimum substitute for river sand, in order to evaluate the compressive strength, split tensile strength, and flexural strength. In the production of concrete, river sand is an essential ingredient. River sand is rising in price and availability. Finding suitable substitutes for river sand is, therefore, the objective. You may utilize crusher dust, which is also called Robo-sand, instead of river sand. One reason robo-sand is finding usage in the building industry is its resemblance to river sand. You may use Robo-sand in place of some of the fine aggregate and metakaolin in place of some of the cement. The experimental examination in this project focused on the M-35 concrete grade. In this concrete mix, the ratio of Robo sand to sand remained constant, but the ratio of Metakaolin to cement varied from 5% to 20%. By changing the percentage replacement of material until the strength is equal to that of traditional concrete, the appropriate proportion of cement or fine aggregate may be established. Due to the scarcity of fine aggregate and the exorbitant price of cement, a partial material substitution has become necessary. Compressive, tensile, and flexural strengths are all evaluated here. We want to achieve optimal results in this study by using metakaolin as a cement substitute. It is believed that the ideal value for metakaolin is 15%. We may now try replacing part of the fine aggregate with Robo sand by progressively increasing the quantity, knowing how to keep the metakaolin proportion constant. Concrete cubes, cylinders, and beams are all tested for compressive, tensile, and flexure strengths. Beams, cubes, and cylinders are assessed after 7, 28, and 90 days of cure.

Keywords: Robo Sand, Metakaolin, Compressive strength, Split tensile strength, Flexural strength.

INTRODUCTION

General:

People who work in the construction industry will likely tell you that concrete is their go-to material. The aggregates of an artificial material are bonded together when cement and water are mixed. Because of technological advancements, concrete and mortars may now be tailored to suit a wide variety of applications by altering their strength, workability, durability, and other features. Cement, fine and coarse aggregate, water, chemical and mineral admixtures, and specific proportions of each are required to accomplish this.

Portland cement is becoming more necessary in developing countries. Making Portland cement is one of the leading causes of CO_2 in the air. As a partial cement replacement, metakaolin enhances the strength of concrete by combining with Ca(OH)2, a by-product of cement's hydration process, to create more C-S-H gel. Metakaolin is a byproduct of the heating process of kaolin clay. Due to the activation-induced loss of water in its composition, a significant structural rearrangement will happen. For adequate thermal activation, the suggested temperature range is 600 to 750ºC. The primary arguments in favor of incorporating clay-based pozzolans into concrete and mortar have focused on the materials' increased accessibility and enhanced durability. The calcining temperature and the kind of clay also have a role. Increasing your strength is another attainable objective, particularly at the peak of your healing process. Early strength growth is caused by the filler effect and the acceleration of cement hydration.

MATERIALS AND METHODOLOGY

Metakaolin:

The metakaolin with a specific gravity of 2.5 is supplied by Astro Chemicals of Chennai and is used as an alternative to cement. Metakaolin is a chemical phase that is formed when kaolinite is heated. The water is removed from kaolinite by heating it to a temperature between 400 and 500 degrees Celsius, which then forms metakaolin, an amorphous aluminosilicate. Al2O3:2SiO2. 2H2O is the chemical formula for kaolinite. Metakaolin, being a pozzolanic chemical, is white in color. The Metakaolin's reactivity may be altered by grinding it to a finer consistency. Metakaolin has many distinguishing features, including the ones listed below:

Chemical Composition of Metakaolin

chemicals	Percentage
SiO_2	62.62
Al_2O_3	28.63
Fe_2O	1.07
MgO	0.15
CaO	0.06
Na_2O	1.57
K_2O	3.46
TiO_2	0.36
LOI	2.00

Kaolinite Sources:

The quality and reactivity of metakaolin are greatly affected by the qualities of the raw material. For the production of metakaolin, a variety of primary and secondary sources containing kaolinite may be used:

- Very pure kaolin deposits,
- Less pure kaolinite deposits, tropical soils
- Where kaolinite and oil sand tailings are present
- Effluent from paper sludge operations are also potential sources of kaolinite.

Forming Metakaolin:

There are no interlayer cations or water molecules in the T-O clay mineral kaolinite. How the structural layers are stacked determines the dihydroxylation temperature. The dehydroxylation temperature range for disordered kaolinite is 530–570 °C, while for ordered kaolinite it is 570–630 °C. The pozzolanic activity of disordered, dehydroxylated kaolinite is greater than that of orderly, ordered kaolinite. The removal of the chemically linked hydroxyl ions during the dihydroxylation of kaolin to metakaolin is a very energy-intensive process, making it an endothermic reaction. At temperatures higher than those required for dihydroxylation, kaolinite undergoes a transformation into metakaolin, an amorphous material with a complicated structure that, thanks to layer stacking, maintains some long-range order.

Tetrahedral and pentahedral coordination forms in the octahedral layer's aluminum. To make a pozzolan, a supplemental cementitious substance, it is necessary to roast the ingredients until they are almost completely dihydroxylated, but not burned. Overheating may lead to sintering, which forms a dead, charred, nonreactive state; in contrast, this results in an amorphous, highly pozzolanic state.

Refractory, containing mullite and a defect Al-Si spinel. Reported optimum activation temperatures vary between 550 and 850 °C for varying durations, however the range 650-750°C is most commonly quoted. In comparison with other clay minerals kaolinite shows a broad temperature interval between dihydroxylation and recrystallization, much favoring the formation of metakaolin and the use of thermally activated kaolin clays as pozzolans. Also, because the octahedral layer is directly exposed to the interlayer (in comparison to for instance T-O-T clay minerals such as smectites), structural disorder is attained more easily upon heating.

Advantages of Metakaolin:

- Enhanced tensile and compressive strengths
- Less permeability, including permeability to chlorides
- Efflorescence is less likely to occur, which is when atmospheric carbon dioxide and water-borne calcium reach the surface, where the two react to form calcium carbonate and a white residue.
- A higher level of resistance to chemical attacks
- A longer lifespan - Less impact of alkali-silica reactivity (ASR)
- Improvements to concrete's workability and finishing
- The fact that concrete becomes denser via "particle packing" causes a decrease in shrinkage.

Use of Metakaolin:

- Concrete that is both lightweight and very strong and efficient.
- Two types of concrete: precast and poured-mold.
- ferrocement and fiber cement items
- Reinforced concrete using glass fibers
- Stucco and mortar

Robo Sand:

Sand created at stone quarries is called robo sand. It may be used in place of river sand in building projects. The crushing machine at "Donabandaquary" is where Robo Sand is sourced from. At the time of collection, it was dry and had a sieve size of 4.75 mm. The particles have a cubical form. The specific gravity and fineness modulus of ROBO Sand are 2.68 and 3.34, respectively. The grading is in line with Zone II.

As an alternative to river sand, robo sand works just as well. Manufactured in the same manner as for more than a million years ago by nature. It has become an indispensable material for quality-conscious builders due to its many benefits over river sand. In order to make robo sand, cutting-edge equipment and machinery equipped with first-rate technology use a Rock-Hit-Rock crushing approach.

Manufacture of Robo sand:

Manufacture of Robo sand is done in three steps

- Creating Stone and Mines
- Grinding
- Crushing by Stages II and III
- Screening
- Washing
- Grading
- Drying
- Storage and transportation

How Robo sand superior to river sand:

- the form of the particles,
- increased compressive strength,
- longer lifespan,
- a plethora of other benefits
- eliminates problems with building faults
- High-quality and readily available

Advantages of Robo sand:

- Save a ton of money
- Everything is pure and undamaged.
- Screening is not conducted to ensure consistent graduating.
- Eco-friendly green sand

RESULTS AND DISCUSSION

Test and Results:

In order to ascertain the design mix qualities of concrete, a battery of laboratory experiments was conducted. As part of the strength criteria, the following parameters are measured:

- Compressive Strength
- Split Tensile Strength
- Flexural Strength

Compressive Test:

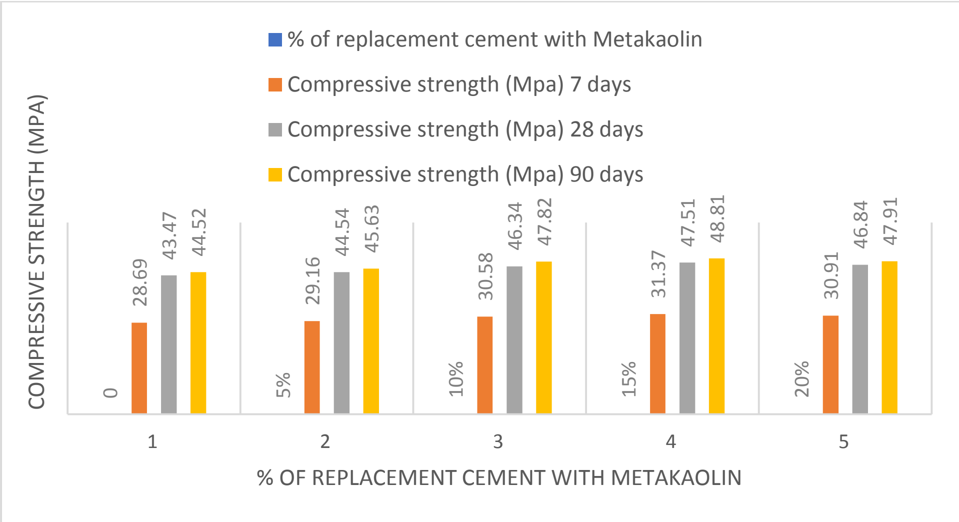
I.Findings from the Compressive Strength Test (Metakaolin as a Cement Substitute)Applying a crushing force to the surface of a cube yields its compressive strength. Crushing strength is another name for it. The compressive strength of concrete is determined by casting cubes with dimensions of 150 mm x 150 mm x 150 mm. This section presents the findings of the compressive strength tests conducted after7,28, and 90 days.

Metakaolin optimum:

We determine the mix proportions by substituting several amounts of Metakaolin for OPC, ranging from 0% to 20%..

Compressive Strength Test Results (Replacement of cement with metakaolin)

S.No.	% of Metakaolin	Compressive strength (Mpa)		
		7 days	28 days	90 days
1.	0%(Conventional concrete)	27.71	42.57	44.52
2.	5%	29.16	44.54	45.63
3.	10%	30.58	46.34	47.82
4.	15%	31.37	47.51	48.81
5.	20%	30.91	46.84	47.91

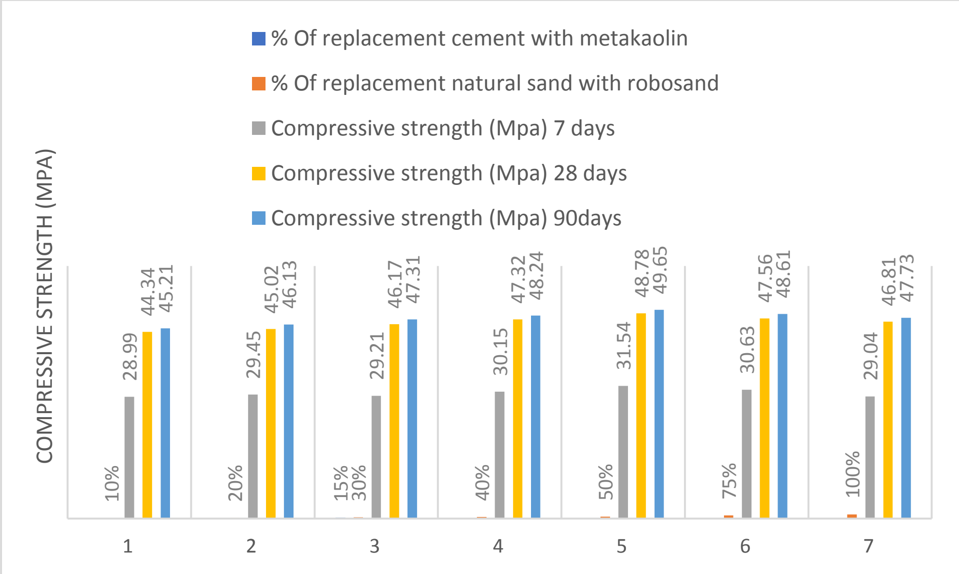


Metakaolin Cube Compressive Strength after7,28, and 90 Days

The optimal percentage of Metakaolin replacement, according to the experiments, was 15%. The properties of cement are maintained when metakaolin is used as a 15% alternative.

Results from the Compressive Strength Test (Using Robo sand and metakaolin in lieu of cement)
Compressive Strength Test Results (Replacement of cement with metakaolin and river sand with Robo sand)

S.No.	% Of metakaolin	% Of Robo sand	Compressive strength (Mpa)		
			7 days	28 days	90days
1.	15%	10%	29.89	43.74	45.21
2.		20%	29.45	45.02	46.13
3.		30%	29.21	46.17	47.31
4.		40%	30.15	47.32	48.24
5.		50%	31.54	48.78	49.65
6.		75%	30.63	47.56	48.61
7.		100%	29.04	46.81	47.73



Compressive strength Of Metakaolin & Robo sand for 7,28 & 90 days

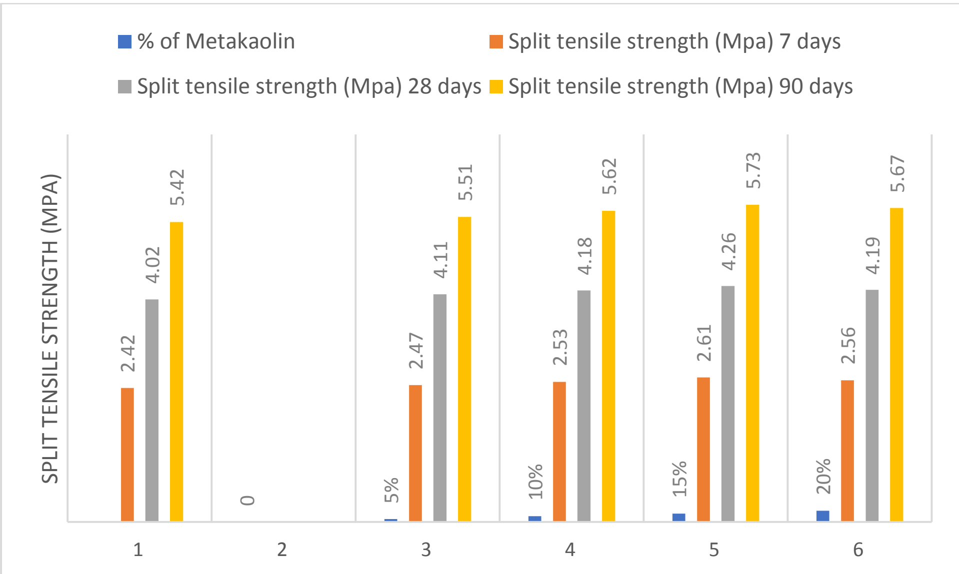
Split Tensile Test:

I. Split Tensile Strength Test Results (Replacement of cement with metakaolin)

On the compression testing equipment, cylinders with a diameter of 150 mm and a height of 300 mm were subjected to split tensile. In order to determine the split tensile strength, the failure load was documented.

S.NO	% of Metakaolin	Split tensile strength (Mpa)		
		7 days	28 days	90 days
1	0% (nominal mix)	2.42	4.02	5.42
2	5%	2.47	4.11	5.51
3	10%	2.53	4.18	5.62
4	15%	2.61	4.26	5.73
5	20%	2.56	4.19	5.67

Results from a Split Tensile Strength Test (Replacement of cement with metakaolin)



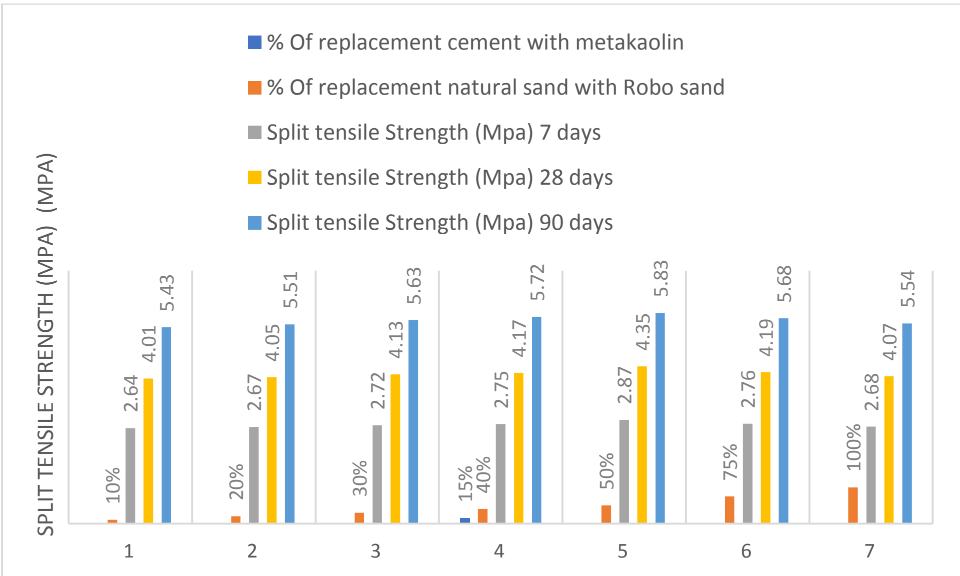
The metakaolin split tensile strength after 7, 28, and 90 days

This graph shows that the 15% Metakaolin mix has the highest split tensile strength rating when compared to the other blends.

II. Split tensile strength Test Results (Replacement of cement with metakaolin and river sand with Robo sand)

Results from a Split Tensile Strength Test (using Robo sand and metakaolin)

S.No.	% Of replacement cement with metakaolin	% Of replacement natural sand with Robo sand	Split tensile Strength (Mpa)		
			7 days	28 days	90 days
1.	15%	10%	2.64	4.01	5.43
2.		20%	2.67	4.05	5.51
3.		30%	2.72	4.13	5.63
4.		40%	2.75	4.17	5.72
5.		50%	2.87	4.35	5.83
6.		75%	2.76	4.19	5.68
7.		100%	2.68	4.07	5.54



The 7, 28, and 90-day split tensile strengths of Robo sand and Metakaolin

Flexural Test:

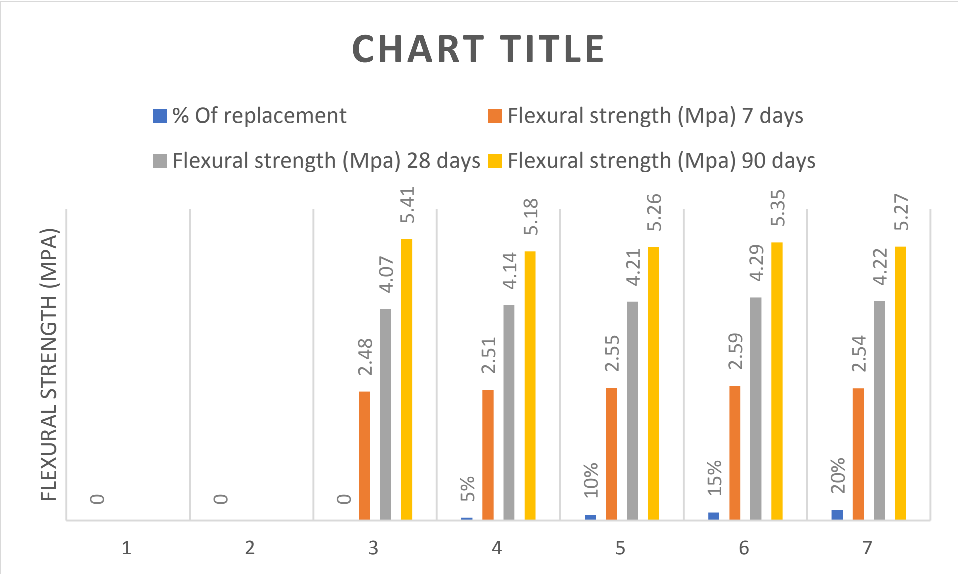
I. Results from a Flexural Strength Test (Replacement of cement with metakaolin)

Beams were subjected to a flexural test by use of a universal test stand in order to determine their flexural strength. Casting a 100 mm x 100 mm x 500 mm beam is the standard method for determining concrete's flexural strength. The flexural strength test results for both the 7-day, 28-day and 90-days testing periods are shown below.

Results from a Flexural Strength Test (Replacement of cement with metakaolin)

S.No.	% Of replacement cement with metakaolin	Flexural strength (Mpa)		
		7 days	28 days	90 days
1.	(nominal mix)	2.48	4.07	5.41
2.	5%	2.51	4.14	5.18
3.	10%	2.55	4.21	5.26
4.	15%	2.59	4.29	5.35
5.	20%	2.54	4.22	5.27

Flexural strength Of Metakaolin for 7,28& 90 days

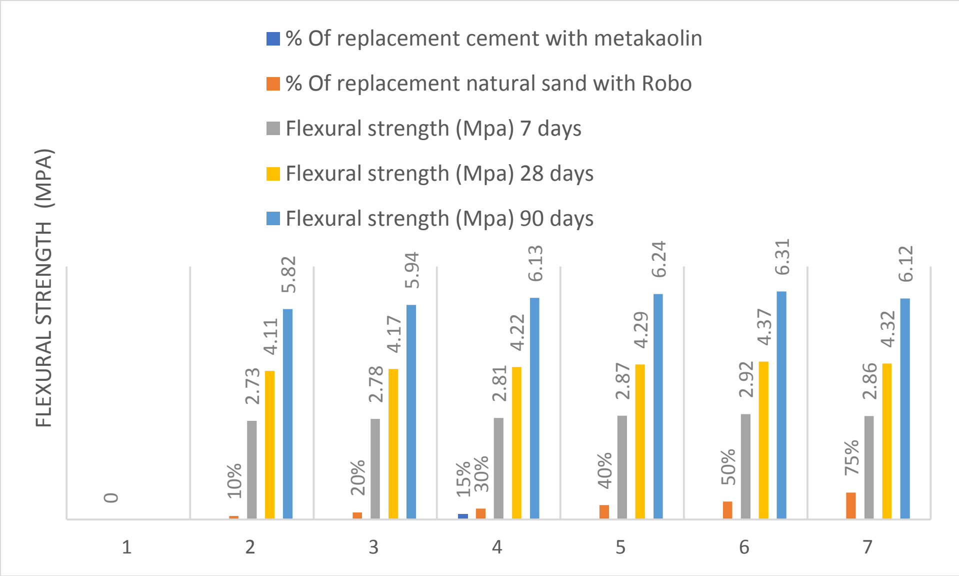


Flexural strength Of Metakaolin & Robo sand for 7,28&90 day

II. Results from a Flexural Strength Test (Replacement of cement with metakaolin and river sand with Robo sand)

Data on flexural strength tests (Replacement of cement with metakaolin and river sand with Robo sand)

S.No.	% Of replacement cement with metakaolin	% Of replacement natural sand with Robo sand	Flexural strength (Mpa)		
			7 days	28 days	90 days
1.	15%	10%	2.73	4.11	5.82
2.		20%	2.78	4.17	5.94
3.		30%	2.81	4.22	6.13
4.		40%	2.87	4.29	6.24
5.		50%	2.92	4.37	6.31
6.		75%	2.86	4.32	6.12
7.		100%	2.80	4.27	5.91



Comparing the 7, 28, and 90-day flexural strengths of Robo sand and Metakaolin

RESULTS AND DISCUSSION

Conclusions

- The compressive strength (49.65 Mpa), flexural strength (6.31 Mpa), and split tensile strength (5.83 Mpa) performance are all best attained by the concrete mixture that contains 15% metakaolin, regardless of the age..
- Metakaolin improves the workability of newly mixed concrete when used in part as a cement substitute; so, super plasticizers are not much needed..
- Concrete with 15% Metakaolin and 50% Robo consistently exhibits the best performance throughout all ages in terms of compressive strength (49.65Mpa), flexural strength (6.31Mpa), and split tensile strength (5.83Mpa)..
- Metakaolin and Robo sand concrete are acid-sensitive, hence the resulting values are marginally lower.
- When it comes to durability, H_2SO_4 loses more strength than HCL.
- In comparison to concrete made using river sand, Robo sand concrete has a somewhat better compressive strength (7% to 11%).

Scope for Further Investigations:

- Several experiments may be performed by substituting different admixtures for cement, fine aggregate, and coarse aggregate.
- Additionally, other materials, both natural and man-made, such fly ash, silica fume, GGBS, lime stone dust, and pozzolans, might be evaluated. Additionally, on-site testing might benefit from nondestructive tests.
- The water-to-solids ratio may be decreased by adding a variety of super plasticizers to the mixture.
- Water permeability, chloride ion penetration resistance, corrosion of steel reinforcement, and other tests pertaining to durability characteristics may also be conducted.

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