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Characteristics Properties and Microstructure Analysis of Concrete by Replacing Natural Sand by M-Sand, Flyash

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Abstract: A good quality concrete is produced by careful mixing of cement, sand, coarse aggregates, water and admixtures in proper proportions so as to obtain an optimum quality and economy. About 35% volume of concrete is comprised of sand. Nowadays, due to constant sand mining the natural sand is depleting at an alarming rate. Sand dragging from river beds has led to several environmental issues. This has led to a scarcity and significant increase in the cost of natural sand besides leading to scarcity of water because of degradation of water bodies and depletion of water bed.

In the present project work, an attempt will be made to study the various characteristic properties of concrete by replacing Natural Sand with Manufactured Sand, Flyash. Initially, concrete mix design is carried out for M-20 mix after conducting the various tests on natural sand such as specific gravity, fineness modulus, silt content, bulk density etc. At the same time, tests are carried out on cement, coarse aggregates and chemical admixtures used for the mix design. Later, the natural sand in concrete is replaced by manufactured sand and flyash in various percentages such as 0%, 20%, 40%, 60%, 80% and 100%. The effect of mixing proportions and water-cement ratio are studied in parallel. The workability characteristics of fresh concrete by slump cone test are noted for each percentage replacement and for various dosages of the chemical admixture.

For compressive strength, concrete cubes of size (150mm*150mm*150mm) are casted and for tensile strength, concrete cylinders of diameter 150mm and length 300mm are casted and for flexural strength, concrete beams of size (500mm*100mm*100mm) are casted. After 28 days of curing, the various properties of concrete are tested and the results are compared by using Energy Dispersive Spectroscopy (EDS) for microstructure of Concrete.

Keywords: M-sand, flyash, Cement, Concrete, Compressive strength, Flexural strength, Split tensile strength, Energy Dispersive Spectroscopy (EDS)

I. INTRODUCTION

A good quality concrete is produced by careful mixing of cement, sand, coarse aggregates, water and admixtures in proper proportions so as to obtain an optimum quality and economy. About 35% volume of concrete is comprised of sand. Nowadays, due to constant sand mining the natural sand is depleting at an alarming rate. Sand dragging from river beds has led to several environmental issues. This has led to a scarcity and significant increase in the cost of natural sand besides leading to scarcity of water because of degradation of water bodies and depletion of water bed. [1]

Ordinary Portland cement is an always demand, expensive and extremely important material in the construction industry. Now in India, it is evaluated that the once-a-year consumption of cement concrete is to the tune of 400metric tones. This will clearly cause an equal demand on the materials like sand, groups and other materials needed to produce huge amount of cement concrete. This will naturally cause reduction of all the valuable things from nature linked in making cement concrete every year. Also the production of huge amounts of cement needs large amount of energy, cause emission of CO_2 and carry forward the connected problems. Therefore investigators are concentrating on finding out the additional cementations materials which can replace the cement partially or fully. In this direction, fly ash, blast furnace slag, silica fume, metakaoline and rice husk ash have shown a promising results to replace the cement partially. This way came into existence the blended cements. This way some of the industrial wastes are effectively used in the production of concrete. Fly ash is usually used as replacement of cement, as an admixture in concrete, and in manufacturing of cement. Whereas concrete comprising fly ash as partial replacement of cement poses problems of delayed early strength development, concrete containing fly ash as partial replacement of fine aggregate will have no delayed early strength development, but rather will increase its strength on long- term basis. Fly ash is a by-product of the combustion of pulverized coal in thermal power plants. [1, 2]

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Manufactured sand is a substitute of river sand for concrete construction. Manufactured sand is produced from hard granite stone by crushing. The crushed sand is of cubical shape with grounded edges, washed and graded to as a construction material. The size of manufactured sand is less than 4.75mm. Manufactured sand is alternative choice for river sand. Due to wild expanding construction industry, the demand for sand has increased very, causing shortage of good river sand in most part of the word. The use of manufactured sand has been increased, due to the reduction of good quality river sand for the use of construction. Another purpose for use of M-Sand is its accessibility and transportation cost. Another important ingredient is river sand. Sand is a naturally occurring granular material composed of finally divided rock and mineral particles. As the term is used by geologists, sand partials range in diameter from 0.0625 to 2 millimeter and individual practical in this range size is termed a sand grain. The next smaller size class in geology is silt: particles smaller than 0.0625 mm down to 0.004 mm in diameter. The next larger size class above sand is gravel, with particles ranging from 2mm up to 64mm. Sand is transported by wind and water and deposits in the form of beaches, dunes, sands spits, and bars and related features. [1, 2]

II. MATERIALS AND METHODOLOGY

A. Cement

Ordinary Portland Cement (O.P.C) confirming to IS: 12269-1987, ACC 43-Grade O.P.C procured from a single source was used, the properties of which tested in the laboratory, are as follows in Table 2.1:

Table 2.1: Physical properties Ordinary Portland cement

Particulars	Experimental results	As per standard
Initial setting time	30 Minutes	30 minutes minimum
Final setting time	180 Minutes	600 minutes maximum
Normal Consistency Test	35%	--
Specific Gravity Test	2.86	--

B. Fine Aggregates

As per IS 383-1970; the fine aggregate shall consist of naturally occurring gravel and sand or their combination. Good quality Zone-II fine aggregates were used. The various test results for the fine aggregates are as follows in Table 2.2:

Table 2.2: Physical properties of fine aggregate (IS: 2386 – 1963)

Properties	Experimental results	Permissible limit as per IS : 2386 – 1963
Specific gravity	2.65	Should be between the limit 2.6- 2.7
Fineness modulus	3.08	--
Water Absorption	6.06%	--

C. Coarse aggregates

As per IS 383-1970; the coarse aggregate shall consist of naturally occurring stones and gravel. They shall be hard, strong, dense, durable, clear and free from adherent coating. Also, it should be free from injurious amount of disintegrate pieces, alkali, vegetable matter and other harmful substance. In the present study the locally available aggregates from crusher, consisting of two fractions (i.e. 20mm size, 16mm size and 10mm size fractions) were used. Results of the preliminary test conducted are presented below in Table 2.3:

Table 2.3: Physical properties of coarse aggregate (IS: 2386 – 1963)

Properties	Experimental results	Permissible limit as per IS : 2386 – 1963
Specific gravity	2.7	Should be between the limit 2.6- 3.0

D. Manufactured sand

Table 2.4: Physical properties of manufacture sand

Properties	Experimental results
Specific gravity	2.55

E. Flyash

Table 2.5: Physical properties of flyash

Properties	Experimental results
Specific gravity	2.20

F. Methodology

As the current work involves the study of various properties such as workability, compressive strength and the flexural strength, parametric studies were carried out on the samples of concrete with replacement of Natural sand by M-sand, Fly ash. These parametric studies involved the use of the following three parameters:

1) Percentage of cement content
2) Water cement ratio
3) Mix proportion

G. Parameters used for the Study

1) *Percentage of Cement Content:* Cement passing through 850 micron IS sieve and does not contain any coarser material, dust. Main function of cement to act as a binding material and also helps in producing workability and uniformity in mixture.
2) *Water Cement Ratio:* The ratio of Water content to the total cementations content (i.e., W/C ratio) was constantly kept as 0.50.
3) *Mix Proportion:* The mixing proportions for preparing the concretes containing Flyash was determined based on the mix design carried out by varying the paste contents viz.0%,20%, 40%, 60%,80% and 100%and carrying out the calculations.

Table 2.6: Mix Design for M20 Grade

Sl. No	Material	Quantity Kg/m^3
1	Cement	394
2	Fine aggregate	632.70
3	Coarse aggregate	1032.3
4	Water	197
5	Water-cement Proportion	0.5

III. RESULTS AND DISCUSSIONS

Results of experiments on compressive strength, flexural strength, split tensile strength and workability for different Flyash replaced concretes have been presented below with those of control concrete. Visual observations during mixing and compaction of all the concrete suggested that the concrete were homogeneous; there was no segregation and bleeding and the mixes were compactable. The fresh state performance of the Flyash concrete was comparable with that of the control concrete.

A. Mechanical Properties

1) *Compressive Strength Test:* The compressive strength of M20 grade of concrete with varying percentages of Fly ash & Manufactured sand. The test was conduct on 150x150x150mm cube specimens after the concrete specimens were cured for 28 days. The test procedure was carried out in accordance with IS: 516-1959 specification. Compressive Strength = (Failure Load / Area) in N/mm^2

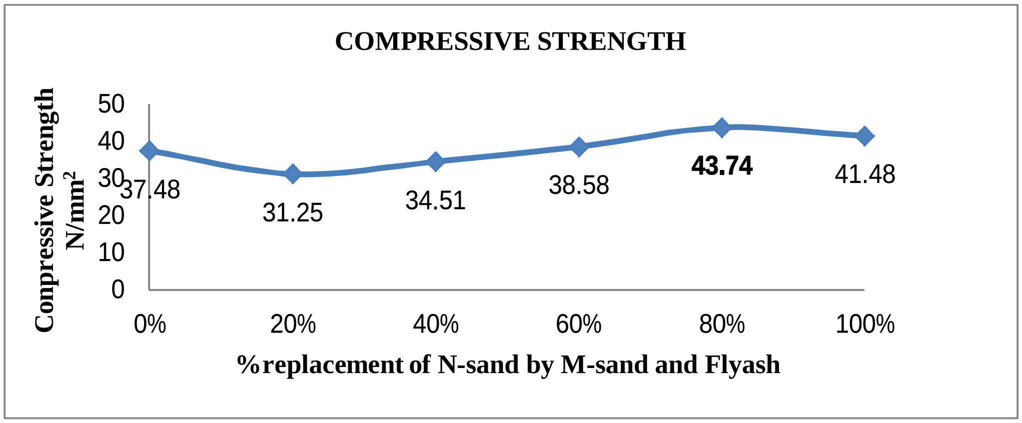

Figure 3.1: Variation of compressive strength of concrete produced by replacing Natural sand by M-sand and Flyash

2) *Split Tensile Strength;* It is defines as the strength of concrete in tension. Due to the brittle nature of concrete, it is very weak in tension and take less tensile load. Whenever tensile force is applied it develops cracks and leading to failure. The test Concrete specimens for split tensile test were of 150mm diameter and 300mm height. Procedure was carried out in accordance with IS: 5816-1999. Split tensile strength is (2*failure load) / (π* dia. of specimen*length of specimen)

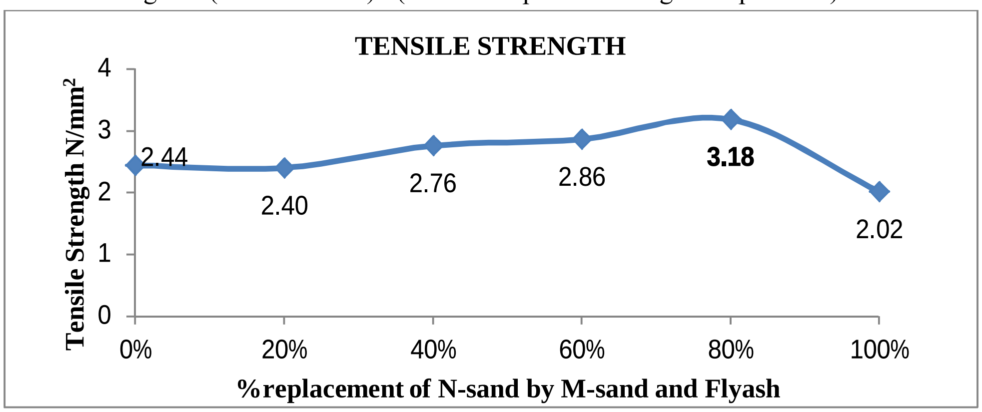

Figure 3.2: Variation of tensile strength of concrete produced by replacing Natural sand by M-sand and Flyash

3) *Flexural Strength Test*: Flexural strength of a concrete is a measure of its ability to resist bending. Flexural strength can be expressed in terms of 'modulus of rupture'. Concrete specimens for flexural strength were of dimensions 100x 100x500 mm. The specimen is subjected to bending, using two point loading unit it fails. The distance of the loading point is 133mm and the effective span (L) is 400mm. The test procedure was carried out in accordance with IS: 516-1959 specification.

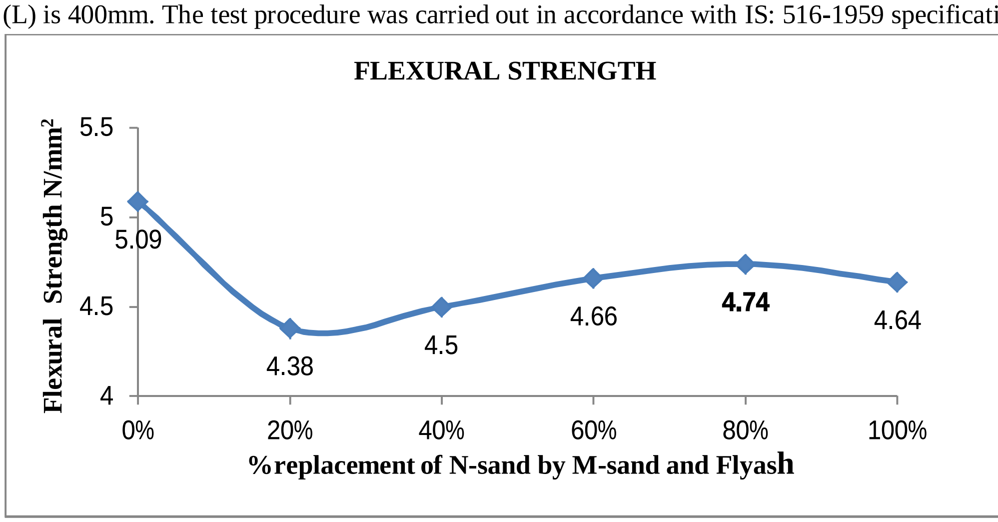

Figure 3.3: Variation of Flexural strength of concrete produced by replacing Natural sand by M-sand and Flyash

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4) *Workability Test Results*

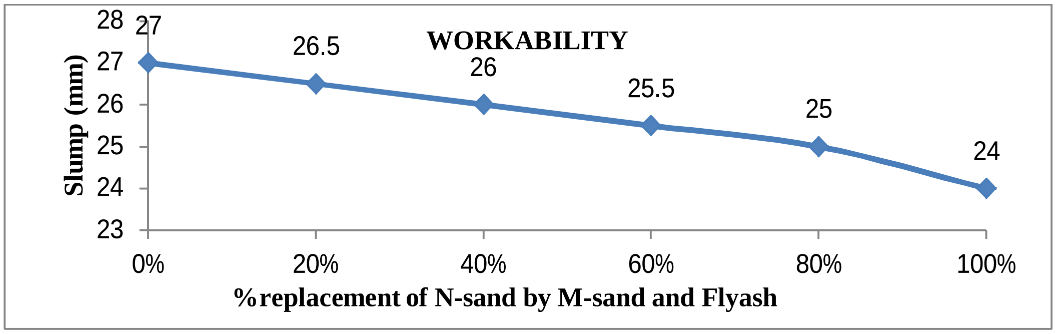

Figure 3.4: Variation of slump values with different percentage replacement of Natural sand by M-sand and Flyash

5) *Observations And Discussions On Test Results:* The workability test (slump values) results carried out with different percentage replacement of natural sand by M-sand, flyash. The variation of slump values at different replacement levels of natural sand by M-sand, flyash is shown in figure 3.4. From the slump test results obtained, it is observed that as percentage replacement of natural sand by M-sand, fly ash is increased there is decrease in slump value. The decrease in slump values is mainly attributed to the cohesive and stiffer mix resulted with higher flyash content along with M-sand and reduced water content.

The test results clearly indicate that there is significant improvement in compressive strength, split tensile strength, flexural strength of concrete in which natural sand by M-sand, flyash in various percentages. The test results also indicate that all the characteristics strengths of natural sand by M-sand, flyash concrete continued to increase with age.

The results of the compressive strength obtained for different percentage replacement of natural sand by M-sand, flyash is shown in figure 3.1 indicated that there is an enhancement in compressive strength for 0%, 20%, 40%, 60%, 80%, 100% replacement. The enhancement for compressive strength is mainly attributed to pozzolanic action of flyash, leading to the densification of the matrix, forming a denser calcium silicate hydrate (C-S-H) gel and reduced w/c ratio. Beyond 80% replacement level for natural sand replacing M-sand and flyash the lack of significant increase in strength of concrete mixtures is probably due to the non-availability of calcium hydroxide from hydration reaction. This may indicate that some flyash particles remain unreacted and act as filler material, without any contribution for the strength. The test results of splitting tensile strength of sand replaced fly ash concrete mixtures are shown in figure 3.2. This may be attributed to the pozzolanic reaction forming denser C-S-H gel and reduced w/b ratio. Beyond 80% M-sand and flyash content does not contribute to further hydration due to the non availability of calcium hydroxide.

Similar observations were made in case of flexural strength test also. The flexural strength of concrete mixtures with natural sand replacement by M-sand, flyash is shown in figure 3.3 continued to increase with age.

This is believed to be due to the improved interfacial bond between paste and aggregates as a result of the pozzolanic reaction of flyash with calcium hydroxide.

B. Microstructure Properties

Energy Dispersive Spectroscopy (EDS) Analysis:

To observe the microstructure of the concrete subjected to the environment condition, the EDS analysis was conducted to determine the existing compounds after reactions with external corrosive ions.

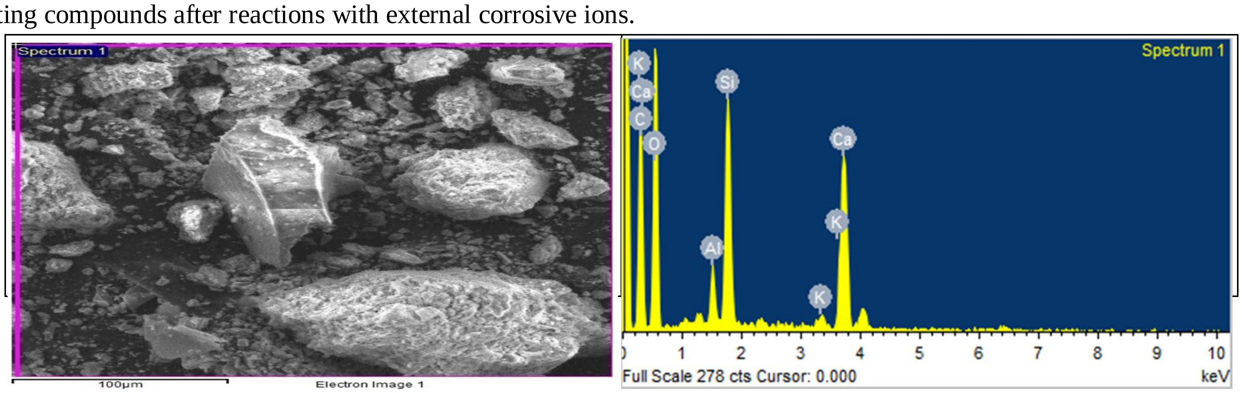

Figure 3.5: EDS analysis of Conventional concrete with no replacement of Natural sand by M-sand and Flyash

The image of conventional concrete(No replacement) sample presents large amounts of white blocky crystals with the fine granular crystals on the surface, as well as small bar-like particles and fine cracks, shown in figure 3.5. The EDS analysis identifies the existence of aluminum, silica, calcium and feldspar and wollastonite compounds.

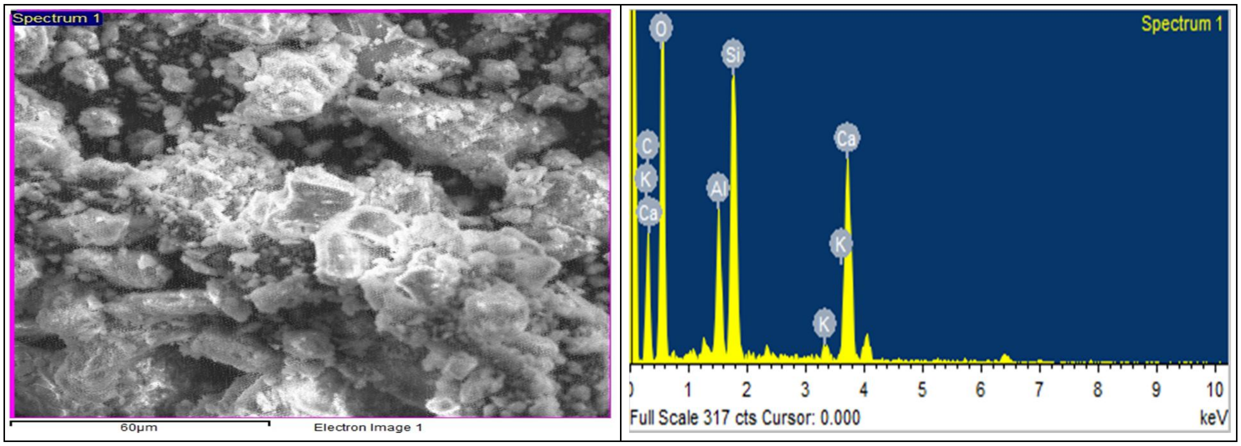

Figure 3.6: EDS analysis with 80% replacement of Natural sand by M-sand and Flyash

According to the EDS results, it is supposed that these white blocky crystals are gypsum and the fine granular crystals are thenardite, and the bar-like particles are ettringite. In the image of 80% replacement level for natural sand replacing M-sand and flyash for concrete sample, there are abundant white blocky crystals with the fine granular crystals on the surface, as well as the occurrence of fine cracks. The EDS analysis from figure 3.6, confirms that the white blocky crystals are gypsum and the fine granular crystals are thenardite. Low Al peak in the EDS image signifies the little amount of ettringite.

IV. CONCLUSIONS

A. Slump values are found to reduce with increase in percentage replacement of Natural sand by M-sand, flyash to achieve workable mix suitable dosage of superplasticizer is necessary.

B. There is significant improvement in compressive strength, split tensile strength, flexural strength ofconcrete when 20%, 40%, 60% and 80% of natural sand is replaced by M-sand and flyash.

C. Conventional concrete shows at 28 days compressive strength as 37.48 N/mm^2, split tensile strength of 2.44 N/mm^2 and flexural strength of 5.09 N/mm^2.

D. The 80 % replacement of natural sand by M-sand and flyash variation resulted in strength values above that of the design. However, the best results were achieved with 80 % replacement of Natural sand by M-sand and flyash. The partial replacement of Natural sand by M-sand and flyash can therefore make up to 80 %(40% M-sand +40% flyash).

E. Beyond 80% replacement level for Natural sand replacing M-sand and flyash the lack of significant increase in strength of concrete mixtures is probably due to the non-availability of calcium hydroxide from hydration reaction. This may indicate that some flyash particles remain unreacted and act as filler material, without any contribution for the strength.

F. The OPC concrete presents more complex pore internal surface, higher porosity and less micro-pore than the concrete incorporating flyash. In the cyclic sulfate environment, repeated hydration and dehydration of sulfates produce the expansive stress in pores, aggravating the demolishment of concrete structure.

G. The EDS analysis that sulfates react with the hardened cement paste in the concrete exposed to the sulfate environment. This produces various corrosive products, which is determined by the composition of the cementitious materials. These expansive products accumulate to cause the occurrence of cracks in the structure, leading to the destruction of concrete.

H. The EDS results showed that the non-reactive materials used as a replacement for Natural sand and cement could also give micro filler effect and nucleation site for hydration on Natural sand and cement.

I. Thus, the microstructural change in concrete is mainly due to surrounding conditions such as time, temperature, chemical degradation due to acid attack etc., the microstructure of concrete varies with respect to the proportion of concrete ingredients such as cement, aggregates, and water content.

J. Results of investigation reveal that it is feasible to replace natural sand by M-sand flyash to achieve strength, economy and to solve the problem of waste disposal.

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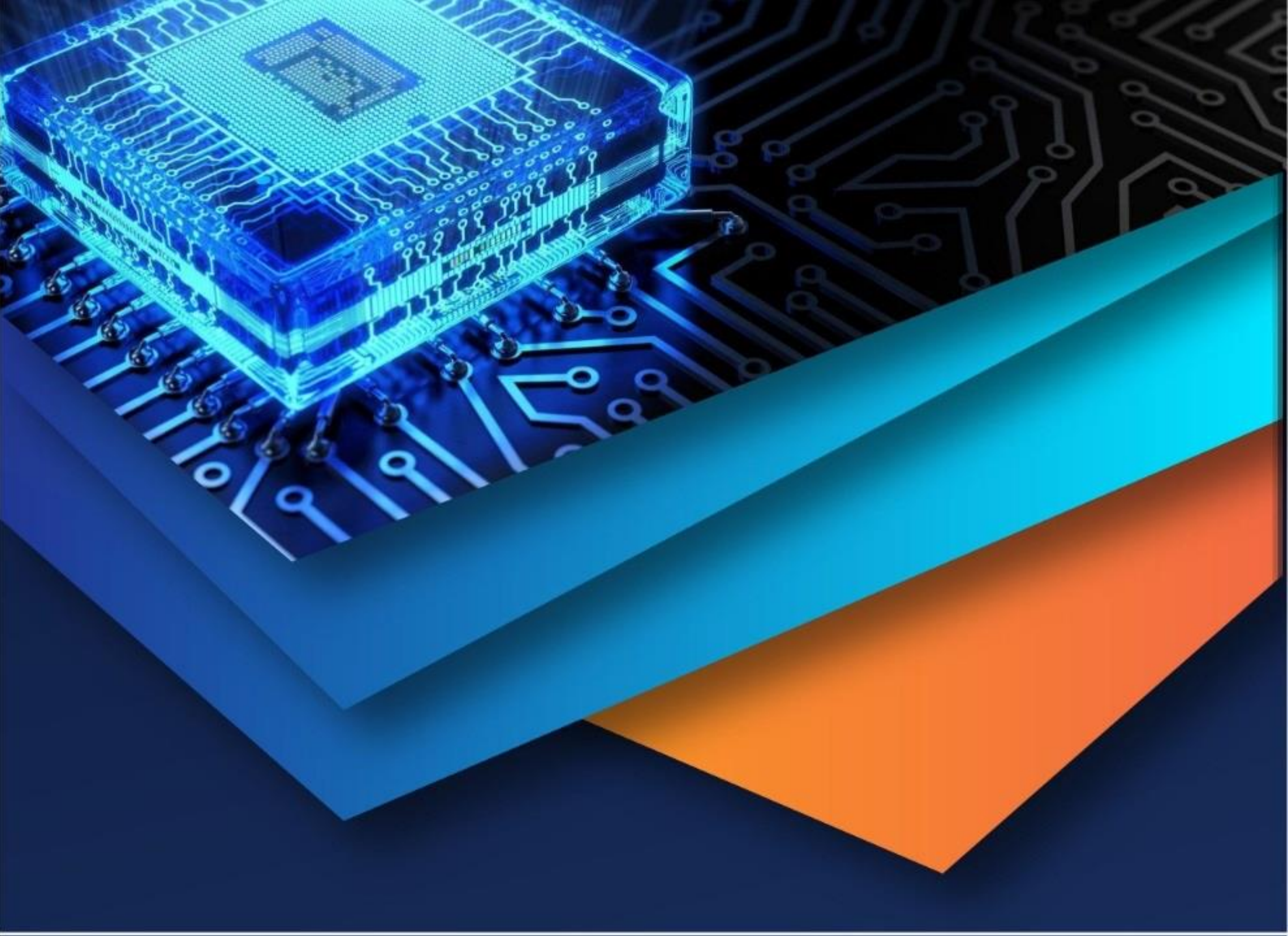
Photo Gallery

 **Concrete Cubes. Beams and Cylinder casted and ready for curing in curing tank**	 **Compressive Strength test (CTM equipment)**
 **Tensile Strength test (UTM equipment)**	 **Cracked formed in cylinder after applying load**



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