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CONCRETE STRENGTH, DURABILITY, AND STRUCTURAL PROPERTIES ARE AFFECTED BY THE ADDITION OF MANUFACTURED SAND AS FINE AGGREGATE

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ABSTRACT

It is commonly used in buildings, with an annual consumption of more than 10 billion metric tons. Concrete comprises between 65 per cent and 80 per cent aggregates responsible for its fresh and hardened properties. There are around 20-30% fine aggregates in the aggregate mix, which comprise about 25% to 40% of its volume. As a fine aggregate, sand is widely used in concrete manufacturing and processing. Riverbeds supply the vast majority of the earth's natural sand. As a result of both overuse and pollution from neighbouring factories, these natural resources are rapidly depleting. In the construction industry, river sand is often supplied locally and transported. It is mostly sand used for making concrete and concrete products. For several reasons, natural sand cannot be used directly in the concrete manufacturing process. The sand is extracted from riverbeds in excess quantities, damaging the environment and containing an organic and soluble chemical that affects the durability of concrete and shortens its life. Authority officials periodically impose sand mining bans to prevent further deterioration and highlight natural sand's importance as a groundwater filter. As natural sand is scarce and construction activity is rising, a concrete product that matches natural sand's qualities is urgently needed. Concrete can be reinforced with manufactured sand, which is abundant in quarries. It is manufactured sand made from crushed rock aggregate. Crushed rock aggregates produce many fines, typically clay or silt-sized less than 0.075 mm. This study examines how sand's different chemical and physical properties affect the strength and durability of concrete of various strengths after washing it with water. The aim is to determine how different manufactured sands affect concrete strength and durability. From 0% to 100%, replacing natural sand with artificial sand affects substantial quality. Various physical and chemical characteristics of manufactured sand were measured experimentally and compared to those of natural sand. These characteristics included specific gravity, fineness modulus, water absorption, surface wetness, size, form, chemical composition, and minerals present. The specific gravity, fineness modulus, water absorption, and surface moisture values of manufactured sand in varying concentrations have been factored into the mix design. At different curing times, the fresh and hardened properties of concrete, such as workability, compressive strength, splitting tensile strength, flexural strength, modulus of elasticity, and Poisson's ratio, were measured for different replacement levels of manufactured sand. This helped find the best replacement level. Based on these, the relationship between concrete's mechanical properties was found. Mortar and concrete specimens made with either 100 per cent natural sand, 100 per cent manufactured sand, or the optimal replacement level were subjected to a battery of durability tests, including those for alkali-aggregate reaction, drying shrinkage, impact strength, abrasion, rapid chloride ion penetration, corrosion, acid attack, water absorption, sorptivity, and water permeability. The composition and structure of the particles confirmed those findings. Reinforced Cement Concrete (R.C) beams made with produced sand had their load-bearing ability, ductility factor, energy absorption capacity, toughness indices, and stiffness measured and compared to standard concrete samples. With only Young's modulus and Poisson's ratio as parameters, a mathematical model for determining the structural parameters of any concrete mixture was developed using the finite element analysis program ANSYS. Using synthetic sand in substantial preparation has been demonstrated not to compromise concrete's mechanical, durability, or structural qualities, based on the research conducted. The automatic, durability, and structural attributes of concrete made with manufactured sand improved with an increase in the replacement level of manufactured sand content. In contrast, the qualities of concrete with manufactured sand are enhanced if the concrete is blended at a ratio of 70% manufactured sand to 30% natural sand. Artificial sand is therefore encouraged for use as fine aggregate in concrete because of these benefits.

Keywords: Analysis, Compressive Strength, Flexural Strength, Manufactured Sand, Rapid Chloride Permeability, Sulphate Attack, Split Tensile Strength.

I. INTRODUCTION

Concrete is a common building material, but it is also used for various other purposes. Its yearly consumption rate is astounding. It is second only to water in terms of world consumption. In the concrete industry, cement, water, sand, and aggregate are combined to make popular concrete. The aggregate content of concrete has a direct and far-reaching impact on concrete quality. On the other hand, water and cement do not modify any particular attribute except in the quantity in which they are used. In contrast, aggregates have infinite variations in shape and grading. As part of concrete, coarse and fine aggregates comprise between 65% and 80% of its volume. Sums are significant to the fresh and hardened qualities of concrete. Typical concrete mixes contain about 20-30% fine aggregate.

II. LITERATURE REVIEW

Jeffrey et al. (2003) concluded that quarry fines are produced due to quarry extraction and processing activities. Extraction and processing could be optimized to generate minimal fines based on the nature of the rocks and the processes at play. However, variables pertinent to the stones and the operations at play all impact the fines generated. A British Geological Survey (2003) study found that particle size varies depending on the type of crusher and source rock. For primary crushers, fines were 1% to 10%. They were 5% to 30% for secondary crushers and tertiary crushers. Comparatively, metamorphic and igneous rocks have fines of 10-30%, and sandstone has fines of 35-40%. It was found by Petavratzi (2006) that the fines produced by the various ores were unique in their physical characteristics, and the amount paid by each varies. Cone crushers replaced HSI crushers by Mitchell and Benn (2007). A 21 per cent improvement in fines was achieved by reducing the percentage of fines from 38 per cent to 30 per cent at the same feed rate, which resulted in a 20 per cent increase in aggregate production per hour in 20mm size. Persson (1998) and Fletcher et al. (2002) described an image analysis method to characterise the grain size and shape distributions of fine aggregate. This might be a functional classification system for determining the utility of quarry products in construction materials like concrete. Through X-ray tomography, image analysis-type techniques, and spherical harmonic analysis, Garboczi et al. (2001) demonstrated the complete 3-D mathematical characterization of aggregate particles. The shape of aggregates in three dimensions can be stored in a database, and different aggregates can be characterized. Following Smith and Slaughter (1996), quarries approved by the US Department of Transportation must always maintain a grading target of between 0% and 7% passing the #100 sieve and between 2% passing the #200 sieve. So, people have started adding fines to enhance functionality. According to research by Shukla et al. (1998), stone dust can be used in concrete and mortar as a fine aggregate similar to sand. In some concrete recipes, stone dust can be substituted for sand up to 40% of the time without sacrificing strength. A study by Ahmed and El Kourd (1989) found that adding micro fines, referred to as "dust", to concrete resulted in increased shrinkage. A total of seven batches of concrete were mixed and analysed over a year. With increasing microfine concentrations, drying shrinkage was more significant. Ozyildirim investigated the influence of chloride ions on the permeability, corrosion, and permeability of concrete water in 1993. The cement type, w/c ratio, and curing temperature affected these properties.

III. METHODOLOGY

Characterizing Manufactured Sand

Analysis of hydrometers: Hydrometers are used to gauge too-small particles in soils, silts, and clays. The distance and duration of descent determine the grain diameter.

Microscopical analysis: Concrete's workability, strength, and durability are greatly influenced by fine aggregates. Both natural and synthetic sand were examined under a high-resolution microscope for their form and surface texture. A fine aggregate's form and texture have a far more significant impact on its durability and strength than a coarse aggregate's.

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Mineralogy: Natural aggregate of fewer than 75 microns is composed mainly of silt and clay minerals. Silt and clay minerals make up the bulk of the particles. As part of several specifications, such as AS 2758.1, the percentage of passing 75 microns is limited in controlling clay and silt fines, leading to increased water and cement demand, shrinkage, and cracking. The following analyses determined the type of minerals in the aggregate because surface coatings of clay reduced the strength of the bond between the whole and cement paste.

Method of settlement: As described in AS 1141.33, the volumetric silt test is used throughout this thesis to determine the amount of silt and clay relative to sand-sized particles. The settling method is used to assess harmful components in sand rapidly. This analysis determined the proportion of silt and clay to sand-sized particles as expressed as a percentage.

Concrete And Concrete Design Mix Sand Made from Manufacture

Construction cement: The chemical and physical properties revealed and based on Portland pozzolana cement as specified in IS 1489 - 1991. It describes the results of tests performed on the coarse aggregate using the protocol in IS: 2386 - 1963. Table A 1.3 shows the results of the tests performed on crushed aggregate that is 20mm downsize.

Aggregates of fines: In the past, the fine aggregate was made from river sand mining. However, modern sand has replaced river sand. An artificial sand percentage ranged from 0% to 100% and was labelled A, B, C, D, E, F, G, H, I, J, and K.

Mix Design: A mix design is divided into two phases.

- Components of concrete (cement, aggregate, water, and admixtures).
- To produce concrete with the desired workability, strength, and durability, the optimal proportions of these ingredients must be calculated ('proportioning').

As a result, each manufactured sand replacement option had to be calculated for its specific gravity and fineness modulus. The percentages of each mixture were recorded, and the letters A through K were assigned to represent the numbers (0, 10, 20, 30, 40, 50, 60, 80, 90, and 100). IS 10262 - 1982 was followed to develop the concrete mix formulas.

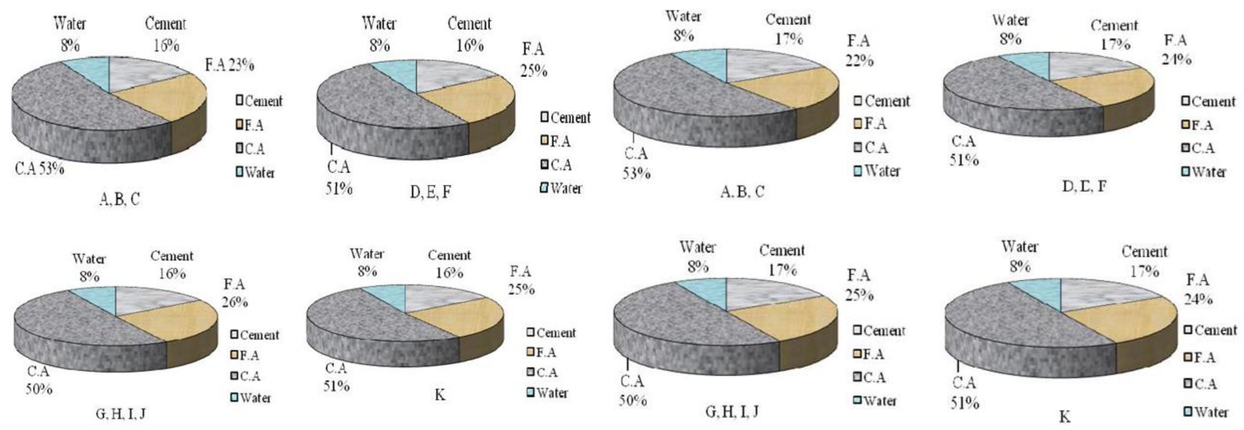

Figure 1: Percentages of ingredient

IV. RESULTS AND DISCUSSION

Compressive Strength: Comparing the compressive strengths of concrete grades M 20, M 30, and M 40 illustrates the relative rates at which important qualities M 20, M 30, and M 40 develop strength, respectively.

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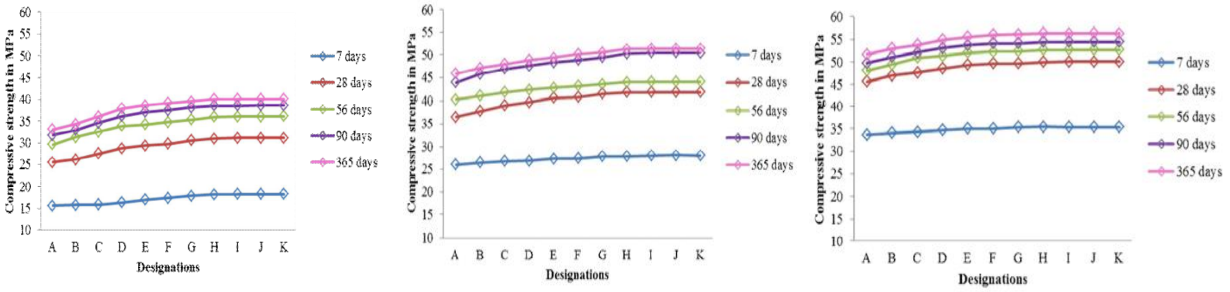

Figure 2: Compressive strength of m 20 grade, m30 grade and m 40 grades

Flexural Strength: According to the data, the flexural strengths improve up to a 70% concentration of artificial sand. Concrete strength of twenty-eight days in 20-grade concrete, the flexural strength achieved at seven days, fifty-six days, and three hundred and sixty-five days is 80%, 137%, and 144%, respectively. Early and late phase strength accomplishments are maximized for 30 & 40-grade concrete grades, respectively.

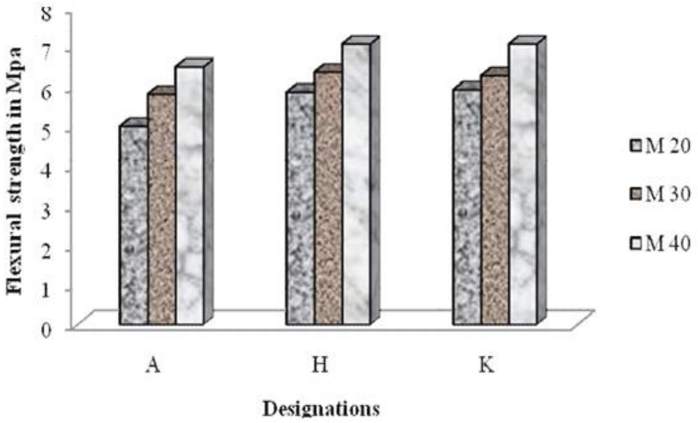

Figure 3: Comparison between the flexural strength Grade 20,30,40

ANSYS-Based Analysis of Beams: In Ansys mechanical and Ansys multi-physics, the pre-processing (geometry creation, meshing), solver, and post-processing modules cannot be exported. These programs do static and dynamic structural analysis (linear and non-linear) using finite element models, among other mechanical problem-solving capabilities (both linear and non-linear).

Model Development: Before a model can be made, the material attribute must be specified. In this preprocessing part, the active cross-section coordinate system was used to establish pivotal spots in the modelling process. By utilizing the line command to link these landmarks together, and the fillet function to cut the line into the terrain, we were able to create an intricate design. After that, the extrude function was used to turn the area into volume, and the model was built for the necessary length of time.

Meshing: Afterward, the mesh command was used to split the element into smaller pieces suitable for finite element analysis, and the resulting volume was formed. During the meshing process, the individual components were combined into a single whole; for example, a line element with a predefined area was extruded to create a 3D volume.

Conditions at the Boundary: After the meshing process was complete, the support condition was specified by constraining the ends along the x and z axes. The support condition was then applied, and the central point load was established as a force acting on the midpoint of the upper surface of the member. The problem was fixed once the user entered the necessary information and clicked the "Solution" icon.

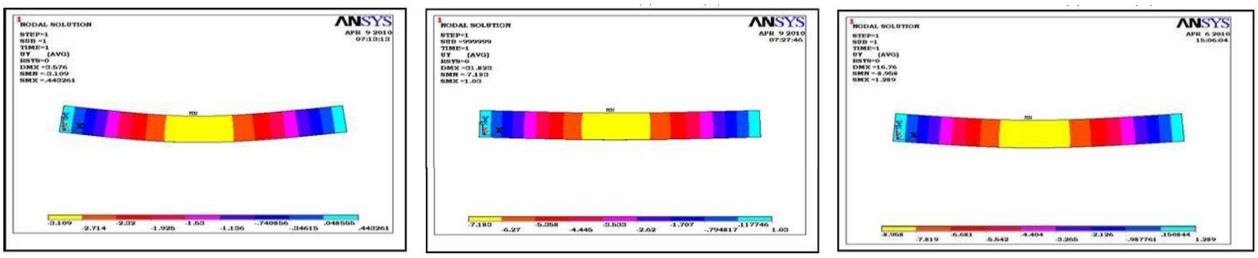

Figure 4: Deflection pattern of M 20,30 and 40 grade Beams

V. CONCLUSION

The research aims to determine how concrete's physical and chemical properties are affected by the amount of sand produced. Based on these experimental studies, we conclude that manufactured sand containing a high alumina concentration sets quickly when reacted with cement. Consequently, the concrete becomes less manageable. Concrete can be improved regarding workability, strength, durability, and structural characteristics by including produced sand in the mix. A ten-step examination of concrete's fresh and hardened characteristics with manufactured sand concentrations ranging from 0% to 100% results in the following findings. In the presence of 100% manufactured sand, the slump value is reduced by approximately 60%. In the presence of manufactured sand blended with natural sand, the slump value is reduced by approximately 23%-38%. Replacing up to 70% of natural sand can maximise strength gains. The strength gain plateaus beyond that concentration because of the high concentration of tiny particles. Concrete with a higher cement concentration and lower water content can achieve greater strength sooner than concrete with a lower water concentration. Concrete with 70% manufactured sand has approximately 20% more compressive strength, 15% more splitting tensile strength, and 20% more flexural strength than concrete with only natural sand. With 70% manufactured sand, concrete gains a strength increase of 12-20% compared to the 28-day strength, and its modulus of elasticity increases by 8 per cent. As a result of the manufactured sand, which makes up 70 per cent of the mix, seven per cent more Poisson's ratio is achieved. The strengths that exceed IS standards are compression, splitting tensile, flexural, and modulus of elasticity. Even though 100% manufactured, sand has better strength qualities, a mixture of 70% manufactured sand and 30% natural sand produces superior results. A study was conducted to determine the durability of concrete made with 100% manufactured sand, 70% manufactured sand, and 100% natural sand as replacements. A 4% and 17% decrease in the expansion percentage due to alkali-aggregate reaction is observed when using either 100% or 70% manufactured sand, respectively. Abrasion resistance increases by 5% to 15% when using 100% produced sand, compared to 5% and 15% when using 70% produced sand. The drying shrinkage strain for 100% manufactured sand is reduced by 3 per cent, and for 70% manufactured sand, it is reduced by 10%. When the impact resistance energy is measured after seven days, 28 days, and 56 days after using 100% manufactured sand, the increase is approximately 5%, 10%, and 15%; after seven days, 15%, and 20%; when the impact resistance energy is measured after seven days, 15%, and 20%, respectively. Chloride ions are less able to pass through the Due to its reduced capacity for absorption, manufactured sand has a less adverse impact on corrosion and has the least impact on high-grade concrete. The concrete produced with sand is very acid resistant. The loss of durability qualities from manufactured sand is negligible at a 70% replacement level, as it reduces water permeability, absorption, and sorptivity by around 20%. Lastly, concrete specimens made from 70% manufactured sand showed a greater ability to resist porosity and durable properties than regular concrete. SEMs were used to examine concrete made with natural and artificial sand and their microstructural parameters, Energy Dispersive Spectroscopy (EDS) and X-ray Diffraction (XRD). Based on the investigation mentioned above, the following conclusions were drawn. Using a scanning electron microscope (SEM), the images show that the natural sand particles are spherical, while the particles of the produced sand are angular and elongated. Using EDS, minerals such as silica, calcium, alumina, and oxides can be measured in natural and synthetic sands. Its primary constituent, crystalline silica, was verified by X-ray diffraction research. ANSYS finite element analysis software has been used to analyze concrete beams made with natural sand and manufactured sand, and the results have been compared with an experimental study. There is a delay in the onset of the first crack in R.C. beams made with 70% artificial sand compared to those made with natural sand. The load-bearing capacity of synthetic sand is 15 to 20 per cent higher than that of natural sand in 70 per cent of cases. You will notice a ductility improvement of around 8% when using 100% manufactured sand compared to natural sand; when using 70% manufactured sand, you will notice a ductility improvement of around 19%. Energy absorption capacity improves by about 6% with 100% produced sand and about 34% with 70% produced sand. It has a slight advantage over natural sand in toughness indices but a disadvantage in toughness indices in 70% manufactured sand. Concrete rigidity is more rapidly degraded by manufactured sand than by natural sand. Analytical models constructed by this method are equally as effective as experimental results. Hence, any grade of R.C. beam may be analysed without destroying any beams. According to the tests, synthetic sand concrete performs similarly to natural sand concrete. A 70 per cent substitution rate of manufactured sand in concrete improves the structural behaviour of the concrete. Synthetic sand is a viable material for construction projects due to its increased strength, stiffness, energy absorption capacity, and flexibility.

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