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To Study the Potential of Sandstone Quarry Dust to be Used as A Partial Substitute of Natural Sand in Concrete: A Review

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ABSTRACT:

The use of quarry waste to replace natural sand in the construction of buildings and other structures to eliminate the requirement for natural sand. We're looking into the feasibility of employing quarry waste and how it affects the strength and workability of concrete. Initially, cement concrete cubes with varied proportions of cement concrete + quarry dust (M30) were investigated. These concrete raw materials, namely river sand and gravel, are likewise straining to meet the fast increasing demand in many parts of the world.. The sources of good quality river sand and gravel are depleting very fast. According to United Nations Environment Program (UNEP) report, "Sand-rarer than one thinks", published in March2014, sand and gravel has now become the most widely used natural resource on the planet after water. These are now being extracted at a rate far greater than their renewal. Crushed sands, fine aggregate produced from stone crushing, has become very popular in areas where natural sand is not abundantly available or where there is scarcity in the supply of natural sand.

For thousands of years, people have used concrete in ground-breaking construction projects. The demand for concrete is rising very quickly around the world as a result of the ongoing housing boom and other growth efforts in the construction industry. According to a research released by the United Nations Environment Programme, almost 12 billion tonnes of concrete are produced annually throughout the world. Large amounts of natural resources are needed to produce such volumes of cement and aggregate. For instance, the consumption of cement increased three-fold during the past 20 years, from 1.37 billion tonnes in 1994 to 3.7 billion tonnes in 2012, primarily as a result of Asia's rapid economic development. Surprisingly, China accounted for 58% of global cement use. The main objective of the thesis is to determine whether sandstone quarry dust can partially substitute for natural sand in concrete. In this study, the control concrete mix is contrasted with various concrete quality. which contains 100% natural sand, and Sandstone quarry dust is substituted by natural sand in concrete mixtures at various substitution rates of 10%, 20%, 30%, 40%, and 50%. The study's several goals are listed below

To compare the workability of concrete mixes including quarry dust from sandstone as a partial replacement for natural sand with the control concrete mix. To compare the density, splitting tensile strength, and compressive strength of concrete mixes including crushed sandstone as a partial replacement for natural sand with a control concrete mix. To assess the water absorption and sorptivity of concrete mixes including dust from a sandstone quarry in place of some of the natural sand. To establish the ideal ratio of sandstone quarry dust to natural sand for good workability, hardening, and durability qualities.

Keyword: Quarry Dust, workability, compression strength, flexural strength, sorptivity, Crushed sands.

INTODUCTION:

The price of this sand is rising, which eventually raises the cost of construction, as the availability of adequate natural sand close to the site of consumption is running out. Finding a substitute material that not only meets the technical requirements of fine aggregate but is also widely accessible is necessary for the sustained growth of infrastructure in the modern world. In the past, extensive study has been conducted to identify alternative sources of fine aggregate. Fine aggregate made from crushed stone, known as crushed sands, has grown in popularity in locations where natural sand is in short supply or is not widely accessible. The Mumbai-Pune motorway was a project where getting natural sand proved challenging. This led the building company to employ crushed sand to produce the roughly 20 lakh cubic metres of concrete required for the construction. The high concentration of micro-fines, or particles smaller than 75 microns, in this type of sand, however, might negatively impact the characteristics of concrete. Therefore, when crushed sand is used in concrete, At the time of mix design, the proportioning of different raw components is vital. Today, thanks to continued research and development in this area, fine aggregate with the required qualities is produced by crushing stone. A purpose-made crushed fine aggregate made from an appropriate source material is what is referred to as manufactured sand. Its manufacturing often entails crushing, screening, and maybe washing. It may also require separation into distinct fractions, recombining, and mixing. In regions where natural sand is few or unavailable, manufactured sand is proving to be a highly useful alternative. To produce fine crushed aggregate with better shapes, better crushers are typically introduced.

QUARRY DUST Quarry dust is defined as the leftovers, tailings, or waste products from the extraction and processing of rocks at a quarry's crushing plant. It is also referred to as rock dust, stone dust, or quarry debris. The primary goal of rock crushing and sizing in quarries has often been to generate coarse graded aggregates of various sizes and road construction materials that adhere to particular norms and specifications. A certain fraction of the rock is ground down throughout the course of a quarry's routine production procedures to a size that prevents it from being used as a component of coarse aggregates.

APPLICATIONS OF QUARRY DUST

There are many uses for quarry dust in the infrastructure and building industries:

1. In bituminous mixes, such as Dense Bituminous Macadam (DBM), Bituminous Macadam (BM), Bituminous Concrete (BC), etc., quarry dust is utilised as a fine aggregate.

2. Quarry dust is also used in the base and sub-base layers of Wet Mix Macadam (WMM), Granular Sub Base (GSB), and other materials while building roadways.

3. It is also used to make a variety of building products, such as lightweight aggregates, bricks, and tiles.

4. Additional applications for quarry dust include building embankments and covering landfills.

PROPERTIES OF QUARRY DUST

There are various ways that quarry dust differs from natural sand:

(i) Mineralogy - While quarry dust's mineralogy is dependent on the parent rock from which it was created, natural sand is often siliceous in nature;

(ii) Micro-fine Content - Quarry dust contains significantly more micro-fines (material passing a 75 micron sieve) than natural sand;

(iii) Water absorption - Quarry dust has a higher water absorption rate than natural sand because it contains more micro-fines;

(iv) Particle Size Distribution - Natural river sand is normally consistently graded, but quarry dust is typically badly graded or gap graded;

(v) Particle Shape: While quarry dust has an angular shape, natural sand typically has spherical particles;

(vi) Surface Texture - Quarry dust has a rough surface texture compared to natural sand, which has a smooth surface texture.

SPECIFICATIONS FOR CRUSHED SAND Stone dust or quarry dust does not have standardised criteria, but we can gain an idea of its characteristics by comparing it to the specifications for crushed sand as mentioned in several standards. Because crushed sand differs from river sand in many ways, multiple standards have modified the specifications for crushed sands used as fine aggregate in concrete. The grading specifications for crushed sand are laid forth in British Standard, BS 882:1992, and they differ slightly from those for natural sand. The distinction has to do with the micro-fine composition. For standard concreting, BS 882:1992 permits a micro-fine concentration of up to 16% by mass of crushed sand, 9% by mass for heavy-duty floors, and only 4% by mass of natural sand. Additionally, the maximum for crushed sand's material percent passing a 150 micron screen has been raised to 20%, but the same limit for natural sand is only up to 15%. Table 1.3 compares the requirements for crushed sand and unprocessed river sand as stated in BS 882:1992.

LITERATURE REVIEW:

Shi-Cong and Chi-Sun (2009) investigation on the results of replacing 25%, 50%, 75%, and 100% of river sand with crushed fine stone. They noticed that the control mix has the largest slump, and that workability of concrete steadily deteriorated as they gradually replaced more natural sand with crushed fine stone. Concrete with 100% river sand had a lump measurement of 60 mm; concrete with 100% crushed fine stone had a lump measurement of 30 mm. They came to the conclusion that the angular shape of crushed fine stone, which resulted in an increase in water demand, is what causes the loss in workability with the addition of crushed fine stone to concrete. As a result, more water was required to generate concrete that was as workable as the control.

Raman et. al. (2011) examined the impact of using quarry dust in place of natural sand on the workability of concrete made with high strength rice husk ash. To get the desired strengths of 60 MPa and 70 MPa, respectively, two series of concrete, C60 and C70, were created. 10%, 20%, 30%, and 40% of the natural sand in each series was replaced with quarry dust, and 10% of the cement in all mixtures was swapped out for rice husk ash. All concrete mixes from both series had excellent workability and met the desired minimum slump of 150mm thanks to the addition of superplasticizer. They noticed that adding quarry dust as a partial sand substitute in both of the series, C60 and C70, caused a deterioration in the workability of concrete mixes.

Vijayalakshmi et. al. (2013) examined the impact of replacing river sand with granite powder at replacement levels ranging from 0% to 25% on the workability of concrete. They noticed that when the rate of substitution increased, the workability of concrete decreased. The concrete mixtures with substitution rates of 20% and 25% had very poor workability. They came to the conclusion that the difference between river sand and granite powder's surface roughness, particle shape, and particle size distribution is what causes the decrease in workability. 90% of the particles in granite powder were finer than 50 microns compared to natural sand, increasing the specific surface area of fine aggregate and, as a result, the water need. Granite powder particles' angular geometry and rough surface texture

Singh et. al. (2016) examined the impact of replacing natural sand with granite cutting waste on concrete workability at replacement levels ranging from 0% to 40%. They noticed that as more natural sand is replaced with granite cutting waste, the workability of concrete significantly decreases. They came to the conclusion that the increased friction between concrete particles caused by granite cutting waste's more angular and rough surface roughness than river sand was the cause of the deterioration in concrete's workability.

Cordeiro et. al. (2016) examined the impact on concrete workability of replacing natural sand with crushed granite aggregate at replacement levels of 10%, 30%, and 50%. They created concrete with a 200mm to 220mm slump range and a goal strength of 50 MPa. They noticed that when the amount of natural sand replaced with crushed granite aggregate increased, so did the dosage of the super plasticizer. Super plasticizer dose for control concrete was 0.16%, but it was increased to 0.17%, 0.19%, and 0.23% for concrete with replacement levels of 10%, 30%, and 50%, respectively. They came to the conclusion that the increased dosage of super plasticizer meant the concrete's water consumption had grown along with the amount of crushed granite aggregate present.

Bonavetti and Irassar (1994) studied the qualities of mortar prepared by substituting three different types of stone dusts for natural sand, ranging from 0% to 20% for each stone dust: quartz dust, granite dust, and limestone dust. They noticed that when the amount of stone dust increased, more water was needed to keep the flow steady. Water usage only slightly increases for mortars made with 5% stone dust.

When more than 10% of the stone dust was added, the increase happened quickly. They came to the conclusion that since stone dust has a higher surface area than natural sand, there is a corresponding rise in water consumption.

Satyendra Dubey et al. (2015) intended to investigate how Metakaolin affected the concrete's compressive strengthening. In concrete of grade M25, substitute 0, 5, 10, or 15% MK for the cement. The findings showed that 10% MK is the best replacement and that other MK percentages, including 5 and 15%, are also acceptable, significantly improved the strengthening properties of concrete when compared to normal concrete.

Hajime Okamura et al. (2003) The authors argue that when self-compacting concrete is widely employed to the point that it is considered "Standard Concrete" rather than "Special Concrete," it will be successful in producing long-lasting and dependable concrete structures that require minimal maintenance.

R.SriRavindrarajah, et al. (2003) The features of flowing concrete and self-compacting concrete mix with varying percentages of high-water lowering super-plasticizer were investigated experimentally by the author. Drying shrinkage is influenced by superplasticizer dosage.

ShettyR.G,et al. (2004) Self consolidating concrete is appropriate for concreting in dense reinforcement structures, according to the authors, who also explained the methodology used to design and test SCC mixes, as well as the methods used to test the concreting walls.

Frances Yang,et al. (2004) The process for developing SCC, as well as its components and mix proportioning procedures, are done in this. It lists numerous advantages of adopting SCC techniques used to assess its features. The author proposes several model applications of SCC, such as Toronto International Airport, and it presents the preventive actions that should be implemented for creating and developing the mix. For the 68-story high-strength SCC was employed to produce compactly reinforced parts poured in below-freezing temperatures.

Geert De Schutter,et al. (2005) In this inquiry, the results of creep and shrinkage are given. When experimental data are compared to some traditional methods, the ACI model provides accurate predictions. The models proposed by "Delarrard" and "Model Code" lead to in underestimation of the deformations. The use of SCC needs no extra provisions taken for the structure.

"The European Guidelines for SCC (2005) The proposed specifications and associated test adopted for site-mixed concrete is offered aiming to facilitate standardization at European code.The method is to encourage increased adoption and use of SCC.The EFNARC defines SCC and many of the technological terms utilized to define its properties and function.They also present data on standards connecting to testing and to related constituent materials used in the manufacture of SCC.

AnirwanSenguptha, et al. (2006) According to the EFNARC 2005 code, the author discovered the best mixture for making SCC. The EFNARC criteria were met in all design mixtures, which showed good segregation resistance, passage ability, and filling ability. It was required to use a lot of powder in the design of SCC. The SCC has a higher powder content, which results in higher compressive strengths.

G. Giri Prasad, et al. (2009) For toughened qualities, the author constructed M60 grade SCC compared it to a routinely manufactured concrete mix. The collected experimental data were confirmed using analytical equations for the stress-strain curve presented by several authors. The values of stock at peak stress during axially compressioning for both concretes were found to be close to 0.002, as stated in IS:456-2000.

MIX PROPORTIONING OF CONCRETE INGREDIENTS

To set the percentage of aggregate in concrete, All-In aggregate grading for 20mm nominal size aggregate was employed in accordance with BIS 383:1970 standards. Trial and error was used to determine the proper proportions of 20mm nominal size aggregate, 10mm nominal size aggregate, and natural sand in the concrete. A constant proportion of 20 mm nominal size aggregate, 10 mm nominal size aggregate, and natural sand was used to compute the quantities of coarse aggregate and fine aggregate at the time of mix design. based on this all-in aggregate grading.

Concrete mix design followed IS 10262:2009 guidelines. The control concrete's grade was set at M30, and the desired slump was 100mm. We considered the exposure conditions to be moderate. According to the IS 10262:2009 process, the target strength was first estimated using an appropriate standard deviation value. According to the target strength of the concrete to be achieved, the estimated water content was calculated for the required workability, and the free w/c ratio was selected based on experience. The cement content was computed using the expected water content and free w/c ratio. The quantity of coarse and fine aggregate was determined based on the volume of aggregate in concrete, and the proportion was fixed in accordance with all-in aggregate grading. The SSD (Saturated Surface Dry) condition was used to compute the quantities of coarse and fine aggregate. Accordingly, based on the moisture content of the coarse aggregate and fine aggregate at the moment of casting, any necessary water corrections must be made.

Concrete mixes containing sandstone quarry dust were determined based on the proportions of the various constituents in control concrete. Concrete mixtures of 10%, 20%, 30%, 40%, and 50% quarry dust in place of natural sand were referred to as QD10, QD20, QD30, QD40, and QD50, respectively.

MIXING OF INGREDIENTS AND CASTING OF SAMPLES

Mixing of Ingredients All concrete combinations were prepared and mixed in a laboratory using a drum mixer. A drum mixer is a mechanical device that mixes cement, coarse aggregate, fine aggregate, and water into a homogeneous mass inside of a rotating drum. The conditions for both the coarse and fine aggregates were dry. Therefore, prior to the mixing process, the appropriate water corrections were done. Cement, coarse aggregate, fine aggregate, and water were all accurately weighed to within 1.0 grammes. The coarse and fine aggregate were entirely dry mixed before the drum mixer was turned on. The cement was then added and swirled in the drum mixer to produce a homogenous mass. To prevent any water loss during the mixing stages, water was finally carefully added. The drum mixer was turned until a uniformly coloured and consistent lump of concrete was obtained. Throughout the entire process, attention was paid to the perfect blending of all materials. Immediately following the completion of the mixing procedure, the workability of all concrete mixtures was evaluated.

Sample Preparation

In steel moulds, all of the concrete examples were cast. Before the components for the concrete were mixed, all the moulds were thoroughly cleaned and oiled. Before casting processes, they were appropriately tightened to the proper dimensions. Care was taken to make sure there would be no gaps to allow slurry to slip through. Using a vibrating table, concrete sample were crushed into two layers. After the casting procedures, concrete samples were demolded and put in the curing tank after being kept in the casting room for around 24 hours. Below is information about the specimens that were cast for the various tests:

1. Compressive Strength: Cubical specimens 150mm x 150mm x 150mm were formed to evaluate the concrete's compressive strength.

2. Splitting Tensile Strength: To test the splitting tensile strength of concrete, cylindrical specimens with dimensions of 150 mm in diameter and 300 mm in height were cast.

3. Water Absorption: Cubical specimens measuring 70.6 mm x 70.6 mm x 70.6 mm were formed to test the concrete's water absorption.

4. To test the sorptivity of concrete, cylindrical specimens with a diameter of 100mm and a height of 50mm were cast.

5. Rapid Chloride-Ion Permeability: To evaluate the concrete's rapid chloride-ion permeability, cylindrical specimens with a 100mm diameter and 50mm height were produced.

TEST PROCEDURES

Workability

Concrete's workability refers to how easily it can be correctly mixed, transported, compacted, and finished with the least amount of homogeneity loss. The Slump Test is the test that is most frequently used to assess the workability of concrete in the construction industry worldwide. Slump testing was used to assess the concrete's workability in accordance with Indian Standard Specifications found in BIS 1199:1959. A mould in the form of a frustum of a cone with a bottom diameter of 200mm, a top diameter of 100mm, and a height of 300mm was filled with four roughly equal layers. Then, using 25 strokes of a standard tempering rod, each layer was tempered.

Figure Slump Test of Concrete

Mould was removed by raising it vertically after the area had been filled and levelled, allowing the concrete to settle. Slump in millimetres, which is the height difference between the mould and the highest point of the subsiding concrete mass, was used to express the workability testing results.

Compressive Strength: It is believed that the most significant characteristic of hardened concrete is its compressive strength. Compressive strength tests were conducted in accordance with Indian Standard Specifications using the steps outlined in BIS 516:1959. Using standard cube specimens measuring 150mm 150mm 150mm, the compressive strength of concrete was assessed at ages of 7 days, 28 days, and 90 days. Concrete's compressive strength was tested using a Compression Testing Machine (CTM) with a 5000 kN capacity. To guarantee adequate curing, concrete specimens were demolded 24 hours after casting and placed in the curing tank. At each indicated age, the specimen was positioned in the middle of the CTM bearing plates, and a constant, uniform load of 140 kg/cm2/min was applied. The maximum force that each specimen could withstand was recorded after the load was increased until the specimen broke.

Figure : Compressive Strength Test on Compression Testing Machine

The compressive strength was calculated according to the following formula:

$\sigma = P/A$

where,

σ = Compressive Strength (N/mm^2)

P = Maximum load sustained by the cube (N)

A = Area of cross section of cube (mm^2)

The average compressive strength of three specimens at 7 days, 28 days, and 90 days for each concrete mix was used to calculate the results of the compressive strength tests.

Density of Concrete: The density of concrete is an important consideration since it has a significant impact on how a structure's dead weight is determined. When the 150mmx150mmx150mm cubical specimens were being demolded for the compressive strength test, the mass of three random cubes was measured using a weighing scale with a 10 kg capacity and an accuracy of 1.0g, and the 1-day density of concrete was determined using the formula below:

$\rho = M / V$

where,

ρ = Density of concrete in kg/m^3

M = Mass of 150mm×150mm×150mm cube in kg

V = Volume of cube in m^3

Splitting tensile Strength The tensile strength of the concrete must be determined in order to minimise breaking in tension zones because concrete is strong in compression but very weak in tension. An indirect way to assess the tensile strength of concrete is splitting. The splitting tensile strength test was performed in accordance with Indian Standard Specifications using the steps outlined in BIS 5816:1999. Utilising typical cylindrical specimens with dimensions of 150 mm in diameter and 300 mm in height, the splitting tensile strength of concrete was assessed at ages of 7 days, 28 days, and 90 days. To guarantee adequate curing, concrete specimens were demolded 24 hours after casting and placed in the curing tank. Concrete's compressive strength was tested using a Compression Testing Machine (CTM) with a 5000 kN capacity. Each specimen was positioned in the centre between the bearing plates of the CTM for the evaluation of splitting tensile strength, with appropriate packing strips at the top and bottom to achieve proper load distribution, as illustrated in Figure 3.4. Continuously and consistently, loads between 1.2 N/mm2/min and 2.4 N/mm2/min were applied. The greatest load that each specimen could withstand was recorded, and the load was raised until the specimen cracked along the vertical axis. The following formula was used to get the splitting tensile strength:

$\sigma st = 2P/\pi DL$

where,

σst = Splitting Tensile Strength (N/mm2)

P = Maximum load sustained by the cylinder (N)

D = Diameter of cylinder (mm)

L = Length of cylinder (mm)

The average splitting tensile of three specimens at 7 days, 28 days, and 90 days for each concrete mix was reported as the test's results' splitting tensile strength in N/mm2.

Fig. Splitting Tensile Strength Test of Concrete

Water Absorption To understand concrete's durability characteristics, one must first understand its pore structure. Concrete's ability to absorb water is a sign of how dense its microstructure is. Concrete's ability to absorb water was assessed at various times in accordance with ASTM C 642-13's protocol.

The size and shape of the specimens for the water absorption test are not specified by the standard procedure, with the exception that each specimen must have a volume of at least 350 cm3 and a weight of at least 800g, and that no portion may have visible fissures, cracks, or broken edges. After an initial 28-day curing period, water absorption tests were conducted at 7 and 28 days on cubical specimens measuring 70.6mm by 70.6mm by 70.6mm. The concrete specimens' oven dry mass and saturated mass were estimated using the formula shown below to measure how much water the concrete specimens absorbed:

Absorption after Immersion (%) = $((B - A) / A \times 100)$

where,

B = Oven Dried mass of specimen in air (g)

A = Mass of surface-dry specimen after immersion in air (g)

The average water absorption of 3 specimens at 7 days and 28 days following the first curing of 28 days for each concrete mix in% was used to calculate the results of the water absorption testing.

Sorptivity The flow of liquids through interconnected pores is a key factor in determining how long concrete will last. Concrete's sorptivity is the capillary action's one-dimensional rate of water absorption. Concrete's sorptivity was assessed in accordance with the guidelines in ASTM C 1585 - 4. After an initial curing period of 28 days, a rate a sorption of water test was conducted on typical cylindrical specimens with dimensions of 100 mm in diameter and 50 mm in height. Each specimen was produced in accordance with ASTM C 1585 - 04's instructions. Epoxy coating was used to seal the specimen's sides, and the specimen's curved outer surface was covered with adhesive tape. Each specimen's initial mass was measured and documented. Figure 3.5 contains the schematic diagram of the experimental process. A stop watch was started as soon as the specimen was submerged in water, and measurements of the specimen's mass were made after 5, 10, 20, 30, 60, 120, 180, and 240 minutes. At each designated time interval, the specimen was lifted, the area that had come into contact with water was dried with a towel, and the mass of the dry surface was noted.

First, the rate of water absorption, I, was computed for the computation of the sorbtivity of the concrete specimen by dividing the change in mass of the specimen by the product of the ross-sectional area of the test specimen and density of water. The unit of I is mm3/mm2 or mm, and the density of water will be assumed to be 0.001 g/mm3 for this purpose.

I = mt / (a*d)

Where,

I = Rate of absorption (mm3/mm2 or mm)

Mt = the change in specimen mass at time t (g)

a = Exposed area of the specimen (mm2)

d = Density of water (g/mm3)

Now, a curve was created by plotting the rate of water absorption, I, against the square root of time in minutes, t0.5. A linear regression analysis was used to determine the curve's slope. This curve's slope is measured in units of mm3/mm2/min0.5 or mm/min0.5, and it is known as sorbtivity. The average sorptivity of 2 specimens at 7 days and 28 days following the first curing of 28 days for each concrete mix was used to determine the results of the sorptivity testing.

Figure : Sorptivity Test of Concrete Samples

SUMMARY:

The goal of the current experimental investigation was to determine whether sandstone quarry dust could substitute some of the natural sand in concrete. By substituting quarry dust for natural sand in concrete at various percentages, workability, compressive strength, splitting tensile strength, water absorption, and sorptivity were tested. According to test results, sandstone quarry dust, an industrial waste product, can be used in place of natural sand in concrete.

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