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The Benefits of Using Refurbished Steel Mill Scale for Fine Aggregate on Concrete Performance

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ABSTRACT: The Rapid Chloride Ion Penetration Test (RCPT), Sorptivity (water permeability), Acid Attack, and Impressed Voltage test (Accelerated Corrosion) were performed to evaluate the durability and corrosion resistance of the material. The ultrasonic pulse velocity and electrical conductivity tests were also carried out. Spectroscopic electron microscopy was employed once again on cured concrete to study its internal structure. Studies have indicated that increasing the percentage of steel mill scale used to substitute fine aggregate in concrete improves the hardened concrete's strength. When used at a 60% replacement rate, steel mill scale has thesame beneficial effect on strength and durability as other forms of reinforcement. However, steel mill scale particles need additional water in order to keep their workability. Results for testing of strength, durability, and microstructure were shown to be linearly connected. Therefore, it is acceptable to conclude that steel mill scale may be utilized as a feasible and effective alternative for natural river sand to produce a sustainable concrete with enhanced strength results and durability, so contributing tothe solution of the solid waste disposal concerns.

KEYWORDS: concrete, Steelmillscale and microstructure

I. INTRODUCTION

Concrete, the most used building material, is made up mostly of filler componentsthat are held together by a binder. In order to improve the characteristics of concrete, occasionally admixtures are added to the mix. Nearly 70% of the volume of cement concrete is taken up by aggregates. Between 1900 and 2010, the quantity of natural resources used in global infrastructure development rose by a factor of 23. The most extensively mined materials are sand and gravel (79 percent, or 28.6 gigatons annually in 2010). A. Torres et al (2017) The construction industry in India now accounts for 6.3% of

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GDP, but that number is expected to rise to as high as 13% by 2028. The expansion of the construction sector has a multiplier effect on overall demand. There is a severe shortage of building aggregates in India at the moment. Demand for river sand has expanded as the usage of concrete has grown in all facets of building. Since river sand has a high silica concentration, it is the material of choice for making concrete, and its popularity consequently rises. As a result of this need, there has been a dramatic increase in the quarrying of river sand, which has had a devastating effect on river ecosystems. Because to sand mining, major environmental concerns have arisen, along with the destruction and relocation of people's means of subsistence. The mining of sand in India is mostly uncontrolled. So mining is a simple procedure that requires little effort. The unregulated sand mining by a number of individual investors has significantly impacted sand prices in several regions of the nation. The government has passed legislation to stop the excessive use of river sand. The Ministry of Environment, Forest, and Climate Change (MoEF& CC) developed the Sustainable Sand management guidelines for 2016 to regulate sand mining in the country and protect the nation's river sand resources.

II. DURABILITY STUDIES

Buildings made of concrete must perform admirably not only within the limits of their mechanical characteristics but also throughout the long term. Concrete should be able to withstand the intended load in addition to meeting the requirements of any applicable construction rules or standards. It is robust because, in addition to bearing weight, it must endure and remain strong for as long as it is expected to serve its purpose. Concrete must be durable enough to survive any kind of deterioration, whether it be mechanical, chemical, physical, or caused by reactions between the ingredients themselves. Most degradation rates are decreasing dramatically as a result of physical processes.

Water Absorption

Examining the durability attributes of a material is a standard method for determining its water permeability. In order to determine how well a material absorbs water and how much of its structure is permeable, we used the procedure outlined in ASTM C 642- 82. The water absorption was determined using the dried 150mm x 150mm x 150mm cube samples. When the weight of the cubes in the oven stayed the same, theywere thrown into a bowl of water. Once a continuous weight gain was seen, it was recorded and tracked. At the completion of the experiment, the rate of absorption was compared to the rate observed 30 minutes into the experiment (this represents the initial superficial absorption). At the conclusion of every instance, 28 days of absorption was assessed. The capacity of absorption is calculated by dividing the quantity of water absorbed by the dry mass of the specimen. It is most often stated as a percentage.

$$\text{Percentage of water absorption} = [(B - A) / A] \times 100$$

Where,

A = Mass of the oven dried sample.

B = Mass of the saturated sample.

Absorption properties are a surrogate for pore volume and permeability because ofthis. IS 1237 - 1980 specifies a 10% maximum average water absorption rate.

Permeable Voids

According to ASTM C 642 - 82 on curing samples, the sample's permeability was determined. Also, the specimens with a dimension of 150 mm x 150 mm x 150mm cubes have been utilized. In the 28th day of curing the cubes is withdrawn from the tank for curing. The clean surface is cleaned using dry cloth as well as the weightsand sizes of saturated surfaces dry cubes are recorded. Cubes are baked at 105 degreesuntil their masses have stabilized. Submerging the oven-dried cubes in water causes their weight to stabilize. Gains in weight are monitored regularly until a steady state is reached.

Percentageof permeablevoids =—x100

Where,

A = Mass of the surface dried saturated sample.

B = Mass of the oven dried sample.

V = Volume of the specimens.

Scanning Electron Microscope (SEM)

Calcium hydroxide and calcium silicate react to regulate the hydration process of cement paste. To create back-scatter electron images (BSE), scientists may make advantage of this comprehensive method of microstructural development using Scrivener (2004). After cubes of concrete had dried for 28 days, core samples were removed and analysed using scanning electron microscopy. The sample was cut into

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cubes with a dimension of approximately 10 millimetres, and one face of each cube was flattened. With order to stop any further hydration reactions, the samples were

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doused in acetone. In order to increase conductivity, gold was sputtered onto the cube specimen. Scanning electron microscopy (SEM) pictures of the samples were taken.

The hydration process enlarges the microstructure of the cementitious material. Cement hydrates are formed when anhydrous cement granules are exposed to water. Energy Dispersive X-Ray Analysis (EDX), also known as Energy Dispersive Spectroscopy (EDS) or Energy Dispersive Atomic X-Ray Analysis (EDAX), is an x- ray technique used to identify the elements present in a sample. Some examples of possible uses are found in reformulating and troubleshooting existing products or researching new ones. EDX systems are add-ons to Electron Microscopy (EM) and Transmission Electron Microscopy (TEM) equipment, where the microscope's imaging capabilities are utilised to determine the nature of the sample under study.

Information gleaned from EDX analysis is represented as spectra with peaks corresponding to the elements that make up the real structure of the specimen. Sample and image analysis now include a mapping component. Topography pictures created from SEM images may reveal the size, shape, and roughness of particles, as well as the presence or absence of surface roughness and fractures. The phase distribution and chemical composition of smooth surfaces may be analysed using this method.

III. LIMITATIONS

• Self-compacting Since concrete is a relatively recent technological development, reliable and thorough quality assurance and control measures are essential. Onlytrained workers should create and put in place SCC systems.

• One reason why SCC have more plastic shrinkage than regular vibrated concrete is because they don't leak on the outside or the inside as regular concrete does. Therefore, SCC must be dried soon upon installation to prevent the breaking of the surface.

• SCC's lower modulus of elasticity may be attributed to its smaller MSA (nominal maximum size of aggregate) and its lower proportion of coarse aggregates in SCC's volume. The ensuing SSC reduction in size will be somewhat higher as a result.

IV.RESULTS AND DISCCUSION

The results of our laboratory experiments on the behavior of both fresh and hardened concrete are presented in this chapter. Multiple tests, including those for compressive factor, slump, and fiber, were performed on the freshly mixed concrete. Cubes for

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compressive strength, split cylinders for tensile strength, and beams for flexural strength, all tested with and without fiber reinforcement. Static loads were applied to the beams to determine their service load and ultimate load. Tests of tensile and bending strengths are conducted. There were several fracture patterns. This report details what was learned from the inquiry.

When mixed with water, cement, and aggregates, new concrete forms a semisolid substance that can be shaped into almost any form. The mechanical and durability qualities of hardened concrete are entirely dependent on those of fresh concrete, even though the hardened state is the ultimate result. During the whole casting process, freshly mixed concrete should be simple to mix, carry, and work with. The new concrete workability was investigated with a battery of workability tests.

We used a slump cone test to determine the new concrete's ease of shaping. Table 4.1 displays the findings of a study that measured the slump of concrete with varying % substitutions of steel mill scale for fine aggregate. Slump value variation for various replacements is graphically shown in Figure 4.1.

Table 4.1 Slump value for numerousheights of steel mill scale spare

Steelmillscale spare (%)	Slump(mm)	Workability
0	75	**Medium(shear)**
20	70	**Medium(shear)**
40	50	**Medium(true)**
60	50	**Medium(true)**
80	45	**Low(true)**
100	**40**	**Low(true)**

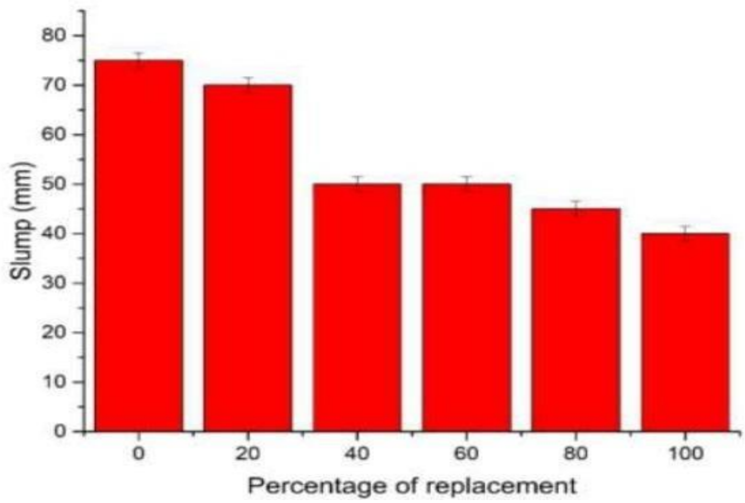

Figure 4.1 Slump value for various replacement levels

In Table 4.1, we can see that the slump value for the control mix with no fine aggregate substitution is 75mm. Slump value drops from 75 mm at 0% replacement to 40 mm at 100% replacement when steel mill scale is added. Therefore, the increased proportion of steel mill scale in situ has a negative impact on the workability of new concrete (Singhal et al. 2015 and Ozturk et al. 2020).

A compaction factor test was carried out to ascertain the new concrete's workability with varying amounts of steel mill scale replacements. Table 4.2 and Figure 4.2 both display the outcomes of the testing.

Table 4.2 Compaction factor for various steel mill scale replacements

Steelmillscale replacement (%)	Compactionfactor
0	0.99
20	0.97
40	0.96
60	0.96
80	0.95
100	0.93

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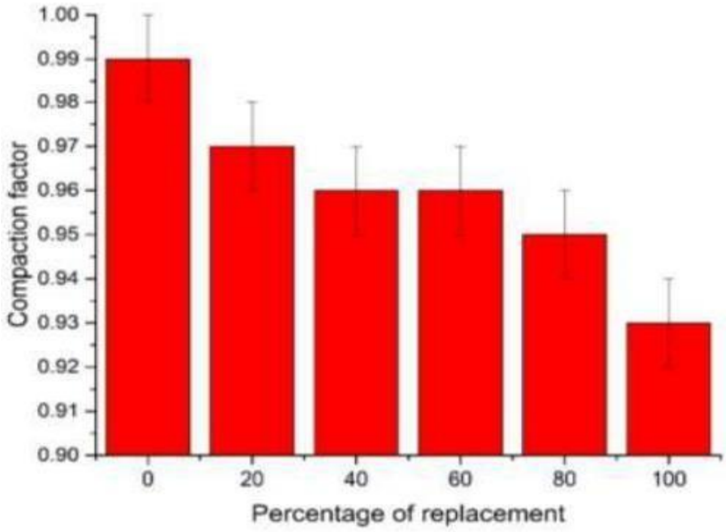

Figure 4.2 Compaction factor for various steel mill scale replacements

Table 4.2 shows that the compaction factor values of concrete produced using various steel mill scale substitutes decrease when steel mill scale is added. Increasing the percentage of replacement causes a decrease in compaction factor, from 0.99 at 0% replacement to 0.93 at 100% replacement. Like the slump cone, the results of the compaction factor show that adding steel mill scale to concrete reduces the material's workability. The form and surface roughness of steel mill scale greatly affect the amount of water needed for concrete. The increased surface roughness of steel mill scale increases the internal friction between the cement paste and the particles.

Moreover, the granules of steel mill scale are considerably smaller than those of regular sand.

The greater surface area is a result of the finer texture of mild steel scale. Concrete's workability is diminished when steel mill scale is added, since more water is needed to bond the two together (Singhal et al. 2015 and Ozturk et al. 2020).

The results of a research comparing the densities of conventional concrete and concrete made with increasing percentages of steel mill scale for small particles (20%,40%, 60%, 80%, and 100%) are shown in Figure 4.3.

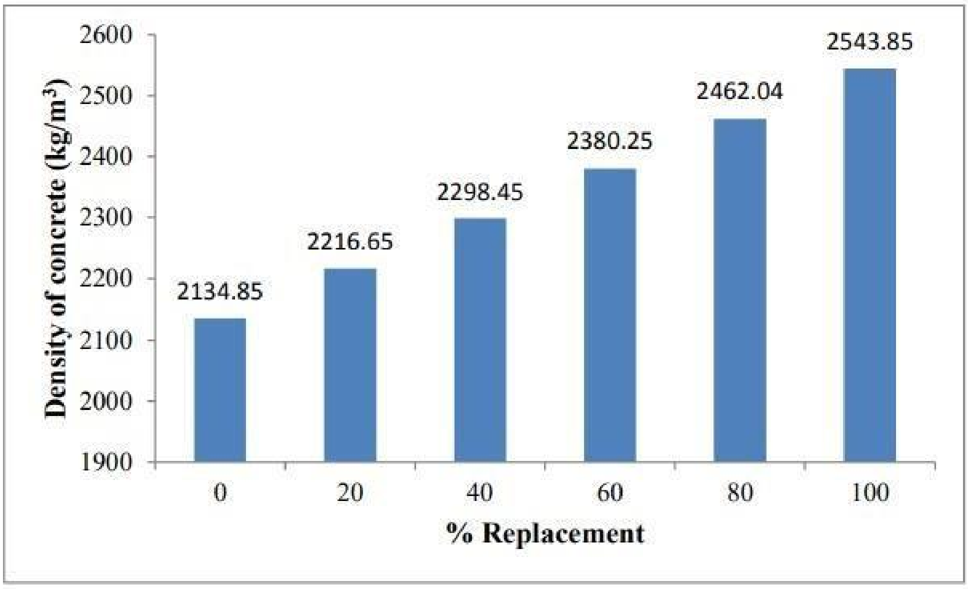

Figure 4.3 Concrete density for various replacements

The standard mixture had a density of 2134.85kg/m3. Concrete density is shown to grow gradually with the addition of steel mill scales, reaching a maximum of 2543.85kg/m3 at 100% replacement. When steel mill scale was used in lieu of sand, the density increased by around 20%.

Rough steel mill scale surfaces bond well with cement mortar, resulting in thick concrete. The finer steel mill scale particles also contribute to the increased density of the concrete. In concrete, this small particle fills the spaces between the coarser aggregates, making the material denser. With increased density, concrete also gains in its own weight. While this change does result in a little increase in self-weight, it is outweighed by the cost savings and improved performance that result from makingthis substitution.

CONCLUSION

Following the results of the experimental investigation, the following conclusions may be drawn;

Particles in steel mill scale, as seen by scanning electron microscopy (SEM), have an uneven form and a harsh surface roughness. With this, the particles may better interlock with one another to form stronger cement mortar.

This is supported by XRD findings that reveal steel mill scale particles include a wide variety of iron oxides, such as wustite, hematite, and magnetite. As a result, we can see that the particles of river sand are crystalline, whereas those of steel mill scale are amorphous. Therefore, it improves capacity for stuffing.

According to the results of the fresh concrete's slump test, the concrete displayed a shear slump from 0% to 20% steel mill scale replacement, and the true slump is formed with the constant addition of steel mill scale until 100% replacement. In spite of the strict IS 456-2000 guidelines, concrete became more difficult to work with as the amount of steel mill scale used in its stead increased. Compaction factor values also dropped when steel mill scale totally replaced river sand.

For every 20% of sand substituted with steel mill scale particles, concrete density increased by 4%, 8%, 12%, 15%, and 19%. Reason being the high specific gravity. Steel mill scale's fine size and rough texture encourage bonding with cement pastes, which in turn results in the production of high dense concrete.

For every 20% of sand replaced with steel mill scale, the compressive strength of the resulting concrete increased by 10.5%, 16.3%, and 32.3%; for 80% and 100% replacement, the strength increase was hardly noticeable. Ideally, you want to replace 60% of your cells, where strength is strongest. However, 100% replacement has a higher compressive strength than the controlled blend.

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