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Strength Characteristics of Cement Mortar With Stone Dust Replacement

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ABSTRACT

The demand for natural sand is quite high as there is an extensive use of concrete in the era of globalization and this will lead to certain problems in the construction field. India is one of the countries that are facing the same problems as other developing countries. Due to this situation, some developing countries are facing a shortage in the supply of natural sand. Quarry dust is one of the alternatives to replace the natural sand. This experimental study is undertaken to determine the optimum mix ratio of river sand and quarry dust in cement mortar. Three types of mix proportions of cement with sand were practiced in the mortar mixes that are 1:1, 1:2, 1:3 (cement: sand) and sand is partially replaced with stone dust 0%, 20%,40%,60%,80% and 100%.

Compressive strength is decreased if there is more content of quarry sand in the mixture. The compressive strength of the samples was determined on the 7th and 28th days. Results obtained indicate that the compressive strength of concrete increase with the increase of age. Mix ratio 1:1 (cement: sand) with replacement of 40% stone dust gives the highest compressive strength. More stone dust into the mortar mix as partial replacement material to sand resulted in the lower compressive strength. This can partly be attributed to the properties of the stone dust and sand which might contribute to the negative effects in the strength of the cubes

Key words, Concrete, natural sand, compressive strength, stone dust

1. INTRODUCTION

Sand is the one of main constituents of concrete making about 35 % of volume of concrete used in construction industry the paucity of suitable river sand for use as fine aggregate, in construction applications, digging sand, from river bed, in access quantity is hazardous to environment. The deep pits dug in the river bed, affects the ground water level. Erosion of nearby land is also due to and the recent construction boom has led to a dramatic increase in the price. Additionally various government agencies have put restrictions on sand quarrying to conserve this diminishing natural resources. This has prompted many engineers to look for alternate materials that are cheaper while possessing similar characteristics. One such alternative is the use of stone dust a byproduct of crushers.

The usage of stone dust is widely used in construction industry especially in producing cement or concrete blocks. In the process of making compressed concrete blocks, the design and construction procedures for load bearing and non-load bearing block work are not well documented in many national and international design codes or standards. So an experimental work is needed to study the effect of the different ratios of cement and sand on compressive strengths. Based on the results of compressive strengths the mix can be used for load bearing or non load bearing purposes.

2. LITERATURE SURVEY

Nagabhushana and Sharada bai (2011) replaced the natural sand with Crushed Rock Powder (CRP). The strength of mortar containing 40% CRP is much higher than normal mortar containing only sand as fine aggregate. Though the trend in variation of compressive strength with percentage of CCRP (???) was found to be similar to that of CRP mortar, the strength of CCRP mortar is less than that of CRP mortars. It is better to use CRP without removing the finer particles. For lean mortar mixes, CRP can be replaced up to 100%. For rich mortar mixes, CRP can be replaced up to 40%. It is concluded that the compressive strength, split tensile strength and flexural strengths of concrete are not affected with the replacement of sand by CRP as fine aggregate up to 40%. Hence, CRP can be effectively used to replace natural sand, without reduction in the strength of concrete with CRP replacement level up to 40%.

Ahmad and Mahmood (2008) have observed that the workability of concrete manufactured with crushed sand was lesser than that manufactured with natural sand. This reduction was from 6% to 11%.

Mahendrana and Nagamani (2008) studied the physical and chemical properties of quarry rock dust as per the requirements of codal provisions.. Natural river sand, if replaced by hundred percent quarry rock dust from quarries, may sometimes give equal or better than the reference concrete made with natural sand, in terms of compressive and flexural strength. Studies reported here and elsewhere have shown that the strength of quarry rock dust concrete is comparatively 10-12 percent more than that of similar mix of conventional concrete. Also the result of this investigation shows that drying shrinkage strains of quarry rock dust concrete are quite large to the shrinkage strain of conventional concrete. However, at the later age, they have shown equal strain than conventional concrete. The durability of quarry rock dust concrete under sulphate and acid action is higher than the conventional concrete. Permeability test results clearly demonstrates that the permeability of quarry rock dust concrete is less compared to that of conventional concrete. The water absorption of quarry rock dust concrete is slightly higher than conventional concrete. Therefore, the results of this study provide a strong support for the use of quarry rock dust as fine aggregate in concrete manufacturing. Thus, it can be concluded that the replacement of natural sand with quarry rock dust, as full replacement in concrete is possible. However, it is advisable to carry out trial casting with quarry rock dust proposed to be used, in order to arrive at the water content and mix proportion to suit the required workability levels and strength requirement. However, more research studies are being made on quarry rock dust concrete necessary for the practical application of quarry rock dust as fine aggregate

The 7.05 × 7.05 × 7.05 cm mortar cubes were tested by Sivakumar and Prakash (2011) to determine the compressive strength properties of different specimens. The compressive strength was obtained as per IS: 516 (1959)by testing on the mortar cube at 3, 7 and 28 days . The 28 days compressive strength of 100% replacement of sand with quarry dust of mortar cube (CM 1:1) was 11.8% higher than the controlled cement mortar cube. The 3, 7 and 28 days compressive strength of cement mortar had shown a decreasing trend compared to the reference concrete.

Rao (2010) has opined that the compressive strength of concrete can be improved by using admixtures. From his experimental results it is proved that, ROBO (???) sand can be used as alternative material for the fine aggregate i.e., sand. Based on the results the compressive and split tensile strengths are increased as the percentage of ROBO sand increased. The percentage of increase in the compressive strength are 19.64% and 8.03% at the age of 7 and 28 days and the percentage of increase in the split tensile strength is 1.83% at the age of 28 days, by replacing 30% of sand with ROBO sand with 1.5% admixture. GGBS can be used as one of the alternative material for the cement. From the experimental results 50% of cement can be replaced with GGBS. The percentage increase of compressive strength of concrete is 11.06% and 17.6% at the age of 7 and 28 days by replacing 50% of cement with GGBS and 25% of sand with ROBO sand.

3. MATERIAL AND METHIDS

3.1 CEMENT:

The history of cementing materials is as old as the history of engineering construction. Some kind of cementing materials were used by Egyptians, Romans and Indians in their ancient constructions. It is believed that the early Egyptians mostly used cementing materials, obtained by burning Gypsum. Not much light has been thrown on cementing material, used in the construction of the cities of Harappa and Mohenjo-Daro.

3.1.1 Early history of modern cement:

The investigations of Vicat led him to prepare an artificial hydraulic lime by calcining an intimate mixture of limestone and clay. This process may be regarded as the leading knowledge to the manufacture of Portland cement. James Frost also patented a cement of this kind in 1811 and established a factory in 9incomplete???).

3.1.1.1 Manufacture of Portland cement:

The raw materials required for manufacture of Portland cement are calcareous materials, such as lime stone or chalk, and argillaceous material such as shale or clay. Cement factories are established where this raw materials are available in plenty. Cement factories have come up in many regions in India, eliminating the inconvenience of long distance transportation of raw and finished materials.

The process of manufacture of cement consists of grinding the raw materials, mixing then intimately in certain proportions depending upon their purity and composition and burning them in a kiln at a temperature of about 1300-1500^{0}C, at which temperature, the materials sinters and partially fuses to form nodular shaped clinker. The clinker is cooled and ground to fine powder with addition of about 3-5% of Gypsum. The product formed by using the procedure is Portland cement.

There are two processes known as “wet” and “dry” processes depending upon whether the mixing and grinding of raw materials is done in wet or dry conditions. With a little change in the above process we have “semi-dry” process also, where the raw materials are ground dry and then mixed with about 10-14% of water and further burnt to clinkering temperature.

In the wet process, the lime stone brought from the quarries is first crushed to smaller fragments. Then it is taken to a ball or tube mill where it is mixed with clay or shale as the case may be and ground to a fine consistency of slurry with the addition of water. The slurry is a liquid of creamy consistency with water content of about 35 to 50%, wherein particles, crushed to the fineness of Indian Standard Sieve No. 9, are held in suspension. The slurry is pumped to slurry tanks or basins where it is kept in an agitated condition by means of rotating arms with chains or blowing compressed air from the bottom to prevent settling of limestone and clay particles. The composition of slurry is tested to give the required chemical composition and corrected periodically in the tube mill and also in the slurry tank by blending slurry from different storage tanks. Finally, the corrected slurry is stored in the final storage tanks and kept in a homogeneous condition by the agitation of slurry.

3. 1.2 Laboratory Testing:

The following tests are usually conducted in the laboratory:

- Standard consistency test
- Setting time test
    - Initial setting time
    - Final setting time
- Strength test
- Soundness test

3.1.2.1 Standard Consistency Test:

For finding out initial setting time, final setting time and soundness of cement, and strength a parameter known as standard consistency has to be used. It is pertinent at this stage to describe the procedure of conducting standard consistency test. The standard consistency of a cement paste is defined as that consistency which will permit a Vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from mould. The apparatus is called Vicat Apparatus. This apparatus is used to find out the percentage of water required to produce a cement paste of standard consistency. The standard consistency of the cement paste is some time called normal consistency (CPNC).

The following procedure is adopted to find out standard consistency. Take about 500 grams of cement and prepare a paste with a weighed quantity of water (say 24 per cent by weight of cement) for the first trial. The paste must be prepared in a standard manner and filled into the Vicat mould within 3-5 minutes. After completely filling the mould, shake the mould to expel air. A standard plunger, 10 mm diameter and 50 mm long is attached and brought down to touch the surface of the paste in the test block and quickly released allowing it to sink into the paste by its own weight. Take the reading by noting the depth of penetration of the plunger. Conduct a 2nd trial (say with 25 per cent of water) and find out the depth of penetration of plunger. Similarly, conduct trials with higher and higher water/cement ratios till such time the plunger penetrates for a depth of 33-35 mm from the top. That particular percentage of water which allows the plunger to penetrate only to a depth of 33-35 mm from the top is known as the percentage of water required to produce a cement paste of standard consistency. This percentage is usually denoted as ‘P’. The test is required to be conducted in a constant temperature (27° + 2°C) and constant humidity (90%).

3.1.2.2 Setting Time Test:

An arbitrary division has been made for the setting time of cement as initial setting time and final setting time. It is difficult to draw a rigid line between these two arbitrary divisions. For convenience, initial setting time is regarded as the time elapsed between the moment that the water is added to the cement, to the time that the paste starts losing its plasticity. The final setting time is the time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure. In actual construction dealing with cement paste, mortar or concrete certain time is required for mixing, transporting, placing, compacting and finishing. During this time cement paste, mortar, or concrete should be in plastic condition. The time interval for which the cement products remain in plastic condition is known as the initial setting time. Normally a minimum of 30 minutes is given for mixing and handling operations. The constituents and fineness of cement is maintained in such a way that the concrete remains in plastic condition for certain minimum time. Once the concrete is placed in the final position, compacted and finished, it should lose its plasticity in the earliest possible time so that it is least vulnerable to damages from external destructive agencies. This time should not be more than 10 hours which is often referred to as final setting time.

The Vicat Apparatus shown is used for setting time test also. The following procedure is adopted. Take 500 gm. of cement sample and gauge it with 0.85 times the water required to produce cement paste of standard consistency (0.85 P). The paste shall be gauged and filled into the Vicat mould in specified manner within 3-5 minutes. Start the stop watch the moment water is added to the cement. The temperature of water and that of the test room, at the time of gauging shall be within 27°C ± 2°C.

(a) Initial Setting Time

Lower the needle (C) gently and bring it in contact with the surface of the test block and quickly release. Allow it to penetrate into the test block. In the beginning, the needle will completely pierce through the test block. But after some time when the paste starts losing its plasticity, the Vicat Apparatus and Accessories. Automatic Vicat Apparatus needle may penetrate only to a depth of 33-35 mm from the top.

(b) Final Setting Time

Replace the needle of the Vicat apparatus by a circular attachment. The cement shall be considered as finally set when, upon, lowering the attachment gently cover the surface of the test block, the centre needle makes an impression, while the circular cutting edge of the attachment fails to do so. In other words the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5 mm.

3.1.2.3 Strength Test:

The compressive strength of hardened cement is the most important of all the properties. Therefore, it is not surprising that the cement is always tested for its strength at the laboratory before the cement is used in important works. Strength tests are not made on neat cement paste because of difficulties of excessive shrinkage and subsequent cracking of neat cement. Strength of cement is indirectly found on cement sand mortar in specific proportions. The standard sand is used for finding the strength of cement. It shall conform to IS 650 (1991). Take 555 grams of standard sand (Ennore sand), 185 grams of cement (i.e., ratio of cement to sand is 1:3) in a non-porous enamel tray and mix them with a trowel for one minute, then add water of quantity P + 3.0 per cent of combined 4 weight of cement and sand and mix the three ingredients thoroughly until the mixture is of uniform colour. The time of mixing should not be less than 3 minutes nor more than 4 minutes. Immediately after mixing, the mortar is filled into a cube mould of size 7.06 cm. The area of the face of the cube will be equal to 50 sq cm. Compact the mortar either by hand compaction in a standard specified manner or on the vibrating equipment (12000 RPM) for 2 minutes. Keep the compacted cube in the mould at a temperature of 27°C ± 2°C and at least 90 per cent relative humidity for 24 hours. Where the facility of standard temperature and humidity room is not available, the cube may be kept under wet gunny bag to simulate 90 per cent relative humidity. After 24 hours the cubes are removed from the mould and immersed in clean fresh water until taken out for testing.

The periods being reckoned from the completion of vibration. The compressive strength shall be the average of the strengths of the three cubes for each period respectively.

3.1.3 Curing

The operation of curing is designed to overcome the problems of loss of hydration and freezing of the mortar. If cured correctly, the mortar becomes impermeable and durable and has a dense, hard surface that is free from cracks and crazing. There are various methods of curing available, depending upon the situation in which the mortar is being used. The mortar cubes are cured in curing tank for a period of 28 days.

3.1.4 Workability test

Workability of mortar is its ease of use, measured by the flow of the mortar. The standard flow tests uses a standard conical frustum shape of mortar with a diameter of four inches (10 cm). This mortar sample is placed on a flow table and dropped 25 times within 15 seconds. As the mortar is dropped, it spreads out on the flow table. The initial and final diameters of the mortar sample are used to calculate flow. Flow is defined as the increase in diameter divided by the original diameter multiplied by 100. Laboratory mixed mortar, where conditions are more controlled, should have a flow of approximately 110.

3.2 Sieve analysis

Fine aggregate used in mortars is sand. Coarse aggregate used in concrete is the broken stone. The coarse aggregate unless mixed with fine aggregate serves no purpose in cement works. The size of the fine aggregate is limited to maximum 4.75 mm (480 microns) beyond which it is known as coarse aggregate.

Fineness modulus is only a numerical index of fineness, giving some idea of the means size of the particle in the entire body of aggregate. Determination of fineness modulus may be considered as a method of standardization of the grading of the aggregates. It is obtained by sieving a known weight of given aggregate in a set of standard sieves and by adding the % weight of material retained on all the sieves and dividing the total percentage by 100.

3.3 Replacement of sand with stone aggregate

1) Take 1 kg sand from 10 kg by quartering in clean dry plate
2) Arrange sieves in order of Nos. 480, 240, 120, 60, 30 and 15 keeping sieve 480 at top and 15 at bottom. Fix them in the sieve shaking machine with the pan at the bottom and cover at the top.
3) Keep the sand in the top sieve to carry out the sieving in the set of sieves as arranged before for not less than 10 minutes.

4) Find weight retained on each sieve.

The above procedure is followed for partial and full replacement of sand with stone dust.

3.4 COMPRESSIVE STRENGTH

Compressive strength of CRP mortars: The materials required for the number of specimens were dry mixed and then mixed with calculated amount of water. The quantity of water is obtained as per IS: 4032 (1988). It is given by Percentage of water equal to (P/4 +3) percent of combined weight of cement and fine aggregate, where P is the percentage of water required to produce a cement paste of standard Consistency.

While preparing the specimens for each proportion, a reference mix using cement and natural sand is prepared. This is done in order to compare CRP mortar with the normal mortar. For each CRP replacement, the total fine aggregate quantity is obtained as the combination of natural sand and CRP. For example, the first set of specimens consists of 20% CRP and 80% of natural sand as fine aggregate. For each mortar mix and for each replacement level of CRP, 18 specimens were casted. The results were obtained by testing 6 specimens each at 3 days, 7 days and 28 days. The testing of specimens was carried out as per IS 4031 (1988). Specimens were tested with a gradually increasing compressive load until they fail by crushing

4. DISCUSSION ON RESULTS

The following results are discussed below

4.1 Percentage bulking:

Stone dust is replaced as 20% 40% 60% 80% and 100% as fine aggregate for determining percentage bulking, the results are plotted in Fig. 4.1..

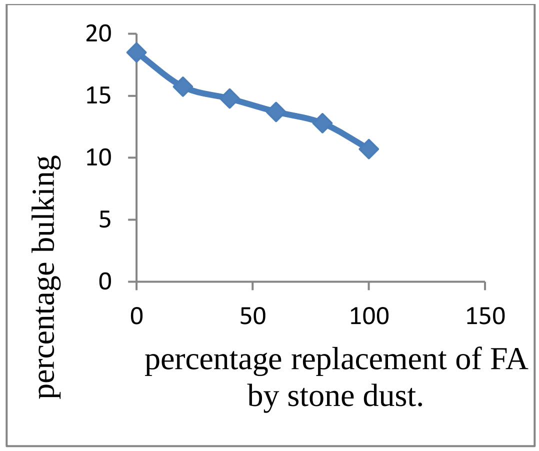

Fig.4.1 Percentage replacement of FA by stone dust v/s percentage bulking.

- Percentage bulking is gradually decreases with replacement of stone dust.
- In case of volume batching can be preferred as the replacement of stone dust increases.
- The reason for this behaviour can be attributed to the fact that the crushed rock powder particles being longer and angular do not promote the formation of double layer between the particles.

4.2 SIEVE ANALYSIS

Stone dust is replaced as 0%, 20%, 40%, 60%, 80% and 100% as fine aggregate for determining fineness modulus of aggregate, sieve analysis has been done and the results are plotted in Fig. 4.2.

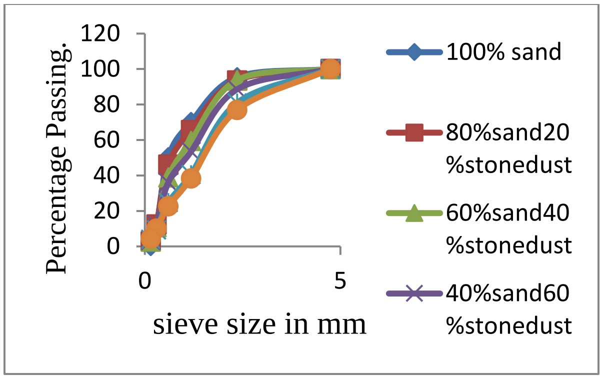

Fig.4.2 sieve size in mm v/s percentage passing

- It is observed that with increase in percentage of stone dust results in the increase of fineness modulus
- Fineness modulus increases with increase in replacement of stone dust. Because the stone dust used is having more finer content (2.36-300 micron).
- Aggregate of the same fineness modulus which require the same quality to produce the mix of same consistency and strength.
- Higher the fineness coarse the aggregate lower the fineness modulus results in more past making concrete workable.
- As the fineness modulus increases with the increasing stone dust i.e., workability is getting reduced.

4.3 Compressive strength at 7 days:

Stone dust is replaced as 20% 40% 60% 80% and 100% as fine aggregate for determining the compressive strength at 7 days. Percentage replacement of stone dust v/s compressive strength at 7 days has been plotted in Fig. 4.3.

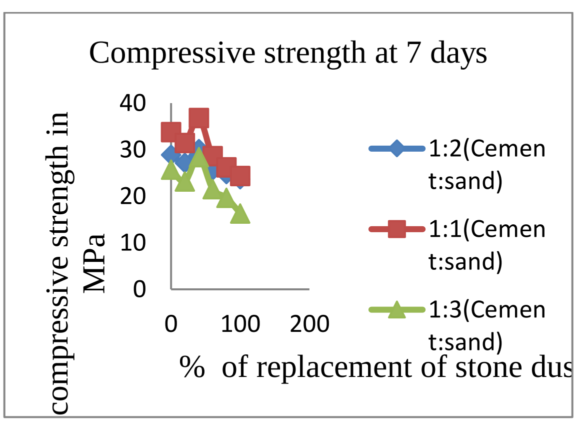

Fig.4.3 Percentage replacement of stone dust v/s compressive strength at 7 days

4.4 Compressive strength at 28 days:

Stone dust is replaced as 20% 40% 60% 80% and 100% as fine aggregate for determining the compressive strength at 28 days. Percentage replacement of stone dust v/s compressive strength at 28 days has been plotted in Fig. 4.4.

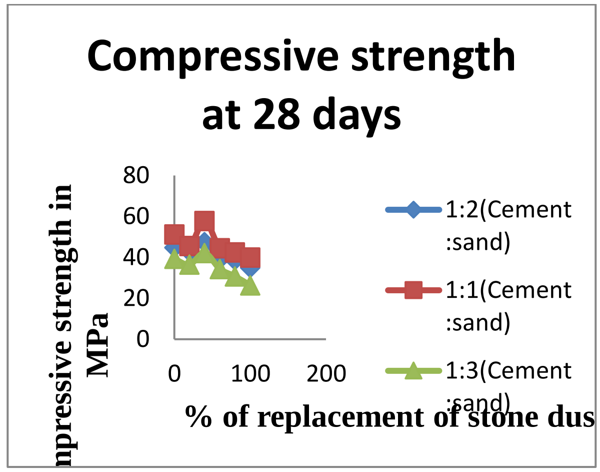

Fig.4.4 Percentage replacement of stone dust v/s compressive strength at 28 days.

CONCLUSION

It can be seen from the results of this study that the combination of quarry dust to replace the conventional river sand in the production of cement mortar for the construction industry and should be encouraged where there is comparative cost advantage.

It is observed that the compressive strength of 1:1, 1:2, 1:3 mix proportions at 40% stone dust are higher than normal mortar.

A 6% increase in magnitude of compressive strength is observed compared to normal mortar with 40% replacement of sand with stone dust for 1:1.

For compressive strength 40% replacement with stone dust in cement mortar is found to be a best alternative for replacement

Reference

1. Nagabhushana and H. Sharada bai "Use of crushed rock powder as replacement of fine aggregate in mortar and concrete" Indian Journal of Science and Technology. Vol. 4 No. 8 (Aug 2011)
2. Saeed Ahmad , Shahid Mahmood" effects of crushed and natural sand on the properties of fresh and hardened concrete" 33rd Conference on

our world in concrete & structures: 25 – 27 August 2008, Singapore.

3. R. Mahendrana, N. and Nagamanib, K., 2008, "Strength and durability properties of concrete containing quarry rock dust as fine aggregates", ARPN Journal of Engineering and Applied Science, Vol.3(5), pp 2026.
4. A. Sivakumar and Prakash M. "Characteristic studies on the mechanical properties of quarry dust addition in conventional concrete" Journal of Civil Engineering and Construction Technology Vol. 2(10), pp. 218-235, October 2011 Available online at
5. P. N. Rao, **"**High performance concretewith GGBS and ROBO sand" Venu Malagavelli et. al. / International Journal of Engineering Science and Technology Vol. 2(10), 2010, 5107-5113.