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Optimization on Strength Properties of Concrete by Partial Replacement of Fine Aggregate with Granite Powder

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ABSTRACT

The most commonly used fine aggregate all over the world is river sand. River sand is expensive due to excessive cost of transportation from natural sources. The granite is an igneous rock which is widely used as a constructional material in different forms. The byproduct produced from granite industry is granite powder, which is largely left unused and is hazardous to human health because they are airborne and can easily inhaled. The granite powder waste can be utilized for the preparation of concrete as a partial replacement of sand. The percentage of granite powder added by weight of sand is 0,5,10,15,20. The cubes are casted using M30 grade mixes. This experimental study presents the test results of compressive strength and split tensile strength for 7,14,28 days. Test results indicate that the use of granite powder and admixtures in concrete has improved the performance of concrete in strength as well as in durability aspect.

1. INTRODUCTION

Concrete is one of the major construction materials being utilized worldwide. Concrete is made usually from a properly proportioned mixture of cement, water, fine and coarse aggregates and often, chemical and mineral admixtures. Cement is the important binding material in concrete. Fine aggregate is an essential component of concrete. The global consumption of natural river sand is very high due to the extensive use of concrete. In particular, the demand for natural river sand is quite high in developed countries owing to infrastructural growth. In this situation some developing countries are facing a shortage in the supply of natural sand. The non-availability of sufficient quantity of ordinary river sand for making cement concrete is affecting the growth of the construction industry in many parts of the country. Therefore, the construction industries in developing countries are under stress to identify alternative materials to reduce the demand on river sand.

In order to reduce the dependence on natural aggregates as the main source of aggregates in concrete, artificially manufactured aggregates and artificial aggregates generated from industrial wastes provide an alternative for the construction industry. Some alternative materials have already been used in place of natural river sand. For example, fly ash, slag and lime stone, siliceous stone powder, rock dust and quarry waste were used in concrete mixture as a partial replacement of natural sand. The experimental parameter was the percentage of granite powder substitution. The cubes and cylinders were prepared using 0%, 5%, 10%, 15%, 20% and 25% of fine/natural aggregate substituted by GP waste. To understand fully the influence of GP waste on the behavior of concrete, several tests such as, slump cone, split tensile strength, flexural strength, and compressive strength tests were performed. Hence the assumption is granite powder aggregate could be an alternative to natural sand in preparation of concrete.

Granite powder, one of the byproducts in granite stone crushing process, not being used for any applications other than filling-up low-lying areas is identified as a replacement material for river sand in concrete. The granite waste generated by the stone crushing industry has accumulated over the years. Only insignificant quantities have been utilized and the rest has been unscrupulously dumped resulting in environmental problems. Presently, all the processing units are disposing this industrial waste by dumping it in open yards, that nearly occupying 25% of the total area of the industry. Only insignificant quantity has been utilized and the rest has been dumped unscrupulously resulting in pollution problems. With the enormous increase in the quantity of waste needing disposal, acute shortage of dumping sites, sharp increase in the transportation and dumping costs necessitate the need for effective utilization of this waste. The present work is aimed at developing a concrete using the granite scrap, an industrial waste as a replacement material for the fine aggregate. By doing so, the objective of reduction of cost of construction can be met and it will also help to overcome the problem associated with its disposal including the environmental problems of the region. Accordingly, this project work will examine M20, M30 and M40 grades of concrete were cast by varying the percentage replacement of sand with granite powder. It is suitable for concrete mix and improves the properties of concrete i.e., compressive strength etc. The objectives of various properties of concrete using silica fume have been evaluated. Further to determine the optimum replacement percentage comparison between the regular concrete and concrete containing granite powder is done. It has been seen that when cement is replaced by granite powder compressive strength increases up to certain percentage. But higher replacement of fine aggregate by granite powder gives lower strength. Properties of hardened concrete via Ultimate Compressive strength, Flexural strength, Split Tensile strength has been determined for different mix combinations of materials and these values are compared with the corresponding values of conventional concrete

Advantages of granite powder in concrete

- Improves the strength properties when compared to normal concrete
- Reduces the cost of construction to some extent

LITERATURE REVIEW

DoddaNagaraju (jun-2017) An experimental study on partial replacement of granite powder in fine aggregate. Concrete mixture consists of cement, fine aggregate and coarse aggregate. By replacement of sand with granite powder is a lighter material compared to aggregates. Compressive strength and split tensile strength tests were conducted on all the specimens at 7 days, 21 days and 28 days' time period. By replacing the granite powder in concrete, the strength of concrete increases. The test results show clearly that the replacement of fine aggregate with granite powder by 25% is found to give high strength when compared to normal concrete.

S. Arulkesavanetal (mar-2017) examined the possibility of using granite powder as replacement of sand in the concrete. The test results indicated that the compressive strength, flexural strength and split tensile strength increased with addition of granite powder with 10% replaced by weight of sand and further addition of granite powder was found to be decrease the strength values. The optimal percentage replacement was found to be 10% of granite powder.

DigeS.Setal (2016) Granite fines, which are the by products produced from granite industries. The cost is very less when compared to the river sand. Concrete is prepared with granite fines as a replacement of fine aggregate in different proportions namely 0%, 10%, 15%, 20% and 25%. Various tests such as compressive strength, split tensile strength and flexural strength were carried out. The test results reported that the material can replace upto25% but the optimum strength values were observed to be found at 15% of granite fines replacement.

Karthiketal (2016) Investigates experimental investigation on concretewith partially replacementof cement and fully replacement of sand. Fluorescent lamp powder as one of the new materials into the concrete replaces the cement. Physical and chemical properties of fluorescent lamp powder satisfy the requirements of Ordinary Portland Cement. Replacement of the sand with quarry dust increases the workability. Increase of percentages of iron slag in the concrete mix, the compressive strength also increases.

Mr.G.Rajaetal (may-2016) Granite fines can be effectively used as a replacement material for fine aggregate in concrete. The percentage replacement of granite fines to fine aggregate are 0, 10, 20, 30, 40, 50 and 100. For the purpose of investigation cubes were casted with different proportions and these were tested after 28 days curing for compressive strength, split tensile strength and flexural strength. The test results show that the increase in strength with replacement of granite fines.

Mr.B.Senthiletal (2015) examined that the quarry dust has been proposed as an alternative of fine aggregate that gives additional benefits to concrete such as increase in the strength of concrete over concrete made with equal quantities of river sand. Sand has been most important material for construction industries. Due to increase in the cost of sand and decreasing the sand resources they replaced the quarry dust in place of sand. From the results of experimental investigation, the materials such as quarry and granite waste can be used as a replacement for fine aggregate. It is found that 30% replacement of fine aggregate by industrial waste give the maximum result in strength and quality aspects than conventional concrete.

Arivumangaietal (2014) examined the properties of concrete by varying the granite powder as a replacement of sand in concrete that have originate from granite crushed units along with admixtures such as silica fume, fly ash and superplasticizer as a partial replacement of cement. The test results show clearly that granite powder as a partial replacement of sand has beneficial effects of concrete and the optimum strength values were found at 25% of granite powder and thus also improve the chemical resistance of concrete.

Sudhir.S.Kalpateetal(2013)studied about effect of quarry dust as a partialreplacement of sand in concrete and has revealed that with increase of percentage of granite fines resulted in decrease in workability and compressive strength reached maximum at replacement percentage of 25% and later decreased.

Dr.T.Felixkala(may-2013) studied the performance of concrete made with partial replacement of fine aggregate with granite powder and also partial replacement of cement with 7.5% silica fume, 10% flyash and 10% slag subjected to water curing is conducted for finding the mechanical properties such as compressive strength, split tensile strength, modulus of elasticity, flexural strength and water absorption characteristics of concrete mixtures. The test results show clearly that granite powder as a partial replacement has beneficial effects on mechanical properties and the optimum values are found at 25% of granite powder.

EXPERIMENTAL WORK:

The following materials are used in concrete mix:

- Cement
- Fine aggregate
- Coarse aggregate
- Granite powder
- Water

TESTS ON MATERIALS:

TESTS ON CEMENT

- ✓ NORMAL CONSISTENCY OF CEMENT
- ✓ FINENESS OF CEMENT
- ✓ INITIAL AND FINAL SETTING TIME
- ✓ SPECIFIC GRAVITY OF CEMENT

TESTS ON FINE AGGREGATE

- ✓ SIEVE ANALYSIS OF FINE AGGREGATE
- ✓ SPECIFIC GRAVITY OF FINE AGGREGATE
- ✓ WATER ABSORPTION OF FINE AGGREGATE
- SPECIFIC GRAVITY OF GRANITE POWDER

MIX DESIGN:

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in two states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labour. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economic compromise, and depends on the size and type of job.

The cost of labour depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labour to obtain a degree of compaction with available equipment.

Requirements of Concrete Mix Design:

- The requirements which form the basis of selection and proportioning of mix.
- The minimum compressive strength required from structural consideration.
- The adequate workability necessary for full compaction with the compacting equipment available.
- Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions.
- Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

TYPES OF MIX:

Nominal Mix

In the past the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement-aggregate ratio which ensures adequate strength are termed nominal mixes. These offer simplicity and under normal circumstances, have a margin of strength above that specified. However, due to the variability of mix ingredients the nominal concrete for a given workability varies widely in strength.

Standard mix

The nominal mixes of fixed cement-aggregate ratio (by volume) vary widely in strength and may result in under- or over-rich mixes. For this reason, the minimum compressive strength has been included in many specifications. These mixes are termed standard mixes.

IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20, M30, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28-day cube strength of mix in N/mm2. The mixes of grades M10, M15, M20 and M30 correspond approximately to the mix proportions (1:3:6), (1:2:4), (1:1.5:3) and (1:1:2) respectively.

Designed Mix:

In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down. This is most rational approach to the selection of mix proportions with specific materials in mind possessing more or less unique characteristics.

Mix Proportion Designation

The common method of expressing the proportions of ingredients of a concrete mix is in the terms of parts or ratios of cement, fine and coarse aggregates.

For e.g., a concrete mix of proportions 1:2:4 means that cement, fine and coarse aggregate are in the ratio 1:2:4 or the mix contains one part of cement, two parts of fine aggregate and four parts of coarse aggregate. The proportions are either by volume or by mass. The water cement ratio is usually expressed in mass.

Principles of Mix Design

- The environment exposure condition for the structure

➢ The grade of concrete, their characteristic strength's and standard deviations
➢ The type of cement
➢ The types and sizes of aggregates and their sources of supply
➢ The nominal maximum sizes of aggregates
➢ Maximum and minimum cement content in kg/m^3
➢ Water cement ratio
➢ The degree of workability of concrete based on placing conditions
➢ Air content inclusive of entrained air
➢ The maximum / minimum density of concrete
➢ The maximum/minimum temperature of fresh concrete
➢ Type of water available for mixing and curing
➢ The source of water and the impurities present in it.

Environmental Exposure Conditions :(Clause 8.2.2.1 and 35.3.2):

S. o	Environm ntal	Exposure condition
1	Mild	Concrete surface protected against eather expect those situated in coastal eas
2	Moderate	Concrete surfaces sheltered from severe rain freezing whilst wet concrete exposed to ndensation and rain concrete continuously der water concrete in contact or buried under n-aggressive soil concrete surfaces sheltered om saturated salt air in coastal area.
3	Severe	Concrete surfaces exposed to sever rain, ernate wetting and drying or occasional eezing whilst wet or severe condensation. oncrete completely immersed in sea water ncrete exposed to coastal environment.
4	Very vere	Concrete surfaces exposed to sea water ray, corrosive fumes or sever freezing nditions whilst wet. Concrete in contact with buried under aggressive sub-soil
5	Extreme	Surfaces of members in tidal zone members tidal zone members in direct contact with uid/solid aggressive chemicals.

TESTS CONDUCTED:

After the mix design, the casting of specimens is the next step in this experimental study. The various types of specimens, such as Cubes, Beams, and Cylinders, were casted using standard procedures. The prepared samples were tested in the laboratory to determine their strength characteristics according to the standard procedures specified in the respective IS codes.

Compressive Strength

Casting of Cubes

Compression test was carried out on 150 x 150 x 150 mm size cubes. The specimens were loaded at a constant strain rate until failure. The compressive strength is decreased with an increase in the percentage of Metakaolin and M-Sand in Cement and Fine aggregate. Results for compressive strength of cubes for 3 days, 7 days and 28 days N/mm^2.

Split Tensile Strength

Casting of Cylinders

The test method covers the determination of the splitting tensile strength of cylindrical concrete specimens, such as molded cylinders of size 150 mm diameter and 300 mm height. This test method consists of applying a diametric

compressive force along the length of a cylindrical concrete specimen at a rate that is within a prescribed range until failure occurs. This loading induces tensile stresses on the compressive stresses in the area immediately around the applied load.

Flexural Strength

Casting of Beams

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 6 x 6 – inch (150 x 150 – mm) concrete beams with a span length at least three times the depth. The flexural strength is expressed as modulus of rupture (MR) in psi (Mpa) and is determined by standard test method ASTM C 78 (third-point loading) or ASTM C 293 (center point loading).

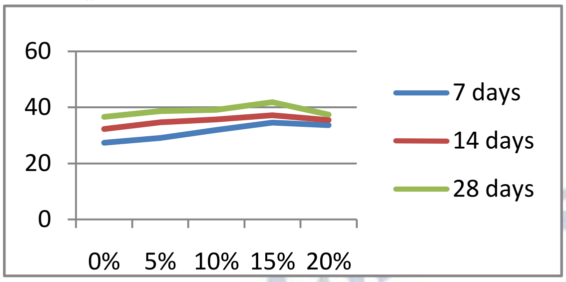
Table:1Compressive strength of the concrete cubes

PERCENTAGE OF GRANITE POWDER ADDED	SPLITTENSILE STRENGTH(N/mm2)		
	7 DAYS	14 DAYS	28 DAYS
0%	2.86	3.32	3.74
5%	2.89	3.36	3.89
10%	3.41	3.50	3.91
15%	3.48	3.69	4.21
20%	3.46	3.54	3.98

RESULTS

The Compressive strength of the concrete cubes with Sand Replacement

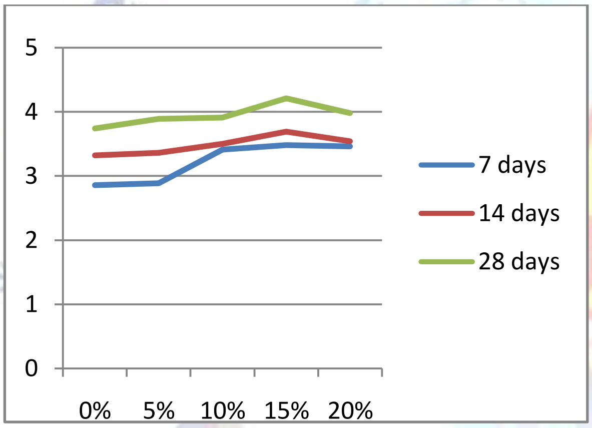
Graph:1



The Split Tensile Strength of the concrete cylinders with Sand Replacement

Table :2 Tensile strength of the concrete cylinders

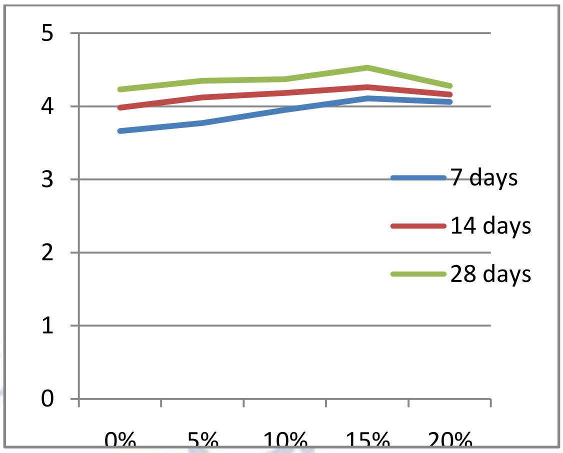
Graph:2



The Flexural strength of the concrete Prisms with Sand Replacement:

Table:3 Flexural strength of the concrete prisms

PERCENTAGE OF GRANITE POWDER ADDED	FLEXURAL STRENGTH(N/mm2)		
	7 DAYS	14 DAYS	28 DAYS
0%	3.66	3.98	4.23
5%	3.77	4.12	4.35
10%	3.95	4.18	4.37
15%	4.11	4.26	4.53
20%	4.06	4.16	4.28



Graph:3

CONCLUSIONS:

The following conclusions are drawn from this investigation:

- It is observed that the compressive strength and flexural strength of concrete can be improved by partial replacement of granite powder for fine aggregate.
- From the above experimental results, it is proved that, granite powder can be used as partial replacement for the natural sand, and the compressive and flexural strengths are increased as the percentage of granite powder is increased up to optimum level. The optimum percentage of replacement of natural sand by granite powder is 15%
- Due to scarcity of natural sand and its high cost could encourage the adoption of granite powder by replacement of natural sand.
- The Split Tensile Strength increases with the increase in percentage of granite powder as well as with 15% of granite powder and the maximum Tensile Strength obtained is 3.29N/mm^2.
- The Flexural Strength also increases with the increase in percentage of granite powder as well as with 15% percentage of granite powder and the maximum Flexural Strength obtained is 4.70 N/mm^2.
- The maximum increase in Compressive Strength, Split Tensile Strength, and Flexural Strength is higher than compared to that of the conventional mix at the age of 28 days.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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