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(**Vikash Kumar**)

DEPARTMENT OF CIVIL ENGINEERING

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY

JAIPUR, RAJASTHAN-302017

CERTIFICATE

This is to certify that the dissertation report on **“A study on use of Quarry dust as fine aggregate in mortar”** which is submitted by **Vikash Kumar** (2014PCW5170), in partial fulfillment for the Master of Technology in **Water Resource Engineering** to the Malaviya National Institute of Technology, Jaipur. It is a record of student’s own work carried out by him under our supervision and guidance during academic session (2014-2016). This work is approved for submission.

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ABSTRACT

Stone industries of Rajasthan are spread across all its districts, from the backbone of its economy. So there is a huge amount of quarry waste generated from the industry, which is also critical from the environment point of view. Quarry dust is just dumped in the open creating health hazards. This affects the productivity of the soil. It reduces permeability which prevents from ground water recharge. Due to huge demand of natural aggregate it is our need to look for the alternative resources. In this study an investigative experiment is reported on the mechanical properties of mortar modified by quarry dust as replacing material of fine aggregate. An endeavor has been made to evaluate the compatibility of quarry dust as construction materials. Properties of mortar are investigated with the replacement of 30%, 50%, 70%, and 100% of fine aggregate.

In this report, investigation will be carried out to use such in mortar, hence different tests were carried out as Compressive strength, Workability – Flow table test, Capillarity Test, Evaluation of durability properties, Water absorption and drying shrinkage on mortar mix. Results are compared to control mix and experimental mixes (using quarry dust in different replacement ratios).

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CHAPTER -1

INTRODUCTION

1.1 General

In the recent past good attempts have been made for the successful utilization of various industrial by products (such as fly ash, silica fume, rice husk ash, foundry waste) to save environmental pollution. In addition to this, an alternative source for the potential replacement of natural aggregates in mortar has gained good attention. As a result reasonable studies have been conducted to find the suitability of quarry dust in conventional mortar. The function of the fine aggregate is to assist in producing workability and uniformity in the mixture. The river deposits are the most common source of fine aggregate. Now-a-days the natural river sand has become scarce and very costly. Hence we are forced to think of alternative materials. The Quarry dust may be used partially in the place of river sand.

The most common challenge faced by any manufacturing industry is the problem associated with depleting energy resources and the associated CO_2 emissions. The cement industry is no different, with that the manufacture of OPC produces 6% of the global carbon di oxide emissions. Though there are enough regulations for the production and use of OPC and concrete, the aspiration of economic growth fuelled by population and economic growth has projected that the demand can be as high as four times by middle of this century.

Apart from the cement production, aggregate and metal ore extraction too has caught the attention of environmentalists. Haphazard mining has depleted the natural resources, leading to imbalance in the ecosystem. Industries consume a lot of energy for processing these ores (15% of total electricity usage and 11% of total final energy consumption), consequently emitting greenhouse gases and producing wastes on a large scale. Though not on a satisfactory level but a few of these wastes have found suitable applications in some form elsewhere. In addition to all this the quality of natural rock is bound to decline, which would magnify these problems further. On the other hand the non-availability of sufficient quantity of ordinary river sand and aggregates for making cement concrete is affecting the growth of construction industry in many parts of the country. Hence, the use of industrial or agricultural by-products for partial/complete substitution in concrete is an environmental friendly method of disposal of large quantities of such materials that would otherwise pollute land, water and air and also reduce the stress on naturally occurring minerals.

1.2 Quarry Dust

The dust is selected from the nearest source as raw materials without any processing of the dust from the quarry. Quarry dust, a by-product from the crushing process during quarrying activities is one of those materials that have recently gained attentions to be used as concreting aggregates, especially as fine aggregates. Quarry dust have been used for different activities in the construction industry, such as road construction, and manufacture of building materials, such as lightweight aggregates, bricks, tiles and autoclave blocks.

Figure 1.1 Quarry dust

The quarry dust is the by-product which is formed in the processing of the granite stones which broken downs into the coarse aggregates of different sizes.

1.3 Canal lining

Hydraulic structures are anything that can be used to divert, restrict, stop, or otherwise manage the natural flow of water. Here the study area of hydraulic structure is canal lining. There are different types of canal lining, but this study only focus on the cement- mortar lining and brick lining. The canal is said to be lined with bricks when the sides and bed are protected with brick Surfacing laid in cement mortar.

Canal lining is that method of reducing seepage loss of irrigation water by adding associate impervious layer to the perimeters of the ditch. Water saved by canal lining may reduce by 30 to 50 % of irrigation water from canals, thus adding lining will create irrigationsystems additional economical.Canallinings are accustomed st op weed growth, which may unfold throughout associate irrigation system and scale back water flow. Lining a canal may stop waterlogging around low lying areas of the canal. Lining results in several others advantages like discharge increases, reduce the size of canal, maintenance of canal (which results in the increase revenue) etc.

1.4 Objective of study

The objective of this study is to find suitable utilization percentage of quarry dust which is produced from the quarrying process of the sand stone. Conventional fine aggregate is proposed to be partly replaced in mortar. The impact of research shall be reduction in environmental pollution, saving of fertile land undergoing barren process and saving of natural aggregate. The main focus of this study is to observe and analyze the strength, water absorption, voids ratio, capillarity and durability properties of mortar incorporated with quarry dust.

CHAPTER-2

LITERATURE REVIEW

Following is a review of research works carried out till date where quarry dust has been utilized as fine aggregate in manufacture of concrete, mortar and bricks.

M.Fauzi ***et.al*** Silica fume and fly ash are used to replace 10% of cement by weight. They are used either separately or in combination with quarry dust in the concrete mixes. Quarry dust is incorporated to replace 20% and 40% of sand in the respective mixes. Super plasticizer and air entraining admixture are used as chemical admixtures to control the flow ability of fresh concrete. This chapter focuses on the physical properties of fresh concrete mixes that are monitored batch by batch. The properties of fresh mixes are determined in respect of slump, slump flow, V-funnel flow, air content, mix temperature, and unit weight. It is observed that the properties, particularly, the flow and the entrained air content are influenced by the presence of mineral and chemical admixtures. In presence of super plasticizer, silica fume provides better flow properties than fly ash. Besides, the incorporation of quarry dust improves the flow ability of fresh mixes. The outcome of the study given in the chapter suggests the use of quarry dust as partial replacement of sand to augment the flow ability of high performance concrete.

Nagabhushana1 and H. Sharadabai present investigation aims in the study of properties of mortar and concrete in which Crushed Rock Powder (CRP) is used as a partial and full replacement for natural sand. For mortar, CRP is replaced at 20% 40%, 60%, 80% and 100%. The basic strength properties of concrete were investigated by replacing natural sand by CRP at replacement levels of 20%, 30% and 40%.This study reveals that in case of cement mortars, the natural sand can be replaced by 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 ofCCRP mortar is less than that of CRP mortars. It is better to use CRP without removing the finer particles. 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%.

BabooRai ***et.al.***This paper presents the results of an experimental investigation carried out to evaluate the compressive strength and transverse strength of 1:3mortar mixes in which natural sand was replaced with 20%, 50%, and 100%quarry dust by weight which were further modified by partially replacing cement with four percentages (15%, 20%, 25%, and 30%) of low calcium fly ash. The compressive strength was determined at 3, 7, 28, and 50 days of age while transverse strength was determined at 28 and 50 days age. Test results revealed that the combined use of quarry rock dust and fly ash exhibited excellent performance due to efficient micro filling ability and pozzolanic activity. From the present investigation and limited observations reported, the combined use of quarry rock dust and fly ash exhibited excellent performance due to efficient micro filling ability and pozzolanic activity. It was observed that the decrease in early strength by the addition of fly ash is ameliorated by the addition of quarry dust. Therefore, the results of this study provide a strong recommendation for the combined use of quarry rock dust and fly ash in

Mortar/concrete manufacturing. Quarry dust qualifies itself as suitable substitute for river sand. Thus, it can be concluded that the replacement of natural sand with quarry dust, as partial replacement, in mortar/concrete is possible.

TasniaHoque et.al. In this paper an investigative experiment is reported on the mechanical properties of mortar modified by stone dust as replacing material of both fine aggregate and cement. An endeavor has been made to evaluate the appropriateness of stone dust as construction materials. Properties of mortar are investigated with the replacement of 25% and 50% of fine aggregate and also 5% of cement by stone dust. Cubes and briquette samples were casted and tested after a curing period of 3, 7 and 28 days. Several samples were made by using above proportion to get the effect on mortar. Results of this work have indicated that 25% replacement level exhibit higher strength than the controlled sample. Therefore, this paper provides insight regarding how to interpret mechanical properties of mortar, how stone dust as a partially material play a role, and comparative analysis between fresh mortar and modified mortar.

This investigation focuses on the comparison between fresh mortar and modified mortar. In this study the effect of sand replacement by stone dust on the properties of normal strength with varying water-cement this study discloses that in case of cement mortars, the natural sand can be replaced by stone dust. The strength of mortar containing 25% stone dust is higher than normal mortar containing only sand. But the replacement of cement results in the decrease of strength of mortar. So it can be concluded that, stone dust is quite appropriate to be selected as the substitution of fine aggregate but not as the replacement of cement. Stone dust has a potential to provide alternative to fine aggregate minimizing waste products. Thus the stone dust will introduced as a functional construction materials.

A. Sivakumar and Prakash M. Quarry dust is a waste obtained during quarrying process. It has very recently gained good attention to be used as an effective filler material instead of fine aggregate. In the present study, the hardened and durable properties of concrete using quarry dust were investigated. Also, the use of quarry dust as the fine aggregate decreases the cost of concrete production in terms of the complete replacement for natural river sand. This paper reports the experimental study which investigated the influence of 100% replacement of sand with quarry dust. Initially cement mortar cube was studied with various proportions of quarry dust (CM 1:3, CM 1:2, and CM 1:**1).** The analysis of experimental data showed that the addition of the quarry dust improved the strength properties of concrete which was on par with that of conventional concrete. From above testing results, it is inferred that the quarry dust may be used as an effective replacement material for natural river sand. The increase of cement content in the mortar phase shows an increase in the strength. The fine quarry dust tends to increase the amount of super plasticizers needed for the quarry mixes in order to achieve the rheological properties. The 28 days compressive strength of 100% replacement of sand with quarry dust of mortar cube (CM 1:1) is 11.8% higher than the controlled cement mortar cube. The 56 days maximum Compressive strength for 100% replacement of sand with quarry dust of 400 kg/m3 at F/C=0.6 was 17.45% higher than the reference concrete.

At 56 days the maximum split tensile strength 100% replacement of sand with quarry dust of 400 kg/m3 at F/C=0.6 was 15.25% higher than the reference concrete. The maximum modulus of elasticity at 100% replacement of sand with quarry dust of 300 kg/m3 at F/C=0.6 is 10.24% higher than the reference concrete. When the quarry dust has high fineness, its usage in the normal concrete is limited because it increases the water demand.

G.Balamurugan, Dr.P.Perumal. This experimental study presents the variation in the strength of concrete when replacing sand by quarry dust from 0% to 100% in steps of 10%. M20 and M25 grades of concrete were taken for study keeping a constant slump of 60mm. The compressive strength of concrete cubes at the age of 7 and 28 days were obtained at room temperature. Also the temperature effect on concrete cubes at 100oC on 28th day of casting was carried out to check the loss of strength. Concrete acquires maximum increase in compressive strength at 50% sand replacement. The percentage of increase in strength with respect to control concrete is 24.04 & 6.10 in M20 and M25 respectively. After heated to 100oC, the maximum compressive strength is obtained at 50% sand replacement. The percentage of reduction in strength with respect to control concrete is 6.67 & 13.80 in M20 and M25 respectively. Due to thermo shock also the compressive strength is maximum at 50% sand replacement only. The percentage of reduction in strength with respect to control concrete is 13.01 & 16.22 in M20 and M25 respectively.

ChandanaSukesh et.al. The reduction in the sources of natural sand and the requirement for reduction in the cost of concrete production has resulted in the increased need to identify substitute material to sand as fine aggregates in the production of concretes especially in Concrete. Quarry dust, a by-product from the crushing process during quarrying activities is one of such materials. Granite fines or rock dust is a by-product obtained during crushing of granite rocks and is also called quarry dust. In recent days there were also been many attempts to use Fly Ash, an industrial by product as partial replacement for cement to have higher workability, long term strength and to make the concrete more economically available. This present work is an attempt to use Quarry Dust as partial replacement for Sand in concrete. Attempts have been made to study the properties of concrete and to investigate some properties of Quarry Dust the suitability of those properties to enable them to be used as partial replacement materials for sand in concrete. The Replacement of the sand with quarry dust shows an improved in the compressive strength of the concrete. As the replacement of the sand with quarry dust increases the workability of the concrete is decreasing due to the absorption of the water by the quarry dust. The results shows that the decrease in the workability of concrete when the percentage of the replacement is increasing. The workability is very less at the standard water-cement ratio and the water that is required for making the concrete to form a zero slump with a partial replacement requires more water. The test conducted at 50% replacement showed that the water-cement ratio increased to 1.6 at which the slump cone failed completely. The ideal percentage of the replacement of sand with the quarry dust is 55% to 75% in case of compressive strength. The further increasing the percentage of replacement can be made useful by adding the fly ash along with the quarry dust so that 100% replacement of sand can be achieved.

CHAPTER-3

METHODOLOGY

3.1 Material used and testing of raw materials

The properties of materials used that is fineness modulus and specific gravity using Pycnometer of sand and quarry dust. As well as the sieve analysis of sand and quarry dust was determined in the laboratory. The compressive strength, tensile strength, shrinkage, abrasion and durability has been carried out using the standard procedure as per IS code.

Following raw materials are used:

1. **Cement**: Portland Pozzolana Cement (PPC) procured locally conforming to IS 1489 (Part 1) was used.
2. **Fine aggregate/sand**: River sand was obtained locally and sieve and specific gravity test run on the materials.
3. **Fine aggregate/Quarry dust**: the quarry dust was obtained from Gunawata and sieve and specific gravity test run on the materials. Material passing through 4.75 mm was acquired and sieve analysis, bulk density and specific gravity tests were carried out.

The various tests run on the materials and code they conform to be given in the table:

Table 3.1 IS code used for different Testing

SI.No	Test	IS code Specification
1	Specific gravity of fine Aggregate	IS 1727-1967
2	Specific gravity of Cement	IS 1489(Part 1):1991
3	Sieve Analysis	IS 383-1970
4	Compressive strength	IS 2250: 1981
5	Capillarity Test	ASTM C 1403-00
6	Workability	IS 2250: 1981
7	Durability	ASTM C 267-01
8	Water absorption	ASTM C 642-06
9	Shrinkage	ASTM C 1148-92

3.2 Mix Proportioning:

The common method of expressing the proportions of ingredients of a mortar mix is in the terms of parts or ratios of cement and fine aggregates. For e.g. a mortar mix of proportions 1:6 means that cement and fine aggregate are in the ratio 1:6 or the mix contain one part of cement and six parts of fine aggregates. The proportions are either by volume or by mass.

3.3 Preparation of specimens

The raw material is weighted as per mix and dry raw material is mixed in pan and after dry mix water mixing as the water cement ratio. The mould were oiled to prevent adhesion of mortar on mould walls. Then mortar is used to cast cubes 50mm x 50mm x 50mmn for compressive strength, 70mm x 70mm x 70mm for Durability and water absorption test.

The mould were filled in three layers with each layer fully compacted using a vibrator and finally top surface was leveled using trowel.

3.4 Curing of Specimens

After 24 hours, the cubes are de-moulded and are fully immersed in a curing tank with their top surface under water for the required duration. Some cubes are tested after 7 days and some tested after 28 days.

3.5 Testing on Specimens

3.5.1 Workability

Workability of mortar is its ease of use measured by the flow table test. The standard flow tests uses a standard conical frustum shape of mortar with a diameter of 100mm (4inches). This mortar sample is placed on a flow table and dropped 25 times within the 15 second. As the mortar is dropped, it spreads out on the flow table and its diameter changes. The initial and final diameters of the mortar sample are used to calculate flow. Flow is defined as the change in diameter divided by the initial diameter multiplied by 100.

FLOW = $[(D_f - D_i)/D_i] \times 100$

Where, D_f = diameter after flow.

D_i = initial diameter of mortar sample.

3.5.2 Density, Absorption and Voids

This test has been performed according to the code ASTM C 642 – 06.

Oven Dry Mass—Take the mass of the portions, and place it in an oven at a temperature of 100 to 110 °C for not less than 24 h. After removing the specimen from the oven, allow it to cool in air to at temperature of 20 to 25 °C and determine the mass. If the specimen was comparatively dry when its mass was first determined, and the second mass closely agrees with the first, consider it dry. If the specimen was wet when its mass was first determined, t procedure till then two consecutive reading comes close to each other (difference between two consecutive values should be within 0.5%). Designate this last value A.

Saturated Mass after Immersion— Immerse the specimen in water, after final drying, cooling, and determination of mass, at room temperature for not less than 48 h and first reading is determined after 48h then take the further reading at an interval of 24h. When two consecutive reading comes within the difference of 0.5% of the larger value, stop this and designate the final reading as B.

Immersed Apparent Mass— Suspend the specimen, after immersion and boiling with the help of wire-mesh and determine the apparent mass in water. Designate this apparent mass D.

By using the following formula determine the result

Absorption after immersion, % = $[(B - A)/A] \times 100$

Bulk density, dry = $[A/(B-C)].\rho = g_1$

Apparent density = $[A/(A - C)]\cdot\rho = g_2$

*V*olume of permeable pore space (voids), % = $(g_2 - g_1)/g_2 \times 100$

Where:

A = mass of oven-dried sample in air, g

B = mass of surface-dry sample in air after immersion, g

C= apparent mass of sample in water after immersion and boiling, g

g_1 = bulk density, dry, Mg/m3 and

g_2 = apparent density, Mg/m3

ρ = density of water

3.5.3 Compressive Strength Test

The compressive strength test are perform on mortar after 7 days and 28 days curing of mortar cubes as per IS 2250: 1981. Three specimens of 50mm x 50mm x 50mm were tested .The standard loading rate on cube was 6 MPa/S. Compressive strength was calculated by dividing the load at failure by the cross sectional area of specimens.

$$F=P/A$$

Where, F=compressive strength of mortar cube

P=load applied on mortar cube

A =cross sectional area of mortar cube

3.5.4 Ultrasonic pulse Velocity Test

This test was performed as per methodology adopted by Pozonio – Antonio. Test was conducted to find out the homogeneity as well as voids, cracks and other characteristics. Test carried out on 70mm x 70mm x70mm cubes. Mortar cubes was completely drying after curing.

Figure 3.1 UPV Test

3.5.5 Capillary Test

This test has been performed according to the code ASTM C 1403 – 00. Take a balance machine of sensitivity 0.1g and immersion tank of minimum size of 300 x 300 x 75 mm3 and with a suitable cover to minimize the evaporation and place a mesh support to give the minimum clearance of 3mm from the bottom. Cube size of 50 x 50 x 50 mm3 put in the immersion tank on the mesh. Before putting into the tank take weight of the cube specimen also. Take minimum of three specimens from each mortar batch. Place the immersion tank on a flat surface. Pour water to the immersion tank so that the specimens are partially immersed in 3.0 ± 0.5 mm. At 15min, 1hr, 4hr, and 24hr, measure the weight in grams tothe nearest 0.1 g of each specimen. Wipe off surface water from each specimen with a moist cloth prior to each weighing. And complete the weighing within 1min.

Calculate and note the result as AT the water absorption in grams/100 cm2, at each time period, T, for each specimen

$$A_T = (W_T - W_O) \times 10000 / (L_1 \times L_2)$$

Where:

W_T= the weight of the specimen at time T in grams.

W_O= the initial weight of the specimen in grams.

L_1= the average length of the test surface of the mortar specimen cube in mm and

L_2= the average width of the test surface of the mortar specimen cube in mm.

3.5.6 Shrinkage Test

This test was performed as per ASTM C 1148-9a, test conducted on 25 X 25 X 285mm. this molds are moist in 48h and after 48h the specimen remove from mold and moist cure until specimen age 72h from age of molding. After 72hfrom age of molding measure with a length co5mparator. Measure the length of the specimen 4, 11, 18 and 25 days.

Calculate the % shrinkage, *S*, of the five specimens

$S = [(L_1\text{-}L)/L_o]X100$

L_o= effective gage length, cm

L_1= initial measurement after removal from moist cure, cm

L= measurement during or after drying, cm

Figure 3.2 Shrinkage Test

3.5.7 Chemical Resistance on Mortar

This test performed according to C 267-01 on cube size 50mm X 50mm X 50mm after curing of 28 days.

Na2SO4Attack: - Take Distilled water and Na2SO4 in water tight plastic container and proportion of Na2SO4 is 5% of total solution. Cube should be completely immersed in Na2SO4 solution. At 7 days and 28 days, minimum 3 cubes of each specimen will be carried out from the solution. Calculate the weight and compressive strength of the Cubes specimen. After that compare the percentage difference in weight and compressive strength.

H2SO4 Attack: - This test is similar to the Na2SO4 attack. Prepare a solution of normal water and H2SO4, and proportion of H2SO4 is 5% of total solution. And rest of the procedure of the tests follow as H2SO4methodology.

NaCl Attack: - This test is carried out on the cube of size 70mm. Prepare a solution of NaCl and normal water and proportion of NaCl is 10% of total solution. After exposure to the salt solution, the cubes were split in to two. 0.1N $AgNO_3$ solution was sprayed. Change in color was noted. The portions where mortar remained colorless indicated the penetration of salt solution.

Figure 3.3 sample in Na_2SO_4

CHAPTER-4

RESULTS AND DISCUSSION

4.1 Material Tests

In materials testing was performed**:**

- Sieve analysis for gradation of sand and quarry dust as per IS2386 (Part I): 1963…
- Specific gravity test for sand and quarry dust and cement.

4.2 Sand gradation

Locally available river sand has been use as fine aggregate for the test perform on 200gram sand

Table 4.1 Sieve Analysis of sand

Sieve sizes	**Weight retained**	**Cumulative weight retained**	**Percentage weight retained**	**Percentage passing**
4.75 mm	0	0	0.00	100.00
2.36 mm	4	4	2.05	97.95
1.18 mm	16	20	10.23	89.77
600 µm	38.5	58.5	29.92	70.08
300 µm	88	146.5	74.94	25.06
150 µm	41	187.5	95.91	4.09
75 µm	3.5	191	97.70	2.30
Pan	4.5	195.5	100.00	0.00
Total	195.5			

Fineness modulus=2.13

4.2.1 Quarry Dust gradation

As the quarry dust were to fine aggregate perform sieve analysis done 200 gram

Table 4.2 Sieve Analysis of Quarry dust

Sieve sizes	Weight retained	Cumulative weight retained	Percentage weight retained	Percentage passing
4.75 mm	0	0	0.00	100.00
2.36 mm	4	4	2.05	97.95
1.18 mm	48	52	26.67	73.33
600 µm	28	80	41.03	58.97
300 µm	33	113	57.95	42.05
150 µm	30	143	73.33	26.67
75 µm	35	178	91.28	8.72
Pan	17	195	100.00	0.00
Total	195			

Fineness modulus= 2.01

Figure 4.1 Gradation curve

4.2.2 Specific gravity test for cement, sand and Quarry dust

Find out Specific gravity test by pycnometer test and Le-Chatelier's test for cement

Table 4.3 Specific Gravity of various materials

Materials	Specific gravity
Sand	2.72
Quarry dust	2.75
Cement	3.15

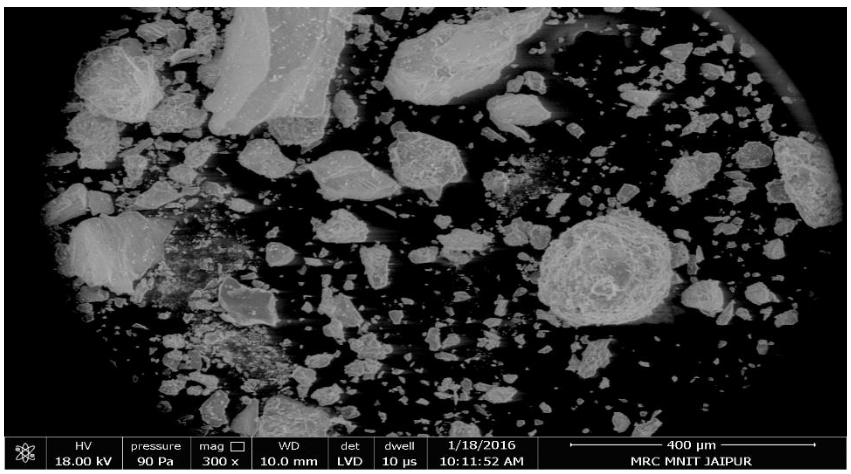


Figure 4.2 SEM of Quarry dust

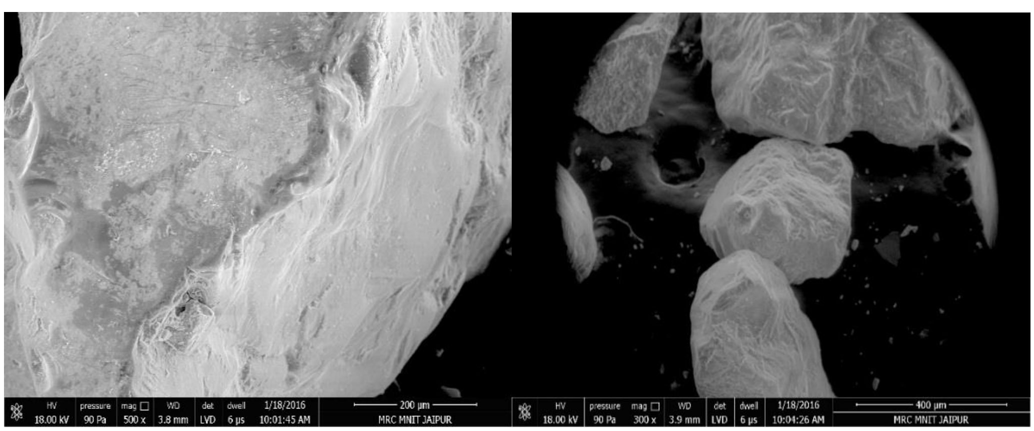


Figure 4.3 SEM of Sand

4.2.3 Chemical Proportions

This test performed at XRD –diffraction on quarry dust

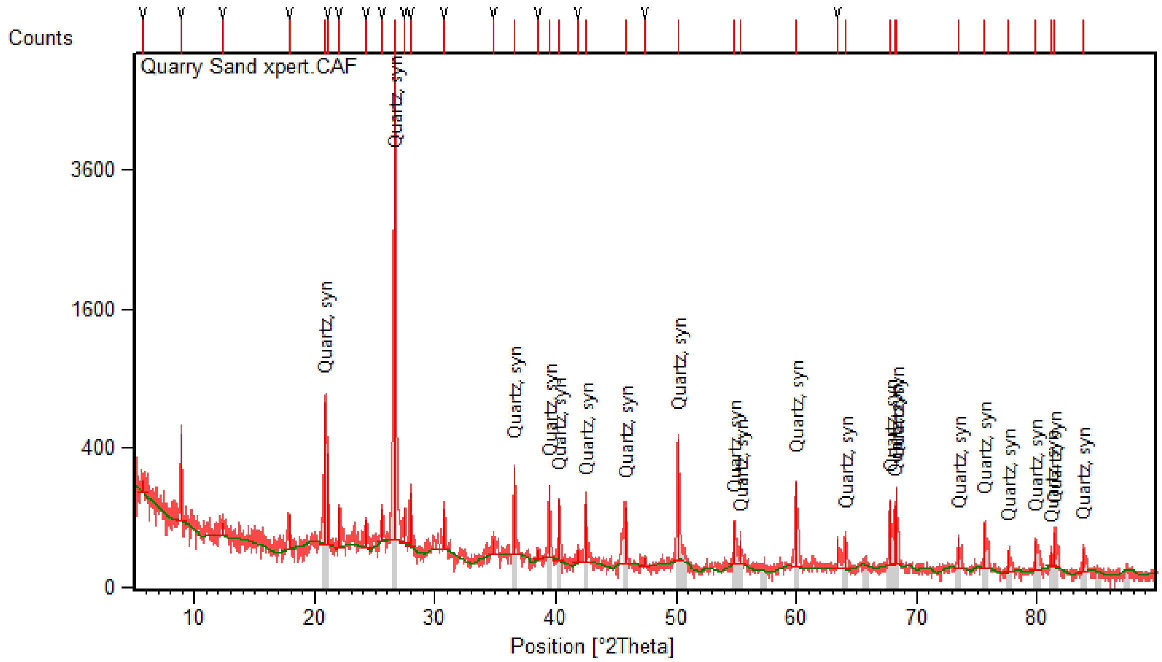


Figure 4.4 XRD Pattern for Quarry dust

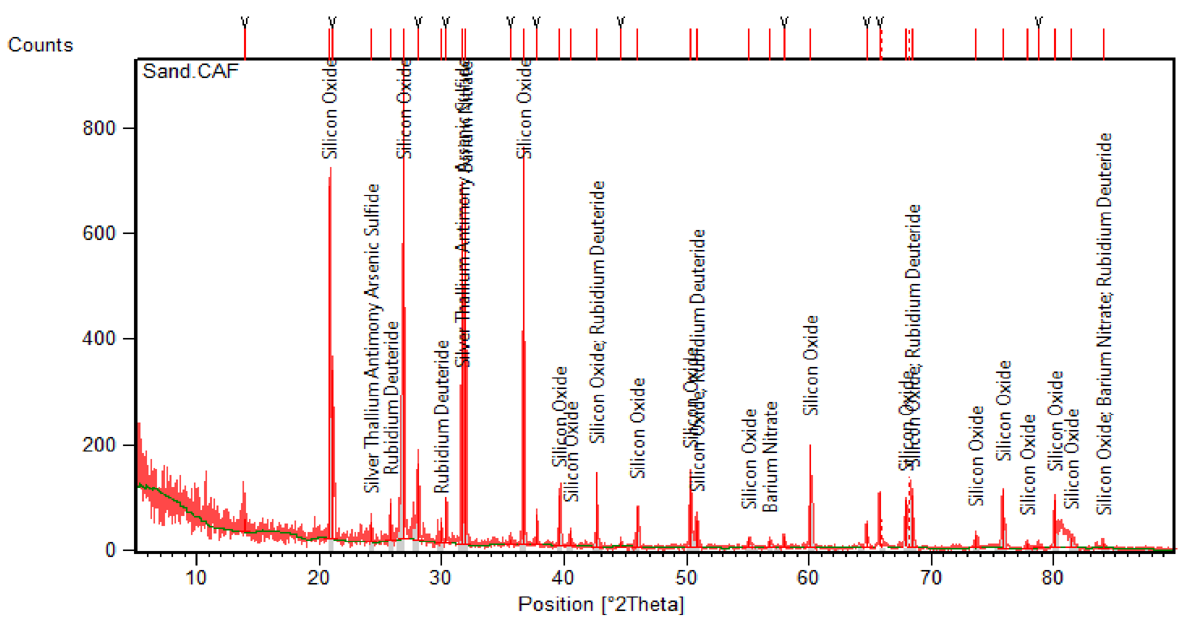


Figure 4.5 XRD Pattern for Sand

Table 4.4 Chemical Analysis of Quarry dust

Element	Proportion
O	49.41
Si	18.66
C	17.2
K	6.39
Al	5.99
Fe	1.34
Mg	1.01

Table 4.5 Chemical Analysis of Sand

Element	Proportion
O	54.07
Si	19.09
K	10.09
C	8.57
AL	7.20
Fe	0.67
Na	0.31

4.2.4 Flow test:-

Table 4.6 W/C Ratio as per substitution

Substitution	**W/C ratio**
0%	1.30
10%	1.32
20%	1.32
30%	1.32
40%	1.32
50%	1.34
60%	1.36
70%	1.39
80%	1.44
90%	1.50
100%	1.54

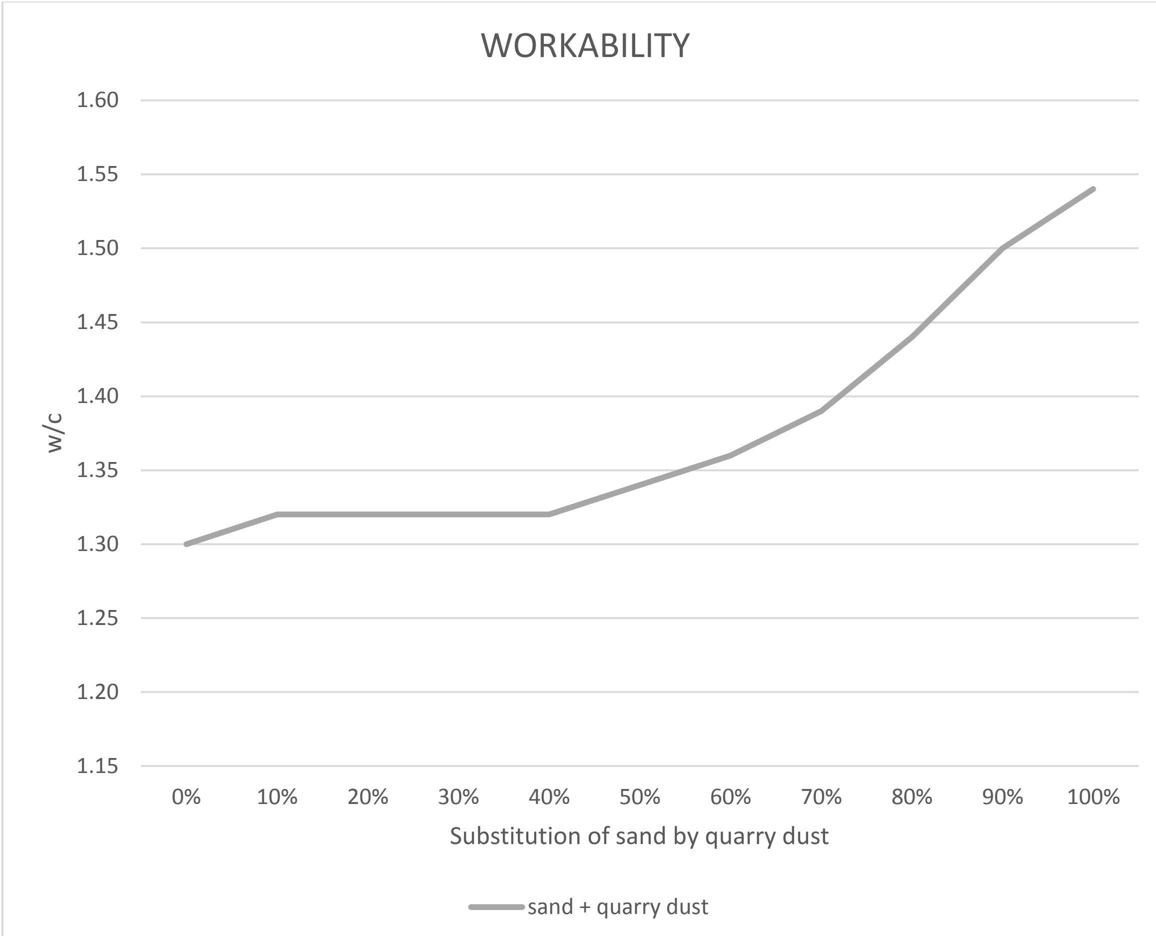


Figure 4.6 Quarry dust replacement workability

Initially when sand is replaced by quarry dust then W/C ratio increase slightly but after that up to 40% replacement it does not changes and beyond 40% replacement, it increases. Water-cement ratio always more than the control mix.

4.3 Compressive strength:-

Compressive strength measure by compressive strength Testing Machine after curing of 7 days and 28 days on 3 cubes (50x50x50mm^3) size.

Table 4.7 Compressive strength for (1:6) mortar

Substitution	7 Days (N/mm^2)	28 Days (N/mm^2)
0%	1.88	2.84
10%	3.13	5.69
20%	2.05	3.29
30%	3.41	3.88
40%	3.33	4.55
50%	3.16	5.03
60%	2.66	4.19
70%	2.89	3.64
80%	2.5	4.04
90%	2.98	3.57
100%	2.28	3.93

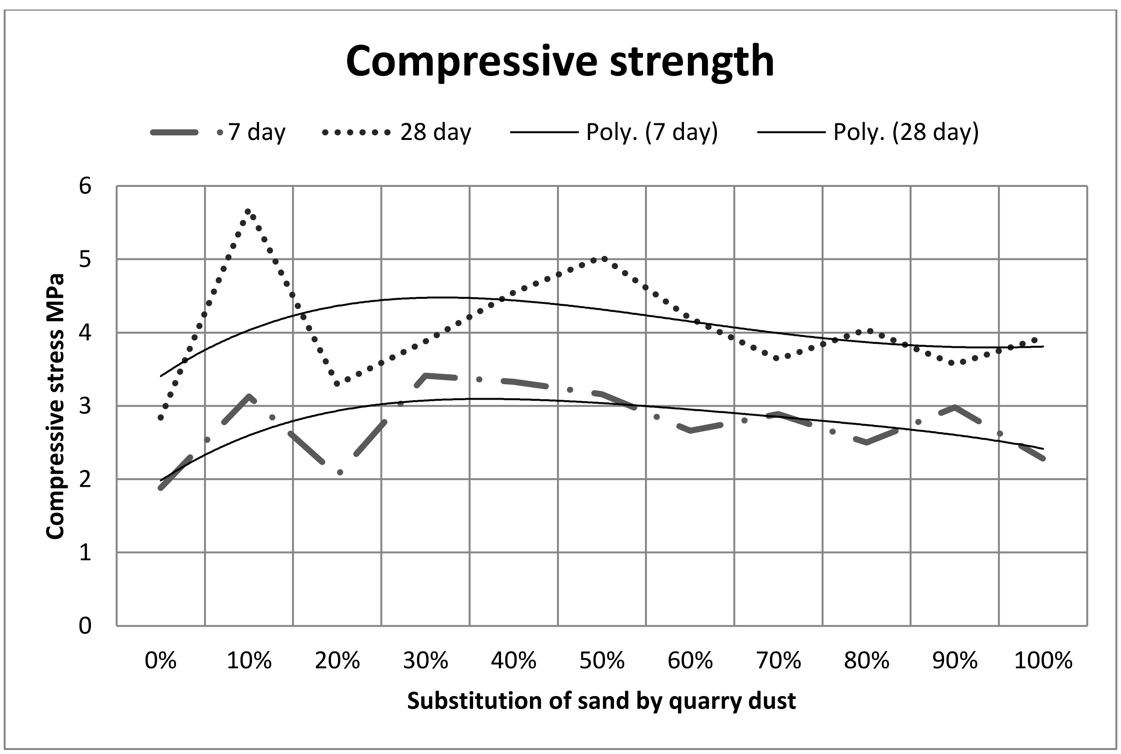


Figure 4.7 compressive strength at 7 and 28 days for Quarry dust replacement

Fig –show that maximum compressive strength occurs at 7 days, when 30% replacement of sand by quarry dust and decreases for the 20% but it always greater than the control mix. At 28 days the maximum strength is coming at 10% substitution and sudden decrease for 20% replacement but it is always greater than the control mix.

4.4 Ultrasonic pulse Velocity (UPV) Test: -

The method measuring the time of travel of an ultrasonic pulse passing through the mortar being of 70mm side of cube. Higher velocity is obtained then mortar quality is good in terms of density, uniformity, homogeneity etc.

UPV show the reading display in microsecond.

Pulse velocity =length/time

Maximum pulse velocity is at 0% and 50 % (which is equal) substitution of sand by quarry dust = 3230.769 m/s

Table 4.8 Substitution and UPV

Substitution	**UPV(m/s)**
0%	3230.769
30%	3165.829
50%	3230.769
70%	2903.226
100%	3000

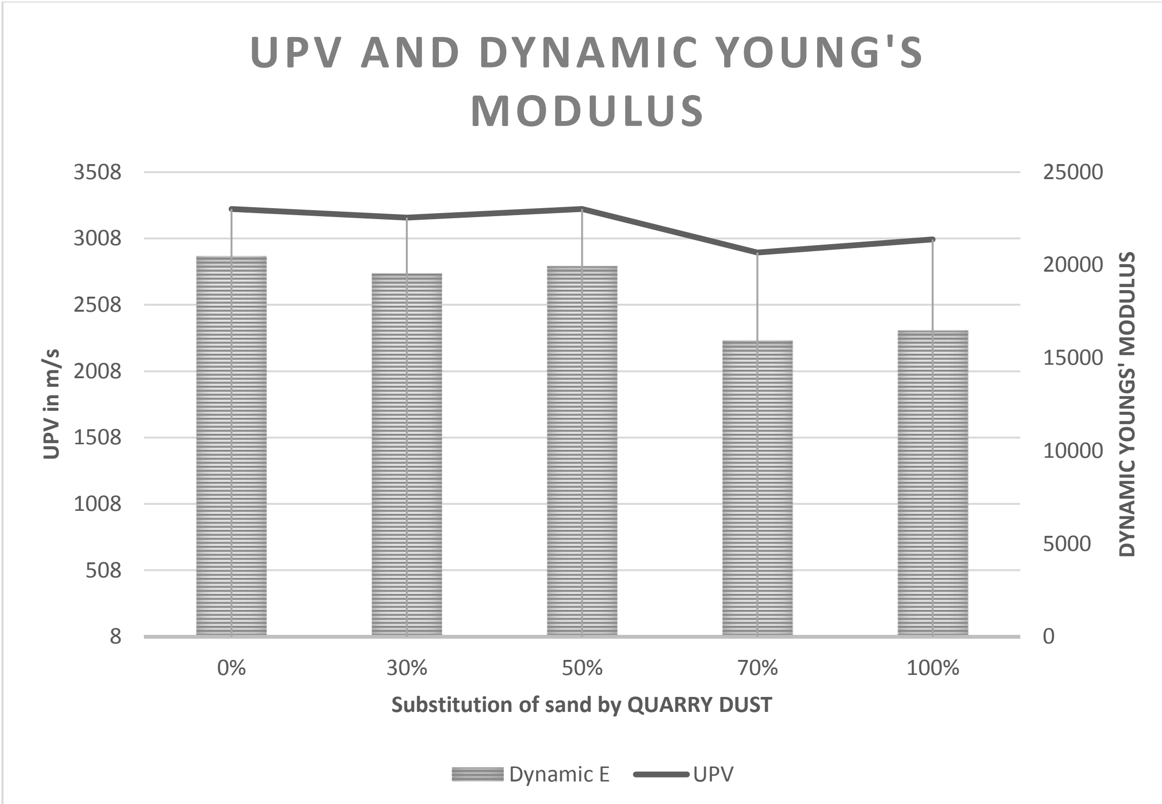


Figure 4.8 Relation b/w UPV, dynamic young modulus and substitution of sand by quarry dust

4.5 Rate of water absorption (Capillarity test):-

In this graph show that 100 % substitution of sand by quarry dust, more the rate of water absorption and in all other cases rate of water absorption is less than control mix and minimum at 50% replacement.

Table 4.9 Capillarity Test

Sample	Water absorption(g)/100cm^2			
	0.25h	**1h**	**4h**	**24h**
0%	21.3	42.7	77.3	81.3
30%	14.7	33.3	70.7	92.0
50%	5.3	10.7	32.0	92.0
70%	14.7	33.3	74.7	100
100%	44	85.3	124.0	128.0

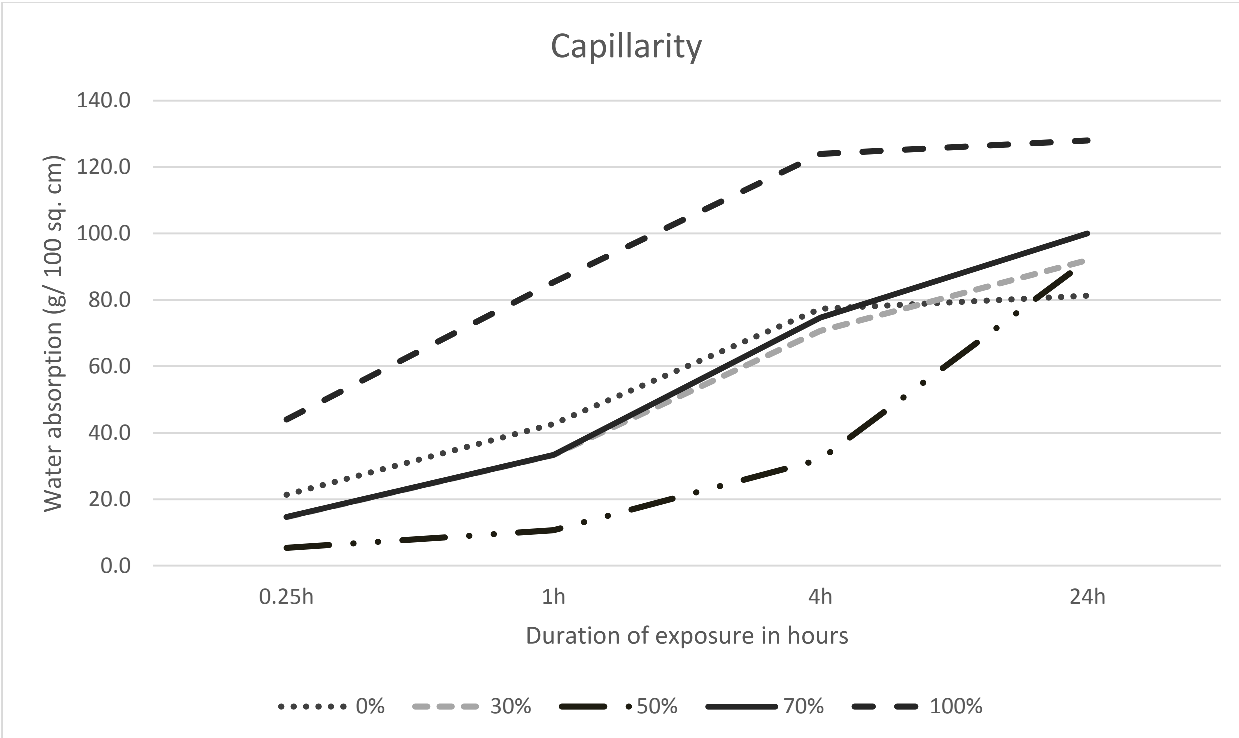


Figure 4.9 Water absorption v/s duration of exposure

4.6 Shrinkage Measurement: -

Drying shrinkage measure by length comparator after 4, 11, 18and 25 days of air storage room. Graph show that initial day shrinkage increase but last days (25 days) shrinkage almost constant. 25% and 50% substitution of sand by quarry dust drying shrinkage are less in starting days than control mix.

Table 4.10 Shrinkage measurement

Specimen	**Percentage drying shrinkage**			
	4days	11days	18days	25days
0%	0.00038	0.0004	0.00042	0.00038
30%	0.00048	0.00062	0.00058	0.00058
50%	0.00059	0.00099	0.00099	0.001
70%	0.00072	0.00076	0.00076	0.00076
100%	0.00066	0.00066	0.00067	0.00086

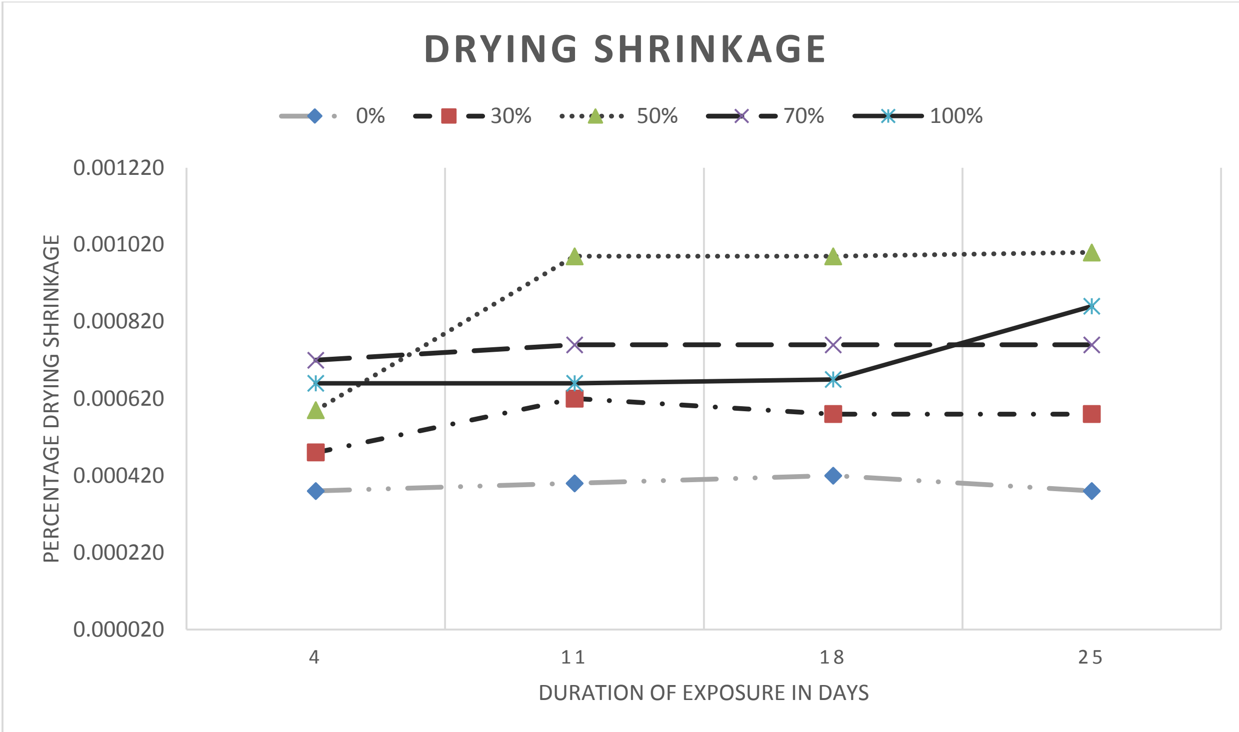


Figure 4.10 drying shrinkage % vs duration of exposure

4.7 Water absorption: -

Table 4.11 Water absorption and permeable voids

Sample	Water absorption %	Permeable voids %
0%	9.79	19.17
10%	11.50	22.36
20%	10.14	19.95
30%	10.86	21.16
40%	10.86	21.33
50%	12.61	24.07
60%	11.58	22.55
70%	12.71	24.04
80%	13.18	24.93
90%	14.11	25.96
100%	14.38	26.29

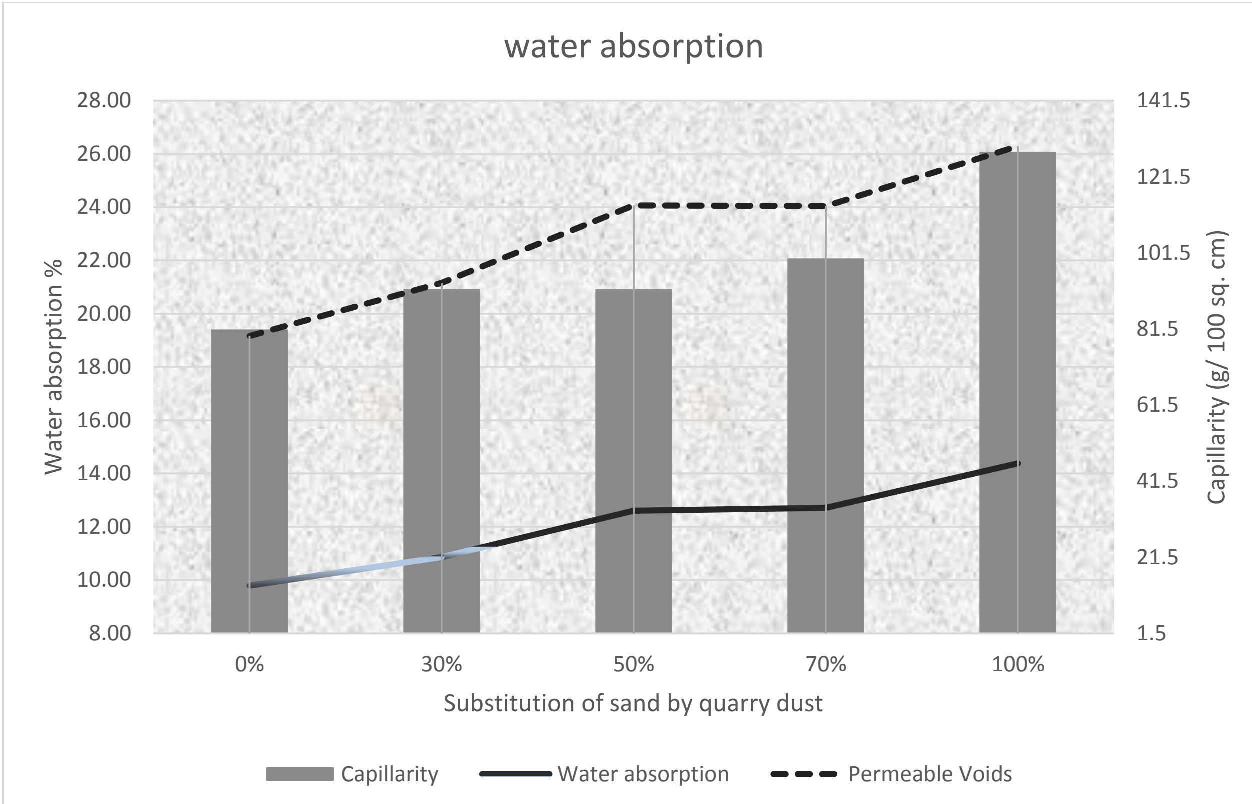


Figure 4.11 Water absorption, voids and capillarity

Fig. show that water absorption of control mix 9.79%, after the replacement of sand by quarry dust water absorption is always more than the control mix. Then so no proper good result find out by this replacement. But 20% or 30% replacement mix, show water absorption nearly control mix. If permeable voids increase so water absorption property also increase.

4.8 Durability

4.8.1 Sulphate Attack

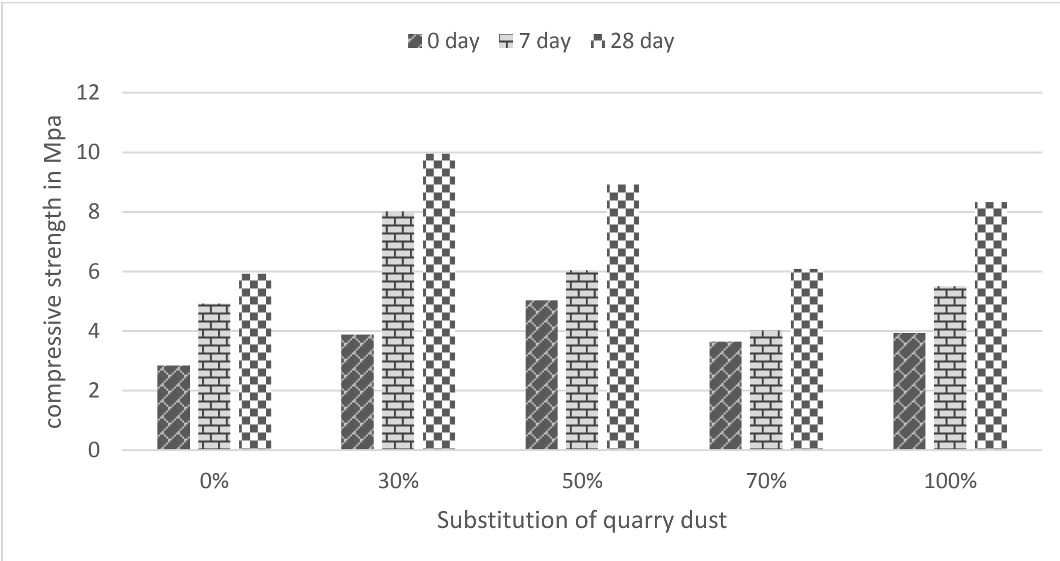
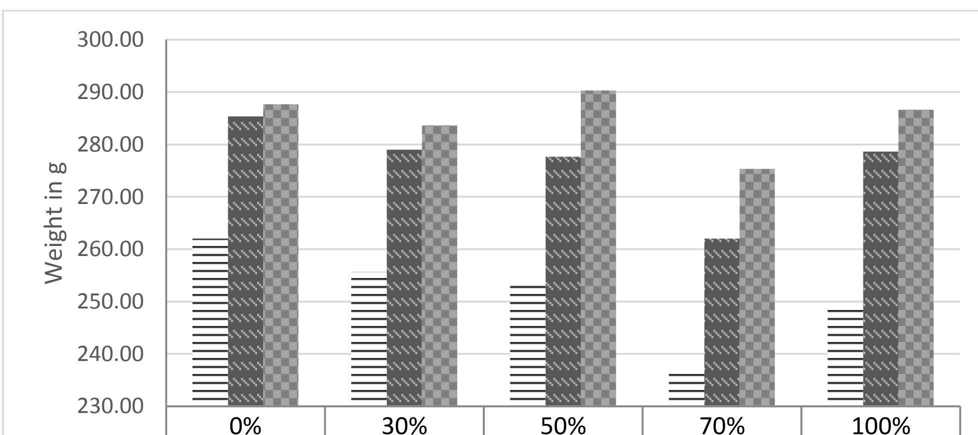


Figure 4.12 Compressive Strength exposed to sulphate solution at 7 and 28days

It is clear from the graph that the compressive strength of the substituted mortar is always more than the control mix, and when it is exposed to the sulphate solution it does not affect the compressive strength of the mortar. Maximum compressive strength is 10 Mpa at 30% substitution.



	0%	30%	50%	70%	100%
0 day	262.00	255.67	253.83	236.50	248.50
7 day	285.33	279.00	277.67	262.00	278.67
28 day	287.67	283.67	290.33	275.33	286.67

Figure 4.13 Weight of specimen when exposed in Na_2SO_4

From fig it can be seen that the lesser percentage of weight change for the 30% substitution in comparison to the other substitution, and %change in the weight (10.9) is slightly more than the control mix.

4.8.2Acid Attack

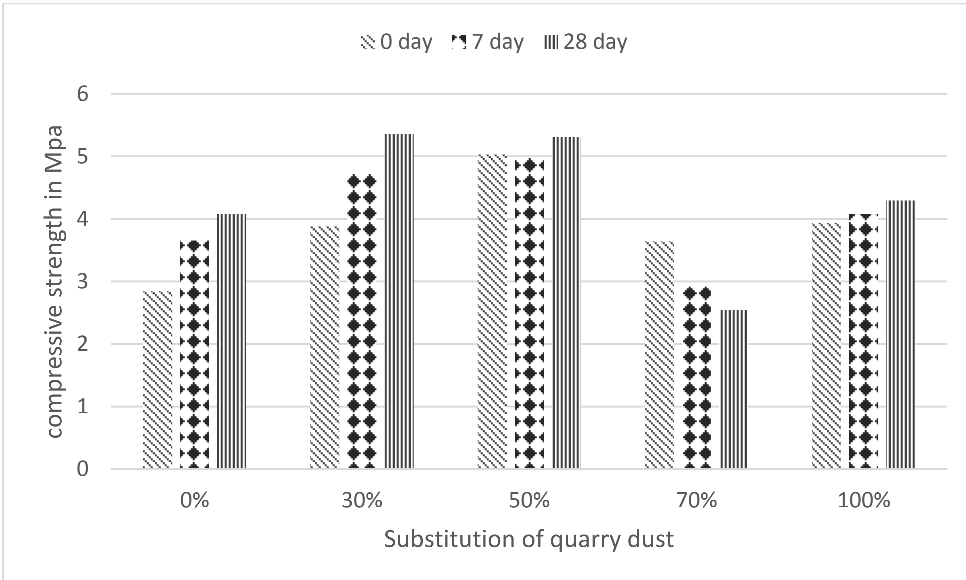


Figure 4.14 Compressive strength when exposed to acid solution

Fig. shows that when mortar is exposed to the acid solution, the compressive strength is always more than control mix, except 70% substitution. In 70% substitution compressive strength at 7days and 28days both are less than control mix.

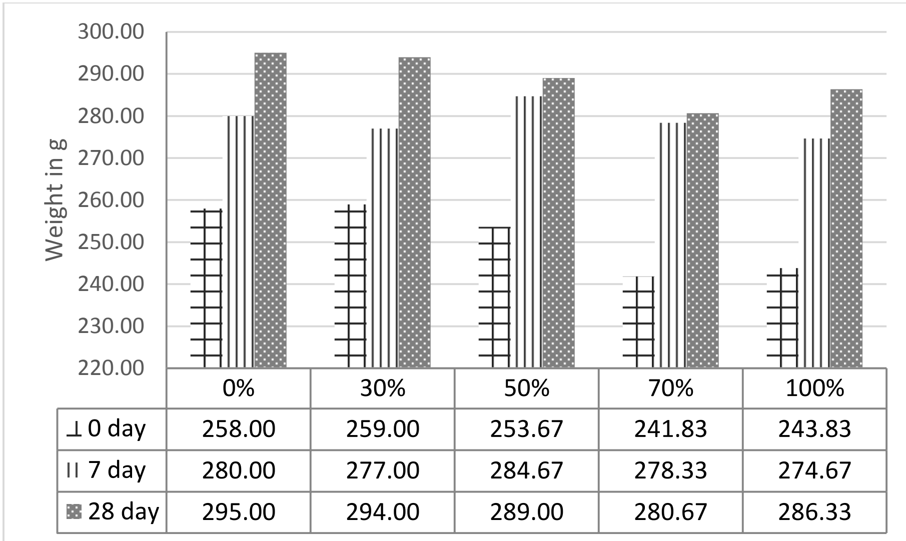


Figure 4.15 weight when exposed to acid solution

Percentage change in weight for 30% substitution is less than the control mix but for others substitution it is more than the control mix.

4.8.3 Nacl Attack

Table 4.12 penetration depth variation

Specimen	**Penetration Depth(mm) at 28 days**
Mortar with 0% replacement	Full penetration
Mortar with 30% replacement	Full penetration
Mortar with 50% replacement	Full penetration
Mortar with 70% replacement	Full penetration
Mortar with 100% replacement	Full penetration

Figure 4.16 Sample exposed to NaCl attack at 28days

In all cases (means in each substitution) the penetration depth is coming full, it simply indicates that porosity is more. And we can also see from the result of permeable voids that as the quarry dust percentage increases, the permeable voids also increases.

CHAPTER-5

CONCLUSION

After analyzing all the results we can conclude the following observations:

1. At 10% replacement of sand by quarry dust achieve the maximum strength, but in all other cases (20% to 100%) of substitution compressive strength is always greater than the control mix. It means that replacement of sand by quarry dust enhance the compressive strength of the mortar.
2. Rate of water absorption is more than the control mix in case of 100% substitution but in others cases it is less than the control mix.
3. Initial day shrinkage increased with increase in substitution but last days (25 days) shrinkage almost constant. 30% and 50% substitution of sand by quarry dust drying shrinkage are less in starting days than control mix.
4. After the replacement of sand by quarry dust water absorption is always more than the control mix. But 20% or 30% replacement mix, shows water absorption nearly equal to control mix.
5. Durability test, 30% replacement shows the good result in case of both sulphate and acid attack. Change in % weight is also less than the control mix in case of 30% substitution.
6. Based on the result we can recommend that 30% substitution is optimum substitution. It can be used for the canal lining withcaution.

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