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Durability Aspects in Reference to Permeable Voids and Leaching of Calcium Hydroxide in Concrete with Quarrysand and Flyash

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Abstract— *The concrete industry is constantly looking for supplementary cementitious material with the objective of reducing the solid waste disposal problem. Fly ash (FA) and Quarry sand (QS) are some among the solid wastes generated by industry. The Quarry sand is one such material which can be used to replace sand as fine aggregate. To overcome from this crisis, partial replacement of natural sand (NS) with Quarry sand and partial replacement of cement with FA can be an economic alternative. This research is carried to study the effect of replacement of sand by Quarry sand and cement by fly ash with using admixture in concrete, especially in reference to permeable voids development, compressive strength, leaching of* $Ca(OH)_2$ *in curing water and RCPT at 28, 56 and 90 days of age.*

A M25, M30, M40 Grade concrete were chosen for research. The mix design was carried out and three combinations were chosen, first combination using 100% Natural sand and 100% cement (treated as controlled mix).In second combination 100%Natural sand is replaced by Quarry sand and cement remains100%. In third combination 30% cement is replaced by Fly ash and 45% Natural sand is replaced by Quarry sand (treated as critical mix). These were chosen from 30 combinations of variable % of Natural sand and Quarry sand and fly ash. The study is aim at understanding the performance of critical mix in reference to controlled mix and concrete containing 100% quarry sand. It is observed that if quarry and is used for concrete then suitable percentage natural sand and fly ash must be added to achieve desired compressive strength and performance of concrete.

Keywords— Cement, Fly ash (FA), Quarry sand (QS), Natural sand, compressive strength, permeable voids, RCPT.

I. INTRODUCTION

Concrete is the most widely used construction material in civil engineering industry because of its high structural strength, stability and durability. Recent technological developments have shown that these materials can be used as valuable inorganic and organic resources to produce various useful value-added products. Researches on incorporating industrial waste products into potential construction material to produce sustainable concrete have been on the rise in recently. Fly ash (FA), Quarry sand are such industrial waste products. The researchers focused on using Fly ash and Quarry sand as possible replacement for conventional cement and natural sand. However FA have been investigated as supplementary mineral admixtures in concrete. Quarry sand has been used as a replacement material for Natural sand (fine aggregates). Sustainability has become more and more imperative all over the world, especially in the production of concrete. The global consumption of natural sand is to high due to extensive use in concrete. Utilization of these materials for sustainable concrete which contributes to reduction of environmental pollution as the production of conventional construction materials such as cement and natural sand could be reduced. Substantial energy and cost saving can result when industrial by-product are used as partial replacement for the energy intensive portland cement. The purpose of this research to study the effect of Fly ash and Quarry sand on workability, compressive strengths, permeable voids, pH and Leaching of and Fly ash and comparative reduction in the cost of cement and Natural sand .The detailed experimental investigation is come to study the effect of replacement of cement by Fly ash and Natural sand (Fine aggregate) by Quarry sand.

In this research we prepared specimen of cubes for compressive strength test, pH, and leaching test and beams for permeable voids test. Three samples for each set of percentage have been taken for conducting test and average of results are taken. The samples were tested at the age of 28 days and 56 days 90,180 days. The test on hardened concrete are compressive strength test as per IS: 516-1959, Methods of sampling and test for Quick lime and hydrated lime as per IS 1514:1990, permeable voids test as per ASTM C642-97.

M. G. Shaikh and S. A. Daimi [1] studied comparison about natural sand and artificial sand with dust, by checking durability properties through the measurement of permeable voids, water absorption, acid attack and chloride permeability test as well as compressive strength test.

Assan Tajik Ghashghaei, Abolfazl Hassani [2] presented a study evaluating the relationship between porosity and permeability coefficient for pervious concrete. Jayeshkumar Pitroda, Dr F S Umrigar [3] concluded that when excess water in concrete is evaporated, it leaves voids inside the concrete element creating capillaries which are directly related to the concrete porosity and permeability. G. Roa-Rodriguez, W. Aperador, A. Delgado [4] analyzed the role of chlorides in causing corrosion in the alkali-activated slag (AAS) concrete, its mechanism of action, the critical threshold on. Rapid Chloride Permeability test (RCPT) was conducted to measure the chloride permeability; relative permeability (RP) and the AC resistivity were measured on concrete as per the guidelines of ASTM C1202. T. de Larrarda, F. Benboudjemaa, J.B. Colliata, J.M. Torrentib, F. Deleruyelle [5], A simplified model for calcium leaching in concrete is presented. It is based on the mass balance equation for calcium in the porous material. An Cheng, Sao-Jeng Chao and Wei-Ting Lin, [6] Leaching of calcium ions increases the porosity of cement-based materials, consequently resulting in a negative effect on durability since it provides an entry for aggressive harmful ions, causing reinforcing steel corrosion. This study investigates the effects of leaching behaviour of calcium ions on the compression and durability.

Sreekantan P, George Mathew [7] discussed about the influence of presence of higher percentage of fine particles in quarry sand on the mechanical properties of high strength concrete containing fly ash and it is studied that, the higher percentage of fine particles in quarry sand does not affect significantly the engineering properties of high strength concrete when river sand is replaced with 50% quarry sand along with a 25% replacement of cement with fly ash.

Chandramouli K. Srinivasa Rao P., Seshadri Sekhar T., Pannirselvam N. and Sravana P. [8] the present experimental investigation. The rapid chloride permeability tests were conducted for a period of 90, 180, 365 and 720 days. The test results show that the addition of glass fibres exhibit better performance. Caijun Shi, Dr. Burlington, [9] studied the virtual a measurement of electrical conductivity of concrete, which depends on both the pore structure characteristics and pore solution chemistry of concrete. They also studied the effects of several factors, such as cement composition, replacement of cement with supplementary cementing materials and inclusion of aggregate, on the electrical conductivity or RCPT results of hardened cement mortars and concrete. Prakash Joshi and Cesar Chan [10] performed Rapid Chloride Permeability Test by monitoring the amount of electrical current that passes through a sample 50 mm thick by 100 mm in diameter in 6 hours (see schematic). The sample is typically cut as a slice of a core or cylinder. A voltage of 60V DC is maintained across the ends of the sample throughout the test. One lead is immersed in a 3.0% salt (NaCl) solution and the other in a 0.3M sodium hydroxide (NaOH) solution.

The Objectives and scope of present study are –

1. To understand compressive stress development in concrete mixes containing natural sand, quarry sand and combination containing fly ash as third ingredient.
2. To understand the development of permeable voids at 28, 56, 90 days in above combinations.
3. To understand the leaching of calcium hydroxide in curing water at various ages and co-relating it with compressive strength development and formation of permeable voids.
4. To confirm and compare the test results obtained for permeable voids with the rapid chloride permeability test.

II. MATERIALS USED

The materials used in experimental investigation include:

A. Cement

Ordinary Portland cement (OPC) 43 grade was used in which the composition and properties is in compliance with the Indian standard.

B. Aggregate

Good quality river sand was used as a fine aggregate conforming to Zone - II of IS: 383- 1970. It have fineness modulus of 2.735, specific gravity of 2.66 and water absorption 1% and Quarry sand from sidheshwar quarry plant Pachgaon, Nagpur, conforming to Zone- II of IS: 383-1970. It has fineness modulus of 2.85 , specific gravity of 2.91 and water absorption 2.5%. The coarse aggregate passing through 20 mm and retained on 10 mm sieve is used in research. Its specific gravity is 2.85 and water absorption 0.8%.

C. Fly ash

In the present investigation Class F Fly Ash from Koradi Thermal Power Station, Nagpur was used as cement replacement material. The properties of fly ash are conforming to IS 3812-1981 of Indian Standard Specification for Fly Ash for use as Pozzolana and Admixture. Specific gravity of 2.216.

D. Superplasticizer

AC-PLAST-BV 430(Apple Chemie, Nagpur) as a high range water reducing admixture for obtaining a workable mix was used in research, Strength increased 0.20 and Specific gravity 1.14

III. EXPERIMENTATION

3.1 Permeable voids Test -

This test method covers the determination of density, percent absorption, and percent voids in hardened concrete. This test method is useful in developing the data required for conversions between mass and volume for concrete. It can be used to determine performance with specifications for concrete and to show differences from place to place within a mass of concrete. The sample consist of any desired shape or size, except that the volume of each portion shall be not less than 800gm and each portion is free from observable cracks, fissures or shattered edges. In this research permeable voids test is carried out for each sample as per ASTM C 642-97. Fig. 1 indicates samples and procedure used for this test.

3.2 Leaching of Calcium Hydro oxide - $Ca(OH)_2$

In this research leaching of calcium hydroxide is carried out for each sample as per IS 1514:1990. The leaching process means, when solid compound in the concrete are dissolved by water and then transported away, either due to concentration gradients (diffusion) or by the flow of water (convection). The external or capillary pressure may cause water to flow. When material dissolves from the concrete, water will carry away the loose parts and the concrete and will become weaker. If percolating water is soft, the leaching effect on the concrete will be strong. The water diffuses into the concrete and dissolves hydration products (and aggregate, if it is easily soluble). Dissolved material will diffuse out of the concrete to the bulk of pure water in the curing water. This is a slow leaching process. If water also percolates through the concrete due to pressure gradients, the water will reach much more internal area of soluble products. The dissolved material will also be carried away by the flow of water and out of the concrete. This can be a rapid leaching process; depending on how fast the water is percolated through the concrete and how much internal area the water will meet on its way. Leaching is the name of the whole process of dissolving and transporting substances out of the concrete. Samples were kept in separate containers, curing water was analysed at 28, 56 and 90 days, fig. 2 indicates the samples for leaching test.

Leaching effects

When solid material is leached, the porosity will increase and the amount of OH" -ions will decrease in the pore solution and in the pore walls. When the porosity increases, the water permeability will increase and the leaching process will accelerate. When the porosity increases, the strength will also decrease.

3.3 Rapid Chloride Permeability Test

The rapid chloride permeability test (RCPT) - ASTM C1202. These standards specify the rating of chloride permeability of concrete based on the charge passed through the specimen during six hours of testing period. Dry concrete is a semi-conductor or insulator. Electrical conductivity of water saturated concrete depends on not only the pore structure and but also the chemistry of pore solution. The transport of chloride ions has little to do with the chemistry of pore solutions, but many factors such as cement composition, aggregate, concrete mixing proportions, use of supplementary cementing materials, chemical additives, etc. can have very significant effects on the concentration of conductive ions in the pore solution. RCPT has been used to evaluate the chloride permeability of hardened cement concretes made with special cements or supplementary cementing materials

Procedure of Rapid chloride permeability test

According to ASTM C1202 test, a water-saturated, 50 mm thick, 100 mm thick diameter concrete specimen is subjected to a 60 v applied DC voltage for 6 hours using the apparatus and the cell arrangement is shown in Figure. In one cell container is fill with 3.0% NaC1 solution and in the other container is with 0.3 Normal NaOH solution. The total charge passed is determined and this is used to rate the concrete according to the criteria included as Table 1.

Procedure of Rapid chloride permeability test

According to ASTM C1202 test, a water-saturated, 50 mm thick, 100 mm thick diameter concrete specimen is subjected to a 60 v applied DC voltage for 6 hours using the apparatus and the cell arrangement is shown in Figure. In one cell container is fill with 3.0% NaC1 solution and in the other container is with 0.3 Normal NaOH solution. The total charge passed is determined and this is used to rate the concrete according to the criteria included as Table 1.

IV. OBSERVATIONS BASED ON EXPERIMENTATION

1) Compressive strength gain in critical mix containing 45%Q.S+55%N.Sand30%F.A. is found similar to that of controlled mix containing 100% Natural sand. The gain of compressive strength in case of concrete containing 100% quarry sand is much lower than other two mixes. This clearly indicate that the gain of compressive strength compromised by using quarry sand can easily be compensated by using fly ash of adequate quantity (as indicated by fig. 3 to fig. 5)
2) Development of permeable voids at various ages is much higher in case of mix containing 100% Quarry sand as fine aggregate and that in critical mix lies in between mix containing100% Quarry sand and 100% Natural sand. This confirms that the fly ash is resulting in pore refinement; this is indicated in fig. 6 to fig. 8.
3) Leaching of calcium hydroxide in curing water is lower for the critical mix as indicated by fig. 9 to fig. 11. This justifies that the fly ash is reacting with calcium hydroxide to form secondary C-S-H and thus helping gain of compressive strength and pore

refinement properties. The RCPT results as indicated in fig. 12 to fig. 14 justify the result obtained using permeable voids test.

4) To understand the similarities in compressive strength development and permeable voids development graphs indicated in fig. 16 to fig. 17 are drawn. The trends shown in this figure by controlled concrete mix and critical mix are fairly similar at 28 days , 56 days, 90 days of age while the trend shown by mix containing 100% quarry sand .is significantly different.
5) It has been observed that when 100% natural sand replaced by Quarry sand, compressive strength decreases, since water absorption of quarry sand is more than natural sand, which decreases workability and compressive strength. It is observed that when natural sand is replaced by 45% quarry sand and cement replaced by 30% fly ash at initial stage compressive strength is lower than compressive strength of controlled concrete and it increases as the age increases and it is due to secondary hydration. (Refer fig. 3, fig. 4 and fig.5)
6) Permeable voids are decreasing with age of curing. Permeable voids (pores) get dissolved as curing period increases due to secondary hydration which increases density. When 100% natural sand is replaced by quarry sand internal voids (pores) increases. Fly ash reduces the pores. (Refer Fig. 6, fig. 7 and fig. 8)
7) It is found that, the strength of concrete increases with decrease in permeable voids.
8) The amount of Leaching of Cementious material like Calcium Hydroxide ($Ca(OH)_2$) is decreases with increasing curing period. It is also observed from comparison of permeable voids, leaching of $Ca(OH)_2$, It is also observed that extraction (leaching) of $Ca(OH)_2$ is decreasing from lower grade to higher grade of concrete.

V. CONCLUDING REMARK

Many past researchers have been figuring out the use of quarry sand as replacement of natural sand in concrete. The major stress are in past researches are in water requirement and compressive strength. However the present research point out towards carrying out test such as Determination of permeable voids at various ages, RCPT result in addition to compressive strength. It is recommended that when quarry sand is used as fine aggregate fly ash must be added to desired proportion to give the performance of concrete containing quarry sand to be similar to that of containing 100% Natural sand. The studies like leaching of calcium hydroxide in curing water gives a new dimension the parameter leading to compressive strength in understanding the parameters leading to compressive stress development and voids development in concrete.

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[12] IS 1514:1990 Methods of test for Leaching test
[13] ASTM C642-97 methods of test permeable voids test
[14] ASTM C1202 Rapid Chloride Permeability

Table.1:

Charge passed (coulombs)	**Chloride Ion penetrability**
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

RCPT ratings (per ASTM C1202)

Table.2: Compressive Strength, Permeable Voids and Leaching of $Ca(OH)_2$ in curing water

Identification Symbol	**Mix Type**	**Comp. strength in MPa**			**Permeable Voids in %**			**Leaching of $Ca(OH)_2$ in mg/L**		
		28 Days	56 Days	90 Days	28 Days	56 Days	90 Days	28 Days	56 Days	90 Days
M25 -B	M25 (100% N.S.+100%C)	26.33	28.50	30.40	15.60	14.95	13.27	30.24	25.20	13.40
M25-G	M25 (100% Q.S.+100%C)	19.55	24.00	25.27	25.17	22.17	21.06	34.43	28.70	16.20
M25-D3	M25 (70%C&30%FA +55%NS&45%QS)	28.33	29.70	31.70	17.76	16.68	15.29	30.08	23.20	9.60
M30-B	M30 (100% N.S.+100%C)	35.55	36.25	37.25	9.89	9.11	8.89	29.24	23.70	12.34
M30-G	M30 (100% Q.S.+100%C)	21.30	26.22	28.17	16.09	14.07	13.17	33.19	27.60	15.87
M30-D3	M30(70%C&30%FA+55 %NS&45%QS)	33.33	36.00	37.20	15.10	13.49	12.22	28.31	21.60	8.60
M40-B	M40 (100% N.S.+100%C)	40.22	44.12	46.12	8.33	7.29	7.21	28.43	22.80	11.00
M40-G	M40 (100% Q.S.+100%C)	25.10	28.00	29.51	11.84	11.74	10.31	32.47	28.70	14.50
M40-D3	M40 (70%C&30%FA +55%NS&45%QS)	41.77	46.88	49.10	9.81	9.28	9.02	27.67	20.70	6.90

Table.3: (Rapid Chloride Penetration Test Results on selected samp

Identification Symbol	**Mix Type**	**RCPT Charge (Columbs Passed) 28 days**	**RCPT Charge (Columbs Passed) 90 days**
M-25 -B	M25 (100% N.S.+100%C)	1285	1100
M25-G	M25 (100% Q.S.+100%C)	1534	1450
M25-D3	M25 (70%C&30%FA +55%NS&45%QS)	1372	1280
M30-B	M30 (100% N.S.+100%C)	1332	1060
M30-G	M30 (100% Q.S.+100%C)	1445	1350
M30-D3	M30(70%C&30%FA+55%N S&45%QS)	1364	1200
M40-B	M40 (100% N.S.+100%C)	1307	980
M40-G	M40 (100% Q.S.+100%C)	1320	1020
M40-D3	M40 (70%C&30%FA +55%NS&45%QS)	1113	1100

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Fig. 1: Samples for Permeable Voids Test

Fig. 2: Samples kept for determination of leaching of $Ca(OH)_2$

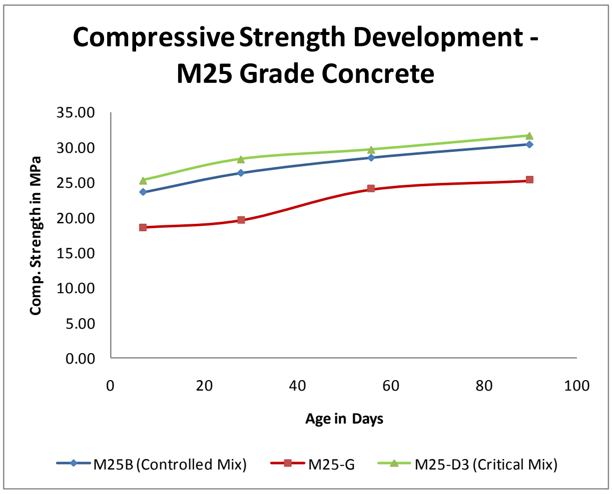

Fig. 3: Compressive strength of M25 concrete

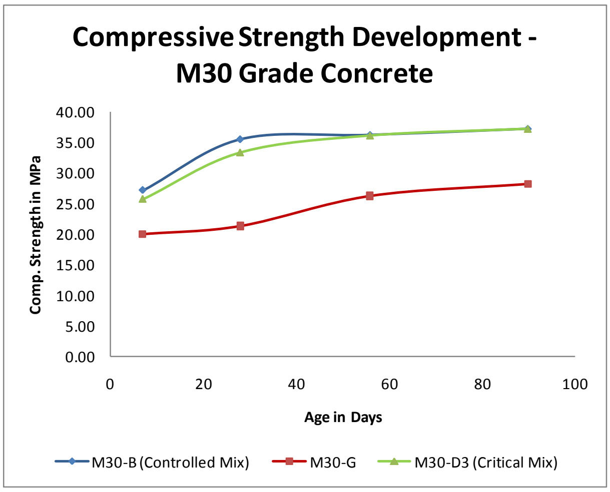

Fig. 4: Compressive strength of M30 concrete

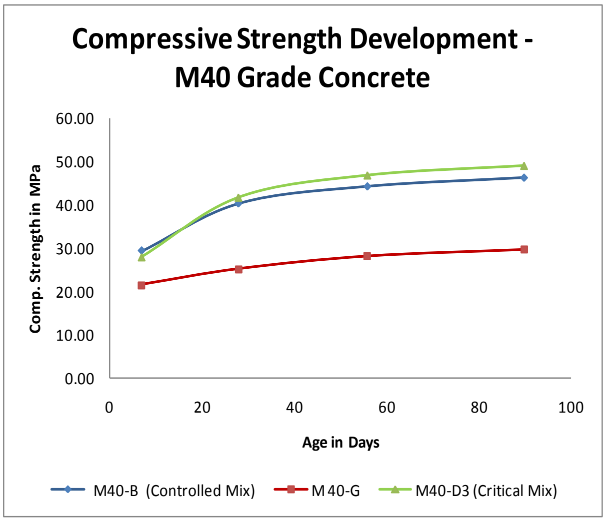

Fig. 5: Compressive strength of M40 concrete

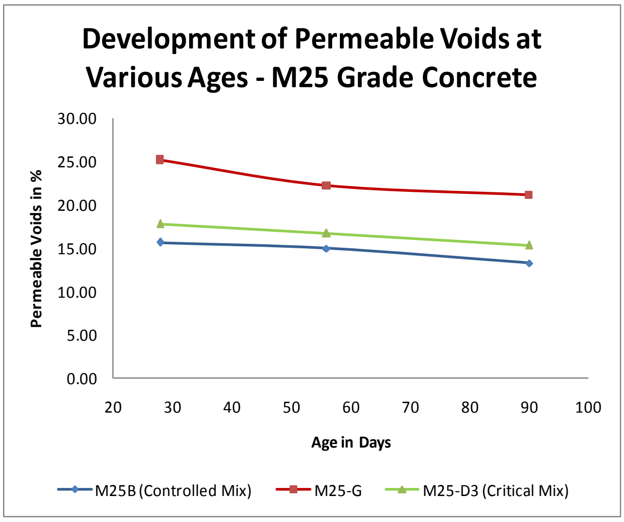

Fig. 6: Permeable Voids in M25 concrete

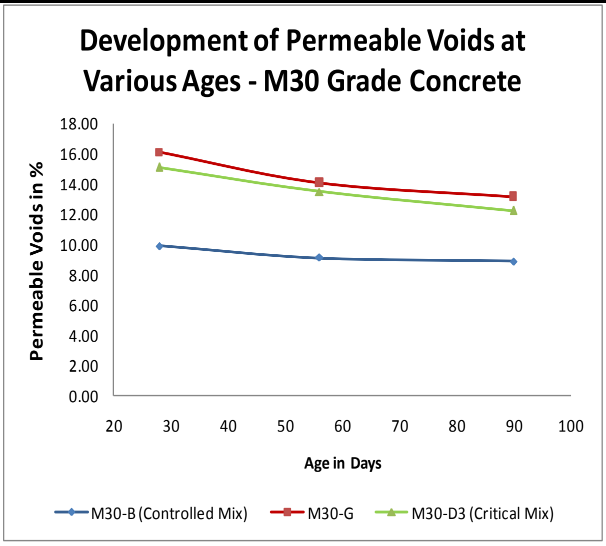

Fig. 7: Permeable Voids in M30 grade concrete

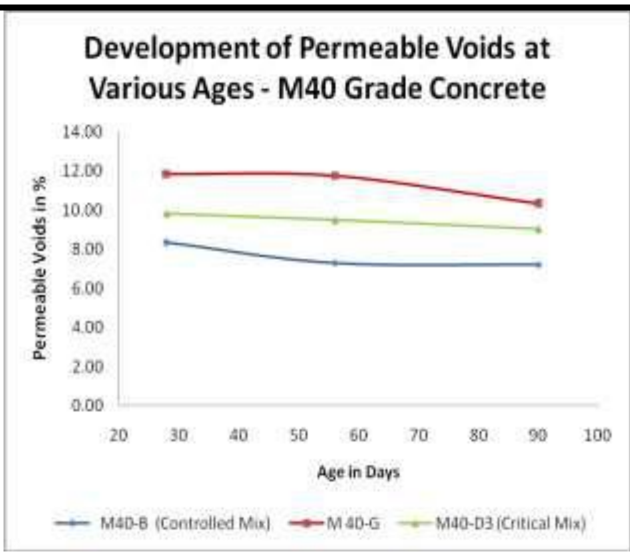

Fig. 8: Permeable Voids in M40 grade concrete

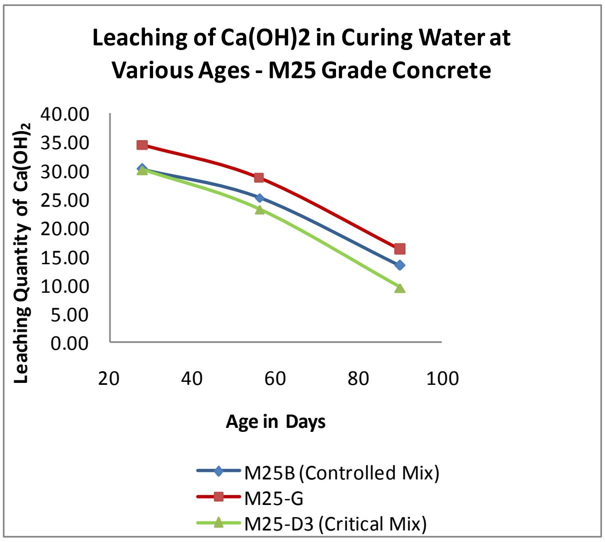

Fig. 9. Leaching of $Ca(OH)_2$ in M25 concrete

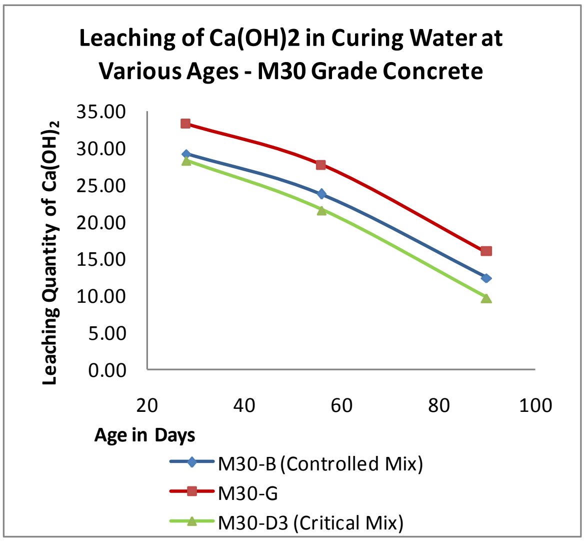

Fig. 10. Leaching of $Ca(OH)_2$ in M30 concrete

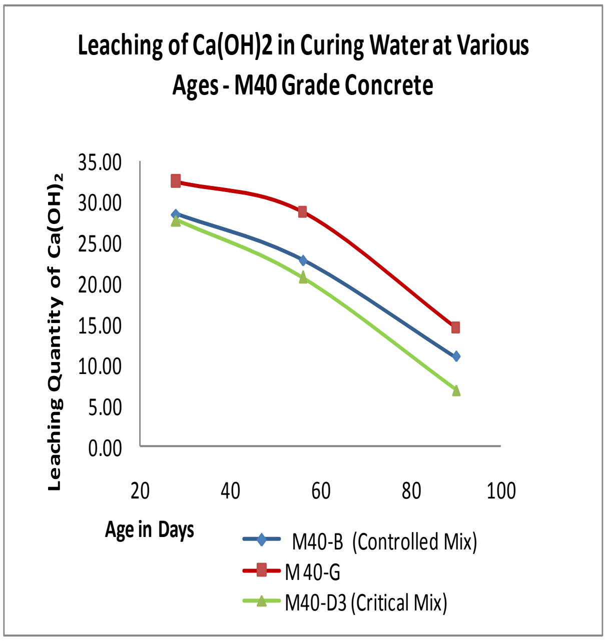

Fig.11: Leaching of $Ca(OH)_2$ in M40 concrete

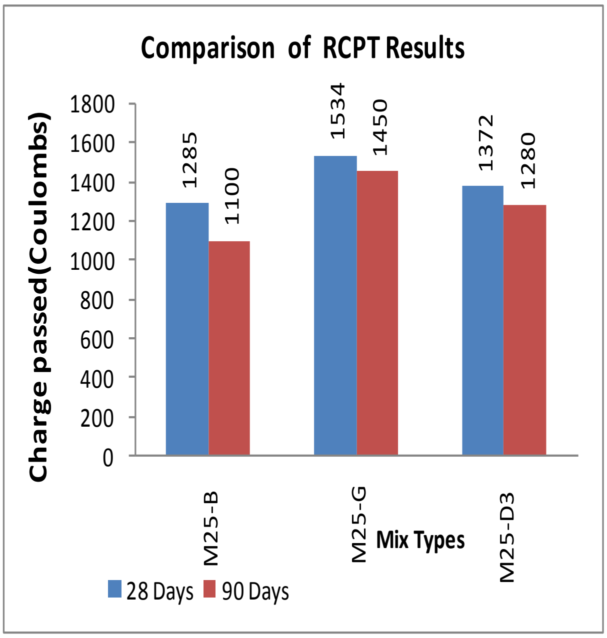

Fig. 12: Rapid Chlorid permeability for M25 Grade concrete

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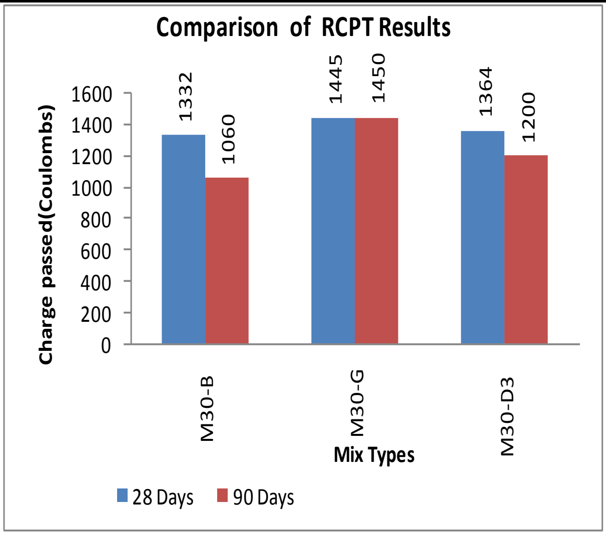

Fig. 13: Rapid Chlorid permeability for M30 Grade concrete

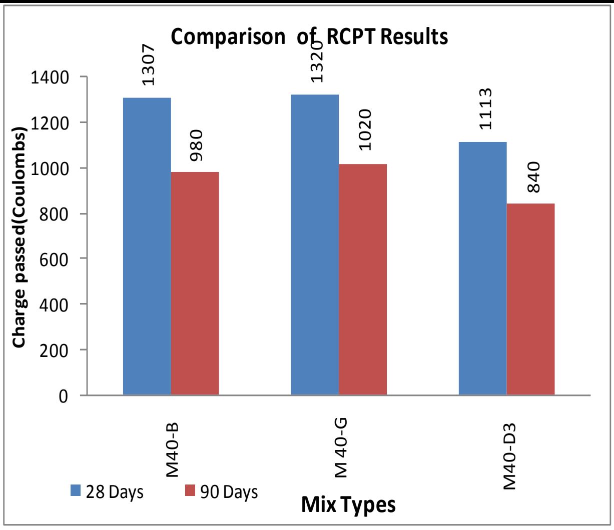

Fig.14: Rapid Chlorid permeability for M40 Grade concrete

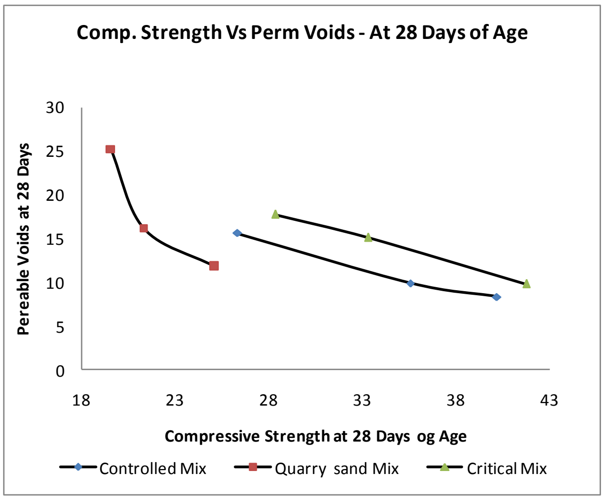

Fig. 15: Effect of permeable voids on copressive strength after 28 days curing

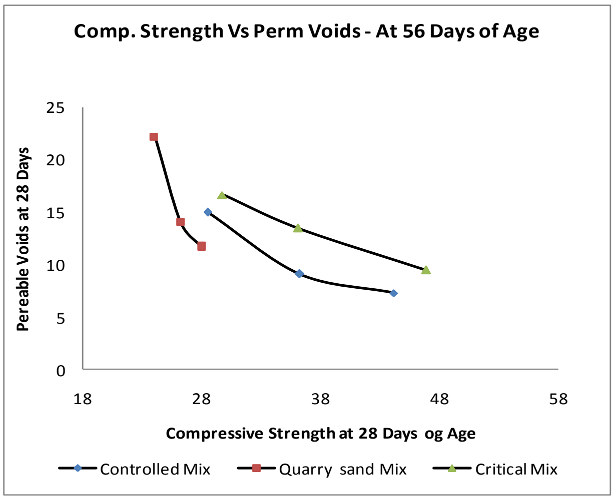

Fig. 16: Effect of permeable voids on copressive strength after 56 days curing

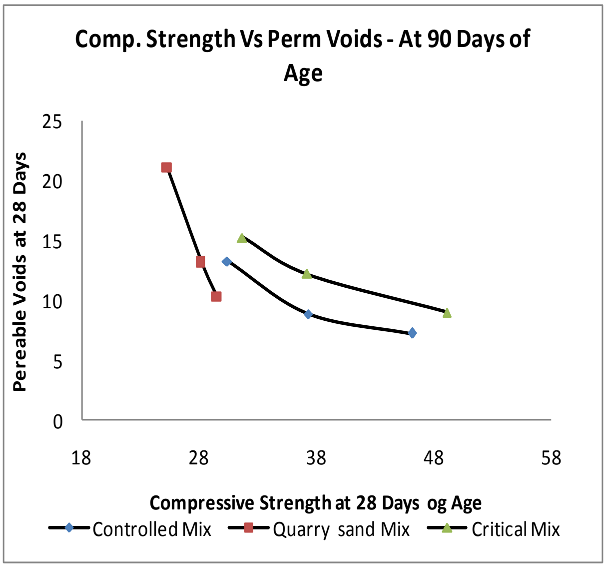

Fig. 17: Effect of permeable voids on copressive strength after 90 days curing