International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-12, October 2019

Sulphate attack Resistance of Geo-polymer Concrete made with Partial Replacement of Coarse Aggregate by Recycled Coarse Aggregate

T. Srinivas , R. N. Koushik

Abstract: ***The primary intent of this paper is to study replacement of coarse aggregate with RCA of M40 grade concrete in different proportions such as 0%,10%, 20%, 30% and 40% and also to collate the results of geo-polymer concrete made with recycled coarse aggregates(GPCRCA) with geo-polymer concrete of natural coarse aggregate(GPCNA) and controlled concrete of respective grade. Geo-polymer concrete (GPC) is observed to be more resistant towards sulphate attack, with both in (CA) and (RCA) to a replacement of 30%, when it is compared with the similar grade of controlled concrete(CC). The durability of the concrete cubes are analyzed by immersing in 5% concentration solutions for a time period of 15, 45,75 and 105 days, The change of weight and compressive strength towards resistance is evaluated . Results stipulated that Geo-polymer concrete is highly resistant to Sodium sulphate and Magnesium sulphate.***

Keywords: ***Geo-polymer Concrete, Recycled Aggregate, Alkaline Solutions, Controlled concrete Sodium sulphate and Magnesium sulphate***.

I. INTRODUCTION

Portland cement is the leading material for manufacturing of concrete around the world, an demand of over 1.5 billion tons is fulfilled annually. However, the Portland cement production is energy-intensive it also releases a notable volume of (CO_2) to the atmosphere. Thus, the development of geo-polymer concrete can play a very vital role in the context of sustainability and environmental issues. Geo-polymer binders can offer a similar performance to conventional cementitious binders in a range of applications and also reduce greenhouse gas emissions. The availablity of geo-polymers depends on materials factors such as availability, price, specific demand of user .

Revised Manuscript Received on October 30, 2019.
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Microstructure and properties of geo-polymers rely strongly on the character of the initial raw materials although the microscopic characteristics of alumino-silicate primarily based geo-polymers might seem similar. Using the coarse aggregate that is recycled from (C&D) waste, that reflects within the environment and economic benefit.

Durability of concrete is that the most essential property that evaluates the life of concrete. Exposure of concrete with external environment is one among the numerous factors that indicate the durability of concrete. There are several chemical attacks like acid attack, alkali attack etc. The extent of decay throughout sulphate attack of concrete rely on the chemical nature of anions present within it. Type of aggregate and concrete additionally influence the intensiveness of sulphate attack. Although OPC is that the wide used binder in the construction industry, the resistance for chemical attacks in sulphates is a major factor. When cement composites are extensively damaged by sulphates where as Ca(OH)2 is dissolved and the hydrated silicate and aluminium phases are decayed. In the past several few years geo-polymer binders have emerged together of the conceivable chance to OPC binders as a result of their resistance against sulphate attack

II. MATERIALS

A. *Ordinary Portland Cement*

The 53-grade of ordinary Portland cement is utilized and procured was tested in accordance for physical properties with the IS: 4031-1968 and ascertained to be conforming the numerous specifications of IS 12629-2009.

B. *Fine Aggregate(FA)*

In this, FA utilized is procured from local sources. The sand utilized is free away from clay matter, organic impurities silt and silt. The physical properties of fine aggregate like specific gravity, bulk density, gradation & fineness modulus were tested in accordance with IS: 2386. The sand is confirmed of Zone-II of IS 383-1970.

C. *Coarse Aggregate*

The angular crushed aggregate with maximum size of 20mm procured from the M.V crushing plant is utilizes in the present study. The aggregate particle size of 20mm is taken for this experimental setup.

Properties of coarse aggregate are tested in accordance with IS: 2386-1963.The specific gravity of coarse aggregate is found to be 2.63.

D. *Fly Ash*

In this work, the low calcium Class F-fly ash is utilised, which is procured from Vijayawada thermal power station , Andhra Pradesh.

E. *Ground Granulated Blast Furnace Slag*

GGBS is a by-product of the steel industry. GGBS comprises basically of calcium silicates and different bases in molten condition developed simultaneously with Fe in a blast furnace.

F. *Recycled Coarse Aggregate (RCA)*

RCA of C&D waste is gathered and it is a better replacement for Natural coarse aggregate NCA which is up to 40 percent of all waste generated worldwide. RCA and NCA are taken at a proportion of 40% and 60% for this study to validate cube strength, Split tensile strength, and flexural strength. By adding recycled coarse aggregate (RCA) it reduces foot print on environment by improving sustainable development. The strength of ordinary Portland cement concrete OPCC utilizing RCA depends greatly on the percentage of recycled aggregate used. Utilizing recycled aggregate can result in less mineral depletion

G. *Water*

Water free away from chemicals, other forms of impurities , oils are utilized for mixing of concrete as per IS: 456:2000.

H. *Sodium Hydroxide*

$Na(OH)_2$is one of the major ingredients of geo-polymer concrete which is most commonly used as an alkaline activator for geo polymerization. The following are the specifications of Sodium hydroxide and this material is procured from the local laboratory chemical vendors in Hyderabad. The physical appearance of sodium hydroxide pellets are in white solids Specifications are tabulated in table1 as given by the suppliers.

Table 1: Shows Physical properties of NaOH

Molar mass	40 gm/mol
Appearance	White solid
Density	2.1 gr/cc
Melting point	318^0c
Boiling point	1390°C
Amount of heat liberated when dissolved in water	266 cal/gr

I. *Sodium Silicate Solution*

Sodium silicate solution is a alkaline liquid participates a significant role as an activator in the geo-polymerisation process, it also reduces porosity. If excess amount of $Ca(OH)_2$ is present in concrete then it binds with surface thereby increasing durability and water resistance. This material is procured from the local laboratory chemical vendors in Hyderabad. Specifications are tabulated in table 2 as given by the suppliers.

Table 2: Properties of Na2SiO3 Solution

Specific gravity	1.57
Molar mass	123.06 gm/mol
Na_2O (by mass)	15.35%
SiO_2 (by mass)	30.00%
Water (by mass)	56.00%
Weight ratio (SiO_2 to Na_2O)	2.09
Molarity ratio	0.98

J. *Super Plasticizer*

Super plasticizer (MasterRheobuild920SH) was used as water reducing admixture, it increases workability. It is added in 1.5% to the binder.

K. *Table 3: Physical properties of Super plasticizer*

L. *State*	M. *Liquid*
N. *Colour*	O. *Dark Brown*
P. *Density*	Q. *1.20*
R. *Chloride content*	S. *0.074*
T. *Chemical name*	U. *Naphthalene formaldehyde polymers*
V. *Dry material content*	W. *39.38*
X. *P^H*	Y. *8.40*

III. EXPERIMENTAL INVESTIGATION

A. *General*

The main objective of this paper is to study the Durability properties of geopolymer concrete of grade G40 when natural coarse aggregate is replaced with recycled coarse aggregate in different proportions such as 0%,10%, 20%, 30% and 40% and also to compare the results of geo-polymer concrete made with recycled coarse aggregates with geo-polymer concrete of natural coarse aggregate and controlled concrete of respective grade. The specimens of size 100 mm cubes were casted the specimens were cured at 60°C for a period of 24 hours .

B. *Mixing and Casting of Geo-polymer Concrete*

Geo-polymer concrete is casted by utilizing the similar method which is employed within the conventional concrete. In the laboratory, the fly ash and also the aggregates were mixed along in dry by using a pan mixer for a time of two minutes, then the alkaline liquid was mixed with the super plasticizer and extra water if any required. An alkaline solution of Na(OH)2 &Na_2SiO_3 with molarity 10M are used alkali activators to synthesis the geo-polymer in this study. The alkaline liquid of the mixture was then added to the dry material and the mixing continued usually for additional two minutes. The fresh concrete was casted by the standard ways utilized in the case of conventional concrete. The workability of the fresh concrete was measured by means of the standard slump test.

IV. SULPHATE RESISTANCE

The Sodium sulphate and Magnesium sulphate attack resistance of geo-polymer concrete is evaluated. To carry the sulphate attack resistance test within the present investigation techniques of immersion is adopted. Specimens are immersed in acid solutions after casting and curing.

The concentration of Sodium sulphate and Magnesium sulphate solutions are 5%. The analysis is conducted after period of 15,45,75 and 105days from the date of immersion. Solutions are kept at room temperature. The solution is replaced at regular intervals of 15 days to takecare concentration of solution throughout the test period. The percentage weight loss, percentage cube strength loss is evaluated. The geo-polymer concrete decreases weight .when the sulphate concentration increases and the same effect is reflected after 105 days of immersion in sulphates. The weight of GPC specimen before and after immersion is shown in figure. The cube strength of geo-polymer concrete immersed in Na_2SO_4 and $MgSo_4$ concentrations are evaluated. The comparison of cube strength with Conventional M40 grade concrete is also shown below.

V. TEST RESULTS

The various weights, percentage of weight loss & cube strength loss of controlled concrete with RCA and geo-polymer concrete along with recycled aggregate is calculated at 5% concentration of HCL and H_2SO_4 is as shown below.

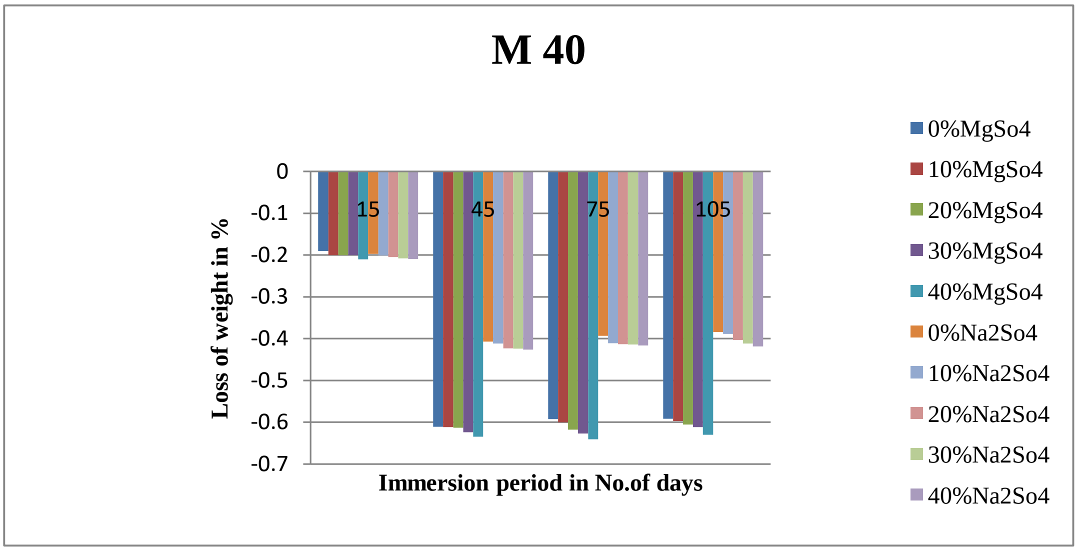
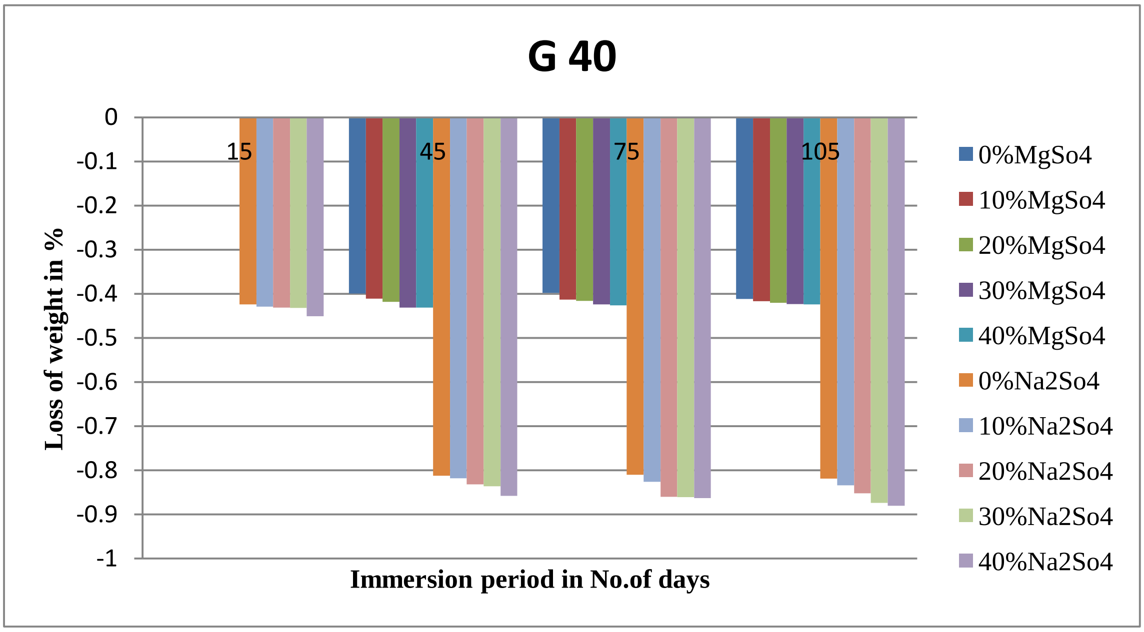


Fig : Percentage weight loss in controlled concrete (M40) when immersed in 5% concentration



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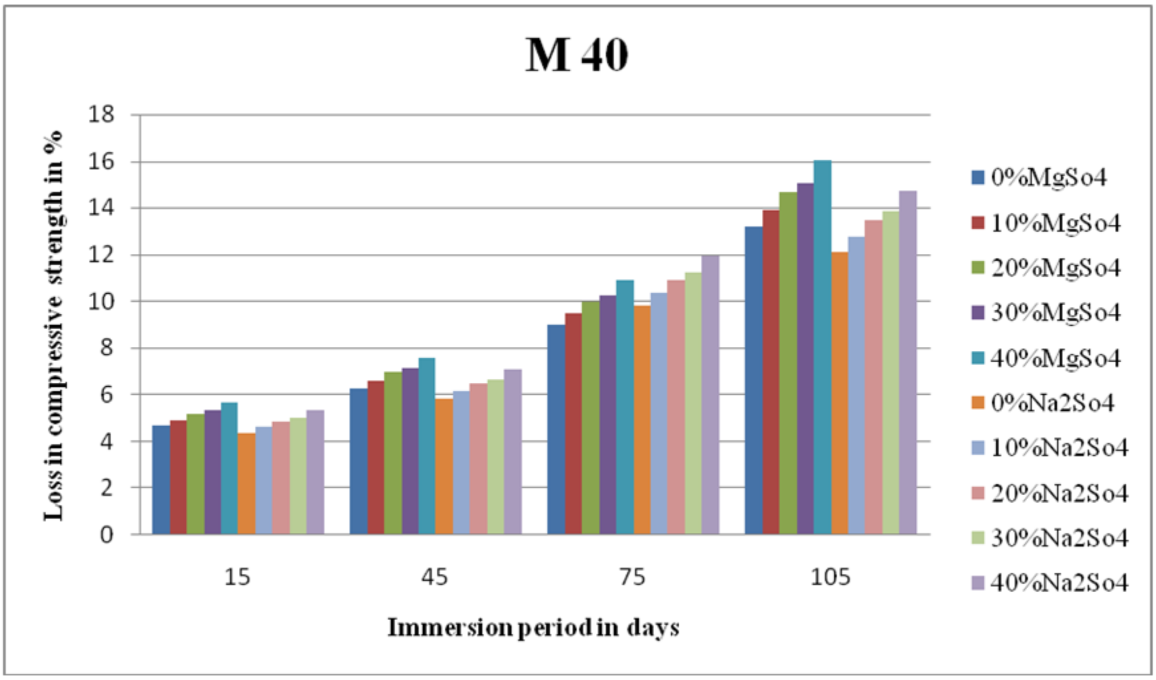

Fig : Percentage compressive strength loss in M40 when immersed in 5% concentration

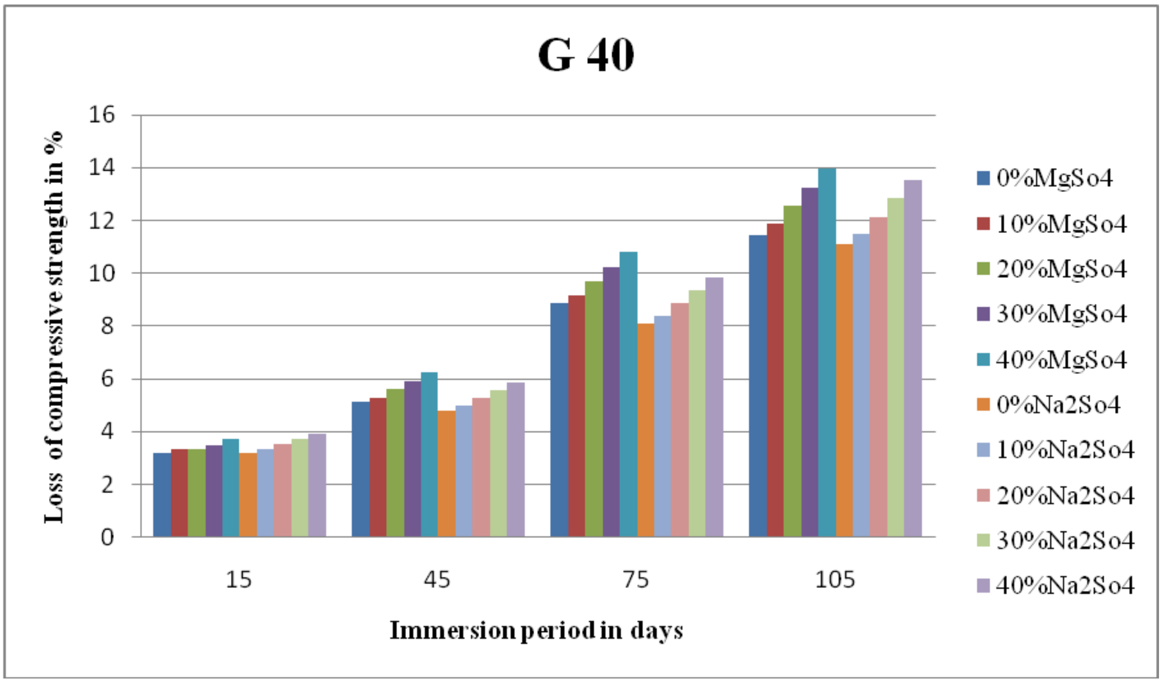

Fig : Percentage compressive strength loss in G 40 when immersed in 5% concentration

A. *Acid Durability Factors*

The (ADFs) can be calculated .

ADF = Sr (N/M)

Where, Sr = Relative strength at N days, (%)

N = No. of days the durability factor needs to be calculated.

M = No. of days the exposure of specimens to be terminated.

ATT was finished at 105 days. Thus M= 105

B. *Acid Attack Factors*

The decay of surface at each corner of the affected face and therefore the opposite face is measured in terms of the mm for each of the two cubes and the (AAFs) per face is calculated as follows.

AAF = (8 corners of every 2 cubes in loss) / 4

The Tables 5.15 to 5.16 shows the (ADFs) and (AAFs) of both grades of geo-polymer and controlled concrete specimens exposed to 5% concentration acids of NA2SO4 and MGSO4 solution at various days of immersion.

Retrieval Number: L25091081219/2019©BEIESP
DOI:10.35940/ijitee.L2509.1081219
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

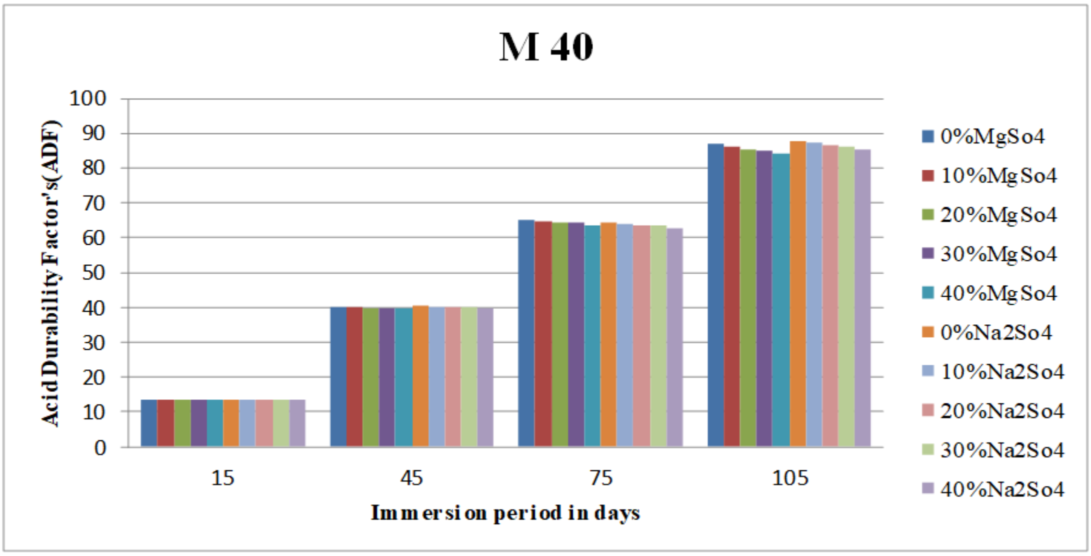

Fig : Acid Durability Factors of M 40 when immersed in 5% concentration of sulphates

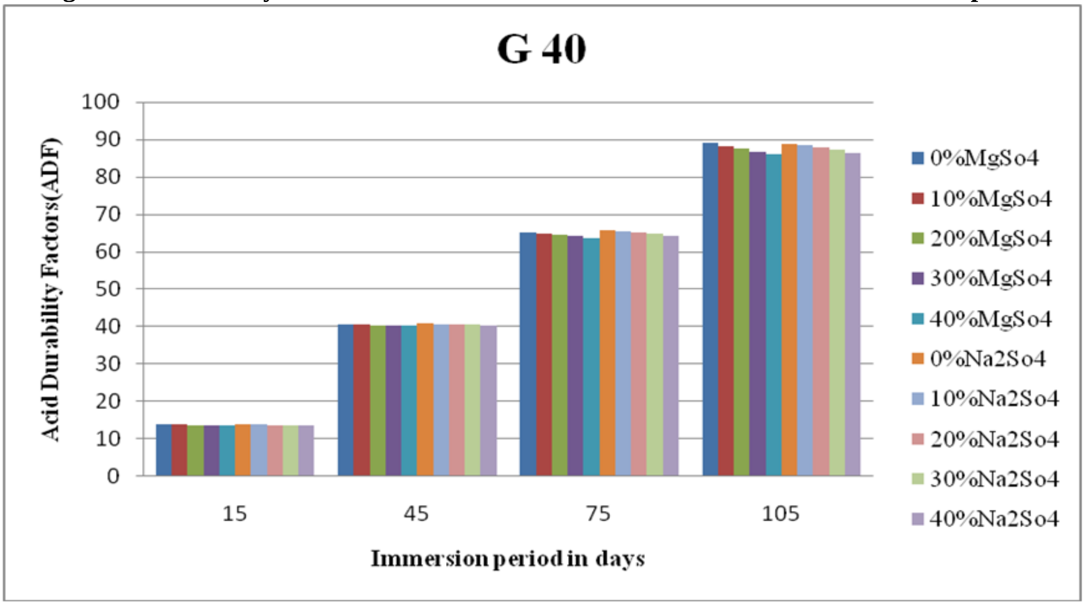

Fig : Acid Durability Factors of G 40 when immersed in 5% concentration of sulphates

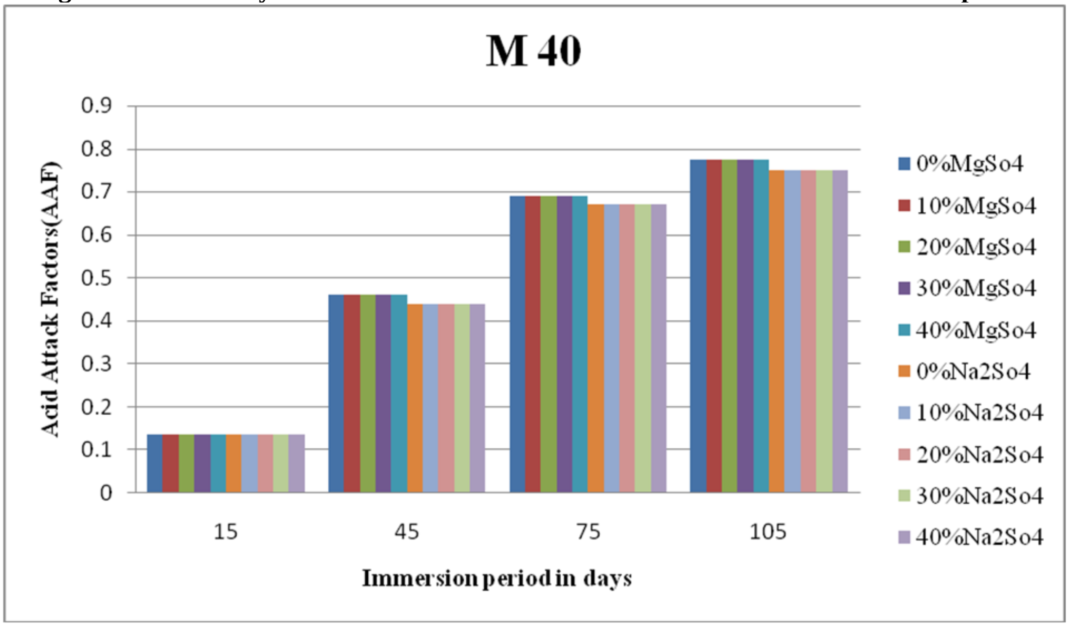

Fig : (AAFs) of M 40 when immersed in 5% concentration of sulphates

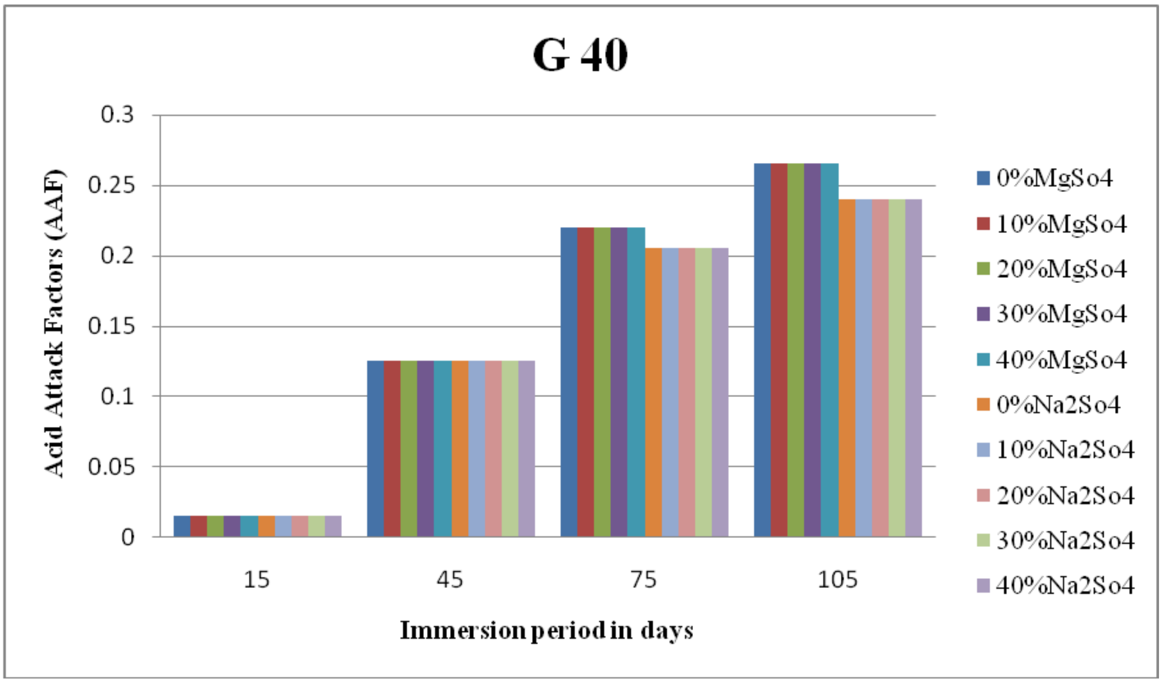

Fig : Acid Durability Factors of G 40 when immersed in 5% concentration of sulphates

VI. CONCLUSION

The conclusions can be drawn as follows :

i. The percentage loss of cube strength in CC, when subjected to $MgSo_4$ for 15 days to 105 days is in between 4.680 to 16.042, where as in geopolymer concrete it is in between 3.207 to 13.961. Thus GPC is more resistance to CC.

ii. The loss of percentage of compressive strength of CC, when exposed to Na_2So_4 for 15 days to 105 days is in between 4.389 to 14.726, where as in GPC it is in between 3.216 to 13.522. Therefore GPC is more resistance than controlled concrete.

iii. The % loss of weight is increased with increase in time of immersion for both conventional and geopolymer concrete when the specimens are subjected to $MgSo_4$ and Na_2So_4.

iv. When compared to CC, this GPC has better durability properties. Due to its outstanding cube strength, this GPC is suitable for structural application and GPC has no visible signs of surface deterioration.

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