iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** XII **Month of publication:** December 2017

DOI:

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor :6.887
Volume 5 Issue XII December 2017- Available at www.ijraset.com

Sulphur-Infiltrated Concrete and its Properties

Aqib Parmar [1], Dr. K.B. Parikh [2]
[1]*PG Student, Applied Mechanics Department, Government Engineering College, Dahod, Gujarat, India*
[2]*Associate Professor, Applied Mechanics Department, Government Engineering College, Dahod, Gujarat, India*

Abstract: Developed techniques of impregnating sulphur in porous materials like concrete has produced a whole new type of composite which is known as Sulphur-Infiltrated Concrete (SIC). An effective way of using Sulphur is to produce a concrete which show great improvement in strength than the conventional one. Not only strength but other properties like resistance to corrosion, water impermeability and rapid hardening have also been achieved. Modulus of elasticity, durability and resistance to repeated cycles of freezing and thawing can be increased significantly by impregnating sulphur in Portland cement concrete. It can be used in precast industry, fencing posts, sewer pipes, railway sleepers, irrigation canal etc. The technique to produce SIC is very simple, inexpensive and effective. Here an attempt is made to collect detailed research overview of some very important properties like Compressive strength, Modulus of elasticity, Density, Strain at rupture, Duration of infiltration, Splitting-tensile strength.

Keywords*: Compressive Strength, W/C Ratio, Freezing And Thawing, Acid Attack, Alkaline Attack, Brine Attack, Neutral Solution Attack.

I.INTRODUCTION

There are some well known methods of improving the properties of concrete like subsequent polymerization of monomers by radiation, by impregnation of Portland cement concrete with organic monomers and by thermal catalytic techniques. The use of polymer impregnated concrete has big hinderance in terms of high prices of monomers which prevents its commercial use of polymer impregnated concrete(PIC). As the prices of oil increases day by day there are no chances of getting monomers cheaply in near future[1]. The strength of concrete is achieved by the fact that porous bodies like concrete which have randomly distributed pores have region of stress concentration when loaded externally. The stress concentration would be modified if a porous body is impregnated by some material. The penetration of impregnant in the smaller pores will show us the extent of modification[4]. The impregnating material should satisfy following: Low cost material, Abundant occurrence, suitable melting point(100-400^{o}C), melt with low viscosity, melt wet surface of concrete, mechanical strength and stiffness, chemically inactive, low vapour pressure of solid, fire-proof. On the basis of above requirement sulphur satisfies most of the properties hence sulphur has been chosen as impregnating material[1].

Sulphur infiltrated concrete is a relatively new material and it differs in manufacture, handling and testing with respect to Portland cement concrete but is similar in final appearance[10]. SIC is prepared by immersing conventional concrete specimen into molten sulphur. . When other construction material deteriorate rapidly at the same time SIC which is manufactured by impregnating sulphur tends to have high strength against corrosion and are not attacked by many mineral acids and salt solutions. Sulphur is a thermoplastic material with the use of it SIC is produced which performs excellent in acidic and salty environment.

There was lot of demand for sulphur during WW-I. In 1921 a study was conducted on the use of sulphur to produce a building material and mortar with 40% sulphur which in turn results in a material having a very high resistance against acidic environment and was having good mechanical properties but a major set back comes into the picture when temperature changes occur and there was reduction in bending strength of mortar[11]. In 1940 the above mortar was developed by additives and it was widely suitable for construction in acidic environment. In 1960 viscosity of this material was focused and in 1970 durability of this material was focused. Due to its (SIC and Sulphur asphalt) environment friendly and cost effective these materials have been used widely. Still researches and innovation are going on in countries like America, Canada, Poland and Russia[11]. In many countries availability of sulphur has increased significantly in last few decades. There are several methods to obtain sulphur like Sulphur mines, Coal refining, Refining of crude oil and natural gas, Refining sour gas and Removal of hydrogen sulphide from crude oil and natural gas[11].The most important raw material to produce sulphuric acid is sulphur and is abundant available at certain places like Gulf coast of United States, and in Poland where about several hundred million tons have been estimated in Tarnobrzeg deposits. From the environmental point of view sulphur is becoming a major problem as it is a by product from cleaning of natural gas and oil. Tensile strength of elemental sulphur was found to be 1.1 MN/m^2 and compressive strength was 22.6 MN/m^2 [3].

SIC is known to have inherent weakness to water as SIC losses its weight, its compressive strength, loss of sulphur from surfaces[12]. The conventional concrete properties cannot be implemented to find properties of SIC as conventional concrete gain strength in water whereas SIC weakens in water. In conventional concrete when water dries shrinkage occurs but in SIC when sulphur cools shrinkage occurs[2].

II. LITERATURE REVIEW

1) *Niels Thaulow et al. (1973)* studied the effect of sulphur loading on properties like Compressive strength, Modulus of elasticity, Density and Strain at rupture of SIC. He concluded that compressive strength of SIC increases by a factor of 2.7. [1]

The following results were obtained by him:

TABLE I: PROPERTIES OF SIC . [1]

Sr.NO	Properties	SIC cylinder	Concrete cylinder	Units
1	Sulphur loading	8.44	0	W%
2	Compressive strength	169	64.2	MN/m^2
3	Modulus of elasticity	$5.68x10^4$	$2.64x10^4$	MN/m^2
4	Density	2.6	2.4	g/cm^3
5	Strain at rupture	$3.4x10^{-3}$	$3.7x10^{-3}$	

2) *M.S.Alam et al. (1980)* performed experiment to present effect on modulus of rupture due to factors such as Duration of Infiltration, Cement/aggregate ratio, Size of aggregate, Rate of cooling, Water/cement ratio, Period of curingon SIC. He found that as the sulphur content increases infiltration in the first 100 minutes increases and it completes at 540 minutes. Longer the duration of infiltration longer will be the infiltrated portion of specimen and hence modulus of rupture increases.Tensile strength of sulphur concrete (without cement) is not more than 6.8744MN/m2 whereas SIC has much higher tensile strength. At cement/aggregate ratio of 0.65 maximum modulus of rupture will occur. With sand as only aggregate the modulus of rupture of SIC is over 13.755MN/m2. When above part is replaced by ¾" size aggregate the modulus of rupture reduces to $8.9407MN/m^2$.At w/c ratio of 0.2 to 0.4 modulus of rupture increases and modulus of rupture becomes independent above w/c ratio of 0.7. Up to w/c ratio of 0.4, percentage of sulphur decreases and then it increases. The percentage of sulphur infiltration is minimum at w/c ratio of 0.43. At w/c ratio of 0.42 the porosity becomes minimum. There is no increase in strength when w/c ratio is increased above 0.7.longer the period of curing lesser will be the sulphur infiltration.The optimum period for curing is 3 days. [2] When specimen were cooled at following temperature following changes occurred in modulus of rupture.

TABLE-2: CHANGES IN MODULUS OF RUPTURE DUE TO TEMPERATURE CHANGE. [2]

SR.NO	CONDITION	MODULUS OF RUPTURE
1	Ice cold water (0^oC)	$29.2937MN/m^2$
2	Water (23^oC)	$16.6434MN/m^2$
3	Air (23^oC)	16.6434MN/m2

3) *T.G.Brown et.al(1980)* reported that Ultimate compressive strength increases as the w/c ratio is lowered at constant sulphur content. On one day cured parent concrete a/c plays a negligible role in the strength of SIC. Elevated temperature does not effect ultimate compressive strength. [3]

4) *Malhotra V.M et.al(1975)* performed experiment to show comparison of compressive strength and splitting tensile strength with different sulphur loading percentage in moist concrete cube[4].

TABLE-3: COMPRESSIVE STRENGTH AND SPLITTING TENSILE STRENGTH. [4]

W/C=0.70, a/c=8.5:1, CA/FA=1:1, Duration of moist curing=24 hr, Duration of drying=24 hr, Age at test=54 hr		
Moist cured cubes	SIC	
Compressive strength =13.6MPa Size=(50x50mm)	Sulphur loading=9.1% , Size=(50x50mm)	Sulphur loading=12.6%, Size=(50x50mm)
	Compressive strength of SIC=68MPa	Compressive strength of SIC=108.5MPa
Compressive strength =9Mpa Size=(75x150mm) Splitting tensile strength=1.9MPa	Sulphur loading=12.4% ,Size=(75x150mm)	
	Compressive strength of SIC=72MPa	Splitting tensile strength of SIC = 10.5MPa

5) *P.Kumar Mehta et.al(1979)* through his experimental work he showed that sulphur infiltrate pozzolana cement showed very poor performance whereas sulphur infiltrated gypsum cement showed good moisture resistance. Improvement in moisture resistance with pretreatment of oxalic acid solution or sodium fluorid solution before sulphur infiltration was found to be more effective.[5]

6) *E.E.Berry et.al(1979)* reported that sulphur infiltation and autoclaving is only suitable to produce small concrete items, mass produced concrete items and high quality concrete items. If silica flour is not present in infiltrated concrete then high strength concrete can be obtained from a lean concrete mix and full infiltration can be readily achieved. [6]

7) *M.S.Alam et.al(1983)* said that modulus of elasticity and strength increases through sulphur infiltration and strain at failure decreases through sulphur infiltration. The compressive failure starts from the failure of whole section in the sulphur infiltrated portion of whole section. [7]

8) *R.L.Yuan et.al(1980)* showed effect of w/c ratio. Concrete with low w/c ratio show lower initial rate of sulphur loading then concrete with high w/c ratio. Compared to untreated units water absorption of sulphur treated units is reduced, for the same percentage of sulphur loading low w/c ratio concrete are more effective in reduction of water absorption compared to high w/c ratio concrete.. Sulphur infiltration increases abrasion resistance of concrete slab, for high w/c ratio concrete exibits a better improvement than low w/c ratio. Sulphur infiltrated concrete slab has higher resistance to acid attack then conventional one, lower w/c ratio concrete are more effective then high w/c ratio concrete. For sulphur treated units there is increase in strength and modulus of elasticity as compared to untreated units. This shows that increase is a function of percentage sulphur loading. [8]

9) *J.A. Soles et.al(1978)* evaluated following observation:

a) Sulphur loading- As the depth of sulphur penetration increases compressive strength of cylinder increases. According to Manning and Hope showed in their experiment with polymer, higher pressure may be necessary to fill the finer capillaries consistently.

b) Freezing and thawing- From experiments it has been concluded that long term exposure of testing specimen to freezing in air and thawing in water has shown that SIC is capable of resisting destruction from extreme conditions. Specimen strength was maintained beyond 1000 cycles and after 1000 cycles seldom linear expansion of 0.08% exceed.

c) Aggressive media- Immersion test showed that less than 0.3% water by volume is absorbed when specimen is fully infiltrated over several months, only porosity of 5% was available for filling.

d) Acidic solutions- Acid attack is inhibited by infiltration but not prevented. At higher acid concentration and sulphuric acid is more destructive than hydrochloric acid.

e) Alkaline solution- When test was done with 1.3N NaOH solution with SIC leaching of sulphur occurs rapidly from infiltrated concrete and hence it could not protect hydrated cement phases from other destructive reactions.

f) Neutral solutions- When SIC immersed in neutral and sulfatic solutions(2.5% Na_2SO4) it losses abundant of sulphur. When specimen were placed in concentrated brine solution and where temperature ocassionaly drop 0^oC.After 10 month no sign of deterioration either externally or internally was revealed. [9]

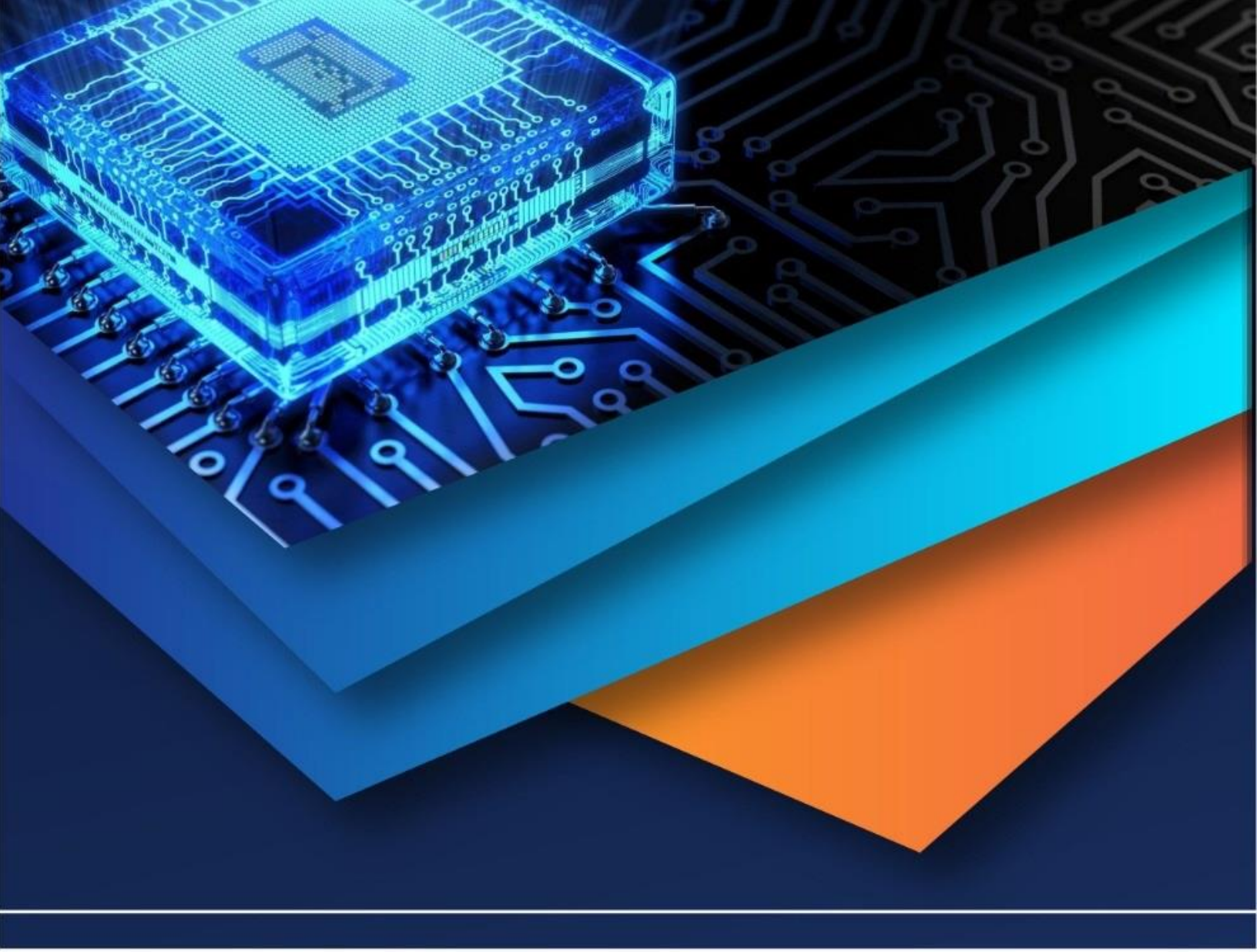
III. CONCLUSION

The following conclusions were drawn from the above literature review. With increase in concentration of sulphur loading properties like compressive strength, modulus of elasticity, density and strain at rupture shows immense change in SIC cylinder specimen. As compared to conventional concrete cylinder, SIC cylinder with 8.4% of sulphur loading has shown increase in compressive strength by $104.8MN/m^2$. Not only in concrete but infiltration of sulphur in cement has shown great improvement in

properties of concrete in terms of moisture. Further to improve moisture resistance of SIC, pretreatment (before sulphur infiltration) with oxalic acid or sodium fluriod solution has to be done. For better sulphur infiltration in SIC high pressure may be required to fill finer capillaries. SIC is far more better in resisting against freezing and thawing against aggressive media.SIC is not able to resist itself from alkaline nature as well as against neutral solution. Effect of acid on SIC is too dangerous and its effect can be inhibit but cannot be prevented.

REFERENCES

[1] Niels Thaulow, (1974), Sulphur-Impregnated Concrete(Sic),Cement And Concrete Research, Vol.4, PP. 269-277.
[2] M.S.Alam,R.S.Juruf, (1983), Factors Influencing The Modulus Of Rupture Of Sulphur Infiltrated Concrete, Cement And Concrete Research, Vol.13, PP. 161-170.
[3] T.G.Brown, M.H.Baluchg, (1980), Mix Design,Durability And Creep Characteristics Of Sulphur Infiltrated Concrete, Cement And Concrete Research, Vol.10, PP. 623-630.
[4] Malhotra V.M.,(1975) Development Of Sulphur-Infiltrated High Strength Concrete, American Concrete Institute Journal, Vol. 72, Issue-9.
[5] P.Kumar Mehta,Suh-Siang Chen, (1979), Studies On Improving Moisture Resistance Of Sulphur Infiltrated Mortar, Cement And Concrete Research, Vol. 9, PP. 189-196.
[6] E.E.Berry,B.B.Hope, (1979) Preparation And Properties Of Sulphur Infiltrated Autoclaved Concrete, Cement And Concrete Research,Vol.9 PP. 667-676.
[7] M.S.Alam,R.S.Juruf, (1983), Prediction Of The Compressive Strength Of SIC For Variable Sulphur Loading,Cement And Concrete Research,Vol.13, PP. 451-458.
[8] R.L.Yuan,W.F.Chen, (1980)Sulphur Treated Concrete Slabs, Advance In Concrete Slab Technology, PP. 75-83
[9] J.A.Soles,G.G.Carette,V.M.Malhotra, (1978), Stability Of Sulphur Infiltrated Concrete In Various Enviornment, Advances In Chemistry, Vol.165.
[10] American Concrete Institute(ACI) Committee, (1998) Guide For Mixing And Placing Sulfur Concrete In Construction, American concrete institute.
[11] Ali Ghasemi Khademi,Hooshyar Imami Kala Sar, (2015), Comparison Of Sulfur Concrete, Cement Concrete And Cement-Sulfur Concrete And Their Properties And Applications,Current World Enviornment, Vol.10, PP 201-207.
[12] E.E.Berry,J.A.Soles,V.M.Malhotra, (1977), Leaching Of Sulphur And Calcium From Sulphur Infiltrated Concrete By Alkaline And Neutral Aqueous Media,Cement And Concrete Research,Vol.7 PP. 185-190.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY