Experimental Study on Properties of Concrete using Latex and Rock Wool Fibre

Prabavathy.S N.K.Amudhavalli

Abstract**: *The research focuses on the use of styrene- butadiene rubber latex and rock wool fibre for the improvement of the mechanical properties of concrete and its effects on elevated temperature. Material properties play a most important part in the performance of concrete material during its lifetime. The Compressive strength of concrete at high temperature is most important in fire resistant design. Cement mortar cube is prepared with varying percentage of latex 0% to 10% by replacing the weight of water with the optimized ratio of mineral wool fibre from 0% to 0.50% to the volume of the mix. The final optimized percentage of styrene butadiene rubber latex and rock wool fibre is of 6% by the weight of water and 0.20% of the volume of mix. This optimized percentage is added to concrete and the variation of mechanical properties, residual compressive strength, mass loss at elevated temperature and water absorption tests are presented*.**

Index Terms**: *Rubber Latex, Elevated temperature, Rock wool fibre, Compressive strength.***

I. INTRODUCTION

Concrete is a composite, the most widely used man-made construction material in the world. The property of the material in the concrete plays an essential part in fire and thermal performance during the life span of the structure. The mechanical properties and the fire safety requirements should satisfy the concrete members which are used in the buildings as specified in the building codes. Concrete adjacent to furnaces, reactors and during the fire are exposed to elevated temperatures and at this stage the strength and durability properties of concrete are considerably reduced.. Therefore, the properties of concrete retained after the fires are of still important in determining the load carrying capacity and for reinstating fire-damaged constructions. When exposed to high temperature, physical structure and the chemical composition of the concrete are changed considerably. Fire safety measures to structural members are measured in terms of fire resistance which is the duration during which a structural member is able to resist fire with respect to structural integrity, stability and temperature transmission [1], [2].

Concrete generally provides higher fire resistance properties among all building materials. The behavior of a concrete as a structural member when exposed to fire mainly depends on thermal, mechanical, and deformation properties of concrete. Alike to other materials the mechanical and deformation properties of concrete changes considerably within the temperature range allied with the building fire. These properties differ as a function of temperature which depends on the composition and uniqueness of concrete. The strength of concrete has a significant influence on its properties at both room temperature and high temperatures. The properties of high strength concrete vary with temperature than those of normal concrete [3]. Normally high strength concrete will withstand high temperature than the normal concrete. However, there is an increase in cost as the cement content increases with the increase in the grade of the concrete. Thus, in order to improve the thermal behavior of the concrete without increasing its grade is of prime importance. Nowadays change in temperature is becoming a major issue across the world. As a result of urbanization, the huge amount of carbon dioxide (CO_2) and carbon monoxide (CO) are produced which causes global warming. For this reason, various civil engineering structures undergo temperature changes and due to this external agents may penetrate the structure and cause deterioration. Hence the structure should be highly resistant towards variation in temperature.

Latex is defined as the dispersion of polymer particles in the water. Styrene butadiene rubber (SBR) latex is a category of high-polymer dispersion emulsion composed of butadiene, styrene and water which can be easily bonded to other materials. In civil engineering field it can be added to increase the flexural and compressive strength of the concrete [4]. The workability of the concrete is increased by adding latex to the concrete [5]. The major problem endured by concrete is the external environmental agents such as acids and sulphates. Latex modified concrete has a high resistant action to acidic and sulphate environments [6-12]. The mechanical properties of the mortar and concrete are enhanced by adding SBR latex [13]. SBR latex has no significant effect on the hydration of the cement for a long term. In the microstructure, the latex film present in the cement substrate makes it possible to increase the toughness and compact degree of the interfacial transition zone [14]. The durability and strength parameters in concrete are enhanced by adding natural fibres or synthetic fibres [15].

Thus, in order to ensure the safety of concrete structure, it should satisfy both mechanical and thermal properties. The various thermal properties of the concrete are thermal conductivity, specific heat, and thermal diffusivity. In this experimental investigation, the effects of elevated temperature on the residual compressive strength of the control concrete (**NC**), latex concrete and latex wool concrete are extensively examined. The optimum percentage of latex added to the concrete is denoted as latex concrete(**LC**) and

Revised Manuscript Received on March 20, 2019.

Prabavathy.S Senior Professor, Department of Civil Engineering, Mepco Schlenk Engineering College, Sivakasi, Tamilnadu, India

N.K.Amudhavalli, Professor, Department of Civil Engineering, CMR College of Engineering & Technology, Hyderabad, Telangana, India.

the optimum percentage of latex and mineral wool fibre added to the concrete is denoted as latex wool fibre concrete (**LWFC**).

II. EXPERIMENTAL WORK

2.1 Materials

2.1.1 Cement

Locally available Ultratech Portland Pozzolana Cement is used in this investigation. The specific gravity of cement is determined by using Le Chatelier Flask as per IS 4031 part-11[16] and is found to be 2.95.

2.1.2 Fine Aggregate

The river sand is used as fine aggregate. The specific gravity of fine aggregate is determined by pycnometer as per IS 2386 part-3 [17] and is found to be 2.62.

2.1.3 Coarse Aggregate

Machine crushed granite aggregate confirming to IS 383-1970 [18] consisting of 20 mm size aggregate which is obtained from the local quarry. The specific gravity of coarse aggregate is found to be 2.64.

2.1.4 Water Potable

Water of pH 7 available in the laboratory is used for making the concrete as well as for the process of curing the specimen.

2.1.5 SBR Latex

Styrene butadiene rubber latex is added to improve the physical properties of concrete. SBR latex used in this investigation is supplied by BASF and the properties are shown in Table I.

Table . I Properties of SBR Latex

Table Aspect	Milky white Styrene butadiene co- polymer matrix
pH	9
Relative density	1.02 @ $25^{0}C$
Solid content	37%

2.1.6 Mineral Wool Fibre

Mineral wool is also known as mineral fibre, which are man-made mineral fibre and man-made vitreous fibre. These fibres are formed by spinning or drawing molten minerals. Rock wool fibre is used which is of basalt rock origin having heat resistance temperature of $750^{0}C$ to $800^{0}C$. Fig. 1 shows the rock wool fibre which is used in this experiment.

2.2 Preparation and Production of Mixtures

Mix design has been done for M20 grade concrete using IS Standard 10262:2009[19] and the mix ratio is 1:1.45:2.53 with water cement ratio of 0.45. Styrene butadiene rubber latex is replaced from 0% to 10% by weight of water at an interval of 1%. Three cement mortar cubes of size 70.6 x 70.6 x 70.6 mm are cast for every percentage of latex (0% to 10 %) and is tested in compression testing machine as per IS 4031[20] to find the optimum percentage which gives increase in compressive strength compared to control mix. Finally with the optimized latex percentage, mineral wool fibre is added from 0% to 0.50% to the volume of the mortar mix at an interval of 0.05%, and the optimum percentage is taken as the maximum amount of volume of fibre added to the mortar mix until there is a reduction in its compressive strength. The final optimum percentage of styrene butadiene rubber latex and mineral wool fibre is added to the concrete to study the mechanical properties and the elevated temperature effect.

Fig. 1 Rock Wool Fibre

2.2 Compressive strength and Flexural strength tests

Fig. 2. (a) Compression test (b) Flexural testing setup

Compressive strength and flexural strength tests are done as per IS 516[21] as shown in Fig. 2 (a) and Fig. 2 (b). Mortar cubes of size 70.6 x 70.6 x 70.6mm and concrete cubes of size 150x150x150mm are cast and it is cured for 28 days. Concrete prism of size 500 x 100 x 100 mm is cast and cured for 28 days and subjected to flexural strength test.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The load is applied through two similar rollers, mounted at the third points of the supporting span. Three specimens of mortar cube are tested for every percentage of latex and mineral wool fibre.

2.4 Split tensile strength and Modulus of Elasticity Tests

Split tensile strength and modulus of elasticity tests are performed according to ASTM C496 [22] and IS 516 standards as shown in Fig. 3 (a) and Fig. 3(b). Specimens of size 150 mm diameter and 300mm height are cast and cured for 28 days. Modulus of elasticity is obtained from the stress-strain curve for each concrete mixture. Three specimens are tested for a particular concrete mix.

Fig. 3 (a) Split tensile strength test (b) Modulus of Elasticity test

2.5 Elevated Temperature test

Elevated temperature test is done to find the mass loss and the residual compressive strength. The cubes are exposed to the elevated temperature in the muffle furnace. The specimens are tested in temperature ranges from 100^0C to 700^0C with an interval of 100^0C for a period of about 2 hours. The test apparatus is shown in Fig. 4(a). The tests are performed on 100 x100 x100 mm concrete cubes cured for 28 days. Three specimens are tested for each temperature variation of concrete mixtures. The mass loss and compressive strength are noted.

2.6 Water absorption test

Fig. 4. (a) Muffle furnace –Elevated temperature test (b) Hot air oven-water absorption test

Water absorption test is conducted in hot air oven by heating the specimen as shown in Fig. 4 (b). Water absorption test plays an important role in durability characteristics of concrete. Concrete cubes of size 150x150x150mm are cast and cured for 28days .The initial weight of the specimen are noted. The test specimens are oven dried in the hot air oven at 105^0C for the period of 24 hours are noted as dry weights..The specimens are immersed in water for the period of 24 hours and surface dried. The weights are noted. Absorption characteristic of concrete is evaluated by calculating the difference in weight of specimen after complete drying in oven at 105^0C and the weight after immersion in water.

III. RESULTS AND DISCUSSION

3.1 Compressive Strength

Table II shows the optimum amount of latex to be added is 6% and further addition of latex decreases the compressive strength. Increase of latex percentage increases the workability but it results in segregation and bleeding of the materials and also in strength reduction. The optimum percentage of mineral wool fibre is 0.20% of the volume of the mortar mix and further addition of wool results in decrease of compressive strength as presented in Table III.

Table II. Compressive strength of cement mortar for different percentage of latex

Latex (%)	Compressive strength (MPa)	
	7 days	28 days
0	14.59	23.17
1	14.43	23.19
2	14.87	24.58
3	14.7	24.2
4	15.23	25.76
5	15.8	26.21
6	**16.93**	**26.96**
7	14.81	24.85
8	14.11	23.17
9	13.2	20.23
10	12.5	18.64

Table III. Compressive strength of cement mortar with latex 6% and different percentage of mineral wool fibre

Latex (6%) + Wool Fibre (%)	Compressive strength (MPa)	
	7 days	28 days
0	15.93	0
0.05	16.54	0.05
0.1	16.16	0.1
0.15	16.18	0.15
0.2	18	0.2
0.25	16.25	0.25
0.3	15.06	0.3
0.35	14.85	22.01
0.4	13.05	20.99
0.45	11.39	19.07
0.5	11.04	18.86

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Latex concrete shows 11% and latex wool fibre concrete shows 12.6% increase in compressive strength when compared to the normal concrete specimen as shown in Fig. 5. This is due to good bonding strength between the latex and ingredients of the concrete, and thus results in increase of compressive strength

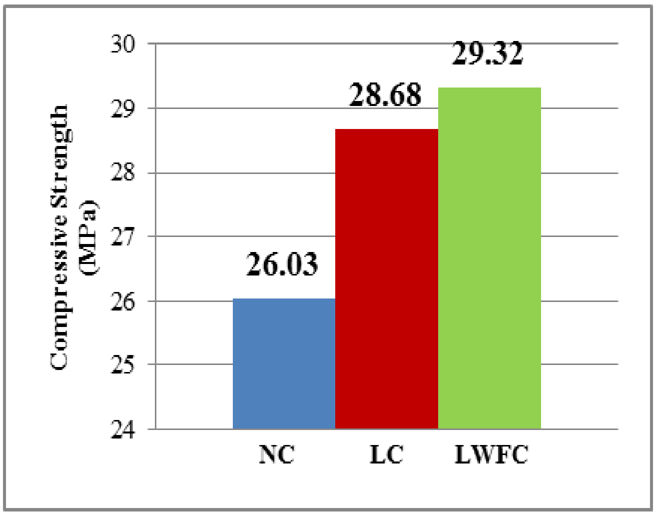

Fig. 5. Variation in Compressive Strength

3.2 Flexural Strength

The flexural of control mix, latex modified concrete and latex modified rock wool fibre concrete test results are presented in Fig. 6. Flexural strength of latex concrete and latex wool fibre concrete shows 2.5% and 4% higher strength than the control prisms. This is due to the addition of rock wool fibre added to the concrete along with the latex which increases the ductility which in turn increases the flexural strength.

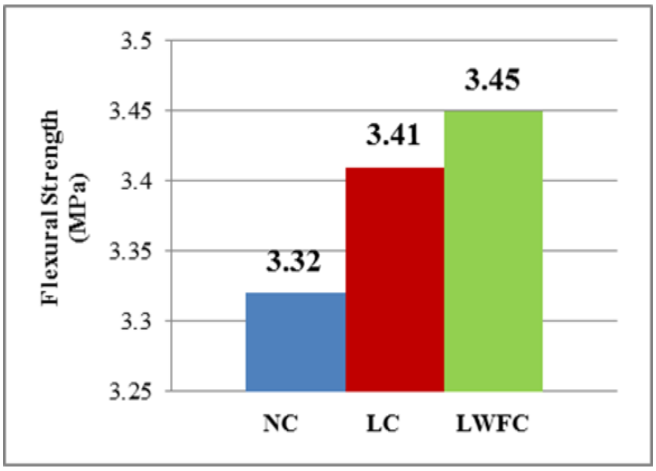

Fig. 6. Variation in Flexural Strength

3.3 Split Tensile Strength

The split tensile strength of normal concrete mix, latex modified concrete and latex modified rock wool fibre concrete results are presented in Fig. 7. The latex concrete shows 17% and latex wool fibre concrete shows 17.5% higher strength than the normal concrete cylinders. This is because of rock wool fibre added to the concrete along with the latex. These fibre bridges the concrete thereby increases the split tensile.

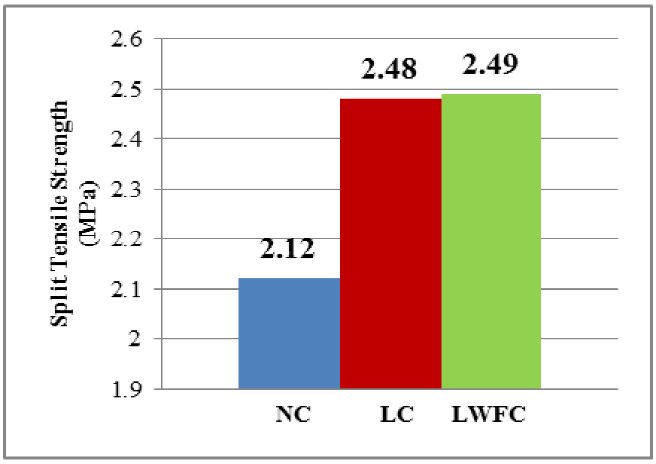

Fig. 7. Variation in Split Tensile Strength

3.4 Modulus of Elasticity

The Young's modulus of concrete is determined from the stress-strain curve. The test result of Latex concrete and Latex wool fibre concrete shows 4.9% and 6% higher than the normal concrete specimen. The results of the Young's modulus are shown in Fig. 8.

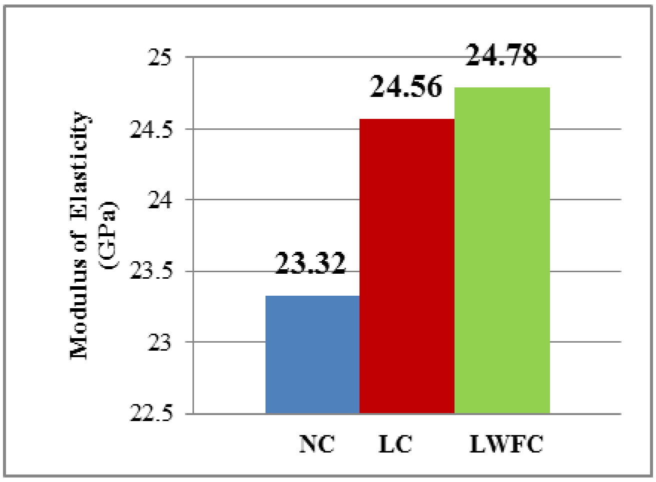

Fig. 8. Variation in Modulus of Elasticity

Fig. 9 shows the stress strain curve for the control mix, Latex concrete and Latex wool fibre concrete.It is indicated from the test results that LWFC and LC withstands more stress with the minimum strain value when compared to the control mix. Control concrete specimens without fiber and latex shows a brittle type of failure and it fails immediately after crack propagation is initiated. It can be seen from Fig. 9, that the latex concrete has an effect on the ultimate strain attained in control concrete and similar trend exists for latex wool fibre concrete. Due to bonding, vertical cracks that appeared in the broken specimens were held together by latex

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

wool fibre concrete .With further increase of load, the specimens failed gradually. Since control concrete is a brittle material, if the fibres are added voids are decreased, the propagation of cracks occurs more gradually, resulting in less brittle failure.

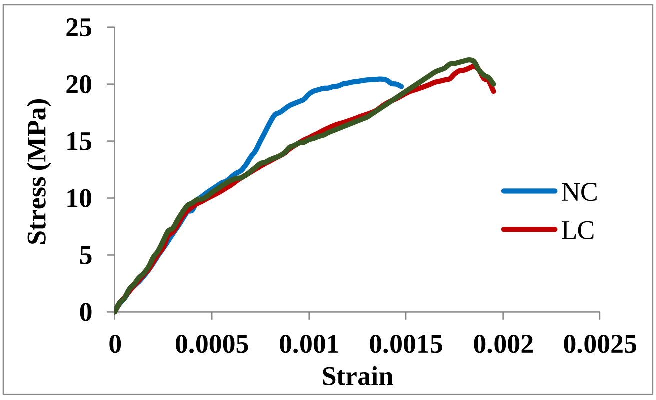

Fig. 9.Comparison Stress strain curve for Latex wool fibre concrete

3.5 Elevated Temperature Test

The density or mass of concrete decreases with increase in temperature due to the loss of moisture content present in it. Fig. 10 (a) illustrates the variation of the mass loss in concrete as a function of temperature made with latex and latex wool fibre. The mass loss is minimum for latex concrete and latex wool fibre concrete when compared to the control concrete. Fig. 10 (b) shows the variation of residual compressive strength at elevated temperature for control, latex and latex wool fibre concrete. The strength of the concrete decreases gradually for control mix upto 300^{0}C and the corresponding residual compressive strength is 20.89 MPa and beyond that temperature there exist a wider variation in the fall of compressive strength. However for latex wool fibre concrete, the compressive strength decreases gradually and the corresponding residual compressive strength at 500^{0}C is 21.9 MPa and at temperature above 500^{0}C there is an abrupt fall in strength. This is due to mineral wool fibre which can withstand a maximum temperature of 750^{0}C.

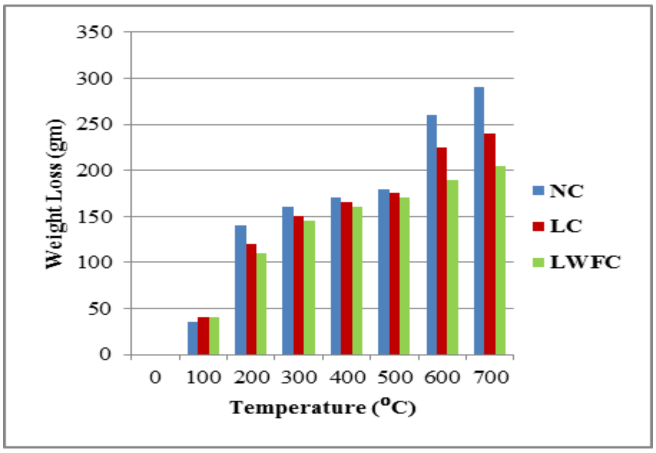

Fig. 10. (a) Mass Loss vs Temperature

3.6 Water Absorption Test

Water absorption characteristics of the concrete play an important role in the durability of the structure. Water absorption is obtained by measuring the increase in mass as a percentage of dry mass. Penetration of water deteriorates both plain concrete and reinforced concrete. Corrosion of the bars in the reinforced concrete will results in cracking and spalling and ultimately reduces the life span of the structure. The result indicates that the water absorption (Average % gain) of latex wool fibre concrete is 15.4% less when compared to control specimen and nearly same as the latex concrete as shown in Fig. 11. This indicates that latex wool fibre concrete and latex concrete is less permeable when compared to the control concrete.

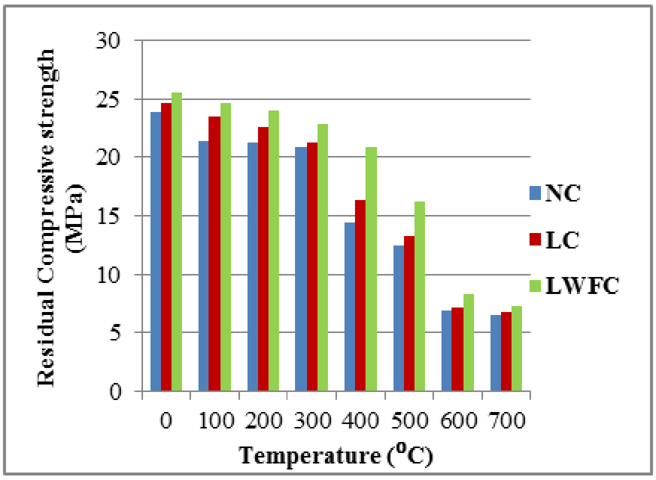

Fig. 10. (b) Residual compressive strength vs Temperature

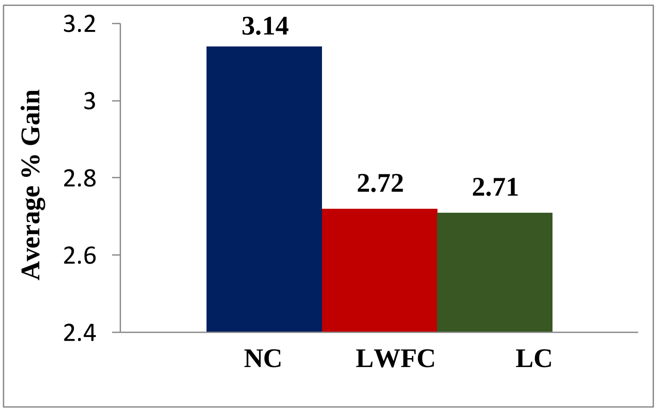

Fig. 11. Variation in Water Absorption Test

IV. CONCLUSION

It is indicated from test results that the Latex Wool Fibre Concrete has a great potential to use in civil engineering structures subjected to high temperatures. Elevated temperature effect and mechanical behavior can be improved by adding latex and rock wool fibre to the concrete.

1) 6% of latex and 0.20% of rock wool fibre in concrete shows improved mechanical behaviour and temperature effect compared to the control concrete.
2) The results of compressive strength of latex wool fibre concrete shows increase in 12.6% of strength when compared to the control concrete.
3) The flexural strength and split tensile strength of latex wool fibre concrete shows 2.5% and 17.5% increase in strength when compared to the control concrete.
4) Latex wool fibre concrete when exposed to elevated temperature, the residual compressive strength values decreases linearly upto 500⁰C whereas in control concrete, the strength decreases linearly upto 300⁰C.This shows that latex wool fibre concrete can withstand upto 500⁰C temperature with minimum loss of compressive strength.

REFERENCES

1. Buchanan, A. H.; Structural Design For Fire Safety, John Wiley and Sons, Chichester, UK, 2002.
2. Purkiss, J. A.; Fire Safety Engineering Design of Structures, Butterworth-Heinemann, Elsevier, Oxford, UK, 2007.
3. Venkatesh Kodur, International Scholarly Research Notices, 2014. DOI: 10.1155/2014/468510
4. Kapil Soni ; Joshi,Y. P.; Performance Analysis of Styrene Butadiene Rubber-Latex on Cement Concrete Mixes; Int. Journal of Engineering Research and Applications, Vol. 4, 2014.
5. Rajan, L.; Wankhade, Amarsinh, B.; Landage, Basavraj A. Konnur; International Journal of Engineering Research,2016,5,257. DOI: 10.17950/ijer/v5i1/061
6. Bala Muhammad; Mohammad Ismail; Construction and Building Materials, 2012, 31,134 DOI:10.1016/j.conbuildmat.2011.12.099
7. Okba, SH.; El-Dieb, AS.; Reda, MM.; Cement and Concrete Research, 1997,27,861 DOI:10.016/S008.-8846(97)00062-8
8. Chaudhary, SK.; Ghoshal, BT.; Deterioration of concrete exposed to sulphate attack; Soc Advancement Electrochem Sci Technol, 2003,38,131.
9. Liang , Y.; Yuan, Y.; Effects of environmental factors of sulphate attack on deterioration of concrete mechanical behaviour; China Univ Mining Tech, 2005,34,452.
10. Vedalakshmi, R.; Sundara, AR.; Srinivasan, S.; Ganesh, KB.; Effect of magnesium and sulphate ions on the sulphate resistance of blended cement in low and medium strength concretes; Adv Cem Res,2005,17,47.
11. Ramakrishnan, V.; Synthetic of highway practice 179 – latex modified concrete and mortars; Washington (DC): NCHRP; 1992.
12. Joao, AR.; Marcos, VA.; Cement and Concrete Composites, 2004, 26, 375. DOI: 10.1016/S0958-9465(03)00022-2
13. Shuyi Yao, Yong Ge; Advanced Engineering Forum, 2012, 5, 283. DOI:10.4028/www.scientific.net/AEF.5.283
14. Gowri, R.; AngelineMary, M.; Effect of glass wool fibres on mechanical properties of concrete; International Journal of Engineering Trends and Technology, vol.4, 2013.
15. Fang Xu ; Mingkai Zhou; Jianping Chen; Shaoqin Ruan; Construction and Building Materials,2014,63,142. DOI: 10.1016/j.conbuildmat.2014.04.054
16. IS (Indian Standard), 1988, Methods of Physical test for Hydraulic Cement. India, IS,4031(part-11):1988 (reaffirmed 1995).
17. IS (Indian Standard), 1963, Methods of Test for Aggregates for Concrete. India: IS, 2386(Part III):1963 (reaffirmed 2002).
18. IS (Indian Standard),1970 , Specification of coarse and fine aggregate from natural sources of concrete. India: IS,383:1970 (reaffirmed 2002).
19. IS (Indian Standard),2009; Concrete Mix Proportioning- Guidelines. India: IS,10262:2009.
20. IS (Indian Standard),1988; Determination of compressive strength of hydraulic cement other than masonry cement. India: IS,4031 (part 6):1988 (reaffirmed 2000).
21. IS (Indian Standard),1959; Methods of tests for strength of concrete. India: IS,516:1959 (reaffirmed 2004).
22. ASTM (American Society for Testing and Materials) ; Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens. ASTM, C496-96.