PERFORMANCE OF NATURAL RUBBER LATEX ADMIXED CONCRETE

Nanna Chandra Gupta[1], Puram Satish[2] Venkat Ram Reddy[3]
Assistant Professors[1,2,3], TKR Engineering College(R9), Hyderabad, Telangana State

ABSTRACT

In recent years, concrete find its wide application in construction field due to its high strength. The tensile strength of concrete is lower than its compressive strength. Nowadays, the properties of the normal concrete can be improved regarding workability, strength characteristics and durability performance from reducing the porosity by compaction, improved paste characteristics and aggregate matrix bond thus resulting high performance concrete. In order to achieve durable concrete, there are two important aspects to be considered which are durability and impermeability. This experimental investigation aims in studying the properties of Natural Rubber Latex admixed Concrete (NRLC) regarding the mechanical and structural performance. In order to improve the durability of concrete natural rubber latex of 1.5% and 2.5% of water was added to concrete. In addition to increased the compressive strength of concrete, mineral admixtures like metakaoline of 12% and copper slag of 40% is used for partially replaced with cement and sand respectively. For improving tensile strength 2% of waste tire rubber strip (WTRS) were used as a secondary reinforcement. The workability test were carried out on fresh concrete and compressive, spilt tensile test, flexural test and durability test were carried out in hardened concrete. The experimental result shows that for NRLC the compressive strength decreased and tensile strength increases.

1. INTRODUCTION

Concrete, unlike any other structural building material, has revolutionized the construction industry. Over the last decades, vast advancement has been made in material technology and in production control, which resulted in the emergence of higher strength grades of concrete. The strength of concrete used in the construction industry has increased gradually over the years. ie, normal strength concrete (NSC) has developed to high strength concrete (HSC).

1.1 HIGH PERFORMANCE CONCRETE

The concrete is said to be high performance if it shows a improved properties compared to ordinary concrete. In this work a concrete with high strength and improved durability characteristics is to be investigated.

High strength concrete has various definitions over a periods of time. As per IS 456 revised IS 456-2000 code, concrete grades are grouped in three categories, namely ordinary concrete (up to M20), standard concrete (M25 to M55) and high strength concrete (M60 to M80). In recent years concrete of compressive strength up to 110 N/mm2 has been used in buildings even in seismic areas.

1.3 POLYMER IN CONCRETE

In recent years the use of polymer in concrete is being enriched by the researches. By the use of polymer, the permeability of concrete can be reduced, workability could be improved and other characteristics can be enhanced to greater extent.

Polymer latexes are being increasingly used in the construction industry as modifiers, especially in hydraulic cement concrete and mortar. Figure 1 presents polymeric latexes used as cement modifiers.

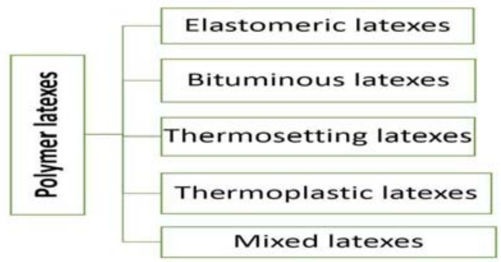

Fig. 1.1. Polymer latexes for concrete modification

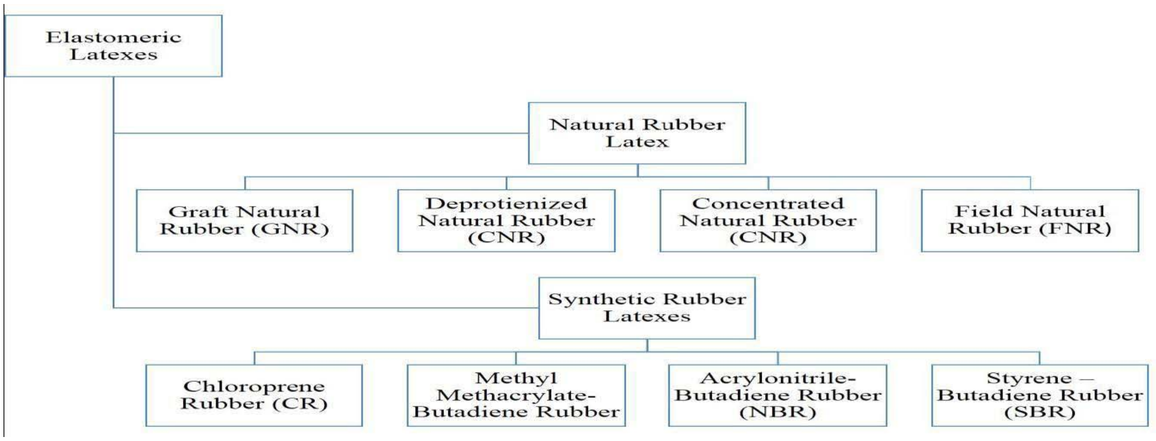

Fig 1.2. Elastomeric latexes for concrete modifications

1.3.1 Advantages of elastomers as modifiers in concrete

- Improvement of workability which normally provides additional ease to complete mixing, proper placement and adequate compaction.
- Enhancement of cement hydration with consequent increase in strength due to water retention capacities of elastomers.
- Greater mechanical properties especially tensile and flexural strengths. This is mainly the result of reduced brittleness in the modified phase.
- Improvement of water tightness, resistance to chemical aggression and freeze-thaw. Ability of elastomers to fill capillaries and voids of the hardened phase normally contributes to these achievements.

1.3.2 Disadvantages of elastomers as modifiers in concrete

- Some elastomers impair certain qualities of concrete. For example, polyvinyl acetate and chloroprene rubber were observed to increase the drying shrinkage of concrete.
- Inclusion of high dosage of elastomer such as NRL into concrete mix could render hardened phase susceptible to strength weakening especially at elevated temperatures.
- In some cases, allergic reactions from exposure to proteins found in NRL could be experienced. Therefore, the use of deproteinized NRL is most recommended.

1.4 NATURAL RUBBER LATEX ADMIXED CONCRETE

Portland cement concrete lends itself to a variety of innovative designs as a result of its many desirable properties. Concrete possess high compressive strength and stiffness with adequate desirable properties under normal environmental conditions. Two characteristics, however, limited its use Concrete inherently is brittle and weak in tension. Several methods have been developed to impart ductile behavior. Broadly, these methods can be grouped as mechanical and chemical. Reinforcing concrete with discrete fibres imparts ductile behavior mechanically. Incorporation of polymeric material forms the chemical method of developing the ability of the material to exhibit ductile response. Natural Rubber Latex is a polymeric material.

1.4.1 Advantages of NRLC

- It improves the resistance to chemical aggression
- It can enhance the property of water exclusion in concrete

- It improves the flexibility of the concrete
- It helps the concrete to withstand a high temperature up to 700° C
- It can be used in dynamic regions.
- It reduces the permeability of concrete and thereby increases the durability of concrete
- Reduces thermal cracking

1.4.2 Disadvantages of NRLC

The disadvantages of using latex in concrete are

- It retards the compressive strength of concrete
- It reduces the workability of concrete
- Measures has to be taken so as to prevent the coagulation of latex due to exposure of atmosphere over a long time.
- Precautions has to be adopted if latex is being used in bare hands since it can cause allergic reactions.
- It may not be economical compared to normal concrete.

1.5 OBJECTIVES AND RESEARCH SIGNIFICANCE

The main objective of this study were

- To investigate the viability of using Natural rubber latex as a constituent in concrete.
- To determine performance of the NRL in high strength concrete by testing its compressive, tensile and flexural strengths.
- To determine the performance of concrete with the addition of WTRS of 2% by weight of cement. In addition 40% of copper slag was also used replacing fine aggregate. 1.1% of modified PCE as Glenium BASF 8233 and 12% of super Pozzolan admixture (Metakaolin) was also added in concrete.

1.6 NEED OF THE WORK

In general the concrete has higher compressive strength when compared to tensile strength. However the durability of concrete is much important that depends on the strength and other properties of concrete. One of the main characteristics influencing the durability of concrete is its permeability to ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potentially deleterious substances. The impermeability is due to the physical structure of concrete. Natural rubber latex is found to be a material that forms a film in the concrete thus reducing its permeable nature. The experiment aims at making the concrete more durable so as to perform satisfactorily in all working environments by the use of Natural rubber latex in appropriate quantity. The investigation is to be carried out to determine the mechanical properties of the NRLC including its durability.

LITERATURE REVIEW

Brindha et al. (2010) carried out the concerning durability and corrosion studies of copper slag admixed concrete; they are conducted on various corrosion and durability tests on concrete containing copper slag as partial replacement of sand and cement using M20 grade concrete at various proportions of copper slag replacement with sand of 0%, 20%, 40%, and 60%, cement of 0%, 5%, 15% and 20% and combination of both (60% sand + 40% copper slag for fine aggregate and 85% cement+15% copper slag for cement) in concrete. They conclude that the compressive, split tensile strength of concrete increases with respect to the percentage of slag added by weight of fine aggregate up to 40% of additions and 15% of cement; the water permeability in concrete reduced up to 40% replacement of copper slag with that of sand and higher resistance against Sulphate attack whereas addition of copper slag for the replacement of cement gives lower resistance.

Dr. Vaishali. G. Ghorpade et al. (2015), studied the effect of steel fibres and Natural rubber latex on the strength and workability of high performance concrete. They concluded that the workability of NRLMFRHPC decreases with increase in the percentage of natural rubber latex and steel fibres. They also concluded that 0.5% of latex and 1.0% of steel fibres can be used for sufficient workability. The compressive strength of concrete is found to increase up to 0.5% of latex with a water binder ratio of 0.325.

Bala Muhammad ET. Al (2017), investigated the impact of non- hydrocarbons in the natural rubber latex regarding the strength of the concrete. On their conclusion of result analysis they

mentioned that the compressive strength of the NRL-MC is affected by the presence of non-hydrocarbons in the latex. Also the strength of normal concrete can be improved by the addition of latex free from volatile fatty acids and metals.

METHODOLOGY

Materials used for making concrete for this study were tested before casting the specimens. Mix design was arrived based on the material properties.

The preliminary tests were conducted for the following materials are Cement, Super Pozzolan admixture –Metakaolin, Fine Aggregates , Coarse Aggregates , Copper Slag , Water , Waste tire rubber strips (WTRS) , Natural rubber latex (NRL) , High Performance Super Plasticizer Based on Polycarboxylic Ether (PCE) - Glenium BASF 8233

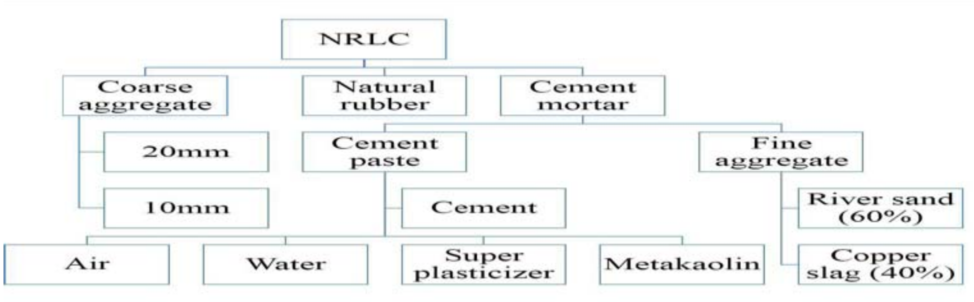

Fig: 3.1 Constituents of NRLC

NRL is a whitish to off-white milky fluid usually obtained by tapping the bark of Para tree (*Hevea Brasiliensis*). In its fresh state, NRL comprises "30%"─"40%" rubber hydrocarbon particles (C5H8) suspended in a serum together with about "6%" non-rubber substances. The non-rubber substances include proteins, lipids, carbohydrates, sugars and traces of some metals such as zinc, magnesium, copper and iron. Natural rubber is a high molecular weight polymer of isoprene (cis-1, 4-polyisoprene). It has a particle diameter of 0.1 ─4.0 µm and a chemical structure as shown in Fig.3.7 .

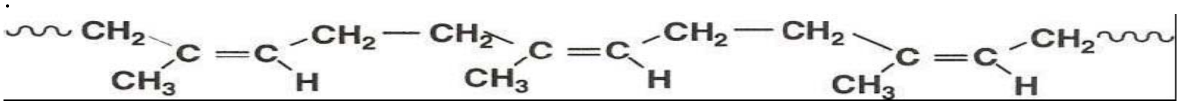

Fig. 3.7 chemical structure of cis-1,4-polyisoprene

3.3. CONCRETE MIX DESIGN

3.3.1. Mix Calculation

The proposed mix design for that experimental investigation is given below:

*Cement Paste Volume = {[(X * Cement Percent) / (100 * Sp. gravity of Cement)] + [(X * Metakaolin percent) / (100 * Sp.gravity of Metakaolin)] + [X * Water cement ratio] +[(X * Admixture dosage percent)/100] + [Air volume]}*

X = Cementitious material in Kg/m3

Table 3. 13 Requirements of materials per M3 and mix proportions with 2.5% NRL

Sl. No.	**Materials**	**Wt. of materials per m3**	**Total wt. of materials per m3**	**Ratio**
1	Cement	592.76 kg	673.60	1
2	Metakaolin	80.83 Kg		
3	Fine Aggregate (Sand)	390 Kg	770	1.16
4	Copper Slag	380 Kg		
5	Coarse Aggregate– 20mm	468 Kg	780 Kg	1.14
6	Coarse Aggregate– 10mm	312 Kg		
7	Fiber (WTRS)	24.60 Kg	24.60 Kg	0.037
8	Water Content	194.33 lit	194.33 lit	0.30
9	Super Plasticizer	7.41 lit	7.41 lit	0.011
10	Rubber latex	5.05 lit	5.05 lit	0.007

RESULTS AND DISCUSSION

4.1. COMPRESSIVE STRENGTH OF NRLC

4.1.1. Compressive strength of NRLC Cubes and Cylinders

The results of 7-days and 14-days compressive strength of concrete mixtures are shown in Table 4.1and 4.2 and Fig. 4.1, 4.2 and 4.3. The compressive strength of NRLC concrete specimens using 1.5% and 2.5% of NRL was decreased compared with the control specimens.

Table: 4.1 Compressive strength of concrete cubes at 7 and 14 days for different percentage of NRL

Percentage of NRL	**At 7days**			**14 days**
Load in KN	**Compressive strength in N/mm2**		**Load in KN**	**Compressive strength in N/mm2**
0%	1070	47.5	1580	70.22
1020	45.33		1565	69.55
1.5%	625	27.78	1150	51.11
525	23.33		840	37.33
2.5%	550	24.48	1040	46.22
540	24		975	43.33

Table: 4.2 Compressive strength of concrete cylinders at 14 days for different percentage of NRL

% of NRL	**At 7 days**		**At 14 days**	
Load in KN	**Compressive strength in N/mm2**		**Load in KN**	**Compressive strength in N/mm2**
0%	360	20.37	845	47.82
1.5%	345	19.52	625	35.37
2.5%	350	19.81	650	36.78

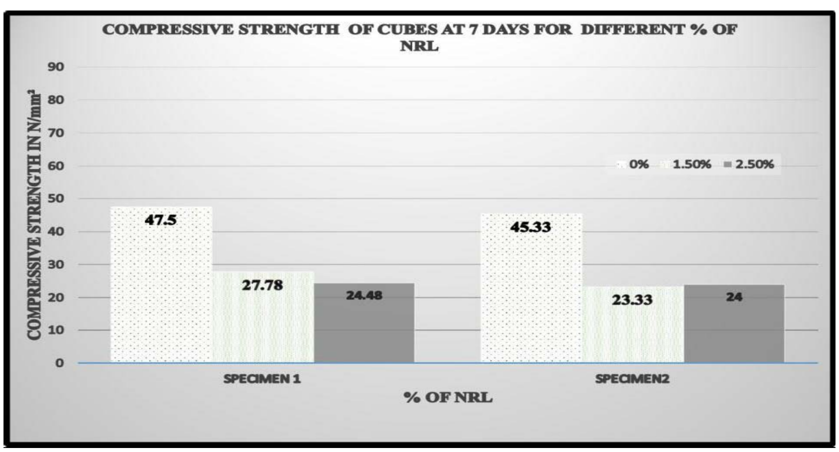

Fig: 4.1 Comparison of compressive strength of cubes at 7 days for different % of NRL

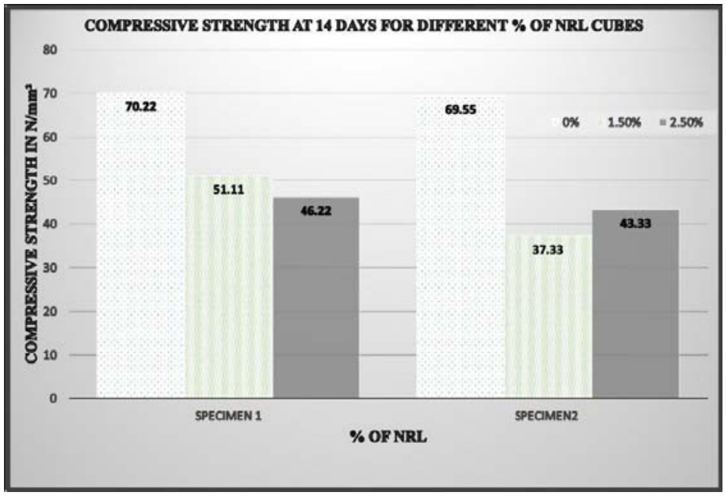

Fig: 4.2 Comparison of compressive strength of cubes at 14 days for different % of NRL

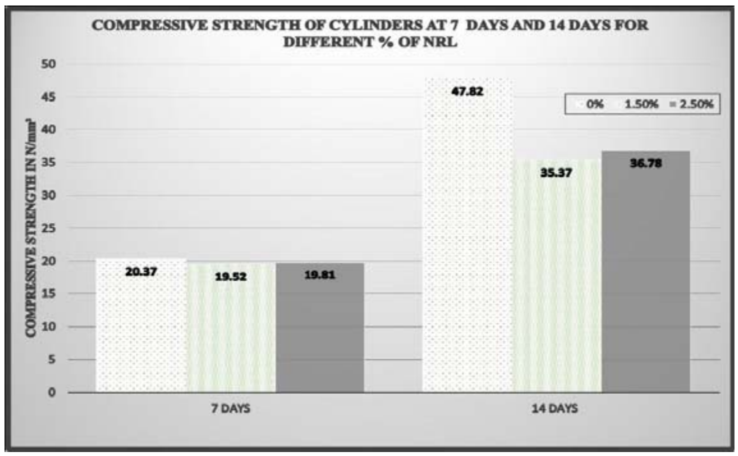

Fig: 4.3 Comparison of compressive strength of cylinders at 7 days and 14 days for different % of NRL

4.1.2. Discussion about NRLC compressive strength

The compressive strength of NRLC cubes was reduced when compare with control specimen. The compressive strength concrete specimens was decreased about 30%. The reason for reduction in the compressive strength of NRLC was the waste tire rubber strips and NRL was used. These factors include:

- As cement paste containing WTRS particles surrounding the aggregates is much softer than hardened cement paste without rubber, the cracks would rapidly develop around the rubber particles during loading, and expand quickly throughout the matrix, and eventually causing accelerated rupture in the concrete.
- The compressive strength of concrete depends on physical and mechanical properties of these materials (which have some superiority over rubber). A reduction in compressive strength of concrete can, therefore, be expected.
- Also the hydrocarbon contents in the latex reacts with constituents of concrete and thus it retards the strength. Since the latex is been ammoniated it causes the reactions that shows adverse effects on concrete strength.

4.2. Results of rebound hammer test

The following table 4.3 shows the test result of rebound hammer test on concrete specimens with 2% of WTRS and 1.5% and 2.5% of NRL.

Table 4.3:- Rebound hammer test report for different percentage of NRL

% of NRL	7 days			14 days
Side	**Top**	**Bottom**		**Side**
0	30	34	26	31
30	31	30		28
1.5%	29	20	16	18
24	18	18		22
2.5%	20	14	19	21
20	21	24		25

4.3. Results of Ultrasonic pulse velocity Test

The test results of UPV tests on the cube and cylinders casted with 2% of WTRS and 1.5% and 2.5% of NRL has been shown in the table 4.3.

Table 4.4:- Ultrasonic Pulse Velocity test results with different percentage of NRL

% of NRL	7 days			14 days		
Pulse velocity in m/s	**Pulse velocity in m/s**					
0	4966	4966	4983	4761	4792	4792
4870	4901	4702	4742	4751		4744
1.5%	4672	4702	4832	4137	4219	4231
4601	4518	4601	4173	4398		4392
2.5%	4411	4322	4531	4512	4537	4521
4518	4477	4531	4322	4336		4326

4.4. Discussions on the rebound hammer and UPV test results

The results of the tests shows that the strength of concrete has reduced to a very low percent. So that NRL and WTRS could be incorporated in concrete to considerable level.

4.5. FLEXURAL STRENGTH OF NRLC

4.5.1. Results for NRLC Flexural strength

The results of flexural strength of NRLC specimens were tested at 14 days as shown in Table 4.5 and Fig 4.4.

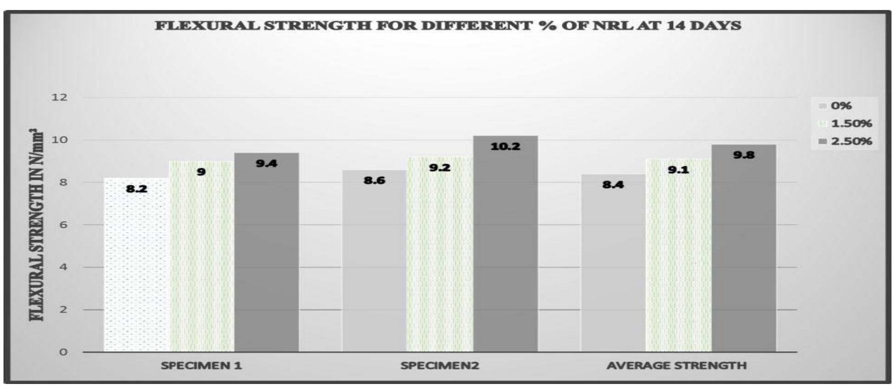

Figure: 4.4 - Flexural strength of NRLC

Table: 4.5 Flexural strength of concrete at different percentage of WTRS (L = 500-50-50) = 400 mm, b = 100mm, & d = 100mm

Sl. No.	% of NRL	Failure Load (P) in KN	Flexural strength (ft = PL/bd2) in N/mm2	Average Flexural strength
1	**0%**	20.5	8.2	8.4
21.5		8.6		
2	**1.5%**	22.5	9.0	9.1
23		9.2		
3	**2.5%**	24	9.4	9.8
25.5		10.2		

4.6. SPLIT TENSILE STRENGTH OF NRLC

4.6.1. Results for Split Tensile Strength of NRLC

The results of split tensile strength of NRLC specimens were tested at 14 days as shown in Table 4.6.

Table: 4.6 Split tensile strength of concrete at different percentage of WTRS (D = 150mm, L = 300mm)

Sl. No.	% of NRL	Failure load (P) in KN	Split Tensile strength ((ft = 2P/ΠD) in N/mm2
1	**0%**	160	6.79
2	**1.5%**	180	7.639
3	**2.5%**	180	7.639

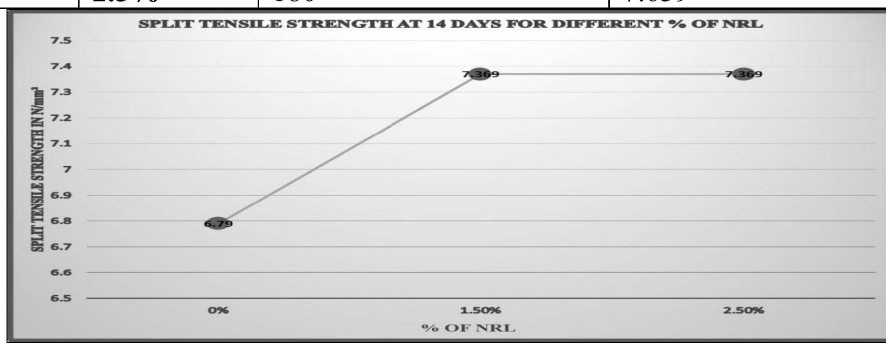

Fig: 4.5 Split Tensile strength of NRLC

4.7. MODULUS OF ELASTICITY

4.7.1. Results

The results of modulus of elasticity for NRLC specimens tested at 14 days as shown in Table 4.7 and 4.8. The stress strain variation for the concrete specimens is shown in fig.4.6.

Table 4.7 Linear stress for different % of NRL

Sl. No.		Load in KN		0%		1.5%		2.5%		
Div	δL	δL/L 1×10-4		Div	δL	δL/L 1×10-4	Div	δL		δL/L 1×10-4
1.	50	-19	-0.038	-2.53	0.5	0.001	0.0000067	19.5	0.039	0.00026
2.	100	- 18.5	-0.037	-2.46	2.5	0.005	0.000033	19.5	0.039	0.00026
3.	150	34	0.068	4.53	4.5	0.009	0.00006	19.5	0.039	0.00026
4.	200	36	0.072	4.8	80	0.160	0.010607	--	--	--
5.	250	40	0.080	5.33	95	0.190	0.00127	--	--	--
6.	300	55	0.110	7.33	100	0.20	0.0013	--	--	--
7.	350	65	0.130	8.67	---	---	---	---	---	---

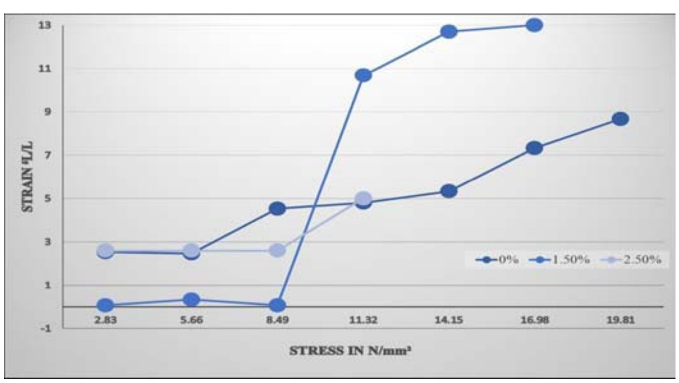

Fig 4.6 Stress- strain variation for different % of NRL

4.7.2. Discussion about the modulus of elasticity of NRLC

The young's modulus of NRLC, decreased when compared with the control specimens. For conventional concrete has the higher modulus of elasticity than concrete with NRL and WTRS. Hence the volume of concrete with coarse aggregate decreases then the WTRS was increased. This effects reduces the modulus of elasticity of NRLC.

CONCLUSION

5.1. SUMMARY

This study presents the reducing of permeability which forms the factor for determining a durable concrete by the inclusion of rubber latex. Also it shows the recycling of construction materials to improve the tensile strength and ductility of high strength concrete. This experimental work shows a partially replacement of cement and sand by metakaolin (12%) and copper slag (40%) respectively and it includes the addition of 2% of WTRS fiber in concrete; also this study deals the structural performance of Natural rubber latex admixed concrete (NRLC). The study reported in this project includes the properties of materials, workability and strength property of concrete.

5.2. CONCLUSION

The following conclusions and recommendations are made based on the experimental investigation.

- NRLC cubes and cylinders were cast with WTRS and copper slag shows a significant reduction in density of concrete compared to that of control specimens.
- The compressive strength of concrete cubes and cylinder specimens with the addition of WTRS was decreased about 3% to 30% to that of control specimens.
- It is recommended to use this concrete in the production of curbs, roads, concrete blocks, and on bearing concrete wall.

REFERENCES

1. Balaha. M.M, Badawy. A.A.M. & Hashish M. (2007), "Effects of ground waste tire rubber as fine aggregate on the behavior of concrete mixes", *Indian Journal of Engineering & Materials Sciences, Vol. 14, 2007, pp. 427-435.*

2. Bala Muhammad, technology, properties and application of NRL elastomers.

3. Bala Muhammad and Muhammad Ismail, "Performance of natural rubber latex modified concrete in acidic and sulphated environments", *Construction and Building materials, 31(212), 129-134.*

4. Bala Muhammad, Muhammad Ismail, Muhammad Aamer Raique Bhutta andZaiton Abdul- Majid, "Influence of non- hydrocarbon substances on the compressive strength of natural rubber latex modified concrete", C*onstruction and Building materials, 27(1012), 241-246.*

5. Brindha S, D. Baskaran and T. Nagan, "Assessment of corrosion and durability characteristics of Copper Slag", *International Journal of* Civil *and Structural Engineering*, *ISSN 0976 –4399.*

6. British Standard Institution "Specification for aggregate from natural sources for concrete (including granolithic)", *BS 882:1991, London, 1991.*

7. Feng Liu, Guixuan Chen, Lijuan Li, "Impact performance of rubber", *Journal* reinforced *of construction* and *building materials 36 (2012) 604 - 616.*

8. Mohammad Ismail,Bala Muhammad and Nur Azia Muhammad, "Durability performance of natural rubber latex modified concrete", *Malaysian journal of civil engineering 21(2): 195- 203 (2009).*

9. T.S. Nagaraj, K.T sundara Raja Iyengar and B. Kameswara Rao, "Super plasticized natural rubber latex modified concretes", *Cement and cement research, vol. 18, pp. 138-144, 1988.*

*10.*Sivakumar. M.V.N, "Effect of polymer modification on mechanical and structural properties of concrete- An experimental investigation"*, International journal of civil and structural engineering, vol. 1, No 4, 2010.*

*11.*M.S. Shobha, Dr. C. shashidhar, Dr. H. Sudarsana Rao, "Strength studies of natural rubber latex modified high performance concrete", *International Journal of Research and Technology, Vol. 2, issue 5, May 2013.*