Suitability of Natural Rubber Latex and Waste Foundry Sand in Cement Concrete

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***Abstract*— Suitability of Natural Rubber Latex (NRL) as an additive and Waste Foundry Sand (WFS) as partial replacement to river sand, in cement concrete was investigated. Experimental study was performed with concrete mixtures containing 1% latex to water ratio, along with 5% and 10% replacement of river sand by WFS. Properties of concrete were studied in both fresh and hardened state. The results of laboratory tests indicate that WFS and NRL reduces the workability of concrete. Slight reduction in splitting tensile strength was observed for mixtures containing NRL and WFS, in comparison to conventional mix. No specific trend was observed for flexural strength at 7 days, but at 28 days the difference was within ±3%, when compared to conventional mix. Strength development for mixtures containing NRL and WFS was slightly lower than conventional mix. The limited results of this study show that concrete containing NRL and WFS do have potential for use as non- structural concrete.**

Keyword - Natural Rubber Latex, Waste Foundry Sand, Cement Concrete

I. INTRODUCTION

Increase in demand on concrete industry and depletion of space for industrial waste disposal leads to proposal of new materials, which can utilize the generated waste and also improve the properties of concrete. In this context, suitability of Natural Rubber Latex (NRL) as an additive and Waste Foundry Sand (WFS) as partial replacement to river sand in cement concrete was investigated. Inclusion of NRL into normal concrete has shown to transform concretes of fairly porous microstructure to a relatively denser matrix. Latex to water ratio has shown to play a major role in improving concrete properties [1]. It is common for concrete to disintegrate at very high temperature, but concrete mixtures can resist high temperature with introduction of elastomers. Endurance capacity against heat can be exhibited by NRL filler, which can extend additional strength to the surface of cement material. It is shown that upto 20% latex to water ratio dosage can be incorporated in mortar without affecting the thermal integrity of the mix [2]. Concrete strength and stability is affected by different constituents present in NRL. Hydrocarbon particles are believed to have film forming and void filling capabilities in concrete mix. Also, 15.8% reduction in compressive strength was observed for specimens with high contents of volatile fatty acids and zinc [3]. NRL in concrete increases the resistance against chemical attack and impact loads [4, 5]. Latex modified concrete provides superior properties such as higher tensile strength, flexural strength, and excellent resistance to abrasion [6]. It can improve waterproofness and provide excellent adhesion [6].

WFS is a material discarded from foundry industry after metal casting process. Both ferrous and non-ferrous industries use high quality silica sand with binders to create metal casting moulds. In past, studies have been carried to utilize WFS in cement concrete as partial replacement to fine aggregate. From literatures, it is observed that the workability of fresh concrete decreases with increase in the percentage of WFS in concrete [7]. Strength of concrete decreased with higher replacement of natural sand with waste foundry sand [8-9]. Flexural strength of concrete mixtures with WFS increased with time. Between 28 days and 365 days mixtures without WFS achieved an increase of 7.5 -13.2%, whereas mixtures with 10% WFS achieved an increase of 10.6 – 14.9% [10]. The modulus of elasticity doesn’t vary significantly and there was increase in drying shrinkage of concrete mixtures with WFS. [11].

The addition of NRL will improve the binding properties of cement concrete and incorporation of limited WFS will utilize industrial waste to some extent without affecting strength properties. Utilization of WFS in cement concrete will also reduce the impact on the environment. The objective of this study is to evaluate the suitability of NRL as an additive and WFS as a partial replacement to river sand in cement concrete. It will consider the combined effect of NRL and WFS on the mechanical properties of concrete.

II. EXPERIMENTAL PROGRAM

In order to investigate the objective of this study, three different concrete mixtures were designed. Control mix with no NRL and WFS was designed as per the IS 10262 procedure [12], and two other mixtures with NRL and different percentage of WFS replacement. 1% Latex to water ratio was used in this study. The benefit obtained at higher latex to water ratio is limited. For instance, strength reductions in concrete with more than 2% latex to water ratio could be due to excess latex which can restrict aggregates from being closely packed, thereby developing weak regions in the matrix [3]. Natural river sand was replaced partially by waste foundry sand. Two replacements, 5% and 10% by weight of river sand was considered in this study. Studies have shown that reduction in concrete strength can be due to presence of binders in WFS [11]. Higher replacements of WFS can reduce the workability and strength of concrete, thereby making it unsuitable for any application. Table I and Table II presents the concrete mixtures evaluated and details of the concrete proportions. In this research, to understand the suitability of natural rubber latex and foundry sand in cement concrete, various tests on fresh and hardened concrete is conducted as per Indian standards. The concrete tests performed are presented in Table III.

TABLE I. Concrete Mixtures Evaluated

Mix Type	Water Cement Ratio	WFS (%)	Latex to Water Ratio (%)
A	0.45	0	0
B	0.45	5	1
C	0.45	10	1

TABLE II. Details of Concrete Proportions

Mix Type	Cement (kg/m^3)	Water Cement Ratio	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	NRL (ml/100 kg of cement)	WFS (kg/m^3)	Water Reducer Dosage, (ml/100 kg of cement)
A	360	0.45	670	1130	0	0	500
B	360	0.45	636	1130	450	34	500
C	360	0.45	603	1130	450	67	500

TABLE III. Tests Performed on Fresh and Hardened Concrete [13-15]

Test Type	Specimen Type	Dimension	Test Standard	Curing Time (days)
Slump	-	-	IS 1199-1959	-
Compaction factor	-	-	IS 1199-1959	-
Unit weight	-	-	-	-
Compressive strength	Cylinder	50mm dia × 100mm long	IS 516-1959	7, 28
Modulus of elasticity	Cylinder	50mm dia × 100mm long	IS 516-1959	7, 28
Splitting tensile strength	Cylinder	150mm × 300 mm	IS 5816-1999	7, 28
Flexural strength	Beam	100 mm × 100 mm × 500 mm	IS 516- 1959	7, 28

III. MATERIALS

A. Cement

Ordinary Portland cement of 53 grade conforming to standards of IS 12269-1987 was used for all the concrete mixtures [16].

B. Natural Rubber Latex

NRL used in this project is shown in Fig. 1. It contains 60% dry rubber which accounts for the majority of the solids. The properties of natural rubber latex is presented in Table IV.

Fig. 1. Sample of natural rubber latex used in this study

TABLE IV. Properties of Natural Rubber Latex

Property	Value
Dry rubber content	60.18%
Total solid content	61.67%
Non rubber content	1.49%
Alkalinity as ammonia	0.80%
Volatile fatty acid	0.035%
Mechanical stability time	7100 s
pH	10.50
KOH	0.60

C. Aggregate

River sand conforming to grading zone-II as per IS 383-1970 [17], with specific gravity of 2.69 and water absorption of 3.09% was used as fine Aggregate. Crushed granite aggregate confining to IS 383-1970 [17], with Specific gravity of 2.5, water absorption 0.6% and maximum nominal size of 20 mm was used as coarse aggregate.

D. Waste Foundry Sand

Four different waste foundry sands were used in this study, as shown in Fig. 2. Chemical analysis was performed on each WFS. The presence of silica ranged from 40% to 80% and iron from 2% to 20%. The individual sieve analysis results of the waste foundry sand is shown in Fig. 3. Particle size distribution shows WFS to be uniform sized and finer than natural sand. However, WFS-4 was coarser in nature due to presence of ferrous material in sand. The specific gravity of WFS ranged between 2.1 and 2.3, and the water absorption was 4%. Practically it is very difficult to handle different types of foundry sand separately, therefore it would make sense to combine them and use it as a single waste material. Hence, in this study, mixture of this waste foundry sand was used and treated as a single waste material.

Fig. 2. Sample of waste foundry sand used in this study

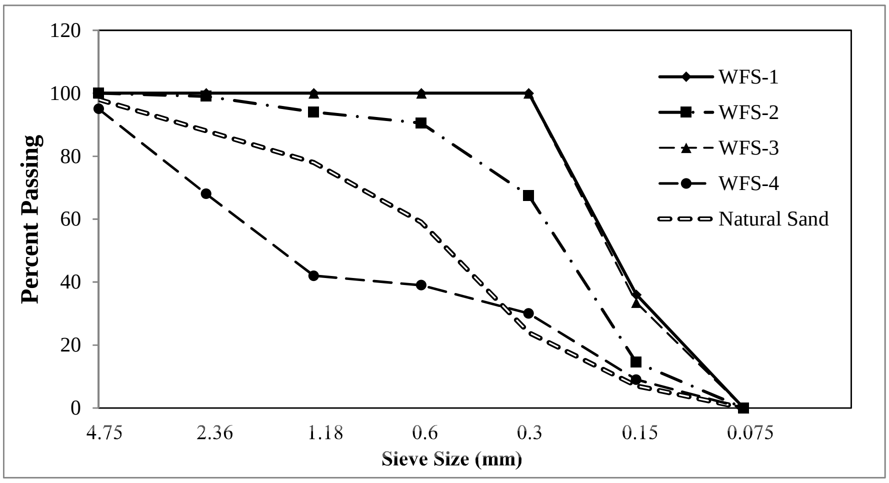

Fig. 3. Particle size distribution of waste foundry sand

E. Water

Clean potable water free from concentration of acid and organic substances is used for making concrete.

F. Chemical Admixture

Master-Glenium SKY 8233 is used as a superplasticizer in this study. It is an admixture based on modified polycarboxylic ether. This admixture is certificated by IS 9103:1999 and IS 2645:2003 [18]. Performance test data for Master-Glenium SKY 8233 is presented in Table V.

TABLE V. Properties of Superplasticizer

Aspect	Light Brown Iiquid
Relative Density	1.08 +/- 0.001
pH	>6
Chloride Ion Content	<0.2%

IV. SPECIMEN PREPARATION AND TESTING

Specimens were casted in steel moulds. Cement, coarse aggregate and fine aggregate are mixed thoroughly by using a mechanical pan mixer. Natural rubber latex with the water is added to the mix. Moulds were poured with concrete in three layers by compacting with tamping rod, followed by vibration with table vibrator. The moulds were kept in vibration for roughly 30 seconds, and it was maintained constant for all the specimens. Three specimens were casted for each test. Demoulding was done after 24 hours and specimens were kept immersed in a clean water tank. After curing the specimens for a period of 7 days and 28 days, it was removed out of tank and kept to dry for 30 minutes before testing. The testing was carried as per the Indian standards mentioned in Table III. Fig. 4 shows the experimental test setup used in this study.

a. b. c. d.

Fig. 4. Experimental test setup **a)** Compressive strength **b)** Modulus of elasticity **c)** Splitting tensile strength **d)** Flexural strength

V. TEST RESULTS AND DISCUSSION

A. Fresh concrete properties

Table VI presents the properties of fresh concrete containing WFS and NRL. The addition of WFS and NRL resulted in slight decrease of workability. With higher replacements of WFS the demand for water will increase and therefore it will affect the fresh properties of concrete. This indicates to maintain the required workability; the dosage of super-plasticizer will increase as the percentage of WFS replacement increases. Compaction factor values show that concrete is of medium consistency, and suitable for flat slabs. The unit weight of concrete indicates that addition of WFS has increased the density of concrete. This behaviour can be explained by the filling ability of WFS, causing the density to be slightly higher than conventional mix.

TABLE VI. Fresh Concrete Properties Containing NRL and WFS

Mix Type	Slump (mm)	Compaction Factor	Unit Weight (kg/m^3)
A	120	0.87	2280
B	80	0.82	2320
C	85	0.91	2330

B. *Hardened concrete properties*

Table VII presents the hardened properties of all the concrete mixtures. At 7 days, the average compressive strength of all the concrete mixtures is similar. However, at 28 days the mixtures with 10% WFS & 1% latex to water ratio showed 12% increase in compressive strength. Slight reduction in splitting tensile strength was observed for mixtures containing NRL and WFS, in comparison to conventional mix. No specific trend was observed for flexural strength at 7 days, but at 28 days the difference was within ±3% when compared to conventional mix.

Fig. 5 and Fig. 6 show the difference in strength properties of concrete containing NRL and WFS with respect to conventional mix. A positive difference indicates that strength has increased with respect to conventional mix, and vice versa. The difference in strength properties of concrete containing NRL and WFS with respect to conventional mix reduces with time. Cement hydration can possibly be affected by the presence of carbon in WFS, causing lower strength at early age of concrete [11]. Fig. 7 shows the difference in elastic modulus of concrete at different curing periods. At 7 days, mix B (5% WFS) and mix C (10% WFS) exhibited 18% and 3% lower elastic modulus than conventional mix. However, at 28 days, increase in elastic modulus was 1.6% and 12% for mix B and mix C, respectively.

For conventional concrete the relative strength gain at 7 days with respect to 28 days strength is in the range of 60% to 80%, for W/C ratio ranging from 0.8 to 0.4, respectively [19]. Strength-time relation is essential in situations when early removal of formwork is required [19]. The relation between 28 days and 7 days strength for concrete containing NRL and WFS is shown in Fig. 8. Development of strength for concrete containing NRL and WFS was slightly lower than the conventional concrete. For concrete containing NRL and WFS the average strength gain was 70% (5% WFS) and 74% (10% WFS) compared to 80% (conventional mix).

TABLE VII. Hardened Concrete Properties Containing NRL and WFS

Mix Type	Compressive Strength (N/mm^2)	Modulus of Elasticity (N/mm^2)	Splitting Tensile Strength (N/mm^2)	Flexural Strength (N/mm^2)
7 days curing				
A	24	23360	2.71	5
B	23	19140	2.31	4.30
C	25	22630	2.30	5.46
28 days curing				
A	35	24400	3.27	5.91
B	35	24800	3.22	6.06
C	39	27348	2.96	5.83

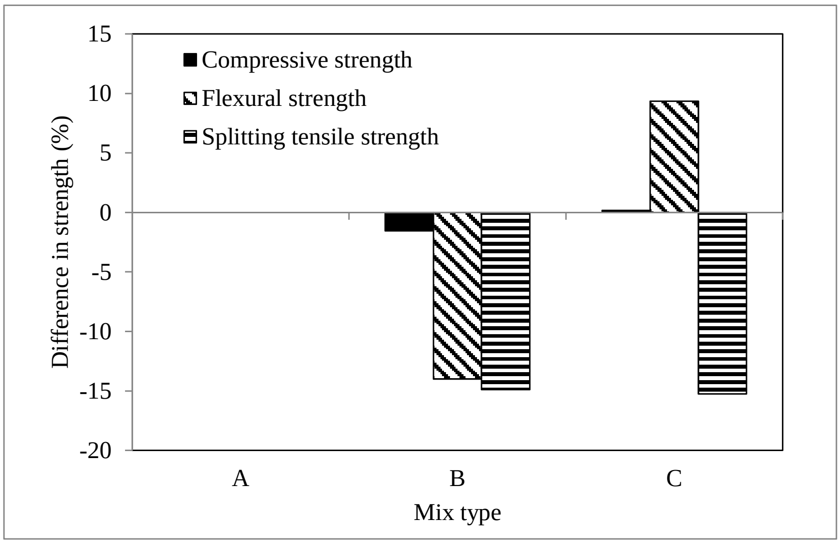

Fig. 5. Difference in concrete strength at 7 days with respect to conventional mix

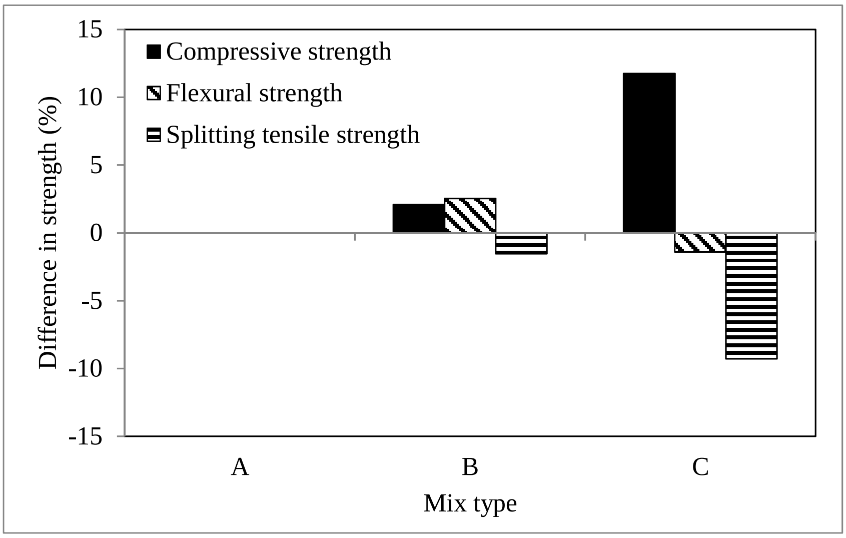

Fig.6. Difference in concrete strength at 28 days with respect to conventional mix

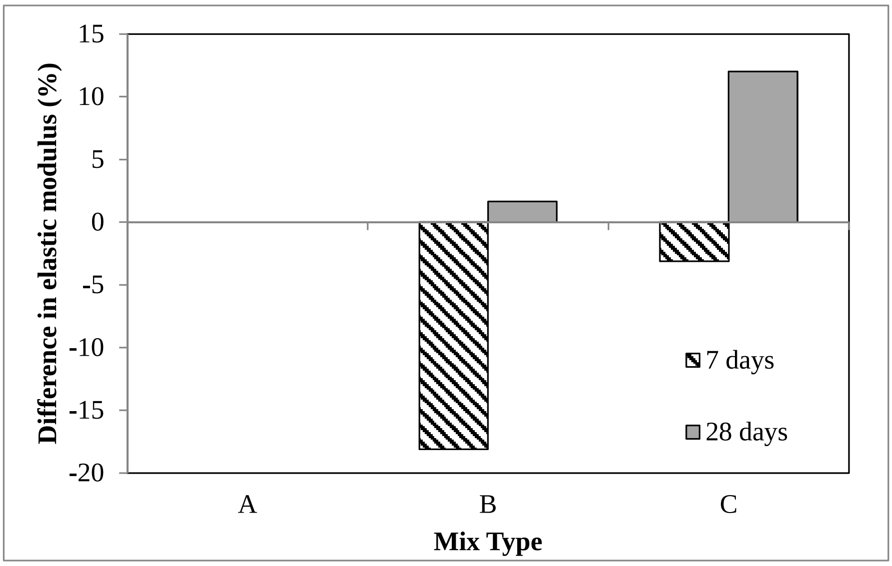

Fig.7. Difference in elastic modulus with respect to conventional mix

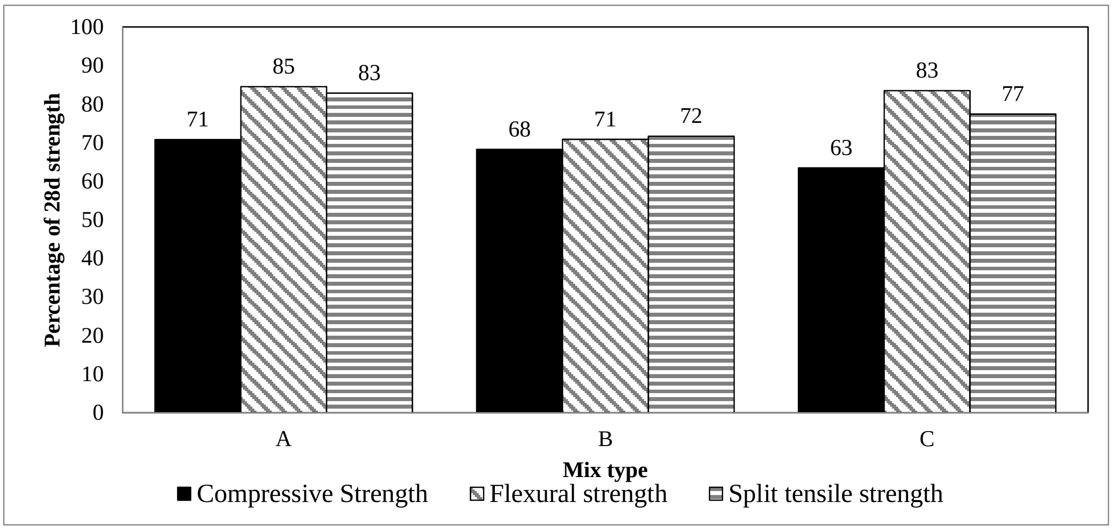

Fig.8. Relative strength gain with time for concrete mixtures containing NRL and WFS

VI. CONCLUSION

The results of laboratory testing program indicate that NRL and WFS can be effectively used in cement concrete. However, higher replacements of WFS will increase the water demand and will affect the fresh properties of concrete. Development in strength for mixtures containing WFS and NRL was slightly lower than conventional mix. There was slight reduction in splitting tensile strength for concrete mixtures containing NRL and WFS. No specific trend was observed for flexural strength at 7 days, but at 28 days the difference was within ±3% when compared to conventional mix. Since, flexural strength was least affected with inclusion of NRL and WFS in cement concrete, further investigation to evaluate the potential of NRL and WFS in non-structural elements like concrete pavements should be studied. In order to find the behavior of material in field, performance based tests like drying shrinkage, coefficient of thermal expansion, and concrete permeability should be investigated.

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