Studies on Workability of Cement Mortar and Concrete using Natural Plasticizer

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Abstract

Concrete is modified with organic or inorganic admixtures to improve its workability. Rain tree pods are the wastes which fall from tree after ripening and are found in tropical countries. In urban areas rain tree pods laying on roads can cause accidents especially in the presence of water due to slipperiness. Alternatively, rain tree pods as plasticizers in cement mortar and concrete has attracted the interest of the researchers. This paper deals with study of the suitability of natural rain tree pod as plasticizer in cement mortar and concrete. The workability of concrete with the natural rain tree pod extract was investigated. The experimental results indicate that the tree pod extract can be suitably used as a plasticizer at an optimal dosage corresponding to the water to cement ratio. The durability test was also performed to ascertain the inertness of the rain tree pod extract. The test results indicated lesser deterioration of cement mortar and concrete.

Keywords: *Rain tree pods, Plasticizer, Durability, Cement mortar and concrete*

1.0 Introduction

Water reducing admixtures lower the amount of water needed to achieve the same slump, lowering the effective water cement (W/C) ratio, and improving concrete workability; additionally, the greater the admixture's water- reducing capacity, the greater the differences between these properties and those of the original concrete. As a result, it is reasonable to conclude that the water reducing admixtures improve the mechanical qualities of concrete prepared with them [1]. It is added in quantities not greater than 5% by mass of cement [2]. The mechanical performance of concrete with recycled aggregates and super plasticizers is generally superior to that of reference concrete containing no admixtures and conventional concrete with inferior mechanical performance [3]. The workability and compressive strength are both

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affected by the time the admixture is added. Water reducer's plasticizing properties are linked to their adsorption and dispersion actions in the cement-water system [4]. PW Zakka et al. examined the Gum Arabic as an economical and better plasticizer with improved viscosity changing effect [5]. GDO Okwadha1 and D M Makomele evaluated the water hyacinth extract as a bio- admixture. Extract of water hyacinth slows the rate of hydration and allows it to flow for longer, resulting in great flowability [6]. Molasses is also attempted as a good plasticizer and a retarder for CSA (calcium sulfo aluminate) cement [7]. M S Shobha studied the use of natural rubber latex with metakaol into produce High Performance Concrete and demonstrated better workability of concrete [8]. T S Nagaraj et al. employed natural rubber latex in concrete mixes and concluded that the use of super plasticizer improves the strength of natural rubber latex concrete [9]. Amrita Hazarika et al. investigated aqueous okra extract as a bio-additive and found that the compressive strength of mortar and concrete containing bio-admixture was greater than the control specimens. The researched bio-admixture can be used to make low-cost, ecologically friendly viscosity enhancing cement composites with better mechanical and durability qualities [10]. S Afroz et al. studied the arrow root as a bio-admixture. The optimum dosage of arrowroot as a bio-admixture was found to be within 1%– 1.5% of cement content [11]. Retarders are crucial to improve the flowability and setting time of concrete in hot climate [12]. Otoko et al. examined palm liquor as a low-cost workability aid and set retarder admixture in tropical hot weather concrete[13]. Nikhil T Retal. Investigated the effect of sugar and SP430 as an admixture on the concrete. The results showed that concrete with sugar as an additive is more workable, strong and durable than that with SP 430[14]. The work undertaken focuses to assess the rain tree pod (RTP) extract as a suitable natural plasticizer (NP) and to study the workability performance of cement mortar and concrete with NP.

2.0 Experimental Details

2.1 Materials

Samanea Saman, often known as the "Rain tree," is a member of the Leguminosae family and is also known as Albizia saman. The crown of the rain tree is shaped like an umbrella. Rain trees typically reach heights up to 15–25 m. It can grow to a height of 50 meters in certain circumstances [15]. Each RTP contains 15-20 seeds (Generally 5-10 seeds per pod in the native range). Rain tree, rain tree flowers, RTP and rain tree seeds are shown in the Fig. 1, 2, 3 and 4 respectively.

Fig.1. Rain tree

Fig.2. Rain tree flowers

Fig.3. Rain tree pods

Fig.4. Rain tree seeds

2.2 Preparation of natural plasticizer

Dried RTPs were collected, seeds and hard fibre were removed from them. Uniform paste was prepared by crushing the RTPs. This uniform paste was soaked in water for three days. The solution which is brown in colour was stirred constantly. It was observed that the froth was formed due to natural fermentation as shown in the Fig. 5. The solution was then filtered to remove the suspended particles after 3 days of soaking then fermented for 12 days by adding yeast. Fig. 6 represents the RTP solution kept for fermentation. The RTP solution was boiled after 12 days of fermentation, then cooled and stored in the refrigerator to arrest the further fermentation process. The solution being acidic in nature, lime was added to make the solution alkaline. The characterization of the solution was carried out by conducting specific gravity test, pH test and DNS **(**Dinitrosalicylic acid) test. DNS test was carried out to know the variation of concentration of sugars in the solution for different fermentation periods.

Fig. 5. Formation of froth in the solution **Fig. 6.** Solution kept for fermentation

2.3 Testing of mortar and concrete

Mix design of M20 was calculated as per IS specifications (IS 10262-2019)[16]. Marsh cone test was carried out on cement paste to determine the optimum dosage of NP. Mortar of 1:3 was prepared, and flow table test was carried out to find the optimum dosage of NP for various W/C ratios. Various workability tests such as slump test, compaction factor test and Vee-Bee consistometer test were performed on concrete mix with plasticizer. Compressive strength and durability of mortar and concrete with NP were tested and compared with those without NP.

Durability test was conducted after 28 days of curing concrete and mortar cubes in acidic solution with5% sulfuric acid. Weight and dimensions of the cubes were noted down before keeping them in the acidic solution. The cubes were kept carefully in the container containing acidic solution in such a way that the cubes were completely immersed in the solution as illustrated in the Fig. 7. Weight and dimensions of the cubes were regularly monitored every week.

Fig. 7. Concrete and mortar cubes immersed in the 5% sulfuric acid solution

Economy is an important factor to be considered in the preparation of any product. Hence, the overall cost involved in the preparation of NP is calculated and compared with the plasticizers available in the market. Cost analysis of NP includes the labor cost (collection of RTP, deseeding and crushing), yeast and lime cost.

3.0 Experimental Results and Discussion

Specific gravity and pH range of the final RTP solution was found to be 1.07 and 7.55-7.85 respectively. The NP satisfies the pH requirement as per IS 9103-1999. DNS test results showed that the concentration of sugars decreased with fermentation period as shown in the Fig. 8. At the end of the 12days fermentation period, most of the sugar concentration was reduced. Table 1 represents the physical properties of NP.

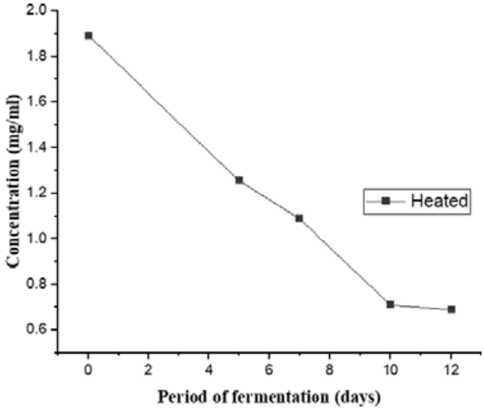

Fig. 8. Variation of sugar concentration with fermentation period

Table1. Physical properties of NP

Sl. No.	Property	NP
1	Appearance	Dark Brown
2	pH	7.55-7.85
3	Specific Gravity	1.07

Optimum plasticizer dosage was determined by Marsh cone test according to ASTM D6910-04. From the Fig.9, it was found that the optimum dosage of NP for cement paste was 0.5% by weight of cement.

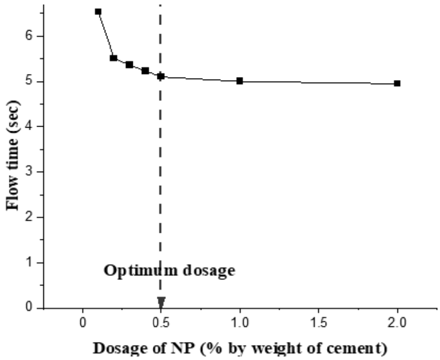

Fig. 9. Variation of flow time with dosage of NP

The flow table test gives an idea about the workability of cement mortar. Variation of optimum dosage of NP for different W/C ratio is shown in the Fig. 10. It was found that the dosage of NP decreased with the increased W/C ratio. Percentage flow of mortar with NP for W/C 0.45 was 110% compared to 20% for the control mix. Fig. 11 represents the flow of mortar with 210mm diameter (110% flow).

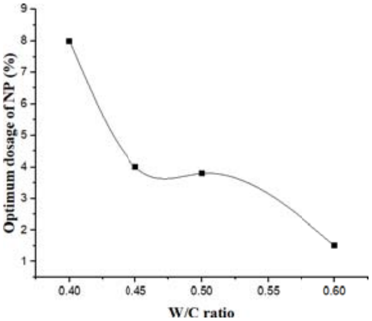

Fig. 10. Variation of optimum dosage of NP for different W/C ratio

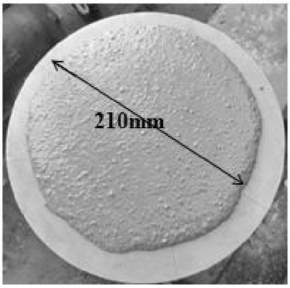

Fig. 11. Flow of mortar with 210mm diameter

Slump test was carried out on M20 grade concrete mix. It was found that the required 100mm slump was achieved at 0.5% dosage of NP. Slump of control mix concrete was found to be 30mm. Fig. 12 and Fig.13 represents the 30mm and 100mm slump respectively.

Fig. 12. 30mm slump

Fig. 13. 100mm slump

Compaction factor for M20 grade of concrete with NP dosage of 0.5% by weight of cement was found tobe 0.906. Vee-bee time of 4.21sec was obtained for concrete with NP of 0.5% dosage. Compressive strength test results for concrete and mortar are illustrated in the Table 2 and Table 3 respectively.

Table2. Compressive strength of concrete

Type of sample	**Size of the cube, mm**	**Dosage of NP (%)**	**Weight(kg)**	**28 days compressive strength (MPa)**
Control mix concrete	150	0	8.32	32.17
Concrete with NP	150	0.5%	8.35	27.87

Table 3. Compressive strength of mortar

Type of sample	**Size of the cube, mm**	**Dosage of NP (%)**	**Weight(kg)**	**28 days compressive strength (MPa)**
Control mix mortar	70.6	0	0.728	36.714
Mortar with NP	70.6	4%	0.761	24.67

From durability test results, it was observed that the cubes kept in acidic solution for 28 days deteriorated as shown in the Fig. 14. The degraded concrete and mortar cubes were washed and dried before the weight and dimensions were taken and later tested in compression to find its compressive strength. Table 4 represents the durability test results for concrete and mortar cubes. The percentage strength reduction for concrete with NP was 44.025%, compared to 47.155% for control mix. Similarly, the percentage strength reduction for mortar with NP is56.811%, compared to 65.02% for control mix. Variation of percentage weight loss with time for concrete with NP and control mix concrete as well as mortar with NP and control mix mortar is shown in Fig 15(a) and 15(b) respectively. Percentage weight loss for concrete and mortar was found to be less when NP is used.

Fig. 14. Degraded concrete and mortar cubes after acid attack

Table 4. Durability test results for concrete and mortar

Sample Type	Percentage Reduction in weight after 4 weeks	Percentage reduction in compressive strength after 4 weeks
Control mix concrete	11.504	47.155
Concrete with NP	8.697	44.025
Control mix mortar	40.84	65.026
Mortar with NP	31.413	56.811

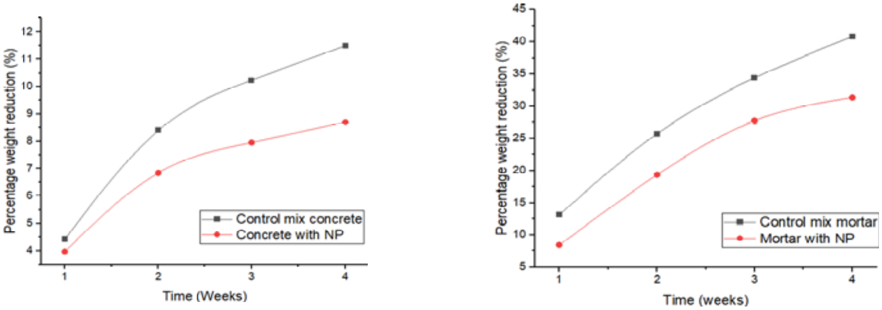

Fig. 15. Weight loss with time for a) concrete specimens with NP and b) mortar with NP

Table 5 and Table 6 represents the cost analysis of RTP plasticizer and cost comparison with the plasticizers available in the market respectively. Cost analysis showed that the cost reduction of 55.15% to 77.58% is achieved when the NP is used compared to the various chemical plasticizers available in the market.

Table 5. Cost analysis of RTP plasticizer

Labour cost (₹)	Lime cost (₹)	Yeast cost (₹)	Total cost for 20 litre RTP plasticizer (₹)
300	7.56	96	403.56

Table 6. Comparison of cost between RTP plasticizer and chemical plasticizer

Total cost per liter (₹)		Cost ratio and percentage savings	
Chemical plasticizer	**RTP plasticizer**	**Cost ratio**	**Percentage savings**
45 to 90	20.18	0.45 to 0.22	55.15 To 77.58

4.0 Conclusion

The following conclusions were drawn from the test results:

- TheidealperiodforfermentationoftheRTPsolutionis12days.
- Cement 0.50wt. % is the optimal content of NP forcement paste with a W/C ratio of 0.45.
- Flow table test results indicated that the percentage flow of mortar with NP is greater than that without NP.
- Slump test, compaction factor test and Vee-Bee consistometer test results showed that the NP is effective in inducing good workability.
- Durability test results indicated that the use of NP did not degrade the concrete.
- Cost reduction of 55.15% to 77.58% was achieved when NP was used.

Declaration

Conflict of interest on behalf of all authors, the corresponding author states that the reisno conflict of interest.

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