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ENHANCING MECHANICAL PROPERTIES OF NO-FINES CONCRETE: EPOXY MODIFICATION AND CURING CONDITIONS

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Abstract – The present study considers the influence of curing techniques on normal weight concrete (NC), no-fines concrete (NFC) and epoxy modified no-fines concrete (ENFC) with the emphasis on compressive, splitting tensile and flexural strength properties. For each type in triplicate, specimens were cured under water, in open atmosphere and under laboratory conditions. Copious tests show that NC was the most effective type for which water cured samples displayed 4415 psi of compressive strength, 441.32 psi of splitting tensile strength and 160.48 psi of flexural strength. Absence of fine such as sand in the mixtures of NFC broadly disadvantaged the concrete until the water cured samples reached a compressive strength of 1413.12 psi, coupled with good tensile and flexural strengths making it a good candidate for light weight structural applications. Higher levels of NFC were achieved with the addition of resin especially epoxy whereby treated specimens ENFC samples of water cure showed a compressive strength of ENFC26365 psi, splitting tensile strength of239.6psi and flexural strength of193 psi which exhibited both strength and flexibility. The analysis finally recommends optimum curing and material optimization modifications for the improvement of NFC mechanical properties as though water curing and epoxy modification dirt cheap concrete replacements for the conventional type.

Keywords – No-Fines Concrete; Epoxy Resins; Curing Conditions; Strength Properties.

1. INTRODUCTION

According to A. M. Neville, concrete can be categorized under any construction material without reference to the end application. This construction material remains popular and, in fact, is used widely due to its attributes of strength, durability and multi functionality. Ordinary concrete comprises sand, gravel, coarse and fine aggregates that are mixed with water and cement paste in certain ratios that harden to support construction activities. In addition to these kinds of concrete, more advanced kinds of concrete including no-fines concrete can also be used for construction work.

No-fines concrete is concrete made without considering the usual fine aggregates in the mix ratio and therefore there results a cellular structure with prisons of voids interlinking each of the old prisms. According to M. Uma Maguesvaria, V. L. Narasimha (2013), this type of concrete has the only cement and coarse aggregate. Maltola (1976) postulated that ordinary and lightweight no-fines concrete could when placed produced be made with normal weight and lightweight rounded and crushed aggregates respectively. The absence of fine aggregates provides hay lighter material which means that the density is lessened and hence is more favorable for areas where weight is a concern yet still requiring good thermal resistance however it has some disadvantages in terms of mechanical strength compared to normal weight concrete.

The importance of no-fines concrete arises from its special usage in Europe, particularly in the building of single and multistory houses as cast-in-situ load bearing walls or for flooring surfaces (Mohan, 1981). This paper explains the reasons for providing such services to no-fines concrete. Same kind of concrete was also built and developed in a hurry in the United Kingdom as such no-fines concrete premises are made use of without reconstruction. The attribute was also renowned in Canada where it served both house building and non residential highrise like Toronto houses and the Ottawa federal centre building. It further advanced into the same vein in Canada when even by the year 1973, the Canadian Standards Association had also come up with a standard concerning no-fines concrete. Another category of no-fines concrete is the Light weight concrete which is low in density or has a porous structure that is more applicable in a few construction features at the time of need of insulation and less weight (Milena Rangelov et al, 2017).

It is common knowledge that no-fines concrete possesses merits of having a low weight and also excels in thermal insulation properties, however its strength properties in comparison with the normal weight concrete are rather weak. However, this is intentional since this kind of concrete composites has no fine gravels which would form particles to bond with other components within the standard concrete. This therefore has brought in the notion of more investigation to be carried out on how for instance epoxy resin could increase its strength. Epoxy resin is quite inexpensive and in addition to that it does not expand which makes it very good for use as an encapsulating medium within the material because this liquid is very adhesive.

The present work focuses on the possibility to improve no-fines concrete with the use of epoxy and analyze the behavior of such a modified concrete matrix under various curing conditions. The properties of the modified epoxy resins no-fines concrete, the plain no-fines concrete and the normal weight concrete were evaluated against water curing, open atmosphere and laboratory curing conditions in mechanical tests. This research is aimed at defining to what extent the mechanical properties of no fines epoxy resins concrete can be improved by applying the resin under various environmental conditions as determined through compressive, splitting tensile and flexural testing.

Therein, initial findings show that the modification of concrete with epoxy resin as an additive enhances the compressive strength of the no-fines concrete, especially in water curing conditions where better bonding and hydration is achievable. These results point out that the no-fines concrete incorporated with epoxy resin may have applications in areas where high levels of durability and structural performance are required without offsetting the basic efficiency of construction methods.

2. MATERIALS AND METHODS

2.1 Methodology

This research adhered to ACI 318-21 standards in preparing and examining concrete specimens with different mixes, these were normal weight concrete (NWC), no-fines concrete (NFC), and epoxy-modified no-fines concrete (EM-NFC). The mix ratio for normal weight concrete was 1:2:4. For no-fines concrete and epoxy-modified no-fines concrete, a 1:6 mix ratio cement to coarse aggregates was used while the water to cement ratio was set at 0.45. This was set because past studies had shown that setting this ratio gave the best results in terms of compressive strength as reported by L JiaHao et al. (2019). Epoxy modified no fines concrete also consisted epoxy resin to enhance the mechanical characteristics of the concrete admixture.

Both spherical and rectangular concrete specimens were cast for compressive, ceramic tile shearing, and flexural bending tests to determine compressive, splitting, and flexural strength, respectively. The specimens underwent three types of curing so that the results could include the effect of weather conditions on sample exposure: specimens were cured in a lab environment, specimens were cured in ambient weather, and specimens were cured in water to facilitate thorough curing of the samples. All the samples were cured for 28 days before the test procedures so that uniform strength and maturation of all the samples was achieved.

After the curing process, mechanical property tests were done on the samples. A compressive strength test conducted in accordance with the ACI 318-21 guidelines evaluated the maximum internal axial load that the samples could take before collapse. The splitting tensile test conducted based on ASTM C496 aimed at measuring the tensile strength of the samples which is necessary to improve understanding of the behaviour of tension in the material and its cracking properties. Moreover, bending strength tests were carried out on relatively long rectangular prisms for the purpose of assessing the bending strength of the samples as recommended in ACI 318-21. Lastly, the concrete unit weight was effectually measured using ASTM C138 whereby the aim was to assess the weight of skeleton-inclusion concrete intermixed with no-fines and epoxy-modified no-fines with that of normal weight concrete.

2.2 Materials

The materials applied for this research were purposefully chosen according to the requirements of the industry. The cement of all the concrete mixes was consistent with its specifications as per ASTM C150-05 (2005) for Portland cement as well as the BS 12 (1991) standard which was for ordinary Portland cement (OPC) which met these requirements.

Coarse aggregates were procured from the Margalla hill quarry which is known for the quality of the aggregate and the water absorption per cent is controlled at 0.58%. These aggregates were used in both the normal weight and no-fines concrete mixes. The physical properties of the aggregates like size and gradation were chosen to assist the mechanical properties of the concrete mixes to be enhanced.

The bisphenol epichlorohydrin-based polymers were utilized on the epoxy-modified no-fines concrete in compliance with the ISO 3673 standards. This was to guarantee that the epoxy resin provided the basic performance needed for structural concrete by ensuring that proper bonding and strengthening were achieved on the no-fines concrete matrix. The aim of incorporating epoxy resin was to enhance the performance characteristics of the no-fines concrete, particularly density, and strength, under different curing environments.

2.3 Testing of the Specimens

This approach uses what is known as a tri angled sampling technique where three different curing conditions will be obtained. The first batch will be immersed in water for a period of 28 days and will be modified. The second batch will be kept at room temperature in the laboratory with no curing. The third batch will be dry cured for a duration of twenty eight days and placed in an open space. For each of these curing conditions, preparation of no fines concrete with and without epoxy resin and of normal concrete is in the ratio of 1:6:1. To ensure that there is no variability in the way the samples are subjected to various testing processes, the samples will be prepared in compliance with the ASTM standards. Approximately

27 samples will be gotten whereby for every curing condition there will be 9 samples and 3 samples for each type of concrete. This sampling method therefore tackles the problem of studying the influence of epoxy resin on the mechanical properties of no fines concrete subjected to different curing conditions.

3. RESULTS AND CONCLUSION

3.1 Unit Weight

Calculating unit weight, or density, is of great importance in considering the mechanical aspect of concrete. In this investigation, three concrete mixtures were studied: normal weight concrete (NC), no fines concrete (NFC) and epoxy modified no fines concrete (ENFC). The unit weight of normal weight concrete (NC) lies within the bounds of 2200 kg/m3 and 2600 kg/m3, while the result obtained in this study stands at 2370 kg/m3. However, no-fines concrete (NFC), which does not contain fine aggregates, was in the unit weight range of 1500 kg/m3 to 1800 kg/m3 with 1683 kg/m3 being a test value. Presence of large voids in the concrete mix devoid of fine aggregates increases void content and thus decreases the density. Though there was no great density increase when the epoxy resin was incorporated with the mix, the density of the ENFC ranged from 1600 kg/m3 to 1900 kg/m3 T whilst still in the effective density category with regard to the resin specific gravity. These unit weight values are important as they relate to the density features of the concrete mixtures and the degree of their mechanical characteristics.

Table 1 Unit Weights

Batch	Concrete Type	Unit Weight
B1	Normal Weight Concrete (NC)	2370 kg/m^3
B2	No-Fines Concrete (NFC)	1683 kg/m^3
B3	Epoxy Modified NFC (ENFC)	1720 kg/m^3

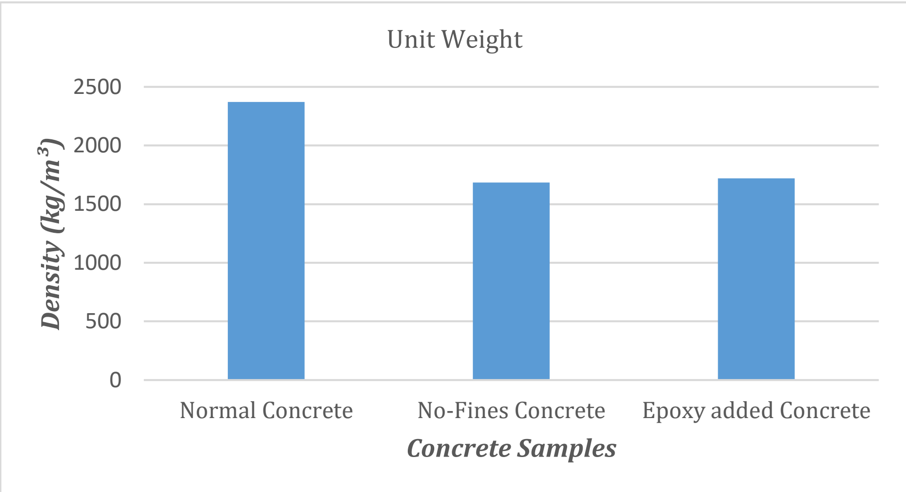

Figure 1Unit Weight

3.2 Compressive strength

Three curing methods of normal weight concrete were used in the study to establish its compressive strength: water curing, curing in open atmosphere, and curing in a laboratory. Water curing produced the most compressive strength average of 3210 psi which implies the material has a high compressive after curing due to sufficient moisture being retained during the entire curing duration. However, the concrete samples that were allowed to cure in the open air had an average compressive strength of 2266.3 psi, which is still less than that of the water cured samples but was still able to support considerable compressive loads. Last but not the least, in the environment of standard lab conditions, the averaged compressive strength was 2201 psi. The compressed specimen is tested under controlled and pressed where the conditions of evaporation specified earlier are weighted on the curing of concrete within the laboratory. These have been pointed out in detail all their ways that these curing conditions have an adverse effect on the structural characteristics of typical weight concrete with water clearly emerging as the best amongst all per curing method.

Table 2 Comparison of Compressive Strength

Concrete Type	Curing Condition	Average compressive strength PSI
Normal Weight Concrete	Water	3210
	Open atmosphere	2266.3
	Lab Environment	2201
No-Fines Concrete	Water	1104
	Open atmosphere	1015.1
	Lab Environment	987
Epoxy Modified NFC	Water	1854.72
	Open atmosphere	1664.76
	Lab Environment	1618.68

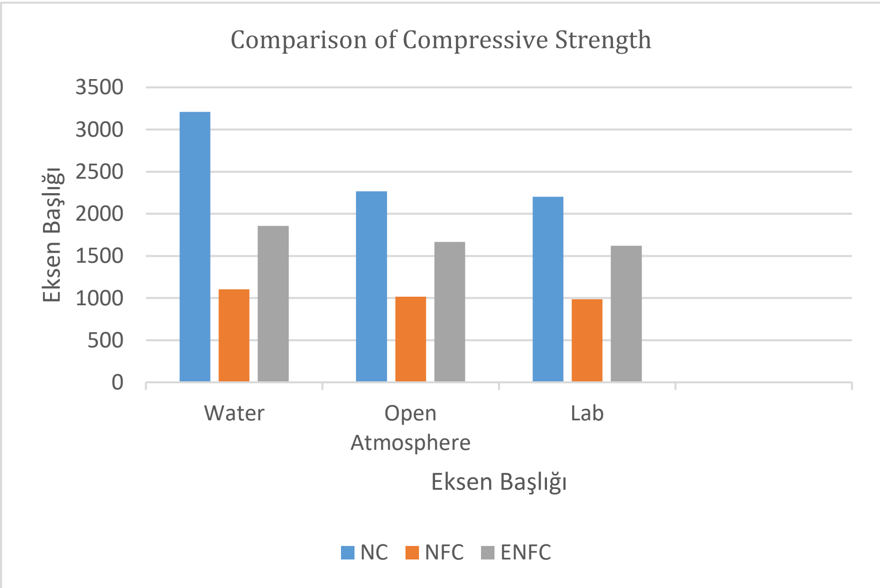

Figure 2Comparison of Compressive Strength

3.3 Splitting Tensile Strength

In this paper, different curing methods were assessed concerning the splitting tensile strength of normal weight concrete (NC), no-fines concrete (NFC), and epoxy-modified no-fines concrete (ENFC). Regarding NC, water curing provided the best results with a value of 441.32 psi, followed by open atmosphere at 352.728 psi, and lab curing being least effective with a strength of 127.92 psi. In particular, it is evident that water curing improves the tensile property of NC to great extents; air curing is also efficient albeit moderately, while laboratory curing gives low figures because it takes place in a highly regulated environment.

In most of the cases, tensile strength of NFC was comparatively less than other because there was no inclusion of fine aggregates. Water-cured NFC samples showed an average strength of 141.312 psi while open atmosphere bar curing was 119.78 psi and lab curing was 110.554 psi. Though the tensile strength

of sustainable concrete was lower as compared to NC, nonetheless, NFC still showed reasonable resistance against cracking especially when immersed in water.
The addition of epoxy resin in ENFC was helpful in terms of improving the tensile strength under all curing conditions. The tensile strength of samples cured in water was 236.5 psi, in an open atmosphere 181.8 psi and in the laboratory 162.9 psi. Water curing incorporated the highest tensile stress resistance owing to the epoxy modification and optimal bonding at the aggregates-concrete interface.

Table 3 Comparison of Splitting Tensile Strength

Concrete Type	Curing Condition	Splitting tensile strength (PSI)
Normal Weight Concrete	Water	441.32
	Open atmosphere	352.78
	Lab Environment	127.92
No-Fines Concrete	Water	141.1
	Open atmosphere	119.78
	Lab Environment	110.55
Epoxy Modified NFC	Water	236.5
	Open atmosphere	181.8
	Lab Environment	162.9

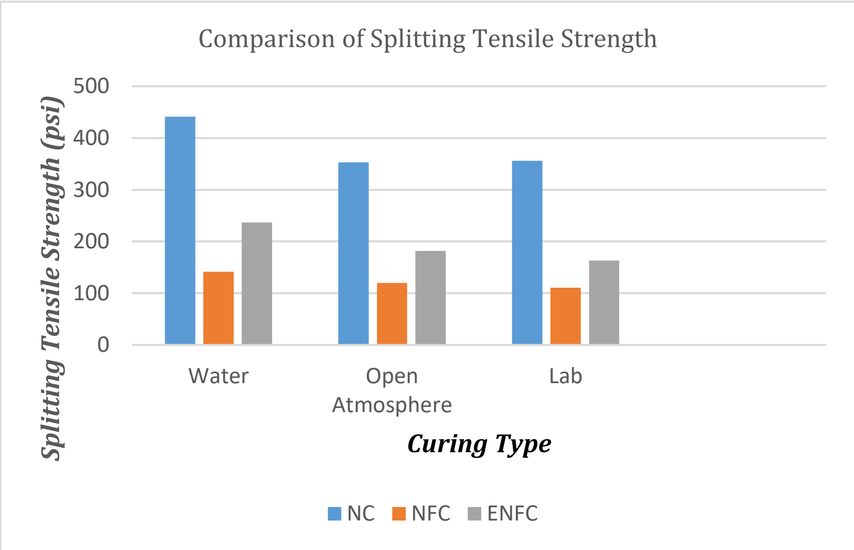

Figure 3Comparison of Splitting Tensile Strength

The tensile strength of the no-fines concrete specimens shown in the figure above was influenced by the different types of curing conditions: water, exposed in the open air, or laboratory curing. It was found that the tensile strengths of specimens cured in water are 12.8%, in open atmosphere 11.8% and in laboratory setting 11.2%.

3.4 Flexural Strength

It provides the details of the flexural strength test results in terms of the bending resistance of normal weight concrete (NC), no-fines concrete (NFC) and epoxy-modified no-fines concrete (ENFC) in various curing conditions. In case of normal weight concrete, the maximum average value of flexural strength of 160.48 psi was recorded when the specimens were cured with water whereas, lower values were recorded at open atmosphere and lab curing with averages of 130.64 psi and 127.92 psi respectively. With improving curing & secondary matrix, proper water curing produced improved bending strength of concrete as the matrix was enhanced.

As for the no-fines concrete, considerations of flexural strength turned out to be lower than for concrete with coarse aggregate, as no fine aggregate is applied. However, acceptable curing values were achieved e.g. with a water cure curing resulted in 22.6 psi, open atmosphere curing at 18.3 psi, and lab curing at 16.75 psi. These values are about 2%, 1.8% and 1.6% of the compressive strength of these cores respectively. Even if NFC is rather weak in bending as compared to NC, it exhibits a fair resistance to transverse loads, especially after water curing.
Conducted on epoxy-modified no-fines concrete, this test's results showed higher performance than the control NFC with average flexural strength of water-cured slabs reaching the average of 19 psi, 17.54 psi and 13.16 psi in open atmosphere and lab curing respectively. As expected, water cured resin membranes had very little effect on interfacial bonding of layer epoxy, so flexural strength of those samples was less than that of water cured samples.

Table 4 Comparison of Flexural Strength

Concrete Type	Curing Condition	Flexural strength PSI
Normal Weight Concrete	Water	160.48
	Open atmosphere	130.64
	Lab Environment	127.92
No-Fines Concrete	Water	22.6
	Open atmosphere	18.3
	Lab Environment	16.75
Epoxy Modified NFC	Water	19
	Open atmosphere	17.54
	Lab Environment	13.16

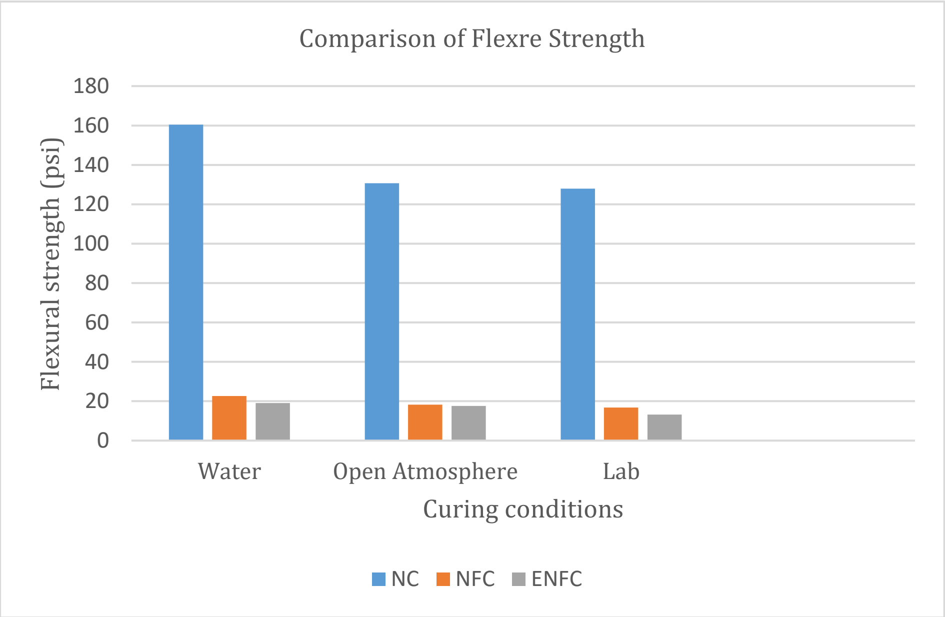

Figure 4 Comparison of Flexural Strength

4. CONCLUSION

This study provides new and significant information on the mechanical performance of normal weight concrete (NC), no-fines concrete (NFC), and epoxy modified no-fines concrete (ENFC) for the conditions of curing. Generally, NC yielded the best performance with regard to water-cured samples, having a compressive strength of 4415 psi, a splitting tensile stress of 441.32 psi, and flexural strength of 160.48 psi. These results highlight the better durability of NC, which is most beneficial in structural applications that encounter great compressive, tensile, and bending forces.

NFC received slightly encouraging results in compressive strength even though it does not have fine aggregates. The water-cured NFC recorded a compressive strength of 1413.12 psi, and flexural and splitting tensile strengths of 22.6 psi and 141.312 psi respectively. While these values are quite low compared to the strength attained by NC, they point towards the applicability and viability of NFC as lightweight concrete chiefly when optimization is done on curing processes and mix design.
It was found out that the performance of the NFC has been greatly improved by the epoxy modification. The water-cured ENFC had compressive strength, splitting tensile strength, and flexural strength of 2365 psi, 236.5 psi, and 19 psi, indicating better interfacial adhesion within the concrete.
To summarize, properly applied water curing and epoxy modification should allow achieving appropriate values of compressive strength and overall mechanical performance of NFC. Such developments give a bigger area of usage for NFC in construction works, where, among other requirements, low weight of materials with high performance is needed as the solution to replace traditional concrete in an environmentally friendly and favorable manner.

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