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DURABILITY PERFORMANCE OF NATURAL RUBBER LATEX MODIFIED CONCRETE

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Abstract: Deterioration of concrete due to chemical aggression normally through transporting agents is a serious menace to the two major qualities of concrete; strength and durability. This paper reports the findings of a study conducted to assess the effect of natural rubber latex on resistance to the ingress of sodium sulphate (Na_2SO_4) and moisture into hardened concrete. Two principal categories of concrete (normal and modified) involving different grades and sizes were developed. Concentrated natural rubber latex was used in this study. The quantity of the latex was varied from 0 – 5% and 0 – 10% latex/water ratio (*L/w*) for the chemical resistance and water absorptions respectively. A simulated aggressive medium containing 2.5% Na_2SO_4 serves as the curing environment for the chemical detections. Results have shown that attack due to Na_2SO_4 and moisture absorptions are seriously influenced by the amount of latex added into the mix and period of exposure. It is further comprehended that the general moisture ingress is significantly affected by concrete grade. In fact, within the time frame considered in this work, the optimum amount of concentrated latex for maximum resistance to Na_2SO_4 penetrations is 1.5% (*L/w*) while for minimum water absorption is 5% (*L/w*). The outcome of the work therefore, identifies and indicates the level of efficiency and importance of using appropriate quantity of latex concentrate in the modification process of normal concrete, especially in the areas of sulphates attack and water ingress.

Keywords: *Latex-modified concrete, natural rubber latex, latex concentrate, chemical resistance, sodium sulphates and water absorption.*

1.0 Introduction

The inclusion of both natural and synthetic latexes into concrete and mortar mixes began in the twentieth century [1,2]. Since then there has been a tremendous increase in the number and type of synthetic polymer latexes [3]. In fact, in recognition of the global development in the areas of elastomeric latexes, these substances were classified in ASTM C 1042-85 as remulsifiable latexes which should be used only in applications other than immersion in water or high humidity, and non-remulsifiable latexes which are applicable to vice-versa. However, little attention was given to natural latex, though it has numerous outstanding qualities when compared with its counterpart. For example, according to John, Kondou and Bradley [4-6] NRL has superior qualities over other elastomeric latexes, especially in the areas of high performance applications that require excellent mechanical characteristics such as high tensile strength and resilience as well as abrasion resistance.

One of the major factors for the deterioration of concrete is the attack from environmental factors such as sulphates and acids [7-11]. Meanwhile, failure of hydraulic cement concrete to perform effectively in aggressive environments during the anticipated service life has been attributed to the particulate orientations of the concrete, particularly the cement-sand matrix. Indeed, According to Nawy [12], deterioration, long-term poor performance and inadequate resistance to hostile environment, coupled with greater demands for more sophisticated architectural form, led to accelerated research into the microstructure of cements matrix resulting into more elaborate codes and standards. Concrete matrix consists of pores and voids interconnected by channel or existing micro cracks, which are the main contribution to its moisture permeability. In fact, one of the most impressive characteristics of polymer modification is its ability to resist the entry of water and aggressive agents, thereby improving its impermeability and consequently saving the concrete from undue attack. It is believed that the polymer film lining the capillary pores and micro cracks does an excellent job in subsidizing the fluid flow in polymeric products [13]. This research is therefore set out to investigate not only the applicability of NRL into concrete, but also to determine appropriate quantity of latex to be added without impairing strength characteristics as well as evaluating the impact of concrete grade on its efficiency.

2.0 Materials and Methods

2.1 Materials and Materials Mix-Design

Ordinary Portland cement was used throughout, and its chemical composition, physical and mechanical characteristics are shown in Table 1. Crushed granite stones and naturally occurring river-washed quartz sand were employed as coarse and fine aggregates respectively. While the maximum nominal size of the coarse aggregate is 20 mm, ASTM sieve No. 4 is considered as a demarcation between the two classes of aggregates. Concentrated latex was used as the modifier, and its chemical analysis is presented in Table 2.

Mixed proportions for the two concrete grades used in this work were shown in Table 3. While grade 30 (G30) concrete is involved in chemical resistance and water absorption properties, grade 50 (G50) is employed in the later only. In order to avoid excess mixing water, 52% of the volume of latex meant for inclusion into each particular batch is usually applied [1], and this has been maintained throughout.

Table 1: Chemical composition, physical and mechanical properties of the cement

Chemical		Physical/Mechanical	
Composition	Magnitude (%)	Property	Magnitude (%)
Silicon dioxide (SiO_2)	20.1	Surface area (Blair's) m^2/kg	290
Aluminium oxide (Al_2O_3)	4.9	Initial setting time (min)	105
Ferric oxide (Fe_2O_3)	2.4	Final setting time (min)	190
Calcium oxide (CaO)	65	Compressive strength (N/mm^2)	
Sulphur oxide (SO_3)	2.3	1 day	20
Magnesium oxide (MgO)	3.1	3 days	30
Insoluble residue	1.9	7 days	40
Loss on ignition	2	28 days	50
Lime saturated factor	0.85	Soundness (mm)	8.7

Table 2: Chemical analysis of latex concentrate

Property	TSC%	DRC%	NRC%	pH	VFA%	NH_3%	MST(s)	Specie
Value	61.54	60.09	1.45	10.07	0.018	0.25	1227	Multiple

Note: TSC = Total solid content
DRC = Dry rubber content
NRC = Non rubber contents
VFA = Volatile fatty acid No.
NH_3 = Alkalinity
MST = Mechanical stability time (sec)

Table 3: Mix proportions

Concrete grade	OPC (kg/m^3)	Coarse aggregate (kg/m^3)	Fine aggregate (kg/m^3)	W/C ratio	Latex* (liters)	Strength ** (N/mm^2)
G30	425	915	780	0.54	11.5	34.2
G50	525	1270	210	0.4	10.5	52.6

* 5% latex/water ratio ** 28 days cubes strength

2.2 Specimen Preparations and Curing Conditions

Batching and mixing were conducted in accordance with BS 1881-125: 1986. In the mixing process, the latex used is added to the mixing water. 100 mm cubes were opted for Grade 30 concrete in chemical resistance test, while both 100 mm and 150 mm cubes were opted for Grade 30 and Grade 50 in water absorption test. Slumps for the G30 and G50 concretes were observed to be 42 mm and 17 mm respectively. All specimens were covered with wet burlap for a day followed by immersion in water at 23 ^{0}C. In order to avoid excessive strength weakening from the intended aggressive attack, such that compressive strength test may not be possible, specimens for chemical resistance were allowed to develop 28 days strength in the ordinary water. A further 24 hour drying in the normal laboratory condition was given to the specimens, aimed at withdrawing surface water, before a complete immersion into a 2.5% Na_2SO_4 solution. On the other hand, specimens for water absorption were removed from the ordinary water after the first 28 days of immersion.

2.3 Specimen Testing

At the end of the Na_2SO_4 solution immersion periods (7, 28, 56 days), specimens were tested for compressive strength. All the compressive strength tests were in conformity with BS- EN 12390: Part 3 (2008). The compressive strength of specimens was taken by dividing the maximum load (N) with the specimen area (mm^2).

Measurement of water absorption was conducted in accordance with BS 1881–122: 1983; Method for Determination of Water Absorption. The 28 day cubes were cored at diameter of 75 mm each and this is in compliance with the standard used. The cores were kept in an oven for 72 hour at 105 ± 5^{O}C followed by subsequent cooling for 24 h in dry airtight vessels. The measured absorption of each specimen is calculated as the increase in mass resulting from immersion in water for 30 min. The absorptions were calculated using the formula:

Absorption = [(saturated weight – dry weight)/dry weight] x 100%
Correction factor = vol. of specimen (mm^3)/ [surface area (mm^2) x 12.5]
Corrected absorption = Absorption x correction factor (nearest 0.1%)

3.0 Results and Analysis

3.1 Residual Compressive Strength

Figure 1 shows the comparison of compressive strength between normal concrete and latex modified concrete with addition of 1.5, 3 and 5 % of latex.

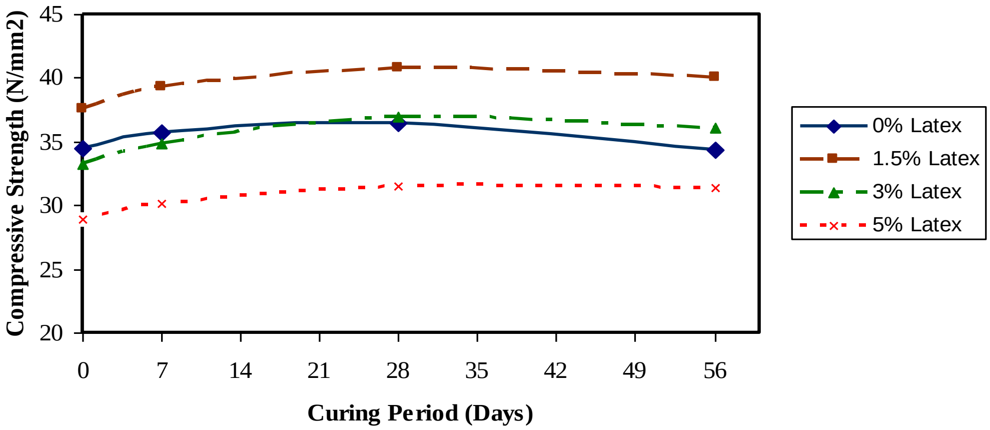

Figure 1: Effect of latex dosage on compressive strength

Focusing on the outcome of the result it can be seen that 1.5% latex addition gives higher compressive strength when compared with the normal and other modified concrete. This superiority of 1.5% was maintained even in the aggressive solution. Furthermore normal concrete which is initially next to 1.5% modification is observed to have reduced drastically in compressive strength more than the reduction in other modifications. The impact of the latex inclusion is clearly seen as the modified concrete entertained little reduction in compressive strength when compared with the normal concrete. This is because the curve for the normal concrete is going down more than the curves for the modified concrete. In contrary, normal concrete is not resistance to Sulphates [1]. However, in this project, it is observed that modifying the normal concrete with the natural rubber latex improves the sulphates resistance property. This is in line with the finding of [16] where he reported that the latex films will normally envelope the aggregate during the cement hydration. Thus, the films prevent Na_2SO_4 particles from penetrating into the concrete during the aggression. Figure 1 also shows that higher percentage of latex may provide better resistance towards Na_2SO_4 attack. This is because 5% entertained the least reduction in compressive strength, which indicates higher blockage qualities against penetration of the Na_2SO_4 ions. Therefore the higher the latex the more effective will be the resisting capacity. However, observations throughout the experiment have shown that latex modified concrete tends to have honeycombs as the latex-water ratios increase and certainly reduces the early strength of concrete. This is similar to findings by the present authors in a previous work [17].

In addition, throughout the curing period there was no eroded residue of sand particles, nor that of cement or latex was seen in the base of the Na_2SO_4 solution. Henceforth, variations in weights of specimens at the end of the curing exercise were also noticed to be insignificant.

As a conclusion, the best latex percentage to be added in a mixture to resist the sulphate attack where strength is of greater importance is 1.5%. However, where durability supersedes strength more latex can be added beyond 1.5% for better protection.

3.2 Resistance to water ingress

3.2.1 Optimum latex required to provide minimum water absorption

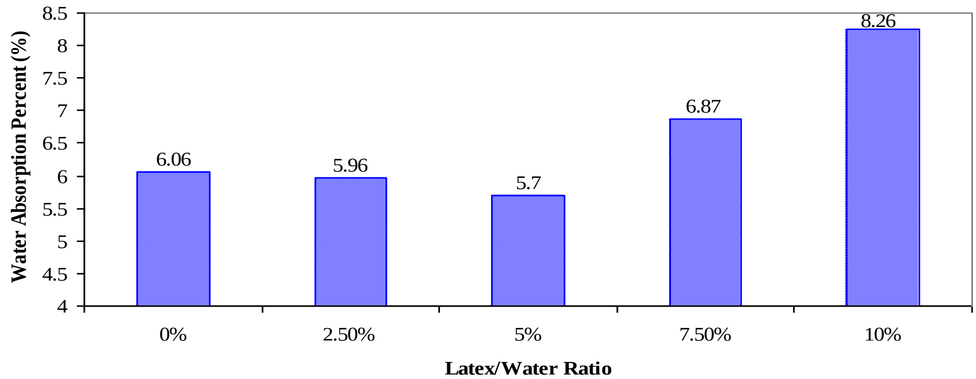

Figure 2: Effect of latex dosage on Water Absorption

Figure 2 shows the water absorption result conducted on G30 concrete. It can be seen from the figure that 5% L/w ratio provide the most effective dosage among other quantities used as it allows for minimum water absorption in the concrete. According to [16], latex-modified concrete have a structure in which larger pores can be filled with polymers therefore reducing water absorption, water permeability and water vapor transmission. However, specimens with higher than 5% NRL-water ratio give poor water exclusion properties toward concrete [18]. This is probably due to excess latex pushing aggregates further away thus creating a room for higher absorption. In addition, physical observations during the experiment have clearly indicated a technical lapse in the suitability of this method in assessing the water absorption of LMC. The idea of keeping cores in an oven for 72 h at 105 ± 5^{O}C resulted in destroying the immediate latex on the cored surfaces thereby paving a way for more absorption during the 30 min immersion. In fact, signs of protruded latex were witnessed after removing the specimens from the oven. Thus, an alternative drying at ambient or close to room temperatures will be more suitable.

As a conclusion, 5% latex-water ratio gives the most effective water exclusion improvement compared to normal latex and other modifications. Meanwhile, according to [16], the inclusion of natural rubber (NR) into concrete can only increase its water absorption capacities. However, the quantity of latex used in the research was 10% latex/cement ratio which represents about 20% latex/water ratio. In other words, the latex/cement ratio used in that research was quite higher than the appropriate dosage for the most effective water exclusion improvement.

3.2.2 Impact of different concrete grade

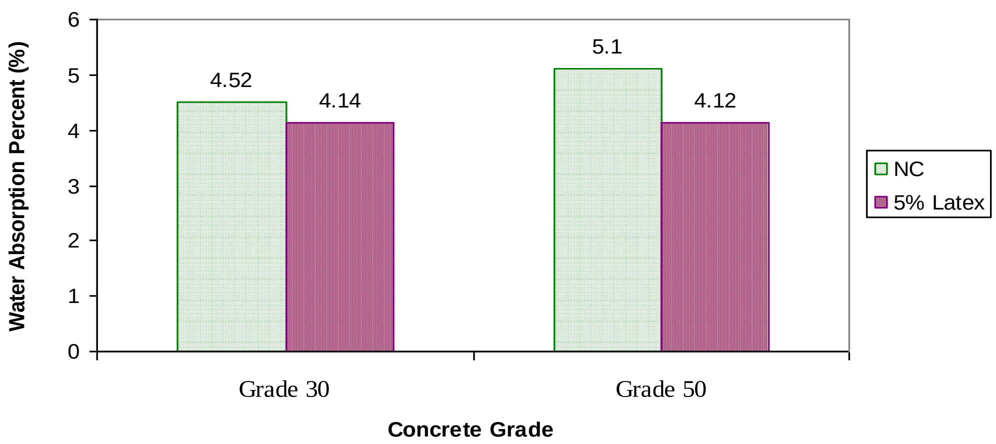

Figure 3: Effect of concrete grade on Water Absorption

Figure 3 presents the water absorption result for different grade of concrete. As shown in the figure, it can be seen that the modified concrete in both grades (G30 and G50) give better water absorption characteristics when compared with the normal concrete of the same grade. This figure also shows that Grade 50 latex-modified concrete gives higher water exclusion capacity compared to Grade 30. This is because the higher grade consists of less fine aggregate, thereby creating room for more spaces in between the larger coarse aggregates. In fact, this is possibly the main reason why unmodified G50 absorbs more water than G30 as shown in Figure 3. Therefore, the latex will have more room to act. In summary, higher grade of concrete gives better water exclusion capacity.

4.0 Conclusions

Based upon the findings in this investigation the following conclusions were drawn:

1. Inclusion of appropriate dosage of natural rubber latex into concrete as a modifier enhances its durability against sodium sulphate (Na_2SO_4) attack and improves its water exclusion capacity.
2. 1.5% latex/water ratio proves to be the optimum quantity for protection against the ingress of sodium sulphate (Na_2SO_4) while maintaining highest strength. However, where durability supersedes strength, higher latex/water ratio can be added as it does provide higher protection qualities but lower strength values.
3. The results of this study indicate that 5% is the optimum latex/water ratio to give maximum water exclusion capacity to the concrete.
4. Higher grade of latex/modified concrete gives better water exclusion capacity.

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