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Behaviour of Plain and Reinforced Concrete: Specimens Subjected to Nitrate Solution.

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BEHAVIOUR OF PLAIN AND REINFORCED CONCRETE SPECIMENS SUBJECTED TO NITRATE SOLUTION

سلوك عينات الخرسانة العادية والمسلحة الموضوعة في محلول نيترات الصوديوم

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ملخص البحث :

يشتمل البحث على دراسة معملية لتحديد تأثير املاح نيترات الصوديوم على خواص الخرسانة العادية و المسلحة وعلى وجه الخصوص مقاومة الضغط و الوزن الحجمي. و المتغيرات التي اخذت لكل من العينات الخرسانية العادية و المسلحة التي اختبرت في هذا البحث هي محتوى الاسمنت بالخلطة حيث اخذ محتويين ٣٥٠، ٤٥٠ كجم لكل متر مكعب خرسانة كما انه قد استخدم ثلاثة تركيزات لاملاح نيترات الصوديوم في الماء و هم ١٠٠، ٢٥٠، ٥٠٠ جزء من المليون كما ان مدة غمر العينات الخرسانية في هذة المحاليل كانت ٢٨، ٦٠، ١٨٠ يوم اعتبارا من ثاني يوم بعد صبها. و لقد تم معالجة عينات اخرى في الماء العادي للمقارنة. ولقد تعرضت العينات الخرسانية المسلحة التي تم صبها في هذا البحث الى نفس الظروف التي تعرضت لها العينات الخرسانية العادية. ولقد اظهرت الدراسة ان حديد التسليح لم يتعرض لاي صدا تحت تاثير التركيزات المختلفة لمحلول نيترات الصوديوم وبالنسبة للخرسانة فان التركيزات المنخفضة للمحلول قد سمحت بالفلحة الى اعماق اكبر من التركيزات الكبيرة وبالتالي احدثت انخفاضا في الضغط و الوزن نتيجة التفاعلات الداخلية.

ABSTRACT

This research was conducted to determine the effect sodium nitrate solutions on the mechanical properties of pla and reinforced concrete with special attention to the compressi strength and unit weight. The main variables taken in consideration in this research were the cement content in t concrete mix, the concentration of the sodium nitrate soluti and the duration of exposure. Reinforced concrete specimens we also exposed to the same condition as plain concrete to determi the effect of sodium nitrates on their strength and the corrosi of steel.

INTRODUCTION

The problem of concrete destruction and deterioration has been widely noticed during the last few years in Egypt. Many existing reinforced concrete structures suffered from severe deterioration within a relatively short time after construction, especially those exposed to severe conditions.

Structures in industrial areas as well as in the coastal areas are exposed to severe conditions from weather polluted with chemical gases which attack them. The soil and under ground water are considered the main sources of chemical substances which may affect the foundations and other structural elements in contact with them. These problems also appear in the agricultural areas due to the chemical fertilizers and irrigation water which may cause a very destructive effect on the sub-soil structural elements existed in these zones.

One of the chemical substances which may be existed in these environments is nitrates. The salts of nitric acid and the nitrates, are readily soluble in water. Among the salts of nitric acid, are sodium nitrate ($NaNo_3$), potassium nitrate (KNO_3), calcium nitrate [$Ca(NO_3)_2$], nickel nitrate [$Ni(NO_3)_2$], lead nitrate [$Pb(NO_3)_2$]..etc. Their effect on plain and reinforced concrete structures requires more studies particularly in cases of early age concrete [1,2]. Therefore; this research has been drawn to study the effect of the sodium nitrate ($NaNO_3$) on concrete structure. The conclusions reached in this research would be taken into consideration by the designers and sites engineers dealing with structures exposed to nitrate solution.

2- EXPERIMENTAL TECHNIQUE AND PROGRAME

Mechanical properties tests, physical measurements with special attention to loss in own weight and geometrical changes and visual inspection were carried out on two main sets plain and reinforced concrete specimens which included cubes of total number 144. The R.C. cubes set was reinforced with 4 mild steel bars 13 mm diameter and 130 mm height. The concrete cubes were casted in standard moulds (150x150x150 mm).

Two concrete mixes with two cement contents (250 and 450 kg/m^3) representing poor and rich concrete types were used. Table (1) summarizes concrete constituents used in this investigation.

2-1 PREPARATION OF THE SODIUM NITRATE SOLUTIONS

Field observation in nature of the deterioration process of R.C. structures constructed in aggressive surrounding medium takes long time because the rate of corrosion or deterioration is normally slow. For obtaining rapid results and reasonable information about the development of such complicated phenomena, rapid testing techniques are used. However, using high concentrations of the nitrates is usually used to accelerate their effects on the concrete specimens in the laboratory.

Sodium nitrates solution ($NaNO_3$) with three different concentrations were chosen to represent the surrounding media in which the concrete specimens were immersed. These concentrations were 100, 250 and 500 mgm/lit (100 ppm, 250 ppm and 500 ppm). The constituents of the pure sodium nitrates are as follows;

Formula	$NaNO_3$
Nitrogen	16-48%
Sodium	27-50%
Appearance	white crystalline
S.G.	20°C/4°C 2.257.

2-3 Preparation of Specimens

Dry constituents of the concrete mix including cement, sand and gravel were firstly mixed for one minute to insure the uniformity of the mix. Mixing water was added gradually and the constituents were mechanically mixed for a period of two minutes. The slump and compacting factor tests were carried out on all concrete mixes. Vibrating table and hand tamping were used during placing of concrete to insure full compaction. Specimens were removed from the moulds 24 hours after casting, then immersed in the nitrate solutions with different concentration until they were tested. Duration of exposure to the nitrate solutions chosen in this study were 28, 60 and 180 days. A group of specimens were immersed in tap water for the same periods for comparison. Concrete cubes were marked and weighted. For each set three specimens were prepared. Summary of the programme of the experimental work carried out in this research is given in table (2).

Ordinary portland cement used was tested with special attention to its setting time and compressive strength. Tap water was used for concrete mixing. The gravel used was free from injurious materials and of a good quality. The particle shape was generally a combination of round and semi-angular shape. The surface texture was more or less smooth and uniform. the sand used was composed of siliceous material and almost free from impurities.

3. Results and Discussions

3.1 Compressive strength

The relationship between the plain concrete compressive strength and sodium nitrates concentration in the surrounding solutions can be seen in Figs. (1 and 2). Sodium nitrate solution with relatively lower concentration has higher destructive effect on the concrete compressive strength than those solutions with higher concentrations. A reduction of about 30% in the strength was observed with specimens immersed in sodium nitrate solution with concentration of 100 ppm. It was found that as the sodium nitrate concentration increased in the surrounding solution, the reduction in the concrete compressive strength decreased. Specimens immersed in sodium nitrate solution with 500 ppm. concentration showed slightly higher compressive strength than that immersed in tap water especially after 180 days of immersion. This phenomena was observed in both cases of concrete mixes with cement content of 250 and 450 kg/m^3 of concrete as shown in Figs. (3-5). This phenomena was observed even with the increase of duration of exposure.

3.1.2 Unit Weight

Figures (6.a and 6.b) show that the weight of the concrete cube immersed in sodium nitrate solution with 100 ppm concentration decreased with the increase of the exposure duration. However, those specimens immersed in sodium nitrate solution with higher concentration of 250 ppm showed lower reduction in their weight even with longer exposure duration. Negligible reduction in weight was recorded for those specimens immersed in sodium nitrate solution with 500 ppm concentration. These results coincide with the results obtained concerning the compressive strength.

4. Reinforced Concrete Samples

Figures (7 and 8) show that the same trend observed for the plain concrete specimens was also formed with the reinforced concrete specimens concerning the reduction in strength for specimens exposed to $NaNO_3$ with a lower concentration of 100 ppm. The harmful effect decreased with the increase of the sodium nitrate solution concentration. In comparison with those specimens cured in tap water, those specimens exposed to sodium nitrate solution with 500 ppm concentration displayed very close compressive strength for the different exposure duration taken into consideration in this research.

Visual inspection was carried out on the specimens exposed to sodium nitrate solutions with different concentrations after exposure to different durations. Traces of salt deposits were observed on the surface of these specimens. No rust stains were observed on the surface of the reinforced concrete specimens exposed to $NaNO_3$ with different concentrations. After compression testing of the reinforced concrete specimens the steel bars were examined and no signs of rust were observed. Figures (9 and 10) show the concrete test specimens and the steel bars taken from the reinforced concrete specimens exposed to different $NaNO_3$ concentrations.

The results obtained in this research might be explained taking into consideration the physico-chemical reactions occurred due to the existence of concrete in sodium nitrate solutions with different concentrations. It is worth mentioning that two main factors are affecting the strength of concrete under this circumstances. The hydration process increases the strength of concrete, while the sodium nitrate might decrease the strength due to the reaction process with the concrete constituents. Sodium nitrate solutions with lower concentrations permits the concrete penetration to big depths which greatly decreases the concrete strength within short time. The hydration process which increases with time increases the concrete strength and consequently overcomes the destructive effect of $NaNO_3$ which occur at the early age of 28 days and nearly vanishes after that.

At high concentrations of the $NaNO_3$ solutions the salt faces difficulties in penetrating the concrete surface to big depths and consequently deposits at the surface. This operation closes the surface voids and prevents other penetration of the solution. The guiding factor is then the hydration process. This is the case with $NaNO_3$ solution with 500 ppm concentration.

The destructive effect of sodium nitrates might also be referred to the free lime of concrete which combines with the acid radical and consequently dissolves it and seepage it away and causes both the reduction in weight and in compressive strength.

Moreover, the pH values of the $NaNO_3$ solutions with different concentrations were measured as shown in Table (3). It was found that in spite of the slight variation in the PH values, they have the same trend as compressive strength and the reduction in the unit weight. The lower compressive strength and unit weight of concrete were found with those specimens exposed to $NaNO_3$ solutions with lower pH values.

CONCLUSIONS

Out of this research study and for the ordinary portland cement concrete, it can be concluded that,

1. Existence of concrete structures in contact with sodium nitrate solution of concentration up to 500 ppm, the highest values used in this study, indicated no signs of the corrosion of reinforcing steel bars.
2. In the early age of concrete, sodium nitrate solutions with lower concentrations permits the concrete penetration to big depths which decreases the concrete strength. The hydration process which increases with the time increases the concrete strength and consequently overcomes the destructive effect of the sodium nitrate solution.
3. Sodium nitrate solutions with high concentrations caused deposit of the salt on the concrete surface which led to sealing of the surface voids and consequently, minimizing the penetration of the solution inside the concrete elements.

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Table (1) Mix proporation of concrete

Cement Kg/m^3	Water W/C	Water Lit/m^3	Mix Proporation C	Mix Proporation S	Mix Proporation G	Slump mm	Comp. Factor
250	0.55	137.5	1	2.678	5.357	0.80	0.95
450	0.45	202.5	1	1.290	2.580	0.80	0.95

Table (2) Programme of experiments

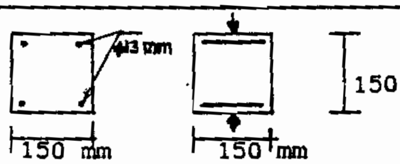
Cement Content	$250\ kg/m^3$	$450\ kg/m^3$
W/C	0.55	0.45
$NaNO_3$ Concentration P.P.M.	0, 100, 250, 500 (0 - tap water)	
Period of exposure to solution (days)	28, 60, 180	
Type of Concrete	Plain, Reinforced	
		

Table (3) Variation of PH values with concentration of $NaNo_3$

Concentration P.P.M.	PH values
Blank	6.9
100	6.82
200	6.9
300	7.1
450	7.25
500	7.35

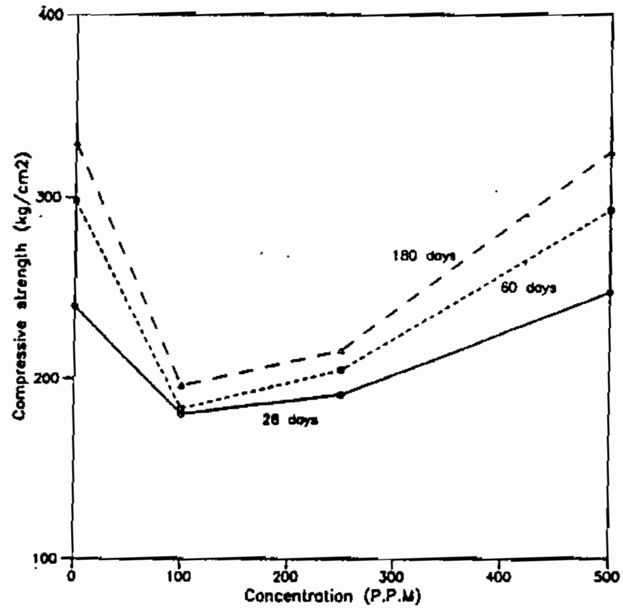


Fig. (1) Concrete compressive strength for different Na NO_2 concentration (250 kg cement/ m^3 concrete)

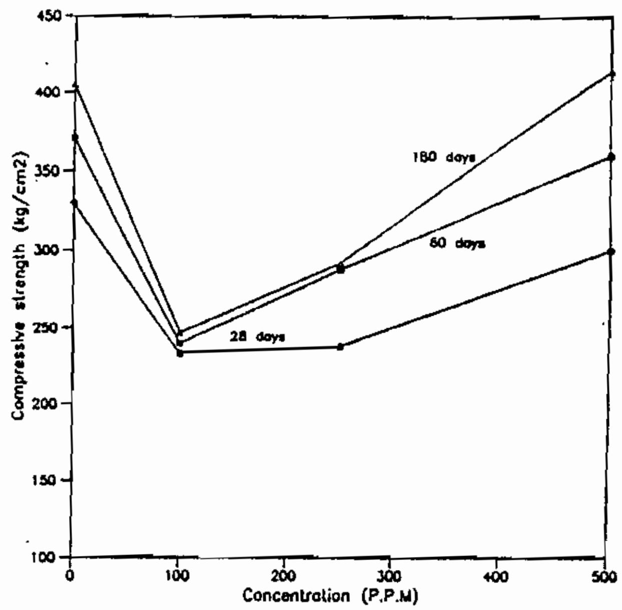


Fig. (2) Concrete compressive strength for different Na NO_2 concentration (450 kg cement/ m^3 concrete)

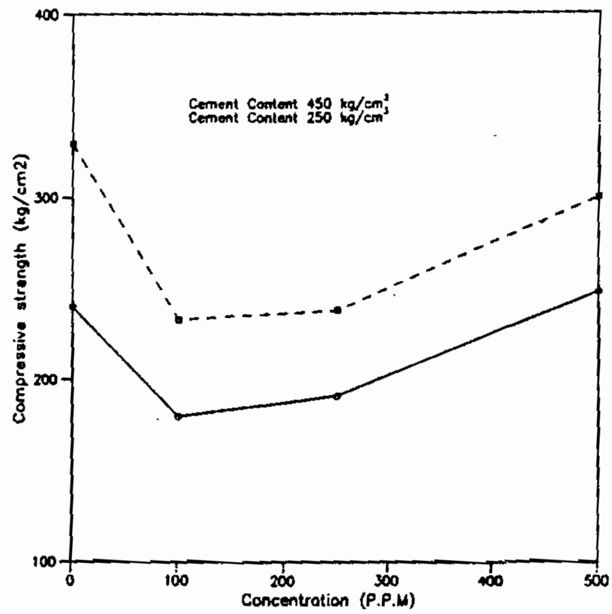


Fig. (3) Concrete compressive strength for poor and rich concrete curred in Na NO_3 solution (28 days curring)

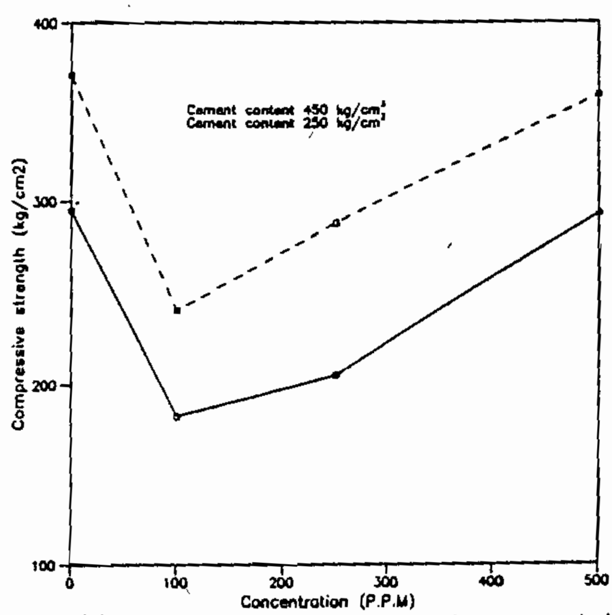


Fig. (4) Concrete compressive strength for poor and rich concrete curred in No NO_3 solution (60 days curring)

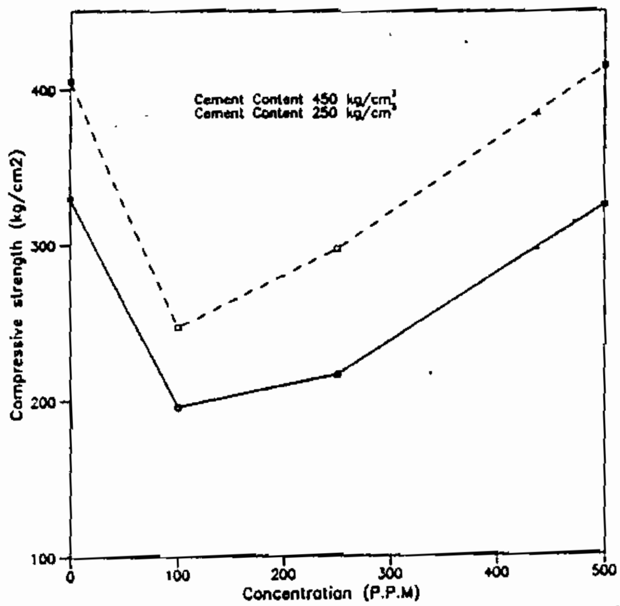


Fig. (5) Concrete compressive strength for poor and rich concrete curred in Na NO_3 solution (180 days curring)

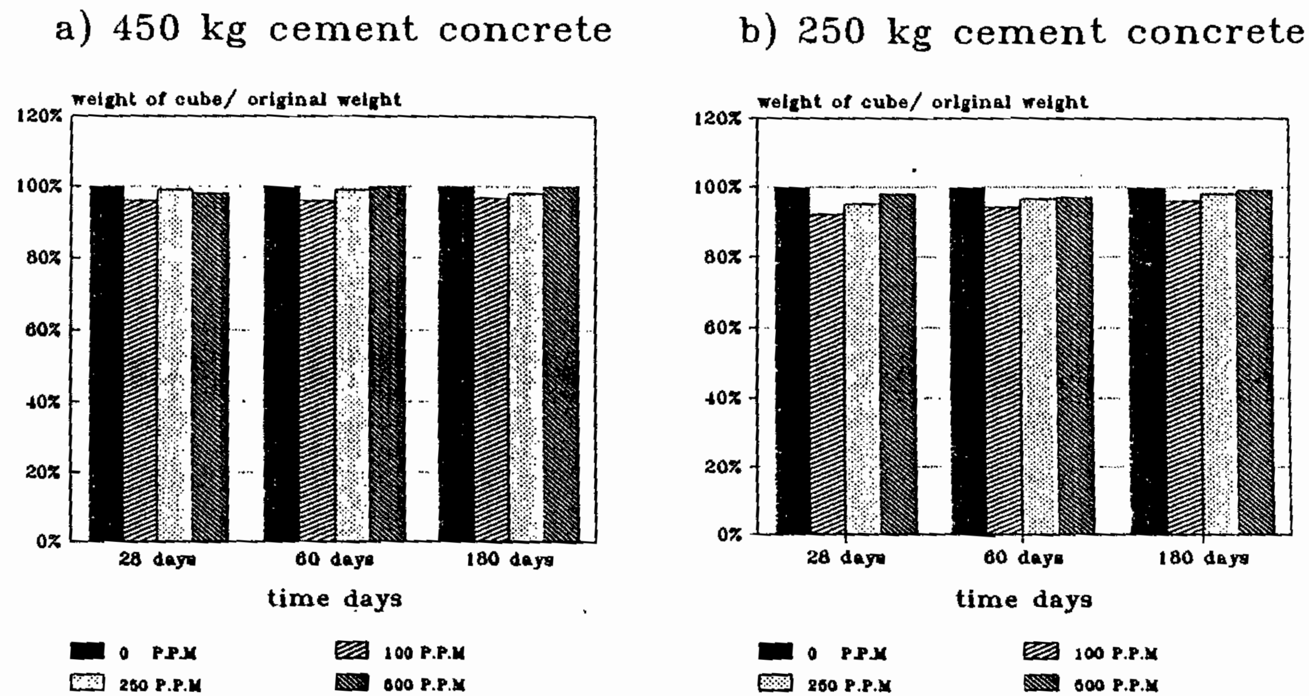


Fig (6) Weight of concrete cubes curred in different NaNO3 concentration

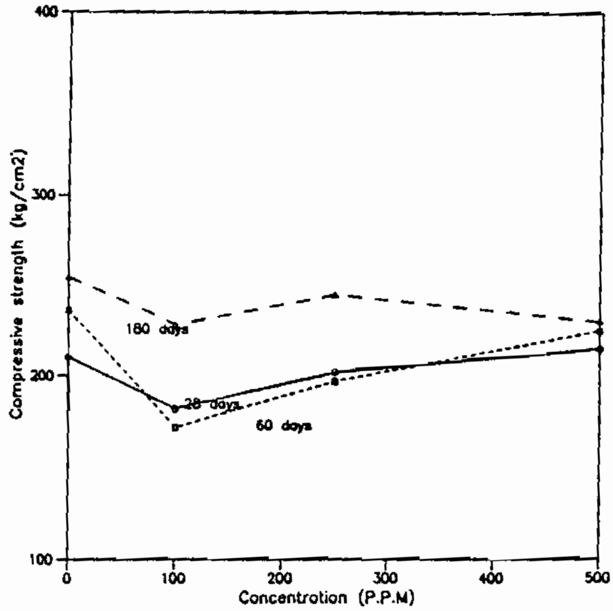


Fig. (7) Compressive strength of R. C. cubes curred in differ
Na NO_3 concentration (250 kg cement/ m^3 concre

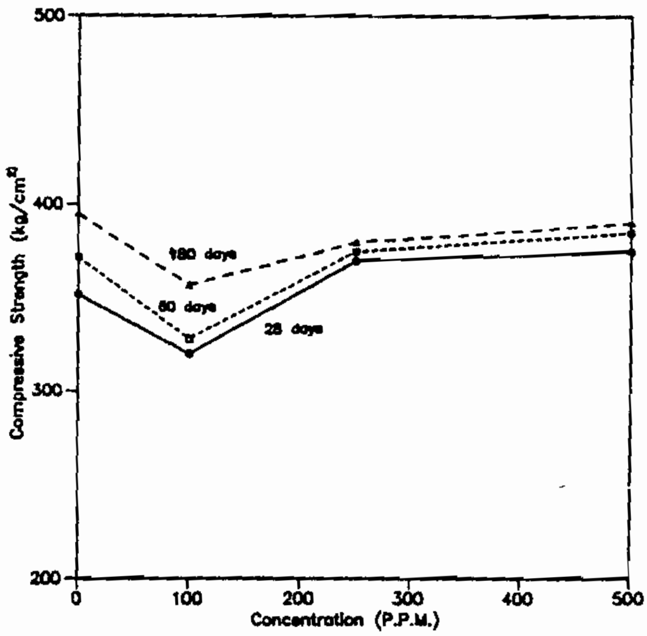
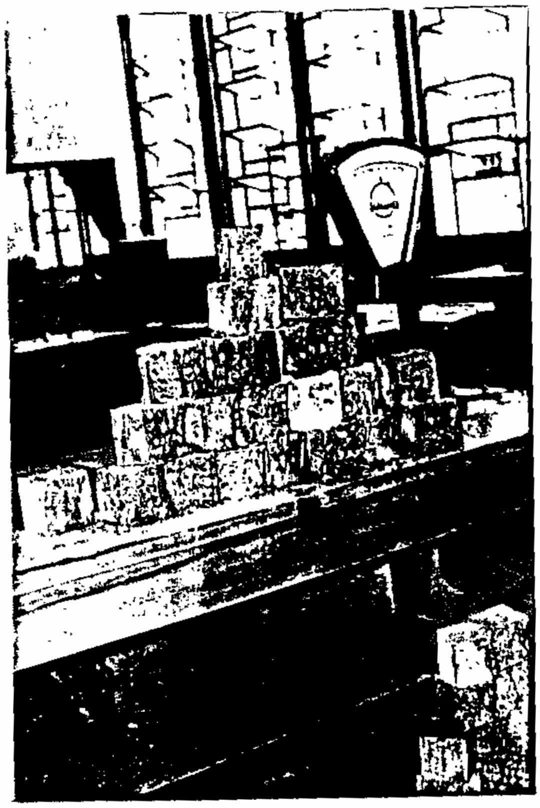
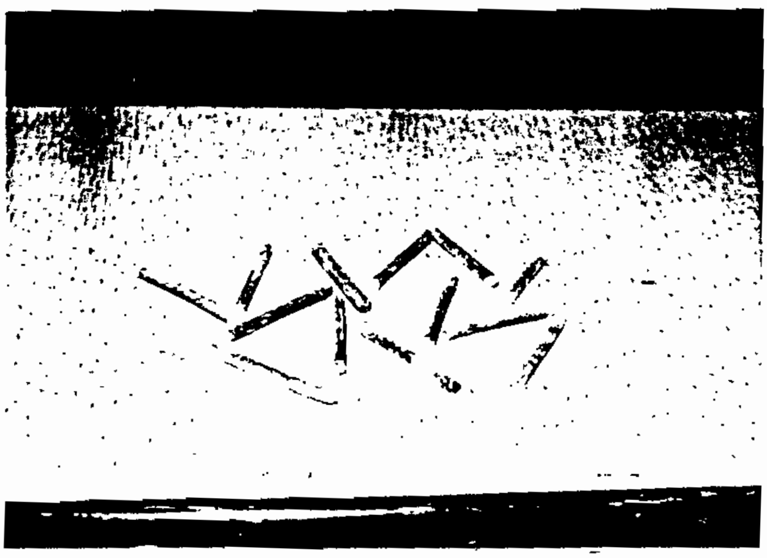


Fig. (8) Compressive strength of R. C. cubes curred in different
$NaNo_3$ concentration (450 kg cement / m^3 concrete)



fig(9) Reinforced Concrete Cubes After Compression Tests.



Fig(10) Reinforced Steel Pieces Taken From the R.C. Samples After Compression Tests.