Effect of High Percentage of Sodium Chloride (Nacl) on the Behavior of Reinforced Concrete Beams

S. Abd El- salam m. of ASCE[1], H. Shehab Eldin[2], E.A. El-Shamy[3] and Sh. M.M. Shawky[4]

Str. Eng. Dept., Fac. of Eng., Z.U., Egypt
s.salam@link.net, hshehabeldin@yahoo.com emanelshamy@hotmail.com, shosho602@yahoo.com.

Abstract: In this paper an experimental investigation is carried out to study the effect of high percentages of sodium chloride (NaCl) on the structural behavior of R.C. beams. The experimental study contained thirteen of R.C. beams with fixed steel reinforcement and a common concrete mix by adding different high percentages of salts by weight of cement (S/C) to the mixing water of concrete mix. The beams were tested up to failure, and the influence of variable factors on the structural deformations such as, failure loads, strains, cracking behavior and modes of failure were reported. Also, the mass' loss of steel reinforcement bars was studied.

[S. Abd El- salam , H. Shehab Eldin, E.A. El-Shamy and Sh. M.M. Shawky. **Effect of High Percentage of Sodium Chloride (Nacl) on the Behavior of Reinforced Concrete Beams.** Life Sci J 2012; 9(3):315-320]. (ISSN: 1097-8135). http://www.lifesciencesite.com. 43

Keywords: Experimental method, corrosion, sodium chloride, R.C. structures.

1. Introduction

The problem of deterioration of concrete structures due to corrosion of steel reinforcement has received worldwide of attention. Even though current codes of practice provide recommendations and precautions to avoid corrosion, evidence of corrosion of steel in concrete continues to be reported in the field situations (Leema *et al.,* 2009).Chloride may be presented in the concrete from several sources. Soluble chlorides may be introduced in the fresh concrete by the use of aggregates contaminated by chlorides, saline water when used as mixing water. In addition, some cement may contain amounts of chlorides. Chlorides may be also inter the hardened concrete from the surrounding environments, such as sea-water, soil and industrial zones (Mohamed *et al.,*1995). The chloride ions in concrete are considered to be the major cause of corrosion (Mustafa *et al.,* 2007). Generally after casting concrete, a passivity film is formed surrounding the steel bars and protects them from corrosion initiation. Chloride ions depassivate the protective film, and the embedded steel bars in concrete are no longer protected against corrosion in the presence of moisture and oxygen. The corrosion products are expansive in nature and effectively cause a tensile stresses around the reinforcing steel.

Once sufficient corrosion has occurred, splitting cracks typically develop and loss of bond is observed (Transportation, 2006). Moreover, the cross section of reinforcing bar is decreasing, thus reducing the load-carrying capacity of the concrete member.

Thus, in general the use of steel in salty concrete is not recommended and this is probably the most serious disadvantage if the material is to be used for structural applications. The development of reliable methods for predicting chloride affect into concrete is very important to determine the service life of a reinforced concrete structure. A number of studies have been carried out to understand the effect of different percentage of chloride ions as 0.1% to 3.5% of weight of concrete mix (Mohamed *et al.,*1995, Atia *et al.,* 1996, , Abdel Salam *et al.,* 1998 & 2000, , Tarek *et al.,* 2001, Jon *et al.,* 2001, Li *et al.,* 2001 & 2002, T.R.B., 2006, , Mustafa *et al.,* 2007 and Leema *et al.,* 2009). Other researchers studied the behavior of reinforced concrete structure at percentage of sodium chloride up to 5% of weight of concrete mix (Abdel Salam *et al.,* 1998 & 2000, Nhan *et al.,* 2006 and Kutarba, 2007).

The main objective of this study was to quantify how high percentage of (NaCl) on the concrete mix of R.C beams by loading influences on the R.C beam behavior.

2. Experimental program

The test program consisted of three groups of reinforced concrete rectangular beams with fixed reinforcement and concrete constituents when exposed to four percentages of sodium chloride (NaCl) by weight of cement(S/C). In addition different corrosion time periods were considered. Details of the tested beams and concrete mix were given in Tables 1 &2.

The beams were tested to failure and the influence of variable factors on the structural deformation, initial cracked-load, steel and concrete strains and mode of failure were reported.

Details and testing of beams

Each rectangular beam was 100 mm * 250 mm in cross section and 1600 mm long. The internal longitudinal high grade steel reinforcement consisted of 2 ϕ 12 mm at the bottom and 2 ϕ 10 mm bars at the top of the beam as shown in Figure 1. Three different batches of concrete mixtures with different percentage of sodium chloride (NaCl) by weight of cement(S/C) of 0%, 1%, 5% and 10% were used for the construction of the three groups of beams as shown in Table 1. After 28 wet and dry days, the specimens were left in natural weather out side the laboratory without any curing. Groups (A, B & C) of concrete beams were tested to failure after three time periods of 6, 12 & 18 months, respectively.

Structural testing

Once beams reached the target ageing (6, 12 or 18 months) they were tested to failure. Beams were test with load applied symmetrically at two points at mid-span through a spreader beam load application points near the center of the specimen were spaced 500 mm apart load was measured with load cell placed between the spreader beam and hydraulic cylinder.

Measurements

Displacement was measured at mid-span of the beam and underlying load section as shown in Photo 1. Concrete strain was measured using electrical strain-gage located at the compressive face at mid-span between the load points. Electrical strain gage was pasted at mid-span on the longitudinal main steel on one side of the beam face. The test setup and its instrumentation placement are shown in Figure 1 & Photo 1.After verification of data collection, the load was increased monotonically until failure, loading was suspended at 2 KN intervals to mark and measure cracks. For each group of spacemen, percentage of steel mass-loss was calculated by weighting 20 cm long of each steel reinforcement bar after corrosion and divided it by the weight of the same part of steel bar of control spacemen at (S/C)=0% .

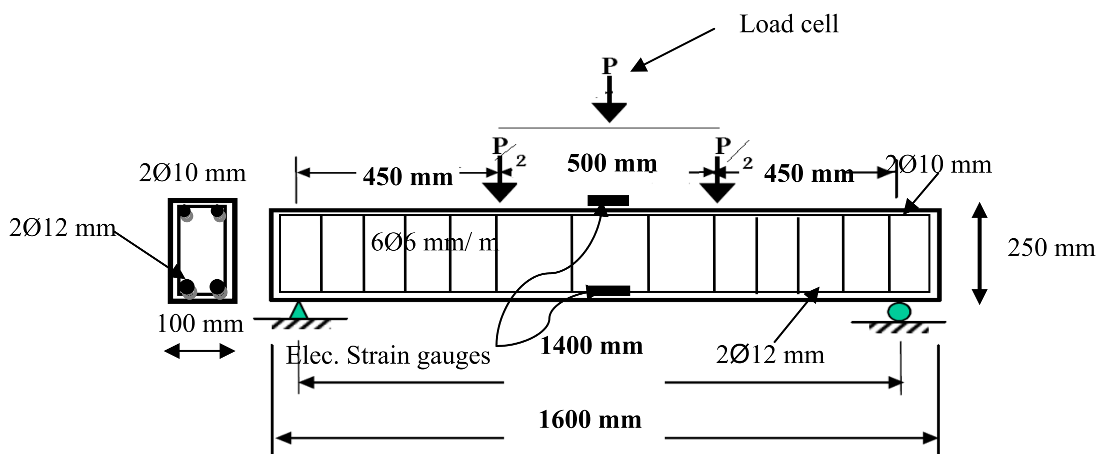


Figure (1): Set up details.

Photo (1): Test setup

3. Results and Discussion

The main objective of this series of testes was to establish the effect of different high percentages of sodium chloride(S/C) and ageing time periods on the structural behavior of R.C. beams. From the data obtained during the experimental program, results are presented here.

Figures 2&3 show that both percentage of salt(S/C) and time period had a significant effect on the load capacity of tested beams; which decreases about 40% than in case of (S/C)=0% as the (S/C) and the time period increase specially at (S/C)=10% and time period =18 months as shown in Figure 3; on the other hand, first cracked load (p_{cr}) and yield load (p_y) showed a continuous increase as the (S/C) increases up to 10% in group (A) of specimens, may attributed to formation crystals which fills the concrete pores leading to a reduction in the porosity of the concrete and hence increasing the compressive strength of the concrete.

Typical load deflection curves for tested beam are shown in Figures 4&5 for different ageing and percentage of salt(S/C). It can be seen that the deflection was always increases with increasing the time periods in average equal to 25% from group to other duo to a continuous reduction in the stiffness and the flexural rigidity of tested beams with ageing as shown in Figure 4.However, Figure 5 shows strength of tested beams increases up to 10% at (S/C)=1%& 5% than in their strength at (S/C)=0%,respectively.And the beams strength decreases about 20% at (S/C)=10% due to the reduction of steal section , pitting corrosion and effect of corrosion on the mechanical properties of steel bars. As well as degradation of the steel- concrete bond with ageing.

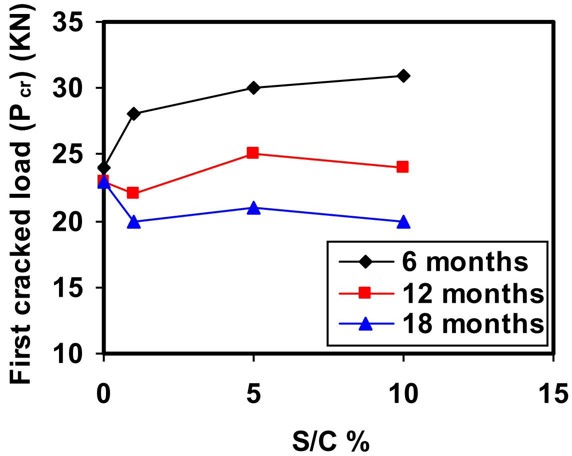
Figures 6 shows the load-strain curves of concrete and steel reinforcement for group C. It is indicated that the rate of strain increases for steel, through the whole range of loading, was higher than that for concrete, although varying degrees. This may be attributed to the interaction between the load level, the reduction of the effective bond strength and the crake propagation. Group C of tested beams showed extensive cracking, large deflection, neutral axis movement towards the compression edge and plenty of warning prior to flexural followed by compression failure. While the beams with (S/C)=10% showed greater neutral axis depth at failure because of wider cracking before and after loading and greater deflection as shown in photo 2.The effect of percentage of salt (S/C) on percentage of steel mass-loss due to corrosion for each group of specimens is shown in Figure 7. In general, it is indicated that, the percentage of steel mass-loss increases as the percentage of salt (S/C) and the time period increases especially at (S/C)=10% at 18 months time period.

Table (1): Details of the test program

Group No.	Specimen No.	% NaCl of Cement Weight(s/c)	Corrosion time period
Control	C. B. 1	0	28 days
A	C. B. 2	0	6 months
	X. B. 1	1	
	X. B. 4	5	
	X. B. 7	10	
B	C. B. 3	0	12 months
	X. B. 2	1	
	X. B. 5	5	
	X. B. 8	10	
C	C. B. 4	0	18 months
	X. B. 3	1	
	X. B. 6	5	
	X. B. 9	10	

Table (2): Concrete Mix.

Composition	kg/m3 of concrete
Coarse aggregate (20 mm)	1250
Washed and dried fine aggregate	625
Cement	350
Water	162.5



Figure(2): Effect of percentage of S/C on first cracked-load at different time periods.

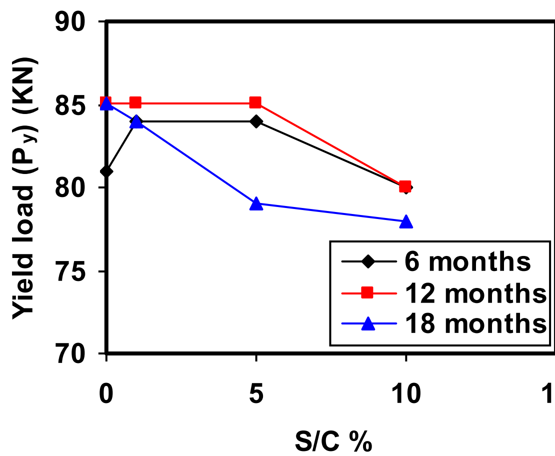


Figure (3): Effect of percentage of S/C on Yield- load at different time periods.

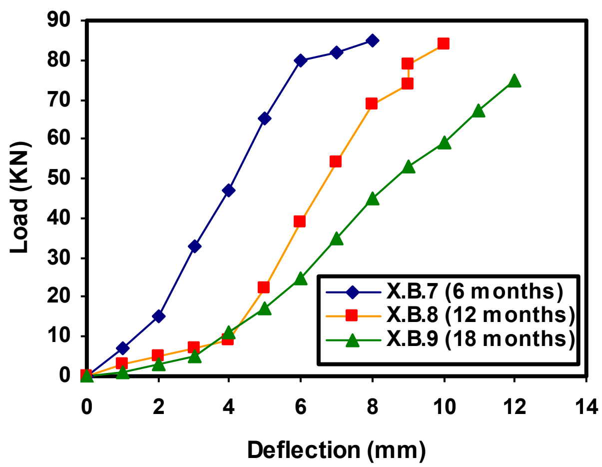


Figure (4): Effect of corrosion time period on load–Deflection relation at mid-span at s/c=10%.

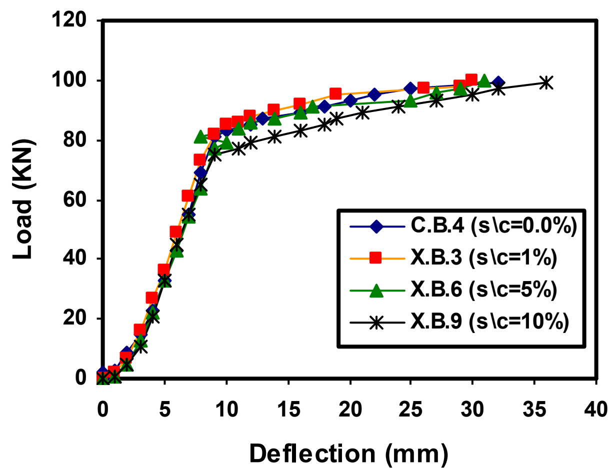


Figure (5): Effect of percentage of salt (s/c) on load-deflection relation at load-section at 18 months time period.

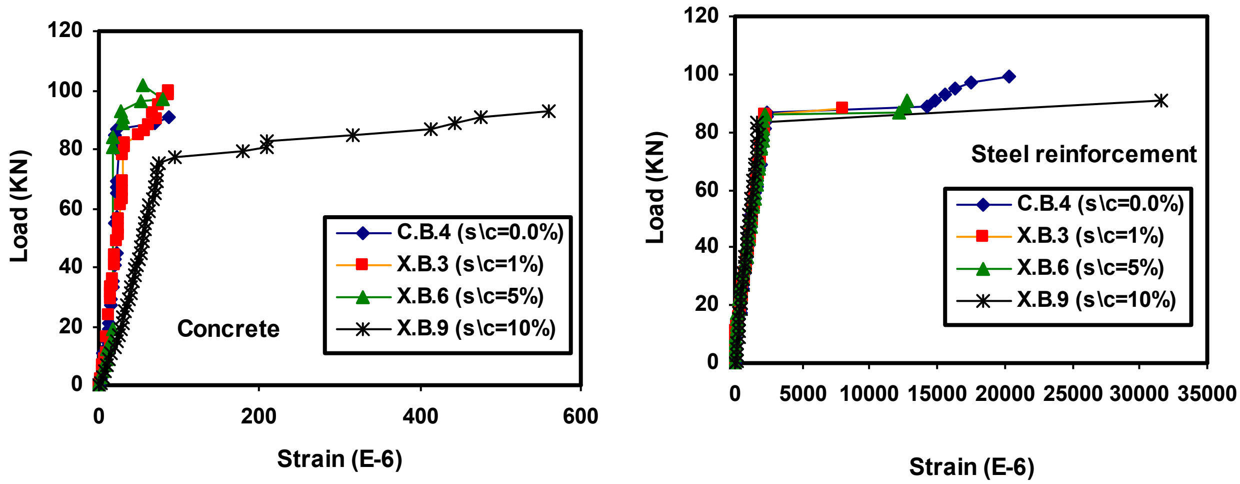


Figure (6): Effect of percentage of salt (s/c) on load-strain relation on concrete and steel reinforcement at 18 months time periods.

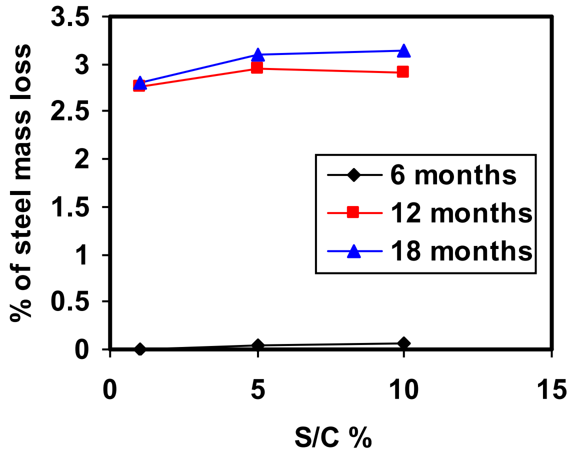


Figure (7): Effect of percentage of(s/c) on the percentage of steel mass loss.

Photo 2. Effect of salt-percentage (s/c) on failure-mode of tested beams at 18 months age.

Conclusion

Based on the test results and discussion presented in this paper, the following conclusions are drawn on the structural behavior of R.C. beams with high percent of sodium chloride (NaCl).

Flexural rigidity of beams with different percentage of sodium chloride at 6months age showed marginal increases compared with (S/C)=0% control beam ,however tested beams with (S/C)=1%and 5% at 18 months age maintaining their stiffness. With increased age, the corrosion is gradual and slow until the stability of steel reinforcement affected, both loss of stiffness and strength develop rabidly at an accelerated rate especially at (S/C)=10%.Cracking behavior of beams at (s/c)=1% at age equal 18 months tend to be concentrated in the central part (pure bending zone) of the beam and they tended to form at closer space, on the other hand, the cracks of beams at (S/C)= 5% and 10% of sodium chloride were more and distributed over the central part and followed with inclined cracks outside the pure bending. The 10% percent of sodium chloride showed a significant effect on the loss of structural integrity and stiffness of tested beam. The percentage loss is about 30% at 18 months age.

Acknowledgement

This work is supported by the Laboratory of Structural Engineering Department, Faculty of Engineering Zagazig University

Corresponding author

5. References

1. Leema Rose, K. Suguna and P.N. Ragunath (2009). "Strengthening of Corrosion-Damaged Reinforced Concrete Beams with Glass Fiber Reinforced Polimer Laminates", Journal of Computer Science, 5 (6): 435-439.
2. Mohamed G., S. Abdel Salam, H. Sayed, & W. Fahmy (1995). “Structural Behaviour of R.C. Beams Deteriorated Due to Chlorides Content” Proceedings of Second Interl. Conf. For Building & Construction, Inter Build 95, June 22-25, Cairo, Egypt .
3. Mustafa Sahmaran, Mo Li, and Victer C Li (2007). "Transport Properties of Engineered Cementitious Composites under Chloride Exposure". ACI Materials Journal V. 104. No. 6.
4. Transportation Research Board (2006). "Control of Cracking in Concrete". State of the ART, Trasnslation Research Cicular E-C107. Concrete Committee Washington, DC 20001 www.TRB.org.
5. Kutarba M.P., J.R. Brown and H.R. Hamilton (2007). "Repair of Corrosion Damaged Concrete Beams with Carbon Fiber-Reinforced Polymer Composites".Composites Research Journal Volume 1, Issue 4 ,Page 36
6. Nhan The Tran QI Huang (2006). "Influence of Cracks on Chloride-Induced Corrosion in Reinforce Concrete Structures". A. Master Thesis, Department of Civil and Environmental Engineering, Chalmers University of Technology, Gothenburg, Sweden.
7. Li, C.Q. (2002). “Initiation of Chloride-Induced Reinforcement Corrosion in Concrete Structural Members-Prediction”, ACI Structural Journal, 99, (2): 133- 141.
8. Li, C.Q. (2001). “Initiation of Chloride-Induced Reinforcement Corrosion in Concrete Structural Members-Experimentation”, ACI Structural Journal, 98 (4), 502-510.
9. Jon, W.L., and Zhao, Y.X. (2001). “Effect of Corrosion on Bond Behavior and Bending Strength of Reinforced Concrete Beams”, Journal of Zheijang University (SCIENCE), 2(3) 298-308.
10. Tarek Uddin, M., Nobuaki, O., Makota, H., and Tsunenori, S. (2001). “Effect of Crack Width And Bar Types on Corrosion of Steel in Concrete”, Journal of Materials in Civil Engineering, 13, (3) 194-201.
11. S.Abdel Salam, M. Kamal, Hosain B., Loay. A. (2000). “ Performance of Repair Methods in Costal Structures”, Proceedings of 8th Arab Structural Eng. Conference, Cairo University, Cairo Egypt, October.
12. S. Abdel Salam , M. Kamal , Hosain B., Loay. A. (1998). “Chloride Induced Corrosion of Structures in Marine Environments”, Proceedings of Arab Conf. For Structures Rehabilitation and Repair , Cairo , Egypt , Sep.
13. Atia G. A. M., S. Abdel Salam, Abdel Aziz H. Fahmy W. (1998). “Analysis and Repair of Choloride Beams” Proceedings of Cairo 1st. Interl. Confe. on Concrete Strucs., Conce., Research Lab., Cairo Univ, Jan. 2-4, 1996, Cairo, Egypt.

5/22/2012