ARGEO CONFERENCE

REPORT ON THE INVESTIGATION ON THE USE OF BRINE WATER FOR CONCRETE WORKS

Report Prepared by

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1.0 INTRODUCTION

The utilization of geothermal energy produces brine water used to drill new wells, and for reinjection. The use of brine water for concrete works would decrease the abstraction of fresh water sources. The purpose of this research is to investigate the use of brine water for concrete works in the geothermal industry.

This research was conducted in Olkaria Kenya and used different water sources namely: lake water, brine water from a well, brine water from the cooling towers, and brine water from the brine pumping station. The research was conducted in two trials. The first trial was conducted by analyzing concrete materials, preparing and testing concrete cubes for strength achieved after twenty eight days. The second trial was conducted by testing concrete cubes for strength achieved after seven, fourteen, twenty one and twenty eight days.

The results from the first trial indicated that brine water can be used in the preparation of concrete as the cubes achieved maximum strength. This trial however had limitations in the mixing of concrete and was tested only after twenty eight days, thus a second trial was conducted to further test the concrete strengths. The second trial involved the testing of the concrete cubes for strength after seven, fourteen and twenty eight days. The cubes on average achieved maximum strength for the water types tested. The analysis of the trials conducted is discussed below.

2.0 TRIAL I

The first trial was conducted in four stages:
1) Testing of samples (water, cement, sand and aggregates)
2) Casting of concrete cubes (Class 25 and Class 30)
3) Soaking of cubes
4) Testing and analysis the cubes

Four different water types were used during the mixing of the concrete namely:
a) Raw water from Lake Naivasha
b) Brine from a Well
c) Brine from a power plant cooling towers (water 1)
d) Brine at the brine pumping station (water 2)

2.1 Testing of Samples

The following samples and quantities were collected and analyzed:

a) Ordinary Portland Cement (50 kg) strength 42.5
b) Sand 20 kg
c) Aggregates 40 kg (ballast size 14/20)
d) Water samples (10 liters) of each of the four water types listed above

The analysis of the cement is shown in table 1.

Table 1. Chemical Analysis of Cement

Components	Bamburi Power Max Cement 42.5
Insoluble Residue, % m/m	1.71
Loss on Ignition @900°C	2.75
Magnesium as MgO, % m/m	2.00
Sulphates as SO3, % m/m	3.19
Chlorides as CL % m/m	0.005

The sand was graded and results are summarized in table 2.

Table 2. Sand Analysis

BS sieve size (mm)	% passing BS sieve by weight	Specification Limits	Remarks
10	100		The sample tested falls in "M" of the BS/KS specification
5	96.8		
2.36	89.5	65-100	
1.18	77.3	45-100	
600	58.9	25-80	
300	31.2	May-48	
150	17.4		

The aggregates were tested for: texture, water absorption, sodium sulphates design mix, flakiness and compressive tests as shown in table 4.

Table 4. Chloride Analysis of Sand and Aggregates

Component	Sand	Aggregates
Chloride content as NaCl, % m/m	0.001	0.001

The water samples were tested for: pH, alkalinity, chlorides, sulphates, and total dissolved salts as shown in table 5.

Table 5. Chemical Analysis of Water Samples

Components	Lake Naivasha Water	Brine Pond Water 1 (pumping station)	Brine Pond Water 2 (power plant)	Brine Water
PH	6.91	7.36	3.17	9.46
Total dissolved solids ppm	322.5	1817.0	196.5	1905.0
Total alkalinity as CaCO3, ppm	117.5	112.5	Nil	392.5

Cloride content,CL ppm	12.4	667.4	81.1	731.3
Sulphate content, SO3, ppm	16.8	77.9	50.4	61.2

Summary of Sample Results

The cement and aggregates analyzed met the specifications and were used in the preparation of the cubes. The sand was unsuitable and was substituted with river sand. Each of the water samples analyzed shall be used to prepare concrete cubes.

2.2 Casting of Concrete Cubes

Concrete mixes are categorized in different classes of strength which vary depending on the mixing ratios of cement, aggregates, sand and water. The classes of concrete range from Class 10, 15, 20, 25, 30 and 40 whose differences lie in the mix ratios for cement, sand, ballast and water as shown in table 6.

Table 6: Class of Concrete

Class of Concrete	Mixing Ratios Cement: Sand: Aggregates: Water	28 Days Nominal Strength (N/mm2)
15	1:3:6	15
20	1:2:4	20
25	1:1.5:3	25
30	1: 1:2	30
35	(Appropriate Design Mix)	35
40	(Appropriate Design Mix)	40

This research prepared concrete mixed for Class 25 and 30 of cement. A total of 64 cubes were cast over a period of four days for each water samples as shown in table 7.

Table 7. Work plan for concrete testing trial mix design

Stages	Concrete Cubes	Duration
Cube Making	Cast 16 cubes using lake water 8 No. C25 cubes 8 No. C30 cubes	1 day
	Cast 16 cubes using brine water 8 No. C25 cubes 8 No. C30 cubes	1 day
	Cast 16 cubes using brine pond water 1 8 No. C25 cubes 8 No. C30 cubes	1 day
	Cast 16 cubes using brine pond water 2 8 No. C25 cubes 8 No. C30 cubes	1 day

At the time of concrete mixing, cement 42.5 was unavailable, and instead cement 32.5 was used for mixing the cubes. The MOR staff instead used the following mixing ratios for the cubes Class 25 mix ratio of 2:1.5:1 and Class 30 mix ratio of 2:1:2.

2.3: Soaking of Cubes for 28 days

The cubes were soaked in each of the water types for 28 days to achieve concrete strength, after which they were taken to the laboratory for crushing.

2.4: Testing and Analysis of Cubes

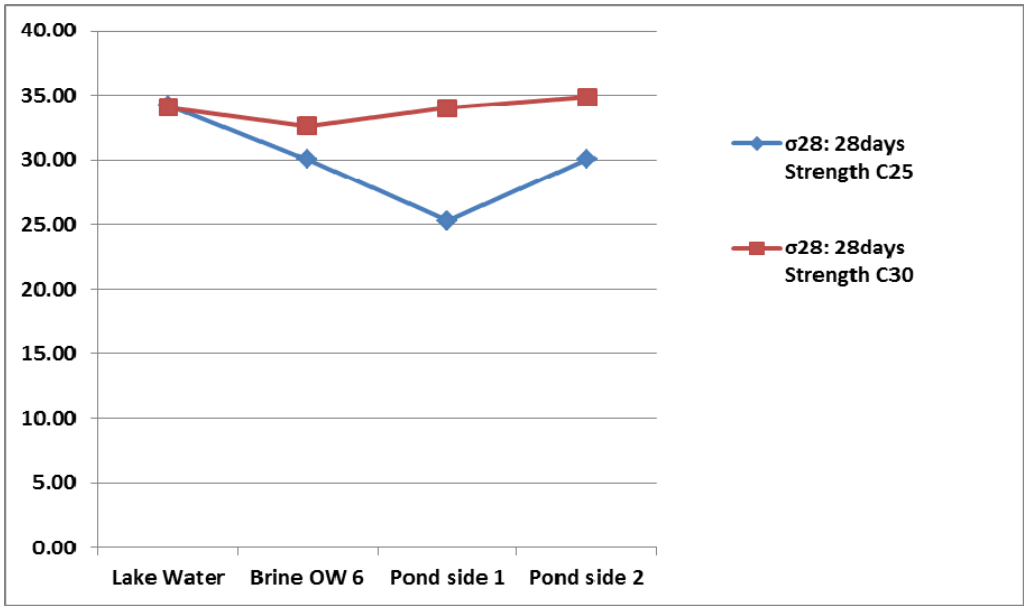
The cubes were soaked for 28 days after which the samples were taken to the laboratory for crushing. The average results for each of the 9 cubes tested for Class 25 and Class 30 concrete cubes are shown in tables 9 below. The detailed cube strength for each cube is attached in the Appendixes.

Table 9: Concrete Cubes Compressive Strengths

Water Type	28days Strength C25	28days Strength C30
Lake Water	34.21	34.05
Brine OW 6	30.03	32.60
Pond side 1	25.31	34.00
Pond side 2	30.04	34.86

The concrete tests results were graphed as shown below.

Graph 1: Concrete Cube Strengths after 28 days



2.5 SUMMARY

The nominal strength achieved after 28 days should be 25 N/mm2 or greater for class 25 of concrete. The average strengths of the cubes cast for Class 25 concrete are
36.4, 28.8, 26.1, 30.2 N/mm2 as shown in table 9. All the cubes cast for each water type achieved maximum strength.

The nominal strength achieved after 28 days should be 30 N/mm2 or greater for class 30 of concrete. The average strengths of the cubes cast for Class 30 concrete are
34.5, 32.6, 34.0, 32.1 N/mm2 as shown in table 9. All the cubes cast for each water type achieved maximum strength.

2.6 CONCLUSION AND RECOMMENDATIONS

The results from the research on the use of brine water for concrete works shows that the nominal strengths after 28 days for class 25 and class 30 of concrete were achieved for each water samples i.e. lake water, brine from well , brine from the cooling tower and brine from the pumping station; and thus can be used for concrete works during construction. It is also recommended that:

1. Further research on trial mixes using cement type 42.5 for a comparison of the nominal strengths achieved
2. Further research for a comparison of the nominal strengths achieved after 7, 14, 21 and 28 days
3. Chemical analysis of the concrete cubes cast with fresh water and brine water

3.0 TRIAL TESTS II

The second trial was conducted in three stages namely:

1) Casting of concrete cubes (Class 25)
2) Soaking of cubes for 7, 14, 21 and 28 days
3) Testing and analysis of the cubes

Three water types were used during the mixing of the concrete namely:
a) Raw Water from Lake Naivasha
b) Brine water from Well
c) Brine Pond from power plant cooling towers (water 1)
The water type from the brine pumping station was not used during the second trial, as the chemical properties of the water are affected by rain water and other debris and is hence not consistent.

3.1 Casting of Concrete Cubes

This research prepared concrete mixed for Class 25. A total of 36 cubes were cast in one day for each water samples as shown in table 11.

Table 11. KenGen work plan for concrete testing trial mix design

Stages	Concrete Cubes	Duration
Cube Making	Cast cubes using lake water	2 hours

	12 No. C25 cubes	
	Cast cubes using brine water 12 No. C25 cubes	2 hours
	Cast 12 cubes using brine pond water 1 12 No. C25 cubes	2 hours

The mix ratio 2:1.5:1 for the Class 25 concrete was used to cast the cubes.

3.2 Soaking of Cubes

The cubes were soaked in each of the water types for 7, 14, 21 and 28 days to achieve concrete strength, after which they were taken to the laboratory for crushing.

3.3 Testing and Analysis of Cubes

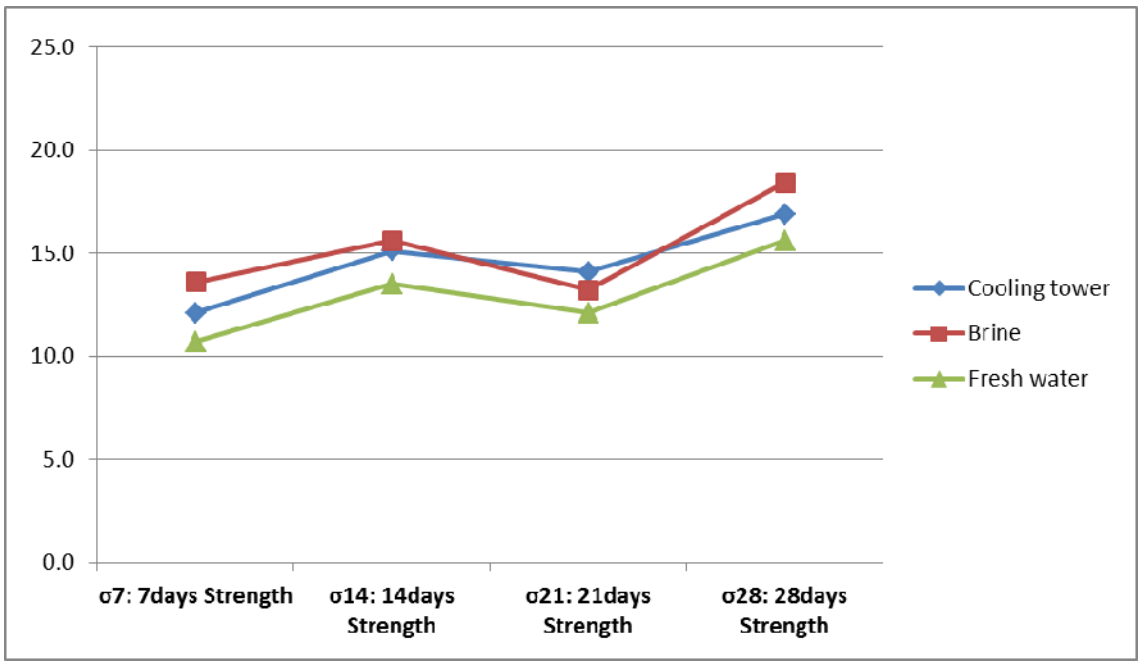
The cubes were soaked for 7, 14, 21 and 28 days after which the samples were tested and crushed at the. The average results for each of the cubes tested for Class 25 are shown in tables 12 below. The detailed cube strength for each cube is attached in the Appendixes.

Table 12: Concrete Cubes Compressive Strengths

Type of Water used	σ7: 7days Strength	σ14: 14days Strength	σ21: 21days Strength	σ28: 28days Strength
Cooling tower	12.1	15.1	14.1	16.9
Brine	13.6	15.6	13.2	18.4
Fresh water	10.7	13.5	12.1	15.6

The concrete tests results were graphed as shown below.

Graph 1: Concrete Cube Strengths



3.4 SUMMARY

The nominal strength achieved after 28 days should be 25 N/mm2 or greater for class 25 of concrete. The average strengths of the cubes cast for Class 25 concrete are
16.9, 18.4 and 15.6 N/mm2 as shown in table 12. All the cubes cast for each water type did not achieve maximum strength.

3.5 CONCLUSION AND RECOMMENDATIONS

The results from the research on the use of brine water for civil cement works shows that the nominal strengths after 28 days for class 25 were not achieved for each water sample i.e. lake water, brine water, and cooling tower water. This therefore means that none of the water samples used is suitable for concrete mixing.

This research results contradict the results from the first research which showed that each water type achieved maximum strength. Furthermore it is also known that the fresh water is suitable for use in concrete works and is extensively used in construction. It is likely that the concrete cubes were interfered with during curing and hence the skewed results. The following recommendations can therefore be made.

1. Preparation of concrete cubes that shall be soaked in an area free from interference.

2. A chemical analysis of the water samples to be used during concrete mixing.

3. Testing of the cubes after six month to determine if the cube strength is maintained.