Investigation of physical factors and chemical reactions in Roller compacted concrete dams in Russia

Masoud Golshani[1], Ali Arash Ronassi[2], Vyacheslav Vatslavovich Babitsky[3]

[1] PhD student, Department of Concrete technology and Construction Materials, Belarusian National Technical University, Minsk, Belarus
[2] Assistant Professor, Department of Physics, Payam-e Noor University , PO BOX 19395-3697 Tehran, Iran.
[3] Professor of Technical Sciences, Department of Concrete technology and Construction Materials, Belarusian National Technical University, Minsk, Belarus,
masoudgolshani@yahoo.com

Abstract: According to the abundant use of engineer and factor designer about the function of concrete in different environmental conditions, it's important to analyze the methods and new technologies of factors and concrete and adopted with environmental condition and function of Russia. One of the main causes of destroyed concrete in RCC dams is the alkali-carbon reaction of the aggregates. In this paper, the aggregates are chosen from three well known RCC dams in Russia. Mortar bar method, accelerated mortar bar test, accelerated concrete prism test were performed on experimental samples and some solutions were expressed for the concrete to be remained properly. According to the results, it is concluded that among these three methods, accelerated mortar bar test (choosing appropriate Expansions criterion) , is the best method to the evaluate Alkali-carbonate reactions.
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1. INTRODUCTION

Concrete is used widely all around the world because of its obvious advantages. The quality of concrete depends on the quality of the three important criteria which are cement, stone and water and profession during its making, pouring and operating.

The history of finding stones Alkali reaction gets back to the 1930s, Which in that time some non explainable expansion were observed in some of main concrete structures in California State such as some schools, bridges and coastal walls.

Figure 1- Samples of Cracking Caused by Alkali Reaction of Stones

In that time no reasons were found for these cracking and expansions until late in 1930s. An American engineer named Stanton, keeping mortars cylinders in special conditions observed that in the surface of them, cracking similar to real mentioned cracks in concrete structures has occurred. After more searches and changing the conditions, the reason for the cracking and expansions were discovered, that is the alkali reaction of the stones.

Chasse vent in 1937 were in charge of measuring the amount of reactions of ashes with the use of Potassium solution. Purdon in 1940 did the first wide laboratory experiment on clinker cement which includes ash and sodium chloride and the alkali which were made by Alkaline salt. [16]

In late 1957, Glukhovsky found out the possibility of producing cement which is made from the mixture of calcium and or Aluminum silicate with no clay and Alkaline iron solution. He named it dust cement and called the concrete dependent to it as dust silicate. Based on its primary mixture this could have been divided into 2 groups: Alkali mixture system $Me_2O–Me_2O_3–SiO_2–H_2O$ and ground Alkali mixture system $Me_2O–MeO– Me_2O_3 – SiO_2 –H_2O$.

In the resent years a wide range of experiments are performed on cement having Alkali reactions and the concrete resulted from it. Trief-type and F-type cement of Scandinavia (Fross 1983) and Alkali cement mixtures are from the latest examples. (Davidovits 1988, Roy and Slisbee 1992)[16].

In 1981, Davidovits in French produced a mixture, combination of alkali, lime and dolomite. He named this mixture geopolymer because it had a polymer structure. Malek and the colleagues in 1968 and Krivenko in 1994 completed and expanded these studies.

About the mechanism of the expansion in this process, different ideas are available. One suggestion is that expansion by the absorbing humidity with the clay which is not already humid. The other suggestion is that clay increase the ability of reacting in stones. In the research by Gratton-Below in 2005, he suggested that dolomite decomposition reaction can produce noticeable expansion itself; however the later researches showed that this cannot be the reason for the expansion. The purpose of the research is to evaluate the behavior of the stones from the aspect of ability in carbonate Alkali reaction which is used in construction of concrete dams in the country. The following dams are listed here:

A- Bureiskaya Dam
B- Buchtarma Dam
C- Tashkumyr Dam

The general characteristics of the dams are as followed:

Table.1- general characteristic of the researched dams

Name	Country	type	Length	Height from foundation
Bureiskaya	Russia	Gravity RCC	714 m	136 m
Buchtarma	Kazakhstan	Gravity RCC	450 m	90 m
Tashkumyr	Kyrgyzstan	Gravity RCC	320 m	75 m

Figure 2- Bureiskaya dam, Buchtarma dam, Tashkumyr dam

In March 1996 was approved in Spain the *Technical Safety Regulation of Dam and Reservoirs* (RTSPE), applicable to a great number of Dams and reservoirs.

The Regulation was planned as a more opened norm than the Instruction, establishing the dam safety conditions that must be observed in the different stages of the dam life: project, construction, first filling, operation and decommissioning.

2. CEMENT INGREDIENTS

The cement used in Lab is chosen from the common types which are used in construction in Russia. The physical and chemical characteristic of the cement is shown in table 2.

Table 2- physical and chemical characteristic of cement

Physical experimental	result	Chemical decomposition	Result	Cement mixture (Boy method)	Calculated amount
Softness (cm^2/gr.)	2960	SiO_2	20/65	C3S	48/09
The first absorbing time	185	Al_2O_3	5/5	C2S	22/90
The final absorbing time	200	Fe_2O_3	2/95	C3A	9/58
Auto clav expansion	0/17	CaO	67/67	C4AF	8/98
-	-	MgO	3/68	-	-
-	-	Na_2O	0/49	-	-
-	-	K_2O	1/02	-	-
-	-	SO_3	1/73	-	-
-	-	Reduced weight because of burning	3/03	-	-

3. EXPERIMENTS

The most read information about the being reaction potential concrete stone is resulted from their function is real condition in available factor. But if this information isn't available, or depending on some reason isn't reliable, thus the stone should go under microscope in Lab. In addition in most cases it is need that before making concrete stones become evaluated very fast. This will cause the experiment method to be fast, reliable, simple and repeatable.

In this paper the result of the 3 following experiments are analyzed:

1- mortar bar method ASTMC586
2- accelerated mortar bar test ASTMC1260
3- accelerated concrete prism test STMC1293

It should be emphasized that the results are compatible with patent of "Construction tools to determine the kinetics of the carbonation of concrete", registered by U20110602 in Belarus by the corresponding author. .

3.1. MORTAR BAR METHOD ASTMC586

This method published in to the American standard in 1966. In this method, mortar bar with the diagonal of 9 mm and length of 35mm or prism with this measurement 9×9×35 mm in the 1N NaOH and 23°C temperature is soaked. Then, their length re measured in identified time periods [2].

This experiment is applied for identifying reactionable carbonate with Alkali which is according to the expansion of 0.1%, but about the time in Americans standards mentions that usually this expansion in stones takes place in 28 days from putting them in sodium [3]. By the way, the criterion of 10% expansion in 4 weeks and 20% expansion in 16 weeks is suggested. The results of this experiment for the active silica- Alkali stones are not satisfying. [13].

Accepting or refusing the stone resource is not preferred according to this experiment [3].

3.2. ACCELERATED MORTAR BAR TEST ASTMC1260

In this experiment, the stones are separated based on suggested aggregates, then using cement with the amount of expansion in equal to 0.2 (C151, autoclave test), special mortar bar samples are produced. After sampling with 23°C water, they are soaked in the normal 80°C sodium solution. After 24 hours, they write the first expansion and continue it for 16 days. Finally, depending on the reached expansion, the criteria of the harmfulness and usefulness of the stones are categorized as follow:

- If the expansion is less than 0.1% of the sample, in most cases the stones are not harmful.
- If the expansion is more than 0.2% of the sample, stones are in the range of harmfulness.
- If the amount of expansion is between 0.1% and 0.2% the stone are both harmful and not, so we need other informative such as ASTMC295 which is used for calculating the percentage of active stone, ASTMc856 which issued for identifying Alkali reaction and also registered local information.

3.3. ACCELERATED CONCRETE PRISM TEST ASTMC1293

In this method concrete prism having dimensions less than 75×75×275 mm and more than 75×75×405 mm (In American standard the measurement is 75×75×285 mm) are prepared kept in the environment with temperature of 38^{oc}. This experimental can evaluate the ability of stones in making harmful expansion in concrete because of silica-Alkali or Carbonate Alkali reaction [5, 6]

4. RESULTS

4.1. MORTAR BAR METHOD EXPERIMENT'S RESULT

The abstract of the results about different stone is presented in table 3. As it is seen, the expansion's average of the all samples is less than 0.1%. Therefore, of this all samples are evaluated inactive. In Japan carbonate stones were investigated under this method. Although the results of the short time (28 days) were similar, but in the later months the result differed completely [17]. So maybe one month time isn't suitable for evaluating stones. As it is seen the expansion related to the stone of Tashkumyr Dam is less than average of the sample's expansion.

Table 3-the result of mortar bars method.

Sample- Bureiskaya Dam	R-R1	R-R2	R-R3
Expansion after being in Alkali for 28 days	0.028	0.039	0.025
Average	0.027		

Sample - Buchtarma Dam	R-D1	R-D2	R-D3
Expansion after being in Alkali for 28 days	0.028	0.059	0.020
Average	0.024		

Sample - Tashkumyr Dam	R-S3	R-S2	R-S1
Expansion after being in Alkali for 28 days	-0.059	0.040	0.025
Average	0.039		

4.2. ACCELERATED MORTAR BAR TEST'S RESULT

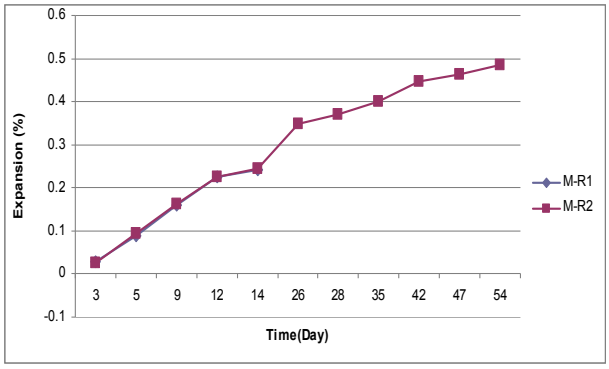

Diagram1-the diagram of the expansion of the foundation prism samples related to Bureiskaya dam's stone.

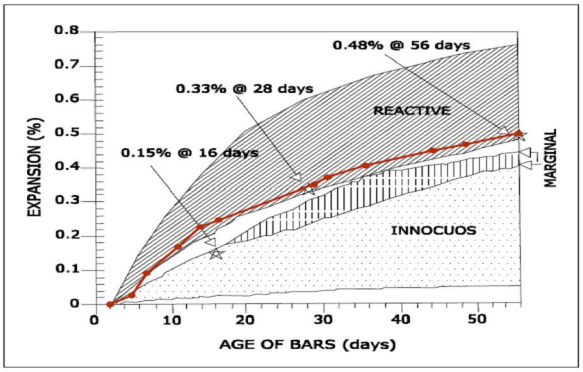

Diagram2-comparision with Hooton and Rogers related to Bureiskaya dam's stone [8].

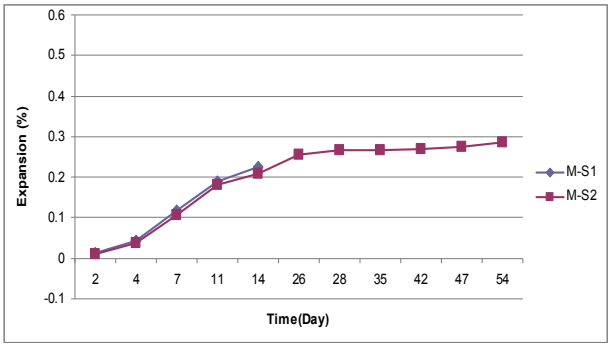

Diagram 3-the diagram of the expansion of the mortar bar samples related to Tashkumyr dam's stone.

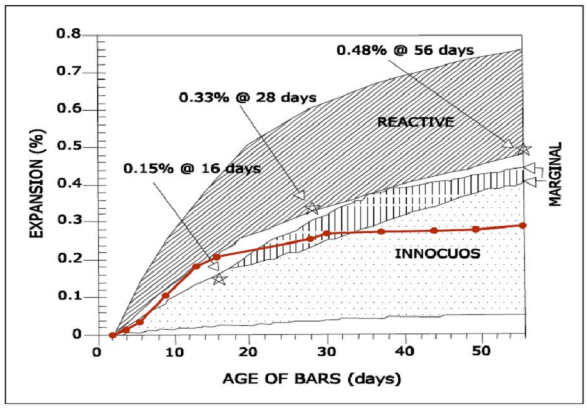

Diagram4- comparison with Hooton and Rogers related to Tashkumyr dam's stone [8]

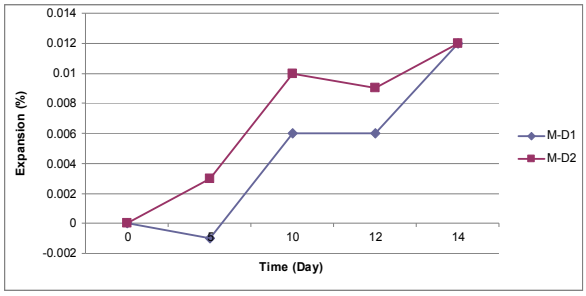

Diagram 5-the diagram of the expansion of the mortar bar samples related to Buchtarma dam's stone.

4.3. ACCELERATED CONCRETE PRISM TEST

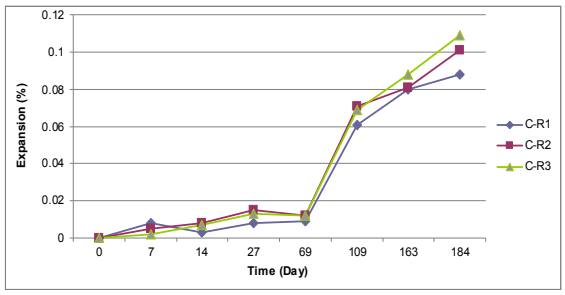

Diagram 6-the diagram of the expansion of the concrete prism samples related to Bureiskaya dam's stone.

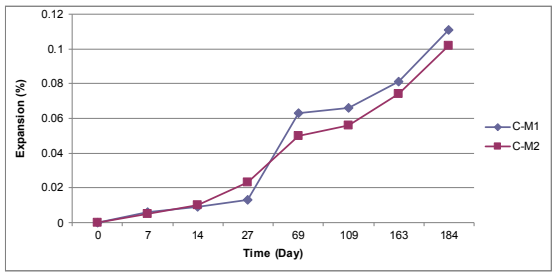

Diagram 7- the diagram of the expansion of the concrete prism samples related to Tashkumyr dam's stone.

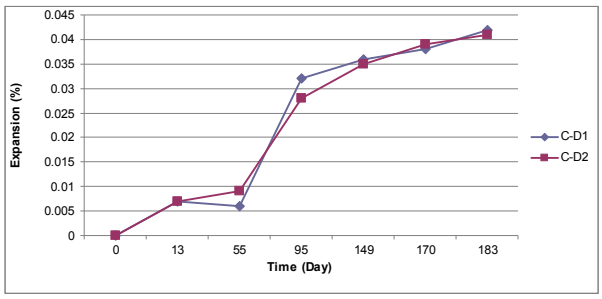

Diagram8- the diagram of the expansion of the concrete prism samples related to Buchtarma Dam's stone.

5. ANALYZING THE RESULTS OF EXPERIMENTS

Table 4 shows the expansions measured by the 2 methods of mortar bar method and accelerated mortar bar test. As it is seen, with increasing in 14days-expansion of mortar bars, 28days-expansion of mortar bars show fluctuations. The expansion of mortar bars related to the stone of Tashkumyr dam is approximately 7 times more than the expansion related to the stone of Buchtarma dam.

Moreover, with the method of mortar bar all stones were evaluated non-active, however based on the results of accelerated mortar bar method, according to Canada standard criterion just 2 stones and with the Hooton and Rogers's criterion only one of the stones were evaluated as non-active. Thus, the similarity between the results of mortar bar and accelerated mortar bar methods are more with this criterion.

Table.4- the relationship between the results of mortar bar and accelerated mortar bar methods (28 days and 14 days)

Stone	Buchtarma	Bureiskaya	Tashkumyr
28 day expansion of concrete prism (%)	0.011	0.242	0.216
14 days expansion of stone prism (%)	0.024	0.027	0.039

Table.5 shows the relationship between the results of expansion in the 2 method of mortar bar method and accelerated concrete prism method. As it is observed, with increasing in 6month-expansion, 28day-expansion of the stones presents fluctuations. In the accelerated concrete prism method, all the stones were evaluated active which is completely different from the mortar bar experiment.

Table.5- the relationship between the results of expansion of the 2 methods of mortar bar and accelerated concrete prism methods (28 day and 6 month)

Stone	Buchtarma	Bureiskaya	Tashkumyr
28 day expansion of concrete prism (%)	0.041	0.098	0.106
14 days expansion of stone prism (%)	0.024	0.027	0.039

Based on the results, in all the stones with increasing in expansion of the concrete mortars the concrete prisms also increase, but after that in Bureiskaya's stone, it decreases.

6. CONCLUSION

Usually, the most real information about the potential of Activities of stones or effect of the substances or other criteria in concrete is reached by analyzing the concrete's function in available cases. But in the case of having no access to this information, we make the needed condition in Labs. In most cases it's needed to evaluate stones before construction which needs methods to be fast, reliable and repeatable. Among these methods petrography is always the first step. This experiment is nearly fast and inexpensive and if it is done by an experienced expert, it can be used for accepting or refusing a stone or at least prevent incorrect choice and decrease expensive and time-wasting Lab's experiments.

Among chemical methods for identifying the potential of the Alkali-silica reaction, the method ASTM C289 isn't reliable. The corrected method of ASTM c289 is complex and it's repeatable. Moreover, it is not more effective than simple solutions like NBRI.

Among the methods of mortar bars, the method ASTM C227 is not preferred since the results are extremely affected by the keeping condition, the ration of water to cement; Alkali amount also the time duration is 6 month which is too long.

Among the investigated methods, the accelerated concrete prism method is suggested. (ASTMc12660, csAA23.25I, NBRI).

However, it's better not to use this method to refuse a stone. It is a suitable experiment because just a low number of destroying stones remained unidentified.

Finally although Canada's standard think that the accelerated mortar bar method is suitable for evaluating silica-Alkali process but some researcher, such as (Mingshu, Min Deng, Xianghui Lan, Zhorgzi, Xu, Tang)[13] have used this to evaluate Carbonate-alkali reaction with changing the criterion level of expansion.

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