Analyzing Usual Classification Methods of Construction Joints for Reducing Permeability of RCC Dams

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Abstract
In RCC dams, different layers are executed with the thickness of 30 t0 35 cm according to bulk of sources, available facilities, methods of execution, providing and assuring density of the RCC. The execution of RCC especially in hydraulic structures should be done in a way that the executed structure have consonant blocks for the intended goals.
it is clear that the characteristics and the conditions of boundaries between layers is the most effective parameter in determining the boundaries between layers. Although this kind of execution causes higher speed in execution in comparison of usual concrete dams, and it also reduces problems of voluminous concrete placing in sites significantly but the stability of dams against side forces because of relative weakness in shear strength between layers in the place of joints needs especial attention and it is one of the important factors that is important to dam designers.
According to technical codes in RCC dams, joints are categorized into four groups, hot, warm, cold, and very cold. Necessary works are done according to the kinds of joint. The standard to define these joints is the amounts of maturity factor which is the product of temperature of the surface of the concrete and time based on Fahrenheit that will be defined after the experimental study and defining time.
It seems that this definition is too broad and the most important problem of it is, not mentioning the time of setting of concrete in calculation which is the important factor in determining time span for any kind of joints. In this artical the researcher tries to propose ways to proof the subject according to codes and to find new ways to categorize these joints to promote safty factor of permeability in the place of joints in real conditions.
Keywords: Roller Compacted Concrete, Maturity factor, Time of Setting, Permeability.

1. INTRODUCTION

Roller-Compacted concrete (RCC) dams can be considered as the most important development in dam construction technology over the 40years, which its identification turns back to 1970s during two conferences of 1970 and 1972 in Asilomar, a state in California USA under title of “Economic Construction of Concrete Dams” [1]. Experts in these two meetings were seeking new type of materials for dam construction, which can meet safety of concrete dam and can also include speed of implementing embankment dams. This could result in creation of roller-compacted concrete dams as a new type of dams in 1974.

Roller-compacted concrete, before being a new type of material, has been a modern method for implementation and has been similar to classic concrete dams in terms of safety. The method could cause implementation of concrete dams with lower costs and could also play vital role in regard with rapid implementation of the project [2]. Over the years, roller-compacted concrete has been widely applied for constructing pavement of roads, highways, airports and implementation levels of industries such as petrochemistry, fineries, ports and so on. Now, the technology has found special position in different constructional domains.

Permeability of implemented dams with RCC has been constantly one of the main concerns existed for implementation of these dams. The problem has been specifically important in regard with joints and this has been because of increase in number of horizontal joints. Hence, permeability of these joints can have considerable effect on amount of permeability of these dams.

According to existing technical codes for RCC dams, joints can be classified in 4 groups of hot, warm, cold and vary cold and required conditions for implementation of the next layer would be defined adjusted with type of the joint. General criterion for defining these joints can be regarded as maturity factor, which can be defined in form of multiplication of surface temperature of concrete in time based on °F. After examining the joint in laboratory conditions, temporal limitation would be determined and then it would be named.

It seems that definition is general and the most important weakness of it can be lack of considering setting time of concrete in calculations, which can be regarded as one of the most important factors in determining time periods for attributing to each type of joints.

MokhtarPouryani, Siosemarde and MikailZadeh (2013) [3] have investigated classification of implemented joints in RCC dams based on setting time through constructing samples in three different environmental modes including processing in curing room, inside the room and under open air based on maturity factor. Obtained results from their studies indicated that the concrete can result in different setting times under different environmental conditions and this issue can indicate that concrete surface humidity is more important than concrete surface temperature. According to physic of this issue, this mode may be resulted from manner of transferring temperature of concrete under different environmental conditions. In addition, their results indicated that with a constant mixing pattern, in the first setting, different values would be obtained for maturity factor. In other words, not only temperature and time can affect setting time and maturity of joints, but also humidity has also important and effective role. The study indicated that method of classification of joints based on setting time can present more acceptable results for different environmental conditions.

At the present study, as a result of these results, new series of examinations have been provided in framework of existed regulations to investigate and compare both attitudes carefully and to consider setting time in classification of joint, so that they can evaluate permeability in space of joints in both classification systems with two different cuties of cement materials. In addition, in order to make the research applicable, applied materials in one of the roller-compacted concrete dams has been applied, which is under construction in West of Iran.

2. MIXED RCC MODEL

2.1. CEMENT MATERIALS

Achieving low exothermal action in massive concrete can be met mainly through using pozzolanic materials and overloads in cement. At the present study, pozzolanic cement type II from Kurdistan's Cement Factory (Bijar) with 25% pozzolanhas been applied. In addition, for the purpose of enhancing validity of the comparisons, two cuties of 125 and 150kg/m^3 of cement materials have been applied.

2.2. AGGREGATES

Rock materials have been considered in 4 levels of aggregation including a group for fine aggregates, 2 groups for coarse aggregates and one group for combining fine and coarse materials based on table 1. Maximum size of aggregates has been also considered to 50mm [4].

Table 1: mixed pattern of RCC applied in this study

Type of cement	Cement (kg/m^3)	W/C	D_{max} (mm)	Aggregate Percent %				Vebe time (sec)	Unit weight (kg/cm^3)	V_p/V_m (Ave.)
				0-3 (mm)	0-5 (mm)	5-25 (mm)	25-50 (mm)			
Special pozzolanic of Bijar Iran	125	0.9	50	13.5	31.5	27.5	27.5	15	2455	0.45
	150	0.9	50	13.5	31.5	27.5	27.5	15	2455	0.45

According to research topic, bond of joints is so important. Roller-Compacted layers with weak bond include lower caulk quality and lower shear strength. In this regard, bed making mortar was used for 2-layer joint for the first time by 1980 in Shimajigawa Dam Japan [1]. In first series of experiments of the study, 4 types of mortar mixing patterns for inter-layer spaces have been applied according to table 2 for purpose of investigating impact of increase in cutie of cement materials in inter-layer mortar on quality of joints. However, in the second group of experiments, according to the main objective of the present study for purpose of classifying joints and necessity of applying a uniform pattern for achieving desired target, cutie of cement materials was assumed fixed.

Table 2: mixing pattern of inter-layer mortar applied in first and second series of experiments

	Cement (kg/m³)	W/C	Aggregate Percent %		Air (%)	Fresh Concrete		Compressive Strength (kg/cm²)	
			0-3 (mm)	0-5 (mm)		Slump (cm)	Unit weight (kg/cm³)	7	28
First series of experiments	400	0.7	30	70	2.5	17	2230	118	180
	450	0.63	30	70	2.5	21	2240	130	183
	500	0.59	30	70	2.5	16	2200	178	241
	550	0.56	30	70	2.5	16	2200	181	245
second series of experiments	400	0.66	0	100	2.5	20	2240	130	236

3. MAKING SAMPLES

RCC samples can be made for different purposes and in different forms. At the present study, in all conducted tests, cubic frames with size of 15×15cm have been applied for purpose of making 34 samples (2 samples as control samples) in order to test depth of penetration based on European Standard EN-12390-8. Also, cylindrical frames with size of 30×15cm have been also applied for purpose of making sample to determine bond strength based on ASTM c1245.

Density of samples was measured based on type of joint with two rectangular cubic overloads with weight of 9.1 and 11.6kg (choosing weight of overloads has been based on the stress created in the test of determining web time).

Because of nature of the test, in order to investigate the joint between two layers, the test was implemented in hot joints in cubic frame each sample and ion two layers with thickness of 7.5cm and in cylindrical frame in two layers with heights of 15cm. In other types of joints, it was implemented in cubic frame of each sample and in two layers with thickness of 7cm and in cylindrical frame in two layers with heights of 14.5cm with a layer of inter-layer mortar with thickness of 1cm.

Figure 1. first layer of concrete in the cubic and cylindrical frames

In order to optimize surface of joints in warm, cold and supercool joints before implementation of the second layer, some actions have been taken as follows:

- ✓ Ridging surface: according to presented explanations in regard with removing mortar from surface of joint, the surface has been ridged.
- ✓ Implementation of bed mortar: after ridging and fastening the frame again, firstly bed mortar with thickness of 1cm was implemented based on mixture pattern and then the second layer was implemented.

At the present study, in order to determine time periods for attributing to each type of joint in method of maturity factor, defined ranges in technical specifications of one dam, which is under construction in west of Iran, has been applied based on second row of table 3.

In addition, in order to achieve classification system based on setting time, proposed values of MokhtarPouryani et al (2013) have been applied based on third row of table 3.

Figure 2. ridging layer surface

Before starting sample making and using ASTM C403 test, primary and ultimate setting times have been determined for each mixing pattern. Based on obtained results from these tests for primary and secondary setting times, with a suitable approximation for both values of mixing cutie, primary setting time has been considered to 5hrs and secondary setting time has been considered to 12hrs and tests have been also conducted through considering these values.

Table 3. defining types of joint based on both classification systems

Type of joint	Defining joint based on		Conditions of implementing next layers
	Maturity factor (°F-hr)	Setting time	
Hot Joint	<1022	Before primary setting	Can be implemented with no arrangement
Warm joint	1022~2012	Before ultimate setting	Weak zones would be removed from surface of implemented layer using water or wind pressure and there is no need to ridge aggregates.
Cold joint	2012~3994	4 times higher than primary setting	Weak zones would be removed from surface of concrete using pressure of water or wind in a manner that aggregates can be ridged and sand-cement mortar with thickness about 2cm can be implemented.
Supercool joint	>3994	8times higher than primary setting	Similar to cold joint

4. RESULTS

4.1. OBTAINED RESULTS FROM STRUCTURED TESTS BASED ON MATURITY FACTOR INDEX

Figure 3 illustrates depth of penetration of water in RC in vertical direction on the joints. Based on presented classification by Neville, one can classify quality of joints based on test of depth of penetration based on table 3. In addition, it has been found that if the depth is less than 50m, concrete would be in level of "impermeable" and depth less than 30mm can make concrete to be in level of "impermeable under destructive conditions" [5]. National Regulation of stability of concrete in the Persian Gulf and Oman Sea has also limited depth of penetration of water in concrete to maximum level of 50mm [6].

According to table 4 and diagram of figure 3, RCC125 sample of warm joint and samples of supercool joints both are in permeable limit and other samples are in impermeable limit. As a result, optimization regulations should be revised for these joints.

In addition, diagram indicates that through implementation of concrete in a layer in the sample without joint and implementation of hot joint before ultimate setting of concrete, almost uniform surface of permeability would be obtained and this can be because of suitable bond of materials located in two sides of the joint.

Table 4. classification quality of joints by Neville

Type of joint	Depth (mm)	Quality
Without joint	83.7	Permeable
Hot	84.4	Permeable
Cold with optimization	75	Permeable
Cold without optimization	100	Permeable

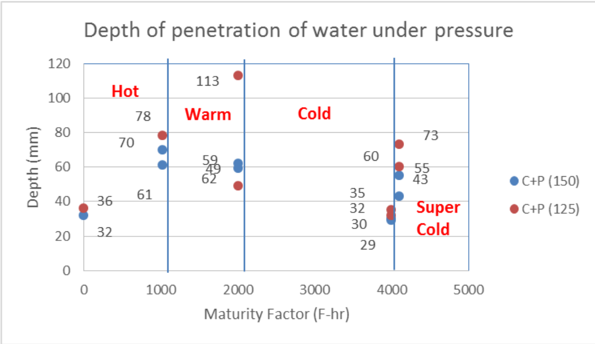

Figure 3. diagram of depth of samples in joints

In figure 4, results of bond strength of samples have been presented based on ASTM C1245 standard. The diagram indicates issues as follows:

- ✓ Except for supercool joint, permeability would be reduced along with increase in bond strength.
- ✓ As it is obvious in the diagram, increase in maturity factor can result in rise of tensile strength of joint.
- ✓ Increase in cutie of cement materials in hot and warm joints due to the implementation of the next layer before stiffening of the concrete, the way would be paved for movement of aggregates downward to the beneath of coarse aggregates that are connected to the lower layer. As a result, bond strength in place of joint would be enhanced.

Ridging parameter of concrete surface in cold and supercool joints can enhance bond strength of joint and increase in cutie of cement has no vital role.

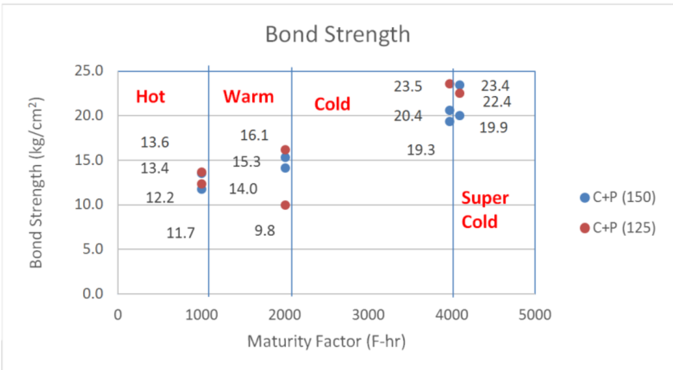

Figure 4. diagram of bond strength according to ASTM C1245 standard

4.2. RESULTS OF STRUCTURED TESTS BASED ON SETTING TIME INDEX

In all experiments for both values of mixture cutie, primary setting time has been equal to 3hrs and secondary setting time has been considered to 12hrs and tests have been conducted with these assumptions.

According to diagram of figure 5, almost all samples are located in impermeable limitation. In regard with hot, cold and supercool joints, increase in cutie of cement can cause reduction of permeability and in warm joint the issue would be reverse. As a result, as it was found about classification based on maturity factor, preparations of this joint for purpose of optimizing caulk level should be revised.

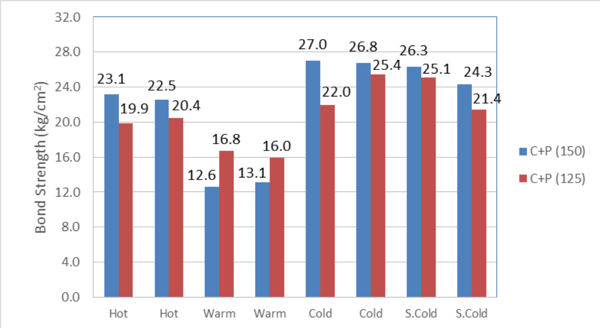

Figure 6. diagram of bond strength in joint

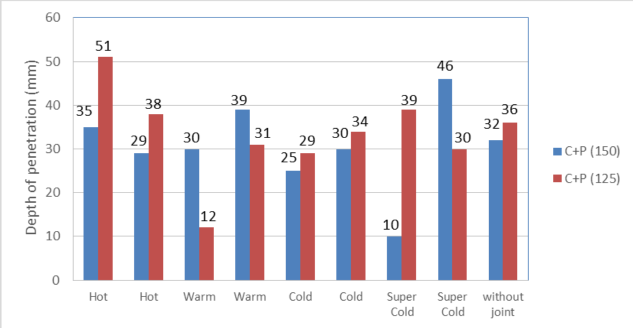

Figure 5. diagram of depth of penetration of samples in joint

Diagram of figure 6 illustrates bond strength of structures samples based on setting time. Clearly, in warm joint because of lack of ridging parameter, value of bond strength has been reduced in joint between the two layers. In addition, diagrams indicate increase in bond strength with the increase in cutie of cement materials of RCC mixture, except for in warm joint.

4.3. Comparing two methods of joint classification in terms of depth of penetration

Comparing mean value of obtained results from testing depth of both classification methods based on diagram of figure 7 indicates that:

- ✓ The diagram indicates properly expected results of the proposed method of the study, so that values of permeability in how and warm joints are low and in classification based on setting time, they are lower than values of similar joints in maturity factor method.
- ✓ Obtained values in hot joint indicate penetration level equal to the joint-free sample.
- ✓ There is considerable difference in penetration values of warm joint and in two methods, which can be because of the time of being exposed to layer surface. More delay in working time in layer surface can result in dryness of the surface and more decline of water than the optimized humidity rate and increase in porosity. The value, based on presented diagrams in the previous paragraph has been obtained to 29hrs for maturity factor and to 12hrs for setting time.
- ✓ According to ultimate setting time of concrete while creation of cold joint, as it was found from first series of experiments, ridging parameter of the first layer surface before implementation of second layer has the main role in reducing penetration value in joints. As it s obvious from the diagram, penetration values of both methods of classification are almost equal in cold joint.
- ✓ In supercool joint, the difference of values can only be because of human error while performing construction and density operations.

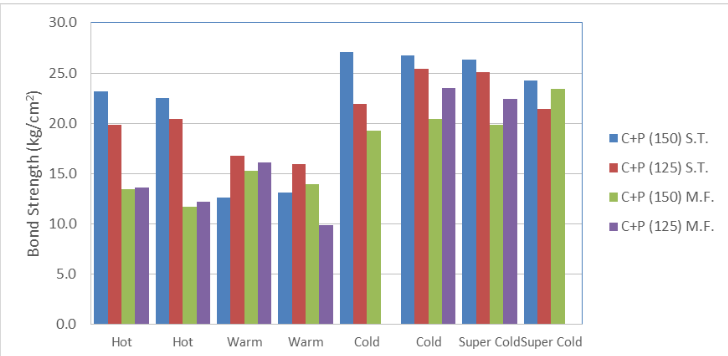

Figure 8. comparison diagram of bond strength of joint

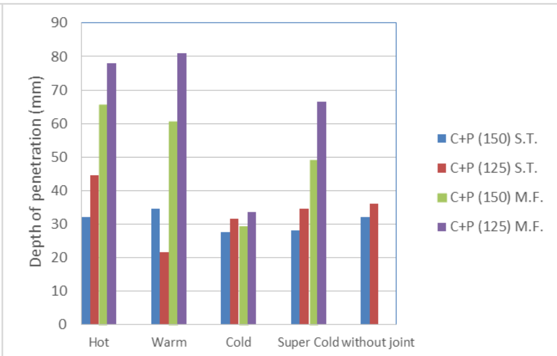

Figure 7. comparison diagram of depth of penetration

Comparing mean values of obtained results from bond strength in joint between two methods of classification based on diagram of figure 8 indicates that:

- ✓ Bond strength in place of joint of hot and warm joints in method of setting time is higher than maturity factor. This can be because of better penetration of mortar of the joint in RCC.
- ✓ Increase in cutie of cement material mixture, bond strength of joint would be also increased, except for warm joint.

5. CONCLUSION

Obtained results from the study are presented as follows:

- ✓ Through replacing setting time based on tables and diagrams for definition of hot and warm joint, one can obtained lower values of penetration compared to maturity factor.
- ✓ Obtained values in hot joint indicate equal penetration level with the joint-fr ample.
- ✓ There is significant difference between penetration values of warm joint in two methods, which can be because of the time exposing to layer surface. More delay in working time can result in dryness of layer surface and more decline of waer than optimized humidity rate and increase in porosity. The value is equal to 29hrs for maturity factor and is 12hrs for setting time.
- ✓ Bond strength in joint of how and warm joints in setting time method is higher than maturity factor, which can be because of better penetration of existing mortar in inter-layer joint.
- ✓ Obtained results indicate that definition of warm joint and required preparations for implementation of concrete under warm joint are not sufficient. Hence, it is necessary to revise definition of warm joint and its preparations. Dunsten et al (2012) has also offered ridging using broom on layer surface in warm joint.
- ✓ In this study, increase in amount of cement materials can result in decrease in permeability rate. Mixture pattern and applied materials in this study indicate that the lowest permeability rate has been obtained in cement materials to 150kg/m3.
- ✓ Because of considerable difference between the times of exposition of layer to each classification system, obtained results of implementation of maturity factor have more permeability than classification method based on setting time.

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7. REFERENCES

1. Warren hard Henson, (1997), “Roller-compacted Concrete dams”, Journal no.14, pub. Power Ministry, national Committee of Great Dams of Iran, pp.283
2. ChasemiHooman, (2001), “investigating effective factors in RCC permeability”, MA thesis, Tehran University, Collage of Civil Engineering, Technical University, Iran
3. MokhtarPouryaniSayed Bashir, SioseMarde, Maroof, YousefZadehMikail, (2014), “classification of implementing joints in RCC dams based on setting time”, 7th national Congress of Civil Engineering, Engineering Collage of ShahidNikbakht, Zahedan University, Iran.
4. MokhtarPouryaniSayedbahsir and SioseMarde, Maroof, YousefZadehMikail, (2013), “pattern of RCC dams mixture with attitude to dams with average cement materials”, 7th national Congress of Civil Engineering, Engineering Collage of ShahidNikbakht, Zahedan University
5. Neville, M.P. (1999), “properties of concrete”, trans. Hormuz Family, Research Center of Construction and Housing, first edition, p.910
6. MoukhtarPouryaniSayed Bashir, (2014), “investigating permeability of implemented joints in RCC dams”, MA thesis of water-civil engineering, Islamic Azad University Mahabad Branch, Engineering and Technical University, Iran
7. Dunsten et al, (2012) “The Tensile Strength Of For RCC Dams”, 6th International Symposium on Roller Compacted Concrete (RCC) Dams, Zaragoza, Spain.