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Study the Relationship between Gel-Pores Water and Slump in Concrete Mix Design

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***Abstract*—water in concrete mix considers the main factor controlling the workability of fresh concrete mix. The role of the water in concrete mix is divided in two parts. The first part is the quantity of water required for compete hydration of cement paste. The other part is the quantity of water required for workability and absorption of aggregates in concrete mix (gel-pores water). Excess water content in fresh concrete will result in capillary cavities while inadequate water content will result in incomplete hydration and lack of durability.**

The adequate quantity of required water for proper workability and durability is governed by gel-pores water value. It is reported that the slump of ordinary concrete values are interrelated and corresponded to changes in gel-pores water.

This relationship can reflect the limitations of water required for adequate workability and durability in which concrete mix with an approximate value of slump can be achieved.

Keywords—gel-pores water; concrete mix; aggegates; workability;

I. INTRODUCTION

Fresh concrete is a specific mixed material which can be poured and molders into any desire shapes. The relative quantity of the material, (cement, water, and aggregates) controls the properties of concrete in both wet and hardened state. Water content has more significant influences on the workability [1]. The higher the quantity of water the higher will be the fluidity of concrete, which consider one of the major factors affecting concrete workability.

The workability of concrete mix should be suitable for each specific application [2]. Suitable workability is designed to ensure that the operations of handling, placing and compaction can be undertaken efficiently. At work site, untrained supervisor tend to adding more water for increasing workability. This practice is often resorted to because it is the easiest corrective measures at site [3]. Increasing water content should be the last recourse for improving the workability of concrete. In case of uncontrolled concrete in site, more water can be added with corresponding to adding more quantity of cement so that water/cement ratio should be constant to ensure same strength.

The workability of concrete is mainly governed by the shape, size, texture, and grading of the aggregates. Previous study [4] shows that for a value of water cement ratio (w/c), there is one specific value of fine/coarse ratio in which concrete mix gives best appropriate workability. Parenchio [5] developed a miniature slump test for cement paste in which less quantity of paste and testing time is achieved.

A. Objective of the study

As water content plays significant rules for modifying the workability of the concrete, the objective of this study is:

- Study the effect of gel-pores water on the workability of concrete.
- Study the relationship between gel-pores water and the slump of fresh concrete mix.
- Produce a guideline for concrete workability based on gel-pores water and slump values.

B. Methodology (study method)

The methodology for studying the effect of gel-pores water on concrete workability is based on theoretical equations. Theses equations were derived from water absorption and volumetric equation which is widely used in concrete mix design with some assumptions. By using equations, verity of water content can be generated. The theoretical result data is compared with laboratory slump test data to get the relationship between the gel-pores water and slump test values. Using this relationship, a guideline for a variety of workability with all of concrete components can be presented. The following is the assumptions and the equations used in this study.

1. Assumptions

- $\boldsymbol{\rho}_c$ = (specific gravity of cement) = 3.1
  w_c = (the rate of required water to cement for completing of paste hydration "bound water") = 0.23
- $\boldsymbol{\rho}_A$ = (specific gravity of aggregates) = 2.9
- w_{An} = (max absorbed water required by weight of aggregates for absorption) = 2%
- w_A = (rate of required water to aggregate for completing absorption and workability) = 0.04

- c/w = (the rate between cement to water) = 2
- a = (air entrainment as percentage) = 0

2. Equations

- $\frac{C}{\rho_c} + \frac{A}{\rho_A} + w + a = 1000$ (volumetric equation)

Where:
C = cement, A = aggregates, w =water

Since a = 0, the equation become:

- $\frac{C}{\rho_C} + \frac{A}{\rho_A} + w = 1000$
- $W = C * W_C + A * W_A$ (water absorption equation)

By combining the previous equation we get

- $C = \frac{1000 * W_A}{(0.553+b) * W_A + (\frac{1}{\rho_A} * b)} \pi r^2$

Where $b = \frac{W}{C} - 0.23$

- $A = \frac{1000 - C * (\frac{1}{\rho_C} + W_C)}{\frac{1}{\rho_A} + W_A} \pi r^2$
- $W_A = \frac{\frac{1}{\rho_A} * b * C}{1000 - (0.553+b) * C}$

C. Study programs

1) Theoritical study

By using the previous equations and the assumptions with varity values of gel-pores water, a table with variable concrete components data can be generated as follows:

TABLE I. GENERATED CONCRETE PROPORTIONS USING NUMIRICAL EQUATIONS

W_k	C kg/m3	W dm^3/m^3	A kg/m^3
0.022	198	99	2428
0.025	220	110	2375
0.028	241	121	2325
0.032	268	134	2261
0.035	287	144	2215
0.038	306	153	2171
0.042	329	165	2115
0.045	346	173	2075
0.048	362	181	2036
0.052	383	191	1987
0.055	398	199	1952
0.058	412	206	1917
0.062	430	215	1874
0.065	443	222	1842
0.068	456	228	1812
0.072	473	236	1772
0.075	485	242	1735
0.078	496	248	1717

2) Expermintal study

From the previous table, fifty four specimens were prepared based on different gel-pores water values (W_A) to perform slump test procedure as follows:

- Fifty four concrete mix tests with variable (W_A) value was prepared (Table (I))
- The slump moulds were filled in 3 layers, each approximately 1/3 of the height of the moulds
- Each layer was tamped 25 times by the tamping rod all over the cross section of the layer
- After the top layer has been rodded, a trowel and tamping rod used to smooth the concrete surface level
- The mold was removed immediately from the concrete by raising it in a vertical direction
- The differences in levels between the height of subside concrete and the height of the molds were measured
- A Table (II) contains all the slump values was presented.

II. RESULTS AND DISCUSSION

From the previous table, the slump values of the concrete mixes were variable and correlated with the W_A values. The relationship between the slump values and gel-pores water can be shown as below.

TABLE II. PROPOTIONS OF CONCRETE DATA USED AND AVERAGE SLUMP TESTS VALUE FROM EXPERIMENTAL STUDY

W_A	C kg/m3	W dm3/m3	A kg/m3	H mm
0.022	198	99	2428	≈ 6.00
0.025	220	110	2375	≈ 15.00
0.028	241	121	2325	≈ 24.00
0.032	268	134	2261	≈ 36.00
0.035	287	144	2215	≈ 45.00
0.038	306	153	2171	≈ 54.00
0.042	329	165	2115	≈ 66.00
0.045	346	173	2075	≈ 75.00
0.048	362	181	2036	≈ 84.00
0.052	383	191	1987	≈ 96.00
0.055	398	199	1952	≈ 105.00
0.058	412	206	1917	≈ 114.00
0.062	430	215	1874	≈ 126.00
0.065	443	222	1842	≈ 135.00
0.068	456	228	1812	≈ 144.00
0.072	473	236	1772	≈ 156.00
0.075	485	242	1735	≈ 165.00
0.078	496	248	1717	≈ 174.00

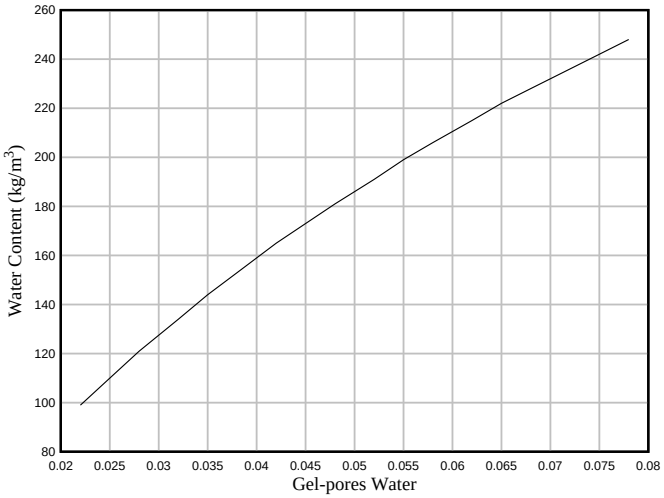

Fig. 1. Effect of gel-pores water on water (workability) at constant w/c ratio

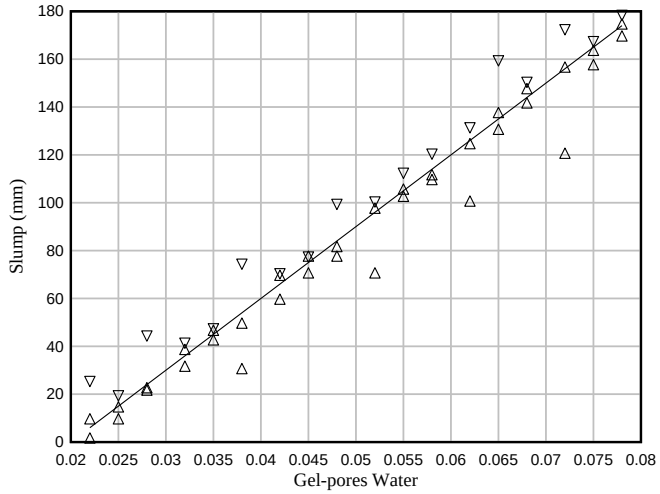

Fig. 2. Effect of gel-pores water on average slump value at constant w/c ratio

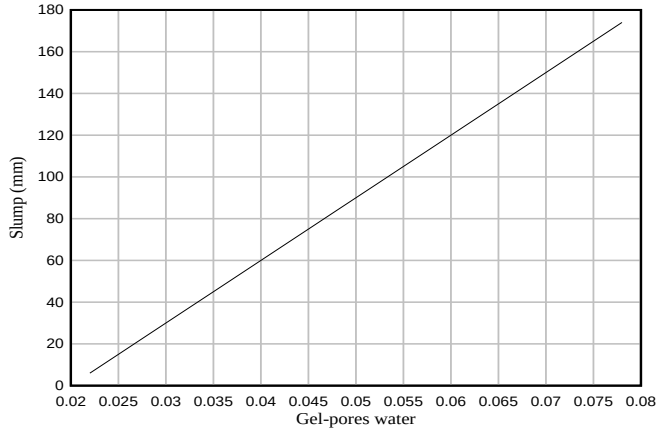

Fig. 3. The relationship between gel-pores water and slump at constant w/c ratio

From the previous Table and graphs, effect of gel-pores water on workability of concrete is clear causing increasing on the slump values. The increasing values were variables for each increasing in gel-pores water.

- Increasing in slump value by 3mm for each 0.001 increasing in gel-pores water
- Increasing in workability for each increasing in gel-pores water and slump value
- A guideline of concrete workability can be presented based on the relationship between gel-pores water and slump values

III. SUMMARY AND CONCLUSION

It has been studied the effect of gel-pores water on workability, and slump in concrete mix. It was noticed that the gel-pores water plays significant rule in workability of concrete mix.

The increasing in gel-pores water causes increasing in slump value followed by increasing in workability of fresh concrete. The strength of the concrete mix remains without impairing due to the increasing of workability and slump since c/w remains constant on all experimental tests. The conclusion of this study can be summarized as following.

- Gel-pores water is considered the most important and major factor affecting the proportioning and the workability of fresh concrete mix design.
- Any increasing in gel-pores water value corresponds on increasing in slump value followed by increasing in workability
- The correlation between gel-pores water and slump can be considered as a guideline for concrete mix design and for further study.

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