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Research article

MATHEMATICAL MODEL TO PREDICT THE RATE OF CAPILLARITY ABSORPTION INFLUENCED BY POROSITY IN CONCRETE STRUCTURE

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Abstract

Mathematical model to predict the rate of capillarity absorption in concrete structure has been mathematical expressed. the model was develop to predict the rate of capillarity absorption under the influence of porosity in concrete formation, the rate of capillarity in concrete structures are through some conditions in concrete formation, but the study examined the pores distribution in concrete from the heterogeneity of aggregate, this deposit high percentage of void, more so water cement ratio were considered to determine the rate of capillarity under the influence of standard application thorough mix proportion. The rates of absorption express the percentage of void and porosity thus defined concrete formations. To predict the rate of capillarity and absorption in concrete, mathematical model were find suitable to predict the rate of capillarity and absorption under the influence of porosity, the governing were derived and it produce the expressed model. The model can be applied by experts to predict the rate of capillarity rise and absorption in concrete formation.

Keywords: mathematical model, capillarity, absorption and concrete

1. Introduction

Rising countries like Nigeria including Malaysia has the most speedy growing construction industries, thus making the building material such as cement in huge demand. Much demand has been confirmed on cement for several years in Nigeria including other developing as projected by other researcher one of them is the industrial analyst Pelabur [2000: Kartini et al, 2000] an increase of 14 million tonnes from 11.4 million tonnes in the year 2000, and this would absolutely enhance in the year 2008. so, it is time we glance into the use of local, sustainable and cheap raw materials or industrial waste materials in substituting cement. One such waste material is agricultural waste rice husk, which constitute about one-fifth of 600 million tonnes of rice produced annually in the world [brozeoak, 2003]. Rice husk ash, which is the product of burning rice husk, is a pozzolanic material that can be used as partial cement replacement in concrete [Mahmud,et al 2005,zhang and Malhota,1996,chtveera and Ninityongstill,1995,Mehta and Montero, 1993,Hwang and Wu 1989,cook,1996]. Its cement replacement capability not only reduces the demand of Portland cement, but it durability performance is better [Wee et al 2000,Irasseret al 1996,Mangat and Khatib 1995kartini et al 2005,Kartini and Mamdah, 2006,Kartini et al 2007, Kartini,et al 2010]. The reasons are firstly, the consumption of portlandite, calcium hydroxide $Ca(OH)2$, reduces the formation of gypsum due to the pozzolanic reaction; secondly, densification of pore structure thus reducing the permeability because of the formation of secondary C-S-H; and thirdly, reduction of tricalcium aluminates C3A content reduces the aluminates bearing phases. Other advantages in using pozzolans in concrete to name a few are:- improved workability at low replacement levels, reduced bleeding and segregation, low heat of hydration, lower creep and shrinkage, high resistance to chemical attack at later ages and low diffusion rate of chloride ions resulting in a higher resistance to corrosion of steel in concrete [karhinah, 2000]. Studies carried by Kartini et al. [Irasser et al 200, Margat and Khatib, 1995, Kartini et al 2005, Kartini and Mamadah,2006, Kartini et al 2007], Gambhir [2000], and Hwang and Chandra [1997] showed that the outstanding technical benefit of incorporating cement replacement materials is, it Significantly improves the durability properties of concrete to various chemical attacks due to its reduced permeability arising from a pore refining process. These properties are difficult to achieve using pure Portland cement alone.

2. Theoretical Background

Increase in mass due to water in pores of the concrete constituents. After the mass of the sample in air is determined, the coarse aggregate is positioned in a wire container hang in water for determination of its obvious mass in water. The evident mass of the sample in water is less than that in air, and the loss in mass is equal to the mass of the water displaced. Therefore, the loss in mass is the mass of a volume of water equal to the aggregate volume. After the mass in water is determined, the sample is oven-dried and its oven-dry mass is determined. After the mass of the sample in air is determined, the coarse aggregate is placed in a wire basket suspended in water for determination of its apparent mass in water. The apparent mass of the sample in water is less than that in air, and the loss in mass is equal to the mass of the water displaced. Therefore, the loss in mass is the mass of a volume of water equal to the aggregate volume. After the mass in water is determined, the sample is oven-dried and its oven-dry mass is determined. Water absorption is an important factor due to the porous structure of the aerated lightweight concrete. The water absorption test is done using the samples prepared at the age of 28 days using standard method experimentally. The purpose of this test is to identify the capability of the concrete to absorb water. There are three samples for each test and the average result will be taken. These properties are particularly important in concrete, as well as being important for durability. (J.H Bungey, 1996). It can be used to predict concrete durability to resist corrosion. Absorption capacity is a measure of the porosity of an aggregates; it is also used as a correlation factor in determination of free moisture by oven-drying method (G.E Troxell, 1956). The absorption capacity is determined by finding the weight of surface-dry sample after it has been soaked for 24 hr and again finding the weight after the sample has been dried in an oven; the difference in weight, expressed as a percentage of the dry sample weight, is the absorption capacity (G.E Troxell, 1956). **A**bsorption capacity can be determine using BS absorption test. The test is intended as durability quality control check and the specified age between is 28-32 days (S.G Millard)**.**

Capillarity pore represent the space not filed by solid components of the hcp; therefore the volume and size of the capillarity void depend on the distance between unhydrated cement particles in the fresh mixed cement paste i.e. water cement ratio and degree of hydration, in well hydrated and low water cement ratio paste, the capillarity void range from 100 to 500A, whereas in high water cement ratio pastes at early ages of hydration in capillarity void may be as large as 300to 500A. Air void in concrete are due to either entrapped air during casting or internationally entrained by using an air entraining agent.

3. Governing Equation

$$\phi \frac{\partial c}{\partial t} = \frac{M}{A} \frac{\partial^2 c}{\partial X^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (1)$$

The governing equation were formulated to predict the rate capillarity and absorption on concrete structure, the model express the parameters that influence the capillarity and absorption in concrete, the deposition of porosity in concrete in the pores distributions are one of the influential parameters in capillarity and absorption in concrete formation.

There are aggregate particle voids, and there are voids between aggregate particles. As solid as aggregate may be to the naked eye, most aggregate particles have voids, which are natural pores that are filled with air or water. These voids or pores influence the specific gravity and absorption of then aggregate materials. There are aggregate particle voids, and there are voids between aggregate particles. As solid as aggregate may be to the naked eye, most aggregate particles have voids, which are natural pores that are filled with air or water. These voids or pores influence the specific gravity and absorption of the aggregate materials. The voids within an aggregate particle should not be confused with the void system which makes up the space between particles in an aggregate mass. The voids between the particles influence the design of hot mix asphalt or Portland cement concrete. The expressed mathematical equation defined the base of capillarity and absorption in concrete formation .

Substituting solution $C = XT$ into equation (1) we have

$$X^1 T = \frac{M}{A} X^{11} T \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (2)$$

Dividing equation (2) by ZT

$$\phi \frac{T^1}{T} = -\frac{M}{A} \frac{X^{11} T}{X} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (3)$$

From equation (3) we have

$$\phi \frac{T^{1}}{T} - \frac{M}{A}\left(\frac{X^{11}}{X}\right) \qquad \text{..........................} \quad (4)$$

$$\frac{\phi T^{1}}{T} - \frac{X^{11}}{X} \qquad \text{..........................} \quad (5)$$

Considering when Ln x 0 $\longrightarrow$

$$\phi T^{1} = \frac{M}{A}\frac{X^{11}}{X} - T = \lambda^{2} \qquad \text{..........................} \quad (6)$$

$$\frac{\phi T^{1}}{T} = \lambda^{2} \qquad \text{..........................} \quad (7)$$

$$\frac{X^{1}}{X} = \lambda^{2} \qquad \text{..........................} \quad (8)$$

$$\frac{M}{A} = \lambda^{2} \qquad \text{..........................} \quad (9)$$

This implies that equation (10) can be expressed as;

$$\frac{M}{A}\frac{X^{11}}{X} = \lambda^{2} \qquad \text{..........................} \quad (10)$$

$$\frac{M}{A}\frac{X^{2}}{X} = \lambda^{2} \qquad \text{..........................} \quad (11)$$

$$\phi \frac{d^{2}y}{dx^{2}} = \lambda^{2} \qquad \text{..........................} \quad (12)$$

$$\frac{M}{A}\frac{d^{2}y}{dx^{2}} = \lambda^{2} \qquad \text{..........................} \quad (13)$$

$$\frac{d^{2}y}{dx^{2}} = \frac{\lambda^{2}}{\phi} \qquad \text{..........................} \quad (14)$$

$$d^{2}y = \left(\frac{\lambda^{2}}{\phi}\right)dx^{2} \qquad \text{..........................} \quad (15)$$

$$\int d^{2}y = \int \frac{\lambda^{2}}{\phi} dx^{2} \qquad \text{..........................} \quad (16)$$

$$dy = \frac{\lambda^{2}}{\phi} dx^{2} \qquad \text{..........................} \quad (17)$$

$$dy = \frac{\lambda^{2}}{\phi} x\, dx \qquad \text{..........................} \quad (18)$$

$$\int d^2 y = \int \frac{\lambda^2}{\phi} X \, dx + C_1 \qquad \text{………………………..} \quad (19)$$

$$y = \frac{\lambda^2}{\phi} x^2 + C_1 x + C_2 \qquad \text{………………………..} \quad (20)$$

$$\boxed{y = \frac{\lambda^2}{\phi} + C_1 x + C_2} \qquad \text{………………………..} \quad (21)$$

The influence of capillarity in concrete has been stressed, the rate of absorption in concrete has been defined, the rate of absorption are determined by the air void and porosity percentage in the structural formation of concrete, this condition were expressed in the derived model were the influential parameters in the system were denoted with mathematical symbols, porosity played major roles in this condition, because concrete are made of different material whereby cement become the binding agent under the influences of cement paste, the rate of permeability in concrete were stressed in this dimension, so the condition expressed in [21] were highlight the parameters in terms of establishing their relationship, the expression were defined under the influence of capillarity action in concrete formation.

$$y = 0$$

$$\Rightarrow \frac{\lambda^2}{\phi} x^2 + C_1 x + C_2 = 0$$

Applying quadratic expression, we have

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \qquad \text{………………………..} \quad (22)$$

Where a = $\frac{\lambda^2}{\phi}$, b = C_1 and c = C_2

Concrete rate of capillarity are determined by the void and porosity in the concrete structure , mix ratio are one of the determinant in concrete workability, such quality to attained it maximum compressive strength are serious condition that should be examined in concrete formation, the rate of capillarity and absorption were examined to be on exponential state, so to evaluate the rate of capillarity in this condition, application of quadratic expression were find suitable in the system, the expression from quadratic function express the rate of capillarity and absorption in the concrete applied in the system, poor water cement ratio and quality material may develop high content of absorption and capillarity in concrete structure.

$$x = \frac{-(C_1) \pm \sqrt{(C)^2 - 4\left(\frac{\lambda^2}{\phi}\right) C_2}}{2C_1} \qquad \text{………………………..} \quad (23)$$

$$= \frac{-C_1 \pm \sqrt{C_1^2 - 4C_2 \frac{\lambda^2}{\phi}}}{2C_1} \qquad \text{..........................} \quad (24)$$

$$x = \frac{-C_1 + \sqrt{C_1^2 - 4C_2 \frac{\lambda^2}{\phi}}}{2C_1} \qquad \text{..........................} \quad (25)$$

$$x = \frac{-C_1 + \sqrt{C_1^2 - \frac{4C_2\lambda^2}{\phi}}}{2C_1} \qquad \text{..........................} \quad (26)$$

$$x = \frac{-C_1 - \sqrt{C_1^2 - \frac{4C_2\lambda^2}{\phi}}}{2C_1} \qquad \text{..........................} \quad (27)$$

$$t = 0 \; C = 0 \qquad \text{..........................} \quad (28)$$

The establishment of boundary condition were necessary in the system due to the rate of capillarity and absorption, these boundary values were express in the system to determined there various limits , the boundary condition were considered with respect to time of absorption and the concentration in the fluid , the boundary values were integrated in further derived expression were the parameters are correlate with limit of capillarity action and absorption of the fluid in the concrete structures.

Therefore, $X_{(x)} = C_1 \ell^{-M_x} + C_2 \ell^{M_{2x}}$ .... (29)

$$C_1 CosM_{1x} + C_2 SinM_{2x} \qquad \text{..........................} \quad (30)$$

$$y = \frac{\lambda^2}{\phi} + C_1 + C_2 \qquad \text{..........................} \quad (31)$$

$$\boxed{C_{(x,t)} = \left(C_1 \, CosM_1 \frac{\lambda^2}{\phi} x + C_2 \, Sin \, M_2 \frac{\lambda^2}{\phi} x \right)} \qquad \text{..........................} \quad (32)$$

The expression in [32] the absorption denoted as [C] with respect to distance and time, the expression define the condition of the concrete absorption, the rate of absorption are the influence of period and distance of absorption i.e. the thickness of the concrete in the construction project expression are precisely concern with the rate of absorption under the influence of period of absorption and the length of absorption, these include the rate of capillarity in concrete structure and distance covered in the capillarity rise. The microstructural properties are influenced by the pores distribution under the influence of void in the concrete structures.

But if $x = \frac{v}{t}$

Therefore, equation (32) can be expressed as:

$$\boxed{C_{(x,t)} = \left(C_1\, Cos M_1 \frac{\lambda^2}{\phi}\frac{v}{t} + C_2\, Sin\, M_2 \frac{\lambda^2}{\phi}\frac{v}{t} \right)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (33)$$

The rate of capillarity are determined by some certain condition, this is expressed in several ways the concept of developing mathematical model was to ensure reliable method to determine the rate of capillarity and absorption in concrete to be predictive, the will help construction engineers to monitor the rate of capillarity rise in concrete, these rate capillarity in concrete. The model in [33] express the condition of capillarity rising through velocity in the pore space distribution in the void under the influence of permeability in concrete, the rate of these parameters determined the rate of absorption thus generation of capillarity rise in concrete formation. The internal pore characteristics are very significant properties of aggregates. The size, the number, and the continuity of the pores distribution through an aggregate particle may affect the strength of the aggregate, abrasion resistance, surface texture, specific gravity, bonding capabilities, and resistance to freezing and thawing action. Absorption relates to the particle's ability to take in a liquid. Porosity is a ratio of the volume of the pores to the total volume of the particle. Permeability refers to the particle's ability to allow liquids to pass through. If the rock pores are not connected, a rock may have high porosity and low permeability Surface texture is the pattern and the relative roughness or smoothness of the aggregate particle. Surface texture plays a big role in developing the bond between an aggregate particle and a cementing material. A rough surface texture gives the cementing material something to grip, producing a stronger bond, and thus creating a stronger hot mix asphalt or Portland cement concrete. Surface texture also affects the workability of hot mix asphalt, the asphalt requirements of hot mix asphalt, and the water requirements of Portland cement concrete. Some aggregates may initially have good surface texture, but may polish smooth later under traffic. These aggregates are unacceptable for final wearing surfaces. Limestone usually falls into this category. Dolomite does not, in general, when the magnesium content exceeds a minimum quantity of the material. The expressions develop to the rate of both high or low capillarity and absorption under the influence of degree of porosity.

4. Conclusion

The rate of capillarity and absorption are base on the percentage porosity in concrete formation. The pore distribution in concrete are through the rate of heterogeneity of concrete material aggregate, water cement ratio are one of the influence that determine the rate of porosity in its formation, the rate of absorption are determine through the formation of concrete, the constituents under the influence of water cement ratio, another major influence is the rate of compaction. The express model was formulated considering the major variables in the system. The derived model were able to correlate the parameter in terms of their relation were they are expressed in the system. There are aggregate particle voids, and there are voids between aggregate particles. As solid as aggregate may be to the naked eye, most aggregate particles have voids, which are natural pores that are filled with air or water. These voids or pores influence the specific gravity and absorption of the aggregate materials. There are aggregate particle voids, and there are voids between aggregate particles. As solid as aggregate may be to the naked eye, most aggregate particles have voids, which are natural pores that are filled with air or water. These voids or pores influence the specific gravity and absorption of the aggregate materials. The voids within an aggregate particle should not be confused with the void system which makes up the space between particles in an aggregate mass. The voids between the particles influence the design of hot mix asphalt or Portland cement concrete. The hardness of the minerals that make up the aggregate particles and the firmness with which the individual grains are cemented or interlocked control the resistance of the aggregate to abrasion and degradation. Soft aggregate particles are composed of minerals with a low degree of hardness. Weak particles have poor cementation. The rate of percentage of porosity determine the rate of absorption and capillarity rise in concrete formation, there are under the influence of concrete characteristics, the express model were able to monitor the rate of capillarity and absorption under the influence of water cement ratio for concrete mix.

References

[1] American Concrete Institute 2007 advancing concrete knowledge American Concrete Institute Advancing concrete knowledge
Cement and aggregate Australia: 2006 Curing of concrete www.concrete .net.au

[2] Kartini, K. Mahmud, H.B. Hamidah, M.S. 2010 absorption and permeability performance of selangor rice husk ash blended grade 30 concrete

[3] Pelabur Magazine –PNB (2000). *Sektor pembinaan pulih: Permintaan simen naik*. Edition 5 (8522/12/2000), 36-37.

[4] Bronzeoak Ltd. (2003). *Rice husk ash market study*. EXP 129, DTI/Pub URN. 03/668.

[5] Mahmud, H.B.; Edi Majuar.; Zain, M.F.M.; and Hamid, N.B.A.A. (2005). Strength, durability and shrinkage of high strength rice husk ash concrete. *7th International Symposium on Utilization of High Strength/High Performance Concrete*, Washington D.C, USA

[6] Zhang, M.H.; and Malhotra, V.M. (1996). High performance concrete incorporating RHA as a supplementary cementing material. *ACI Material Journal*, 93(6), 629-639.

[7] Chatveera, B.; and Nimityongskul, P. (1995). High strength concrete using modified rice husk ash. *Proc. of the 4th International Conference on Concrete Engineering and Technology*, TS IV 1-12, Malaysia

[8] Mehta, P.K.; and Monteiro, J.M. (1993). *Concrete structure, properties and materials*. 2nd edition, Prentice-Hall, Eaglewood Cliffs, New Jersey, ISBN 0- 13-175621-4, 113-264.

[9] Hwang, C.L.; and Wu, D.S. (1989). Properties of cement paste containing rice husk ash. *ACI*, SP-1. 14, Editor: Malhotra, V.M., 733-765.

[10] Cook, D.J. (1986). *Rice husk ash in cement replacement materials*. Concrete Technology and Design, Edited by Swamy, R.N., Surrey University Press, United Kingdom, Vol. 3, 171-196.

[11] Wee, T.H.; Suryavanshi, A.K.; Wang, S.F; and Anisur Rhaman A.K.M. (2000). Sulfate resistance of concrete containing mineral admixtures. *ACI Materias Journal*, 97(5), 536-549.

[12] Irasser, E.F.; Did Miao, A.; and Batio, O.R. (1996). Sulfate attack on concrete with mineral admixtures. *Cement and Concrete Research*, 26(1), 113-123.

[13] Mangat, P.S.; and Khatib, J.M. (1995). Influence of fly ash, silica fume and slag on sulfate resistance of concrete. *ACI Materials Journal*, 92(5), 542-552.

[14] Krishna, R.N. (2008). Rice husk ash – An ideal admixture for concrete in aggressive environment. *Seminar on recycling Construction Waste for Sustainable Development*. Organized by CREAM, UiTM, ACCI and CSM, Kuala Lumpur

[15] Gambhir, M.L. (2006). *Concrete technology*. 3rd Edition, New Dehli: Tata McGraw-Hill Publishing, ISBN 0-07-058374-9, 1-658

[16] Mehta P.K and Mannjshan, D 1980 pore size distribution and permeability of harden cement paste, chemistry of cement pastes, chemistry of cement, 7th intertnational congress, p.5

[17] Parrott L.L and Killoh D. C prediction of cement hydration, chemistry and chemically related , properties of cement of cement British ceremics:proceeding 35:41-53 sept 1984

[18] Parrott L.L: Effect of changes in U.K cement upon strength and recommendation curing time concrete journal of the concrete pp22-24 septh 1995

[19] Mehta P. K : concrete structures properties and material, p 450, pretence-hall inc Eng wood cliff, new jersey (Jan, 1986)

[20] Feldman R. F and Screda, P.S A model for hydrated port Harcourt paste a deduced from sorption –length change and mechanical properties Rem Bulletin,1,(6) 509-520, Paris (Nov- Dec, 1968)

[21] Vamchandram V. S and James J.B. (1999) Handbook of Analytical Techniques in concrete science principle and practice, Noves publication, William Andrew publishing, llc Norwich, new U.S.A, 540-561