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Research article

MODELING THE DEGREE OF SATURATION ON CONCRETE STRUCTURE INFLUENCED BY PRESSURE INDUCED WATER

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Abstract

Material analysis through standard evaluation should be on of the best practice in construction , concrete structure are designed base on the types of load it can carry, the design of concrete structure has lots of principle in other to achieve its goal for any propose construction project, when concrete are expose to several rain it will continue to reduce its strength, the condition are base on the constituent use to form the concrete, permeability in concrete are the major parameters that determine the degree of saturation in concrete structure, the rate of saturation are determined by the rate of permeability in concrete, this condition are reflected from the homogenous of the aggregate, if heterogeneous aggregate are applied in concrete structure the percentage of permeability will be very high. The condition will no doubt increase the degree of saturation influenced by water induced pressure, the pressure in the study is the constant high rain intensities experience in most part of deltaic environment, several environmental factors has been stress as one of the major factors on high degree of saturation influenced by water induced pressure in concrete structure, mathematical model to monitor the degree of saturation influenced by water induced pressure were express through mathematical equation, the expression were developed through the influential parameters in the system, the express mathematical equation were derived to express there the rate of penetration of water through induced pressure, the derived mathematical model will definitely determine the degree of saturation influenced by water induced pressure in concrete structures.

Keywords: modeling degree of saturation, concrete structures and pressure induced water.

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1. Introduction

Since cement paste envelopes the aggregate particles in hardened concrete, it is the permeability of the paste that has the greatest influence on the permeability of concrete (Collins et al 1996). Permeability of the hydrated cement paste is closely related to the capillary porosity, which depends mainly on the solid/space ratio of paste. At a given degree of hydration, porosity increases with decrease in the solid/space ratio of paste. Therefore, the solid/space ratio, which is inversely proportional to the water/cement ratio, determines the permeability. The permeability steeply increases with decrease in the solid/space ratio below a critical value of 0.7 (Mehta and Monteiro, 1993). For the same degree of hydration, introducing sand particles into the cement paste, results in higher permeability (Halamickova and Detwiler, 1995). However, it is widely reported that there is no defined relationship between porosity and permeability. Large variations in permeability of concrete having nominally similar porosities are frequently observed (Nayme and Liston, 1980, Mehta and Mamohan, 1980, Hughes, 1995, and Biatha, 1980). Permeability of concrete is not so much a function of the porosity as it is a function of the size, distribution and the continuity of capillary pores. High quality concrete at an early age has a total void volume of about 20 to 25% and about 10 to 25% at a mature age (Hughes,1980 Mehta and Manmohan 1980) observed that the permeability of hardened cement paste is negligible (irrespective of its porosity The volume of pores in most natural aggregates is usually under 3% and rarely exceeds 10% (Mehta and Monteiro,1993), while the capillary pores in a typical cement paste range from 20 to 40%. Many researchers have attempted to develop the applicable relationship between permeability and pore pressure since (Powers et al 1958) first reported the relations between permeability and porosity. (Nayme and Illston 1980) reported an influence of maximum continuous pore radius on permeability. (Hughes, 1985) reported the influence of average pore radius on permeability by using the Poiseuille formula. (Mehta and Monteiro,1993) took pore size distribution into account and proposed an empirical formula to express the relationship between permeability and pore structure. A model relating permeability of cement paste with its pore structure, determined by MIP, has been reported by (Cui and Cahyadi, 2001 Shamsad, et al 2005).

2. Theoretical background

Most concrete only partially saturated and the initial ingress of water and dissolved salt is dominated, at least initially, by capillary absorption rather than either water permeability or ion diffusions. A wide variety of water absorption test of concrete have been developed. These test measure the weight gain of a sample, volume of water entering the sample, depth of penetration, or a combination thereof, by either complete immersion of dry sample in water, exposing only one face to water or spraying the specimen surface with water. Absorption is either measured at a single, arbitrary time or measuring the rate of absorption (by change of mass).although in all these test the absorption process is proportional to the square root of time over a specified time period, the sorptivity varies a great deal between test .the water penetrating test, standardized in developed nation like Germany, this method involves subjecting one end of the unsaturated concrete to a pressure head. The measure of water penetrations are achieved either by measuring the volume of water entering the sample or by splitting open the cylinder and measuring the average depth of discoloration (due to wetting) taken as equal to the depth of penetration, Moreso the usual external hydraulic force in structure are small compared to that of capillarity tension. The study from this dimension are from experimental method but the study focus on the analytical modeling techniques, this is to apply mathematical principle to model the behaviour of saturation on concrete structure. There are several equations many applied to model water penetration most of this equation could not predict the rate of water entering into concrete structure, but the model develop to monitor the rate of saturation on concrete structure influenced by pressure induced water will definitely develop better solution,, most structure are designed and construct for different purpose as development is every day activities wanted by man, but in developing nation were most infrastructures are done by government, several infrastructures are proposed by governments to be completed as specified, but in most time they do not complete the structures, most of the projects are abounded, based on this process, structures designed to carry impose loads suffers lots of deformation from several angles, reinforced concrete structures suffers lots of several attacks from lots of environmental effect, the paramount problem concrete structure face is pressure induced water from several constant high rain intensities, especially from the deltaic environment were lots pollution has generated lots of acidic rains, this constant rain on such structure results constant water induced on the structure resulting to degradation of compressive strength of the concrete. The degradation of these structures is through the increase of degree of saturation penetrating from the degree of permeability in the concrete structure water induced pressure, the rate of permeability in such structure can be determined from the type of material use to form the concrete, for water induced pressure in concrete structure reduce the compressive strength of the concrete due high rain intensities, the rate of absorption of water induced through the pressure determined the rate permeable the concrete casted to carry an impose load, absorption rate can be determined from this dimension. The developed mathematical equation formulated were expressed base on several condition that cause the rate water induced pressure in concrete structures. The developed governing equation\ is stated below.

3. Governing Equation

$$q\frac{1}{A}\frac{\partial c}{\partial t} = K\Delta h\frac{\partial c}{\partial x} \qquad \text{…………..} \qquad (1)$$

Equation (1) is the governing equation that express the degree of saturation on concrete structure influenced by water induced pressure most concrete constituent are made of homogeneous and heterogeneous fine and coarse aggregates , the two types of aggregate are applied to form concrete depending on the type of structures and types of load it will carry, these conditions determine the rate permeability percentage the concrete will generate, the governing equation express will thoroughly the parameters that determined the rate of saturation influenced by pressured induced water.

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

$$q\frac{1}{A}XT^{1} = K\Delta hX^{1}T \qquad \text{…………..} \qquad (2)$$

$$q\frac{1}{A}\frac{T^{1}}{T} = K\Delta h\frac{X^{1}}{X} \qquad \text{…………..} \qquad (3)$$

$$q\frac{1}{A}\frac{T^{1}}{T} = K\Delta h\left(\frac{X^{1}}{X}\right) \qquad \text{…………..} \qquad (4)$$

$$\frac{T^1}{T} = \frac{X^1}{X} \qquad \text{…………..} \qquad (5)$$

Considering when $Ln\,x \to 0$

$$\frac{T^1}{T} = K\Delta h\frac{X^1}{X} - T = \lambda^2 \qquad \text{…………..} \qquad (6)$$

$$q\frac{1}{A}\frac{T}{T} = \lambda^2 \qquad \text{…………..} \qquad (7)$$

$$K\Delta h\frac{X^1}{X} \; = \lambda^2 \qquad \text{…………..} \qquad (8)$$

$$K\Delta h \; = \lambda^2 \qquad \text{…………..} \qquad (9)$$

This implies that equation (9) can be expressed

$$K\Delta h\frac{X^1}{X} \; = -\lambda^2 \qquad \text{…………..} \qquad (10)$$

$$K\Delta h\frac{X^1}{X}\frac{dy}{dx} \; = \lambda^2 \qquad \text{…………..} \qquad (11)$$

$$K\Delta h\frac{dy}{dx} \; = \lambda^2 \qquad \text{…………..} \qquad (12)$$

$$\frac{dy}{dx} \; = \frac{\lambda^2}{K\Delta h} \qquad \text{…………..} \qquad (13)$$

$$dy \; = \left(\frac{\lambda^2}{K\Delta h}\right)dx \qquad \text{…………..} \qquad (14)$$

$$\int dy \; = \int \frac{\lambda^2}{K\Delta h}dx \qquad \text{…………..} \qquad (15)$$

$$dy \; = \frac{\lambda^2}{K\Delta h}\times dx \qquad \text{…………..} \qquad (16)$$

$$\frac{dy}{dx} \; = \frac{\lambda^2}{K\Delta h} \qquad \text{…………..} \qquad (17)$$

$$dy \; = \frac{\lambda^2}{K\Delta h} \; dx \qquad \text{…………..} \qquad (18)$$

$$\int dy \; = \int \frac{\lambda^2}{K\Delta h}dx + C_1 \qquad \text{…………..} \qquad (19)$$

$$y = \frac{\lambda^2}{K\Delta h}\int dx + C_1 \qquad \text{………….. (20)}$$

$$\frac{\lambda^2}{K\Delta h}x + C_1 \qquad \text{………….. (21)}$$

$$y = \frac{\lambda^2}{K\Delta h}x + C_1 \qquad \text{………….. (22)}$$

Calculations on the indoor radon entry rate by pressure-driven flow rely on the permeability coefficient of the concrete. The permeability coefficient is the transport coefficient for permeability, and is the proportionality constant in Darcy's law that relates fluid flux through a porous material (e.g., concrete) to the pressure gradient. In typical radon problems, the pressure difference across the foundation walls may range between 1 - **20** Pa. However, there exists very little experimental data on the permeability coefficient of air in concrete for these low-pressure differences. On the process of increase in degree of saturation through permeability in concrete, other influence that degrade the compressive strength of concrete are express in the process of high degree of increase in saturation, the coefficient of permeability in concrete structure are expressed from the constituent of the concrete fine and coarse aggregates. More so concrete is a type of porous material that can be physically and chemically damaged due to its exposure to various environments from the placing of concrete to its to the service life. In particular some external hazardous elements, such as sulfate, chloride ion, and carbon dioxide, permeate in concrete over a long-term period as a solution or a gaseous state and cause physical damage due to chemical reactions. These reactions affect the corrosion of steel bars applied in concrete and that decreases the durability life and strength of such steel bars. The stated consequences from the state environmental conditions affect the compressive strength of concrete due to constant pressure induced water, such environmental condition has been express in the model by application of separation of variables through discretizing of the parameters in the system. The application from equation (2) to (22) thoroughly express the parameters, this streamline the functions of the parameters in the system.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2ac} \qquad \text{………….. (23)}$$

$$a = \lambda^2, \; b = \lambda^2 C_1$$

$$x = \frac{-\left(\lambda^2 C\right) \pm \sqrt{\left(C_1\right)^2 - 4n\frac{\left(\lambda^2\right)}{K\Delta h}}}{2\frac{\lambda^2}{K\Delta h}} \qquad \text{………….. (24)}$$

$$x = \frac{-\lambda^2 C \pm \sqrt{\lambda^2 C_1^{\,2} - 4\frac{\lambda^2}{K\Delta h}}}{2\frac{\lambda^2}{K\Delta h}} \qquad \text{………….. (25)}$$

$$x = \frac{-\lambda^2 C \sqrt{\lambda^2 C_1^{\ 2} - 4\frac{\lambda^2}{K\Delta h}}}{2\frac{\lambda^2}{K\Delta h}} \qquad \ldots\ldots\ldots\ldots.. \quad (26)$$

Further expression to derived the model continue through the application quadratic functions the expressed quadratic application were find suitable to express the parameters function in accordance with their relevant area in the system the rate of permeability determine the rate of water induced pressure in concrete structure, this condition are expressed through the application of these concept the application of the quadratic approach will definitely defined the rate of pressure in concrete structure.

Substituting equation (26) into the following boundary and initial values condition

$$t = 0, C = 0 \qquad \ldots\ldots\ldots\ldots.. \ (27)$$

To monitor the rate water induced pressure through degree of saturation in concreter, boundary value were established , this mathematical concept are applied to determine the parameters limits in the system, the boundary condition will be applied to express the condition of water penetration through induced pressure, the constituents of the materials fine coarse and cement that form concrete experiences setting within certain time through change of state under the influence of hydration through cement paste. The condition of concrete structure in attaining strength demand several stage through the hydration from the binging agent between fine sand coarse aggregates and water. Therefore,

$$X_{(x)} = C_1 \ell - M_{1x} + M_{2x} \qquad \ldots\ldots\ldots\ldots.. \quad (28)$$

$$C_1\, CosM_{1x} + Sin\, M_{2x} \qquad \ldots\ldots\ldots\ldots.. \quad (29)$$

$$y = \frac{\lambda^2}{K\Delta h} + C_1 \qquad \ldots\ldots\ldots\ldots.. \quad (30)$$

$$C_{(x,t)} = \left[C_1\, CosM_1 \frac{\lambda^2}{K\Delta h}\frac{d}{v} + Sin\, M_2 \frac{\lambda^2}{K\Delta h}\frac{d}{v} \right] \qquad \ldots\ldots\ldots\ldots.. \quad (31)$$

This study attempts to develop a method that penetrates pressure induced water through the rate of permeability in concrete , the rate environmental effect in most cases develop corrosion inhibitors up to the location of steel bars and investigate the penetration depth of corrosion inhibitors by verifying moisture migration in concrete under applied pressure. In the penetration of water in concrete, the penetration depth are according to the passage of time, it can be estimated using the Darcy's law, this concept express the coefficient of permeability in concrete structure which is also applicable to the penetration of sand stratums under low pressure conditions. Meanwhile, it is necessary to analyze the penetrative diffusion flow accompanied by internal deformation under high pressure conditions. Other conditions are from constant water induced pressure in concrete, the material in concrete varies, this is in accordance with the effect from environmental condition , most structures abandoned in deltaic environment are abound to experience fast deterioration of concrete strength from this environmental factors ,the developed model in (31) are express to monitor the rate penetration with respect to time, the express model in (31) assess the rate of penetration of pressures induced water under the influence of time in the system.

But if $T = \frac{d}{v}$

Therefore, equation (31) will be expressed as the form

$$C_{(x,t)} = \left[C_1\, CosM_1 \frac{\lambda^2}{K\Delta h} x\ Sin M_2 \frac{\lambda^2}{K\Delta h} \right] \quad \text{…………..} \quad (32)$$

The mathematical expression in (32) is the model equation to monitor the degree of saturation influenced by water induced pressures, the study consider the rate of abandoned construction project in deltaic environment, the study area has several environmental factors that lead to high degree of saturation influenced by water induced pressure the rate of environmental effect concrete structure affected by environmental condition develop fast degradation of concrete deformation. More so Efflorescence is a surface defect of concrete which has more aesthetic rather than structural consequences. Basically, it is a crystalline deposit of salts (carbonates, sulphates, chlorides), usually white, that forms on or near the surface of concrete products Efflorescence usually consists of carbonates of calcium, sodium and potassium originating from the cement, but can also consist of salts from the surrounding environment. Iron oxides from the concrete can give the efflorescence a yellow / brown tint. The bulk of the various efflorescence types is calcium carbonate, also known as «lime bloom» or «lime weeping ». Efflorescence forms when soluble salts are dissolved by water migrating through the material and then precipitated at its surface by chemical reaction or by evaporation of the salt solution. These can be developed from environmental conditions. The final express model considered these condition that attack concrete in deltaic environment that are more severe, the expression from this dimension will definitely monitor the rate saturation influenced water induced pressure.

4. Conclusion

Permeability of concrete is not so much a function of the porosity as it is a function of the size, distribution and the continuity of capillary pores. High quality concrete at an early age has a total void volume of about 20 to 25% and about 10 to 25% at a mature age several studies has carried out to establish the relation between permeability and pressure induced water in concrete structures, the rate of permeability are through the distribution of the micropores in concrete, this condition are determine from the type of materials applied to form a concrete structures, for example the type of aggregates use to form concrete develop different degree of permeability base on the rate uniformity under the influence of gradations. If the concrete aggregate are heterogeneous it implies that the concrete will definitely produce high percentage of permeability, the rate of saturation will decrease, constant increase of saturation after curing the increase the strength of the concrete ,further induced of water penetrating through the rat of permeability will definitely decrease the compressive strength of the concrete and it performance, the durability of the structural element will definitely experience structural deformation from this dimension. The developed model will monitor the rate of saturation and determine the rate of water induced pressure in concrete structures.

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