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Research article

MATHEMATICAL MODEL TO MONITOR DIFFUSED CHLORIDE COEFFICIENT INFLUENCED BY INGRESS AND REHYDRATION ON MASS CONCRETE STRUCTURE

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Abstract

Mathematical model to monitor diffused chloride coefficient influenced by ingress and rehydration on mass concrete structure has been evaluated. This concept was carried out to monitor the rate of diffused chloride in mass concrete formation, the rate of chloride coefficient are through several concrete characteristics formations, water cement ratio are expressed as one of the major influences in concrete performance, this include the rate of workability in its formation and its compressive strength, the model were develop to monitor the period of ingress from diffused chloride, the study is imperative because it will definitely predict the rate of diffused chloride under the influences of ingress and rehydration of mass concrete structures, construction engineers will applied the expressed mathematical model to monitor the rate of diffused chloride through ingress and rehydration in construction industries, the study has also express the influence from micropores in concrete through the percentage of porosity and void in concrete formation, drastic measure will be applied to avoid excessive porosity that will allowed serious attack from diffused chloride in concrete formations.

Keywords: Mathematical model, diffused chloride coefficient, rehydration and mass concrete structure

1. Introduction

The capability of chloride ions to break through the concrete should be known for design as well as quality control purposes. The infiltrations of the concrete by chloride ions some are very slow in chloride transport, most times it a slow process. It cannot be determined precisely in a time frame that would be useful as a quality control measure. Therefore, in order to assess chloride infiltration, a test technique that accelerates the procedure is needed, to allow the determination of diffusion values in a reasonable time. The speeds of ingress of chlorides into concrete are determined on the pore structure of the concrete, which is pretentious by factors as well as materials, construction practices, and age. The infiltration of concrete is clearly connected to the pore structure of the cement paste matrix. These are pressured by water-cement ratio of the concrete, the inclusion of extra cementing materials which serve to subdivide the pore structure [McGrath, 1996], and the degree of hydration of the concrete. The older the concrete, the superior level of hydration that has occurred and thus the more highly developed will be the pore structure. This is especially true for concrete containing slower reacting supplementary cementing materials such as fly ash that require a longer time to hydrate [Tang and Nilsson, 1992; Bamforth, 1995]. The rate of chloride penetration into concrete is affected by the chloride binding capacity of the concrete. Concrete is not inert relative to the chlorides in the pore solution. A portion of the chloride ions reacts with the concrete matrix becoming either chemically or physically bound, and this binding The rate of chloride penetration into concrete is affected by the chloride binding capacity of the concrete. Concrete is not inert relative to the chlorides in the pore solution. A portion of the chloride ions reacts with the concrete matrix becoming either chemically or physically bound, and this binding reduces the rate of diffusion. However, if the diffusion coefficient is measured after steady-state conditions have been reached, then all the binding can be presumed to have taken place and this effect will not then be observed. If a steady state condition has not been reached, then not all the binding will have occurred and this will affect the results. The chloride binding capacity is controlled by the cementing materials used in the concrete. The inclusion of supplementary cementing materials affects binding, though the exact influence is unclear [Byfors, 1986; Rasheeduzafar, et al., 1992; Sandberg and Larrson, 1993; Thomas, et al., 1995]. Also, the C3A content of the cement influences its binding capacity, with increased C3A content leading to increased binding [Holden, et al., 1983; Midgely and Illston, 1984; Hansson and Sorenson, 1990]. Another method to accelerate the flow of chloride ions into concrete is by exposing one face of the concrete to a solution containing chloride that is under pressure. This will serve to drive the chlorides into the concrete under both convection and diffusion. This will be governed by the equation [Freeze and Cherry, 1979]: The depth to a known chloride concentration can be conveniently determined using a colorimetric technique such as the silver nitrate spray procedure described previously. This value can also be used to determine water permeability using the Valenta equation [Valenta, 1969].

2. Theoretical background

The rate of ingress of chlorides into concrete depends on the pore structure of the concrete which is affected including material, construction practice, and age. The permeability of concrete is obliviously related to pores structure of cement paste matrix. This will be influenced by the water cement ratio of concrete, the inclusion of supplementary cementing materials which serve to subdivide the pore structure, the hydration that has the degree of hydration of the concrete. The older the concrete, the greater amount of hydration that has occurred and thus the more highly develop will be the pore structure. These especially true for concrete containing slower reacting supplementary cementing material such as fly ash that require to a longer time to hydrate.

Reinforced concrete structures are exposed to harsh environments yet is often expected to last with little or no repair or maintenance for long periods of time (often 100 years or more). To do this, a durable structure needs to be produced. For reinforced concrete bridges, one of the major forms of environmental attack is chloride ingress, which leads to corrosion of the reinforcing steel and a subsequent reduction in the strength, serviceability, and aesthetics of the structure. This may lead to early repair or premature replacement of the structure. A common method of preventing such deterioration is to prevent chlorides from penetrating the structure to the level of the reinforcing steel bar by using relatively impenetrable concrete. The ability of chloride ions to penetrate the concrete must then be known for design as well as quality control purposes. The penetration of the concrete by chloride ions, however, is a slow process. It cannot be determined directly in a time frame that would be useful as a quality control measure. Therefore, in order to assess chloride penetration, a test method that accelerates the process is needed, to allow the determination of diffusion values in a reasonable time. Capillary absorption, hydrostatic pressure, and diffusion are the means by which chloride ions can penetrate concrete. The most familiar method is diffusion, the movement of chloride ions under a concentration gradient. This occurs when concrete have a continuous liquid phase and there must be a chloride ion concentration gradient.

3. Governing equation

$$\phi \frac{\partial c}{\partial t} = n \frac{\partial c}{\partial x} + DCi \frac{\partial c}{\partial t} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

The governing equation expresses the rate of diffused chloride coefficient influenced by ingress and rehydrations on mass concrete structures, this expression are based on the parameters used to formulate the system for the study. To express more on the study it has to relate some certain mechanism for chloride ingress is permeation, driven by pressure gradients. If there is an applied hydraulic head on one face of the concrete and chlorides are present, they may permeate into the concrete. A situation where a hydraulic head is maintained on a highway structure is rare, however.

Using $C = XT$ as solution for equation (1)

$$\phi T^1 = nX^1T + DCi\, X^1T \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Dividing equation (2) by ZT

$$\phi \frac{T^1}{T} = \frac{nX^1}{X} + DCi \frac{X^1}{X} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

From equation (3) we have

$$\phi \frac{T^1}{T} = -\lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$\phi T^1 + \lambda^2 T = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Also from equation (3) we have

$$\phi T^1 = \frac{nX^1}{X} + DCi \frac{X^1}{X} = \lambda^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Also from (2) we have

$$\frac{nX^{1}}{X} + DCi\frac{X^{1}}{X} = \lambda^{2} \qquad \text{……………………….. (7)}$$

$$n\frac{X^{1}}{X} + DCi\frac{X^{1}}{X} = 0 \qquad \text{……………………….. (8)}$$

$$X^{1} + X^{1} + \frac{1}{\phi}X = 0 \qquad \text{……………………….. (9)}$$

$$X^{1} + X^{1} + \beta X = 0 \qquad \text{……………………….. (10)}$$

Where $\beta = \frac{1}{\phi}$ ……………………….. (11)

Suppose $X = \ell^{M_x}$ in (10)

$$X^{1}M_{1}\ell^{M_x},\ X^{1} = M^{2}\ell^{M_x} \qquad \text{……………………….. (12)}$$

$$XM^{2}\ell^{M_x} + M\ell^{M_x} - \beta\ell^{M_x} = 0 \qquad \text{……………………….. (13)}$$

$$\left(XM^{2} + M - \beta\right)\ell^{M_x} = 0 \qquad \text{……………………….. (14)}$$

But $\ell^{M_x} \neq 0$

$$XM^{2} + M - \beta = 0 \qquad \text{……………………….. (15)}$$

Applying quadratic expression, we have

$$M_{1,2} = \frac{-1 \pm \sqrt{1+4\beta x}}{2x} \qquad \text{……………………….. (16)}$$

$$M_{1} = \frac{-1 + \sqrt{1+4\beta x}}{2x} \qquad \text{……………………….. (17)}$$

$$M_{2} = \frac{-1 - \sqrt{1+4\beta x}}{2x} \qquad \text{……………………….. (18)}$$

Therefore,

$$X_{(x)} = C_{1}\ell^{M_x} + C_{2}\beta\ell^{M_{2x}} \qquad \text{……………………….. (19)}$$

$$= C_{1}CosM_{1x} + C_{2}SinM_{2x} \qquad \text{……………………….. (20)}$$

Solving from equation (3)

$$\boxed{T_{(t)} = T_{(o)}\,\ell^{\frac{-\lambda^{2}}{\phi}t}} \qquad \text{……………………….. (21)}$$

The expressed model in [21] is precise on the rate of time on diffused chloride coefficient influenced by ingress and rehydration, the period of migration including the rate of diffuse initial concentration to final concentration, the period coefficient of chloride are ingress and rehydrate through constant saturation or absorption, the expressed model at this stage, are monitoring the condition to determine the time of hydration. More studies have been carried precisely on port land cement, such concept especially the useful one ordinary Portland cement. When Portland cement is mixed with water, heat is liberated. This heat is called the heat of hydration, it generate the result of the exothermic chemical reaction between cement and water. The heat generated by the cement's hydration raises the temperature of concrete. During normal concrete construction, the heat is dissipated into the soil or the air and resulting temperature changes within the structure are not significant. However, in some situations, particularly in massive structures, such as dams, mat foundations, or any element more than about a meter or yard thick, the heat cannot be readily released. The mass concrete may then attain high internal temperatures, especially during hot weather construction, or if high cement contents are used When Portland cement is mixed with water, heat is liberated. However, in some situations, particularly in massive structures, such as dams, mat foundations, or any element more than about a meter or yard thick, the heat cannot be readily released. The mass concrete may then attain high internal temperatures, especially during hot weather construction, or if high cement contents are used. The expressed model was able to consider these parameters in detailed on the rate of diffused chloride coefficient influenced by ingress on rehydration in mass concrete structures.

Hence the solution of equation (21) can be rewritten

$$C_{(x,t)} = \left(C_1 \, CosM_{1x} + C_2 \, Sin\, M_{2x}\right)\ell^{\frac{-\lambda^2}{\phi}t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (22)$$

The expression in this dimension detailed several conditions under the influence of time and distance simultaneously, the rates of exponential condition were stressed in the study, thus influences of porosity base on the micropores distribution in mass concrete formation, most concrete formation are heterogeneity, therefore the rate of porosity percentage are at higher rate in mass concrete structures. Such condition were thoroughly examined on the system, this implies that the rate of diffused chloride are through the rate of porosity in mass concrete, the rate of ingress are determined by the rate of micropores under the influences of void rate in mass concrete, both parameters establish a relationship on the determination deposition of diffused chloride in mass concrete. The rates of rehydration at this condition are base on the reaction of chloride with cement paste in the process of ingress in the concrete.

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

Therefore, equation (22) can be written as

$$C_{(x,t)} = \left(C_1 \, CosM_1 \frac{v}{t} + C_2 \, Sin\, M_2 \frac{v}{t}\right)\ell^{\frac{-\lambda^2}{\phi}t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

The expression in [23] shows the purpose of speed of flow on the migration diffused chloride in the concrete structure, this condition also include ingress on rehydration on the migration process on diffused chloride in concrete formation. A more common transport method is absorption. Concrete surface is exposed to the environment, it will undergo wetting and drying cycles. When water (perhaps containing chlorides) encounters a dehydrated surface, it will be drawn into the pore arrangement though capillary suction. Assimilation is determined by dampness gradients. More so, apart from mass concrete characteristically, the deepness of drying is little, though, and this transport mechanism will not, by itself, bring chlorides to the level of the reinforcing steel unless the concrete is of tremendously deprived quality and the reinforcing steel is shallow. It does serve to quickly bring chlorides to some depth in the concrete and reduce the distance that they must diffuse to reach the rebar [Thomas, et al., 1995].

Of the three transport mechanisms described above that can bring chlorides into concrete to the level of the rebar, the foremost technique is that of dispersal. It is unusual for a important hydraulics head to be exerted on the structure, and the effect of absorption is limited to a shallow wrap area. In the bulk of the concrete, the micropores remain soaked and chloride ion migration is controlled by concentration gradients. The speed of ingress of chlorides into concrete depends on the pore structure of the concrete, which is affected by factors as well as materials, construction practices, and age. The penetrability of concrete is visibly connected to the pore structure of the cement paste matrix. This will be pressured by the water-cement ratio of the concrete, the inclusion of supplementary cementing materials which serve to subdivide the pore structure [McGrath, 1996], and the degree of hydration of the concrete. The older the concrete, the greater amount of hydration that has occurred and thus the more highly developed will be the pore structure. This is especially true for concrete containing slower reacting supplementary cementing materials such as fly ash that require a longer time to hydrate [Tang and Nilsson, 1992; Bamforth, 1995].

4. Conclusion

Mathematical model to monitor diffused chloride coefficient influenced by ingress and rehydration on mass concrete structure has been evaluated. The expressed developed governing equations were developed to monitor the rate of diffused chloride coefficient under the pressure of ingress in mass concrete structures. Several parameters that influence the system were considered when developing the governing equation, the expressed mathematical equation was derived considering various condition that develop diffused chloride, the rate of ingress and rehydration were expressed in detailed, the model develop some boundary conditions to monitor their various limit at different conditions. These boundary values were integrated on the derived equation in other to express their function in detailed in concrete formation. In most cases, however, excessive amounts of chloride in concrete originate from external sources. The penetration of chlorides into the concrete occurs by various transport mechanisms depending on the exposure conditions. There are important amounts of chlorides in salt water, but chlorides are more limited in groundwater and soil. Developed countries de-icing salts are used to combat the accumulation of snow and ice on transport infrastructures are the maximum source of chlorides. In seawater, chlorides frequently pose a superior threat to steel in concrete than sulfates do to concrete as calcium sulphoaluminate or ettringite (the enormous response product of sulfate and tricalcium aluminate in the cement) is additional soluble in the presence of chloride and thus does not development destructive. Portland cement reacts with sodium chloride to form chloroaluminates or *Friedel's* salt, thus immobilizing the *chloride* and reducing the *free chloride ions* available to depassivate the steel. In most cases, too much amounts of chloride in concrete invented from exterior sources. The infiltration of chlorides inside concrete occurs by a variety of transport, it is determined on the exposure conditions. There are important amounts of chlorides in seawater.

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