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Ahmad Jabbar Hussain Alshimmeri
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ABSTRACT

26 pipes have been cast and tested in this research. **9** specimens were cast with different diameters and thicknesses to study the structural behavior of ferrocement pipes. The mix ratio of the mortar used was 1:2 (cement /sand) by weight and the w/c was 0.45. Through applying simply supported load test to the specimens the deflection on the pipe circumference in the middle were recorded besides the ultimate loads and cracks. The results showed that the increase in thickness causes the ultimate strength of ferrocement pipes to increase when keeping the diameter constant. When changing pipe thickness from 20 to 30 and 40mm and keeping diameter 300mm, the increase in the ultimate strength is about 10.3% and 24.1% respectively. When changing pipe thickness from 20 to 30 and 40mm and keeping diameter 350mm, the increase in the ultimate strength is about 22.0% and 57.7% respectively. When changing pipe thickness from 20 to 30 and 40mm and keeping diameter 400mm, the increase in the ultimate strength is about 31.8% and 72.7% respectively. The increase in diameter causes the ultimate strength of ferrocement pipes to decrease when keeping the thickness constant. When changing pipe thickness from 20 to 30 and 40mm and keeping diameter 400mm, the increase in the ultimate strength is about 31.8% and 72.7% respectively. When changing pipe diameter from 300 to 350 and 400mm and keeping thickness 30mm, the decrease in the ultimate strength is about 8.5% and 17.1% respectively. When changing pipe diameter from 300 to 350 and 400mm and keeping thickness 40mm, the decrease in the ultimate strength is about 8.9% and 15.6% respectively. Adopting the program ANSYS10.0, the theoretical analysis of ferrocement pipes has been conducted. The experimental and theoretical results have been found almost identical.

15 specimens used to assess the performance and durability of ferrocement pipes exposed to aggressive solutions have been constructed with the same diameter and thickness. They were divided into three sets: **5** ferrocement pipes were cast using mortar of mix proportion 1:2 cement : sand by weight with 0.337 w/c ratio by weight and 4% by weight of cement HRWRA. They were designated by SP_0, SP_1, SP_2, SP_3, and SP_4. **5** ferrocement pipes were cast using mortar of mix proportion 1:2 cement : sand by weight with 0.39 w/c ratio by weight, 4% and 10% by weight of cement HRWRA and HRM respectively. They were designated by M_0, M_1, M_2,

M_3, and M_4. **5** ferrocement pipes were cast using mortar of mix proportion 1:2 cement: sand by weight with 0.45 w/c ratio by weight. They were designated by N_0, N_1, N_2, N_3, and N_4. From the results it is found that the ultimate strength of the specimens SP's increases compared to the reference specimens N's, and the increase in the ultimate strength for the specimens M's is more. The ultimate strength of the specimens SP_0 and M_0 increased by 4.0% and 37.6% respectively compared to the reference specimen N_0.The ultimate strength of the specimens SP_1, SP_2, SP_3 and SP_4 increased by 14.2%, 19.3%, 27.4% and 39.9% compared to the reference specimens N_1, N_2, N_3 and N_4 respectively. The ultimate strength of the specimens M_1, M_2, M3, and M_4 increased by 49.5%, 56.3%, 66.5% and 76.8% compared to the references specimens N_1, N_2, N_3 and N_4 respectively. The ultimate strength decreases in general with exposure time for the three sets (N_1, N_2, N_3 and N_4), (M_1, M_2, M_3 and M_4) and (SP_1, SP_2, SP_3 and SP_4). All types of cracks and their positions for the 15 ferrocement pipes were not affected by severe salts and time of exposure.

2 ferrocement pipes were used to study the effect of protective layer on the behavior of ferrocement pipes exposed to aggressive solution. The two pipes were prepared with similar dimensions. They were reinforced as other pipes and were cast using the same mix proportion of mortar 1:2 cement : sand by weight with no admixture and 0.45 w/c ratio. From the results it is found that when comparing the ultimate strength of EP's pipes with reference pipe (N_0), an increase by 9.8% is noticed. The suggested method of protection gives ferrocement pipes an efficient protection.

Permeability of ferrocement pipes was tested for six specimens SP_o, SP_4, N_0, N_4, M_0, and M4 exposed to aggressive solutions for 0 and 360 days. Besides, the effect of admixture and aggressive solutions on pipe permeability was investigated. A decrease was found in the coefficient of permeability for specimens SP_4 and M_4. For absorption the test indicated that there is a decrease in absorption for the specimens SP's and M's.

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Abbreviations

EP1,EP2 : Ferrocement pipe specimens submerged partially in the aggressive solutions for 0 and 360 days respectively, with plastic covering and epoxy paint

F.M. : Finite element

HRWRA : High range water reducing agent

HRM : High reactivity metakaolin

M_0,M_1, M_2, M_3 and M_4 : Ferrocement pipe specimens with HRM and HRWRA, submerged partially in the aggressive solution for 0, 90, 180, 270 and 360days respectively

N_0,N_1, N_2, N_3 and N_4 : Ferrocement pipe specimens with no admixtures, submerged partially in the aggressive solution for 0, 90, 180, 270 and 360days respectively

SP_0,SP_1, SP_2, SP_3 and SP_4 : Ferrocement pipe specimens with HRWRA, submerged partially in the aggressive solution for 0, 90, 180, 270 and 360days respectively

General symbols

$[A]^T$, $\{a\}^T$: Transpose of matrix [A] and vector {a}

$[A]^{-1}$: Inverse of matrix [A]

d , ∂ : Differential symbols

det, | | : Determinant of a matrix or absolute value

{ } : Vector

[ ] : Matrix

Δ : Denoting Incremental quantity

Scalar

E : Modulus of elasticity

E_m : Modulus of elasticity of mortar

E_s : Modulus of elasticity of steel

F : Functions

$f_c^{'}$: Uniaxial compressive strength of concrete (cylinder test)

$\mathbf{f_u}$: Ultimate strength of steel

$\mathbf{f_y}$: Yield strength of steel or stress at specified yield

$\mathbf{f_t}$: Uniaxial tensile strength of concrete

$\mathbf{f_r}$: Modulus of rupture of concrete

H’ : Hardening parameter

$\mathbf{H_s}$: Hardening parameter of steel

V : Volume

u , v, w : Displacement components, in x , y and z-directions

x , y , z : Cartesian coordinates

α_1 , α_2 : Tension-stiffening parameters

ε : Normal (or direct) strain

ε_{cu} : Ultimate strain of concrete

ε_{sy} : Strain in steel at stress f_y

ε_{su} : Strain in steel at stress f_u

ξ, η, ζ : Natural (or local) coordinates

ϕ : Curvature

ν : Poisson’s ratio

σ : Normal stress

σ_o : Effective stress at onset of plastic deformation

σ^* : Effective stress

Matrix

[A] : Displacement gradient matrix

[B] : Strain-nodal displacement matrix

[D] : Constitutive matrix

[J] : Jacobian matrix

[K] : Stiffness matrix

[N] : Shape function

[T] : Transformation matrix

Vector

$\{\sigma\}$: Stress vector

$\{\varepsilon\}$: Strain vector

$\{F^a\}$: External load vector

$\{F^{nr}\}$: Internal load vector

$\{R\}$: Residual load vector

$\{U\}$: Displacement vector

$\{u\}$: Nodal displacement vector

Subscripts and superscripts

c : Mortar

cr : Cracking

e : Elastic component, or element quantity

s : Steel

t : Tension

y : Yielding