RESEARCH ON DURABILITY OF MAGNESIUM CEMENT REINFORCED CONCRETE IN A VARIETY OF FACTORS AND EXPERIMENTAL CONDITION OF BITTERN EROSION

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Abstract

Aiming at the durability problem of magnesium cement reinforced concrete beams under the action of multiple factors in Chaerhan salt lake area in Golmud city, Qinghai province. This paper outlines a comprehensive experimental investigation about the durability of magnesium cement reinforced concrete beams under multiple factors effect through mass, relative quality and elastic modulus. Multiple factor tests conditions were carried out including test of bittern erosion, dry-wet cycle and freeze-thaw cycle. The results demonstrate that after wet-dry cycle and bittern erosion tests, freeze-thaw cycles from 0 to 180 cycles have little effect on the deterioration of concrete specimens. In 180 to 270 freeze-thaw cycles tests, magnesium cement reinforced concrete beam specimen's performance degraded continuously and eventually the beam's component was close to failure simultaneously the reinforcement corrosion was also very serious. In accordance with experimental analysis, magnesium cement concrete demonstrates a proficient performance when it is exposed to bittern erosion, dry-wet cycle and freeze-thaw cycle.

Keywords: Magnesium cement reinforced concrete; bittern erosion; dry-wet cycle; freeze-thaw cycle; durability

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1. INTRODUCTION

Chaerhan salt lake is inland dry lake which is located in south eastern part of qaidam basin in Qinghai, with a total area of 5856 km^2. It is a typical chloride type salt lake and is also known as the China's largest salt lake. At the same time, it is also one of the most famous interior salt lakes in the world. Currently, Chinese government is vigorously developing the use of these salt lake resources. In fact, it has invested in construction of a large number of buildings, which greatly increased the use of concrete in salt lake zone. Native and foreign scholars pay more attention to research on durability of concrete based on a variety of single factors furthermore; the study has delivered a lot of results however it cannot accurately reflect the actual conditions of concrete under the multiple factors - . Magnesium cement compared to ordinary Portland cement has many significant advantages, such as fast hardening and high mechanical strength and strong resistance to bittern erosion etc… nevertheless magnesium cement products have constraints of its wide range of applications disadvantages for example poor water resistance.

At present, the research work of magnesium cement reinforced concrete members is relatively lower. The application of magnesium cement is mostly limited to non-load-bearing components. Could or could not magnesium cement concrete be introduced in the field of load-bearing structures; this is the main focus of current study. Based on the requirement of the research and development of corrosion-resistant concrete in western salt lake area, if magnesium cement, sand and gravel could be combined together, their cooperative work with steel bar surface coating treatments in the structural members can lead to a new era of building materials production.

2. EXPERIMENTAL PROGRAM

2.1 Chemical Properties

When magnesium is in its metal form it can burn very easily in air. However, in order to start the reaction the magnesium metal needs a source of energy. When the magnesium metal burns it reacts with oxygen found in the air to form magnesium oxide.

$$2Mg + O_2 \rightarrow 2MgO \text{ (600-650° C, burning on air)}.$$
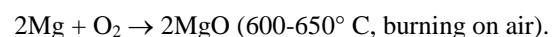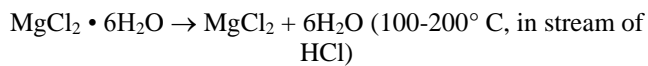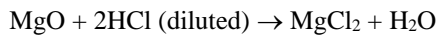
After it burns, it forms a white powder of the magnesium oxide. Magnesium gives up two electrons to oxygen atoms to form this powdery product. This is an exothermic reaction.

Mg is oxidized and Cl is reduced to Cl⁻ ions by accepting electrons, this kind of reaction is called an oxidation-reduction (redox) reaction.

$$Mg + Cl_2 \text{ (moisture)} \rightarrow MgCl_2 \text{ (ambient temperature)}$$

The acidity of HCl is been neutralized by MgO due to neutralization reaction.

$$MgO + 2HCl \text{ (diluted)} \rightarrow MgCl_2 + H_2O$$

$$MgCl_2 \cdot 6H_2O \rightarrow MgCl_2 + 6H_2O \text{ (100-200° C, in stream of HCl)}$$

2.2 Materials and Mix Proportions

Light burning magnesium oxide (MgO) after determination of activity of 60% (shown in Table 1); industrial magnesium chloride (MgCl₂) in a crystalline state at ambient temperature, of the chloride magnesium hexahydrate formula MgCl₂ • 6H₂O, white, flaky (shown in Table 2); super plasticizer using KD naphthalene super plasticizer; fly ash of class I made in Lanzhou, the products of combustion in a power plant, iron-gray powder, specific gravity of 1.65 (shown in Table 3).

Table 1: Chemical composition of light calcined magnesia (mass ratio, %)

MgO	CaO	Fe	Others
90	2.5	1.0	6.5

Table 2: Chemical composition of industrial magnesium chloride (mass ratio, %)

MgCl₂·6H₂O	SO₄²⁻	K+Na	CaCl₂	others
97	0.2	0.7	0.2	1.9

Table 3: Chemical composition of pulverized fuel ash (mass ratio, %)

Fe	SiO₂	Al₂O₃	CaO	TiO₂	S	P
11.20	40.50	22.90	2.37	1.43	0.15	0.076

Coarse aggregate stone (fine stone) is related to continuous gradation, with qualified performance indicators. Gravel, fine aggregate grading is continuous and is classified in medium sand II area. Magnesium chloride solution and water are used in the laboratory bittern solution using distilled water. Reinforcement are HPB235, $f_y = 210$

N/mm², the longitudinal reinforced by 10 mm diameter thread steel bar, stirrup used light round bar diameter is 6 mm.

2.3 Experimental Methods

At first, magnesium cement reinforced concrete beam specimen of size 500 mm×100 mm×75 mm was prepared; and next, that specimen was putted in bittern solution and immerse for 54 h, afterward the electric hot fan was used to blow the specimen for 6h, so that the surface temperature of the specimen could vary between 40 ℃ ~ 50 ℃, after a while the specimen was putted in air cooling and standing for 12h up to 72h as a dry-wet cycle (cumulative 3d). The mass and relative elastic modulus of the specimen was measured every 20 cycles. In order to accelerate the destruction of concrete, freeze-thaw cycles were added into all specimens; each freeze-thaw cycle time is about 3h and as the result in the specimen appears a slight damage; after every 15 times, the mass of a specimen and relative dynamic elastic modulus were determined until in the specimen appears more serious damage.

The compounding ratio and grouping numbers used in the specimens are shown in Table 4 and Table 5. The immersing solution is mainly made of sodium chloride and sodium sulfate (shown in Table 6).

Table 4: Mixing proportion of magnesium cement reinforced concrete

Mg O (kg)	Plasticizer	Fly ash	Sand	Stone	MgCl₂ (L)	Slump(mm)
6.3	1.14	1.14	14.2	21.2	3.9	45

Table 5 Grouping and numbering of magnesium cement reinforced concrete

Experimental condition	Specimen number
laboratory wet and dry cycle freeze-thaw cycles	GSDR1
	GSDR2
	GSDR3
	GSDR4

Table 6: Main corrosive ions of chaerhan salt lake (mg/l)

element	total(10³)	Na⁺	K⁺	Mg²⁺	Ca²⁺	Cl⁻	SO₄²⁻	HCO₃⁻	CO₃²⁻	PH
max	555.06	108200	16610	94420	51860	365080	37440	470	1480	7.90
min	50	270	20	2110	140	124360	20	120	130	4.60
average	321.3	68360.5	5977.78	35129.7	4241	204209	22290	127.4	171.6	6.89

3. TEST RESULTS AND ANALYSIS AFTER BITTERN EROSION, DRY AND WET CYCLES AND FREEZE-THAW CYCLES

3.1 Selection of Evaluation Indexes and Parameter

In this process, the curve of the relative mass and relative dynamic elastic modulus was measured. The relative mass and relative dynamic modulus of elasticity evaluation parameters (ω_1 , ω_2) were used as concrete durability evaluation 1, 2,3,4,5.

Based on the corresponding norms and combined with the natural characteristics of Golmud, considering the practical condition of test operation and laboratory, and finally taking into account the operability of the test, relative mass evaluation parameter (ω_1), relative dynamic modulus of elasticity evaluation parameter (ω_2) and relative dynamic modulus of elasticity (E_r) were selected as durability evaluation parameter of concrete.

The following formulas:

$$\omega_1= (W_r-0.95)/0.05 \qquad (1)$$

Where W_r is the relative mass.

$$W_2 = (E_r - 0.6)/0.40 \qquad (2)$$

According to the standard for test methods of long-term performance and durability of ordinary concrete (GB/T 50082-2009), the relation between ultrasonic velocity and relative dynamic modulus (E_r) can be expressed as:

$$E_r = \frac{E_t}{E_0} = \frac{v_t^2}{v_0^2} \qquad (3)$$

Where E0 is the initial dynamic elastic modulus, E_t is the dynamic elastic modulus at time (t), v_0 is the initial ultrasonic velocity, vt is the ultrasonic velocity at time (t).

3.2 Results and Analysis of Relative Mass Evaluation Parameters

3.2.1 Relative Mass Evaluation Parameters after Wet and Dry Cycle
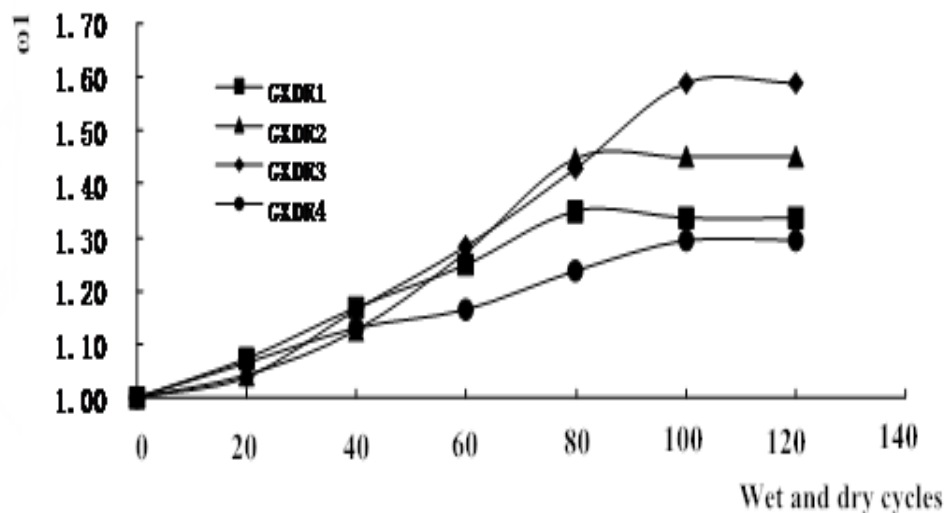

Fig.1: Evaluation parameters (ω_1) under dry-wet circulation

As it can be seen from the graph, in the interval of times 40 to 60 wet and dry cycles ω_1 of GXDR3 has sharply increased compared to DXDR4 which has a low rate of increase. From 80 to 100 times of wet and dry cycles, ω_1 for GXDR1 and GXDR2 has decreased while for GXDR3 and GXDR4 ω_1 was still gradually increasing. From 100 and 120 times of wet and dry cycles, the value of ω_1 remained constant to all specimens.

Briefly, the relative mass evaluation parameter ω_1 of the specimens has been gradually increased up to 80 times of dry and wet cycle (shown in Fig.1). After a certain number of cycles, it is observed that the growth rate decreases. The specimen, after several times of wet and dry cycle, due to bittern erosion and wet and dry effects, the destruction of spalling is more serious, so the trend of increasing mass is getting smaller and smaller, and ultimately no longer increase, and began to tend to reduce small trend[7] .

3.2.2 Relative Mass Evaluation Parameters during 0-180 Cycles of Freeze-Thaw Cycles

After 120 times of wet and dry cycle, the relative mass evaluation parameters (ω_1) of the specimens are larger than the reference value (shown in Fig.2), and its value also shows an increasing trend, indicating that the overall performance of the component also is within the normal range. So, freeze-thaw cycles were added in order to accelerate the destruction of concrete[8].
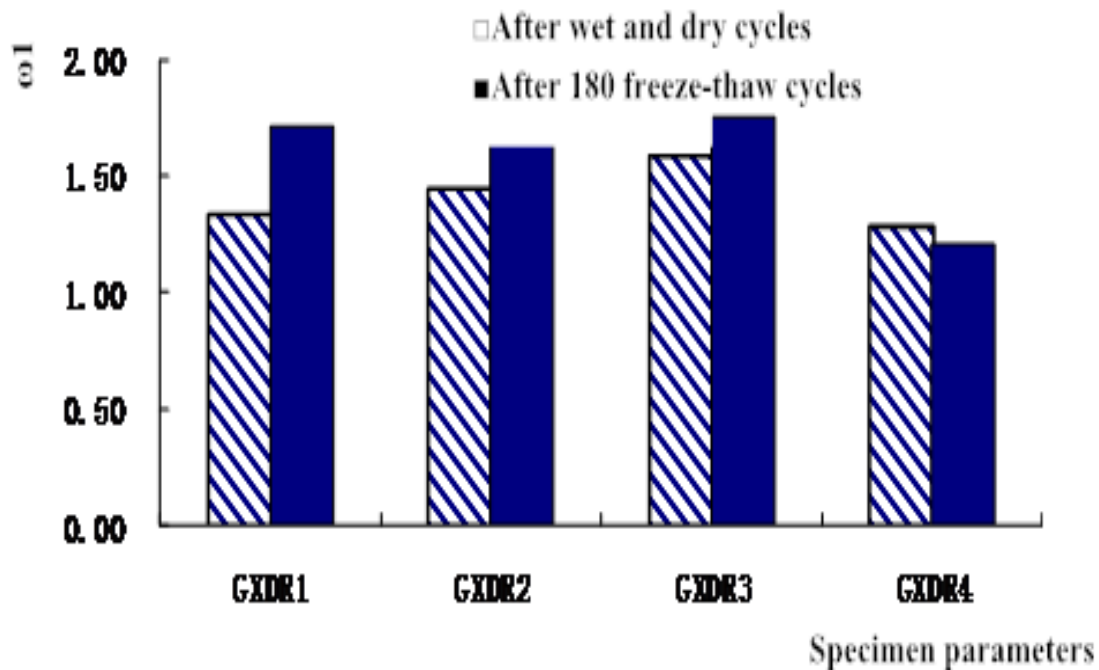

Fig. 2: Evaluation parameters (ω_1) after dry-wet circulation and freezing-thawing cycle

As shown in Fig.2, it can be observed that the values of the relative mass evaluation parameters (ω_1) of the specimens GXDR1, GXDR2, GXDR3 gradually increased compared with the end of dry-wet cycle and only GXDR4 slightly decreased.
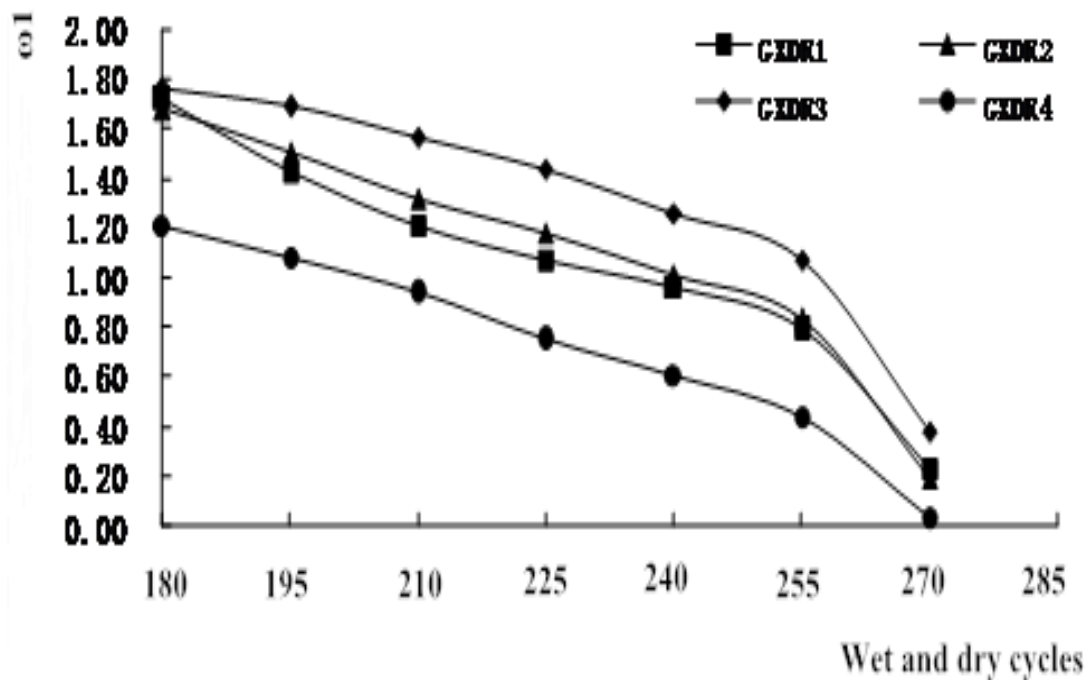
Fig. 3: Evaluation parameters (ω_1) after dry-wet circulation

3.2.3 Relative Mass Evaluation Parameters during 180-270 Cycles of Freeze-Thaw Cycles

The values of the GXDR1, GXDR2, GXDR3 and GXDR4 (shown in Fig.3) were slowly decreased during the 180 to 255 freeze-thaw cycles. During the freeze-thaw cycles of 255 to 270, the values were sharply decreased. Since the ω_1 of the GXDR4 specimen has been about zero, the freeze-thaw cycle is stopped[10].

3.3 Results and Analysis of the Relative Dynamic Elastic Modulus Evaluation Parameters

3.3.1 Relative Dynamic Elastic Modulus Evaluation Parameters during Wet and Dry Cycle

(1) Relative dynamic elastic modulus in the longitudinal direction (500mm)

As shown in Fig. 4, from 0 to 60 times of wet and dry cycles, ω_2 of all specimens has been continuously increasing, and from 60 to 100 times of wet and dry cycles, ω_2 for all the specimens has sharply increased, however from 100 to 120 times of wet and dry cycles, ω_2 has decreased. Briefly, it can be concluded that after wetting-drying cycles, in the longitudinal direction, relative dynamic elastic modulus evaluation parameters ω_2 has been greater than one, and showed the increasing trend at first and then decreasing trend.
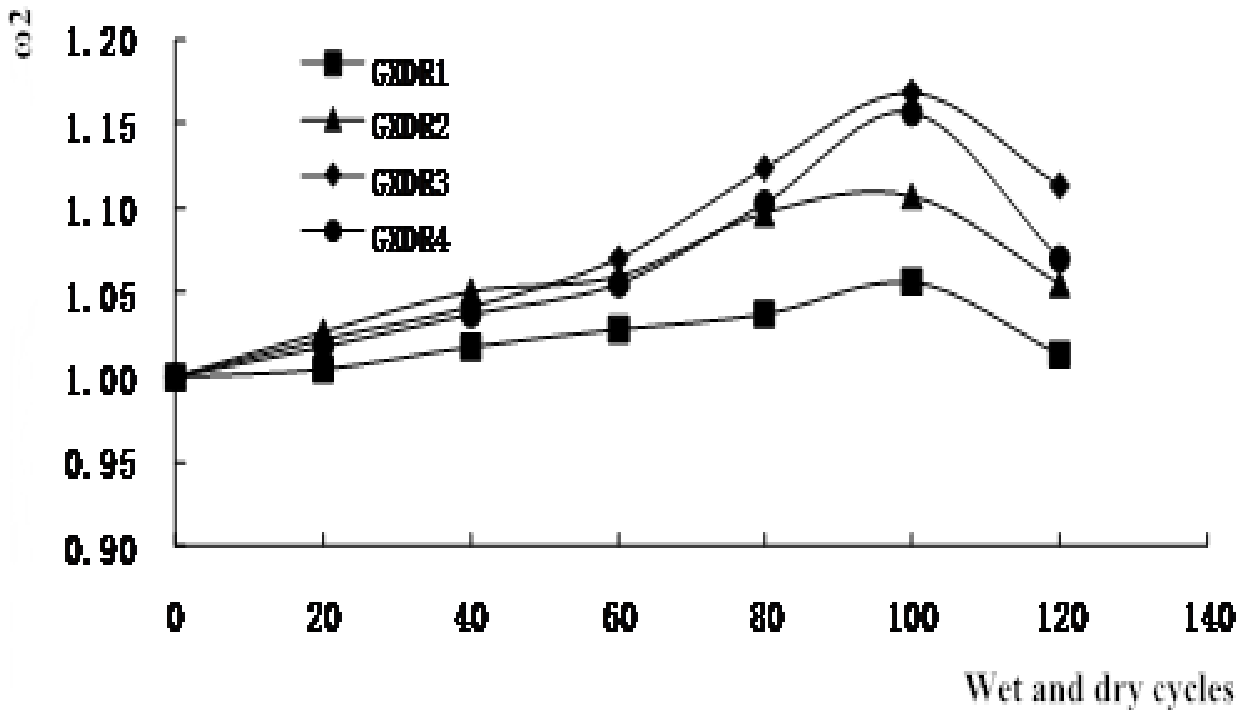
Fig. 4: Relative dynamic modulus of elasticity (ω_2) across the length after dry-wet circulation

(2) Relative dynamic elastic modulus in width direction (75mm)

Relative dynamic elastic modulus the evaluation parameters ω_2 have the same trend with the length direction (shown in Figure 5) in the width direction.
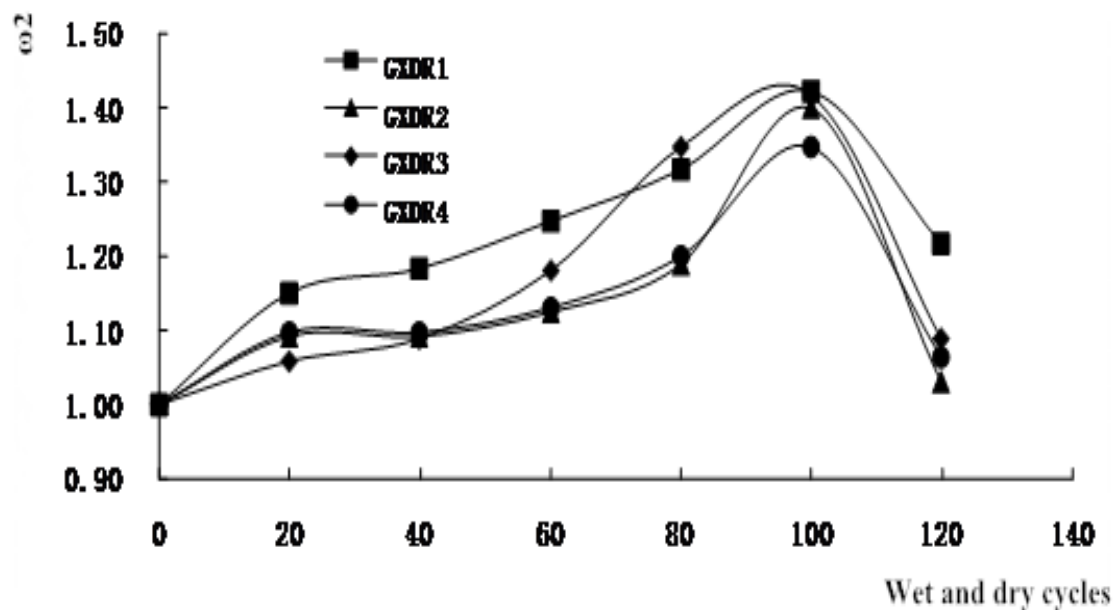

Fig. 5: Relative dynamic modulus of elasticity (ω_2) across the width after dry-wet circulation

Throughout the wet and dry cycle (shown in Fig.4, 5), overall trends of the values of relative dynamic modulus of elasticity ω_2 are increasing at 0 to 100 cycles. After 100 cycles, it is decreased. It indicates that performance of

concrete begins to deteriorate, after 100 wetting-drying cycles, the relative dynamic elastic modulus gradually decreases.

After 120 dry and wet cycles relative dynamic elastic modulus evaluation parameters of all specimens are larger than the reference value, and its value has also been a growing tendency before 100 cycles, after the end of 100 cycles begin to decline, the concrete begins a slight deterioration. In order to accelerate the destruction of concrete, freeze-thaw cycles were added into all specimens.

3.3.2 The Relative Dynamic Elastic Modulus Evaluation Parameters after 0-180 Cycles of Freeze-Thaw Cycles
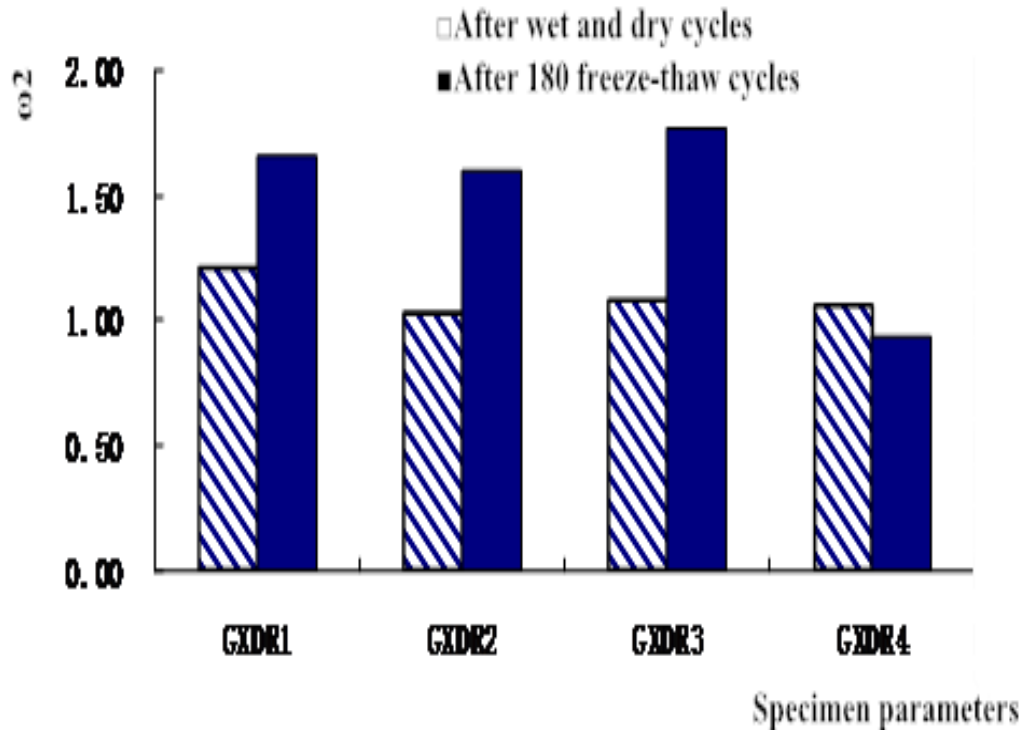

Fig. 6: Evaluation parameters (ω_2) after dry-wet circulation and freezing and thawing cycle

At the end of the wet and dry cycle (shown in Fig.6), the relative dynamic modulus of the specimens GXDR1, GXDR2, GXDR3 and GXDR4 evaluates the value of the parameter ω_2, after 180 cycles of freezing and thawing -,only the value of GXDR4 has been decreased, the other three values have increased.

the freeze-thaw cycle (shown in Fig.7) in the interval of 180 to 270 cycles, indicating that the deterioration of the concrete is becoming more and more serious. To 270 cycles, the relative dynamic elastic modulus of each specimen evaluation parameters ω_2 values are about zero, and the concrete failure occurs.

3.3.3 The Relative Dynamic Elastic Modulus Evaluation Parameters during 180-270 Cycles of Freeze-Thaw Cycles

The values of the relative dynamic elastic modulus evaluation parameters ω_2 are continuously decreasing during
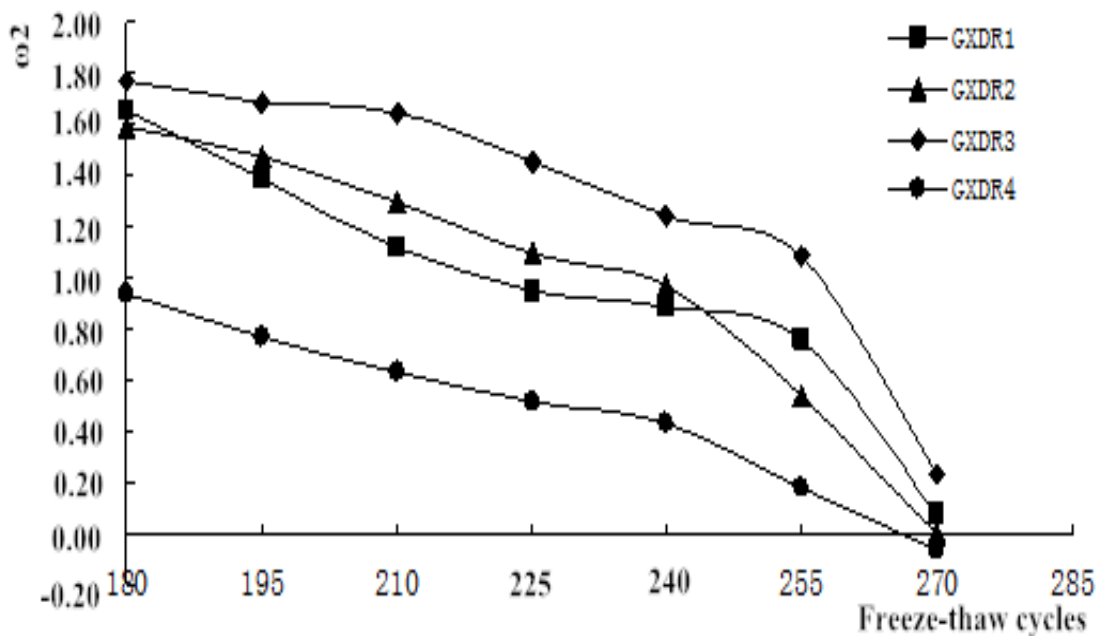
Fig 7: Evaluation parameters (ω_2) after freezing-thawing cycle

The relative dynamic elastic modulus evaluation parameters of GXDR2 and GXDR4 after 240 cycles of freeze and thaw cycles of GXDR2 and GXDR4 were decreased sharply, and when the value drop down to around 0 at the end of 270 freeze-thaw cycles concrete has been damaged. As result of the end of the test, magnesium cement reinforced concrete beam specimens have been occurring more serious corrosion, there is no need of its short-term loading and steel corrosion test.

5. CONCLUSION

(1). After 120 times of wet-dry cycle process, indicating that magnesium cement reinforced concrete beam specimen in the first 100 times during the wet and dry cycle performance continues to strengthen, after 100 times its performance is no longer enhanced.

(2). After 180 times freeze-thaw cycle accelerated test, indicating that the performance of magnesium cement reinforced concrete beam specimen is still strengthening and also the resistance to bittern erosion is very strong.

(3). During 180 to 270 times freeze-thaw cycle process, indicating that magnesium cement reinforced concrete beam specimens continue to deteriorate, and ultimately near to failure state. The durability of magnesium cement concrete in salt lake area is effective and its resistance to bittern erosion is prominent.

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