Study on the Rule of Concrete Corrosion in Harsh Environment

Liming Zhang*1, Jia Li2, Hongfa Yu3 and Qinpeng Zhan1

1School of Civil and Architectural Engineering, Nanchang Institute of Technology, Nanchang, Jiangxi, 330099, China
2Libray, Nanchang Institute of Technology, Nanchang, Jiangxi, 330099, China
3Department of Civil Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing, Jiangsu, 210016, China

*Corresponding author’s e-mail: zhmnuaa@126.com

Abstract. The surface corrosion of 3 type concrete beams in hostile environment is researched by measuring concrete beams surface corrosion content, and the effect of test condition, concrete strength and corrosion time on concrete beams surface corrosion is analyzed. The result show that corrosion time is positively related to corrosion time; the beginning peeling time is longer with the increasing of concrete compressive strength; the capacity of concrete anti-stripping is increased with the increasing of concrete compressive strength. The formula of predication concrete beams surface stripping is set up by use of test data, which can be present in predicating concrete service life.

1. Introduction
Early damage of concrete structure under Corrosion environment (salty soil, marine environment, deicer salt) exists almost all over the world [1-4]. The reason of the concrete strength decrease is a volumetric expansion of sulphate crystal [5-6]. The reason is the steel corrosion which mainly results from free chloride ingestion [7-8]. Concrete scaling and damage are accelerated by combination of sulphate crystal and free chloride ingestion. Therefore, Concrete surface scaling in chloride salt in solution environment is one important directions of the prediction of concrete service time in corrosive environment and is becoming the hot spot of nowadays researches. In order to extract concrete scaling pattern in corrosive condition more quickly as the concrete scaling pattern in corrosive condition. The influence of test environment, corrosion time and concrete compressive strength on concrete beams surface corrosion, The formula of predication concrete beams surface stripping is set up by use of test data, which can be present in predicating concrete service life.

2. Experimental

2.1 Materials and Mix Proportion
Portland cement with P.I52.5 is provided by Huaxin cement company in china. Jian Bi power plant in china presents silica fume Chemical Compositions of cementitious materials is listed by table 1. Lan Zhou in China put forward river sand with 2.5 fineness mode and lime stone aggregate with 19mm maximum. Drinking water. The sample size is 500mm×75mm ×100mm.
Table 1 . Chemical compositions of Cement and Silica fume

| Raw material | SiO$_2$ | Al$_2$O$_3$ | CaO | MgO | SO$_3$ | Fe$_2$O$_3$ | MnO | TiO$_2$ | Na$_2$O |
|--------------|---------|-------------|-----|-----|--------|-------------|-----|---------|---------|
| Cement       | 21.35   | 4.67        | 62.60 | 3.08 | 2.25   | 3.31        | —   | —       | —       |
| Silica fume  | 85.16   | 0.06        | 0.56 | 2.10 | —      | 0.75        | —   | —       | —       |

Table 2 . Mixed Proportions and Compressive Strength of Concretes

| sample       | W/B   | Mixed Proportions/(kg·m$^{-3}$) | Slump/mm | 28d Strength/MPa |
|--------------|-------|---------------------------------|----------|------------------|
|              |       | Cement Fine Aggregate Coarse Aggregate PCA®(I) Water |          |                  |
| C30          | 0.53  | 368.0 — 735 1103 — 195 | 75 | 31.3 |
| C50          | 0.35  | 412.2 — 687 1145 1.42 160 | 168 | 58.6 |
| C80SF10      | 0.23  | 531.0 59 708 1062 5.85 136 | 46 | 80.6 |

SF-silica fume; PCA®(I)-Sup- performance (water reducing admixture)

2.2 Test Procedures
Corrosion solution is Cha Er Han salt lake brine, and is measured by plasma - atomic emission spectroscopy.

Table 3 . The chemical composition of Cha Er Han salt lake brine

| Name | Na$^+$ | K$^+$ | Mg$^{2+}$ | Ca$^{2+}$ | Cl$^-$ | SO$_4^{2-}$ | HCO$_3^-$ | CO$_3^{2-}$ |
|------|--------|-------|-----------|-----------|-------|-------------|-----------|-------------|
| Content/(mg.l$^{-1}$) | 68360 | 5977 | 35130 | 4241 | 204209 | 22290 | 127.4 | 171.6 |

The wet-dry cycles are determined experimentally as follow: one wet-dry cycle is consist of firstly immersing 50 hours in lab room, then staying 2 hours at room temperature, at last heating 8 hours with manufacture at 60℃ cementitious temperature. Concrete surface peeling is measures at 90d、180d、270d、330d、360d、480d、540d.

Concrete beams peeling content is computed with equation 1.

$$\Delta W = \frac{(G_{\text{MAX}} - G_t)}{SA}$$ (1)

$\Delta W$ is concrete beams peeling content at specific corrosion time (g/m$^2$) ; $G_{\text{MAX}}$ is the maximum mass of concrete beams (g) ; $G_t$ is the mass of concrete beams at t time; SA is concrete beams surface area(m$^2$).

3. Results and discussion

3.1 The process of concrete surface spalling
Figure 1 shows that C30 concrete beam surface peeling under wet-dry cycle with corrosion time variation, C30 concrete beams surface is not peeling after 28d under standard curing condition shown in Fig1(a). Concrete beams start light surface spalling at corner after corrosion 180d in wet-dry cycle in Fig1 (b); the concrete surface spalling depths is increasing and extending to centre after corrosion 330d in wet-dry cycle as shown in Fig1(c); the concrete surface spalling has gradually developed to flake after corrosion 480d in wet-dry cycle in Fig1 (d); the concrete surface is flaked off completely after corrosion 480d in wet-dry cycle in Fig 1(e).

(a) C30, standard curing 28d   (b) C30, wet-dry cycle 180d
3.2 The influence of concrete compressive strength on concrete surface beginning peeling time and rate

Figure 2(a) shows that the beginning peeling time (BPT) of C30 concrete, C50 concrete and C80SF10 under wet-dry condition is 290d, 330d and 480d respectively. BPT of C50 and C80SF10 concrete is 1.18 and 1.45 times of BPT of C30 concrete. Thus, BPT of concrete beams under corrosion environment decreased with increasing of concrete compressive strengths. The quantity of concrete surface peeling is increased with the increasing of corrosion time.

As shown in Figure 2(b), concrete beams surface peeling rate is more slowly with increasing of concrete compressive strengths; the earlier concrete surface begins peeling time, the concrete beams surface peeling rate is more sooner.

3.3 Study on relationship between surface peeling depths and surface peeling content

As shown in Figure 1: Firstly concrete beams start light surface peeling at corner, then has gradually developed to flake, finally is flaked off completely. The size of Concrete beams is 500mm×75mm×100 mm. It is assumed that whole concrete beams in corrosion environment surface peeling off. The equation of surface peeling content $M_L$ and corrosion time is established as shown in model 2.

$$M_L = 285h_t'$$  \hspace{1cm} (2)

In equation: $M_L$ is concrete beams surface peeling content at t time (g); $h_t'$ is concrete beams surface peeling depth at t time (mm).

4. Conclusions

The surface peeling rule of concrete under wet-dry cycle environment was studied and the equation between surface peeling content and corrosion time was established, the major conclusion of this paper as follows:
1) When corrosion time is over the beginning peeling time (BPT), the concrete beam is beginning to peel off; BPT of concrete beams under corrosion environment increased with increasing of concrete compressive strengths.

2) Concrete beams surface peeling rate is more slowly with increasing of concrete compressive strengths; the earlier concrete surface begins peeling time, the concrete beams surface peeling rate is more sooner.

3) The capacity of concrete anti-stripping is increased with the increasing of concrete compressive strength. The formula of predication concrete beams surface stripping is set up by use of test data, which can be present in predicating concrete service life.

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References
[1] Zhang Li-ming, YU Hong-fa, HE Zhong-mao. (2011) Chloride ion diffusivity of salt lake concrete (in Chinese). J. Journal of Central South University (Science and Technology), 42(6):1752–1755.
[2] Zhang Li-ming, YU Hong-fa. (2014) Influence of dry-wet cycles on chloride diffusion coefficient (in Chinese). J. Journal of Hunan University (Natural Sciences), 41(3):25–30.
[3] Petcherdchoo A. (2013) Time dependent models of apparent diffusion coefficient and surface chloride for chloride transport in fly ash concrete. J. Construction and Building Materials, 38(1):497-507.
[4] Safelhan M, Ramezanianpour A. (2013) Assessment of service life models for determination of chloride penetration into silica fume concrete in the severe marine environmental condition. J. Construction and Building Materials, 48:287-294.
[5] Jianming Gao, Zhenxin Yu, Luguang Song, et al. (2013) Durability of concrete exposed to sulfate attack under flexural loading and drying–wetting cycles. J. Construction and Building Materials, 39:33-38.
[6] Emilia Vasanelli, Francesco Micelli, Maria Antonietta Aiello, et al. (2013) Long term behavior of FRC flexural beams under sustained load. J. Engineering Structures, 56:1858-1867.
[7] Lorenzo Graziani, Enrico Quagliarini, Federica Bondioli, et al. (2014) Durability of self-cleaning TiO2 coatings on fired clay brick façades: Effects of UV exposure and wet & dry cycles. J. Building and Environment, 71:193-203.
[8] Mehdi Khazazdeh Moradllo, Mohammad Shekarchi, Meghdad Hoseini. (2012) Time-dependent performance of concrete surface coatings in tidal zone of marine environment. J. Construction and Building Materials, 30:198-205.