International Journal of Civil Engineering and Machinery Manufacture

Volume 1, Issue 2, August 2016

Part II

Publisher: HongKong New Century Cultural Publishing House
Address: Unit A1, 7/F, Cheuk Nang Plaza, 250 Hennessy Road, Wanchai, Hong Kong
Tel: 00852-28150191
Fax: 00852-25445670

Contents

A Study on Durability Performance of Unbonded Prestressed Concrete Beam
Shasha DENG······(84)

Study on Ultrasonic Method of Testing on Concrete Crack Depth
Hongyuan CHENG······(88)

Analysis of Pavement Performance Evaluation Index
Huiping CAO······(95)

Discussion on the Problems Existing in the Construction Technology of Municipal Road Engineering
Rontiris······(99)

Review on the Study of Road Traffic Emergency Evacuation in Foreign Countries
Cheng CHEN······(102)

Analysis of Debris Flow on Slope Surface and Simplified Calculation of Groove Bottom of V Type Drainage Structure
Qiang WANG, Yuli ZHAO, Wei GONG······(108)

Study on the Influence of Mixture Uniformity on Asphalt Pavement based on ABAQUS
Wei GONG1, Yuli ZHAO2, Qiang WANG1······(113)

Application of Research Local Elements in the City Parks
Xueyuan CHEN······(117)

Traffic Organization and Traffic Safety in the Construction of Municipal Road Engineering
Franzese······(121)

Research on the Design of Communication Space of the Teaching Bulilding
Hao ZHANG······(124)

The Key Technical Factors Analysis of Road Reconstruction and Design
Nianchuan QIAN······(128)

Analysis of Shear Stress Distribution of Three Kinds of Typical Asphalt Pavement based on Finite Element
Xiongwei LIN······(133)

Performance Issues of Pavement with Cementitiously Stabilized Layers
Junlin WANG······(137)

Properties of Cementitiously Stabilized Materials
Junlin WANG······(140)

Cause Analysis and Solution to the Quality Problems of Municipal Road Engineering
McLoughlin······(144)

Study on the Function and Applicability of Traffic Calming Measures in Urban Residential Areas
Yuan CHEN······(147)

Survey on the Formation Top-down Crack
Jianfeng ZHENG······(150)

Research on Synchronization of Jacking up based on Programmable Logic Controller (PLC) to Replace Bridge Bearings
Jiabin CAO······(154)

Review of Research Status of Phase Change Materials in Road Engineering
Mahmassani······(158)

Study on the Jacking Force of Girder Closure for Contimuour Rigid Frame Bridge

Wei ZHANG……(162)

A Study on Durability Performance of Unbonded Prestressed Concrete Beam

Shasha DENG
School of Civil Engineering, Chongqing Jiaotong University, Chongqing, 400074, CHINA

Abstract: Unbonded prestressed concrete members can not only play the role of prestressed tendons to improve the performance of the concrete structure, but also make the structure design more reasonable and cost saving. However, compared with bonded prestressed concrete structure comparison, unbonded prestressed concrete structure is more prone to corrosion damage caused by structural durability failure to use security structure lay hidden. Therefore, in this paper, the mechanical properties of the non bonded prestressed concrete after corroded are studied, and the mechanical properties of the non bonded prestressed tendons after corroded are studied by the static tensile test.

Keywords: Vertically irregular frame structure; Durability; Loss of corrosion

1. Introduction

Prestressed structure has good spanning capabilities, good durability and good economic performance, and it can greatly reduce the consumption of energy and resources, so prestressed structure is widely used to long-span bridges, long cantilever buildings, dams and other practical engineering. The durability of concrete structure means that the concrete structure and its components can against the influence of the external environment[1], harmful substances erosion and other damage under the joint action of normal working environment and internal factors within the specified time. The concrete structure and its components will still be able to meet the expected function without making a large repair.

Compared with bonded prestressed concrete, the unbonded prestressed concrete is more prone to failure of the durability under the same conditions, so the durability problem is more serious, but there is little research on this aspect at home and abroad. This paper is a research of unbonded prestressed concrete corrosion damage of this type of engineering practice. The deterioration of the performance of the unbonded prestressed concrete structure after corrosion damage has been analyzed. This will be helpful to predict the service life of the existing unbonded prestressed structure in the corrosion environment, and has important practical significance.

2. Capability of the Unbonded Prestressed Reinforcement after Corroded Damage

In real life, because the construction is simple, saving cost, so the unbonded prestressed concrete structure is widely used in bridges, industrial plants and other large span load-bearing structure. Prestressed steel strand is the key to this kind of structure, the corrosion of prestressed steel strand is one of the important factors to reduce durability of the unbonded prestressed concrete structure[2], it will cause to attenuation of prestressed reinforced strength, deformation and the elastic modulus. It has significant effects on the mechanical behavior of unbonded prestressed reinforced concrete structure.

It has made some achievements in the law of degradation of bonded steel strand after corrosion by scholars at home and abroad, however, there are few studies on the mechanical properties of the unbonded steel strand. Now it has made a experiment research on the mechanical properties of unbonded prestressed steel strand after corrosion, the mechanical properties of unbonded steel strand after corrosion has been obtained according to the test results, and the change in deformation, strength and elastic modulus of cohesive steel strand are analyzed, so it provides a theoretical basis for analysis of corroded unbonded prestressed concrete structure residual bearing capacity.

2.1. The experience

1) Corrosion Test

The corrosion test of unbonded prestressed steel strand is achieved through the electrochemical accelerating corrosion. the steel strand used in this test is 1×7-12.7, its value of tensile strength standard is 1860, cross-sectional area is 98.7 mm2, theoretical weight of per meter is 0.774Kg, and the specimen's length is 1000 mm, it takes specimen 300mm central region as corrosion considering test piece clamping length problem during the tensile test and other parts use tape wound to prevent corrosion. Since there is no established bond between steel strand and concrete of unbonded prestressed concrete beams, therefore it can be directly placed in the steel strand in electrolytic corrosion without the need to simulate concrete package environment.

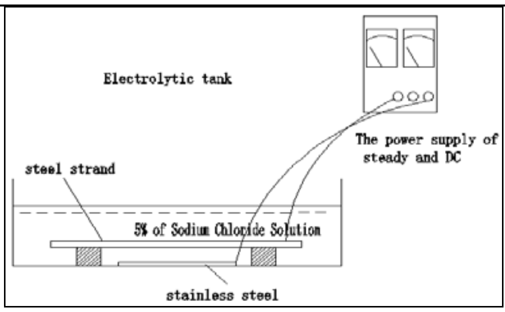

Figure 1. Device of accelerated corrosion

The test consists of 12 strands, and the number will be divided into 4 groups, then3 groups of positive strand which are connected in series with DC power supply is used for corrosion test, the other 1 groups is as blank. According to the electrochemical principle, the steel wire which is connected with the positive electrode is a corrosion anode and the cathode is a stainless steel plate which is connected with the negative electrode of the DC voltage stabilized power supply. The steel wire and stainless steel plate connected on the NaCl electrolyte solution, forming a loop through the NaCl solution. Steel strand of the anodic is corroded after electrify. In order to make the steel strand able to fully contact with the electrolyte, the test pieces on both ends padded a small pieces of wood, the test specimen should be soaked for one day before electric corrosion. In the process of corrosion, it is required to observe the change of the height of the liquid level regularly, and height of the liquid level lower than the position of the steel wire is not allowed, because it will cause short circuit.

According to Faraday's law, it shows that corrosion process of steel strand can be controlled through the length of corrosion time and the strength of the current. After the test specimen has reached a predetermined corrosion rate, the power is stopped[3]. And the specimen is taken out from the NaCl solution to be weighed and recorded as the initial mass. After weighing is completed, the steel strand of each group should be pickled after corrosion in order to reduce the error caused by pickling. Each test piece in the pickling needs to compare with the stainless steel wire without corroded, and the quality of the record records as mn2. After washing the rust on the surface of the steel wire, it should be rinsed with clean water and then rinsed with $Ca(OH)_2$ for neutralization treatment. Finally rinses it again with water, washes it. After completing the steps above, the strand should be put into a dry oven for baking, and remove the specimen after 12 hours with an electronic balance weighing quality after pickling, it is denoted as mn3 and mn4, The actual corrosion rate of steel strand is:

$$\eta = \frac{(m_{n2} - m_{n4}) - (m_{n3} - m_{n1})}{m_{n2}} \times 100\%$$

Figure 2 is a corroded steel wire pickling dried State. We can see from the graph, corrosion of steel wire strands become more and more serious as the corrosion rate increasing,. When the corrosion rate is 13.08%, stranded wire appears corroded phenomenon.

Figure 2. Static Tensile Test (Corrosion result)

The static tensile test of the unbonded prestressed tendons after corrosion is carried out strictly according to the standard "G2228-2002". According to the experimental results, the mechanical properties such as the nominal yield strength, nominal ultimate strength and elongation of corroded prestressed tendons were determined, as shown in Figure 3.

Figure 3. Static Tensile Test of Steel Strand

The Results of Static Tensile Test of Corroded Prestressed Tendons is shown as Table 1.

Figure 4 and Figure 5 are failure modes of prestressed tendons with different corrosion rates. From the diagram can be seen, steel wire appears phenomenon of loose after prestressed reinforcement which not corroded stretched. The corroded prestressed tendons in the outer steel wire at the depths of the pit break out phenomenon of broken wire, and with the increasing of the corrosion rate, the phenomenon of broken wire is more obvious[4].

Table 1. The results of static tensile test of corroded prestressed tendons

Test piece number	1	2	3	4	5	6	7	8	9	10	11	12
Theoretical corrosion rate	0	0	0	4.36	4.36	4.36	8.72	8.72	8.72	13.08	13.08	13.08

(%)												
Measured corrosion rate (%)	0.012	0.011	0.012	4.34	4.39	4.38	8.73	8.78	8.69	13.03	13.08	12.99
Nominal ultimate strength(MPa)	2002.2	1981.6	2004.2	1775.2	1783.4	1772.3	1548.4	1551.3	1549.2	1314.3	1321.8	1323.2
Nominal yield strength(MPa)	1690.2	1695.7	1686.9	1563.7	1548.9	1553.6	/	/	/	/	/	/
Nominal elastic modulus （104MPa)	21.73	21.24	21.36	20.18	20.21	20.35	18.78	18.56	18.91	15.72	15.98	16.08
Elongation (%)	5.25	5.31	5.33	1.47	1.42	1.49	0.76	0.72	0.69	0.14	0.09	0.11

Figure 4. Destruction Form at Corrosion Rate of 0

Figure 5. Destruction Form at Corrosion Rate of 8.72%

a) The Elongation after Corrosion

According to the experimental data, the relationship between the corrosion rate and elongation of corroded prestressed tendons can be obtained, as shown in Figure 6. Using MathCAD to fit can get the formula (1), the correlation coefficient is 0.998, the fitting formula is more ideal.

$$\delta_\eta = 5.272 - 1.84\eta^{0.5} + 9.227\times10^{-3}\eta \quad (0 \le \eta \le 13.08) \quad (1)$$

In the formula:

δ_η -elongation(%);

η -Corrosion rate(%);

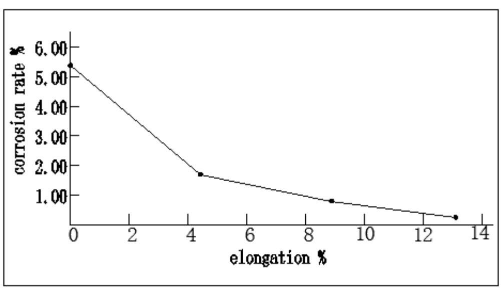

Figure 6. Change Law of Elongation with the Increase of Corrosion Rate

Static tensile tests show that the elongation of prestressed tendon is decreased with the corrosion rate increasing; meanwhile, the phenomenon of the neck shrinkage of prestressed tendons is less and less obvious. All of these indicate that the plastic property of the steel strand is poor, and the worse the plastic performance, the greater the corrosion rate. Due to corrosion, the cross section of the prestressed tendons is seriously weakened, and the plastic deformation is mainly concentrated in the area where the cross section is weakened at the time of stressed. Therefore, it is prone to stress concentration phenomenon in the weakened section of the cross section, which leads to the failure of the specimen.

b) Nominal Yield Strength

Prestressed steel strand belongs to the hardened steel with high tensile strength; therefore it does not appear obvious yield point and the steps in tensile test. When the residual strain is 0.2%, the corresponding stress is used as the nominal yield strength of the steel strand. Tests show that the brittle characteristics of prestressed tendons are more and more obvious with the increasing of corrosion rate, and the nominal yield strength decreases gradually[5].

c) Nominal Ultimate Strength

The ratio of the ultimate load and the cross section area of the corroded front can be defined as the nominal ultimate strength. The nominal ultimate strength of corroded steel strand is reduced; the main reason is the following two points: at first, the effective cross-sectional area of corrosion is reduced; secondly, the degree of corrosion caused by cross section is different, the tensile strength decreases after the stress concentration is produced. With the increasing of corrosion rate, the nominal ultimate strength of the steel strand is significantly decreased.

According to the test data, the relationship between the nominal ultimate strength and the corrosion rate is obtained, as shown in Figure 7. Using MathCAD to fit, the nominal ultimate strength formula is 2, the correlation coefficient is 0.999, and the fitting effect is good.

$$f_{ptk,\eta} = 1999 - 51.744\eta \quad 0 \le \eta \le 13.08 \quad (2)$$

In the formula:

$f_{ptk,\eta}$ -Nominal ultimate strength(MPa);

η -Corrosion rate(%);

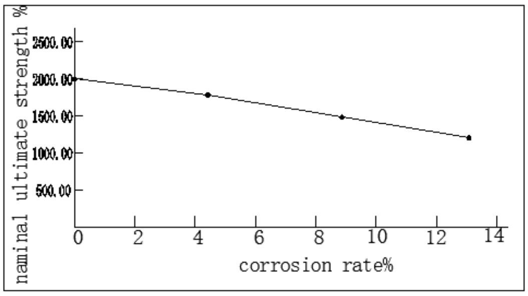

Figure 7. Change Law of Nominal Ultimate Strength with the Increase of Corrosion Rate

3. Conclusion

After static test, the corrosion of steel strand and non bonded partially prestressed concrete beams after strand corroded are analyzed, and the following conclusions are obtained:

a) Through the static tensile test, the related performance deterioration of the unbonded prestressed tendons was studied. The results show that the deformation ability corroded pre-stressed tendon plastic decreases. At the same time, the nominal yield strength, ultimate strength and nominal elastic modulus of the prestressed tendons are gradually decay with the increasing of the corrosion rate.

b) With the increasing of corrosion rate, the fracture height of the test beam is reduced, the number of cracks is reduced, and the average distance between cracks is increased.

References

[1] Zhu Pinghua,, “Durability design and assessment of concrete structures,” [Doctoral Dissertation],Zhe Jiang: School of civil engineering, University of Zhejiang, in Zheng Jiang,2006.

[2] Zheng Yaming, Ou Yangping, An Ling, “Experimental study on mechanical properties of corroded steel wire[J],” Modern Transportation Technology, pp. 33-36, June 2005.

[3] Zeng Zhixin, Song Xiaolei, “Performance test of Liang Jing bearing capacity of corroded reinforced concrete[J],” Journal of Huaqiao University (Natural Science Edition), pp. 92–95, January 2011.

[4] Yu Fang, “Research on the performance of partially prestressed concrete beams after corrosion of steel strand[D],” [Doctoral Dissertation], Dalian Technology University,2013.