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STUDY ON THE CRACKING PATTERN OF CONCRETE TOWER

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ABSTRACT

This paper presents the evaluation for the safety performance of the concrete tower, the performances of the concrete tower cracking behavior is simulated and studied experimentally, which make safety evaluation with fractal theory and verify the method through the 1:4 scale model in laboratory based on fractal theory. The results show that the damage evolution of concrete tower has fractal characteristics, which can quantify the relationship of carrying capacity of cable-stayed tower and the fractal dimension to evaluate the safety performance of the cable-stayed tower.

Keywords: Damage evolution, Racking behavior, Fractal dimension.

1. INTRODUCTION

More than 75% domestic concrete towers crack because of external loads, changes in temperature of the inside and outside of the box, construction technology and so on. The tower safety issues have caught the attention of the bridge experts and scholars and a complete evaluation method of tower safety performance need to be explorded to avoid accident. Domestic and foreign studies show that there are some theory and techniques of safety performance evaluation of cable-stayed bridge. For example, Genetic Algorithms [1], Neural Networks [2] and Fuzzy Theory [3] were applied to do the reliability and safety assessment studies of cable-stayed bridge, AHP was used to establish the evaluation index system of cable-stayed bridge and several methods were combined to do the safety assessment of cable-stayed bridge.However, there are few theory and techniques to evaluate the safety performance of cable-stayed bridge when the tower crack occurs and now domestic and foreign studies show that mature theoretical system of safety evaluation under tall tower cracks state has not appear. This paper combines numerical simulation and model test to establish the safety assessment model based on fractal damage theory [4]~[9] which could be used to evaluate the security status of cable-stayed bridge after tower crack has occured. The study results have extremely important theoretical significance to evaluate the security status of the cable-stayed tower.

2. THE FINITE ELEMENT CALCULATION

The main bridge span is (149.12+332+113) m of the concrete Towers and double cable plane prestressed concrete tower and cable-stayed bridge, using reinforced concrete “H” type ,and the tall tower closes to132.3m, the short one is 99.5m, the finite element method of whole bridge model is shown in figure 1.

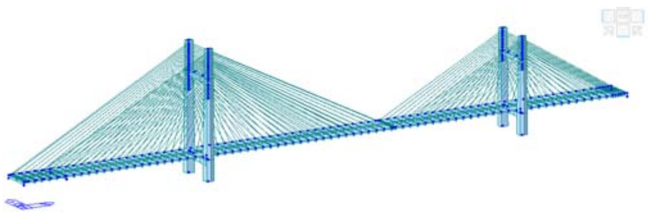


Figure 1. Finite element of full bridge

Conduct child model processing around cable guide hole of cable tower segment shown in Figure 1. The model considers the effect of prestressed steel (simulated by cooling) and ordinary steel (simulated by truss element). Boundary conditions are adopted the consolidation process at the bottom and free style in other elements. This process simulates the phenomenon of cable guide hole from crack initiation to crack growth and the concrete damage with the increasing of stayed-cable force.

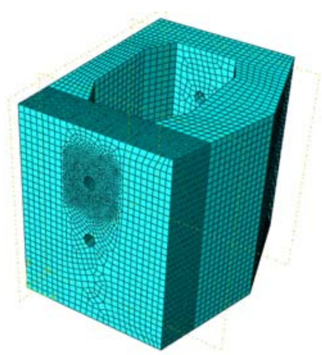


Figure 2. Segment of cable pylon models and child models

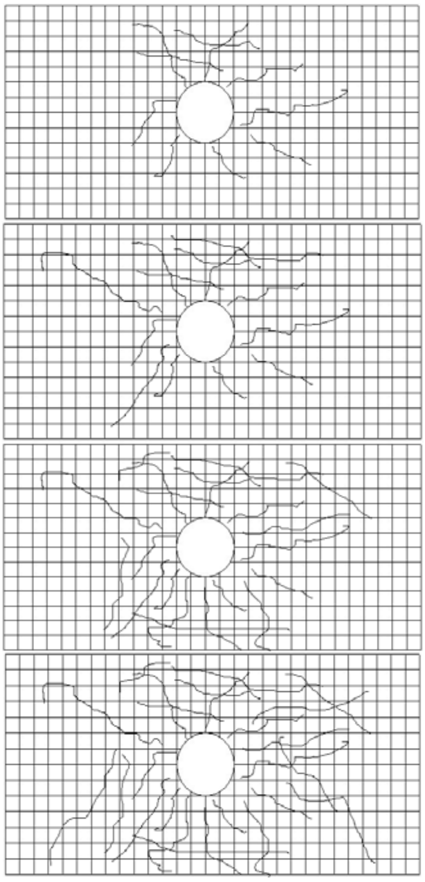


Figure 3. Crack distribution and mesh generation

From Figure 3, the tower crack number is gradually increasing with the growth of the load. When calculated loads exceed the tower limit load, fractal dimensions obtained from the crack complexity can evaluate the tower safety performance.

It can realize different meshing of concrete fractal crack on the surface of the cable tower to deal with the matrix by applying the box counting method and the resize image. Then record the non-empty pixel units to achieve the measuring goal. This paper applies mat lab to write programs. By writing m documents, complete the image processing and measuring. The used mat lab command flows are as follows: imwrite, imread, imfeature, bw1 = im2bw (aa1, level), level = gray thresh (aa1), rgb2gray and so on. Through the calculation, the corresponding fractal dimension values of the five load levels are 1.05, 1.37, 1.67, 1.82, and 1.98.

3.MODEL TEST

3.1 Loading under bearing capacity limit state

Determine the bearing capacity limit load of stayed cables: F=1.1× (1.2×final cable force＋1.4×the largest cable force caused by the moving load).

Table 1. Load classification and loading time of limit loading

serial number	hoisting jack 1 The loading tonnage (KN)	hoisting jack 2 The loading tonnage (KN)	The loading time (Minutes)
1	1000 x1/16	1000 x1/16	10
2	1500 x1/16	2000 x1/16	10
3	2000 x1/16	3000 x1/16	10
4	2500 x1/16	4000 x1/16	5
5	3000 x1/16	5000 x1/16	5
6	3500 x1/16	5400 x1/16	5
7	4000 x1/16	5400 x1/16	5
8	4500 x1/16	5400 x1/16	5
9	5000 x1/16	5400 x1/16	5
10	5400 x1/16	5400 x1/16	5
11	the bearing capacity limit load:6000 x1/16	5400 x1/16	5
12	The increasing number of each level: 200KN x1/16	5400 x1/16	Collect data once per level

In the whole loading process, pay close attention to the stress state of each measuring point. In order to facilitate the operation, unless the measuring point forces mutation, the collection of each measuring point data is only in the loading tonnage. Pay attention to the cracks and their changes and take photos in the loading process. After the experimental operation, according to the data, analyze the stress influence of loading process on each segment concrete, rebar's and pre-stressed reinforcing steels in model, and compare with the results of theoretical analysis, studying stress distribution. Explaining: When loading until the model crack initiation, in order to more accurately record the cracks development trend, loading level can be reduced; when strain gauges change anomalously, structure may be destroyed. This moment, slow down the loading speed in order to get accurate damage load.

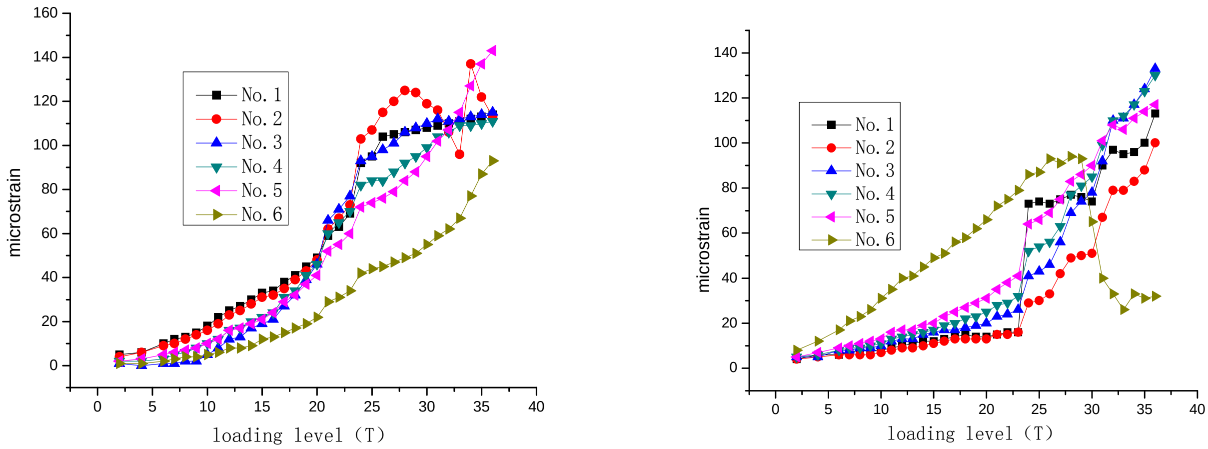
In the whole loading process, if the tower chamber cracks develop obviously, or the steel strain test shows that the steel has yielded, continue to load slowly. During this period, record the crack distribution pattern corresponding to each level load, check and analyze the anchorage zone cracks failure mode, and evaluate the tower safety by the fractal theory.

3.2 Cable tower segment model structure behavior after cracking

As the load grade is gradually increased, the tensile strain, which on the concrete strain gauge of the outside of the cable tower guide hole, increases gradually ,tower hole starting-crack, crack propagation, when the load reached 35t, east and west side has a full length crack through to the top of the tower, as shown in Figure 4 (a), (b), (c).

(a) Assembling reinforcement (b) concrete placement (c) crack distribution

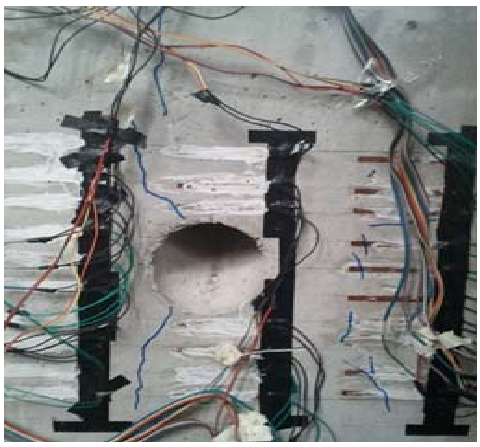
Figure 4. Scale model experiments



(a) The west cable concrete micro-strain change curve (b) The east cable concrete micro-strain change curve

Figure 5. The micro-strain of Cable tower concrete curve

From Figure 5, under the influence of the huge stay cable tension,concrete which is around outside of the cable guide hole of the cable bent tower is in tension state. Macroscopic FEM calculation can reach the main reasons of cracking, which the tower hole tensile strain exceeded ultimate tensile strain and concrete crack. The experimental model verifies the accuracy of the preliminary calculation work.



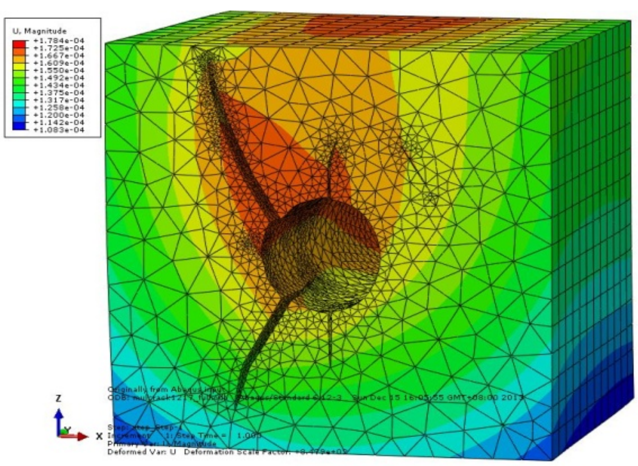


Figure 6. Contrast figures of finite element results with section model results

From Figure 6, the model test shows that the hole edge crack initiation, propagation and coalescence because the hole tensile strain exceed the standard, which it is accordance with finite element, and crack growth trends are basically the same.

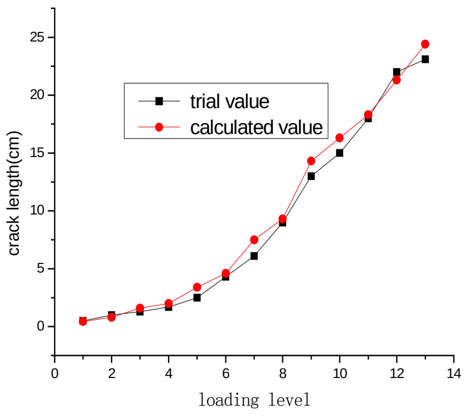


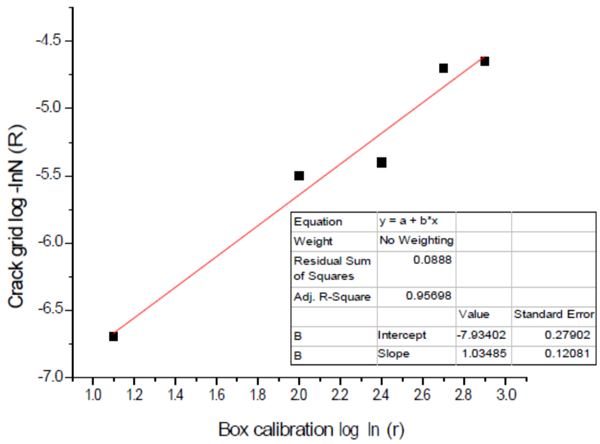
Figure 7. Crack length comparison of experimental and calculated value

To take the lateral funiculus hole in a crack as an example, painting a comparison figure of crack propagation length of experimental and calculated value with the increasing of load levels, which is shown in Figure 7. From Figure 7, after the tower cracked, the crack length changing value of numerical simulation and the test are very closed with increasing load grade. It verifies the accuracy of the calculation method

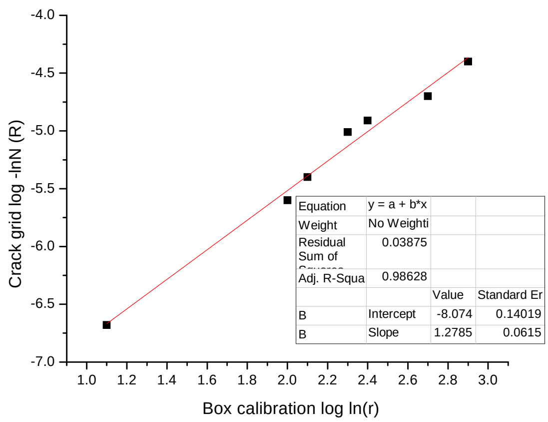
3.3 The calculation of tower fractal dimension

According to the loading cracked tower pictures, using box counting method, and the combination of resize image processing matrix, which realize different meshing of concrete fractal crack whose in the cable tower surface, and then to recorded by the non empty pixel units, using MATLAB writing a program to calculate the tower with the load increasing levels of variation in fractal dimension change.

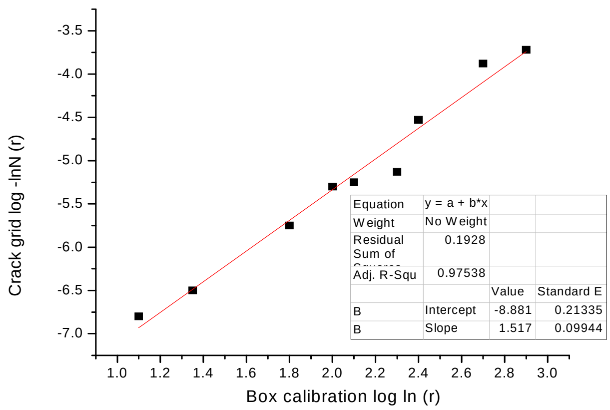
Measuring the fractal dimension of surface cracks is generally used box-counting method. From the cracks appear to structure damages, the load state corresponding to crack at all levels for summary, the method of calculating fractal-dimension as follows: Use square network whose side length is r to cover the crack distribution area of the cable tower cracking, change network density by changing the grid size r, and then get grid number N (r) including cracks in different scales. Finally, draw the relation curve between lnN (r) and ln (r). This paper gives five kinds of conditions of fractal dimension calculation diagram, as shown in figure 8.



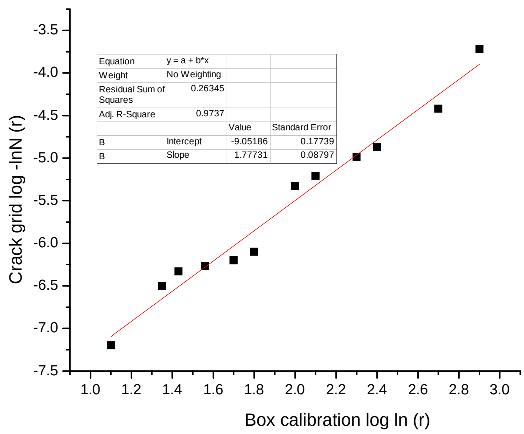
Load condition 1 (5T)



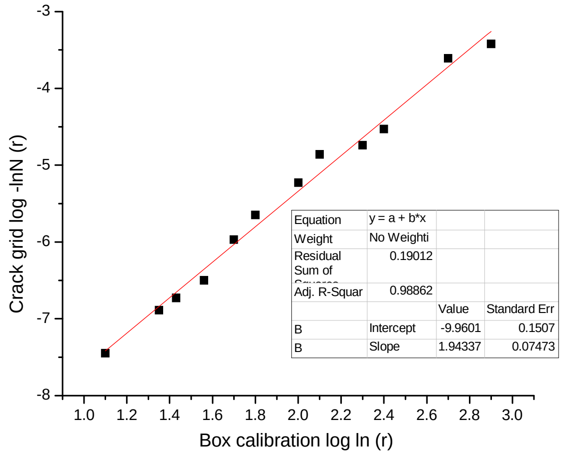
Load condition 2 (10T)



Load condition 1 (15T)



Load condition 2 (28T)



Load condition 5 (35T)

Figure 8. Calculation of fractal dimension

From the results of load condition 1 to 5, we can see that fractal dimension values of load conditions from 1 to 5 are respectively 1.02, 1.27, 1.51, 1.77 and 1.94.

From the FEM we can get that fractal dimension values are 1.05, 1.37, 1.67, 1.82 and 1.98 corresponding to the five load grade. Combining with the laboratory results, we can get the fractal dimension comparison shown in figure9,the laboratory results, we can get the fractal dimension comparison shown in figure9.

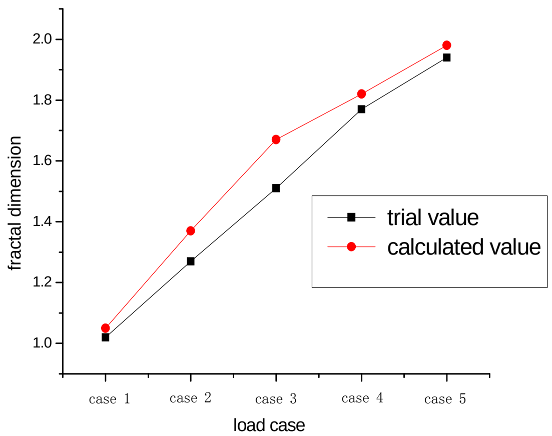


Figure 9. Compared with the finite element calculation results test

From the figure 10, from the results of the FEM model and the model test under the same load condition, fractal dimensions under each level load are very close. Also it verifies the reliability of the fractal theory when evaluating the cable tower safety performance.

Through the analysis of cable tower segment model test, we can get the conclusions as follows:

① Under the influence of huge cable force, the concrete around the cable hole outside of cable tower is under the tension state. And it has high similarity with the FEM calculation. The main reason for the cable hole cracking is that the strain of tower cable tower around the hole is bigger than ultimate tensile strain, so cracks. The experiment model also verifies the accuracy of the previous calculation work.

②The contrast of model test and the FEM model, we know that with the increasing of the load grade, crack length changing value of numerical simulation calculation value are very close to experimental measurement's. So it verifies the accuracy of the calculation method.

③ Fractal dimension values of the FEM calculation results is very close to the model test calculation results under the same load condition. It verifies the reliability of the fractal theory when evaluating the cable tower safety performance.

4. CONCLUSION

Combining numerical simulation and scale model test, we made detailed records about the crack distribution in different load conditions. And combining the fractal theory, we evaluate the safety condition of cable tower in different load conditions. Fractal dimension is able to depict the extent of cable tower damage. Fractal dimension at ultimate load is corresponding to the biggest damage, and it provides quantitative indicators for the cable tower. It can get a conclusion as follows: When fractal dimension is 1, it indicates no cracks or small damage. When fractal dimension is 2 or close to 2, it indicates serious damage or completely destroying. The dimensions of the average crack always arrange from 1 to 2. It means that the size of fractal dimension values explicitly expresses the degree of structural cracking. And the correspondence between cable tower safety performance and the fractal dimension can be made based on the above analysis. The main conclusions are as follows:

1) According to the model test, the excessive tension strain leads to crack initiation and extension until the run-through around the cable guide hole, which is in accordance with finite element result and the crack growth trends in both cases are essentially the same.
2) Under the same load condition, the results of the FEM model and the model test show that fractal dimensions under each level load are very close,

which verifies the reliability of the fractal theory in evaluating the cable tower safety performance.

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