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The Performance Evaluation of Concrete Filled Steel Tubular Arch Bridge

Ma Wei-long
(School of Civil Engineering and Architecture, Chongqing Jiaotong University, Chongqing 400074, China)

Abstract
In this paper, the system assessment theory of he concrete filled steel tubular arch bridge which is based on the theory of the reliability of system reliability is researched through the finite element analysis software ANSYS. Because the concrete filled steel tube arch bridge has the characteristics, such as the components numerous, complex forces, unable to list the of the explicit limit state equation, so use the probability design module of ANSYS (PDS) technology for the performance evaluation of the concrete filled steel tubular arch bridge with the combination of the reliability theory of monte carlo (MC) method, the response surface method (RSM) and the equivalent normal distribution method (JC method).According to the measured data and documents, selecte the random variables which have a large influence on structure reliability as the input parameters and use APDL language to write the structural response's parameterized model of concrete filled steel tubular arch bridge. Then fit the response surface equation and get its statistical sampling parameters, and finally using Matlab program based on JC method to calculate the reliability index of the components. According to the structure characteristics of concrete filled steel tube arch bridge, the whole structure is as a series of arch rib series, derrick, floor system, selection of components of the minimum reliability index as the system's reliability index.

Keywords: Concrete filled steel tube arch bridge; Reliability theory; PDS technology; Performance evaluation

I. Introduction

Since 1990,when China's first concrete filled steel tubular arch bridge--popular pale east river bridge in Sichuan was built[1], the concrete filled steel tube arch bridge in China got rapid development, because the concrete filled steel tubular arch bridge has advantages of high strength, convenient construction, aesthetically pleasing, and comes at a time when China's massive traffic infrastructure construction period[2].At the same time, because the current theory of the concrete filled steel tubular arch bridge is not very perfect and lack of experience in the design, on struction, operation management, the built concrete filled steel tubular arch bridge appeared all sorts of security Problems which are Crisis use safety such as arch rib concrete pavement, derrick fracture .So the performance of the concrete filled steel tubular arch bridge evaluation become a concerned focus in the current engineering. At present, the concrete filled steel tubular arch bridge safety assessment methods include conventional comprehensive evaluation method, Delphi expert evaluation method , the expert system method, analytic hierarchy process (AHP) method, grey correlation evaluation method, defect status indicators, the artificial neural network, fuzzy comprehensive evaluation, internal force envelope limit evaluation method, the reliability method [3, 4], and so on. But all of the evaluation methods having advantages and disadvantages have a significant

difference from the actual engineering application. This paper introduce the performance evaluation of concrete filled steel tube arch bridge based on the theory of the reliability using the ANSYS PDS Technology with the combination of the monte carlo method, the response surface method, equivalent normal distribution method. The calculation process is shown in figure 1:

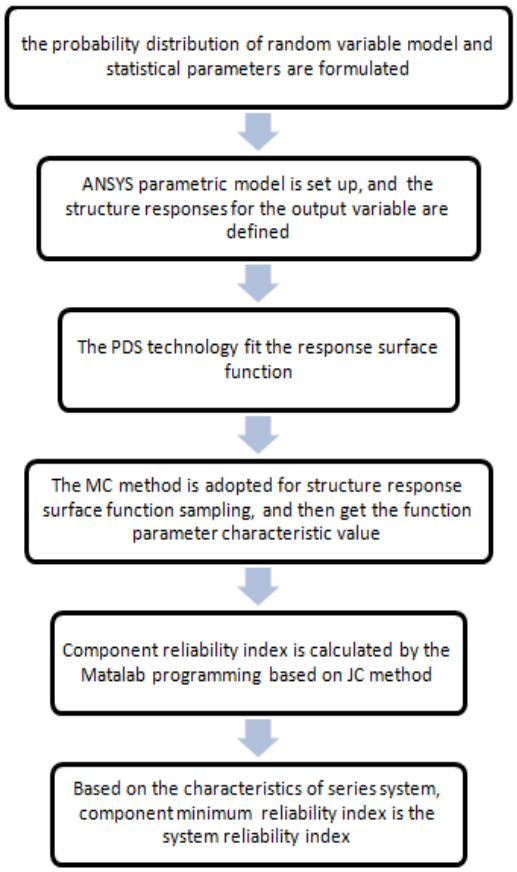

Figure 1 ANSYS structural reliability of steps

II. the General Situation of the Engineering

Figure 2 is a concrete filled prestressed steel tube concrete arc bridge, whose parameters are as follows : arch axis is quadratic parabola ,calculation span is 60 meters, width of bridge deck is net - 11.25 meters (driveway) + 2 x 1.3 meters (pavement), calculation rise is 12 meters, rise-span ratio is 1/5. Derrick spacing is 4 m, tie bar, bar for prestressed concrete structures. The bridge panel is aside on the beam, through the bridge deck pavement Connection to the overall. Substructure adopts Column pier, bored piles foundation. This bridge main technical standards are as follows:

(1)The design load: steam - 20, hang - 100;

(2) The seismic fortification standards: 7 degrees

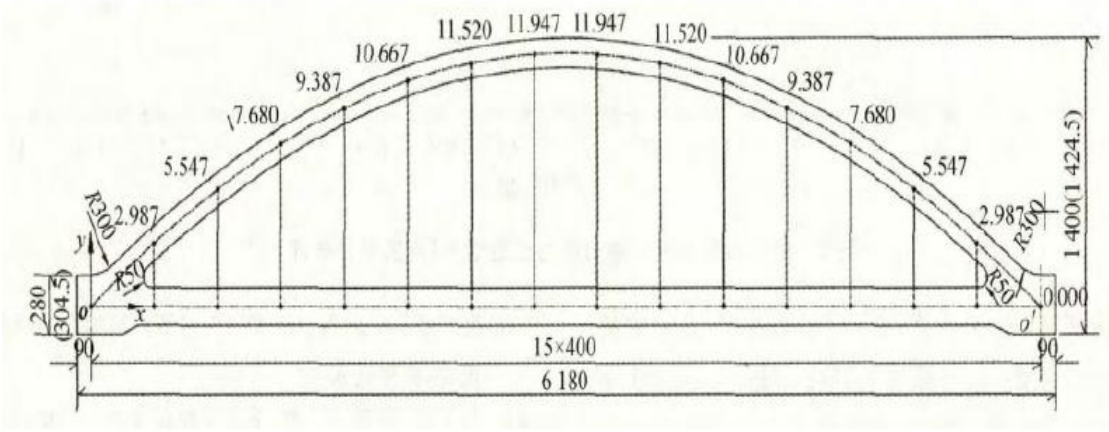

Figure 2: bridge elevation (unit: cm)

III. Reliability Analysis of Concrete Filled Steel Tube Arch Bridge

3.1the Determination of Random Variables

According to the current research results, the main factors influencing the structural reliability are

the vehicle load, concrete calculation mode, steel calculation mode, etc. The random variables[5,6,7] for the reliability analysis of the concrete filled steel tube arch bridge are shown in table 1.

Table 1: characteristics probability distribution of random variables

random variable		the mean	coefficient of variation	distribution type
vehicle load	X1	0.7882	0.112	the extreme I type
crowd load	X2	0.5768	0.3911	normal distribution
The intensity of steel pipe	X3	1.08	0.08	normal distribution
Strength of concrete	X4	1.32	0.135	normal distribution
Steel pipe calculation	X5	1.15	0.13	normal distribution
The concrete calculation	X6	1.45	0.135	normal distribution
Steel pipe elastic	X7	1	0.1	normal distribution
The concrete elastic	X8	1	0.1	normal distribution
Steel strand elastic	X9	1	0.1	normal distribution
dead load	X10	1.0212	0.05	Normal distribution
Second phase dead load	X11	0.9865	0.1114	normal distribution

3.2finite element modeling

According to the bridge floor system structure, the arch axis linear as well as the main arch rib concrete strength data to modify the finite element model, the resulting finite element model conforms to the real bridge. on the choice of elements, the main arch rib use double-cell: steel beam element--beam44 and concrete beam element-- beam44;derrick use bar element--link10;tie rod, beams with beam element--beam44;bridge panel use the plate element--shell63.The bridge deck pavement and the tie bar prestressed use equivalent load simulation and the vehicle load adopts full bridge load in the most unfavorable conditions. The whole bridge finite element model is shown in figure 2.

3.3 Fitting the Response Surface and the Solution of the Reliability Index

Limit state equation is the key to judge structure failure or not and the foundation of reliability assessment. In this paper, the limit state equation of concrete filled steel tubular arch bridge are based on concrete and steel tube of the allowable stress. Set up the steel tube arch rib, tie rod, beam and arch rib concrete and the limit state function of the derrick.Then extract the two maximum stress indicators of the concrete and steel tube the as the failure criterions and establish the limit state equations, The equation is as follows:

By the concrete material yield stress as a limit state equation:

By the steel tube material yield stress as a limit state equation:

Among them: Xi for the table 1 set of random variables:

σcmaxrepresentation the maximum Mises stress of concrete of arch bridge during the current operation;

σsmaxrepresentation the maximum Mises stress of steel tube of arch bridge during the current operation;

[σc] representation the allowable stress of s concrete;

[σs] representation the allowable stress of steel tube.

Through the analysis, concrete and steel material strength parameters affect the normal use of structure system state significantly..So the response surface of the structure can be fitted by them, respectively based on the serviceability limit state equation of the structure's material strength. The response surface equation are shown in table 2

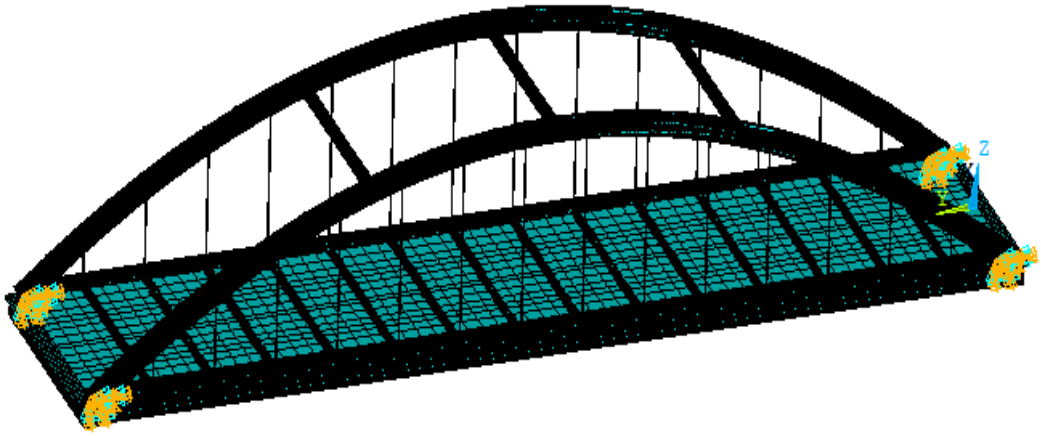

figure 2 :The finite element model

Table 2 items and the coefficient of response surface equation

	Function ZG1	Function ZG2	Function ZG3	Function ZG4
constant term	1.2126e8	1.87697e7	2.30361e6	1.1778e7
X1	-8.4297e5	-1.47893e5	4.64087e4	-3.77656e4
X2	-2.41011e5	-4.2509e4	1.17151e4	2.67562e3
X3	1.19097e7	—	—	—
X4	—	3.1524e6	2.29261e6	3.15234e6
X5	-7.27503e6	—	—	—
X6	—	-1.21151e6	-2.0547e6	-1.93471e6
X7	-4.44707e6	1.97106e5	2.13361e4	5.28404e3
X8	4.37402e6	-1.51508e5	-5.17167e4	—
X9	3.11305e6	5.52394e5	-2.27597e4	7.29534e3
X10	-2.80421e6	-4.86135e5	3.30082e5	1.41149e5
X11	-9.68864e5	-1.69645e5	1.00478e5	2.2153e4

According to the structure characteristics of the concrete filled steel tube arc bridge, the main arch rib, tie rod, and the structure of bridge deck structure are as a series (Because the derricks of the bridge have just for been replaced, which can be thought as absolute safety status, so the tie bar for the calculation of reliability index don't need for reliability analysis). Evaluated the tandem structure characteristics, Select the structure reliability index of the evaluation at the lowest level as the system's reliability index. According to the front of the Matlab program, use the JC method for the computation of the statistical parameters of random variables. Then obtain the results as follows: the reliable indicator of function ZG1 (the main arch rib's steel pipe compression stress) is $\beta = +\infty$; the reliable indicator of function ZG2 (main arch rib concrete's compressive stress) is $\beta = 35.7865$; the reliable indicator of function ZG3 (tie bar concrete compressive stress) is $\beta = 6.5708$; the reliable indicators of function ZG4 (beam compressive stress of concrete) is $\beta = 21.7993$. The reliability index of the tie bar concrete compressive stress is as bridge upper system reliability index of concrete filled steel

tube arch bridge, namely β=6.5708, failure probability Pf= 2.5029e-11. According to the highway bridge technique condition evaluation standard [8] and the Bridges safety level standard based on the component [9], the final evaluation is for a class of the bridge upper structure system.

IV. Conclusion

This paper introduce the performance evaluation of concrete filled steel tube arch bridge- whose functions are unable to list clearly- based on the theory of the reliability using the ANSYS PDS Technology with the combination of the monte carlo method, the response surface method, equivalent normal distribution method.

Evaluation results show that the bridge of the tie bar's reliability index is minimum, but still higher than the lower limit of the first kind's bridges. The reliability indexes of the steel tube arch rib and the concrete arch rib, concrete beams are far higher than the lower limit of the first kind's bridges. Comprehensive the facts the bridge into use fixed number of year shorter, the strength index decline not obvious, no significant injury of actual testing results, the bridge which is in good condition can ensure the safety of the operation.

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