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Fatigue Reliability Analysis of the Stay Cables of Cable-stayed Bridge under Combined Loads of Stochastic Traffic and Wind

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Key words : Cable-stayed bridge; Stay cables; Wind load; Random vehicle load; Fatigue reliability

Abstract: The existent studies on cable stays fatigue for the serviced cable-stayed bridge generally only considered traffic or wind load action respectively. The long span cable-stayed bridges are very sensitive to wind load, so the fatigue estimation of cable stays considering traffic and wind load simultaneously is very important for the bridge safety. In the present research, taking an actual bridge as an example, based on linear cumulative damage theory, fatigue reliability of cable stays is analyzed under combined load of vehicles and wind. Firstly, based on the long-term traffic survey and wind speed data, traffic and wind load probability distribution models for the bridge are built respectively. Secondly, an intensive computational work is performed to obtain stress time history of the stay cables in the typical time block by running self-compiled Bridge-Vehicle-Wind interaction dynamic response analysis program. Thirdly, the stress result is updated in accordance with traffic growth and extreme wind speed changing in service period. The stress amplitude and frequency are attained by rain-flow cycle counting method. Finally, the fatigue damage limit state function of cable stays is proposed based on linear cumulative damage theory, and solved by Monte-Carlo method. The analysis result shows that the effect of buffeting wind load on the fatigue reliability of cable stays is significant, the influence degree increases generally in accordance with the order from short cable to long cable. The fatigue life of cable under designed safety probability reduces by the range from 2% to 63%, average 50% compared to only considering traffic load. So fatigue assessment of stay cables should take traffic and wind loads together into account. The proposed analysis framework offers a referenced fatigue assessment approach for conventional long span bridges.

1. Introduction

Stay cables are important structural components of cable-stayed bridge. A number of operating cable-stayed bridges worldwide show that stay cables are most vulnerable and lowest life components[1,2,3,4]. The stay cables work in high tensile stress status under vehicles and wind load action during operation period, its fatigue performance always is the focus of research.

Recent years, the dynamic effect of cable-stayed bridge under moving traffic load and wind load became more remarkable with development in span scale, so this invokes more focus on fatigue problem of stay cables. Considering the double randomness characteristic from fatigue resistance and load, researching and evaluating existing cable fatigue is necessary based on reliability method. Some researches about stay cables fatigue have been carried out. Lu wei brought out a modified fatigue reliability formula by assuming the fatigue life accorded with the Weibull distribution and considering the effect of mean tension stress, based on the accurate bridge buffeting analysis of time history, the fatigue reliability of stay cables is analyzed under designed wind speed [5]. It was hypothesized that within one random stress cycle, the dispersion between the maximum and minimum stress of the nodes was content with Rayleigh distribution. The formula of fatigue reliability of stay cables was formulated and the simple formulas for the estimation of fatigue life were presented [6]. Yang Mei-liang formulated fatigue reliability formulas with stress time history of cables simulated by Monte-Carlo random method based on the vehicle load spectrum model [7]. Past studies on the project includes fatigue design method considering design vehicle load, wind-induced fatigue, fatigue estimation based on the traffic load for the stay cables, but the stay cables fatigue reliability research combining vehicle and wind load action is very limited and is not found in the published documents.

This paper discusses the stay cable fatigue reliability of long span cable-stayed bridge by the cumulative fatigue damage theory, and takes stay cable fatigue resistance randomness and load effect randomness into consideration comprehensively by using the self-developed analysis program for wind-vehicle-bridge coupling vibration. The results provide a good reference for stay cable system maintenance and safety evaluation.

2. Fatigue reliability analysis model of the stay cable

2.1 Fatigue resistance of the stay cable

Because of the influencing factors existing, such as component materials, production processes and methods, surface conditions, external environment and etc, fatigue resistance of stay cables has apparent randomness and includes internal and external two types. Among them, the internal randomness mainly depends on the material structure, composition material, uneven distribution of defect properties and etc, and the external fragmentation is mainly caused by the uncertain factors such as external load randomness, work environment and etc.

S-N curve is a basic equation that describes the fatigue resistance of structure or component material. It reflects the relationship between the stress amplitude and number of stress cycles, and generally can be obtained by constant amplitude cyclic loading test for the structure or component materials. The high cycle fatigue common function of S-N curve is

$$NS^m = C \qquad (1)$$

In the formula, S is expressed as stress amplitude; N is expressed as number of cycles; m and C are the deferent constants associated with the structural details. However, the stay cable is always in high stress during the operation period, and the research indicates that mean tensile stress will reduce fatigue life. The given experimental results by Suh Jeong-In and Chang Sung Pil [8] show that, Goodman equation can better reflects the influence of the average tensile stress on the cable fatigue life. After revised, S-N curve formula can be rewritten as

$$NS_{eq}^m = C \qquad (2)$$

In the formula, $S_{eq} = k_e S$ is equivalent stress amplitude, $k_e = 1/(1 - S_m / S_b)$ is ultimate strength of the material, S is expressed as random stress amplitude; N is taken as 2×10^6 times in accordance with the Design Specification of Highway Cable Stayed Bridge of China.

1.2 Model of fatigue reliability analysis

In the present paper fatigue cumulative damage model is adopted for stay cable fatigue reliability analysis. Structural fatigue damage is the process of gradual accumulation under random load. With the increasing of cycle number, fatigue damage grows monotonely. The safety margin equation can be written as

$$\boldsymbol{D}(\boldsymbol{n})-\boldsymbol{D}_c \leq 0 \tag{3}$$

where, $\boldsymbol{D}(\boldsymbol{n})$ is the cumulative damage which is a stochastic process increasing monotonely with cycle number n; $\boldsymbol{D}_c$ is critical damage value and can be regarded as random variable. The component is safe when the above equation is satisfied. The component fatigue reliability can be written as

$$P_r = P(D(n)-D_c \leq 0) \tag{4}$$

The fatigue damage can be expressed by Miner linear cumulative damage rules as

$$D(n)=\sum_{i=1}^{n}\Delta D_i=\sum_{i=1}^{n}\frac{1}{N_i} \tag{5}$$

The cyclic stress amplitude of the stay cable changes continuously under operation load, we can substitute Eq.(1) into Eq.(5), the Eq(5) can be written as

$$D(n)=\sum_{i=1}^{n}\frac{S_i^m}{C}=\frac{nE(S^m)}{C} \tag{6}$$

So the fatigue limit state equation can be expressed as

$$\frac{nE(S^m)}{C}-D_c=0 \tag{7}$$

When the cumulative fatigue damage exceeds the critical damage value, fatigue failure occurs. In linear fatigue analysis excluding load interaction, fatigue effect produced by random stress process can be described equivalently with the constant amplitude fatigue stress [9]. The equivalent fatigue stress S_{eq} can be expressed as

$$S_{eq}=\left(\frac{\sum n_i S_i^{\,m}}{\sum n_i}\right)^{\frac{1}{m}}=\left[E(S^m)\right]^{1/m} \tag{8}$$

We put Eq.(8) into Eq. (7), so the fatigue limit state equation can be written as

$$\frac{nS_{eq}^m}{C}-D_c=0 \tag{9}$$

Among them, material properties parameter C is generally considered to follow Lognormal distribution, and its logarithmic mean value and standard deviation can be obtained by constant amplitude fatigue test. For the stay cable, D_c is generally considered to follow the Lognormal distribution that means value is 1.0 and the standard deviation is 0.3. The external load randomness is determined by the stress spectrum simulation and statistically analyzing equivalent stress amplitude. The definite analysis process can be described as follows: at first, the stress time history of the stay cables in variety of typical time block can be achieved by simulating analysis, and which is analyzed though Rain-flow counting method to gain the stress range and cycle number; After that, the equivalent stress amplitudes in all time block can be figure out. At last, we statistically analyze the equivalent stress amplitude in various typical periods and fit out random distribution type of the equivalent stress amplitude.

1.3 Fatigue reliability calculation

At present, there is many methods to calculate reliability. The fatigue reliability analysis of the cables relates to many random variables according with different distributions, normal methods may face to large error and very complex mathematical calculations. Monte-Carlo method has many good characteristics in the numerical simulation of structural reliability and has the ability to resolve the problems straightly. For example, with the Monte-Carlo method, the convergence speed is independent of the dimension of the basic variables, and the complexity of the limit state function has nothing to do with the simulation, also we no need the state function equivalent linearization and normalized random variable. There for, Monte-Carlo method is adopted in this paper.

Because other analysis methods may bring out the system error and calculation difficulty in math, Monte-Carlo method is generally taken as a correctness verification tools to structural reliability. As long as obtaining the random distribution type and parameters of the variables, the reliability index can be computed by Monte-Carlo method. In the paper, the sample program for multifarious distribution random variables is compiled in Matlab adopting Latin Hypercube sampling method. The fatigue reliability analysis process of the cables can be described as follows:

(1) Obtain the cable's fatigue life curve and probability distribution through existing experiment and research results;

(2) The stress time history of the cables in many typical time periods is computed with the analysis program, then the stress amplitude and cycle number are obtained through statistical accounting method;

(3) Based on the Miner cumulative damage theory, the equivalent fatigue stress in typical time periods could be achieved. After that, the random distribution types and parameters of equivalent stress amplitude is educed by the probability statistics analysis method;

(4) Based on the obtained stress cycle number of the cables during the various usage periods, the time-dependent fatigue reliability of the cables is analyzed by Monte-Carlo method.

2 Calculation and simulation of stay cable stress spectrum

2.1 Bridge overview

The Nanjing Yangtse River second bridge is taken as the project background for research. It is a 58.5+246.5+628.0+246.5+58.5m five span continuous semi-floating system cable-stayed bridge. The main beam is the flat streamlined steel box girder, its height in center line is 3.5m. The center distance between cables on the deck is 33.6m. The bridge tower is reinforced concrete structures and 195.41m height. The tower shape is inverted Y structure composed of double column. There are 80 stay cables in the bridge. The distance of standard cables on the beams is 15m. The layout of the bridge and the cable number are shown in Figure 1.

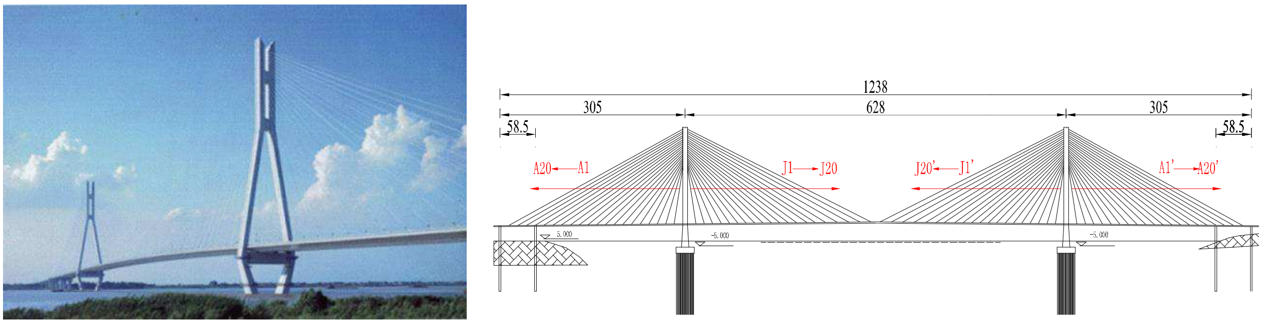

Figure 1 Layout of the bridge

2.1 Traffic load simulation

Traffic load across bridge is a random process, and the vehicle type, weight and spacing at any time follows a certain random distribution [10]. In the paper, based on the need and characteristic of cable fatigue damage probabilistic analysis, the simulation research of random traffic load is carried out by taking the Nanjing Yangtse River second bridge as studying object. Firstly, the average daily traffic volume and its annual growth rate of the bridge could be obtained by the traffic volume survey and investigations. After that, the vehicles are classified into 6 classes according to the vehicle type, axle number and weight characteristics reference to related research. Finally, vehicle type, vehicle weight and vehicle distance are chosen as characteristic parameters in stochastic simulation program.

Based on the observational traffic data of the bridge, we carry out goodness-of-fitting of the random distribution type of the vehicle characteristic parameters adopting the K-S method. The random variable parameters of vehicle load are computed by maximum likelihood method.

Taking the annual average daily traffic volume as a simulation sample size, we simulated the random vehicle load by Monte-Carlo method and get the random vehicle load spectrum considering influence of annual traffic growth rate. The specific simulation steps and results are listed in the author's degree thesis in detail [11].

The average daily traffic volume of 9325 vehicles on the building bridge of 2001 are taken as an example to simulate, and the results are illustrated in the Figure 2 to Figure 4. Seen from the chart, the random vehicle simulation results coincide well with the measured values, and can be used in bridge evaluation and analysis as actual vehicle load spectrum.

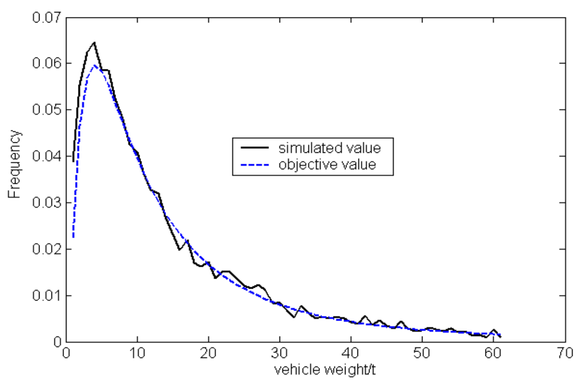

Figure 2 Vehicle type simulations

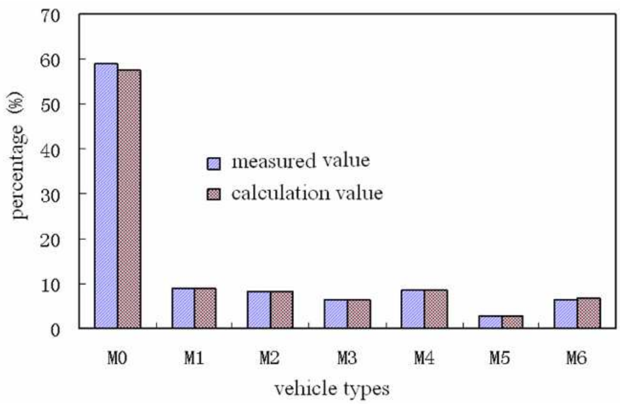

Figure 3 Simulation of vehicle weight

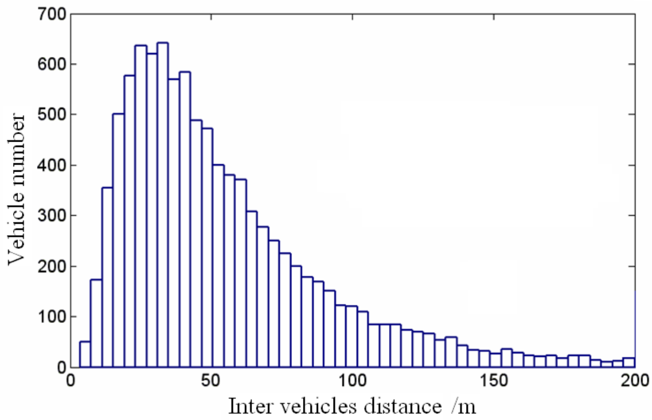

Figure 4 Simulation of vehicle distance

2.2 Probabilistic description of wind

The Nanjing Yangtse River second bridge locates in the Bagua Zhou island channel of Yangtse River in Nanjing, and is influenced seriously by typhoon and monsoon effect. The power index of wind speed along the height distribution is 0.142 in the bridge site, surface conditions is between class I and II, and surface roughness is chosen as 0.03m. The basic design wind speed is 40m/s on the deck height in 100-year return period. Base on the statistic data the wind speed in 30-year return period is 36.8m/s on the bridge site [12]. The wind load probability model in this study mainly includes extreme and average wind speed two parts.

2.2.1 Extreme wind speed

The extreme wind speed is a main factor in bridge buffeting analysis and evaluation, and affected by distribution type of wind speed, sample records data of wind speed, measurement error of wind speed, time-distance conversion of average wind, sites conversion of average wind, local topography, surface roughness and so on. Yearly maximum average wind speed belongs to extreme random variables which is the maximum wind speed observed with the provisions of duration in one year. According to the yearly maximum wind speed data and statistical hypothesis testing, it is considered that the probability distribution obeys the extreme I distribution[12], and its distribution function is list in equation (1)

$$F_G(u) = \exp[-\exp(-\frac{u-b}{a})] \qquad (10)$$

The distribution parameters of extreme wind speed can be obtained from the designed wind speed (encountered in 100 years) and the construction basic wind speed (encountered in 30 years).

$$1-\frac{1}{30} = \exp\left[-\exp\left(-\frac{36.8-b}{a}\right)\right], \quad 1-\frac{1}{100} = \exp\left[-\exp\left(-\frac{40-b}{a}\right)\right] \qquad (11)$$

The bridge site wind speed scale parameter is available with $a = 2.632$ and the location parameter with $b = 27.892$ by solving this equation. Whereupon, the bridge site designed wind speed in different return periods can be derived. The results are shown in Table 1.

Table 1 Basic wind velocity under different return period

return period /year	5	10	20	30	50	100	150
wind speed/(m/s)	31.2	33.6	35.2	36.8	38	40	60

2.2.2 The distribution of average wind speed

Average wind speed may come from any direction and its intensity and frequency in every direction are different, therefore, the distribution rule of average wind speed must be considered. The measured results indicate that the direction of the higher wind speed has smaller degree of dispersion, the other wind speed, especially the low wind speed, the wind direction distribution is more discrete [13]. Therefore, it's necessary to consider the distribution rules of wind direction. Strictly speaking, the average wind action should be described by the joint probability density function of the wind direction and strength, however, the related statistical data are extremely scanty. At present, the general method is to use marginal probability density to describe the wind action. The plane of wind action is usually divided into 16 directions averagely around the cycle of taking the structure as center, thereby constitute a wind rose diagram. The statistical analysis is carried out for the appearance frequency and intensity distribution within each region, and accordingly the distribution rules of wind is obtained.

Study shows that, in a certain wind direction, the appearance probability of different average wind speed obeys Weibull distribution [13]

$$p(\bar{v},k,c)=\frac{k\bar{v}^{k-1}}{c^k}\exp\left[-\left(\frac{\bar{v}}{c}\right)^k\right] \tag{12}$$

In the equation, $p(\bar{v},k,c)$ is expressed as the probability density function, $\bar{v}$ is the average wind speed, and k, c are the Weibull distribution parameter. According to the wind speed measured information[14], the wind speed distribution frequency in all directions in bridge site is listed in table 2. For the buffeting of cable-stayed bridge, the relative transverse wind load action has main effect on the structure dynamic response, while the effect is very weak from other directions. In the paper, only the roughly transverse wind load (NNE, NE, SSW and SW four directions) with 23% appearance frequency is considered for the fatigue reliability of the stay cables. The Weibull distribution parameters of above average wind speed are derived from the wind speed statistics and correlative information of the bridge site areas in the last 40 years, $k=1.75, c=5.86$. The frequency distribution of the average wind speed is obtained by Monte Carlo simulation and showed as Figure 5.

Table 2 The appearance frequency of each wind direction in bridge site

Direction	N	NNE	NE	ENE	E	ESE	SE	SSE
Frequency %	5	6	8	9	11	11	7	5
Direction	S	SSW	SW	WSW	W	WNW	NW	NNW
Frequency %	3	3	6	8	5	4	4	5

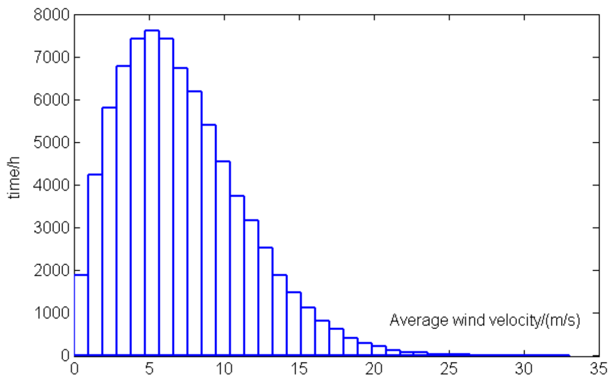

Figure 5 Distribution of lateral wind within 40 years

3 Analysis of stress spectrum

3.1 Calculation process of stress spectrum

For the bridge example, the structural dynamic response under random traffic and combining random traffic and different wind speed action respectively is analyzed with the self-compiling Wind-Vehicle-Bridge dynamic response analysis program. In the calculation random traffic volume is chosen as the annual average daily traffic volume, the average wind load is adopted with 5～40m/s speed range and 5m/s as a level.

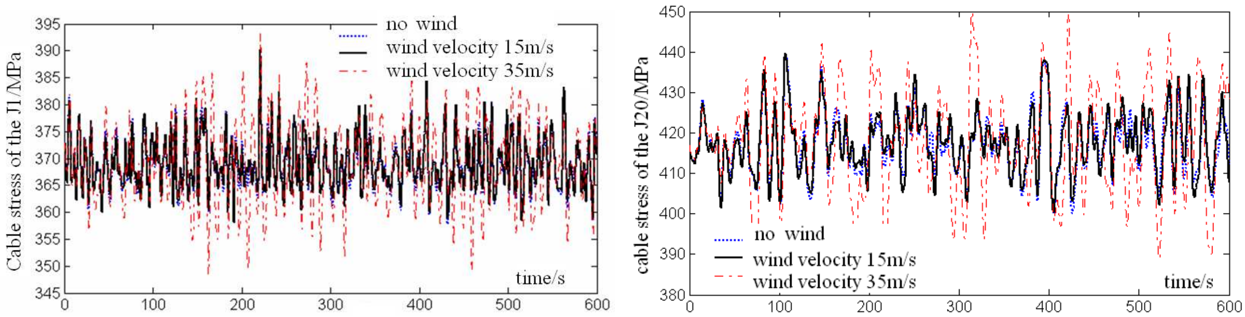

Figure 6 Influence of different wind velocity on cable force under random vehicles

In Figure 6, taking the J1 and J20 (the cables in river side) as an example, the cables force time history is compared under combining random traffic and different wind speeds. The results shows that the cable force is controlled by vehicle load in low wind speed, while by wind load significantly in high wind speed.

The calculation method and process of the cable stress spectrum is given as following:

(1) The random traffic load is simulated by self-compiling program, and then renews the annual average daily traffic data block according to the traffic volume growth forecast. Assumed daily traffic volume stops increasing when it is up to 60000.

(2) The stress time history of stay cables is computed under random traffic loads and different wind speeds action in the typical by the Wind-Vehicle-Bridge dynamic response analysis program.

(3) The rain flow method is used to count the stress amplitude and the cycle number of the cable stress time history.

(4) According to the average wind simulation results, the statistics analysis of the cables stress spectrum is carried out in the different operation periods.

3.2 The analysis of the stress spectrum results

In this section taking the year of 2001 as an example, the influence of the traffic and wind load on the cable stress spectrum is analyzed. The stress spectrum distribution of the cables (cable J1 and J20 for example) under combined action of wind and random vehicle load is illustrated in Figure 7. In the figure, the wind speed has a significant effect on the cable stress spectrum distribution. The effect on the long cable is greater than the short, for instance, the stress spectrum in the high wind speed of 35m/s increases by one time compared with no wind. However, the probability of high wind speed occurs during the design life is very small, the effect of wind load on the cable fatigue reliability need further analysis and verification.

The equivalent stress amplitude is calculated by line Miner cumulative damage criteria based on multi-group loads simulation and structural response analysis in the typical time duration. The statistical analysis and probability distribution optimal fitting of the samples shows that the equivalent stress amplitude S_{eq}^{i} could be described by Lognormal distribution, and the corresponding distribution parameters could be got by maximum likelihood method and moment estimation method. Figure 8 gives the equivalent stress amplitude histogram for the cable A1, A20, J1 and J20.

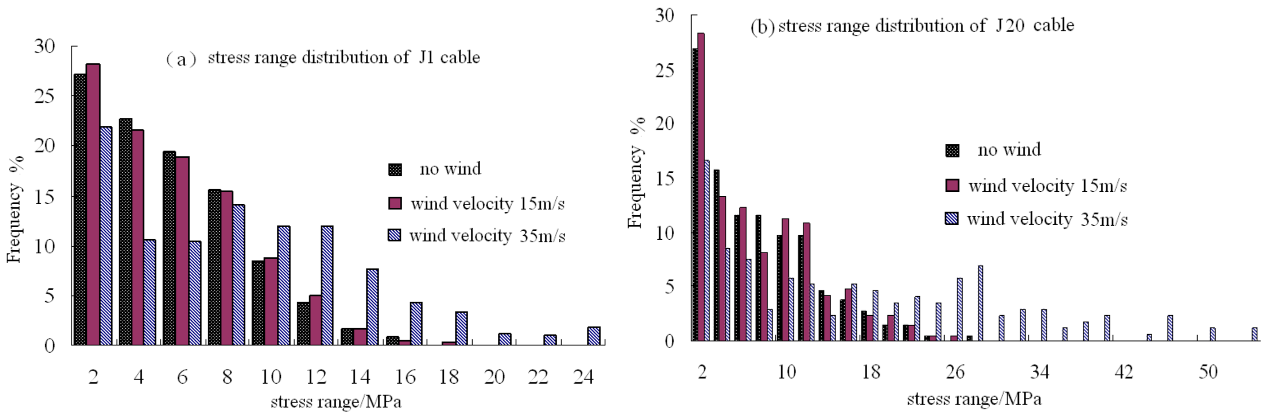

Figure 7 Influence of different wind velocity on cable force under random vehicles

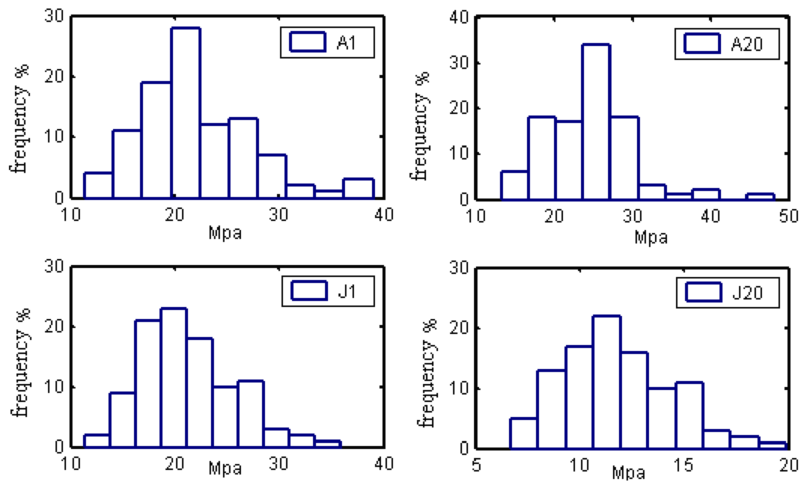

Figure 8 Distribution of cable equivalent stress amplitude

4 Fatigue reliability analysis of the stay cable

4.1 The fatigue analysis parameters definition

There is no fatigue reliability index for stay cables in bridge specification of China. The stay cable is considered as interchangeable components in modern bridge design, in this paper aim reliability index is defined 3.5 in accordance with the rules on steel component fatigue limit state in reliability design of railway bridge. The fatigue reliability of cable is computed by Monte-Carlo method based on the Latin Hypercube sampling.

All the random variables is listed in Table 2 for the fatigue reliability analysis of the cables according to the equation (9). Among them the cable material performance parameter m is 3.645, and the stress amplitude cycle number n changes with the traffic volume growth.

Table 2 Random input parameters of cable fatigue reliability analysis

Parameters	Mean	Distribution type	Mean	Variance
S_{eq}	Equivalent fatigue stress	Lognormal	The stress range based on the statistical analysis	
C	Fatigue performance parameters of the material	Lognormal	5.2047e17	1.6684
D_c	Damage threshold	Lognormal	1.0	0.3

4.2 The influence on fatigue reliability of wind load

The existing research about prediction and evaluation of bridge fatigue damage, only vehicle load is taken into account generally. But long-span cable-stayed bridge is high sensitive to wind load, therefore, it's necessary to consider the effect of wind vibration. Taking the fatigue reliability computed results of the year in 2001 as example, the effect of wind load action is showed in Fig.9. As it can be seen from Figure 9, wind load has a significant effect on the fatigue reliability of cables and reduces the fatigue reliability index of full-bridge cables in different degrees. Where, the wind load has less effect on the short cable near the tower, and greater effect on the long cables of shore side and the cables of 1/4 span in river side, and little on the A10 to A14 cables near auxiliary piers in side span.

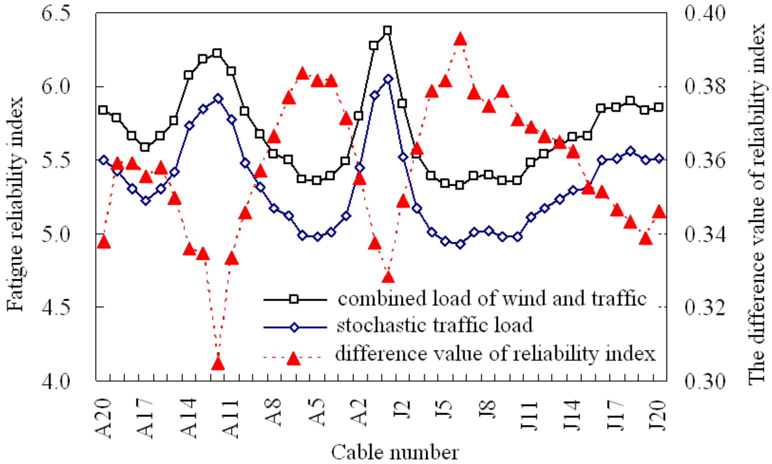

Figure 9 Influence of wind load on cable fatigue reliability

The comparison of fatigue reliability index and margin shows that the A5 and J6 have the least reliability and are influenced most significantly of wind load in the whole bridge cables. So during daily bridge maintenance, the cables with low reliability should be focused on to ensure the structure operation safety in accordance with the distribution rule of fatigue reliability.

4.3 Time-dependent fatigue reliability and fatigue reliable life analysis of the stay cables

With the growth of service period, the traffic volume increases continually, and the probability of high wind speed appearance becomes higher. Therefore, the time-dependent fatigue reliability of cables in service life is an important problem deserved to research.

Firstly, taking the J6 cable with the lowest reliability as an instance, its time-dependent fatigue reliability is analyzed and result is showed in Figure 10. From the figure we can see, the fatigue reliability index decreases continually with the service period increasing, and the declining rate grows rapidly especially in the former 30 year. From that, the maintenance management of the bridge in the initial period is essential for lasting and enhancing the service life of cable system. The time-varying curve describing the effect of wind load in Figure 10 indicates that the wind load has significant influence on the cable fatigue reliability, and the effect extent enhances continuously with the service time prolonging. The relative influence value increases from 7.4% in the first year to 32.4% in the first hundred years. All these results indicate that it is necessary to consider wind load action in design or evaluation of cable-stayed bridge for the cable system.

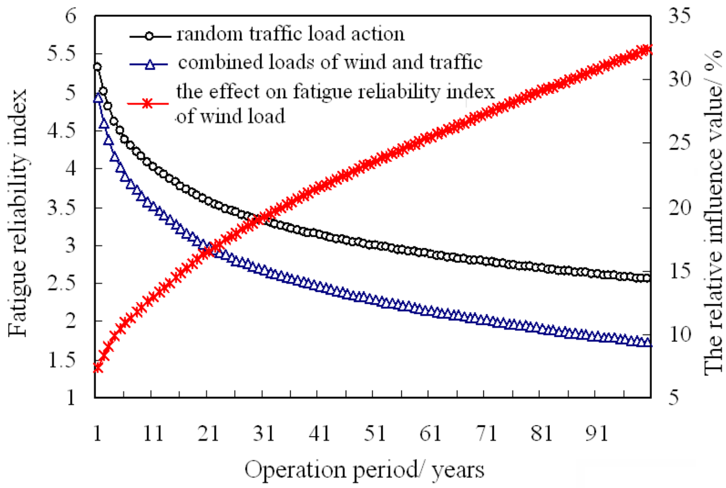

Figure 10 Time-dependent fatigue reliability of the J6 cable

Then the fatigue reliable life of full-bridge cables is predicted and analyzed based on the target reliability index 3.5 and the target reliability 0.99767. The results are shown in Figure 11, the wind load has a great influence on the fatigue reliable life of cables, and the influence rules and result could be described as followed: (1) Wind load has less effect on the short cables in the vicinity of the tower and the cables near the auxiliary piers, and greater effect on the side spans near the bank side and the cable of auxiliary span; (2) The effect has growing trend near the river side from short to long cables; (3) For the cables on the bank side, the relative least reliability A5 and A6 cable has 25 years reliable life under random traffic and the life reduces to 12 years while considering the combined action of wind and traffic; (4) On the river side, the cable J6 has least reliable life 23 years only considering vehicle load, and the life fall to 11 years while including combined loads of wind and vehicles; (5) The analysis results indicate that the cable's fatigue reliable life reduces 2%~63% and average 50% for the effect of wind load action.

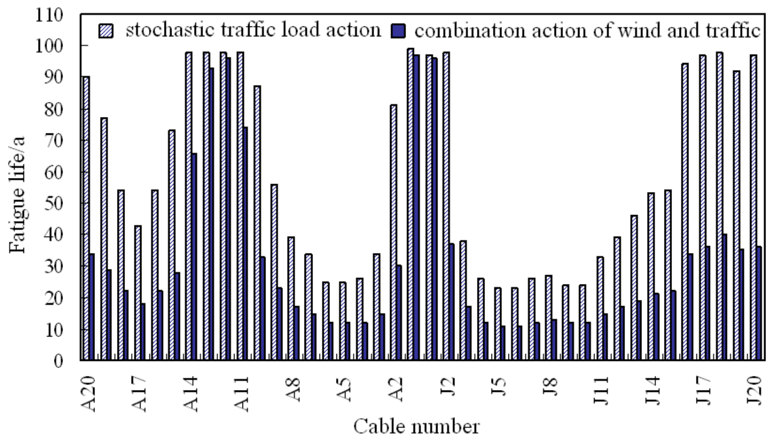

Figure 11 Fatigue reliability life predictions of the cables

5 Conclusion

The exploratory analysis and research on the fatigue reliability of stay cables for the long-span cable-stayed bridge is carried out considering combined action of the random traffic and wind load in this study for the first time. The following conclusion can be obtained:

(1) Based on the cumulative fatigue damage theory, the fatigue reliability analysis model and solution method for the stay cables is established and given;

(2) Adopting numerical simulation analysis method, the cable stress spectrum is analyzed considering the combined action of random vehicle and wind load, the computed method and procedure of cable stress spectrum under complex dynamic action is brought out;

(3) The analysis result of the cable stress amplitude in typical time block reveals that, dynamical wind load shows a greater effect on the long cable than the short cable for stress amplitude, and the equivalent stress amplitude follows Lognormal distribution;

(4) The obtained fatigue reliability distribution rules of the full-bridge cables could be as the reference in maintaining and designing homothetic bridge; thought as under the random vehicle load is analyzed and that suggests the maintain and examination for the cable system of the bridge.

(5) The time-dependent fatigue reliability analysis and the life prediction of the cables shows that, the influence on the fatigue reliability of wind load increases with the service period extending, the declining effect on fatigue life of the cables is about 50% averagely.

Reference :

[1] Agerskov H, Nielsen JA. *Fatigue in steel highway bridge under random loading*. Structure Engineering. ASCE. (125), 152-162. (1999)

[2] G. D. Tang, H. Yang. *Health of the bridge boom and cable diagnostics*. Highway.9. (2002)

[3] X. Shang, Y. Xu. *Safety-based cables' condition evaluation of cable stayed bridge with grey theory*. Journal of Chang'an University. 24(1), 52-55. (2004)

[4] Huang Y P, Xu P, Jiang Y J. *Examination of localized corrosion and lifetime evaluation for steel cable*. Corrosion Science and Protection Technology. 18(2), 132-136. (2006)

[5] Lu W, Qiang S Z, Jiang Y L. *Buffeting fatigue reliability analysis of cable-stayed bridge*. China Journal of Highway and Transport, 14(4), 63-66. (2001)

[6] LI Chun-xiang, LI Wei-wei. *Analysis of wind-induced fatigue of inclined cables*. Journal of vibration and shock, 28(9), 135-140. (2009)

[7] YANG Mei-liang, LI Bo, HUANG Li-pu. *Fatigue reliability analysis of the stay cables of paritally cable-stayed bridge.* Journal of Changsha communications university. 23(1), 6-10. (2007)

[8] SUH Jeong-In, CHANG Sung Pil. *Experimental study on fatigue behavior of wire ropes*. International Journal of Fatigue, 22(4), 339-347. (2000)
[9] R.Tovo. *On the Fatigue Reliability Evaluation of Structural Components under Service Loading*. International Journal of Fatigue. (23), 587-598. (2001)
[10] T.J. Miao, T.H.T. Chan. Bridge live load models from WIM data[J]. Engineering Structures. (24), 1071-1084. (2002)
[11] LI Yan. *Wind –vehicle-bridge dynamic response and fatigue reliability of cables of long span cable-stayed bridges*. Harbin, China. Harbin institute of university. (2008).
[12] Transportation Department of the People Republic of China. *Resistance wind design specification of highway*. The people transport publishing house. (2004)
[13] H. F. Xiang. *Wind resistance theory and practice of model bridge*. The people transportation publishing house. (2006)
[14] Z. Y. Zhang, C. Liu. *Calculation of designing wind velocity and wind observation at the Nanjing Yangtze River second bridge*. Scientia Meteorologica Sinica. 20(2), 200-205. (2000)
[15] Z. J. Dang. *Fatigue resistance of stay cables*. Bridge Constructure. (4), 18-21. (1999)

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