Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, Volume No.22, September 2024

Temperature Control of Concrete Structure in Bridge Construction by Renewable Energy Technology

Ziwei Zuo[1] and Gang Qu[2]

[1] China Highway Engineering Consulting Corporation
Beijing (China)
E-mail: **zuoziwei@gmail.com**

[2] The Third Construction Co. Ltd. of China Construction the Fifth Engineering Bureau
Changsha, Hunan (China)

Abstract. In this study, the classical display nonlinear dynamic analysis method was used to detect the temperature of concrete structures in bridge construction. Firstly, two different bridge construction test methods, the Winfrith subfunction and CSCM subfunction, were selected to detect the nonlinear temperature of the simulated concrete, and the temperature of the bridge concrete structure and the residual velocity of solidification were detected and analyzed by combining the nonlinear dynamic algorithm for data processing. The results show that the data of the nonlinear dynamic test in this paper agree with the actual requirements, and the accuracy rate is about 90~95%. In addition, the Winfrith subfunction calculates the data of the large strain force of photovoltaic temperature control energy on concrete. It identifies the nonlinear characteristics of high strain rate, especially the effect of photovoltaic heating, battery stable power supply heating, and the effect of wind on water vapor dissipation, which further proves that renewable energy technology can monitor the temperature of concrete structures in bridge construction, and effectively detect and identify concrete problems to support the construction and later use of bridge concrete.

Key words. Renewable Energy Technology, Bridge Construction, Concrete Structure, Temperature Control.

1. Introduction

With the rapid development of the social economy and the strengthening of environmental protection awareness, resource and environmental protection have been paid more and more attention, and the problems between the construction industry and resources, energy and the environment have gradually become prominent [1], [2]. Based on the "carbon peak and carbon neutral" goal, it is urgent to change and innovate in the construction industry and promote sustainable design. Based on this, it is necessary to study the temperature control of concrete structures in bridge construction for renewable energy technology. Bridge construction is the key bridge connecting the region and space and the main link in the construction of transportation infrastructure [3], [4]. Under the environment of China's "maritime power" and "transportation power" strategy and the "Belt and Road" initiative, bridge construction has become an urgent demand of China's economic development. In recent years, China's bridge engineering construction has made remarkable global achievements in design, construction, disaster prevention, management and maintenance, and materials and other technical fields, which have made significant breakthroughs. Among the completed bridge projects, Sutong Bridge, Wuhan Tianxingzhou Yangtze River Bridge, Nanjing Dashengguan Yangtze River Bridge, Shandong Jiaozhou Bay Bridge, Ma'Anshan Yangtze River Bridge, etc., have won wide praise around the world with their unique bridge design, construction and scientific research achievements [5], [6]. Among the construction projects, the world's top projects, such as the Hong Kong-Zhuhai-Macao Bridge have attracted the attention of the global bridge industry, demonstrating China's strength in bridge construction. However, in recent years, bridge engineering has been faced with many uncertain factors, complex and severe operation environments, great construction difficulties and other problems, which have brought new challenges to the future bridge engineering construction in China.

The main building material of modern bridge engineering is concrete. Concrete has been widely used in key structural areas such as cable towers, beam bodies [7], [8], pier bodies and caps in these projects, with the study of the national bridge structure gradually moving toward a longer, wider, deeper route, bridge engineering is urgently needed to meet the needs of these engineering new concrete technology. First of all, for the concrete conveying of bridge cable tower and ultra-high cable tower, as well as the construction of beam body, pier body and cap, it is necessary to ensure that the concrete in the operation process shows good fluidity, stability and low viscosity, so as to prevent the bridge construction process and quality problems caused by the poor operation effect. Next, in contemporary bridge construction, concrete damage is very common. Large structures such as cap and pier columns have a large section size, which increases the risk of concrete temperature increase and cracking in the hydration process. At the same time, the surface body of thin-wall structures such as box beam, T beam and combined beam is relatively large, increasing the maintenance difficulty after construction, and the water loss speed is accelerated, thus increasing the risk of dry shrinkage and cracking.

Based on the previous analysis, this study used ANSYS / LS-DYNA, a traditional nonlinear finite element dynamics analysis software, and borrowed from previous studies and use. This study selected Winfrith (* MAT _ 84) and CSCM (* MAT _ 159) models. These two models have smaller parameters, making them easier to use. Next, the study was conducted with the Mizuno. J *et al.* The 1 / 7.5 scale bridge model, this model can be applied to the bridge concrete structure of different thicknesses and the finite element (FEM) numerical simulation. Through the results of comparative analysis, this study can test the effectiveness and accuracy of the numerical simulation technology in this study, which also provides a set of practical and reliable simulation technologies for the following analysis and evaluation of bridge construction.

2. Analysis of Related Problems

Through the instantaneous response analysis of bridge renewable energy application, the key is correctly describing the nonlinear bridge construction relationship and failure criteria of concrete materials. The Winfrith and CSCM concrete bridge construction model [9].

A. Winfrith Model of Renewable Energy Materials Bridge Construction

The characteristic of this model is that each cell can display three direct rupture surfaces λ . The Winfrith model is shown in formula (1): $Y(I_1,J_2,J_3)$

$$Y(I_1,J_2,J_3)=aJ_2+\lambda\sqrt{J_2}+bI_1-1 \tag{1}$$

In formula (1), the compressive strength factor represents the direct crossing index a , J2 represents the construction value, b represents the compressive strength ratio, and I1 Representative unit construction value [10]. Based on the above factor analysis, the direct crossing index model was constructed λ , As shown in formula _ (2):

$$\lambda=\begin{cases} k_1\cos\left[\frac{1}{3}\cos^{-1}(k_2\cos(3\theta))\right],\cos(3\theta)\geq 0 \\ k_1\cos\left[\frac{\pi}{3}-\frac{1}{3}\cos^{-1}(-k_2\cos(3\theta))\right],\cos(3\theta)\leq 0 \end{cases} \tag{2}$$

In formula (2), k_1,k_2 is a representative of the function of the tensile strength ratio of concrete, (f_t/f_c) as determined by the uniaxial compression, tensile, biaxial compression and triaxial compressive test.

B. The CSCM Model for the Temperature Control of the Concrete Structure

This model consists of two parts $R^2(J_3)$: the structure temperature control surface $F_f^2(I_1)$ and the hardened compressed concrete structure temperature control $F_c(I_1,\ K)$. The CSCM model is defined as the model index of three stress invariants $Y(I_1,J_{2,},J_3)$, as shown in formula (3):

$$Y(I_1,J_{2,},J_3)=J_2\text{-R}^2(J_3)F_f^2(I_1)F_c(I_1,K) \tag{3}$$

In formula (3), the reduction coefficient of the main stress invariant represents the temperature control surface of the structure and the temperature control of the hardened concrete structure, where K is the temperature control hardening parameter of the concrete structure $F_c(I_1,K)$. This multiplication allows a continuous smooth combination between the concrete structure's temperature control and the structural surface's intersection. Construct the structural temperature control model, as shown in formula (4):

$$F_c(I_1,K)=\begin{cases} 1-\frac{(I_1-L(K))^2}{(X(K)-L(K))^2},I_1\geq L(K) \\ 1,I_1\leq L(K) \end{cases} \tag{4}$$

In formula (4), it represents the temperature control coefficient of the structure $(I_1-L(K))$. At that time, the temperature control of the concrete structure is elliptical $I_1\geq L(K)$. Represents the foundation temperature control value $X(K)-L(K)$, at that time, the temperature control surface of the structure and the concrete structure temperature control intersection $I_1=L(K)$, when the structure surface L (K)and the concrete structure temperature control initial intersection, equal to I1, Intersection model, as shown in formula (5):

$$L(K)=\begin{cases} K,K\geq K_0 \\ K_0,\ K\leq K_0 \end{cases}; \quad X(K)=L(K)+RF_f(I_1) \tag{5}$$

In formula (5), representing the temperature of concrete structure in different periods $K=(K_0,K_1,\cdots,K_n)$, with the compression of the plastic volume K0, the temperature control of concrete structure expands outward (X (K) and K increase), when the plastic volume expands, the temperature control of concrete structure shrinks (X (K) and K decrease). The temperature control motion of concrete structure is controlled by the hardening criterion, from which the temperature control motion model is obtained, as shown in formula (6): ε_v^p

$$\varepsilon_v^p=W\left[1-\exp^{(-D_1(X-X_0)-D_2(X-X_0)^2}\right] \tag{6}$$

In formula (6), ε_v^p is the plastic volume strain; W is the largest plastic volume strain; X0 is the initial position of the temperature control of the concrete structure (K=K0).

These parameters X0, R, W, D1 and D2 are determined by the peripheral compression test and the uniaxial strain test.

3. Results Analysis

A. *Experimental Results of Renewable Energy Technology Applied to the Temperature Control of Bridge Concrete Structures*

Whether using a small-scale bridge or large-scale bridge models, the concrete structure of renewable energy application or the high-speed temperature regulation test of the whole containment bridge has extremely high cost and complexity. In order to reduce the number of tests, with the concrete strain, high strain rate of nonlinear building correlation in-depth exploration and the progress of finite element simulation science, by contrast, more economical and easy to operate numerical simulation analysis in complex concrete structure and the interaction of renewable energy application played a crucial role. As time went on, this view was also accepted by the designers. In addition, through numerical simulation analysis, this study can obtain accurate specific numerical information on stress, strain and displacement field, which plays a key role in the design but is often not available in practice. Obviously, reasonable tests are necessary in order to test the success of numerical analysis techniques. The study used a variety of commercial software to simulate finite element (FEM) values for validation analysis. Morikawa. H and Mizuno. J is for the experiment of using different thicknesses of reinforcement and bridge concrete structure in the 1/7.5 scale bridge model and takes the numerical simulation method of the discrete element method (DEM) to test the effectiveness of the discrete element method in the simulated temperature control experiment.

Through the numerical simulation and analysis of this study, this study can obtain accurate specific numerical information on stress, strain and displacement field, which plays a key role in the design but is often not obtained in practice. Reasonable tests are necessary to test the success of numerical analysis techniques.C. Heckotter, Akram Abu-Odeh, SYKong and other researchers have carried out target-target heat exchange experiments for some reinforced concrete and bridge concrete parts. The study used a variety of commercial software to simulate finite element (FEM) values for validation analysis. The different thicknesses of reinforcement and concrete structures in the 1/7.5 scale bridge model are used, and the numerical simulation method of the discrete element method (DEM) is used to test the effectiveness of the discrete element method in the simulated temperature control experiment. Figure 1 shows the schematic diagram of an air pressure-driven temperature control device, 1/7.5 scale bridge model and 80mm thick semi-bridge concrete structure (HSC 80) respectively.

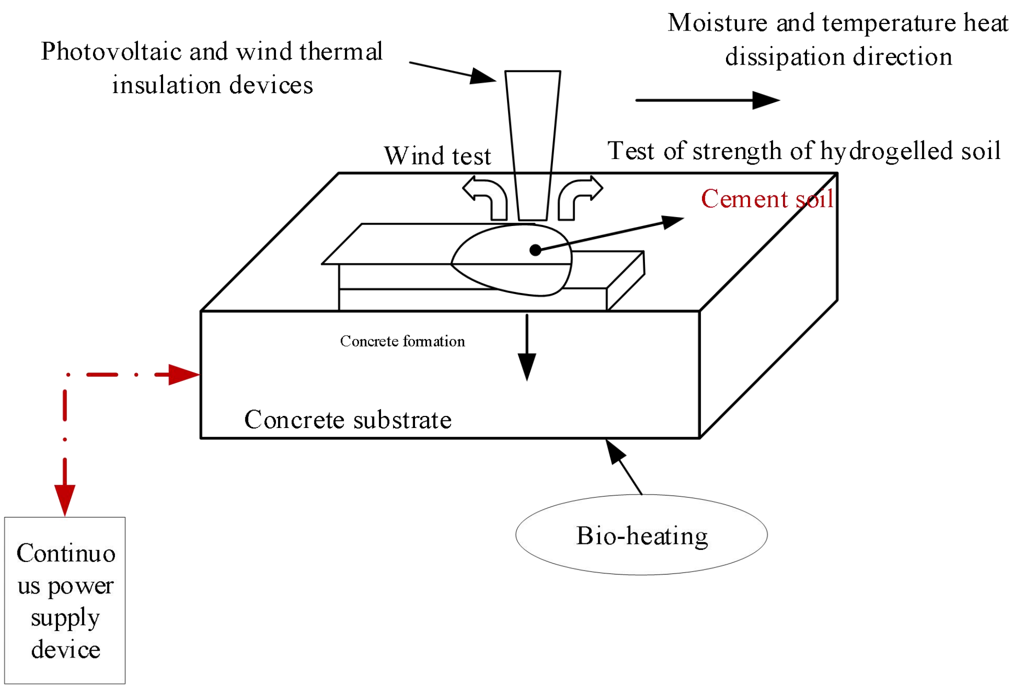
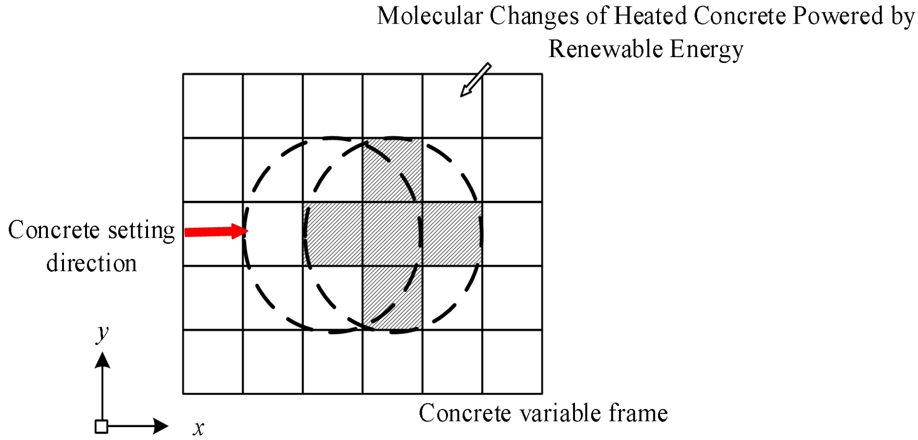
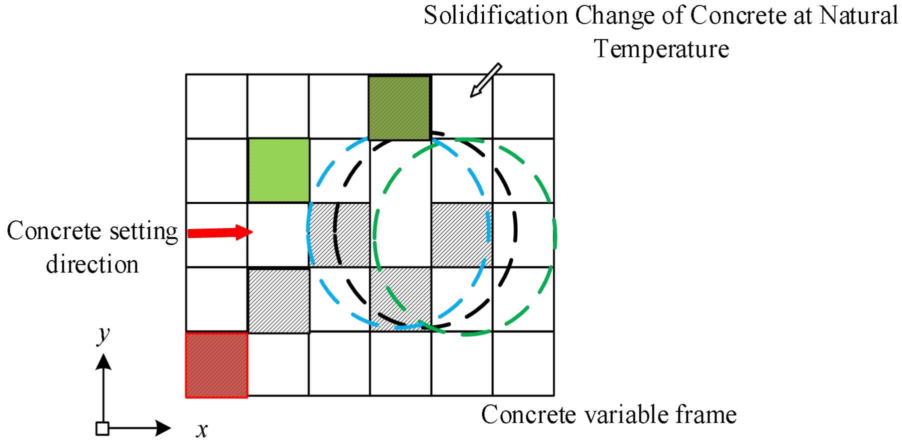


Figure 1. Schematic Diagram of Air Pressure-Driven Temperature Control Device (Unit: m)

The contents in Figure 1 were analyzed microscopically and analyzed for solidification changes between molecules, as shown in the figure below.



(a) Distribution of Steel Reinforcement



(b) Distribution of Shear Nails

Figure 2. Schematic Diagram of Semi-Bridge Concrete Structure (HSC 80)

B. Analysis of the Temperature Control Model Results of the Concrete Structure in the Bridge Construction by the Renewable Energy Technology

1) Finite Element Model Analysis

Given these concrete bridge structures of various thicknesses, this study will establish a steel bar, steel plate, shear nail, and concrete model independently. The basic unit of concrete is Solid164, using a single point of integral way. The basic unit of the three-node beam is Beam161, while the shell unit Shell163 is used to represent the steel plate. This study used Solid164 solid units and Shell163 shell units to simulate the 1/7.5 scale bridge model. The concrete structure of the HSC 80 semi-bridge and the finite element model of its scaler bridge are detailed in Figure 3.

All the information is consistent in the material parameters of the reduced bridge and the concrete structure. Among them, the choice of dynamic reinforcement factor (DIF) is determined according to the design. This study uses the ANSYS / LS-DYNA software to build steel bars, steel plates, shear nails and other elements. This model is able to deal with mixed states of isotropic and plastic forcing hardening, especially those of isotropic plastic forcing materials with strain rate effects. Plain concrete has fewer model parameters and uses the simpler * MAT _ WINFRITH _ CONCRETE two material models.

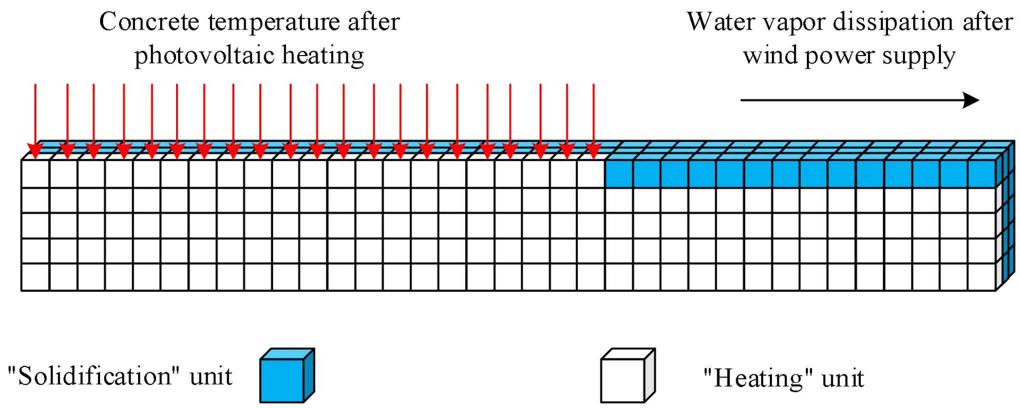


Figure 3. Finite Element Model of Half-Bridge Concrete Structure (HSC 80)

2) Failure Analysis of Renewable Energy Materials

The keyword * MAT _ ADD _ EROSION is used to manage the damage of renewable energy materials. The damage form of this model includes 7 different damage forms, such as pressure, primary stress, effect force, primary strain, structural strain, critical stress and stress pulse damage. In practice, the study could set a variety of temperature control standards to deal with one substance. Once a part's pressure or compression condition meets the requirements specified by the Erosion algorithm, the part will lose function and cannot be further analysed. Considering that the intensity of renewable energy material will change according to the change of compression rate due to the influence of temperature control load, it is inappropriate to choose compression to set temperature control in this case, so this project chooses compression to set the failure standard of renewable energy material.

3) Comparative Analysis of Numerical Simulation and Experimental Results

This study focuses on comparing the finite element numerical analysis results, namely the experimental results, with the calculation results of the discrete element method (DEM), and comparing the temperature control experiments of bridge concrete structures of various thicknesses and types. For controls of the speed time curves of the FSC60, HSC60 and the FSC 80 and HSC 80 structural temperature control experiments, see the graphs where "FEM" represents the results of this experiment using * MAT _ 84.

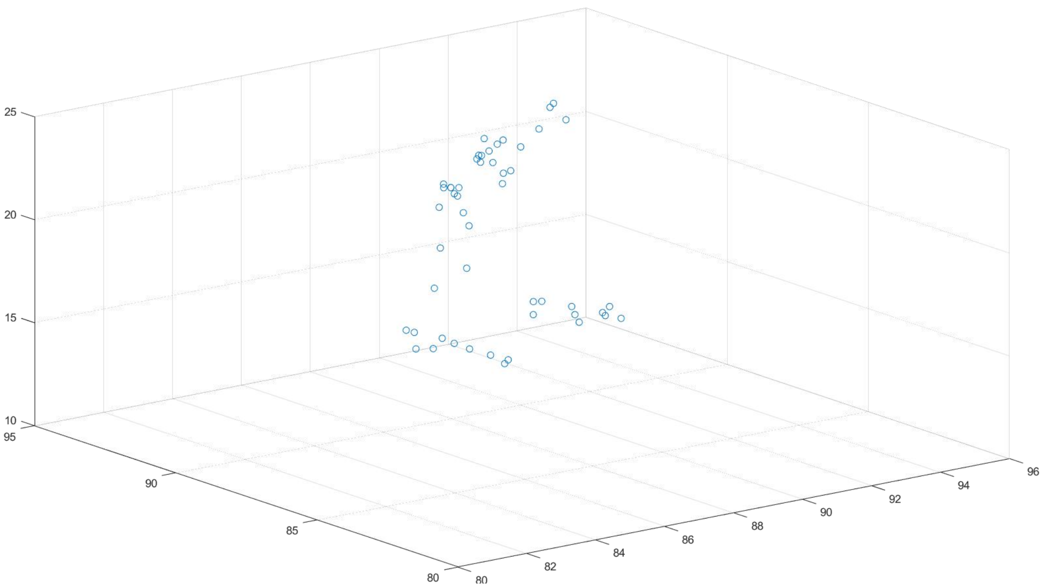


Figure 4. Speed Time Curves of the Engine in the FS C60 and HSC60 Structural Temperature Control Experiments

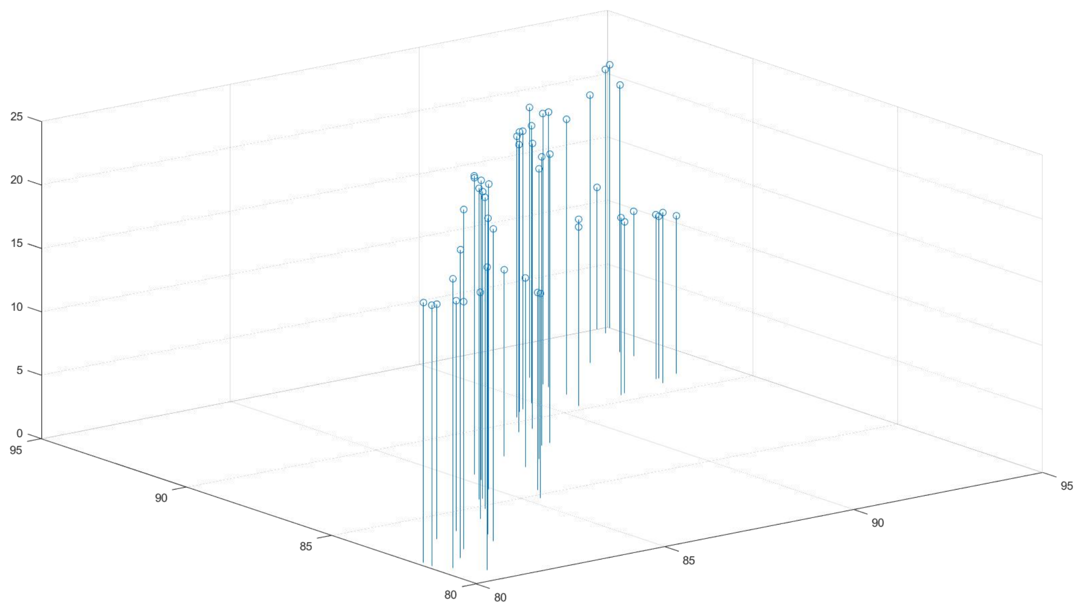


Figure 5. Speed Time Curves of FSC 80 and HSC 80

According to Figure 6, in the initial renewable energy use, the engine operation rate gradually decreases, at about 5 milliseconds, the engine starts to fight the concrete building, and the operation rate in the process drops sharply to about 8 milliseconds. The engine then shakes and changes like a sine wave, and the remaining running rate matches the test data. According to the chart, the movement rate of the engine in the initial phase is almost the same as on the chart, about 5 milliseconds when the engine began to fight against the concrete building. In a short time, the aircraft's speed dropped sharply to about 8 ms. However, the structure of the FSC 80 and HSC 80 was not destroyed, so the remaining rate of the aircraft was 0. The whole steps of the rate change of this aircraft are consistent with the results of the test.

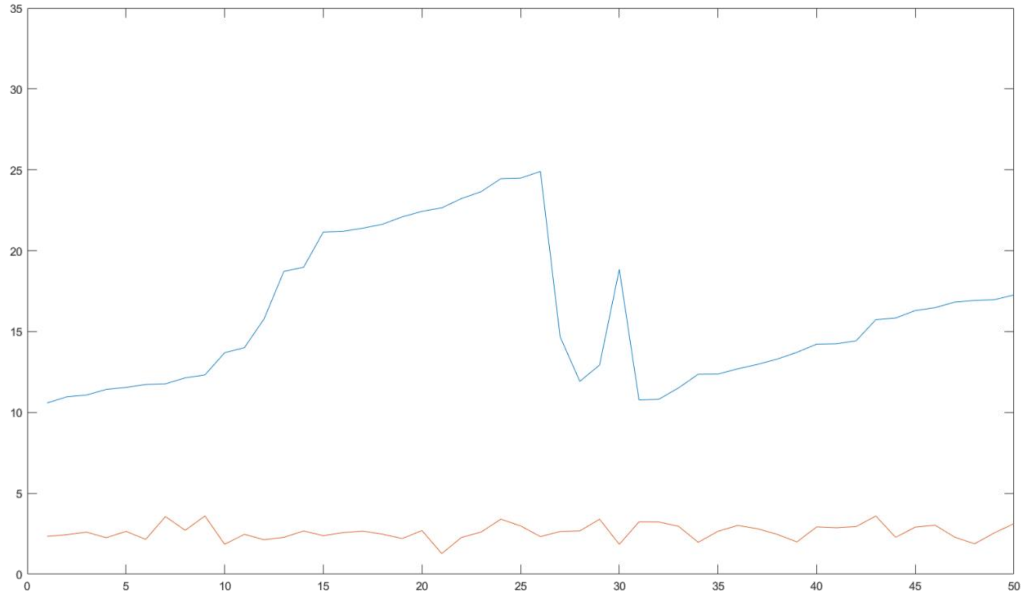


Figure 6. Displacement Time Course Curve of FSC80 Structural Back Plate

As shown in Figure 7, in the simulation of the structure of the HSC 80, the temperature regulation of the bridge while entering the HSC 80 structure; similarly, the numerical simulation results of the temperature regulation and deformation mode at the front and back end of the HSC 80 structure are shown in detail in the relevant experimental results. After data analysis, the study concluded that using renewable energy did not damage the HSC 80 structure and that the engine rebounded slightly at a 12ms speed, which coincides with the study results. The temperature control range of the concrete at the front end of the structure estimated by the material model of * MAT _ 84 is 41cm, and this value is very close to the actual tested 45cm. In this range, only a small part of the concrete is fully temperature-controlled, or 8cm, while the others are 6.4cm, which is very close to the actual 6.5cm tested. However, all these data derived using the material model of * MAT _ 159 are lower than the actual-tested data. According to the time series of back plate displacement shown in the chart, data analysis shows that the measurement of * MAT _ 84 is consistent with the actual measurement, while * MAT _ 159 is slightly lower than the actual measurement.

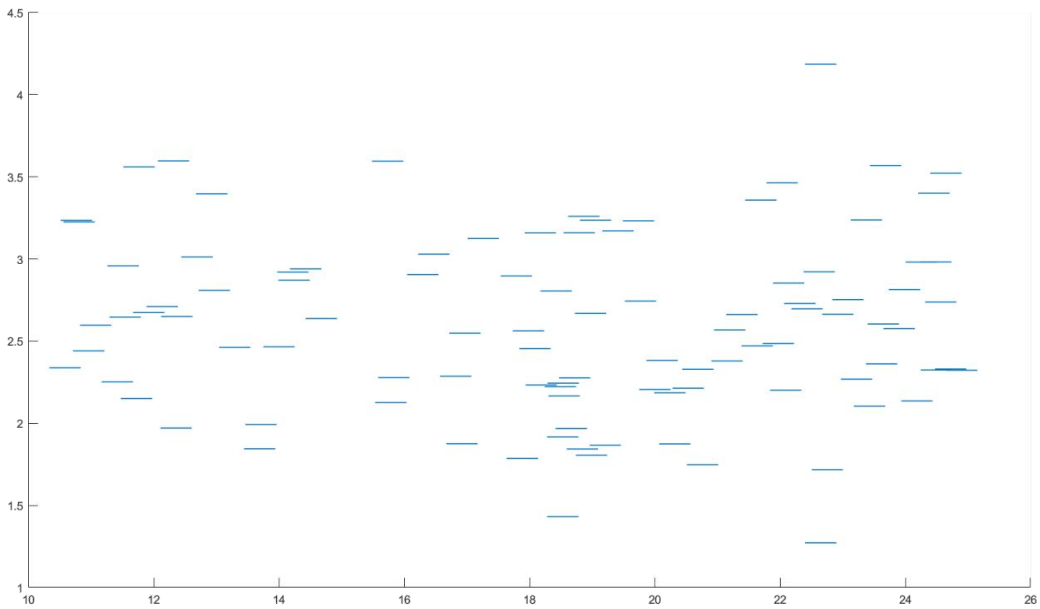


Figure 7. The Displacement Time Course Curve of the Back Plate of the HSC80 Structure

As shown in Figure 8, when the bridge model applies vertical renewable energy HSC120 structure at a speed of 146m / s, the temperature control process of the HSC120 structure of the bridge renewable energy application is shown in the Figure, showing the numerical simulation and test results of temperature regulation and deformation mode at the front end and back end of the HSC120 structure in detail. The numerical interpretation results reveal that the HSC120 structure is not affected by renewable energy sources. The results of the * MAT _ 84 material model indicated that the concrete structure was barely damaged, which is consistent with the test conclusion; the results of the * MAT _ 159 material model slightly broke the core area of the rear concrete structure. Based on the displacement time series of the back plate shown in the chart, the comparison with the data found that the highest and residual displacement calculated by the * MAT _ 84 and * MAT _ 159 material models exceeded the experimental results.

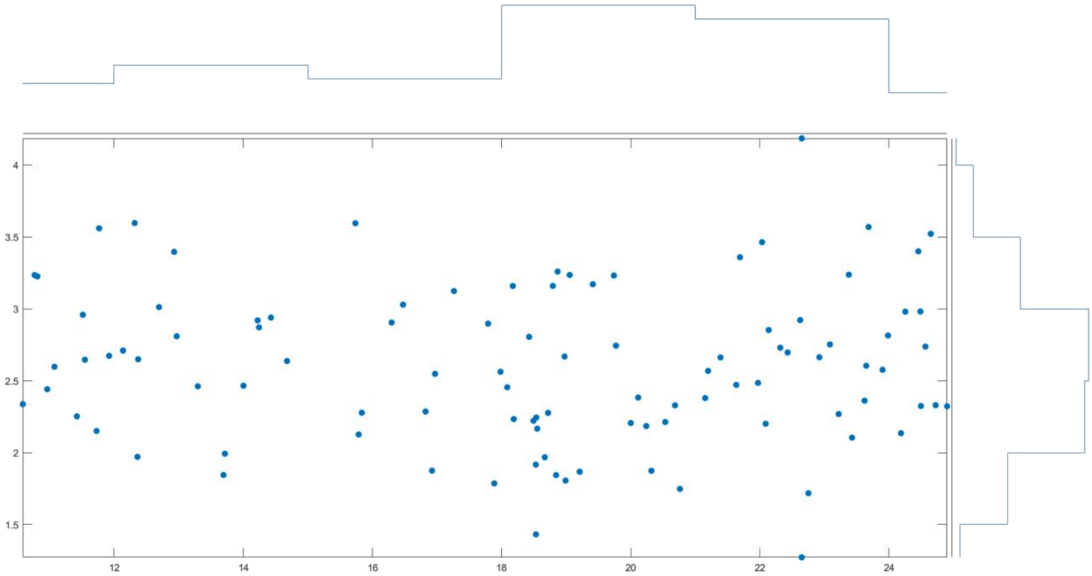


Figure 8. Displacement Time Course Curve of the Back Plate of the HSC120 Structure

4. Conclusion

In conclusion, this study used ANSYS / LS-DYNA, a traditional nonlinear kinetic analysis tool, to simulate the practical tests of full-bridge concrete structures (FSC) and semi-bridge concrete structures (HSC) in Japan. The data show that the results obtained roughly match the actual data such as the temperature regulation method of the bridge, the residual rate of the engine and concrete fragments, and the shape of the steel plate on the back. After comparing the data analysis of two different renewable energy building methods (Winfrith and CSCM methods), the study found that this method can more accurately depict the nonlinear characteristics of concrete at large and high strain rates. The research results confirm how to choose the appropriate temperature control model parameters of renewable energy technology in the bridge construction process and confirm the practical application and effectiveness of all analytical means. This also provides a set of useful and trustworthy strategies for the simulation analysis of future large-scale bridge construction.

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