Structure performance testing of the precast layered assembled noise barrier pillar

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Abstract: The precast pillar of the precast layered assembled noise barrier pillar is steel fiber reinforced concrete prefabricated components, but its structure performance is unknown. This paper presents testing the deflection change of the top and the strain on the bottom of the precast layered assembled noise barrier pillar under loads. The equivalent elastic modulus of the precast pillar and the precast layered assembled noise barrier pillar was obtained by processing the results. The following conclusions are obtained from the test results (1)when the load was less than 2 times of design load value, the precast pillar cylinder is in normal working condition, its equivalent elastic modulus increased with the increasing load; when the load was more than 2 times of design load value, cracks appear in the precast pillar cylinder, and its equivalent elastic modulus decreases with the increasing load.(2) In normal working condition, the equivalent elastic modulus of the precast pillar was more than 60GPa, when the precast pillar works with cracks, it was more than 45GPa. (3)The equivalent elastic modulus of the precast layered assembled noise barrier pillar decreased with the increasing load. After cracks appearing in the precast pillar, the decreasing trend of the equivalent elastic modulus was accelerated. (4)In normal working condition, the equivalent elastic modulus of the layered assembled precast noise barrier pillar was 64GPa and it was more than 34GPa when it broke.

Keywords: Noise barrier, the precast pillar, joint, bending stiffness, elasticity modulus

At present, noise barrier uses plate-insert non-metallic noise barrier in high-speed railway, its common figures are shown in reference [1]. The structure of noise barrier is mainly composed of three parts: the structure foundation, the H section steel pillar and the acoustic board [2,3].The design height of noise barrier in the line of Chengdu to Pujiang was 7m, the height is much higher than 3m which is the height of original plate-insert non-metallic noise barrier. The installation of noise barriers were needed to face the following problems:(1)It must rely on large transport vehicles and lifting equipment.(2)The lifting height must be more than the height of the noise barrier when using large transport vehicles and lifting equipment. It causing low construction efficiency because all construction projects must be conducted within the maintaining sky-light. (3)It endangers the safety of the workers and existing railway equipment when the large transport vehicles and lifting equipment works.(4)It has to rely on the construction road for large transport vehicles and the necessary construction site when installation. It is unable to achieve for these requirements when construction in the areas of adjacent to existing operating railway and dense buildings in cities. To solve these problems, the project of layered assembled noise barrier for near operating railway was put forward by Chengdu railway administration combined several units. The new noise barrier project changed the H section steel pillar into prefabricated pillar which is made of steel fiber reinforced reactive powder concrete. The new precast pillar is shorter, conducive to the transportation and construction. Precast layered assembled noise barrier pillar (PPLANBP) is made up with several different lengths of precast noise barrier pillars which join together between each other, the height of splice is 7m. The effect picture of the layered assembled precast noise barrier is shown in figure 1.

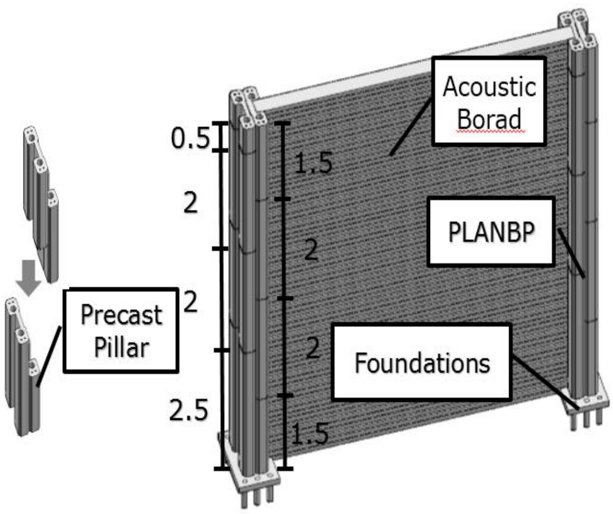

Fig. 1. Effect picture of noise barrier

The structure of precast pillar is a relatively new type of concrete structure. This structure used C120 high strength concrete, but the structure performance is unknown after the steel fiber is built-in. So we need to test the structure performance of precast pillar which is the main load-carrying structure of the new type of noise barrier. PLANBP was joined together by precast pillars, the structure performance of PLANBP has changed because of the joints between precast pillars, so we need to test the structure performance of PLANBP.

The loads of noise barrier is derived from horizontal aerodynamic load caused by high-speed train and natural wind load. Under the action of load, the PLANBP pure bending deformation occurred, and the load is transmitted to the foundation of the PLANBP. Resistance of an object to bending deformation is measured by the bending stiffness. It is the product of the inertia moment multiplied by the elastic modulus. In the case of a certain section size, the elastic modulus is the only variable of bending stiffness, so we need to test the equivalent elastic modulus of the precast pillar cylinder and overall assembly precast pillar.

1. Testing principle

The main load of PLANBP is uniformly distributed which is inconvenient for field testing. So it was replaced by the concentrated load, which is changed from the uniformly distributed load. According to the design load given by the design institute, the concentrated load of PLANBP is 11.87kN. Under the action of horizontal load, the PLANBP pure bending deformation occurs. Therefore, the equivalent bending stiffness and elastic modulus of the precast pillar and PLANBP are obtained by the bending stress/strain formula and deflection formula of the cantilever beam in the tests.

1.1 Strain-measurement method

According to the literature [4,5], the bending moment calculation formula of PLANBP is shown in Figure 1, and the structural bending moment diagram is shown in Figure 2.

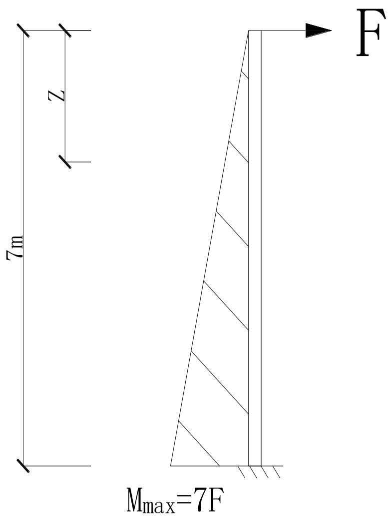

Fig.2. Structure bending moment diagram under load

$$M = F \cdot z \tag{1}$$

F——value of the load, when it is1.0, given by the design institute (11.87KN), the design loading scheme is obtained, which is shown in table 1;

Table1. Test table for performance of noise barrier structure with layered structure

Num.	Load level	Horizontal force T （kN）	The oil pressure gauge (MPa)
1	0.6	7.123914	1.555655420
2	1.0	11.87319	2.528492366
3	1.6	18.9971	3.987747786
4	2.0	23.74638	4.960584733
5	2.2	26.12102	5.447003206
6	2.4	28.49566	5.933421679
7	2.6	30.87029	6.419840153
8	2.8	33.24493	6.906258626

z——The distance from the load point to the strain gauge, the vertical distance between the strain gauge and the load is 6.75m in this test. The strain gauge is 0.25m from the fixed point in the test because the stress concentration may exist in the fixed end of precast pillar; according to the literature [4,5], the relationship between bending moment M and stress of pure bending members is shown in Type(2):

$$\sigma = \frac{My}{I} \quad (2)$$

y——Distance from the strain gauge to the centroid of the cross section, by section size (shown in Figure 4), the value is 0.225m;

I——Inertia moment of cross section, according to the section size (shown in Figure 4), it is 1.4464×10-3m4;

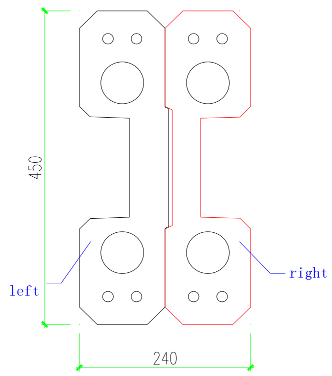

Fig.3. Sectional drawing of the precast pillar of layered assembled noise barrier

The relationship between stress and strain is obtained according to the literature [4], which is shown in Type(3).

$$\sigma = \varepsilon \cdot E \quad (3)$$

ε——Strain value, which measured according to the strain gauges arranged at different points in the field, and the seams between the precast pillar of layered assembled noise barriers will crack due to the load, so the strain at the seams is measured with the dial indicator and calculated with the average strain;

E——Equivalent elastic modulus.

According to the literature [4], the relationship between stress and strain is shown in Type(3).

$$E = \frac{F \cdot z \cdot y}{\varepsilon \cdot I} \quad (4)$$

1.2 Bending test method

Based on the force condition of PLANBP, its deformation is pure bending under the load. According to the literature [4,5], its formula was shown in Type(5).

$$\frac{1}{\rho} = \frac{M}{EI} \quad (5)$$

$\frac{1}{\rho}$ ——Curvature, its formula is shown in Type(6)

$$\frac{1}{\rho} = \frac{\frac{d^2\omega}{dx^2}}{[1+(\frac{d\omega}{dx})^2]^{3/2}} \quad (6)$$

In the case of small deflection, ω is less than 0.01*l*, $(\frac{d\omega}{dx})^2 \approx 0$, so from the Type(5) and (6), we can get:

$$\frac{d^2\omega}{dx^2} = \frac{M}{EI} \quad (7)$$

The rotational deformation and deflection of the fixed end of the cantilever beam are all 0, the formula of the deflection of the cantilever beam under the action of concentrated load is solved in Type(7),which is shown in Type(8).

$$\omega = \frac{Fl^3}{3EI} \quad (8)$$

l——the height of PLANBP is 7m.

Thus, the equivalent elastic modulus of PLANBP can be obtained by the deflection of the top of the pillar, which is shown in Type(9).

$$E = \frac{Fl^3}{3I\omega} \quad (9)$$

2. Test content

According to the experimental principle, we need to measure the strain value near the bottom of PLANBP and the deflection on the top of PLANBP before solving the equivalent elastic modulus. To test the strain of the precast pillars, the strain gauges are arranged as shown in Figure 5. [6,7] The deflection on the top of the precast pillar is observed by electronic total station.

The full bridge test method which has higher accuracy than others is adopt in the experiment. [8,9] Because the compressive deformation of the PLANBP is the same as the tensile deformation in non-joint.

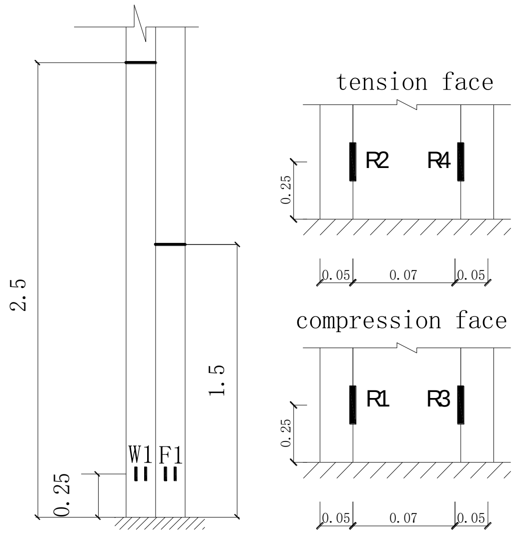

Fig.4. Layout of strain gauge and local magnification of strain gauge of the precast pillar

3. Test results

The field test of PLANBP was carried out on May 31th, 2016. PLANBP for testing was loaded by the loading sequence number as shown in Table 1, the test pillar appeared cracks when the load level is between 2.0 and 2.2(shown in Figure 6), then it broke when the load level is 2.8(shown in Figure 7).

3.1 The test results of the precast pillar

The strain condition of the test under different loads was summarized and sorted out. The results were shown in Figure 8. With the increase of the loads, the strain of the measuring point increased gradually. W1 and F1 were located near the bottom of the precast pillar, the joints of precast pillar were hardly affected by the test results, and they had similar strain results.

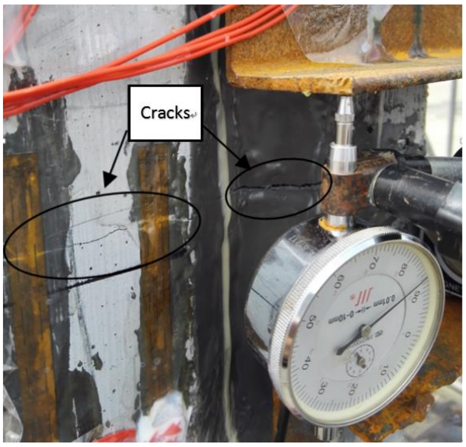

Fig.5. Cracking diagram of precast pillar loaded to 2 load level

Fig.6. Failure diagram of precast pillar loaded to 2.8 load level

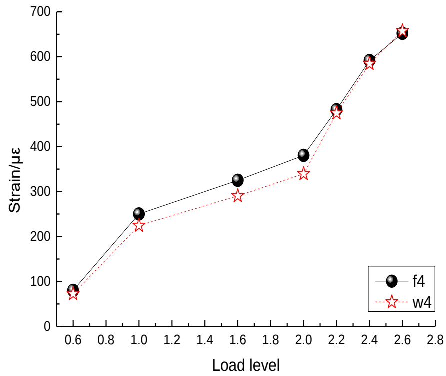

Fig.7. Strain under different loads

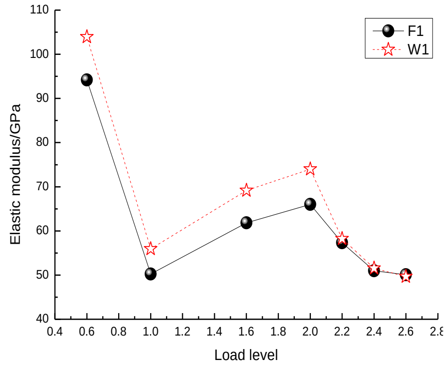

Fig.8. Equivalent elastic modulus of precast pillars under different loads

After processing the strain testing data, the test results variation tendency of the equivalent elastic modulus of the left and right precast pillar were similar under different loads, as shown in figure 9. When the load level was less than 1.0, the measured strain results were relatively low, which leaded relatively large result of the equivalent elastic modulus, so the elastic modulus had a decreasing trend before the load level was 1.0. When the load level was more than 1.0, the equivalent elastic modulus of the precast pillar cylinder was gradually increased with the increase of the load. Because the steel fiber inside the precast pillar gradually withstood tensile stress together with the concrete. When the load level was more than 2.0, the equivalent elastic modulus of the precast pillar cylinder was gradually decreased with the increase of the load. Because the cracking occurred at the 1.5m of PLANBP after the load level reaches 2.0, and the precast pillar withstanding tensile stress changed from steel fiber and concrete of full cross section to steel fiber and part of concrete section. With the increase of the load, the tensile stress of concrete was gradually reduced, therefore the equivalent elastic modulus of the precast pillar gradually reduced. According to the calculated results, the equivalent elastic modulus of precast pillar was more than 60GPa when the load level was 2.0, it was more than 45GPa when the load level was 2.8(when it broke), they all meet the requirements of design institute which the equivalent elastic modulus of precast pillar should be more than 38GPa in design load.

3.2 the test results of PLANBP

The deflection of the test under different loads was summarized and sorted out, and bending deformation figures under different loads were obtained as shown in Figure 9. With the increase of the load, the deflection value of each measuring point increased gradually, the amplitude of the deflection value increases when the load level was more than 2.0.

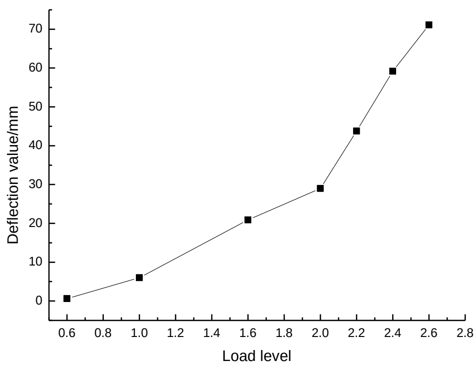

Fig.9. Flexural deformation under different loads

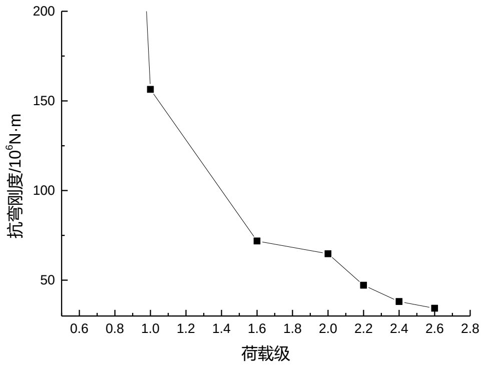

Fig.10. Flexural deformation under different loads

The variation of equivalent elastic modulus in different loads of PLANBP was shown in figure 10. With the increase of the load, the equivalent elastic modulus of the precast pillar decreased gradually. Because the test of bending deformation was about the equivalent elastic modulus of PLANBP, its value decreased with the increase of load. Due to the existence of the joints in PLANBP, the binder in the joints appeared to be failure after applying the load to a certain degree, which leaded to the decrease of the equivalent elastic modulus of PLANBP. The weakening influence of joints on the equivalent elastic modulus was greater than the increasing influence of steel fiber on it, so the equivalent elastic modulus of PLANBP was always falling under the load, but the downward trend decreased when the load level between 1.6 and 2.0, which was in accordance with the increasing trend of the equivalent elastic modulus of the precast pillar at this time. When the level of the load applied was more than 2.0, the decreased amplitude of the equivalent elastic modulus gradually increased with the increase of load, the seamless side of the assemble seam of PLANBP appeared cracks after the load level reached 2.0, with the increase of the load, the tensile stress was gradually reduced, so the decreased amplitude of the equivalent elastic modulus of PLANBP increased. The equivalent elastic modulus of PLANBP was less than the test results of the precast pillar, because of the destruction of the adhesive at the joint and the cracking of PLANBP in the non-joint side of the assemble seam. According to the calculation results, the equivalent elastic modulus of PLANBP is 64GPa when the load level is 2.0, it is more than 34GPa when the load level is 2.8(when it broke), and they all meet the requirements of design institute.

4. Conclusion

PLANBP is a kind of assembled structure which is suitable for the areas of adjacent to existing railways and dense buildings in cities. It can be completed by the construction of manual labour and small construction equipment. The precast pillar is the main bearing part of the structure, but its mechanical properties were unknown, therefore, the equivalent elastic modulus of the precast pillar cylinder and PLANBP were tested by field test.

After the test results have been processed, the change trend of the equivalent elastic modulus of the precast pillar was concluded. The equivalent elastic modulus of the precast pillar gradually increased with the increase of applied load, and it gradually decreased when cracks appeared in the precast pillar. Test results show that the equivalent elastic modulus of the precast pillar is more than 60GPa when the load level is 2.0, and it is more than 45GPa when the load level is 2.8.

The variation tendency of the equivalent elastic modulus is obtained by testing the bending deformation of LA PNBP. The bending deflection gradually increased with the increase of applied load, then the integral equivalent bending stiffness and equivalent elastic modulus of precast pillar were gradually reduced. The equivalent elastic modulus of the PLANBP is 64GPa when the load level is 2.0, and it is more than 34GPa when the load level is 2.8.

From the field test results, it can be known that cracks appeared in the precast pillars when the load was 2 times of the design load, and it broke when the load is 2.8 times. From the contents above, it can be concluded that the precast pillar and LA PNBP meet the requirements of design institute.

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