

completed after the square tube being bonded with AB glue and the cable being fixed, the white cardboard being paved. Maintenance is to make sure that the aqueduct looks properly and check them at regular time.

III. MODEL TEXT

A. Water load experiment

Water load text[5] is done after the completion of aqueduct, and in order to prevent the water soak the white cardboard and reduced model bearing capability, a layer of waterproof membrane is paved on it. During the experiment[6], the load is added by

step way, and set five control point of displacement, A,B,C,D,E, like the Fig .1,and record the data of displacement when adding load.

Add water slowly at both ends of the model, and measure the distance between the displacement control point and the reference plane after the water is stabled in the model.

The aqueduct has been filled with water and can no longer continue adding load when the total mass of water is added to 24kg.The deformation value of the midpoint in the main girder of aqueduct under the load is recorded in table 1.

TABLE I. RECORD TABLE OF DISPLACEMENT OF MIDPOINT UNDER WATER LOAD

The quality of the water (kg)	8	10	15	20	24
The displacement of the center(mm)	1	1.7	2.5	3	4.1

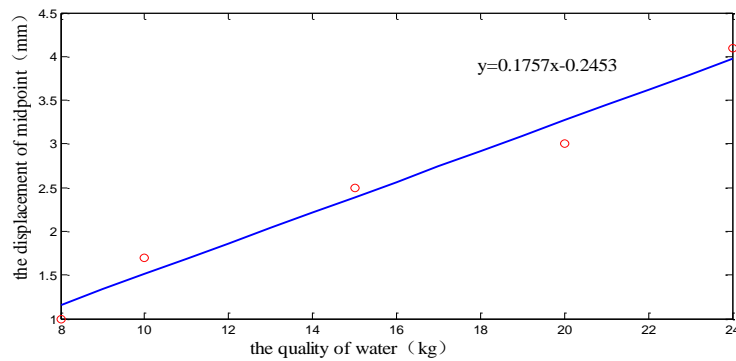


Figure 2. Fitting chart of center displacement changes with the load

The displacement of midpoint is measured to be zero after all the load be removed. Deformation of the model in water load experiment is supposed to be elastic deformation. And the matlab[7] software is used to draw the scatter diagram of the experimental data to verify the hypothesis, as shown in Fig .2. And through regression analysis, the trend line of the displacement value of midpoint with the changing load is obtained, the equation is $y = 0.1757x - 0.2453$, and the regression coefficient $R^2 = 0.9716$, which fits well.

Based on the analysis above, the relationship between displacement and water load of model in the

experiment is proved to be linear relation, and the hypothesis is also confirmed.

B. Sand load experiment

Iron sand with a greater density is used to carry on the load experiment to test the model carrying capacity further more. Repeat the operation of water load experiment, and displacement value of main girder of the aqueduct with greater loads is recorded in table 2.

TABLE II. RECORD TABLE OF DISPLACEMENT OF MIDPOINT UNDER IRON SAND LOAD

The quality of iron sand (kg)	30	35	40	45	52
The displacement of the center (mm)	5	5.5	6.2	6.9	10

It's obvious that there are some deformations which can not be restored in the model after the load be removed, so the deformation of the model in iron sand load experiment is supposed to be plastic deformation, and the matlab software is also used to draw the

scatter diagram of the experimental data to verify the hypothesis, as shown in Fig .3. And through regression analysis, linear and quadratic equation are chosen to fit the data, and quadratic relation is found to fit better by comparison, its regression coefficient is 0.9853.

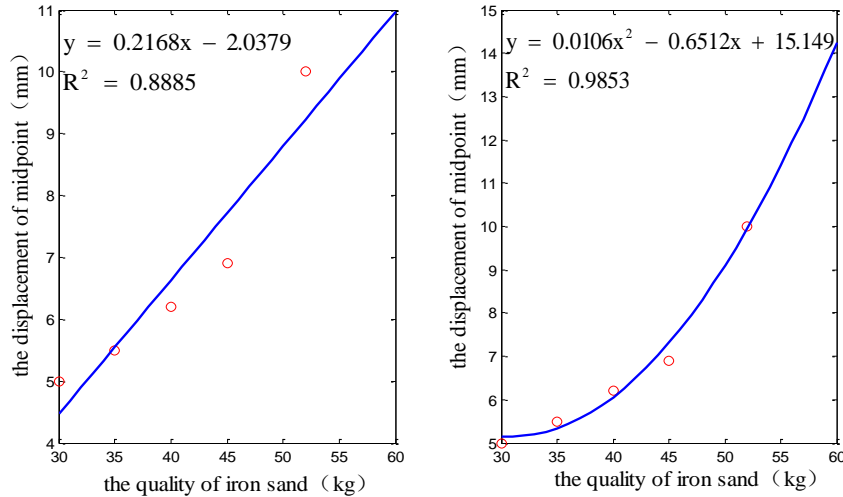


Figure 3. Fitting chart of linear and quadratic relation of displacement changes with load

Based on the analysis above, it can be seen that the deformation of model is plastic deformation when the load on it is more than 30kg, and 30kg can be the demarcation load of elastic deformation and plastic deformation of the model.

IV. MODEL CALCULATION

A. Displacement calculation

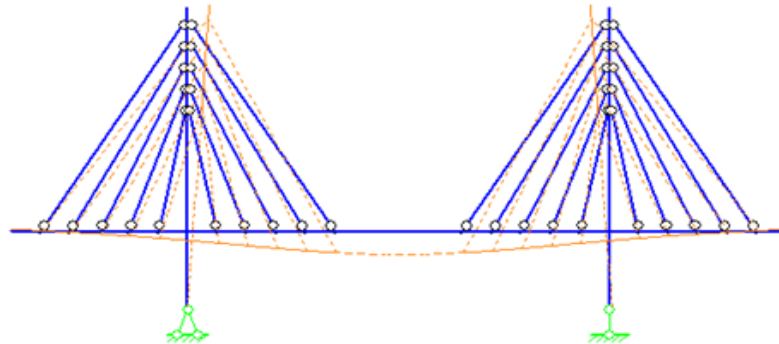


Figure 4. Displacement characteristic chart with structural solver

Based on the analysis of the picture above, the displacement characteristics of the structure are as follows:

- (1) The deformation of model is axial symmetry.
- (2) The deformation of middle of the main girder

is bigger than that of both ends, and the displacement of the middle is downward, but the two ends is on the opposite.

The displacement value of five control point under the load of 52kg is shown in table 3.

TABLE III. RECORD TABLE OF DISPLACEMENT VALUE OF CONTROL POINT

Displacement point	A	B	C	D	E
The value of displacement (mm)	1.5	-7.2	-10	-7	1.3

Based on the analysis of table 3, the characteristic of the main girder with the load of 52kg is consistent with the conclusions above.

2) Error analysis of displacement

The displacement value of center point of the main girder is measured every 5kg from 30kg to 50kg in the

iron sand load experiment. All weight is spread average on the main girder and obtains the value of uniform load when structural solver is used to modeling. And error analysis is made by comparing the calculated results of the structural solver and experiment data, the specific results are shown in table 4.

TABLE IV. STRUCTURE CALCULATION AND EXPERIMENTAL DISPLACEMENT VALUE COMPARISON TABLE

The quality of iron sand (kg)	Uniform load (N/m)	The displacement value of center point of the main girder of structural solver (mm)	The displacement value of center point of the main girder of experiment (mm)	Error analysis
30	147	4.2552	5	17.50%
35	171.5	4.9673	5.5	10.72%
40	196	5.6735	6.2	9.28%
45	220.5	6.3827	6.9	8.10%
52	254.8	7.3246	10	36.53%

The three-dimensional problems are simplified as a two-dimensional problem by Structural solver, there are some errors between the calculation results and experimental results, but the errors are in the allowable range.

B. Stress calculation

1) Mechanical analysis of rod

The cable can be treated as rigid body when it tensions considering the principle of rigidization. The cable is made of Cylindrical nylon rope, whose diameter is 1.4mm, and the maximum axial force of cable is 19.67N. The maximum stress [8][9] is

$$\sigma_t = \frac{F}{A} = \frac{19.67}{\frac{\pi}{4} \times (1.4 \times 10^{-3})^2} = 12.8 \text{MPa} < 70 \text{MPa}$$

(Meets the strength conditions)

The supporting rod is made of square plastic pipe, whose length is 10mm, and the maximum axial force of the rod is 127.4N. The maximum stress is

$$\sigma_c = \frac{F}{A} = 1.27 \text{MPa} < 30 \text{MPa}$$

(Meets the strength conditions)

2) Mechanics analysis of beam

The girder is made of square plastic pipe, whose length is 10mm, and the girder is main part to bear the bending moment, and the maximum bending moment is 2.8N.m. The maximum stress is compressive stress, which occurs at the lower edge, it's

$$\sigma_t = \frac{M}{W} = \frac{2.8}{\frac{10^{-2} \times (10^{-2})^2}{6}} = 16.8 \text{MPa} < 30 \text{MPa}$$

(Meets the strength conditions)

The intersection of main beam and the supporting rod bears both axial force and bending moment, the bending moment is 0.38 N.m, the axial force is 25.7N, the maximum compressive stress is

$$\sigma_c = \frac{F}{A} + \frac{M}{W} = 2.54 \text{MPa} < 30 \text{MPa}$$

(Meets the strength conditions)

V. SUMMARY

- (1) The errors of aqueduct model experimental data and the calculated value of structural solver are in the allowable range, which shows that the model making and relative calculation is accurate [10].
- (2) Through theoretical calculation and actual loading experiment of aqueduct, the limit load of model is about 60kg, and the failure point is at the lower edge of the midpoint of the main girder, and the displacement value is 10mm.
- (3) The demarcation load of elastic deformation and plastic deformation of the model is 30kg.

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