RESEARCH ARTICLE OPEN ACCESS

# Bridge Calculation for Large Transport by Finite Element Method

Wulin[1], Xiaoxia Zhai[1]
[1]Chongqing jiaotong University, China

**Abstract**
Big transportation refers to the contour size more than limit standard as well as loading vehicle or vehicles on the role of a bridge over the total weight design load .The safety, economy and convenience are the key to the heavy transportation, also is the basic principle of large transport. This article is based on an engineering example, adopt the method of finite element analysis, the research can or not certain big load through security bridge, for China's major transportation of provides the basis for the solution of the problem encountered, also for engineering and technical personnel to provide a reference for similar transportation project.
**Keywords:** large transport Finite element method bridge calculation

## I. Introduction

In the 21st century, with the rapid development of transportation industry in China, highway bridge load has become increasingly heavy .Heavy load transportation is an important research topic, Large transport through the bridge security caused great hidden danger to its, the study of his aspect demand has become increasingly。This paper combining with the concrete bridge example calculations with finite element simulation method for large transport.

## II. Bridge example case

2.1 General situation ofBridge

The bridge’s span is 12 m, with 3 m rise, rise-span ratio of 1/4, thickness of arch ring is 0.60 m between solid-web half arc arch, arch ring width is 6.5 m.Bridge patients appearance see figure 1, bridge elevation diagram as shown in figure 2 bridge example plane diagram as shown in figure 3 the bridge cross section diagram as shown in figure 4.

Figure 1 bridge case appearance

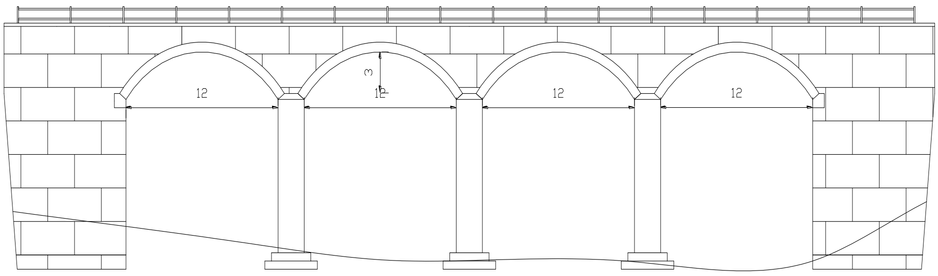


Figure 2 Bridge example elevation

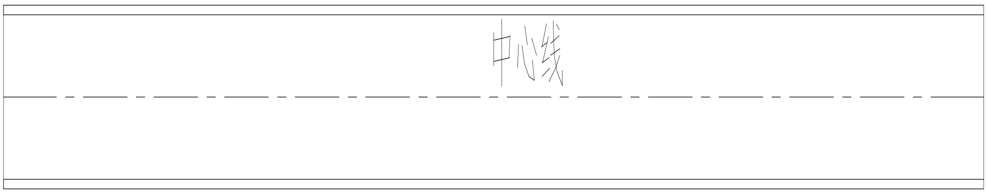


Figure 3 Bridge example plan

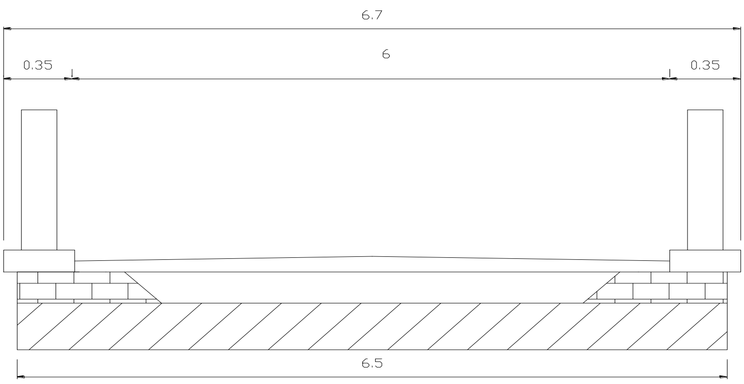


Figure 4 The bridge cross sectional drawing

2.2 Main calculation parameters

The bridge structure size parameters of the table are shown in table 1, bridge material parameters see table 2.

Table 1 Bridge structure size parameter

| Parameter artifacts | Clear span(m) | Net arrowheight (m) | Section size | | Notes |
|---|---|---|---|---|---|
| | | | width(m) | height(m) | |
| main arch ring | 12.00 | 3 | 6.5 | 0.60 | See the specific size Figure 2 ~ 4 |

Table 2 Bridge material parameter

| Member | Materials | Modulus of elasticity (MPa) | Compressive strength $f_{cd}$ (MPa) | Bending tensile strength $f_{tmd}$ (MPa) | Gravity density ( $kN/m^3$ ) | Coefficient of linear expansion (/°C) |
|---|---|---|---|---|---|---|
| Main arch ring | Build by laying bricks or stones MU50 and M7.5 mortar stone | 5650 | 4.14 | 0.074 | 23.0 | 0.000008 |

## III. large transport situation

The large transport Through the example bridge as shown in figure 5for calculate the vehicle load. For the arch on the packing, according to the main arch ring of arch back and consider the arch bridge deck underside of distance on the packing, the weight of the arch on the packing density of gravity for 23 $kN/m^3$. Secondary dead load calculation according to the main arch ring back arch and bridge deck top surface distance considering the quality of the bridge dead load, take the surfacing gravity density for 25 $kN/m^3$.

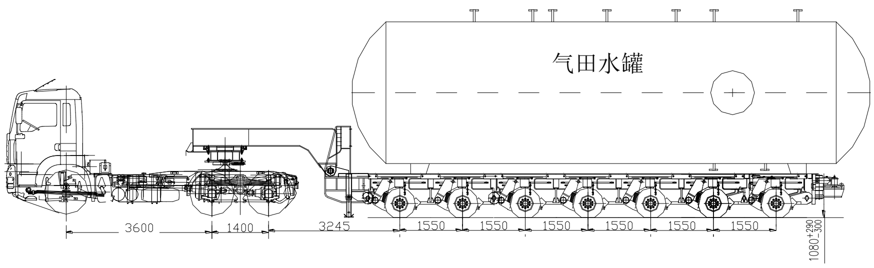


Figure 5 Large transport vehicles diagram (unit: mm)

In order to ensure the safety of large transport vehicles by the example bridge, therefore entrusted by the owners need to relative carrying capacity of the bridge is checked, for the bulk transport vehicle safety will provide theory guide through the bridge. The inspection is mainly for the check computation of bridge bearing capacity.

## IV. Method and basic assumptions

According to the specification JTG article 5.1.3 D61-2005, may be considered for the solid-web arch bridge live load evenly distributed in the arch ring full width, because the bridge for the solid-web arch bridge, so the calculation does not consider the influence of live load transverse distribution, checking according to uniform distribution.

Because the car is checked cargo gross weight is 75.2 t, tractor Howard is 8 t, hydraulic trailer 2 longitudinal 7 is 28 t ,axle load and dynamic gooseneck 8 t, weight 30.2 t.So take the following four conditions for bridge structure calculation.(one condition - the condition of four heavy vehicle axle load parameters see table 3)

condition one: arch bending moment of the vehicle load in the model cloth condition as shown in figure 6.

condition 2: arch axial force of vehicle load conditions in the model cloth as shown in figure 7.

condition 3: the arch foot, vehicle load conditions in the model cloth as shown in figure 8.

condition 4: the arch foot axial force, vehicle load conditions in the model cloth as shown in figure 9.

Table 3 Large transport vehicle parameters

| Vehicle model | 1 axle load (t) | 2 axle load (t) | 3 axle load(t) | 4-10 axle load(t) | Total weigh(t) | 1-2 axle base(m) | 2-3 axle base(m) | 3-4 axle base(m) | 4-10 axle base(m) |
|---|---|---|---|---|---|---|---|---|---|
| Ten axis vehicle | 2.7 | 2.7 | 2.7 | 9.6 | 75.2 | 3.6 | 1.4 | 3.245 | 1.55 |

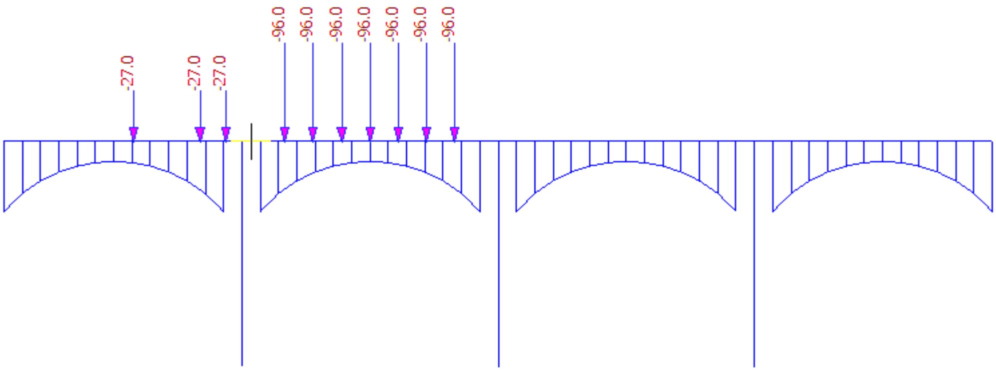


Figure 6 Load condition 1 (arrows indicate axle location)

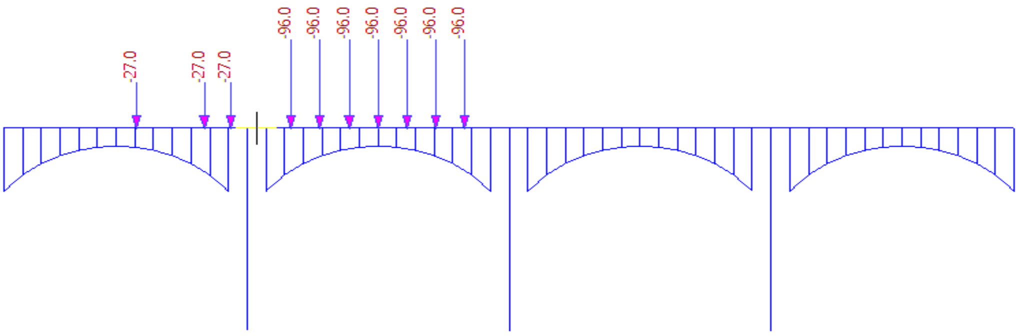


Figure 7 Load condition 2(arrows indicate axle location)

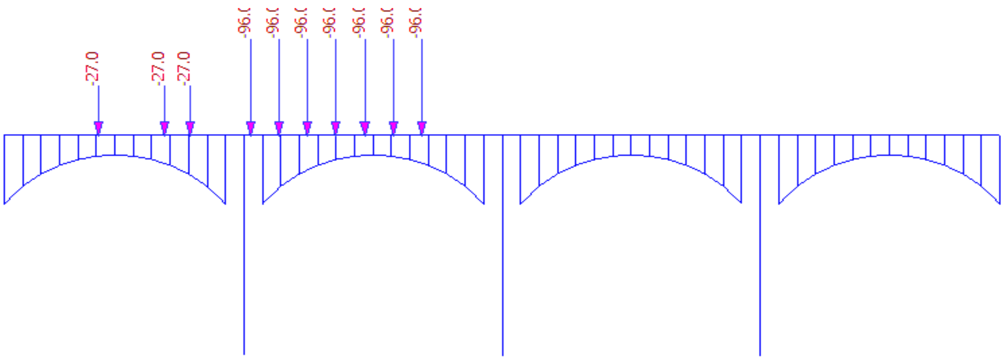


Figure 8 Load condition 3 (arrows indicate axle location)

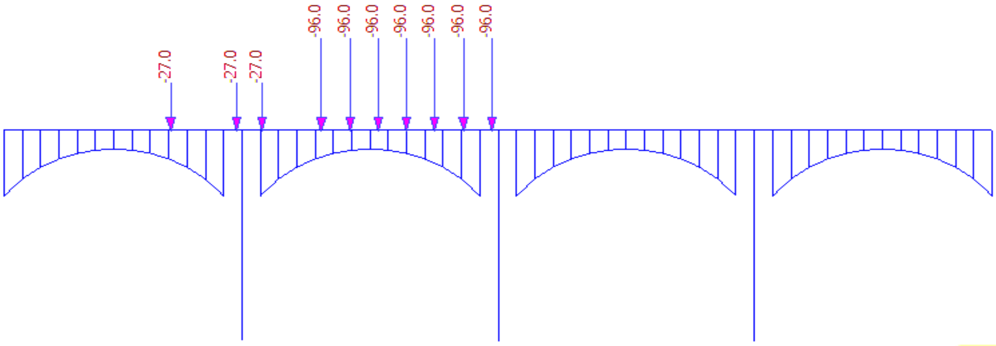


Figure 9 Load condition 4 (arrows indicate axle location)

## V. Set up computing model

### 5.1 Model and simplified

For the purpose of structure is checked, the author must first calculate the values of the most disadvantageous load effect combination, therefore, can be calculated by finite element method (fem), computational tools bridge use special program Midas, whole bridge built 166 units, 119 nodes, structure model diagram shown in figure 10.And the model is simplified as follows: (1) the main arch ring and pier material as the ideal elastic material, material elastic modulus as a constant;(2) does not consider the deck surfacing of the bridge concrete flexural capacity increase; (3) cross section deformation accord with flat section assumption.

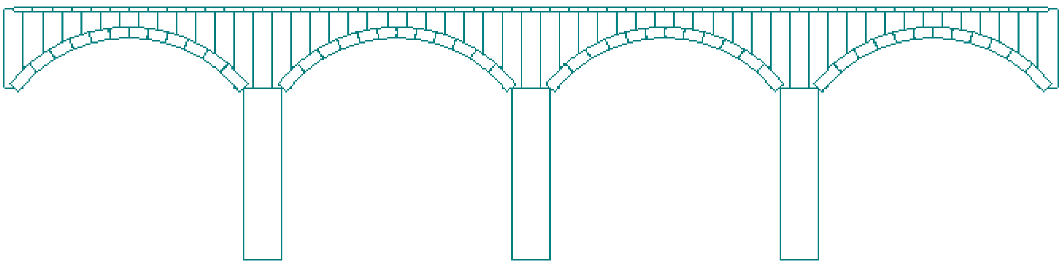

Figure 10 finite element model and cell division diagram

### 5.2 bearing capacity checking computation

5.2.1 Section Strength checking

(1)Coefficient of bridge and $\xi_c$ are checked and determined

According to the specification JTG/T j21-serial open-style - 2011 article 7.1.2, the resistance effect of masonry structure bearing capacity limit state, should according to the results of the bridge test or introducing detection coefficient, cross section reduction factor correction method of calculation.According to the specification JTG/T j21-serial open-style - 2011 article 7.7.1 and article 7.7.5, combined with the bridge inspection and special inspection regularly, calculate = 0.9, $\xi_c$ = 0.95, when the arch ring cross section calculation.

(2)Cross section strength calculation results (heavy vehicle load calculation)

Main arch ring section bearing capacity of strength is checked the results are shown in table 4 ~ 6. Note for table 4~6: the above-mentioned axial force units to kN, bending unit for kN m..The tables $Z_1R_d$ have considered the effect of $\xi_c$ cross section reduction factor.

Table 4 2 # across key section bearing capacity calculation (condition 1, 2)

| Check project / check Cross section | Axial force (kN) | Bending mo ment (kN·m) | Resistance Rd(kN) | Mechanical type | Meet requirements or not | $Z_jR_d$ |
|---|---|---|---|---|---|---|
| Left to arch foot | -4138.3 | -298.82 | 9449.2 | Up tensile bias | Yes | 7772.9 |
| 1L/4 span | -2973.86 | 64.34 | 10921.2 | Under tensile bias | Yes | 8983.8 |
| Vault | -2755.81 | 280.32 | 8245.7 | Under tensile bias | Yes | 6782.9 |
| 3L/4 span | -3168.6 | 60.96 | 10956.4 | Under tensile bias | Yes | 9012.8 |
| Right to arch foot | -4139.13 | -305.58 | 9386.2 | Up tensile bias | Yes | 7721.1 |

Table 5 2 # across key section bearing capacity calculation (condition 3)

| Check project / Check Cross section | Axial force (kN) | Bending mome nt (kN·m) | Resistance Rd(kN) | Mechanical type | Meet requirements or not | $Z_jR_d$ |
|---|---|---|---|---|---|---|
| Left to arch foot | -4041.72 | -213.9 | 10144.5 | Up tensile bias | Yes | 8344.9 |
| 1L/4 span | -2959.63 | 21.6 | 11071.9 | Under tensile bias | Yes | 9107.8 |
| vault | -2734.13 | 268.71 | 8389.1 | Under tensile bias | Yes | 6900.9 |
| 3L/4 span | -3139.69 | 64.88 | 10935.9 | Under tensile bias | Yes | 8995.9 |
| Right to arch foot | -4132.76 | -321.31 | 9231.4 | Up tensile bias | Yes | 7593.7 |

Table 6 2 # across key section bearing capacity calculation (condition 4)

| Check project / check Cross section | Axial force (kN) | Bending moment (kN·m) | Resistance Rd (kN) | Mechanical type | Meet requirements or not | $Z_jR_d$ |
|---|---|---|---|---|---|---|
| Left to arch foot | -4133.78 | -305.19 | 9386.1 | Up tensile bias | Yes | 7721.0 |
| 1L/4 span | -2964.32 | 68.29 | 10898.8 | Under tensile bias | Yes | 8965.3 |
| vault | -2737.75 | 265.16 | 8448.6 | Under tensile bias | Yes | 6949.8 |
| 3L/4 span | -3149.36 | 15.22 | 11083.0 | Under tensile bias | Yes | 9116.9 |
| Right to arch foot | -4043.06 | -214.53 | 10140.0 | Up tensile bias | Yes | 8341.1 |

5.2.2 checking whole “stable –strength”

Under the "masonry highway bridge and culvert design specifications (JTG D61-2005),article .1.4ensuring overall arch" strength and stability "and checking.

Table 7 Main arch ring whole "stable –strength" checking

| Project / Load condition | $\gamma_0 N_d$ (kN) | $Z_1 R_d$ after the reduction (kN) | Strength calculation results |
|---|---|---|---|
| Load condition 1,2 | 2755.81 | 6782.9 | Yes |
| Load condition 3 | 4041.72 | 8344.9 | Yes |
| Load condition 4 | 4133.78 | 7721.0 | Yes |

Note: the above table $Z_1 R_d$ has considered the effect o $\xi_c$ f cross section reduction factor.

5.2.3 The deflection calculation serviceability limit state

Cars are calculated by use of a special bridge finite element software Midas mid-span deflection under load, the calculation results as shown in table 8.

Table 8 live-load deflection

| The position of the bridge | Load condition | The deflection(mm) |
|---|---|---|
| Mid-span of 2#span | Load condition 1,2 | 5.352 |
| Mid-span of 2#span | Load condition 3 | 5.272 |
| Mid-span of 2#span | Load condition 4 | 5.215 |

Under the "masonry highway bridge and culvert design specifications" (JTG D61-2005), article 5.1.11, calculated on effect of combination of short-term effects on a bridge across a range of plus or minus a maximum of the sum of the absolute value of the deflection should not be greater than 1/1000,5.352 mm < span length of 12.00 mm, meet the specification requirements.

## VI. conclusion

Through the study of the structure of the bridge is checked, the theoretical analysis shows that the bridge bearing capacity is too big to meet the 75.2 t transport vehicle traffic demand.large heavy component transport is increasing, the study of this aspect demand has become increasingly prominent, the further study in this respect is an representative research subject.In this paper, combined with the specific calculation of bridge engineering analysis, Provides specific calculated and analysis method ,so as to provide reference for similar projects.

## References

[1.] Zhong-da Chen (1999).retrospect and prospect of China's road transport of bulky (Shanghai highway proceedings of the 4th annual academic).

[2.] The ministry of communications of the People's Republic of China ministry standards. Highway bridge design general specification (JTJ021-89) (1999). people's traffic press..

[3.] The ministry of communications of the People's Republic of China ministry standards (1985). Highway reinforced concrete and prestressed concrete bridge design code (JTJ023-85). People's traffic press.

[4.] Ling-sen Yao (1996). bridge engineering (highway and urban road engineering) . people's traffic press.

[5.] Jian-guo Yi (2001) .bridge calculation example of the concrete beam (plate) bridge "(second edition). people's traffic press .

[6.] Jian-shu Ye (1997) the principle o structure design .people's traffic press.

[7.] Lian- kun Li(2000) . structural mechanics (third edition). higher education press .