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STUDY OF CROSS - SECTION LOAD CAPACITY STONE ARCH RIB ENCLOSED BY REINFORCED CONCRETE

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ABSTRACT: The mechanical behavior and failure mechanism of stone arch rib enclosed by reinforced concrete under different existed stress level is obtained by the three group failure tests of pressed members enclosed by reinforced concrete. The effect of the cross-section load capacity with different stress states is studied by test results. Then an analytical method considering the influence factors is proposed to count cross-section load capacity of stone arch rib enclosed by reinforced concrete.

KEYWORDS: Cross-section Load capacity; Enclosed by reinforced concrete; Existed stress level.

1 INTRODUCTION

The strengthening method of enclosed the construct by reinforced concrete is widely used in strengthening engineering of stone arch bridge [1,2]. Construction skill to enclosing stone arch rib by reinforced concrete is mature methods, but theoretical study is not good enough Especially in Calculation of load capacity [3]. The load capacity of stone arch rib strengthened is generally calculated by Masonry bridge design specification for Highway and Masonry construct design specification [4,5]. The calculating method of design specification is mainly used in all cross section under The disposable loading, but the stone arch rib strengthened is two loading construct and the section consists of different material, so the calculating method of design specification can’t correctly reflect and calculate the ultimate load capacity of the stone arch rib strengthened [6]. The mechanical behavior and failure mechanism of stone arch rib enclosed by reinforced concrete under different existed stress state is obtained by the failure test of three grope of pressed members enclosed by reinforced concrete. Cross-Section load capacity effect of different stress states is studied by test results. Then an analytical method considering the influence factors is proposed to count Cross-Section load capacity of stone arch rib enclosed by reinforced concrete.

2 TEST STUDY

2.1 Test introduction

The model test consists of three groups. The existed stress lever modulus β is 0, 0.4 and 0.8 respectively; the eccentricity is 40mm. in three groups. The strength grade of old Masonry is MU60. The mortar strength is M10. the test dimension is 150mm×150mm×150mm. The thickness of strengthening layer is 40mm, strength grade of pea stone concrete is C40, the longitudinal steel bar is ϕ12@50mm and hoop steel bar is ϕ6@100mm in tests. The Connection shear reinforcement be set in combine face of masonry and concrete for strengthening combine capacity. The existed stress is exerted on corbel by stretch-draw steel strand.

The resistance strain chip is stick on steel bar and concrete in middle cross section for studying Stress state of member strengthened. The disposable loading Destroy test is done using 200T universal testing machine in structure of southwest Jiao Tong University Center Laboratory. Load program first to estimate the ultimate load of the 10% pressure, and then uninstall to 0, with each level is the ultimate load of the 10% load pressure, until the ultimate load of the 90%, then to 5% per level compression until the specimen destroys.

2.2 Test results and analysis

From appearance phenomenon of each specimen the failure of different stress level index of column strengthened is similar with ordinary reinforced concrete column. concrete in strengthening layer is no piece or blocks off When concrete in strengthening layer is knocked down, that shows can bonded together to load for setting share steel bar. But the different failure form of three groups of test specimen is found as shown in Table 1. For the front two groups of specimen When test specimens reach ultimate loading capacity, the strain of concrete edge near axial force reaches its ultimate compressive strain, the specimen is destructed; For the third groups of specimen with the higher stress levels, the strain of core masonry edge near axial force reaches its ultimate compressive strain when the specimen reaches its ultimate load capacity. Then specimen is destructed.

Through test of the three groups of test specimens strengthened, the ultimate bearing capacities are obtained as shown in Table 1. It is obtained that limit strength is 37Mpa, the peak strain is 0.0022, ultimate strain is 0.0042 of Masonry on non strengthened column.

As you can see from table 1, when the existed stress level is relatively small, the load capacity of test specimen is almost same with first group specimens under the disposable loading. The load capacity of test specimen strengthened increased by 1.3% than the disposable test specimen when the existed stress lever index is 0.4 because that the failure form is the strain of enclosing concrete achieve firstly ultimate compressive strain and enclosing concrete strength is made full use when the existed stress level is low; But for the third group test of higher existed stress level the load capacity of test specimen decrease by 13.3% because With the increase of initial stress, composite reinforcement members failure form change.

Table 1. The ultimate load capacity and the concrete stain

Specimen number		β	load capacity	load capacity	ε
The first group	Z11	0	1100kN	1125 kN	0.0045
	Z12	0	1150 kN		
The second group	Z21	0.4	1160 kN	1140 kN	0.0046
	Z22	0.4	1120 kN		
The third group	Z31	0.8	1000 kN	975 kN	0.0019
	Z32	0.8	950 kN		

Damage began in masonry reaches ultimate compressive strain, but the strength of concrete is not fully utilized. Core masonry rigidity is affected and reduces, so the load capacity of core masonry is reduced. Therefore the Effect of existed stress lever on the load capacity of member strengthened cannot be ignored.

3 CALCULATING CROSS-SECTION LOAD CAPACITY

3.1 Calculation assumption

In this paper, the theoretical analysis and calculations are based on the following assumption.

a) The good bonding between the reinforcement layer and structure layer can guarantee the structure works together and deformations are compatible when the second time loading. The tensile force of concrete will not be considered.

b) Material stress strain relationship.

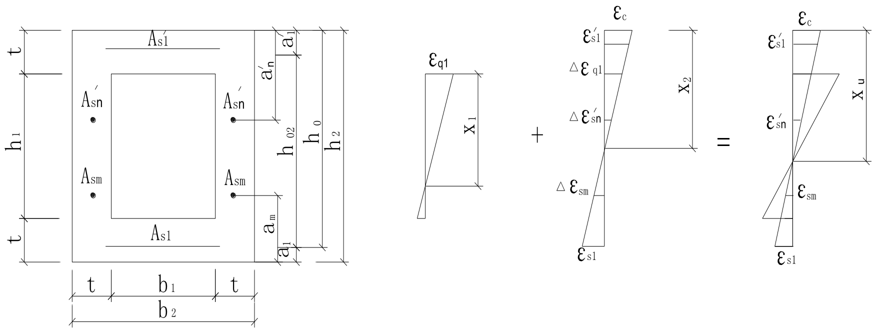
Stress and strain relationship of stone masonry. The relation between masonry stress σ_q and strain ε_q uses parabola and the horizontal line of the combined curve in the reference [6].

The stress and strain relationship of concrete with Non uniform compression uses parabola and the horizontal line of the combined curve in the reference [8]. Steel bar stress and strain relationship is straight line and horizontal line of the combined curve, uses the function relation of reference.

3.2 Analysis of limit failure state

Three limit failure forms can be existed for small eccentric compression composite reinforcement section. Base of the analysis of section stress of construct strengthened as shows as fig.1, three kinds of ultimate failure forms are as follows:

a) The first failure form is the strain of concrete edges firstly its ultimate compressive strain behind the second loading. Failure began from the concrete. The strain of concrete edge near axial force is $\varepsilon_c = \varepsilon_{cu}$, the strain relation is $\varepsilon_{q1} + \Delta\varepsilon_{q1} < \varepsilon_{ult}$ for core masonry, when $\varepsilon_{q1} < \varepsilon_{ult} - (x_u - t)\varepsilon_{cu}/x_u$.



(a) (b) (c) (d)

Figure 1. The stain of cross section (a) section (b) strain of the first phase (c) strain of the second phase (d) strain increment of the second phase

b) The second failure form. The second failure form is the strain of masonry edges near axial force reaches firstly its ultimate compressive strain behind the second loading. $\varepsilon_{q1} + \Delta\varepsilon_{q1} = \varepsilon_{ult}$, $\varepsilon_c \le \varepsilon_{cu}$ when $\varepsilon_{q1} < \varepsilon_{ult} - (x_u - t)\varepsilon_{cu}/x_u$.

c) The third failure form. The Section strengthened is failure because the strain of masonry and concrete edges near axial force reaches their ultimate compressive strain. This exited strain is called boundary exited strain $\varepsilon_b = \varepsilon_{ult} - (x_u - t)\varepsilon_{cu}/x_u$.

3.3 Calculating the load capacity of cross-section

The compression section is divided into n small strip. When The section strengthened reached the limits destruction state the concrete strain or masonry of jth strip is $\varepsilon_{cj} = y_1(x_j)$ or $\varepsilon_{q2j} = y_2(x_j)$, x_j is the distance between the jth strip and the neutral axis. For the first failure or the third failure form the strain of concrete or masonry of jth strip as follows:

$$\varepsilon_{cj} = \frac{x_j}{x_u}\varepsilon_{cu}, \ \varepsilon_{q2j} = \varepsilon_{q1j} + \frac{x_j}{x_u}\varepsilon_{cu} \tag{1}$$

For the second failure form the strain of concrete or masonry of jth strip as follows:

$$\varepsilon_{cj} = \frac{x_j}{(x_u - t)}(\varepsilon_{ult} - \varepsilon_{q1}),\ \varepsilon_{q2j} = \frac{x_j}{x_u - t}\varepsilon_{ult} \tag{2}$$

After the strain of each strip is got, the corresponding stress σ_{cj} and σ_{q2j} is got by their stress-strain relations. Then the load N_j and the moment M_j about the central axle of cross section are got as follows, Z_j is the distance between the jth strip and the center axis in the following formula:

As $x_j \le x_u - t$,

$$N_j = \Delta A_{cj}\sigma_{cj} + \Delta A_{qj}\sigma_{q2j} \tag{3}$$

$$M_j = N_j Z_j = (\Delta\Delta_{cj}\sigma_{cj} + \Delta A_{qj}\sigma_{q2j})Z_j \tag{4}$$

As $x_j \ge x_u - t$,

$$N_j = \Delta A_{cj}\sigma_{cj} \tag{5}$$

$$M_j = N_j \cdot Z_j = \Delta A_{cj}\sigma_{cj}Z_j \tag{6}$$

$$N = \sum_{j=1}^{n} N_j + f_{s1}' A_{s1}' + -\sigma_{s1}A_{s1} \tag{7}$$

$$M = \sum_{j=1}^{n} M_j + f_{s1}' A_{s1}' (h_2/2 - a_1') - \sigma_{s1}A_{s1}(h_2/2 - a_1) \tag{8}$$

In the same manner the strip method is used for the old masonry. Then the whole cross section stress-resultants and moment is got as flows:

$$N = \sum_{j=1}^{n} \sigma_{q1j}\, bx_j \tag{9}$$

$$M = \sum_{j=1}^{n} \sigma_{q1j} bx_j \cdot (h_1/2 - x_1 + x_j) \tag{10}$$

An iteration method is used to count load capacity of member strengthened according to the strip method.

3.4 Counting analysis of test

The computation method using FORTRAN language is compiled a computer program to count specimen. The calculation results are shown in Table 2.

As you can see from table 2 the calculation method and the comparison of test results, the error is less than 10%, so the calculation of this paper is reliable. Then separately on β =0.2, 0.6, were calculated to get that curve Figure 3 of load capacity effects on initial stress level index.

Table 2. The results compare of this method of calculation

Specimen number	β	load capacity of experiment	load capacity of this paper method	N_u' / N_u
The first group	0	1125 kN	1020 kN	0.91
The second group	0.4	1140 kN	1080 kN	0.94
The third group	0.8	975 kN	880 kN	0.90

4 CONCLUSIONS

a) Through the model test shows that, the initial stress levels have a great influence on failure modes and strength. When initial stress is small, failure form of concrete meeting the limit is occur. When the initial stress is relatively large, failure form of masonry meeting the limit is occur.

b) The combined section three failure forms are got by the section strain analysis.

c) An analytical method considering the influence factors of the different mechanical property of material, the existed stress state in stone arch rib and the stress-strain nonlinear relationship is proposed to count Cross-Section load capacity of stone arch rib enclosed by reinforced concrete by the model test and the theoretical analysis.

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