First International Conference on Construction in the 21st Century (CITC-II)
"Sustainability and Innovation in Management and Technology"
10-12 December, 2003, Hong Kong

Modification of Walking Bridge into Semi Heavy Load Bridge by New Steel Connection Opener

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Abstract

A walking bridge was made by KWPA at 1992, on overflow structure, south of Iran. The traffic load forced to build a new bridge on main water channel that it should be carry semi-heavy traffic load. For each span; the one of two connections of the beam was jointed in each side and the other joint was without any connection with column. The main criterion was considered by designer into separate stiffness that the old bridge should be carry the weight of the dead load and the other stiffness should be computed to carry the live load. New steel bridge should be transferring the torsion into column that it is produced by motion of traffic live load. *New opener connection* could be solved the problem and it was invented by designer Afshin Turk 2002. The cost of modify bridge would be consider 7% of total cost of wide bridge (150m).

Keywords

Walking Bridge, Opener Connection, Traffic

1. Introduction

Design conception of bridge is varied by regional condition, population, traffic load and kinds of material. In bridges, main beam section was influenced by support connection. Steel or concrete walking bridge could be designed with live load traffic. Designed sections of bridge could be carry the load that it is allowed by requires load exerted upon the sections. Service load of pedestrian bridge should not be converted into semi-heavy load in structure engineering. A walking bridge was made on over flow structure that it belongs to MARED water channel (Irrigation and Drainage project, Sweden consulting engineering Co. 1975). In original design, the walking bridge has not been forecasted but after some years it was built by local population force. Firstly, the top of concrete cover should be damaged to tie the steel root bars (L shape). Multi span bridge body was suggested with below condition:

- 14 concrete column and 15 span concrete ;total length of bridge =120 m
- column height =1.4 m ; initial width of pedestrian =1.2 m ,span length=6 m

Roots of column steel bars was connected by L shape with top mesh of overflow structure in desired points that it could be carried the safety load. The column has a rigid connection in overflow structure and it is free at the top. Concrete slab with 6m length was made by connection with columns. First a joint is in

left span and the second a rolled joint in right span. In fact, there is only one connection between span and two columns.

2. Modification and Reinforcement

After ten years that this walking bridge was built; the another semi-heavy load bridge should be made to pass new population traffic with span 150m. The project must be spent a lot of money (600000 US$) to building a new heavy load bridge on Mared water channel. It is mentioned that the Mahab-Ghods consulting engineering of project had been declared to employer KWPA with a technical report about "making semi-heavy load bridge is impossible". Afshin Turk who is the supervisor engineer and (p.samani) the mechanical contractor have been decided to build a new bridge on old walking bridge. it should be paid more than 12 times of modified bridge.

3. Design Problem and Executive Limitation

Connection of old Structure; the concrete connection between column and overflow structure has been acted on rigidity because the L shape bend of bars has tied with top mesh of structure; therefore it could be carried torsion and moment into rigid support.

3.1 Slab and Column Concrete Connection

The section of concrete member have been contained a slab (120×12 cm^2) and a beam 35×35 cm^2 with 600cm length in each span. In concrete members span, one of the connections was built by two bend steel bars that it has been acted the same simple joint connection with force vector R (Rx,Ry,Rz). Another connection could not be reacted any resistance that it is exerted on support. Inability is effected by non-reinforced root connection. One end simple joint beam was resulted by installation of two bar roots in end of each span. Therefore the torsion moment could not transferred in this case that it is produced by traffic live load. It is mentioned the initial design had been based on pedestrian traffic. Drought years and financial cost effected urgent starting of Mared main pump station. Below items should be recognized to make new bridge:

- Making a new bridge on old pedestrian body
- Away from extra financial cost ,building long bridge with 150m
- Compulsory condition to built an accessory bridge behind walking bridge
- Project management could not be accepted more deletion against long bridge

With above, innovation design could be solved the problems by using new connection or opener. It is mentioned that the cap modeling could be used in bridge structure to fasten joints.

4. Members Improvment Study to Carry the Load

New connection opener specifications should be transferred the bending moment and forces that they are included the torsion, span directional moment, column directional moment and forces as same as the directions. Firstly, the connection weakness should be modified between beam and column. In ordinary condition, initial connection could not be carried the torsion and moment that it is exerted by beam into column. In each span, one connection has been fixed to carry the force and another useless joint was installed by non-steel rod inside the concrete. Joint modification was improved by opener connection that it would be designed to resist the below items:

- Weight of added steel members on bridge
- Live load traffic, semi-heavy load bridge

5. Design of Innovation Connection

Movement and rotation ($\Delta x,\Delta y,\Delta z,\theta x,\theta y,\theta z$) should be constrained by new connection on a belt acting. Torsion moment had been considered to avoid overturning rapture and it is a main target to satisfy the θ rotations in supports. Concrete connection is the only real anchorage that it could be resist on forces to exerted up on the steel new frame. If the concrete column has assumed on a glass bottle, the resistance force will appear to modeling on a bottle cap. This model of cap belongs the below items:

- Cap strength material
- Steel plate thickness and flexibility
- Required cap root to acting the model

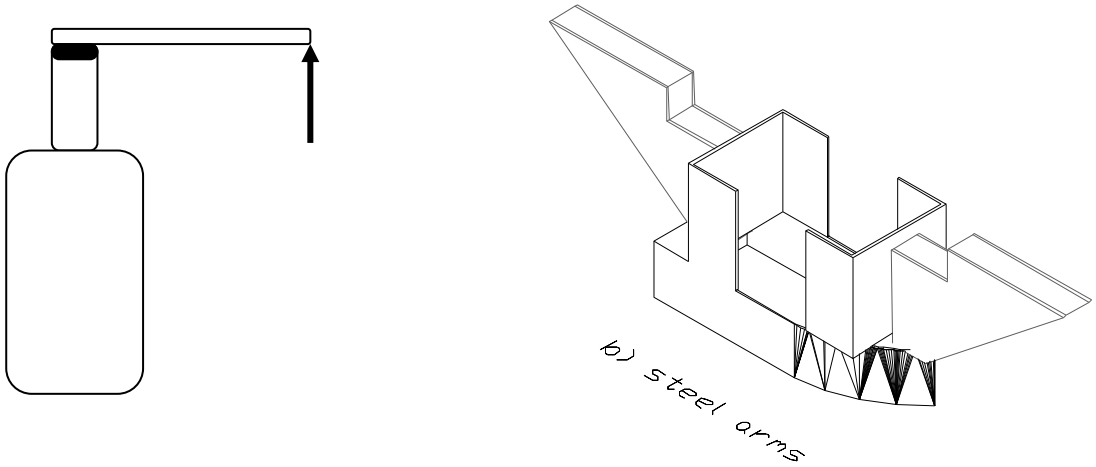
Corresponding above, this connection has been named the opener and it will act as same as the cap model. Notification, steel plate is used by plate flexibility characteristic to bend surfaces. Details of surface will explain in the text. Using the three items above could produce rigid and flexible connection. The plate thickness specially is used on surfaces it should be designed with thickness less or equal 6 mm to desire flexibility and workability installation. Also, the critical cap root length could be analyzed to determine minimum designed length (L_{cr} greater than L_{md}). Torsion and disturbing forces on beam is simulated by the opener cap characteristics to carry the load.

6. Basic Conception and Computation Vision

It is necessary to explain separate stiffness that the designer has determined to clear opener connection phenomena in this text. Traffic live loads should be exerted on steel stiffness and dead load must be carry by old concrete stiffness.

6.1 Cap Modeling

Bridge connection was modeled by a bottle cap to determine the exerted forces up on the main connection. The simulation can be shown in the Figure 1 that the basic concept is used to analyze forces by opener phenomena. Stress distribution and scalar value are tried to show by next figures and reader will be noticing the cap modeling steps.



a)

Figure 1. a) Bottle cap modeling and their usage in semi-heavy load bridge by cap modeling and resistance phenomena. In details, all surfaces should be welded correctly to insure the moving loads. It must be avoided to weld beam ends into supports. b) Ox head and steel arms.

6.2 Stress Distribution Value on Steel Cap Sections

All forces should be determined on bridge to bending the steel plate in cap surface. Cap circumstance is used to cover flexible and rigid cap connection. More detail could be fined in Figure 1. Main stresses are computed to draw by diagrams and sections at x and y directions (z direction is the column axial). Referring to the Figure 1, the main stress could be evaluated by Mxx and Myy.

6.2.1 Steel cap model and steel arms

Opener phenomena could be helped to know, how should the weak connection be modified and which part is needed to cover by steel plates. A long plate is replaced on ox head to help cap modeling and it could be tensed to keep tension on cap area. (Steel arms) Extra live load must be transfer to column and car's axial distance is determined by steel beam. This distance must be advised to avoid any extra un-desirable torsion. Steel arms have been supported to transfer bending moment into cap.

6.2.2 Stress distribution of bending moment and torsion

Critical section of cap is assumed to produce more possible stress by opener theorem that it is acted on un-bolted or un-welded cap by only root length belt's cap. The main assumption has been dictated to mid point of cap. It is mentioned that the cap model has not been connected to main structure with any physical operations. For torsion moment, steel cap could not be divided forces and moment symmetrically but the importance notice can be advised to welding steel arms into cap in high accurate. The mid point in torsion axes could be selected to take more stress.

6.3 Computation Analyzing

In Figure 2, the maximum load on bridge could be considered by the local statistic traffic and it should be limited by maximum modified capacity of new bridge. Traffic live load 1 ton/m is carried by steel members that it is added to improve capacity and it should be strictly exerted on steel beams and cap by steel stiffener separated. Referring the Figure 2, the maximum stress on x direction could be evaluated by using next formula. Myy is the allowable bending moment that it will be occurred on bridge and it is separated into below three parts:

- Dead load, old body bridge and steel members.
- Traffic live load
- Impact forces by using coefficient 40% of live load.

Stress values should be substituted in 3D stress elements to studying maximum tension criterion. Each stress in tension or compressive could be presented in same direction simultaneously.

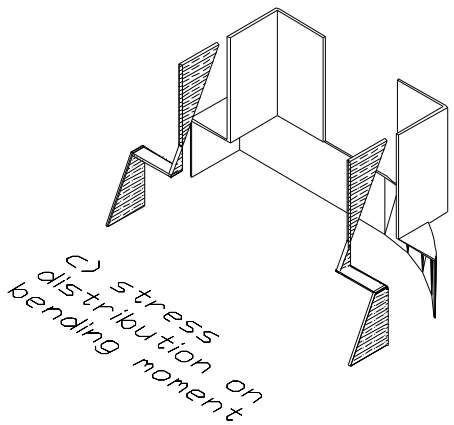


Figure 2. C) Stress distribution, neutral axes is applied at mid point of vertical sections, Myy is exerted by live load and percentage of dead load of old bridge.

$$\sigma_x = \frac{M_{yy}}{S_{yy}} \rightarrow S_{yy} = \frac{I_{yy}}{C}, \quad C = \frac{h}{2} = 57/2 = 28.5cm \qquad and \qquad b = 15cm$$

$$I_{yy} = 2\left(\frac{t.h^3}{12} + \frac{b.t^3}{12}\right) = 2\left(\frac{0.6 \times 57^3}{12} + \frac{15 \times 0.6^3}{12}\right) = 18520cm^4 \Rightarrow S_{yy} = \frac{18520}{28.5} = 650cm^3$$

$$q = q_{LiveLoad} + q_{\mathrm{Im}pact} + q_{DeadLoad} = 1.4q_L + q_D = 1\tfrac{ton}{m} + 40\% \times 1\tfrac{ton}{m} + 0.750\tfrac{ton}{m} = 2.15\,ton/m$$

$$M_{yy} = qL^2/12 = 2.15 \times 36/12 = 6.45 \qquad t.m$$

$$\sigma_x = \frac{645000}{650}(kg.cm/cm^3) = 992kg/cm^2 \cong 1000kg/cm^2 \qquad \rightarrow \sigma_x = 1000kg/cm^2 \qquad (1)$$

$$Torsion \quad Moment: \qquad \sigma_y = \frac{M_{xx}}{S_{xx}} = \frac{T}{S_{xx}} \rightarrow S_{xx} = \frac{I_{xx}}{C}, \qquad C = 28.5cm$$

$$I_{xx} = 2 \times t.h^3/12 = 2 \times 0.6 \times 57^3/12 = 18520cm^4 \Rightarrow S_{xx} = 18520/28.5 = 650cm^3$$

$$M_{xx} = T_{torsion} = q_L.\Delta_{eccentric}.L$$

$$q_L = 1.4tons/m \qquad ;\Delta_{eccentric} = (W_{Bridge} - W_{car})/2 = (2.20 - 1.40)/2 = 0.40m$$

$$T_{torsion} = 1.4 \times 0.40 \times 6.0 = 3.36t.m$$

$$\sigma_y = \frac{T}{S_{xx}} = \frac{336000}{650}(kg.cm/cm^3 = 520\frac{kg}{cm^2} \Rightarrow \sigma_y = 520kg/cm^2 \qquad (2)$$

$$M_{MAX)Beam} = \left(1.4q_L\right).L^2/8 = (1.4\tfrac{t}{m}).6^2/8 = 6.3 \qquad t.m$$

$$S_{req)Beam} = \frac{M_{MAX)Beam}}{\sigma_{Allowed}} = \frac{630000}{1400}\frac{kg.cm}{kg/cm2} = 450cm^3 \rightarrow S = 450cm^3 \rightarrow \qquad 2IPE\,200mm$$

7. Stress Criterion

By using Equation 1 and Equation 2, the maximum normal stresses could be applied to yield steel on cap sections that they are mentioned in Figure 3 by vectors and the Mohr circle will be used to control stress by Equation 3. Critical normal stresses are assumed by rigid and simple joint in each end of the beam. Therefore the maximum bending moment will be produced with $ql^2/8$ at near mid point of beams. In connection joint, values of Equation 2 and zero in another end will appear the maximum bending moment. The beam has been connected with one rigid connection in span. Thermal effects should be considered by joint connection of beam in each span. This system could be moved to expand by hot weather conditions that the new walking bridge has been passed traffic live load more than 16000 tons. Equation 6 will show the criterion values.

$$\tau_{\max} = \left|\frac{\sigma_1 - \sigma_2}{2}\right| \le \tau_{critical} = \frac{\sigma_Y}{2} \qquad \Rightarrow \tau_{\max} = \left|\frac{1000 - 0}{2}\right| = 500\frac{kg}{cm^2} \qquad \le \qquad \tau_{critical} = \frac{\sigma_Y}{2} = \frac{1400}{2} = 700\frac{kg}{cm^2}$$

$$\Rightarrow \tau_{\max} = 500 \le 700 \qquad \rightarrow \qquad O.K \qquad (3)$$

8. Conclusion

Based on Equations 3 and 4; opener connection could be used in modified bridge by referring to Figure 3. Steel connection action should be guaranteed to safe passing on bridge that it is mentioned; in duration 9 month, the total live load 16000 tons has been passed on bridge in the hottest area in south of Iran (Persian Gulf region). Day temperature difference will be appeared in rang 40 degree in centigrade scale. Steel surface temperature was reported by laboratory more than +65 degree in hot days. Equation 7 shall be defined the safety factor and it should be added that the bridge was started at May 2002 and it is working continuously up to date (Feb-May=9 month).

$$TotalWeight = m \times d \times n \times w \qquad = 9 \times 30 \times 30 \times 2 = 16200 tons \tag{4}$$

Where m= month; d= 30 days in month; n= Numbers of moving cars; w= weight of cars (tons)

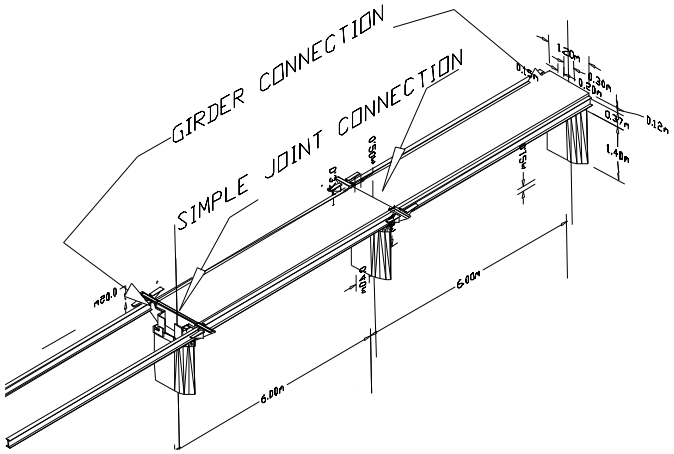


Figure 3. Bridge on overflow structure . It is built to pass traffic by twenty spans in 120m length of overflow. Two steel beams are placed to transfer moment and torsion into new opener connection.

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