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Capacity of Truss Tension Members via High Strength Strands

Résistance d'éléments de poutre à treillis tendus à l'aide de torons à haute résistance

Tragwiderstand von Zuggliedern mit Spannlitzen hoher Festigkeit

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The Walnut Street Bridge crossing the Tennessee River in the City of Chattanooga, Tennessee is a pin connected Camelback Pratt Truss and has the distinction of being the oldest surviving Bridge across the 2400km mile river. The Bridge was designed by a noted consulting engineer, Edwin Thatcher of Louisville, Kentucky, with construction completed in 1891. The structure replaced ferry service and helped to unite both banks of the River during the time of great economic growth in the city. The bridge is 722m in length, with a 238m iron viaduct forming one approach. Six (6) truss spans cross the river channel, three (3) spans at 64m and three (3) spans at 98m. The trusses range from 11.6m to 14.6m deep. The Roadway width is 5.5m, with two (2) 1.5m sidewalks provided. After the construction of the nearby Market Street Bridge in 1917 the bridge saw a decrease in usage. The structure was rehabilitated on various occasions including the replacement of the timber superstructure with steel stringers and an asphalt wearing surface. In 1974, in an attempt to strengthen certain eye bars, U-shaped steel bands were wrapped around the heads. The bridge was eventually closed to all traffic in 1978 due to concerns about its structural integrity.

In the 1980's there began a community spirit to rehabilitate the structure to serve as a Pedestrian Bridge and linear Park. Contributions were raised from private citizen groups and together with a grant from the Federal government and funds from the City, the project became a reality. It is expected the rehabilitated structure will be extensively used for festivals, exhibits, etc. and be a focal point for the resurgence of the river front. In the future the bridge will also be used as a crossing for a trolley system planned by the City. Extreme care in restoring as many historic details as possible would be required as the Bridge is of significant historic value and is eligible for inclusion on the National Register of Historic Places.

The task of restoring the Bridge includes many details including pier, deck and railing work. The major work however and the focus of this paper is to describe the method selected for strengthening the truss members, in particular the tension chords.

Steel eye bars make up the bottom chord and tension diagonals. The bars are in pairs and are up to 15cm x 3cm in section. A maximum of four (4) bars are used in the lower chord. The compression members including the top chord and verticals are composed of steel shapes (either angles or Z's). Existing information indicated low carbon steel was used for all tension members with an allowable design load of 1.1×10^8 Pa.

Inspection and Testing

An in-depth inspection of the trusses showed losses due to rusting and pitting at the eye bar heads to be a common condition. The inspection also revealed the presence of numerous dimples or concave depressions of unknown origin in the head and neck of the eye bars at a large number of the lower joints. No significant losses were noted in the main body of the eye bars. Ultrasonic investigation of the eye bars did not reveal the presence of any cracks. Field metallography and chemical analysis confirmed the presence of low carbon steel. The structure was strain gauged utilizing an actual truck and results compared to theoretical values. Measured strains in the tension members were compared to computed values with the results considered consistent with actual behavior of trusses of this age.

Truss Strengthening

The maximum computed stress in the eye bars under existing dead load is 8.0 x 10^7 Pa. In light of the condition at the eye bar heads it was decided that the maximum allowable stress in the eye bars should be limited to the existing levels, which the trusses have safely sustained. It was also considered prudent to build in redundancy into the truss tension members since many eye bars have existing flaws that may initiate cracks in a fracture critical member.

Conventional strengthening of the truss members by adding reinforcing members was first investigated. Due to the large number of members to be reinforced and the difficulty in providing attachments to the closely packed members, this alternate was rejected. Additionally the final stresses in the eye bars would certainly be higher than the current level as the new and old members would share the applied loads.

A system of post-tensioning the trusses was then explored. The possibility of relieving the eye bars of a large portion of their existing dead load would free up capacity needed to support future live loading. In addition post-tensioning would introduce redundancy in the tension members by providing an alternate load path via the strands.

A system of straight and deflected strands was selected for the post-tensioning. The strands were placed to coincide with the bottom chords and the diagonals fanning away from the mid-span. The strands were deflected at certain lower joints by wrapping them over specially constructed saddles attached to the lower joint pins. Dead anchors secured the strands to the bearing pins and the upper joint pins. Tensioning of the strands is to be performed at the lower chord level via jacking station assemblies which are to be left in place should any adjustments be required in the future.

The strands are 1.5cm diameter Grade 270 coated prestressing strands and are installed in pairs. The post-tensioning stress introduced into the strands is 5.1 x 10^8 Pa or less and results in an equal reduction of force in the eye bars. The strands constitute an internal system of post-tensioning and do not affect the forces in members that are not in line with the strands. The live load stress due to pedestrian loading will be shared by the strands and the eye bars in proportion to their stiffnesses. The eye bars being much stiffer than the strands will pick up most of the live load stress. Under full live load the eye bars will experience stress no greater than 8.0 x 10^7 Pa. Under proposed dead load the stress in the eye bars is reduced to less than 3.45 x 10^7 Pa, the remainder of the dead load being in the cables.

The cost for installing the strands on twelve (12) trusses is estimated at $350,000. A total of 4880m of strands is required. Construction is to start in mid 1990 and be completed by February 1991, the 100th anniversary for the structure.

In summary, it is believed this system of installing strands to add to the load carrying capacity of tension members is a simple and economical method. Post tensioning allows for rehabilitation of structures not otherwise capable of being upgraded, as conventional methods are difficult and expensive to accomplish because of size, access and connection constraints at the pins.