An Investigation into the Deformation Properties of Clamped Concrete Filled Steel Tubes

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Abstract

An investigation into the deformation properties of spliced concrete-filled steel tubes (CFST) (Also called 'Solomon's Knot') is underway. The crossbeam members are unique in that they are formed from 3 m long sheet steel panels that are interlocked along their length. Columns longer than 3-m must be formed by splicing 3-m lengths together, and a unique bolted splice clamp is proposed. Finite element analysis of bending and torsion of butt-spliced beams has been carried out using ANSYS.

Results show that the maximum vertical deformation value of the butt-spliced half scale crossbeam filled with 5000 psi concrete is 1mm under a uniformly distributed bending load of 3000N. Also the system has a twist of 3.15 degrees under torsional load of 3000 N-m.

Introduction

A research organization, the Solar-Powered Automated Rapid Transit Ascendant Network (SPARTAN) Superway at San Jose State University, was founded by Professor Burford Furman and Ron Swenson in 2012 (Furman,et.al.,2017). The Superway is an automated transportation network which utilizes an elevated network of guideways from which are suspended car-sized vehicles ("pod cars"). The pod cars pick up and deliver passengers from stations that are located off the main guideway, like train sidings.

The structural members of the network must be stiff enough to minimize deformation caused by the weights of the guideways, podcars and solar panels. The Superway will use Solomon's Knot cross beam which are mounted above the guideway throughout the infrastructure. Since little prior Finite Element Analysis has been done on cross beams, it was important to find the deformation properties of these beams.

The main objective of this project is to determine computationally (ANSYS) the deformation, bending and torsional stiffness of a Clamped Solomon's Knot beam structure, responding to expected loading.

Methods and Materials

A structured process for the research project has been followed:

- Geometry and configuration
- Design modelling
- Finite Element analysis(FEA)

Materials:

- 11 ga Galvanized steel
- 5000 psi concrete
- Structural adhesive
- 5/16 – nuts, bolts and washers
- #12 – self drilling screws

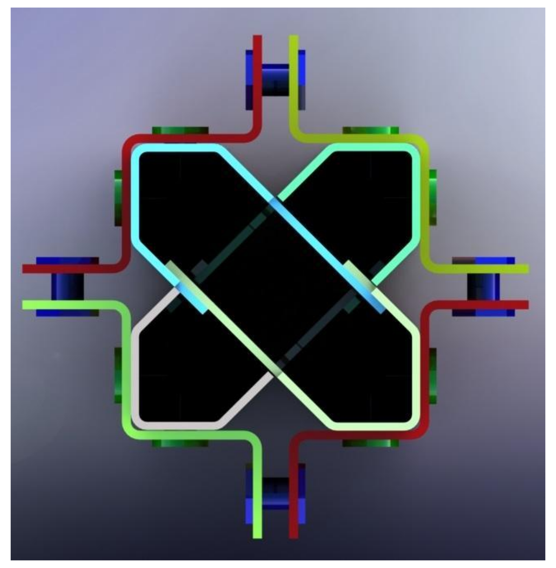

Figure 1. Cross-sectional view of clamped beam without concrete

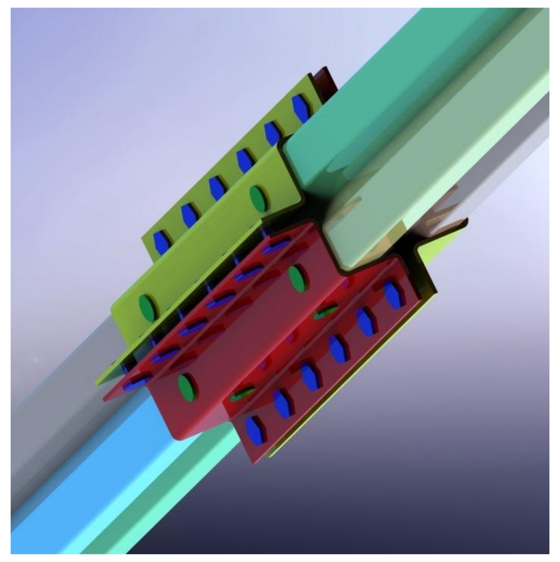

Figure 2. Clamped beam

Analysis

Bending Analysis:

Two cross-beams of 1.5 m length were clamped with the help of friction clamps are assembled and filled with concrete. The model is simply supported at it's ends and is loaded along the top face (along -z axis) as shown in the figure below. The clamped assembly is loaded with uniformly distributed load of 3000 N. The load is applied only on one side of the beam surface, i.e. 4 faces (2 faces on each beam. The whole dynamic analysis was run for a three seconds duration. The force is applied as a stepwise increment.

Torsional Analysis:

The cross-beam was tested under torsional load. A 20 cm long section at the end of the beam was imprinted by face-splitting in ANSYS and fixed. A moment of 3000 N-m(clockwise) was applied to a 20 cm long section at the other end of the beam to determine the torsional deflection properties.

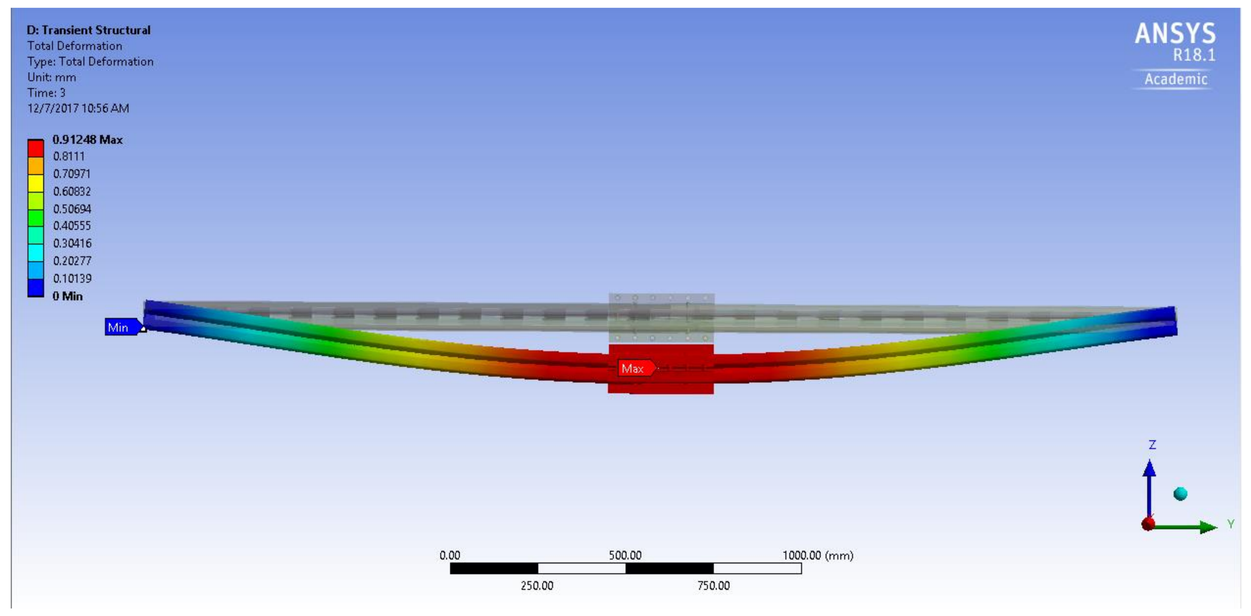

Figure 3. Bending Analysis (Image created using ANSYS)

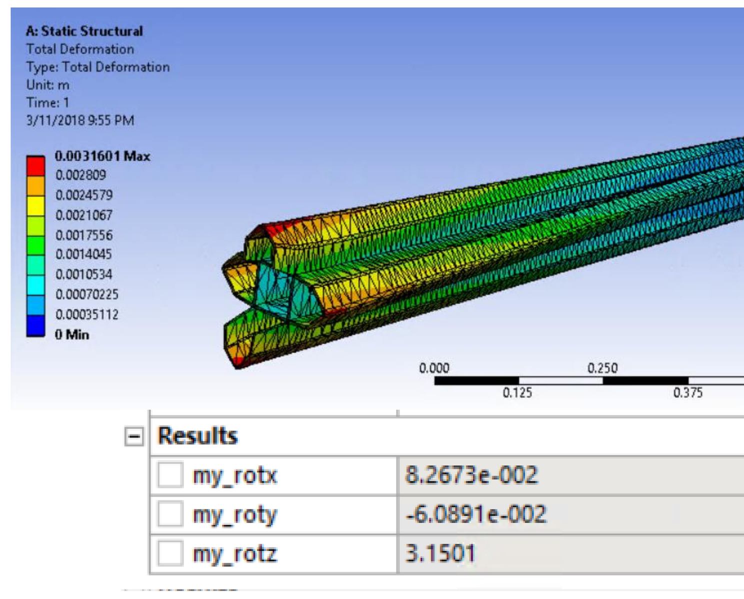

Figure 4. Torsional Analysis (Image created using ANSYS)

Results

In bending, the maximum deformation of the clamped beams is found to be 0.91 mm at the center of the beam, as shown in figure 3 below. So, the bending stiffness of the clamped beams is 3.2 kN/m.

In torsion, a rotational twist of 3.15 degrees was found at the free end when a moment of 3000 N-m was applied to the beam. The torsional stiffness is calculated to be approximately 0.95 kN.m/degree.

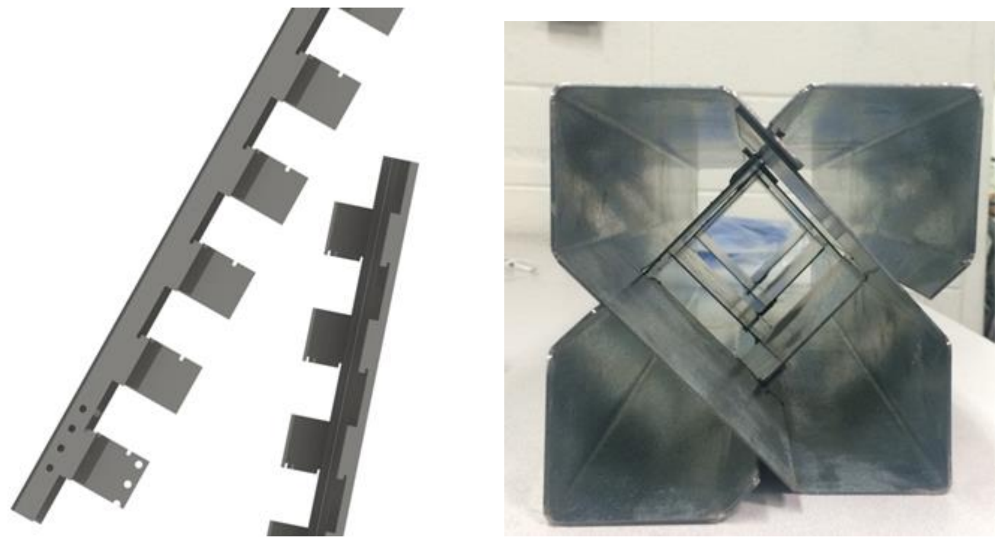

Figure 5. Left: panels of Solomon's Knot beam (Image created using SolidWorks)
Right: Cross-sectional view of clamped beam without concrete

Conclusions

The stiffness value obtained from the ANSYS modelling is used to estimate the maximum load that is required to fail the clamped beam system. Considering the yield strength of steel, the maximum load that is required to fracture the clamp in bending is approximately 25 kN. For torsional test the maximum load is estimated to be 20 kN-m.

The model can be further improved by removing the bonded contact between friction clamp and bolts which makes it a more realistic model. The results will be compared to the experimental results and the stiffness of the clamped Solomon's Knot beam will be found in bending and torsion.

In future, different clamping mechanisms can be developed and tested. By doing so, a library can be built with beams connected using various clamps resulting in clamped systems of various stiffnesses which can be used in different locations in the construction of Spartan Superway project.

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