Static Test Fixture for Spacecraft Handling Systems

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Abstract

The following paper discusses the design of the structural fixture used in static test facility to test and qualify handling systems of I-1K, I-2K, I-3K, I-6K, and INSAT-3D class of satellites and bare structures.

1. Introduction:

The assembled satellites and bare structure of the satellites are handled using specially designed handling cross beams. To ensure the safety of spacecraft, the handling systems are tested and qualified periodically before using. The static test fixture was designed for this specific purpose. The fixture is configured to accommodate handling systems of I-1K, I-2K, I-3K, I-6K and INSAT-3D class satellites (Ref. Table1). The fixture is planned to be fabricated by welding together structural steel beams of different cross section. The designed structure would be bolted to the grouting holes provided on the floor using M24 bolts. During the test, handling system would be connected to the structure using wire ropes and pulled using crane till a specified load is achieved in the wire ropes.

2. Considerations for configuration Design:

The configuration was designed based on the grouting holes matrix provided on the floor of the facility and the handling points required to simulate the spacecraft interfaces. The handling points should lie in the plane, which is parallel to the ground. The structure is designed so that grouting holes should not experience more than 2.5 tonne load. A configuration is worked out with beams and cross beams taking in to account the above constraints. Table 1 show pitch dimensions required for handling each configuration. Figure1 shows the grouting holes matrix and initial configuration.

Satellite class	Pitch dimensions
I-1K (4 Point Handling)	1534mm x 1280mm
I-2K (4 Point Handling)	1664mm x 1464mm
I-3K (4 Point Handling)	1784mm x 1934mm
I-6K (4 Point Handling)	2176mm x 2110mm
INSAT-3D (3 Point Handling)	1639.41mm X1639.41mm X1162mm

Table 1: Pitch data of handling systems for various satellite configurations

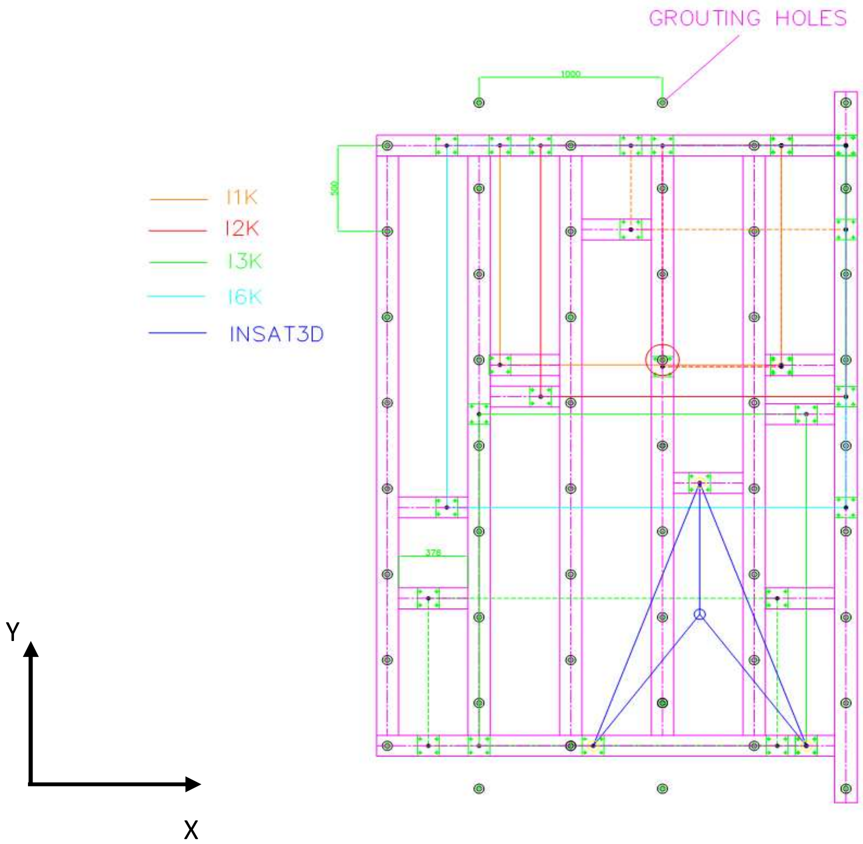

Figure 1: Initial Configuration and grouting hole matrix

3. Design:

In the above configuration the loads and support points pose a statically indeterminate problem. So, Three moment method [1] [3] was used to determine the reactions at the support point and calculate maximum bending moment experienced by the beam with a safety factor of 4. Section modulus for the required beam was calculated using following equations, assuming that the material to be used as Structural steel. For properties of the material refer to Table 2.

Material	Structural Steel
Density	7850 Kg/ m^3
Young's Modulus	2e+11 Pa
Poisson's Ratio	0.3
Yield Strength	2.5e +8 Pa

Table 2: properties of structural steel

$$allowable\ stress = \frac{2}{3} * yield\ strength\ of\ steel$$

$$section\ modulus = \frac{maximum\ bending\ moment}{allowable\ stress}$$

The table 3 shows the maximum bending moment experienced for various configurations and section modulus required for the beam. Based on the above calculations a standard closed box section of dimensions 122mm x 61mm and thickness of 5.4mm whose section modulus is 37 cm^3 was chosen to proceed further. The following figure (Figure-2), shows typical indeterminate problem posed while designing for various configuration and the support points shown are separated by a distance of 500 mm if beam is vertical (y-axis) and 1000mm (x-axis) if it is horizontal in the structure (Figure-1).

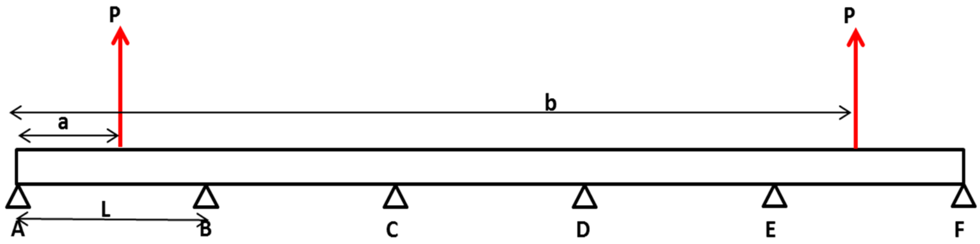

Figure 2: statically indeterminate problem

	no. of equally spaced support points	length of each span L** (mm)	magnitude of point load at a hinge point(tonnes)	Load P* with safety factor 4(tonnes)	a**(mm)	b**(mm)	maximum bending moment (Nm)	section modulus required for steel (cm3)
I-6K	6	500	1.5	6	168	2344	5833	31.36
I-3k	7	500	0.75	3	398	2332	2268	12.19
I-2k	4	1000	0.5	2	134.21	1798.2	2173	11.6864
I-1k	4	1000	0.25	2	750	2284	1512	8.134

Table 3: maximum bending moment and section modulus calculations for various configurations

** Refer Figure-2

4. Finite Element Analysis:

The three moment method assumes that extreme ends of the beam are supported and does not take into consideration effects like stress concentration, corner relief and cross beams. 3D Finite element analysis [2] was carried out for the configuration in Figure-1. The meshing was done using tetrahedral elements [2]. Material properties used for simulation are given in Table2. During the analysis hinge points were considered to be point loads at hinge point and all the grouting holes were assumed to be constrained in all 6 degrees of freedom. For I-6K class analysis it was found that maximum principal stress was exceeding the yield strength of steel by 5 times, so the configuration was changed by increasing the thickness of beams at certain locations from 5.4mm to

19mm, adding extra beams. Figure-3 shows the final configuration of the structure. Table 4 for shows comparison of initial and final configuration analysis results for I-6k class loads.

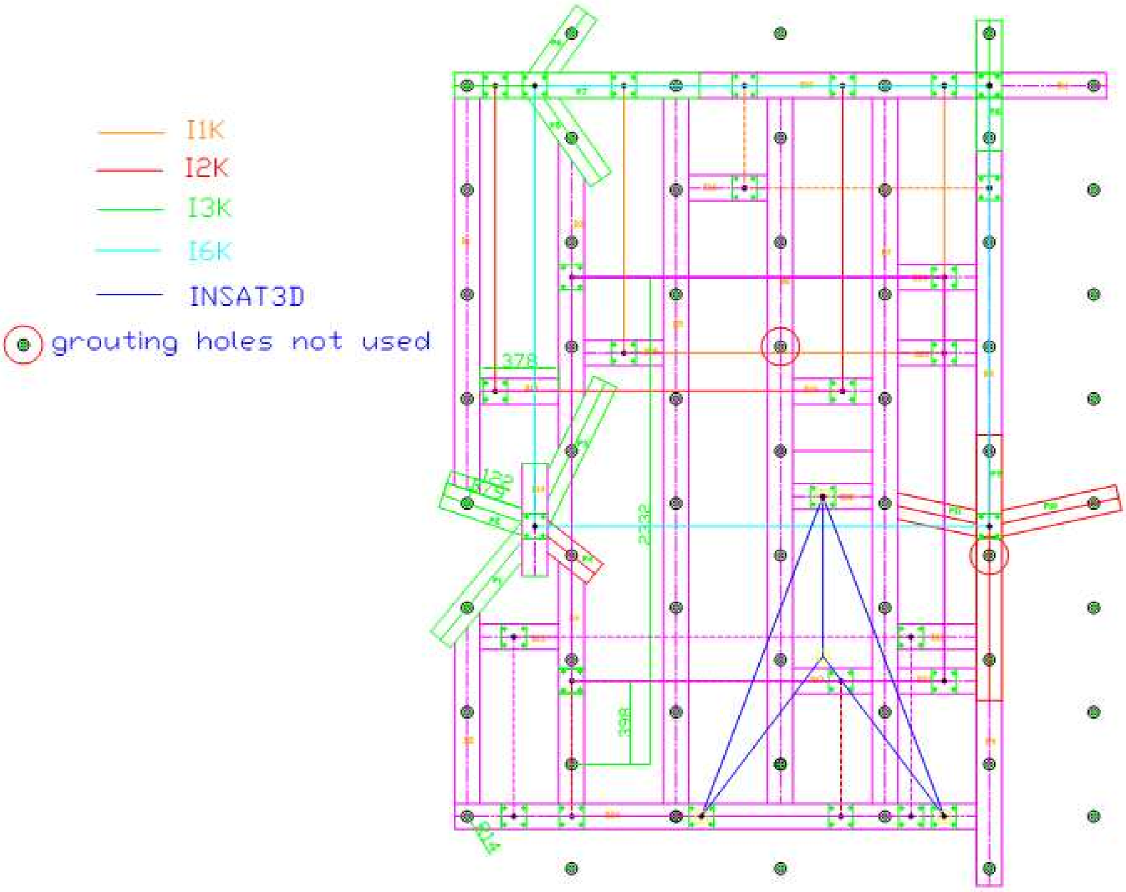

Figure 3: Final configuration of static test fixture

	Initial configuration	Final configuration
Element	85241	84696
Max principal stress	1.08e9 Pa	2.15e8 Pa
Max deflection	2e-3 m	4e-4 m

Table 4: comparison of simulation results for initial and final configuration

Figure-4, 5 show a comparison of principal stress of same location for initial and final configuration for I-6k class satellite loads. It can be clearly seen that increasing thickness and adding cross beam at loading point recued the principal stress.

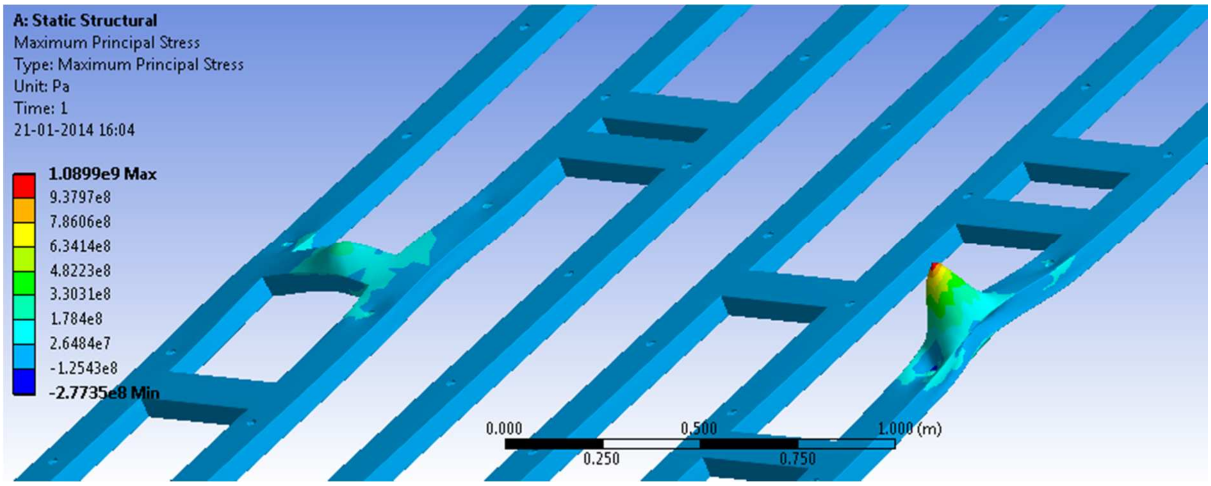

Figure 4: principal stress pallet for initial configuration I-6k load

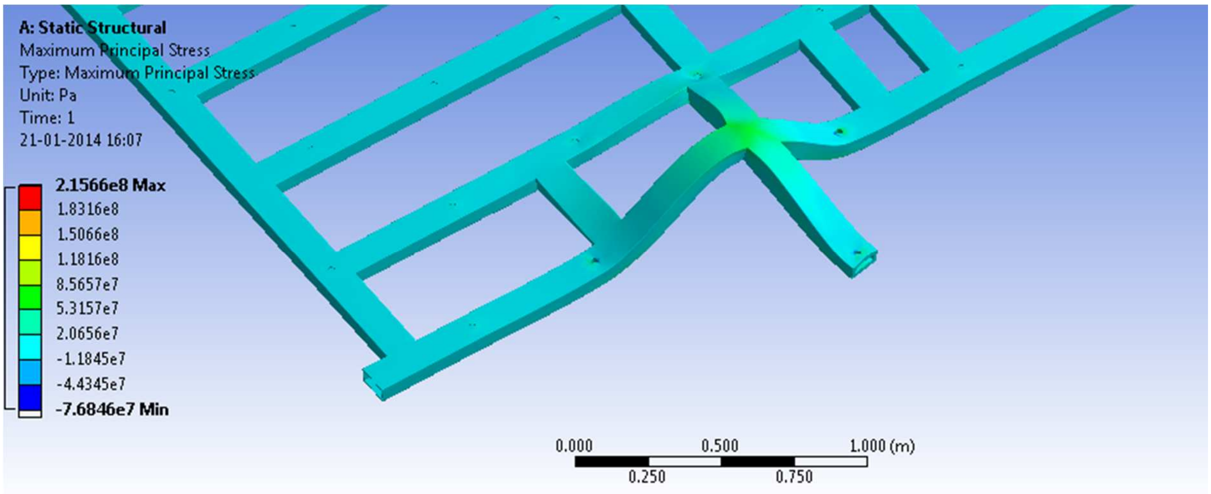

Figure 5: principal stress pallet for final configuration I-6k load

5. Summary:

The Design of Static Test Fixture for testing handling systems of spacecraft's and structure are initiated as a facility build up activity at ISITE. Finite element analysis was done on 3D model of the fixture and a standard box cross section beam was used meeting the design requirements. The designed configuration is being established.

6. References

[1] Timoshenko S.P,Young D.H., Elements of Strength of materials, 234-260.

[2] Yijun liu, Finite element methods, CAE Research laboratory, University of Cincinnati.

[3] CE 130L. Uncertainity Design and Optimisation, the Three Moment Equation for continuous beam analysis, Department of Civil and Environment Engineering, Duke University, Spring-2009.