

Experimental Determination of Deflections and Stress in Guide Rail Fixtures

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ABSTRACT

Guide rails and joint components are significant elements of an elevator system in terms of ensuring safety travel. Bending and buckling stresses are observed due to the loads acting on the guide rails and their fasteners under excessive conditions such as earthquake. In this study, according to EN 81-1, stress and deformations occurred on the joint points and guide rails are calculated and these results are compared with the test data. A hydraulic test setup is designed and constructed for simulating seismic effect of an earthquake.

1. INTRODUCTION

Increasing of urbanization and high-rise buildings, designing of high speed and reliable elevators come into question in the transportation industry. So, elevator systems consist of some components that should have high strength and suitable factor of safety. Examination and optimisation of these kind of structures are significant study area because of the increasing economic restrictions and industrial requirements.

There are a lot of elements in a conventional elevator system. Rail brackets and steel clips are the important parts for fixing guide rails with shaft wall. They also provide the linearity of the guide rails. These are the essential elements of a complete rail fastening system. Guide rails are the most important element of elevator systems in terms of for safety reasons. The basic functions of the guide rails and rail fasteners in the elevator system are to guide the elevator car and counterweight in their vertical travel. There might be some unconformities such as tilting of the car caused by the horizontal movement of the car due to eccentric loads influences the comfort of the car travel. It is also important to provide safety gear operation activation in case of emergency situation. Some excessive forces can be occurred during the elevator car travel, safety gear operation, and seismic activities upon on guide rails and rail fasteners. When guide rails are not mounted properly, especially during the operation of the safety brake guide rail brackets would be subjected to this kind of loads. These loadings cause bending and buckling (or tensile) stresses on fasteners and mounting elements.

Review of literature about the topic shows that the studies related with stress and strain analysis of guide rails, brackets and steel T-clips generally remained limited to the computer environment (Atay 2013).

2. GUIDE RAILS AND EQUIPMENT

Guide rail is the one of the important components of the lift installation. Calculations and analysis of the guide rail and its equipment have to be taken into account while designing of installation project. The loads and forces created by elevator car movement are carried by the rails. Guide rails are used to guide the vertical movement of car and counterweight separately, and minimize their horizontal movement. T90-B type of guide rail were examined in terms of acting loads generated under extreme conditions such as earthquake. Fasteners under certain loading conditions were concerned also. Guide rails brackets, and T-clips can be seen in Figure 1.

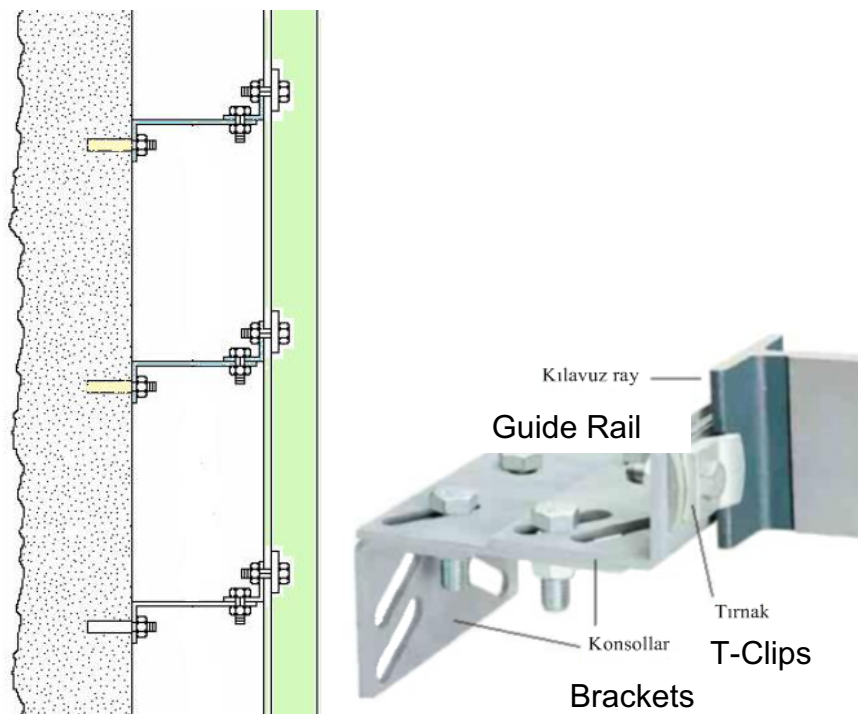


Figure 1. Assembly of complete guide rail fastening system

Examining the behaviour of elevator brackets and its assembly system under certain conditions with finite element methods and experimental studies were inspired by Dr. Merz from HILTI firm in the comprehensive articles (Merz 2008, 2010). The experiments of the guide rail in terms of stress and strain analysis and related simulations carried out in the Elevator (Lift) Technologies Laboratory, ITU Faculty of Mechanical Engineering.

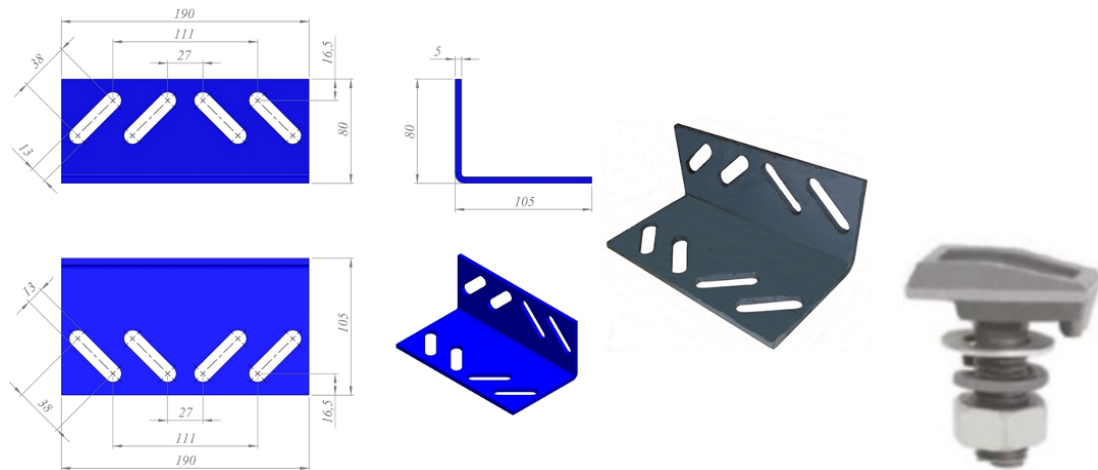


Figure 2. Brackets and T-Bolts

Bracket connection system will make displacements or relative movements under the loads applied during tests. Loads on rail brackets and its joints that for fixing guide rails to wall of the elevator shaft, studied experimentally.

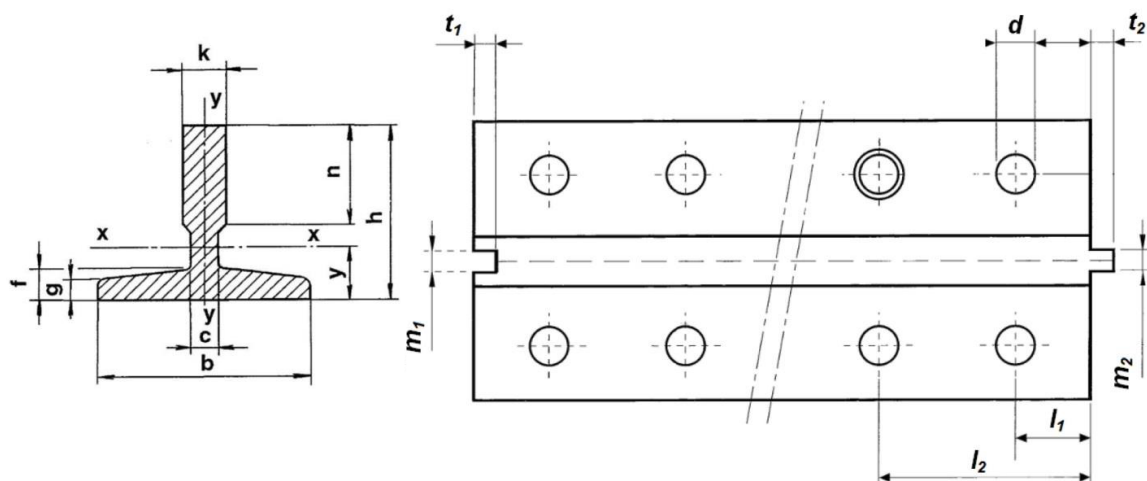


Figure 3. T90B type guide rail

The dimensions of the guide rails in analysis and experimental studies can be seen in Table 1.

Table 1. Guide rails dimensions [mm]

	b	h	k	n	c	g	f	m_1	m_2	t_1	t_2	d
T90B	90	75	16	42	10	8	10	6.4	6.37	7.14	6.35	13

M12 bolts and T3 T-bolts are suitable for T90 guide rails in accordance to the standards (Imrak and Gerdemeli, 2000).

3. TEST SETUP

The basic elements of the elevator system, examination of the different load cases simulation. Experiments to be made by using this experimental set; with the basic elements of the elevator system is aimed to obtain tangible concrete data. For an experimental study on the guide rail brackets and its connections, possibilities within the experimental set system was designed and established with the support and contributions of the sponsor companies. This experimental set system consists of four main structures. These are carrier structural frame that is used to connect the elements to be tested in experimental studies, hydraulic power unit that provides variable loads to be applied, control-drive unit and sensors. The carrier structural frame is used to connect the experimental elements, which is made of St37 material, is a structure formed by the method of welding using profiles from T90 guide rails. The structural analysis of the frame under excessive load simulated in a commercial finite element method solver program and calculations show that the frame can be used for the experiments (Figure 4). The system designed to simulate elevator car loads applied during operation of an elevator was for the application of tensile and shear loads of a guide rail unit.

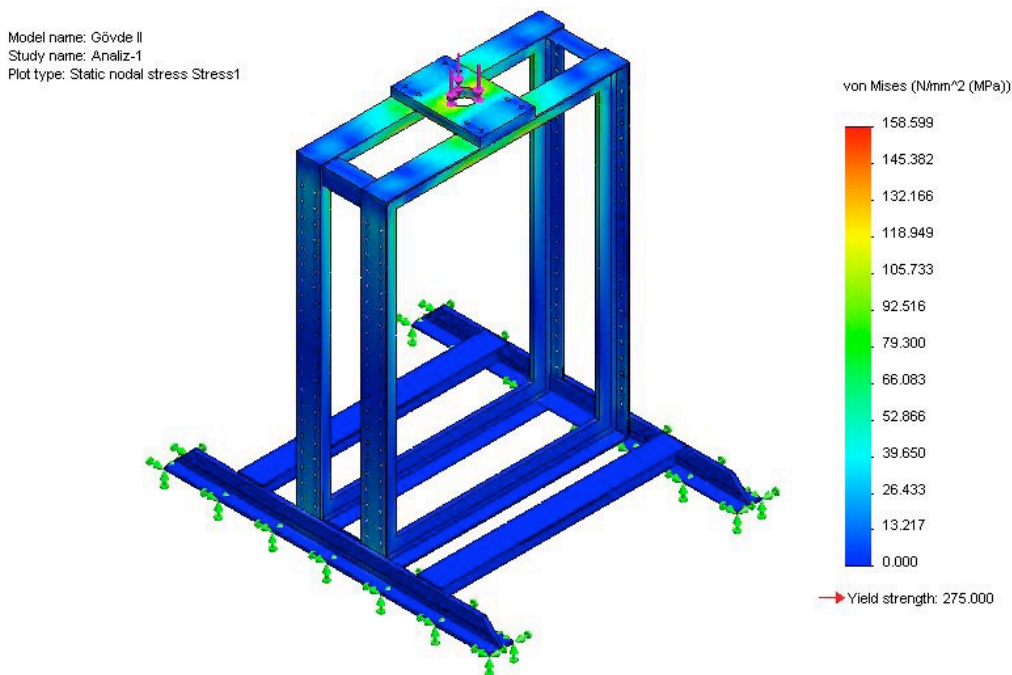


Figure 4. Finite Element analysis of steel frame

The load acting on the frame in the model and the results can be seen in Table 2. The yield stress of the St37 steel is 275 MPa. So, maximum von Mises Stress is under this value, and the safety factor for the steel frame is 1.73.

Table 2. Guide rails dimensions [mm]

Load	50 kN
Max von Mises Stress	158.6 MPa
Equivalent Strain	4.34e-4

A data acquisition and measurement equipment were used during the experimental studies. Test setup was designed for experimental stress analysis of complete guide rail fastening systems, brackets and fasteners were connected to the T90/B guide rails at the hydraulic powered test setup in ITU Faculty of Mechanical Engineering as seen in Figure 5. Available sensors and data acquisition system connected to the guide rail fasteners. Real time data were obtained by examining different loading conditions of the elevator test cabin. Tests were carried out in the test setup. The purpose of the tests is to investigate the forces on the guide rail fasteners and brackets under different loading conditions of elevator cabin and interpret the results as experimentally.

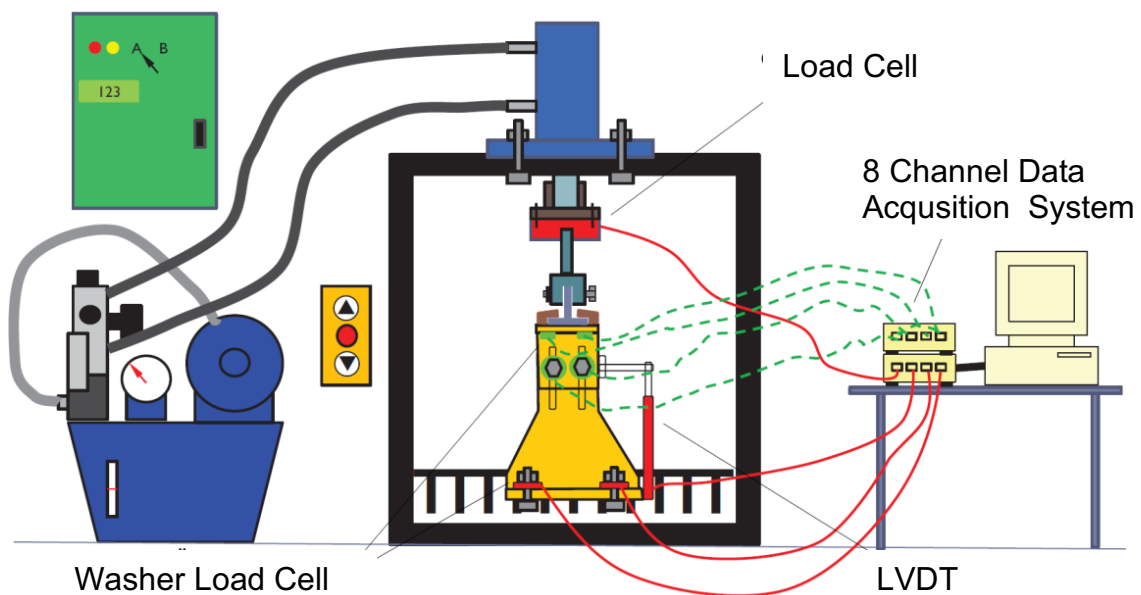


Figure 5. Data acquisition and signal processing system of the test setup

DigiVision Software USB sensor interface device is used to transfer data from sensors to the PC environment (Figure 6). It has 16-bit resolution and allows up to 2500 measurements per second.

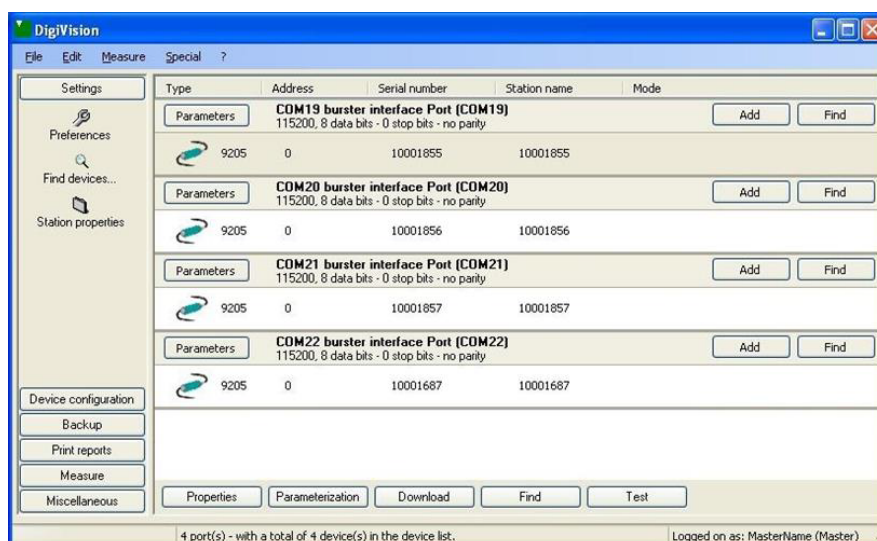


Figure 6. DigiVision data acquisition software

In this study two kinds of load measurement sensors are used: tension and compression load cell and donut load cell. The assembly of the washer load cell can be seen in Figure 7.

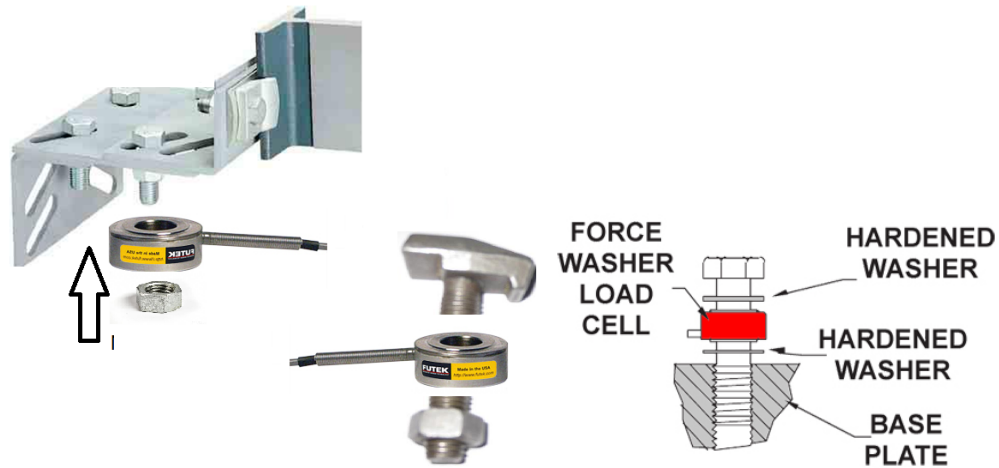


Figure 7. Washer load cell assembly

The donut load cells were used to measure the compression loads on bolts. LVDT (Linear Variable Differential Transformer) is a type of electrical transformer for measuring linear displacements. This sensor is used to determine the relative movement of the bracket system under different loading conditions. It is mounted on the upper part of the bracket with a fixed joint. The other side of the sensor can be rotated about and a pin because of avoiding the effect of the side loads. In this study Burster 8740 model LVDT is used to convert the displacement to the electrical signal (Figure 8).

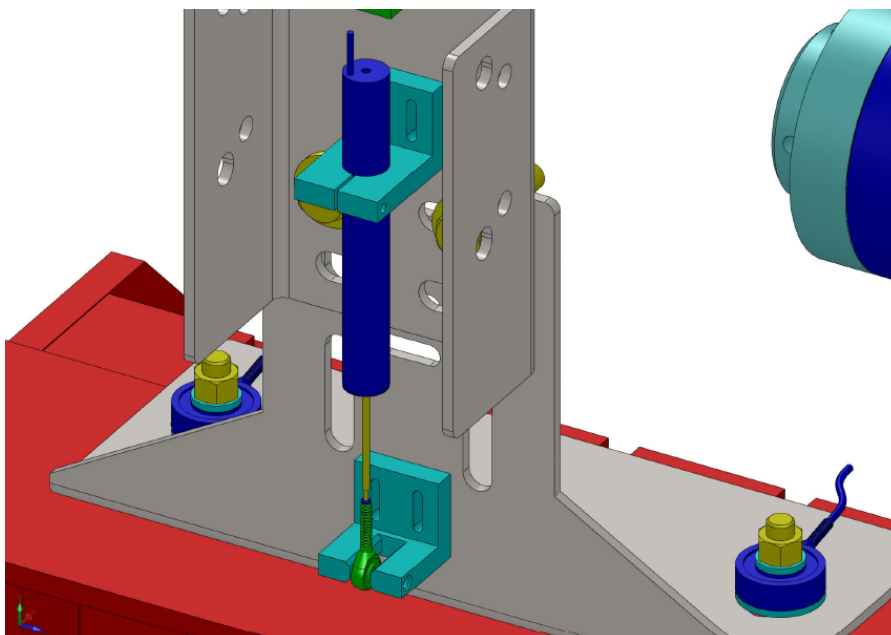


Figure 8. A detail view of Load Cells and LVDT

In the study two kinds of loading conditions simulated separately. Firstly, the hydraulic piston is mounted the top of the frame to act a force at vertical direction. The ability of the hydraulic system allows to create tension or compression effect on the rail and brackets. The force acted by the hydraulic system is measured directly from the load cell mounted between piston and rail as can be seen in Figure 9. In question force also, can be calculated from the hydraulic system's oil pressure. The side forces acting on this load cell should be prevented because of the distraction effects.

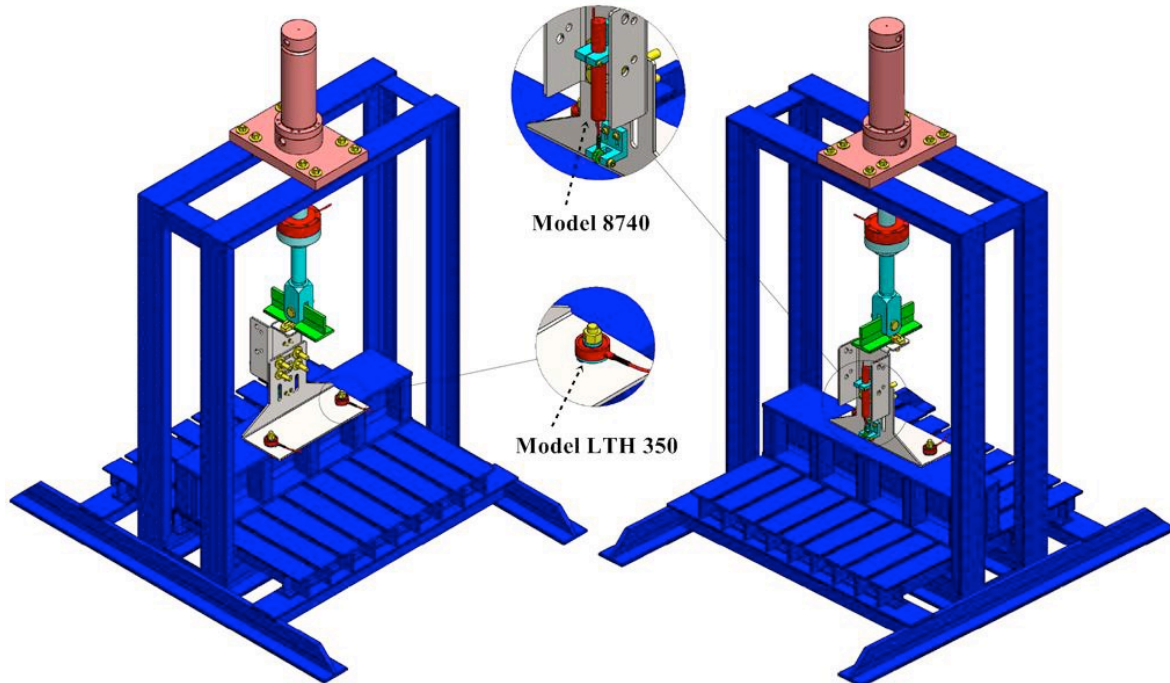


Figure 9. F_y forces simulation and connections

The guide rail and fasteners' relative displacements under acting loads were recorded by the displacement sensor assembled between the bottom and top part of the brackets. The hydraulic piston can be mounted on side of frame to simulation of the side force on the guide rail as seen in Figure 10. Generated force in this situation acting on the system horizontally.

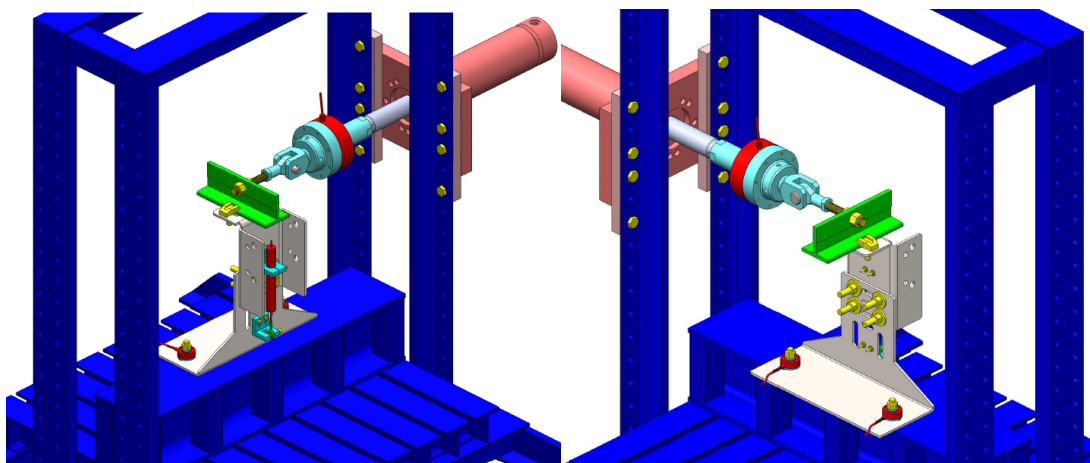


Figure 10. F_x forces simulation and connections

4. TEST RESULTS AND CONCLUSION

The acquiring data from the load cell and displacement sensors converted and analysed with some basic computer codes. The project was developed for the test by Suhan A. 2013, the acting on the guide rail forces horizontally (F_x) were calculated between 1529.7 and 3125.9 N with different loading condition. On the other hand, the vertical forces (F_y) changing in a range between 1,745.8 and 2,618.9 N. The resultant forces were calculated between 2,321 and 4,077.9 N. Although the maximum force can be acted on the guide rail is 4,077.9, tests were carried out with the 5,000 N piston load because of ensuring the confidence of the experiment. The required forces to loosen bolts between the brackets are calculated as minimum 15,099 and maximum 16,177 N. In order to validate the calculated forces creating the frictional forces that connects the brackets, acting load 5,000 N was increased with 500 N steps. It is observed that bolts were loosen under 13,500 N, tough the calculated force is about 15,000 N. This result can be caused by some installation errors. On the other hand, revising of the safety factor of the calculations should be advised.

Although computer simulations and analysis has been improved remarkably since past to present, the experimental studies of the guide rail fasteners system still maintain its importance because of the complexity of overloading conditions such as safety gear operations or earthquakes. This studies can provide lots of design data in order to build safer and reliable elevator systems. This paper especially focused on vertical and horizontal loads and their effects on guide rail fasteners.

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BIOGRAPHICAL DETAIL

Adem CANDAS has been employed as a research assistant in ITU. Mr. Candas received the BSc degree in Mechanical Engineering from ITU in 2010 and MSc degree in Mechanical Design from ITU in 2013 carried out research into PhD thesis.

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Eren KAYAOĞLU has been employed as a research assistant in ITU since 2007. Mr. Kayaoğlu received the BSc degree in Mechanical Engineering from Yıldız Technical University in 2004 and MSc degree in Mechanical Design from ITU in 2009. He has carried out research into PhD thesis. He started to work in a project on Wire Rope Isolators (WRI). He is also a Member of Chamber of Mechanical Engineers in Istanbul, Turkey