Jan A. Karczewski¹, Eligiusz Postek², Stanislaw Wierzbicki¹

¹Warsaw University of Technology, Armii Ludowej 16, 02-637 Warsaw, Poland
²Institute of Fundamental Technological Research, PAS, Świetokrzyska 21, 00-649, Warsaw, Poland

EXPERIMENTAL SHAKEDOWN ANALYSIS OF DOUBLE BUTT, PRESTRESSED, BOLTED CONNECTIONS

Keywords: prestressing, deformability, ultimate load, elastooptic layer,

Abstract. This paper deals with the description of an experiment on double-butt prestressed bolted connections. The goal of the experiment is to verify a 3D computational model of the connection. The connections are loaded cyclically according to a load program based on load variability observed in engineering practice.

1. Introduction

The connections are an integral part of each steel structure therefore the correct design of the connections and the elements cross-sections determines the structural safety. The element cross-sections and the connections influence also the deformability of the structure. The deformability is always limited, so the connections design should meet the relevant requirements [1]. Regarding the deformability the best connections are the prefabricated welded ones. Considering the connections made on site a variety of the bolted joints is dominating. One of their types is a butt-friction connection. However, this type of joints has a disadvantage caused by the necessity of a special treatment of the sticking surfaces in order to achieve assumed load carrying capacity. In conclusion, it seems to be useful to find a connection in which the load capacity remaining after first slip could be purchased even using elements without previous treating. The butt connection with high resistance bolts has this type of features. The considered connection characterises low deformability (especially at the beginning of loading process the deformability is comparable with welded joints) and higher load capacity than the butt-friction one. The higher load capacity is achieved due to exploiting the remaining load capacity after the first slip. The deformability of such a connection after the first slip significantly increases, however, knowing its behaviour it is possible to estimate the maximum load adequately to certain limited deformations. However, due to the fact that the elastic-plastic behaviour of the joint is relatively complicated it is necessary to verify some modelling assumptions.

2. Experiments equipment.

The goals of the experiment are as follows:
- identification of the behaviour of the joint till the first slip
- identification of the behaviour of the joint after first slip
- investigation of the initialisation and development of the plastic zone
- recognition of the shape of the sticking surfaces and their interdependence.

Additionally, stress distribution due to prestressing w.r.t. butt thickness and prestressing force variation during the loading process are also investigated. The investigated connections are divided into four groups distinguished by the particular plates thickness (butts and midplates) and some of the samples are covered by the elastooptic layer and some of them are not prestressed. The contact phenomena between the pin of the bolt and the openings are important, so there is no screw in the butts and midplate zones. The element groups are presented in Fig. 1.

**Fig 1 Tree of the investigated elements**

Sample element is given in Fig. 2. All the plates are made of St3S steel [6]. The bolts are of type M20, class 10.9 [5].

The following quantities are measured: relative displacements of the plates (inductive sensors C1, C2), strains in the regions of the expected plastic zones (tensometers T1, T2, T3). The range and development of the plastic zones using the elastooptic layer is observed. The experiment is conducted in the laboratory belonging to Steel Structures Department at the Warsaw University of Technology. The central control unit is a PC
load increment as $\Delta P = 10$ kN. Passing to the new load increment the "overloading" of 5% of the total load $P$, (at particular load step) is assumed and then the loading amplitude $\Delta P$, is applied cyclically in the range of $P$, and $0.4P$, till the stabilisation of the structural response (shakedown). As a shakedown condition the following one is assumed: considering two respective load cycles the condition $\Delta u_1 = |u_{i,j} - u_{i,j+1}| \leq 0.01$ where $u_i$ is the displacement "$u$" at the beginning of the cycling "$j$" at the increment "$i$". At each new load level "overloading" 1.05 $P$, and the load levels $P$, and $(P, - \Delta P)$ the results are registered and saved.

3. Experimental results

The dependence force-displacement measured with the two gauges placed in the mid-zone of the element is the most important. The curve for the element E-12-6-2s_w is given in Fig.4.

![Force-displacement curve](image)

The first slip takes place at the load level of 75 kN and the significant displacement due to the initial slacks in the connection is noticed. At the load level not higher than 120 kN the displacements are very small and not exceed 0.2 mm (neglecting the displacement arising from the initial slackening). The form of the load-displacement curve is quantitatively and qualitatively consistent with the Authors' expectations. The next important element of the experiment is the monitoring of development of the plastic zones by means of the observation of the isochromes arrangement in the elasto-optic layer during the loading process. The pictures of the isochromes in the polarized light at the end of each load cycle are taken. The plastic zones in the sample E-12-6-2s_w are given in Fig.5. The plastic strains in the region of the photooptic layer
Fig. 6. Curves of force-displacement for elements in Group I.

References

1. Krezkowska, J.A., Kresnowski, Z., Lieb, J., Kressejuk, D., Experimental Analysis of the Bridge...

Fig. 5. E-26-22 W - Stress Transfer Layer.

Conclusions:

- The effectiveness of the compression and connection may be used in the civil engineering.
- The results prove the effectiveness of the conducted research and connection on the
- application of the methodology for verifying the ongoing conducted numerical study of
- the ultimate peak force is not increased due to connection.
- Stress transfer processes connected to the connection durability.

The conclusions are as follows:


In the case of the non-pressed force at the load level above 60KN, the higher load
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