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Abstract of PhD Thesis:

Experimental and numerical analysis of adhesive joints in steel structures

Analiza doświadczalno-numeryczna połączeń klejonych w konstrukcjach stalowych (in Polish)

Despite continuously improved strength characteristics and a wide range of products available on the market, adhesives still are only used in niche applications in civil engineering. The application of adhesives is usually limited for reinforcing existing structures using non-metallic fiber tapes or mats. One of the main reasons for this situation is lack of design approaches and standards as well as limited imprecise or technical data, which is commonly disclosed by manufacturers.

In the current state of computing technology, the most efficient tool supporting the design of non-standard structures is commercially available software. It enables performing advanced analyses, also in the non-elastic state. A necessary condition is, however, reliable recognition of a number of material characteristics of adhesives, and then a verification of numerical models by results of laboratory tests.

While considering an application of a given adhesive in a building structural connection, the actual dimensions of the joint should be taken into account. That imposes the necessity of material collaboration in a relatively long joint - which requires the selection of the

thickness of the adhesive layer and its deformability in such a way that it guarantees optimal load-bearing capacity and rigidity of the connection. Analysis of the available literature references indicates that when steel structural elements need to be joined, such conditions are met by using methacrylic adhesives.

Based on the available publications and standards, a selected methacrylic adhesive (Plexus MA-420) was tested as a part of the doctoral dissertation. The research was divided into several stages. Firstly, adhesive strength tests were performed to determine its tensile, shear (in several schemes) and compressive strengths, as well as relaxation parameters and adhesion to various types of metal substrates. Each study was accompanied by numerical analyses in order to obtain appropriate material model parameters for further, more complex simulations. Secondly, thermal analyses were performed to determine the variation of adhesive parameters in increased temperature. Then, numerical analyses of lap joints based on the previous study on full-size models conducted by an independent team (with the participation of the Supervisor), were performed. Assumptions for the adhesive material model (adopted in the numerical analyses), were based on the Drucker-Prager criterion and the contact layer, enabling simulations of degradation in accordance with the principles of fracture mechanics. This approach showed very good correspondence with the results of laboratory tests.

Finally, additional tests were performer on steel, I-shaped beams strengthened by flat bars located in the tensile zone. The experiments were conducted in two options – undamaged beams and beams with a mechanically produced notch, both reinforced by a steel plate using the adhesives for the bond between the elements. In both cases, a clear increase in the load-bearing capacity was found and full integrity of the adhesive joint was maintained. Numerical analyses of the tested beams allowed for an extensive investigation of the damage mechanisms, including the assessment of areas of plastic deformation of the adhesive.

Tests and analyses performed proved the possibility of accurate modelling of adhesive joints of steel elements. It should be emphasised, however, that the conclusions are limited to the investigated construction cases and one type of methacrylic adhesive. Hence, it is necessary to extend the research by including further construction cases, other types of adhesives and assess their durability in the aspect of environmental factors. Buda Arkadiusz