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Concrete Structures Without Mild Steel Reinforcement

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URL: *http://www.ub.tuwien.ac.at/diss/AC05039266.pdf*
Language of thesis document: *German*

In the first part of this thesis a method that improves the tensile strength of concrete through the use of non-metallic high strength elements is presented. The high strength elements presented in this work are aggregates that act simultaneously as a reinforcing element. In the second part, the development of a construction method for concrete slabs in structural engineering is presented. The slab specimens designed according to the Austrian standards ÖNORM B4700 and B4750 were compared to the pre-stressed slab specimens without further reinforcement. For these purposes, five different slab specimens were cast and tested in a four point bending test. The test results showed that the pre-stressed slab specimens without further reinforcement have roughly the same behaviour as the other tested specimens.

Based on these test a bridge construction is proposed, which improves the durability of the bridges. The prestressed concrete bridges fulfill the requirements of the serviceability limit state and the ultimate limit state without reinforcement bars that are endangered by corrosion. Tensile forces are carried by post-tensioning tendons only. During construction the economic advantage of the design method consists in savings with regard to construction materials, i.e., no reinforcing steel, insulation and coating are needed. Considering the future savings in operation and maintenance, the bridge built in this way will provide a superiour economic performance compared to conventional bridge structures.

Lastly, an example of this design method by the construction of a concrete bridge without reinforcing steel is presented. The Department of Bridges of the provincial government in Salzburg suggested to examine this new bridge design method for the construction of the Egg-Graben Bridge. The construction project has started in the Spring of 2009. The Egg-Graben Bridge is designed as an arch bridge with a length of 50,69 m in the axis of the bridge and the bridge girder curved in plan.

Development, Research and Testing of Liquid–V–Damper

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Language of thesis document: *German*

Nowadays, dynamic problems in structural engineering arise more often because of the use of high strength materials and complex computational simulations. One effective measure against these dynamic problems is the application of tuned liquid column dampers. These are U- or V-shaped tube constructions in which a liquid with an initial deflection moves towards the vibration of the structure. With different closures at the ends of the tubes, the vibration behaviour of the liquid can be strongly affected because of the embedded air volume which operates as an air spring.

Due to the moving liquid in the accurately tuned dampers, a large part of the kinetic energy that affects the construction is dissipated by the tuned liquid column dampers. For the verification of the analytical and numerical derivations, two test series were carried out. As material for the dampers for test series 1, PE-HD water tubes were used. For the second series one of the dampers again was made of PE-HD, the second one was made of Plexiglas to visualize the streaming and sloshing of the liquid in the tubes (see *Fig. 1*). For the ends of the tubes, a special piston construction was developed to make the length of the air spring variable. Furthermore, comparative

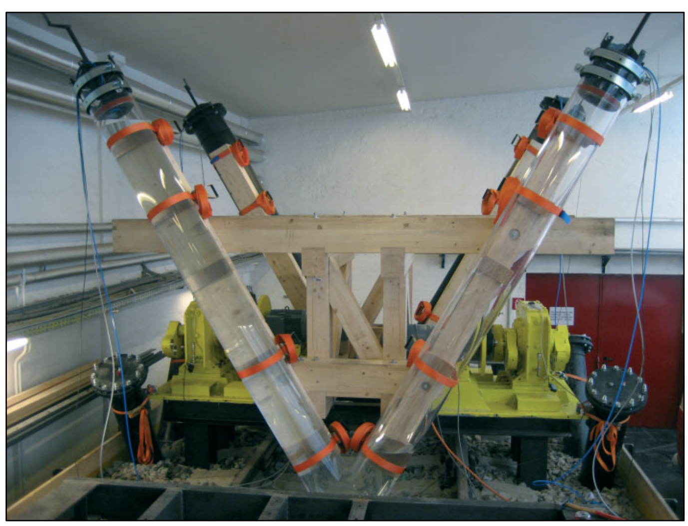

Fig. 1: Liquid–V–Damper made of Plexiglas mounted on the testing bridge designed by the Institute for Structural Engineering – Steel Constructions, Vienna University of Technology

numerical studies were worked out under consideration of all nonlinearities of the dampers. These numerical calculations could verify the measured results of the tests. Numerical results as well as the measured results could show the high effectiveness of the tuned liquid column dampers. That is, a reduction of 73% of the dynamic amplitudes could be reached with a mass ratio (liquid mass to modal bridge mass) of merely 1%. The application of tuned liquid column dampers against vertical bridge vibrations is an effective, easy to tune and economic measure.

Direct Strength Design of Cold-Formed Steel Members With Perforations

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Cold-formed steel (CFS) structural members are commonly manufactured with holes to accommodate plumbing, electrical, and heating conduits in the walls and ceilings of buildings. Current design methods available to engineers for predicting the strength of CFS members with holes are prescriptive and limited to specific perforation locations, spacings, and sizes. The Direct Strength Method (DSM), a relatively new design method for CFS members validated for members without holes, predicts the ultimate strength of a general CFS column or beam with the elastic buckling properties of the member cross-section (e.g., plate buckling) and the Euler buckling load (e.g., flexural buckling). This research project, sponsored by the American Iron and Steel Institute, extends the appealing generality of DSM to cold-formed steel beams and columns with perforations.

The elastic buckling properties of rectangular plates and cold-formed steel beams and columns, including the presence of holes, are studied with thin shell finite element eigenbuckling analysis. Buckled mode shapes unique to members with holes are categorized. Parameter studies demonstrate that critical elastic buckling loads either decrease or increase with the presence of holes, depending on the member geometry and hole size, spacing, and location. Simplified alternatives to FE elastic buckling analysis for members with holes are developed with classical plate stability equations and freely available finite strip analysis software.

Experiments on cold-formed steel columns with holes are conducted to observe the interaction between elastic buckling, load-deformation response, and ultimate strength. The experimental results are used to validate an ABAQUS nonlinear finite element protocol, which is implemented to simulate loading to collapse of several hundred cold-formed steel beams and columns with holes. The results from these simulations, supplemented with existing beam and column data, guide the development of design equations relating elastic buckling and ultimate strength for cold-formed steel members with holes. These equations and the simplified elastic buckling prediction methods are presented as a proposed design procedure for an upcoming revision to the American Iron and Steel Institute's North American Specification for the Design of Cold-Formed Steel Structural Members.

Research on the Failure Mechanism of Curved Bottom Slabs of Long-Span PC Beam Bridges with Variable Depth Box Girder

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Language of thesis document: *Chinese*

In recent years, many long-span PC beam bridges with variable depth box girder have been built in China. Normally, there are many pre-stressing tendons arranged in the curved bottom slab to balance the tension stress caused by dead and traffic loads. To prevent the excessive deflection caused by concrete creep, designers sometimes put more pre-stressing tendons in the curved bottom slab. In some bridges, the huge radial force aroused by pre-stressing tendons causes the curved bottom slab to crack along the pre-stressing ducts. In several of the worst cases, the prestressed tendons have burst out from the bottom slab or the bottom slabs have split into two pieces along the ducts.

In the Design of Highway Reinforced Concrete and Prestressed Concrete Bridges and Culverts (JTG D62 -2004) code of China, there are already some specifications about the thickness of the concrete cover and hairpin bars in concrete slab with curved prestressed ducts. They are similar to those specifications made by the AASHTO LRFD Bridge Design Specifications, Third Edition, 2004. These specifications are not suitable in the case where there are a row of prestressed ducts in the slab.

In this thesis, the mechanism of concrete cracking along ducts and the bursting out of prestressed tendons are quantitatively studied by means of a model test and the FEM method. The analyzed factors include: the curvature of the bottom slab, the amount of prestressing force, the diameter and distance of the prestressing ducts, the arrangment of the longitudinal and lateral reinforcement bars, and, in particular, the function of the hairpin bars. The possible construction errors, which can aggravate the bursting out of the prestressed tendons are also researched. The whole process of typical burst failure in the curved bottom slab was simulated with both the model test and the FEM. Finally, some strategies and suggestions about the design and construction of long span PC beam bridges with variable depth box girder, such as the line shape of the girder bottom, the clear distance between ducts, the amount and shape of hairpin bars, the location error of pre-stress ducts, are proposed.

Local Buckling of Slender Aluminium Sections Exposed to Fire

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Language of thesis document: *English*

Aluminium alloys are used in load-bearing structures such as buildings and ships. For such structures, requirements are put forward on the fire resistance. The set of design models, which enable the determination of the resistance of a structure subjected to fire conditions, is currently incomplete. A design model for local buckling is lacking. Developing such a model is the main aim of this thesis.

A test program was carried out with uniaxial specimens to determine the constitutive properties at elevated temperature. The experimental data were used for modifying and calibrating an existing constitutive model. This model is temperature-, time- and stress dependent. The new model allows for a more accurate determination of the fire resistance than state-of-the-art methods that are only temperature dependent.

A test set-up was developed that is suited to study local buckling at elevated temperature. Tests were carried out on square hollow sections and angular sections (see *Fig. 2*). This experimental program has resulted in validation data on the buckling behaviour of aluminium alloy sections at elevated temperature. The tests were simulated with numerical (finite element) models. For this purpose, the modified constitutive model was implemented in a finite element program. The results of the models agree well with that of the tests.

Based on a numerical parameter study, a calculation method has been proposed for compressed sections exposed to fire conditions. The calculation method distinguishes between sections that are able to reach their plastic capacity before local buckling occurs, and sections that fail by local buckling before the plastic capacity is reached. For the latter case, a prediction model has been developed. The calculation method provides a first and essential step in the fire design of aluminium alloy members.

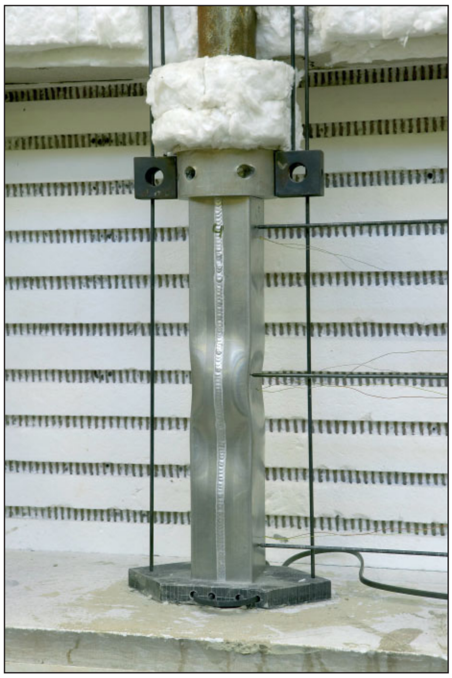

Fig. 2: Welded square hollow section after the compression test at elevated temperature

Optimization of Bridge Systems for Long Crossings

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The thesis investigates possible approaches to define structurally optimized bridge system for long crossings considering criteria of most feasible solution or the solution with the lowest overall construction price. The evaluation of different constructed long bridge crossings and the analysis of project design and construction conditions lead to the conclusion that the optimization of long crossings should be performed taking into account parameters that influence long crossings through different project development phases. Therefore, the investigation took into account influences during the conceptual, preliminary and final design, and during the phase of project construction. The analysis of influences on the structure of long crossing has shown that one bridge system could be optimally developed if the influencing parameters on the structure of long crossing is optimized considering local conditions in the micro- and macro location of the crossing. The optimization procedure has been presented throug newly developed a algorithm that follows the specialities of the bridge system type and considers experienced based decisions made during the project development phases. The optimization method works on the principles of multicriterial symbolically-numerical analysis that uses evaluation of active parameters through qualitative and quantitative analysis. The qualitative part of the analysis uses experienced based design and construction knowledge, and makes decisions by symbolical analysis method PPA („Potential-Problem-Analysis"). The optimization procedure is performed by a suggested algorithm in a series of iterations that make changes on the structure and having changes in the overall construction costs. The comparison of different analyzed bridge system structural solutions will lead towards an optimized bridge system solution for one long crossing location.

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