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Yassin Alghrir

New Concept for a Non-Welding
Connection in Steel Structures
and Steel-Concrete Composite
Structures to Accommodate
Large Building Tolerances
Using Grout

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Large Building Tolerances Using Grout**

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Yassin Alghrir

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Dissertationsschrift von Yassin Alghrir
Fakultät VI – Planen, Bauen, Umwelt
der Technischen Universität Berlin

Vorsitzender: Prof. Dr. sc. Techn. Mike Schlaich
Gutachter: Prof. Dr.-Ing. Volker Schmid
Gutachter: Prof. Dr.-Ing. Salah El-Metwally (Mansoura University)

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Internet: www.shaker.de • e-mail: info@shaker.de

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Abstract

Accommodation of tolerance in huge buildings is one of the challenges confronting the site engineer. Dimensional variation and the accuracy of positioning structural elements are more critical concerns in huge buildings than in other types of structures. The accumulation of the dimensional variations in such structures is significant due to the large dimensions and the dependency of each element on the previous erected element in a long series of successive steps throughout the construction process. Therefore, in this research, with an eye toward tolerance accommodation in huge multi-storey buildings, an adaptable grouted connection is suggested.

The research deals primarily with the strength characteristics of a grouted connection proposed to be employed between steel-to-steel elements or steel-to-concrete elements. The connection has been designed and tested at TU Berlin in the department of Composite structures (Verbunstrukturen). It consists of two toothed steel plates and grout in between; three types of grout have been used. The commercial names of the grout are BETEC180, COMONO, and Sikadur-42; BETEC180 belongs to the family of high-performance cementitious grout, whereas COMONO and Sikadur-42 relate to polymer concrete. Though the compressive strengths of all grout are close, there are substantial differences in the tensile and shear capacity between the cementitious grout and the polymer concrete grout.

Firstly, to investigate the performance of the connection under vertical shear, three tests for each material are conducted. The connection of cementitious grout showed brittle performance, and cracks started to propagate under relatively small loads. On the other hand, the polymer concrete connections displayed more ductile behavior in contrast to the BETEC connection; the displacements of the COMONO and Sikadur-42 connections are 4.5 and 1.7 times, respectively, the displacements of the BETEC connection. Also, the ultimate strength of the COMONO and Sikadur-42 connections is 81% and 74% greater than the parallel strength of the BETEC connection, respectively. Sikadur-42 connection presents the best behavior in terms of ductility and load capacity. However, the failure mode is comparable in all connections.

In order to demonstrate the connection's behavior and to trace the development of stresses and strains inside the connection, three-dimensional nonlinear Finite Element Models (FEM's), for the three different materials, have been carried out using ANSYS software. The FEMs exhibits reasonable good behavior and compatibility with the observations in the experiments. The models are useful in interpreting the stress development within the grout and the failure mode of the connection. Furthermore, the load capacities of the models tie in well with the test outcomes.

In order to calculate the strength of the connection, analytical approaches have been developed. The calculation procedure relies on a strut and tie model and the FEMs. The calculations distinguish between two phases; before and after cracking of the grout. The Utilization of the outcomes from the FEMs improves the results of the analytical approaches. The proposed theoretical approaches are sufficiently accurate to estimate the strength at the level of first cracks and to determine the ultimate strength of the connection.

Kurzfassung

Der Toleranzausgleich zwischen den Einzelbauteilen ist bei der Errichtung großer oder hoher Bauwerke eine besondere Herausforderung für den Bauingenieur. Maßabweichungen in der Geometrie der Bauteile sowie Ungenauigkeiten während des Einbaus auf der Baustelle haben bei hohen Gebäuden eine größere Bedeutung als bei anderen Bauwerken. Da der Einbau eines jeden Bauteils von einer Vielzahl zuvor errichteter Elemente abhängt, summieren sich die einzelnen Abweichungen mit zunehmendem Baufortschritt. Kombiniert mit den bei hohen Gebäuden üblichen, großen Bauteilabmessungen erhöht dies die Signifikanz der Maßabweichungen. Mit Blick auf den Toleranzausgleich bei großen oder hohen Bauwerken wird daher in dieser Arbeit eine variable Vergussverbindung vorgeschlagen.

Ziel dieses Forschungsvorhabens ist die Untersuchung des Tragverhaltens einer vergossenen Verbindung und daran anknüpfend eine Empfehlung für deren Anwendung. Diese Art der Verbindungen kann zwischen Stahlbauteilen oder zwischen Beton- und Stahlbauteilen eingesetzt werden. Die Verbindung wurde an der Technischen Universität Berlin am Fachgebiet Entwerfen und Konstruieren – Verbundstrukturen entworfen und getestet. Sie besteht aus zwei gezahnten Stahlplatten, deren Zwischenraum mit Vergussmörtel gefüllt wird. Es wurden drei unterschiedliche Vergussmörtel getestet: Im Baugewerbe sind sie unter den Namen BETEC180, COMONO und Sikadur-42 bekannt. BETEC180 gehört zur Gruppe der Hochleistungsmörtel auf Zementbasis, wohingegen COMONO und Sikadur-42 auf polymeren Bindemitteln basieren. Obwohl die Druckfestigkeiten aller drei Mörtel ähnlich sind, gibt es erhebliche Unterschiede in der Zug- und Schubfestigkeit zwischen dem zementösen Mörtel und den Polymermörteln.

Zunächst wurden drei Versuche je Verpressmörtel durchgeführt, um die Tragfähigkeit der Verbindung unter vertikalem Schub zu untersuchen. Die Verbindung mit zementösem Mörtel weist ein sprödes Verhalten auf und es bilden sich bereits bei vergleichsweise kleinen Lasten Risse. Die Polymermörtel weisen hingegen ein duktileres Verhalten auf. Die Verformungen in den Verbindungen sind beim Verguss mit COMONO Mörtel 4,5 Mal und mit Sikadur-42 Mörtel 1,7 Mal größer als bei Verbindungen mit BETEC Mörtel. Darüber hinaus ist die Bruchfestigkeit der COMONO und der Sikadur-42 Verbindung 81% beziehungsweise 74% höher als bei der Verwendung von zementösen Vergussmörtel. Die Ausführung mit Sikadur-42 Verpressmörtel weist das beste Verhalten hinsichtlich der Duktilität und der Tragfähigkeit auf. Nichtsdestotrotz sind die Versagensfälle aller drei Varianten vergleichbar.

Um das genaue Tragverhalten sowie die Entwicklung der Spannungen und Dehnungen innerhalb der Verbindung zu untersuchen, wurden dreidimensionale, nichtlineare Finite-Elemente-Modelle (FEM) für die drei Verbindungen mit den verschiedenen Vergussmörteln erstellt. Dazu wurde das Programm ANSYS verwendet. Die FEM geben das im Versuch beobachtete Verhalten angemessen gut wieder. Die Modelle dienen der Interpretation der Spannungsentwicklung innerhalb des Mörtels sowie der Analyse der Versagensarten. Die mit den FEM errechneten Tragfähigkeiten stimmen mit den Ergebnissen der Versuche sehr gut überein.

Darüber hinaus wurden analytische Verfahren zur vereinfachten Bestimmung der Tragfähigkeit von solchen Verbindungen entwickelt. Die Berechnungen basieren auf Stabwerkmodellen und Ergebnissen aus den FEM. Bei den Berechnungen wurde zwischen der Phase vor der Rissbildung und der Phase nach der Rissbildung im Vergussmörtel unterschieden. Durch die Verwendung von Teilergebnissen aus den FEM konnte die Genauigkeit der analytischen Ansätze verbessert werden. Die Ergebnisse der vorgestellten, analytischen Verfahren sind ausreichend genau, um die Traglast kurz vor dem Auftreten erster Risse abzuschätzen und die Bruchfestigkeit der Verbindung zu bestimmen.

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