STRENGTHENING OF BOLTED SHEAR JOINT IN FERROCEMENT CONSTRUCTION

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To my beloved father and mother, family and dear friends.

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ABSTRACT

This study deals with strengthening of bolted shear joint in thin-walled ferrocement construction. Such a joint is attractive because it provides faster and neat means of assembling precast elements into a complete structure. Steel wires, bent into O-Shape and U-shape with or without extra straight wire, are considered as simple inserts around the bolt hole to enhance the joint strength. The parameters investigated include the number of layers of wire mesh (or volume fraction of reinforcement), edge distance of bolt hole and the effectiveness of different types of the steel inserts. Test results have shown that for small edge distance, failure occurs either in cleavage or shearing mode, and the strength of the joint increases with an increase in the edge distance. This continues up to an upper limit set by either tension or bearing failure. For a given edge distance and details of connected members, the strength of a joint can be significantly enhanced by using steel insert, while U-insert is most cost-effective. Available equations for predicting the joint strength in ferrocement composites can be slightly modified to include the effects of these inserts with a good level of accuracy. Since the cleavage failure equation is quite conservative, removing it from consideration or modifying it to reflect test data can improve the accuracy of the predictions of joint strength. As an alternative, strut-and-tie model, herein can predict the joint strength in ferrocement composite as proposed. However it does not perform that well if steel insert is included in the ferrocement plate, as the process to determine volume fraction of reinforcement becomes more complex.

ABSTRAK

Kajian ini adalah berkenaan sambungan ricih bolt dalam pembinaan dinding nipis ferrocement. Sambungan bolt sesuai kerana ia adalah cepat dan tersusun semasa menyambungkan elemen precast kepada suatu struktur yang menyeluruh. Dawai besi, yang dibengkokkan kepada bentuk O dan U yang ditambah atau tidak ditambah dengan dawai lurus, telah digunakan sebagai tetulang tambahan disekeliling bolt untuk meningkatkan kekuatan sambungan. Parameter yang dikaji termasuk bilangan lapisan jejaring dawai (atau peratus isipadu tetulang), jarak ke tepi dari lubang bolt dan kesesuaian tetulang tambahan besi yang berlainan. Keputusan ujian menunjukkan untuk jarak tepi yang kecil, kegagalan dalam "cleavage" atau rich berlaku. Kekuatan sambungan meningkat apabila jarak tepi bertambah. Ini berterusan sehingga satu tahap apabila kegagalan tegangan atau galas berlaku. Untuk jarak tepi dan keadaan sambungan yang ditetapkan, kekuatan sambungan boleh ditingkatkan keberkesannya dengan penggunaan tetulang tambahan besi, manakala tetulang tambahan bentuk U adalah paling kos-efektif. Formula yang ada untuk menjangka kekuatan komposit ferrocement boleh diubah sedikit untuk menambahkan kesan tetulang tambahan dengan ketepatan yang baik. Oleh kerana formula untuk kegagalan "cleavage" sangat konservatif, pengeluaran formula "cleavage" dalam pertimbangan atau pengubahsuaian formula tersebut dapat meningkatkan ketepatan jangkaan kekuatan sambungan. Modal strut-and-tie merupakan satu cara lain untuk menjangka kekuatan sambungan komposit ferrocement. Tetapi keputusannya menjadi kurang tepat jika tetulang tambahan digunakan dalam komposit ferrocement. Ini disebabkan pengiraan peratus isipadu tetulang untuknya adalah sukar.

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INTRODUCTION

Ferrocement is a type of thin reinforced-concrete construction where instead of reinforcing bars, larger amount of smaller diameter wire meshes are used uniformly throughout the cross section and, instead of concrete, mortar is used (Surendra & Naaman, 1978). The ferrocement technique was invented about 160 years ago by Joseph Lambot when he constructed the first ferrocement boat at Brignoles, France in 1848.

Recently, due to increasing labour cost and the need for producing high quality construction material, Industrialized Building System (IBS) is introduced. The system encourages structural components to be manufactured in the factory in mass quantity and assemble them on site by using suitable connections. Ferrocement can be fabricated into any desired shape and, being a thin-walled composite, the components will be lighter for handling and transportation. Assembling these components by using bolted joints will eliminate the requirement for messy wet connection on site and greatly expedite the construction process. The ACI Committee 549 had provided design guide for the fabrication of ferrocement, but there is still a lack of information on bolted connections in precast ferrocement panels.

Since 1994, a number of research programs on the behaviour and strength of bolted joint in ferrocement has been conducted at the National University of Singapore (Mansur et. al., 1994, 2001, Abdullah and Mansur, 1995, Tan, 1999). These investigations identified four different modes of failure for a shear joint and attempted to develop analytical models for predicting the ultimate strength of such a joint. A careful review of the resulting expressions reveal that, for a given geometry and connected member details, joint strength may be enhanced significantly by incorporating simple steel insert of desired shape at suitable location. The focus of this study has therefore been directed toward strengthening of bolted shear joint in ferrocement construction.

1.1 Research Problem

This study concentrates mainly on the problem of identifying the effect of steel inserts on bolted shear joint and their effectiveness in strengthening bolted shear joint.

1.2 Objectives

The objectives of the study are:-

a) To propose suitable ways to strengthen bolted shear joint using steel insert by investigating the available mechanistic models and modifying the models for incorporation of inserts.

b) To verify experimentally the effectiveness of the strengthening method by designing and conducting a series of tests and comparing with the analytical predictions.

1.3 Scope of Project

This research was aimed to propose suitable way to strengthen bolted shear joint. To archive that, some literature study had been done and the equations of four mode of failure were analyzed to see the relationship of the parameters involved. A strut-and-tie model was also constructed to achieve that purpose. From the analysis, steel inserts could significantly increase the strength of the joint. Furthermore, tests on the steel inserts on bolted shear were conducted to verify its effectiveness.