IMPROVING THE PERFORMANCE OF PRECAST CONCRETE BEAM-TO-BEAM CONNECTION WITH INADEQUATE LAP LENGTH

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Dedicated to all my family members

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ABSTRACT

This paper reports on a feasibility study of different types of precast concrete beam-to-beam connections under inadequate lap length. The aim of the study is to develop a beam-to-beam connection, which is able to produce comparable bond strength with the conventional lapping system although the anchorage length is inadequate. A total of six connections were tested for a preliminary study in Phase I. Then, the connection that gave the best performance was selected as the proposed beam-to-beam connection for further study in Phase II. In the studies, steel plates, bolts and nuts system and welding technique were used to enhance the performance of the anchorage system. The welded end plate connection system shows a satisfactory result as it significantly increases the bearing capacity of bars to resist the slippage between reinforcement and concrete. Several unsatisfactorily connections, however, still show potentials of reaching the required loading capacity. Therefore, modification and improvement can be made to improve their performances.

ABSTRAK

Kajian ini mengkaji beberapa jenis sambungan rasuk-ke-rasuk yang mempunyai tambatan tetulang yang tidak mencukupi. Laporan ini melaporkan kebolehlaksanaan sambungan-sambungan tersebut. Objektif kajian ini adalah untuk merekabentuk satu sambungan rasuk-ke-rasuk yang berupaya membekalan kekuatan ikatan yang hampir sama dengan sambungan tradisional walaupun tambatan yang disediakan adalah tidak mencukupi. Terdapat enam sambungan yang dikaji dalam kajian awal Fasa I. Sistem sambungan yang dicadangkan diperbaiki dengan pelbagai cara. Misalnya, menggunakan kepingan-kepingan besi, sistem skrew dan teknik kimplan. Seterusnya, sambungan yang memberikan keputusan yang terbaik akan dipilih untuk kajian yang lebih teliti dalam Fasa II. Ianya digunakan sebagai sambungan untuk menyambungkan rasuk-rasuk pratuang. Sistem tambatan yang menggunakan kepingan-kepingan besi yang dikimpal memberikan keputusan yang memuaskan kerana ia berupaya menambah kapasiti galas tetulang besi untuk menanggung daya gelinciran antara tetulang besi dengan konkrit. Terdapat beberapa sambungan yang kurang memuaskan. Walaupun begitu, keputusan menunjukkan potensi untuk memperbaikan keberkesanannya dalam menanggung beban. Oleh itu, pengubahsuaian dan kemajuan perlu dilakukan supaya ia dapat berfungsi dengan berkesan.

CONTENTS

CHAPTER II LITERATURE REVIEW

CHAPTER III METHODOLOGY

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOL

A_b	-	Area of reinforcing bar (in^2)
A_{tr}	-	Area of transverse reinforcement (in^2)
β	-	Coefficient dependent on the bar type
c	-	Spacing or cover dimension measured from centre of connector (in.)
d_b	-	Bar diameter (in.)
f_{bu}	-	The design ultimate anchorage stress
f'_c	-	Specified concrete compressive strength (ksi)
f'_c	-	Specified compressive strength of concrete (psi)
f_y	-	Specified yield strength of steel reinforcement (ksi)
f'_y	-	Specified yield strength of the connector (psi)
f_{yt}	-	Specific yield strength of transverse reinforcement (psi)
K_{tr}	-	Transverse reinforcement index
l_d	-	Development length of bar in tension (in.)
l_{db}	-	Basic development length of bar in tension (in.)
n	-	Number of bars being developed along the plane of splitting
s	-	Maximum spacing of transverse reinforcement within ld (in.)
ψ_t	-	Reinforcement location factor
ψ_e	-	Coating factor
ψ_s	-	Reinforcement size factor (0.8 for #6 and smaller bars, otherwise 1.0)

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

1.1 Introduction

Reinforced concrete is a combination of concrete, which is strong and relatively durable in compression with reinforcing and steel, which is strong and ductile in tension. In order to maintain the composite action, load transfer between the concrete and steel is essential. It is basically influenced by the bond, which is idealized as continuous stress field that develops in the vicinity of the steel-concrete interface.

When reinforced concrete is subjected to moderate load where the bond stress capacity is not exceeded, there is only relatively little movement between the reinforced steel and the surrounding concrete. However, for severe load condition where localized bond demand exceeds its capacity, localized damage and significant movement between reinforcing steel and the surrounding concrete will occur.

It is know that the force at the free end of a stressed tendon is obviously zero. It require at least a certain distance, known as the transmission length, for the tendon

to develop the full force in order to resist the force subjected to the element. Therefore, insufficient anchorage length will lead to concentration of stresses that need to be resisted by bonds and leads failures of structure.

In precast concrete structures, attention should be given to connections and joints. The quality and the behaviour of connections will directly influence the structure performance. Sufficient anchorage length in certain precast concrete connections is essential to ensure the structure performs in its intended behaviour. In some cases, construction tolerance and insufficient space will lead to insufficient anchorage length and eventually lead to failure at connections.

This paper studies about the matter of tension anchorage length in precast beam-to-beam connections and the method to improve their performance. The study also intended to develop a new anchorage system, which is more effective in developing bond strength with minimum anchorage length.

1.2 Problem Statement

In precast concrete structures, structural elements are assembled together forming skeleton structure frame to transfer loads to the foundations. Precast elements are usually fabricated in factory where the qualities of members are usually properly controlled. Therefore, connections become the most essential factor influencing the performance of the structures, as improper connections among structural members will lead to failure of structures. In order to ensure the loads are properly transfer among structural members, the bond strength between concrete and steels at joints should be greater than the forces to be transferred and the development of the bond strength is influenced by the development length of the anchorage of bars.

The provisions for anchorage of straight bars and hooks sometimes gives detailing problems due to the long development lengths and large bend diameters that are required, particularly when large-diameter reinforcing bars are used. Occasionally the requirements for straight bar anchorage and lap spliced cannot be provided within the available dimensions of elements. Hooked bars can be used to shorten anchorage length, but in many cases, the bend of the hook will not fit within the dimensions of a members or the hooks create congestion and make element difficult to construct. Mechanical anchorage devices can be used to shorten lap splice length, but they frequently require special construction operations and careful attention to tolerances.

1.3 Objective

The objective of the research is as listed below:

a. To study and compare the tension resistance performance of different types of anchorage systems.

b. To develop an anchorage system that is able to perform under inadequate lapping and able to provide comparable bonding strength as the conventional reinforcement bar lapping system.

c. To study the feasibility and loading behaviour of the propose anchorage system as a beam-to-beam connection for precast concrete structures.

1.4 Scope of Study

The scope of this research is limited to the:

a. Study on the anchorage length based on requirements stated in BS 8110: Part 1: 1997.

b. Study of joint of reinforcement bars with inadequate anchorage length.

1.5 Importance of the Study

The study is intended to develop a new anchorage system, which is able to replace the conventional anchorage system in precast concrete structures. The newly developed anchorage system should have shorter requirement of anchorage length. This is able to solve the problem of insufficient space allocation for anchorage system, which will either lead to insufficient development of anchorage length and congestion.

By improving the anchorage performance, the construction method is able be simplified and the erection time can be reduced. Furthermore, this will reduce the construction cost of precast concrete structures by saving time and labour cost. Besides, the reduced length of anchorage length will save the amount of reinforcement bar being used.