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THE EFFECTIVENESS OF INDEPENDENT BENT-UP BARS WITH INSUFFICIENT ANCHORAGE AND INCLINED LINKS AS SHEAR REINFORCEMENT

NOOR NABILAH BINTI SARBINI

A project report submitted in partial fulfillment of the requirement for the award of the degree of Master of Engineering (Civil-Structure)

Faculty of Civil Engineering
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November, 2009

I declare that this project report entitled "The Effectiveness of Independent Bent-Up Bars with Insufficient Anchorage and Inclined Links as Shear Reinforcement" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Dearest,

Thank you for mama, papa, siblings & friends…

Special to,

Azman Hafiidz Aji…

Thank you for always be there.

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ABSTRACT

Shear failure in beams is caused by diagonal cracks near the supports. Any form of effectively anchored reinforcement which intersect these cracks will be able to resist the shear stress to a certain extend. This thesis presents the results of an experimental investigation on six reinforced concrete beams in which their structural behaviour in shear was studied. All the beams were cast with the same grade of concrete and provided with identical amount of main reinforcement. In order to investigate the contribution of the independent bent-up bars with insufficient anchorage and varying amount as well as the inclined links to the shear carrying capacity of the beam. Four of the beams were provided with independent bent-up bars of different amount and anchorage, and one with inclined links. The performances of the beams were measured in terms of deflection, strain, diagonal cracks loads and ultimate loads. The results show that the shear capacities of the beam with inclined links and independent bent-up bars (4T16) of 150 mm anchorage length are higher than that of the conventional designed beam. At the same time, independent bent-up bars of 9T16 with 50 mm anchorage length also give higher shear capacities due to its larger shear reinforcement to cross-sectional ratio of 1.2%. Meanwhile, independent bent-up bars of 4T16 with 50 mm anchorage length to cross-sectional ratio of 0.8% give low shear capacities. It may therefore be suggested that independent bent-up bars of 150 mm anchorage length be used to replace the conventional vertical links as shear reinforcement.

ABSTRAK

Kegagalan ricih di dalam rasuk adalah disebabkan oleh keretakan condong yang wujud berdekatan penyokong. Apa sahaja bentuk tetulang yang merintangi keretakan ini, akan dapat menahan tegasan ricih sehingga sampai had yang tertentu. Kajian ini memaparkan keputusan ujikaji yang telah dijalankan ke atas enam sampel rasuk konkrit bertetulang, yang mana struktur kelakunannya dikaji. Semua rasuk dibina dengan kekuatan gred konkrit yang sama, dan menggunakan bilangan dan jenis tetulang utama yang sama. Bagi mengkaji sumbangan bar condong bebas dengan panjang tambatan yang tidak mencukupi dan kuantiti yang pelbagai, juga perangkai condong terhadap keupayaan rasuk menanggung ricih, empat rasuk telah disediakan dengan kuantiti bar condong bebas serta panjang tambatan yang berbeza, serta satu rasuk dengan perangkai condong. Kelakunan rasuk dalam menghalang ricih dikaji berdasarkan nilai pesongan rasuk, keterikan bar condong bebas, beban ketika keretakan condong berlaku serta bebn muktamad. Keputusan ujikaji menunjukkan bahawa rasuk yang menggunakan perangkai condong dan bar condong bebas (4T16) dengan panjang tambatan 150 mm boleh menanggung keupayaan ricih lebih daripada rasuk yang menggunakan perangkai pugak. Pada masa yang sama, bar condong bebas dengan panjang tambatan 50 mm juga memberikan lebih keupayaan ricih disebabkan oleh bar condong bebas yang lebih daripada 1.2 % terhadap keratan rentas rasuk. Manakala 0.8%bar condong bebas, 4T16 dengan panjang tambatan 50 mm terhadap keratin rentas rasuk memberikan rintangan ricih yang rendah. Justeru itu, bar condong bebas dengan panjang tambatan 150 mm dicadangkan untuk menggantikan perangkai pugak sebagai tetulang ricih.

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LIST OF SYMBOLS

Symbol		Description
A_s	-	Area of reinforcement
A_{sb}	-	Area of steel in bent-up bars
A_{sv}	-	Total cross-sectional area of links at the neutral axis
a_v	-	Distance between zero and maximum moment(shear span)
b	-	Width of a section
b_v	-	Width of the beam for shear resistance
d	-	Effective depth
f_{cu}	-	Characteristic strength of concrete at 28 days
f_s	-	Service stress in reinforcement
f_{tt}	-	Design tensile stress in concrete at transfer
f_y	-	Characteristic strength of steel reinforcement
f_{yb}	-	Characteristic strength of inclined bars
f_{yv}	-	Characteristic strength of link reinforcement
M	-	Moment
s_b	-	Spacing of bent-up bars
s_v	-	Spacing of links
V	-	Shear force
V_b	-	Design ultimate shear resistance of bent-up bars
V_c	-	Total capacity to resist shear force
V	-	Shear stress
v_b	-	Design shear stress resistance
v_c	-	Design ultimate shear stress resistance

α	-	**Angle between a bent-up bar and the axis of a beam**
β	-	**Bond coefficient**
θ	-	**Angle**
$\emptyset$	-	**Bar diameter**
°	-	**Degree**
%	-	**Percent**

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Shear failure in beams is caused by the diagonal cracks near the support. These cracks start at the bottom and extend towards the compression zone. Any form of effectively anchored reinforcement that intersects these diagonal cracks will be able to resist the stress to a certain extend. In practice, shear reinforcement is provided in the forms of vertical links or combination system of vertical links and bent-up bars.

In conventional system of shear resistance, vertical links play an important role in effectively restrains the formation of shear cracks in reinforced concrete beams. This system is preferred due to installing and fabricating simplicity. However, closed arrangement of shear links from various elements at elements intersection (near the support) causes problems in fixing.

The use of bent-up bars along with vertical links as shear reinforcement had been practiced before. In situations where the tensile reinforcement is required to resist bending moment, only some of the rest was bent-up in the region of high shear to form the inclined legs of shear reinforcement. For example, beams which have four bars as the main tensile reinforcement at mid span, two bars may be bent-up diagonally and act as shear reinforcement, while the other two would be left to continue to the support.

However, its application has been less preferred nowadays. The difficulties to form the bent-up bars and required adequate amount of main reinforcement make it rarely used in construction. It is because, in beams with small number of main bars provided, the bent-up system is not suitable because insufficient amount of reinforcement would be left to continue to the support as required by the code of practice.

In this study, an alternative to overcome those problems is using independent bent-up bars. The application of independent bent up bars give strong resistant to the shear cracks due to better redistribution of internal forces across the cracks. In addition, this phenomenon leads to restrict the growth of the inclined cracks and maintain the interface of shear transfer effectively compared to conventional shear resistance system.

The selection of the amount of independent bent-up bars to be used is important. If the amount is too little, those bars will yield at the formation of inclined cracks and cause the beams to fail. This situation is dangerous to the structures. However, too much amount of independent bent-up bars caused a shear-compression failure without the yielding of independent bent-up bars. It meaning that, the beams element will fail in flexure. This situation is not suitable if the objectives of the study are to determine the shear characteristic and contribution of independent bent-up bars to the shear resistance. Besides, in real situation, excessive amount of independent bent-up bars cannot give

profits to the project. Thus, an adequate amount of independent bent-up bars should be obtained sufficiently.

The anchorage length plays an important aspect of independent bent-up bars. If the anchorage length is too long, the position of the successive independent bent-up bars will be apart from the first layer. The question is that; can the inclined cracks passing the second layer and if it is not, it is such a waste to install those independent bent-up bars at the second layer. In this study, specimens are prepared with different anchorage length to study the anchorage length contribution to the shear resistance. The anchorage length is decided based on experience and engineering sense.

1.2 Problem Statement

The congestion near the support due to closed arrangement of shear links causes problems in fixing the reinforcements. For the application of bent-up bars, it has been less preferred nowadays. The difficulties to form as bent-up bars and required adequate amount of main reinforcement make it rarely used in construction. In beams with small number of bars provided, the bent-up system is not suitable because insufficient amount of reinforcement would be left to continue to the support as required by the code of practice. Due to this problems as well as the conventional shear reinforcement, the use of independent bent-up bars and inclined links arranged in the high shear region have been studied.

1.3 Research Objectives

The objectives of this research are :

i) To study the effectiveness of independent bent-up bars as shear reinforcement compared to conventional system.

ii) To study the effectiveness of inclined links as shear reinforcement compared to conventional system.

iii) To compare the shear resistance of independent bent-up bars plus nominal links with inclined links.

iv) To study on the effectiveness of independent bent-up bars with different anchorage length.

v) To study the effects of different amount of independent bent-up bars as shear reinforcement.

1.4 Scope of the Research

This study is based on experimental investigation within the scopes listed below:

i) The test were carried out on six specimens of reinforced concrete beams of identical size of 2300 mm length, 200 mm width and 250 mm of overall depth.

ii) All specimens were provided with identical amount of main reinforcements that is 3T16 with 2T10 as hanger bars.

iii) All specimens were tested to failure with two point load at distance 650 mm from beam edges.

iv) The concrete compressive strength for all specimens is in the ranges of 35±0.5 N/mm^2.

v) The inclination of independent bent-up bars and inclined links are 45° to the longitudinal axis of the beam.

vi) The variables in the specimens are the amount of independent bent-up bars, anchorage length of independent bent-up bars, arrangement of independent bent-up bars and the inclined links as shear reinforcement.