THE USE OF HORIZONTAL AND INCLINED BARS AS SHEAR REINFORCEMENT

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To mama and papa,

Thanks for your support

My dream has come true just because of you

To my beloved husband,

Thanks for your understanding and support

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ABSTRACT

Shear failure in beams are caused by diagonal cracks near the support. Any form of effectively anchored reinforcement that intersects these cracks will be able to resist the shear stress to a certain extent. This project presents the results of an experimental investigation on six reinforced concrete beams in which their structural behaviour in shear were 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 additional horizontal and independent bent-up bars to the shear carrying capacity of the beam, two specimens each were provided with horizontal longitudinal bars and bent-up bars in the high shear region. Two different quantities of additional bars in each of these cases were adopted. The fifth specimen was provided with sufficient amount of shear reinforcement in terms of vertical links, while the other one was cast without any shear reinforcement to serve as control specimens. The performances of the beams in resisting shear in the form of deflection, cracking, strain in the shear reinforcement and ultimate load were investigated. The results show that the shear capacities of the beams with additional horizontal and independent bent-up bars larger than 1.2% of their cross-sectional area are higher than that of the conventionally designed beam with vertical links. It may therefore be suggested that these types of shear reinforcement be used to ease the congestion of links near the supports.

ABSTRAK

Kegagalan ricih dalam rasuk adalah disebabkan oleh keretakan condong yang berlaku berdekatan dengan penyokong. Sebarang bentuk tetulang tambatan yang melintasi keretakan ini berkeupayaan untuk menghalang ricih pada suatu takat yang tertentu. Kajian ini memaparkan keputusan dari ujikaji makmal yang telah dijalankan ke atas enam rasuk konkrit bertetulang dimana kelakunannya terhadap ricih telah dikaji. Semua sampel rasuk dibina dengan kekuatan gred konkrit yang sama, dan menggunakan bilangan dan jenis tetulang utama yang sama. Bagi mengkaji sumbangan atau kesan bar ufuk tambahan dan bar yang dibengkok terhadap keupayaan menanggung ricih, dua sampel rasuk dimana setiap satunya disediakan bar ufuk tambahan dan bar yang dibengkok pada satah kegagalan ricih maksimum. Dua perbezaan kuantiti untuk setiap jenis tetulang tambahan disediakan. Spesimen yang kelima disediakan dengan bilangan tetulang ricih yang mencukupi dalam bentuk perangkai pugak, manakala satu lagi rasuk dibina tanpa menggunakan sebarang tetulang ricih dan bertindak sebagai rasuk kawalan. Kelakunan rasuk dalam menghalang ricih dikaji berdasarkan kepada nilai pesongan, keretakan, keterikan dan beban muktamad. Keputusan ujikaji menunjukkan bahawa rasuk yang menggunakan bar ufuk tambahan dan bar yang dibengkokkan sebagai tetulang ricih lebih daripada 1.2% daripada keratan rentas rasuk boleh menanggung keupayaan ricih lebih daripada rasuk yang menggunakan perangkai pugak. Oleh yang demikian, tetulang ricih jenis ini dicadangkan bagi memudahkan kerja-kerja pemasangan perangkai ricih yang disusun rapat berhampiran dengan penyokong rasuk.

TABLE OF CONTENTS

CHAPTER 2 LITERATURE REVIEW

CHAPTER 3 **EXPERIMENTAL INVESTIGATION**

CHAPTER 4

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOS

LIST OF SYMBOLS

A	-	Area of a cross-section
A_s	-	Area of tension reinforcement
A_{sb}	-	Area of steel in bent-up bars
$A_{s,prov}$	-	Area of tension reinforcement provided
$A_{s, req}$	-	Area of tension reinforcement required
A_{sv}	-	Total cross-sectional area of links at the neutral axis
a_v	-	Shear span
b	-	Width of a section
b_v	-	Breadth of member for shear resistance
c	-	Cover to reinforcement
d	-	Effective depth of tension reinforcement
f_{cu}	-	Characteristic concrete cube strength at 28 days
f_s	-	Service stress in reinforcement
f_{tt}	-	Design tensile stress in concrete at transfer
f_y	-	Characteristic strength of reinforcement
f_{yb}	-	Characteristic strength of inclined bars
f_{yv}	-	Characteristic strength of link reinforcement
L	-	Effective span of a beam
M_{max}	-	Maximum bending moment
s_b	-	Spacing of bent-up bars
s_v	-	Spacing of links
V	-	Shear force at ultimate design load
V_b	-	Design ultimate shear resistance of bent-up bars
V_c	-	Design ultimate shear resistance of a concrete section
v	-	Shear stress
v_b	-	Design shear stress resistance of bent-up bars

v_c	-	Design ultimate shear stress resistance of a singly reinforced concrete beam
α	-	Angle between a bent-up bar and the axis of a beam
β	-	Bond coefficient
θ	-	Angle
ϕ	-	Bar diameter

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

Reinforced concrete (RC) beams are the important structural elements that transmit the loads from slabs, walls, imposed loads etc. to columns. A beam must have an adequate safety margin against bending and shear stresses, so that it will perform effectively during its service life.

At the ultimate limit state, the combined effects of bending and shear may exceed the resistance capacity of the beam and causes tensile crack. Since the strength of concrete in tension is considerably lower than its strength in compression, design for shear is of major importance in concrete structures. However, shear failure is difficult to predict accurately. In spite of many decades of experimental research, it is not fully understood.

The behaviour of reinforced concrete beams at failure in shear is distinctly different from their behaviour in flexure, which may be more dangerous than flexure failure. They fail abruptly without sufficient advanced warning[1] and the diagonal cracks that develop are considerably wider than the flexural cracks.

Shear failures in beams are caused by the diagonal cracks near the support and it had been tested before at Cornell University under third point loading. With no shear reinforcement provided, the member failed immediately upon formation of the critical crack in the high-shear region near the support.

Whenever the value of actual shear stress exceeds the permissible shear stress of the concrete used, the shear reinforcement must be provided. The purpose of shear reinforcement is to prevent failure in shear, such increases the ductility of the beam and considerably reduces the likelihood of a sudden failure.

Normally, the inclined shear cracks start at the bottom near the support at approximately 45^o 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 extent. In practice, shear reinforcement is provided whether in the form of vertical links, inclined links or combination system of links and bent-up bars.

In building construction, vertical links are most commonly used as shear reinforcement, because of their simplicity in fabricating and installing. Normally, links are arranged closely or sometimes double or more shear links are used to resist high shear stress. Congestion near the support of RC beam due to the presence of the closely spaced links can increase the cost and time required in fixing the reinforcement.

The use of bent-up bars along with vertical links had been practical before. In situations where all the tensile reinforcement is not required to resist bending moment, some of the bar was bent-up in the region of high shear to form the inclined legs of shear reinforcement. For example, beams which provide 4 bars of main tensile reinforcement, 2 bars may be bent-up diagonally in shear region and used as shear reinforcement, while the other 2 bars would be left to continue to the support.

However, its application 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 the problems of conventional shear reinforcement, the use of independent inclined and horizontal bars provided in the high shear region are recommended in this project and expected would be able to serve the same purposes. The main advantages of these types of shear reinforcement system are structural effectiveness, flexibility, simplicity and speed of construction.

In this project, the experimental investigation of the system was carried out in which their structural behaviours in shear were studied. Six reinforced concrete beams, which contained different types of shear reinforcement were designed and prepared for laboratory testing. In this investigation, all the beams are allowed would be fail only in shear, so adequate amount of tension reinforcement were provided to give a sufficient of bending moment resistance.

In order to investigate the contribution of the additional horizontal and inclined bars to the shear carrying capacity of the beam, two specimens each were provided with horizontal longitudinal bars and inclined bars in the high shear region. The other two specimens each were cast without shear reinforcement as control specimen and the other one was provided with sufficient amount of shear reinforcement in terms of vertical links. External forces were loaded within a sufficient distance near the support. The performances of the beams in general and in resisting shear in particular were compared in terms of deflection, cracking and ultimate load.

The results from the laboratory testing are very useful to determine the effectiveness of independent inclined and horizontal bars as shear reinforcement. It is anticipated that both types of additional bars increase the shear capacity of the beam and therefore be suggested to use as alternative shear reinforcement.

1.1 Objectives

In general, the aim of this project is to investigate the behaviour of rectangular beams in shear. In a more specific terms, the objective of this study are as follow :

a) To study the effectiveness of additional longitudinal bars in resisting shear forces in rectangular beams.

b) To study the effectiveness of independent inclined bars as shear reinforcement.

c) To determine the optimum amount of both types of shear reinforcement to achieve a shear capacity similar to that of a normal links system.

1.2 Scope of the study

This study is based fully on the experimental investigation to be carried out with the scope given below :

a) The study was based on experimental investigation on six rectangular reinforced concrete beams.

b) All specimens were of the same size and reinforced with identical amount of longitudinal steel.

c) The beams were tested to failure with two point loads near the support to give a shear span to effective depth ratio of 2.5

d) The concrete compressive strength of the specimens on the testing day was in the range 30 to 35 N/mm^2.

e) The variables in these specimens are the shear reinforcement systems, which are vertical links, independent inclined bars and additional horizontal bars.

BIBLIOGRAPHY

1. S.K.Mallick (1985), “Reinforced Concrete”, Mohan Primlani for Oxford & IBH Publishing Co.

2. F K Kong, R H Evans (1987), “Reinforced and Prestressed Concrete”, Van Nostrand Reinhold (UK) Co.Ltd.

3. Arthur H.Nilson (1997), “Design of Concrete Structures”, The McGraw-Hill Companies, Inc.

4. Gaetano Russo, Giuliana Somma and Denis Mitri, “Shear Strength and Prediction for Reinforced Beams without Stirrups”, Journal of Structural Engineering (Jan 2005).

5. R.F.Warner (1976), “Reinforced Concrete”, Pitman Australia.

6. I.C.Syal (1984), “Reinforced Concrete Structures”, a.h.wheeler & co.

7. T.J.Macginley (1990), “Reinforced Concrete : Design Theory and Examples”, E & FN SPON.

8. A.M.Neville (1973), “Properties of Concrete”, Pitman Publishing LTD. UK

9. P. Kumar Mehta (1986), “Concrete : Structure, Properties and Materials”, Prentice-Hall, Englewood Cliffs, New Jersey