

**THE USE OF HORIZONTAL AND INCLINED BARS AS SHEAR
REINFORCEMENT**

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

FACULTY OF CIVIL ENGINEERING
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NOV, 2005

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

ACKNOWLEDGEMENT

In preparing this thesis, I am very thankful to many people, which have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my supervisor, P.M Dr. Ramli Abdullah for their guidance, advices and friendship. Without his continued support and interest, this thesis would not have been the same as presented here.

I am also very thankful to Makmal Kejuruteraan Awam, Universiti Teknologi Malaysia (UTM) for their cooperation, guidance and advices. Without their cooperation, this project would not successfully complete as I wished. I hope our friendship with all staff in laboratory would not last and our cooperation could be continued in the future.

My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Lastly, I am grateful to all my family members and my dear husband for their support and motivation. Thank you....

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	TITLE	PAGE
	TITLE	i
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
	LIST OF PHOTOS	xv
	LIST OF SYMBOLS	xvii
	LIST OF APPENDICES	xix
CHAPTER 1	INTRODUCTION	
	1.1 Objectives	4
	1.2 Scope of the study	5

CHAPTER 2 LITERATURE REVIEW

2.1	Shear	6
2.2	Shear stress variation in rectangular beams	7
2.3	Shear stress variation in reinforced rectangular beams	9
2.4	Shear failure in beams without shear reinforcement	10
2.5	Types of shear failure	12
2.6	Shear reinforcement in beams	14
2.6.1	Types of shear reinforcement	17
2.6.2	Shear resistance of a beam with vertical links	18
2.6.3	Shear resistance of a beam with bent-up bars	21
2.7	Reinforced concrete beams	24
2.7.1	Stress-strain relations	24
2.7.1.1	Concrete	24
2.7.1.2	Steel	25
2.7.2	Design formulae for rectangular section (BS 8110)	26
2.8	Shear resistance in design calculation (BS 8110)	27
2.9	Summary	29

CHAPTER 3	EXPERIMENTAL INVESTIGATION	
3.1	Introduction	41
3.2	The model of shear reinforcement system	42
3.2.1	Details of beam B1	42
3.2.2	Details of beam B2	43
3.2.3	Details of beam B3	43
3.2.4	Details of beam B4	44
3.2.5	Details of beam B5	45
3.2.6	Details of beam B6	46
3.3	The materials of reinforced concrete beam	46
3.3.1	Concrete	46
3.3.2	Steel reinforcement	49
3.3.3	Mould	50
3.4	Manufacture of specimens	51
3.5	Slump test	52
3.6	Compression tests : cube test	53
3.7	Instrumentation	54
3.8	Test procedure	55

CHAPTER 4

CHAPTER 4	69
TEST RESULTS	
4.1 Beam B1	70
4.1.1 Specimen behaviour during the test	71
4.1.2 Test results	71
4.2 Beam B2	72
4.2.1 Specimen behaviour during the test	73
4.2.2 Test results	73
4.3 Beam B3	74
4.3.1 Specimen behaviour during the test	75
4.3.2 Test results	75
4.4 Beam B4	76
4.4.1 Specimen behaviour during the test	76
4.4.2 Test results	77
4.5 Beam B5	77
4.5.1 Specimen behaviour during the test	78
4.5.2 Test results	79
4.6 Beam B6	79
4.6.1 Specimen behaviour during the test	80
4.6.2 Test results	

CHAPTER 5	
ANALYSIS AND DISCUSSION	106
5.1 Introduction	107
5.2 Analysis and discussion of test results	107
5.2.1 Shear resistant	110
5.2.2 Strain	111
5.2.3 Deflection	112
5.3 Shear stress analysis	112
5.3.1 Beam B1	113
5.3.2 Beam B2	113
5.3.3 Beam B3	114
5.3.4 Beam B4	115
5.3.5 Beam B5	116
5.3.6 Beam B6	
CHAPTER 6	
CONCLUSION AND RECOMMENDATIONS	121
6.1 Conclusion	122
6.2 Recommendations	
	123
REFERENCE	
	124
BIBLIOGRAPHY	

LIST OF TABLES

TABLE NO.	TITLE	PAGE
3.1	Shear reinforcement system	57
3.2	Proportion of concrete mix design	57
4.1	Ultimate load of beams with various shear reinforcement system	81
4.2	Deflection data for beam B1	82
4.3	Deflection data for beam B2	83
4.4	Deflection data for beam B3	84
4.5	Deflection data for beam B4	85
4.6	Deflection data for beam B5	87
4.7	Deflection data for beam B6	89
5.1	The difference in percentages of ultimate load compared to beam B2 as control specimen	118
5.2	The difference of shear resistant between theory and test result	118

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	AA-Shear plane	31
2.2	Principal stresses in a beam	31
2.3 (a)	Shear	32
2.3 (b)	Distribution of shear stresses in rectangular beams	32
2.4	Shear stresses variation in reinforced rectangular Beams	33
2.5	Inclined cracks pattern	33
2.6	Failure due to a_v/d ratio	34
2.7 (a)	$a_v/d > 6$	34
2.7 (b)	$6 > a_v/d > 2$	35
2.7 (c)	$a_v/d < 2$	35
2.7 (d)	$a_v/d = 0$	36
2.7 (e)	Shear reinforcement	36
2.8	Types of shear reinforcement	37
2.9	Vertical links	37
2.10	Vertical links and the analogous truss	38
2.11	Bent-up bars system	38
2.12	Truss theory	39
2.13	Stress-strain curves for concrete	39
2.14	Stress-strain curves for steel reinforcement	40
3.1 (a)	Beam 1	58

3.1 (b)	Beam 2	58
3.1 (c)	Beam 3	59
3.1 (d)	Beam 4	59
3.1 (e)	Beam 5	60
3.1 (f)	Beam 6	60
3.2	Concrete strength-day relationship	61
4.1	Load-deflection relationship for beam B1	91
4.2	Load-deflection relationship for beam B2	92
4.3	Load-deflection relationship for beam B3	93
4.4	Load-deflection relationship for beam B4	94
4.5	Load-deflection relationship for beam B5	95
4.6	Load-deflection relationship for beam B6	96
4.7	Load-deflection relationship for all beams	97
4.8	Load-strain relationship	98
5.1	Ultimate load-beam relationship	119
5.2	Maximum deflection-beam relationship	120

LIST OF PHOTOS

PHOTO NO.	TITLE	PAGE
3.1	Beam without shear reinforcement (B1)	62
3.2	Beam with shear and nominal links in the form of vertical links (B2)	62
3.3	Beam with nominal links and horizontal bars (B3)	63
3.4	Beam with nominal links and increased amount of horizontal bars (B4)	63
3.5	Beam with nominal links and inclined (B5)	64
3.6	Beam with nominal links and increased amount of inclined bars (B6)	64
3.7	Mechanical mixer	65
3.8	Machine for bent-up bar	65
3.9	Steel moulds	66
3.10	G-clamps	66
3.11	Steel moulds for cube concrete	67
3.12	Cube test	67
3.13	Test setup	68
4.1	Compression test of cube concrete	99
4.2 (a)	Beam B1 without shear reinforcement, failed in shear	100
4.2 (b)	Shear cracks on beam B1	100

4.3 (a)	Beam B2 with vertical links, failed in shear	101
4.3 (b)	Shear cracks on Beam B2	101
4.4 (a)	Beam B3 with horizontal bar as shear reinforcement, failed in shear	102
4.4 (b)	Shear cracks on beam B3	102
4.5 (a)	Beam B4 with an increased amount of horizontal bar as shear reinforcement, failed in shear	103
4.5 (b)	Shear cracks on beam B4	103
4.6 (a)	Beam B5 with independent inclined bar as shear reinforcement, failed in shear	104
4.6 (b)	Shear cracks on beam B5	104
4.7 (a)	Beam B6 with an increased amount of independent inclined bar as shear reinforcement, failed in flexure	105
4.7 (b)	Crushing the concrete at the compression zone	105

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

APPENDIX	TITLE	PAGE
A	Analysis	126
B	Concrete mix design form	131

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 warning¹ 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° 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/mm².
- e) The variables in these specimens are the shear reinforcement systems, which are vertical links, independent inclined bars and additional horizontal bars.

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