

INFLUENCE OF INDEPENDENT BENT-UP BARS ON THE SHEAR  
CAPACITY OF REINFORCED CONCRETE BEAMS

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*To my beloved parents, brothers, sisters and friends.....*

*Especially to,*

*My father, who found in his heart the well*

*And tolerances to allow me follow my dreams and aspirations.....*

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## ABSTRACT

Reinforced concrete beams are designed to resist bending due to applied moments; however it is equally important to design them for shear in order to avoid sudden failure due to shear forces. This paper aims at studying the effectiveness and feasibility of the use of independent bent-up bars systems as shear reinforcement. The proposed systems are to replace the conventional stirrups and stand alone as shear reinforcement. The effect of different parameter involved in the shear phenomenon were reviewed in order to better understand the behavior of reinforced concrete beams when exposed to shearing forces. For verification, a beam with conventional stirrups was used as a control specimen to which the results obtained were compared. As was expected, all the proposed systems provided better shear resistance than the control; beam, this can be seen by the maximum loads at which they failed, the less cracks formed in the shear spans and by the type of failure where they all failed in bending except for specimen B6. B1 failed at load 220 kN, this beam was the control beams reinforced in shear with R6-50mm links. B2, B3, B4, B5 and B6 failed at 245kN, 230kN, 230kN, 240kN and 240kN, respectively. Specimen B2 was reinforced with least amount of shear reinforcement of all the specimens, about 20 percent less than the control specimen, yet showed the highest resistance and the highest ductility where it failed at load 240kN and a maximum deflection of 24.51mm. Similarly specimen B4 failed at 230 kN and had relatively high ductility where the maximum deflection occurred at failure was 21.71mm. On the other hand B3, B5 and B6 still provided more shear resistance than the control beam, however showed very low ductility where the beams failed at maximum deflections of 10.5mm, 9.91mm and 10.22mm, respectively. All in all, independent bent-up bar systems are effective in resisting shear and hence; should be used on their own and not only if combined with stirrups.

## ABSTRAK

Rasuk konkrit bertetulang direkabentuk untuk merintang lenturan disebabkan perletakkan momen; walaubagaimanapun kepentingannya sama pada rekabentuk ricih dalam mengelakkan kegagalan mendadak disebabkan daya ricih. Kajian ini bertujuan mengkaji keberkesanan dan kebolehlaksanaan penggunaan sistem bar bengkok atas bebas sebagai tetulang ricih. Kesan parameter yang berbeza juga terlibat di dalam fenomena ricih dikaji semula dalam usaha memahami kelakuan ricih pada rasuk konkrit bertetulang. Rasuk tetulang pugak konvensional telah digunakan sebagai specimen kawalan dimana hasil keputusan yang didapati telah dibandingkan. Seperti yang telah dijangkakan, kesemua sistem yang telah dicadangkan menyediakan rintangan ricih yang lebih baik daripada kawalan; rasuk, ini dapat dilihat pada beban maksimum kegagalan berlaku, keretakan terbentuk berkurangan pada rentangan ricih dan dimana kesemuanya gagal dalam lenturan kecuali specimen B6. B1 telah gagal pada beban 220 kN, rasuk ini adalah rasuk bertetulang kawalan dengan ricih R6-50mm tetulang pugak. B2, B3, B4, B5 and B6 telah gagal pada 245kN, 230kN, 230kN, 240kN dan 240kN. Spesimen B2 dengan tetulang ricih yang paling sedikit, kira-kira 20 peratus kurang daripada spesimen kawalan, menunjukkan rintangan dan kemuluran tertinggi dimana kegagalan berlaku pada beban 240kN dan pesongan maksimum sebanyak 24.51mm. Spesimen B4 gagal pada 230kN dan mempunyai kemuluran agak tinggi dimana pesongan maksimum berlaku pada 21.71mm. Sebaliknya B3, B5 dan B6 masih menyediakan lebih rintangan ricih daripada rasuk kawalan, walau bagaimanapun menunjukkan kemuluran yang terendah dimana rasuk gagal pada pesongan maksimum 10.5mm, 9.91mm dan 10.22mm. Secara kesimpulannya, penggunaan sistem bar bengkok atas bebas adalah berkesan dalam merintang ricih dan ia sepatutnya digunakan sendiri dan bukan sahaja dikombinasikan dengan tetulang pugak ricih.

## TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	<b>DECLARATION</b>	<b>ii</b>
	<b>DEDICATION</b>	<b>iii</b>
	<b>ACKNOWLEDGEMENTS</b>	<b>iv</b>
	<b>ABSTRACT</b>	<b>v</b>
	<b>ABSTRAK</b>	<b>vi</b>
	<b>TABLE OF CONTENTS</b>	<b>vii</b>
	<b>LIST OF TABLES</b>	<b>xi</b>
	<b>LIST OF FIGURES</b>	<b>xii</b>
	<b>LIST OF SYMBOLS</b>	<b>xvi</b>
<b>1</b>	<b>INTRODUCTION</b>	
	1.1 Background	1
	1.2 Problem Statement	2
	1.3 Objectives of the Study	3
	1.4 Scope of the Study	3
<b>2</b>	<b>LITERATURE REVIEW</b>	
	2.1 Introduction	5
	2.2 Modes of Failure in Beams without Shear Reinforcement	9

2.2.1	Diagonal Tension Failure	9
2.2.2	Shear Compression Failure	10
2.2.3	Splitting “True Shear”	10
2.3	Variables influencing the Shear Strength of RC Beams	11
2.3.1	Effect of Shear Span-to-Depth Ratio ( $a/d$ )	11
2.3.2	Effect of the Compressive of Concrete, $f_{ck}$	12
2.3.3	Effect of Tensile Reinforcement Ratio, $\rho$	14
2.3.4	Effect of Flexural Member Size	16
2.4	Crack Shear and Ultimate Shear Strengths	17
2.5	Different Configurations of Shear Reinforcement	19
2.6	Shear Design in Codes of Practice	20
2.7	Members Not Requiring the Design of Shear Reinforcement	20
2.7.1	Requirements in BS 8110-1:1997	20
2.7.2	Requirements in BS EN 1992-1-1:2004	22
2.8	Member Requiring the Design of Shear Reinforcement	23
2.8.1	Requirements in BS 8110-1:1997	23
	2.8.1.1 Stirrups (Vertical shear Links)	24
	2.8.1.2 Bent-up Bars	26
2.8.2	Requirements in BS EN 1992-1-1:2004	31
	2.8.2.1 Members with Vertical Shear Reinforcement	32
	2.8.2.2 Members with Inclined Shear Reinforcement	33
	2.8.2.3 Members with Bent-Up Bars	33
2.9	Summary	35

### **3 EXPERIMENTAL INVESTIGATION**

3.1	Materials	37
3.1.1	Formwork	37
3.1.2	Concrete	38
3.3.3	Reinforcement	39

3.2	Specimens Preparation	39
3.2.1	Design of Control Specimen, B1	39
3.2.2	Reinforcement Arrangements in the Specimens	41
3.2.2.1	Specimen B1	41
3.2.2.2	Specimen B2	43
3.2.2.3	Specimen B3	44
3.2.2.4	Specimen B4	45
3.2.2.5	Specimen B5	45
3.2.2.6	Specimen B6	46
3.2.3	Casting the Specimens	48
3.3	Testing Method	50
3.4	Summary	52

## **4 EXPERIMENTAL RESULTS**

4.1	Cubes Compressive Test Results	53
4.2	Beam Results	55
4.2.1	Specimen B1	55
4.2.1.1	Specimen's Behavior	56
4.2.1.2	Test Results	57
4.2.2	Specimen B2	58
4.2.2.1	Specimen's Behavior	58
4.2.2.2	Test Results	59
4.2.3	Specimen B3	61
4.2.3.1	Specimen's Behavior	61
4.2.3.2	Test Results	62
4.2.4	Specimen B4	64
4.2.4.1	Specimen's Behavior	64
4.2.4.2	Test Results	66
4.2.5	Specimen B5	67
4.2.5.1	Specimen's Behavior	67
4.2.5.2	Test Results	69
4.2.6	Specimen B6	70



4.2.6.1 Specimen's Behavior	70
4.2.6.2 Test Results	72
4.3 Summary of Test Results	74
<b>5 ANALYSIS AND DISCUSSION</b>	
5.1 Analysis and Discussion of Test Results	77
5.1.1 Shear Resistance	77
5.1.2 Modes of Failure	81
5.1.3 Deflection Analysis	83
5.2 Summary	84
<b>6 CONCLUSION AND RECOMMENDATIONS</b>	
6.1 Conclusion	86
6.2 Recommendations	87
<b>References</b>	88
<b>Bibliography</b>	89
<b>Appendices</b>	90

**LIST OF TABLE**

<b>TABLE NO.</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Values of $v_c$ provided in BS8110	22
2.2	Form and area of shear reinforcement in beams (BS8110-1:1997)	25
2.3	$\beta$ values provided in BS8110: part 1 Clause 3.12.8.4, table 3.26	31
4.1	Cubes compressive strengths	54
4.2	Summary of the shear reinforcement arrangements in the six specimens	74
4.3	Summary of the lab test results	75
5.1	Percentage difference of maximum loads at failure compared to the control specimen, B1.	80
5.2	Theoretical and experimental shear resistance values	80
5.3	Shear reinforcement and the failure location	82

**LIST OF FIGURES**

<b>FIGURE NO.</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	A beam tested for shear under point loading	7
2.2	Shear stress in a rectangular beam of a uniform section	8
2.3	Configuration of diagonal tension cracks	9
2.4	Configuration of a web shear crack	10
2.5	Shear crack configuration when the shear span is less than the effective depth of the member	11
2.6	Shear span and effective depth definition	12
2.7	Beam section reinforced with I section, longitudinal reinforcement, and transverse web reinforcement I	13
2.8	Beam section reinforced with longitudinal reinforcement	14
2.9	Effect of tensile reinforcement ratio on shear strength of flexural member	15
2.10	Beams of different sizes tested to study the effect of size on shear strength	17
2.11	Effect of different tensile reinforcement ratios on $V_c$ and $V_u$	19
2.12	Different stirrups configurations	25
2.13	Different inclined system configurations	27

2.14 (a)	Equivalent single truss system;	28
2.14 (b)	Inclined bars crossing Crack	28
2.15	Truss model for the design of shear reinforcement (BS EN 1992-1-1:2004)	32
2.16 (a)	Single bent-up bars system	34
2.16 (b)	Multiple bent-up bars system	34
3.1	Formwork prepared for the casting of the six beams	38
3.2	Specimens cross-section and tensile reinforcement	40
3.3	Stress block diagram for the proposed cross-section	40
3.4	Reinforcement arrangements in the control specimen B1	42
3.5	Shear links in specimen B1 after being fixed in place	42
3.6	Reinforcement arrangements in specimen B2	43
3.7	Reinforcement arrangements in specimen B3	44
3.8	Reinforcement arrangements in specimen B4	45
3.9	Reinforcement arrangements in specimen B5	46
3.10	Reinforcement arrangements in specimen B6	47
3.11	Stiffeners used to ensure the dimensional details of the beams	48
3.12	Test specimens and cubes covered with a plastic cover	48
3.13	Test specimens after removing the formwork	49
3.14	Schematic of the testing frame	50
3.15	The actual testing frame after placing a test specimen	51
3.16	LVDTs used to measure beam deflections at multiple locations	51

3.17	The concrete strain gauge attached to the surface of the concrete	52
4.1	Cube compressive strength development from the casting day to the last testing day	55
4.2	Specimen B1 at failure with close ups at failure points and cracking in the shear spans	56
4.3	Load-deflection behavior for specimen B1	57
4.4	Specimen B2 at failure with close ups at failure points and cracking in the shear spans	59
4.5	Load-deflection behavior for specimen B2	60
4.6	Load-strain behavior on both sides of specimen B2	60
4.7	Specimen B3 at failure with close ups at failure points and cracking in the shear spans	62
4.8	Load-deflection behavior for specimen B2	63
4.9	Load-strain behavior on both sides of specimen B3	63
4.10	Specimen B4 at failure with close ups at failure points and cracking in the shear spans	65
4.11	Load-deflection behavior for specimen B4	66
4.12	Load-strain behavior in specimen B4	66
4.13	Specimen B5 at failure	67
4.14 (a)	Left hand side shear span where shear cracks are not visible	68
4.14 (b)	Right hand side shear span where one clear shear crack occurred	68
4.15	Load-deflection behavior for specimen B4	69
4.16	Load-strain behavior in specimen B5	70

4.17	Specimen B6 at failure	71
4.18	Crack pattern in the shear span in specimen B6	72
4.19	Load-deflection behavior for specimen B6	73
4.20	Load-strain behavior in specimen B6	73
5.1	Ultimate loads at failure of the six specimens	79
5.2	Maximum deflections obtained at failure	83
5.3	Comparison of the deflections obtained for the six specimens	84

**LIST OF SYMBOLS**

$A$	-	Area of a cross-section
$A_s$	-	Area of tension reinforcement
$A_{sw}$	-	Cross-sectional area of shear reinforcement as links or bent-up
$A_{s,prov}$	-	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
$f_{ck}$	-	Characteristic concrete cube strength at 28 days
$f_{yk}$	-	Characteristic strength of reinforcement
$L$	-	Effective span of a beam
$M$	-	Bending moment
$S_b$	-	Spacing of bent-up bars
$S_v$	-	Spacing of links

V	-	Shear force at ultimate design load
V <sub>b</sub>	-	Design ultimate shear resistance of bent-up bars
V <sub>c</sub>	-	Design ultimate shear resistance of a concrete section
v	-	Shear stress
v <sub>b</sub>	-	Design shear stress resistance of bent-up bars
v <sub>c</sub>	-	Design ultimate shear stress resistance of a singly reinforced concrete beam
V <sub>Rd,c</sub>	-	Concrete shear capacity based on Eurocode 2
α	-	Angle between a bent-up bar and the axis of a beam
ρ <sub>o</sub>	-	The reference ratio = $\sqrt{f_{ck}} / 1000$
ρ	-	The required tension reinforcement ratio at mid-span to resist moment due to the design loads



## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Background**

Beams are designed to resist deflection due to applied moment; however this is not adequate because there are other failures that are more dangerous than flexural failure. Shear failure or more properly termed as “Diagonal Tension Failure” is one example of those failures that could lead to the collapse of the beam if it is not designed properly to resist the applied shear stress.

The beam is designed first for flexural resistance, and then checked if it is requiring the design of special shear reinforcement. The check is dependent on the shear stress applied compared to the shear capacity of the section before considering the shear reinforcement. The main goal of the design is to make sure that the beam fails in flexural before shear.

There are two types of inclined cracks in reinforced concrete beams: flexural shear cracking and web shear cracking. The web shear cracking occurs at the point when the principal tensile stresses exceed the concrete tensile strength. On the other

hand, the flexural cracking occurs when the shear and tensile stresses exceed the tensile strength of the concrete. The web shear cracks usually occur near the supports, while the flexural cracking occur, while the flexural cracks occur in the mid-span where the moment is maximum, in simply supported beams for example.

In reinforced concrete beams with no shear reinforcement, the shear strength is provided by the aggregate interlocking, the shear stress in the beam compression zone, and the dowel action resulting from the flexural longitudinal reinforcement <sup>[15]</sup>. It is generally practiced to neglect all the factors except for the concrete stress, the reason is that the effect of the other factors is relatively small.

In reinforced concrete beams with shear reinforcement, the shear strength is provided by all of the factors mentioned earlier in addition to the shear reinforcement that provided resisting shear stress to the cracking stress. Shear reinforcement when present in RC beams allows for maximum utilization of tension reinforcement, and permits a ductile failure mode rather than sudden and dangerous.

## **1.2 Problem Statement**

The use of bent-up bars for shear reinforcement has not been so popular due to the difficulty of fabrication. However the combination of vertical shear links and bent-up bars has been used, it was not so common. In accordance with the design codes BS8110 and EC2, the bent-up bars require anchorage length that is dependent on the diameter of the bars to be used, in some cases; the anchorage could go through the concrete cover and project to the outside. In addition, the use of bent-up bars means less reinforcement is provided to resist shear and worries occur that it will not provide the needed shear capacity. This study will study the feasibility of using an independent bent-up bars system than can be fabricated and installed in a much

easier manner than the one in practice. Furthermore, the bent-up bars to be provided will have insufficient anchorage lengths in order to study if the shear capacity provided is adequate. The main purpose of this study is to foresee if the design shear capacity can be provided by the bent-up bars alone without the vertical shear links.

### **1.3 Objectives of the Study**

The main objectives of the study are as follows:

- I. To investigate the effectiveness of using independent bent-up bars systems as shear reinforcement in rectangular beams.
- II. To study the effectiveness of bent-up bars with insufficient anchorage length for shear reinforcement.
- III. To compare the different proposed shear reinforcement alignments to a conventionally reinforced concrete beam.

### **1.4 Scope of the Study**

Six rectangular reinforced concrete beams are going to be cast and test for the effectiveness of the proposed shear reinforcement alignments. All the beams are going to have the same size and the same longitudinal reinforcement and only differ in the shear reinforcement.

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