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 merintangi 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, keretakkan 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 sepesimen 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 merintangi ricih dan ia sepatutnya digunakan sendiri dan bukan sahaja dikombinasikan dengan tetulang pugak ricih.

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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
Asv	-	Total cross-sectional area of links at the neutral axis
a_v	-	Shear span
b	-	Width of a section
bv	-	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
Vb	-	Design ultimate shear resistance of bent-up bars
Vc	-	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
$V_{Rd,c}$	-	Concrete shear capacity based on Eurocode 2
α	-	Angle between a bent-up bar and the axis of a beam
ρ_o	-	The reference ration = $\sqrt{fck}$ /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 [15]. 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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