THE EFFECTIVENESS OF WELDED INCLINED BARS AS SHEAR REINFORCEMENT IN RECTANGULAR BEAM

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Specially dedicated to my beloved Family and Kaduna State Overseas Scholarship

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ABSTRACT

The use of bent-up bars as shear reinforcement has received little preference from the designers due to the unavailability of space for the anchorage, and also due to the insufficient number of mid-span bars to be bent-up in the shear region near the supports. Welded independent inclined bars (WIB) are not affected by these two shortcomings. This report presents the results of laboratory test on rectangular reinforced concrete beams in which the effectiveness of WIB as shear reinforcement were studied. In order to investigate the influence of the quantity, spacing and the inclined angle of the WIB on the shear capacity of the beams, five beams were tested. All the beams were identical in size and quantity of flexural reinforcement. The control beam was provided with vertical links, while the other four were provided with WIB of different amount, pitch and inclination angle to the longitudinal axis of the beams. The specimens were tested to failure and their performance was measured in terms of ultimate load, deflection and crack patterns. The results obtained show that all the beams with WIB achieve larger ultimate loads than the control beam. It also reveals that the beams with larger quantities of WIB and larger inclination angle are stronger in shear that they failed in flexural. The results suggest that the WIB can be applied as shear reinforcement in the design of rectangular reinforced concrete beams.

ABSTRAK

Penggunaan bar condong sebagai tetulang ricih kurang mendapat penerimaan daripada pereka bentuk kerana kekurangan ruang untuk tambatan, dan juga kerana kekurangan bilangan tetulang pada pertengahan rentang untuk dibengkokkan dalam rentang ricih yang berhampiran dengan penyokong. Bar condong berkimpal bebas (WIB) tidak terjejas oleh kedua-dua kelemahan ini. Laporan ini membentangkan keputusan ujikaji makmal keatas rasuk segiempat bertetulang konkrit dimana keberkesanan WIB sebagai tertulang ricih telah dikaji. Bagi mengkaji pengaruh kuantiti, sela dan sudut kecondongan WIB keatas keupayaan ricih rasuk, sebanyak lima batang rasuk teleh diuji. Kesemua rasuk adalah sama dari segi saiz dan kuantiti tetulang lenturan. Rasuk kawalan disediakan dengan pautan menegak, manakala empat batang rasuk lagi disediakan dengan WIB daripada kuantiti, sela dan sudut kecondongan terhadap paksi memanjang rasuk yang berbeza. Kesemua specimen diuji hingga gagal dan prestasi specimen diukur dari segi beban muktamad, pesongan dan corak keretakan. Keputusan yang diperolehi menunjukkan kesemua rasuk yang disediakan dengan WIB mencapai beban muktamad yang lebih besar berbanding rasuk kawalan. Ia juga menaempilkan bahawa rasuk dengan kuantiti WIB dan sudut kecondongan yang lebih besar mempunyai kekuatan ricih yang lebih tinggi sehigga gagal dalam lenturan. Hasil daripada kajian menunjukkan bahawa WIB boleh digunakan sebagai tetulang ricih dalam rekabentuk rasuk segiempat konkrit bentetulang.

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LIST OF SYMBOLS

A_c	-	Cross-Section Area of Concrete
$_nA$	-	Equivalent Concrete Area
A_s	-	Cross-Section Area of Reinforcement
A_{sw}	-	Cross-Section Area of Shear Reinforcement
b	-	Overall Width of a Cross-Section
d	-	Effective Depth
f_c	-	Compressive Strength of Concrete
f_{ck}	-	Characteristic Strength of Concrete
f_{ctm}	-	Mean Tensile Strength of Concrete
f_t	-	Tensile Strength of Reinforcement
f_{yk}	-	Characteristic Yield Strength of Reinforcement
h	-	Overall Depth of a Cross-Section
s	-	Spacing of Reinforcement
x	-	Neutral Axis Depth
z	-	Lever Arm of Internal Forces
E_c	-	Young's Modulus of Concrete
E_s	-	Design Value of Modulus of Elasticity of Reinforcing Steel
E_y	-	Yield Strain
M	-	Bending Moments
M_{cr}	-	Cracking Moment
M_u	-	Ultimate Moment
M_y	-	Yield Moment
P	-	Applied Load
V	-	Shear Forces
V_{Ed}	-	Maximum Shear Force

$V_{Rd,c}$	-	Design Shear Resistance of a Section Without Shear Reinforcement
X_{ck}	-	Compression Strain
X_s	-	Tensile Steel Strain

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CHAPTER 1

INTRODUCTION

1.1 General

Shear failures in reinforced concrete (RC) beams are undesirable due to their brittle nature which causes sudden collapse with little or no warning. Moayyad et al stated that structures are mainly designed to exhibit ductility characteristics in order to give amplitude warning of impending collapse. The causes of shear failure are likely to be associated with the stress conditions in the region of the path along which the compression force is transmitted to the supports after the occurrence of diagonal cracks. Beams fail immediately upon formation of critical cracks in the high shear region near the beam supports.

In the design of a RC member, consideration has to be made on the flexure first which leads to the size of the section and the arrangement of reinforcement to provide the necessary resistance for moments then the shear. Limits are placed on the amounts of flexural reinforcement to ensure ductile type of failure for the member before the shear design for beam. The design for shear should ensure that the shear strength for every member in the structure exceeds the flexural strength. The shear failure mechanism varies depending upon the cross-sectional dimensions, the geometry, the types of loading, shear span to depth ratio (a/d), tension steel ratio (ρ), compressive strength of concrete (f_{ck}), size of coarse aggregate, density of concrete, tensile strength of concrete, support conditions, clear span to depth ratio (L/d), grade of tension reinforcement and end anchorage of tension reinforcement (Marta, 2014).

According to Moayyad et al, when the value of actual shear stress exceeds the permissible shear stress of concrete used, the shear reinforcement should be provided. The purpose of shear reinforcement is to prevent failure in shear, and to increase beam ductility and subsequently the likelihood of sudden failure will be reduced. Normally, the inclined shear cracks start at a plane perpendicular to the principal tensile stress and above the neutral axis subjected to normal compressive stresses in addition to shearing stresses of the beam near support at approximately 45° and extends toward the compression zone. Any form of effectively anchored reinforcement that intersects these diagonal cracks will be able to resist the shear forces to a certain extent. In practice, shear reinforcement is provided in the forms of stirrups and combination system of stirrups and bent-up bars. Stirrups are most commonly used as shear reinforcement in practice today, for their simplicity in fabrication and installation were spacing between stirrups is reduced to resist high shear stress. Congestion near the support of RC beams due to the presence of the closely spaced stirrups increases the cost and time required for installation. The combination of bent-up bars with stirrups had been used in the past where all the tensile reinforcement is not needed to resist bending moment, some of the tensile bars were bent-up in the region of high shear to form the inclined legs of shear reinforcement.

1.2 Problem Statement

Stirrups are most commonly used shear reinforcement in construction because of their simplicity in fabrication and installation were spacing between stirrups is reduced to resist high shear stress near the support of RC beams leading to congestion of the stirrups near the support which can increases the cost and time required for installation and according to Ozcebe et al, vertical stirrups is insufficient in resisting shear failure of structural members. The combination of bent-up bars with stirrups had been used in the past and according to Lucca et al, its' advantage was that they acted as flexural reinforcement while they also worked as shear reinforcement, but not preferred nowadays due to difficulties in construction were the combination of bent-up bars with stirrups used as shear reinforcement in which the tensile bars are bent-up in the high shear region and according to the code of practice which states that at least 40% of tensile reinforcement can be bent-up as shear reinforcement in the shear region of beam near the support. Reinforcement bars can be bent diagonally in shear region while the others are straightened up to the support. Unfortunately, bent-up bars are rarely used especially in beams with small number of bars been provided. The combination of bent-up bar with stirrups system is not suitable due to insufficient straight bars left to be extended to the support as required by the code of practice.

Hence, the main purpose of the study is to determine how independent welded inclined bars can be used as shear reinforcement in rectangular RC beams such that it is not affected by the number of straight bars extended to it.

1.3 Research Objectives

The objectives of the study are:

i. To assess the effectiveness of welded inclined bars in relation to its shear resisting capacity.

ii. To study the performance of the welded inclined bars systems as shear reinforcement in rectangular RC beams.

iii. To examine the effect of welded inclined bars with different inclination angle for shear resisting capacity.

1.4 Scope of Study

The study focus on the experimental investigation with the scope listed below;

i. The study was based on the experimental investigation on five rectangular RC beams

ii. All the specimens has identical dimensions of 0.2m width, 0.25m depth and 2.3m length.

iii. All the beams has the same amount of reinforcement which is 3H16 and 2H10 for tension and compression respectively.

iv. The specimens were designed with concrete compressive strength of $30N/mm^2$.

v. Demec buttons were attached to each specimen diagonally at the shear span of the two sides near the supports.

vi. The beams were tested in a Magnus frame test set-up.

vii. 3 Linear Voltage Displacement Transducer (LVDT) were placed under the specimen at the two point loads and mid span of the beam.

viii. The test was carried out in load vs deflection relationship.

ix. Continuous increased of the load on the specimen until the load decreased with the increased in deflection, the ultimate load for the beam was reached.

In the investigation, all the beams were allowed to fail only in shear, so adequate amount of tension reinforcement were provided to give a sufficient bending moment resistance.

1.5 Methodology

The research work reviewed of relevant literatures in order to acquire an in-depth understanding of the issues related to the subject and also discussion with professionals on the subject matter.

The experimental study was carried out to investigate the influence of welded inclined bars of different shear reinforcement to check the shear resistance conditions of rectangular RC beams. The experiment was carried out at the laboratory in Faculty of Civil Engineering Universiti Technologi Malaysia (UTM).

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