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BEHAVIOUR OF WIDE REINFORCED CONCRETE BEAM IN SHEAR

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

Faculty of Civil Engineering
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DECEMBER 2010

I declare that this project entitled "*Behaviour of wide reinforced concrete beam in shear*" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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To my lovely mother, and to my honorable father
and to my dear brothers

Thank you all for the plentiful supports

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ABSTRACT

Wide reinforced concrete beams were been used in buildings to reduce reinforcement congestion and floor heights for a required headroom. The beam in most of these cases is wider than that of the supporting columns. Consequently, their shear capacity might be effected and differ from that of conventional beams. This project report presents the test results of ten wide beam specimens in which their shear performances were studied. The influence of the support widths (100%, 50% and 25% of the beam width), the arrangement of flexural reinforcement across the beam width, and the presence of shear reinforcement in the forms of vertical links, were investigated. The test setup was made similar for all the specimens, two pointed load were distributed equally on the beam width, each at distance equal to 630 mm from the center of support, therefore, all the specimens failed in diagonal tension shear. The results showed that the narrow support has no effect on the shear strength of concrete and the influence of concentrating the flexural reinforcement within the support width has no significant effect on the shear strength of concrete. On the other hand, the links efficiency reduced by 80 % due to the narrow support, and the influence of concentrating the flexural reinforcement within the support width recovers their efficiency to 100 %.

ABSTRAK

Rasuk lebar konkrit bertetulang digunakan dalam bangunan untuk mengurangkan kesesakan tetulang dan ketinggian tingkat yang dikehendaki pada ruang bilik. Rasuk dalam kebanyakkan kes adalah lebih lebar supaya ia dapat menyokong tiang. Oleh sebab itu, kapasiti ricih rasuk lebar kemungkinan memberi kesan dan berlainan daripada rasuk konvensional. Laporan projek ini telah menghasilkan keputusan ujian ke atas sepuluh spesimen rasuk lebar di mana kelakuan ricih di kaji. Pengaruh terhadap lebar penyokong (100%, 50% dan 25% lebar rasuk), penyusunan tetulang utama merentasi lebar rasuk, dan kehadiran tetulang ricih dalam bentuk perangkai pugak telah dijalankan. Perbentukkan ujikaji telah dibuat sama untuk kesemua spesimen, dua titik beban diagihkan secara samarata pada lebar rasuk, di mana setiap jarak bersamaan 630 mm daripada pusat penyokong. Oleh itu, kesemua spesimen gagal dalam penjuru ricih tegangan. Keputusan telah menunjukkan bahawa penyokong yang sempit tidak memberi kesan ke atas kekuatan ricih konkrit dan pengaruh pada penumpuan tetulang utama dalam lebar penyokong tidak memberi kesan jelas pada kekuatan ricih konkrit. Dengan kata lain, keberkesanan perangkai dikurangkan sebanyak 80% disebabkan oleh penyokong yang sempit, dan pengaruh yang menumpukan pada tetulang utama dalam lebar penyokong dengan mendapat semula kebersanannya kepada 100%.

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A_s	-	Area of tension reinforcement
A_{sh}	-	Area of shrinkage bars
A_v	-	Area of links
a_v	-	Shear arm
b	-	Beam width
b_s	-	Support width
d	-	Effective depth
f_{cu}	-	Concrete strength
f_y	-	Tension reinforcement strength
f_{yv}	-	Characteristic strength of links
h	-	Overall section depth
k	-	Ratio of support to beam widths ($k=b_s/b$)
L	-	Total span length
L_0	-	Effective span length
M	-	Moment
S_v	-	Spacing of links along the member
V	-	Shear force due to ultimate load
ν	-	Design shear stress at a cross-section
ν_c	-	Design concrete shear stress
w_s	-	The width in which the (ρ_s) distributed in
γ_m	-	Partial safety factor for strength of material
ρ	-	Percentage area of tension reinforcement ($\rho=100A_s/b.d$)
ρ_s	-	Percentage area of tension reinforcement on (w_s)

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CHAPTER 1

INTRODUTION

1.1 Introduction

Reinforced concrete beams are common elements in more than 80% of the structures around the world, used as horizontal members transferring the load from the floor slab to the vertical members, also, it used for stiffening the structure, by connecting the columns together creating a stiff structural system.

These beams are made from concrete, which it is easy to shape, various geometries could be found in the structures, depending on the structure requirements and also the design, where flanged concrete beams could be found as L, T or double T shapes, and the another shapes which are not common such the hollow beam section as trapezoidal or box shape.

The most common reinforced concrete beams are inform of solid rectangular shape, and there is no concrete structure does not have it, since the design procedures and requirements are simple, beside, construction of these beams does not required complexity or special tools.

Even through the rectangular solid beams variation in the length, width and depth is possible, where deep, shallow and conventional beams are considers rectangular in shape and the difference is only by their behaviour, which finally affect the design procedures and requirements.

The deep reinforced concrete beams are rarely use in structures, and mainly used as transfer girders, supporting new planted columns in which changing in the structure plan is required, in addition, it is common in the tall building system as outriggers, used to increase the stiffness of the structure by reducing the affect of lateral load.

The shallow and the conventional reinforced concrete beams are widely used in all types of concrete structures, the solid slab and the beams which carry it are an example, and usually the length to the depth ratio of these members exceeds 5, therefore, it designed as slender beams, where the section first design to resist the flexural stresses by providing adequate reinforcement, then, checking the section for shear and deflection.

In addition, the design procedures are the same for both the shallow and the conventional beams, and it is provided in all the practical design codes in a simple manner, based on experimental and theoretical investigations.

The conventional concrete beam usually has width to depth ratio in the range of 0.5 to 0.75, increasing the width of such beams so that exceed the depth is a usual practice in structural design, the solid slab is an example of such geometrical changes as mentioned before, where shallower sections can be used to resist flexural moment and shear forces, if adequately designed.

When the conventional beam has obvious width compared with its depth, shallow beam section form as a result, and since the shallow term usually refer to the slab, a wide reinforced concrete beam term was given to such geometry change, and these beams are frequently used as primary structural members in buildings, especially in Middle East counties, supporting the slab and transferring the load from the slab to the columns or walls.

In situation where increasing the beam depth is not an option, designers usually turn to increase the beam width to achieve the required strength or to reduce reinforcement complexity, In addition, the use of wide beams in the building provide practical advantages such as simplifying the formwork, reducing the reinforcement detailing and increasing the net floor height which will reduce the total height of the building.

1.2 Problem Statement

In design, the practical codes are differing in manner and united by result, to provide safe and practical design, the BS 8110 (1997) is one of the famous and reliable codes for design concrete structures, provide equations and requirements especially in design concrete beams.

The shear design of slender beams either conventional or shallow slab is specified in clause 3.4.5 in BS 8110 (1997), where the shear capacity of concrete beam if shear reinforcement are not provided is a function of the concrete grade, beam depth and the percentage of flexural reinforcement, while if shear reinforcement are provided, another function added to the mentioned based on the link sectional area, spacing and the strength of link bars.

The support condition is always taken as the beam width in BS 8110 (1997), while the narrow support is a fact when the beam width exceed the column width, and such situation is common when the wide reinforced concrete beam used, where these beams are usually supported by columns in which the ratio of the column width to the beam width is less than 1.0, which influence the behaviour of beam in shear failure.

Studying the behaviour of wide reinforced concrete beams under shear failure, especially the diagonal tension shear failure, is as important as flexural failure, because such failure is forming from the combination of both flexure and shear cracks, which it is brittle and suddenly fails.

Accordingly, the prediction of shear capacity using the BS 8110 (1997) or other design codes may lead to incorrect shear capacity, since the consideration for narrow support is not counted, therefore, an experimental investigation conducted in this project to study the behaviour of such beams in shear, to provide guidance through safe and practical design.

In addition, the arrangement of flexural reinforcement in beams were limited for two purposes only, improving the compaction of concrete during casting and minimizing the flexural cracks width at service loading. Where as stated previously, the shear capacity of beams is a function of flexural reinforcement ratio, and since the wide beams have obvious width, therefore, arranging the flexural reinforcement in these beams to enhance or increase the shear strength is possible to serve both the practical and the design requirements.

1.3 Objectives of the study

The general aim of the investigation was to determine the shear performance of wide reinforced concrete beams with variation in support width and the arrangement of flexural reinforcement. In more specific terms, the objectives of the study are as following:

a) To evaluate the influence of the width of support on the shear strength of wide beams with and without shear reinforcement.

b) To determine the effect of flexural reinforcement arranged uniformly across the width on the shear capacity of wide beams having narrow support, provided with and without shear reinforcement.

c) To determine the effect of flexural reinforcement concentrated within the support width on the shear capacity of wide beams having narrow support, provided with and without shear reinforcement.

1.4 Scope of the study

The study was carried out within the following scope and limitations:

a) The study was based on laboratory tests on 10 reinforced concrete wide beams of the same cross section and span length.

b) All beams were reinforced with the same amount of flexural reinforcement.

c) The breadth to overall depth ratio of all specimens was 3.0.

d) All specimens were cast from the same batch of concrete mix, designed to achieve a compressive strength of 30 N/mm^2.

e) The beams were tested to failure using two point loads applied on the whole width at a distance of three times the effective depth from the support.

f) The specimens were simply supported on steel rollers at both ends during the test.

g) The 10 specimens were differing in at least one variable, therefore, the result based on single specimen behaviour.

CHAPTER 2

LITERATURE REVIEW

2.1 Wide reinforced concrete beams in shear

Reinforced concrete beams in general are classified according to the geometry as shown in Figure 2.1, where the main purpose of these horizontal members is to transfer the load from the floor to the vertical elements. The selections of their geometries are constrained by both structural and architectural requirements, where each type has different design approach and requirements.

The conventional rectangular beam is the most common one used in concrete structures, where the proportion of the width to the depth usually lies in the range of 0.5 – 0.75, which provides adequate stiffness.

Further, the construction of these beams had low degree of formwork and reinforcement complexities, while in situations where continuous beam are required; the top flexural reinforcement at the junction with column reinforcement arise the complicating in construction.

The flanged concrete beams such as T-beam and inverted L-beam have economical advantages by reducing the required concrete quantity, based on the design assumption, the tensile resistance of concrete at the tension face assumed negligible, in addition, the top sides of these beams are enlarged, additional flexural resistance is provided by the top flange in continuous beams situation at the support.

The requirements in design of such beams according to ACI 318 (2008) are taking place by limiting the flange width, where for T-beam, the effective flange width which use in design should not exceeds the (span length/4), (web thickness + 16 times flange thickness) or center to center of the next beam, and for inverted L-beam, the effective flange width should not exceeds the (span length/12), (6 times the flange thickness) or half the clear distance to the next beam.

In addition, since the web thickness of these beams is quite small comparing with the conventional beam width, hence, the concrete shear strength is always less than conventional beams if the depth fixed among them.

The other beams geometries such the L-beams and inverted T-beams are commonly used in pre-cast concrete structures, where the enlargement in the bottom flange is mainly to provide support bearing to the pre-cast slab, and the box shape or trapezoidal beams are rarely used in structural buildings, and its application limited in pre-stress highway or pedestrian bridges.

The conventional rectangular beams are the most commonly used in practice, since complexity in both reinforcement and formwork is low compared with other types of beams, beside, the achieved stiffness and simplify in the design procedures increase the use of such beams in structures.

The dimensional proportion for conventional rectangular beam may change due to structural, architectural, electrical or mechanical demands, where from architectural point of view, reducing the depth of beams to make it hidden within the slab, provides excellent lighting, air circulation, finishing and internal appearance, and also reduce or eliminate the obstructions of the electrical and mechanical installations, such as pipe lines, and external electrical wires.

Such geometrical change is common in structural design, where increasing the beam width such that exceeding its depth, solid slab is an example, where shallower sections can be used to resist flexural moment and shear forces, if adequately designed. From this point; the structural designers usually turn to increase the beam width to achieve the required strength or to reduce reinforcement and construction complexity.

These rectangular beams which have obvious width to depth ratio, so called wide reinforced concrete beams, are designed as conventional rectangular reinforced concrete beams, and usually, the ratio of their width to depth is more than two.

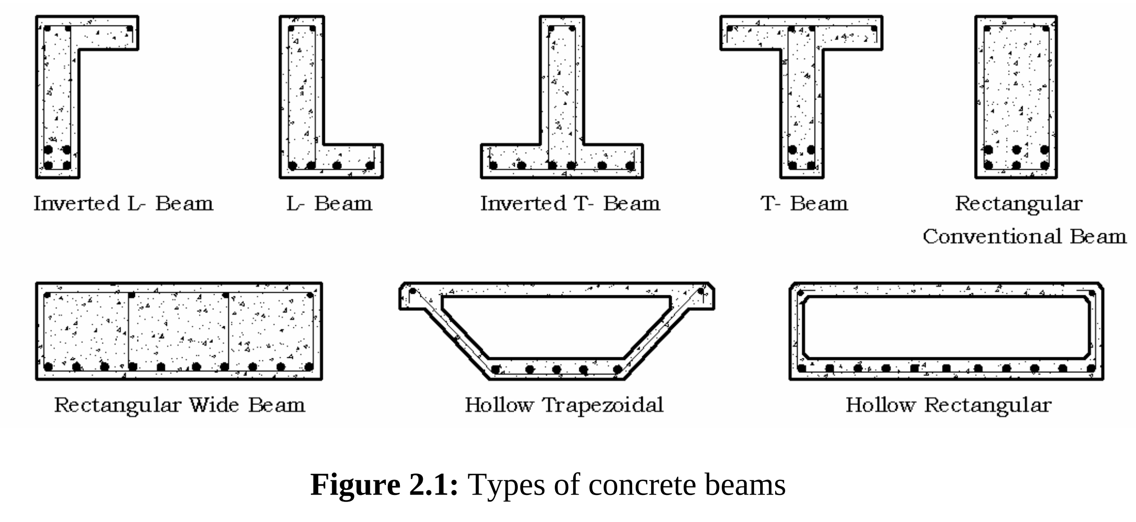

Figure 2.1: Types of concrete beams

The study focuses on the wide reinforced concrete beams, in situation where increasing the beam depth is not an option; designers usually turn to increase the beam width to achieve the structural or architectural requirement. These beams are usually supported by columns, which result in narrow support situation.

Photo 2.1 shows wide reinforced concrete beam supported by narrow support, this type of beams commonly used in Middle East counties, since economical advantages provided by eliminating the obstructs, allows the use of the net floor height.

The obvious narrow support may reduced by providing so called column capital, these enlargement in the column head mainly used in flat slab to enhance punching shear capacity, Photo 2.2 shows a wide reinforced concrete beam supported by circular column, where a column capital used to eliminate the occurrence of punching shear.

Photo 2.3 shows wide reinforced concrete beam during construction, the beam width increased such that the slab depth and beam depth are made equal, to minimize the formworks and reinforcement details.

The support condition affects the beam behaviour by relocating the maximum flexural and shear stresses, most practical design codes refer to the support condition without considering the extent of their width and narrow support width is not considered in any case, consequently, the behaviour of such beams may differ, both flexural and shear stresses may exhibit changes in magnitude or and location.