BEHAVIOUR OF UNBONDED REINFORCEMENT BAR ANCHORED IN GROUTED SPIRAL UNDER INCREASING FLEXURAL BENDING

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To My Beloved Family and Friends

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ABSTRACT

This project report presents a research on the behaviour of beam with unbonded reinforcement bars being anchored into grouted spiral reinforcement at both ends and subjected to flexural loading. The use of spiral reinforcement is rather a new concept used in construction industry and still being studied on its application. Spiral reinforcement is believed to improve the bonding between concrete and steel, and currently being used in precast concrete connection. A series of laboratory testing was carried out to obtain required values which demonstrate the behaviour of beam anchored with spiral reinforcement. Total of six concrete beam specimens containing grouted spiral reinforcement were constructed and tested for flexural capacity, deflection and bond-slip of reinforcement. The parameters included in study were different inner diameter (33mm and 58mm) and pitch distance (15mm and 30mm) of spiral reinforcement. By using simple statistically and graphical method, analysis was carried out to determine the effectiveness of end anchorage in providing full flexural resistance to the concrete beam. The results were analysed for bond stress around the reinforcement bar under the effect of spiral confinement. Comparisons of results are carried to determine the influence of inner diameter and pitch distance of spiral reinforcement to the flexural capacity of concrete beam. From the test and analysis, it is found that even with unbonded reinforcement, the grouted spiral reinforcement at beam ends were able to provide full tension support to concrete beam in resisting flexural loading. Despite the unbonded section of reinforcement, the concrete beam able to sustain higher flexural load, estimate 23% more than typical concrete beam. The test also showed that increment in inner diameter or pitch distance of spiral reinforcement will reduce the bond strength between grout and reinforcement bar and subsequently reduced the flexural capacity of the concrete beam.

ABSTRAK

Laporan projek ini membentangkan penyelidikan mengenai sifat rasuk yang mengadungi tetulang tidak terikat yang ditambat dalam tetulang berpintal berturap di kedua-dua hujung apabila dikenakan bebanan lenturan. Penggunaan Tetulang berpintal adalah konsep baru yang digunakan dalam industri pembinaan dan masih dikaji atas kegunaannya. Tetulang berpintal dipercayai dapat menguatkan ikatan antara konkrit dan besi, dan sedang digunakan dalam sambungan konkrit pra-tuang. Sesiri ujian makmal telah dijalankan untuk mendapatkan nilai-nilai yang diperlukan untuk menunjuk sifat rasuk yang ditambat dengan tetulang berpintal. Sejumlah enam spesimen rasuk konkrit yang mengandungi tetulang berpintal berturap telah dibina dan diuji untuk memperoleh kapasiti lenturan, pesongan dan linciran ikatan tetulang. Parameter yang termasuk dalam kajian adalah berbeza diameter dalaman (33mm dan 58mm) dan jarak puncak (15mm dan 30mm) tetulang berpintal. Dengan menggunakan kaedah statistik dan grafik mudah, analisis dijalankan untuk menentukan keberkesanan penambat dalam menghasilkan rintangan lenturan penuh kepada rasuk konkrit. Keputusan juga dianalisis atas tegasan ikatan sekitar tetulang atas kesan kurungan tetulang berpintal. Perbandingan keputusan juga dibuat untuk menentukan pengaruh diameter dalaman dan jarak puncak tetulang berpintal ke atas kapasiti lenturan rasuk konkrit. Daripada ujian dan analisis, ia mendapati bahawa walaupun dengan tetulang tidak terikat, tetulang berpintal berturap di hujung rasuk dapat memberi sokongan tegangan penuh kepada rasuk konkrit dalam menyokong muatan lenturan. Walaupun dengan sebahagian tetulang tidak terikat, rasuk konkrit dapat menampung beban lenturan yang tinggi, anggaran 23% lebih beban berbanding rasuk konkrit biasa. Ujian ini juga menunjukkan bahawa perningkatan diameter dalaman atau jarak puncak tetulang berpintal akan mengurangkan kekuatan ikatan antara turapan dan tetulang, dan seterusnya mengurangkan kapasiti lenturan rasuk konkrit.

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LIST OF SYMBOLS

f_b	-	Shear force
σ_{lat}, f_n	-	Normal or lateral confining pressure
dx	-	Pull-out by reinforcement
$F_{(x)}$, $F_{(x+dx)}$, F_{st}	-	Tension force
P	-	Flexural load
Δ	-	Pull-in by reinforcement
δ	-	Deflection
ε	-	Strain of reinforcement
T	-	Tension load
λ	-	Elongation of reinforcement
f_{cu}	-	Characteristic strength of concrete
f_y	-	Characteristic strength of reinforcement
L_e	-	Effective length of beam
x	-	Depth of neutral axis of beam
A_s	-	Total cross section area of tension reinforcement
A_s'	-	Total cross section area of compression reinforcement
b	-	Width of beam
d	-	Effective depth of beam
M_u	-	Ultimate moment
P_{max}	-	Maximum flexural load
δ_{allow}	-	Allowable deflection
L	-	Total span of beam
L_b	-	Bonded length of reinforcement
A_b	-	Total bonded surface area of reinforcement
σ_b	-	Bond stress
ε_s	-	Tangential strain in the pipe

t	-	Thickness of pipe wall
E	-	Modulus of elasticity of pipe
d_i	-	Inside diameter of the pipe

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CHAPTER 1

INTRODUCTION

1.1 General

Subjected to flexural loading, the strength of a concrete beam mostly depended on the capacity of the longitudinal reinforcement to carry the bending moment. The bond between the reinforcement steel and concrete has a great influence on the moment-carrying capacity of the concrete beam. Realising the importance of bond between the reinforcement and concrete, researchers and engineers have tried to improve the bond between reinforcement and concrete which contributes a major factor for reinforcement slip and beam deflection. The improvements also minimize the failure and crack width of the reinforced elements. For the purpose of improvement, spiral steel reinforcement has been introduced as a confinement medium. The application of spiral reinforcement is still at the early stage. Large diameter spiral reinforcement is commonly used in constructing cylindrical concrete column. It has been proven that concrete column with spiral reinforcement inside tend to be more durable compared to the typical rectangular column. Spiral reinforcement with smaller diameter is currently used as the confinement medium for precast concrete connection. Several research works had been carried out to study the properties of concrete component with spiral reinforcement especially on the bond behaviour of reinforcement under the influence of spiral reinforcement confinement. Better understandings on the properties and behaviour thus widen and improve the application of spiral steel reinforcement such as application within concrete beam and slab. In this research, the behaviour of the beam specimen and also the reinforcement anchored with grouted spiral reinforcement is studied by using flexural test. This research also intended to show the significance influence of the concrete-steel bond at the beam ends on the overall capacity of the concrete beam.

1.2 Problem Statement

In studying the bond around reinforcement within concrete element, many researchers had used the methods of pull-out test or direct pull-out test. The wide use of this method is due to its simplicity of the procedure. The test sample is small which is cylindrical in shape with both diameter and height estimated ten times of diameter of reinforcement bar used. Another test method that can be used in studying concrete-reinforcement bond is beam flexural test. The size of the beam specimen varies. The uncommonly use of beam test is due to the specimen sizing. The cross section of beam specimen required to extend to regions that not affecting the concrete-reinforcement bond based on the diameter of reinforcement. The larger the diameter of reinforcement used, the larger the beam specimen became. In beam test, only certain part of the reinforcement to be studied is bonded to the concrete while other part is wrapped to disconnect the reinforcement from the surrounding concrete. Despite the large size of specimen, beam test is considered better in representing the actual condition than pull-out test. Loading method used in pull-out test is purely tensile load while in beam test, whereas flexural load and bending moment is applied onto the specimen. Figures 1.1 (a) and (b) show the differences between pull-out test and beam test. More over that in the design stage of concrete element, bending moment is much considered than tensile force which may vary along the depth of concrete element.

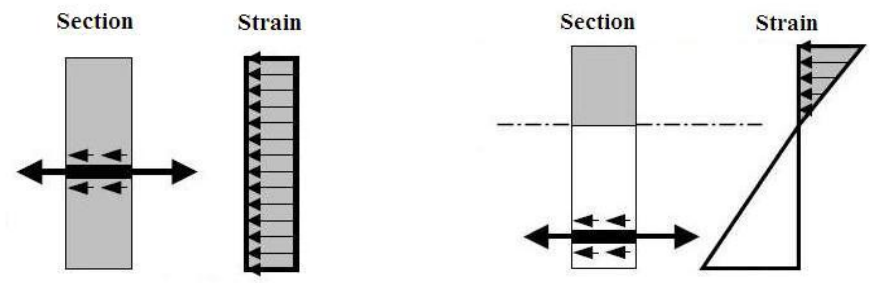

Figure 1.1: (a) Stress transfer in pull-out test, (b) Stress transfer in beam test

The bond between the reinforcement and concrete is a fundamental problem that influences overall behaviour of concrete elements. Research works had been done to understand bond behaviour and propose methods to improve the bond between those two materials. Understanding on the bond helped to determine the anchor length of a bar, suitable placement of reinforcement in concrete element, thickness of concrete cover, potential failure and cracking under excess loading and so on. Most of the improvements proposed to enhance bond between reinforcement and concrete are based on material changes, such as usage of ribbed bar, FRP (Fibre-Reinforced Polymer) bar or coated reinforcement bar, replacement of ordinary concrete with high strength concrete, self-compacting concrete (concrete with added superplasticizer) or fibre-reinforced concrete and so on. Another type of improvement to bond is by changing the structural design within the concrete element which is the usage of confinement medium around the reinforcement. Some of the confinement mediums being studied are spiral or helix reinforcement, stirrups, FRP wrapping and so on. In current research, spiral reinforcement is being studied to determine significance it as a confinement medium has on the concrete-reinforcement bond and also the capacity of the concrete element.

1.3 Aims and Objectives

For proper proceeding of current research, several objectives are needed to be set and the objectives are as followed.

I. To investigate the effectiveness of the end anchorage in providing full tension capacity of reinforcement bar.
II. To study the influence of inner diameter of spiral reinforcement which grouted over longitudinal reinforcement at beam ends on the flexural capacity of concrete beam.
III. To study the influence of pitch distance of spiral reinforcement which grouted over longitudinal reinforcement at beam ends on the flexural capacity of concrete beam.
IV. To study the behaviour of longitudinal reinforcement with grouted spiral reinforcement at beam ends under flexural bending.

1.4 Scope of Study

In narrowing the field of study concerning the effect of grouted spiral confinement under flexural bending, several scopes of study as followed are derived.

I. Laboratory testing to be conducted on the proposed beam specimens for their flexural capacity under two-point loading flexural test.
II. The laboratory test consists of six beam specimens designed with spiral reinforcement of varying inner diameter and pitch distance.
III. SikaGrout-215 to be used as grout medium over the spiral reinforcement and longitudinal reinforcement.
IV. Concrete grade 40 to be used to cast the beam specimen completed with grouted reinforcement within.

1.5 Significance of Study

In current research, experimental testing is done in investigating the significance of spiral reinforcement of different specification on the flexural capacity of concrete beam. Different method is used within the current research other than the experiment procedures commonly used by many researchers. Study is done on understanding the influence of inner diameter and pitch distance of the spiral reinforcement on the properties of concrete beam. Better understanding on bond behaviour through current research may help in proposing a new kind of improvement to construction industry. Current research may also be a vital reference for research on confinement effect using different type of methods.

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