BOND BEHAVIOR OF GROUTED SPIRAL AND SPLICE CONNECTION UNDER DIRECT AXIAL AND FLEXURAL PULLOUT LOAD

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"To my beloved parents and my lovely wife, for their encouragement and support"

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ABSTRACT

The conventional grouted connections with corrugated aluminium sleeves have been used widely in precast concrete construction. The main problem of the conventional grouted sleeve connections is the need for long embedded lengths reinforcement rebars to achieve full continuity. There is a tendency for the long rebars to touch the sleeve wall and subsequently preventing penetration of grout around the rebar. Since the grout inside the sleeve cannot be inspected after installation, there is doubt that the main rebar is fully bonded. This study proposed a grouted spiral connection which can overcome the use of long embedded length of connected rebars. The main objective of this study was to investigate the effect of spiral confinement on the bond stress-slip relationship. The experimental program was carried out in two phases, Phase I and Phase II. In Phase I, a total of thirty-six spiral connections were subjected to increasing direct axial pullout loads. Then, in Phase II, a total of twelve beams comprising spiral connections were subjected to flexural pullout loads. Parameters considered in this study were pitch distance and diameter of spiral connections. The experimental results showed that the use of smaller pitch distance and spiral diameter resulted in higher bond strength. However, the spiral diameter had more dominant confinement effect such that it increased the bond strength of direct and flexural pullout tests very dramatically by 34.5% and 40%, respectively. In addition, lower bond strength from the beam tests was reported as compared to the axial pullout tests. The bond strengths obtained from the flexural pullout tests were within the range of 0.74 to 0.79 times the bond strengths of the axial pullout tests. Finally, analytical equations were proposed to express the bond stress-slip relationship and bond strength of the grouted spiral connection.

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ABSTRAK

Penggunaan sambungan *grout* konvensional dengan salur aluminium telah digunakan secara meluas dalam pembinaan konkrit pratuang. Masalah utama daripada sambungan *grout* konvensional adalah keperluan panjang tambatan untuk mencapai kekuatan penuh. Terdapat kecenderungan untuk tetulang bar yang panjang menyentuh dinding salur dan seterusnya menghalang penembusan *grout* di sekitar bar. Oleh kerana grout di dalam salur tidak boleh diperiksa selepas pemasangan, terdapat keraguan tetulang utama tidak terikat sepenuhnya. Kajian ini mencadangkan satu sambungan gegelung *grout* yang boleh mengatasi masalah penggunaan tambatan tetulang keluli yang terlalu panjang. Objektif utama kajian ini adalah untuk menyiasat kesan kurungan gegelung ke atas hubungan tegasan ikatan-gelinciran. Program eksperimen telah dijalankan dalam dua fasa, Fasa I dan Fasa II. Dalam Fasa I, sejumlah tiga puluh enam sambungan gegelung dikenakan tindakan beban tegangan paksi. Di dalam Fasa II, sebanyak dua belas rasuk dengan sambungan gegelung dikenakan beban lenturan. Parameter yang dikaji adalah jarak antara gegelung dan diameter gegelung penyambung. Keputusan eksperimen menunjukkan bahawa penggunaan jarak antara gegelung dan diameter gegelung yang kecil dapat meningkatkan kekuatan ikatan. Bagaimanapun, kesan diameter adalah lebih dominan dalam meningkatkan kekuatan ikatan dengan peningkatan sebanyak 34.5% dan 40% masing-masing bagi ujikaji beban paksi dan lenturan. Di samping itu, kekuatan ikatan yang lebih rendah didapati berlaku pada ujian rasuk berbanding dengan ujian tegangan paksi. Kekuatan ikatan yang diperolehi daripada ujian lenturan adalah dalam julat 0.74-0.79 kali ganda kekuatan ikatan tegangan paksi. Akhirnya, persamaan analitik telah dicadangkan untuk menyatakan hubungan tegasan ikatan- gelinciran dan kekuatan ikatan bagi sambungan gegelung *grout*.

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LIST OF SYMBOLS

P	-	Applied load
d_b	-	Diameter of main bar
l_d	-	Embedded length
τ	-	Average bond stress
U	-	Bond strength of concrete
f_n	-	Lateral confining pressure
f_{cu}	-	Concrete compressive strength
f_{bt}	-	Bond stress
T_b	-	Bond force
A_b	-	cross sectional area of spliced bars
A_{tr}	-	Area of transverse reinforcement normal to the plane of splitting through the anchored bars
C_{min}	-	Smaller of minimum concrete cover or ½ of clear spacing between bars
f_{yt}	-	Yield strength of transverse reinforcement
s	-	Spacing of transverse reinforcement
n	-	Number of bars developed or splice at the same location
C_{So}	-	Side cover
C_{Si}	-	1/2 of the bar clear spacing
C_S	-	Minimum (C_{So} , C_{Si} + 6.4m)
C_b	-	Bottom cover
C_{max}	-	Maximum (C_b, C_S)
τ_{max}	-	Maximum bond strength
S	-	Slip
s_1	-	Slip at maximum bond strength of τ_1
α	-	a curve-fitting parameter

f_c'	-	Tensile strength of concrete
f_s	-	Steel stress
X	-	Distance from loaded face pullout bond specimen.
x	-	Distance from center of embedded bar
D	-	Diameter of cylindrical grout
D_s	-	Diameter of spiral
P_s	-	Pitch distance of spiral
L_s	-	Length of grouted spiral connection
L_e	-	Embedded length of main connected bar
Nc	-	Number of Coil
h	-	Rib height
c	-	Rib spacing
υ	-	Rib inclination
$f_{c,g}$	-	Compressive strength of grout
σ	-	Stress
K_s	-	Stiffness
R_s	-	Strength ratio
$f_{u,b}$	-	Maximum stress at failure
P_u	-	Load capacity
$f_{sy,b}$	-	Specified yield strength
T	-	Tensile load in the main bars of beam specimen
a	-	Shear span
j	-	Distance between the resultant tensile and compressive loads
Υ	-	Ratios between bond strength of axial and flexural pullout
β	-	A curve-fitting parameter
A_g	-	Confined grout, cross sectional area
f_{spiral}	-	Tensile stress in spiral
A_{spiral}	-	Cross sectional areas of the spiral
d_{spiral}	-	Diameter of cross sectional area of spiral
d_{sb}	-	Diameter of splice bar
P_{g}	-	Tensile strength of grout in connection
P_{spiral}	-	Tensile load endured by the spiral

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The construction industry in Malaysia has shifted from conventional reinforced concrete system to industrialized building system (IBS) through the application of precast concrete system. The precast concrete system has led the building market to an extremely competitive environment. Using this system, considerable amount of building components are fabricated in factories in a fully controlled condition by means of proper equipment. The precast concrete system has considerable advantages such as certainty in cost and time, enhancing occupational health and safety, achieving higher construction productivity and quality, reliance on manual foreign labor, and decreasing the cost of construction [1].

In 1960, Ministry of Local Government and Housing visited a number of European countries for evaluation of their housing development program [2], which led to initiating IBS in Malaysia. Then, the government dedicated about 22.7 acres of land along Jalan Pekeliling, Kuala Lumpur to a great project that consisted of seven blocks of 17 stories flat, 3000 units of low-cast flat, and 40 shop lots [3].

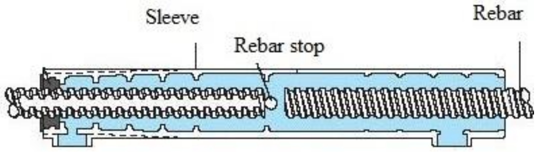
In 2006, the Malaysian construction industry re-introduced the IBS system with the expectation the new technologies in precast concrete can be adopted for innovative construction techniques. For instance, the Construction Industry Master

Plan (CIMP) 2006-2015 published in December 2006 was an attempt to plan the direction for future developments of the Malaysian Construction Industry. In the 2005 Budget, the construction of 100,000 units of reasonably-priced houses using IBS was pledged by the government. The *Surat Pekeliling Perbendaharaan Bil. 7 Tahun* has *2008* strongly asserted that the government's projects must use IBS in their construction process not less than 70% of the whole structures [1]. These efforts demonstrate the situation of IBS in the construction industry of Malaysia.

One of the major concerns that commonly arise with regard to the use of prefabricated precast concrete components is the needs to develop quality connections in a way to maintain the structural integrity through the precast sections [4]. In the precast continuous construction system, both the design and structural details of the precast connections should have the same features of cast-in-place connection [5]. In this regard, the America Concrete Institute (ACI) has published different details on how to emulate cast-in-places in the precast construction sites [6]. On the other hand, still there is not enough supplementary information in the ACI code regarding the design of precast connections in particular the knowledge related to continuity and bond in reinforcement bars.

In order to achieve full continuity of reinforcement bars for joining precast concrete components, grouted splice connectors are preferred and employed (see Figure 1.1). Grouted splice connectors have shown the capability of being used as connections in the precast concrete structures. These connectors reduced the splice length for ensuring the continuity of steel bars considerably [7]. The splice connectors make the installation process simpler and solve the problems of bar congestion and detailing, especially in structures that are heavily reinforced[8]. For the first time, in the late 1960s [9, 10], this splice method was introduced by Dr. Alfred A. Yee upon the invention of NMB splice sleeve® [10]. From that time, different types of mechanical couplers such as BarSplice Double Barrel Zap Screwlok©, Lenton Interlok® [11, 12] Lenton QuickWedge©, etc. have been developed and commercialised. Most of the splice connectors have been invented by private individuals and are difficult to obtain the technical details due to the proprietorship rights. Due to limited literature regarding the behavior of grouted splices connections, researchers prefer to investigate the non-proprietary splice that is inexpensive. Table 1.1 shows the differences between the commercial connections and non-proprietary splice connections which were studied in this research. The commercial splice connections normally required special mould to fabricate and are made from cast iron. On the other hand, the proposed non-proprietary connectors required steel pipe, spiral and splice bars only. Concerning the performance, an adequate splice connector should be capable of providing high quality assurance in bond strength even with short spliced lengths. In this splices technique, the strength of the splice joint relies heavily on the anchorage bond.

Table 1.1: Comparisons of the commercial and proposed connections of this research

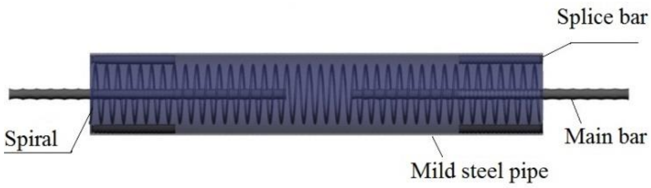
<table>
<tr><th>Commercial splice connector</th><th>Proposed splice connector in this research</th></tr>
<tr><td>


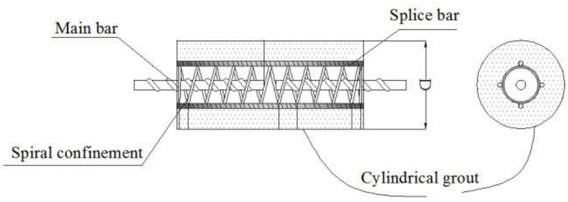
NMB splice sleeve

Double Barrel Zap Screwlok

Lenton Interlok
Characteristics of commercial splice connectors:

Need special moulds to fabricate the thread and splice which is expensive
Cast iron is used for the splice which is brittle
Proprietary

</td><td>


Steel pipe with spiral confinement


Spiral confinement with four splice bars
Characteristics of proposed non-proprietary splice connectors:

Steel pipe spiral and splice bars of connections are easily available in the market with inexpensive materials
These types of connections can be fabricated easily without any special mould.
Non-proprietary

</td></tr>
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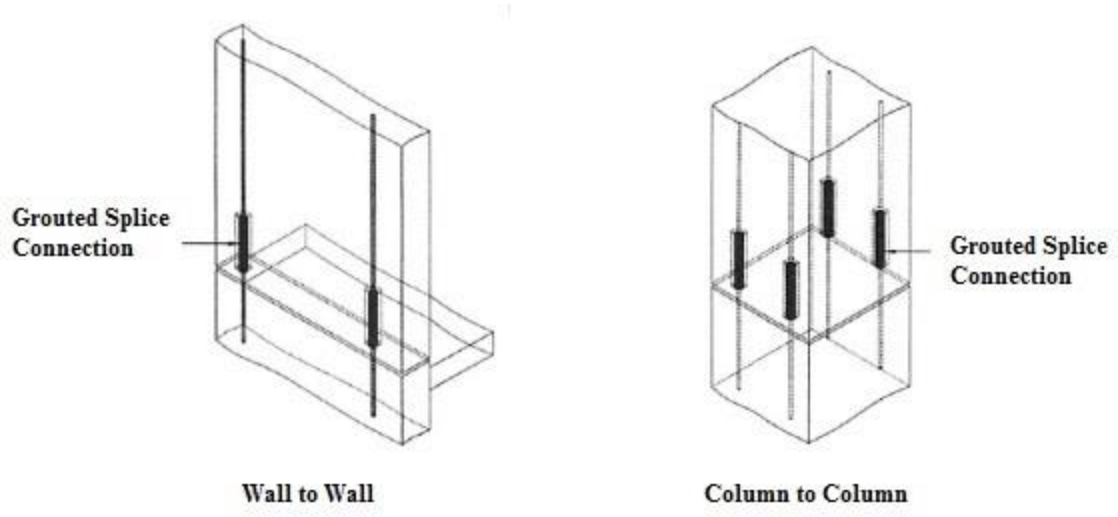

Figure 1.1 Grouted splice connection in precast concrete components [13]

Usually the bond development has strong effect on the interaction between the grout and splice bar for the grouted splice connections, that are usually used in connecting precast concrete components. In fact, the mechanism of load transfer between the precast concrete components depends on the quality of adequate bond provided by the grouted splice (Figure 1.2) [14]. Investigation works on the factors that affect the bond were studied greatly over the last 40 years and as a result, considerable modifications have been introduced to bond clauses in design codes worldwide [15]. Detailed evaluations of bond strength and bond behavior are complicated, as the magnitude of bond strength is influenced by a wide range of factors. For example, the CEB-FIP Model Code 90 [16] includes not less than 10 parameters which influence the anchorage bond behavior.

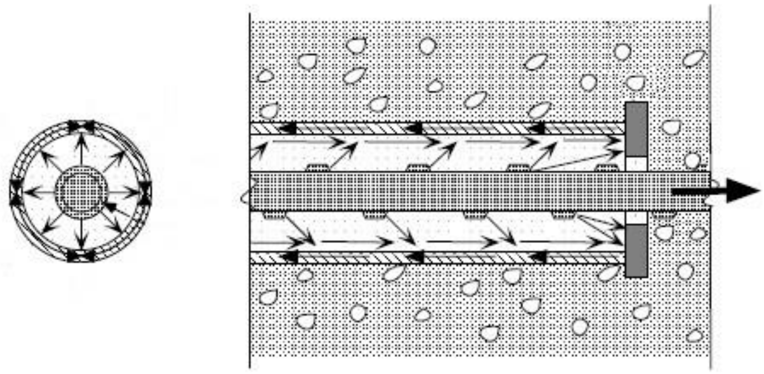

Figure 1.2 Mechanism of load transfer [17]

In the bond aspect, one of the key factors that can improve the value of bond stress is the present of confinement between the steel bar and grout. The confinement can influence the anchorage bond and reduces the required embedment length of the spliced steel bars [7, 18-20]. The application of confinement delays early development of the splitting cracks either by expansion resistance or bridging of surrounding materials of the steel bars.

This study concentrates on the behavior of proposed grouted splice connections with spiral confinement. To investigate the behavior of new splice connections, it is very essential to know the interactions and also internal stress distribution among the deformed steel spliced bars and its surrounding materials.

1.2 Background of Study

In reinforced concrete structures, the reinforcement bars attain continuity through lapping full anchorage lengths of the steel bars [21]. On the other hand, the long bar lapping lengths may be impractical in cases where there is not adequate space for the accommodation of the required bar development lengths, especially in structures that are heavily reinforced and in cases where larger bar sizes are used, leading to impractical lapping lengths, or it may be not permissible to be lap spliced by codes [8].

In precast concrete structures, prefabricated components such as wall to wall and column to column need to be jointed together by ensuring the continuity of rebars from the lower component to upper components. To join the prefabricated elements of the precast concrete systems, the lengthy lapping system have not been shown quite appropriate. For example, long extruding starter bars provided for embedment in the adjoining structural elements in the installation process often cause problems of transportation and handling. As a result, for ensuring the ease of the installation and maximizing the speed of construction process, there is a need for short bar anchorage length

The grouted splice offers a feasible solution to connect the prefabricated elements during erections. During the assembly process, prior to pouring or pumping the grout in the sleeves, the short extruding steel bars could be inserted to the pre-embedded sleeves in the targeted elements. Using this technique, the problem of long embedded lengths can be solved and the process of handling and installation can be performed more easily.

In general, using grouted splices, discontinued bars can be spliced at short embedded bar lengths. Though, the bond performance may be different because of variations existing in the grouted splice configurations. Knowing these issues, the grouted splices responses should be investigated, particularly regarding the bond behavior, for identification of the major factor like confinement that has impact on the bond mechanism in grouted splices.

The influence of confinement on the ductility and compressive strength of compression members has been reported by many researchers [22-26]. Their work was based on the confinement of members along their full length. The confinement effect using spirals or ties on lap splice lengths and development of the longitudinal reinforcement was investigated in their work. Based on the shape of confinement, circular spirals provide a continuous confining pressure around their axial axis [27].

The concept of spirally confined lap splices of deformed bar comes from the above theory to generate the strength required for connecting the reinforcement bars together (see Figure 1.3). So, In order to employ spiral confinement in grouted connections, more investigations are required rather than relying on speculated predictions. Thus, it is essential to understand the responses of the grouted splices when subjected to the load cases of direct axial and flexural pullout loads. Other forces that may occur in the splice are axial force-moment and axial compression-moment. the work by Kuttab and Dougill [28] has shown that most of the grouted connections in precast column components experienced axial force–moment interaction characteristics. Hence, multi-phases of experimental studies are carried out to study the behavior of proposed connections caused by the bond stress-slip relationship of individual short deformed steel by spiral reinforcement. The confinement provided by the spirals is part of the proposed short splicing method which increases the bond strength. The spirals characteristics and properties are applied in Industrial Building Systems (IBS) where other types of mechanical spliced connections could be substituted by this connection.

Figure 1.3 Spiral confinement in splice connections [29]

1.3 Problem Statements

The problems that need to be addressed in grouted splice connections are:

1. The conventional grouted sleeve connector is one of the famous methods for joining precast concrete components (see Figure 1.4). According to the finding of Kuttab [28], the combination of axial and flexural loads interaction characteristics of grouted sleeve connectors has to be equal to the parent column. Due to this axial and flexural load interaction, long embedded length of 35 times bar diameter based on BS 8110 [21] is needed to achieve the full continuity of reinforcement bars. The main problem in using this connection is the installation process of the grouted sleeve connectors which is quite difficult and it is not easy to achieve with any accuracy. The main bars in the sleeve may not always be perfectly located at the centre of sleeve (See Figure

1.5). There is a tendency the long bars to touch the wall of the sleeve in the precast component, so preventing penetration of grout around the bar and it is not allowing the grout to fill all the voids inside of the sleeve completely. Since the grout inside the sleeve cannot be inspected after installation, there is doubt that the main bar is fully bonded. So, it is necessary to provide the system which can be assembled by prefilling [8].

2. There is not much research works on the effect of spiral confinement on the bond behavior of grouted splices. Therefore, there is a need to study the confinement effects in the grouted splice connectors.

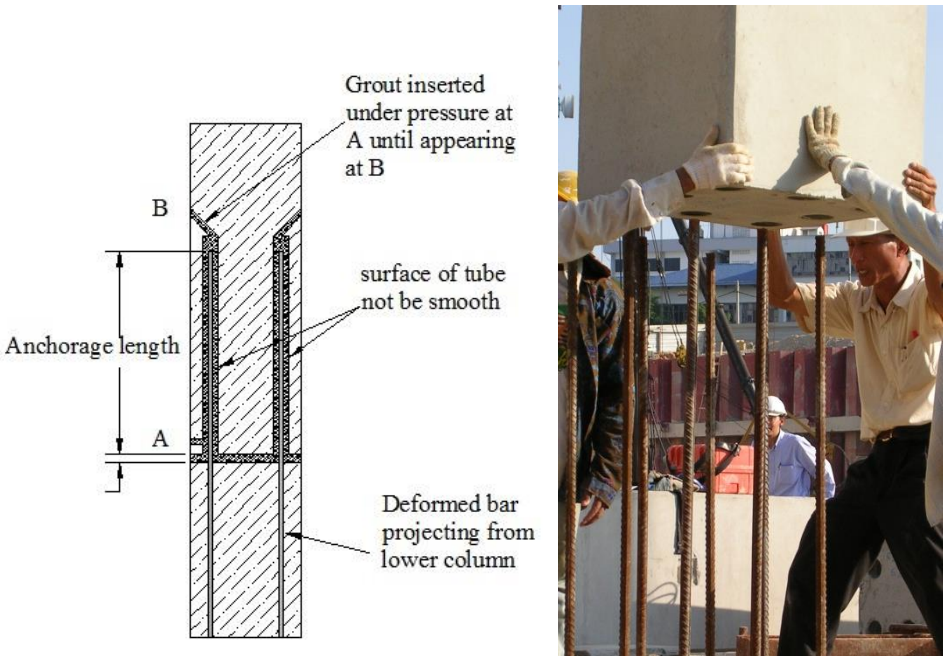

Figure 1.4 Projecting the long embedded length in conventional grouted sleeve [30]

Figure 1.5 Cross section through grouted sleeve column splice [31]

1.4 Objectives

Owing to these important characteristics, the bond behavior of reinforcement embedded in grout needs to be investigated accordingly. The key factor governing the anchored-bar behavior in confined grout is the local bond stress-slip relationship. Consequently, to develop new splice connections, it is important to understand the internal stress and the local bond stress-slip relationship between various main connected bars and their surrounding materials. Failure of bond leads to slippage in reinforcement bars and consequently failure of structural members.

To achieve the task of solving the problems stated above, this research is outlined with several main objectives as follows:

i. To investigate the performance of spiral confinement and splice bars to the behavior of connected deformed steel bars in grouted connections under direct axial and flexural loads.

ii. To study the effect of spiral configurations on the bond stress-slip behavior of the deformed steel bars under direct axial and flexural loads.

iii. To study the comparison of direct axial and flexural pullout loads on the bond behavior of deformed steel bars in grouted spiral connection.

iv. To propose equations for predicting the bond strength and bond stress-slip relationship of the grouted spiral connections under direct axial and flexural loads.

1.5 Scope of Research

The scope of the research program includes:

a. The experimental tests of grouted spiral connections with different configurations of spiral confinement.

b. The investigation of the performance of the proposed grouted spirals when subjected to load cases of direct axial and flexural pullout.

c. The study of responses of the grouted spirals towards tree considered parameters, pitch distance of spiral, diameter of spiral and type of main bars.

d. The development of simplified equations for predicting the responses of the connections under mentioned load cases

e. Additionally, two major phases of experimental tests involves

i) Testing of thirty-six grouted spiral specimens under monotonic direct axial pullout to study the behavior of the connections under tension.

ii) Experimental testing of twelve full-scale beam specimens, connected with grouted spirals, under flexural pullout loads to acquire the response of the steel deformed bars in grouted spiral connections.

Furthermore, the scope of the test results for each phase comprises:

a. Phase I – Direct tensile axial pullout test of grouted spiral connections
   i. Failure load capacity
   ii. Bond strength
   iii. Bond stress-slip behavior
   iv. Stress-strain response
   v. Failure mode

b. Phase II – Flexural pullout test of the steel deformed bars in grouted spiral connections
   i. Failure load capacity
   ii. Bond strength
   iii. Bond stress-slip behavior
   iv. Stress-strain response
   v. Failure mode

Lastly, the scope of analytical research consists of:

a. Analysing the bond stress-slip relationship of the grouted splices under direct axial and flexural pullout loads from the experimental results in Phases I and II.
b. Deriving equations to predict the bond strength of the grouted spiral connections under tensile and flexural pullout loads.
c. Evaluating the effect of spiral confinement on the bond stress-slip relationship by calculating the bond energy
d. Comparison of the experimental test results to other researcher to validate the data.

1.6 Thesis Organization

Chapter 2 presents a review of the available literature and the present state of knowledge regarding grouted connections and mechanism of bond stress.

Chapter 3 describes the experimental program, including the details of test specimens, connection configurations, material specifications, instrumentations, test setup and procedures.

Chapter 4 presents the results and discusses the responses of grouted spiral specimens when subjected to increasing direct axial pullout loads.

Chapter 5 displays and discusses the test results and response of full-scale beam specimens, connected with steel deformed bars in grouted spiral connections, under flexural pullout loads.

Chapter 6 presents the analytical derivations for predicting the bond strength response and bond stress-slip relationship of the proposed grouted spiral connections under direct axial and flexural pullout loads.

Chapter 7 summarizes and concludes the entire research carried out.

REFERENCES

1. Hamid, Z.A., Kamar, K. A. M., Raham, A. H. A. *Industrialized Building System (IBS)*. 2009.
2. Thanoon, W. A. M., Peng, L. W., Abdul Kardir, M. R. The Experiences of Malaysia and other countries in industrialised building system. *Proceeding of International Conference on Industrialised Building Systems. 2003.*
3. Kamar, K., M. Alshawi, and Z. Hamid. Barriers to industrialized building system (IBS): The case of Malaysia. in In BuHu 9th International Postgraduate *Research Conference (IPGRC),* Salford, United Kingdom. 2009.
4. Tibbetts, A.J., M.G. Oliva, and L.C. Bank. Durable fiber reinforced polymer bar splice connections for precast concrete structures. *Composites & Ploycon*, 2009. 15-17.
5. American concrete insitute. *Design Recommendations for Precast Concrete Structures*, ACI 550. 1993.
6. ACI-ASCE Committee. *Emulating Cast-in-Place Detailing in Precast Concrete Structures*. 550. 2001.
7. Einea, A., T. Yamane, and M.K. Tadros. Grout-filled pipe splices for precast concrete construction. *PCI journal*, 1995. 40(1). 82-93.
8. American concrete insitute. *Mechanical Connections of Reinforcing Bars.* ACI 439. 1991.
9. Splice sleeve North America, I.H.e.o.N.S.S.; Available from: http://www.splicesleeve.com/history.html.
10. Yee, A.A. *Splice sleeve for reinforcing bars with cylindrical shell.* U.S. 3552787 A. 1986.
11. Albrigo, J., L.J. Colarusso, and E.D. Ricker. *Method of forming concrete structures with a grout splice sleeve which has a threaded connection to a reinforcing bar.* U.S. 5366, 672. 1994.
12. Albrigo, J., L.J. Colarusso, and E.D. Ricker. *Reinforcing bar splice and system for forming precast concrete members and structures.* U.S 5468, 524. 1995
13. Spiral Connector Product Guide, H.D.B.a.B.A.L.
14. Pecce, M., Manfredi, G., Realfonzo, R., and Cosenza, E. Experimental and analytical evaluation of bond properties of GFRP bars. *Journal of materials in civil engineering*, 2001. 282-290.
15. Cairns, J. and G. Plizzari. Towards a harmonised European bond test. *Materials and Structures*, 2003. 36(8). 498-506.
16. FIB-Féd. Int. du Béton. *CEB-FIP Model Code 1990.* 1993.

17. kim, Y.m. *A study of pipe splice sleeves for use in precast beam-cloumn connections*. Master of sience in enginieering, The University of Texas at Austin; 2000.
18. Untrauer, R.E. and R.L. Henry. Influence of normal pressure on bond strength. *ACI Journal Proceedings.* 1965.
19. Robins, P. and I. Standish. The influence of lateral pressure upon anchorage bond. *Magazine of Concrete Research*. 1984. 36(129). 195-202.
20. Moosavi, M., A. Jafari, and A. Khosravi. Bond of cement grouted reinforcing bars under constant radial pressure. *Cement and Concrete Composites,* 2005. 27(1). 103-109.
21. British Standard Insitution. *Structural Use of Concrete - Part 1: Code of practice for design and construction.* 1997.
22. Pfister, J.F. and A.H. Mattock. High Strength Bars as Concrete Reinforcement, Part 5: Lapped Splices in Concentrically Loaded Columns. *Portland Cement Association, Research and Development Laboratories,* 1963.
23. Pfister, J.F. Influence of Ties on the Behavior of Reinforced Concrete Columns. *ACI Journal Proceedings,* 1964.
24. Mander, J.B., M.J. Priestley, and R. Park. Theoretical stress-strain model for confined concrete. *Journal of structural engineering*, 1988. 114(8). 1804-1826.
25. Mander, J., M. Priestley, and R. Park. Observed stress-strain behavior of confined concrete. *Journal of structural engineering*, 1984. 114(8). 1827-1849.
26. Orangun, C., J. Jirsa, and J. Breen. A Reevaulation of Test Data on Development Length and Splices. *ACI Journal Proceedings,* 1977.
27. Park, R. *Reinforced concrete structures*.John Wiley & Sons. 1975.
28. Kuttab, A. and J. Dougill. Grouted and dowelled jointed precast concrete columns: behaviour in combined bending and compression. *Magazine of Concrete Research*, 1988. 40(144). 131-142.
29. Heng, L.J.M.a.J.W.L. *Blueprints for Successful Public Housing Development.* Singapore Concrete Institute. 2006.
30. FIB-Féd. Int. du Béton. *Structural Connections for Precast Concrete Buildings: Guide to Good Practice*. 2008.
31. Elliott, K.S. and C. Jolly (2013). *Multi-storey precast concrete framed structures*. Wiley. 2013.
32. Lancelot, H.B. Mechanical splices of reinforcing bars. *Concrete Construction*, 1985. 30(1). 23.
33. Henin, E. and G. Morcous. Non-proprietary bar splice sleeve for precast concrete construction. *Engineering Structures*, 2015. 83. 154-162.
34. American concrete insitute. *Cement and concrete terminology.* ACI Special Publication. 1967. ACI 116.
35. M. K. Thompson, J. O. Jirsa, J. E. Breen, and R. E . Klingner. *Anchorage behavior of headed reinforcement*: literature review. 2002.
36. Ferguson, P.M., J.E. Breen, and J.O. Jirsa. *Reinforced concrete fundamentals.* 1988.
37. Goto, Y. Cracks formed in concrete around deformed tension bars. *ACI Journal Proceedings*. 1971.
38. Mains, R.M. Measurement of the distribution of tensile and bond stresses along reinforcing bars. *ACI Journal Proceedings*. 1951.

39. Jiang, D., S. Shah, and A. Andonian. Study of the transfer of tensile forces by bond. *ACI Journal Proceedings.*1984.
40. Brenes, F.J., S.L. Wood, and M.E. Kreger. *Anchorage requirements for grouted vertical-duct connectors in precast bent cap systems.* 2006.
41. Feldman, L.R. and F.M. Bartlett. Bond strength variability in pullout specimens with plain reinforcement. *ACI Structural Journal,* 2005. 102(6).
42. Eligehausen, R., E.P. Popov, and V.V. Bertero. *Local bond stress-slip relationships of deformed bars under generalized excitations.* 1982.
43. Soroushian, P. and K.-B. Choi. Local bond of deformed bars with different diameters in confined concrete. *ACI Structural Journal*, 1989. 86(2).
44. Hussein, L. *Analytical modeling of bond stress at steel-concrete interface due to corrosion.* Master of applied sience. Ryerson University, Canada, Torento; 2011.
45. American concrete insitute. *Bond and development of straight reinforcing bars in tension.* ACI 408. 2003.
46. Hong, S. and S.-K. Park. Uniaxial bond stress-slip relationship of reinforcing bars in concrete. *Advances in Materials Science and Engineering,* 2012.
47. Treece, R.A. and J.O. Jirsa. Bond strength of epoxy-coated reinforcing bars. *ACI Materials Journal,* 1989. 86(2).
48. American concrete insitute. *Bond Under Cyclic Loads.* ACI 408. 1992.
49. Lutz, L.A. *The mechanics of bond and slip of deformed reinforcing bars in concrete*. Cornell University; 1966.
50. Wang, H. An analytical study of bond strength associated with splitting of concrete cover. *Engineering Structures,*2009. 31(4). 968-975.
51. Gallus Rehm, C Van Amerongen. The basic principles of the bond between steel and concrete. *Cement and Concrete Association,* 1968.
52. Quayyum, S. *Bond behaviour of fibre reinforced polymer (FRP) rebars in concrete.* Master of applied sience. University of British Columbia; 2010.
53. Ling, J.H., Ahmad Baharuddin Abd. Rahman, Abdul Karim Mirasa, Zuhairi Abd. Hamid. Performance of cs-sleeve under direct tensile load: part 1: failure modes. *Malaysian Journal of Civil Engineering*, 2008. 20(1). 89-106.
54. Xu.F, Zhimin Wu, Jianjun Zheng, Yu Hu, and Qingbin Li. Experimental study on the bond behavior of reinforcing bars embedded in concrete subjected to lateral pressure. *Journal of materials in civil engineering*, 2011. 24(1). 125-133.
55. Soroushian, P., Ki-Bong Choi, Gi-Hyun Park, and Farhang Aslani. Bond of deformed bars to concrete: effects of confinement and strength of concrete. *ACI Materials Journal,* 1991. 88(3).
56. Ichinose, T., Y. Kanayama b, Y. Inoue c, J.E. Bolander Jr. Size effect on bond strength of deformed bars. *Construction and building materials*, 2004. 18(7). 549-558.
57. Ling JH, Ahmad Baharuddin Abd. Rahman, Hamid Z (2008). Failure modes of aluminium sleeve under direct tensile load. *3rd International conference on postgraduate education.* Malaysia: Penang. 2008.
58. Loo, G.K. *Parametric Study of Grout-Filled Splice Sleeve Integarated with Flexible Aluminium Tube for Precast Concrete Connection*. Bs.c thesis, Universiti Teknologi Malaysia; 2009.
59. Ling, J.H., Ahmad Baharuddin Abd. Rahman, Izni Syahrizal Ibrahim, Zuhairi Abdul Hamid. Behaviour of grouted pipe splice under incremental tensile load. *Construction and building materials,* 2012. 33. 90-98.

60. Ling, J.H., A.B. Abd Rahman, and I.S. Ibrahim. Feasibility study of grouted splice connector under tensile load. *Construction and building materials,* 2014, 50. 530-539.
61. Einea, A., S. Yehia, and M.K. Tadros. Lap splices in confined concrete. *ACI Structural Journal,* 1999. 96(6).
62. Darwin, D.; Tholen, M. L.; Idun, E. K.; and Zuo. Splice strength of high relative rib area reinforcing bars. *ACI Structural Journal,* 1996.
63. American concrete insitute. *Building Code Requirements for Reinforced Concrete.* ACI 318. 1962
64. Tepfers, R.. *A theory of bond applied to overlapped tensile reinforcement splices for deformed bars.* Chalmers University of Technology; 1973.
65. Eligehausen, R. Bond in Tensile Lapped Splices of Ribbed Bars with Straight Anchorages. *German Institute for Reinforced Concrete, 1979.* 118.
66. Francisco J. Brenes, S.L.W., and Michael E. Kreger. *Anchorage Requirements for Grouted Vertical-Duct Connectors in Precast Bent Cap Systems*. Center for Transportation Research The University of Texas at Austin; 2006.
67. Darwin, D.; McCabe, S. L.; Idun, E. K.; and Schoenekase, S. P. Development length criteria: bars not confined by transverse reinforcement. *ACI Structural Journal*, 1992. 89(6).
68. Esfahani, M.R. and B.V. Rangan. Local bond strength of reinforcing bars in normal strength and high-strength concrete (HSC). *ACI Structural Journal,* 1998. 95(2).
69. Esfahani, M.R. and B.V. Rangan (1998) Bond between normal strength and high-strength concrete (HSC) and reinforcing bars in splices in beams. *ACI Structural Journal,* 1998. 95(3).
70. Farndon, S.J. *The Effect of Normal Pressure on Bond in Light-Weight Concret.* Loughborough University; 1982.
71. Tepfers, R. Cracking of concrete cover along anchored deformed reinforcing bars. *Magazine of Concrete Research*, 1979. 31(106). 3-12.
72. Alavi-Fard, M. and H. Marzouk. Bond of high-strength concrete under monotonic pull-out loading. *Magazine of Concrete Research*, 2004. 56(9). 545-557.
73. Jansson, P.O. *Evaluation of grout-filled mechanical splices for precast concrete construction*. 2008.
74. Coogler, K.L., K.A. Harries, and M. Gallick. Experimental study of offset mechanical lap splice behavior. *ACI Structural Journal*.2008. 105(4).
75. Lee, S.-H. and H.-K. Kim. Development of Steel Pipe Splice Sleeve for High Strength Reinforcing Bar (SD500) and Estimation of its Structural Performance under Monotonic Loading. *Journal of the Korea institute for structural maintenance and inspection,* 2007. 11(6). 169-180.
76. Abukawa, M. *Mortar-filled type reinforcing bar joint.* U.S 6851245 B1. 2005.
77. Hope, P.F. *Reinforcing bar coupling system*. U.S 4666326 A. 1987.
78. Oh, M.H. and E.J. Wilson, *Reinforcing bar splice with cutting edge bolts.* U.S 20080172979 A1. 2008.
79. Dahl, K.L. *High strength grouted pipe coupler. U.S 6679024 B2.* 2004.
80. Oliva, M.G. and L.C. Bank. *Splice system for connecting rebars in concrete assemblies.* U.S 8413396 B2. 2013.

81. Orangun, C., J. Breen, and J.O. Jirsa. *The strength of anchor bars: a reevaluation of test data on development length and splices*.Center for Highway Research, University of Texas at Austin; 1975.
82. Zuo, J. *Bond strength of high relative rib area reinforcing bars*., University of Kansas, Civil and Environmental Engineering; 1998.
83. Zuo, J. and D. Darwin. Splice strength of conventional and high relative rib area bars in normal and high-strength concrete. *ACI Structural Journal*, 2000. 97(4).
84. Haskett, M., D.J. Oehlers, and M. Mohamed Ali. Local and global bond characteristics of steel reinforcing bars. *Engineering Structures,* 2008. 30(2), 376-383.
85. Adajar, J., Teukai.Y, and Hiroshi.I. An Experimental Study on the Tensile Capacity of Vertical Bar Joints in a Precast Shearwall. *Transaction of the Japan concrete institue,* 1993. 15(2). 1255-1260.
86. Nilson, A.H. Nonlinear analysis of reinforced concrete by the finite element method. *ACI Journal Proceedings,* 1968.
87. Kankam, C.K. Relationship of bond stress, steel stress, and slip in reinforced concrete. *Journal of structural engineering*. 1997. 123(1). 79-85.
88. Nilson, A.H. Internal measurement of bond slip. *ACI Journal Proceedings*, 1972.
89. Mirza, S.M. and J. Houde. Study of bond stress-slip relationships in reinforced concrete. *ACI Journal Proceedings*, 1979.
90. Rilem/CEB/FIP. *Bond test for reinforcing steel: 2.Pullout test*. 1970.
91. Tastani, S. and S. Pantazopoulou. Experimental evaluation of the direct tension-pullout bond test. *Bond in concrete from research to standards,* Budapest, Hungary. 2002.
92. Tastani, S. and S. Pantazopoulou. Behavior of corroded bar anchorages. *ACI Structural Journal,* 2007. 104(6).
93. Hamza, A.M. and A.E. Naaman. Bond strength of reinforcing bars in SIFCON. *ASCE.* 1991.
94. De Larrard, F., I. Shaller, and J. Fuchs (1993). Effect of the bar diameter on the bond strength of passive reinforcement in high-performance concrete. *ACI Materials Journal,* 1993. 90(4).
95. Rilem/CEB/FIP. *Bond test for reinforcing steel: 1. Beam test*. 1970.
96. E. Cosenza, G. Manfredi, M. Pecce, and R. Realfonzo. Bond between Glass Fiber Reinforced Plastic Reinforcing Bars and Concrete Experimental Analysis. *ACI Special Publication,* 1999. 188.
97. Dancygier, A.N., A. Katz, and U. Wexler. Bond between deformed reinforcement and normal and high-strength concrete with and without fibers. *Materials and Structures*, 2010. 43(6). 839-856.
98. Hosseini, S.J.A. *Effect of spiral on the bond stress-slip relationship in the splice sleeve connector.* Ms.c tehsis. Universiti Teknologi Malaysia; 2011.
99. Hosseini, S.J.A., Abd Rahman AB. Effects of spiral diameter on the bond stress-slip relationship in grouted sleeve connector. *Malaysian J Civil Eng,* 2013. 12(1).
100. Hosseini, S.J.A., Abd Rahman AB. Analysis of spiral reinforcement in grouted pipe splices connectors. *GRAĐEVINAR Journal*, 2013. 65(6). 1-10.
101. Hosseini, S.J.A., Koushfar Kiarash, Abd Rahman AB, Razavi Meysam. The bond behaviour in reinforced concrete, state of the art, Part 1. *Cement-Wapno-Beton*, *2014.* (2). 93-105.

102. Hosseini, S.J.A., Koushfar Kiarash, Abd Rahman AB, Razavi Meysam. The bond behaviour in reinforced concrete, state of the art, Part 2. *Cement-Wapno-Beton*, 2014. (6).
103. ASTM. Standard *Test Methods for Testing Mechanical Splices for Steel Reinforcing Bars.* ASTM A1034/A. 2005.
104. Tran, B.H., Y. Berthuad, and F. Ragueneau. *Essais PIAF: Pour Identifier l'Adhérence et le Frottement.* 18ème Congrès Français de Mécanique. 2007.
105. ASTM. *Standard Test Method for Comparing Bond Strength of Steel Reinforcing Bars to Concrete Using Beam-End Specimens.* ASTM A944-05. 2005.
106. British Standard Insitution. *Steel for the reinforcement of concrete, Weldable reinforcing steel,Bar, coil and decoiled product, Specification.* BS 4449. 2005.
107. Abrams, D.A. *Tests of bond between concrete and steel.* 1913.
108. Ling, J.H., Ahmad Baharuddin Abd. Rahman, Abdul Karim Mirasa, Zuhairi Abd. Hamid. Performance of cs-sleeve under direct tensile load: part II: structural performance. *Malaysian Journal of Civil Engineering*. 2008. 20(1). 107-127.
109. Gambarova, P. and G. Rosati. Bond and splitting in bar pull-out: behavioural laws and concrete cover role. *Magazine of Concrete Research*, 1997. 49(179). 99-110.
110. Lura, P., G. Plizzari, and P. Riva. 3D finite-element modelling of splitting crack propagation. *Magazine of Concrete Research*, 2002. 54(6). 481-493.
111. Ling, J.H. Behaviour of grouted splice connections in precast concrete walls subjected to tensile, shear and flexural loads. PhD thesis. Universiti Teknologi Malaysia, Faculty of Civil Engineering; 2011.
112. Steuck, K.P. *Anchorage of Large-Diameter Reinforcing Bars Grouted into Ducts*. University of Washington; 2007.
113. Kemp, E.L., F. Brezny, and J. Unterspan. Effect of Rust and Scale on the Bond Characteristcs of Deformed Reinforcing Bars. *ACI Journal Proceedings*, 1968.
114. Benmokrane, B. and B. Tighiouart. Bond strength and load distribution of composite GFRP reinforcing bars in concrete. *ACI Materials Journal*, 1996.