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Pelajar : Norliana binti Manap

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THE BEHAVIOUR OF SLEEVE CONNECTION WITH SPIRAL REINFORCEMENT AND ADDITIONAL LONGITUDINAL BAR UNDER DIRECT TENSILE LOAD

NORLIANA BINTI MANAP

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

Faculty of Engineering
Universiti Teknologi Malaysia

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Dedicated to my beloved husband, Mohd Saruni and my son, Darius Al Hatadi

ACKNOWLEDGEMENTS

Alhamdulillah, in the name of Allah, with His blessing and generosity, I have finally completed this project successfully. First of all, I would like to convey my thankfulness and appreciation to my project supervisor, Assoc. Prof. Dr. Ahmad Baharuddin Abd. Rahman for his excellent supervision, guidance and endeavor in making this project successful; as I gained a valuable knowledge that no book would have written.

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ABSTRACT

One of the important precast concepts is all the precast elements must be connected for the stability. Therefore, the connection systems of the precast concrete structure must be designed in such a way that its structural performance is equivalent to that of a monolithic concrete structure. In most cases, conventional bar lapping system shows detailing problems due to its long development length, particularly for large diameter steel bars to be embedded in precast concrete structures. As an alternative, splice sleeve connector can be utilized as connection system, splicing reinforcement bars extruded from structural element to ensure continuity among them. However, the existing splice sleeve connectors in the market are proprietary and patented by foreign companies resulting in the high cost of adoption, particularly in Malaysia Therefore, this research aims to remedy this by developing a new splice connector that is tailored to the needs of the Malaysian construction industry. This new splice connector utilizes a simple transverse reinforcement which consists of R6 spiral bar and welded with four additional longitudinal Y10 bars. This project report summarizes the experimental programmed and also the performance of the proposed splice connector under axial tension. The influence of several parameters of the proposed connector is identified. These parameters include the infill material, reinforcement bar embedment length, spiral diameter and configuration of the additional bar. The experiments examined the tensile strength as well as the failure mode of the connectors. The result shows that the proposed sleeve connector of 33 mm and 58 mm diameter, with at least 200 mm of embedment length could provide a satisfactory structural performance that can develop the fracture capacity of the reinforcement bar. Thus, show that the connector could achieved the required strength with less required embedment length as compared to the conventional lapping system.

ABSTRAK

Satu konsep pratuang yang penting adalah kesemua elemen pratuang harus bersambung untuk kestabilan. Maka, sistem penyambungan dalam struktur konkrit pratuang harus direkabentuk agar pencapaian strukturnya adalah bersamaan dengan struktur konkrit monolitik. Dalam kebanyakan kes, sistem tradisional tindihan tetulang memberikan masalah perincian tetulang kerana jarak besi tertanam yang panjang, dan kesukaran tetulang keluli berdiameter besar untuk dibenamkan dalam struktur konkrit pratuang. Sebagai alternatif, lengan penyambung boleh digunakan sebagai sistem penyambungan, dimana ia menyambungkan tetulang keluli yang terjulur dari elemen struktur dan menjamin kesinambungan diantara mereka. Namun, sambungan jenis ini adalah hak milik syarikat-syarikat luar negara, sekali gus mengakibatkan peningkatan kos pembinaan secara keseluruhan sekiranya sistem sambungan ini digunakan di Malaysia. Maka, kajian ini adalah bertujuan untuk menyelesaikan masalah ini melalui penghasilan suatu sambungan seumpama yang baru serta mampu memuaskan keperluan industri pembinaan di Malaysia. Sambungan baru ini menggunakan tetulang melintang ringkas yang terdiri daripada gegelung keluli R6 yang dikimpal bersama empat tetulang tambahan memanjang, Y10. Laporan projek ini merumuskan perjalanan ujikaji serta pencapaian sambungan baru tersebut di bawah beban tegangan pugak serta kesannya terhadap pengaruh beberapa parameter kajian seperti bahan pengisi, jarak tetulang keluli yang tertanam, diameter gegelung dan kedudududukan tetulang tambahan. Kekuatan tegangan dan bentuk kegagalannya turut dikenalpasti. Hasil kajian menunjukkan sambungan yang menggunakan diameter gegelung 33 mm dan 58 mm dengan sekurang-kurangnya 200 mm panjang tetulang yang tertanam, memberikan pencapaian struktur yang memuaskan dimana ia menyebabkan kegagalan terikan pada tetulang keluli. Ini menunjukkan penyambung tersebut mampu mencapai kekuatan yang diperlukan pada jarak besi tertanam yang lebih pendek berbanding sistem pertindihan tradisional.

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θ	-	Bond angle
U	-	Bond strength of concrete
f_n	-	Lateral confining pressure
f_c'	-	Concrete compressive strength
T_s	-	Tangential force in a small length Δl of the pipe
t	-	Tangential strain in the pipe
l	-	Small longitudinal length of the pipe
E	-	Modulus of elasticity of the pipe
d_i	-	Inside diameter of the pipe
f_{bu}	-	Bond stress
β	-	Coefficient dependent on the bar type
f_{cu}	-	Infill compressive strength
P	-	Failure load
φ_e	-	Nominal bar diameter
L_d	-	Embedment length

CHAPTER I

INTRODUCTION

1.1 An overview on splice sleeve connector

The successful structural performance of precast concrete systems depends open the connection behaviour. Improper connections among structural members will lead to failure of structures. The configuration of the connection affects the constructability, stability, strength, flexibility and residual forces in the structure. A good connection system for precast concrete structures should not consume much space within the available dimensions of the structural elements to avoid congesting of reinforcement bars and to reduce complexity during fabrication. The method and erection process should also be simple to reduce the requirement of the manpower for the construction. Besides, the analysis and design method should be reliable and accurate for economical purpose.

Several splice methods have been invented to fulfill the requirement of lapped length for the continuity of reinforcement bars and one of those inventions is by the used of grouted splice sleeve connector. The sleeve is made either by available steel pipes or specially designed steel mould. The basic concept of this connection is two steel bars are inserted into the sleeve connector from both ends to meet at mid length of the sleeve. The purpose of the steel bars is to provide continuity for the tensile forces. Then, high strength grouts is poured into the sleeve as bonding material and simultaneously, perform as load transferring medium in the sleeve connector.

The splicing methods can be used as connection system in precast wall panels. The splice sleeve connectors are cast together with prefabricated wall panels. Then, the extruded vertical reinforcement bar from the upper wall panels will be properly inserted into the sleeve connector located at lower wall panels. By proper installation of the connection, the sleeves are able to develop the full strength of the bars and continuity of reinforcement between upper and lower precast wall panels (PCI Committee, n.d.).

1.2 Problem statement

In precast concrete structures, attention should be given to connections and joints. Joints can rightly be asserted as the weakest and the most critical points of a precast concrete structure especially in terms of bonding between the reinforcement and concrete (Korkmaz and Tankut, 2005). When a reinforced concrete structure is subjected to severe load, where the localized bond demand exceeds its capacity, localized damage and significant movement between reinforcing steel and the surrounding concrete will occur. Therefore, the connection systems of the precast concrete structure must be designed in such a way that its structural performance is equivalent to that of a conventionally designed, cast-in-place, monolithic concrete structure (ACI Committee 550, n.d.).

In normal practice of precast wall, continuity between upper precast walls and lower precast walls are carried out by lapping the reinforcement bars. However, this practice often caused congestion in the connection and may created honeycomb or voids in concrete if precaution is not taken during concreting. Therefore, the splice sleeves have been invented to eliminate these problems. However, such splice sleeve connectors usually require a special casting process due to the complexity of the sleeve designs. Furthermore, the splice sleeve connectors available in the market usually require a specially designed, high strength cementitous grout. Besides, this type of connectors could only be purchased from foreign companies and therefore, the overall cost of adopting splice sleeve connection system would probably outweigh the savings gained as mentioned above.

1.3 Objective of study

The specific objectives of this study are as follows:

i. To identify the performance of the sleeve connector with spiral reinforcement and additional longitudinal bar as an alternative method for traditional reinforcing bars lapping in connection for precast concrete wall panels.

ii. To investigate the failure modes of the sleeve connectors to understand the factors that govern their tensile capacity.

1.4 Scope of study

The scope of work will focus on studying the behaviour of sleeve connector with spiral reinforcement bar and additional bar for precast wall panel connections. To carry out the objectives, 30 specimens with various spiral diameters, length, and configurations were prepared and loaded under axial tension. Two bars of Y16 were aligned at the centre of the sleeve connector from an end, contacting to each other from the other end at the mid span of the sleeve connector. Their failure modes, as well as the failure mechanisms were investigated in order to understand the factors that govern their capacity.

1.5 Significant of study

The successful structural performance of precast concrete system depends open the connection behaviour. Improper connections among structural members will lead to failure of structures. In this study, laboratory testing will be conducted to assess the behaviour and performance of the sleeve connection with spiral reinforcement and additional longitudinal bar by studying the load-displacement relationships, stress-strain relationships and failure modes of the connections. The characteristic and behaviour of the proposed connections can be acquired so that they can be applied in Industrialized Building Systems (IBS) as an alternative for conventional cast in-situ reinforced concrete structures. The application of sleeve connectors in precast concrete structures can accelerate the speed of erection, significantly reduce the required reinforcement bar lap length, and guarantees higher quality assurance.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Precast concrete can be defined as concrete, which is cast in some location other than its final position in a structure (Phillips and Sheppard, 1980). The precast concrete elements are reinforced either with mild steel reinforcing bars or with pre-stressing strands. It has been use since the latter part of the 19th century in which several factors such as rising steel costs, material shortages during the Korean conflict, the expanded highway construction program, and the development of mass production methods to minimize labor costs have all been factors leading to the use of precast concrete in United States.

One of the important precast concepts is all the precast elements must be connected for integrity and stability (Hartland, 1975). The connections between the precast elements need to be rigid to form a bridging link to provide structural stability and safety to the precast system. A stable structural system will only be formed when the precast structural elements are jointed together. Thus, it is important to consider in the design stage its stability and safety throughout all stages from construction to completion stage. The overall behaviour of a precast building is very much dependent on its connections which should be able to transmit the vertical and horizontal loads to the structural elements, ductility to deformation, volume changes, durability, fire resistance and production.

The traditional method of connecting reinforcing bar is lap splicing. Lap splicing requires the overlapping of two parallel bars. The overlap load transfer mechanism takes advantage of the bond between the steel and the concrete to transfer the load. The load in one bar is transferred to the concrete, and then from the concrete to the ongoing bar. The bond is largely influenced by deformations (ribs) on the surface of the reinforcing bar and the strength of the surrounding concrete. However, as the technology of construction advances, the traditional method were found to be costly largely due to the amount of reinforcing bars used in the splice lapping. In addition, splice lapping occupied a large amount of space and congestion of reinforcing bars at columns or walls connection may result in voids or honeycomb concrete if proper precaution is not taken during concreting. In view of the problems encountered, the introduction of mechanical couplers or grout splice sleeves provides an alternative solution for connecting reinforcing bars.

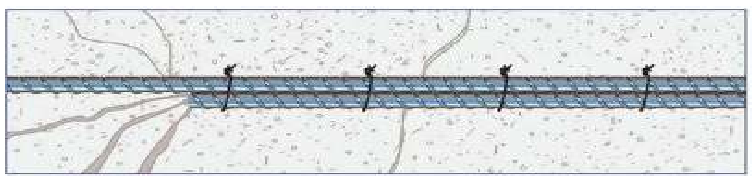

Figure 2.1 Lap splicing connection

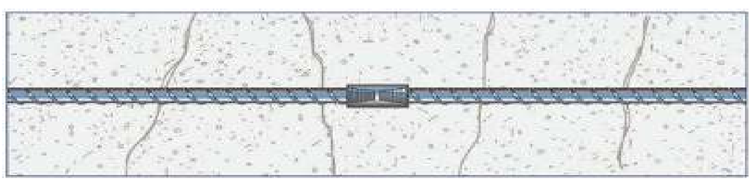

Figure 2.2 Mechanical splicing connections

2.2 Grouted splice sleeve

Grout filled splices were first developed in 1970s by Dr. Alfred A. Yee, for connecting precast elements and were widely used in North America since late 1980's. It can be used to connect column to foundation, column to column, wall to wall and the like. A sleeve is a cylindrical shape mechanical steel coupler that is utilized to splice reinforcement bars. It is a type of the end-to-end rebars connectors, which utilized non-shrink high strength grout as load transferring medium and bonding material. Reinforcing bars are insert into the sleeve from both ends to meet at the centre before grout is filled. Applications of sleeve in precast concrete structures as connection systems can accelerate the speed of erection, significantly reduces required rebar lap length, and guaranties higher quality assurance.

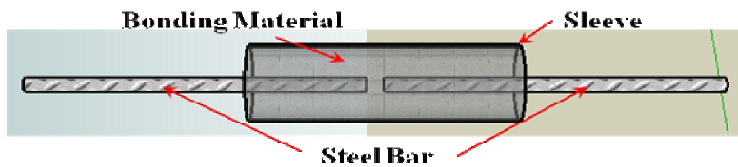

Figure 2.3 Typical splice sleeve connector

Basically, the most important part of the grout filled splices were the bonding action between the reinforcement and concrete. The adequacy of a sleeve is governed by the tensile resistance and bonding properties of the grout. The sleeve confines the grout that bonds the reinforcement in order to enhance the bonding performance. It enhance bonding property to grab on reinforcement bars firmly, and take parts in sustaining tensile load itself to ensure continuities of reinforcement bars. A sleeve should offer bonding and tensile resisting capacities that are comparable to the tensile resistance of reinforcement bar in order to ensure optimum usage of rebar capacity. In addition, the design of splice sleeve connectors for precast concrete wall systems should conform to the requirements of "emulative connection" as stated in ACI report 550.1R-01(ACI Committee 550, n.d.). In the report, it was stated that the connection systems in a precast concrete structure must be designed in such a way that its structural performance is equivalent to that of a conventionally designed, cast-in-place, monolithic concrete structure.

2.2.1 NMB Splice-Sleeve® Systems

The original grout-filled splice sleeve were invented by Dr. Alfred A. Yee in late 1960. It was then introduced to Japan by Nisson Master Builders (NMB) and given the connector's name as NMB Splive-Sleeve® system. Figure 2.4 shows the available of NMB Splice-Sleeve® in market. The sleeve has an integral rebar stop in the mid portion which indicates the specified embedment of the rebar into the sleeve and an optional setscrew to hold the bar in the narrow end. The uniform exterior dimension of the sleeve permits use of stirrups or hoops of the same size throughout the length of the sleeve. It can use to connect bars of the same size or any size smaller than the sleeve size. The only grout to be used in the NMB Splice-Sleeve® is called SS Mortar®. It is a special non-metallic Portland cement based filler grout. The grout can attain high early strength up to approximately 4,000psi (≈28MPa) in 24 hours and attain over 14,000psi (≈97MPa) compressive strength in 28 days (SNA, n.d.).

Figure 2.4 NMB Splice-Sleeve® Connector and SS Mortar®

At the precast plant, the sleeves are embedded precast element on one end of the main reinforcing bars to be connected. The bars protrude from the other end of the precast member. At the building site, the precast members are joined by inserting the protruding bars from the end of one precast member into the sleeves of the adjacent member. The sleeves are then grouted, in effect making the reinforcing bars continuous through the connection. It is particularly appropriate for use in joining vertical precast concrete structural elements (columns and shearwalls). This is because the sleeve can be embedded completely in the precast elements at the manufacturing yard and when the elements are joined in the erection process, there is no need to make a closure pour or to perform other cosmetic patching after the bars are joined (SSNA, n.d.).

However, special precautions must be taken to insure that movement does not take place after any of the grouting operations until sufficient strength in the grout is achieved to permit removal of supporting devices. Precast elements may thus be assembled without any closure pour or formwork. Spaces between precast wall elements are grouted with non-shrink mortars (ACI Committee 439, 1991).

2.2.2 LENTON® INTERLOCK

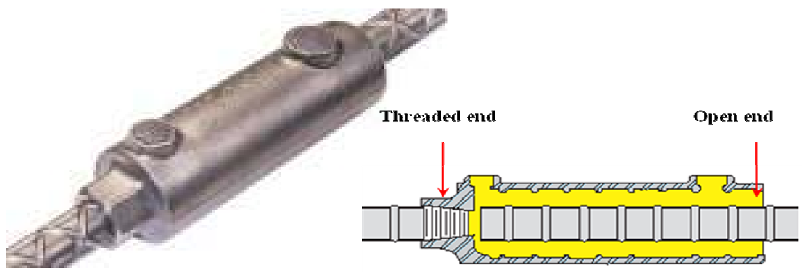

Figure 2.5 LENTON® INTERLOCK

LENTON® INTERLOCK system is another famous grouted splice sleeve which is patented under ERICO Company. A typical LENTON® INTERLOCK splice sleeve is shown in Figure 2.5. Generally, LENTON® INTERLOCK system is designed to splice reinforcing bars of diameter 20mm through 45mm. The sleeves are straight cylinders with one end threaded and the opposite end having internal annular ridges spaced approximately 1 inch (25.4mm) on center. Assembly of the connection is normally done in two separate stages. The LENTON® INTERLOCK threaded end is fastened to the coupler at a prefabricated yard prior to placement of concrete in the precast member. The connection is complete at the job site, where the exposed reinforcement bar of the adjoining panel is positioned within the interior of the coupler.

The system consists of a splice sleeve and ERICO HY10L grout, which is a non-shrink, cementitious mixture. At construction site, the connection is subsequently completed by pouring or pumping HY10L grout into the interior of the sleeve. The minimum compressive strength of HY10L should reach 8500psi (58.6MPa) at 28days. All spaces within the sleeve must be fully grouted (ERICO, n.d.).

LENTON® INTERLOCK were invented in an attempt at such a splice system is something similar to the grout splice system invented by Dr. Alfred A. Yee. According to the inventors (Albrigo et al., 1995), a splice sleeve has to be sealed when forming the precast members at the bar end and at the open mouth into which the bar from an adjoining member will project. If it is not properly sealed, concrete when cast will enter the sleeve requiring time to clean out and, since it may not be cleaned out perfectly, lessening the effectiveness of the splice. To overcome this problem, they suggested incorporating, at one end, a threaded socket to receive a threaded reinforcing bar. The sleeve and bar can be joined simply by threading the sleeve on the end of the bar and tightening the sleeve as required. In this manner the sleeve becomes a tensile and compression extension of the bar and when the sleeve is properly tightened on the bar, the end of the connector is then sealed. This is the major difference between this splice sleeve system and NMB Splice Sleeve systems.

This thread mechanism allows the sleeve length to be shorter than those in NMB Splice Sleeve systems. As observed from the previous review on NMB Splice Sleeves, both the reinforcing bars (from upper and lower walls) have to extend into the mid length of the sleeve. However, in the case of LENTON® INTERLOCK systems, the sleeve length can be reduced as the sleeve does not need to be long enough to house two reinforcing bars and thus the sleeve length can be reduced.

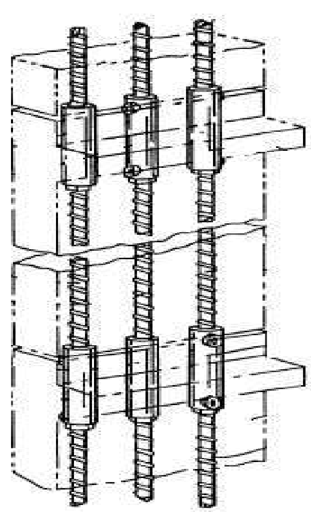

Figure 2.6 A series of walls connected using LENTON® INTERLOCK (Albrigo et al., 1995)

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Dedicated to my beloved husband, Mohd Saruni and my son, Darius Al Hatadi

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My greatest appreciation is conveyed to my husband, Mohd Saruni for his support, encouragement and countless blessing which have always been the source of motivation for me in pursuing my dream. Thank you for the relentless patience and for being always at my side.

And truly deeply thanks to my mother, Normah Bt. Mohd Diah and my family for their love and blessing. Last but not least, my course mates, Yati, Linda, and Shahrul, thank you for the cooperation and encouragement. I sincerely wish you all a bright and rewarding future. Thank you very much.

ABSTRACT

One of the important precast concepts is all the precast elements must be connected for the stability. Therefore, the connection systems of the precast concrete structure must be designed in such a way that its structural performance is equivalent to that of a monolithic concrete structure. In most cases, conventional bar lapping system shows detailing problems due to its long development length, particularly for large diameter steel bars to be embedded in precast concrete structures. As an alternative, splice sleeve connector can be utilized as connection system, splicing reinforcement bars extruded from structural element to ensure continuity among them. However, the existing splice sleeve connectors in the market are proprietary and patented by foreign companies resulting in the high cost of adoption, particularly in Malaysia Therefore, this research aims to remedy this by developing a new splice connector that is tailored to the needs of the Malaysian construction industry. This new splice connector utilizes a simple transverse reinforcement which consists of R6 spiral bar and welded with four additional longitudinal Y10 bars. This project report summarizes the experimental programmed and also the performance of the proposed splice connector under axial tension. The influence of several parameters of the proposed connector is identified. These parameters include the infill material, reinforcement bar embedment length, spiral diameter and configuration of the additional bar. The experiments examined the tensile strength as well as the failure mode of the connectors. The result shows that the proposed sleeve connector of 33 mm and 58 mm diameter, with at least 200 mm of embedment length could provide a satisfactory structural performance that can develop the fracture capacity of the reinforcement bar. Thus, show that the connector could achieved the required strength with less required embedment length as compared to the conventional lapping system.

ABSTRAK

Satu konsep pratuang yang penting adalah kesemua elemen pratuang harus bersambung untuk kestabilan. Maka, sistem penyambungan dalam struktur konkrit pratuang harus direkabentuk agar pencapaian strukturnya adalah bersamaan dengan struktur konkrit monolitik. Dalam kebanyakan kes, sistem tradisional tindihan tetulang memberikan masalah perincian tetulang kerana jarak besi tertanam yang panjang, dan kesukaran tetulang keluli berdiameter besar untuk dibenamkan dalam struktur konkrit pratuang. Sebagai alternatif, lengan penyambung boleh digunakan sebagai sistem penyambungan, dimana ia menyambungkan tetulang keluli yang terjulur dari elemen struktur dan menjamin kesinambungan diantara mereka. Namun, sambungan jenis ini adalah hak milik syarikat-syarikat luar negara, sekali gus mengakibatkan peningkatan kos pembinaan secara keseluruhan sekiranya sistem sambungan ini digunakan di Malaysia. Maka, kajian ini adalah bertujuan untuk menyelesaikan masalah ini melalui penghasilan suatu sambungan seumpama yang baru serta mampu memuaskan keperluan industri pembinaan di Malaysia. Sambungan baru ini menggunakan tetulang melintang ringkas yang terdiri daripada gegelung keluli R6 yang dikimpal bersama empat tetulang tambahan memanjang, Y10. Laporan projek ini merumuskan perjalanan ujikaji serta pencapaian sambungan baru tersebut di bawah beban tegangan pugak serta kesannya terhadap pengaruh beberapa parameter kajian seperti bahan pengisi, jarak tetulang keluli yang tertanam, diameter gegelung dan kedududukan tetulang tambahan. Kekuatan tegangan dan bentuk kegagalannya turut dikenalpasti. Hasil kajian menunjukkan sambungan yang menggunakan diameter gegelung 33 mm dan 58 mm dengan sekurang-kurangnya 200 mm panjang tetulang yang tertanam, memberikan pencapaian struktur yang memuaskan dimana ia menyebabkan kegagalan terikan pada tetulang keluli. Ini menunjukkan penyambung tersebut mampu mencapai kekuatan yang diperlukan pada jarak besi tertanam yang lebih pendek berbanding sistem pertindihan tradisional.

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θ	-	Bond angle
U	-	Bond strength of concrete
f_n	-	Lateral confining pressure
f_c'	-	Concrete compressive strength
T_s	-	Tangential force in a small length Δl of the pipe
t	-	Tangential strain in the pipe
l	-	Small longitudinal length of the pipe
E	-	Modulus of elasticity of the pipe
d_i	-	Inside diameter of the pipe
f_{bu}	-	Bond stress
β	-	Coefficient dependent on the bar type
f_{cu}	-	Infill compressive strength
P	-	Failure load
φ_e	-	Nominal bar diameter
L_d	-	Embedment length

CHAPTER I

INTRODUCTION

1.1 An overview on splice sleeve connector

The successful structural performance of precast concrete systems depends open the connection behaviour. Improper connections among structural members will lead to failure of structures. The configuration of the connection affects the constructability, stability, strength, flexibility and residual forces in the structure. A good connection system for precast concrete structures should not consume much space within the available dimensions of the structural elements to avoid congesting of reinforcement bars and to reduce complexity during fabrication. The method and erection process should also be simple to reduce the requirement of the manpower for the construction. Besides, the analysis and design method should be reliable and accurate for economical purpose.

Several splice methods have been invented to fulfill the requirement of lapped length for the continuity of reinforcement bars and one of those inventions is by the used of grouted splice sleeve connector. The sleeve is made either by available steel pipes or specially designed steel mould. The basic concept of this connection is two steel bars are inserted into the sleeve connector from both ends to meet at mid length of the sleeve. The purpose of the steel bars is to provide continuity for the tensile forces. Then, high strength grouts is poured into the sleeve as bonding material and simultaneously, perform as load transferring medium in the sleeve connector.

The splicing methods can be used as connection system in precast wall panels. The splice sleeve connectors are cast together with prefabricated wall panels. Then, the extruded vertical reinforcement bar from the upper wall panels will be properly inserted into the sleeve connector located at lower wall panels. By proper installation of the connection, the sleeves are able to develop the full strength of the bars and continuity of reinforcement between upper and lower precast wall panels (PCI Committee, n.d.).

1.2 Problem statement

In precast concrete structures, attention should be given to connections and joints. Joints can rightly be asserted as the weakest and the most critical points of a precast concrete structure especially in terms of bonding between the reinforcement and concrete (Korkmaz and Tankut, 2005). When a reinforced concrete structure is subjected to severe load, where the localized bond demand exceeds its capacity, localized damage and significant movement between reinforcing steel and the surrounding concrete will occur. Therefore, the connection systems of the precast concrete structure must be designed in such a way that its structural performance is equivalent to that of a conventionally designed, cast-in-place, monolithic concrete structure (ACI Committee 550, n.d.).

In normal practice of precast wall, continuity between upper precast walls and lower precast walls are carried out by lapping the reinforcement bars. However, this practice often caused congestion in the connection and may created honeycomb or voids in concrete if precaution is not taken during concreting. Therefore, the splice sleeves have been invented to eliminate these problems. However, such splice sleeve connectors usually require a special casting process due to the complexity of the sleeve designs. Furthermore, the splice sleeve connectors available in the market usually require a specially designed, high strength cementitous grout. Besides, this type of connectors could only be purchased from foreign companies and therefore, the overall cost of adopting splice sleeve connection system would probably outweigh the savings gained as mentioned above.

1.3 Objective of study

The specific objectives of this study are as follows:

i. To identify the performance of the sleeve connector with spiral reinforcement and additional longitudinal bar as an alternative method for traditional reinforcing bars lapping in connection for precast concrete wall panels.

ii. To investigate the failure modes of the sleeve connectors to understand the factors that govern their tensile capacity.

1.4 Scope of study

The scope of work will focus on studying the behaviour of sleeve connector with spiral reinforcement bar and additional bar for precast wall panel connections. To carry out the objectives, 30 specimens with various spiral diameters, length, and configurations were prepared and loaded under axial tension. Two bars of Y16 were aligned at the centre of the sleeve connector from an end, contacting to each other from the other end at the mid span of the sleeve connector. Their failure modes, as well as the failure mechanisms were investigated in order to understand the factors that govern their capacity.

1.5 Significant of study

The successful structural performance of precast concrete system depends open the connection behaviour. Improper connections among structural members will lead to failure of structures. In this study, laboratory testing will be conducted to assess the behaviour and performance of the sleeve connection with spiral reinforcement and additional longitudinal bar by studying the load-displacement relationships, stress-strain relationships and failure modes of the connections. The characteristic and behaviour of the proposed connections can be acquired so that they can be applied in Industrialized Building Systems (IBS) as an alternative for conventional cast in-situ reinforced concrete structures. The application of sleeve connectors in precast concrete structures can accelerate the speed of erection, significantly reduce the required reinforcement bar lap length, and guarantees higher quality assurance.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Precast concrete can be defined as concrete, which is cast in some location other than its final position in a structure (Phillips and Sheppard, 1980). The precast concrete elements are reinforced either with mild steel reinforcing bars or with pre-stressing strands. It has been use since the latter part of the 19th century in which several factors such as rising steel costs, material shortages during the Korean conflict, the expanded highway construction program, and the development of mass production methods to minimize labor costs have all been factors leading to the use of precast concrete in United States.

One of the important precast concepts is all the precast elements must be connected for integrity and stability (Hartland, 1975). The connections between the precast elements need to be rigid to form a bridging link to provide structural stability and safety to the precast system. A stable structural system will only be formed when the precast structural elements are jointed together. Thus, it is important to consider in the design stage its stability and safety throughout all stages from construction to completion stage. The overall behaviour of a precast building is very much dependent on its connections which should be able to transmit the vertical and horizontal loads to the structural elements, ductility to deformation, volume changes, durability, fire resistance and production.

The traditional method of connecting reinforcing bar is lap splicing. Lap splicing requires the overlapping of two parallel bars. The overlap load transfer mechanism takes advantage of the bond between the steel and the concrete to transfer the load. The load in one bar is transferred to the concrete, and then from the concrete to the ongoing bar. The bond is largely influenced by deformations (ribs) on the surface of the reinforcing bar and the strength of the surrounding concrete. However, as the technology of construction advances, the traditional method were found to be costly largely due to the amount of reinforcing bars used in the splice lapping. In addition, splice lapping occupied a large amount of space and congestion of reinforcing bars at columns or walls connection may result in voids or honeycomb concrete if proper precaution is not taken during concreting. In view of the problems encountered, the introduction of mechanical couplers or grout splice sleeves provides an alternative solution for connecting reinforcing bars.

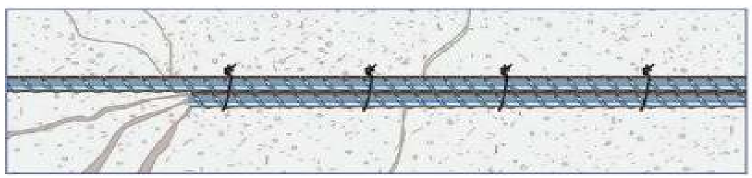

Figure 2.1 Lap splicing connection

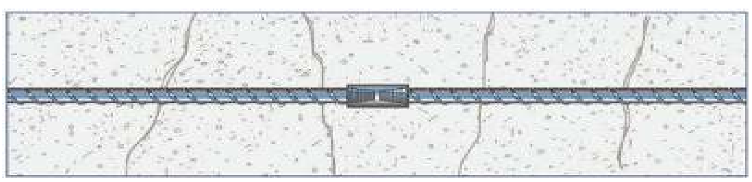

Figure 2.2 Mechanical splicing connections

2.2 Grouted splice sleeve

Grout filled splices were first developed in 1970s by Dr. Alfred A. Yee, for connecting precast elements and were widely used in North America since late 1980's. It can be used to connect column to foundation, column to column, wall to wall and the like. A sleeve is a cylindrical shape mechanical steel coupler that is utilized to splice reinforcement bars. It is a type of the end-to-end rebars connectors, which utilized non-shrink high strength grout as load transferring medium and bonding material. Reinforcing bars are insert into the sleeve from both ends to meet at the centre before grout is filled. Applications of sleeve in precast concrete structures as connection systems can accelerate the speed of erection, significantly reduces required rebar lap length, and guaranties higher quality assurance.

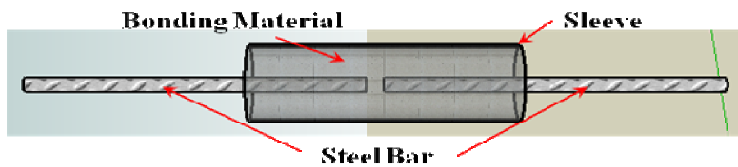

Figure 2.3 Typical splice sleeve connector

Basically, the most important part of the grout filled splices were the bonding action between the reinforcement and concrete. The adequacy of a sleeve is governed by the tensile resistance and bonding properties of the grout. The sleeve confines the grout that bonds the reinforcement in order to enhance the bonding performance. It enhance bonding property to grab on reinforcement bars firmly, and take parts in sustaining tensile load itself to ensure continuities of reinforcement bars. A sleeve should offer bonding and tensile resisting capacities that are comparable to the tensile resistance of reinforcement bar in order to ensure optimum usage of rebar capacity. In addition, the design of splice sleeve connectors for precast concrete wall systems should conform to the requirements of "emulative connection" as stated in ACI report 550.1R-01(ACI Committee 550, n.d.). In the report, it was stated that the connection systems in a precast concrete structure must be designed in such a way that its structural performance is equivalent to that of a conventionally designed, cast-in-place, monolithic concrete structure.

2.2.1 NMB Splice-Sleeve® Systems

The original grout-filled splice sleeve were invented by Dr. Alfred A. Yee in late 1960. It was then introduced to Japan by Nisson Master Builders (NMB) and given the connector's name as NMB Splive-Sleeve® system. Figure 2.4 shows the available of NMB Splice-Sleeve® in market. The sleeve has an integral rebar stop in the mid portion which indicates the specified embedment of the rebar into the sleeve and an optional setscrew to hold the bar in the narrow end. The uniform exterior dimension of the sleeve permits use of stirrups or hoops of the same size throughout the length of the sleeve. It can use to connect bars of the same size or any size smaller than the sleeve size. The only grout to be used in the NMB Splice-Sleeve® is called SS Mortar®. It is a special non-metallic Portland cement based filler grout. The grout can attain high early strength up to approximately 4,000psi (≈28MPa) in 24 hours and attain over 14,000psi (≈97MPa) compressive strength in 28 days (SNA, n.d.).

Figure 2.4 NMB Splice-Sleeve® Connector and SS Mortar®

At the precast plant, the sleeves are embedded precast element on one end of the main reinforcing bars to be connected. The bars protrude from the other end of the precast member. At the building site, the precast members are joined by inserting the protruding bars from the end of one precast member into the sleeves of the adjacent member. The sleeves are then grouted, in effect making the reinforcing bars continuous through the connection. It is particularly appropriate for use in joining vertical precast concrete structural elements (columns and shearwalls). This is because the sleeve can be embedded completely in the precast elements at the manufacturing yard and when the elements are joined in the erection process, there is no need to make a closure pour or to perform other cosmetic patching after the bars are joined (SSNA, n.d.).

However, special precautions must be taken to insure that movement does not take place after any of the grouting operations until sufficient strength in the grout is achieved to permit removal of supporting devices. Precast elements may thus be assembled without any closure pour or formwork. Spaces between precast wall elements are grouted with non-shrink mortars (ACI Committee 439, 1991).

2.2.2 LENTON® INTERLOCK

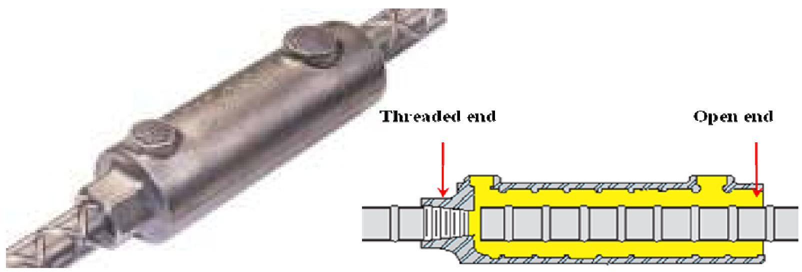

Figure 2.5 LENTON® INTERLOCK

LENTON® INTERLOCK system is another famous grouted splice sleeve which is patented under ERICO Company. A typical LENTON® INTERLOCK splice sleeve is shown in Figure 2.5. Generally, LENTON® INTERLOCK system is designed to splice reinforcing bars of diameter 20mm through 45mm. The sleeves are straight cylinders with one end threaded and the opposite end having internal annular ridges spaced approximately 1 inch (25.4mm) on center. Assembly of the connection is normally done in two separate stages. The LENTON® INTERLOCK threaded end is fastened to the coupler at a prefabricated yard prior to placement of concrete in the precast member. The connection is complete at the job site, where the exposed reinforcement bar of the adjoining panel is positioned within the interior of the coupler.

The system consists of a splice sleeve and ERICO HY10L grout, which is a non-shrink, cementitious mixture. At construction site, the connection is subsequently completed by pouring or pumping HY10L grout into the interior of the sleeve. The minimum compressive strength of HY10L should reach 8500psi (58.6MPa) at 28days. All spaces within the sleeve must be fully grouted (ERICO, n.d.).

LENTON® INTERLOCK were invented in an attempt at such a splice system is something similar to the grout splice system invented by Dr. Alfred A. Yee. According to the inventors (Albrigo et al., 1995), a splice sleeve has to be sealed when forming the precast members at the bar end and at the open mouth into which the bar from an adjoining member will project. If it is not properly sealed, concrete when cast will enter the sleeve requiring time to clean out and, since it may not be cleaned out perfectly, lessening the effectiveness of the splice. To overcome this problem, they suggested incorporating, at one end, a threaded socket to receive a threaded reinforcing bar. The sleeve and bar can be joined simply by threading the sleeve on the end of the bar and tightening the sleeve as required. In this manner the sleeve becomes a tensile and compression extension of the bar and when the sleeve is properly tightened on the bar, the end of the connector is then sealed. This is the major difference between this splice sleeve system and NMB Splice Sleeve systems.

This thread mechanism allows the sleeve length to be shorter than those in NMB Splice Sleeve systems. As observed from the previous review on NMB Splice Sleeves, both the reinforcing bars (from upper and lower walls) have to extend into the mid length of the sleeve. However, in the case of LENTON® INTERLOCK systems, the sleeve length can be reduced as the sleeve does not need to be long enough to house two reinforcing bars and thus the sleeve length can be reduced.

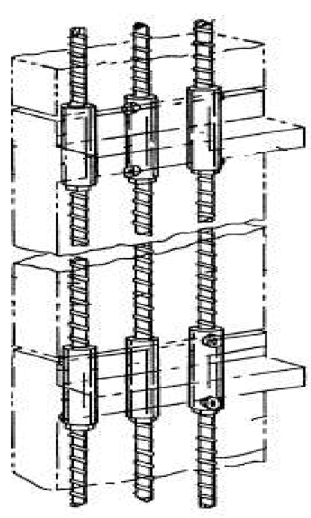

Figure 2.6 A series of walls connected using LENTON® INTERLOCK (Albrigo et al., 1995)