PERFORMANCE OF WALL PANELS WITH GROUTED SLEEVE CONNECTOR UNDER SHEAR AND BENDING

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ABSTRACT

This study discussed on the performances of concrete wall panels with grouted sleeve connector under shear and bending test. A substantial fraction of grouted sleeve connector behaviour has been investigated by several researchers from 90's century. Majority of early researches were specific under direct tensile test on connector only. The results show a few failure modes on grout slippage, sleeve fractured and bar fractured and this is considered as Phase 1 in the development of grouted sleeve connector. In Phase 2, the satisfied and selected grouted sleeve connectors from prevised research in Phase 1 were used in precast concrete wall panel. This study was conducted to develop a sleeve connector, using no spiral and reinforced bars only. Then, the connector tested under shear and bending test to study the connection's performance between the bonding of grout and precast concrete wall and analysed the types of failure mode occurred. The performance of connections was evaluated based on the ultimate loading capacity, displacement, strain, stress and failure mode where the strain will record from the use of LVDT (Linear Variable Differential Transducers). The results show that the wall specimens using no spiral and reinforced bar connectors, Wall A (1-connector) achieved satisfactory structural performance with the ultimate shear capacity 36 % and 66 % higher than Wall B (2-connector) and control wall. Based on the analysis of result, this concluded that the shear cracking at the grout and surface concrete was because of the bonding is not strong.

ABSTRAK

Tesis ini membincangkan tentang persembahan panel dinding konkrit dengan penyambung lengan diturap di bawah ricih dan ujian lenturan. Satu pecahan besar diturap tingkah laku penyambung lengan telah disiasat oleh beberapa penyelidik dari abad 90-an. Majoriti kajian awal adalah khusus di bawah ujian tegangan langsung pada penyambung sahaja. Keputusan menunjukkan mod kegagalan beberapa pada grout gelinciran, lengan patah dan bar patah. Dalam Fasa 2, penyambung lengan berpuas hati dan dipilih diturap dari penyelidikan sebelumnya telah digunakan dalam pratuang panel dinding konkrit. Kajian ini dijalankan untuk membangunkan satu penyambung lengan, tidak menggunakan lingkaran dan bar diperkukuhkan sahaja. Kemudian, penyambung diuji di bawah ricih dan ujian lenturan untuk mengkaji prestasi sambungan antara ikatan grout dan dinding konkrit pratuang dan menganalisis jenis mod kegagalan berlaku. Prestasi sambungan telah dinilai berdasarkan keupayaan memuatkan, anjakan, ketegangan, tekanan dan kegagalan mod utama di mana terikan akan merakam dari penggunaan LVDT (Linear Variable Transduser Berbeza). Keputusan menunjukkan bahawa spesimen dinding tidak menggunakan lingkaran dan penyambung bar bertetulang, Wall A (1-penyambung) mencapai prestasi struktur memuaskan dengan keupayaan ricih muktamad 36% dan 66% lebih tinggi daripada Wall B (2-penyambung) dan kawalan dinding. Berdasarkan analisis keputusan, ini membuat kesimpulan bahawa ricih retak di grout dan permukaan konkrit adalah kerana ikatan tidak kuat.

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CHAPTER 1

INTRODUCTIONS

1.1 BACKGROUND OF STUDY

Nowadays, the concept of precast concrete is ideal to meet future demand with higher specifications in terms of strength, beauty, integrity and durability of precast concrete. Moreover, in terms of performance for commercial, industrial, civic and domestic, it can make the construction work faster and efficient, more economical, environmental friendly and high quality assurance. Besides, the needs in the construction industry of the precast concrete are high demand due to the high strength, beauty, integrity and durability. From the bridges of incomparable beauty and sustainability to office buildings that blend with the environment. From the very latest in manufacturing and processing plants to high-tech chip fabrication buildings. Segmental bridges, airport control towers, college dormitories to huge parking structures, they're all about precast concrete. The sandwich two-panels are quietly good as it can withstand good weather either for hot or cold season.

The first documented modern use of precast concrete was in the cathedral Notre Dame du Haut which was constructed in France in1923. In meanwhile, that time only screen walls the precast. Precast wall panels were wide used in buildings that been provided with no loads were carried perhaps the force exerted by the wind only. In the instance, the precast wall panels have also been used more widely as a load bearing unit, wall supporting formwork, and shear walls. Reinforcement, particularly with steel becomes a major important when casting the precast panels.

The main difference between precast concrete and cast in-situ concrete was the structural continuity. The structural continuity of cast in-situ concrete is inherent and follows as the progression of the construction. For precast concrete structure, the structural continuity for each precast member is discrete. Therefore, an effort to ensure the structural continuity for precast concrete members to being created is vital. A stable structural system of a system of a precast building only can formed by the structural members in the precast building after the joints are well connected. Therefore, the selected grouted sleeve connector was designed and constructs a vital strength In order to withstand vertical loads and horizontal forces, as well as sustaining the stability and integrity of the structure, the connection must exhibit the ability of transferring loads, possess sufficient strength and ductility to manufacture economical, easy to handle and simple to erect.

The most versatile and practical method of connecting precast elements together to form a structural frame is to extend the reinforcing steel from the precast units into the in-situ reinforced concrete. This method reduces the sensitivity to precast concrete dimensional tolerances and provides structural safety, continuity and monolithic action at all connections throughout the framing system. It also alleviates the close precision normally required in member dimensions and in erection operations while providing virtually "fail-safe" connections. Mechanical steel couplers for connecting reinforcing steel bars in precast concrete have been widely used to joint vertical structural elements such as columns and wall panels. They have also been used effectively to connect horizontal precast units together. Some examples of composite connections are illustrated in Figure 1.1.

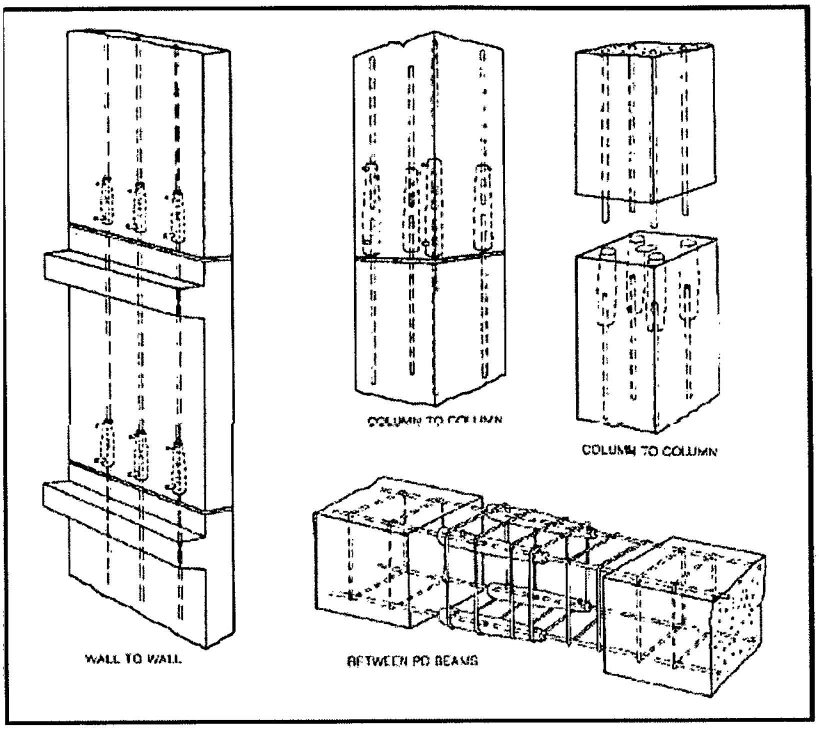


Figure 1.1: Typical arrangements of splice sleeve connections between different precast concrete components.

Source: Alfred A. Yee (2001)

Currently there are two types of methods that have been practiced to connect the precast structural members are conventional reinforcement bar lapping practice or by using the mechanical connector. In Malaysia, the precast structural members are normally connected via lapping of the reinforcement steel bar because the use of mechanical connector is expensive and mostly vendors are a foreign company.

The mechanical connector also called as sleeve connector. They can be grouted or threaded to connect the reinforcing steel bars and dowel bars at the two sides. Normally the sleeve is cast in one of the precast element to receive the dowel bars which projected either from the foundation or the lower precast concrete members and later fill with non-shrink grout. Thus the structural continuity can be achieved through the bonding strength of the grout and the bars across the sleeve. Cement grouted sleeves have previously been used only as a means of strengthening, connecting and repairing simple tubular members in a jacket structure. This paper describes a case history in which grouted sleeves have been used as a means of strengthening tubular joints. These joints had been shown by reanalysis of the structure to have an inadequate safety factor against shear failure.

Therefore, this study will focus on the preparation and testing specimens sleeve grouted connections through tensile test. The design selected for sleeve connection is to use the bar and the bar elongated as main reinforcement in the connection. Some have connection's parameter selected to study the effect of different parameters on the strength splice connections provided. The splice connections are also applied on the precast concrete wall structures and tested through shear and bending tests to investigate the behavior of grouted sleeve connections are used.

1.2 PROBLEM STATEMENT

The behavior of grouted sleeve connector has been investigated by several researchers from 90's century. The majority of early researches were specific on tensile resistance under direct tensile test. The results show a few failure modes on grout slippage, sleeve fractured and bar fractured. According to McDermott (1999), splice connections will ease the installation process and solve the problem of congestion bars, especially for structures which require a lot of assembly.

So, some modification steps should be taken to amend the purpose of the grouted sleeve connector for the precast concrete wall to secure the stability of structural organization. Because of numerous problems caused by overlapping system bar conventional, splice connection is appropriate connection type and can used to splice reinforcement bars from the other wall structure to ensure continuity between the two wall panels (Einea et al., 1995). AC313 requires any splice connector to be evaluated under direct tensile load and should achieve strength more or equal 1.25 of specify the yield strength of the reinforcement used. Then, the connector should be tested further for shear and bending to evaluate the performance of the connector under varying loading conditions.

1.3 OBJECTIVE OF STUDY

The objectives of the study are:

1. To determine the functioning of the wall panels with grouted sleeve connectors under shear and bending test
2. To analyze the types of failure during run the test
3. To make a comparison behavior between different number of connections

1.4 SCOPE OF STUDY

(a) Design connection GE Series involves the use only bar reinforcement and the sleeve.
(b) Link bars used are of mild steel with a diameter 6 mm (R6), while the reinforcement bars are of high yield steel diameter 16 mm (Y16).
(c) The specimens tested under shear and bending test using frame machine.
(d) The compressive strength of the concrete of the wall specimen during the test run ranged from 30 N/mm2 and for sika around 58 N/mm2
(e) The used of strain gages to measure strains in the main reinforcement and at the grouting part
(f) The precast wall specimens consist of three small walls are prepared and tested with one and two numbers of connectors.

1.5 RESEARCH SIGNIFICANCE

This paper presents the structural performance of grouted sleeve connectors without spiral tested through shear tests in the laboratory. The sleeve filled with grout as the bonding material between the reinforcing bar and the sleeve. This was to acquire the feasibility of the proposed connectors in precast concrete structure. Their performance was evaluated based on their load-displacement graph, ultimate tensile load, corresponding displacements at ultimate states and failure modes. Besides, the performances measured based on parameter different number of connectors per wall panels.

In addition, sleeve connections are produced can be used as an alternative to the system connections commonly used at construction sites and can replace the use of long peg bar and cut construction costs. This study is not provide direct selection of an economical but thus contributing to the development of systems connection of Building Systems (IBS) in Malaysia. The advantages of using this connection in the construction industry to accelerate the construction period and provide a higher quality of construction and guarantee.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Confined splice connection is a connection that is used to connect the two reinforcement bars to be more short-range. Reinforcement bar is the input from both sides of the end of the connection and located in the central connection before grout is included as bonding material. The splice connections also have first developed in the 1970s by Dr. Alfred A. Yee (Manap, 2009) and are widely used for about two decades ago around the 1980's in North America, Europe and Japan (Einea et al., 1995). These splice connections can be used to connect the reinforcement bars from pole to pole, beam to column, post to the site, beam to beam and wall-to-wall as shown in Figure 2.1 (Splice Sleeve North America, Inc. 2003).

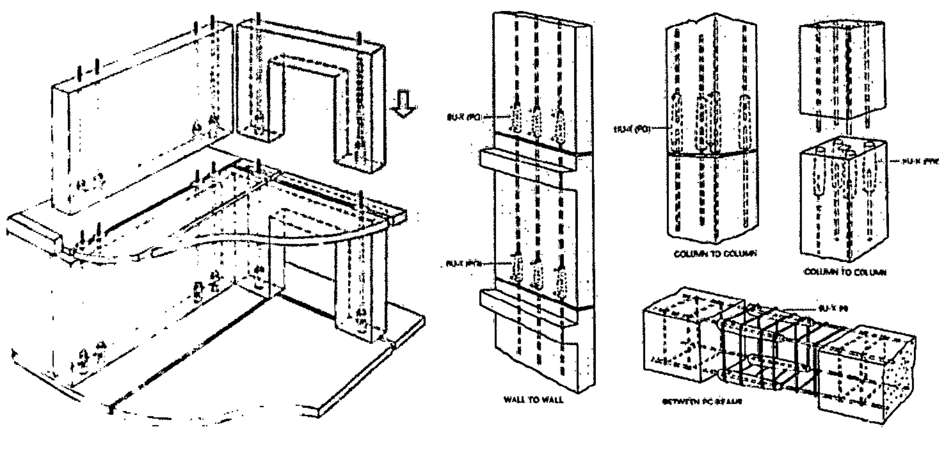


Figure 2.1: Variation connection of Splice Sleeve

Source: Splice Sleeve North America, Inc. (2003)

In principle, the most important part of the splice connection is the resulting bond strength in the connection itself. The bonding strength depending on the length of adequate anchorage and tensile resistance between reinforcement bars and grout material in the connection. Design connections should also follow criteria as determined by ACI 133 standard stated by Shuhaimi (2012).

Splice connection also depends on the strength of brackets produced to form the bond strength in the connection quite long than the short anchorage can be used compared to the conventional system of using the overlapping bars. Accordingly, this study was conducted to investigate the behaviour of the new connection design under shear load test when applied in a concrete wall precast specimen and tested in the laboratory. The study conducted by researchers previously also explained in this chapter.

2.2 BOND THEORY

According Moosavi et al. (2003), the bond can be expressed as the effect grip the annulus that is usually concrete or cement on the length of the peg-reinforcement bars to prevent from slipped out the connection. In addition they concluded that both of its compression strength and brackets as form of reinforcement bars used to play an important role in produce a low load or high capacity. In addition, there are three components important for the bonding that is bond adhesion, friction and force cement interlocking ribs.

Additionally, Untrauer and Henry (1965), has also said that the strength of bond can be defined as the resistance to separation of mortar and cement of reinforcement bars and other materials in a contact situation. Efficiency of the resulting bond can also measure the ability of reinforcement bars in reach full capacity in the connection strength.

Figure 2.2 shows three main types of connections developed by TxDOT Research Project 1748. Grout pocket connections derive their name from the fact that they incorporate precast voids or pockets formed in the bent cap to accommodate connectors. Grouted vertical duct connections incorporate corrugated ducts to serve as sleeves to house the connectors. Bolted connections are similar to grouted vertical duct connections, but the connectors run through the entire depth of the cap and are anchored by bearing at the top. Table 2.1 shows the advantages and disadvantages of the bent cap connections. The first phase of testing served to develop anchorage design provisions for straight or headed bars embedded in grout pockets or ducts. The following expressions were provided for required development length:

Grout pocket connections,

$$l_d = \frac{0.022 d_b f_y}{\sqrt{f'_c}} \tag{2.1}$$

Grouted vertical duct connections,

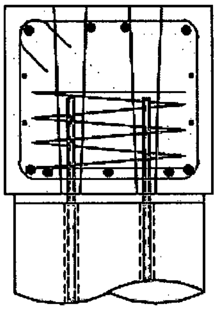
$$l_d = \frac{0.024 d_b f_y}{\sqrt{f'_c}} \tag{2.2}$$

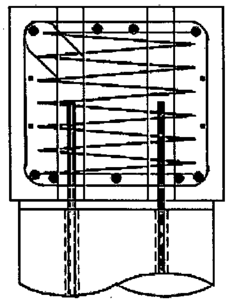
Where, l_d is the required development length (in.), d_b is the nominal diameter of the connector (in.), f_y is the specified yield strength of the connector (psi), and f'_c is the specified compressive strength of the concrete (psi).

Table 2.1: Advantages and disadvantages of bent cap connection types

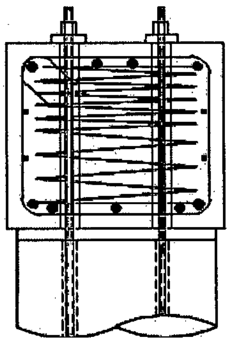
Grout Pockets	Grouted Vertical Ducts	Bolted Connection
+ simple grouting operations	+ stay-in-place ducts	+ stay-in-place ducts
+ large construction tolerances	+ smaller volume of grout needed	+ optional post-tensioning
- potential congestion of cap reinforcement	+ minimal interference with cap reinforcement	+ minimal interference with cap reinforcement
- large exposed top surface	+ more limited exposed top surface	- exposed cap top anchorage needs to be protected

Source: Francisco Javier Brenes (2005)





a) Grout pocket connection b) Grouted vertical duct connection



c) Bolted connection

Figure 2.2: Connection types developed by TxDOT Research Project 1748

Source: Francisco Javier Brenes (2005)

2.3 THE PROVISIONS OF THE CODE DESIGN

A set of guidelines is highly demanded and specified which required to follow the minimum standard of safety for constructed such any structures were developed. The main purpose of building codes are to gives protection and general welfare by protect health public as they relate to the construction and occupancy of buildings and structures.

The provisions of this code are not intended to prevent the installation of any materials or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved.

An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

2.3.1 ACI 318

The "Building Code Requirements for Structural Concrete (ACI 318-99)" is meant to be used as building code and substance from documents that provide recommended practice, detailed specifications, complete design procedures and design aids.

Grout shall be mixed in equipment capable of continuous mechanical mixing and tension that will produce uniform distribution of materials, passed through screens, and pumped in a manner that will completely fill in the connector and the voids between connections of the precast wall. Temperature of members at time of grouting shall be above 35 F and shall be maintained above 35 F until field-cured 2-in. cubes of grout reach a minimum compressive strength of 800 psi.

Grout proportioned in accordance with these provisions will generally lead to 7-day compressive strength on standard 2- in. cubes in excess of 2500 psi and 28-day strengths of about 4000 psi. The handling and placing properties of grout are usually given more consideration than strength when designing grout mixtures.

Connection details should provide for the forces and deformations due to shrinkage, creep, and thermal effects. Connection details may be selected to accommodate volume changes and rotations caused by temperature gradients and long-term deflections. When these effects are restrained, connections and members should be designed to provide adequate strength and ductility.

2.3.2 AC 313

Acceptance Criteria For Mechanical Connector Systems For Steel Reinforcing Bars implies another name as AC 133 which to establish requirements for mechanical connector systems for steel reinforcing bars to be recognized in an ICC Evaluation Service, Inc. (ICC-ES), evaluation report.

The criterion is applicable to reinforcing bar connectors that are field-assembled onto the ends of reinforcing bars that have been prepared at a factory or the jobsite. Additional requirements, for cementations grouted sleeve steel reinforcing bar connectors, are described in Annex A.

Connector systems for sleeve-type systems installed with grout, the coupler system typically is the steel sleeve and grout. For systems utilizing a coupler installed onto bars that have specially prepared ends, such as bars with threaded ends, the connector system components are the coupler and the bars.

The fabricator must assemble the couplers onto the ends of the steel reinforcing bar as required by the evaluation report applicant in a manner consistent with the qualifying test specimens. The evaluation report must include a sufficiently detailed description of the method of installing the couplers onto the reinforcing bars and specifications, or refer to specific documents that contain this information.

For Type 2 splices, connections using the fabricator-prepared assemblies of couplers and steel reinforcing bars, tested in static tension, must develop 100 percent of the specified tensile strength of the steel reinforcing bar and 125 percent of the specified yield strength of the reinforcing bar for use under the IBC or IRC. This may be demonstrated in test reports submitted to the code official.

2.4 EFFECT OF FAILURE

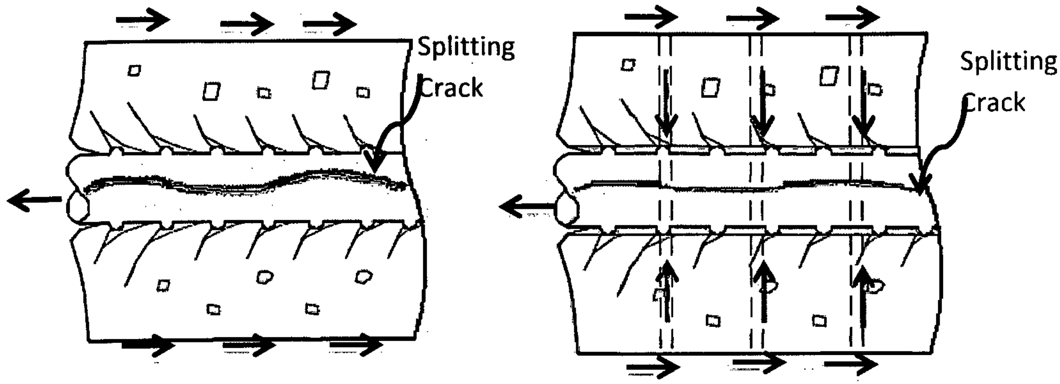
Two major modes of failure observed throughout the test. The failure modes provide essential information in this study. Despite of demonstrating the manner of defects of the specimens at ultimate state, they also described the causes of failure that should be taken into account in future development and design of an adequate splice sleeve connector like bar slippage and grout slippage.

The main failure modes of connections with shear keys are shear failure along the shear connectors for too closely spaced shear keys and crushing of the grout on the stressed side of the shear keys for Grouted Joints with an appropriate shear key spacing. In this case, usually diagonal cracks occur in the grout. More detailed information on the characteristic properties and the failure mechanisms are for example described by the Department of Energy (1982), Billington (1978), Lamport (1988) or Billington et al. (1980).

The fatigue performance of Grouted Connections highly depends on the loading regime. According to Hordyk (1996) the slope of the S/N-curve increases with a decreasing stress ratio (R), especially in reverse loading. In case of compression-compression loading the slope of the S/N-curve is small. In either case the number of cycles to failure exhibits large scatter. Figure 2.3 and 2.4 shows the pattern of bond failures of the grouted connector and the grouted ducts under the splitting, shearing during the run testing (pull-out).

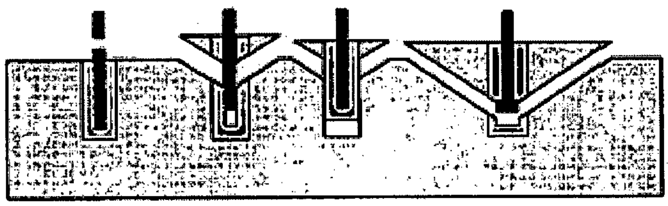
2.5 GROUTED SLEEVE CONNECTIONS.

Grouted Connections or Grouted Joints are a well-known method for fixing offshore structures to the seabed. For fixed offshore platforms usually shear connectors are used to increase the load-bearing capacity. This technology is also used for repair and strengthening of aged offshore structures.



a) Bond Failure by Splitting

b) Bond Failure by Shearing of Concrete Keys in Between Ribs (Pull-out)



Steel Adhesive Plug Concrete Breakout

c) Basic failure modes for grouted connector

Figure 2.3: Several examples of bond failure

Source: Francisco Javier Brenes (2005)

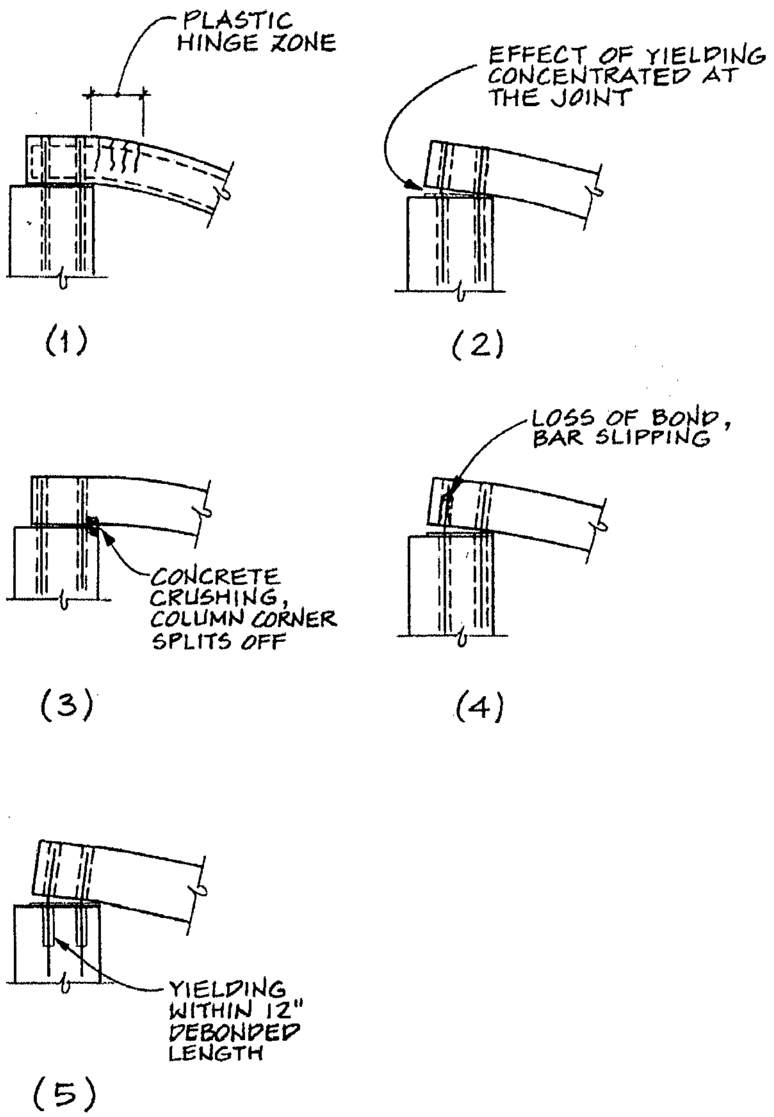


Figure 2.4: Flexural failure mechanisms for precast connection using grouted ducts

Source: Francisco Javier Brenes (2005)

The major parameters that characterized the load-deformation behaviour and the ultimate load are the compressive strength of the grout, the ratio of diameter to thickness (D/t) of pile, sleeve and grout and the ratio of height to spacing (h/s) of the shear keys. The Figure 2.5 shows the grouted joints in fixed offshore platforms, characteristic properties and design with and without shear keys.