CONSTRUCTION PROCESS AND CONTROL OF THE DETAILING IN ORDER TO GUARANTEE THE ASEISMIC BEHAVIOR OF THE RC ELEMENTS

By Mario A. Vélez C.

(For the course of Earthquake Engineering 1994-1995)

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Abstract

Actually, in the Peruvian construction activity, it is necessary to find solutions to some problems like the control of the quality and the high cost of the buildings, specially when the seismic activity of the zone is considered. This purpose has to be carried out developing the knowledge about the structural behavior of the buildings taken in account the teaching of strong earthquakes, and guaranteeing the reliability of the construction.

Usually the research is addressed to the study of structural models comparing results obtained with theoretical and mathematics tools with the results obtained in labs experiments, in order to identify patterns and equations to describe the behavior of the elements (Structural model).

However, since several years ago, the field of the construction in Peru remains in a "non-industrial level" without the development of new techniques or new construction models and sometimes in the control of the quality construction, a decrease tendency was founded.

That is the way that to arise the intention to study this matter. Demonstrate the importance of the construction process in order to guarantee the adequate behavior of the resulting structures, analyzing and learning aspects of the constructions developments, the detailing and their control in Japan.

In order to carry out this purpose several construction sites were visited and were observed the next process: Detailing reinforcement, Gas pressured welding, Concrete casting process and Precast construction method. Firstly were reviewed the Japanese and American codes and some theoretical background in order to establish the state of the art of these topics.

1 INTRODUCTION : GENERALITIES

1.1 General and motivations

There is more to design than proportioning a structural section or obtaining forces and stresses. Overall economy, and feasibility and ease of construction, are some of the equally important aspects of a good design. In fact, an elaborate analysis becomes worthless if the computations are not translated into successful structures. Such may be the case when the structure is represented by a set of poorly detailed drawings. Structural analysis is no more than one of the many tools used for the skillful engineer in the total process design. It is necessary but insufficient prerequisite of a good design. To reinforce a concrete structure correctly, the designer must possess a penetrating understanding of its behavior and understanding beyond the establishment of the equations of equilibrium and strain compatibility.

This understanding must be bases on a thorough knowledge for the properties of materials and structural behavior as evidences by test, rather than on the results obtained from mathematical models [1], [2].

1.2 The importance of the detailing, the adequate construction process and its control

A reason for detailing is to ensure that the possibility of error is reduced to a minimum. For that, the contractor should know the precise requirements with regard to sizes and positioning of reinforcement cover distances, concrete strengths, etc.

Many young engineers forget basic fact that the detail drawing is the only positive link between the design engineer and the contractor and that sit meetings and visits are of secondary importance to good clear detail drawings.

It is of equal importance that details as well as calculations, should be thoroughly checked (possibly more important) since with calculations a safety factor or the behavior of the structure can compensate for an error, were as a wrongly placed system of reinforcement or the omission of some bars due to a badly produced drawing can lead to local failure: i.e. several cracking during earthquake. Use of upper limits of reinforcement ratios permitted is likely to lead to insurmountable construction problems especially at frame joints.

1.3 Structural Details and process to study

In order to control the construction process, it is necessary to understand the real behavior (accompanied with the respective analytic, practical and theoretical explanation) of the resulting structures, after casting the concrete.

1.3.1 Detailing and placing of reinforcement

1.3.1.1 Development bond and anchorage.

Development bond.- One of the topics to be studied is the development bond length in the reinforcement bars. How is its control in the construction site and what are the practical problems to its implementations [3]

Anchorage. - During the earthquake the failure of anchorage should be prevented, because it causes the rapid strength reduction and the poor energy absorption in hysteretic characteristics. In order to avoid this situation “standard hooks” are provided to the end part of the bars [4].

1.3.1.2 Beam- column joint

Usually in the beam-column, joint zone can occur very high reinforcement congestion. Also usually the designer does not consider this problem in the design time, therefore he does not know how will be the behavior of this joint during an eventual earthquake. From another point of view, in the construction, problems with the construction procedure place will occur.

The “AIJ Standard for Structural calculation of Reinforced Concrete Structures” [5] does not require the design of beam column joints.

1.3.2 Gas Pressured Welding

A special joint between two reinforcement bars will be described in this study. In Japan, reinforcement splices in recent decades have been almost always made by a process known as "Gas pressured welding" Some no adequatte Pressure welded splices were observed to fracture in the 1995 Hyogoken-Nanbu earthquake**".**

1.3.3 Concrete Casting Process

In the "1995 Hyoigoken – Nanbu earthquake" it was observed a big damage in reinforced concrete structures. Most of the analysis and interpretations about the failures reason are addressed to the design field. Clearly, there is a relation between year of construction (current design code) and building damage during this earthquake, but also it is necessary to apply more attention about the construction process and its control when the concrete is placed in its final position. In this study, some observances and recommendations about the concrete casting process will be presented.

1.3.4 Precast Construction System

A very interesting matter is the construction process using prefabricated reinforced concrete elements. They are assemblage, using special joints, with the elements "cast in situ".

The control of the quality and adequate construction assemblage process become in very important matter.

2 STATE OF THE ART FOR THE TOPICS TO STUDY

2.1 Regulation codes

2.1.1 Japan regulation codes

The primary and fundamental regulation is given by "THE BUILDING STANDARD LAW OF JAPAN [7]

The "AIJ STANDARD FOR STRUCTURAL CALCULATION OF REINFORCED CONCRETE STRUCTURES" (hereinafter abbreviated as the **AIJ Standard**) indicates one method of structural calculations for structural design of ordinary reinforced concrete structures.

The "JAPANESE ARCHITECTURAL STANDARD SPECIFICATION FOR REINFORCED CONCRETE WORK – JASS 5" [8] (hereinafter abbreviated as the **JASS 5**) gives Standard specification to cast – in- place reinforced concrete work, including the concrete work of framed reinforced concrete structures, and plain concrete work..

The Architectural Institute of Japan publishes the "AIJ STRUCTURAL DESIGN GUIDELINES FOR REINFORCED CONCRETE BUILDINGS" [9] (hereinafter abbreviated as the **AIJ Design Guidelines**). This is a set of design guidelines that consider an earthquake design method based on ultimate strength concept for reinforced concrete buildings structures, which shall form a yielding mechanism during a strong earthquake. The **AIJ Design**

Guidelines is a supplement the use of **AIJ Standard** , that can be employed for various types of structures.

2.1.2 North – American regulation codes

The definitive design specification for reinforced concrete building in USA is:

The "BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE (ACI 318M-89) (Revised 1992) AND COMMENTARY (ACI 318RM-89) (revised 1992) (Hereinafter abbreviated as the **ACI 318M-89**) published by The American Concrete Institute. This code provides minimum requirements for design and construction of reinforced concrete structures. Also, **ACI 318M-89** makes reference to the another official ACI publications.

2.2 Review of Selected Important Factors

2.2.1 Development bond and anchorage

Mainly the bond of deformed bars depend on the mechanical interaction mechanism. In the figure 1 is shown the interaction forces between the steel and the concrete.

2.2.1.1 Development bond-Splitting failure

The radical component of the forces on the concrete and the mechanism shown in the figure 2 generates the called splitting failure.

2.2.1.2 Development bond – Confinement

The splitting cracks reduce the bond resistance. The magnitude of splitting cracks can be controlled if the concrete that surrounds a bar can be confined.

2.2.1.3 Development bond – Reinforcing bar cover

Increased concrete cover has been found that increase the resistance against splitting. However, this not improve the bond performance in proportional ratio. For large size, the beneficial effect is not very significant. The effect (increase cover – increase resistance against splitting) is significant in medium size top bars.

2.2.1.4 Development bond- Position of the bar

The ultimate bond strength is drastically reduce in the case of horizontal bar compared with vertical bars. It is due to the position of the bars in relations to the downward movement of the surrounding concrete, caused by settlement of the fresh mixture. The amount of settlement depend on the extent of concrete, caused by settlement of the fresh mixture. The amount of settlement depend on the extent of bleeding of the fresh concrete and the rate at which water is permitted to escape from the formwork [10].

2.2.1.5 Development bond – Beam –column joint

Alternate yielding in tension and compression at a critical section in this zone can occur. The gradual loss of bond can result in penetration of yielding into the anchorage zone, drastically decrease the effective development length, available to absorb the yield strength of the bar. This means to be carefully with adequate implementation of the anchorage in the beam-column joint, and to be sure about that the all the perimeter of the section of the reinforced bar is embedded in concrete (See item 3.1.2).

2.2.1.6 Anchorage- depending of direction of concreting

In the figure 3 is shown the relationship for hooked anchorage of deformed bars with the directions of the concreting, and the relationship between different degrees of bends and the directions of the concreting. The bend with less than 180º turn does not necessarily provide anchorage superior to a local deformations in the concrete appear, which increased the slip in the embedded bar.

The strain distribution in the steel measured along the hook in such a test reveals that the bar force is transferred rapidly into the concrete and the straight portion following a hook is generally ineffective (see figure 4).

2.2.2 Beam – column joint

As it was wrote before, **AIJ Standard** does not require the design of beam column joints. In opinion of the Professor S. Otani [11], "… the lack of significant earthquake damage observed in reinforced concrete joints in Japan is the probable reason for this; however, the damage in a joint may be have been hidden behind architectural coverage, or premature column failure may have reduced the actions in the joint".

Big shear forces (stresses) are transferred to the joint from the beams and columns causing diagonal cracking of the joint concrete and yielding of lateral reinforcement. At the same time the beam reinforcement yields at the face of the joint under the planned beam-yielding mechanism causing bod deterioration along the beam reinforcement within the joint. Due to these effects will occur a reduction in the stiffness and energy dissipation capacity. Usually to avoid the shear failure in the beam-column joint lateral reinforcement is placed, but this reinforcement cannot eliminate the source of the stiffness degradation.

In the figure 5 [12] is shown how is the efficiency in joints depending of the detailing. K.Kitayama [13] proposed an expression for the limitation of the beam bar size in beam – column joint, in which the column width and the diameter of the bar influence final behavior of the joint.

So, it is not only important to provide numerical design or resistance to the joint, also is decisive to define the distribution of the reinforcement to ensure the adequate behavior during an earthquake.

2.2.3 Gas pressured Welding

The "Japan Pressure Welding Society" and **JASS 5** in the section 10.6 give the specifications for this kind of reinforcement splicing procedure.

The procedure must follow the next specifications given in **JASS 5:**

a. Welders shall possess ability in accordance with JIS Z 388 (Standard Qualification Procedure for Gas Pressure Welding Technique) which is appropriate for the work, and the certificate shall be submitted for the approval of the architect/engineer.

b. Reinforcing bars shall be cut and fabricated such that the shapes and dimensions after gas pressure welding are as specified.
c. Before pressure welding, the surface to be welded shall be cleared completely of injurious material by grinding and shall be made as flat as possible on the day of welding.
d. The parts to be welded shall be heated and pressured to the form in accordance with (1) through (4) below.
   (1) The diameter of swelling shall be not less than 1.4 times the diameter of reinforcing bars in principle.
   (2) The length of swelling shall be not less than 1.2 times the diameter of reinforcing bars, and its shape shall be smooth with no sag.
   (3) The axis eccentricity shall be not more 1/5 the diameter of reinforcing bars
   (4) The distance between the top of swelling and the welded face shall be not more than ¼ the diameter of reinforcing bars.
e. Gas pressure shall not be done during strong wind or rain. However, where cover, shade or other protection is provided, it maybe done on the approval of the Architect/Engineer.

After pressure welding is finished, welded parts shall be in accordance with 12.5 (Quality control) and inspection sheets shall be submitted for the approval of the Architect/Engineer. In the next item **JASS 5** specifies the procedure to follow when inadequately welded parts are located. In general the inadequately welded part shall be cut and pressure-welded again.

When any lot of welded parts is rejected on inspection in accordance with 12.5 specifies to follow this procedure.

(i) Welding work shall be stopped immediately. The cause of he defect shall be investigated, and necessary improvement shall be introduced. Work shall be resumed on the approval of the Architect/Engineer.
(ii) All of the remaining welds of the rejected lot shall be inspected by ultrasonic inspections. Inadequately welded parts shall be removed for new welding or reinforced with supporting bar. The method of ultrasonic inspection and the inspectors shall be approved by the Architect/Engineer.

2.2.4 Concrete Casting Process

2.2.4.1 General

Through the time he concrete casting process did not change basically. Adam Neville [14] gave the net comment: “Many new standards and recommended practices have been written, and thousands upon thousands of research papers have been published but there has been only a modest number of novel and important practical developments. Alas, this situation contrasts sharply with the rate of change in fields such a communications”. This study confirms this opinion.

2.2.4.2 Placing

JASS 5 6.6 d.-, indicates that free fall height in placing concrete shall be such that the segregation of the concrete is avoided. In contrast with this ambiguous specification, The Standard Specification for Design and Construction of Concrete Structures (7.4.2(8)) [15], indicates that for placing concrete in high height forms the distance form the outlet of the chute, pipe, bucket, hopper and other devices to the placement surface shall be, as a rule, 1.5m or less.

ACI 318M-89 develops the placing techniques specifications in the chapter 5. Also this code makes incidence in that the concrete shall be deposited as nearly as practical in its final position to avoid the segregation due to rehandling or flowing.

ACI 318M-89 6.4.5 indicates that beams, girders or slabs supported by columns or walls shall not be cast or erected until concrete in the vertical support member is no longer plastic. The respective comment (ACDI 318-89M R6 .4.5) explains that delay in placing concrete in members supported by columns and walls is necessary to prevent cracking at the interface of the slab and supporting member, caused by bleeding and settlement of plastic concrete in the supporting member.

When the placement consist of several layers, concrete delivery should be scheduled so that each layer is placed while the preceding one is still plastic to avoid the cold joints.

2.2.4.3 Consolidation

JASS 5 6.7 (a.-and b.-) specifies that spud vibrators shall be used on each fresh layer of concrete and inserted vertically to a depth so that the tips for vibrators penetrate the top level of the previously placed layer of concrete. The distance between insertions shall be not more than 60 cm. and vibrating shall be continue until cement paste rises to the concrete surface.

The action of the vibrator liquefy the mortar and drastically reduce the internal friction between aggregate particles. While in this condition, concrete settles under the action of gravity. When the vibration is discontinued, friction is reestablished [16].

The layers should be as level as possible so that the vibrator does not need to move the concrete lateral, since this might cause segregation.

It can be distinguished two stages in the consolidation process by vibration. The first stage is the subsidence or slumping of the concrete and the second stage is the deaeration or removal of entrapped air bubbles.

Honeycomb occurs when the mortar does not fill the space between the coarse aggregate particles. The presence of honeycomb indicates that the fist stage of consolidation has not been completed at these locations.

Honeycomb is generally caused by: Using improper or faulty vibrators, Improper placement procedures, Poor vibration procedures, Inappropriate concrete mixtures, Congested reinforcement.

Insufficient clearance between the reinforcing steel is an important cause of honeycomb. In establishing steel spacing, both the designer and builder must keep in mind that he concrete must be consolidated.

2.2.5 Precast Construction System

2.2.5.1 Outline of Precast System

The information to be presented was taken from the paper "Existing Precast Frame System in Japan" [17], and commented by the author of this paper.

Firstly, it is convenient to describe briefly the development of precast frame structures in Japan. The first P.C. structure was a wall structure in 1950 for apartment houses. Then the develop of this technique began in 1960. The two major problems were the cost and the license and permission. The High cost was mainly because it was necessary to produce precast members in small lots due to the large variety of size and shapes of the members.

In 1989 the construction industry, after recession phenomena, could not provide a sufficient supply of skilled workers. Particularly, the shortage of carpenters was serious.

So, then the purpose of the development of new precast frame system was clearly defined, the precast frame method require less formworks. So, construction companies restarted the competition of developing such systems.

As a conclusion: The precast frame system was developed as a method to shorten skilled workers not as a result of the pursuit of a substantial solution.

In order to compare the PC system with the traditional construction system, the cost of a conventional cast-in-site concrete column is 66,000 Yen/m3 and using the PC System for the same column is around 134,000 Yen/m3. About the construction period varies with methods of manufacturing columns, but usually 4 to 7 days/floor.

The total area of formwork can be reduced by 50 to 90 %. The volume cast –in- place concrete reduce by 30 to 60%.

2.2.5.2 Typical Precast Frame System

Corresponding to the configuration of precast members and the location of connections, typical precast frame system in Japan are classified in:

1. PC Frame System
    a. Column – tree System
    b. Single – members System
    c. Semi –precast composite system (is used for floor slabs)
2. PC Wall System
3. PC Wall - Frame System

Column-tree System

This system uses two dimensional precast members (Types A and B in figure 6). The precast members are jointed at the center of beams and columns. Perpendicular beams are jointed generally at their ends.

The principal problems with this System are:

1. Manufacturing and transportations cost are high due to its complex shape.
2. In some cases thickness of slabs cannot be included in the depth of a beam of rectangular cross section, so the cross-sectional performance of the beam is lower than monolithic beam.
3. Column joints are located at the middle of the story height. It is to have aesthetic consideration to make the joint.

Single-members System

All the precast members (columns, beams and floor slabs) are made separately and they are connected as one body through cast- in-situ concrete. In some cases, columns are cast-in-situ, (Types C, E, E' and F in figure 6).

In this system, precast members are semifinished components. However , since almost no formworks are required at the construction site, the shortening construction period and saving skilled workers are made possible.

The weakness point of this system are the beam-column joints. It is necessary to have very clear the design of the joints and its control during the construction.

A variance of this system is the Precast Skill System (Figure 7), which uses precuts hollow box columns, and U-shape section precast beams. They are designed to reduce the weight of precast members.

Floor Slab System

This system is a semi-precast composite slab system. Consist in to use a thin precast slabs and cast-in-place concrete for he top par of the slab. Most of the construction site use this slab system.

It does not require formworks, and for that it is one of the highly efficient constructions method.

In the table 1 (17) is shown characteristics and cross sections of some half PC floor slab construction system.

PC Wall System

In this construction system precast shear walls are incorporated to the structural system. It is used for the joints sleeve joints using special high strength, non shrink mortar.

PC Wall- Frame System

This System incorporates both elements to the structural model: Walls and Frames.

2.2.5.3 Connections

As it was written before, the most important matter from the structural point of view, in PC System are the connections between the PC members.

Each company developed and they continue developing own connections systems.

In the table 2 [17] is shown a general classification of connections.

Increase the priority to research rather than to application. Specially to study the connections (Design and construction method) in order to have the same structural performance as that of conventional monolithic reinforced concrete.

3 PRESENTATION AND DESCRIPTION OF CONTRUCTION PROCESS EXAMPLES

3.1 Detailing implementation

3.1.1 Anchorage and development bond in upper part of column reinforcing bar.

This case consist in RC column C10 (Figure 8). The section of the column is 800x800 mm. It is reinforced with 16 bars D25 and stirrups D13 @100 mm. Three beams arrive to the top part of the column.

G33A 500x800, 8 D25, ST D13 @ 200 (both sides of the column)

G15 500x700, 9 D25, ST D13 @ 200

So, the confined depth by the beams is an average length of 750 mm.

The end part of reinforcing bars of the column do not have a standard hook for anchorage. Before to cast the concrete, four standard hooks are added to the four corners bars.

The calculation for the necessary development length of the reinforcement of the column was made using the **ACI 318M-89**, and using **JASS 5**. Considering the **ACI 318M-89** it was obtained Id= 560 mm. With JASS 5 specification (table 10.5 in JASS 5, without hooks) it was obtained Id=750 mm. Theoretically it is not necessary to make standard hooks at the end part of the reinforcement. Furthermore if it is remembered the graphic shown in the figure 3, where for vertical bars the anchorage performance is better without standard hook [1].

From the economical and practical point of view this knowledge is very important because in the construction site is difficult to make this standard hooks, specially if the diameter of bar is greater than D13. Also, in this way is avoided the reinforcement congestion in this zone.

3.1.2 Anchorage of horizontal reinforcement of wall in column

In this case it is possible to observe the importance of the detailing and its control. The horizontal reinforcement of the RC shear wall W15 (e=200) anchor in the SCR column C2 (700x700) (see figure 9).

This reinforcement finish in a standard hook is in contact with the surface of the structural steel. This mean that only the half of the perimeter of the bar will be embedded in concrete. So, it will be more easy that during an earthquake slip occur in the bend part of the bar. The perimeter detailed mechanism of bond transfer model shown in the figure 1 will not happen.

Therefore, it is very important to guarantee the adequate specification and detailing in order to ensure that in the construction place the resulting structure will be like the previous theoretical model.

3.1.3 Heavy reinforcement in beam-column joint.

In the figure 10 is shown the circular RC column C16, d=900, 14 D25, ST D13@100. To this column arrive four beams:

G35 500x1000, 11 D25 +4 D10 (top reinforcement 6 D25) ST D13 @200

G16 A500x1000, 10 D25+6 D13 (Top reinforcement 5 D25) ST D13 @200

G17 500x1000, 17 D25 + 6 D13 (Top reinforcement 9 D25) ST D13 @200

PG3 650x1000, 8 D25 + 4D13+4c-7-12.7 o (Top reinforcement 4D259 ST D13@100

The beam PG3 is a post-tension girder and it has additionally 4 ducts for the post-tension cables.

The joint is too congested as it is shown in the figure. Instead a RC beam-column joint, finally a "Steel ball joint" will be obtained. It will be impossible to cast in adequate way the concrete due to the insufficient clearance between the reinforcing steel. The concrete should be flow from the neighbor beams and for the worker will be impossible to carry out the consolidation process of the column. Especially in the bottom part there is a very high risk that occur "honeycomb".

As will be explained in the item "Concrete casting process", usually the concreting is for both vertical and horizontal elements at the same time, and in this case the height to cast is around 3.5m. (the first part was already casted).

The contractor uses special admixtures or additives, like superplastifiers or air –entraining, but these ones (see "Concrete Casting Process") do not replace a good consolidation using vibrators. In the item "Consolidation" (Chapter 2) it was mentioned that the concrete layers should be as level as possible so that the vibrator does not need to move the concrete lateral since this might cause segregation.

One more time the detailing about how to put all the reinforcement in the joint was neglected or ignored by the designer. How it is possible to ensure the behaviors of this joint during an earthquake?.

3.2 Gas Pressured Welding

3.2.1 Description of the welding procedure

The process is simple, but the experience of the welder plays a main role.

Firstly the surface to be joined is cleaned and polished as a plane as possible (See figure 11(a)). In the figure 11(b) is shown how the two bars are joined using a special devices and the welder starts to applying fire to the joint. At the same time pressure is applied. Finally (Figure 11(c)) the splice is ready with the "mushroom" shape at joint. In the figure11 (d) is shown the devices used in this process.

3.3 Concrete casting process

Actually, the main worry for this topic is to control the quality of the final product. Many times only is possible to know about the concrete quality after occurrence an earthquake.

Casting together the vertical and the horizontal elements form the theoretically point of view is better. Because it is obtained monolithic elements. Also it is faster than to cast first columns and shear walls and then the beams and slabs- floors.

However, this procedure implies to the contractor o be carefully and increase the control of the concrete quality and also the control of the casting process. One more time the experience of the workers is very important because sometimes for the man who is placing or consolidating the concrete is impossible to see what is happening in the bottom part of a column or a thin wall (See figure 12(a) and (b)) and usually appear honeycomb in these parts and it is necessary to do reparation (See figure 12(c)).

Similar situation occur in congested areas where is impossible to cast the concrete close to its final location. Sometimes this situation is avoided using hoppers and trunks. But, no always this solution it is possible to implement. In this case is necessary to increase the flowability of the mixture by the judicius use of concrete admixtures. They provide high- slump concrete without altering the proportionate water/cement. However, the chemical admixtures does not replace the requirements for good consolidation by vibration.

A superplasticized concrete mix with flowing consistency is about 10% more expensive than an ordinary plastic concrete mix with the same strength [17].

According to earlier studies, superplasticized concrete with flowing consistency needs only 20 to 50% of the compaction work necessary for ordinary concrete.

The bond strength of the reinforcement bars in superplasticized concrete has been studied by the Swedish Cement and concrete Research Institute and the conclude that only about 20% of the vibration required for ordinary concrete was sufficient to achieve satisfactory bond between the reinforcement and flowing concrete.

Normally the radius of action of the vibrator in a superplasticized concrete concrete is 20-30 % greater than in normal concrete. The necessary vibration time can be reduced by about 50%. However, in practice, the possible reduction of he number of vibrators has been found to be rather limited. The practical application has in many cases been to use an vibrator “one size” smaller than that used for ordinary concrete.

In the construction site was observed that for the operator is more difficult to judge from the appearance of the surface of he concrete mix when the vibration is sufficient.

In situation where it can not be guaranteed that the proportionate mixture will be able to flow to the form face due to congestion, the use of modified mixture containing aggregate of a reduced maximum size. The aggregate used to the casting shown in figure 12 (b) was small stone with a maximum nominal size equal to 20 mm. Another solution to cast concrete in difficult situation is to consider opening in the formwork to avoid a high distance to the final location of the concrete. In congested zones where the concrete cannot be reached by the vibrator, it maybe help to vibrate exposed portions of the reinforcing bars [16]. In this case shall be used a “for vibrator” attached to the bar.

It must be avoided that the concrete flows laterally, specially through the column (See figure 12(d)) (JASS 5 6.6). Because the pouring was a monolithic casting (Wall-column and beam – slab) for the operator was impossible to control the flowing and the placing of the concrete, specially due to it was a superplasticized concrete. The direction of the cast operation was opposite to the direction that the flow of the fresh mix. In the same figure 12(d) it is shown a diagonal “pour line” which indicate that the vibrator was not lowered far enough to penetrate the layer below the one being vibrated, and started hardening before to placing the next layer of concrete.

The problem in congested zones increase when SRC elements are used. In those cases the labor of the designer is very important defining i.e. new joints, or details like the shown in the figure 13.

In the figure 13(a) a SRC beam-column joint is shown. Due to the shape of this joint the pouring will be difficult. In the figure 13(b) appear the same beam-column joint but special design related to the detail was considered taking in account the construction process.

3.4 Precast Construction System

3.4.1 Manufacture of prefabricated building member

3.4.1.1 Precast walls

This system is used commonly for housing (4 or 5 stories). KAWAGOE factory was visited and the fabrication process for this RC elements was observed.

The production system consists in a circuit of moving steel tables on the floor. Over these tables is carried out the fabrication process of these walls.

Firstly, the formwork is prepared according with the shape and the specifications previously established (see figure 14(a)). Parallely the reinforcement is cut and bent by handling or using automatics machines (see figure 14(b)). Right after the reinforcement is placed in the formwork (Figure 14(c)). Special devices like are shown in the figure 14(d) are installed to the joint system in the bottom part of the walls. Also the cables, ducts, boxes, and other installations are placed according with the requirements (Figure 14(e)). After to checking the right location of the different elements inside the wall, the casting of the concrete starts (see figure 14(f)). The concrete used has a small water/cement ratio. One of the reasons is that the control of the consolidation is easy due to the position of the wall on floor. Two ways of consolidation is used. The first one is the vibration table and the another one is using internal vibrator. The finishing of the surface is shown in figure 14(g) , and is used manual method and automatic method. Right after this the wall goes to the steamer curing process (60-70º C). This process take around two hours. Five hours after casting concrete the wall can be removed and storage (Figure 14 (h) and (i)). Finally the Steel table is cleaned and it is ready to start over it the fabrication of a new wall. In average to fabricate one wall it takes 8 hours. In one day the factory produce approximately 140 walls, and in seven days they are ready to assemble in the construction place.

3.4.2 Construction and assemblage at site

3.4.2.1 SRC Layered Construction System

This system belongs to "single- members method" mentioned in the previous chapter. It will be described the construction process of one SRC building for apartments (See figure 15 (a)).

Firstly the repetitive process start with erection of the steel columns using cranes and the arrangement of the reinforcement (See figure 15(b)). This step takes for each column around 15-25 minutes, including the adjust of the provisional bolts, see figure 15 (c). In this figure it is shown the provisional plate to adjust provisionally the joint in order to make later the welding arc. Right after is the process continues with the joint of reinforcing bars using special devices (See figure 15 (c)).

In the figure 15(d) is shown the precast element, and in this case it already has the finishing, because it is an exterior element. After to finish to set the columns of one level, start the setting of Precast girders and beams (See figure 15(e)). They are adjusted using bolts and welding (See figure 15(f) and (g). The next step is to set the "half precast slab-floors"(see figure 15(h) and (i)). In these elements are already cast the half depth with outside reinforcement like it is shown in the figures 15(h) and (i). This reinforcement guarantee that after to cast the concrete it will be a monolithic structures together with the precast part and also the transmission of the stresses.

The formwork of columns and beam-column joints are setted and then the concrete is placed.

Special attention is set to the beam-column joint process control. In the figure 15(g) is shown a joint plate before to set the welding.

Finally in the figure 15(j) is shown the beam-column joint allowing a monolithic structure.

4 CONCLUSIONS

(i) Constructions aspects and its quality control have been studied.

(ii) The anchorage detailing plays a very important role in order to guarantee that the all the stresses are developed before that the yield mechanism occur.

(iii) Concrete casting process techniques have not been developed or improved in significant way.

(iv) Sometimes in the traditional construction process detailing implementation is a problem, yet. Because usually the construction process is not taken in account at the design time.

(v) The economical factor must guide the development of the new research and technologies, with the same importance that the structural reliability.

(vi) The precast system allow a better quality control. Therefore it is guaranteed a good behavior during an earthquake.

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REFERENCES

[1] R. Park and T. Paulay, “Reinforced Concrete Structures”, Wiley Interscince Pub., N. York

[2] Aycardi L., Mnder J., and coaut., “Seismic Resistance of Reinforced Concrete frame Structures Designed only for gravity loads: Experimental Perfomance of Subassemblages”, Title N 91-S53, ACE Structural Journal, Vol. 91, No 5, Sept.-Oct. 1994, p.p 552-563.

[3] Bilal S Hamad, “Bond Strenght improvement of Reinforcing Bars with specially Designed Rib Geometries”, Title N 92-S1, ACI Structural Journal, Vol. 91, No 1, Jan-Feb. 1995, p.p 3-13.

[4] ACI Committee 318, “Building Code Requirements for Reinforced Concrete (ACI 318-89)(Rev. 1992) and Commentary (ACI 318RM-89)(Rev. 1992)”, American Concrete Institute, Detroit, May 1992, p.p 347.

[5] Architectural Institute of Japan, “AIJ Standard for structural Calculation of Reinforced Concrete Structures” – English edition, Edited and published by Architectural Institute of Japan, Tokyo, Sept. 1991, p.p 48.

[6] Architectural Institute of Japan , “Preliminary Reconnaissance Report of the 1995 Hyogoken-Nanbu Earthquake”, prepared by working group for the English Edition with the participation of Engineering research Center of Univ. of California, Tokyo, Japan, April 1995, p.p 216.

[7] Ministry of Construction of Japan, “The building Standard Law of Japan” edited by Building Guidance Division & Urban Building Division Housing Bureau The Ministry of Construction and published by the Building Center of Japan, Tokyo , July, 1990 , p.p 352 .

[8] Architectural Institute of Japan, “Japanese Architectural Standard Specification for Reinforced Concrete work – JASS 5”, English Edition, edited and published by Architectural Institute of Japan, Tokyo , April,1993, p.p. 166.

[9] Architectural Institute of Japan, “AIJ Structural Design Guidelines for Reinforced Concrete Buildings”, English edition, prepared by Working group for the English Translation of the R/C Guidelines and Standard and edited by Architectural Institute of Japan, Tokyo, March, 1994, p.p. 207.

[10] G.B. Welch and B.J.F. Patten, “Reduction in concrete –steel bond with Horizontally Embedded reinforcement", UNCIV Report N R-8, February 1967, University of New South Wales, p.p. 26.

[11] Otani S., k “Proposal of Ultimate Strength Design Requirements for RC Buildings with Emphasis on Beam-Column Joints”.

[12] Mac Gregor J., “Reinforced Concrete- Mechanism and Design”, New Jersey, 1992, p.p. 842.

[13] Kitayama K., Otani S., Aoyama H., “Development of design criteria for RC interior Beam-column joints”, SP 123-4, Fourth U.S.-N.Z.- Japan-China Seminar on design of Concrete beam-column joints, Hawaii, 1989.

[14] Neville A., “Is our research likely to improve concrete?”, published in Concrete International, March , 1995, Volume 17, N 3, London, p.p. 45-47.

[15] Japan Society of Civil Engineers, "Standard Specification for design and construction for concrete structures- 1986, part 2 (construction)", English edition, prepared by JSCE Committee on Standard Specification for design and construction of Concrete Structures, edited by JSCE, Japan, 1986, p.p. 306.

[16] ACI Committee 309, "Guide for Consolidation of Concrete", ACI , Detroit,1988, p.p.40.

[17] Precast Committee in Building Contractors Society of Japan, "Existing Precast Frame System in Japan", Building Contractors Society of Japan, First Meeting of the U.S.-Japan joint Technical Coordinating Committee on Precast Seismic Structural System (JTCC-PRESS), San Diego, California, November 29-December 1, 1990, p.p. 108.

[18] Forssblad L., "Need for Consolidation of Superplasticized Concrete Mixes", ACI Publication, Steven H. Gebler Editor, SP 96-3, Michigan, 1987, p.p. 19-37.

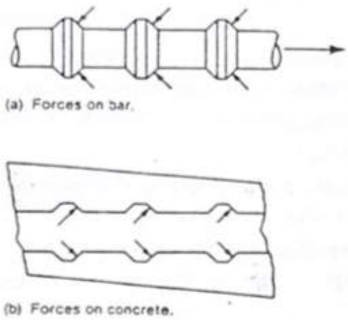


Figure 1. Bond transfer mechanism

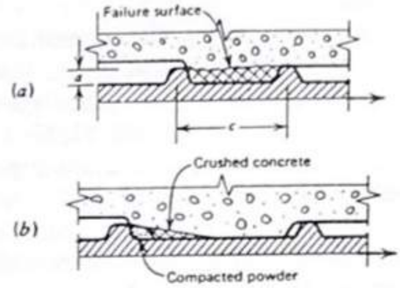


Figure 2. Failure mechanism at the ribs of deformed bars
(a) a/c > 0.15 (b) a/c < 0.10

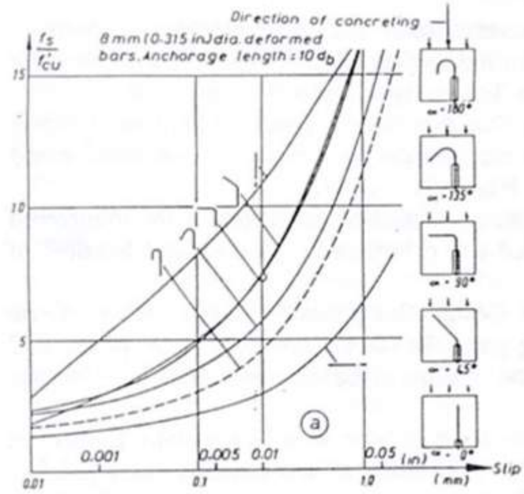


Figure 3. Influence of direction of the concreting and the shape of anchorage [1]

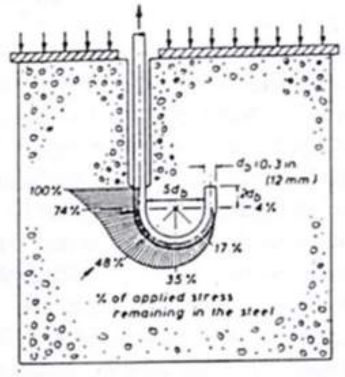


Figure 4. Stress distribution for hooks

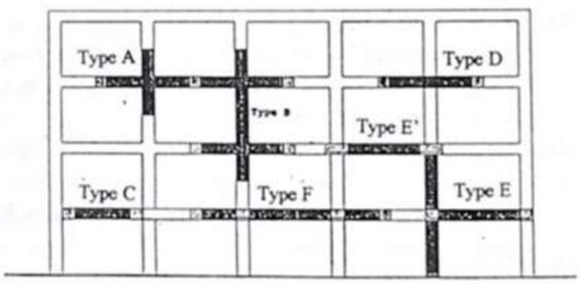


Figure 6. Various precast units in frame system

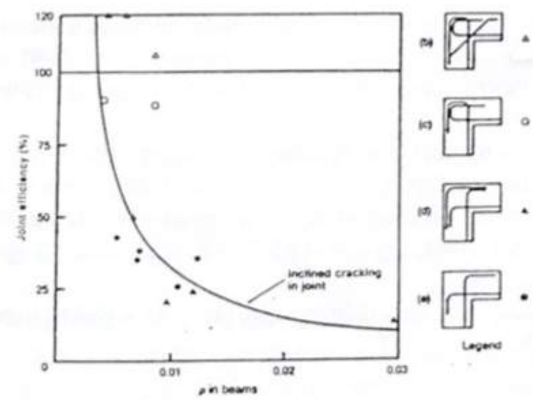


Figure 5. Measured efficiency of open ing joints[12]

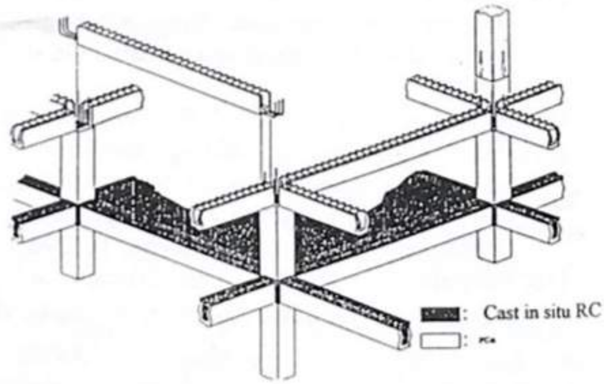
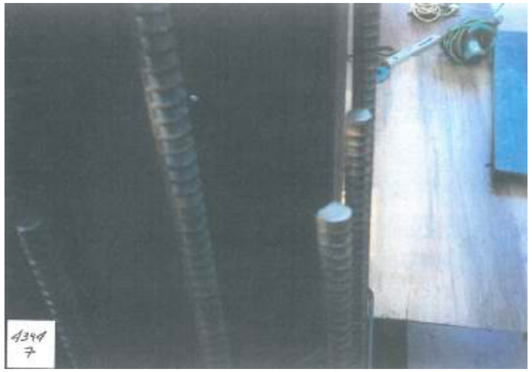


Figure 7. U-shape section precast beam

Figure 8. Column C10 – Detailing

Figure 9. Anchorage in column

Figure 10. Heavy congestion reinforcement in top part of the column



(a) Polishing the bars

(b) Applying fire and pressure

(c) Process finished.

(d) Devices utilized

Figure 11. Gas pressured Welding process

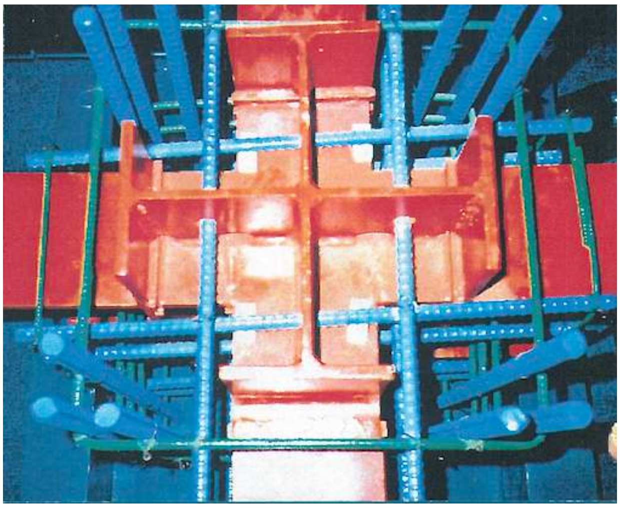
(a) Placing concrete in SRC column

(b) Placing concrete in RC wall

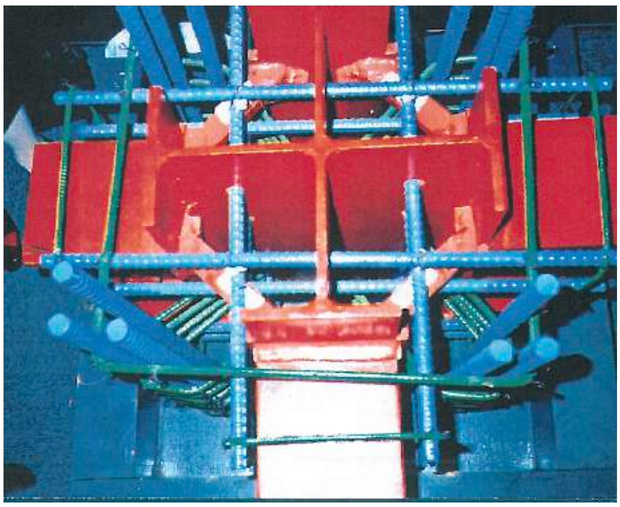
(c) Repaired “Honeycombs”

(d) “Pour line” in RC wall

Figure 12. Concrete casting process



(a) Without consider construction process



(b) Considering Construction process

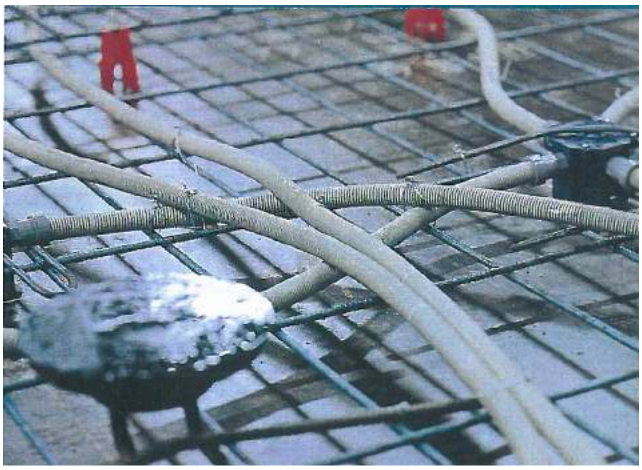
Figure 13. SRC Beam-column joint

(a) Preparing the formworks

(b) Preparing the reinforcement

(c) Reinforcement finished

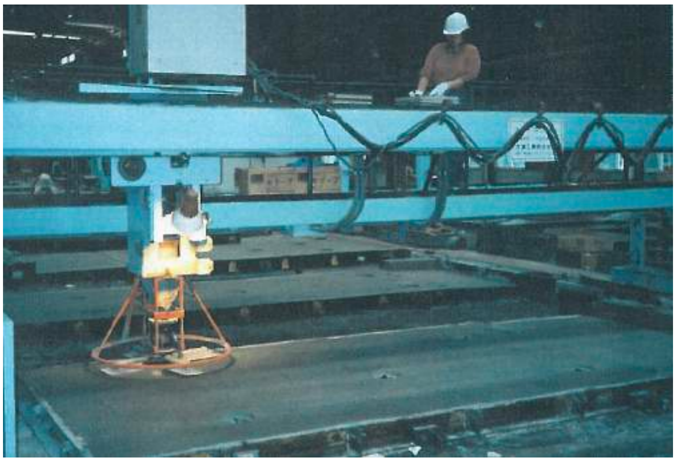
(d) Special devices for connections



(e) Embeded installations

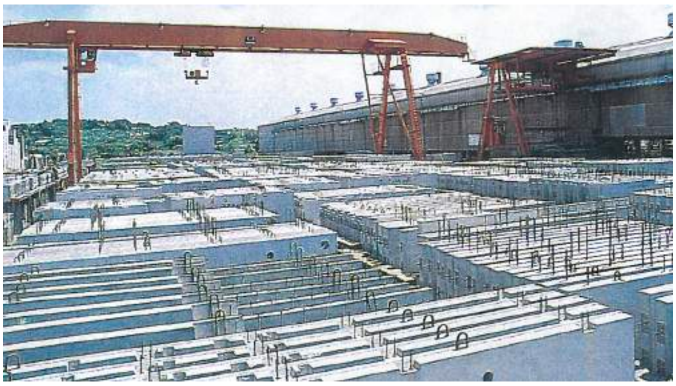
(f) Pouring of the concrete

Figure 14. Manufacturing of Prefabricated walls



(g) Surface finishing

(h) Removing finished panels



(i) Stocked walls

(j) Cleaning the steel casting bed

Figure 14. (Continuation) Manufacturing of Prefabricated walls

(a) General view of the construction site

(b) Placing the Steel column

(c) Detailing in column connection

(d) Precast members

(e) Placing Girders and Beams

(f) Detailing of Girder-column connection

Figure 15. SRC Layered construction System process

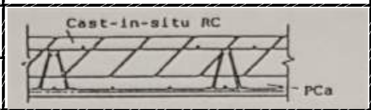
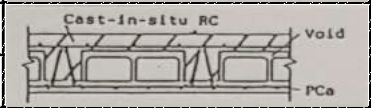
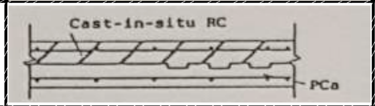
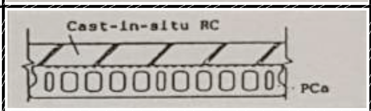
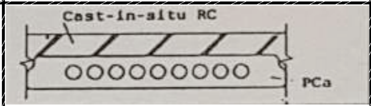
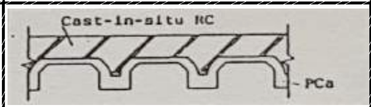
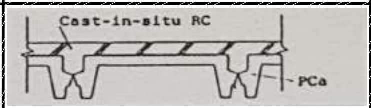
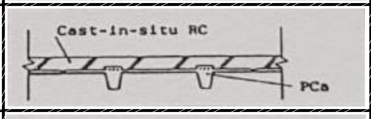
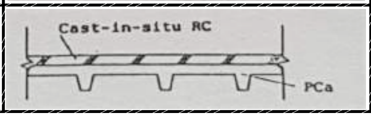
(g) Steel Plate connection

(h) Half-precast slab detail

(i) Half-precast slab

(j) Beam-column joint, after concrete casting

Figure 15. (Continuation) SRC Layered construction System process

Name of System	Shape of cross section	RC or PS	In-plane shear transfer mechanism
OMNIA KAISER		RC	Truss bar + Rough surface
OMNIA VOID KAISER VOID		RC	Truss bar + Rough surface
PICOS		RC	Cotter
SPANCRETE		PS	Cotter
DYNASPAN		PS	Cotter
FC		PS	Truss bar + Rough surface
π SPAN		PS	Cotter
P.CS		PS	Truss bar + Rib
FTT		PS	Truss bar + Joint

RC: Reinforced Concrete
PS: Prestressed Concrete

Table 1. Half PCa composite floor slab construction system

Beam-column connection	Beam Full-precast		Top and bottom bars passing through Double U-shaped anchorage Knob anchorage
	Beam Half-precast (Top bar passing through)		Bottom bar passing trough Bottom bar bent anchorage Bottom bar hooked anchorage
	Outer-shell structure		Bottom bar lap joint
Column connection	Full-precast		Splice. Sleeve Welding
	Outer-shell precast		Gas-pressure welding Splice sleeve Lap joint
Beam connection	Full-precast		Welding Splice sleeve
	Half-precast (top bar passing through)		Bottom bar lap joint Botom bar gas-pressure welding
Wall connenction	Horizontal connection	Full-precast	Lap joint (loop reinforcement) Without wall reinforcement (cotters alone) Splice sleeve Welding
		Outer-shell precate	Lap joint Welding
	Vertial connection	Full-precast	Anchorage into column (Joint bar) Lap joint Without wall reinforcement (cotters alone)
		Outer-shell precast	Anchorage into column Lap joint

Table2. Classification of connections