PREM SYSTEM AND PREFABRICATED WET STRUCTURAL JOINT COLUMN: THE CONNNECTING LINK


PREM System – reinforced concrete technology


PREM System – composite steel-concrete technology

1. REINFORCED CONCRETE FRAMED STRUCTURES

1.1 Reinforced concrete cast-in-place structures

The cast in place reinforced concrete structures owe their success and diffusion to many factors:

- flexibility of use;
- relatively simple technology;
- monolithicity;
- hyperstaticity;
- structural ductility;
- small amount of equipment;
- adaptable logistics;
- light lifting equipments.

The limits are few but very specific:

- slower schedule;
- higher costs with complex structures

1.2 Full Prefabrication and its regression towards monolithism

To overcome the constraints of the traditional reinforced concrete technology, in terms of schedule, in the 50's/60's the full prefabrication system was born, characterized by a series of elements juxtaposed to one another not in a monolithic but in an isostatic configuration.

In the proper fields of application, the advantages are bright:

- Faster construction and lower costs for single-storey industrial buildings and for multi-storey structures with long spans and heavy loads.

However there are some restrictions:

- regularity of the structural elements is mandatory due to predetermined formworks;
- difficult adaptability of the system to buildings with complex shapes;
- structural elements with important transversal dimensions.

With the incoming of very stringent anti-seismic regulations, in terms of resistance and even more in terms of deformability, the need to transform even the full prefabricated system to a monolithic and hyperstatic structure was born, forcing its own nature and regressing to the completive cast-in-place, which is not in its DNA, with evident heavy impacts on its efficiency, costs, production and installation times.

1.3 Prefabrication through components, monolithic by nature, and its evolution

The traditional monolithic reinforced concrete system had also another natural and improving evolution that merged the best of prefabrication and of casting on site.
Trying to speed up and industrialize construction, around the mid part of the last century there was a progressive evolution of precast elements into a monolithic structure (PREM beams and steel tubular columns filled with concrete). The latest step in this process was the prefabricated Wet Structural Joint (WSJ) column.
The WSJ column is therefore the natural union of partial precast components with completive casting and the realization of the original goal of structural integrity between these two elements.

1.4 Prefabricated wet structural joint column: the connecting link

The WSJ prefabricated column historically fit into the technology evolution as the connecting link between a prefabricated system that has improved (the inborn hyperstatic and half-prefabricated one) and another one that has developed (the inborn isostatic and full-prefabricated one).
The column as a structural element is the same but it can be combined in the first case with light components such as PREM beams, to create a monolithic joint in all respects, and in the second case with more complex and expensive heavy prefabricated beams and their seismic joint connection problems.

2. PREM SYSTEM: IN MEDIO STAT VIRTUS

Prefabrication can often meet the requests of a building market where costs and schedule are two fundamental elements with better and faster solutions. Those who have been working for years in designing steel and composite prefabricated structures know this and are committed to develop technologies that are increasingly adaptable to different design situations.

Basic elements of the PREM system are PREM beams, the steel-concrete WSJ columns and the prefabricated WSJ column, all completed on site with cast in place concrete.

In fact, the feature that PREM beams have being self-supported during laying phases is a guarantee of quick assembly and safe on site operations. The inborn self-supporting capacity involves a reduction of the bending moments in the joints, as they are relieved by the effects of the structural own weights: the joints are therefore less stressed and therefore more easily assembled than the corresponding version cast in place.

PREM System, moreover, has a wide range of Composite Reticular Prefabricated Beams, with steel base, concrete base or with no base, made with any type of steel, smooth or ribbed, and of any structural category foreseen by current standards: composite steel-concrete or reinforced concrete. Moreover, PREM beams can be combined with columns cast on site and any kind of prefabricated elements, composite WSJ, vibrated reinforced concrete WSJ with squared, rectangular and ogival sections, and to any kind of prefabricated slab (hollow core slabs, floor plates, etc.).

Fig. 1, 2, 3, 4, 5, 6, 7 – Wet structural joints typical of PREM Building System

2.1 Third millennium multistorey prefabricated wet structural joint columns

The prefabricated wet structural joint column is made in factory with a concrete class suitable for the specific project. Furthermore, in the design and production, proper attention is paid to the arrangement of the vertical reinforcement in order to guarantee total geometric compatibility with the horizontal beams and reinforcements converging to the columns and with the anchoring equipment and reinforcements embedded in the foundation.

Fig. 8,9,10,11,12,13,14 – Typical images of prefabricated wet structural joint columns

2.1.1 Connection to the foundation: types and design

The connection to the foundation with a prefabricated "shoe".

The connection of the columns, both at the foundations and at the joint between multi-storey segments, is currently made by means of CE marked steel inserts commonly called "shoes".

During the realization of the foundations, a group of anchor bolts must be positioned in the reinforcement cage, which, by means of a metal template, will be easily positioned within the permitted tolerances. Anchor bolts are made of steel elements which have a threaded part, protruding from the foundation casting, and in the lower part they end with projections of proper shapes to ensure anchorage even with reduced overall dimensions.

The installation of the columns is made arranging the nuts and washers on the threaded anchoring bolts and adjusting the installation height and planarity. Once this quick preparation phase has been completed, the column is laid, along with the following insertion of washers and fixing nuts. Then the perfect verticality is adjusted through the rotation of the lower nuts and then the final tightening of the upper nuts and the installation of counter nuts are made, without ever using props nor trunks. The installation of the column is completed with the restoration of the section by means of not shrinking mortar with proper controlled mechanical characteristics.

In the case where "shoe" inserts, available with multiple strength characteristics, are not sufficient to transfer the project actions, the system can be integrated with the use of additional reinforcement bars contained within corrugated sheaths inserted in the column, without losing the system advantages: no propping nor slacking.

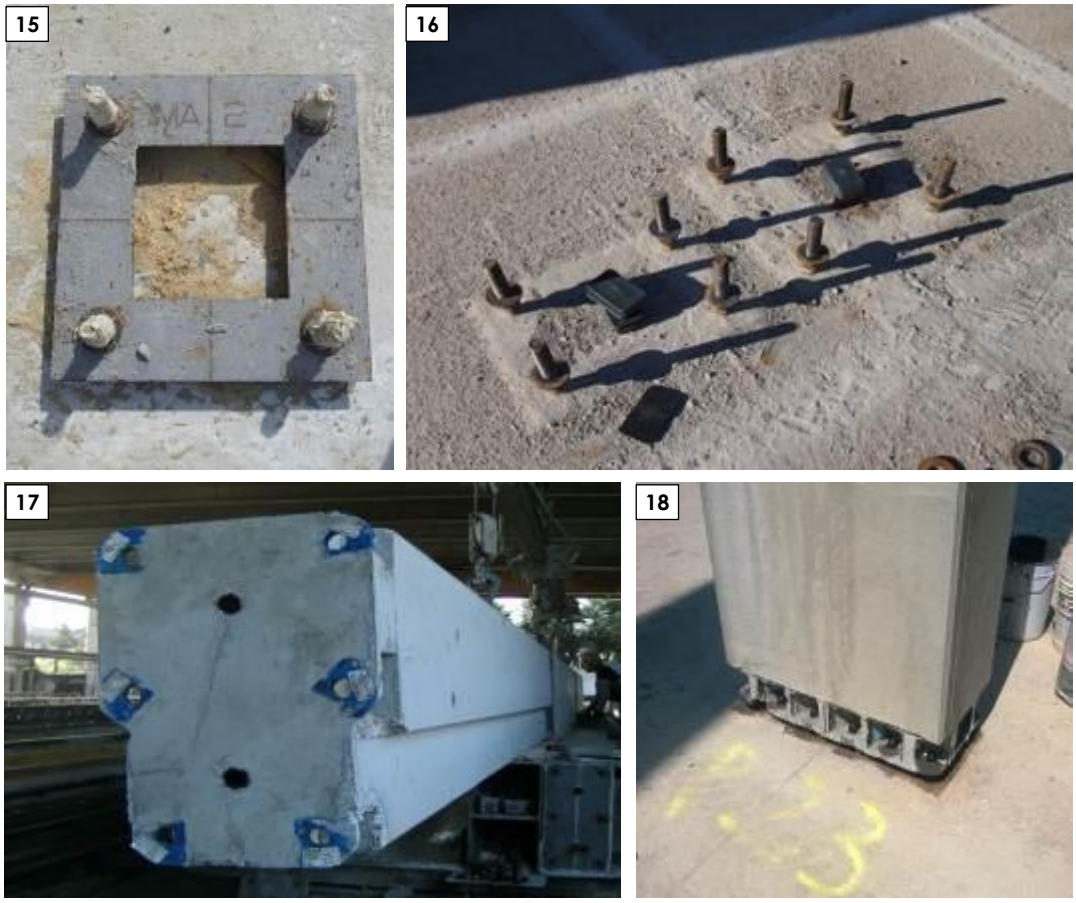


Fig. 15, 16, 17,18 – Connection to the foundation with prefabricated "shoe".

The connection to the foundation with bars and corrugated metal sheaths.

As an alternative to shoes, solidarization can also be achieved by inserting not shrinking controlled strength mortar into appropriate sheaths, around the bars, inserted into prefabricated elements during production (corrugated sheaths).

Two characteristic sections of this typology (atypical with respect to reinforced concrete cast in place) are the foundation attachment section and the overlapping portion of reinforcement bars of the prefabricated element.

Normally in a cast in place column we would have the overlapping of the column bars and those protruding from the floor.

In any case, we would always have an overlap of bars, but that overlapping would take place at each floor, while in a prefabricated wet structural joint column this overlapping occurs only at the base of a multi-storey segment, with a much more linear reinforcement for the remaining floors.

The solution allows different benefits such as: less use of steel (since at each overlap bars are counted twice), higher and more controlled quality (because overlapping is not left to the lower accuracy of the construction site), saving time and crane usage.

The apparent restriction to set the sheaths in fixed points, actually implies a particular precision, which becomes a strong point, because the position of the bars is guaranteed, contrary to what usually happens on the construction site.

The foundation connection section (Fig. 19, Section A-A) is constituted entirely of mortar and protruding bars; during assembly one or more stirrups are added, if required by the project, to guarantee the confinement effect of the area thus defined (for large grouting depths).

The overlapping bars and internal reinforcement section of the column (fig. 19, Section B-B) differs from the C-C section, due to the presence of the corrugated sheaths filled with mortar and double reinforcement (cage + filament bars).

Of course it is necessary that the bars inserted into the foundation have sufficient overlapping to transfer their stresses to the column through the sheaths.

The connection area of the column with the foundations, (section A-A and section B-B), is particularly critical as it must be verified with amplified stresses to consider the over-resistance coefficients in a seismic zone. This second type of connection, however, involves slowdowns during assembly phases and is therefore applied only in residual cases.

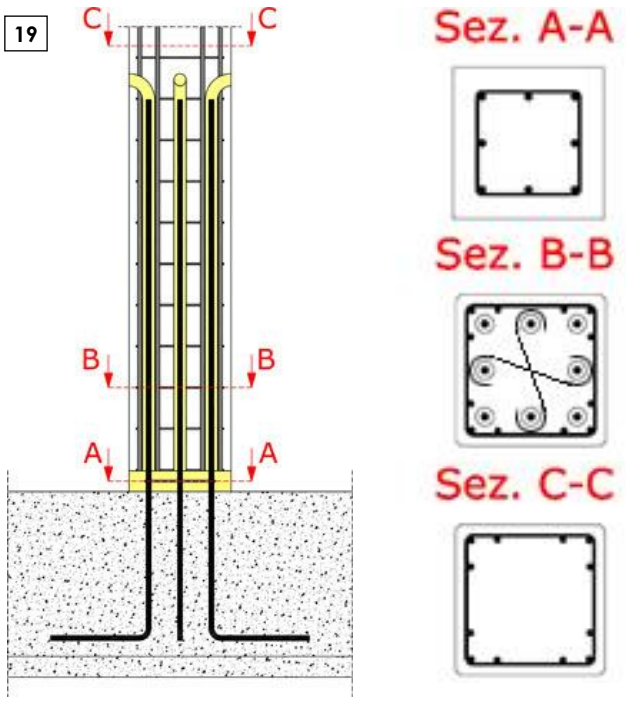


Fig. 19 – Connection to the foundation with protruding bars and sheaths.

2.1.1 Beams on columns laying: solutions and evolution

A structural and conceptual joint of the prefabricated wet structural columns is the beams and columns one, that must satisfy the structural needs of the first phase, during dry assembly, and of the second phase of continuity and structural monolithism. In fact, the laying of the beams on the columns includes the extension of the longitudinal reinforcements, beyond the end of the concrete bottom of the beams themselves, and the possibility of making an integrative casting that gives structural continuity to the joint. The solutions follow two alternative approaches: taper the column reinforcement at the joint and laying the beams directly on the shaft, or keep the column reinforcement cages continuous and equip the column with shelves.

The first approach, in the second phase, leaves a joint without shelves and, therefore, completely identical to a reinforced concrete cast in place structural joint.
We can therefore understand why this solution has gradually and definitely become the standard one for the most advanced productions: the required precision, in fact, is much greater both in the design and in the production phase. For completeness, however, we also report the other solutions practiced, now, in residual cases or by less innovative manufacturers.

2.1.1.1 Laying without shelves

In order to guarantee a proper support to the beams in the casting phase, a more compact column reinforcement cage is formed, which is overlaid to the lower and upper cage and appropriately sized to consider the reduced geometry and supply the due resistance during laying phase.
The solution presents the maximum appeal against higher costs of reinforcement and laying, and a greater accuracy both in the design and in production phases.

Fig. 20, 21, 22, 23, 24, 25 –beams laying on wet structural joint prefabricated columns without shelves

2.1.1.2 Temporary reinforced concrete shelf

This solution provides sufficient bearing capacity only for the first phase loads, while the second phase loads will be transmitted directly to the columns core through the integrating bars of the beams and the concrete.

Fig. 26 – wet structural joint prefabricated columns with temporary reinforced concrete shelves

2.1.1.3 Permanent reinforced concrete shelf

This solution supports both the first and second phase loads thanks to the larger dimensions and appropriate reinforcements set up into the shelves. The integrating reinforcements of the beams converge to the joint, and the completive castings is made only to guarantee the monolithism for the transmission of the moments to the column and the other beams converging into the joint. Less aesthetic appeal and production costs are evident.

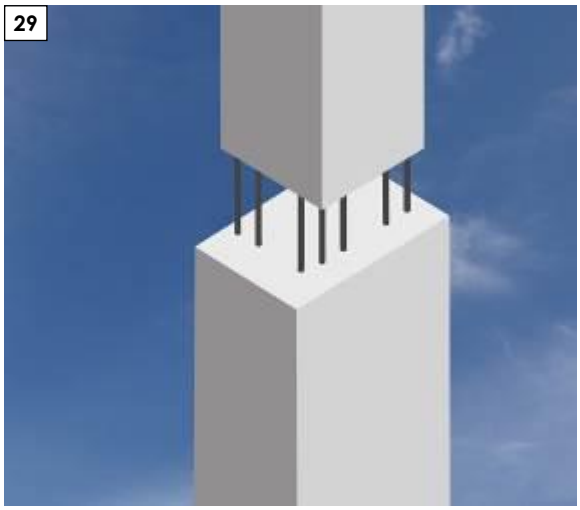
Fig. 27 – wet structural joint prefabricated columns with definitive reinforced concrete shelves

2.1.1.4 Retrievable shelf

It is a temporary steel shelf placed on bushings, with nuts and washers, able to support the first phase loads until the completed concrete is cast. Then it can be easily be removed and reused.
The advantage of this typology is not to have, at the end of the construction, any encumbrance to the beams intrados, just like with the solution without shelves with the advantage of not having to taper the bars, but the disadvantage lies in its greater cost.

Fig. 28 – wet structural joint prefabricated column with retrievable shelf

2.1.1.5 Tapering shelf



It is made with the simple tapering of the column under the slab. It is certainly the most natural solution but, unfortunately, in order to be realized, geometric and loading compatibility must be coexistent floor by floor, which is not always possible. In fact, when there are many levels, the dimensions at the base of the columns can become relevant to allow the succession of tapers between the floors. This situation is not always compatible with architectural requirements. Furthermore, the support of the slabs remains uncovered and must therefore be propped up during casting phases.

Fig. 29 – wet structural joint prefabricated column with tapering shelf

2.2 PREM beam specificity

The most natural choice, with the prefabricated wet structural joint columns, is to use PREM beams with reinforcing bars with concrete bottom for the execution of the horizontal supporting structure. Both these types of columns and beams fall into the same structural category of reinforced concrete and they are both CE marked.

For the same reason, with the composite wet structural joint columns, the natural combination is with composite steel-concrete beams, both with a steel or a concrete base. However, if there is no particular need to have only one structural category, mixed applications are also possible.

Fig. 30, 31, 32 – reinforced concrete and composite steel–reinforced concrete PREM beams on wet structural joint prefabricated columns without shelves

2.3 System Installation

2.3.1 Dry installation sequence with "shoe" typology

A

A

A. Preparation of the installation site
The template for the anchor bolts positioning is removed leaving the lower nuts and washers for the placement of the shoes.

B. Element handling

1. Coupling: inserting bar and safety pins.
2. Column lifting and verticalization with eventual use of the jib.
3. Column placement on the lower layer of nuts and washers on the anchor bolts. During the descent phase, the column is "guided" by the operators so as to coincide with the bolts. At this stage no positioning errors can be made as the shoes are guided directly by the bolts with the control of line and level.
4. Leveling verticality and adjusting the quote: by acting directly on the lower nuts, both the desired quote and verticality are easily obtained.

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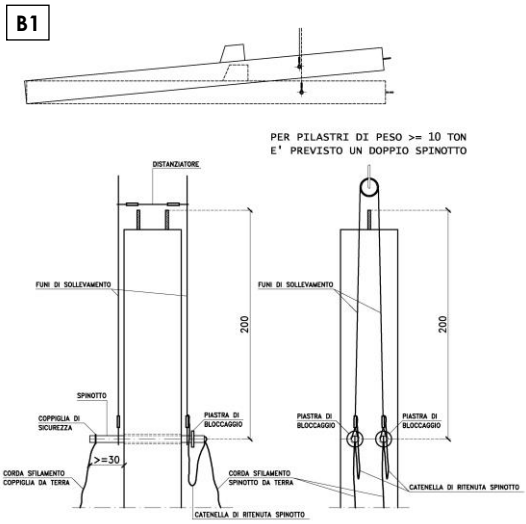
B1



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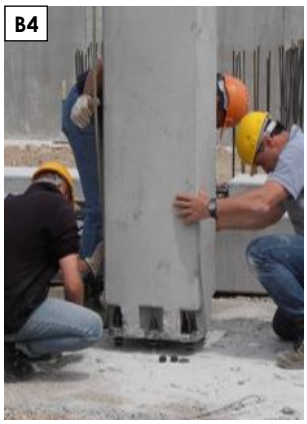

B4

5. Locking of all settings.
6. Load release, safety pin disengagement, bar release and column release.

C. Preparation of ground connection

The connecting zone is molded using wooden strips sealed with polyurethane foam at the edges to prevent the mortar from dripping.

2.3.2 Dry installation sequence with typology without "shoe"

A. Preparation of the installation site

Inside the bars previously embedded by the contractor, a stack of small size steel plates is placed in a central position, so the floor shelves are at the correct level. The plate fulfills the fundamental function of keeping the column raised from the foundation to allow its connection by means of the mortar. The assembly maneuver shown here is the same even in the case that the bars come out of the column intrados and the corrugated sheaths are positioned in the foundation.

B. Element handling

1. Coupling: inserting bar and safety pins.
2. Column lifting and verticalization with eventual use of the jib.
3. Column positioning on the plates being driven by the protruding bars: the column is "guided" by the operators so as to coincide with the protruding bars. At this stage the precision used in the execution, with a tolerance of +/- 2 cm, is of fundamental importance.
4. Pull-push props fixing: the props are firmly fixed to the column, on the bushes positioned on two orthogonal sides, and to the foundation, using dowels.
5. Adjustment of vertical position of the element: by means of a rod equipped with a level indicator (or with a plumb line fixed to the top of a long rod), by adjusting the length of the props, the element is brought into a vertical position.
6. Load release, safety pin disengagement, bar release and column release.

C. Preparation of ground connection

The connecting zone is molded using wooden strips sealed with polyurethane foam at the edges to prevent the mortar from dripping.

B3

B4

B5

C

2.4 Integrative casting: characteristics and working of concrete into the joints

2.4.1 Foundation

I. Connection to foundation
In the case of a column which provides only "shoes" connection at the base, the assembly is completed with the final tightening of the bolts and the anchor bolts and the casting with blocking mortar between the bottom of the column and foundation, after the positioning of appropriate confinement brackets as indicated in Fig. 11.
In the case of a column that needs additional bars, which are reflected in corrugated sheaths arranged inside, the sheaths must be fully grouted until they overflow.
The grout used for this phase must be non-shrink and has characteristics (controlled and certified) of high compressive strength, fluidity and adhesion.

Fig. 33 – Complementary casting on foundation

2.4.2 Intermediate floors

A point to pay attention to, in a system with structural wet joints, concerns the relationship between the concrete strength class of the prefabricated columns and the concrete used for the complementary casting of the floors.
In correspondence with the section completed with the castings on site, local verifications of the column must be made using the lower resistance class, that is normally the class of the completion castings on site, with consequent penalization of the performances.
This aspect occurs for example at joints not completely confined to perimeter columns, while for internal columns, with completely confined joints, the increasing of compressive strength of the completion concrete can be used; an increase that, in some cases, may involve the achievement of the same strength class as the prefabricated column.

3. CONCLUSIONS

With PREM system, with inborn wet structural joints, the gap between casting on site and full-prefabrication has been closed. Today these two solutions are no longer separated.
The Designer and the Contractor, therefore, only need to identify more exactly the solution that best suits the needs of their site because the choice is no longer as easy as in the all black-and-white old days: technology and the market today have made available the full scale of the greys.

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