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PRECAST BEAM-COLUMN CONNECTION FOR INDUSTRIAL BUILDINGS

BY

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Abstract. In precast industrial halls structures, a key factor is the beam-column connection. The preferred beam-column connection is made with dowels due to simplicity in assembly stage and low cost.

The hinged connection between beams and columns is an important element in what regards the overall behaviour of the precast concrete industrial building under seismic loads. Basic design is based on the theoretical response of the structure in regards to vibration modes and/or top displacements and in essence is the calculation of the element sections based on those values.

Because the overall behaviour of the structure is influenced by the connections type used, it is considered that the designed connection has to have as much as possible an overall behaviour as the theoretical connection assumed.

In this paper we will underline the flaws used in practice/design with current connection and we will propose a new type of connection to be used in future which has already been patented by our company.

Keywords: precast; connection; beam; column; design.

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1. Introduction

This paper aims to underline the differences between international codes and design recommendations and design practices commonly used in Romania.

The usage of dowel pinned connection between beam and column has been presented in both “SAFECAST Project: European research on seismic behaviour of the connections of precast structures” and FIB bulletin 78 “Precast-concrete buildings in seismic areas: State-of-art report” as having two vertical dowels protruding the beam and the holes are filled with no shrinkage grout.

A finite element in depth 3D analysis was made using Atena software in which we studied the behaviour of the connection under lateral loading as presented in Fig. 1.

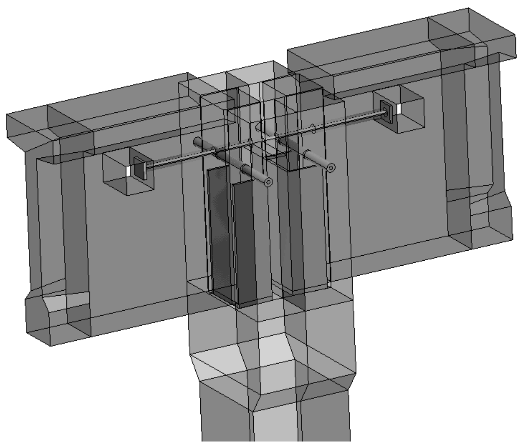

Fig. 1 – Overview of the designed connection in Atena.

2. Fib 38, Safecast/JRC Recommendations

“Joint Research Centre – Design Guidelines for Connections of Precast Structures under Seismic Actions” (Paolo Negro & Giandomenico Toniolo, 2012)– dowel connections for beam-column are presented in chapter **3.2**. and the conclusions are as follow:

- beam-column connection is treated as hinged connection;
- the sleeves are filled with no-shrinkage mortar of adequate strength to ensure by bond the anchorage of the dowels;

- to avoid splitting damage, rubber pads can be used with non-adherent dowels, but this will require a different device to transfer horizontal seismic actions without hammering;
- in case of seismic action, under the contemporary horizontal and vertical shakes, the connection shall work instantly also in the absence of weight;
- this type of connection provides a hinged support in vertical plane of the beam and a full support in the orthogonal vertical plane as shown in figure 3.2.3 (Fig. 2);

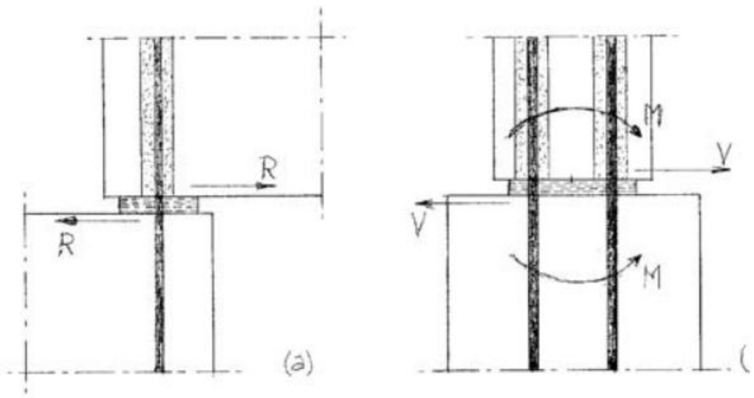

Figure 3.2.3

Fig. 2 – Behaviour of dowel connection presented in JRC.

In FIB bulletin 78 “Precast-concrete buildings in seismic areas: State-of-art report” (2016) conclusions are as follow:

- beam-column connection is treated as hinged connection;
- the mostly used pinned connections are with one or two parallel vertical steel dowels (fig. 5-3) arranged in the direction normal to the plane of the frame;
- the connection is adequately anchored in the body of the column/corbel and protrude into grouted ducts in the beam;
- the dowels provide resistance against horizontal relative displacement and actions between beam and column (fig. 5-4a) (Fig. 3) as well as some moment resistance against the out-of-plane overturning of the beams (fig. 5-4b) (Fig. 3);
- the vertical ribbed metal ducts are filled in-situ by nonshrink grout to ensure transmission of lateral forces.

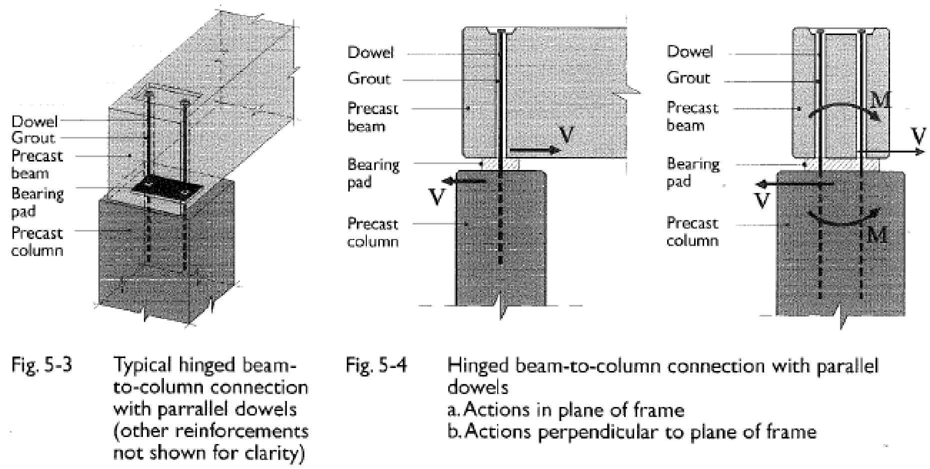

Fig. 3 – Behaviour of dowe connection presented in FIB 78.

3. The Most Common Beam-Column Connection Used in Romania *vs*. the Prescriptions Given by Fib and JRC

One of the most widely used beam-column connection for precast industrial buildings in Romania is presented in Fig. 4.

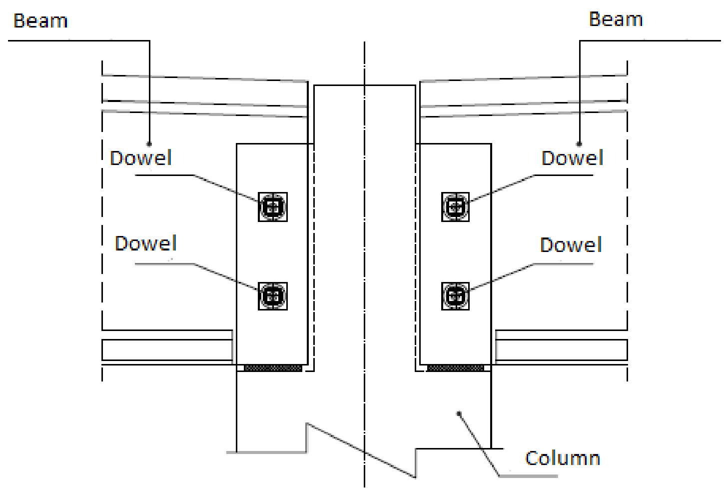

Fig. 4 – Beam-column connection used in Romania for precast industrial buildings.

If we are to compare this type of connection with the connection presented in both FIB and JRC, we observe immediately some major differences:

- the steel dowels are placed in the horizontal direction and not vertical as suggested in FIB and JRC;
- usually the ducts are not filled with anything due to technological issues, thus providing no anchorage and in the eventuality of a seismic action, hammering effect will be present which has to be avoided at any cost as presented in both FIB and JRC;
- the connection does not only transfer vertical displacements in the plane of the beam, but also a moment resisting type of connection, thus leaving us with the question if this connection can still be considered as hinged in the plane of the frame?

Looking at those differences that we observe immediately we are likely to say that this connection is not suitable for usage in seismic areas and therefore we would like to present another connection type that is currently under research in our company SC SIMPLEX PROJECT SRL as presented in Fig. 1.

Although both FIB and JRC consider the behaviour of vertical dowels beam- column connection as being hinged, we see from the experimental data that not even this type of connection behave as a fully hinged connection. The dowel effect is shown on Fig. 5.

In chapter **3.2.3** of SAFECAST they note a shear ductility "In testing, failure mode a of dowel connection displayed a local shear ductility, due to the flexural and tensional deformation of the dowels within the joint gap". Also in chapter **3.2.4** Dissipation – "Cyclic tests performed in the longitudinal direction of the beam show a medium dissipation capacity due to the alternate deformations of the dowels within the joint gap. For small thicknesses of this gap the dissipation capacity would decrease sensibly. Also crushing of the concrete around the dowels occurs for large shear displacements reducing the energy dissipation capacity." Additional Decay information are given in 3.2.6 "Cyclic tests show that, at any displacement level before failure, strength decay occurs after each of the three cycles. At the third cycle this strength decay can reach the 25% of the value of the first cycle."

This entire information raise the question if even this type of connection can be considered as hinged. This fact has a major importance in global analysis design and in the design of column section (due to this hinge connection assumption we end up with very large sections for columns which in reality don't have so much force transmitted due to the non-perfect hinge connection executed but designed as fully hinged).

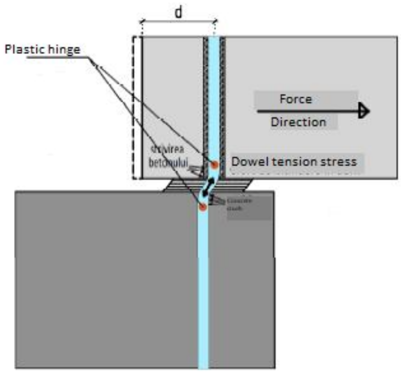

Fig. 5 – Dowel effect.

4. Nonlinear 3D Analysis Performed in Atena for Proposed Beam-Column Connection

Following the idea of how the proposed connection should work, the next step in the research was to optimize it with the help of a numerical model. Due to large computational time required, 1st step in our numerical research was to optimize the node area and therefore only 1 column and parts of the joining beams were modelled (Fig. 6).

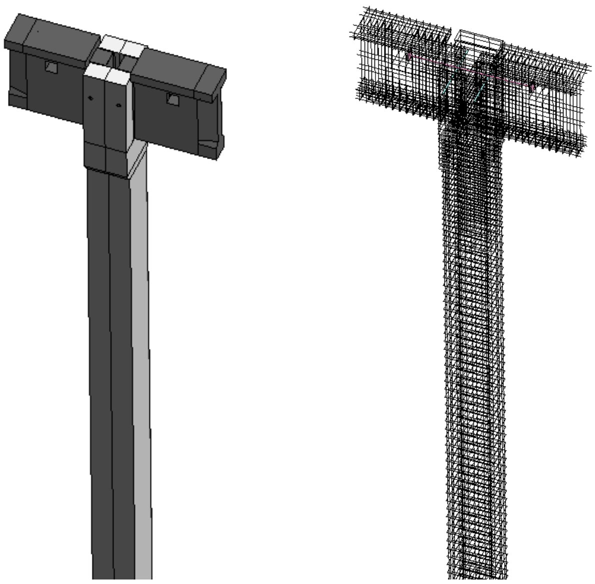

Fig. 6 – Beam-column proposed connection modelled in Atena (solid geometry and reinforcement geometry).

The connection was subjected to a lateral load (simulating seismic action) applied to one of the beams, while the other beam had a line support that allowed sliding but providing constrains in the perpendicular and vertical plane of the frame.

Output analysis file showed a good behaviour of the proposed connection, failure was attributed to column failure due to lateral loading (Fig. 7). A similar analysis was made just for the column with a lateral load applied and failure was happening at the same top displacement.

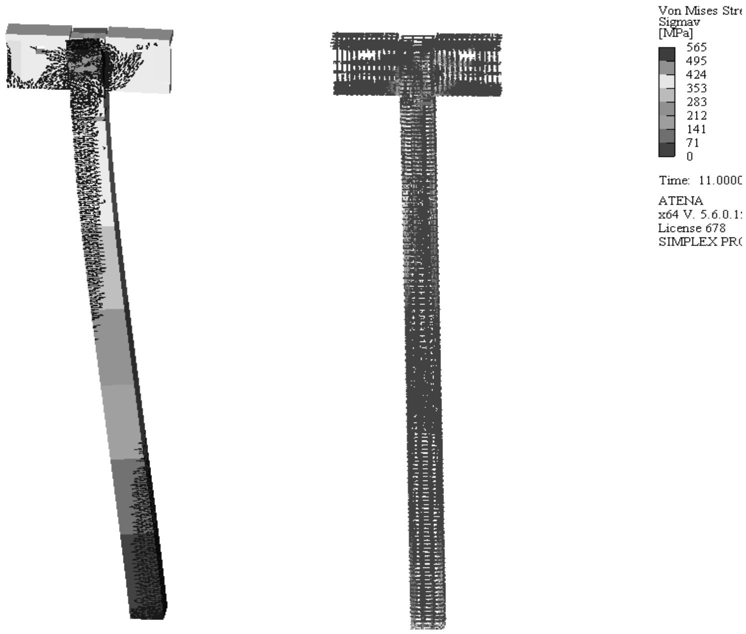

Fig. 7 – Beam-column proposed connection output displacements/cracks and reinforcement Von Misses Stress.

5. Conclusions and Future Research Directions

Due to encouraging results shown in the numerical model, the next step in our research will be to model a full frame with 5 spans model and afterwards to make an experimental model with the help of which we will further calibrate the numerical model. After the numerical model will be verified by experiment, a parametric study will be analysed with the help of which we can provide very simple table calculations, so any design engineer could use this solution without any effort.

The proposed solution is part of a file with registration number OSIM nr. A/10064/2017.

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* * * OSIM file nr. A/10064/2017.

CONEXIUNEA GRINDĂ-STÂLP PENTRU HALE INDUSTRIALE PREFABRICATE

(Rezumat)

În cazul halelor industriale prefabricate, un factor de mare importanţă este conexiunea grindă-stâlp. În cazul structurilor prefabricate, structurile în cadre având conexiunea grindă-stâlp realizată cu dornuri este preferată, în special pentru clădirile hală din cauza simplităţii de montare, costului mic.

Îmbinarea articulată dintre grinzile principale şi stâlpi, respectiv îmbinarea articulată dintre grinzile secundare şi stâlpi constituie un aspect important în ceea ce priveşte răspunsul clădirii prefabricate tip hală parter la solicitări orizontale din seism. Proiectarea efectivă se bazează pe un răspuns teoretic acceptabil în ceea ce priveşte deplasările la vârf şi/sau modurile de vibrare ale clădirii şi constă, în mare, din predimensionarea şi verificarea elementelor structurale ce alcătuiesc clădirea.

Deoarece răspunsul unei clădiri este şi în funcţie de tipul de îmbinare folosit se consideră că îmbinarea proiectată trebuie, pe cât posibil, să se apropie cât mai mult posibil de ipotezele teoretice ale acesteia.

Prezenta lucrare are drept scop evidenţierea defectelor folosite în proiectare/execuţie prin folosirea unei conexiuni cu dornuri de oţel şi se propune folosirea unei conexiuni inovative pe viitor care se află în curs de patentare de către compania noastră.