ADVANCED CONNECTIONS FOR PRECAST CONCRETE STRUCTURES

Vaclav Vimmr

STU-K, a.s., Prague, v.vimmr@stu-k.cz / CZ-154 00, Czech Republic

Abstract

Mechanical joint systems developed for particular applications can be in some cases used in rather innovative ways. Paper deals mainly with joints of various kinds of frames, particularly joints between columns, beams to columns, beams to beams and bracing elements to columns. In principle both fully rigid and pin joints are considered together with fixing of columns to foundations. A simplified formula for calculation of shear resistance of reinforced joints according to Eurocode 2 is presented. Attention is also paid to composite steel concrete floor structures based on hollow steel elements and hollow-core slab elements. Although any other floor elements can be used in combination with lightweight steel beams.

Keywords: Column shoes, connections, corbels, Deltabeams, frame structures, hollow cores, wall shoes

1 Introduction

Advantages of precast concrete technology are well recognised in many countries around the world. Precast concrete offers for instance higher speed of construction, reduced number of workers on building sites, lower dependence on weather conditions and with regards to jointing methods possibility of dismantling of structures. Recently performed research (Toniolo, 2012) and experience from earthquakes confirm that precast concrete structures can successfully withstand earthquake as any other appropriately designed and executed structures. This important lesson has been learnt from severe L'Aquila earthquake in April 2009. Precast concrete frames survived there very well. However success of precast concrete structures is conditioned by suitable and effective solution of connections and joints. There are generally lots of methods utilized in engineering practice. Some of them are dealt with in the SAFECAST research programme and included in Toniolo's report. This paper concentrates mainly on mechanical joint systems. Wide range of special products for connections is commercially offered on the market. Although some products were originally developed for certain field of application they might be used also different way.

2 Joints of columns to foundation

There are various methods of jointing columns to foundations. So-called pocket foundation foots were commonly used in past but the tendency is towards application of anchor bolts and column shoes (see Fig. 1(a) and (b)). Function of such joints is more straightforward and closer to cast in situ approach. The main advantage of that solution from technical point of view is easy rectification in vertical direction, joint is capable to carry out loads immediately after column erection and tightening of nuts, and foots can be significantly smaller. More detailed technical and economical comparison of both systems has been presented by (Vimmr, 2011). The most critical aspect during construction is correct location of anchor bolts. Special fixing frames are thus recommended. The system is universal and can be used for any kind of foundation of columns e.g. footings, piles or slabs.

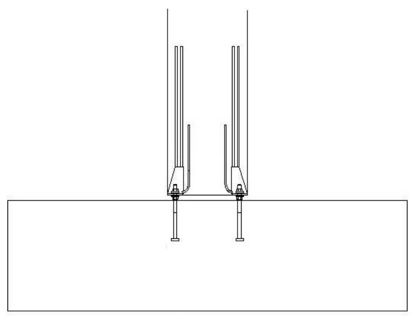

Fig. 1 (a) Column fixed by means of anchor bolts and column shoes

Fig. 1 (b) Column shoes.

3 Joints of frames

There are various systems used in practice. It depends if we need rigid joints or just pin joints among individual structural elements when horizontal forces are resisted by walls, shafts or other bracing structural elements.

3.1 Beams to columns

Very practical solution is based on the application of Gerber beams when beams are continuous over columns and pin joints of beams are located in regions of minimum bending moments. Such joints of beams and columns can be assumed as fully rigid when beams are fixed by columns due to relevant vertical forces in columns or compressed by anchor bolts.
In principle reinforcing bars can be interconnected by couplers that are easy to install in composite concrete structures when reinforcing bars are located in cast in situ part of beams.
In case of larger cross sections of beams columns shoes can take over the role of reinforcement couplers. The advantage of this approach is the possibility to eliminate unwanted compression forces in reinforcing bars bended close to a column surface (see Fig. 2 (a)), while tensile forces are transferred by column shoes functioning as couplers. Such situation appears for example in frame corners exposed to both positive and negative bending moments. Compression in bars can be eliminated just by omitting nuts below column shoes located in beams ends (see Fig. 2 (b)).
When multi-storey columns are designed and joints between beams and columns are not expected to transfer bending moments but just vertical shear forces, horizontal axial forces and torsion products so-called PCs corbels might be the convenient solution. They replace traditional concrete corbels that usually cause inconveniences during production of columns. This is extremely useful especially when 3 or even 4 beams should be connected to columns in one nodal point and concrete corbels should be created on all 4 sides of rectangular columns. Fig, 3 shows on the top embedded part of the PCs Corbel that does not extend from the column surface and the bottom part of the Figure shows completed corbel. Those parts are mounted after production of columns either in prefab plants or on building sites. Beams must be provided by so called beam shoes that enable transfer of forces from beams to corbels and their geometry fits to a shape of corbels.

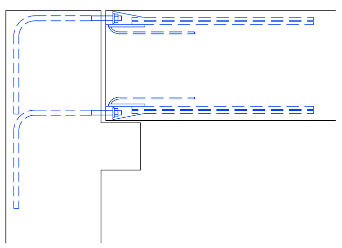

Fig. 2 (a) Example of the arrangement

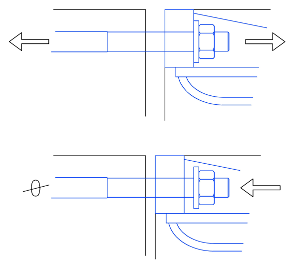

Fig. 2 (b) Coupler working in tension only.

3.2 Columns to columns

Jointing of columns can be done by anchor bolts anchored in lower columns and column shoes placed in the bottom of upper columns. There is no particular problem when columns are interrupted by beams. In such a case vertical holes are provided in beams so that anchor bolts can pass through. Anchor bolts exposed to compression must be secured against buckling in those sections.

Fig. 3 PC Corbel

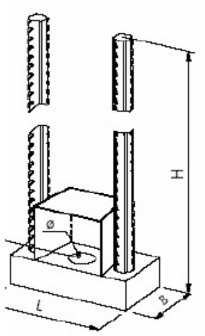

Fig. 4 Wall shoe

3.3 Beams to beams

Joints of beams outside of columns can be designed as pin joints resisting shear forces and axial forces. When pin joints are situated close to zero points of bending moments structural behaviour of such frames is very similar to frames with fully rigid joints. Pin joints can be created as rebated joints employing concrete corbels and vertical rods.

4 Joints of walls

When walls are designed as stiffening elements with minimum vertical load they might be exposed to vertical tension in horizontal joints. In such cases wall shoes (Fig. 4) could be successfully applied. Similar to columns shoes wall shoes can be used as reinforcement couplers. No matter whether it is for horizontal or vertical joints. Joints based on wall shoes are capable to transfer not only axial forces but shear forces as well.

Design shear resistance V_{Rdi} of a joint in a presence of properly anchored reinforcement crossing the joint can be calculated according to 6.2.5 (Eurocode 2, 2004)

$$V_{Rdi} = cf_{ctd} + \mu\sigma_n + \rho f_{yd}(\mu \sin\alpha + \cos\alpha) \le 0{,}5\nu f_{cd} \quad (1)$$

If influence of joint mortar on shear strength can be neglected, there are no normal compressive stresses and reinforcement is perpendicular to the joint plane the equation (1) can be simplified to

$$V_{Rdi} = \rho f_{yd} \le 0{,}5\nu f_{cd} \quad (2)$$

where

$\rho = A_s / A_i$

A_s is area of reinforcement

A_i is area of a joint

ν is a strength reduction factor according to national Annexes. The recommended value follows from

$$\nu = 0{,}6\left[1 - \frac{f_{ck}}{250}\right] \quad (3)$$

f_{yd} , f_{cd} and f_{ck} are strength values according to Eurocode 2.

5 Composite system for flat slabs

Flat slabs are very popular structures for multi-storey frame buildings. Traditional cast in situ flat slabs are relatively expensive due to high consumption of reinforcement per square meter and apart from that self weight of the structure is rather high. A more effective approach to flat slabs is based on prestressed hollow-core slab elements supported by special hollow steel beams that are filled by concrete to create composite steel concrete structure. Example of such a beam is on Fig. 5. Thanks to composite action of steel and concrete and some special provisions fire class rating R120 can be satisfied without additional fire protection measures. Steel beams can support also filigran plates or ordinary cast in situ slabs as it is described in (Vimmr, 2008) and illustrated by Fig. 6. Experience from engineering practice shows extremely wide range of applicability of the composite system thanks to its geometrical flexibility. Easy handling of lightweight hollow steel elements is particularly appreciated in reconstructions, if floor slabs must be replaced and space restrictions might be limiting factor.

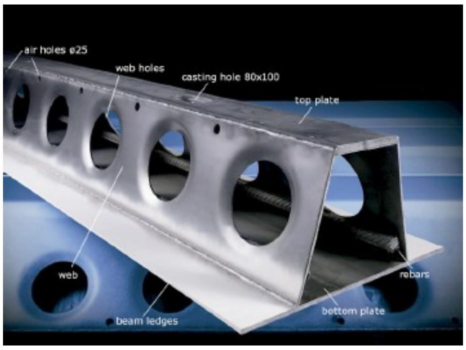

Fig. 5 Deltabeam

Fig. 6 Deltabeam supporting different slabs

6 Conclusions

It has been shown that special mechanical joint systems can be used not only in basic application fields for which they have been developed, but there are also innovative possibilities dependent on creativity of engineers. The advantages of application of mechanical joint systems are growing with regard to the fact that systems were carefully calculated, tested and finally approved and consequently offer higher level of reliability in comparison to “home made” products.

References

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