PRE-FABRICATED CONCRETE IN HIGH RISE BUILDINGS IN BRUSSELS

The Brussels skyline will soon be filled up with high-rise buildings. In Brussels, before the 1990s, pre-fabricated concrete elements were little used in high-rise office buildings. The last decade has only seen the use of pre-cast slabs in high-rise buildings, integrated into a steel structure cased in concrete or some special protection to provide fire resistance. Recent developments in the pre-cast concrete industry have reversed this tendency, and in the most recent high-rise buildings constructed in Brussels, ERGON has used precast concrete elements on a large scale. The success of pre-fabrication in these new projects has been ensured by the use of high strength concrete on the one hand and the development of new production techniques and new products on the other. Of course, it goes without saying that these innovations and the creativity in terms of design are also a fundamental part of this success.

The use of pre-fabricated concrete elements in high-rise buildings offers the following advantages compared to other systems:

- 2 hours fire resistance without any additional protection.
- Speed of construction
- Very little deformation of floors thanks to the use of pre-stressed elements
- Better acoustic insulation of the floors where hollow core pre-cast concrete floor slabs are used.
- More space available for the technical services were TT elements are used.
- The financial aspects are far from being the least important of the advantages.

These advantages were all confirmed on the ground over several years in three projects, mainly:

- The Vazon Tower in Luxembourg (19 floors)
- Extension of the Madou Tower in Brussels (15 floors)
- Extension of the Botanique Tower in Brussels (18 floors)

In the meantime, these various projects have been completed by numerous construction sites for high-rise towers where ERGON has provided the pre-fabricated elements. We will go into more details in the following text as concerns the "North Galaxy", the "Dexia Tower" and the "Central Plaza" building.

“NORTH GALAXY” PROJECT

This project, recently carried out, situated in the Northern part of Brussels, is the irrefutable proof that pre-cast concrete is an interesting alternative solution for the construction of high rise office buildings. The impressive North Galaxy building consists of a block of 6 floors surmounted by two tours of 30 floors each. The initial design made provision for a structural steel solution cased in concrete.

Having received the order for the floors and the columns for the infrastructure as a result of a variation order to the original structural steelwork design consisting of concrete encased HD sections and to the cast in situ concrete floors, ERGON put forward a proposal to the Interbuild Willemen-CIT-Blaton-Van Laere joint venture for a solution consisting entirely of prefabricated elements. In order to be accepted by the joint venture and by the client, this proposal had to respond to a series of conditions:

- be financially more interesting
- meet the date for completion required by the client
- respond to the technical conditions provided for in the initial project namely, the dimension of the elements, the space available for the technical services and for fire resistance.

Following the catastrophes of 9/11, all these conditions were met by the requirements to take all necessary measures in order to avoid a phenomenon of progressive collapse.
Having studied our proposed solution in depth, the joint venture reached the conclusion that our alternative solution was more economical than the original one with a steel structure and Hollow-Rib floor slabs. Moreover, our system provided for a reduction in the period for completion and responded perfectly to all the technical requirements. The ERGON solution was therefore adopted. The basis for the success of this pre-fabricated concrete solution was the use of high strength concrete as well as the use of a new TT element; we will come back on these various points later on.

The speed of construction was also a determining factor, the erection of the pre-fabricated elements went ahead like clockwork at a rhythm of two floors every eight working days. Not a single building in Belgium could pride itself on such a rapid speed of erection. The stability of the two towers is ensured by a rigid cast in situ core constructed using climbing formwork. The execution of the core had on average always three of four weeks advance in its execution compared to the erection of the pre-fabricated elements. As the building went up, the tower cranes had to be adapted. Since the cranes were fixed at the edges of the building, each floor to which the cranes were fixed had to provide for an integrated diaphragm effect to allow for the horizontal forces; the erection of the pre-fabricated structure had therefore to follow the central core as quickly as possible.

The use of high strength concrete was an important factor in the construction of the *North Galaxy* project. Concrete quality C 50/60, used to be considered the best in the 1970s and 1980s. Higher quality concretes were used only sporadically for small experimental projects. It was in 1992 that ERGON started using high strength concrete C 80/95 (80 N/mm² on cylinder, 95 on cube) to a large extent for the infrastructure of Building D3 in the *Quartier Leopold* in Brussels. This first application is the departure point for a more intensive use of C80/95 concrete for pre-fabricated projects, this concrete being used rather more for the columns than for the beams. For all that one might have wanted to wait to use a concrete with an even superior strength, ERGON voluntarily chose to limit the quality of the concrete to C80/95 in recent projects under construction. Standardisation requirements are actually limiting the development of even better qualities of concrete.

The requirements called for in terms of the fire resistance of high strength concrete elements as well as the composition of more expensive concrete make the use of concrete class C90/105 uninteresting. Increases in the price of steel will perhaps reverse this tendency and possibly make structures using higher quality concrete interesting over time.

High strength concrete as well as the new products conceived for the *North Galaxy* project are at the basis of this success. The TT elements have been designed in such manner that they can be used for other projects. The formwork for the circular columns and the TT elements will make it feasible - subject to some modifications - to use these elements in other projects.

**Circular columns two storeys high**

For the *North Galaxy* project, circular double-storey height columns with two corbels (one for each level) have been used. In total 7 sets of moulds have been made in order to allow for the fabrication of 35 columns every week. 676 double-storey height columns have been fabricated with an average coefficient of 26 identical columns. The columns for the infrastructure of the building have been made using self-compacting concrete quality C80/95. The quality of the concrete and its reinforcement ratio diminish progressively as the building rises through its upper floors. The construction of such columns is technically complicated requiring a lot of labour and a significant investment in moulds. Nevertheless that was worth the trouble since for each two storeys it was possible to save three days in the erection programme and hence there were not just savings in hard cash but also in the erection programme leading to a reduction in site overheads. A further advantage was that it was generally not necessary to pour the compression screed at each intermediate floor and the contractor therefore had considerable latitude in planning and executing those areas which needed to be cast in situ.
**TT floor slabs 190mm thick**

A technical solution using classical honeycomb floor slabs did not allow sufficient height for the special technical services. For this reason, for the *North Galaxy* project, ERGON developed a new TT element with a height of just 190mm.

A TT element is more expensive than a traditional hollow floor slab but in the case of a high rise building it offered several advantages:
- the ducts for the special technical services can be placed in between the ribs and above the intersecting transversal ducts that run (at right angles) beneath these elements.
- the TT elements can be provided with a cantilever bearing which permits them to have a higher clearance at the level of the bearing of the beam.

These two advantages made reduced storey heights possible, which is an important advantage in the case of multi-storey buildings. (With a saving of 12cm for each floor over 30 floors one obtains an additional floor for the entire tower).

In addition to the above-mentioned advantages, the pre-cast elements - thanks to their width of 2.4m - can be put in place twice as fast as standard hollow floor slabs Type SP. Moreover the adaptation of the larger width is much easier than for the standard hollow floor slabs Type SP. Furthermore, this TT element has already been used in other projects and a second cross-section 260mm high has been foreseen for larger spans.

**“DEXIA TOWER” PROJECT**

At the Place Rogier in Brussels one can already see the structure of the *Dexia Tower*, a building of 37 floors is already complete. This is a project which, for all its characteristics, is nevertheless very special.

The architectural designs were developed by the bureau d’études as a load-bearing structure consisting of steel and concrete. A maximum amount of pre-fabrication had been introduced into the design. HD sections had necessarily been foreseen for the columns in order to limit the dimensions and take the very heavy loadings. The steel sections were provided by Buyck, and ERGON undertook the additional reinforcement and concreting. This solution was anything but straightforward given the very strict admissible tolerances. In order to make the columns as simple as possible ERGON reduced the number of HD steel sections using high strength concrete quality C80/95 in combination with a very high proportion of steel (sometimes more than 7% steel). In order to reduce the number of operations for the erection, a significant number of double storey height columns were provided. The floors consist of standard pre-stressed floor slabs Type SP and pre-stressed beams. A U-shaped element was placed at right angles to each column in order to allow for the intersection of ducts in the false ceiling. Given the very heavy loadings and the limited height available, certain beams were provided with structural steel inserts.

Such a building cannot be designed without making provision for contingencies such as the means to prevent progressive collapse. The structural engineers had foreseen two metal plates put in place during the second phase of the beams welded to a metal plate anchored in the column. Horizontal stability is ensured by a compression screed.

Moreover the erection is not simple either. Columns must be erected with very strict tolerances and in perfect contact with the steel plates. The other elements are also subject to the same strict tolerances. The production of elements and their erection called for very strict supervision in order to respond to the project requirements.

We should also mention the construction of the pre-fabricated concrete used in part of the rigid core of the infrastructure. The objective of the client was to construct the building “up and down” simultaneously executing both the infrastructure and the superstructure. Thanks to the use of pre-fabricated concrete, the core elements of the building in the infrastructure could be carried out very quickly.

For this central core, ERGON provided 28 pre-cast columns having a total weight of 41.7 tons. These 28 columns are not columns in the true sense of the word but, once connected with the in situ concrete, form the central core of the underground parking area consisting of four levels of a new...
tower of 37 storeys pointing into the Brussels skyline. You have got it, this is not an everyday project and the erection even less so. All the columns are provided with a 168mm diameter longitudinal steel tubular exactly in the centre line of the column and destined to hold the column in place vertically.

After checking the position of various accessories and the positioning of certain nuts, locknuts and threaded studding, the column is wrapped up in three lays of plastic in order to avoid all contact with the bentonite into which the column will be plunged. Now it is ready for transport. As soon as it arrives on site, the column is temporarily laid out in order to bend the projecting steel reinforcing bars into position for connecting with the foundations. Two metal angles are placed at the head of the column. A plumb line is drawn across the circular metal pipe with, at its extremity, a metal plate placed centrally in relation to the centre line of the column. The projecting reinforcement for the connections with the foundations are at the foot of the column. It is precisely to avoid damaging these reinforcing bars that the columns are manipulated using two cranes. At this point the column is suspended vertically from the crane and is put into its final position above the foundation reinforcement.

The column is then lowered into the foundation cage to the required level where it hangs in the foundation reinforcement at its foot. Once this operation is completed, the temporary supports for the foundation reinforcement are withdrawn and the column can continue along its path in the bentonite until the two angles come to rest on the bearers. At this point the column is 1 meter above its final position.

The lifting bolts can now be removed. A steel framework with lifting eyes is bolted (4M 36 screwed to the 40mm diameter bars) to the head of the column. This framework is secured in line with the central line of the column. The column is then lifted up by means of this metal frame, the bearers are withdrawn and the whole unit is placed on four hydraulic jacks levelled relative to fixed reference points. The jacks allow for the correct positioning of the column and its verticality is controlled by means of the circular metal tube immersed in the concrete. Once having levelled the coordinates X, Y and Z, the whole assembly framework is secured.

The following day, the remainder of the operation can continue, the position of the column is checked again and adjusted as necessary. Once the foot of the column has hardened (concreted in the bentonite), the space occupied by the bentonite is backfilled with aggregate. The metal levelling framework is removed and re-used for the following columns.

Once all the columns have been erected, the threaded studding is screwed into the dowels cast into the column and once the reinforcing steel has been put in place, the ground floor can be cast in place like a simple oversite concrete slab. The construction of the superstructure can now begin up to the 20th level. Simultaneously, the earthworks for the lower levels can be carried out level by level. Before the 20th level is reached, the 4 lower levels must be completed and the columns of the central core must be connected in order to form rigid lateral supports. The columns have been made using concrete quality C70/85.

General contractor: AM BPC – Vinci Construction – CIT Blaton
Technical control: Seco
Owner: Brussels Business Center s.a.
Advisor to the owner: Immo Consultance sprl
Project management: Procos
Architects: AM M. & J.-M. Jaspers-J. Eyers & Partners-Samyn and Partners, architect and engineers
Structural Engineer: Setesco s.a.
“CENTRAL PLAZA” PROJECT

The Central Plaza building in the heart of Brussels near the Central Station consists of a tower block of 15 storeys and is already in the phase of completion. It is some time now that we have been busy with this building of 15 floors situated near the Central Station.

On plan, this building has an oval shape with 41 columns for each floor. Patios have been provided for in different places at different levels in such manner that none of them is identical. The structural engineer had designed this building using cast in situ concrete believing that a such structure could not be prefabricated.

Following a long period of preparation and coordination, a system was developed using columns of 500mm up to 800mm diameter of various heights and concrete qualities varying from C50/60 up to C80/90 in combination with beams RZ, RT and RR, thus making it possible to construct the patios using a pre-fabricated concrete structure.

Two of these patios carry through five floors. The columns in these areas are 17,7m high and consist of tubular metal cylinders filled with concrete. Pre-fabricated beams rest on these columns at a height of 35 m. In order to put these beams into position, two temporary stagings had to be provided on the external elevation of the building which, in the area around the Central Station in Brussels, is not an easy thing to do given the small amount of available space. Ten years ago, this kind of building could never have been pre-fabricated but computer assisted conception methods helped the architects create forms that are more complex than can actually be designed using these techniques.

In order to fabricate concave beams, convex with a cantilever, a very careful control is necessary especially for the pre-stressed elements. Whether on site or in the factory, the setting out of works using a radius of 37,71m is not an easy matter, but pre-fabrication techniques have once again proven that there is very little that cannot be pre-fabricated and made reality these days.

General contractor: L. De Waele
Architect: Montois
Structural Engineer: Ingénieurs Associés

NEW PROJECTS UNDER CONSTRUCTION

In the wake of the projects described above, ERGON is in the process of constructing three other high rise buildings:
- “Ilot 65” in the area of the North Station. This building of 22 storeys has a very special layout on plan and already 17 storeys are completed.
- “LEX 2000” situated in the rue de la Loi consisting of 14 storeys and a very complex structure which as you can see from the plan has risen up to level 4
- The project known as “Covent Garden” near the Dexia Tower has an elliptical form and consists of 26 floors and at the moment has reached the 5th level

These 3 projects carried out in pre-fabricated concrete are based on one or other of the principles used in the three buildings described above.

By way of conclusion, I think we have reason to confirm that for high rise buildings, pre-fabricated concrete has made enormous progress and has overtaken all other methods of construction. ERGON has without doubt certainly contributed to this evolution, thanks to its detailed customized solutions for its clients. These magnificent references which have already been carried out as well as the projects now under construction which are themselves just as magnificent, served to underwrite ERGON’s future as well as that of pre-fabricated concrete construction techniques in Belgium.

C. De Cauwer
Director General
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ERGON sa Marnixdreef B-2500 LIER
http://www.ergon.be
Essential points in the Belgian construction process where pre-cast solutions are used:

1. Most - if not all - major construction projects for buildings in Belgium are initially designed as traditional cast in place concrete by the client's consulting engineer;

2. General contractors look to propose "alternative solutions" (variants) so as to be able to put forward a more attractive offer to their clients in terms of cost, time and quality;

3. ERGON sells "project solutions" to contractors; not just "pre-cast concrete";

4. ERGON looks at the proposal as presented and unless the volume of concrete can be reduced by 30% or more and correspondingly the reinforcing steel and the time for erection, the possibility of putting together an "alternative pre-cast solution" is not followed up;

5. In practice, almost anything can be pre-cast these days, in most instances with major economies over traditional cast in place solutions;

6. The role of the insurance arrangements - namely the Belgian system of "Project Insurance" which covers the building against defects for the decennial guarantee without any possibility of recourse against the "guilty party", is absolutely fundamental to this innovative method of working.

7. The role of the "Technical Controller" (SECO) is also fundamental to the process since the controller acts as the "technical guardian" of the insurance policy. This is normally taken out by the client (but sometimes the contractor). SECO decides what can or cannot be insured and hence what can or cannot be built. In contrast to other countries, the really great advantage of this way of working is that the liability for technical and functional performance of the building is carried by the insurance policy thereby absolving the design team and the contractor and his sub-contractors (named in the policy) from liability in the event of defects or failures;

8. ERGON has the in-house capability to develop the full technical design from the client's initial proposals. Since less concrete and steel (pre-stressed reinforced concrete is +/- 3,5 times stronger than concrete reinforced with mild steel bars, and an 80/95 concrete mix is +/- 3 times stronger than normal cast in-situ concrete) is used than in the cast in place solution, accommodating HVAC services and/or reduced storey heights leads to further economies;

9. Acoustic performance between floors is enhanced;

10. Total fire-resistance of the structure is ensured;

11. In theory; if not in practice, there are virtually no limitations to the height of prefab buildings;

12. Technical designs take account of both possible terrorist attack (since 9/11) and the phenomenon of progressive collapse;

13. Fabrication is carried out in factory-controlled conditions using various grades of high performance self-compacting concrete and pre-stressed reinforcing steel;

14. Erection is fast (as much as one floor every 4 working days) and can be carried out in almost any climatic conditions;

15. Employment regulations in Belgium allow for workers to be laid off (technically unemployed) during slack periods on basic pay (state intervention);

16. Health and safety on site: fewer men = fewer accidents!

17. Medium sized (SME) enterprises also use this system, erecting low rise pre-cast concrete apartments and offices in Belgium. Hence the techniques tend to "trickle down" through the whole industry. This is not something exclusively for large firms!

John Goodall
Brussels
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