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Hybrid Structures in Challenging Architecture

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Abstract
New building materials and construction technologies make the building industry of today look different from the one of some years ago. Structural steel, cast-in-situ concrete, and precast concrete are now common and compete with each other in the construction market. Joining forces to seek synergy rather than confrontation is the emerging trend. The result of this trend is the growing number of hybrid structures in today’s building practice. Hybrid, or mixed construction with precast concrete, means combining the use of precast concrete with other materials, such as steelwork, timber, cast-in-situ concrete, and glass for the benefit of the building process at large.

There are two recent examples of this development in the Netherlands. The first is the office tower ‘Malietoren’, constructed over the motorway A12 entering the city of The Hague. The second is the 100-meter high sloping office tower ‘Belvedere’ in Rotterdam. The ambitions of the architect Renzo Piano to make this second tower appealing but still market price competitive was made possible because of a hybrid structure.

This paper will consider the concepts, alternatives, final solutions, and details of these two architecturally appealing buildings in illustrating the hybrid development. In both cases, precast concrete has played an important role.

Benefits of Hybrid Construction
Hybrid construction maximizes the structural and architectural advantages by combining components made from different materials. To achieve this, cooperation between the architect, structural engineer, services engineer, manufacturer, supplier, and contractor is required. Hybrid, or mixed construction, must be distinguished from composite construction. Composite is defined as different materials acting homogeneously.

In hybrid construction the different materials may work together or independently, but will always provide advantages over the use of a single material. In today’s engineering practice, builders and users are discovering that hybrid construction is essential to meeting architectural requirements, providing hard finish surfaces, minimize structural floor depths, achieve better sustainability, and ensure rapid construction. All of these translate into substantial savings and better quality into the end product.

Hybrid construction methods vary considerably depending upon the type of construction and the building’s function. Varying methods reflect local trends, environmental and physical conditions, relative material and labor costs, and local expertise. The fib-commission 6-Prefabrication, Working group on Mixed Construction (the author of this paper is a member of this Working group), recently reported at the May 2000 ‘Second International Symposium on Prefabrication’ in Helsinki, Finland, that although permutations for hybrid construction are numerous, the following could be seen as a guide for their most common forms and combinations:
<table>
<thead>
<tr>
<th>Building Type</th>
<th>Mixed Precast Construction Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Offices</td>
<td>In situ concrete frame with precast flooring and facades, with possible masonry wall or cross-steel bracing. Steel work frame with precast shear walls, flooring, and facades. Precast frame with steel raker (‘Mansard’ type) or steel roof truss. Precast frame with pitched timber truss.</td>
</tr>
<tr>
<td>Retail and Shopping</td>
<td>In situ concrete or steel frame with precast flooring and facades. Precast load bearing wall with cast in situ floors. Masonry load bearing walls with precast floors.</td>
</tr>
<tr>
<td>Parking Garages</td>
<td>In situ concrete frame with precast flooring, with possible masonry wall or cross-steel bracing. Ditto steel work frame.</td>
</tr>
<tr>
<td>Industrial and Warehouses</td>
<td>Steel frame with long-span precast wall units. Precast columns with flat or pitched steel roof truss. Steel frame with precast floors (for office areas).</td>
</tr>
<tr>
<td>High Rise Residential</td>
<td>Precast load bearing walls with cast in situ floors or composite precast in situ floors. Masonry load bearing walls with precast floors.</td>
</tr>
<tr>
<td>Stadia</td>
<td>Steel frame including raker beams, with precast terraces. Cast in situ frames with precast terraces. Precast columns with steel raker beams and precast terraces. Combinations of above with sloping steel or pretensioned precast roof rafters.</td>
</tr>
</tbody>
</table>
The same working group reports that:

- Today, hybrid construction is being used in more than 50 per cent of the new multi-story buildings. This has once been the domain of in situ concrete and structural steelwork. Precast concrete is ideally suited to hybrid construction as it may readily be combined with other materials, such as steelwork, timber, in situ concrete, masonry, and glass, for the benefit of the building process at large.

- Precast concrete, as the dominant material in hybrid construction, reduces on-site operations. The reasons are less wet concrete to place, fewer loose reinforcing bars to set, and fewer structural components with their formwork to erect. There is also less construction noise to disrupt local communities. Prefabricated components can also provide a working platform for workmen, increasing their total workability. All of these reasons create a safer working environment.

- Various case studies claim that hybrid construction can save between 10%-20% in construction time.

- Hybrid construction is, by definition, cost effective. It maximizes the beneficial structural and architectural advantages by using components made from different materials. However, the technique requires cooperation between architects, consulting engineers, manufacturers, suppliers, and contractors.

- In some cases, client and architectural demands can only be satisfied using mixed construction.

**Office tower ‘Malietoren’ in The Hague**

Our growing human population and its demands for living and working spaces are often in contradiction with our striving for saving grasslands, forests, and natural resources. Multiple uses of spaces for our building activities is one answer to this dilemma.

Office tower ‘Malietoren’ (see Fig. 2) is such a case. It is situated over the motorway A12 ‘Utrechtse Baan’ entering the city of s-Gravenhage ‘The Hague’ (see Fig. 1). The building is almost square in plan, 40m long by 32.2m wide (see Fig. 5). The floor is designed as an entry and reception area (see Fig. 4). Above this entry are five car-parking levels. They are accessed by a spiral ramp cantilevered halfway over the motorway on the north face of the building. The sixth and seventh floors are conference facilities whilst the thirteen floors above them are designed for offices. The building’s services are concentrated on the top floor, bringing the building’s total height to 74m.

**The Structure**

Building over an existing motorway is never easy. The Utrechtse Baan motorway – effectively a watertight reinforced concrete trough sunk into the ground – could not be closed without severely affecting the life of The Hague. As a result, it had to be bridged over to prevent any disturbance, including additional loads or penetrations into the trough.

The best solution proved to be a composite concrete transfer truss structure with a height of 8.2m and a span of 32.2m at the entrance level (see Fig. 5). It also satisfied the architectural perception in terms of structural demands and economy. The 2m deep precast, prestressed, and post-tensioned lower chord of the truss was designed to function, in the erection stage, as a simply supported beam. It carried the weight of the ground floor and acted as a construction platform. Since the beams and working floor were prefabricated, they could be placed in a single night (see Fig. 3). Diagonals and the upper chord were added with B65 in situ concrete. The floors above this transfer truss are precast hollow-core slabs on precast, prestressed concrete beams (see
Fig. 5). This solution is very economical and quick to erect.

**Innovation**

The two-story, high-strength B85 precast concrete columns are innovative. A simple and inexpensive connection, using steel plates and epoxy resin injection, resulted in an enhanced speed of erection and a minimum reinforcement cross sectional area of 8% (see Fig. 6). Structural steel bracing was integrated into a precast concrete façade (see Fig. 7). The simple in situ concrete connections create a stabilizing façade tube for the entire building (see Figs. 2 & 5). The final result is a high quality building respecting the environment and ecology at a very competitive price.

**Client:** Multivastgoed (Real Estate Development) Gouda, the Netherlands

**Contractor:** Wilma Bouw The Hague, the Netherlands

**Architect:** Benthem Crouwel Architecten Amsterdam, the Netherlands

**Structural Engineer:** Corsmit Consulting Engineers: Rijswijk, the Netherlands In cooperation with Ove Arup & Partners, London, UK

J.N.J.A. Vambersky continues his discussion of ‘Hybrid Structures in Challenging Architecture’ with Renzo Piano’s ‘Belvedere’ sloping office tower in Rotterdam in the next issue of the CTBUH Review.