1. Introduction

Many ongoing developments in building activity are inspired by social and economic factors that have marked our society in recent decades:

- Fierce competition between construction materials and techniques: concrete versus steel, precast concrete versus in situ concrete or steel.
- successive economical crises
- growing environmental consciousness
- higher demands as regards labour circumstances and general comfort

The key words governing the evolution of the construction activity in general and precast concrete in particular are efficiency, durability and respect for the environment. Prefabrication possesses a large potential in this field to become a leading actor in the building activity of the future.

2. Market demands

The above mentioned trends started during the 1980s and have been gradually taking shape ever since. Before getting into technical details, it might be interesting to describe the meaning of the most prominent factors behind these changes.

- **Structural efficiency:** The idea here is to design structures and develop systems so that the building offers maximum efficiency to the user. For example create maximum exploitation capacity of the available building space by using more slender building components like in slim floor structures etc. Competition between different construction materials and systems is more and more judged in terms of performances and costs. Systems offering more floor area inside the building volume are increasingly competitive.

  **Flexibility in use:** Certain types of buildings are frequently required to be adaptable to the user’s needs. This is especially the case with offices, but housing might also need to be more adaptable in the future. The most suitable solution to this effect is to create a large free internal space without any restriction to possible subdivisions.

  **Optimum use of materials:** Each construction material possesses specific properties and optimum applications. Until recently, the structure of a building was mostly build in the same material. Now, the tendency is to use construction materials that are best suited for the particular function within the project.

  **Speed of construction:** Because of the slowness of traditional in-situ construction methods, long construction delays have been accepted. Today, the demand for a speedy return on investment is becoming more and more important: the decision to start the work is postponed until the last moment, but the initially agreed construction delay has to be met. In addition, projects are getting more complex, which is not in favour of short construction delays. One of the solutions taken by the general contractor, is to put more responsibilities on subcontractors.

  **Quality consciousness:** Quality has a broad meaning. Not only do the quality of materials and execution have to respond to higher standards than before, but also the quality in the domain as regards user friendliness, comfort and aesthetics is becoming more important. Several precasting companies have already obtained the ISO-9000 label, and a lot of work is being done in the field of European Standardisation.

  **Adaptability:** In the future, building design will have to take into account not just the direct costs for construction and exploitation, but also the deferred cost for adaptation or demolition. In other words we shall
have to design for the whole building's life span from cradle to grave. In this context, there will be much less demolition of entire buildings, but owners will rather choose for renovation. The initial concept of the entire building will therefore have to take account of the life span of the different components of the building: load bearing structure: 50 to 100 years and more; external envelope: 20 to 60 years; services: 10 to 20 years; finishes: 5 to 15 years. Consequently everything apart of the main structure should be designed replaceable and renewable within the normal building life to avoid early termination; thus we have to design our buildings for sufficient inherent flexibility and adaptability to permit full reconfiguration of spaces and services. Periodic refurbishment, major modifications, replacements and improvements throughout the building life shall be possible. An inherent condition for reuse will be the complete inspectability of all building components.

*Protection of the environment:* In many countries the design of buildings and structures continues to be determined solely by the factors of "capital" and "labour" employed by ecologically unregulated market economies. This will become expensive when "nature" is added as the third market-determining factor with the full cost required to be paid.

Preserving the environment is becoming globally increasingly important. In Europe, some governments are already imposing regulations as regards plastic, recovering of packaging, recycling of waste, ground pollution by chemicals, etc. It is expected that more severe restraints will be imposed in construction, e.g. with respect to emissivity of materials, shortage of raw materials, waste dumping, energy consumption etc.

3. Solutions offered by precast concrete

Prefabrication has often been the prelude to modernisation in many fields: working conditions, advanced manufacturing technology, speed of construction and environmental friendliness. The latest developments to respond the market needs are described below.

4. New materials

*High performance concrete,* with compressive stresses exceeding 80 MPa, is now being used routinely in precast concrete. Initially, the applications were for heavy loaded columns, where the cross-section can be significantly reduced. Other applications include heavy bridge beams, long span roof beams, products with high durability requirements, etc.

**Fig. 1.** Relative load bearing capacity of columns
Self compacting concrete, is a variant solution for high strength concrete (up to C80), but with far better opportunities in precast concrete. Whereas high performance concrete essentially focuses an increase of the product performances (strength and durability), self-compacting concrete will also have a serious impact on the production process. The self compacting concrete need no vibration and thus opening a lot of advantages as low noise level during casting, less mould pressure, rapid casting, easy casting when using dense reinforcement or when having thin or complicated cross-sections, less air pores at the surface and easy to pump.

5. Products

Hollow core units are now the most widely used type of precast flooring: in Europe the annual production is about 20 million m². This success is largely due to efficient design and production methods, choice of unit depth and capacity, surface finish and last but not least structural efficiency. For many years, the maximum depth of prestressed hollow core floor units was 300 mm. However, recent developments in Northern Europe have led to a 500 mm deep unit.

In the context of sustainable construction, precast hollow core scores better than other types of floors, because of the rational use of the materials. The presence of longitudinal voids in the cross-section leads to a 50% saving in concrete compared with a plain slab, and at the same time cuts the amount of prestressing steel by 30 % because of the lower self-weight.

Hollow core products suite also very well the purpose of flexibility and adaptability because of the large span/performance capacities. Presently, it is common practice to realise with a hollow core floor of 400 mm thickness, a span of 17 m for a live load of 5 kN/m². In Finland, the 500 mm thick unit permits already to span 21 m with a live load of 5 kN/m². In Sweden, the concept to span from one facade to the other without intermediate support is currently applied in office buildings. This evolution is still progressing.

Light roof units. One of the perceived inconveniences of concrete is its self-weight. However, mass in a building can control heat flow in such a way as to conserve energy - a property still ignored by many designers. For industrial building roofs, the energy conserving aspect of mass is less important than the limiting span-load capacity due to the large self-weight.

Fig. 2. Prestressed roof unit with spans up to 30 m and low self-weight

The latest developments for roof units are slender beams with large openings and complex wafer-form cross-sections, with wall thickness of 20 mm. The realisation of such thin concrete sections is now possible with the help of fibre reinforced concrete. As a result, roof units spanning 6m to 30m can now be made with a self-weight of only 100 to 200 kg/m².

6. New systems

Multi-storey precast concrete frames are constructed with columns and beams of different shapes and sizes, stair and elevator shafts, and floor slabs. The joints between the floor elements are executed in such a way that concentrated loads are distributed over the whole floor. The system is widely used for multi-storey buildings up to 20 storeys and above.

The structural frame is commonly composed of rectangular columns over one or more storeys height (up to four storeys). The beams are normally rectangular, L-shaped or inverted T-beams. They are single span beams, simply supported and pin-connected to the columns or concrete corbels, or by specially developed hidden connection details. Hollow core floor slabs are by far the most common type of floor slabs in this type of structure.
Production processes

In the coming decade, the challenge for the precast concrete industry is automation. There are already good examples in the domain of pipes and small products with large series, such as terrazzo tiles, railway sleepers etc. In the area of building components, most has still to be done. Among the precursors are the hollow core slab, lattice girders and some small products. Also for internal wall units there exist fully automated production systems. The most suited solution for the main reinforcement of beams and floor units, is prestressing on long beds. The advantage of prestressing compared to mild steel reinforcement is that it gives high capacity for low labour input. The only remaining obstacle is the automatic incorporation of stirrups of different shapes and sizes. The solution probably lies in fibre concrete, using steel fibres or other types yet to be developed.

In several countries, waste dumping is discouraged by high taxation. For precast concrete plants, rejected elements, concrete debris, waste concrete, residual slurry from cleaned mixers or material from sawing the concrete, grinding and other processes, will therefore have to be processed. Waste concrete and slurry are already recovered and recycled in several factories. They are ideal for recycling because their origin is known. Research carried out on concrete made with recycled aggregates reveals that the proportion of coarse recycled material in structural concrete can be safely increased to 20% of the total amount of aggregates in the mix.

7. Examples of application of precast buildings

a. Industrial and commercial buildings, parking garages etc.

Systems, using frames composed of columns and beams, are still widely applied. The most prominent current changes are larger spans, lighter structures, new types of connections. A new system for industrial buildings is using load bearing sandwich walls in architectural concrete and long span light-weight TT roof units. The latter have a self weight of 180 to 200 kg/m² and are spanning from facade to facade over up to 30 m. The system offers a more rational, economical and aesthetic construction.

b. Housing

Large wall panel systems combined with hollow core slab floors are still currently used for housing
projects. However, the design has become much more flexible. The formerly rigid bloc shaped realisations have now replaced by much more lively architectural designs.

In the Netherlands, a new hybrid system for domestic projects has been introduced successfully in the beginning of the 1990's. The internal load bearing walls are made with large smooth silica stone blocs with accurate dimensions and tooth and groove connection. They are glued together to form the wall. The blocs are pre-cut at the factory to form the openings for windows, doors and other details. Only a slight rendering is needed to finish the walls. The precast hollow core units are supported on the walls. The external envelope of the houses is made with brick masonry.

c. Office buildings

Current trends in office buildings point towards more prefabrication, more efficiency e.g. through a flat under surface for floors without underneath beams and corbels, reduced site activity by incorporating ducts and conduits in the floor elements, and safer and faster construction.

_Slim floor structures_ offer an effective solution to reduce the total floor construction height by supporting the floor elements on the bottom flange of a steel beam. This enables to realise a shallow floor in which beams and slab elements are integrated within the same depth. The hence combined units form a composite structure. The FIP Commission on Prefabrication has just published an Guide to Good Practice with design guidelines for "Composite floor structures".

Stone is highly regarded as a cladding material or finish. Its expense can be mitigated by using thin veneers in precast concrete facade units. The system provides not only economy, but also better quality, speed of construction and higher safety than traditional in situ solutions.

_Split structure facade_ concerns a facade construction in which the two leaves (inside leaf and outside leaf) are fabricated separately and erected separately. The load-bearing leaf of the facade consists of simple framed panels placed with the smooth moulded side towards the interior of the building. The precast floor units are supported on these elements. Afterwards an air tight joint sealing is applied and an insulation layer is attached to the exterior face of the wall panels and finally the exterior cladding panels are erected. The exterior cladding can be made in precast concrete or in other materials. Very often the window frames are placed over several storeys giving a large architectural freedom to the design

_New types of hidden corbels_: Column corbels often are inconvenient, especially in residential and administrative buildings. Recent developments go towards hidden steel corbels. The advantage of the solution is that the intersection between beam and column is neat, without an underlying corbel. The connection is also attractive from the aesthetic point of view. Various solutions are available on the market, of which some are given below.

d. Other types of buildings

Stadia and grandstands are often constructed in precast concrete because of the extra short construction delays. There are numerous good examples in many countries. Last year, a large arena for ice hockey for 40,000 people was constructed in Helsinki in 6 months.

<Fig. 4. Hidden beam-to-column connection>

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**SIUOLAIKINIAI SURENKAMŲ STATYBINIŲ KONSTRUKCIJŲ GAMYBOS BŪDAI**

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**S a n t r a u k a**

Surenkamų gelžbetoninių gaminių gamyba visada pranašavo statybos modernizaciją daugelyje statybos srityje: darbo sąlygų, pažangią technologijų, statybos trukmę ir gamtosaugos. Esamus pasikeitimus Europos surenkamo gelžbetonio srityje sąlygojo visa eilė tinkos poreikių, tokių kaip konstrukcijų efektyvumas, optimalus medžiagų

<Sliding steel plate>
panauojimas, statybos trukmė, universalus panaudojimas, kokybė, pritaikomumas tolesniam panaudojimui ir gamtosauga. Surenkami gaminiai turi didelį potencialą šių poreikių patenkinimui.

Medžiagų srityje vis daugiau naudojama aukštos klasės ir sąvaiame susitikinančių betonų. Vis daugiau naudojamas Fibrobetonas.

Viena iš betono neparkerių fizinio sąlybų – didelis betono ir gelžbetonio konstrukcijų savasis svoris. Surenkamų gaminų pramonė apeina šį nepatogumą gamindama sudėtingesnius mažesnio svorio gaminius dažniausiai naudojamus perdangoms ir denginiams. Kita tendencija, parduoti produktų kartu su paslauga; naujo tipo apšiltintos fasado plokštės, išvados konstrukcijų sistemos ir kita.

Renkantis statybines konstrukcijas, matoma aiški tendencija eiti prie grakštesnės statybos, pavyzdžiui, palengvintas perdenginys. Kita naujovė surenkamų elementų derinimas kartu su kitų tipų konstrukcinėmis medžiagomis. Aiški tendencija biuro pastatuose naudoti daugiau surenkamų elementų, didinti statybos efektyvumą, mažinti statybos sąnaudas ir trumpinti statybos laiką.

Surenkamų elementų gamyboje orientuojamasi į automatiizuotą ir aplinkai poveikio nedarant gamybos būdą.

Straipsnyje aprašomos įvairios naujoves, surenkamų gelžbetoninių elementų medžiagų, elementų sistemų, gamybos būdų srityje, pateikiamas pavyzdžių.

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Internationally known as a notoriety in the domain of precast concrete, through his numerous publications and conferences all over the world.

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