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Management summary
ver 3

Super-light structures
Design the future

www.super-light.dk
0. Super-light structures with Pearl-chain reinforcement
Super-light structures with pearl-chain reinforcement is a new revolutionary technology that opens possibilities of building load-bearing structures with much less resources and with several other advantages compared to traditional constructions of concrete and steel.

Some benefits are:

1. Material savings of more than 50 %.
2. Energy and CO₂ savings of more than 50 %.
3. Architectural expressions never seen before.
4. Half price or less.
5. No Scaffolding, cheaper moulds, and faster production.
6. Improved durability.
7. Extreme thermal insulation.
10. Increased safety for fire, earthquake, and explosions.

This moves the limits for resource economic buildings.
The new technology consists of a new constellation of well-known materials and parts. All construction methods needed have been widely used for at least 30 years, and if high-strength concrete is avoided, they have been applied for more than 100 years, and the structures can be designed according to present codes as for example Eurocodes. Only the overall engineering perception of the structure is new. However, this does not deviate more from traditional building technology than many other unusual structures, which are built every day. To be sure, full-scale tests have been made to verify, that nothing has been overlooked.

This means that we have

√ Proof of concept and
√ Proof of technology and

No further development or investments are required before application.

Applications are many: Buildings, Halls, Shopping centers, Towers, Facades, Roofs, Shells, Bridges, Stadiums, Off-shore structures, Tunnels, Floating foundations, and even Ships are among the many possibilities.

The benefits mentioned above make it very possible that these structures soon will be implemented in practice, so that we will have a Proof of market. The wide range of applications implies that the consequences of this new system are extensive.
0.1 Super-light structures

Steel structures are considered to be light compared to concrete structures. The new structures are often light compared to steel structures, and therefore they are called "super-light".

The basic idea of super-light structures is to build a skeleton of a strong material interacting with a stabilizing layer of a light material.

The strong material can for example be made of concrete, brick, or high-strength concrete and the light material can for example be light-weight concrete. However, the basic principle can be applied for any strong and light material. The light material is usually much cheaper than the strong. It fills out the shape of the structure and applies the load on the skeleton, which is often curved to be optimized. It protects the strong material of the skeleton from impacts and fire, and it prevents it from buckling, which typically increases the load-bearing capacity of the skeleton 4 times. The strong material can be cast out in a duct or a groove made in the light material, or it can be established in advance for example as pearl-chain reinforcement.
0.2 Pearl-chain reinforcement
Pearl-chain reinforcement is a new invention made during the development of the super-light concrete concept. It reduces the price of optimized structures considerably and makes the building processes more efficient. By means of pearl-chain reinforcement it becomes affordable to provide structures with shapes, which have previously been unthinkable. This allows more resource-economical design, because it removes practical hindrances for application of compression zones with optimal curved shapes.

Pearl-chain reinforcement is a curved compression zone like a spine of a skeleton designed as a chain of prefabricated segments of a strong material assembled by one or more prestressing wires. Casting the compression zone into a light material, the compressive strength of the zone may be used almost fully, because the light material hinders buckling of the zone. This is comparable to the way a spine of a skeleton interacts and is kept in place and stabilized by the surrounding soft parts of a body.

0.2.1 Compression zones
Prestressing is used for assembly and for stabilizing the chain during erection and casting of the adjacent light material.

0.2.2 Tension zones
If pearl-chain reinforcement is prestressed with a large compression force, the chain can take tensile forces as unloaded compression.

This application makes it possible to make prestressed light-weight concrete, which so far has been almost impossible, because creep of the light-weight concrete would unload the prestressing, and because the prestressing wires may rust if they are not protected by a more dense structure like a pearl-chain.
1 Material savings of more than 50 %.
Light materials such as foam concrete or natural or artificial light aggregate concrete of density 600 kg/m³ or aerated concrete contains mostly air and a few quantities of cheap clay and cement. Therefore, considerable material savings are a consequence of the replacement of strong and heavy materials with light ones for a major part of the structure. Design cases are made to demonstrate this.

2 Energy and CO₂ savings of more than 50 %.
Using the new technology material and energy consumption can be more than halved and consequently CO₂ emissions from production, transport, and erection are more than halved.

3 Architectural expressions never seen before.
By means of pearl-chain reinforcement, very advanced 3-dimensional curves can be created from simple prefabricated core elements which are assembled by prestressing wires or rods. Many curved design projects have from time to time been abandoned for economical reasons. Curved moulds, extensive scaffolds, and labour for production have been too expensive. Super-light structures with pearl-chain reinforcement turn these conditions upside down, because it now becomes affordable to make a curved design. Since arches and curved structures usually gives optimized supports for loads, this leads to a situation, where the cheapest and most resource saving design is curved. Therefore, in the future, it must be foreseen that architecture may change as a consequence of the new technology from rectangular shapes to more organic curved expressions.
4 Half price or less.
By means of super-light structures, engineers can place compressive forces in optimal paths and the strong material is used to the fullest extent. The remaining part of the structure is filled with a cheap light material. This is the reason why super-light structures can be made much cheaper than traditional structures, where the strong and relatively expensive materials are not confined to a minimum.
If the overall design is made so that tensile forces can be avoided, price reductions of a factor 10 may often be within range.
A number of design cases have been made to document these statements.

### Price Example
Beam 30 m long 1.5 m high load 27 kN/m (2.7 ton per meter)

<table>
<thead>
<tr>
<th></th>
<th>Price Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Super-light optimal arch</strong></td>
<td>1.0</td>
</tr>
<tr>
<td>473 dkr/m ≈ 63 €/m</td>
<td></td>
</tr>
<tr>
<td><strong>Super-light simple beam</strong></td>
<td>7.4</td>
</tr>
<tr>
<td>3,504 dkr/m ≈ 467 €/m</td>
<td></td>
</tr>
<tr>
<td><strong>Prestressed concrete T beam</strong></td>
<td>8.4</td>
</tr>
<tr>
<td>3,990 dkr/m ≈ 532 €/m</td>
<td></td>
</tr>
<tr>
<td><strong>Welded steel beam</strong></td>
<td>46.9</td>
</tr>
<tr>
<td>22,165 dkr/m ≈ 2,955 €/m</td>
<td></td>
</tr>
</tbody>
</table>
5 No Scaffolding, cheaper moulds, and faster production
A pearl-chain or a skeleton of pearl-chains is assembled by prestressing so that it can be erected without the need for provisional support.
It may also carry moulds for the light material, so that scaffolding can be completely avoided.
The weight of the light weight concrete can be 4 times less than that of ordinary concrete and the pressure on the moulds is 4 times less. Therefore, the moulds can be made of lighter and cheaper materials like for example textiles, which may contribute to a further lowering of the price, energy consumption, and CO₂ emission from the building process. Low weight of the moulds makes it easier for the pearl-chain reinforcement to support them. The many new materials, which can be applied due to the low mould pressure, give architects new possibilities for detailing surface textures and shapes of the structures.

6 Improved durability.
Light aggregate concrete does not have the same problems with cracks and frost damages etc. as more dense concrete. Modern investigations and more than 2000 years experiences with a large number of walls, floors, arches, vaults, cupolas, water basins, quays, bridges, and tunnels from Aswan to Scotland document that the material is extremely durable for the weather, water, mechanical impact, earthquake, and fire.

7 Extreme thermal insulation.
The new constructions are insulating like wood without problems of rot and fire, and wood is therefore not anymore needed in resource economic buildings.
Light-aggregate concrete with a density of only 600 kg/m³ is cast wet at DTU and foam concrete is available of the same density, strength and stiffness for structures.
Insulation can be further improved by embedding mineral wool or ultra-light blocks of aerated concrete of densities 100-150 kg/m³. However, foam concrete is also available from 2-400 kg/m³ with very low conductivities as a "floating" insulation material.
8 Better indoor-climate.
Application of light aggregate- or aerated concrete in super-light structures introduces a moisture buffer. This absorbs moisture when the air is humid and releases moisture when it is dry leading to an improved in-door climate compared to what you experience in traditional concrete buildings.

9 User friendly operation and maintenance.
Walls and ceilings of light-weight concrete, as you will find in super-light buildings, are much easier to drill holes and drive nails in than in traditional concrete buildings. Grooves can easily be cut and covered again, and electric wires, pipes, and ducts can be inserted and made invisible with a minimum of effort. This offers good possibilities for changes, repair and maintenance.

10 Increased safety for fire, earthquake, and explosions.
Most indoor structures, tunnels and off-shore structures should be designed for fire, which usually means that steel structures are protected by insulating plaster, mineral wool or intumescent paint, and traditional concrete structures are over-sized or protected by mineral wool. Especially if a high-strength concrete is applied, it has to be protected for explosive spalling caused by high pressure of steam in the dense material. Light-weight concrete of a super-light structure can be made very fire resistant and is capable of protecting the strong skeleton. If the skeleton is made of high-strength concrete, it is sufficient to apply 60 mm light concrete protection of density 600 kg/m³ in order to protect it from most fires.
Light-weight concrete is capable of absorbing energy from mechanical impact and deformations. This is the reason why the materials have proved to be beneficial for crash barriers. Super-light structures are therefore capable of damping the effect of impact and shakings from explosions and earthquakes increasing the safety for people in buildings made from it.