Key data

General:
Gross building area:: 28,000 m²
Public opening: October 1997
LWAC volume: 4,800 m³

Light weight concrete LC25:
Compressive strength: 25 MPa
Fresh density: 1700 kg/m³
Dry oven density: 1600 kg/m³
Slump: 8-10 cm
Light Weight Aggregate: Arlita F-5
Water cement ratio (nominal): 0.60
E-modulus: 18000 Mpa

References:
[3]: ECCS No. 91-5: “Architechtiture Steel”
Guggenheim Museum, Bilbao, Spain; LWAC floor slabs

Recognised as one of the most representative work of architecture of the late 20th century, the Guggenheim Museum is the masterpiece of one of the foremost American architects of nowadays, Frank O. Gehry.

In order to reduce the weight of the structures due to the special soil conditions, floor slabs was cast using Light Weight Aggregate Concrete (LWAC).

**General description**
The Guggenheim Museum in Bilbao, Spain provides a unique architectural view using traditional construction materials like steel and glass in combinations with special ones like titanium, Spanish limestone and LWAC.

To design this precious jewel of the Spanish city of Bilbao, the engineers had to solve a tremendous problem, the poor quality of the soil on the shore of the Nervion river, mostly made up of industrial waste accumulated during decades of steel production.

The weight of the gigantic structure of the Museum had to be reduced in every possible way. One of the most important actions taken was the choice of a super light floor slab structure, designed with a zincated steel corrugated plate (galvanized), connected to a concrete slab 60 to 80 mm thick.

The system is light by itself, but the use of expanded clay in the concrete reduced the total weight roughly 30 %. This concrete was used in every single horizontal structure, even the roof, and a total of 4.400 m³ of LC-25 was placed by means of pneumatic pumps.

**Construction:**
To be able to achieve the design density with a compressive strength of 25 MPa, the readymix plant used a mix provided by Aridos Ligeros, consisting of ARLITA F-5, a special lightweight product with a bulk density of 550 kg/m³, particle density of 900 kg/m³ and a size range between 3 and 8 mm.

The concrete was made in the nearby plant of Cavia in Ortuella, transported by truck and placed by pneumatic pumps.
The tunnel is a part of the new highway system from Oslo to the Swedish border and is scheduled to be completed in 2009.

The Være Tunnel was rehabilitated in 2004 with the LWAC slabs and the Road Department is still monitoring the frost values behind the slabs.

A total amount of >120000 m$^2$. LWAC slabs need about 27,000 m$^3$ Leca LWA which is contracted by Spennccon and will be supplied from May 2007. The future is bright for this construction method and it is good reason to expect several new supplies.
Tunnel vaults of light weight concrete

Arch shaped light weight aggregate concrete (LWAC) precast slabs with low density are a considerably challenge from both a constructive and concrete technology point of view. Through several years it has been performed development and full scale testing of physical characteristics of the tunnel concept. Now, another tunnel is under construction.

The reason for using LWAC instead of normal density concrete in tunnel vault is the increased frost insulation with about 4 times. In northern countries frost inside tunnels may lead to ice formation behind the concrete vault and the concrete or loose rock may be pushed out and fall down into the tunnel with severe consequences. The solution so far has been a combination of normal density concrete slabs and an insulation material.

Unfortunately, most insulation materials are combustible and in addition many materials release toxic gases while burning. New fire protection requirements from EC was supported by the Chief Executive in the Road Department and combustible insulation materials are now being phased out. LWAC in not combustible and with an addition of poly propylene fibers the slabs has proven to manage heavy hydrocarbon fire without spalling.

In addition to fire- and frost protection the LWAC slabs must prevent ground water leakage into the tunnel and also support as a mechanical protection between the rough blasted mountain surface and the traffic. A LWAC density of $<1400 \text{ kg/m}^3$ with a characteristic compressive strength of $>15 \text{ MPa}$ was required.

To achieve the requirements at the Være Tunnel, Leca 2-4 mm and 4-10 mm from Leca Rælingen was used together with a high performance cement paste. For such concrete with large volume of LWA, the LWA quality is essential to achieve best possible characteristics.

In addition the LWAC must be workable and fill the form and create smooth surfaces without honeycombs. The result was a concrete density of $1350 \text{ kg/m}^3$ and an average compressive strength of almost 20 MPa. The requirements for the surface were satisfied.
Structural features:
The church roof and walls are plate and shell structures without effective stiffeners except for at the boundaries. The walls are founded directly on rock and partly on casted piles to rock. The LWA concrete used in the roof is of higher strength than the LWA concrete used in the walls. This is because the roof slab has relatively long spans and therefore larger local bending moments with less beneficial axial force than the walls.

References:
Snarøya Church, Norway

Situated close to Oslo, Snarøya Church offers a special architectonic view of a church constructed with the use of lightweight aggregate concrete (LWAC). The church was constructed in the sixties.

Key data

General:
- Number of seats: 250
- Opened: 1968
- Costs: NOK 1.25-1.45 mill

LWA concrete walls.
- LWAC B-200 with characteristic cube strength 20 MPa and density 1400 kg/m³.
- Leca 400 3-10 mm 770 Liters/m³.
- Sand 630 kg/m³.
- Cement 420 kg/m³.
- Density (dry) 1420 kg/m³.

LWA concrete roof slab.
- LWAC B-250 with characteristic cube strength 25 MPa and density 1600 kg/m³.
- Leca 400 3-10 mm 700 Liters/m³.
- Sand 680 kg/m³.
- Cement 450 kg/m³.
- Density (dry) 1550-1650 kg/m³.

The reasons for applying LWAC

The architect wanted to use concrete as construction material to get a uniform material look on large surfaces combined with relatively large spans. The insulation ability and the low dead weight made the LWAC very suitable for these purposes.

Architectural features:

The church is situated in flat surroundings, but integrated in a local rock crag. The entrance was placed on top of the rock crag, and the high church walls was curved around down to the flat surroundings. All walls consist of parts of curves and straight lines, in the church corners separated by windows in whole height, giving a special light inside the church. The walls are a little inclined.
Structural features:
The roof consists of 10 inclined section, rising from the floor level, with a 2.1 m difference between each section. The roof plates were designed to support dead load and wind loads. Snow loads were not taken into account because the roof inclination us more than 60°, actually 67°. The roof plates are stiffered by trusses with chords embedded in the same plates, while the diagonals are architectural details fully expressed. Load tests were carried out in order to control the plate strength by using two half size scale models. The results proved pure tension failures of reinforcement with no sign of bond or shear failures. The real load failure was about 10% higher than the theoretically calculated. The plated were reinforced by two layers of galvanised steel mesh 5c150mm in two directions.
The lightweight structure consists of LWAC with characteristic compression strength at 25 MPa and a density of 1650 kg/m3. The concrete is casted in situ. There have been no durability problems reported by using LWAC in the structure. The code used NS 427 did not contain the use of LWAC, and the project is therefor adjusted to use of normal concrete.

References:
[1] Jan Inge Hovig, "Ishavskatedralen, arkitektens ide", Betongen i dag, no. 5 (Norwegian) 1966
[2] Ivar Vamnes, "Ishavskatedralen, den konstruktive løsning", Betongen i dag, no. 5 (Norwegian) 1966
The Polar Sea Cathedral, Tromsø, Norway

Situated in the city of Tromsø and surrounded by the Tromsdalstinden mountains, the Polar Sea Cathedral is with its very special architecture been one of the most famous tourist attractions in northern part of Norway. The cathedral was constructed in the mid sixties. The special roof and main structure consist of lightweight concrete.

General description
The building is located in a site close to the Tromsø River and the Tromsø Bridge in the northern part of Norway. Tromsø is characterised with the 3 month long polar night and is known for a lot of snow in the wintertime. The church comprises a main 740-seat nave with a 90-seat chapel in a lower level. The architectural shapes derived from the analysis of the particular site conditions and from the need to keep a constant and uninterrupted relation between interior spaces and landscaping.

The most outstanding building feature is the inclined roof consisting of lightweight concrete sections, which enabled to meet important insulation requirements and to reduce the structure weight. The use of lightweight concrete allowed reducing the structural load about 50% as compared with a conventional rib structure with inner insulation. It was obtained a high degree of insulation with no thermal bridges, involving considerable cost savings.

Key data

- Maximum height of church: 28 m
- Number of seats: 740 + 90
- Number of roof sections: 10
- Roof section width: 4.25 m
- Roof section thickness: 0.3 m
- Construction period: 1964-1965
- LWA: Leka 400, 3-10 mm
- Measured density concrete: 1650 kg/m³
- Cement: 175 kg

Team involved:

- Client: Tromsøysund County
- Architect: Jan Inge Hovig
- Design: Dr. Ing. Aas-Jakobsen AS
- Contractor: Ing. F. Selmer A/S
- LWA supplier: Norsk Leca
The Troll West is a floating platform operating at the North Sea oilfield with the same name 70 km north west of Bergen, Norway. The concrete structure is installed at a water depth between 315-340 metres. Exposed to a harsh marine environment, the design life requirement for the structure is more than 50 years.

To give the construction enough buoyancy, it was planned to install an extra floater unit. Research and studies concluded that use of concrete with lower density would solve the problem. During the construction period, there was developed and utilised a new concrete where natural coarse aggregate was partly replaced by LWA (Light Weight Aggregate). The MND (Modified Normal Density) concrete has a density reduction of about 10%, but still maintain most of the mechanical properties from ND (Normal Density) concrete.

### Some key data for the project

**Master Plan**
- May. 92
- Contract award
- Jan. 93
- Start of construction in dry dock
- Jun. 93
- Tow-out from dry dock
- Oct. 94
- Ready for module mating
- Feb. 95
- Complete installation
- Nov. 95

**Key Data**
- Water depth: 315-340 metres
- Concrete floater weight: 19,200,000 tonnes
- Concrete, C 75: 19,000 m³
- Concrete, MND 75: 21,000 m³
- Reinforcement (ordinary): 17,500 tonnes
- Reinforcement (pre-stressed): 3,400 tonnes
- Column diameter: 29.0 metres
- Column spacing (width): 101.5 metres
- Total height concrete floater: 65 metres
- Wall thickness: 0.4-0.9 metres
- Reinforcement ratio: 294-414 kg/m³
- Prestressed reinforcement ratio: 55-104 kg/m³

**Application of high strength LWA concrete for tension leg platforms**

A large displacement is necessary to achieve the buoyancy required for a floating platform. The hull of the platform has to withstand large hydrostatic pressures. A high strength concrete shell...
is ideal for such forces. High strength normal density concrete and high strength light weight aggregate concrete was already utilised in many structures in Norway and the experience with the material was well known. The bottom pontoon slabs and the beginning of shafts were built in dry dock, and then towed out on water for gliding the platform shafts. The Troll West was original planed with HSND concrete. To give the construction enough buoyancy in “out of dock situ”, and to give the structure improved general floating properties an extra floater unit was planed installed. Further studies concluded that use of concrete with lower density had several advantageous properties. During the construction time a new type of concrete where normal coarse aggregate was partly replaced by LWA to reduce the total weight was developed and utilised, the MND concrete. The use of MND concrete was introduced while the structure was under construction. Therefore only 21000 m³ of total 40000 m³ concrete used was MND. The MND is used in the 4 columns and at the top of the bottom pontoon. The rest of the shaft structure used ND C75 with 3% air. The total reduction of weight is 5200 tons. The same type of concrete is also used in the gravity based (condeep) Troll Gas platform. The MND concrete has a density reduction of about 10%, still maintain most of the mechanical properties from ND concrete. The MND concrete was developed during intensive research and development at SINTEF in 1992-1993.

Exposed to a harsh marine environment, the designed lifetime for the structure is more than 50 years. This design life required following demands to the concrete: Chloride diffusion coefficient $D<30 \text{ mm}^2/\text{year}$, $w/(c+s) < 0.38$ and maximum curing temperature was $<700^\circ C$.

Concrete mix design
The reduced weight is achieved by replacing some of the natural coarse aggregate with lightweight materials made of expanded clay. The other constituents are the same as used for ND concrete of high strength. The objective of the research project (SINTEF 92-93) was to determine and document the effect on mechanical properties. The results revealed a slightly reduced compressive strength, reduced E-modulus and fracture energy, and slightly increased tensile strength while replacing some of the coarse aggregate by LWA. The density was reduced by 200 kg/m³ by replacing 50% of the natural coarse aggregate with Leca 800. Due to the demands of strength and mechanical properties a.s Norsk Leca developed the Leca 800 for this project. The Leca 800 has a bulk density of 800 kg/m³ for 4-8 and 8-12 mm and gives a concrete with better mechanical properties then the existing Leca 750. The dry particle density is 1450 kg/m³ that is considerably lighter then normal aggregate density at approximately 2600 kg/m³.

Constituents (kg/m³)
Natural sand 0-5 mm (dry weight) 911
Natural coarse aggregate 5-20 mm dry weight 455
LWA Leca 800 4-12 mm (dry weight) 240
Air-entraining admixture 1
Superplasticizer 7
Cement (High strength Norcem) 420
Silica fume (dry weight) 12
w/(c+s) corrected for water absorption 0.38

Properties of hardened concrete
The table below shows the requirements and results from the concrete production during the dry dock phase. Both strength and density comply with the requirements.

<table>
<thead>
<tr>
<th>Property</th>
<th>req. mean</th>
<th>st.dev. charact.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slump (mm)</td>
<td>&gt;</td>
<td></td>
</tr>
<tr>
<td>Wet density (kg/m³)</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>7 day density (kg/m³)</td>
<td>&lt;</td>
<td></td>
</tr>
<tr>
<td>7 day strength (MPa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 day density (kg/m³)</td>
<td>&lt;2250 ±30 2220</td>
<td></td>
</tr>
<tr>
<td>28 strength (MPa)</td>
<td>&gt;75</td>
<td>80</td>
</tr>
<tr>
<td>E- Modulus GPa</td>
<td>32 ±3 31,9</td>
<td></td>
</tr>
</tbody>
</table>

Compressive strength is measured on 100 mm cubes. Cylinder/cube strength ratio is between 0.86-0.89. Density of hardened concrete is measured on water stored cubes. The MND concrete had good resistance to chloride diffusion and complied with the demand, but the contractor needed to install water pipelines to reduce the curing temperature.
Structural features:

Lightweight structural concrete has been used in renovation and enlargement in 3 important motorway projects in Spain, namely the A-8 and A-6 motorways.

On the motorway Autovía del Cantábrico (A-8), on the specific part from Barres to Ribadeo, the old bridge “Puente de los Santos” was enlarged to receive another traffic lane in each direction. To be able to execute such a project on an old bridge, Lightweight structural concrete was the obvious solution.

The same situation was the case on the bridge “viaducto Rio San Pedro”, also on A-8, but in between Dueñas and Novellana.

On the motorway A-6, the bridge over the river Esla was rehabilitated to be able to receive the new and more intense traffic load.
In all 3 of the above mentioned case stories, the main idea by the project engineers was to use the already existing infrastructures. In case of demolition of the old structures and building new bridges, it would have been more expensive and for sure take a lot more time to execute. Using lightweight structural concrete the engineers managed to save both money and time and in a sustainable way utilize already existing infrastructures, even though they earlier was designed for different loads and stresses.

In all 3 projects ARLITA F7 was used as the lightweight aggregate. Due to the complexity of the structures, different concrete mix designs were used, with densities from 650kg/m³ to 1.850kg/m³ and respective compressive strength from 2MPa to 60MPa.

Year of the 3 projects: 2008
The Expo’98-Lisbon International Exposition took place in 1998, focusing on the oceans and their future importance. A number of exceptional structures were made for the event, one of the most spectacular being the Portuguese National Pavilion including the sagged parabolic membrane slab roof cast by means of Light Weight Aggregate Concrete (LWAC). The dimensions of the canopy are 65 m x 50 m, and the slab thickness is 20 cm.

**General description**

The Portuguese National Pavilion consists of the main 3 storey multipurpose building and the slab canopy, which is described in the following. The pavilion provided conditions for the reception of delegations present at Expo’98. The canopy structure is a 20 centimetre thick parabolic membrane concrete slab hanging from prestressed tendons anchored along the two short sides into slabs placed on top of a reinforced concrete structure of shear walls and stiffeners. LWAC was chosen as material due to low dead weight, so that the horizontal forces in roof and supports could be reduced to a minimum at the same time as appropriate strength and stiffness was maintained. The total weight of the roof was reduced by approximately 430 tons using LWAC. It is the first time that a structure of this type is cast with LWAC in Portugal.

**Key data**

**General data:**
- Data of execution: autumn 1997
- Type of structure: Suspended slabs (canopy)
- Total length in plan view: 65 m
- Total width in plan view: 50 m
- Slab thickness: 0.2 m
- Sag: 3 m
- Longitudinal slope: 0.3 m
- Minimum height above floor: 10.0 m
- Typical centre distance tendons: 0.6 m

**Light weight concrete:**
- LWAC LC 25: 750 m$^3$
- Quoted strength: LC 25
- Achieved strength fck: 30 MPa
- Standard deviation: 2.6 MPa
- Quoted maximum density: 1850 kg/m$^3$
- Achieved fresh density onsite: 1835 kg/m$^3$
- Workability (slump): 16 cm
Pumping details:
- Presaturation of LWA: 17%
- Maximum pumping distance: 60 m
- Type of pump: Piston pump
- Pump pressure: 100-150 bar
- Production: 80 m$^3$/h
- Decline of workability: From 16-8 cm

Mix design:
- Cement: Portland Type I 42.5 420 kg/m$^3$
- Fly ash: 100 kg/m$^3$
- Silica fume: MS 610 from MBT 15 kg/m$^3$
- LWA: Leca 2-4 (1,6-5,5 mm) 234 kg/m$^3$
- Sand: 1,5-2,5 mm 587 kg/m$^3$
- Sand: 0-1,5 mm 251 kg/m$^3$
- Water: 196 kg/m$^3$
- SP: Rheobuild 561 MBT 6 l/m$^3$

The mix design gives a theoretical density at 1828 kg/m$^3$. The LWA used are supplied from Leca Portugal, which belong to the Exclay International family. The particle size is from 1,6 mm to 5,5 mm. Bulk density is 5 00 kg/m$^3$ and particle density is 900 kg/m$^3$.

Concrete development:
In order to provide the adequate weight and resistance for the concrete, Betecna – Betao Pronto developed a special concrete. Several tests were made in order to obtain the best results regarding absorption of water by expanded clay, and the modifications of concrete properties was evaluated carefully.

Construction:
The cast of the roof over more than 3900 m$^2$ of falsework started with a central strip 2.5 m wide. It continued with the help of 4 concrete pumps with a production of 80 m$^3$ per hour in accordance with Figure 1. The average delay at working casting joints was no more that 45 minutes in order to get a full continuity in the bottom surface of the slab. The concrete placing took 10 hours and was done in one operation.

Knowing that an error of 1% in the cable force would cause a deviation of 10% of the longitudinal slope of the roof, special emphasis had to bed put on the posttensioning procedures.

Structural system:
The sagged roof will induce large horizontal forces at top of the shear wall with stiffeners. Due to the use of LWAC, these forces are minimised. The shear walls insure the force transfer for the horizontal loads from dead-weight, wind and earthquake between the roof and the underground pile foundations. The roof itself is a 20 centimetre thick parabolic membrane LWAC slab. The membrane tension due to sag is compensated by using long posttension cables anchored in support slabs on top of the shear walls.

References:
Structural features:

Lightweight structural concrete was used to renovate the deck of the bridge "Ponte de Fão" over Rio Cávado, located in Espomende in the North of Portugal. The bridge was inaugurated in 1892, why it certainly was time for renovation. In 1986 the bridge was classified as a construction of public interest – a monument of steel structure.

Lightweight concrete has also been used in other renovation / rehabilitation bridge projects in Portugal.
Bridge over the river Cávado

By using lightweight concrete for renovation of the deck, the old steel structure would not “suffer” for additional loads and the structural / economical aspects would be solved in the best way.

The lightweight concrete developed for this project was a LC30/33, with a density less than 1.700kg/m3.

Volume: more than 400m3 of LC30/33

Year: 2006 / 07

Project: Lisconcebe

Execution: Mota-Engil Engenharia / Qualibetão
Specific conditions for Lightweight Aggregate Concrete (LWAC) in the Norwegian norms.

This overview intends to identify and explain what characters are different for LWAC compared directly to Normal Density Concrete (NDC) for the two Norwegian norms NS 3473 and NS-EN 206. LWAC is defined as concrete with lower density than normal density concrete NDC were parts or all normal density aggregate (NDA) are changed with Lightweight aggregate (LWA). The LWA is usually based on expanded clay or expanded shale. In Norway Expanded clay is most common. Following norm is covering LWA: Følgende standard dækker lettislag: NS-EN 13055-1 Lightweight aggregates. Part 1: Lightweight aggregates for concrete, mortar and grout. (Lette tilslag, Del 1: Lette tilslag for betong, mørtel og injiseringsmasse.)

The author takes reservations for any inconsistencies in this work and recommends the users themselves to study the norm and use this overview as and guide and introduction to the norms.

Part 1: Specific differences between LWAC and NDC in accordance to NS 3473

- In paragraph 3.30 is LWAC defined as concrete with oven dry density \( \rho \) between 800 and 2000 kg/m\(^3\) and NDC is defined as concrete with oven dry density \( \rho > 2000 \) kg/m\(^3\). Note that the definition is concerning oven dry density and that density measured during site conditions is higher (see guidelines). Note also that the regulations in NS 3473 is only valid for LWAC with oven dry density \( \rho > 1200 \) kg/m\(^3\). There exist no regulations covering LWAC with density between 800 and 1200 kg/m\(^3\).

- In paragraph 7.2.2 is extended control required for structures were characteristic compressive strength \( f_{ck} \) \( > f_{ck1} \) were \( f_{ck1} = 45 \) N/mm\(^2\) and \( \rho_1 = 2200 \) kg/m\(^3\).

- In paragraph 7.3 accept the norm the use of both NDA and LWA in the same mix. Lower strength grade for load bearing structure is LB 12 and for prestressed structures LB 30.

- In paragraph 7.4 “Additional requirements for use of LWA” is the norm demanding that the requirement in NS-EN 206-1 with the national appendix NS 3465 is complied with. In addition it is demanded that were the water absorption of concrete can make any influence this should be tested under current situation.

- In paragraph 9.2 can the E-modulus in serviceability limit state \( E \) be calculated by the use of cylinder compressive strength \( f_{ck} \). For LWAC the E-modulus is reduced with \( (\rho/\rho_1)^2 \) were \( \rho_1 = 2200 \) kg/m\(^3\).

- In paragraph 9.3 shall the creep index \( \dot{E} \) be multiplied with \( (\rho/\rho_1)^2 \) were \( \rho > 1800 \) kg/m\(^3\), \((3\rho/\rho_1)^2 \) for \( \rho < 1500 \) kg/m\(^3\) and for densities in between, linear interpolation. \( \rho_1 = 2200 \) kg/m\(^3\).

- In paragraph 11.1.1 is the compressive strength grades for LWAC LB 12 to LB 75. Note that CEN uses the term LC and that CEN has two grades less than NS 3473. It is also required that LWAC of all grades comply with the cylinder compressive strength \( f_{ck} \). For LWAC the E-modulus is reduced with \( (\rho/\rho_1)^2 \) were \( \rho_1 = 2200 \) kg/m\(^3\).

- In paragraph 9.9 shall the creep index \( \dot{E} \) be multiplied with \( (\rho/\rho_1)^2 \) were \( \rho > 1800 \) kg/m\(^3\), \((3\rho/\rho_1)^2 \) for \( \rho < 1500 \) kg/m\(^3\) and for densities in between, linear interpolation. \( \rho_1 = 2200 \) kg/m\(^3\).
res that for LWAC with intended compressive strength $f_{cck} > f_{cck}(U/U1)2$, $f_{cck} = 65$ N/mm² and $p_1 = 2200$, a proof by testing that a characteristic compressive strength of 15% more than anticipated can be achieved. This can be proven by either reducing the w/b-ratio or by extending the curing time. This requirement is for many LWAC mixes hard to comply with and should be considered at early stage in planning.

- In paragraph 11.1.6 it is required that concern must be taken regarding the moisture level of the concrete when testing splitting tensile strength.

- Paragraph 11.3 requires that the E-modulus $E_{cn}$ and strain at maximum stress $\varepsilon_{co}$ shall be tested for LWAC and NDC $>B75$. Alternatively a simplified bilinear stress-strain diagram may be used.

- In paragraph 12.3.3.3 concerning shear and frame work method capacity for compressive rupture, the constant figure for LWAC is 0,5 while for NDC is 0,6 in $f_{csp}$.

- In paragraph 12.9 another expression is used for LWAC than NDC in 12.9.2 and 12.9.3. In paragraph 12.9.5 the expression for bending reinforcement around a core the diameter $D$ must be multiplied with 1,5 for LWAC.

- In paragraph A.7.3.5 calculations of forces the average density for LWAC is $p + 175$ kg/m$^3$ which are 50 kg more than NDC. The difference is caused by higher potential water absorption for LWAC.

- In paragraph A 12.4.4 capacity for compressive rupture by torsion. Use 0,5 instead of 0,6 in the expression $T_{ccd} = 0,6 f_{cd} A_0 t_c$ for LWAC.

- In paragraph A 12.5.3 calculation of average tension stress between cracks the $D_{max}$ is 0 for LWAC.

- In paragraph B 3.2-B 3.8 the minimum dimensions for beam, walls, columns etc for fire protection is stated in the table. Use LWAC with quartzous sand will reduce the minimum dimensions required in table B1.