New developments in applied concrete technology

Current practice: Lightweight Aggregates for use in Concrete

Concrete is a material that has been in use in construction since the Roman times, when slaked lime was mixed with pozzolana, a volcanic ash from Mount Vesuvius. It has come a long way over the last 2,000 years to be one of the most used building materials. Looking around our built environment there will hardly be a structure that doesn't contain it, as its versatility, durability and cost-effectiveness continue to make it a key component in today's buildings. However, Normal Weight Concrete (NWC) can cause issues during design, as its natural density is high in relation to its strength, meaning a greater dead weight when compared to other building materials. This can be addressed in a number of ways, depending upon the required properties of the concrete and its end use.

■ Andrew Doel, Lytag Ltd, UK ■

By far the largest use of lightweight concrete is in the production of concrete blocks. This may be achieved using activating agents such as aluminium powder, which reacts in the slurry mixture of cement or lime/pfa and water, forming gas bubbles, to produce aerated building blocks. However, using lightweight aggregates (LWAs) in place of dense aggregates can also reduce the concrete weight, and is commonly known throughout the industry as Lightweight Aggregate Concrete (LWAC)
LYTAG is one such lightweight aggregate, which uses Pulverised Fuel Ash (PFA), the by-product from coal-fired power stations, in its manufacture. Pelletising the ash, by adding a controlled amount of water in specially designed dish pelletising pans, produces rounded pellets. These are then heated on a sinter strand to a temperature of between 1000°C and 1250°C. The result is a round, hard, honeycombed structure of interconnecting voids within the aggregate, sizes of which range from 14 mm down to fines.

Lightweight Concrete

LWAC is not just confined to the commodity market – indeed, with the use of appropriate Lightweight Aggregates and good mix design technology the full range of concrete mix types may be produced successfully. These range from no fines screeds or bonded fills, using just coarse aggregate, cement and water, with densities in the region of 1100 kg/m^3 and strengths of 6-10 N/mm^2, to structural LWAC, using lightweight coarse aggregate and natural sand, with oven dry densities in the order of 1750 kg/m^3, and strengths up to 70 N/mm^2. With today's admixtures it is fairly straightforward to produce self compacting LWAC with oven dry densities in the region of 1450 kg/m^2 and strengths in excess of 40 N/mm^2 using both coarse and fine LWAs.

The requirements for Lightweight Aggregates for use in concrete, mortar and grouts are covered in EN 13055-1 [1], which came into effect in 2002. To meet the requirements of the standard for LWA, primarily the material must have a loose bulk density less than 1200 kg/m^3 or a particle density less than 2000 kg/m^3.

A wide range of concrete applications can use LWAs, although not all types of LWA will be suitable for every application. LWAC is a widely accepted alternative to NWC, and design requirements can be derived from BS 8110 [2]. However, it should be noted that during 2008, the new Eurocode 2 (EN 1992 1-1 [3]) will begin to replace this. The concrete standard, EN 206-1 [4], provides guidance on the use of lightweight aggregate concrete, specifically with regard to strength class and density class which ranges between 800kg/m^3 and 2000kg/m^3.

With good concrete practice a given, a number of reports covering a wide range of structures, have concluded that LWAC is certainly as durable as NWAC, and in some cases performs better [5, 6].

Using LWA in structural concrete

LWAC is now a standard type of concrete, regularly produced by most readymix concrete producers and some concrete plants even have LWA for use in structural concrete as a stock material. However, it should be noted that the properties of the LWAC will be a little different to those of NWC, in terms of production, transportation and placement. Specific properties such as grading, shape, surface texture, absorption, specific gravity, and reaction to moisture changes can all affect the handling of the LWAC.

It is because of LWAC's different properties that, in the past, there has been some reluctance in pumping this type of concrete. Although LWAC containing LYTAG coarse aggregate and natural fines has been successfully pumped for many years, there has continued to be issues with mixes containing both lightweight coarse and fines. However, through advances in admixture technology the use of LYTAG, in both the coarse and fine fractions, with consistencies around 600 mm flow (Consistence Class F5), it is now possible to pump lower density LYTAG LWAC. Once in place, the compaction, curing and quality of the concrete will have more of an affect on its strength and durability, than the type of aggregate used in the mix. The added benefit of using a coarse/fine LWA mix is additional weight saving – by replacing the natural coarse aggregate with LYTAG coarse can reduce in-situ concrete density by around 25 per cent. By combining coarse and fine LWAs, savings in excess of 35 per cent can be achieved.
As part of the development of pumpable and Self Compacting Lightweight Aggregate Concrete (SCLWAC) works trials were carried out by LYTAG, the results of which are shown in Table 1 [7].

Using LWA in precast concrete

Precast concrete manufacturers are also utilising lightweight aggregate to increase productivity, reduce unit weights or to produce larger units of the same weight.

Lightweight Aggregate is used extensively by precasters, from smaller concrete products such as lintels, posts and street furniture to assist with manual handling, to large scale units for bridges and stadia. Using just coarse aggregate provides a weight saving of around 25 per cent over NWC, leading to significant advantages in production techniques, reduced fixings, logistics and crane requirements. Larger panels can also be cast, which reduces the number of joints, speeds up construction

Tab. 1: Test results for pumpable and self compacting lightweight aggregate concrete [7]

Mix number	1	2	3
Mix designation	P450 Pump	P450 Pump	P450 SCC
Mix design			
CEM 1 (Kg/m³)	450	450	450
4/14 Lytag (m³)	0,64	0,64	0,55
0/4 Lytag (m³)	0,55	0,55	0,63
Free water/cement ratio	0,44	0,44	0,40
Fosroc Structuro 11180	0,4%	0,4%	0,6%
Consistence (on site) (mm)	630	530 +16 l/m³ water – 630	780 slump flow
Consistence (pipe end) (mm)	580		760
7 day strength (N/mm²)	30,8	31,6	28,4
7 day strength (gesättigt) (Kg/m³)	1788	1821	1796
28 day strength (N/mm²)	41,5	42,9	38,7
28 day strength (N/mm²)	40,2	40,9	39,1
28 day mean (N/mm²)	41,0	42,0	39,0
28 day density (sat)	1799	1809	1809
28 day density (sat)	1798	1822	1811
28 day density mean (sat)	1799	1816	1810
Concrete density			
7 day density (sat) (Kg/m³)	1795	1818	1801
Oven dry density (Kg/m³)	1444	1463	1450

and cuts mould costs. External walls also have improved thermal insulation over those cast with normal weight aggregate. By using both coarse and fine LWA, weight savings of over 35 per cent mean that significant manual handling benefits can be utilised in smaller precast units.

The redevelopment of Wimbledon Centre Court has used LWAC precast units as it enabled the contractors to extend within the existing building without requiring major support work to be undertaken to the surrounding structure and foundations (Figure 1). The same work would not have been possible using NWC, as the structure, as it stood, would not have been able to support the additional weight.

Through working with the precast market and admixture suppliers, LYTAG designed the first self compacting LWAC for use in walls of a lightweight bathroom pod, being cast vertically and of thin section meant it was impossible to get poker vibration into

■ Andy Doel is Managing Director of Lytag Ltd having worked in a variety of roles in the concrete and aggregate industry after starting his career conducting polymer research.

rwoods@camarguepr.com

Fig. 1: Precast components made from lightweight aggregate concrete for the redevelopment of Wimbledon Centre Court, UK

the walls, so self compacting concrete was the only option. The even grading and high fines content of 0/4mm LYTAG meant that when combined with LYTAG coarse aggregate and cement a very good grading curve was achieved. The admixture was a polycarboxylate polymer based superplasticising admixture specifically for precast operations and engineered for high-performance flowing concrete [7].

Using LWA in civil engineering

LWAs should be considered for use as an alternative to NWA in series 500 and 600 of the UK Manual of Contract Documents for Highway Works – Volume 1 - Specification for Highway Works. Depending on the particular LWA, the particle shape and porous nature of the material means it is free draining, allowing water to pass through rapidly and it also has a relatively high absorption allowing it to soak up excess water quickly.

LYTAG's Geo-fill can be used as a bulk fill material either bonded with cement or unbonded. Densities are typically 700 to 900 kg/m^3, depending upon the ambient moisture content, and, compared to NWAs, reduces the dead load and lateral pressure on surrounding ground or structures. Typically it is used in civil engineering applications as fill, especially around bridge abutments or near supporting walls, as its lightweight nature reduces pressure on these structures. Due to the spherical nature of the Geo-fill aggregate, minimal compaction is required when placing, eliminating the need for mechanical compaction, reducing time and noise pollution. Lightweight structural fill can also be produced by mixing Geo-fill with cement to produce a more stable bulk fill.

Using LWA in screed

Lightweight floor screeds have proved important where the thickness or loadings of using traditional sand: cement screed are a concern. LYTAG no fines screed is a cement bonded LWA normally used as a base coat. Where a smooth finished surface is required a thin sand: cement topping is applied. The UK national standard BS 8204-1 [8] covers the use of LWA screeds. Depending upon the application, a no fines base coat of 10:1, 8:1 or 6:1 by volume is used.
This can be bonded to a concrete sub-base, unbonded or floating over an insulation layer. The material can be laid in deep sections and is easily formed to falls. The free passage of air through the no-fines base coat can improve drying rates over a comparable thickness sand: cement screed. Low shrinkage characteristics (0.04%) and a λ value that is three to four times lower than traditional screeds all add to the benefits of lightweight no fines screeds.
It was for these reasons that a LYTAG no fines base coat screed was used in Heathrow's new Terminal 5 (Table 2, Figures 2, 3)). In excess of 125,000 m^2 of an 8:1 no fines screed was laid in the upper hall of the terminal building. This had a thin sand: cement topping onto which terrazzo ceramic floor tiles were laid.

Financial considerations

The financial implications of using a different material are a critical concern. A number of research exercises [5, 9] have shown that whilst the cost of the actual LWAC may be higher than NWC, it will not increase the overall cost of the project, and in many cases can actually reduce the costs. Eurolightcon's report into 'The economic potential of lightweight aggregate concrete in c.i.p. concrete bridges' looked at the cost implications of LWAC in four bridges in Norway [9]. The report showed that the saving obtained by using LWAC, was up to 2% of the estimated construction cost, which is significant when the cost of such projects is considered. This however can only be achieved if the LWAC benefits are taken into account from the initial design stages.

When extensions or remedial works are carried out, the additional weight added to a structure needs to be considered. To use normal weight concrete or screed, could potentially add significant work and costs to a project. By using lightweight materials this can allow the works to be carried out without the additional constraints. An excellent example of this was the Wimbledon Centre Court redevelopment referred to earlier.

Sustainability

Sustainability too continues to be an important consideration, and this is especially so for the construction industry. We all have a responsibility to meet our current needs without compromising the ability of future generations to meet theirs and using secondary aggregates is one way we can make a difference. By using such materials that are recognized and proven, we assist in diverting materials going to landfill, and reduce demand for virgin, normal weight natural aggregates. For example, every tonne of LYTAG used saves the extraction of two tonnes of natural aggregate. There is also a positive impact on our environment

Tab. 2: Properties of LYTAG no fines base coat for Heathrow's new Terminal 5

Mix (Vol.)	Compressive strength of No-fines BaseCoat (N/mm^2)	Approx. Dry Density of Base Coat (kg/m^3)
10:1	7,0	1060
8:1	9,0	1120
6:1	11,0	1180

Fig. 2: Constructing the lightweight LYTAG no fines base coat screed for Heathrow's new Terminal 5, UK

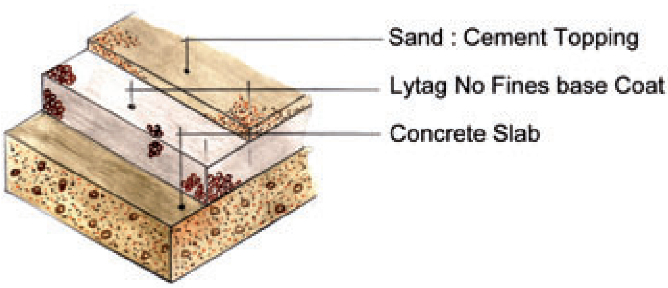

Fig. 3: Basic concrete slab and no fines lightweight screed build up

as more LWA can be transported in one load, reducing the number of vehicle movements and associated emissions.

Closing remarks

The evidence shows that LWA are a strong and proven alternative to NWA in a wide variety of applications. Using LWAC brings a number of benefits – financial, architectural, technical and environmental and in many cases, using LWAs can produce a concrete that offers greater structural or performance requirements than NWAs. In today's climate, where clients want bigger, better, sustainable and more cost effective structures, including a LWA is one way to help deliver on all levels.

References

[1] EN 13055-1:2002 Lightweight aggregates. Lightweight aggregates for concrete, mortar and grout

[2] BS 8110-1:1997 Structural use of concrete Code of practice for design and construction for design of structural concrete

[3] EN 1992 1-1 Design of concrete structures General rules and rules for buildings

[4] EN 206-1:2000 Concrete Specification, performance, production and conformity

[5] Technical guide No. 8 - Guide to the use of Lightweight Aggregate Concrete in Bridges – CBDG – Concrete Society – June 2006

[6] In-situ tests on existing LWAC structures – Eurolightcon Document BE96-3942/R16, March 2000

[7] Article Concrete Magazine Feb 2005 Developments in lightweight self-compacting and pumpable concrete Alan Beattie

[8] BS 8204-1 Screeds, bases and insitu floorings – Concrete bases and cement sand levelling screeds to receive floorings – code of practice

[9] The economic potential of lightweight aggregate concrete in bridges - Eurolightcon Document BE96-3942/R22, June 2000