# LIGHTWEIGHT AGGREGATE CONCRETE IN NORWEGIAN BRIDGES

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A main characteristic of Norway is its long coastline. During the last century, a vast number of marine concrete structures have been built to facilitate communications and transportation. Since the 1970s, the discovery of large oil and gas fields off the Norwegian coast created the need for a number of gravity based as well as floating concrete production platforms.

Like the rest of the world in the late 1970s, Norway faced the problem of chloride-induced corrosion in our marine infrastructure. A program was, therefore, started to improve concrete quality and to develop models enabling us to assess the performance of these structures. This development resulted in the introduction of high strength, high performance concrete (HSC/HPC). Consequently, we were able to include concrete with characteristic cube strengths up to 15,000 psi (105 MPa) in our design code in 1989. In the same year, the Norwegian Roads Administration introduced a requirement for a water-binder ratio of less than 0.40 combined with the use of silica fume on all their infrastructure projects.

*HPC lightweight aggregate concrete was used to reduce the weight of the main span on the Stolma Bridge*

## Lightweight Aggregate Concrete In Bridges

To help bridge designers in their efforts to create optimum structures, the Norwegian concrete industry, in the mid 1980s, started to combine the technology of HSC/HPC with that of lightweight aggregate concrete (LWAC). The first pilot project, constructed in 1987, was a 49-ft (15-m) long pedestrian bridge built with LC-60—a lightweight concrete with a cube compressive strength of 8700 psi (60 MPa). Later, ten major bridges were built with this material in Norway. These comprised free cantilever, cable stayed, and pontoon bridges. The spans of the two latest free cantilever bridges—Raftsundet at 978 ft (298-m) and Stolma at 988 ft (301-m)—represent world records.[1]

The motivation for using LWAC for free cantilevers has been twofold. Firstly, the effect of reduced dead load is obvious. Secondly, the construction method requires a balanced load on both sides of the pylon during construction. This limits the choice of span lengths and the possibility of placing pylons according to the topography. However, by being able to adjust the material density of the cantilevers, the designer achieves greater freedom.

Two of the bridges represent the revitalisation of an old concept—the pontoon bridge. Bergsøysundet (1992) with its 3000 ft (914 m) length, and Nordhordland (1993) with its 4088 ft (1246-m) length used LWAC of LC-55 (8000 psi or 55 MPa) in a total of 17 pontoons.[2] Again, dead load was important for the buoyancy, but equally important was the need to reduce the draft of the pontoons. Environmental considerations strictly limited the impact to the tidal water in the fjords.

## LWAC Qualities

The structures are designed with concrete characteristic cube strengths of 8000 and 8700 psi (55 and 69 MPa) and densities in the range of 119 to 122 lb/cu ft (1900 to 1950 kg/cu m). Aggregates are made from expanded clay or shale. The specified water-binder ratio requirements have been less than 0.40, while actual ratios have been as low as 0.33. Silica fume has been used in all structures. In contrast to the North American tradition, dry lightweight aggregate has generally been used.

## Field Performance

During the last 15 years, extensive research has been carried out in Norway to verify the LWAC's performance in a marine environment. This research includes the development of a service life model and laboratory and field-exposed test specimens. Typically, a number of test elements have been cast at the bridge sites and exposed in the tidal and splash zones as a part of the construction project. The results have given us the confidence that LWAC will withstand the design life of more than 100 years with comfortable margins.[3]

Ten years ago, the Roads Administration was sceptical about the use of high strength LWAC without any proven field performance. Today, their attitude has changed and they regard this technology as mature and a natural choice in the repertoire of materials needed to optimize bridge design.[4]

## Codes and Regulations

All the structures have been designed according to the Norwegian Standard NS 3473. This has been updated both for HSC and LWAC several times during the 1990s. However, standards covering the materials and construction aspects of LWAC were not updated. The projects have, therefore, been constructed according to special project specifications.

The situation is changing with the new set of joint European concrete standards.[5] The parts on materials and construction have now been revised. The LWAC provisions are the fruits of major research projects in Europe[6] and represent state-of-the-art technology.

## Economy

LWAC has a higher unit price as delivered from the batching plant. Savings in concrete and reinforcement quantities must compensate for this. However, reduced foundation costs, increased buoyancy, or the opportunity to apply different design concepts dominate the economy. All the LWAC structures have undergone an economical analysis to justify the choice of material. A number of these analyses are described in Reference 7.

## Conclusion

To maintain the use of concrete in bridge construction, the range of material combinations had to be broadened in the 1970s and 1980s. The introduction of higher strengths and better performance in marine and de-icing salt environments was the first step. The second step was to give the designer the possibility of combining these characteristics with the freedom to specify density. Without these quantum leaps in technology, concrete's leading position in this market would have been questionable.

## References

In June 2000, the Second International Symposium on Structural LWAC was held in Kristiansand, Norway. Ninety-six papers from more than 30 countries were presented. The proceedings are available from the Norwegian Concrete Association, www.betong.net.no. The following papers give more in-depth information on the subject of this article:


1. Rosseland, S. et al., "The Stolma Bridge—World Record of Free Cantilevering"
2. Jakobsen, S. E., "The Use of LWAC in the Pontoons of the Nordhordland Bridge, Norway"
3. Helland, S., "Service Life Modelling of Marine LWAC Structures"
4. Melby, K., "Use of High Strength LWAC in Norwegian Bridges"
5. Helland, S., "LWAC in the New European Standards on Materials and Execution"
6. Mijnsbergen, J. et al., "EuroLightCon – A Major European Research Project on LWAC"
7. Fergestad, S. et al., "The Economical Potential of LWAC in 4 Different Major Bridges"