Light Weight Concrete Application in Latvian Bridges

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Summary

Lightweight aggregate concrete (LWAC) offers various favourable technical properties compared to normal weight structural concrete. The use of LWAC for reconstruction of historical 125 year old stone bridge allow maintain the historical view and increase the load carrying capacity. For reinforced concrete bridges designed 40 – 50 years ago the use of LWAC will help to extend the service life by change of some deteriorated or unsuitable (new requirements for width of carriageway etc.) parts with structures from LWAC. The use of LWAC in new bridge structures allow to design thinner and smarter structures. Paper discuss the application of the LWA concrete in reconstruction and construction of bridge structures, as well the results of investigation of the properties of LWAC.

Keywords: bridge, concrete, construction, lightweight aggregate, reconstruction.

1. Introduction

Traditionally the LWAC (mainly from expanded clay) in Latvia has been applied in buildings for many years. The improvement of the technology of production, mix composition and execution, has considerably changed the nowadays LWAC properties. The uses of various admixtures have increased the strength, stress-strain modulus and decreased creep that made possible to use of LWAC for hardly loaded bridge structures.

Last time achievements in investigation of LWAC [1], [2] allowed using them in bridge structures. The LWAC is a competitive alternative to normal density concrete. This paper deals with four bridge projects, where the LWAC is used by different reasons.

In reconstruction of more than 125 year old stone arch bridge in Kandava town the LWAC was used as fill material in the over arch structure to hold constant dead load and obtain enough hard basements for the wearing course.

For the bridge over the Lielupe River with the common length of 160 m the use of ribbed over-arch structure from LWAC decrease the self-weight of superstructure and balance the increase of live load, as well ensure that the increased traffic load did not increase the stresses under the foundation slab.

At new overpass over road A2 the LWAC is used to achieve a more slender superstructure of aesthetic reasons.

2. Reconstruction of 125 year old stone arch bridge

The bridge over Abava River was completed in 1873. The bridge consists of four 8.60 m long and 8.70 m wide stone vaults and 12.00 m long side wings (Fig.1). The width of piers at water level reached 2.10 m and the thickness of vault in top point was 1.20 m. The bridge facades and icebreakers were made from split stones. The bridge has 6.30 m carriageway with two 1.25 m vide sidewalks.

Fig.1 View on bridge facade

The assessment of existing bridge structures indicated that the basic structures were reparable. The restoration works should preserve the original quality of the structures and respect, as far as possible, the historical look of the bridge.

The design provide the reconstruction of the existing carriageway structures, strengthen and waterproofing of the upper side of the vaults, initiation of cracks, and replace the sand backfill in over arch part with LWAC (Fig. 2).

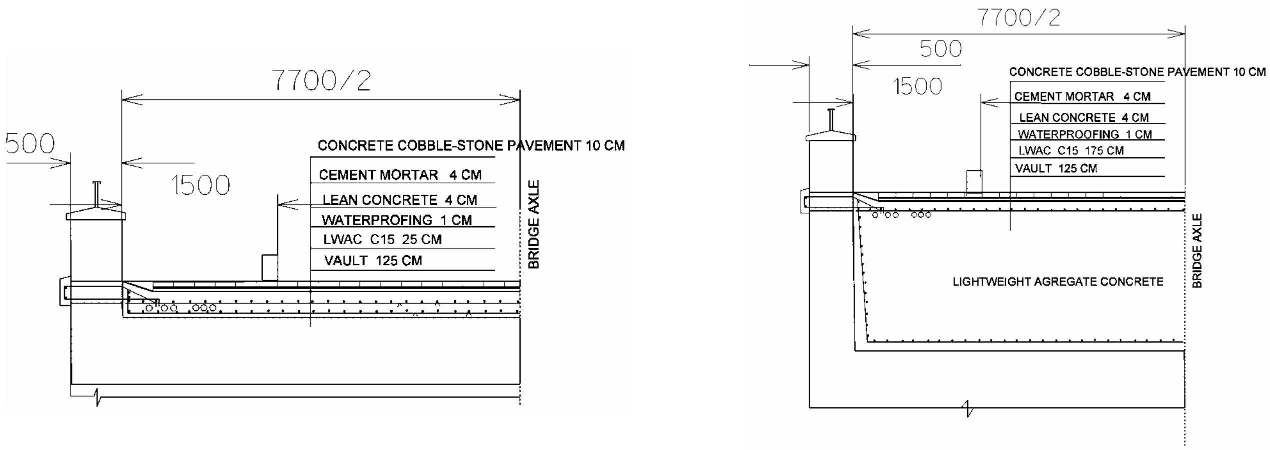

Fig. 2 Cross section in middle of the span and on pier

As backfill was used LWAC class LC16/18, with density 17 kN/m^3. The use of LWAC decreases the total dead load of the span structures and allowed to avoid the strengthening of foundations [3].

3. Reconstruction of multi-span arch bridge

The bridge over the Lielupe River with the common length of 160 m is located in the central part of Jelgava town (Fig.3). The bridge has three 41.42 m long and 13.90 m wide flat reinforced concrete arches; spandrel walls with variable width (Fig.4); 9.00 m wide carriageway based on sand infill and 2 x 2.25 m wide sidewalks (Fig.5).

The assessment of the bridge indicated severe deteriorations in important structures. As well the intensity of the traffic flow has increased considerably and two-line roadway could not satisfy up-to-date and long-term traffic requirements. The actual bridge condition was qualified as precarious and needing a major restoration and widening of roadway till 4 traffic lines and sidewalks integrated with a bikeway.

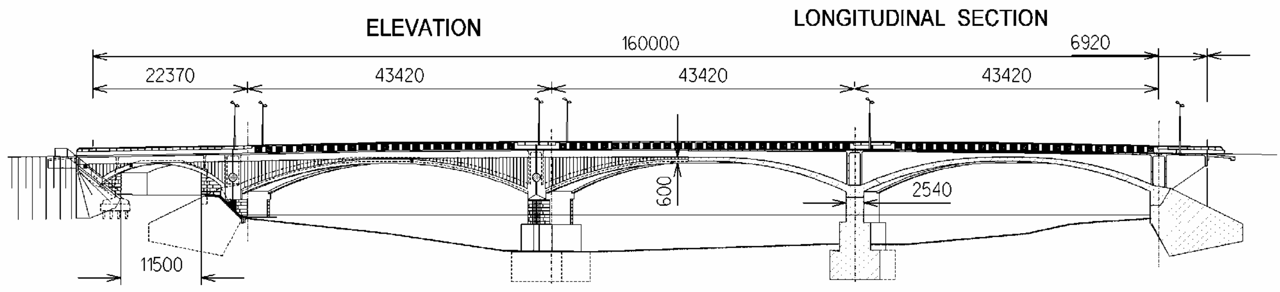

Fig.3 Elevation and section of bridge structure after reconstruction

Fig.4 View on bridge before reconstruction

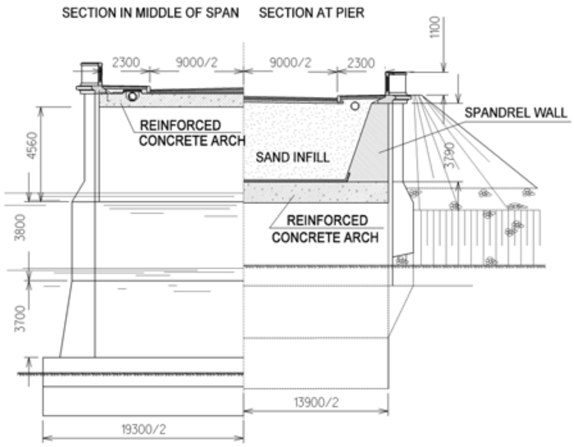

Fig.5 Cross-section before reconstruction

The results of inspection indicated that the condition of concrete in the arches were acceptable for reconstruction and further strengthening, the spandrel walls were evaluated as unacceptable and piers and abutments, including foundations were in appropriate condition. The results of assessment and analysis pointed that the foundations of the pier and abutment were heavily utilized and increase of load on foundations were unwelcome.

At the same time was the strong recomendation from town municipality to widen the bridge deck till 22 m (instead of 13.60 m). The use of traffic loads proposed in Eurocodes and requirements for new bridge deck size the stresses in arches and foundations from the live and dead loads increased considerably. The problem complicated the wet clay grounds under the spread foundations, therefore was decided to design over-arch structure with minimum weight.

After some discussions was decided to widen and strengthen the arch structures and to rebuild the overarch structure form longitudinal LWAC ribs (Fig.6, Fig.7).

For side walls and the deck slab were accepted normal weight reinforced concrete class C40/50, that allowed design enough thin structures. Increase of the bearing capacity in the arch will be achieved by widening of arches symmetrical from both sides. For widening of arches normal weight reinforced concrete class C40/50 were accepted.

The ribs in middle part of over-arch structure are made from LWAC LC30/35 but from sides – from normal weight concrete. The use of ribbed over-arch structure instead of sand or lightweight concrete fill required the discontinuing of the spandrel wall structures and installation of expansion joints over the piers and abutments. Composition and properties of LWAC are shown in Table 1.

The use of ribbed over-arch structure from LWAC allowed to decrease the self-weight of superstructure and balance the increase of live load and ensure that the increased traffic load do not increase the stresses under the foundation slab [4].

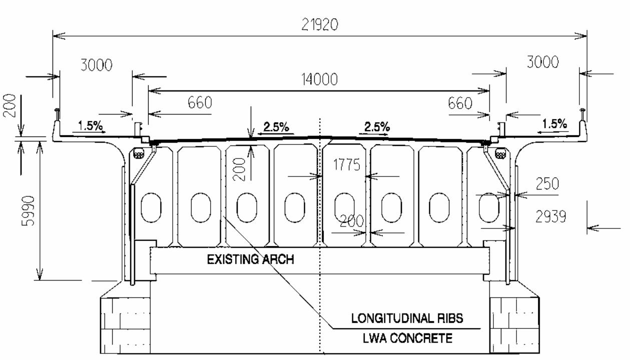

Fig.6 Cross-section of span structures after reconstruction

Fig.7 View on bridge after reconstruction

Table 1. Properties of the lightweight aggregate concrete LC30/35 used for over-arch structure

Mix design:		
Portland cement CEM 42.5 SR	kg/ m^3	495
Natural sand 0.5-4 mm	kg/ m^3	860
Limestone powder	kg/m^3	25
Lightweight aggregate 1-5 mm	kg/m^3	310
Superplasticizer	%	1
w/c		0.47
Mechanical properties:		
Mean cube strength $f_{c,mean}$	MPa	35.1
Density, dry	kg/m^3	1803

4. New overpass over road A2

The overpass over road A2 is designed as board-stayed system and is the first span structure that is completely made from LWAC. The overpass is located near the Riga border and link the Riga bypass with incoming road. The overpass consists of 3 spans, 18 + 40.55 + 18 m and total length 76.55 m (Fig.8) and 15 m wide carriageway (Fig.9). The total length of the overpass was determined by requirements of under passing road width and balance of the structure. The superstructure of the overpass consists of slab, pylon and pull board (Fig.10).

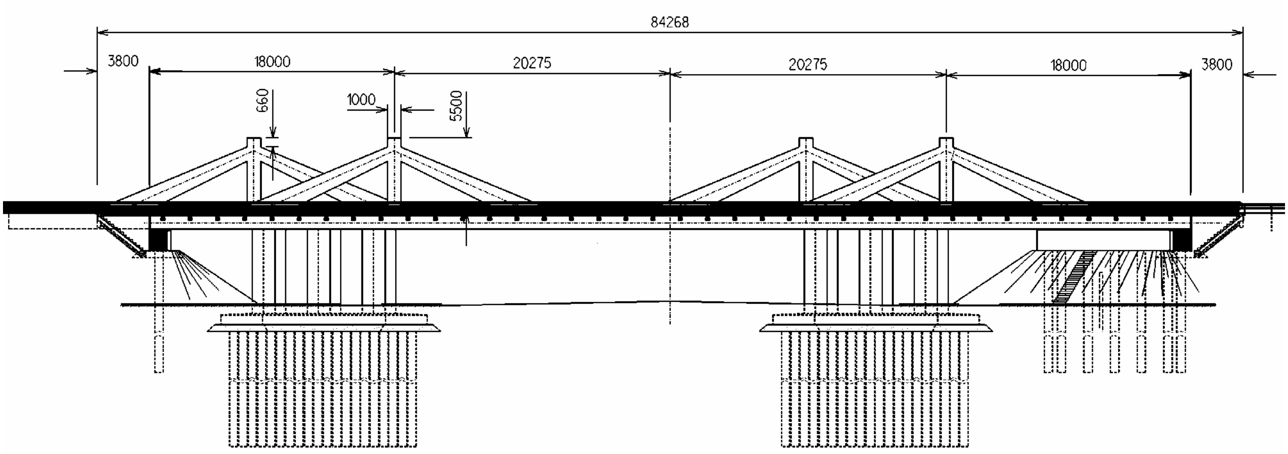

Fig.8 Elevation drawing of board-stayed overpass

Due to exposed location of the overpass, it was decided to use slender superstructure with a nice appearance. This was met by using LWAC LC 45/50 in the slab, resulting in a reduced section height.

The pylons and board sections are made from normal weight concrete C 35/45. The slab is prestressed by three cables on pylons via boards. Each post-tensioning cable consists of 19 strands 15.2 mm in diameter and are pre-stressed with 3430 kN each.

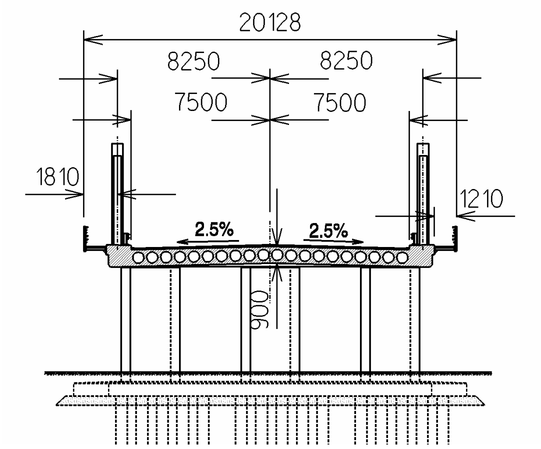

Fig.9 Cross-section of the overpass

Fig.10 Overpass under construction

Five pre-stressed cables are located across the slab and two cables are located in edge beam between the ends of board sections. These post-tensioned cables consist of 12 strands with 15.2 mm in diameter and are pre-stressed with 2360 kN each.

LWA concrete LC 45/50 mix composition was elaborated in Riga Technical University, used method of mix design is based on aggregate optimal packing theory. Some correction was introduced in cooperation with ready-mix concrete producer and supplier. Concrete mix was delivered by truck mixers, minimum drum rotation rate was provided.

Concrete mix are characterized by good workability, homogeneity and high flowability (cone slump > 25 cm, cone flow 60 cm, it almost corresponds to Self-Compacting Concrete). Preliminary method of concrete pumping was regarded. Experimental pumping indicated on non-controlled behaviour of LWA concrete mix in system under high pressure (up to 8 MPa). In spite on high flowability, mix was very viscous and mix blocking took place. As result, for concreting the crane and concreting tanks was used. Duration of concreting works was 52 hours without interruption, total amount of concrete 1100 m^3. Problem of pumpability of high strength LWA concrete is the theme for future investigations. Use of pumps should increase rate and quality of concreting works as well as should take an economical effect.

Non-continuous laboratory control of concreting work was carried out. Test results for cube samples after 28 days shows compressive strength 70 MPa and density 1990 kg/m^3.

5. Study of properties of LWA concrete

Table 2. Properties of the lightweight aggregate concrete LC45/50

Mix design:		
Portland cement 52.5 SR	kg/ m^3	396
Lightweight aggregate 4 – 8 mm	kg/ m^3	166
Lightweight aggregate 6-12 mm	kg/m^3	284
Sand 0.5-4 mm	kg/m^3	995
Superplasticizer	kg/m^3	4.7
Silica fume	kg/m^3	26
Water	kg/m^3	179

Various aspects of proposed LWA concrete mix composition before the placing were studied in Riga Technical University [5]. The obtained optimal mix composition is given in Table 2.

The concrete was homogeneous and binding with a good texture. The lightweight aggregates take up 33% from total volume.

The kinetics of hardening is shown in Fig. 11 and the stress-strain diagram in Fig.12.

After 28 days the test cubes had a density 2045 kg/m^3. The 112 day's density was measured 2006 kg/m^3. Air content was 4%.

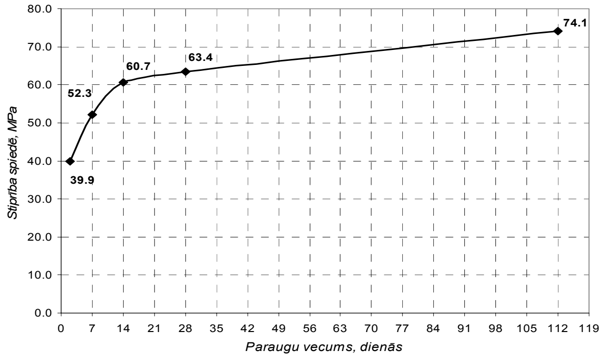

Fig.11. Compressive strengths versus age

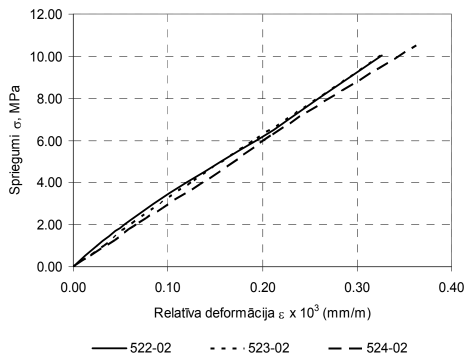

Fig.12 Stress – strain digamma

After 2 days the compression strength of test cubes achieved 39.9 MPa that is 63% of the 28 days strength – 63.4 MPa. After 112 days the cubic compression strength achieved 74.1 MPa (see Fig.11) and tensile strength 3.15 MPa.

By quantifying of the modulus of elasticity in verification range of 0 – 10 MPa was established linear stress and strains relationship (see Fig.12). The average modulus of elasticity of the test beams was obtained 30.1 10^3 MPa.

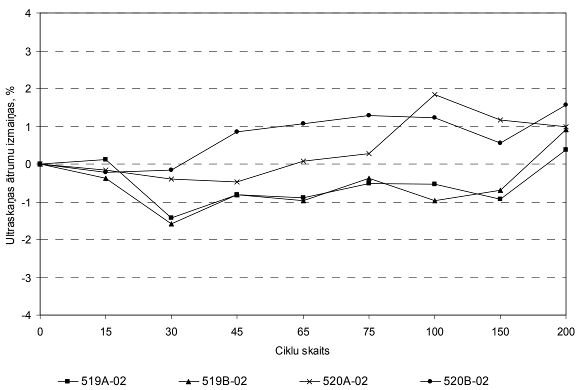

Fig.13 Change of Ultrasonic speed depending of number of freeze – thaw cycles

The test samples showed good water tightness (average penetration 17 mm) and excellent resistance against freeze-thaw and freeze-de-icing-salt attack.

The freeze-thaw resistance was investigated with ultrasonic method on samples saturated with 5% NaCl. The obtained results (Fig.13) showed that the concrete could withstand more than 200 freeze-thaw cycles in 5% NaCl solution. It corresponds to 600 cycles in normal water.

6. Conclusions

The use of high strength LWAC will decrease the dead load of the bridge structures without reduction of load carrying capacity. In many cases the use of LWAC will help by reconstruction and widening of existing bridge structures. Investigation of properties of LWAC samples shows excellent mechanical properties of material and good durability.

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