EURASIAN JOURNAL OF ACADEMIC RESEARCH
Innovative Academy Research Support Center
UIF = 8.1 | SJIF = 5.685
www.in-academy.uz

FOREIGN EXPERIENCE IN THE USE OF HIGH-STRENGTH EXPANDED CLAY CONCRETE IN BRIDGE CONSTRUCTION (LITERATURE REVIEW)

Raupov Ch.S.[1]
[1]Tashkent State Transport University, Professor
Malikov G.B.[2]
[2]Tashkent State Transport University, Doctoral Student
Zokirov J.J.[3]
[3]Tashkent State Transport University, Master's student

https://doi.org/10.5281/zenodo.7119543

ARTICLE INFO

Received: 24th September 2022
Accepted:26th September 2022
Online: 28th September 2022

KEY WORDS

world experience in the use of expanded clay concrete, high-strength lightweight concrete, strength of lightweight concrete, high-strength expanded clay concrete, reduction of the bulk mass of structures, savings in reinforcing steel, specific strength, average density, bridge span, roadway plate.

ABSTRACT

The paper presents foreign experience in the use of high–strength expanded clay concrete in bridge structures, sets the average density ranges according to the European standard EN 206-1 for structural lightweight concrete, world experience in the development of lightweight concretes with increased strength and prospects for the development of high-strength lightweight concrete, the benefits of using lightweight concrete in bridge construction, a tendency to increase the proportion of structural lightweight concrete with a strength of 45 - 70 MPa in bridge construction. Based on the analysis and generalization of a number of experimental and theoretical studies conducted by us and various authors devoted to the complex application of structural expanded clay concrete instead of equal-strength heavy concrete on natural dense aggregates, the advantages of structural expanded clay concrete of both technological and constructive nature are presented.

CEBFIB information materials [3, 4] provide information on the effectiveness of using light concrete in sufficiently large volumes in the USA, Western Europe, Australia in the construction of vertical frames, prestressed trusses, cantilever roof elements with a span of up to 30 m, large-span beams, ceilings, coating plates, large-sized shells, coatings of various configurations, bridge spans.

The long and positive experience in the operation of domestic bridges made of expanded clay concrete and sinter concrete in the absence of cracks and other defects in the superstructures makes it advisable to use such structures more widely in bridge construction.

The benefit of using lightweight concrete in bridge construction boils down to one thing – reducing the own mass of the structure. Thus, light concrete gives the greater savings, the greater part of its own mass of the entire design load. The use of lightweight concrete of different systems allows bridges to reduce the own weight of superstructures by 20...30%; savings in fittings in all cases, it turns out, from 6 to 15% with a reduction in the total cost from 7 to 12%, excluding transportation and installation costs.

The economic and technical advantages of lightweight concrete in the construction of engineering structures were confirmed as early as 1937 during the construction of the roadway plate of the San Francisco-Oakland Suspension Bridge. The more than 36-year existence of the bridge plate has proved that such coatings withstand the effects of salts well during winter operation [1-5].

Improving the operational properties of lightweight concrete is an urgent task both from the standpoint of reliability of the operation of structures and for expanding the scope of application. The calculated justification for the development of such technological solutions is presented in [6, 7]. In this work, it is shown that the introduction of a new technology "is advisable not only under the condition of superior performance characteristics, but also with a significant reduction in the volume of the product (structure). Also, an important factor that reduces the requirements for the geometry of the product is a decrease in the average density of the material." This is demonstrated by the data in Table 1.1 [8].

It follows from Table 1.1 that with a simultaneous reduction in the volume of the structure (the result is achieved with a given design scheme only by changing the geometry of the section, and, consequently, by increasing the strength of the material) and the density of the material from which it is made, the cost of a technological solution that provides these operational properties can be significantly increased.

Essentially similar results were obtained by other authors [8, 9]). The use of lightweight structural materials allows you to reduce costs by 1.5...2.5 times compared to equally strong heavy analogues. Moreover, some architectural forms are structurally feasible only when using composite materials with a low average density [9].

The combination of the properties of structural lightweight concrete provides ample opportunities for design and economic efficiency by increasing the payload of structures, improving earthquake resistance, fire safety, the possibility of reducing the cross-section of structures, reducing material consumption (concrete and reinforcing steel), as well as additional advantages during transportation and installation of prefabricated elements.

Traditionally, high-strength concrete (VPB) is understood as heavy concrete, the compressive strength of which is at least 60 MPa [7]. However, this formulation does not take into account the weight characteristics of the material, which are estimated by specific properties, for example, average density. For heavy concrete, this property varies in the range of 2200...2500 kg/m^3. As a unified parameter for the classification of both heavy and light concretes, the specific strength index R_{sp} is used:

$$R_{sp} = R_{comp}/\rho_{rel} \qquad (1)$$

where R_{comp} is the compressive strength of concrete, MPa, ρ_{rel} is the average density of concrete reduced to the true density of water.

The use of lightweight composites in civil, marine or special construction has long been recognized as justified and reliable

[10-12]. For the first time, the use of such materials in civil engineering can be found more than 2000 years ago, for example, in ancient structures of the Roman Empire [13], in which light aggregates of volcanic origin were used [14] to produce light concretes. Currently, such concretes are produced using shale, expanded clay or expanded slag [15], and in recent years pumice, perlite, microspheres, diatomite, foamed glass and aerogel have become widespread [15].

Nevertheless, international experience shows the possibility of obtaining structural lightweight concrete with a strength of 57 to 102 MPa at an average density of 1600 to 1900 kg/m³ [17]. The introduction of pozzolan additives, such as silica, fly ash, metakaolin, volcanic dust, shale or calcined clay) into the composition of light concrete in combination with water-reducing additives allows for strength up to 35...70 MPa at an average density of 1500...1900 kg/m³ [18].

Improving the operational properties of lightweight concrete is an urgent task both from the standpoint of reliability of the operation of structures and for expanding the scope of application. The calculated justification for the development of such technological solutions is presented in [8]. In this work, it is shown that the introduction of a new technology "is advisable not only under the condition of superior performance characteristics, but also with a significant reduction in the volume of the product (structure). Also, an important factor that reduces the requirements for the geometry of the product is a decrease in the average density of the material." This is demonstrated by the data in Table 1 [8].

Table 1. - Dependence of $c'_{c,n}/c'_{c,b}$ on $C_{c,b}/C_{c,n}$, ρ_b/ρ_n and the ratio $V_{sb}/V_{s,n}$

Ratio ρ_b/ρ_n	Ratio $V_{c,b}/V_{c,n}$					
	1,5	2,0	2,5	3,0	3,5	4,0
0,9	0,81	0,89	0,96	1,04	1,11	1,48
1,0	0,73	0,80	0,87	0,93	1,00	1,33
1,1	0,67	0,73	0,79	0,85	0,91	1,21
$C_{c,b}/C_{c,n}$=2,0						
0,9	0,61	0,67	0,72	0,78	0,83	1,11
1,0	0,55	0,60	0,65	0,70	0,75	1,00
1,1	0,5	0,55	0,59	0,64	0,68	0,91

Notes: The indices "b" and "h" correspond to the "basic" and "new" variants, respectively; V_s *- the volume of the structure* ρ *- the density of the material;* C_s *– the cost of the structure;* c'_c *- the unit cost of the construction material.*

It follows from Table 1 that with a simultaneous decrease in the volume of the structure (the result is achieved with a given design scheme only by changing the geometry of the section, and, consequently, by increasing the strength of the material) and the density of the material from which it is made, the cost of a technological solution that provides these operational properties can be significantly increased.

Essentially similar results were obtained by other authors [8, 9]). The use of lightweight structural materials allows you to reduce costs by 1.5...2.5 times compared to equally strong heavy analogues. Moreover, some architectural forms are structurally feasible only when using composite materials with a low average density [9].

Currently, structural lightweight concrete with compressive strength in the range from 35 to 41 MPa is successfully used for the production of precast and prestressed concrete structures in North America [19, 20]. Due to the high consumption of Portland cement and the small size of the lightweight aggregate (9 or 13 mm), some enterprises produce concrete with a strength of 40...50 MPa [21].

In Russia, the experience is based mainly on theoretical developments of compositions based on ceramic fillers [22]. Depending on the size of the expanded clay aggregate, lightweight concretes with an average density of 1500 ...1600 kg/m³ and a compressive strength of 37 ...44 MPa can be obtained.

The performance properties of lightweight concrete developed by research groups from different countries are presented in Table 2.

Table 2. Operational properties of light concrete

Year	A country	Compressive strength, MPa	Average density, kg/m³	Specific strength, MPa	A source
1999	Norway	65,0…70,0	1900…1930	25,0…27,0	[23]
2002	Germany	14,0…25,0	1800…1850	13,3…14,4	
2003	Turkey	30,0…40,0	1800…1860	16,1…22,2	
2004	Japan	47,0…54,0	1800…1860	27,5…30,0	
2007	Russia	46,0…48,0	1600…4650	25,4…28,7	
2010	Malaysia	43,0…48,0	1870…1990	22,9…24,1	
2011	Portugal	40,0…80,0	1500…2000	26,6…40,0	
2012	REC NT	40,0…70,0	1300…1500	30,0…50,0	
2014	Korea	40,6…50,7	1540…1670	26,4…30,4	[24]
2015	Germany	64,0…67,8	1690…1695	37,9…40,0	[25]
2016	Vietnam	30,0…44,0	1750…1900	17,1…23,2	[26]
2019	Brazil	68,0…80,7	1487…1991	40,5…45,7	[27]

A comparative analysis of the presented data shows that high-strength lightweight concretes developed by Russian researchers can compete with foreign analogues. However, in order to occupy a leading position, it is necessary to increase the specific strength of such concrete to 50 MPa.

In Europe, the USA and a number of other countries, the use of structural lightweight concrete has a very wide practice [28]. For example, in Norway alone in 1989-1997, approximately 200 thousand m3 of such light concrete were laid. Among the unique structures built using reinforced concrete on expanded clay is the building at New York International Airport, in which four sections overlap the room with a side of 90 and 60 meters (expanded clay concrete with a strength of 41 MPa, a density of 1850 kg / m^3), as well as the dome of the assembly hall of the University of Illinois, during the construction of which the replacement of heavy concrete with light it allowed to reduce the weight of the building by 6.8 thousand tons .

More than 800 bridge structures in North America are built of lightweight concrete, for example, the Sebastian Inlet Bridge in 1965 [29] (Figure 1). The Chesapeake Bay Bridge is an example of the reuse of standard solutions made of structural lightweight concrete in the construction of bridges. The first of the two structures was erected in 1953, and the second in 1975. The Oresund Bridge in Norway (Figure 2) with a maximum structural span of 298 m was the longest concrete cantilever span in the world in June 1998. The construction of this structure was carried out using concrete on a light aggregate with a strength of 60 MPa.


Figure 1. Sebastian Inlet Bridge


Figure 2. Raftsund Bridge

In recent decades, there has been a tendency to increase the proportion of structural lightweight concrete with a strength of 45-70 MPa in vertical load–bearing elements of high-rise buildings, prestressed prefabricated slabs of coatings and floors, structures of bridges and offshore structures (Norway, Holland, USA, Germany, Great Britain, Japan, etc.) [30-35]. According to experts, the use of lightweight concrete reduces material costs by 1.5 – 2.5 times compared to conventional heavy concrete of a similar strength class. At the same time, some architectural design options are structurally feasible only when using high-strength lightweight concrete [39].

The European standard EN 206-1 for structural lightweight concretes sets the ranges of average density from 1.1 to 2.0 kg/dm^3, compressive strength – classes from LC8/9 to LC 80/88.

Modern structural lightweight concretes are mainly produced using artificial porous aggregates in the form of fractionated expanded clay gravel (Liapor 3, Liapor 8 – Germany; Leca 670, Leca 800 – Denmark, Italy, Norway); ash gravel (Lytag – Holland, Great Britain), as well as porous rocks, for example, pumice, volcanic tufa (Pumice – Iceland) [39].

There is a well–known foreign experience of using high-strength lightweight concrete in the construction and reconstruction of roads, bridges and overpasses in the USA, Japan, Norway, Germany, Finland and other countries [3 - 5, 36-38]. The effectiveness of the use of lightweight concrete in bridge spans is determined primarily by the ratio of the own weight of these structures to the total calculated constant and temporary loads. For the last 20-30 years, light concrete has been used mainly in the world practice of bridge construction in most countries.

The most interesting is the use of lightweight reinforced concrete in the construction of the San Francisco - Oakland Bridge. The clothing of the six-lane roadway of this bridge with a length of 6.43 km is made of lightweight reinforced concrete. Previously, the issue related to the abrasion index of light concrete was studied. It was found that after five years of operation, the abrasion rates of concrete were within the normative values [38]. Concrete with a cement consumption of 362 kg /m^3 is characterized by a compressive strength of 25 MPa at the age of 28 days, an average density in the air-dry state of 1520 kg/m^3.

Russia also has experience in the use of high-strength expanded clay concrete in the construction of road bridges, airfield coatings (light concrete with compressive strength from 30 to 50 MPa), prefabricated slabs for highways, which gives an economic effect of 12-15% [38, 39].

Since 1954, Prof. I. G. Ivanov-Dyatlov began work on the research and implementation of concrete on expanded clay in bridge construction. In 1958, a road bridge was constructed in the Moscow Region from 7.5 m span beams made of expanded clay concrete with a strength of 28.2 MPa and a density of 1670 kg/m^3.

In 1959, a road bridge with spans of 7.5 and 10.5 m of class B25 expanded clay concrete with a density of 1850 kg/m^3 was built on the Ryazan Highway near Moscow. The bridge structures were found in good condition during the survey. Piles were also made of expanded clay concrete there.

The advantages of expanded clay concrete were revealed especially vividly when it was used for slabs of the roadway of bridges with steel and prestressed reinforced concrete main beams. Bridge train No. 426 together with MADI produced and tested expanded clay concrete slabs for four overpasses on the Volokolamsk Highway. Tests have shown that structures made of expanded clay-reinforced concrete of classes B15-B25 worked for strength and crack resistance better than structures made of heavy iron-concrete.

In 1961, Volgogradgidrostroy, according to the MADI project (RF), built the first prestressed five-span road bridge in Europe with a length of 102 m and design spans of 15.2+3x21.9+ 15.2 m across the Akhtuba River with prefabricated prestressed box-section beams of expanded clay concrete of class B30 and a monolithic slab of expanded clay concrete of class B25. Compared with the heavy concrete bridge variant, the total weight of the superstructures decreased by 27%, the consumption of working fittings – by 18%, and the cost – by 11% [45].

The most striking example of the use of structural expanded clay concrete in bridge construction is the Stolma Bridge in Norway, built in 1998. This bridge is the world's longest multi-span segmental bridge with box-section beams. The main span of the bridge is 301 m . This span is mounted from several elements, the longest of which is an element with a nominal length of 184 m, and it is he who is made of structural expanded clay concrete. The technical justification for the use of expanded clay concrete in this bridge was the need to compensate for the significant difference between the weight of the structures of the main span and the weight of the structures of shorter bridge spans [39].

Other examples of the use of expanded clay concrete in bridge construction are the Sunday Bridge and the Raftsund Bridge. In both bridges, the length of the main span is 298 m .

Bridge construction is one of the most conservative areas of the construction industry. It usually takes many years to agree on any changes in the bridge design concerning building materials. The exception to this rule was the reconstruction of the bridge over the Volga River near the city of Kimry, which ended in November 2007 [40].

In the USA, extensive experience has been accumulated in the use of high-strength lightweight concrete on aggregates such as expanded clay for the construction of bridge spans. A characteristic feature of bridges being built in the USA is the use of lightweight concrete for the construction of the roadway, while other, less material-intensive bridge elements are made of steel or heavy concrete. At the same time, the light concrete of the roadway, designed for very intensive traffic (4 or more thousand cars per day), on some bridges is protected from abrasion by a layer of concrete on granite, asphalt, or polymers. On many bridges, there is no protective layer on the light concrete roadway at all. Due to the use of light concrete, significant savings are achieved in weight (up to 30% of the weight of the heavy concrete slab) and in cost (up to 4% of the total cost of the bridge). After 17 and 35 years of operation of light concrete roadway slabs, a survey was conducted on a number of bridges, which did not reveal any cases of destruction or serious defects of the slabs, despite the use of salt to remove ice from the roadway [40].

There are 150 bridges in the USA and Canada, the roadway slabs of which are made of lightweight concrete. In the USA, more than half of the roadway plates of 86 bridges were examined. After 12 years of operation, the plates are well preserved with a few exceptions, where damage can be attributed to technical defects. Currently, the bridges are in good condition, which is confirmed by surveys of bridge elements and, in particular, sinter concrete and expanded clay concrete slabs of the roadway.

A bridge has been built on the Tohoku railway line, including 6 steel spans of 62 m long and 4 spans of 40 m on approaches covered with split beams of prestressed lightweight concrete. Research and experimental construction of bridges in Japan revealed a minimum economical span of 40 m.

In Japan, lightweight concrete has found wide application due to its high seismicity. Under these conditions, its increased impact strength and reduced bulk mass contribute to the creation of earthquake-resistant structures. Research on the use of lightweight concrete as a structural material has been conducted in Japan since the early 60s of the last century. As a filler, "mazalite" was used – expanded clay shale. It was found that with a strength class of B30–B40, the density of light concrete is 20-30% less than heavy concrete, and the modulus of elasticity is 40-50% less.

According to Japanese experts, laying light concrete requires more precautions than heavy concrete, since the concrete mixture is easier to segregate, the filler can float, and other things being equal, a more rigid concrete mixture is obtained.

A bridge was built on the Tohoku railway line, including 6 steel spans of 62 m long and 4 spans of 40 m on approaches covered with split beams of prestressed lightweight concrete [45].

A bridge over the Arakava River has been built on the Sobi-Main railway line. The flyovers on the approaches to the bridge with a length of 105 and 98 m, consisting of spans from 15 to 32 m, are made of light concrete, and not only superstructures, but also columns of supports and foundation grillages were erected from light concrete. The use of precast reinforced concrete structures has reduced the construction time.

During the construction of the Sobi-Main railway, over 50 bridges were built of lightweight concrete.

Research and experimental construction of bridges in Japan revealed a minimum economical span of 40 m. The efficiency calculation was performed for prestressed girder superstructures in accordance with the conditions and prices existing in Japan.

Extensive studies of lightweight concrete have been conducted in Germany, in terms of its use as a structural material. As a result of the research, we came to the conclusion that lightweight concrete can also be used for bridge structures, but it is necessary to take into account some of its features. Such features include a smaller modulus of elasticity, which determines the increased deformability of structures made of light concrete, a reduced frequency of natural vibrations of structures made of light concrete, which must be taken into account in dynamic calculations, increased shrinkage and some other properties. For structural lightweight concretes in Germany, a durable porous filler "Korlin" was created, which also has a low water absorption. Now it is used for structural lightweight concrete in other countries of Western Europe [40]. Corlin is a granular expanded clay. In the manufacture of corlin, clay is crushed and mixed with additives. Then the mass is fed into a vacuum press, formed in the form of bars, passing which through the rollers, granules are obtained. The raw granules are dried, then fired in a rotary kiln at a temperature of 1300- 1400 ° C, while the granules swell. After cooling, the resulting filler is divided into fractions.

In the 70s, several large road bridges were built in Germany according to a three-span scheme using light concrete in the central span, similar to a number of bridges in the Netherlands, Such is the Fulingen Bridge near Kolon with a full length of 242.4 m, it has spans 53,2+136,0+53,2 M. The middle part in the central span with a length of 84 m is made of light concrete. The use of such a combination of light and heavy concrete in different spans affected the redistribution of moments from external loads and gave a reduction of moments in the middle of the span by 50%, on supports by 12%, with a density of light concrete 1800 kg / m3 and a strength of 45 MPa. The advantages of such a design were discussed above in connection with bridges built in the Netherlands. Then a road bridge was built across the Rhine River in Wiesbaden according to the scheme 65+105+65 m is already entirely made of lightweight concrete. Of interest is the use of a new type of lightweight concrete, which is becoming widespread in Germany for prefabricated bridges called light - ordinary concrete "Leichter – Normalbeton"). It is similar to heavy concrete, but 20% of the medium fractions of a large dense aggregate is replaced by a light porous one, which provides a concrete density of about 2000 kg/m^3 and reduces its own mass by 10-15%, and the modulus of elasticity up to 25%.

Based on the practical experience of using light concrete, French specialists have made a technical and economic analysis of the feasibility of using it in bridges of various systems and believe that many factors affect the technical and economic indicators when comparing bridges made of heavy and light concrete: the type of structure, the share of the cost of foundations from the cost of the entire structure, the gain that can give weight reduction in the reduction of the foundation, the conditions of work, the equipment that the construction company has, the distance of the porous aggregate transportation and some other circumstances [40].

Such a building material is in great demand in Germany, the Netherlands, the Czech Republic and other countries where expanded clay is spoken of as an environmentally friendly material, since it contains only environmentally friendly products, and blocks of expanded clay are called "bioblocks". In Europe, expanded clay is used in 40% of construction sites. There are examples of the construction of bridges made of light concrete in Germany, Denmark, Australia, Austria, Switzerland, Belgium, France and other countries [41].

The above indicates the obvious prospects of structural lightweight concrete for use in modern structural systems of buildings and engineering structures. Currently, this is one of the most important tasks of the development of the country's construction complex [3 – 5].

Bridge construction is one of the most conservative areas of the construction industry. It usually takes many years to agree on any changes in the bridge design concerning building materials. An exception to this rule was the reconstruction of the bridge over the Volga River near the city of Kimry, which ended in November 2007 [42].

In Japan [43], due to the growth of automobile traffic, the bridge was reconstructed in order to reduce the load on metal structures, using road slabs with a specific strength of 27.1...30.3 MPa (average density of 1810-1850 kg/m^3).

In 1999, the largest bridge "Stolma bridge" of a free cantilever structure with a length of the main span of 301 m was built in the south of Norway (Figure 3) [44].

Figure 3. Stolma bridge in Norway, built of high-strength lightweight concrete

A feature of the Stolma bridge design is the use of lightweight concrete with a density of 1931 kg/m^3 and a strength of 70 MPa when concreting 182 meters of the central part of the bridge. Reducing the weight of the central element of the structure made it possible to distribute the loads on the columns, the bearing capacity of which perceives only 90% of the mass of the surface part. The composition of the concrete used in the construction used high–quality cement (420 kg/m^3), silica (35 kg/ m^3), sand (700 kg/ m^3), light filler Leca-800 (600 kg/m^3) and water in the amount of 208 l/m3. Due to the use of a porous filler In / C, the ratio was 0.495, which made it possible to obtain LC60 concrete with a specific strength of 36.5 MPa.

Figure 4. Stavset expanded clay concrete bridge in Norway (span between supports 150m) [44]

Expanded clay concrete is ideal for the construction of bridges. Because it has not only the strength of ordinary concrete with significantly less weight, but also provides a reduction in the cost of constructing a bridge. The peculiarity of expanded clay concrete when used in bridge construction opens up a lot of creative freedom, without the need to compromise on static stability. Due to the low density of expanded clay concrete from 0.8 to 2.0 kg / m^3, it has a significantly lower weight than conventional concrete and allows it to reach a strength of 65 MPa, in particular for thin load-bearing structures (Fig. 4) [44].

The most widely used lightweight concrete on artificial porous aggregates is used in the UK, USA, Japan, the Netherlands, Germany, since the 30s [45-47]. In bridge construction in the USA, light concrete is used mainly for small and medium spans, as well as slabs of the roadway of large girder and suspension bridges.

An example of such bridges is the Verrazano Narrows suspension Bridge in New York, the largest in the world by span (1,298 m). The bridge is two–tiered, each level has a roadway with a width of 6 lanes for motor transport. Despite heavy traffic, after 7 years of operation, the wear of the lightweight concrete slab of this bridge was no more than 1 sm from the original thickness [45].

For the first time, lightweight concrete was used in the construction of two bridges over the Cape Cod Canal (Massachusetts) with a length of 700 m with four traffic lanes, the main span of 185 m is made in the form of a steel through arch, the superstructure is suspended. The roadway is made of 18 cm thick slabs of prestressed lightweight concrete, the surface of which is covered with a 5 sm thick layer of asphalt. In 1964, the traffic intensity reached 50 thousand cars per day. By that time, the asphalt concrete pavement was badly damaged and, in addition, due to the frequent use of salts as an anti-icer, the concrete in the drainage system collapsed. In 1981, the roadway of both bridges was replaced with slabs of light concrete. Thus, the use of lightweight concrete in the structures of bridges across the Kane-Cod Canal has ensured more than 45 years of their operation with only one major repair.

In the UK , the first road bridge made of prestressed lightweight concrete was built in 1969 . The bridge over the river Reed in Northumberland County had a span of 17 m with a roadway width of 3.6 m . The cross section consisted of eight prefabricated prestressed beams united by a monolithic slab of the roadway. For light concrete, a filler "Litag" (a type of expanded clay) was used. The concrete density of the main beams was 1890 kg/m^3, the concrete strength on the 28th day was 49.0 MPa. Then several more road bridges were built in England from similar lightweight concrete /85/.

The experience of using lightweight concrete in civil construction in the Netherlands and specially conducted studies allowed it to be recognized as suitable for bridge construction. The first bridge made of light concrete, which is experimental, was built in 1968 on the Buiten-Laide canal. With a total length of 49 m, it included 3 spans of 15.5 m each, covered with split beam superstructures. In each span, 16 factory-made beams were installed, prestressed according to the Dividag system. In the manufacture of beams, a light filler berwilite was used, obtained by swelling from shale. The actual strength of concrete was obtained 32.0-35.0 MPa, density 1660 – 1690 kg / m^3, tensile strength determined by splitting 2.5–3.0 MPa. Depending on the age of the concrete, the stress state and the loading speed, the modulus of elasticity varied from 16500 to 21700 MPa.

The new superstructure was designed with continuous beams according to the scheme 2x13.4+16.0+2x13.4+10.5 m. It was built on a scaffolding of monolithic concrete with prestressed beams according to the Freissinet system. Carlin was used as a placeholder. Later, light concrete was used to plate the roadway in the steel-reinforced concrete bridge "Tolen" on the Eastern Schel-da-Rhine Canal. Bridge diagram 49,9+140,0+49,9 M. The central span is reinforced with a flexible arch. The use of light concrete in the slab instead of heavy made it possible to reduce the constant load by 680 tons . We used lightweight concrete of class B40–B45 with corlin filler, which, as it became known by this time, gives the best performance in structures. As a result of the use of light concrete instead of heavy, significant savings in the cost of construction were obtained.

The experience of constructing bridges described above in the Netherlands made it possible to use light concrete in larger and more complex structures. So, 3 bridges were built on the Maas-Waal canal according to the scheme 38,3+112,2+38,3 M. Several variants of these bridges were compared, the cheapest was a variant of a girder box-shaped superstructure made of light concrete in the central span. The height of the beams is variable, from 2.0 m in the middle of the central span to 4.5 m above the intermediate supports. In the coastal spans, concreting was carried out currently it is used in any spans overlapped by reinforced concrete superstructures. on scaffolding, and in the central span – by a hinged method from two sides. Corlin was used as a filler for concrete. The calculation was based on concrete class B40, modulus of elasticity 21,000 MPa, density 1900 kg/m^3, allowable compressive stress at bending 13.0 MPa, tensile strength - 0.5 MPa, shrinkage and creep – 20% more than that of heavy concrete. The use of lightweight concrete in the central span made it possible to reduce the weight by 26% and reduce the length of the coastal spans from 47 to 37 m and thus reduce the total length of the bridge and, accordingly, its cost [45-47].

In the following years, lightweight concrete was used in the Netherlands on a number of other major bridges. So, on the Vaal River near the city of Thiel, light concrete was used to manufacture a suspended span structure with a length of 65.0 m of a girder-cable-stayed bridge made according to the scheme 77,5+95,0+267,0+95,0+ 77,5 Light concrete is also used in the central spans of large bridges, similar to those described above on the Maas-Waal canal. These are the Zutphen Bridges on the Issel (78,2+125,8+74,8 m), Ravensway on the Amsterdam Canal (78,75+150,5+78,75 m), Houten on the Amsterdam–Rhine canal (75+143+75m), Zoolen on the same canal (78.75+4x150,5+78.75 m) and Arnhem (73,6+136,5+73,6 m) [45-47]. Thus, great strides have been made in the Netherlands in the use of lightweight concrete in bridge construction and

References:

1. Raupov, Ch., Shermukhamedov, U., & Karimova, A. (2021). Assessment of strength and deformation of lightweight concrete and its components under triaxial compression, taking into account the macrostructure of the material. In E3S Web of Conferences (Vol. 264, p. 02015). EDP Sciences.

2. Raupov, Ch., Karimova, A., Zokirov, F., & Khakimova, Y. (2021). Experimental and theoretical assessment of the long-term strength of lightweight concrete and its components under compression and tension, taking into account the macrostructure of the material. In E3S Web of Conferences (Vol. 264, p. 02024). EDP Sciences.

3. Lightweight Aggregate Concrete. Codes and standards. State-of-art report prepared by Task Group 8.1. CEBFIP (fib), Stuttgart, – 1999. – 44 p.

4. Lightweight Aggregate Concrete. Recommended extensions to Model Code 90 International Federation for Structural Concrete (fib). Task Group 8.1. – Stuttgart, 2000. – 258 p.

5. Raupov Ch.S. Expanded clay concrete for transport construction: Monograph /Tashkent: Tamaddun, 2020. – 356 p.

6. Зыонг Тхань Куй. Высокопрочные легкие фибробетоны конструкционного назначения. Дисс. на соискание ученой степени кандидата технических наук. Национальный исследовательский московский государственный строительный университет. Москва. 2020. – 201 с.

7. Баженов Ю.М. Технология бетона. Издательство Ассоциации строительных вузов. М. 2003. 499 с.

8. Королев, Е.В. Методика оценки экономической целесообразности внедрения нанотехнологии / Е.В. Королев, А.А. Чевычалов // Нанотехнологии в строительстве. 2012. №2. с. 25–31.

9. Звездов, А.И. Высокопрочные легкие бетоны в строительстве и архитектуре / А.И. Звездов, В.Р. Фаликман // Жилищное строительство. 2008. № 7. С. 2–6.

10. Spitzner J., Thienel K.C. Hochfester Leichtbeton – Ein europäisher Baustoff mit Zu- kunft // Darmstädter MassivbauSeminar. Bd. 15: Betonbau in Europa. Technische Hochschule. Darmstadt, 1996.

11. Holm, T.A. Performance of structural lightweight concrete in a marine environment/T.A. Holm // American Concrete Institute. 1980. Vol. 65. P. 589–608.

12. Seabrook, P.I. High strength lightweight concrete for use in offshore structures: utilisation of fly ash and silica fume / P.I. Seabrook, H.S. Wilson // International Journal of Cement Composites and Lightweight Concrete. 1988. Vol. 10. № 3. P. 183–192.

13.Mays, G.C. The performance of lightweight aggregate concrete structures in service / G.C. Mays, R.A. Barnes // The Structural Engineer. 1991. Vol. 69. № 20. P. 351–361.

14. Ries J.P., Holm T.A. A Holistic Approach to Sustainability for the Concrete Community-Lightweight Concrete-Two Millennia of Proven Performance. 2004. Information Sheet 7700. 1 ESCSI, Salt Lake City, Utah. – 15 p.

15. ACI-213R-14 Guide for Structural Lightweight Concrete American Concrete Institute. 2014.

1. 16. Wu, Y. Development of ultra-lightweight cement composites with low thermal conductivity and high specific strength for energy efficient buildings / Y. Wu, J.Y. Wang, P.J. Monteiro, M.H. Zhang // Construction and Building Materials. 2015. Vol. 87. P. 100–112.

17. Zhang, M.H. Permeability of high-strength lightweight concrete / M.H. Zhang, O.E. Gjorv // CI Materials Journal. 1991. Vol. 88. № 5. P. 463–469.
18. Holm T.A., Bremner T.W. State-of-the-art Report on High-strength, Highdurability Structural Low-density Concrete for Applications in Severe Marine Environ- ments, US Army Corps of Engineers. Report No. ERDC/SL TR-00-3 // Engineer Re- search and Development Center. 2000.
19. Hoff G.C. Guide for the use of low-density concrete in civil works projects. –US Army Corps of Engineers. Engineer Research and Development Center, ERDC/GSL TR-02-13 (TR INP-02-7). 2002.
20. Holm T.A., Bremner T.W. State of the art report on high strength, high durability structural low-density concrete for applications in severe marine environments. US Army Corps of Engineers, Engineering Research and Development Center. ERDC/SL TR-00-3. 2000.
20. Raupov, C., & Malikov, G. (2022). DETERMINATION OF PHYSICAL AND STRUCTURAL-MECHANICAL CHARACTERISTICS OF EXPANDED CLAY CONCRETE. Science and innovation, 1(A5), 264-275.
21. Mehta P.K., Monteiro P.J.M. Concrete: microstructure, properties, and materials (3rd ed.). McGraw-Hill. New York. 2006.
22. Фаликман, В.Р. Высокопрочный легкий бетон: технология и свойства / В.Р. Фаликман, Ю.В. Сорокин, О.М. Горячев // Бетон и железобетон. 2005. № 2. С. 8-11.
23. Иноземцев А.С., Королев Е.В. Динамика развития высокопрочных лёгких бетонов. Анализ мировых достижений // Международный научно-исследовательский журнал = Research journal of international studies, 2013. – №12-1 (19). – С. 87-94.
24. Choi, J. Influence of fiber reinforcement on strength and toughness of all- lightweight concrete / J. Choi, G. Zi, S. Hino, K. Yamaguchi, S. Kim // Construction and Building Materials. 2014. № 69. P. 381-389.
25. Iqbal, S. Mechanical properties of steel fiber reinforced high strength light- weight self-compacting concrete (SHLSCC) / S. Iqbal, A. Ali, K. Holschemacher, A.T. Bier // Construction and Building Materials. 2015. Vol. 98. P. 325-333.
26. Thai, K. C. Anh huong cua keramzit den cuong do chiu nen cua be tong /K.C. Thai, D.H. Pham, T.C Dang.// Tap chi khoa hoc Giao thong van tai 2016. Vol. 50. P. 3-8.
27. Ч. С., Р. ., Г. Б., М. ., & Ж. Ж., З. . (2022). Методика Испытания Керамзитобетона При Кратковременном И Длительном Испытании На Сжатие И Растяжение И Измерительные Приборы. Miasto Przyszłości, 25, 336–338. Retrieved from http://miastoprzyszlosci.com.pl/index.php/mp/article/view/390
27. Felipe Basquiroto de Souza, Oscar Rubem Klegues Montedo, Rosielen Le- opoldo Grassi, Elaine Gugliemi Pavei Antunes Lightweight high-strength concrete with the use of waste cenosphere as fine aggregate // Matéria (Rio J.) 2019 vol.24 no.4, 10.1590/s1517-707620190004.0834
28. Rossignolo, J.A. Properties of highperformance LWAC for precast structures with Brazilian lightweight aggregates / J.A. Rossignolo, M.V.C. Agnesini, J.A. Morais // Cement and Concrete Composites. 2003. Vol. 25. P. 77–82.
29. Holm T.A., Bremner T.W. State-of-the-Art Report on High-Strength, High- Durability Structural Low-Density Concrete for Applications in Severe Marine Environ- ments. 2000.

30. Исаев, В.Ф. Керамзитобетон в мостостроении / В.Ф. Исаев // Тезисы докладов 111 Всесоюзной конференции по легким бетонам. – М.: Стройиздат. – 1985. с. 146–147.
31. Clarke, J.L. Structural Lightweight Aggregate Concrete / J.L. Clarke // Pub- lished by Blackie Academic & Professional, an imprint of Chapman & Hall, Wester Cleddens Road, Bishopbriggs, Glasgow G64 2NZ. – Taylor & Francis e-Library. – 2005. – 148 P.
32. Holland R.B. High Strength Lightweight Concrete Properties of the I–85 Ramp over State Route 34 / R.B. Holland, F.L. Kahn // HPC Bridge Views. – Issue 61, May/June 2010. P. 1–10.
33. Liles P. High Strength Lightweight Concrete for Use in Precast, Prestressed Concrete Bridge Girders in Georgia / P. Liles, R.B. Holland // HPC Bridge Views. – Issue 61, May/June 2010. P. 1–10.
34. Weiss, W.J. Improving Concrete Bridge Decks with Internal Cur- ing, Concrete / Di C. Bella, D.P. Bentz // Bridge Views. – Iss.69. – 2013.
34. Ch. Raupov, G. Malikov, & J. Zokirov (2022). DETERMINATION OF THE BOUNDARY OF THE LINEAR CREEP OF EXPANDED CLAY CONCRETE DURING COMPRESSION. Science and innovation, 1 (A4), 301-306. doi: 10.5281/zenodo.6981518
35. Фаликман, В.Р. Высокопрочный легкий бетон: технология и свойства / В.Р. Фаликман, Ю.В. Сорокин, О.М. Горячев // Бетон и железобетон. – № 2. – 2005 с. 8–11.
36. CEB–FIP Model Code for Concrete Structures. – Vol. II: 3rd edition CEB. – Paris. – 1978.
37. Dunbeck, J. Evaluation of High Strength Lightweight Concrete Precast, Prestressed Bridge Girders, Master's Thesis // Georgia Institute of Technology, – 2009, – 186 pp.
38. Гузенко С.В. О применении конструкционных легких бетонов в мостостроении / Транспортное строительство. – №9. – 2007. с. 10–13.
39. В.В. Бондарь. Конструкционный керамзитобетон в строительстве. Опыт и перспективы применения. (Белорусский национальный технический университет, Минск). Вестник Польского государственного университета. Серия F. Строительство. Прикладные науки. Строительные конструкции. №8. 2018. с. 112–120. https://journals.psu.by/constructions/article/view/241/191
40. Легкий наноструктурированный бетон для мостостроения. По материалам компании НТЦ Прикладных Нанотехнологий.
http://rkstroy.ru/consult/nanostrukturirovanniy_beton/
41. Ярмаковский В.Н. Легкий бетон: настоящее и будущее / В.Н. Ярмаковский., Т.У. Бремнер // Строительный эксперт. 2005. № 20. с.3– 4.
41. Bahromkulovich, M. G. (2022). DESIGN OF A SPAN BEAM OF A BRIDGE MADE OF TRIANGULAR CROSS SECTION BEAMS MADE OF MATERIALS WITH DIFFERENT PHYSICAL AND MECHANICAL PROPERTIES.
42. Житкевич, Р.К. Высокопрочный легкий бетон / Р.К. Житкевич, К.М., Кац // Всесоюзный семинар «Эффективные конструкции из легких бетонов» Тезисы докладов. Госстрой СССР. М. 1980. с. 73–75.
43. Technical Report Ishikawajimaharima // Evaluation of fatigue durability precast PC slab lightweight high-strength, 2004. Vol. 44, №.2. P. 83–90.
44. Document BE96 – 3942/R14. Structural LWAC: Specification and guideline for materials and production, 2000. p. 69.

45. Строительные решения / Зарубежный опыт применения керамзита в строительстве. Использование керамзитобетона для строительства мостов. 14 Июля 2017. http://proekt.by/index.php?action=profile;u=33
46. Деллос К. П. Керамзитобетон в мостостроении. –М.: Транспорт.1986. –184с.
47. Кузьмич, Д. Н. Опыт применения конструкционного керамзитобетона в зданиях и сооружениях / Д. Н. Кузьмич ; науч. рук. П. В. Кривицкий // Сборник конкурсных научных работ студентов и магистрантов : в 2 частях / Министерство образования Республики Беларусь, Брестский государственный технический университет ; редкол.: Н. Н. Шалобыта [и др.]. – Брест : БрГТУ, 2021. – Часть 1. – С. 213–216. https://rep.bstu.by/handle/data/27652.