CONCRETE FOR ROAD PAVING USING FIBRE AND RECYCLED AGGREGATES

Andrey MISHUTIN [1],
Vladimir ISKOV [2],

[1]Doctor of Technical Sciences, Prof., Odessa State Academy of Engineering and Architecture Ukraine, Odessa
[2]Graduate student, Odessa State Academy of Engineering and Architecture Ukraine, Odessa

ABSTRACT: *Wartime requires innovative approaches to the development of materials and structures capable of providing increased reliability, compressive strength, bending strength, as well as impact strength for the protection of critical infrastructure facilities, in particular energy and transport systems. In the laboratory of the Department of Roads and Airfields, experimental studies of concrete are carried out with the aim of creating materials that meet the requirements of modern conditions. During the period of new construction and reconstruction of new buildings, there is a great need for automobile roads. In the study of concrete for highways, we used metal, basalt and polymer fiber, as well as chemical additives.*
Based on the conducted research, with a number of additives from the Mapei company (superplasticizer, anti-corrosion additive, clogging additive, air-entraining additive, fiber), the following results were obtained:

- *mobility of the concrete mixture in the range from 8 to 18 cm (S-3);*
- *air entrainment - from 3 to 4%, which will allow to obtain frost-resistant concrete;*
- *compressive strength for 28 days - ≥55 mPa, with water absorption up to 2%.*

The requirements of regulatory documents allow the use of secondary materials for the concrete of the base of the upper layer of the road surface. That is, crushed structures in fractions: up to 10 mm; 10-20 mm; 20-40 mm. They can be used after laboratory studies, physical and mechanical characteristics and development of recommendations.
These results make it possible to create concrete with significantly increased operational characteristics, which are necessary to ensure the reliability of objects in wartime conditions.

Key words: *concrete, fiber concrete, road surface, road slabs, aggregates, secondary aggregates, fiber, metal fiber, basalt fiber, polymer fiber, durability.*

Wartime requires innovative approaches to the development of materials and structures that can provide increased reliability, compressive and bending strength, as well as impact strength to protect critical infrastructure, including energy and transport systems.

At the current stage in Ukraine, special attention is being paid to infrastructure development, in particular road construction using cement concrete pavement and rigid pavement layers.

The experience of road construction and maintenance in the European Union, the USA and other developed countries shows that the use of cement concrete has its advantages over other materials. These include increased resistance to rutting, less need for regular maintenance, and increased resistance to environmental influences [1].

The use of modified fibre-reinforced concrete is an opportunity to improve the quality and durability of road pavements and expand the range of materials for transport projects.

In the climatic conditions of Ukraine and most European countries, the main indicators that ensure the durability of rigid pavements are frost resistance and wear resistance of concrete [2].

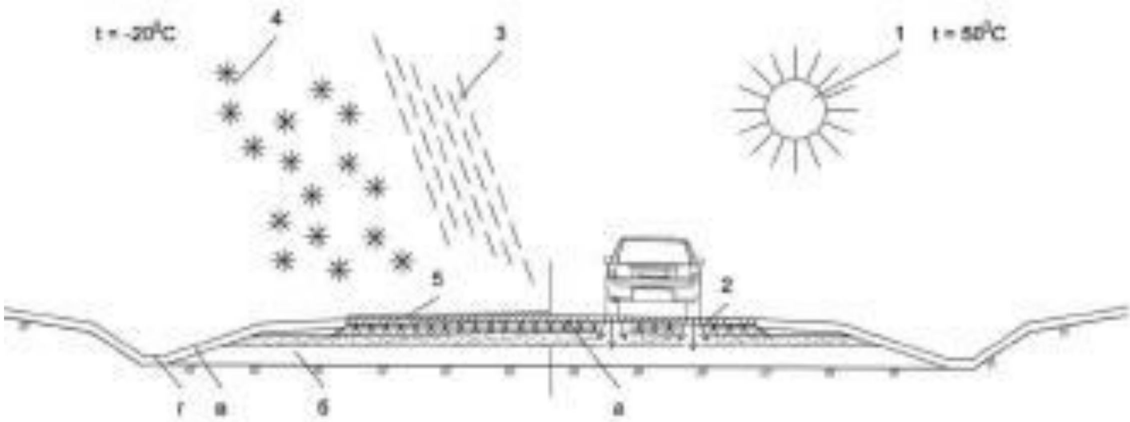

Figure 1. Influence of operational factors on road pavements
a - road pavement; b - subgrade; c - slopes; d - ditches; 1 - impact of temperature -20...+50 °C; 2 - load from vehicles; 3 - rain; 4 - snow; 5 - salt ingredients

The aim of the study is to develop modified fibre-reinforced concrete for rigid pavements and infrastructure transport facilities. Analysis of the combined effect of fibre on the structure and properties of concrete and fibre-reinforced concrete for rigid pavements.
The study used metal, basalt and polymer fibre.

The study of fibre-reinforced concrete properties was carried out using the methods of experiment planning and experimental and statistical modelling (ES-model) based on the optimal 15-point symmetric plan.
Initial materials:

- Portland cement PC I-500 R-N produced by PJSC «Dickergoff Cement Ukraine»;
- Quartz sand from Nikitovsky quarry, Mkr = 2.0;
- Basalt fibre BAUCON®-bazalt with a fibre length of 12 mm and a diameter of 18 µm. The fibre was manufactured by Bautek-Ukraine LLC.

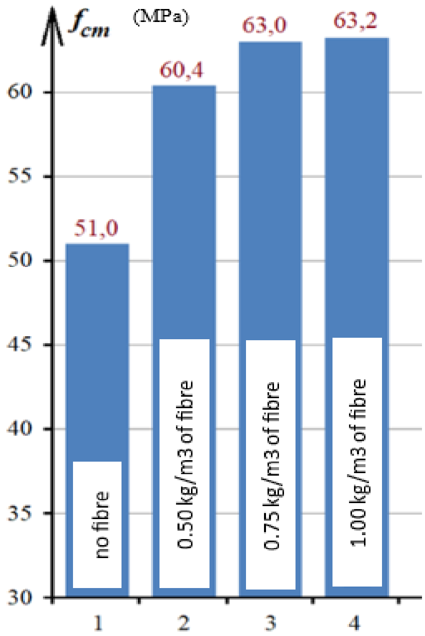

Figure 2. Compressive strength of concrete

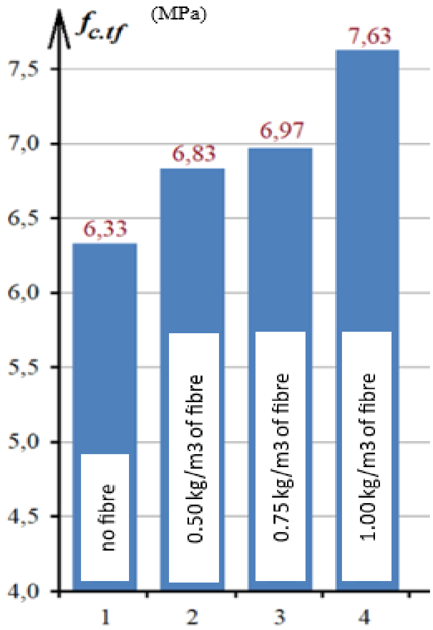

Figure 3. Tensile strehgth in concrete bending

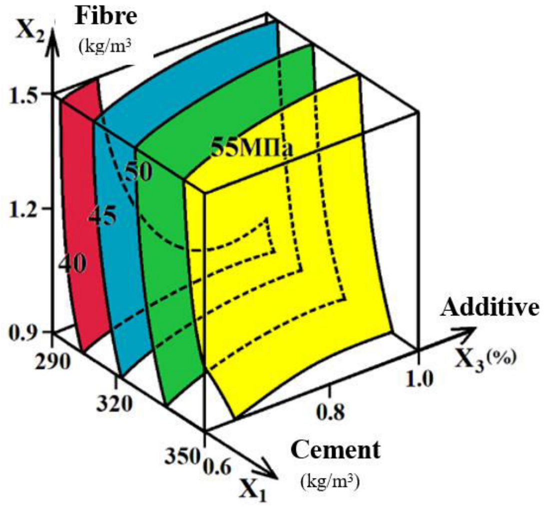

Figure 4. Compressive strength of fibre reinforced concrete at the age

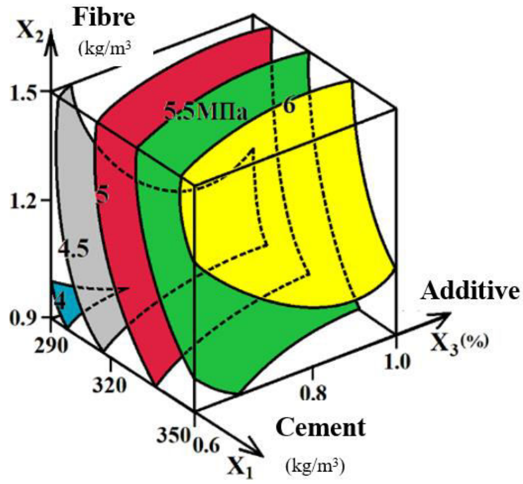

Figure 5. Flexural tensile strehgth of fibre-reinforced concrete at 28 days of age

When using BAUCON®-bazalt fibre in the amount of 0.75-1 kg/m3, the compressive strength of concrete increases by 13-24%, the tensile strength in flexion increases by 21-29% (Fig. 2-4) [3].

In recent years, polypropylene fibre has been widely and successfully used in concrete of rigid pavements. Polypropylene fibre is randomly distributed in the concrete matrix, which provides strength in all directions, and the hydrophobic surface of the fibres is poorly wetted by the cement dough, which prevents the fibre from being crushed when the mixture is mixed [4]. Polypropylene fibre is one of the most environmentally friendly materials for the production of fibre-reinforced concrete for rigid pavements, as it allows for the lowest carbon emissions in the production of the final material.

The single-factor diagrams constructed according to the experimental and statistical model (hereinafter: ES model), reflecting the influence of the varied composition factors on the flexural tensile strength of the studied concrete and fibre concrete of rigid pavements at the age of 28 days in the zones of extremes, are shown in Fig. 6.

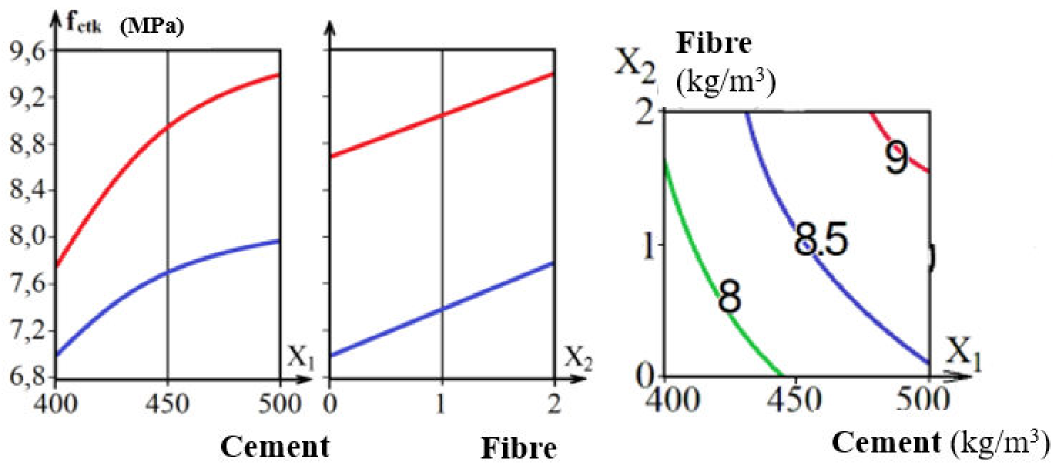

Figure 6. Effect of varying composition factors on the tensile strength of concrete and fibre-reinforced concrete at 28 days in the extremes

The analysis of the diagrams shows the influence of cement and fibre composition factors on the value of tensile strength in flexure of the studied concrete and fibre-reinforced concrete at the age of 28 days.

Dispersed reinforcement with polypropylene fibre is an effective method of increasing the resistance of concrete to tensile stresses. Due to the use of fibre in the amount of 1.5-2 kg/m3, the tensile strength in flexure of concrete of rigid pavements increases by 0.6...0.8 MPa, which is explained by the ability of fibres to absorb tensile stresses [1].

Metal fibre is often used for concrete pavements. It proves to be effective in improving the tensile strength and crack resistance of concrete, and also has a positive effect on the compressive strength. Thanks to the use of metal fibre [5, 6], it was possible to reduce the thickness of the cement concrete pavement layer without deteriorating its operational properties.

The concrete of 2 road slabs 1P30.18.30 reinforced concrete slabs for urban roads with dimensions of 3000*1750*170 mm was studied.
The first one was without fibre (hereinafter referred to as A), the second one - with fibre (hereinafter referred to as B) [7, 8].

The cores were drilled with a Gölz core sampler model KB200, drilling diameter 150 mm.

Figure 7. Drilled cores of the slab

The compressive strength was determined on a hydraulic press MS-1000.

Figure 8. Testing a core of a reinforced concrete road slab on a press

Table 1.

Results of calculation of compressive strength

№/№	*№ core*	*Compressive strength, mPa*	
1	A1	29,7	No fibre
2	A2	28	
3	B1	36,1	With fibre
4	B2	37,2	

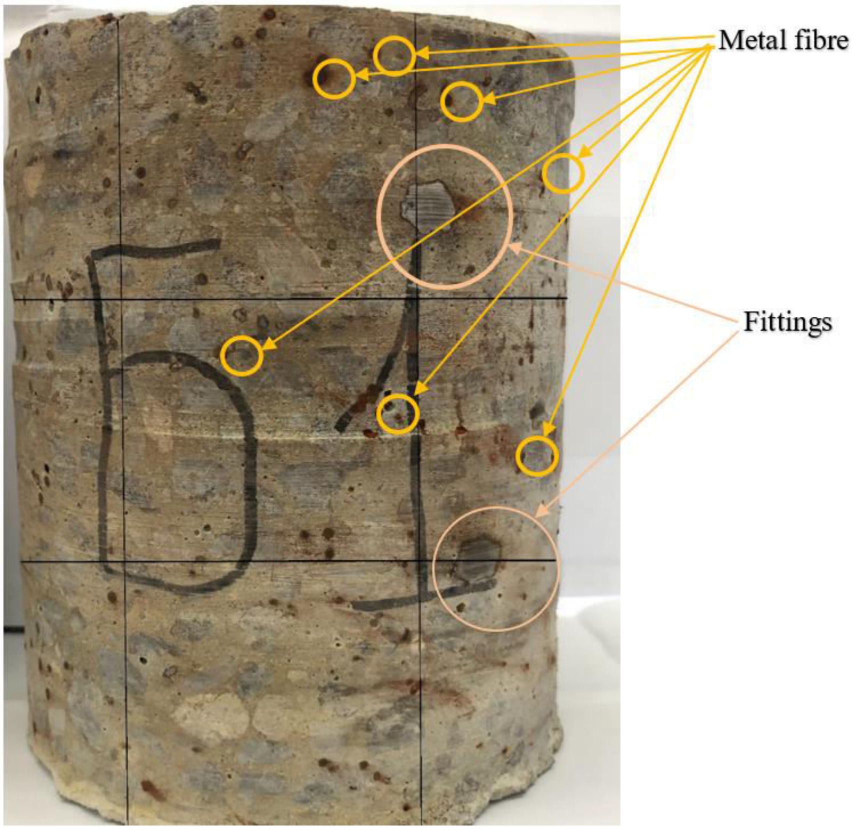

Figure 12. Determination of fibre distribution

After researching and analysing the concrete of 1P30.18.30 road slabs, the following conclusions can be drawn [7, 8]:

1) Concrete with fibre (slab B) has a higher compressive strength of 8.8 mPa, which is 24.38% of concrete without fibre, and amounts to 36.1 mPa.
2) The water saturation of concrete with fibre (slab B) is 55 g more than that of concrete without fibre (slab A), which is 0.8%.
3) Metal fibre - corrodes very quickly when saturated with water, and comes out, thus damaging car wheels - is not recommended for road construction.

The choice of fibre should always be made based on the functional purpose of the structures and their operating conditions, taking into account the types of corrosive effects [9]. In regions where salts are used to combat ice in winter, rapid corrosion of steel fibres is observed. It has been established that under the influence of atmospheric influences, polypropylene fibres provide better durability of concrete than steel fibres, which lose their properties faster. In particular, alkali-resistant fibre is used in road fibre concrete [10]. Therefore, for road pavements in countries with cool and temperate climates, such as Ukraine and Moldova, it is advisable to use non-metallic fibres, primarily polymeric, basalt and glass fibres [1].

The use of aggregates from recycled materials is allowed for concrete of road pavement bases.

Research objective: development of concrete compositions for pavement bases using secondary aggregates. The use of dismantling products of buildings and structures during the reconstruction period as part of their life cycle.

A large amount of construction waste is generated for recycling into secondary aggregates due to destruction caused by military aggression, destruction caused by earthquakes and other natural disasters, dismantling of physically and morally obsolete buildings.

The materials used in the study are secondary aggregates (Fig. 13-16) [11]:

Figure 13. Secondary crushed stone and sand from concrete structures (fractions 0-5, 5-10, 10-20 mm)

Figure 14. Secondary crushed stone from masonry and ceramic tiles (fractions of 8-16 mm)

Figure 15. River gravel (fractions 8-16 mm)

Figure 16. Secondary crushed stone with a heterogeneous composition (fractions 8-16 mm)

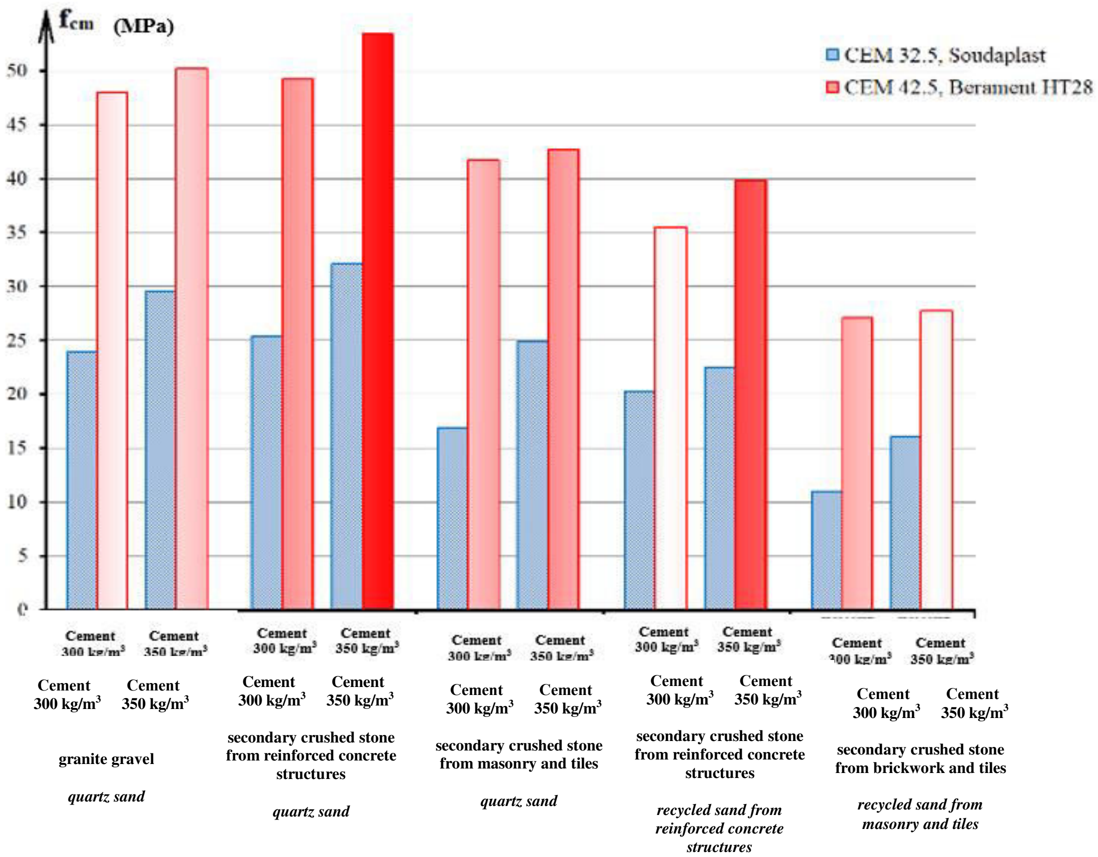

Figure 19. Strength of the tested concrete at the age of 28 days

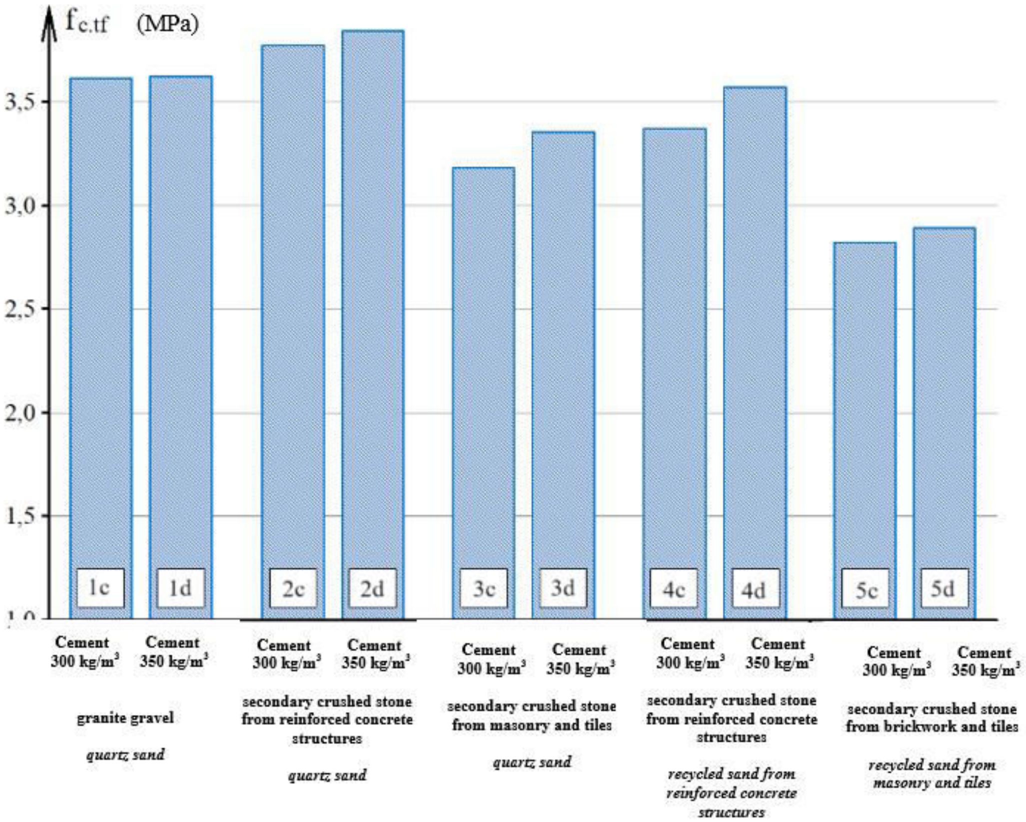

Figure 20. Flexural tensile strength of the tested concrete of the second series

The properties of concrete with different types of coarse aggregate (river gravel, recycled crushed stone from recycled reinforced concrete structures, recycled crushed stone from recycled masonry and ceramic tiles) and sand (quartz, recycled from recycled reinforced concrete structures, recycled from recycled masonry) were studied (Figs. 19-20). It was found that concretes based on secondary aggregates have a compressive strength of up to 45 MPa, tensile strength in bending of up to 3.84 MPa, and frost resistance of F100 [11].
The possibility of using recycled crushed stone with a heterogeneous composition for the manufacture of concrete for road pavement bases has been proven.

The research results make it possible to create concrete with significantly improved performance characteristics necessary to ensure the reliability of facilities in wartime, as well as during the reconstruction and rehabilitation of structures.

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