FEATURES OF WORK AND SCOPE OF APPLICATION OF CRUSHED STONE-MASTIC EXPANSION JOINTS OF BRIDGE STRUCTURES

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Abstract: The paper discusses various aspects of the use of crushed stone-mastic expansion joints in bridge structures, describes the main existing problems and ways to solve them. The experience of application, advantages and disadvantages of this type of expansion joints are given, as well as the scope of their application at the current stage of bridge construction development is outlined.

Key words: Binder, bitumen, mastic, zazaor sealer, metal plate, crushed stone, elastic band.

Аннотация: В работе рассматриваются различные аспекты применения в мостовых сооружениях щебеночно-мастичных деформационных швов, описаны основные существующие проблемы и пути их решения. Приведены опыт применения, достоинства и недостатки данного типа деформационных швов, а также очерчена область их применения на современном этапе развития мостостроения.

Ключевые слова. Вяжущий материал, битум, мастика, уплотнитель зазора, металлическая пластина, щебень, эластичная полоса.

The main part. For the first time applied in Europe, crushed stone-mastic expansion joints have been widely used in Russia, including in our Republic, in recent years. Organizations specializing in the production of expansion joints of various structures and small firms that produce mainly binders for road construction, asphalt concretes, and in addition, as related products, also mixtures for filling crushed stone-

mastic expansion joints are engaged in the manufacture and installation of crushed stone-mastic expansion joints. By the way, this trend is also typical for foreign countries.

Crushed stone-mastic expansion joints are one of the simplest and most affordable structural solutions for expansion joints for bridges with low temperature displacements of spanswithin 5-40 mm [3,6,7] (in some cases up to 50 mm [1,4]). A typical modern design of this type of DSH is shown in Fig. 1.

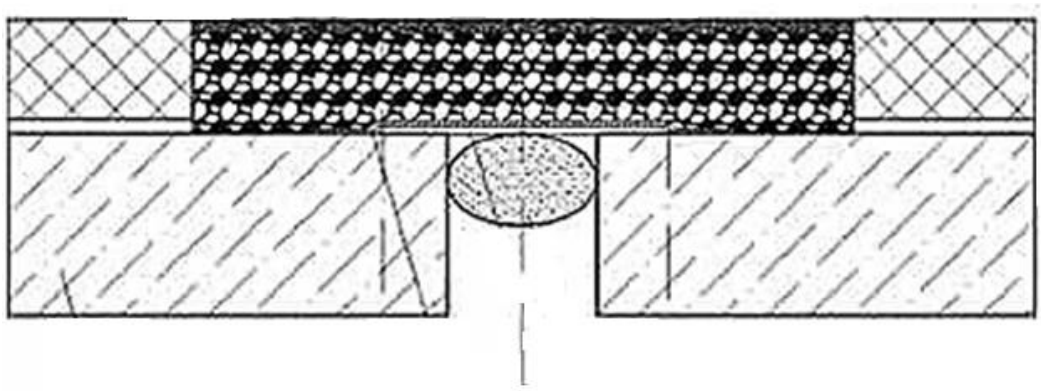

Fig. 1 Construction of a crushed stone-mastic expansion joint

In comparison with other joint designs, crushed stone mastic expansion joints have many advantages, the main ones of which are as follows [2]:

* simple construction of the expansion joint;
* easy repair and replacement of the expansion joint;
* high productivity in the construction of the expansion joint;
* water resistance of the seam;
* low noise emission when driving through the expansion joint;
* smoothness of the seam surface;
* the coefficient of adhesion of the expansion joint surface to the tire, close to the corresponding coefficient for road pavement;
* mobility in all directions;
* ease of manufacturing the component materials and the device of the expansion joint;
* self-healing of crushed stone and mastic mass in case of shallow damage;
* efficiency of the application;
* relatively low cost.

The prevailing opinion about the extreme simplicity of the design and technology of the device of crushed-mastic expansion joints has led to the fact that at present in our country, in the absence of regulatory documents regulating the technology of design, production of component materials and the device of crushed-mastic expansion joints, the expansion joints of this type are arranged on an increasing number of bridge structures, why it is becoming increasingly difficult to navigate among the variety of crushed stone-mastic expansion joints produced by specialized and non-specialized organizations. And it is absolutely impossible to evaluate the consumer properties of crushed stone-mastic expansion joints and develop a general approach to their design.

The situation with the irrational and unjustified design and use of crushed stone-mastic expansion joints, for example, in the USA [5,6,6], has already led to the realization by foreign experts that in matters related to crushed stone-mastic expansion joints, everything is more complicated than it seems at first glance. The result was the initiation of a special research program designed to provide engineers with an understanding of the specifics of the operation of crushed stone-mastic expansion joints in bridge structures and the development of guidelines for the design of crushed stone-mastic expansion joints [5] . Currently, it is established that, despite the undeniable advantages, crushed stone-mastic expansion joints are not free from maintenance and some other problems. The disadvantages of this type of expansion joints include [2]:

* tendency to form ruts, especially at elevated ambient temperatures, which leads to the appearance of unevenness of the pavement;

* tendency to crack formation at low temperatures, which leads to a violation of the waterproofness of the expansion joint;

* creep under load, especially at elevated ambient temperatures and the removal of the expansion joint filler from the seam penalty by passing transport wheels, especially when accelerating or braking it in the area of the crushed stone-mastic expansion joint;

* unsatisfactory operation of crushed stone-mastic expansion joints on superstructures operating for torsion, which results in the appearance of deformations that are uneven along the length of the expansion joint;

* unsatisfactory operation of crushed stone-mastic expansion joints in oblique superstructures and restrictions on the value of the angle of obliquity;

* restrictions on the maximum longitudinal slope of the bridge in the area of expansion joints;

* dependence of the physical and mechanical characteristics of the crushed stone-mastic mixture on the ambient temperature;

* the dependence of the technical and operational characteristics of crushed stone-mastic expansion joints on the geometric dimensions of the fine, the amount of crushed stone-mastic mixture laid, the correctness of its composition, and compliance with the laying technology;

Thus, crushed stone-mastic expansion joints can hardly be considered a universal solution for bridge expansion joints in the specified displacement range. The scope of application of the expansion joint with crushed stone-mastic filling is currently limited to the following cases [2]:

• use as expansion joints on a permanent basis on reinforced concrete and steel-reinforced concrete straight bridges with longitudinal displacements of the ends of superstructures up to 50 mm (optimally 5...40 mm), vertical ones-up to 3 mm, with maximum longitudinal slopes in the area of the crushed stone-mastic expansion joint up to 40 ppm and a cosine angle in the plan up to 45°, uniform vertical and horizontal movements across the width of the span section (no torsion of the spans and bending in the plan), provided that the crushed stone-mastic expansion joint is located outside the areas of acceleration and deceleration of transport and the bridge profile fracture (different slopes of adjacent spans);

• use it as a temporary database.

It is also possible to identify a number of limitations that are imposed on crushed stone-mastic expansion joints even in the design process and are associated with the current difficulties in calculating such structures, designing crushed stone-mastic mixtures and selecting materials for them. Therefore, when laying crushed-mastic expansion joints in the structure of a bridge structure, and even more so, when designing the structure of

such a expansion joint itself, it is necessary to keep in mind some essential features of their operation, given below.

First, the rubble-mastic joint material must be flexible enough to accept the movement of the bridge due to temperature fluctuations, remain watertight and ensure a smooth transition of transport from one superstructure to another. This suggests the need to design crushed stone-mastic mixtures with a stiffness as close as possible to the stiffness of the adjacent road surface and having good adhesion, both to the materials of the road surface and to the material of the roadway plate, which can deform at low temperatures and be resistant to cracking, especially at low temperatures.

The results of studies [5] show that so far, even at the lowest operating temperature (about -40°CC) the stiffness indicators of the crushed-mastic material of the expansion joint and the road surface (these indicators are taken as elastic modules defined for the material of the expansion joint and the road surface as for a solid material) differ approximately twice, the lower value corresponds to the material of the crushed-mastic expansion joint.

As for the indicators of adhesion-adhesion of the crushed stone-mastic expansion joint material to the road surface and the roadway slab along the main contact surfaces, it is necessary to distinguish between adhesion under normal and tangential load application (in relation to the considered contact surface of the mixture of filling and structures of superstructures and road surface). If there is insufficient normal adhesion, cracks are formed along the axis of the crushed stone-mastic expansion joint along the plane of contact of the crushed stone-mastic expansion joint and the road surface, if there is insufficient tangent-the separation of the crushed stone-mastic mass along the base of the expansion joint from the roadway plate.

As a rule, at any temperature, the tensile strength of crushed stone-mastic material is higher than the values of the normal tangential coupling, and the rupture along the contact surfaces will occur at stresses less than the yield stress of crushed stone-mastic material [5], even at the stage of plastic deformations.

The material of the expansion joint must retain the ability to deform by the required amount over the entire operating temperature range for a given area, so it is necessary to take into account the dependence of the characteristics of the material of the expansion joint on the ambient temperature, which has the following character. In the range from the maximum operating temperature to the glass transition temperature of the crushed stone-mastic expansion joint material, at which almost complete disappearance of plastic deformations occurs, the material behaves as viscoelastic with large deformations at the yield point. When passing through the glass transition temperature and further lowering the temperature, the material becomes brittle with a small yield point and is able to perceive a small elongation before breaking. Depending on the temperature, crushed stone-mastic material shows 0.5...7-fold elongation at the yield point (0.5 – at temperatures below the glass transition temperature, 7 - at maximum operating temperatures). Relative plastic deformations also depend on the temperature and are about 0.1...0.3% below the glass transition temperature, while they increase to 1...3% or more above this temperature [5].

Other physical and mechanical parameters of crushed stone-mastic mixtures are also a function of temperature. Thus, with a drop in temperature, the elastic modulus and yield stresses increase along a curve close to the exponent, and the relative plastic deformations also decrease, respectively. The adhesion indices on the main contact surfaces increase with decreasing temperature up to the glass transition temperature, and then their decrease is observed [5].

Attention should be paid to the nature of deformation of the viscoelastic crushed stone-mastic filling mass when working in the expansion joint structure.

It is impossible to ensure a uniform distribution of deformations over the entire width of the expansion joint due to various reasons, for example, heterogeneity of the material, structural design of the expansion joint. Therefore, during the temperature movement of the bridge, the compression of the material in the body of the expansion joint practically occurs only in the area of the section passing through one of the sides of the metal overlapping plate (Fig. 1, sections I or II). Then, this displacement, localized for a

small length, is redistributed toa larger length, the maximum value of which depends on the elastic modulus and can be limited structurally, for example, by an excessively small width of the expansion joint.

From the above, it can be seen that the main task of calculating a crushed stone-mastic expansion joint is to design a crushed stone-mastic mixture and the overall dimensions of the expansion joints, which at any temperature within the operating temperature range will ensure the redistribution of deformations to a sufficient length, the stresses on which will not exceed the permissible values for this material of the crushed stone-mastic expansion joint. It is also necessary to check the adhesion on the contact surfaces to ensure that there are no through cracks leading to functional failure of the joint (leaks).

In addition, one of the most important issues that determines the applicability of a particular crushed stone-mastic expansion joint on the territory of Russia is the issue of determining the minimum permissible operating temperature for a given crushed stone-mastic expansion joint. For example, all crushed stone-mastic expansion joints made by well-known manufacturers in the UK have a lower temperature limit of at least -30°C.
When testing crushed stone-mastic mixtures of three major American manufacturers, the maximum temperature at which internal stresses already lead to cracking of the sample reached -43°C in only one of themC, while the rest remained at -26 ... 27°C [5]. Therefore, the direct use of foreign crushed-mastic expansion joints and crushed-mastic materials in Russian bridges is unacceptable, since, excluding the southern regions, this requires a crushed-mastic expansion joint with a minimum operating temperature of -40°C or less. Apparently, the only solution in this area is the development of domestic crushed stone-mastic mixtures that meet these requirements.

Conclusion. Finally, a test for the formation of ruts, conducted as for samples of road clothing [5], showed that the maximum depth of track on crushed-mastic expansion joints is formed when the number of test cycles is two times less than the minimum value for road clothing. Thus, the track must necessarily be formed on the material of the expansion joint and the functional service life of the crushed-mastic expansion joint

according to this indicator should be less than the service life of the road surface. Taking into account these problems, some foreign experts recommend macadam-mastic expansion joints for use as temporary expansion joints [3] and with some risk – for permanent use.

Some manufacturers of crushed stone-mastic expansion joints currently claim a complete solution to the rut problem, but they do not provide any experimental confirmation of their words. A number of domestic manufacturers also talk about the service life of crushed stone-mastic expansion joints, estimated at 8-10 years, but the author has not yet been able to find confirmation of these figures.

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