Technical Sciences. Architecture and Construction

DOI: https://doi.org/10.63377/3005-4966.2-2025-02
UDC: 69.033.8
IRSTI: 67.09.05

Expansion joints and the interface zone of road pavement on bridges and overpasses

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Received:
06 May 2025
Peer-reviewed:
19 May 2025
Accepted:
20 June 2025

Abstract

When actual intensity of transport traffic considerably exceeds the planned values, it leads to accelerated wear of road surface and formation of rutting. This problem is actual on high-speed main streets of Almaty city. Rutting in asphalt concrete pavement, especially in the areas of expansion joints, causes impacts of motor vehicles' wheels on the ends of joints (metal trims). Such loads lead to rapid failure of all expansion joints that are fixed in the roadway.

It is obvious that the increase in traffic volume contributes to the increase in damage, but it is worth noting that uniform loading with a certain frequency leads to the same result, whereas impact loads occurring after the appearance and progression of damage have a much more damaging effect. To date, most efforts to reduce potholes and rutting at joints with expansion joints have focused on reducing rutting, especially in the areas adjacent to expansion joints. To solve this problem, various constructive solutions of the junction of the bridge pavement with the expansion joint have been proposed, including: the use of transition zones, the introduction of concrete tributaries, the use of damping polymer concrete tributaries (edgings).

Keywords: defects of asphalt concrete pavement, expansion joint, edging, rubber compensator.

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Техникалық ғылымдар. Сәулет және құрылыс

DOI: https://doi.org/10.63377/3005-4966.2-2025-02
ӘОЖ: 69.033.8
ҒТАМР: 67.09.05

Көпірлер мен эстакадалардағы жол жабынының компенсаторлары мен түйіспе аймағы

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Мақала келді:
06 мамыр 2025
Сараптамадан өтті:
19 мамыр 2025
Қабылданды:
20 маусым 2025

Түйіндеме

Көлік қозғалысының нақты қарқындылығы жоспарланған мәндерден едәуір асып кетсе, бұл жол жамылғысының тез тозуына және ойықтардың пайда болуына әкеледі. Бұл мәселе Алматы қаласының жүрдек магистральды көшелерінде өзекті болып отыр. Асфальтбетон төсемдеріндегі, әсіресе компенсаторлық түйіспелердегі ойықтар автокөлік дөңгелектерінің түйіспелердің ұштарына (металл жиектерге) әсер етуіне әкеледі. Мұндай жүктемелер жүріс бөлігінде бекітілген барлық компенсаторлардың тез істен шығуына әкеледі.

Трафик көлемінің ұлғаюы залалдың ұлғаюына ықпал ететіні анық, бірақ белгілі бір жиіліктегі біркелкі жүктеме бірдей нәтижеге әкелетінін атап өткен жөн, ал зақымданудың пайда болуы мен өршуінен кейін пайда болатын соққы жүктемелері.әлдеқайда жойқын әсер етеді. Бүгінгі күні компенсаторлармен түйіспелердегі шұңқырлар мен ойықтарды азайтуға бағытталған күш-жігердің көпшілігі, әсіресе компенсаторларға іргелес жерлерде, ойықтарды азайтуға бағытталған. Бұл мәселені шешу үшін көпір төсемінің компенсатормен түйісуінің әртүрлі конструктивті шешімдері ұсынылды, оның ішінде: өтпелі аймақтарды пайдалану, бетон салаларын енгізу, демпферлік полимерлі бетон салаларын (жиектерін) пайдалану.).

Түйін сөздер: асфальтбетон төсемінің, компенсатордың, жиектің, резеңке компенсатордың ақаулары.

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Технические науки. Архитектура и строительство

DOI: https://doi.org/10.63377/3005-4966.2-2025-02
УДК: 69.033.8
МРНТИ: 67.09.05

Деформационные швы и зоны сопряжения дорожного покрытия на мостах и путепроводах

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Поступила:
06 мая 2025
Рецензирование:
19 мая 2025
Принята в печать:
20 июня 2025

Аннотация
Когда фактическая интенсивность движения транспорта значительно превышает запланированные значения, это приводит к ускоренному износу дорожного покрытия и образованию колейности. Данная проблема актуальна на скоростных магистральных улицах города Алматы. Образование колей в асфальтобетонном покрытии, особенно в местах деформационных швов, приводит к ударам колес автотранспорта по торцам стыков (металлическим накладкам). Такие нагрузки приводят к быстрому разрушению всех деформационных швов, которые закреплены на проезжей части.

Очевидно, что увеличение интенсивности движения способствует увеличению ущерба, но стоит отметить, что равномерная нагрузка с определенной периодичностью приводит к тому же результату, тогда как ударные нагрузки, возникающие после появления и прогрессирования повреждений, оказывают гораздо более разрушительное воздействие. На сегодняшний день большинство усилий по уменьшению выбоин и колейности на стыках с компенсаторами было сосредоточено на уменьшении колейности, особенно на участках, прилегающих к компенсаторам. Для решения этой проблемы были предложены различные конструктивные решения соединения дорожного покрытия моста с деформационным швом, в том числе: использование переходных зон, введение бетонных притоков, использование демпфирующих полимербетонных притоков (кантов).

Ключевые слова: дефекты асфальтобетонного покрытия, деформационный шов, окантовка, резиновый компенсатор.

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Introduction

There are problems with expansion joints on road bridges and overpasses in Kazakhstan [1-3]. These problems are related to several factors - increased traffic load, climatic conditions, quality of materials and human factor (violation of jointing technology) [4-8]. As it is known transport load includes two main factors: the first is dynamic load associated with the intensity of urban traffic, the second is static load associated with the congestion of urban roads in certain directions (traffic jams in peak hours) [9, 10]. The dynamics of motor vehicle traffic is not constant and the speed limit varies from 2 - 5 km/h to the permitted range of 60 km/h. The traffic flow also has significant differences in mass, passenger cars weighing from 900 kg to 3.5 tonnes, buses 12 - 19 tonnes, trucks 2 axles - 18 tonnes; 3 axles - 25 tonnes; 4 axles - 32 tonnes; 5 axles - 35 tonnes are moving on the roads. [11]. Since the axle spacing is different, the dynamic impact is also very different, so wheel impacts cause pavement failure on road bridges and overpasses [12-15]. Prolonged stopping on road bridges and overpasses also adversely affects and deforms the pavement. The increased dynamic impact is due to the difference in height between the top of the expansion joint and the pavement surface, forming a ‘step’ [16-18]. To avoid asphalt concrete rupture, expansion joints are used on road bridges and overpasses, which are made using different schemes and materials [19-20].

Examples of the main defects of asphalt concrete pavements on bridges and overpasses in Almaty are presented in Figures 1 and 2.

Figure 1. Exits on Ryskulov's Kuldzhinsky trakt, Almaty city [photos taken by the author Bondar I.S.]

Figure 2. Transport interchange and exits on the Northern Ring Highway, near Salem Shopping Centre, city Almaty [photos taken by the author Bondar I.S.]

Single profile (beam) expansion joints (DS) of OP-DS-K brand are designed in accordance with the requirements of the organisation's standard STO 41006842-002-2019 and fully meet the requirements of GOST R 1330-2024 and SP 3543330. Expansion joints are designed to provide movement of adjacent bridge (or other) structures to compensate for changes in expansion gaps. Expansion joints can be installed on bridge structures with different types of spans (steel, reinforced concrete, etc.) Girder expansion joints of OP-DSH-K2 brand provide safe and comfortable passage of vehicles over them. Special - design of the DS element guarantees tightness of the expansion joint during operation. High quality of the materials used, as well as a professional approach to the design and production of expansion joints brand OP-DSH-K2 makes them safe in operation throughout their entire service life. The expansion joints were designed for use in bridges with high traffic flows, they are resistant to snow ploughing equipment and loads from extra heavy vehicles.

Methodology

In order to reduce the impact of traffic loads on the joints between two slabs or between a slab and the carriageway, in recent years the maintenance services responsible for the operational safety of the city's roads have started to install expansion joints with rubber expansion joints.

The expansion joint with rubber compensator consists of three parts: hot-rolled profiled steel beam (profile), rubber seals and anchors. Its advantages are simplicity of construction, ease of installation, durability and convenience. The main types of profile (edging) are: C-type (Fig. 3), F-type (Fig. 4), E-type (Fig. 5).

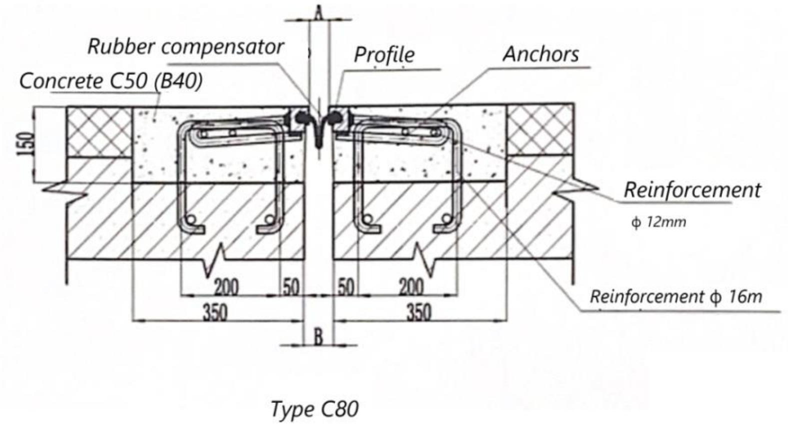

Figure 3. Expansion joint with rubber expansion joint type C80 [the drawings are taken from the website https://k2-engineering.ru/produktsiya/deformatsionnye-shvy/odnoprofilnye-deformatsionnye-shvy, edited by Bondar I.S.]

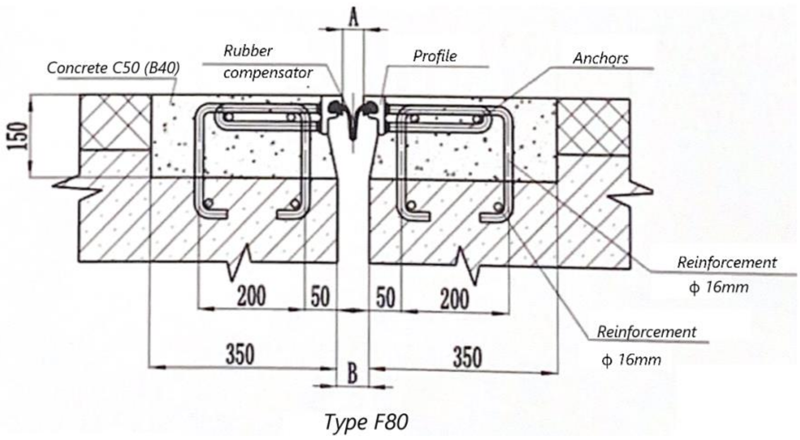

Figure 4. Expansion joint with rubber compensator type F80

[the drawings are taken from the website https://k2-engineering.ru/produktsiya/deformatsionnye-shvy/odnoprofilnye-deformatsionnye-shvy, edited by Bondar I.S.]

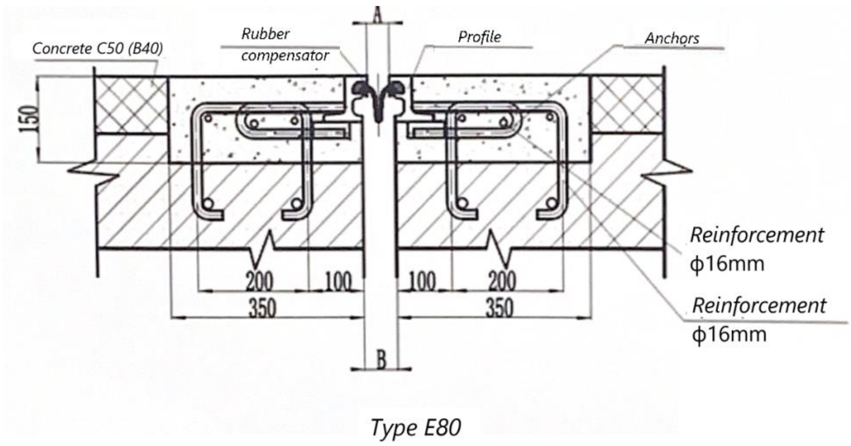

Figure 5. Expansion joint with rubber compensator type E80 [the drawings are taken from the website https://k2-engineering.ru/produktsiya/deformatsionnye-shvy/odnoprofilnye-deformatsionnye-shvy, edited by Bondar I.S.]

Border - elements OP-DSH-K2, edging in the deformation gap contours of adjacent structures (roadway on the structure, the end of the span structure, the edge of the head part of the support or the wardrobe wall of the stand) anchored in them and designed to absorb forces from overlapping gap elements and to protect the edged elements of the structure from destruction under the impact of vehicles. The list of applied edging in beam expansion joints of OP-DSH-K2 grade. The flanges of the edge profile serve for attaching the waterproofing membrane of the deck (Fig. 6).

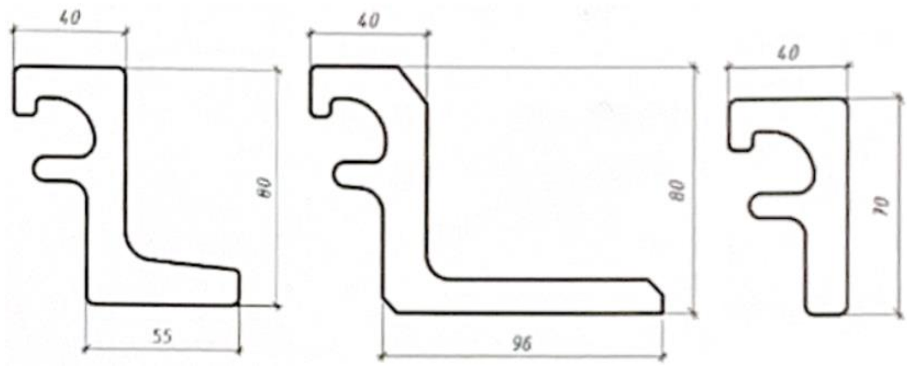

Figure 6. Edging for expansion joints OP-DSH-K2 [the drawings are taken from the website https://k2-engineering.ru/produktsiya/deformatsionnye-shvy/odnoprofilnye-deformatsionnye-shvy, edited by Bondar I.S.]

Table 1. Geometric Characteristics of Bands for Expansion Joints OP-DSH-K2

Type	Displacement (mm)	Installation dimensions (mm)	
		A	B
C80	80	40 (0-80)	50(10-90)
F80	80	40 (0-80)	50 (10-90)
E80	80	40 (0-80)	50(10-90)
1. Under special requirements, displacements can reach up to 100 mm. *2. Installation dimensions A and B are specified at an average temperature.*			

Linearity of the shaped profile used in the DS along the length corresponds to the tolerance of 1.0 mm/1 m, within the whole length - 5 mm/10 m, Screw-shape is not more than 1 mm/1 m. The edge bearing profiles are made of shaped (long) rolled products. The manufacturing plant, which carries out shaping of the steel profile by solid hot rolling or solid hot processing, guarantees the absence of hidden defects along the entire length of the profile. At the request of the project the border of the DS can be made by welding of shaped solid drawn profile and long angle rolled section by continuous welded seam according to GOST 14771, at that 30% (up to 100% at the request of the opening) of welded seams are subjected to ultrasonic examination. Welded seams of OS-DS-K2 grades meet the requirements of GOST 5264, GOST 8713 and GOST 14771.

Bearing profiles (edging) are treated with an increased degree of anticorrosion protection. Anticorrosive coating of DSH corresponds to the category of corrosive aggressiveness of the atmosphere not lower than C4 (high) according to GOST 346672. Durability of anticorrosive coating corresponds to category H (more than 15 years) according to GOST 346671.

The main elements of the beam expansion joint of OP-DSH-K2 brand are edge bearing profiles (edging), anchoring elements and sealing compensator (Fig.7).

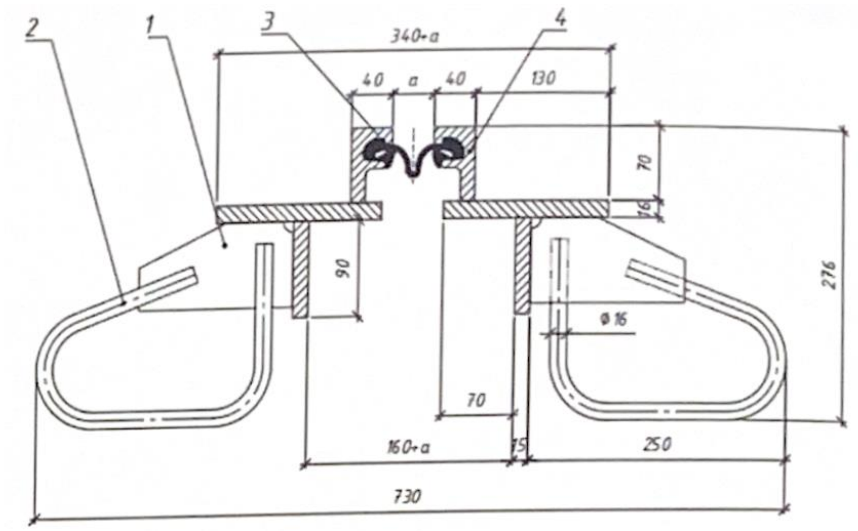

Figure 7. Girder expansion joint OP-DSH-K2 (section) a - opening of DS; 1 - anchor plate; 2 - anchor ring; 3 - compensator; 4 - edging. [the drawings are taken from the website https://k2-engineering.ru/produktsiya/deformatsionnye-shvy/odnoprofilnye-deformatsionnye-shvy, edited by Bondar I.S.]

Due to the presence of various configurations of the bearing profile execution, as well as a large variability of the anchor elements execution, the design of DS can be applied at any dimensions of the expansion joint lining areas and any thicknesses of asphalt pavement or other pavement.

In beam expansion joints, sealing expansion joints are used [21], which allow for a displacement of the structure from 40 to 120 mm. For beam expansion joints with an opening of 100 mm and above, which are used on motorways near settlements with a permitted speed of motor vehicles over 90 km/h, as well as on roads in the settlements themselves, it is recommended to use additional noise-reducing structures. Here are two options of design solutions for noise reduction:

1) application of special noise-reducing plates, such beam DSs are labelled ‘OP-DS-K2-shp’ (Fig. 7);

2) application of expansion joint designs with special wave-shaped borders, such beam joints are labelled ‘OP-DSh-K2-v’ (Fig. 9).

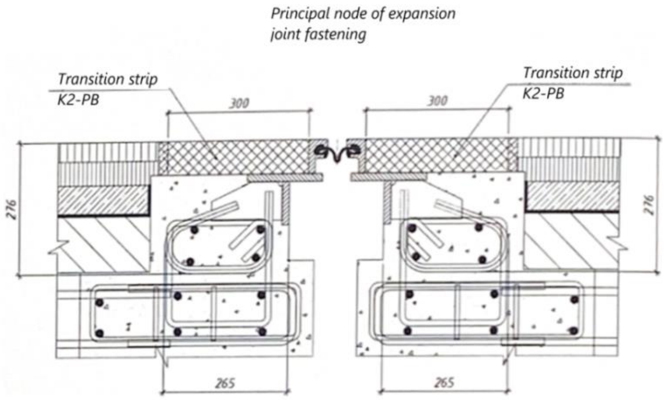

Figure 8. Expansion joint OP-DSH-K2-shp with noise-reducing plate [the drawings are taken from the website https://k2-engineering.ru/produktsiya/deformatsionnye-shvy/odnoprofilnye-deformatsionnye-shvy, edited by Bondar I.S.]

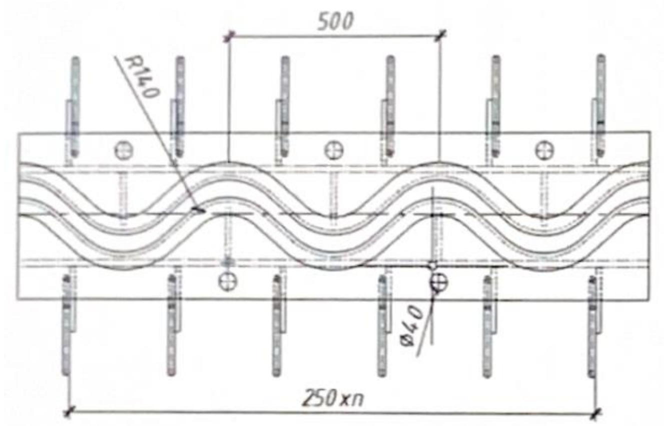

Figure 9. Special wave-shaped border OP-DSH-K2 [the drawings are taken from the website https://k2-engineering.ru/produktsiya/deformatsionnye-shvy/odnoprofilnye-deformatsionnye-shvy, edited by Bondar I.S.]

Figure 10. Photographs of the OP-DSH-K2-in wave-shaped border [the drawings are taken from the website https://k2-engineering.ru/produktsiya/deformatsionnye-shvy/odnoprofilnye-deformatsionnye-shvy]

Results

Let us calculate the total temperature displacement of the free end of the span structure by applying the formula [17]:

$$\Delta_T = \gamma_T \cdot \alpha \cdot L \cdot \Delta T, \quad (1)$$

где γT – is the reliability coefficient for temperature effects;

α – is the coefficient of linear thermal expansion, ($1 \cdot 10^{-3}$);

L – is the design length of the span structure from which the displacements are determined (2×24 m);

Δ_T – range of change of design temperatures from T_{min} to T_{max} taking into account the increase of this range due to the heating of the structure under the influence of sunlight, including non-uniform heating and non-uniform temperature distribution along the cross-section of the element [22].

Normative air temperatures in warm and cold seasons should be set equal: $t_{n,T} \approx +40°C$; $t_{n,X} \approx -40°C$; *can be accepted* $t_{3,T} = t_{n,T} - 15°C$;

$$t_X = t_{n,X} + 15°C;$$

The distances between the edges of OP-DSH-K2 expansion joints of types C80, F80 and E80 measured at different temperatures in the range from -30°C до +30°C are shown in Figure 10.

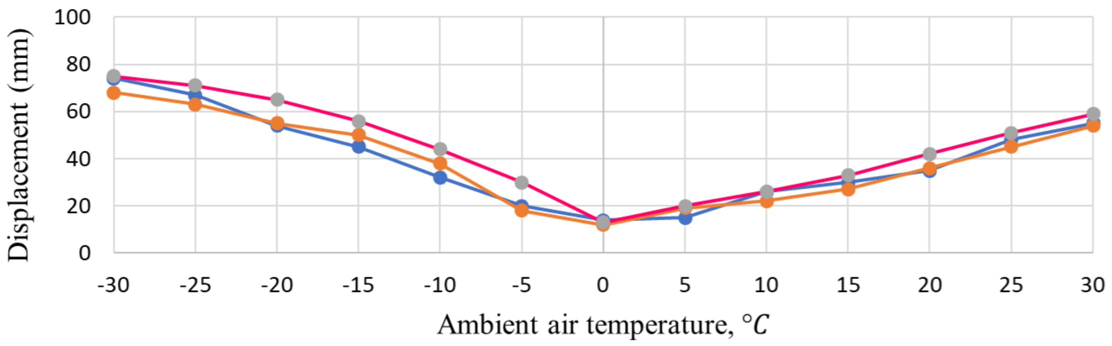

Figure 10. Diagram of dependence of displacement of expansion joints on temperature [The graph was built by the author Bondar I.S.]

Discussion

The calculated width determined by the formula (1) of one joint from the action of temperature -40 ° C is equal to half of this value, that is, if by calculation ΔT turned out to be 16 cm, the half will be 8 cm. For a comfortable passage through the deformation joint the value of its opening should not be more than 8 cm [23], otherwise due to the 'failure' of car wheels between the edging dynamic coefficient (1+μ) increases, which is an additional unfavourable factor, increasing the impact of traffic load on the bridge spans. The presence of defects in the area of expansion joints significantly increases this coefficient (1+μ) due to the disturbance of the smoothness of the carriageway micro-relief.

Judging from the results of Figure 10, the presented types of expansion joints fulfil this task perfectly. The best performance at different temperatures in the range from -30°C to +30°C, i.e. the smallest displacement between the borders of the OP-DSH-K2 expansion joints of the F80 type at -30°C outside temperature was 6.8 cm, and at +30°C the displacement was 5.4 cm.

Conclusion

It has been established that after commissioning of bridges and overpasses in a couple of years deformations, displacements, deep cracks and potholes in the zones of expansion joints will be inevitable in the zones of road asphalt concrete pavement with the depth from 3 cm to 10 cm. Existing damage and deformation of expansion joints on bridges and adjacent pavement areas can cause serious vehicle accidents and road accidents.

Thanks to the use of expansion joints with rubber compensator on the spans of bridges, overpasses and transport interchanges of Almaty city, the operational safety of transport structures has significantly improved, which in turn gave a positive economic effect [24]. The accumulated experience allows adapting the designs of OP-DSH-K2 beam expansion joints of types C80, F80 and E80 for application on oblique spans, on spans with a surface system of drainage devices, with combined traffic of road and tram transport and on railway crossings, approaches to bridges, etc.

Conflict of interest. The corresponding author declares that there is no conflict of interest.

Ссылка на данную статью: Бондарь ИС, Хардиков ПГ, Нурахметова КК, Дигарбаева ТД, Мамедова ЖЭ. Деформационные швы и зоны сопряжения дорожного покрытия на мостах и путепроводах // Вестник Казахского автомобильно-дорожного института = Bulletin of Kazakh Automobile and Road Institute = Kazakh avtomobil-zhol institutynyn Khabarshysy. 2025; 2 (10): 15-26. https://doi.org/10.63377/3005-4966.2-2025-02

Cite this article as: Bondar IS, Khardikov PG, Nurakhmetova KK, Digarbaeva TD, Mamedova ZhE. Deformacionnye shvy i zony sopryazheniya dorozhnogo pokrytiya na mostah i putepro-vodah [Expansion joints and the interface zone of road pavement on bridges and overpasses]. Vestnik Kazahskogo avtomobil'no-dorozhnogo instituta= Bulletin of Kazakh Automobile and Road Institute = Kazakh avtomobil-zhol institutynyn Khabarshysy. 2025;2 (10): 15-26. https://doi.org/10.63377/3005-4966.2-2025-02

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