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17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

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MODULAR EXPANSION JOINTS FOR JOINT OPENINGS IN THE ROAD

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Abstract

In asphalt pavements at high exploitation temperatures, deformation occurs in the form of a rut, whereas at low temperatures cracks and penetration of aggressive fluids into the road construction occur. In both cases, there is a risk that these abnormalities will occur on the connection between the modular devices and the roadway. The paper presents the types of modular expansion joints and their importance for the structures into which they have been installed, as well as the advantages and disadvantages of certain types, the methods of installation and the materials which they are made from. Seamless sealing devices are explained in detail because they don't have parts that need replacing, therefore it is not necessary to maintain them. The advantage of these devices is that they permit vehicle traffic to travel smoothly across expansion joint openings, at the same time ensuring the low noise level and safer and more comfortable driving. A common case while designing new or replacing the existing modular joints is the prediction of too large openings, which are often larger than the actual ones and which is technically unjustified. On many buildings with small expansion joint openings, built-in metal devices are installed, which is not economically viable and unjustified at exploitation level. The installation of seamless devices on objects with small spans or small openings, which are also the most common on the road network, opens up the possibility of a wide application of this type of joints and the solution of many deficiencies in road surfaces. Engineering expertise is required when deciding upon the choice of a suitable modular device, which will meet the high level of exploitation conditions, possess the durability of the asphalt pavement itself and thereby reduce the cost of stopping or diverting traffic when replacing an obsolete device.

Keywords: modular expansion joint, durability of driving surface, water permeability, asphalt pavement bridge

1 Introduction

Modular expansion joints are assemblies that ensure the driveability and continuity of the pavement construction at the expansion points and support longitudinal deformations changes due to temperature changes and concrete creep and prevent their adverse impact on the pavement construction. Initially, these were very simple constructions and consisted of two frontal steel angle sections or plates that had the function of mechanical protection of the transition. New advances in technology include new types of modular expansion joints for bridges, overpasses and viaducts. Large spans of buildings and increased traffic loads followed by higher axle pressures lead to the production of typical transitional bridging devices. The frequent disadvantages of these devices are water permeability, low durability, and inadequate interruptions in the carriageway surface. In the period from 1973 to 1977,

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the American corporation General Tire Inc. has patented a number of solutions for watertight modular devices for bridges based on reinforced elastomeric segments. This solution took precedence over the existing solutions in the form of reinforced panels that have taken over the load. The possibility of deformation was achieved by shear deformation of the elastomer. Anchoring was performed using anchor bolts in an armored-concrete construction. Elements of two meters in length continued to the required length. Making such gadgets was simple and relatively inexpensive, and corporation General Tire Inc. has a world reputation in the polymer field. Therefore, it is not surprising that this solution quickly expanded and applied a lot [1]. This development resulted in the separation of several basic technical solutions, is to say the types of modular expansion joints that will be considered in this paper.

2 Types of modular expansion joints

The types of modular expansion joints differ depending on the material, the dilatation gap, the way of waterproofing, the place of manufacture (at the construction site or in the production plants) and the required installation time on the building. Some modular joints are tailor made and subsequently delivered to the construction site while the others are run immediately on the site itself. For different types of modular devices there are different traffic regulations (partial or total closure of traffic). No expansion joints completely meet all requirements. The most important characteristics of the modular devices are watertightness, low maintenance costs, driving comfort, lightweight installation, silent switchover, cost and quality ratio, and safe and long-term use. Basic division of modular expansion joints:

1) Seamless sealing devices
   - Thorma Joint bituminous modular joints
   - Silent joint bitumen modular joints
   - Polyurethane modular joints
2) Modular joints made of elastomeric elements (rubber)
3) Steel modular joints
4) Multiprofile modular joints

2.1 Thorma joint bituminous modular joints

The THORMA JOINT expansion is an elastic seamless sealing construction for continuous bridging of bridge dilations with small and medium displacements. The main production components are a special high-polymer bituminous binder (polymer-modified bituminous binder) as well as a selected high quality crushed aggregate of uniform granulation and cubic form. The expansion joint has no seams, it is continuous and is located in the plane of the asphalt pavement surface, thus providing a safe and comfortable ride for the participants in the traffic and the noise level is reduced. Figure 1a) shows Thorma Joint modular expansion device in schematic form.

2.2 Silent joint bituminous modular joints

SILENT JOINT are continuous elastic expansion joints. They are developed for the bridging of expansion joints of structural elements of bridges, viaducts, overpasses, underpasses, etc. [2]. They ensure the drive and continuity of the travel structures at the expansion points and support structural changes due to temperature changes and creeps of concrete. Due to the silent transition of vehicles, they are suitable for use near the house. They can be installed in asphalt and concrete pavements. Supports planned displacement without water damage or leaking water. Due to the installation of anchor elements in the construction of the building, the time of installation of the device is prolonged. Figure 1b) shows Silent Joint modular expansion device in schematic form.

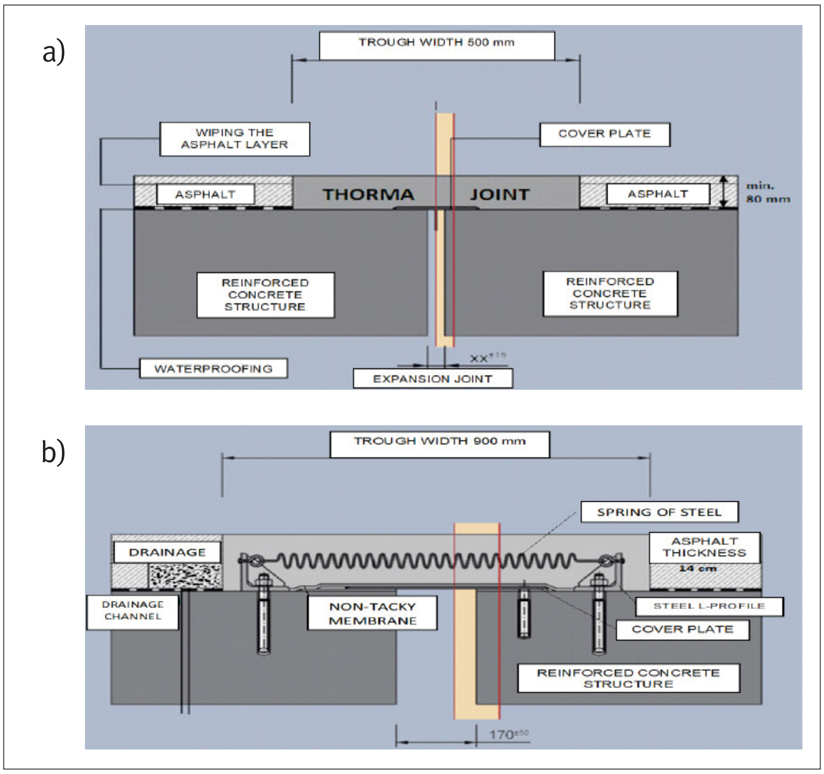

Figure 1 Schematic form of a modular expansion devices: a) Thorma Joint; b) Silent Joint

2.3 Polyurethane modular joints

Unlike the bituminous devices, this devices support larger movements. The coated polyurethane elastic transition device consists of two components of polyurethane in thixotropic (semi-solid) conditions and is protected from solvents. The components are mixed by a cold process and are ready for installation at temperatures above 5 ° C. Laboratory tests have shown that the materials have very high resistance to dampening, thus reducing the possibility of fluid leaking water. Once the appliance is installed it can not be repaired any more. The embedded material is polyurethane and harder than for bituminous devices and therefore it is difficult to move the asphalt into the machine itself, so the epoxy base on the asphalt pavement is made. Figure 2 shows a polyurethane seamless expansion joint in schematic form.

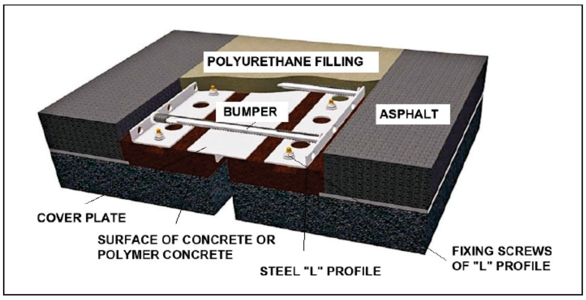

Figure 2 Schematic form of a polyurethane seamless expansion joint [3]

Figure 3 Multiprofile expansion joint with concrete hood [4]

2.4 Modular joints made of elastomeric elements (rubber)

The device consists of a rubber sealing profile located between the two metal edges of the profile. Due to its easy installation and maintenance, it is an ideal replacement when repaired by defective devices, and due to its fast installation, the traffic jam is reduced to a minimum. On the drive part of the machine, there are abrasion-resistant aluminium panels that extend the life of the device. Figure 4 shows an elastomeric expansion joint and figure 5 shows an example of a expansion joint of rubber elements.

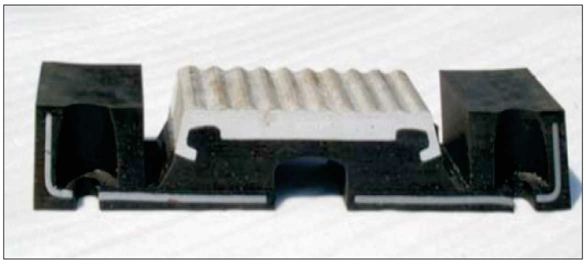

Figure 4 Elastomeric expansion joint [5]

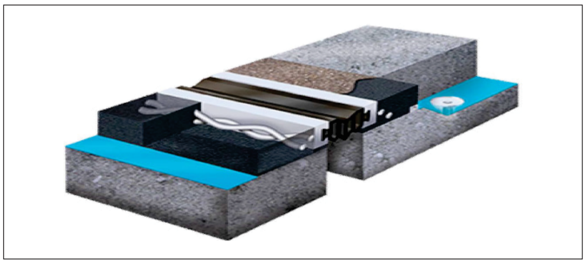

Figure 5 Expansion joint of rubber elements [6]

2.5 Steel modular joints

Comb expansion joints are made up of a number of spatulas and in case of damage, can easily be replaced. Anti-corrosion protection has long-lasting corrosion resistance. Underneath the machine is a rubber sealing gasket that collects water. Figures 6 and 7 show steel expansion joint.

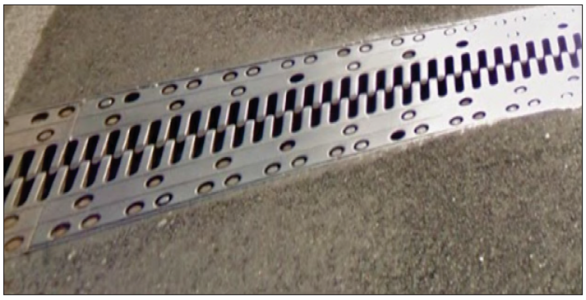

Figure 6 Comb expansion joint

Figure 7 Profiled steel expansion joint [7]

2.6 Multiprofile modular joints

Multiprofile modular joints are known as lamellar dilatation devices or modular expansion joints. All wear-sensitive components can be easily and quickly replaced. Figure 3 shows a multiprofile expansion joint.

2.7 Advantages and disadvantages of a particular type of modular expansion joint

The common characteristics of all types of bituminous expansion joints are simple and fast installation to a temperature of -5 °C as well as the possibility of installation in adverse weather conditions. Also, there is the possibility of subsequent upgrades and the need to only partially close the traffic and release traffic after about 3 hours after the installation is completed. Allow movement in all 3 directions and rotations around all 3 axes. All the devices have a high endurance and allow for the smooth transitions of the vehicle over the same device, and the most important characteristic is water impermeability. An additional characteristic of seamless sealing devices is the installation after installing asphalt or concrete pavements. Table 1 lists the advantages disadvantages of each device.

Table 1 Advantages and disadvantages of a particular type of modular expansion joints

Advantages	Disadvantages
Thorma Joint seamless expansion joint	
· No maintenance required · It is installed after installing a pavement asphalt – fitting into the cargo area · Allows free and secure swinging of snowplow · It has the same level of opacity as on the damp layer of asphalt · It remains firmly attached to the tool basket without the risk of breakage · It does not contain metal parts – the same material as deck · There are no anchoring elements, therefore a shorter installation time is required	· For connection of aggregates and binder ta installation required high temperature · At higher temperature sensitive to plastic deformation and the appearance of a check at long-term concentrated loads · Supports up to ± 20 (25) mm and a distortion up to ± 3 mm
Silent Joint seamless expansion joint	
· Less stress on the coupling of the expansion joint and the pavement asphalt · Equivalent values of the lift surface as well as on other parts of the carriageway · Complete safety and maintenance of the reinforced concrete structure from surface water · Tracks rutting of the driving surface	· Can take horizontal shifts up to +/- 50 (60) mm · More demanding for Thorma Joint installation · It is assembled and slower for installation by Thorma Joint · Because of the anchoring of the steel L profiles it engages the reinforced concrete structure · Requires asphalt thickness of 12-14 cm – reconstruction problem, while new construction is a desirable solution · Not good with long-lasting static load
Polyurethane expansion joint	
· The components can be mixed with a cold process · Have less plastic material than bituminous expansion joints · No signs of wear resistants on the drive surface · Greater mechanical resistance and stability compared to bituminous expansion joints at long-term concentrated loads · Can be applied to new, reconstructed and rail bridges · Not sensitive to vibration	· Allows displacements up to +/- 100 mm · Due to the frequent opening of the joint on slotted sections, water leak into the pavement · There is no possibility of repair or upgrading after the body is made · Required protective barrier design due to asphalt shrinkage · Doubly more expensive than bituminous expansion joints · Demand conditions for pork due to chemical process
Expansion joints of elastomeric elements	
· Allow longitudinal displacements of 50 to 165 mm · Suitable for replacement of defective transducers during repairs · Resistant to slipping on the driving surface	· Frequent damage to aluminium elements · Noise traffic through aluminium elements · Open the expansion joints on the coupling of the tripods
Steel expansion joints	
· Anti-corrosion protection ensures high quality and long-lasting corrosion resistance	· Installation before asphalt pavement layers – flatness problem · Uncomfortable driving and noise · Intermittent damage to the device and the clamp · Cleaning and replacing the tire between the profile
Multiprofile expansion joints	
· Can take horizontal shifts over 2000 mm · Delicate wear parts can be easily and quickly replaced – the cargo area · Lamellar dilatations achieve high durability	· Widespread interruptions in the driving surface · Extremely uncomfortable driving · Complex maintenance · Demanding and long-term replacement

3 Performing a seamless modular expansion joint

Seamless sealing devices have been applied for more than 35 years and a total of over one million cubic meters have been introduced at the world level. In the period from 2003 to 2016 on the territory of Croatia, the Thorma Joint modular devices has been installed on over 70 facilities and has been installed more than 2600 meters. Silent Joint modular devices from 2008 to 2016 are built into 5 buildings with a total length of over 150 meters [8]. Polyurethane modular devices have been frequently applied in Croatia over the last few years and it is important to monitor their behavior in exploitation. Figure 8 shows three types of seamless sealing devices.

The behavior of modular expansion joints in exploitation is visible on bridges across the Sava River in Zagreb (Figure 9). Since the bridges were built in the 60s of the last century and because of the lack of maintenance of the joints and the loss of their functions (watertightness, detrimental effect on the construction of the bridge and the vehicles passing through them, cracking of the asphalt with the modular expansion joint).

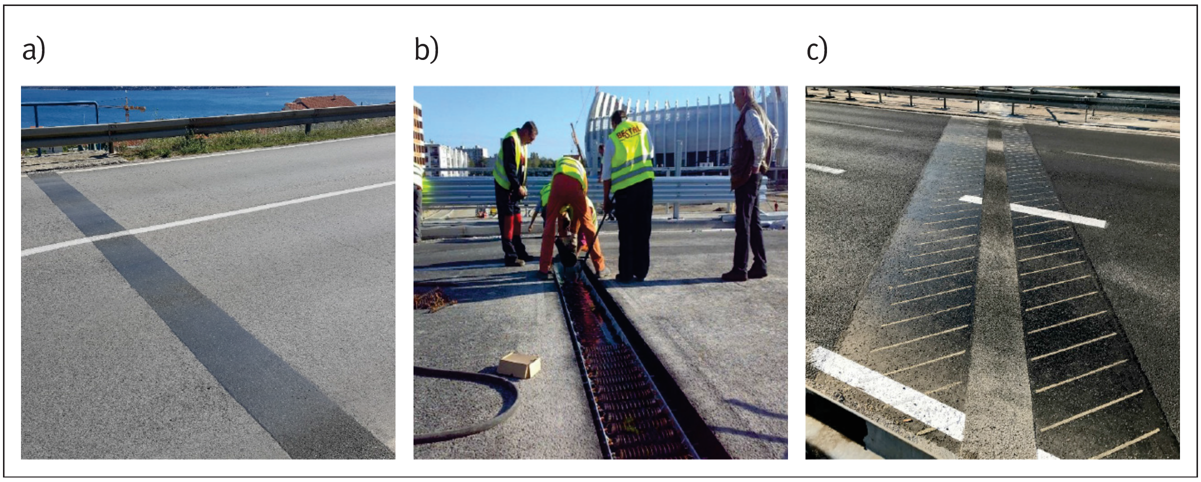

Figure 8 Seamless sealing devices: a) Thorma Joint (D8); b) Silent Joint (by Arena Zagreb); c) polyurethane expansion joint (in Zagreb)

Thorma joint seamless sealing device is produced individually, exclusively on the building ("in situ"). Prior to installing the machine it is necessary to cut the pavement asphalt and cut the waterproofing in the width of 50 cm at the site of dilation. The cut-off basket should be cleaned of impurities. In the dilatation slot between the reinforced concrete elements, a foam rubber sealing strip is inserted so that the binder does not propagate. The complete groove of the expansion joints is to be coated with a high-polish bitumen binder, while the dilatation band over the sealing strip is filled with a binder so that the waterproofness is warranted. Through the expansion joints in the concrete structure to be overlapped to prevent material fall into the groove, lay the galvanized steel cover plate in the width of the expansion. Thereafter, an aggregate and a high-polymer binder are incorporated into the cavity, the sieve is deposited with an eruptive rock of a small fraction of 2-4 mm which has been previously evacuated and heated in a mixer at a temperature of 220 °C. The final layer is compressed by a vibration plate. After cooling, traffic may be released (Figure 1a).
Silent joint seamless sealing device is produced individually, exclusively on the building ("in situ"). To install the device on an object, first remove the asphalt in the width of the transducer. After removing the asphalt, the concrete floor and side of the asphalt are sanded to remove the remains of the insulation. Both sides of the expansion bore holes for screw mounting Φ20 mm, L = 240 mm for mounting the steel L supports. The carriers need to be cleaned and checked for their depth. Two-component material is applied for fixing the carrier, and the fixing screws are injected into the holes. On both sides of the dilatation, the teflon sliding bearings are mounted, thus preventing possible damage to the friction of the concrete and the cover plate. Overlapping foil is made of high temperature resistant non-stick foil. The purpose of the foil is to permanently ensure the ability to move the structure and prevent bitumen bonding to the steel. Thereafter, an aggregate and a high-polymer binder are incorporated into the cavity, the sieve is deposited with an eruptive rock of a small fraction of 2-4 mm which has been previously evacuated and heated in a stirrer at a temperature of 220 °C. The final layer is compressed by a vibration plate. After cooling, traffic may be released (Figure 1b).
The polyurethane seamless sealing device is a completely new product developed on the basis of elastic polymers and can be considered as further improvement in some of the characteristics of bituminous transition devices. The new expansion joint system allows for greater pitch up to ± 100 mm. Before installing the machine it is necessary to cut the asphalt on a certain width. Asphalt is removed and the support ribs are cut that prevent the difference in height between the asphalt and the transition devices, which could be due to the asphalt shattering. At the dilatation sites, the basket should be populated and coated with a coating. Dilation should be covered with the relevant material so as to avoid the collapse of the concrete substrate. After mounting the screws, the polymeric concrete foundation is installed.

Above the dilatation are laid hot galvanized steel angular profiles and cover plates. After the body of the dilatation device is installed, the polyurethane mass of the two components of polyurethane is mounted (Figure 8c).

Figure 9 Examples of modular expansion joints on bridges across the Sava River in Zagreb: a) Zaprešić bridge; b) Podsused bridge; c) Jankomir bridge; d) Adriatic bridge; e) Sava pedestrian bridge; f) i g) Liberty bridge; h) Youth bridge; i) Homeland bridge

4 Conclusion

From the seventies of the twentieth century, solutions and materials were intensively sought to prevent water permeability of modular expansion joints with increased driving comfort, extend their durability, and enable them to bear stirring of the traffic surface. The stirs arise at the site of dilation due to changes in temperature, shrinkage and cracking of the bridge structure and traffic load. There is a tendency to reduce the direct and indirect costs incurred by the use of inadequate modular expansion joints and to reduce noise and other adverse environmental impacts.

Today there are tested and proven solutions that offer great durability for an acceptable price. Damaged or defective expansion joints negatively affect the construction on which they are mounted. Consequences that can be caused by a damaged or defective modular device in the roadway area reduce the safety of road traffic. Propagation of water and various chemicals and precipitation of sipes and garbage in expansion joints causes further damage to the carriageway, reinforced concrete bearing plates, steel structures, abutments, corrosion of the reinforcement. No modular device is free of defects, nor does it fully comply with all requirements. The most important requirement for the transitional device is waterproofing and a safe and comfortable ride. In order to protect the structure from deterioration and to ensure greater traffic safety, transitional devices are to be maintained and those defective and damaged to be replaced by new devices that will ensure the waterproofness and safety of the passage of vehicles and pedestrians. The task of each designer is to acquire the most technically and economically best possible solution for a particular case when choosing a transitional device. In this case, it is necessary to consider the magnitude of the structural displacement and the complexity of the structure itself, the traffic load, the eventual passing of the wheel in the winter and the reduction of the noise level at the crossing of the vehicle. It is recommended to use transitional devices for longer durability. For economic reasons, it is more expensive to incorporate a cheaper and inadequate transition device, since it takes more than a shorter time. Costs of stopping traffic and replacing old devices are often higher than expensive and durable devices. For seamless modular expansion devices it can be concluded that the transition over these devices is more comfortable and quiet and that maintenance is not required, which reduces the exploitation cost. Their characteristic is to allow small and medium displacements of the structure. Most of the bridges, underpasses and overpasses on public roads in the Republic of Croatia because of its dimensions and constructive solutions have the shifts that this group of "seamless sealing devices" can take over.

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