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REVIEW OF THE ROLE OF JOINTS USAGE IN BRIDGE STRUCTURES

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Abstract - *Bridges are very important connecting elements and backbone of highway infrastructure. Joints are used in bridge construction to accommodate the relative temperature movements in concrete, vertical movements due to loading conditions and movements due to shrinkage and creep effects in concrete. This paper tells about the role of joints usage in bridge structures. This paper reviews about different joints used in bridges of highways. It is also describing about various causes of failures of joints and the remedial measures.*

***Key Words*: Movements, Temperature, Shrinkage, creep, Expansion joints**

1. INTRODUCTION

As we all know, concrete is important basic structural material that is very much susceptible to environmental conditions such as temperature. Seasonal temperature variation is causing the concrete to expand and contract. During the summer season, concrete surfaces will undergo expansion and in the winter season, concrete surfaces will undergo contraction. The internal stresses which develop in the concrete due to temperature variations causing cracks in the structural elements. The concrete overall size can be changed because of the warping molecules of concrete subjected to temperature variation. In order to cater the thermal movements in concrete surfaces of bridges, joints are commonly used. Joints are used to separate two or more adjacent bridge elements. The joints are normally weakest part and most vulnerable area in the bridge structure. Extreme care is needed in monitoring of joints in the bridges. If the joints were not properly maintained and designed, the distress at bridge joints causing many maintenance problems, including spalling of concrete at the joint edges and damage of pier caps/capping beams and other bridge elements. The maintenance work of these joints at major bridges becomes very hectic, since these major bridges are subjected to heavy traffic loads all the time. So, the maintenance work cannot be done for longer time for the joints. Hence the joints on a bridge structure should be well designed to perform satisfactorily, for a longer time without requiring frequent repair or replacement. The joints should be well designed to cater free translation, deflection and rotation without causing damage to concrete wearing surface and causing troublesomeness to the traffic.

2. LITERATURE REVIEW

According to Lee [1] Construction and bridge expansion joints are invariably provided in all bridge decks at locations of structural discontinuity between the two elements. An expansion joint or movement joint can also be defined as device or supporting medium which supports the surfacing, and provides a running surface for vehicles to pass over it and filling up the gap between the adjacent bridge deck and abutment or area between two adjacent bridge decks[2]. The bridge expansion joints are designed in such a way that they used to allow continuous traffic over deck slabs of bridge structures accommodating movement, shrinkage, temperature variations on Reinforced and Prestressing Concrete, Composite and Steel structures. According to Raina[3], an Expansion joint is also called as Contraction joint because they accommodating movements in bridge deck spans and abutments. Expansion joint systems are integrated components designed to accommodate the repeated cycles of movement. Proper functioning of bridge expansion joint systems accommodates these movements without imposing significant secondary stresses on the bridge superstructure. According to Aziz[4], Construction joints are sometimes referred as cold joints can be defined as stopping positions in the concrete casting, and they are needed because of inconveniency to cast concrete, in one long continuous concreting operation. The concrete quantity production at site, depends on the number and capacity of concrete mixers available at site and the form work capacity. The alternate stopping and resuming process of concrete casting operation leading to initiate the construction joints.

3.TYPES OF JOINTS

The joints provided in the bridge structure can be further classified into three types namely (a) Construction joint (b) Expansion joint (c) Contraction joint. Expansion joints are provided in bridge decks, to allow the deck movements due to traffic loading and movements caused due to the shrinkage, creep and temperature variations in the concrete and also Post-tensioning shortening, dead load, live load, wind load, seismic load and structural settlements and deflections. The Expansion/Contraction joints can accommodate the movement ranging, from 30mm to 1000mm.Construction joints are the temporary joints, often provided in concrete elements, when the concreting operation of any structural element is stopped temporarily, due to high heat, rain, and failure of concreting machineries such as vibrator and concrete mixer. The construction joints

are provided at the junction of abutment and wing wall due to the different levels. These joints are also provided in protective walls such as retaining walls. These joints cannot be provided at the sensitive locations where shear, moment and bond stresses are high. The location of construction joints should be placed away from the supports. The construction joints can be either vertical or horizontal. In deck slabs, vertical type construction joints are provided. The open type construction joints are provided, in such a manner that they should be sealed to avoid ingress of foreign substances into the concrete member. Shear keys (projections) are also provided with the construction joints. The contraction joint is used to take care of the deformations of the concrete member due to change in temperature. The contraction joint can be provided for part of the deck slab for smaller width. Expansion joints occupy full depth of bridge deck slab as well as for larger widths.

4. CLASSIFICATION OF BRIDGE EXPANSION JOINTS

The various types of bridge expansion joints were used in bridge structures. Some of them were discussed in this paper.

- Buried joint
- Asphaltic plug joint
- Nosing joint/compression seal joint
- Cantilever comb or tooth joint
- Reinforced elastomeric joint
- Elastomeric joint in metal runners
- Modular joints including finger and sliding plates.
- Strip seal expansion joint

4.1 Buried joint

As the name implies, buried joints also known as simple joints, which are provided below the bituminous/asphaltic surfacing or wearing course. These joints are used to cater small movements and can be adopted for simply supported spans, up to 10m.In this joint arrangement, the width of joint is kept as 20mm.A steel plate of size 200mm wide and 12mm thick of weldable structural steel is placed symmetrical, to the centerline of joint to bridge the gap resting freely over the top deck concrete surface. Bituminous or Asphaltic wearing course is laid over the steel plate. Elastomeric pad can also be provided instead of steel plate. This joint allows longitudinal movement about 20 mm and vertical movement of 1.3mm.

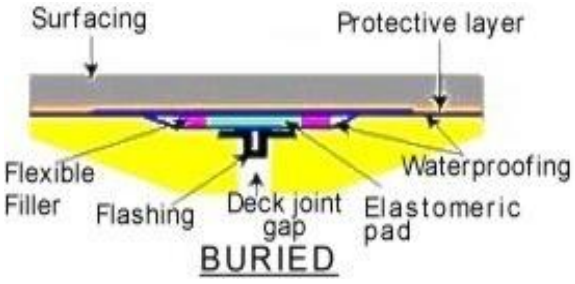

Fig -1: Buried Joint

4.2 Asphaltic plug joint

This joint is also similar to the buried joint. In this joint, asphalt special adhesive (Binder) is applied evenly on the bottom surface of the expansion joint gap. A steel plate or closure plate is placed at the middle of the expansion joint gap, over the asphalt special adhesive coat to make the joint firm and strong. Heat resistant foam caulking/backer rod is available below the closure plate. The Crushed stones heated at high temperature ranging from 130^{o}C to 150 ^{o}C is filled over the expansion joint gap. Finally, the melting asphaltic plug joint is poured over the crushed aggregates and joint is levelled. This type of joints can accommodate longitudinal movement up to 40mm and vertical movement up to 3mm.

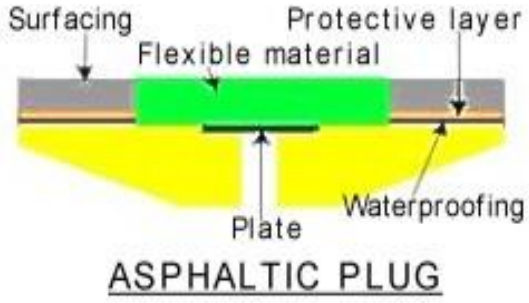

Fig -2: Asphaltic plug joint

4.3 Nosing Joint/compression seal joint

This joint is also called as compression seal joint. A compression seal made up of preformed chloroprene elastomer/extruded neoprene rubber/closed cell foamed joint sealer is provided at the center of expansion joint gap with special adhesive binder. The seal can be used in this joint either of compressed or poured. The edges of joint gap are covered with nosing material made up of steel nosing of angle section. The steel nosing is anchored to the deck with a suitable anchorage system. This type of joints can accommodate longitudinal movement up to 40mm and vertical movement up to 3mm.

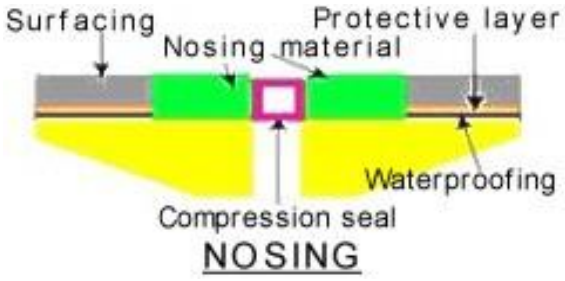

Fig -3: Nosing joint/compression seal joint

4.4 Cantilever comb or tooth joint

In this joint, mating metal comb or saw-tooth plates are provided by means of a pair of individual cast aluminum alloy sections having one-meter length and laid opposite to each other. A series of paired combs are arranged to get a single unit, which is laid over the expansion gap covering the bridge width. The combs are either flame cut from a rolled steel plate or cast in aluminum alloy. A small transition strip is available at the edges of expansion joint gap. The joint metal assembly is anchored to the deck, with the help of tension control fasteners or anchored bolts/Securing bolts. A suitable drainage membrane is also provided at the bottom of expansion joint gap made up of elastomeric looped membrane or stainless-steel water recovery membranes. This type of joints can accommodate longitudinal movement up to 25mm and vertical movement up to 3mm.

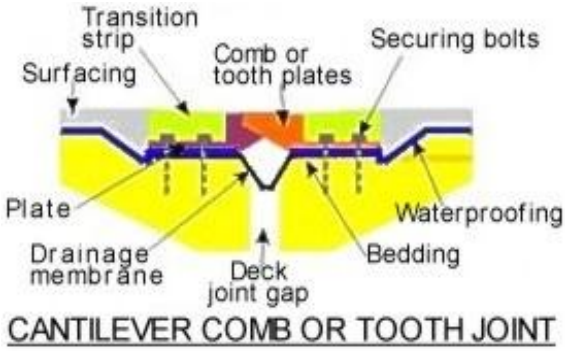

Fig -4: Cantilever comb or tooth joint

4.5 Reinforced Elastomeric Joint

It is a prefabricated mat joint, comprising an elastomer with or without bonded metal plates. This joint is provided with elastomeric unit reinforced by means of metal plates. This joint assembly is then fixed to the bridge deck with fixing fasteners or bolts which are sealed with resin plugs. This joint can accommodate movement by the action of shear deformation of elastomer and opening and closing of elastomeric grooves at upper and lower surface. A small transition strip is available at the edges of expansion joint gap. A suitable drainage membrane is also provided at the bottom of expansion joint gap, made up of elastomeric looped membrane. This type of joints can accommodate longitudinal movement up to 80mm and vertical movement up to 3mm.

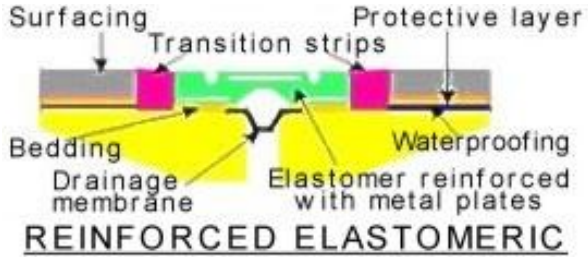

Fig -5: Reinforced Elastomeric joint

4.6 Elastomeric joint in metal runners

This joint is a prefabricated joint comprising an elastomeric seal which is fixed between metal runners or metal rails. The metal runners unit shall be either of single element or multi element. The elastomers are provided between the gaps of metal runners. Multiple metal runners are used to accommodate large movements. In this joint, outer rail connectivity to the deck slab is provided by reinforcement. The transition strip is usually not provided in this joint. Sealant is acting as a transition strip. This type of joints can accommodate longitudinal movement up to 80mm and vertical movement up to 3mm.

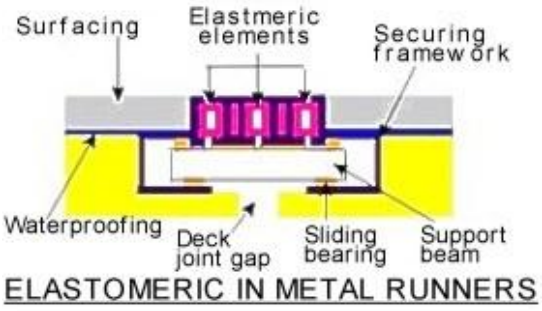

Fig -6: Elastomeric in metal runners

4.7 Modular joints including finger and sliding plates

Modular joints are provided as bridge expansion joints in situation where accommodating of large longitudinal movement is needed. The overall joint setup is of two categories. In the first joint setup, joint assembly is constructed with special steel sections and with suitable elastomers placed in between them. In the second joint setup, called as finger type expansion joints like the cantilever comb or tooth joint, where open type sliding plates are laid over the expansion gap. The fingers are made with rectangular cross section. The sliding plates are provided by means of a pair of individual cast steel sections and laid opposite to each other. This joint can accommodate movement up to 160 mm.

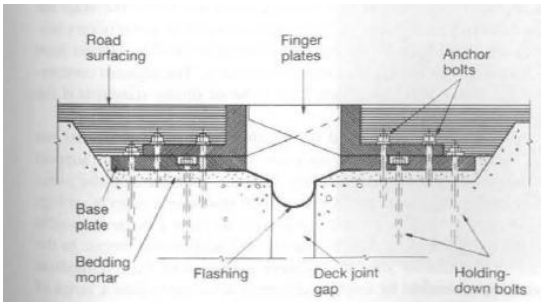

Fig -7: Finger plate joint

4.8 Strip seal expansion joint

This type of joint is widely used in Reinforced concrete T-beam cum deck slab. This joint is used to accommodate medium movement ranging from 40mm to 50mm for medium span bridges. This joint assembly is provided with two edge beams made up of extruded or hot rolled steel section or cellular steel section at the sides of expansion joint gap. The gap of expansion joint is sealed with the elastomeric sealing element or rubber gland to provide water tightness to the joint. The edge beam is usually supported with steel anchor loop and anchor plate which is anchorage to the deck slab reinforcement.

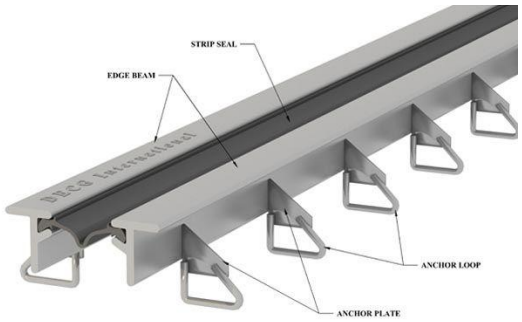

Fig -8: Strip seal expansion joint

5. LONGITUDINAL JOINTS

Apart from the joints discussed in previous section, longitudinal joints are also used in bridge decks. These joints are suitably provided in bridge decks laterally and longitudinally. The riding surface of Reinforced concrete bridge decks, are subjected to severe shrinkage cracks, during climatic condition even though surface reinforcement is provided in wearing coats/surfaces. The shrinkage cracks developed after concreting operation, should be avoided as far as possible. To avoid those cracks and also to provide non-slippery surface, top finished concrete surface is brushed with either brooms or sponges. The problem of arising out of these cracks is now a days become common, in bridges constructed in our country. The joints shall be constructed by sawing the top concrete. The joint groove may be cut after the final set of concrete. This joint can accommodate little movement too. It is not desirable to provide open joints. But sometimes, open joints are also provided in bridge decks with armor angles to protect deck slabs. The open surfaces of joint should be sealed with sealants/fillers and with special concretes such as Ultra High-Performance Concrete and Latex Modified Concrete to arrest the entering of foreign substances. The mixture of bitumen and cement with equal proportions can also be used as a filler material in filling gaps of the joints

6. COMMON DEFECTS ENCOUNTERED IN THE JOINTS

The defects or damages occurring in joints are due to several reasons. It may be of poor materials used in joints, poor workmanship, inadequate supervision during joints installation operation, inadequate periodical maintenance etc… and also by improper installation of joints without strictly followed installation precautions as laid down by the manufacturers.

6.1 Overloading

The overloading due to single axle trucks causes heavy load impact over the expansion joints and reduces the serviceability of joints.

6.2 Rutting/breaking of wearing surface

This defect happens in both open and closed/buried joints. In case of, closed joints due to deck movement, cracks are opening up in the vicinity of joint surfaces. Continuous vehicle impact and water penetration may further damage the cracks leading to rutting of wearing surface. The wearing surface is either concrete or Bituminous/Asphalt. In case of open joints, when the asphalt/bituminous level is below the level of joint level, heavy thrust/impact is possible over the joints and leading the joints to dislodge.

Fig -9: Rutting of wearing surface

6.3 Improper injection of sealants into cracks

Whenever the crack growth is seen over the wearing surfaces of buried/Closed joints, then the crack development

is rectified with the help of flexible sealants. A saw cut is made over the crack, and the sealant is injected into the cracks. Improper injection of sealants into the cracks pushing out the sealants from the saw cut. With the passage of time, this exit sealant is also deteriorated, and crack development becomes unavoidable.

Fig -10: Improper injection of sealants

6.4 Leakage of joints

Leakage of joints is possible mostly in open joints. The ingress of water, dust, grit, ultra violet rays, ozone, petroleum derivatives and salt solutions is reducing the service period of joints. In case of closed/buried joints, the riding surface of joints having voids and porous is subjected to leakage often.

Fig -11: leakage of joint near pedestal

6.5 Loose/damaged fixtures

Damaged Fixtures such as, bolts, nuts, steel fasteners used in joints reduce the service period of joints.

Fig -12: Damaged fixtures in expansion joint

6.6 Joint vegetation

The joints located in the foot path/pedestrian path is often subjected to vegetation growth. This will reduce the joint durability.

Fig -13: Vegetation growth seen in expansion joint

6.7 Loss of material from joint

This defect is encountered mostly in asphaltic plug joint. In this case, as Asphaltic plug material comes out of the joint in the form of either binder or aggregates. Sometimes, flow of binder onto the adjacent road surfacing is also possible.

Fig -14: Loss of Asphaltic plug material

6.8 Debris buildup in the seal

Debris formation on the seal causes the debonding between seal and the nosing material. In this defect, seals are exposed to greater vehicle impact.

Fig -15: Debris build up in the seal in the expansion joint

6.9 Breaking up of other materials

Breaking up of other materials such as cover plates, transition strip, elastomers tends to reduce the serviceability of the joints.

Fig -16: Breaking up of materials from the expansion joint

7. REMEDIAL MEASURES

The following are the key points to be followed in rectifying the defects in the joints.

- ✓ The top levels of joint should be kept below the existing elevation of asphaltic wearing course by at least 2mm to 3 mm. This procedure is to be followed in order to accommodate the settlements in the wearing course.
- ✓ The thickness of deck slab can be increased by at least 2 inches for better installation of the joint assembly.
- ✓ Remedial works can be carried out in the form of filling joint gaps with sealants, arresting the cracks and replace the damaged components of joints and fixing the joint fixtures for the missed/damaged joint fixtures.
- ✓ Proper periodical maintenance is needed to avoid any joint leakages and Vegetation growth over the joints and also to ensure good surface drainage in the wearing surface of bridge decks.
- ✓ Literature, recommendations and specifications of the manufacturer should be strictly followed.
- ✓ Adequate periodical tests/assessments should be carried out in the joints.
- ✓ The materials that is used for repairing of joints should be comply with the specifications as laid down by the respective IRC and MORTH Standards.

8. CONCLUSIONS

The joints are the essential components needed in bridges to allow the movements due to temperature, loadings etc. Without installation of better joints in bridges, the purpose of constructing bridges will not be fulfilled. The serviceability of bridges is largely depended on the joints. Poor joints will decrease the service period of bridges and causing failure to bridges and leading to extra financial commitment in constructing new bridges instead of damaged bridges. Adequate periodical maintenance is needed to take care of joints. Good quality materials should be used in making joint assembly and proper installation of joints is needed by strictly following the installation precautions/specifications as laid down by the joint manufacturers. In addition to the above, installation of joints should be done with utmost care and proper coordination is needed between Engineer, Contractor and Installer during joints installation operation.

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