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Comparative Study for Expansion Joint Type Selection on Bridges with High Seismic Movements.

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Abstract: Expansion joints play a critical role in safely allowing movements in bridges due to temperature, shrinkage, creep, dynamic movement from traffic and seismic demands. For bridges in high seismic zones, movement demands can be significantly higher, hence selecting a proper expansion joint type is essential for ensuring the bridge performs as expected and maintain uninterrupted traffic flow. This study evaluates modular and finger expansion joint types based on space requirements and movement demands. A comparative analysis is performed using available supplier data. The findings of this research aim to assist engineers in selecting a proper expansion joint type.

Keywords: *Expansion joint, modular expansion joint, finger expansion joint, deck movement on bridges, bridges in high seismic zones.*

1. Introduction:

Expansion Joints are used on bridges to allow for movement caused due to temperature, shrinkage, creep, seismic activity, and dynamic movement due to traffic on the bridge. Service life of the entire bridge structure largely depends on their reliability and durability [1]. Different bridge types will have different movement demands on expansion joints. For example, a cable-stayed bridge would have high movement demands on expansion joints due to the flexibility of the structure. The design displacement range of the expansion joints for the Ting Kau and Tsing Yi abutments, due to temperature variation are 339 and 297mm [10]. When such type of bridge is built in a high seismic zone, the movement demands on expansion joints can be significantly higher. During the use of the bridge, the expansion joints are exposed to various defects. Defects can be the result of eight main causes systematised in [6]: (i) inadequate design, i.e., in relation to the movements of the structure; (ii) defects in the technical specifications, such as insufficient adaptation to the service conditions or lack of connection between the joint and the rigid element; (iii) defects in the production, i.e., inadequate anti-corrosion treatment or incorrect geometry; (iv) errors during installation, such is for example incorrect definition of the neutral point of the joint or inadequate anchoring; (v) lack of proper maintenance resulting in accumulation of debris or moisture from vegetation on the deck and water leaks; (vi) changes from the intended conditions of use, such as a deck with a different long-term behaviour than predicted, settlement of abutments or foundations, a higher traffic load than expected; (vii) environmental effects such as higher or lower temperatures (which may already occur during device installation), freeze-thaw cycles; and finally (viii) random impacts due to natural events or human influences. The studies summarised in the above-mentioned study [6] conclude that a large part of the costs in bridge management (up to 20% in some cases) is related to the repair and replacement of expansion joints. In addition, rehabilitation measures that result in disruption, slowing, or detour of traffic flow can cause inconvenience to users and significant indirect costs. Thus, selecting a proper expansion joint type is essential.

Usually for bridges in high seismic zones, seismic demand would govern over other demands. However, appropriate load combinations must be evaluated to accurately determine the design demands. Commonly, two expansion joint types are preferred for high movements, namely modular expansion joints and finger expansion joints. Modular expansion joints have a center beam which is supported by and rolls on a support beam. Center beams will transfer the load from traffic to the system below. Based on the expansion joint size which is dependent on the movement it needs to accommodate, the number of center beams can increase or decrease. Figure 1 shows a schematic for modular expansion joint. Finger expansion joints have fingers in an opposite staggered fashion that slides, thereby allowing deck movements. Figure 3 shows the section through a finger joint and Figure 5 shows the fingers in the opposite staggered fashion.

2. Expansion Joint Type selection:

It has been stipulated that a good expansion joint should [2]:

Accommodate all movements of the structure,

Withstand all loadings,

Have good riding qualities,

Not present a danger to cyclists or other types of traffic,

Not impart undue stress to the structure unless the structure has been designed accordingly,

Be reasonably silent and vibration free,

Give reliable service throughout the expected temperature range,

Resist corrosion,

Facilitate maintenance and repair, and

Control deck drainage to prevent damage to structure below.

Moreover, guideline for European technical approval of expansion joints for road bridges specifies numerous requirements on expansion joint such are mechanical resistance, resistance to fatigue, seismic behaviour, movement capacity, cleanability, resistance to wear, watertightness, safety in case of fire, release of dangerous substances, safety in use, protection against noise, energy economy and heat retention, aspects of durability, serviceability and identification of products [5].

Finger expansion joints are ideal for medium to long-span bridges due to their ability to accommodate significant movements [7]. Modular bridge expansion joints are designed to accommodate large longitudinal expansion and contraction movements of bridge superstructures [8]. Modular expansion joint and finger expansion joint will be covered in this study as these can allow large movement demands on bridges.

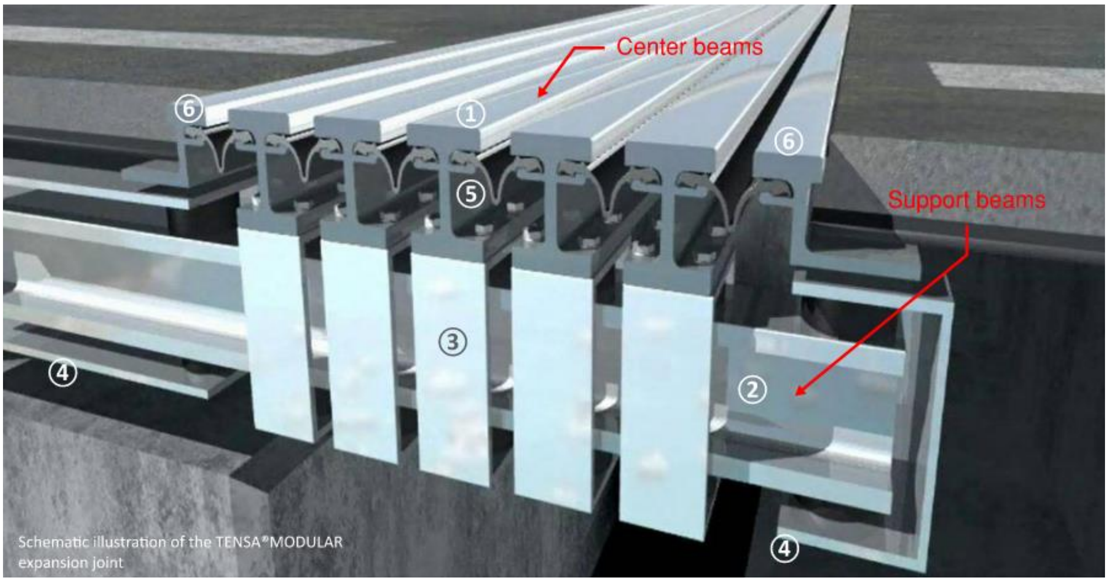

Figure 1: Modular Expansion Joint [3]

Depending on the specific project context, certain factors may take precedence over others in the selection of an appropriate expansion joint type. Therefore, in addition to the key considerations outlined at the beginning of this section, the following three factors should also be carefully evaluated to ensure an optimal joint selection:

2.1 Blockout dimensions required: Blockout dimension is the clearance required in the deck to properly fit the expansion joint. As shown in Figure 2, the dimensions B1xC and B2xC are the blockout dimensions required to fit the expansion joint. Different suppliers have different requirements for blockout dimensions. For example, mageba [3] requires a comparatively large blockout on one side than other. However, DS Brown [12] requires same blockouts on both sides. Hence, if the joint positioning on the deck is such that there are space restraints on one side of the joint, then this can prove to be a contributing factor behind a particular supplier selection.

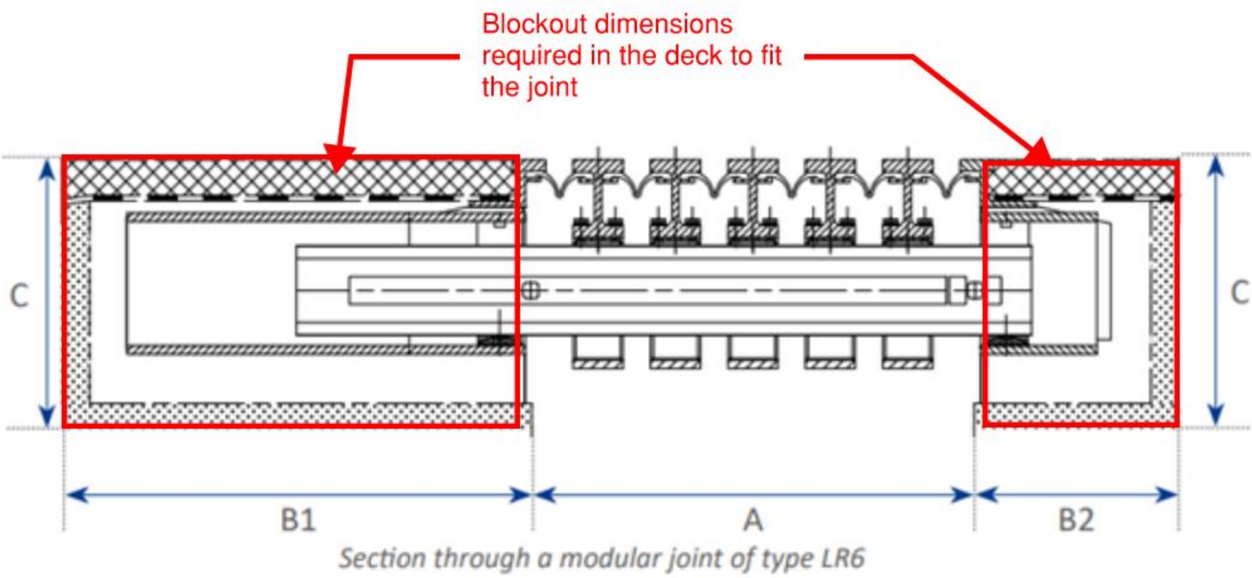

Figure 2: Section through a modular expansion joint [3]

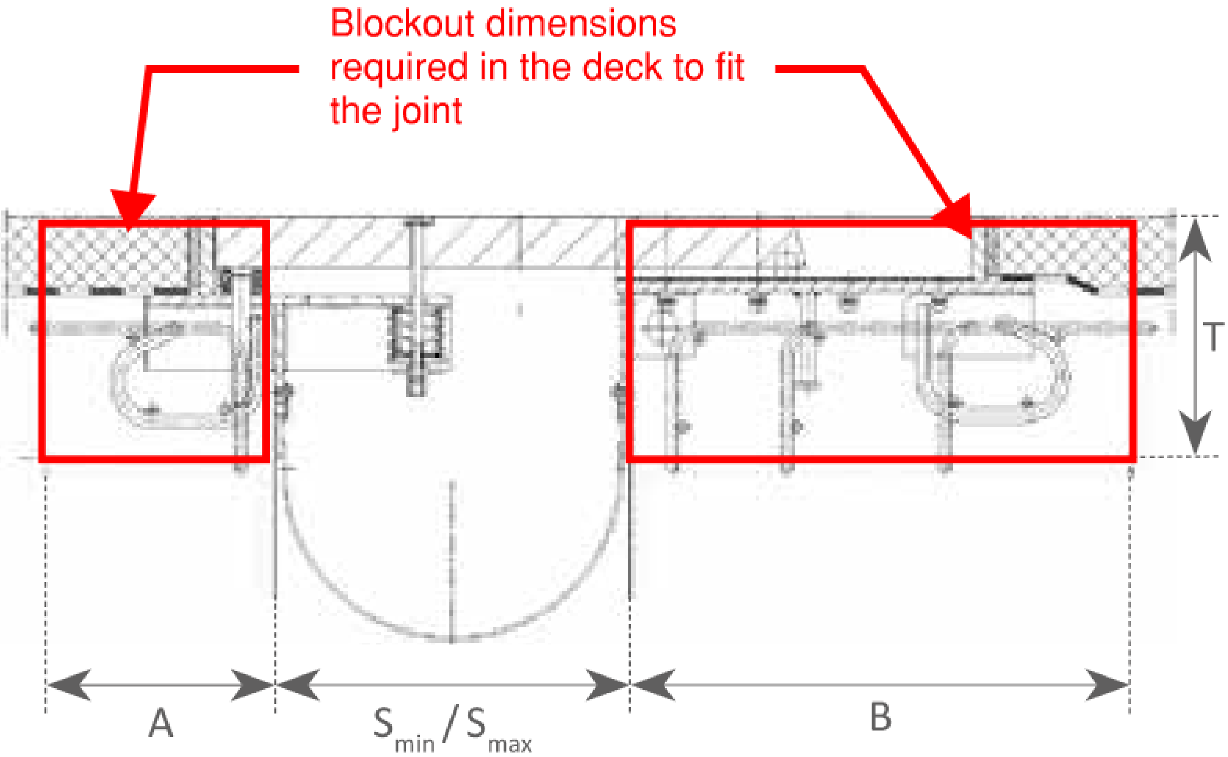

Figure 3: Section through a finger expansion joint [4]

Table 1: Modular expansion joint movement range and type [3]

Type	**Number of gaps**	**Type LR (max. individual gap width 80 mm)**		**Type LR/LR-LS (max. individual gap width 100 mm)**	
		Max. longitudinal movement	Max. transverse movement	Max. longitudinal movement	Max. transverse movement
[-]	[-]	[mm]	[mm]	[mm]	[mm]
LR 2	2	160	± 24	200	± 24
LR 3	3	240	± 22	300	± 22
LR 4	4	320	± 35	400	± 35
LR 5	5	400	± 29	500	± 29
LR 6	6	480	± 36	600	± 36
LR 7	7	560	± 42	700	± 42
LR 8	8	640	± 76	800	± 76
LR 9	9	720	± 85	900	± 85
LR 10	10	800	± 60	1,000	± 60
LR 11	11	880	± 67	1,100	± 67
LR 12	12	960	± 74	1,200	± 74
LR 13	13	1,040	± 80	1,300	± 80
LR 14	14	1 120	± 87	1,400	± 87
LR 15	15	1 200	± 118	1,500	± 118

LR 16	16	1 280	± 126	1,600	± 126
LR 17	17	1,360	± 99	1,700	± 99
LR 18	18	1,440	± 107	1,800	± 107

Mageba's type LR-LS expansion joint consists of sinus plate between gaps in modular expansion joint to reduce noise from traffic. For preliminary joint type selection, if the movement demand is higher than listed in Table 1, then the corresponding values in Table 2 can be extrapolated as the dimensions usually follow a trend.

Table 2: Modular expansion joint dimensions [3]

Type	**Type LR (max. individual gap width 80 mm)**						**Type LR/LR-LS (max. individual gap width 100 mm)**					
	^{A}min	**^{A}max**	**B1**	**B2**	**C***	**Weight**	**^{A}min**	**^{A}max**	**B1**	**B2**	**C***	**Weight**
[-]	[mm]	[mm]	[mm]	[mm]	[mm]	[kg/m]	[mm]	[mm]	[mm]	[mm]	[mm]	[kg/m]
LR 2	100	300	360	320	400	250	140	340	400	320	400 / 425	250/290
LR 3	170	470	440	320	400	320	230	530	500	320	400/425	330/380
LR 4	240	640	520	320	420	410	320	720	600	320	420/445	420/490
LR 5	310	810	600	320	440	490	410	910	700	320	440/465	510/600
LR 6	380	980	680	320	440	580	500	1,100	800	320	440/465	600/710
LR 7	450	1,150	760	320	440	670	590	1,290	900	320	440/465	690/830
LR 8	520	1,320	840	320	465	790	680	1,480	1,000	320	465/490	810/990
LR 9	590	1,490	920	320	465	880	770	1,670	1,100	320	465/490	910/1,100
LR 10	660	1,660	1,000	320	485	1,000	860	1,860	1,200	320	485/510	1,030/1,250
LR 11	730	1,830	1,080	320	485	1,090	950	2,050	1,300	320	485/510	1,120/1,350
LR 12	800	2,000	1,160	320	485	1,180	1,040	2,240	1,400	320	485/510	1,220/1,460
LR 13	870	2,170	1,270	320	515	1,330	1,130	2,430	1,530	320	515/540	1,380/1,630

LR 14	940	2,340	1,350	320	515	1,430	1,220	2,620	1,630	320	515/540	1,480/1,750
LR 15	1,010	2,510	1,430	320	535	1,610	1,310	2,810	1,730	320	535/560	1,670/1,970
LR 16	1,080	2,680	1,510	320	535	1,710	1,400	3,000	1,830	320	535/560	1,780/2,090
LR 17	1,150	2,850	1,590	320	565	1,940	1,490	3,190	1,930	320	565/590	2,020/2,360
LR 18	1,220	3,220	1,670	320	565	2,050	1,580	3,580	2,030	320	565/590	2,130/2,490

Dimensions listed in Table 2 can be seen in the section view of Figure 2.

Table 3: Finger expansion joint dimensions [4]

Type	**Movement capacity**		**s_{min}**		**s_{max}**		**A**		**B**		**T**		**Weight**	
	inches	mm	inches	mm	inches	mm	inches	mm	inches	mm	inches	mm	lb/ft	kg/m
GF 120	4.7	120	6.2	157	10.9	277	13.8	350	13.8	350	13	330	215	320
GF 240	9.5	240	8.1	207	17.6	447	13.8	350	18.5	470	13.8	350	329	490
GF 360	14.2	360	10.3	262	24.5	622	13.8	350	26	660	14.2	360	440	655
GF 480	18.9	480	12.3	312	31.2	792	13.8	350	30.3	770	14.6	370	558	830
GF 600	23.6	600	13.8	352	37.5	952	13.8	350	35	890	15	380	692	1,030
GF 800	31.5	800	17.4	442	48.9	1,242	13.8	350	42.9	1,090	15.4	390	893	1,330
GF 1000	39.4	1,000	20.7	525	60.3	1,532	13.8	350	50.8	1,290	15.7	400	1129	1,680

To better illustrate, an example of comparison between modular and finger expansion joint blockouts from the same supplier is presented herein. Modular expansion joint type LR 3 from Table 1 and finger expansion joint type GF 240 from Table 3 accommodate the same longitudinal movement of 240mm. Blockout dimensions for LR 3 from Table 2 are 440 mm x 400 mm = 176,000 mm^2 on one side and 320 mm x 400 mm = 128,000 mm^2

on the other side. GF 240 requires 470 mm x 350 mm = 164,500 mm^2 and 350 mm x 350 mm = 122,500 mm^2. For LR-LS 10 modular joint type with 1000 mm movement, the dimensions required are 1200 mm x510 mm = 612,000 mm^2 and 320 mm x 510 mm = 163,200 mm^2. For GF 1000 finger joint type with the same movement requires 1290 mm x 400 mm = 516,000 mm^2 and 350 mm x 400 mm = 140,000 mm^2. It can be seen from the two examples here that finger joint requires relatively less blockout dimension than modular joint.

2.2 Drainage System: One of the common themes found from the [11] survey is that many of the State DOT's are dissatisfied with the finger joint drainage trough. This is mainly due to the maintenance of the drainage trough. Other factor that needs to be taken into account for the selection of expansion joint type is the drainage system height requirements. Finger joint utilizes a drainage channel as seen in Figure 4 that is available in different materials per customer preference. On the other hand, modular joint is watertight such that drainage takes place at the bridge surface [3]. There are no additional space requirements for drainage channel on a modular joint. Therefore, if sufficient space is not available below the deck, there might be problems to accommodate a finger expansion joint due to its drainage channel clearance requirements. One such scenario, for example, can be on a cable-stayed bridge, wherein there is an edge girder beneath the expansion joint, and trimming of edge girder is not possible to accommodate finger expansion joint drainage channel. Therefore, if the space or the maintenance requirements cannot be satisfied for the drainage channel on finger joints, then modular joint shall be preferred.

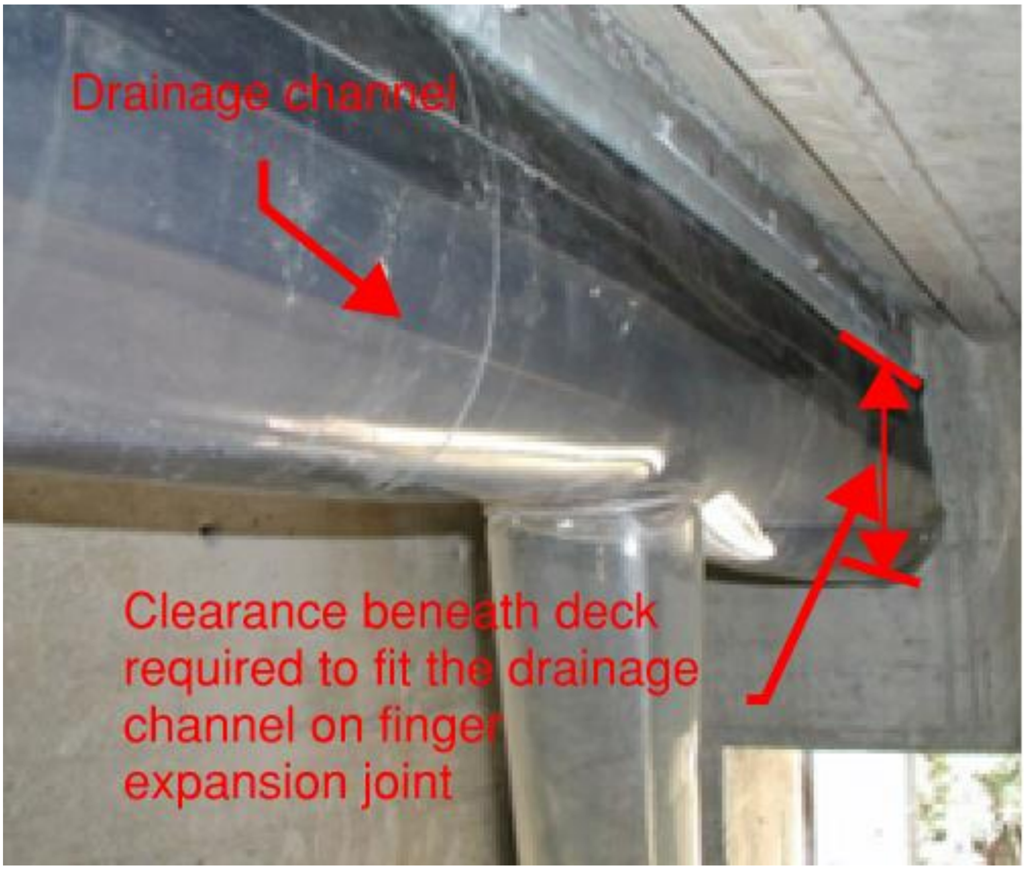

Figure 4: Drainage channel on finger expansion joint [4]

2.3 Transverse movement demand: Transverse movement demand on the bridge depends on its fixity conditions, demands due to traffic, wind demands and the seismic demands on the bridge. Since, finger expansion joint has fingers in an opposite staggered fashion as shown in Figure 5, transverse movements can cause damage to the fingers which will slide against each other, hence needing a replacement. On the other hand, modular expansion joint has center beams that run transversely across the deck, therefore the relative sliding of two surfaces does not seem to be a problem. The expansion joint type suppliers would usually have a transverse movement tolerance that can be accommodated before the joint is damaged, hence that shall be checked against the movement demand. It is recommended, however, to provide a shear restraint in the bridge to take care of the transverse movement demands.

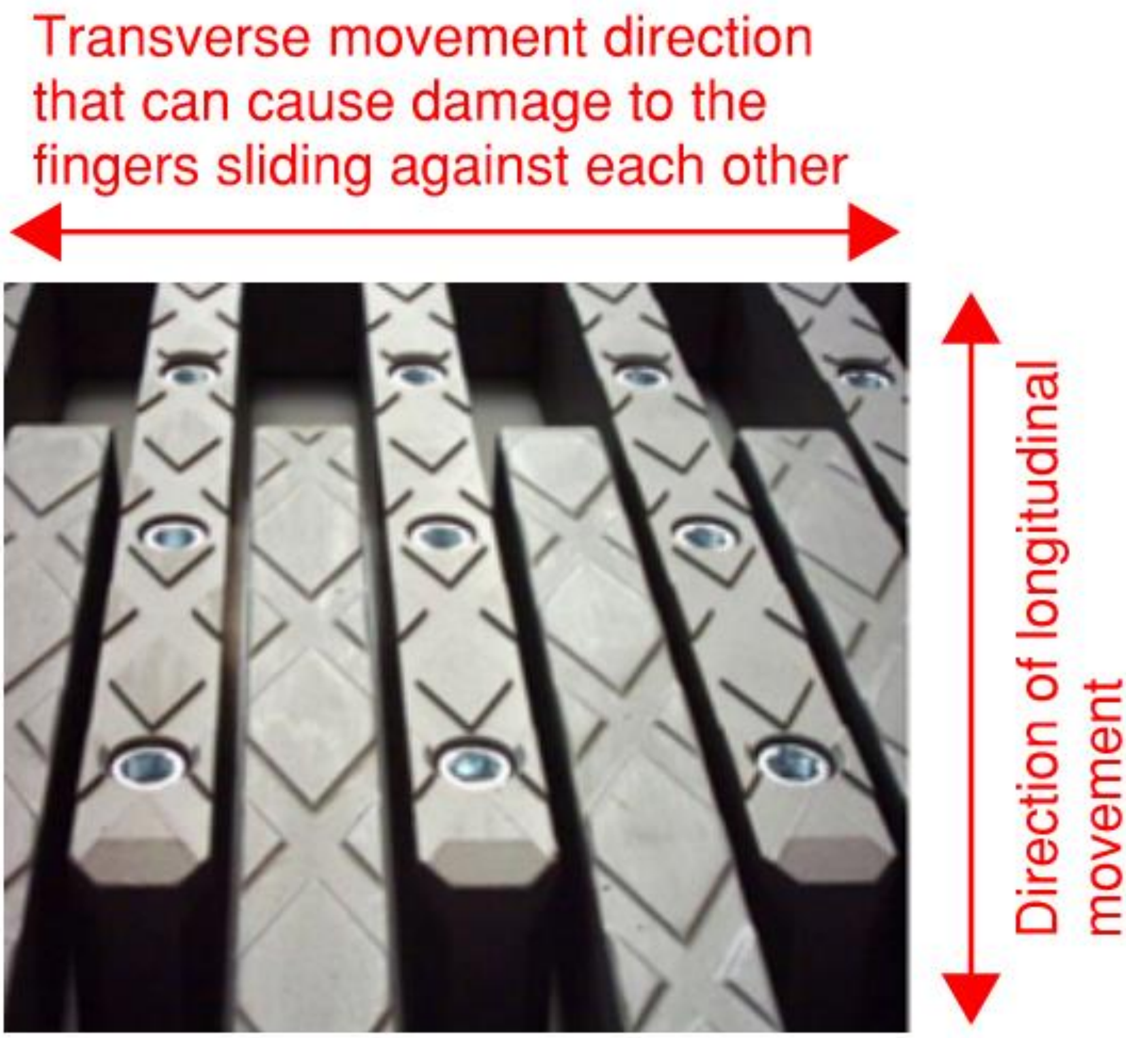

Figure 5: Surface pattern of fingers on the finger joint [4]

Other miscellaneous factors that can be used to come up with a decision include cost of the joints, supplier availability at the bridge site, any other project specific requirements.

3. Conclusion:

Bridge expansion joints are critical components in the structural integrity and operational functionality of bridge systems [9]. Hence, it is very important to choose an expansion joint type that best suits the bridge.

As discussed in this paper, there is no single expansion joint type that best suits all bridge projects. Each joint type exhibits unique performance characteristics and limitations, making it essential to align the selection process with the specific functional and geometric requirements of the project. Critical parameters influencing joint selection include the magnitude of expected longitudinal and transverse movements, design life, maintenance access and frequency, expected durability under environmental and traffic exposure, and spatial constraints on the bridge deck for joint installation.

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