TechStar Lock-Up Devices & anti-seismic expansion joints in Southern Asia

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**ABSTRACT:** A shock transmission unit (STU) is a special mechanism used to link separate elements of structures, intended to share short term impact forces applied to any one element by transmission to all the linked elements. For bridges STU(s) are used to link elements of the superstructure and substructure, to protect the bridge during high seismic activities. This presentation describes the design, installation and operation of STU(s) for bridges. The paper also describes STUs and anti-seismic swivel joints supplied by D.S. TechStar Inc, USA for various installations in Southern Asia. METCO is the sole licensee in India for manufacture of STUs and swivel joints designed D.S. Techstar Inc, USA.

1 WHAT IS A SHOCK TRANSMISSION UNIT (STU) OR LOCK UP DEVICE (LUD)?

A shock transmission unit (STU) is a simple device which provides the engineer a method of temporarily creating a fixed connection, when desirable, which would during normal operations remain as a moveable connection. The device is sometimes referred to as a Lock-Up Device (LUD). The unit is connected between adjoining separate structures or between elements of structures and has a benign effect on the bridge during normal periods of time. Upon receipt of a sudden short duration shock (dynamic) load the device locks up and transmits the load through the structure. In effect the device creates a rigid link within a fraction of a second when the sudden load is applied, affording the possibility of sharing the load throughout the structure. However, once the shock load is removed the device again reverts to its benign influence and the structure behaves in a normal manner.

![Diagram of STU](image)

**Fig. 1.**

In Fig. 1, the mechanism is detailed. The unique characteristics of the unit are achieved by migration of the medium around the piston when very slow movements occur. Therefore, slow structure movements such as temperature change, creep, shrinkage, post tensioning effects and settlement are adequately permitted as the medium will slowly squeeze past the piston and the side wall of the cylinder. However, the medium has a very special characteristic, when stationary it acts as a solid, but will flow very slowly under a constant pres-
sure of slow velocity, but will react again as a solid upon a sudden impact of high velocity. TechStar developed a special silicone compound which flows between the piston and cylinder for these slow movements, but is unable to pass between the piston and cylinder during the impact loading due to the thixotropic characteristics.

Lock-Up Devices are nothing new. They have been used since their introduction in the 1930s and were reintroduced by TechStar to growing acceptance starting in 1990. The advantages of LUDs are numerous and offer the bridge engineer many applications which will result in a less expensive bridge design. The concept of “sharing” the load throughout the structure is the most obvious. By connecting the device to normal expansion areas of a bridge, the structure during the normal course of operation will behave in a normal manner (i.e. the bridge would move as if the device were not present). However, at the first instant of a sudden load applied to the expansion area, the device creates a temporary fixed connection. The LUD should be considered a tension / compression bar in its capacity to transmit the load across the expansion joint or from the superstructure into the substructure. Since the 1990 re-introduction, TechStar has produced LUDs for many projects including the largest capacity LUDs ever utilized. These 25,000 kN (ULS) LUDs were used on the San Francisco-Carquinez Bridge retrofit completed in 1997.

The LUD is connected by brackets and pins to the superstructure and/or substructure, which permits the normal translation of movement. The transmission rod (piston) passes through the entire length of the cylinder so that the volume of the silicone medium remains constant at all piston positions. Under slow movement between the structures the medium flows around the piston and is displaced from one end of the cylinder to the other. The faster the piston is made to move in the cylinder, the greater the force required to do so due to the increasing resistance of the compound until a point is reached when flow of the compound ceases and the unit locks.

When a short term dynamic load is applied through the transmission rod the impact tensile or compression force is passed along the load path of the transmission rod / piston head / silicone medium / cylinder to the adjacent structure or structure element. The rating of the LUD unit defines the maximum impact force which is to be transmitted. The length of the transmission rod is designed to meet the expectations of the normal movement of the bridge at that location, while resisting the axial forces of the specified shock design load. The unique thixotropic characteristics of the silicone medium are present through a wide range of temperatures, therefore, the LUD can be relied upon to perform consistently under all climatic conditions. In Fig. 3 the normal operation is shown and the graph depicts resistance typical of what might be applied by a LUD during the slow movement of the bridge.

2 USE OF THE LUDS IN BRIDGE APPLICATIONS

The LUD permits the bridge engineer the to design a bridge with a virtually maintenance free device that has no effects on the normal bridge operations. The device expands and contracts freely in response to all the long term movements which can be anticipated. The device does act as a temporary rigid bar connection and can be modeled as a fixed connection during impact loads such as seismic loads, road or rail braking and acceleration forces, ship collisions and in retrofit applications to upgrade the load rating of a bridge.

In multi-span structures the LUD is perhaps best applied. When a bridge has a series of abutments and piers, column or bents, the LUD can be used to connect all of these locations and create a continuous struc-
ture for an event which would apply a dynamic load to the structure. The bridge engineer has always wished he could tie the structure together but has been unable till now to do so because a bridge must be permitted to move. The LUD can in effect reduce the amount of load on any given part of the structure.

In Fig. 4, a typical simple span bridge is illustrated. The design calls for each span to have an expansion bearing and a fixed bearing. The breaking forces and longitudinal acceleration forces must be taken by the fixed bearing and the substructure below. Regardless of the number of spans the effect of placing the LUDs to work in series does not change.

By placing LUDs between all the simple support spans, the bridge in effect is made continuous for the purpose of any force which would act upon any individual part of the bridge. The forces affecting one span would now be shared by all fixed bearing locations and the abutment with the braking forces distributed throughout the entire bridge. The first table indicates the actual forces applied to the fixed piers for a braking force of 45 tons. The second table indicates the reduction in force of 20% of the original design at all fixed locations due to the temporary fixing of the expansion locations by the LUD. This is a significant reduction in force and may dictate that the bridge might not have to be replaced.
The LUD can also be applied to a continuous structure. A typical viaduct having a central fixed pier or a fixed abutment and sliding, rocker, or elastomeric bearings at all other locations can benefit from the application of LUDs as well. Consider the seismic loading criteria; the lone fixed pier must withstand all the forces associated with the seismic event. However, by placing the LUDs at all sliding connections as illustrated in Fig. 5, the load is distributed between all piers, not just the fixed pier. This design concept is a significant advantage when the design criteria dictate an overload of the fixed pier.

![Fig.5](image)

The LUD utilization on a concrete box girder design, such as in California, with integral columns and hinge expansion joints is shown. The placement of LUDs within the hinge creates a fixed connection during an earthquake, thus sharing the seismic load with all columns. A hinge joint is often located adjacent to a short column which lacks the ductility to resist the earthquake forces by itself. By placing the LUD at the hinge the load is transmitted across the hinge to the next span and a much taller column which shares the load, reducing the forces applied to the shorter column. This can save a bridge from disaster. In addition, the LUDs prohibits the banging of expansion joints during less severe seismic events.

3 SOUTHERN ASIAN LUD APPLICATIONS

Lock Up Devices have been used on bridge applications within Southern Asia for the past ten years. One of the first applications was on the Jamuna Bridge located in Bangladesh. For this application, the LUDs were coupled within the shear keys of the structure. Following the success of this application, Bangladesh has used LUDs on the Paksey Bridge, the Mohakhali Flyover in downtown Dhaka, and several projects currently in the tender stage at this time. India has used Lock Up Devices a couple of project starting with Bassien Creek Bridge in Mumbai and the Allahabad Bridge currently underway.

The Paksey Bridge project over the Padma River in Bangladesh utilized the largest LUDs thus far supplied to a Southern Asia project. There were 42 LUDs supplied on this project with the largest devices having a capacity of 11,500 kn load/750 mm stroke. These devices were installed onto the concrete box-girder bridge with their brackets already connected commencing in 2001-2. There were many attempts by the Chinese General Contractor to use Chinese supplied LUDs for this project. The construction manager (Parsons Brinkerhoff), the Bangladesh Government, and the World Bank thwarted these attempts and insisted that the LUDs be supplied from an acknowledged supplier with sufficient experience and installation history. We believe this experience requirement is necessary if the bridge owner is to expect long-term satisfactory performance with the LUD in their bridge application.

The Mohakhali Flyover within Dhaka also utilized LUDs and was completed within the past twelve months (2005). The 42 LUDs for this project ranged in size from 4755 kN (4 LUDs) to 3910 kN (38 LUDs). One half of the LUDs were installed during the construction phase of the flyover and the remaining portion were installed after the opening of the structure to vehicular traffic. This staged installation scheme was a result of an extensive testing program required by the contract and enforced by the World Bank and Bangladesh Government. For this project, the World Bank insisted that each LUD be tested at an independent laboratory.
No manufacturer or “factory testing” was considered acceptably independent. All testing was to take place “off site” from the manufacturer at an Independent Testing Laboratory. This created a bottleneck at the testing laboratory and required approximately 8-10 months additional time for the entire testing program.

Thailand has used LUDs on a couple of projects as has Indonesia. Currently, the Industrial Ring Road project connected by two Mega-Cable Stayed Bridges in Bangkok is using 20 TechStar LUDs. The load sizes of these LUDs range from 3500 kN to 4200 kN. These devices are used in the ramp interchange structures at the extreme south end of the bridges. These LUDs are delivered and awaiting installation.

While 100% testing of LUDs is an excellent way of determining the seismic performance of each device, the variance in performance between individual LUDs of the same design remains so small as to be meaningless in relation to the load application on the bridge. This means that excessive testing is conducted that is not meaningful, or of any benefit other than to the testing lab conducting it. Bridge bearings require testing, but according to AASHTO are limited to 1 bearing tested per load category of 25 pieces. These bearings are expected to function daily in their capacity of holding up the bridge. LUDs still being relatively new, are expected to function one day in the future, but in some cases require complete 100% testing. A reduction in LUD testing requirements, with experience, to those of structural bearings would ease General Contractor and manufacturer constraints and be a logical progression in LUD acceptance and wider use. This is the process being followed within the USA and has gained acceptance on many other bridge projects elsewhere in the world. This serves to both shortening the delivery timing and significantly reducing costs. Testing often represents up to 50% of the supplied price for LUDs to the General Contractor. Reductions in the quantities of LUDs tested for contract compliance are already underway for projects being quoted within Southern Asia.

4 USE OF ANTI-SEISMIC “SWIVELING CAPABLE” LARGE-MOVEMENT MODULAR EXPANSION JOINTS

A growing trend in anti-seismic bridge design is to minimize any potential damage at the expansion joints from earthquake displacements. Often these anticipated seismic displacements are beyond the normal thermal longitudinal movement capacity of the expansion joint and also anticipate transverse movements (sideways) and vertical rotations. By utilizing “swiveling-capable” modular expansion joints, designers are able to mitigate these problems. The overall goal in selecting such a multi-directional movement expansion joint for the anti-seismic application is that the expansion joint remains functional for emergency vehicles use immediately after the earthquake event. Overall damage to the expansion joint is minimized and any required cosmetic repair can take place without removing the expansion joint or closing the bridge.

Use of these type of anti-seismic modular expansion joints commenced in Germany, have been used extensively in East Asia on long suspension and cable-stayed bridges in Hong Kong and China, are used in California on box-girder structures and elsewhere within the USA. These are relatively new in Southern Asia bridges. The design modifications needed by these designs from normal modern modular expansion joint systems are relatively minor. Any “Single Bar” modular expansion joint is capable of swiveling. Three manufacturers currently make such systems with sufficient experience to merit consideration. The extent of the swiveling (pivoting) and rotating of an expansion joint is a function of the geometry of the support bar boxes which permit movement of the support bars, trumpeting them to permit the required additional movements, and use of spherical bearings for vertical rotations. Extra-long support bars which extend beyond the normal thermal movement requirements are used to accommodate any longitudinal seismic movements. TechStar modular joints of this type have been used on several key bridges within the San Francisco, CA area including, the San Francisco Airport Interchanges, the Benicia-Martinez Bridge, and Carquinez Bridge, and the San Francisco-Oakland Bay Bridge underway.

The Rupsa Bridge in Bangladesh is a box girder bridge and the first application to use these modular expansion joints in Southern Asia. This bridge, built by Shimizu Construction (Japan), was completed in 2003-4 and required two TechStar expansion joints with 800 mm longitudinal and 150 mm transverse movements.

In Dubai, United Arab Emirates, there is a large land reclamation project underway called Palm Jumeirah. This is a large man-made island shaped like a giant palm tree that extends out into the Arabian Sea. The privately developed Palm Jumeirah Island is to to serve as a gateway to ultra-high luxury housing, hotels, and other tourist attractions on the palm. Connecting the stalk of the tree to the mainland is a large bridge known as the Gateway Bridge. Four large TechStar modular expansion joints, each with 700 mm of longitudinal movement and 300 mm transverse movement are used. These modular expansion joints are installed and the bridge is scheduled to open to “island construction” traffic within the next 30 days.

There have been several attempts to validate manufacturer’s capability to withstand earthquake motions while providing assurance that the expansion joint is capable of long-term performance under normal traffic. We have found that the best assurance can be realized by utilizing a very conservative loading (a high loading factor) in the expansion joint design. We recommend using a 2X AASHTO loading factor for any such appli-
cations as a minimum, irrespective of any long-term Fatigue Testing or other supporting evidence of a manu-
facturers’ performance claims. By using 2X AASHTO, this reduces the spacing between the support bar and gains overall structural integrity to the system. This is what is required in California and is used in Dubai, Abu Dhabi, and elsewhere.