Selection of Laminated Elastomeric Rubber Bearings for Bridges – A Technical Note

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1.0 Introduction

Laminated Elastomeric Rubber Bearings (LERB) are perhaps the cheapest components in a bridge structure. It is economical and it is the first choice of bearing for small to medium span bridges that do not require to accommodate large movements due to expansion or contraction.

The first reputed use of LERB was for the replacement of roller bearings on Pelham Bridge outside Lincoln in 1957 **[1]**. It has come a long way since.

Improper selection from a catalogue that unwittingly leads to an unsuitable bearing results in undersized bearing which could cause bearings to " Walk " in an extreme case.

The composition of the rubber compound LERB is not the subject of this paper. It will be touched on briefly with respect to " Walking Bearings ".

1.1 Case History

Perunding FAISAL, ABRAHAM dan AUGUSTIN Sdn Bhd were the Consulting Engineers for works on the Middle Ring Road 2 Phase 2 Package 6. At Sterling Health Interchange bearings were observed to have become displaced about 1 year after service.

The bearing design selection was checked independently and found to be adequate. We concluded that it could have come adrift due to reduction in friction between bearing, plinth and concrete beam soffit [2].

Subsequently in private inquiries amongst consultants it became apparent that this was not an isolated incident.

2.0 Walking Bearings

2.1 Shear Deformation Before Bearings Walk

Figure 1 shows at time zero when beam and bearing are first in place. At sometime later due to expansion or contraction of bridge deck, the movement of the bridge beam is permitted by shear deformation of the LERB.

A bearing "walks" when there is movement of LERB from its original position on the plinth. This happens when the friction between LERB, the plinth and beam is overcome by the stored energy that caused the bearing to shear in the first place.

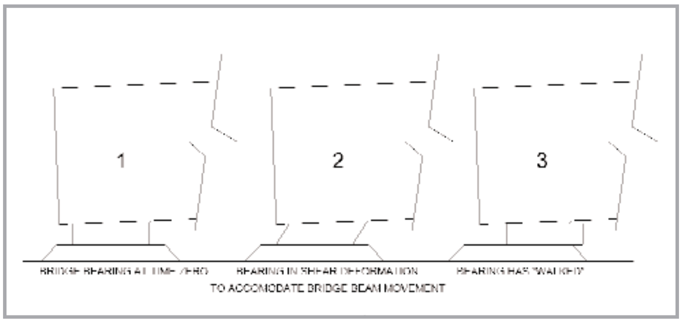

Figure 1

2.2 Forces in Bearing Before Walking

V = Vertical Force (kN) on bearing due to all loads at time of consideration
H = Shear stiffness (kN/mm) of bearing
d = Movement of deck (mm) due to temperature, shrinkage, creep, etc

When the ratio of horizontal force/vertical force between bearings and contact surface exceeds 0.1, the coefficient of friction is overcome and bearing can move i.e. walk.

If

$$\frac{H \times d}{V} > 0.1, \text{ movement takes place} \qquad \textbf{(Equation 1)}$$

In the normal selection process, the designer would ensure that this does not happen.

There are however circumstances when this criterion is not met.

2.3 Reduction of Vertical Load and Coefficient of Friction

Skewed bridges can raise problems. When *Equation 1* is considered for the extreme load case of maximum shear with no live load i.e. deck is loaded with dead and imposed dead load with maximum deck movement due to all causes. When live load is on the deck, the acute corners will lift thereby reducing the value of V while H remains and the coefficient of friction may be exceeded.

One remedy is in the use of softer LERB which are thicker than required. The shear stiffness is reduced and hence in uplift situation the built in horizontal force in the bearing is smaller. Although the vertical force V is reduced , H is smaller to begin with.

In another situation, the formulation of rubber compounding can have a detrimental effect. To satisfy ozone resistance, waxes in the form of paraffin and micro-crystalline, are added during rubber compounding. These waxes bloom and reduces the coefficient of friction between bearings and contact surfaces under load. This has been observed and concluded as a primary cause of bearing slippage **[3]**. Laboratory test on 10 of the samples of walking bearing showed that 8 had contained wax. Another cause has been the use of tapered bearing pads for beams on incline.

Micro-crystalline **[2]** is thought to be a better anti-ozonant as its "wax" bloom does not have such a severe effect as paraffin wax. Video time lapsed camera was used as a tool in this study and the bearings could be seen to walk.

The Tun Abdul Razak Research Centre (TARRC), England **[4]** considers paraphenylenediamine as a better anti-ozonant. It does not have the defect of wax bloom due to addition of micro-crystalline or paraffin wax.

2.4 Forced Rotation in Bearing and Reduction in Capacity

Bearings are sometimes forced into premature rotation by placing bridge beams on an incline on level bearing pads without the designer being aware that this immediately reduces the bearing capacity when designed on the basis of level seating.

The rotational capacity of a bearing is directly related to the vertical load. In bearing catalogues, the rotational capacity is given as

$$10.063 \times 10^{-3} \text{ radian/100kN}$$

in the case of a LERB 250 x 200 x 70 thick.

An analogous situation that illustrates this relationship better is a pad footing under axial and overturning moment.

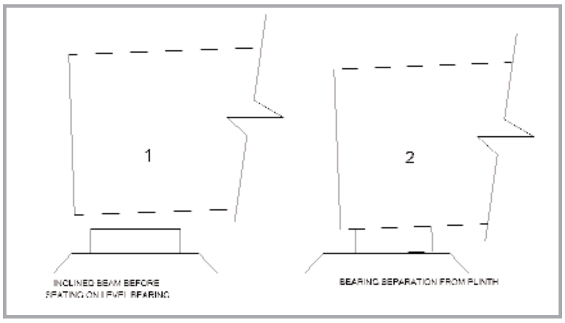

Figure 2

Axial load causes a uniform pressure. If the overturning moment causes a negative pressure that exceeds the uniform pressure, uplift takes place i.e. separation of bearing from plinth takes place. Reduction of contact increases the likelihood of slippage of beam and bearing off the bearing shelve.

When a bearing is in an uplift condition, penetration of moisture can act as a lubricant which reduces the coefficient of friction between surfaces and makes the beam prone to slip.

The rules **[5]** governing rotation capacity and axial load interaction requires that a check for

$$\Delta > (b_e\alpha_b + l_e\alpha_l)/3 \qquad \textbf{(Equation 2)}$$

Where,

- Δ – Total vertical deflection of load case
- α_b – angular rotation across width b of bearing
- α_l – angular rotation across length l of bearing
- l_e – effective length of elastomer
- b_e – effective width of elastomer

To ensure that the case of inclined beams are accounted, *Equation 2* should be modified to have the form

$$\Delta > (b_e\alpha_b + b_e\alpha_{bi} + l_e\alpha_l)/3 \qquad \textbf{(Equation 3)}$$

Where,

α_{bi} – angular rotation across width b of bearing caused by beam inclination.

Beam inclination also induces horizontal forces onto the bearings which causes additional shear deflection of bearings. The horizontal force H_i can be assumed to be equal to the gradient of the inclination expressed as a percentage multiplied by the vertical load,

$$H_i = V \times i \qquad \textbf{(Equation 4)}$$

i = inclination of beam as a percentage.

This would be valid for gradients not exceeding 10%.

At 10% gradient, beams under self load will be in an incipient state of limiting equilibrium. This is an extreme situation which is uncommon. It however illustrates the fact that the friction between surfaces can be overcome merely when placing beams.

2.5 Beam Seating

In *Figure 1 (1)*, the beam soffit is shown with a shoe to ensure a level seating of beam on bearing.

Some **[6]** have advocated that a layer of epoxy be trowelled onto top surface of bearing and beam is brought to bear on unset epoxy while supported by shims.

The Australian Standards **[7]** suggest that using this procedure or fixing a bearing onto a plinth by epoxy is not recommended as a preferred failure zone within the elastomer can take place. Once this happens the coefficient of friction between the ruptured elastomer surface is lesser than that of plinth and elastomer hence slip can take place easily.

There are two safe options that may be used to make good beam seatings viz:-

i) form the shoe within the beams during casting or
ii) use a thicker bearing i.e. one with a greater rotational and shear capacity to cater for the case of inclined beams.

3.0 Bearing Selection Procedure

3.1 Present Procedures

Presently the method that is used in the industry is for a bearing to be selected from a catalogue for a certain performance specification. This bearing size is then checked by the manufacturer by way of calculations before production. The calculations are in effect the design procedure in Part 9 of BS5400.

3.2 Preliminary Selection

Manufacture's catalogue usually give bearing capacity in tabular form. It can be visualised by constructing a 3-dimensional envelope from the information given.

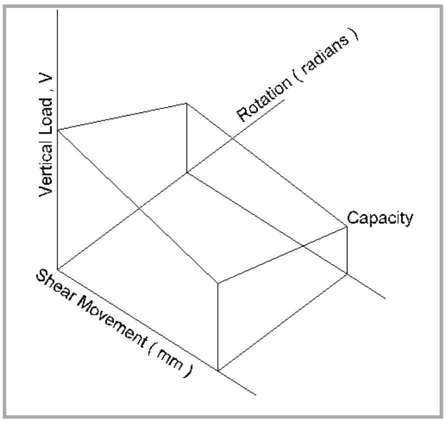

Figure 3

The limits are expressed in tabular form as

Table 1

Maximum Dead Load + Live Load			
No Rotation		Maximum Rotation	
No Shear	Maximum Shear	No Shear	Maximum Shear
503kN	380kN	310kN	233kN

**Taken from Freyssinet PSC Laminated Elastomeric Bearing Catalogue*

The figures given in *Table 1* have been extracted from a catalogue for a particular bearing of size 300 x 150 x 50. The capacity of the bearing is thus 233kN when it is subjected to maximum shear and rotation that it can accommodate. This 3-dimensional envelope would be a good start for bearing selection which is then checked rigorously.

3.4 Australian Standards Procedure

The Australian Standard **[7]** gives a comprehensive method of checking a selected bearing for fitness for intended use. It recommends that the following load-cases be considered:-

(a) Minimum vertical load and the corresponding largest horizontal load and shear deflection
(b) Minimum vertical load and the corresponding largest rotation
(c) Maximum vertical load and the corresponding largest horizontal load and shear deflection
(d) Maximum horizontal load and shear deflection and the corresponding largest vertical load

(e) Maximum horizontal load and shear deflection and the corresponding smallest vertical load
(f) Maximum rotation and the smallest vertical load.

The use of a spreadsheet can facilitate comprehensive check for all the load cases mentioned above.

4.0 Conclusion

The slippage of bearing pads (walking) occurs in Malaysia however is not reported extensively. Skewed bridges are a special case when unloading of the acute corners can cause bearings to slip or walk.

One cause that has been reported **[2, 3]** attributes it to wax blooming that takes place continually. Paraffin wax and micro-crystalline have and is being used in LERB manufacture as an anti-ozonant to satisfy ASTM D 1149. These additives continually bloom to LERB surface. Wax build-up causes reduction in friction, which can lead to walking bearing. Micro-crystalline is the better of the evils. TARRC considers that paraphenylene-diamine as a better anti-ozonant, which does not have this adverse effect.

Placing bridge beams on an incline reduces the rotational capacity of LERB and can promote slippage when the incline is not accounted for.

The Australian Standards AS 1523 offers a good guide for bearing selection and procedures for checking. A spreadsheet can perform this function rapidly.

There is insufficient open sharing of such problems encountered within the engineering fraternity such matters which makes it difficult to offer industry wide solutions.

Acknowledgment

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References

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[7] Australian Standards 1523 – 1981 , Elastomeric Bearings For Use In Structures