BRIDGE BEARINGS REPLACEMENT CHALLENGES – A REVIEW

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***Abstract* -** Bearings are a critical element of bridge structures and play a key role in the distribution of loads from superstructure to substructure. Bearings are of various types and installed in bridge structures based on articulation requirements. Depending on the type of bearing, there is a variation in service life. Bearings also require different types of maintenance work ranging from routine cleaning and greasing to full replacement. This paper focus is based on major maintenance works i.e. full replacement of bearings during their design life. The replacement of bearings poses various design and construction challenges which are highlighted in this paper. Various solutions, which have been implemented in numerous past schemes, are proposed to overcome these design and construction challenges. These solutions provide insight to the reader to overcome these challenges in their schemes at preliminary design stages and can help in the preparation of efficient and economical design.

***Keywords* -** Bearings, Design challenges, Construction challenges, Jacking, Replacement.

1. Introduction

Bearings are critical components of a bridge. They transfer loads between the superstructure and substructure while maintaining the articulation of the bridge. Different types of loading act on bridges which include self-weight (dead load), superimposed, traffic, wind and temperature. These loads create translation and rotational movements which bridge bearings need to accommodate during service life. Bearings are of many types depending on material and fixity [1, 2]. These can be elastomeric (*Figure 1a*), roller (*Figure 1b*), pot (*Figure 1c*), knuckle (*Figure 1d*), leaf (*Figure 1e*), guided and plane sliding (*Figure 1f*). An elastomeric bearing comprises a block of elastomer that may be reinforced internally with steel plates or may be unreinforced [3]. A roller bearing consists essentially of one or more steel rollers between parallel upper and lower steel plates. Pot bearings consist of a metal piston supported by a disc of unreinforced elastomer that is confined within a metal cylinder. Knuckle bearings comprise of two or more members with curved surfaces and allow rotation by sliding one part on another. Leaf bearings have a pin passing through plates fixed alternately to the upper and lower bearing plates. Guided bearings provide restraint in only one horizontal direction and plane sliding bearings only provide translation. According to British Standards BS 5400 Part 1 [4] and Part 9 [5], bearings are required to be designed for 120 years. During this period bearings should be maintained and serviced as per manufacturer requirements. Bearings can be maintained through routine or minor maintenance prior to full refurbishment and replacement. Routine or minor maintenance includes cleaning or re-greasing of bearings and patch re-painting. Niemierko produced a paper on "Modern bridge bearings and expansion joints for road bridges" [6] however the focus was on the bearing components themselves rather than on the design and construction challenges of bearings. Three bridges were studied by Van Lund [7] with various construction challenges discussed, however, design challenges were not considered. Furthermore, the paper was published in 1995 with some of the bridges studied being nearly 100 years old. The purpose of this paper is to discuss present design and on-site challenges related to the replacement of bearings and conclude solutions to overcome these challenges. These solutions will provide insight to the reader to deal with challenges for their future schemes.

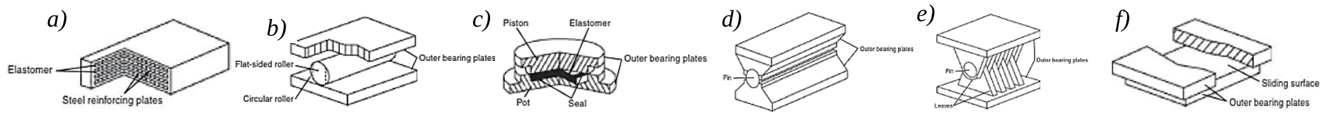

Figure 1: a) elastomeric bearing, b) roller bearing, c) pot bearing, d) knuckle bearing, e) leaf bearing, f) plane sliding bearing

2. Procedural Steps for Bridge Bearing Replacement

The design process for bridge bearings replacement has the following main activities: determination of the articulation and condition of the existing bearings, modelling of the bridge deck to confirm the loading on the bearings, development of a bearing schedule, modelling of jacking arrangements, production of a jacking schedule and temporary works design to undertake the bearing replacement work.

The process begins with a comprehensive preliminary assessment. This involves gathering information about the existing bearings from as-built design drawings as well as from inspection and maintenance reports. On-site surveying of the existing bearings should be undertaken to identify signs of deterioration or damage. Furthermore, surveying is necessary to understand precisely which bearings are in need of a replacement. It is possible that only a particular group of bearings need replacement i.e. the free bearings or mechanical bearing with PTFE. After determining which bearings need to be replaced, finite element analysis (FEA) modelling is undertaken to find the loading applied on bearings from the bridge deck. The model encompasses all the structural constituents of the deck (e.g. main beams, deck slab, parapet beams…) including the geometry and material properties. Furthermore, the modelling includes the various types of loading subject to the bearings such as deck dead, superimposed and live loads. These are calculated using relevant design standards. Finally, the model loading outputs are to be combined in accordance with design standards.

A bearing schedule, which is a detailed document that outlines the specifications and requirements for bridge bearings, is produced. Standard bearing schedule layout can be found in BS 5400 Part 9 [5] but this standard has been withdrawn in 2010 and since replaced with BS EN 1337 Part 1 [8]. The bearing schedule includes information such as the type of bearings required, their dimensions, the load capacities of the bearings from modelling analysis, material compositions of the bearing seating faces as well as specific installation requirements e.g. type of fixing. The overarching purpose of the bearing schedule is to provide information for the design of new bearings.

In order for the bearings to replaced, the bridge deck must be jacked. A jacking arrangement is tested using FEA modelling software such as LUSAS [9] or MIDAS Civil [10] to simulate the loading experienced by the hydraulic jacks to ensure they can withstand the forces and stresses encountered during the jacking process. Furthermore, by modelling the jacking arrangement the stresses experienced by various bridge components (e.g. diaphragm or main beams) can be studied to ensure that they are within acceptable limits.

3. Discussions

3.1 Design Challenges

There are various design challenges with the replacement of bridge bearings. Unknown concrete strength is a significant challenge. Replacing bearings involves jacking entire bridge sections. It is particularly important to know the strength of the section being lifted by the jack e.g. the diaphragm. Design calculations are undertaken to ensure that the concrete section being lifted by a jack can handle the stress from lifting. Suitably sized jacking plates are selected to avoid concrete crushing from excessive stress. If the concrete strength is unknown, it may be necessary to sanction concrete testing of the affected sections. Otherwise, the designer would need to plan for the worst-case scenario (very low strength). This would present additional challenges with finding a jacking and temporary works design that would pass all the design checks.

Figure 2: Hydraulic jack placed on column with limited space

The age of bridge structure is a design challenge. Older bridges were designed using design codes that have since been withdrawn and replaced with newer standards. It is normally the case that new design standards have more strict requirements. In the case where there is a contractual obligation to satisfy the current design standards, there can be various challenges in finding an acceptable solution for bearing replacement. An example is where new design standards define that the deck main beams have a lower loading capacity than what was calculated in the original design. This could cause difficulty in selecting a temporary works design that does not cause the main beams to exceed their new, lower loading capacity.

Another challenge is the limitation of space for the placement of hydraulic jacks. To undertake a bearing replacement scheme, jacks of specific type and size must be placed in positions according to the temporary works design. However, due to poor bridge design, it can be very challenging to find a suitable position for the jacks. For example, the height between the bearing plinth and the bridge deck beam may be too small to fit a suitable jack. It is observable in ***Figure 2*** that there is a limit in available height so only a small jack could be safely placed on the column. Furthermore, it can be seen that there is no space for placing a second jack on this column. There are solutions for these types of limitations such as constructing a temporary shoring tower on which to place jacks, however, the solutions are far more expensive than the conventional method of placing jacks on the existing bridge substructure.

3.2 Construction Challenges

Table 1: Key construction challenges and solution

Construction Challenges	Potential Solution 1	Potential Solution 2
Services/STATs within the work area	Undertake calculations to check if services can allow displacement from jacking	Liaise with the service provider to find a solution e.g. temporarily shutting down the service
Inaccurate information from as-built drawings	Undertake on-site survey	Check if there is enough design tolerance to proceed
Difficulty with removing fixed bearing	Hydro-demolition around the old fixed bearing followed by restoration of the structural member	Implementation of other demolition methods such as drilling and cutting
Traffic Management	Ensure that there are satisfactory lane closures	Ensure that the traffic diversion route is satisfactory
Inadequate Space for equipment to allow breakout of concrete	Acquiring and using more compact equipment	Consider alternative demolition methods

There are various construction challenges that can be faced as shown in *Table 1*. A major construction challenge is when it is discovered on site that the bridge is not as per as built drawings. For example, it is discovered that the spacing between bearings is less than previously known. This may require a change to the jacking arrangement and therefore a new design for temporary works. There may be a delay of weeks for the designer to check and approve an alternative jacking arrangement. Not only would there be a time delay, but there would also be a significant cost to cancel and reschedule equipment, personnel and road closures that were reserved for a particular time to undertake the bridge bearing replacement.

Before undertaking bridge bearing replacement, it is vital to identify and coordinate with the owners of services that may be located near or within the bridge structure. This coordination ensures that services are properly protected. If necessary, services may need to be relocated or temporarily shut down during construction work. If there is a service line that was not accurately identified, there is a risk of damage to that service. Not only can this cause disruption to the service, costly repairs, and financial penalties, it may present a major safety challenge. For example, if the unidentified service was a gas pipe and it was broken during the jacking of the bridge, it would leak gas and possibly cause an explosion. If the service was identified on site just as construction work was getting started, there may be a delay to the project to agree with the service owner whether the service would need to be temporarily shut down or relocated.

Bearings with fixity can present additional challenges that free bearings are not affected by. It is often the case that fixed bearings are bolted in the bridge abutment or beam. There may be a range of issues with removing fixed bearings. The bolts may have corroded or deteriorated over time making them difficult to remove. There may be restrictions related to access, such as limited space, making it challenging for the contractor to use the required equipment for disassembly. It is often the case that the contractor must remove the concrete around the bearing bolts to remove the old bearing. This presents further challenges associated with maintaining the bridge's structural integrity during the bearing replacement work as well as with ensuring that the damaged bridge structural component is refurbished to an acceptable condition.

There are challenges associated with providing temporary fixity or additional restraint to a bridge during bearing replacement work. There is the potential for damage if fixity or restraint systems are improperly installed. This may cause issues, such as overstressing bridge components and causing damage to concrete. These issues can threaten the structural integrity of the bridge. The contractor must ensure that restraint systems are installed correctly and in the case of causing damage to the bridge, there must be liaison with the designer before continuation of works to ensure that necessary repairs are undertaken so that the bearing replacement work is carried out safely.

If a bridge is to have bearings replaced at various abutment or pier locations, then it is necessary to follow a precise plan for the various stages of bearing replacement. It is a construction challenge to successfully coordinate the activities across multiple stages of bearing replacement work while minimising disruption and ensuring there are no delays. This requires effective communication with the various project stakeholders including the designer, principal contractor, sub-contractors and transportation authorities. Furthermore, bearing replacement projects often require lane closures to ensure the safety of workers and bridge users. Managing traffic flow during these closures is challenging and requires effective planning, particularly in heavily travelled routes or where alternative routes are limited.

4. Conclusions

The design and replacement of bridge bearings involves careful consideration of multiple factors to ensure successful implementation. ***Section 2*** of this paper provides a structured approach to the design process behind the replacement of bridge bearings. Various challenges faced in bearing replacement projects were discussed, such as unknown concrete strength, bridges designed under old design codes and access limitations for placing hydraulic jacks. These challenges require innovative solutions and often necessitate additional testing and conservative design assumptions. Furthermore, construction challenges, including discrepancies between site conditions and as-built drawings, the presence of utility services, and the necessity of maintaining bridge structural integrity during bearing removal and replacement, demand thorough planning and effective communication among various stakeholders. Overcoming these challenges is crucial for the successful and safe replacement of bridge bearings, ensuring an extended lifespan and satisfactory performance of bridge structures. Awareness of these challenges can lead to efficient and economical design.

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