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# PARAMETRIC STUDY ON THE NUMBER OF BEARINGS & REDUCTION OF REINFORCEMENT OF PIER CAP OF SLAB BRIDGES

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**Abstract**:The importance of transportation for the prosperity of any country cannot be overemphasized.Transportation needs commensurate with infrastructural development demand shortest routes to cover distances. Bridge structures are the only solutions for such problems.Bridges are essential and vital elements of any road network. Now a days various Bridge construction works are going on all around the world as well as in our state.The vast majority of these bridges are of small or medium spans, where the slab or the beam and slab type of superstructure are the most suitable and preferred solution. It is observed that, In this slab type of bridges mostly 3 no.of Elastomeric bearings are provided to transfer the load from superstructure to sub structure. This only 3 no.of bearings transferring the whole load to substructure and foundation attracted my attention.

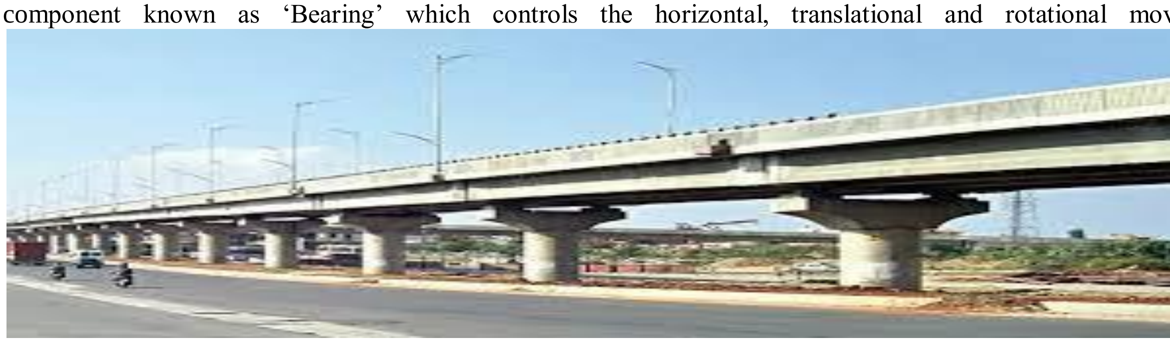
So I decided to work on the Elastomeric bearings, the no .of bearings provided and its effects on the other structure of the project.Bearings are structural equipment or devices installed between bridge substructure and superstructure to transfer the applied load including earthquake loads; wind loads; traffic loads; and superstructure self-weight.

In this project we consider Solid slab type of bridge superstructure of 10m to 15 m span length with open foundation. For each span length of superstructures we designed particular Elastomeric Bearings. For analysis firstly we provide 3 number of bearings and observed its effect on substructure and foundation by designing the substructure. After that we increased the number of bearings and provided 4 number of bearings .Observed the effect on substructure and foundation and found that the pier cap effects the most. We compared both the observations and concluded the result.

**Introduction:**

Bridge Engineering is one of the most fascinating fields in Civil Engineering,calling for expertise in many areas, rangingfrom surveying to statistics, runoff calculations to rubble masonry, steel to structural concrete and materials to modern methods of construction. A successful Bridge Engineer has to have an appreciation of aesthetics and economics, besides ability in analysis and dexterity in design. The materials and procedures involved in the construction of any sizeable bridge are quite varied.

A bridge structure can be divided into two main bodies, the superstructures and the substructures; the superstructures bear its own weight and the traffic load, and the sub structures bear the load from the superstructures.Between the two there is a main component known as 'Bearing' which controls the horizontal, translational and rotational movement of bridges.



Bearings can be termed as the mechanical part of a bridge structure. To aid the movement in the present type of bridge structures bearings have been adopted. The earliest types of bridge bearings are made of steel, but with problems of durability, degradations, flexibility and maintenance different types of bridge bearings have been developed to suit different designs and requirements. Current studies are aimed towards further development of bridge bearings to support and transfer larger forces with higher level of durability for lifespan that matches the bridge lifespan whilst enabling bridge flexibility at a cost effective means.

**Role of bridge bearings :**

Bridge bearings are connections that transfer forces between the bridge superstructure (deck) and the substructures (pier, viaduct or abutment). Temperature difference such as increase in temperature causes the bridge structure to expand/elongate along its length, thereby causing movements in the bridge structure and vice versa, decrease in temperature causes the bridge to reduce in length. During seismic occurrence the bridge foundations take up forces and transfer to the entire bridge structure causing rigorous vibration and movements of the bridge. The bridge structure also vibrates and moves in reaction to forces from heavy traffic (trains, vehicles etc.). Creep, shrinkage and elastic deformation all result in movement of the bridge structure.

**Causes of movement in bridges :**

In general, movements in bridges can be summarized to the following sources: -

- Movements due to shrinkage and creep
- Movements due to traffic loads
- Movements due to dead load of the bridge structure itself
- Movements due to lateral forces acting on the bridge structure such as wind loads
- Movements due to temperature changes
- Movements as a result of settlements in supports (uniform and differential settlements)
- Movements as a result of soil pressure on abutments
- Movements due to horizontal loads such as accelerating, braking, skidding and traction force
- Movements as a result of impact forces such as vehicles colliding with bridge structures (railings, kerbs, edge beams etc.), vehicles colliding with other vehicles, boats and ships colliding with piers
- Movements as a result of seismic activities (earthquakes, earth tremors)

In view of the above, it is imperative to design for the movement in bridges to avoid extra forces and moments that generated when the bridge movement is restricted. These movements in bridges are enabled by bearings. The functions of a bridge bearing is summarized as follows:

**Functions of bridge bearings :**

- Connects the bridge superstructure to the substructure.
- Accommodates and transfers dynamic forces and vibrations without causing wear or destruction to the substructure.
- Enables movement (translational, vertical or rotational) of the bridge structure in reactions to loads.
- Controls the movement in bridge structure; direction and degree wise.
- Ensures that deformations, which occur in the superstructure of the bridge, do not lead to large forces and moments in the substructure.
- Can be used to adjust the dynamic properties of the bridge.
- Bearings reduce shear on the head of the piers, viaducts or abutments.
- Recent bridge bearings are designed to act as seismic protectors that arrest and dissipate energy during earthquakes and other seismic activities.

**Elastomeric bearings** = An elastomeric bridge bearing is a commonly used modern bridge bearing. Elastomeric bearing pads compress on vertical load and accommodate horizontal rotation and provide lateral shear movement. Elastomeric bearing pads are the most economical solution used in construction of large span bridges and buildings.

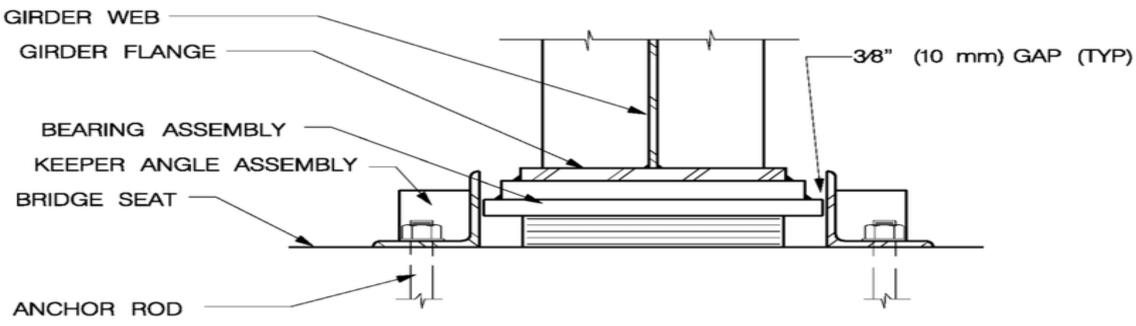



Fig 1.1Elastomeric bearings

**Merits of elastomeric bearings**

- Reinforcing steels are enclosed in elastomer therefore protected against corrosion.
- Long life span with little need for maintenance.
- Suitable for large bearing rotation.
- Good performance under moderate seismic activity.
- Moderate cost.

**Demerits of elastomeric bearings**

- Errors in dimensioning that leads to slide plate been too short, insufficient area of elastomeric lamination, insufficient number of reinforcing steel plate.
- Problems from improper installation such as insufficient anchorage, improper connection between the bearing, substructure and superstructure.
- Defects arising from poor product quality such as corroded steel, inadequate vulcanization, poor rubber quality etc. leading to splitting, slippage, cracking of the rubber.
- Bulging of rubber in bearing due to compression and rotation. 2.3. POT bearings 17 –Delimitation from steel reinforcement as a result of shearing stresses near the edge of the bearing.
- Tears under strong earthquake but easily replaceable compared to other types of bearings.
- Freezing and stiffening of the rubber at low temperatures. - Problem of fatigue as a result of temperature changes the properties of the rubber with time.

**Literature Review**

In previous studies various authors have analyzed different types of bearing considering different load patterns and IRC loads. Railway and road bridges were analyzed with different shaped pier and bearing systems. Ansys and other analytical applications were used for the purpose of modelling and generating results.

**Simon Hoffmann and Hermann Weiher(2012)** the paper has pointed out how single steel elements of sliding bearings can be substituted by UHPFRC and demonstrate their high performance. Results concluded that the single elements required for the design of high performance spherical bridge bearing with UHPFRC calottes.

**Arun Mohan C M and Sowmya V Krishnankutty(2017)** in this paper they investigated that Earthquakes can create serious damage to bridges . Structures already built are vulnerable to future earthquakes. Results concluded that a brief review of several literature presented shows that bearings proves to be efficient for reducing the effects of the damage caused by the bridge by seismic activities.

**S. Priyadarshika and M. Rajkannan(2019)** the paper presented describes the investigation and analysis of bridge pot bearing. Results concluded that in practice where the bearing was supposed to take heavy loads, there would be a lot of vibration which was to be taken into consideration. In the design of PTFE(Poly tetra fluoro ethylene) bearing the analysis has been done considering the above condition.

**K.Abhitej Naidu et al. (2019)** this paper study compared the design of bearing reinforced using ASTM B22 and an optimized alloy with the conventional steel laminates used for bearing reinforcement. Result concluded that the strength of all materials are adequate to be used as a reinforcement for bearing and the values of yield strength and ultimate strength were marginally varied.

**Suthandra Devi S et al. (2019)** the paper evaluated the behavior, performance and experimental of elastomeric bearings. The study includes an experimental evaluation and elastomeric bearing should satisfy the following condition as per IRC 83. Results concluded that this type of bearing a new investigation. The unreinforced elastomeric bearings considerably under load and return to their original shape on removal of the load.

**KhushndyKhilji and Karan Parbhakar (2018)** the study of a machine component which supports another moving machine element. Result concluded that This paper focuses on the importance of bearing and details about the types of bearing. We have mainly studied four types of bearing as they have unique characteristics and applications in the mechanical field.

**Pranay Sable and Pankaj Singh (2018),** In this paper, the designed moments for the different components of superstructure were compared for both types of bridges. Result concluded that comparing moments in deck slab, Corresponding to these moments the calculated reinforcements are also lesser compared to bearing bridges.

**S.R.Kale et al. (2020),** the paper presented the investigation and analysis of bridge pot bearing. Earthquakes can create serious damage to bridges. Structures already built are vulnerable to future earthquakes. Results concluded that in actual where the bearing is supposed to face heavy loads, there would be a lot of vibration which have to be taken into consideration.

**R Arunkiliyal et al. (2017),** the present paper described the comparative study on bridge pot bearing. In this case analysis was done by using ANSYS and SAP 2000 software. Result concluded in practical where the bearing was supposed to take heavy loads, there would be a lot of vibration which have to be taken into consideration

**G. Ghosh et al. (2008),** this paper examined the thermal and seismic response of (i) Traditional Roller-Rocker bearings, and (ii) Isolation Bearings viz. Elastomeric Bearings with and without Dampers, Friction Pendulum Systems (FPS) for a three-span continuous bridge. Result concluded that the performance of different types and arrangements of Traditional Rocker-Roller Bearings and Isolation Bearings has been studied under thermal and seismic loading conditions.

**Summary of Literature Review:**

Analysis of literature gives us an overview about the comparative study of different types of Bearings like Elastomeric bearings, Roller-Rocker bearings, POT PTFEbearings ,Sliding bearings their analysis, earth quake resisting properties, comparison with each other. However there is no reported literature on no.of bearings and its effects on different structures of bridges like the sub structure i.e. pier cap ,pier and foundation of bridges .

**Objective of the Study:**

In this project we consider Solid slab type of bridge superstructure of 10m to 15 m span length with open foundation. For each span length of superstructures we designed particular Elastomeric Bearings. For analysis firstly we provide 3 number of bearings and observed its effect on substructure and foundation by designing the substructure. After that we increased the number of bearings and provided 4 number of bearings .Observed the effect on substructure and foundation. We compared both the observations and concluded the result.

We mainly worked on two parameters i.e. no.of bearings and reinforcement of piercap. Finally we did the parametric study on no.of bearings (elastomeric bearing) and its effect on the different structures of bridge especially pier cap. Did detail analysis of the pier cap, pier and foundation .Found variation in Pier cap due to change in no.of bearings. Comparative change in Reinforcement of pier cap is observed.

**Loading Conditions and Design Considerations**

The Indian Road Congress (IRC) has formulated Standard Specifications and Codes of practice for Road Bridges with a view to establish a common procedure for the design and construction of road bridges in India. The specifications are collectively known as the Bridge Code.Prior to the formulation of the IRC Bridge Code, there was no uniform code for the whole country. Each State (or province) had its own rules about the standard loadings andstresses.Currently, we would follow the IRC Bridge Code. Some of the Code are reviewed under.

**IndianRoadCongressBridgeCode:**The Indian Roads Congress (IRC) Bridge Code as available now consists of eight sections as below:

**Table: Showing Eight Sections of IRCBridge Code**

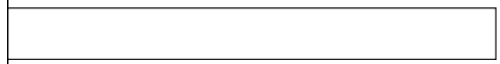
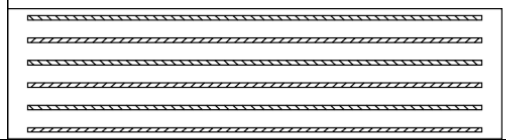
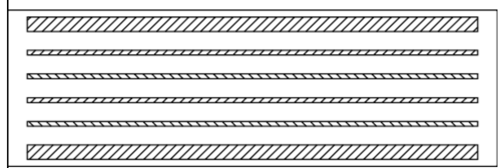
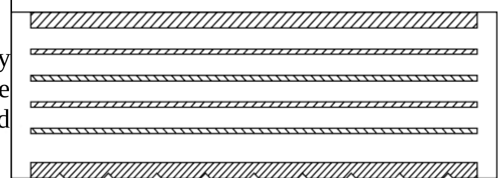
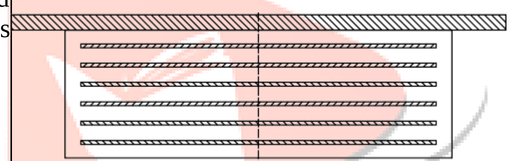
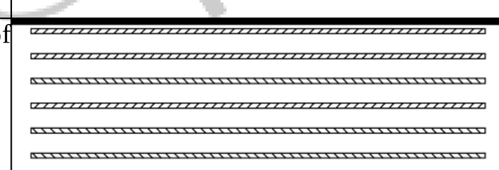
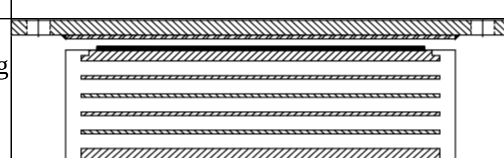
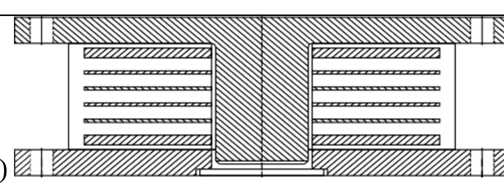
| S. No. | Section | Details |
|---|---|---|
| 1 | Section I | General features of design. |
| 2 | Section II | Loads and Stresses. |
| 3 | Section III | Cement Concrete (plain and reinforced). |
| 4 | Section IV | Brick, Stone and Block masonry. |
| 5 | Section V | Steel Road Bridges. |
| 6 | Section VI | Composite Construction. |
| 7 | Section VII | Foundations and Substructure. |
| 8 | Section IX | Bearings. |

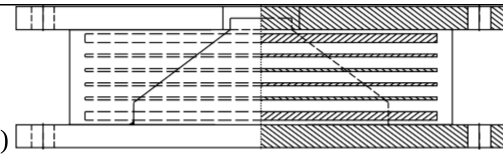
**Elastomeric Bearings**:

Elastomeric Bearings are designed on the basis of "The Standard Specifications and Code of Practice for Road Bridges, Section IX– Elastomeric Bearings, Part-II"

This part of the Specification (referred to as 'Code' hereinafter) applies to elastomeric bearings with or without complementary bearing devices to extend their field of use such as flat sliding elements covered by relevant Part, as used in bridge structures or any other structure with comparable support conditions.

**Table : Types of Elastomeric Bearings**

| | | |
|---|---|---|
| 1) | Type A: Plain pad/Strip bearings |  |
| 2) | Type B: Laminated bearings |  |
| 3) | Type C: Laminated bearings with thicker end laminates:<br>laminate may be on either side or on both side<br>ensures better load distributionensures better rotation<br>back lifting of bearing under shear may be avoided |  |
| 4) | Type D: Laminated bearings with thicker end laminates exposed:<br>Corrosion protection is required on exposed steel surface.May be useful for better frictional resistance at bearing structure interface.Friction, if taken into account, should bebased on tested and certified value<br>Useful for contact with steel structure. |  |
| 5) | Type E: Bearings with separate steel plate directly vulcanised with the bearing- lifting/separation of bearing elastomer at edges from exposed steel plate should be avoided under all loading. |  |
| 6) | Type F: Bearings with positive anchorage:<br>Separate plates provide ease of replacement and fool-proof positive anchorage.Plates may be connected to covered/exposed end laminatesinternal fastening and positive means of location to be adequately designed. |  |
| 7) | Type G: Bearings with PTFE bonded to the elastomer:- bond of elastomer to PTFE is critical and vulnerable. |  |
| 8) | Type H: Bearings with sliding interface:<br>Refer relevant Part covering sliding element for design of sliding interface.Other end may be of any other option asabove. |  |
| 9) | Type I: Bearings with restraint against translation to simulate support condition.<br>a) Typical detail of restraint in form of central pin.<br>b) Typical detail of side restraint.<br>Restraints shall be designed based on relevant Part or other | a)  |

| | | |
|---|---|---|
| | relevant IRC code. | b)  |

**Loads to be considered:**
Loads considered and calculated in accordance with the IRC: 6-2017 for analysis purpose are briefed as below:
**Dead Load:**The dead Load carried by a bridge member consists of its own weight and the portions of the weight of the superstructure and any fixed loads supported by the member. The dead load can be estimated fairly accurately during design and can be controlled during construction and service.
**IRC Standard Live Loads**
Live loads are those caused by vehicles which pass over the bridge and are transient in nature. These loads cannot be estimated precisely, and the designer has very little control over them once the bridge is opened to traffic. However, hypothetical loadings which are reasonably realistic need to be evolved and specified to serve as design criteria.
There are four types of standard loadings for which road bridges are designed:
**IRC Class AA Loading:**This loading consists of either a tracked vehicle of 700 kN or a wheeled vehicle of 400 kN
**IRC Class 70R Loading:**This loading was originally included in the Appendix to the bridge code for use for rating of existing bridges.
**IRC Class A Loading:**Class A loading consists of a wheel load train composed of a driving vehicle and trailers of specified axle spacing's and loads.
**Earthquake Force (EQ):**Forces are calculated based on the dead load and live load on Pier/Abutment. These forces are applied at the Pier/Abutment-deck junction of bridge, in longitudinal as well as transverse direction.
**Temperature Force:** Forces due to temperature loading are calculated for, expansion as well as contraction conditions. These forces are applied at the abutment-deck junction of bridge, in longitudinal direction only at both the ends of bridge.
**Braking Force:** Live load braking force is applied similarly as temperature forces but at only one end of the bridge in traffic direction.
**Earth Pressure:** Earth pressure is calculated based on the coefficient of earth pressure, which in case of an integral bridge is dependent on net displacement due to temperature and braking forces, while for bearing bridges the coefficient of earth pressure is considered as active earth pressure coefficient.
**Design consideration:**
In this project we consider a Solid slab type of bridge superstructure of 10 m to 15 m span lengths with open foundation. For this superstructure we designed particular size ofElastomeric Bearing . Firstly we provided 3 numbers of bearings and observed its effect on substructure and foundation by designing the substructure. After that we increased the number of bearings and provided 4 number of bearings .Observed the effect on substructure and foundation. We compared both the observations and concluded the result.
We mainly worked on two parameters i.e. no.of bearings and reinforcement of piercap. Finally we did the parametric study on no.of bearings (elastomeric bearing) and its effect on the different structures of bridge especially pier cap.Did detail analysis of the pier cap, pier and foundation .Found variation in Pier cap due to change in no.of bearings. Comparative change in Reinforcement of pier cap is observed.

**Methodoly**
**Design steps :**For this study we adopted the following steps:

- Analysis and design of Solid slab type super structure of the bridges having different span arrangements i.e10m to 15 m with open foundation.
- Analysis and design of Elastomeric bearings of the bridges having different span arrangements i.e10m to 15 m of Solid slab with open foundation as Per Indian Standards.
- Design of Pier Cap, Pier and Foundation as Per Indian Standards.
- Compared the effect of number of Bearings provided ,on substructure by changing the number of Bearings provided as 3 per Pier and 4 per Pier.
- Design of Elastomeric Bearing , Pier cap with 3 no.of bearings and Pier cap with 4 no.of bearings are stipulated here.

**Result and Discussion**
**Results:**In Table 6.1is showingthe variation in different data in the design of Pier Caphaving no.of bearings as 3. In Table 6.2is showingthe variation in different data in the design of Pier Cap having no.of bearings as 4. In Table 6.3 is showingthe comparative variation inreinforcement of Pier Cap having no.of bearings as 3 and 4. For 10 m to 15 m Solid Slabthese analytical results were obtained and are as follows:

**Table Showing the variation of different data in the design of Pier Cap**

**(when number of bearings provided per Pier is 3)**

| S.No. | Span length | No.of bearings provided | | |
|---|---|---|---|---|
| | | 3 | | |
| | | Moment Tm | Shear Force T | Shear stress Kg/cm² |
| 1 | 10 | 94.15 | 58.1 | 3.08 |
| 2 | 11 | 106.90 | 54.47 | 3.50 |
| 3 | 12 | 125.87 | 64.13 | 4.12 |
| 4 | 13 | 140.17 | 86.50 | 5.56 |
| 5 | 14 | 158.11 | 97.58 | 6.27 |
| 6 | 15 | 177.44 | 109.50 | 7.04 |

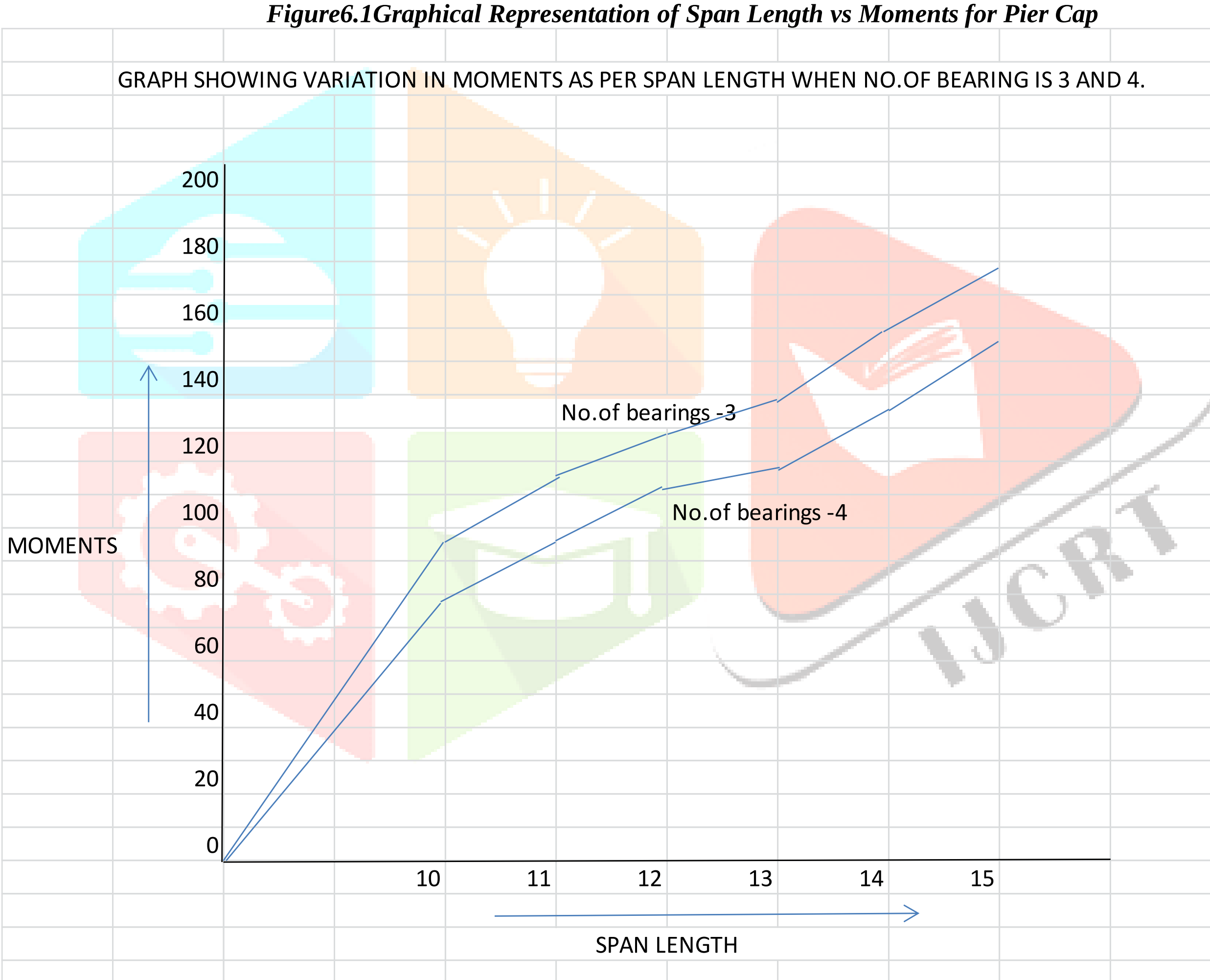
**Table 6.2 Showing the variation of different data in the design of Pier Cap (when number of bearings provided per Pier is 4)**

| S.No. | Span length | No.of bearings provided | | |
|---|---|---|---|---|
| | | 4 | | |
| | | Moment Tm | Shear Force T | Shear stress Kg/cm² |
| 1 | 10 | 77.73 | 47.97 | 3.74 |
| 2 | 11 | 88.26 | 65.97 | 4.24 |
| 3 | 12 | 103.91 | 77.68 | 4.99 |
| 4 | 13 | 115.72 | 71.42 | 4.59 |
| 5 | 14 | 130.53 | 80.56 | 5.18 |
| 6 | 15 | 146.49 | 90.4 | 5.81 |

**Table 6.3Showing the variation in area of steel in Pier cap**
(when no.of bearings provided per Pier is 3 and 4)

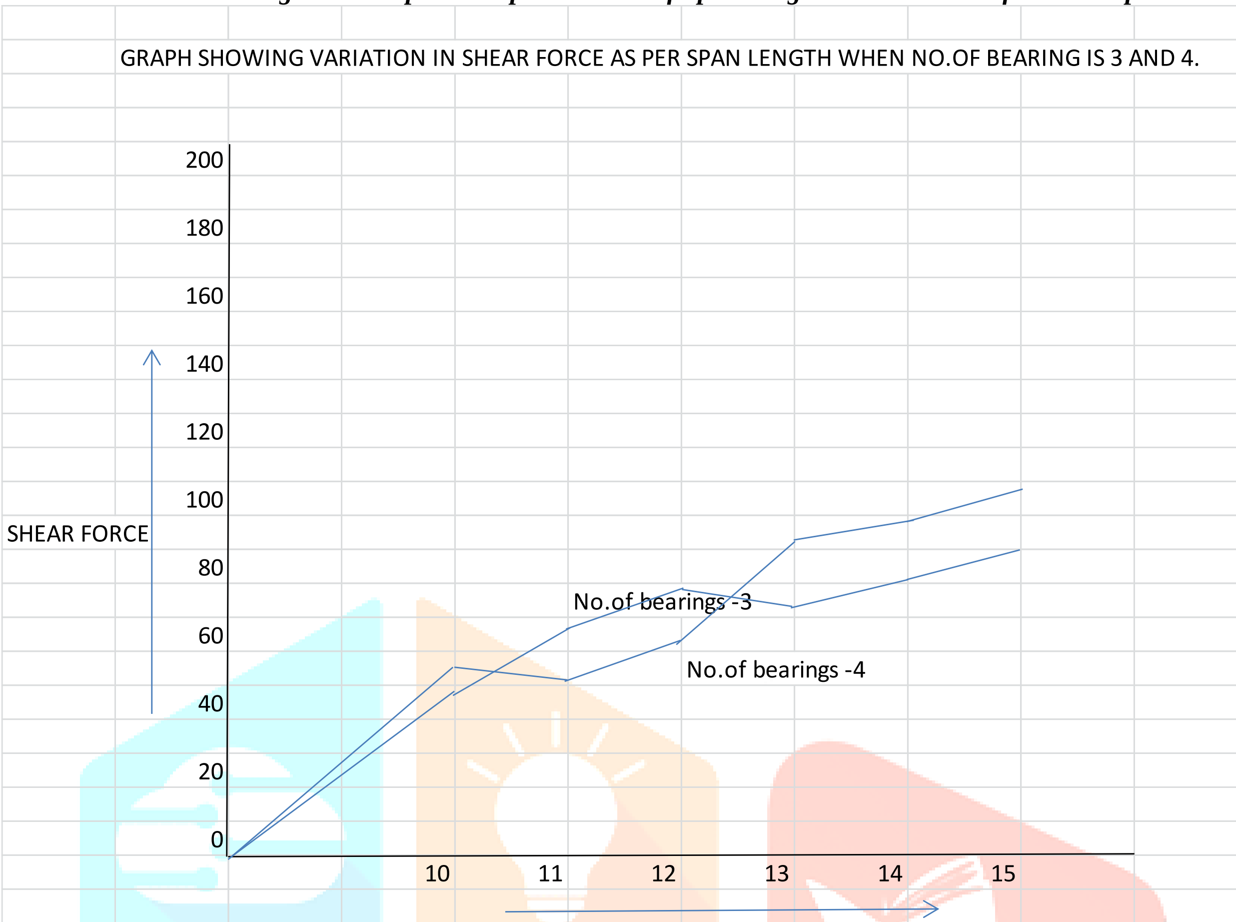
| S.No. | Span length | no.of bearing | no.of bearing |
|---|---|---|---|
| | | 3 | 4 |
| | | Ast cm² | Ast cm² |
| 1 | 10 | 79.23 | 64.05 |
| 2 | 11 | 90.56 | 72.82 |
| 3 | 12 | 106.42 | 85.94 |
| 4 | 13 | 118.66 | 95.81 |
| 5 | 14 | 134.04 | 109.59 |
| 6 | 15 | 150.64 | 121.54 |

*Figure6.1Graphical Representation of Span Length vs Moments for Pier Cap*



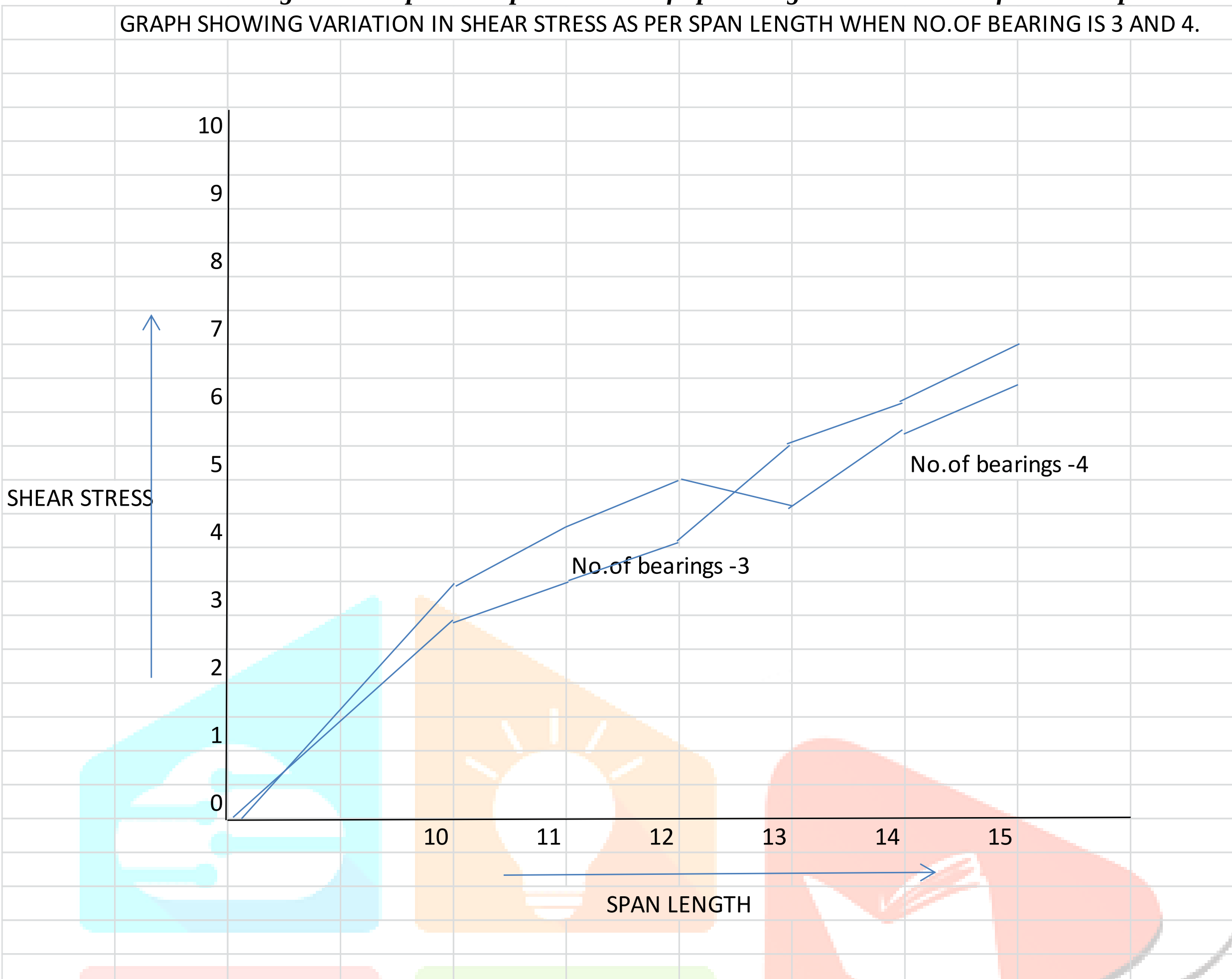

From the above table and graph we observed that when we provide no.of bearings as 4 the Moment reduces in all span lengthas compare to the no.of bearing provided as 3.

*Figure6.2Graphical Representation of Span Length vs Shear Force for Pier Cap*




From the above table and graph we observed that when we provide no.of bearings as 4 the Shear force reduces in most span length i.e in 13m,14m and 15 mas compare to the no.of bearing provided as 3.

***Figure6.3Graphical Representation of Span Length vs Shear stress for Pier Cap***




From the above table and graph we observed that when we provide no.of bearings as 4 the Shear stress reduces in most span length i.e in 13m,14m and 15 mas compare to the no.of bearings provided as 3.

*Figure6.4Graphical Representation of Span Length vs Steel Reinforcement for Pier Cap*


From the above table and graph we observed that when we provide no.of bearings as 4 the Steel reinforcement comparatively reduces in all span length i.e in 10m to 15 mas compare to the no.of bearings provided as 3.

"On comparison of the area of steel we found a comparative reduction in it which over all affects the cost of the pier cap and indirectly affects the economy of the construction."

## CHAPTER VII
## CONCLUSIONS

From the above results, it is clear that when number of elastomeric bearingprovided is 3 the Bending moment , Shear Force, Shear stress and steel required in Pier cap are mostly more as compare tothe Bending moment , Shear Force, Shear stress and steel required when number of elastomeric bearing provided is 4 .Hence whennumber of elastomeric bearings increases the Bending moment , Shear Force, Shear stress and steel required reduces which makes the design of Pier cap economical and durable. As no.of bearings increased the dead weight and live load get distributed on 4 no.of bearings and reduces the moment, shear and reinforcement,

So it can be concluded that as the no.of Bearings provided increased to 4 a comparative reduction in steel reinforcement in pier cap is observed and hence increase in no.of bearing reduces the reinforcement in case of solid slab type superstructure bridge.

**Future Scope:**Further working can be done by varying the dimensions of the pier cap and size of bearing.Bearings proves to be efficient for reducing the effects of the damage caused by the bridge by seismic activities. Bearings are more efficient in reducing the forces and moments on the bridge. They are also effective in reducing the deck displacement. Seismic behavior of various bearings are different. There is future scope for further study in this area to find the most efficient bearing.

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