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Creep Behavior of Elastomeric Bridge Bearing

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Abstract

Elastomeric bearings are widely used as supports for bridge girders. Under seismic excitations, global and local tensile stresses might be developed within the elastomer of bearings, causing fluctuations of their vertical load. Thus an overall study of the international literature proved an acknowledged gap regarding the response of elastomeric bearings under variable axial loads. This research paper deals with the time- dependent creep behavior on elastomeric bearing. The design of bearings was carried out according to Irc 83- part 2:1987.Prony series of viscoelastic was defined with the help of the shear modulus of the bearings. This numerical method was implemented into the analytical software in order to find the behavior of bearing under creep and time variation of axial load.ABAQUS -a Finite element analysis(FEA) research software were used in this study to model the bearing and to find the result analytically with numerical input .Finally the analytical result shows that the bearing experience an initial creep over small duration of the time and further on continuous application of load the bearing experience a constant deformation and tends to fail. Thus from this research it is noted that the bearing behaves as viscoelastic material over a period of time and further increase in time period led to the failure of the structure. Hence from the analytical study we can able to find the various changes in the elastomeric structure, which is then helpful to design a bearing with greater strength.

Key words: *Elastomeric bearing, Creep, Time –dependent, Abaqus, FEA.*

I INTRODUCTION

Elastomers are unique materials due to the fact that they are capable of storing and dissipating energy. Their ability to do so characterizes them as viscoelastic materials. Since they are not truly elastic in terms of Hooke's law, viscoelastic materials (e.g. rubbers) undergo two types of relaxation, namely, strain relaxation (creep) and stress relaxation. In elastomers, stress relaxation is a chemical reaction caused by the breaking of primary chemical bonds whereas; creep is due to an internal Initial Stress. Stress and strain (creep) relaxation to elastomers reorganization of molecules within the elastomer. While stress relaxation results from constant strain on the elastomer, creep or strain relaxation is caused by constant stress. Creep changes exponentially with time being most rapid immediately after the application of the load and diminishing thereafter. The magnitude of creep depends on the composition of the elastomer and type of stress applied.

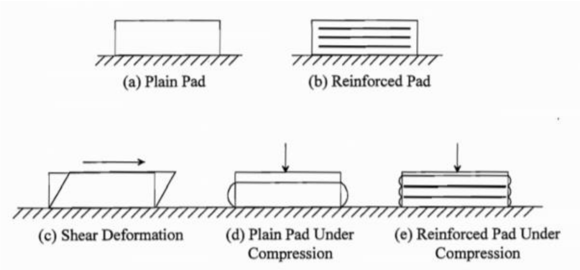


Fig 1 - Plain and reinforced elastomeric bearing

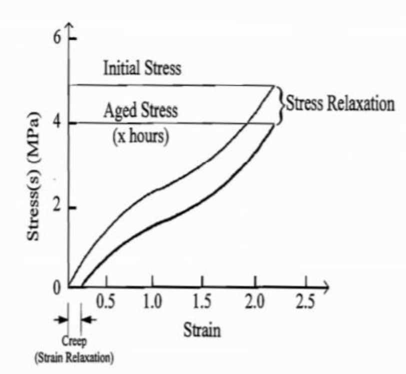


Fig 2- Stress And Strain (Creep) Relaxation to Elastomers

Creep is the time-dependent and permanent deformation of materials when subjected to an externally applied load over an extended period of time. Creep is normally an undesired phenomenon that is often the limiting factor in the lifetime of a material. The creep behavior of a unidirectional composite under a constant load assumes that fiber behaves elastically while the matrix behaves in a viscoelastic manner (6). Viscoelastic or viscoelastic behavior of a material shows itself in various ways, such as creep under constant load, time-dependent recovery of deformation followed by load removal, stress relaxation under constant deformation, and time-dependent creep rupture. The deformation of polymeric materials strongly depends on the duration and rate of loading. It becomes more critical as the temperature reaches Tg.The viscoelastic behavior showed a nonlinear response beyond a threshold stress of 13 ksi at 700°F (2). Distress due to internal rupture may occur at stress levels well below the failure stress for uniaxial tension. This mode of failure is known to be essentially independent of the tensile strength and elongation at break of rubber. It occurs because of hydrostatic tensile stresses that may develop in the bearing. The mode of failure has been verified experimentally, but it should be noted that internal rupture does not necessarily cause a failure of the bearing (3).

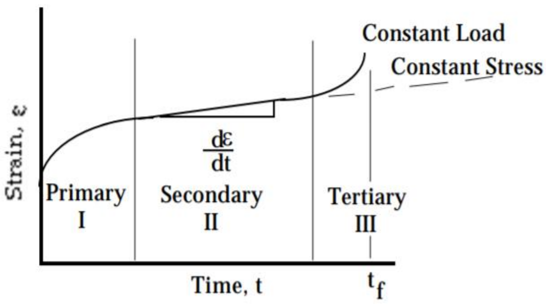


Fig 3- stress time curve for a creep test

MATERIAL USED - Raw Material **:** Low crystallized poly chloroprene rubber such as Neoprene WRT, Neoprene W, Bayprene 110, Bayprene210, Skyprene B-5, Skyprene B-30, DenkaS-40V and Denka M-40, Steel Laminates of mild steel conforming to IS 2062/IS 1079 or equivalent International standard. These paper reports about the analysis of elastomeric bridge bearing in Abaqus with the numerical data obtained by viscoelastic properties of bearing as Prony series.Also this research paper works on the creep behavior on elastomeric bearing which is not mentioned in IRC 83: part 2. So the final results are obtained analytically by applying repetition of load on bearing and failure of bearing occurs over a continuous deformation for period of time.

1. APPLICATION

Elastomeric bearings have also been used in many other applications, including:

• Column to footing isolation

• Isolation of long-span, cast-in-place and precast concrete beams

• Isolation of "floating" roofs

• Acoustical insulation between floors

• Sound and vibration isolation of laboratories and testing facilities

2. **FUNCTION OF ELASTOMERIC BEARINGS**

The Function of the elastomeric bearing is to provide a connection to control the interaction of loading and movements between parts of the structure, usually between super structure and sub structure.

♣ The elastomeric bearings (un-reinforced and laminated) are generally suitable for:-

- Translation movements towards longitudinal and transverse direction.
- Rotation about transverse axis in longitudinal direction& rotation about longitudinal axis in transverse direction.
- Rotation in plan area.
- Loading resisted to vertical, longitudinal and transverse direction.

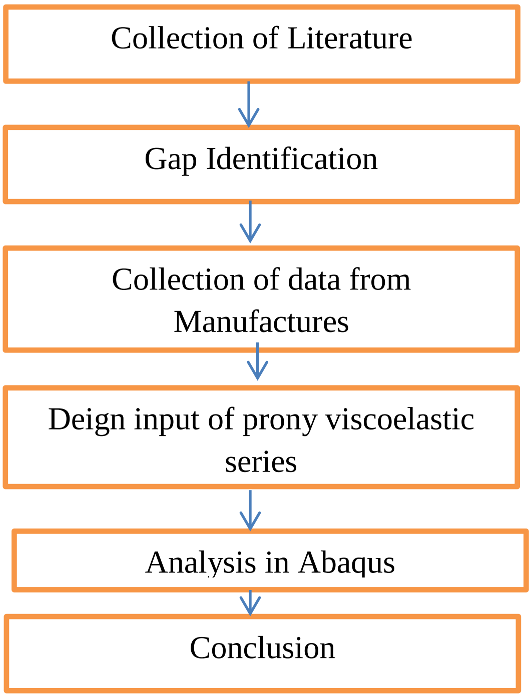
♣ The elastomeric bearings can accommodate transaction movement in any direction and Rotation al movement about any axis by elastic deformation, but they should not be used in tension.

II SCOPE AND OBJECTIVE

The main aim of the project is:

- To find the Behavior of bearing under creep.
- To study the elastomeric bearing under constant dead load over a period of time.
- To analyses the structure by Prony viscoelastic series.
- To find the repetition of loading and effect of rotation due to the time dependent vertical load.

III METHODOLOGY



Generally the methods carried out in this research work are, initially collection of literature for the reference is taken and the gap was identified that IRC 83 :part 2 was not spoken about creep behavior and thus cyclic repetition of vertical load is implemented to find out the behavior of elastomeric bridge bearing. Prony series of viscoelastic parameters are taken from the reference and this data is implemented in FEA software of Abaqus as an input data.

IV DESIGN CONSIDERATIONS FOR ELASTOMERIC BEARINGS

Many factors are important in the design of elastomeric bearings and several of the more critical parameters are listed below:

- Shape factor
- Type of reinforcement
- Effective rubber thickness
- Hardness/Shear modulus
- Compressive creep

The bearing dimensions are 500x300mm which satisfied according to IS83-Part 3:1987

1. $l_o/b_o = 500/300$

   $= 1.66 < 2$

2. $h < 60$ & $h > 36$

Hence 36<60 & 36>30.

3. Shape factor- which is according to cl 916.3.3,

$$S = \frac{\text{Loaded area}}{\text{Loaded area free to bulge}} = \frac{a \times a}{4 \times a \times t} = \frac{a}{4t}$$

S<6 & s>12

4. Hardness is classified according to cl 913.12
5. Technical data of bearing
   a. Design load of bearing is equivalent to 10MPa
   b. Shear modulus of bearing shall be between 0.8MPa to 1.2MPa
   c. Ultimate compressive strength of the bearing shall be more than 60 MPa
6. Prony series

Shear modulus (Gt) = E / 2(1+v)

Creep modulus (E_t) = σ/ε

Normalized shear compliance = $1/G_t$

$$G_t = G_o(1 - \sum_{i=1}^{n} (gi)\left(1 - \frac{e^{-t}}{\tau i}\right) \ )$$

Where, G_o = Instantaneous shear modulus

gi = Relaxation modulus

τi = Relaxation time

The prony series value is obtained with the help of shear modulus collected by the Saradhi Elastomeric Bridge Bearing manufacture companies and also with reference to shank et.al [5].

Table 1 – Properties of Elastomers as per IRC 83(part 2)

SI NO	PROPERTIES	UNITS	REQUIRED VALUE
1	Polymer Content	%	60
2	Ash Content	%	<5
3	Hardness	Shore A	60+5
4	Tensile Strength	N/mm^2	>17
5	Elongation	%	>400
6	Compression	%	<35
7 Accelerated Ageing			
7a	Change in Hardness	Shore A	+15 Maximum
7b	Change in Tensile	%	-15 Maximum
7c	Change in Elongation	%	-15 Maximum
8	Adhesion Strength	KN/m	>7

Table 2 – Prony Series Parameters

Gi	Ti
0.0738	463.4
0.1470	0.06407
0.3134	0.0001163
0.3786	$7.321e^{-}7$

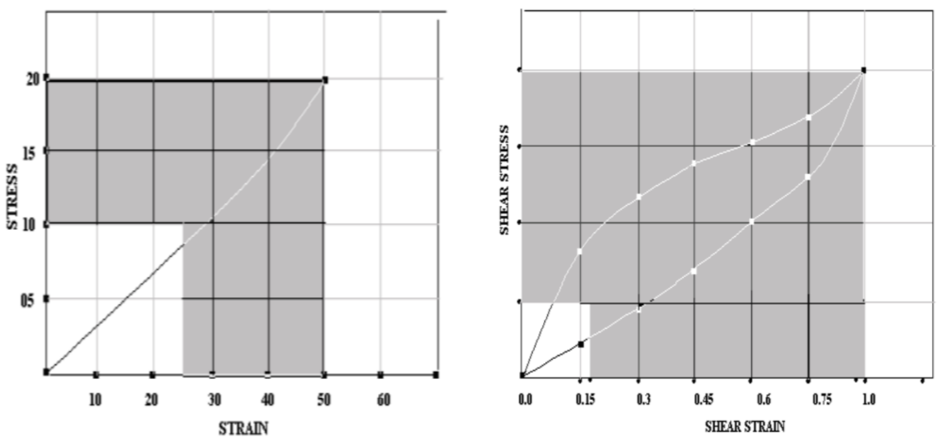


Fig 4- Graph showing the relation b/w stress and strain

Other few factors that accommodate with bearing are:

• Temperature change

• Shrinkage and creep of concrete m deck beams

• Deflections of deck beams

• Substructure movements or foundation settlements

• Horizontal bracing and acceleration forces of heavy truck traffic

• Wind actions.

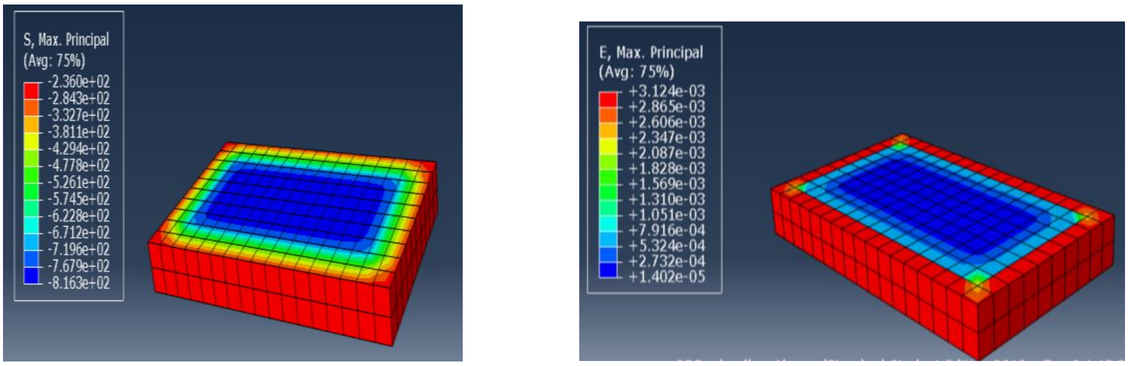
V FAILURE MODES OF ELASTOMERIC BEARINGS

There are many modes of failure for elastomeric bridge bearings:

- Fatigue
- Stability
- Delamination or separation of the elastomer from the reinforcement.
- Serviceability
- Yield and Rupture of reinforcement

VI ANALYTICAL RESULTS

Analysis is done by ABAQUS (Finite Element Analysis) software. The input data are assigned with the help of viscoelastic property in the Abaqus software with various shear modulus and time period. The input data for prony series is collected from the Saradhi manufacture companies of bearing with consolidated shear modulus data.In this analysis the varying load is applied with respect to time and the bearing undergoes a slight rotation and shear deformation which is shown in figures.



(a) (b)

Fig 5 – (a) Stress on Bearing and **(b)** Strain on Bearing

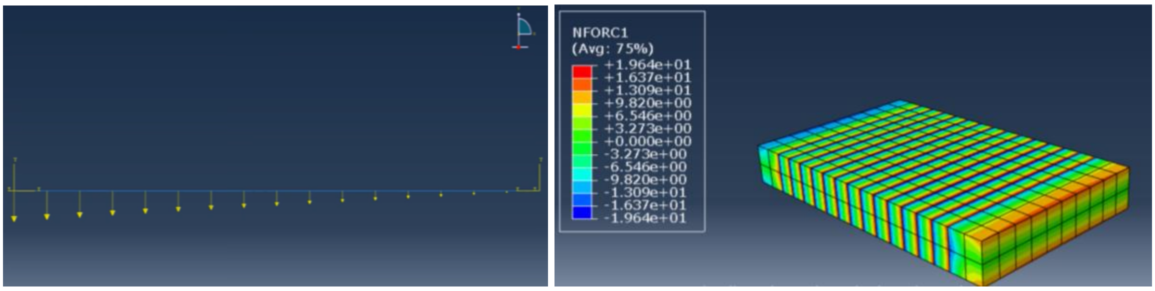


Fig 6– Loading on Bearing

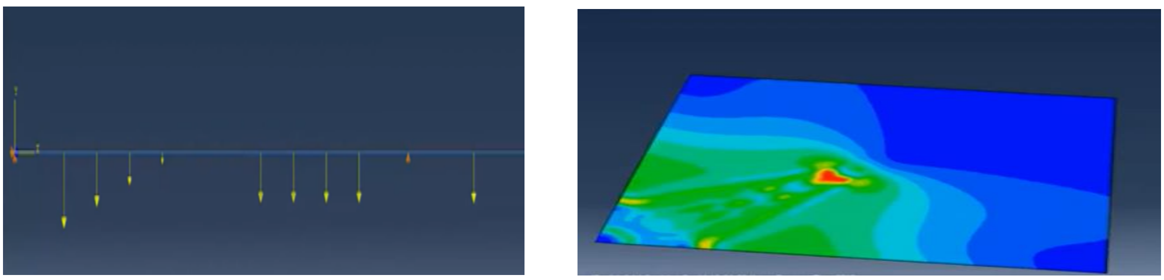


Fig 7– Moving Load on Bearing

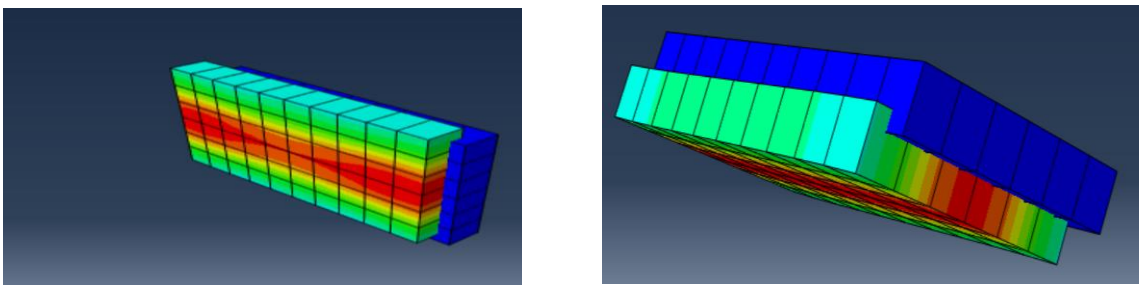


Fig 8 – Rotation condition

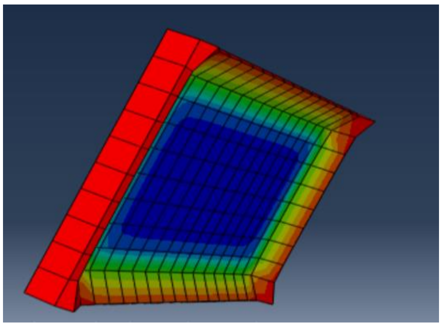


Fig 9 – Deformed state

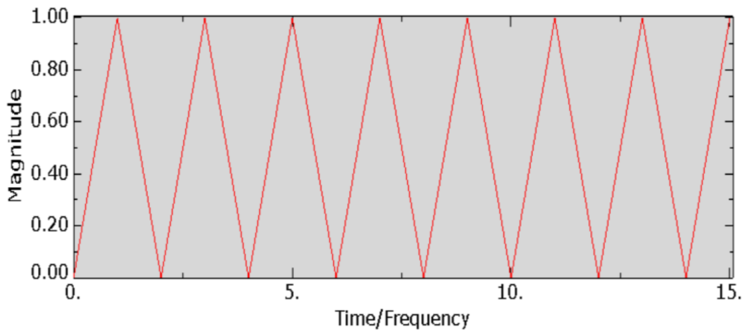


Fig 10 – Graph b/w time and magnitude over a short period of time

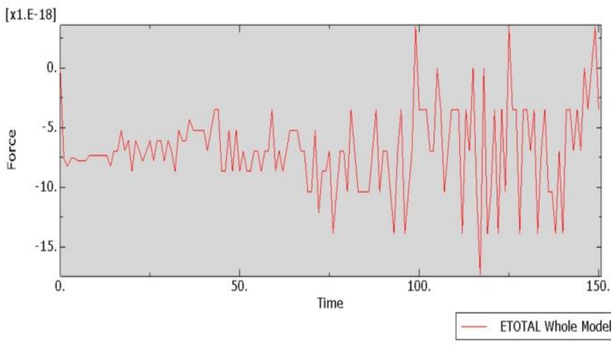


Fig 11- Load vs Time on the structure over a time period T

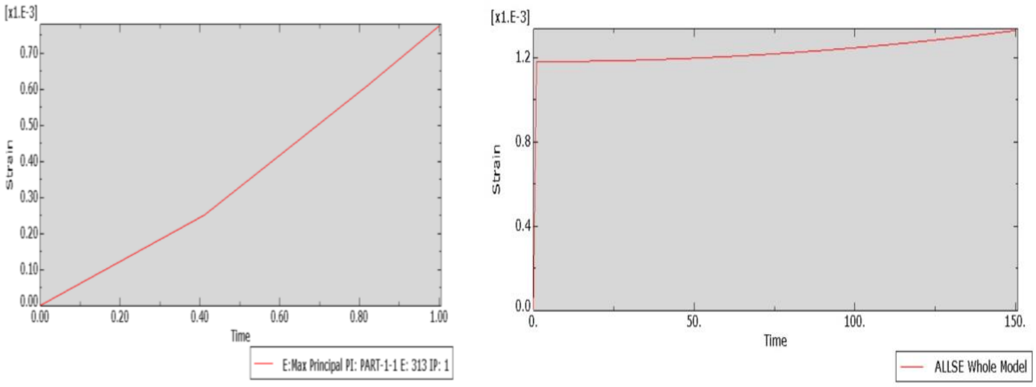


Fig 12 - Graph showing Stain vs Time at various nodes

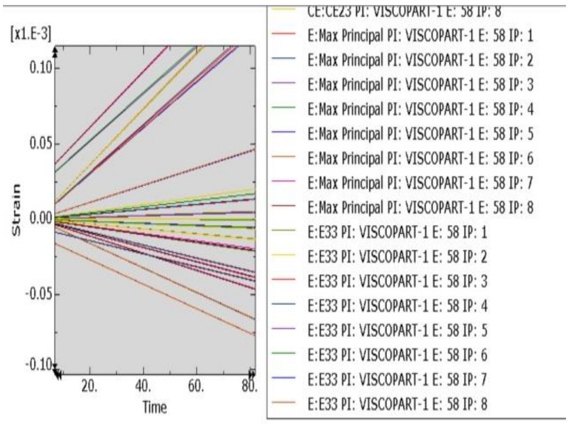


Fig 13 - Overall strain at a particular node over a period of time T

VII CONCLUSION

The Design of Elastomeric Bridge Bearing was done and it satisfied to IRC 83 –Part 2:1987. The variable axial load is applied at a specific time interval. The dead load and the Live load (Moving load of a vehicle on the bridge bearing) are considered in the analysis for a short time period. The behavior of bearing under this load is done analytically. From the analytical results it is showed that initialy on applying load for a time (T_o) there is a small deformation of the material which is in elastic state (i.e., Instantaneous strain occur),further at particular load and variation in time period the creep is Increased . Finally over the last time period the material tends to be in a constant creep which leads to the rupture or failure of the structure. Also by the cyclic repetition of vertical load over a short period of time interval the bearing tends to deform and rotate to specific angle which indicates the relaxation of stress under the absence of load and progression of strain. Further continuation of repetition of loading the bearing occurs a permanent deformation and fails. Thus we can able to find the creep behavior in bridge bearing and also the number of load repetition at a period of time which is useful to design the bearing with increase in strength.

VIII REFERENCE

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