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Nonlinear Analysis of the Bridge Expansion Joint Sealing

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Abstract - *Bridge as well as highway pavements, buildings etc, Needs joints to take care of expansion and contraction caused by temperature changes and seals are used to prevent seepage of water in to the structure so that the life of structure is increased and we need to analysis the performance of the seal before using it. Nonlinear explicit dynamic analysis is carried out in the ABAQUS tool for analyzing the seal performance. Before that the seal model is created in the SOLID EDGE tool then it is imported to the ABAQUS for solving prior to that the model is given with material properties in this study Neoprene material is used then the is discretized using Hexaelement forming the small elements and nodes. Then the model is stressed with the load for nonlinear dynamic analysis. Results from the Non-linear dynamic analysis are compared with the standards and these results showed that the maximum compressive stress is well within the acceptable limit. The tensile stress on the ribs is slightly more than the allowable stress, which in further studies can be optimized.*

Key Words: Neoprene, Nonlinear analysis, Bridge expansion joint seal, Contact stress, Finite element analysis.

1. INTRODUCTION

A synthetic rubber is an artificial elastomer. These are mainly polymers synthesized from petroleum by-products. These rubbers found application in automotive industries for tires, seals, hoses and belts.

Seal is a substance or device which is used to join two or more particles together which in turn helps to prevent them coming apart or to prevent anything passing between them. A mechanical seal is a device that helps combine systems or instruments which prevent leakage (e.g. in a pipes framework), containing pressure, or barring pollution. The capability of a seal is reliant on adhesion in the case of sealants and compression in gaskets; it may also refer to as packing.

Seals can be specified based on the sealing orientation, dimensions, type, applications and material other main parameters for selection of seals are

- Reliability
- Tolerance to the sealing media
- Resistance to extrusion between mating parts
- Installation
- Environmental serviceability

Sealing analysis is done for understanding the behavior of the rubber seal under heavy loading condition there by predicting its performance and life of the seal. Analysis on seals can be done by linear or by nonlinear process.

1.1 Linear And Non-Linear Analysis

1.1.1 Linear analysis

A linear static analysis is an investigation where there is a direct connection holds between displacements and force applied on the material under analysis. In actual practice, this is valid to structural problem only when the stresses are in the elastic range of the material taken at time of the analysis. In a linear static analysis the model's stiffness is said to be constant steady, and the solving procedure is generally short when compared with a nonlinear analysis of the same model.

1.1.2 Non linear analysis

A nonlinear analysis is an investigation where there is a nonlinear connection holds between force applied and displacement. Nonlinear effects can begin from geometrical nonlinearity's (i.e. large deformation), material nonlinearity's (i.e. elasto-plastic material), and contact. These impacts result in a stiffness matrix which not constant during the load application. This is against the linear static examination, where the stiffness matrix is constant. Subsequently, an alternate problem solving methodology is required for the nonlinear examination and in this manner an alternate solver.

Newly launched analysis software makes it possible to get the solution for the nonlinear analysis easily. However, one should know the tools in the analysis software for getting the nonlinear analysis results easily. Nonlinearity is due to the geometric nonlinearity, material nonlinearity and constraint and contact nonlinearity.

1.2 Problem Definition

The seal used in the bridge joint should prevent water seepage and with stand the harsh load and also it has enough stiffness to withstand that loading condition with minimal weight of the seal and checking the performance of the seal. Therefore we have to perform design optimization and conduct a nonlinear analysis for the seal and compare the strength as per the standards.

1.3 Aim

To understand the nonlinear behaviour of the rubber seal used in bridge expansion joint seal and predict the performance under the harsh loading condition and in concrete expansion.

2. OBJECTIVE AND METHODOLOGY

When there is a linear relation exists between applied force and the displacement linear static analysis can be applied to see the performances of the material. In reality it is applied to structural problems in which stress is constrained in the range of linear elasticity of the material. In this type of analysis the model stiffness matrix is steady and getting the answer is an easy procedure. Where as in nonlinear analysis is carried out where a nonlinear relation exists between the applied force and the displacement. Geometrical nonlinearity is the origin of the nonlinear effects i.e. large deformation and material nonlinearities. This results in the stiffness matrix which is not constant, for this a different solving procedure is equipped and different nonlinear analysis solver. Modern software makes it very easy to obtain the solution for the nonlinear problems, but care should be taken to specify model and solution parameters.

2.1 Methodology

The preliminary step in the analysis is to create the geometric model of the bridge joint seal which is modeled using SOLIDEDGE. After the model is created using the software mentioned earlier then it is imported to the CAE tool in which meshing and nonlinear analysis is carried out. Finite element model is created by meshing it with appropriate elements like hexaelement and constraining the model by applying the boundary conditions and material properties then nonlinear analysis for the bridge joint seal is performed using ABAQUS explicit solver. After the analysis design optimization is carried out for minimal weight. Finally the results are compared with the standards.

2.2 Geometric Modeling

The below shown is the figure is the geometric model of the Seal which is used in the Bridge. The modeling has been created using the software SOLIDEDGE tool. In this tool the bridge expansion joint seal is created for the analysis as shown in the figure the dimensions of the bridge joint seal created is of 100mm width and 150mm deep which is placed inside the concrete structure.

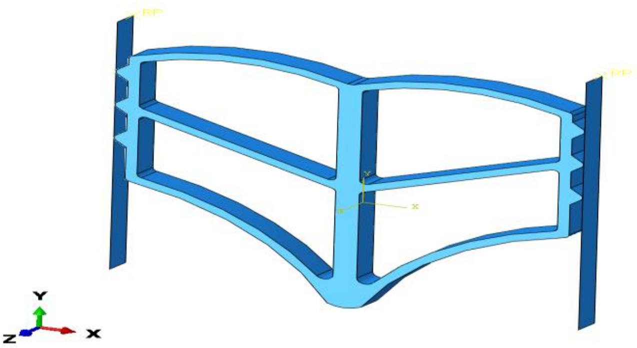

Fig -1: Cross section 3D model of the seal

2.3 Meshing

Meshing is done for refining or to get fine elements it is created to approximate geometry, either a beam mesh (1-D), shell mesh (2-D) or solid mesh (3-D) will be created. The geometric model shown in the below figure is the discretized using linear hexahedra element and linear quadrilateral elements are chosen. In meshing the bridge joint seal Hexahedral elements are used which counts 210817 among the total 219317 elements and Quadrilateral element counts about 8500 among the total nodes.

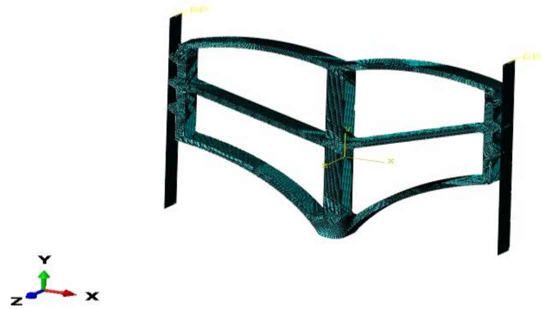

Fig-2: Finite element models of bridge joint seal

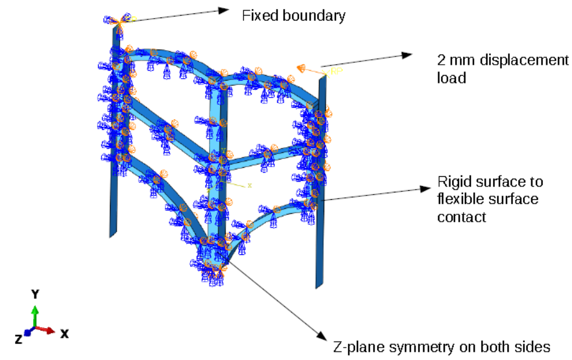

Fig-3: Fine mesh of bridge joint seal enlarged

2.4 Material Properties

Material properties play a vital role in the analysis because it determines the capacity of the material, and it gives the basic knowledge about the material. The sealing material used in the bridge joint seal is Neoprene and its properties are listed in the below table.

Table -1: Material Properties of Bridge joint seal

Sl no	Property	Magnitude
1	Density(kg/m^3)	1700
2	Young's Modulus (Gpa)	1.98
3	Poisson's Ratio	0.49
4	Tensile yield strength (Mpa)	13.8
5	Compressive yield strength (Mpa)	70.8
6	% elongation at break	225

2.5 Loads and Boundary Conditions

The above figure shown is the discretized model of the bridge expansion joint seal with the loads and boundary condition applied. For this analysis, the bridge expansion joint seal is fixed as shown X-axis is fixed in the left end joint it is fixed with Z-plane symmetry and forced to move in X and Y direction as there changes in the climatic condition the surrounding concrete structure will expand and due to the movement of heavy traffic it may also expand in z direction but it is very little, but the large expansion of seal is observed in X and Y direction.

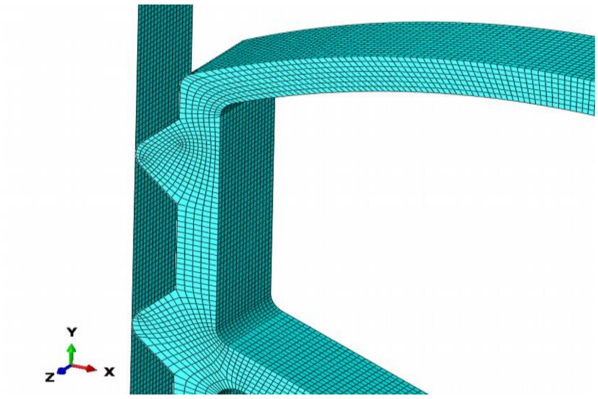

Fig-4: FEM of Bridge joint seal with loads and boundary condition

2.6 TYPE OF ANALYSIS

Nonlinear analysis of the bridge expansion seal is carried out using the ABAQUS tool. Preliminary the seal is modeled in Soildedge and imported to the ABAQUS tool in this meshing is carried out and after applying the material properties nonlinear dynamic analysis is carried out to find out the stress in the seal and durability of the seal.

3. RESULTS AND DISCUSSION

The analysis is carried out for the bridge expansion joint seal with the loads and boundary condition applied to it as mentioned in the earlier section. The following figures show the result obtained from nonlinear analysis.

3.1 Static Analysis Results

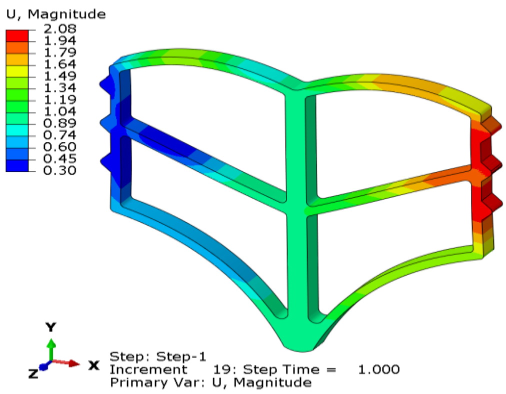

Fig-5: Displacement plot

The above shown figure shows the displacement for the selected bridge expansion joint seal founded when seal is analyzed under the static analysis. Above figure clearly shows the maximum displacement occurs on the bridge expansion joint seal end at a value 2.08mm along the axis of the unfixed end of the bridge expansion joint seal and minimum displacement is viewed at the fixed end of the seal.

3.2 NONLINEAR ANALYSIS RESULTS

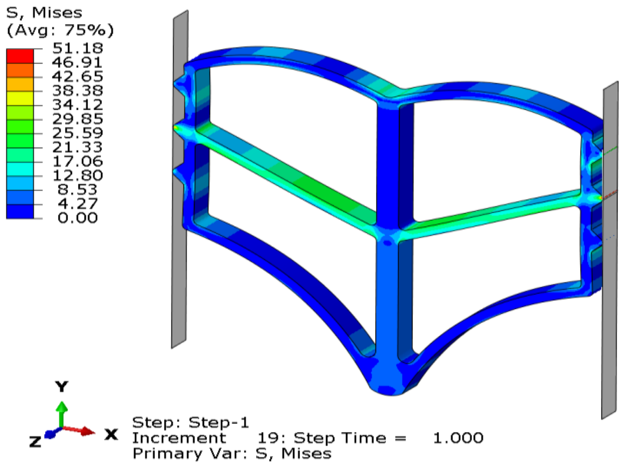

Fig-6: Elemental stress plot

It clearly shows that the seal is subjected to the maximum contact stress found near the two edges at a value of 51Mpa compressive in nature. This value is within the maximum allowable compressive stress of 70Mpa.

The tensile stress in the ribs is about 15Mpa which is just cross the tensile limit of 13.8Mpa.this shows that the section needs additional strength in the rib area to improve stress levels and stiffness needs to be optimized.

4. CONCLUSIONS

The model of the Bridge expansion joint seal was created, discretized and analyzed. The results are tabulated ad presented in the previous chapters.

From the results obtained it can be concluded that,

- The displacement plot shows a very small value which will not affect the normal performance of the bridge expansion joint seal.
- The nonlinear dynamic analysis of the bridge expansion joint seal shows that the contact stress generated are well within the acceptable limit or maximum allowable stress level.
- The tensile stress on the ribs are little bit much than the allowable stress level this shows that the rib section needs additional strength to it which in turn improves stress levels and stiffness needs to be optimized.
- The seal joint is in compressed state and with this prestress supports the expansion in the joints.

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