BRIDGE STRUCTURAL STABILITY ANALYSIS USING MODAL ANALYSIS

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Abstract

A bridge is a man-made object created to cross over an expanse of water, a valley, or a road without blocking the way below it. The goal of the ongoing study is to examine the vibration properties of various material-based bridge structures. The ANSYS simulation programme is used to carry out the modal analysis of the bridge structure. Concrete, silicone rubber, and neoprene rubber were the materials examined in the investigation. For various bridge materials, the mode forms, natural frequency, and mass participation factor are assessed. For neoprene rubber material, the maximum deformation is observed at the bearing region, whereas the bridge structure and crash barrier have lower deformation. For silicone rubber material, the critical region is found to be at the crash barrier, which exhibited maximum deformation and was susceptible to amplitude build up during resonance.

Keywords: Damage, structural evaluation, and bridge

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1. Introduction

A bridge is a "man-made structure intended to cross over a physical barrier, such as a body of water, a valley, or a road, without blocking the passage underneath it. It is intended to guarantee passage over a barrier. According to one theory, the earliest bridges constructed by humans were probably spans made of chopped hardwood logs or planks, followed by spans built of stones(Kim et al., 2007). Romans invented the earliest bridge designs using arches.

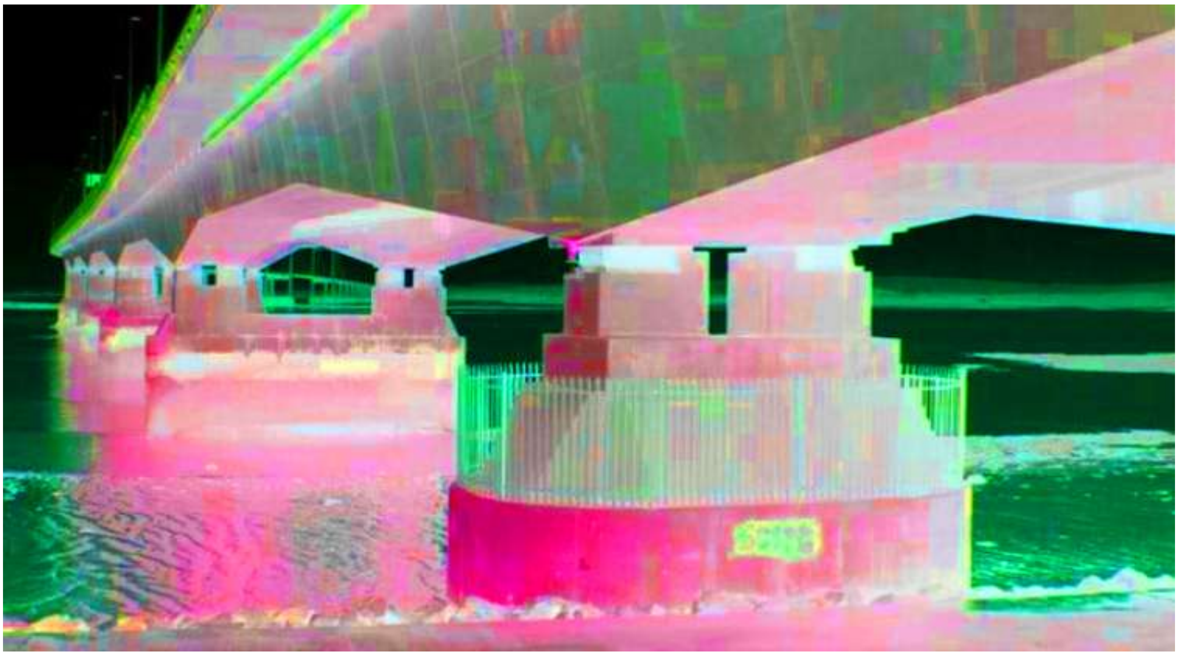


Figure 1: The design of a bridge

Cement was used to counteract the loss of strength in various areas of the stone bridge framework. Several bridge designs were built according to the bridge's intended use. These designs were developed based on several factors, including the kind of terrain, the bridge material, and the bridge's budget.

2. Literature survey

Research on the identification of bridge structure deterioration using vibration response monitoring has been done by (Kim et al., 2007). The precise location of the damage, the extent of the damage, and the impact of temperature were all examined using the vibration amplitude.

Research on the vibration study of the Humber Bridge in Hong Kong was done by Brownjohn et al. "Natural Excitation Technique/Eigensystem Realization Algorithm, Stochastic Subspace Identification, and the Poly-Least Squares Frequency Domain technique" (Fan & Qiao, 2011) were used for the damage identification. The effectiveness of these strategies for crack diagnosis and monitoring has been demonstrated by the study findings.

Researchers (Xia et al., 2012) have studied the monitoring of bridge structure health. Sensors are used in the health monitoring systems to look for cracks. The study concluded that, "despite the increased computational effort and subjectivity required to recognise the system poles, the use of stochastic SSI subspace identification techniques to approximate modal parameters from only output experimental data was found to be preferable to the frequency domain decomposition FDD method"(Xia et al., 2012).

Researchers (Chang & Kim, 2016) studied the effects of different operational and environmental conditions on bridge structure degradation. Abrasion and corrosion in the environment are evaluated, and overloading in the operational environment is taken into account.(Whelan & Janoyan, 2009) According to the analysis, overloading accounted for more than 73% of all bridge collapses, making it the main cause.(Brownjohn et al., 2010)

3. Research Objectives

The goal of the ongoing study is to examine the vibration properties of various material-based bridge structures.(Magalhães & Cunha, 2011) The ANSYS simulation programme is used to carry out the modal analysis of the bridge structure.(Whelan et al., 2009) Concrete, silicone rubber, and neoprene rubber were the materials examined in the investigation.(Koo et al., 2013) For various bridge materials, the mode forms, natural frequency, and mass participation factor are assessed.

4. Methodology

The bridge structure is subjected to FEA model analysis to ascertain the natural frequency and mode shape for the first, second, and third natural frequencies.(Whelan et al., 2009) There are several steps to the analysis.

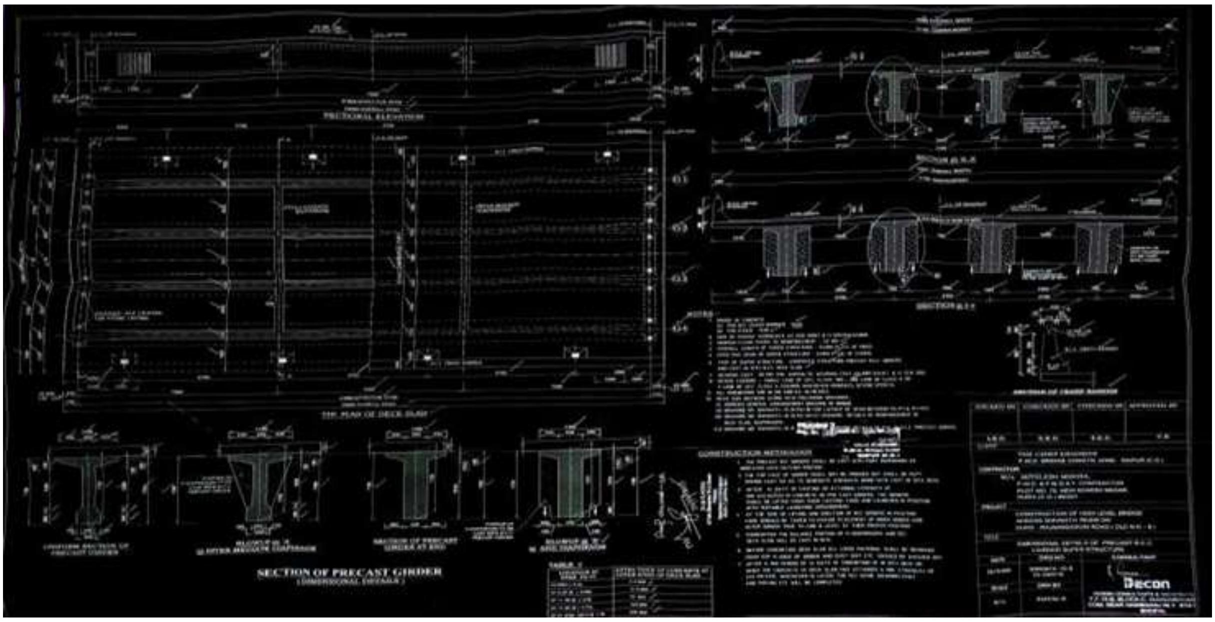


Figure 2: Diagram of the bridge's construction

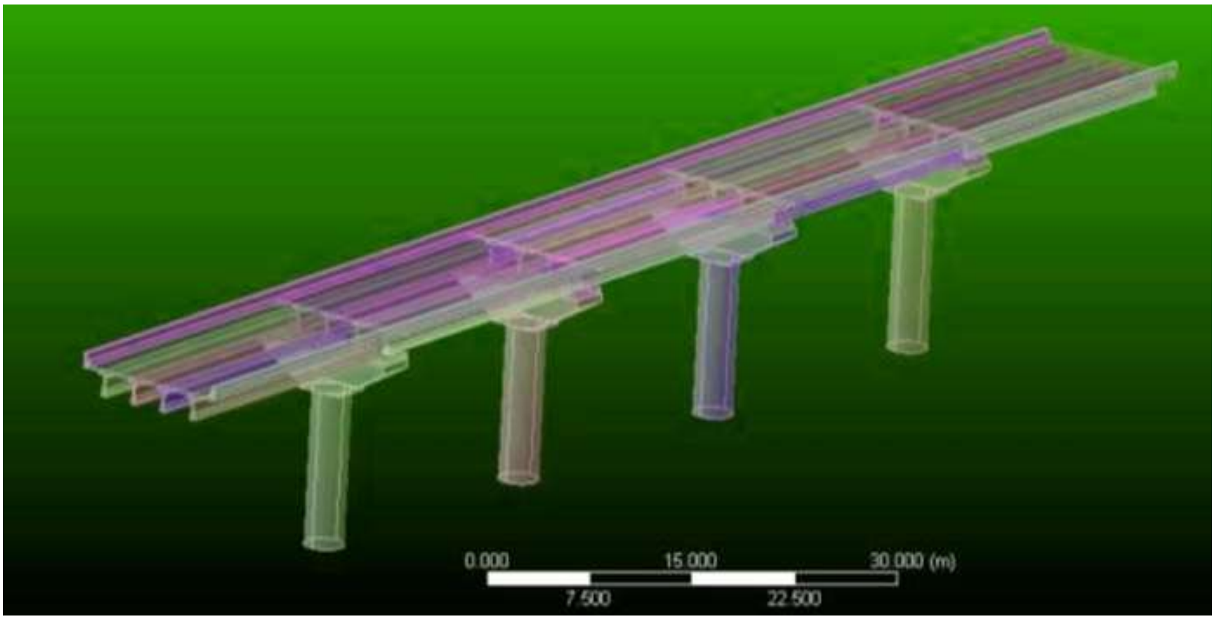


Figure 3: An imported bridge structural model

The bridge construction is created in accordance with the figure 2 design. Geometrical mistakes and surface patches are verified on the bridge structure model.(Bocca et al., 2011; Seo et al., 2016) Figure 3 above depicts the bridge structure produced model.

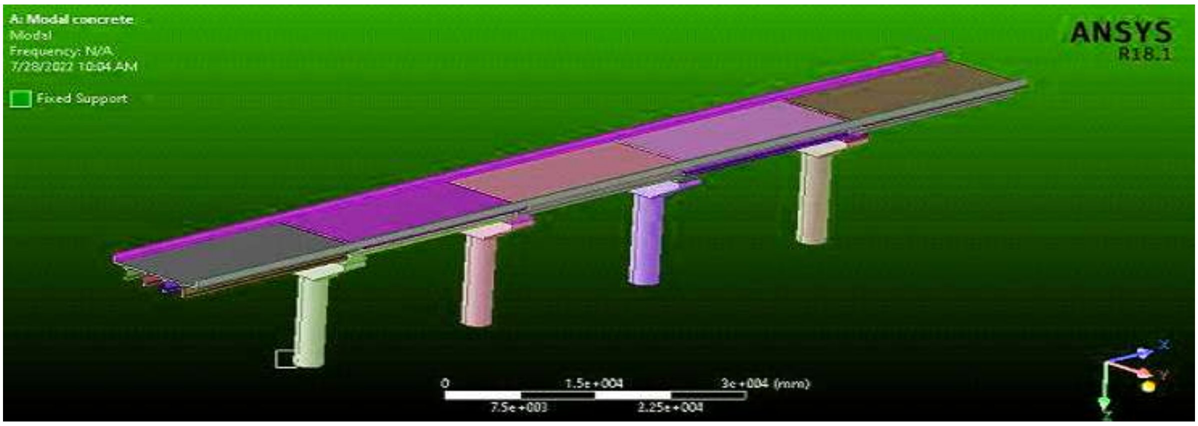


Figure 4: Loads and boundary conditions for modal analysis

For modal analysis, the boundary conditions are applied to the structure. Modal analysis applies a fixed support to the structure's foundation. The sparse matrix solver is used to execute the FEA simulation, and several iterations are completed.(Pakzad et al., 2005; Wardhana & Hadipriono, 2003)

5. Results and discussion

The natural frequency, mode shape, and mass participation factor for concrete, silicone rubber, and neoprene rubber materials are determined through the FEA study.

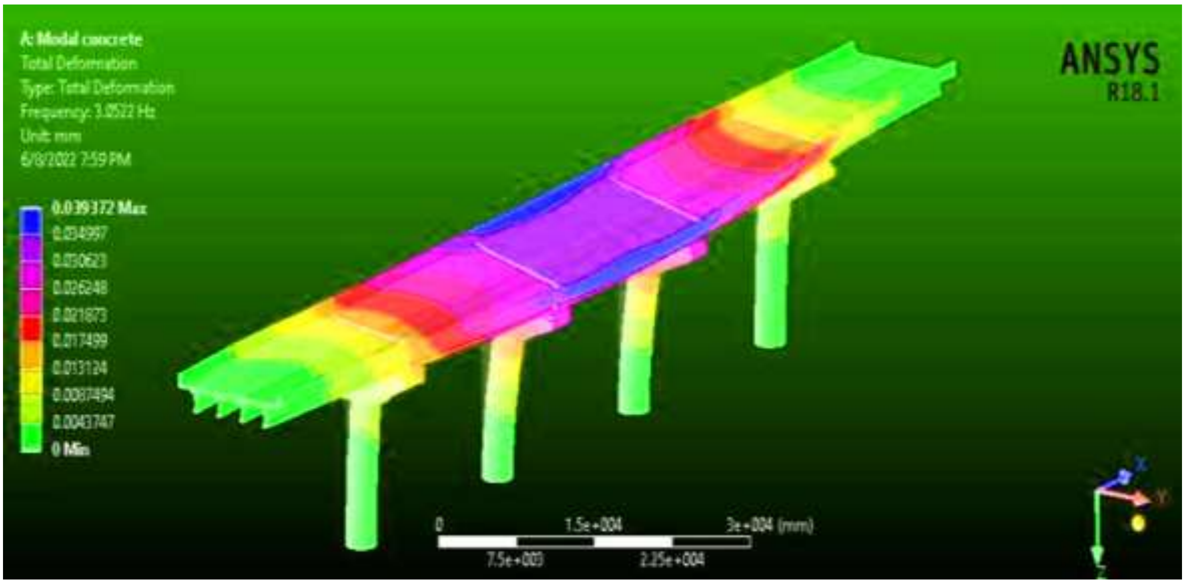


Figure 5: Concrete's first frequency mode form

The highest deformation is seen in the bridge crash barrier zone, where the magnitude of deformation is.039mm, for concrete material bridge deck and first natural frequency mode shape.

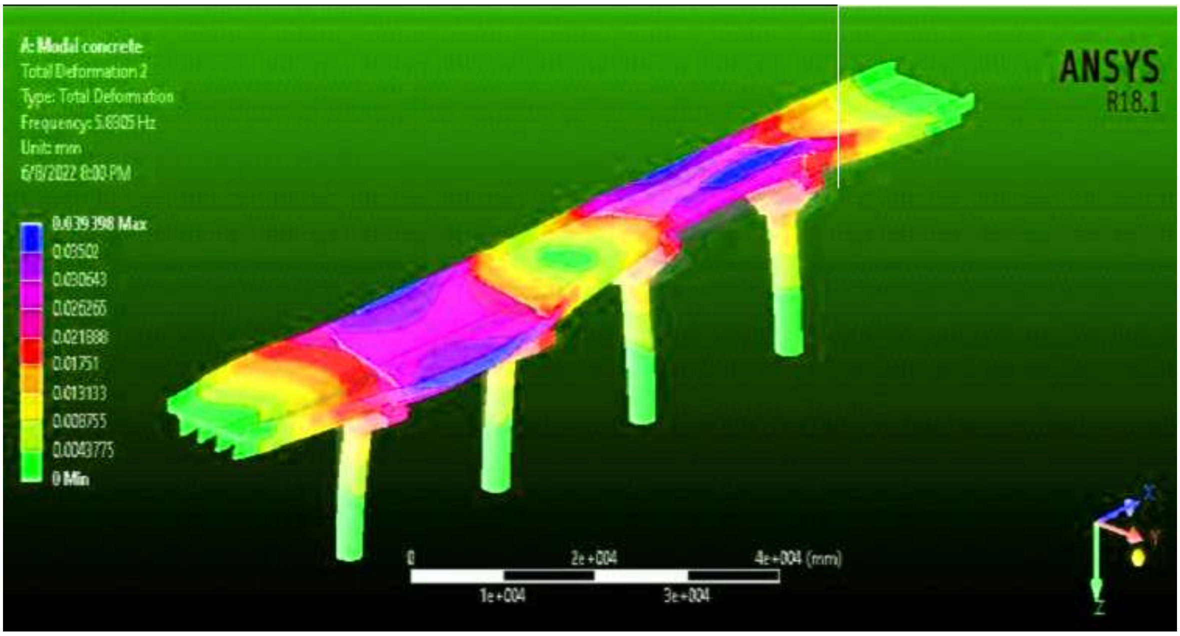


Figure 6: Concrete's second frequency mode form

The largest deformation is seen in the bridge crash barrier zone, where the magnitude of deformation is.0393mm, for bridge decks made of concrete and with a second natural frequency mode shape.

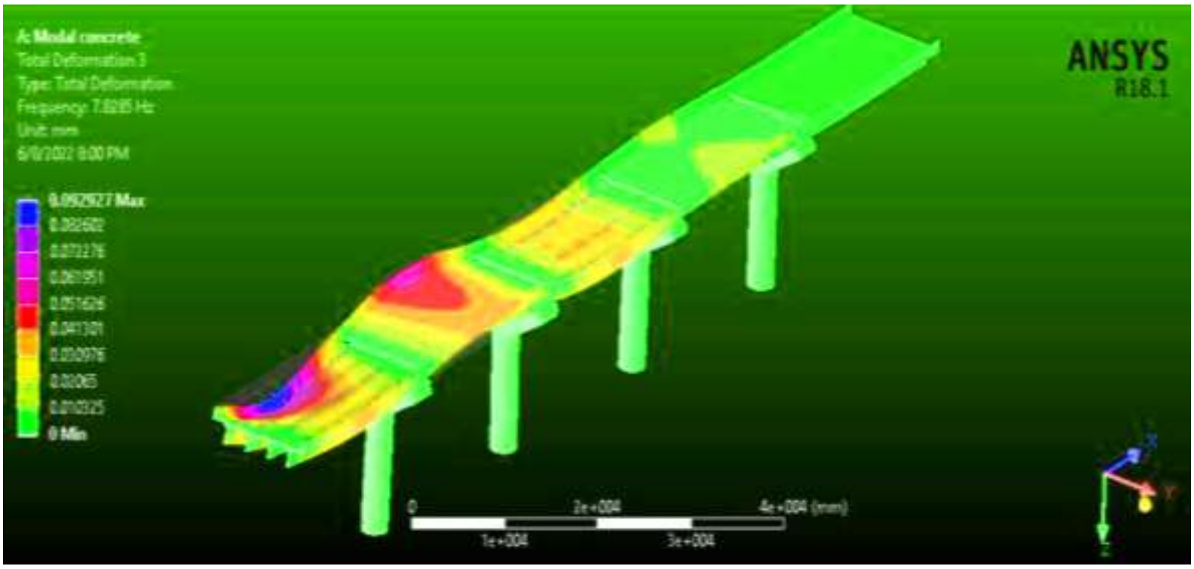
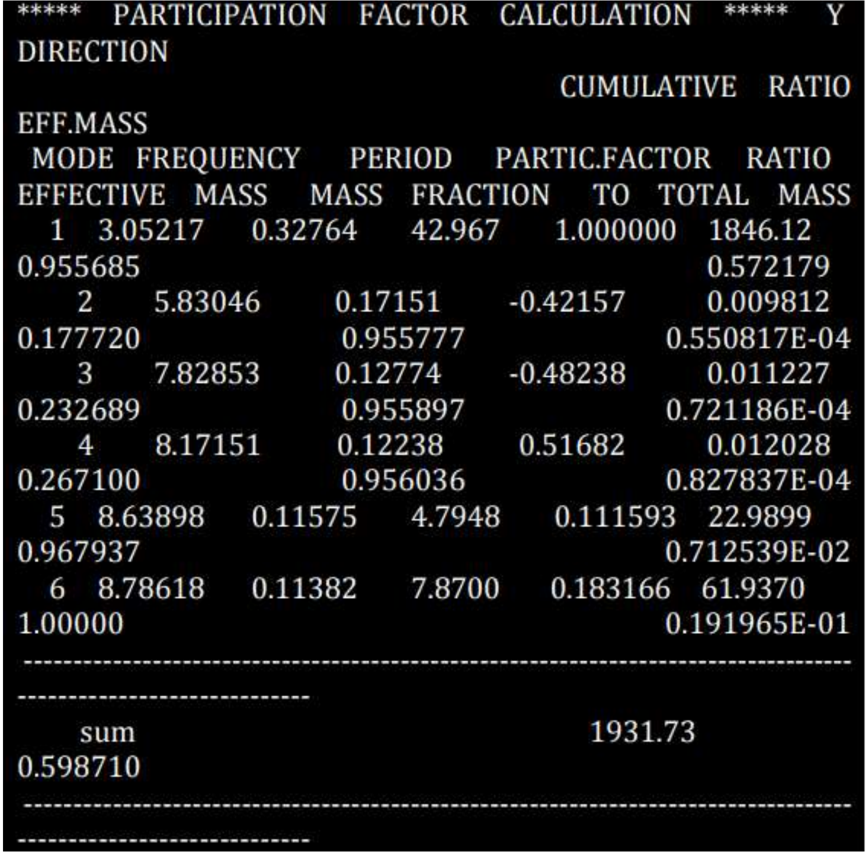


Figure 7: the concrete's third frequency mode form

The largest deformation is seen in the bridge crash barrier zone, where the magnitude of deformation is.092mm, for bridge decks made of concrete and with a third natural frequency mode shape.

Table 1: Concrete material mass participation factor



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***** PARTICIPATION FACTOR CALCULATION ***** Y
DIRECTION
                                        CUMULATIVE  RATIO
EFF.MASS
 MODE  FREQUENCY    PERIOD    PARTIC.FACTOR   RATIO
EFFECTIVE  MASS    MASS  FRACTION    TO  TOTAL  MASS
   1   3.05217    0.32764    42.967    1.000000   1846.12
0.955685                                          0.572179
     2      5.83046       0.17151      -0.42157      0.009812
0.177720              0.955777                  0.550817E-04
     3      7.82853       0.12774      -0.48238      0.011227
0.232689              0.955897                  0.721186E-04
     4      8.17151       0.12238       0.51682      0.012028
0.267100              0.956036                  0.827837E-04
   5   8.63898    0.11575    4.7948    0.111593   22.9899
0.967937                                        0.712539E-02
   6   8.78618    0.11382    7.8700    0.183166   61.9370
1.00000                                         0.191965E-01
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     sum                              1931.73
0.598710
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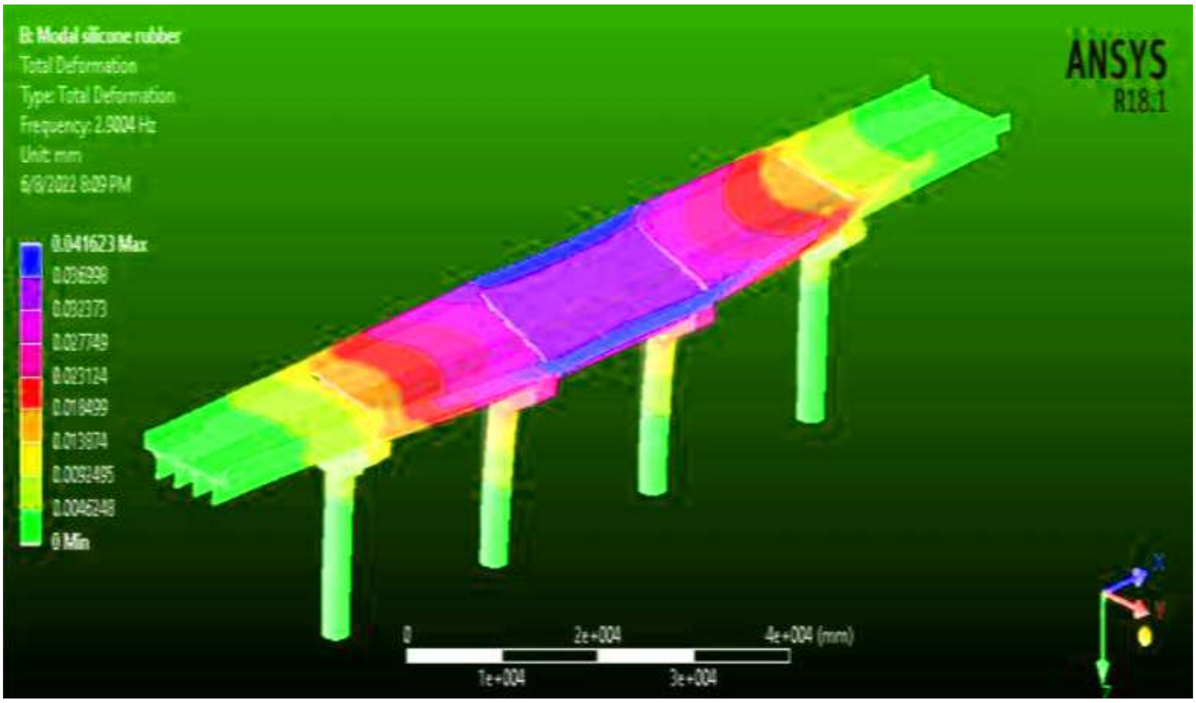


Figure 8: the silicone rubber's first frequency mode form

The largest deformation is seen in the bridge crash barrier zone, where the magnitude of deformation is.041mm, for silicone rubber material bridge deck and first natural frequency mode shape.

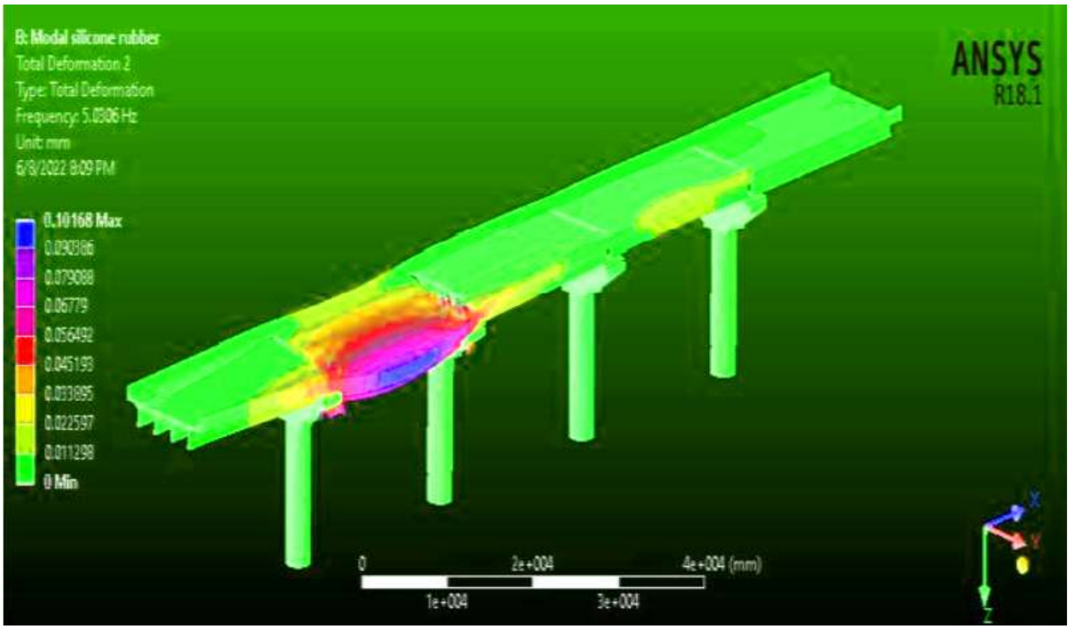


Figure 9: the silicone rubber's second frequency mode form

The largest deformation is seen in the bridge crash barrier zone, where the magnitude of deformation is.101mm, for silicone rubber material bridge deck and second natural frequency mode shape.

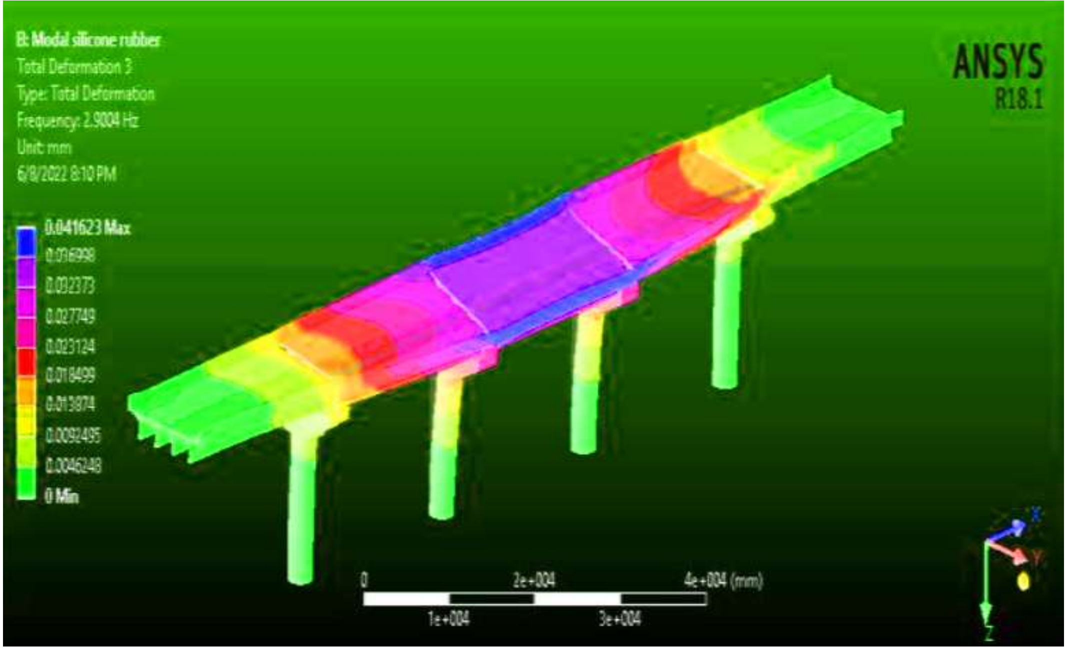
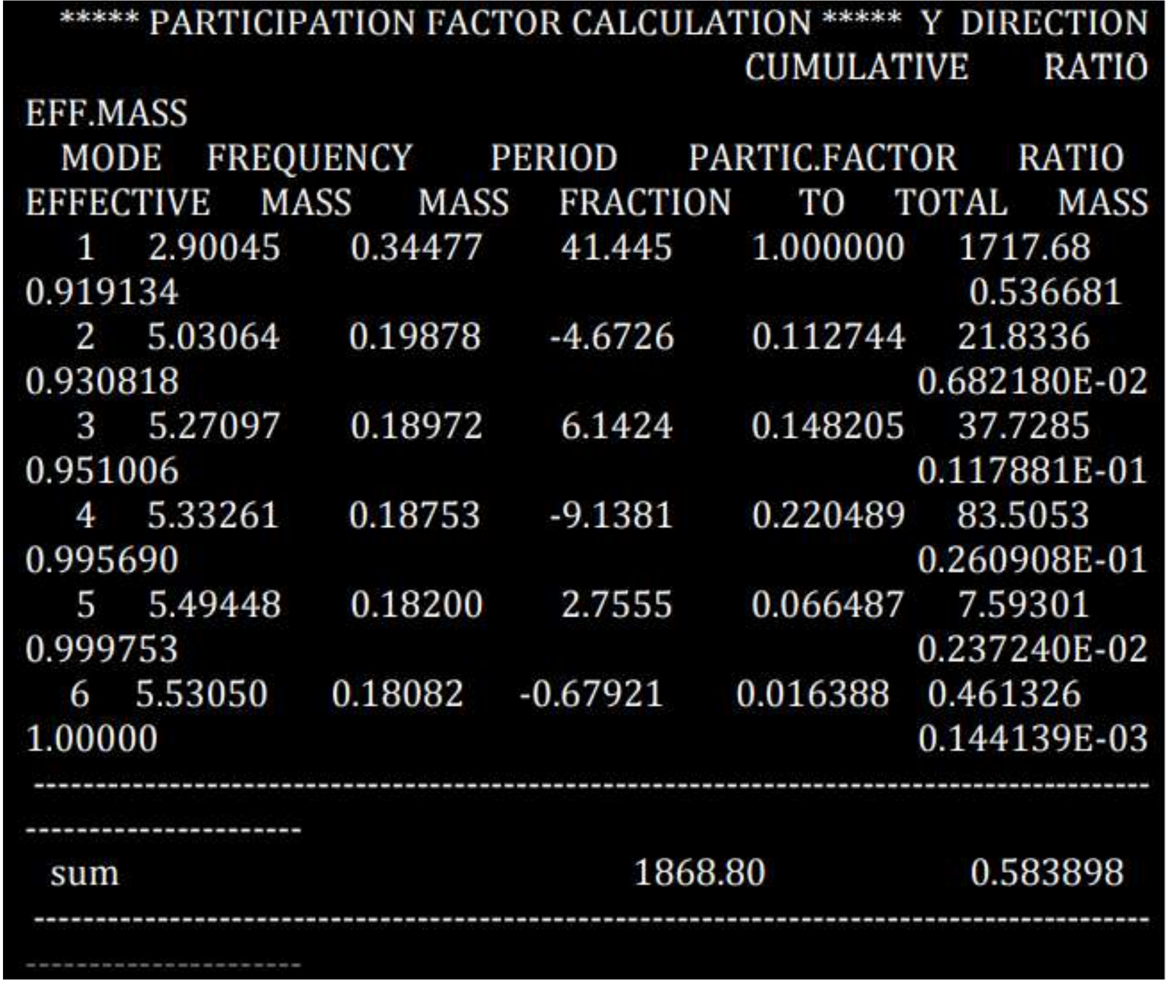


Figure 10: Shape for the third frequency mode of silicone rubber

The largest deformation is seen in the bridge crash barrier zone, where the magnitude of deformation is.041mm, for bridge decks made of silicone rubber and with a third natural frequency mode shape.

Table 2: Silicone material mass participation factor



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 ***** PARTICIPATION FACTOR CALCULATION ***** Y DIRECTION
                                      CUMULATIVE    RATIO
EFF.MASS
 MODE   FREQUENCY    PERIOD    PARTIC.FACTOR    RATIO
EFFECTIVE   MASS    MASS   FRACTION    TO   TOTAL   MASS
   1    2.90045     0.34477     41.445      1.000000    1717.68
0.919134                                                 0.536681
   2    5.03064     0.19878     -4.6726     0.112744    21.8336
0.930818                                               0.682180E-02
   3    5.27097     0.18972     6.1424      0.148205    37.7285
0.951006                                               0.117881E-01
   4    5.33261     0.18753     -9.1381     0.220489    83.5053
0.995690                                               0.260908E-01
   5    5.49448     0.18200     2.7555      0.066487    7.59301
0.999753                                               0.237240E-02
   6   5.53050    0.18082    -0.67921    0.016388   0.461326
1.00000                                                0.144139E-03
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 sum                           1868.80              0.583898
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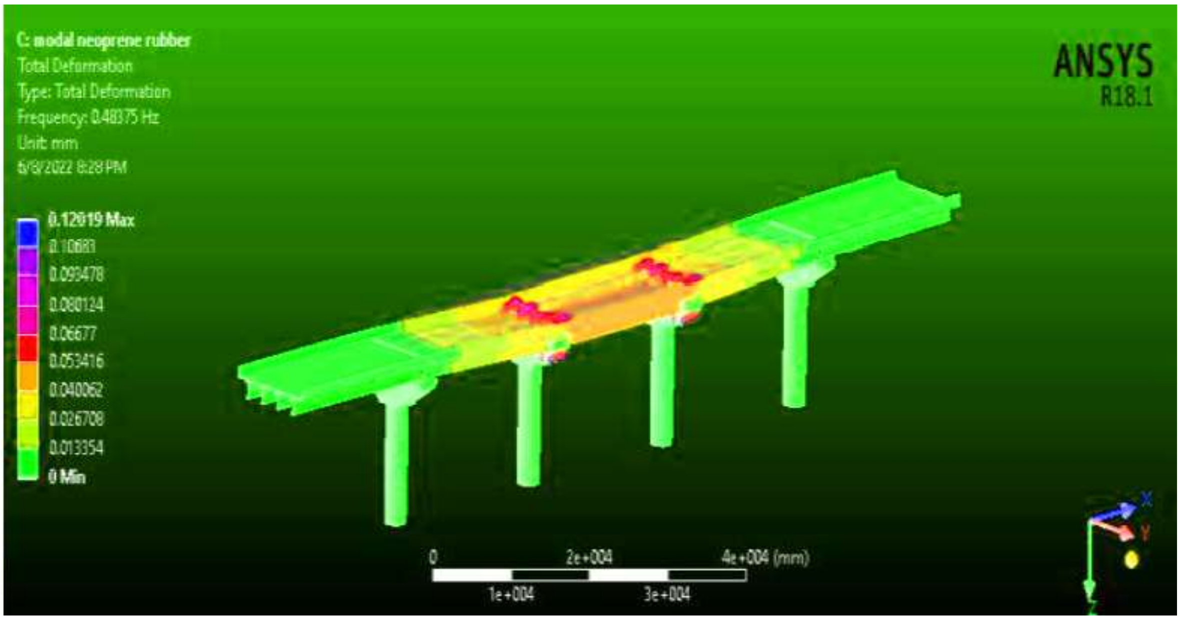


Figure 11: Neoprene rubber's first frequency mode form

With a bridge deck made of neoprene rubber and with a first natural frequency mode shape, the bearing zone exhibits the greatest deformation, with a magnitude of.12 mm.

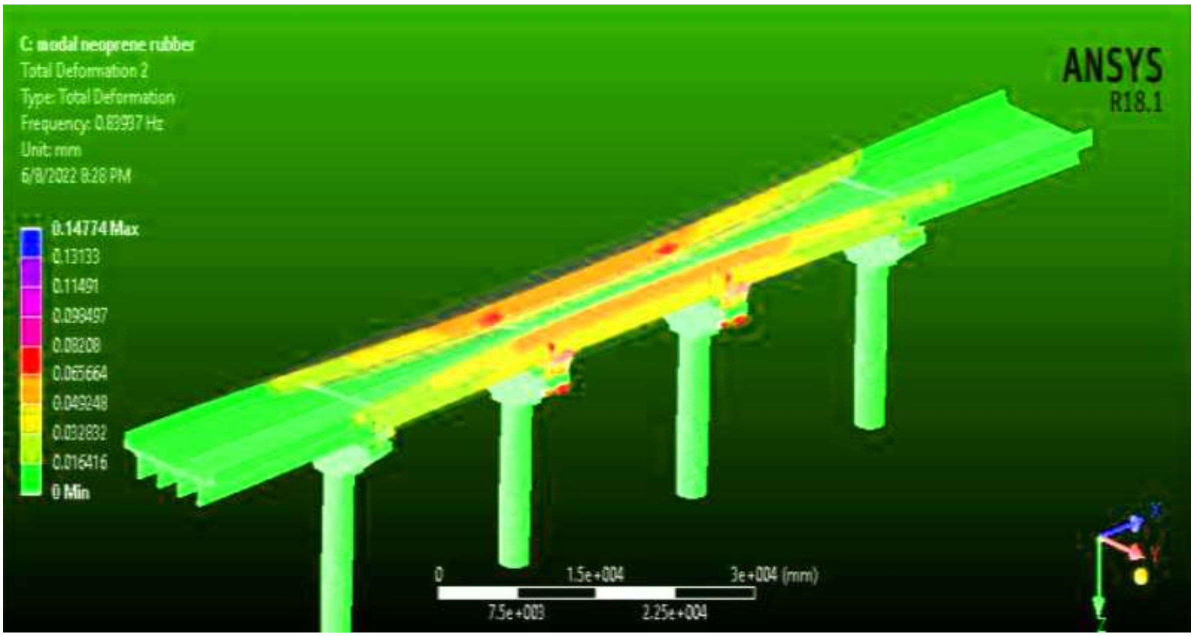


Figure 12: Shape of the second frequency mode for neoprene rubber

On a bridge deck made of neoprene rubber and with a second natural frequency mode shape, the bearing zone exhibits the greatest deformation, with a magnitude of.147 mm.

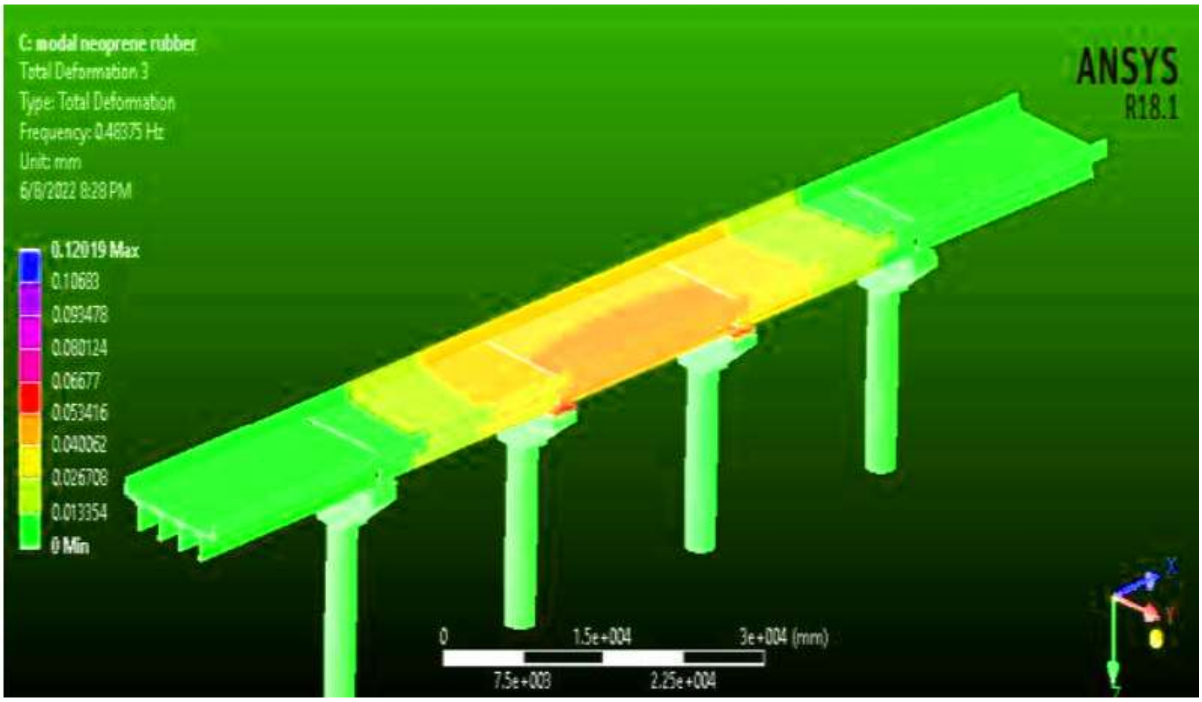
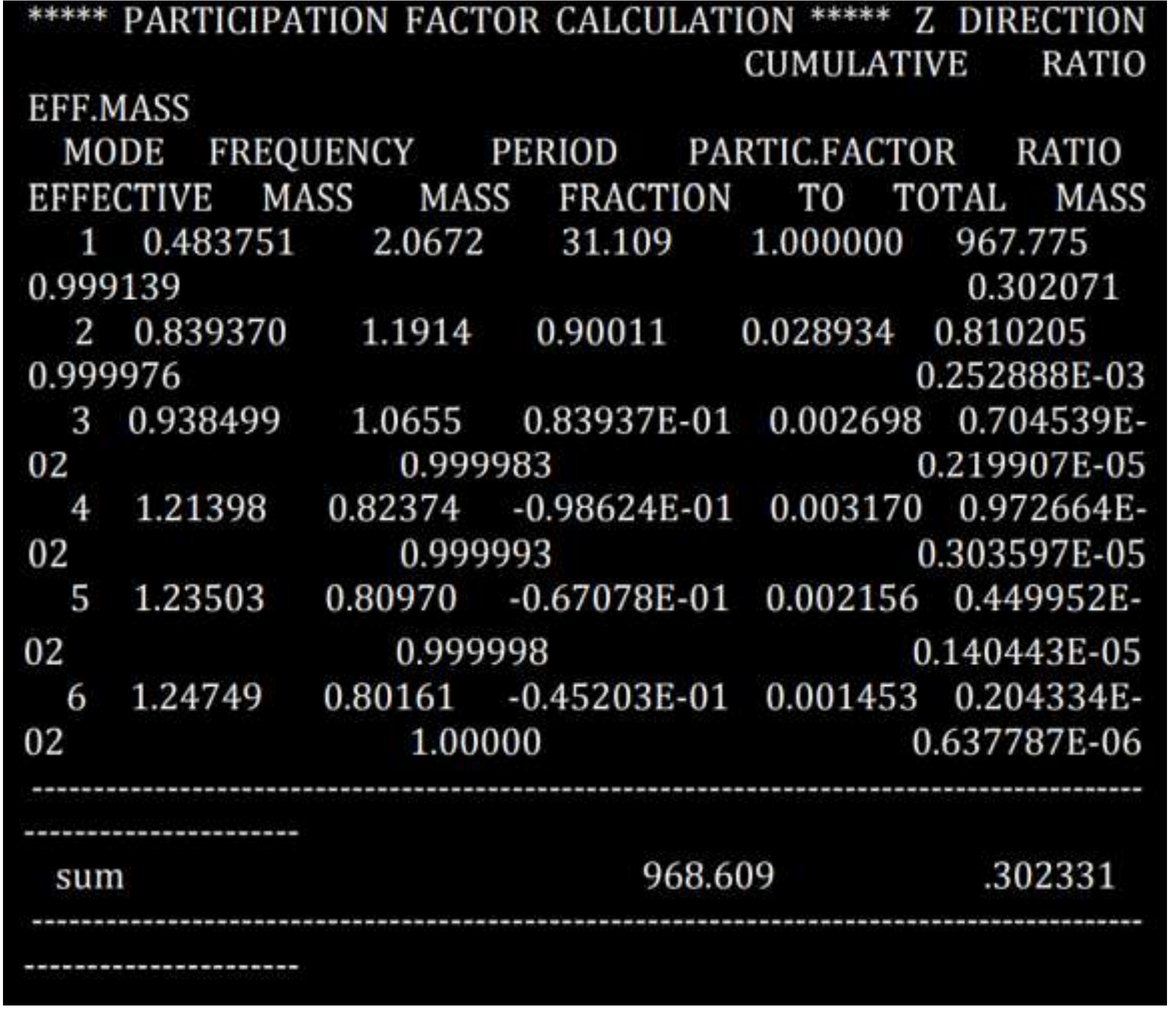


Figure 13: Shape of the third frequency mode for neoprene rubber

On a bridge deck made of neoprene rubber and with a third natural frequency mode shape, the bearing zone exhibits the greatest deformation, with a magnitude of.1201 mm.

Table 3: Neoprene material's mass participation factor



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***** PARTICIPATION FACTOR CALCULATION ***** Z DIRECTION
                                             CUMULATIVE    RATIO
EFF.MASS
 MODE   FREQUENCY    PERIOD    PARTIC.FACTOR    RATIO
EFFECTIVE  MASS   MASS  FRACTION   TO  TOTAL  MASS
  1   0.483751     2.0672     31.109     1.000000    967.775
0.999139                                              0.302071
  2  0.839370     1.1914     0.90011     0.028934   0.810205
0.999976                                              0.252888E-03
  3  0.938499     1.0655    0.83937E-01  0.002698  0.704539E-
02                   0.999983                         0.219907E-05
  4   1.21398     0.82374   -0.98624E-01  0.003170  0.972664E-
02                   0.999993                         0.303597E-05
  5   1.23503     0.80970   -0.67078E-01  0.002156  0.449952E-
02                   0.999998                         0.140443E-05
  6   1.24749     0.80161   -0.45203E-01  0.001453  0.204334E-
02                    1.00000                         0.637787E-06
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 sum                                968.609            .302331
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6. Conclusion

In order to assess the vibration properties of bridge structures, the FEA is a useful technique. The natural frequencies and mode shapes for a bridge made of concrete, silicone rubber, and neoprene rubber are assessed using the results of the modal analysis.

1. The essential areas of high deformation are found using the modal analysis.
2. The key location of the concrete material is discovered to be near the crash barrier, which showed the most deformation and was vulnerable to amplitude buildup during resonance.
3. The key zone is discovered to be near the crash barrier, which showed highest deformation and is vulnerable to amplitude buildup during resonance, according to modal analysis of silicone rubber material.
4. Neoprene rubber material's modal study shows that the bearing zone has the most distortion, whilst the bridge structure and crash barrier experience less deformation.

7. References

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