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Analysis of RCC Box Culvert with Different Shapes and Sizes of Haunches Using ANSYS Software

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Abstract: Recent developments in computer technology have made it possible the use of Finite Element methods for 3D modeling and analysis of RCC structures. Several works have already been done on Finite Element analysis of Box Culverts. In the past study of box culverts, effect of various shapes of haunch has not been considered in Observing the changes of flexural stresses. In this study, Finite Element analysis of Box Culverts is carried out Using ANSYS software. The box culvert is provided with two shapes of haunches viz. straight and circular arc for various sizes. Firstly, straight haunches of size 0.3m, 0.5m,are provided and analyzed and then radial haunches of 0.3m, 0.5m are placed to get analysis done in ANSYS for the same load conditions as for the former conditions. At the end, a comparative study of the two shapes is carried out with respect to total deflection, stress intensityconcentration in the RCC box culverts. The results provided considerable variation in terms of deflections and stresses in the two cases where in circular haunches also shown significant impact on stress and can be uses as replacement of straight haunches that has been extensively used in the presentera.
Keywords:RCC Box Culvert, Haunches, Straight Haunches, Circular Haunches, ANSYS**.**

I. Introduction

Culverts are little bridges that allow natural water drainage to pass beneath highways, taxiways, runways, and train tracks. Pipe culverts, Arch culverts, Box culverts, Bridge culverts, and Metal Box culverts are all examples of culverts. Since 1965, box culverts have been widely employed to meet water drainage requirements when the site characteristics and other load requirements are adequate for construction. Depending on the availability of resources and other site requirements, box culverts might be of the Pre-Cast kind or built on-site. The capacity of a Box culvert to bear a load is determined by number of criteria's, including the type of material used, the form and size of the culvert, and the surrounding materialsupport. Because the capacity and strength of a Box culvert reduces over time as a result of repeated exposure to strong loads, it is critical to understand the nature and kind of loading, as well as how it affects the structure.

Box culverts come in a variety of sizes and utility purposes; depending on the length, depth, and necessity, they can be single celled or multi-celled. Multi-Unit Box Culverts are primarily utilized for vehicular movement crossing under bridge road sections, but they also provide effective mechanical and hydraulic performance for water movement. Box culverts are cost-effective structures due to their monolithic design and concrete base, which eliminates the need for a separate foundation. They are particularly well-suited to areas with non-perennial streams and poor soil. Box culverts can be found in three places. The first is at the bottom of a depression where there is no natural water route. Second, where a natural stream crosses the road, and third, where surface water is carried in ditches beneath the road, as well as a driveway to a neighboring property. However, severe scouring and corrosion are some of the key disadvantages of Box Culvert if not constructed properly, and its serviceability and strength, as well as abrasion and degradation are some of its major limitations.

When exposed to heavy movement and loading, special characteristics are required to carry the load, transfer it to below ground, and thus increase the structure's durability. These challenges are met by using haunches in box culverts that carry heavy loads at the joints. The joints become more rigid, reducing deflection/rotation and, as a result, increasing the structure's moment and shear carrying capacity. Haunches also give frame stiffness, deflections, and permit an efficient bolted moment connection, reducing the necessary depth of the member by raising the member's Moment resistance where the applied moments are greatest. Moving forward, the study examines the use of various haunch sizes and the determination of stresses and other comparison factors using the Finite Element Method in ANSYS software, which provides more exact data than other traditional methods and tools such as STADDPRO.Haunches are used to create a rigid moment connection, and their depth and size are chosen to give a cost-effective manner of transferring moment. The stress-strain theory is used to determine the size of the haunches taken and their capacity. To acquire the Ultimate Load Capacity, the haunch length to be employed can be estimated using the Plastic Capacity tested with different sizes.

The aim of this research is to study the Stress distribution comparison and study of rectangular RCC box culverts with various haunch shapes. Changing the size of the haunches in box culverts to reduce deflection and primary stress concentration.

II. Literature Review

Garg Anil K and Abolmaali Ali in this research investigated the shear capacity of precast reinforced concrete box culverts. Six entire 2.4 scale meter(8ft) boxes were submitted to AASTHO H20 wheel load testing to see if they would fail. The wheel load for location changes from the tip of the haunch as a function of the top slab effectively and significant depth in order to acquire location if crucial shear location. Every single test specimen was gradually loaded up to the failure result, with each load step identifying and recording crake initiation and propagation. Although top scale compression distribution steel was not used during specimen production in several cases, the influence on experimental performance was minimal. The test specimens were loaded, however, to acknowledge shear activity. All tests yielded results and performed in a flexural mode beyond and up to standard factored live load, according to the findings. The researchers determined that shear is not the governing behavioral mode for concrete box culverts, and that the current regulations for box culverts need to be revised.[1].

Garg Anil K and Abolmaali Ali evaluated the shear conduct and limit of precast concrete box culverts exposed to HS 20 truck wheel load in this study. The basic culvert was designed by focusing on fill that was exposed to no depth and placing it top an unbending sheet material. Full-scale trial tests were conducted on 24 standard precast concrete box culverts assigned according to ASTM C1433-05, with the wheel load placed at the distance between the tip of the haunch and the edge of the load plate. The test results also showed that flexure accurately indicated behavior up to and including the AASHTO 2005 determined burden. The test instances' three-dimensional nonlinear limited component models (FEMs) were built and confirmed with the test results. The FEM was used to obtain the three-dimensional volumetric shear force distribution on the top slab of the 42 ASTM C1433-05 boxes, from which the dissemination width for each container was calculated. This was used to calculate the basic calculated shear force for each box, which was then compared to the shear limit conditions set out by theAmerican Concrete Institute. For all of the ASTM C1433-05 boxes, the shear limit exceededthecalculatedbasicshearforce [2].

Primental Mario and Costa A conducted a mathematical and test investigation on built-up substantial box ducts (BC) in this paper. During the development period, a BC beneath a 9.5 m high bank was instrumented and observed. Mathematical investigations were then carried out using a limited component code that took into account the development grouping, the nonlinear conduct of the supported substantial design, and the soil and interfaces' elastic-plastic conduct. When the registered outcomes agreed with the observed behavior, a parametric report was prepared to demonstrate the fundamental boundaries affecting the association component and to evaluate the BC underlying presentation up to disappointment. The impact of BC nonlinear conduct on the connection system was investigated and discussed in both help and extreme ultimate limit state circumstances. It is reasoned that soil pressure and BC nonlinear behavior are directly associated and should be addressed in the planning stage to get a more objective and cost-effective strategy.[3]

Garg Anil K and Abolmaali Ali in this report details the development of a useful software for determining the shear limit of precast RCC box ducts. Complete and point-by-point 3D limited component models (FEMs) of the test cases were generated and inspected in order to duplicate the indicated outcomes. The course frameworks were demonstrated using three-dimensional shells and strong components. The support bars components are established on superficial level components provided by the ABAQUS programming to demonstrate the welded wire textures. The nonlinear hub to surface contact examination approach was used to show the contact surface between the external substance of the base section and the response floor. To catch the issue of nonlinearity, the investigation technique includes an extending stacking history. The loading was placed at a particular distance from the top edge of the crate duct's backside, where the specific distance is the powerful profundity of pressure support at mid-length, in the top section of the container course. A 25.4 cm (10 in.) x 51 cm (20 in.) plate is tentatively used to check the wheel load, such as in FEM, which is used by AASHTO to represent the wheel load of an HS20 vehicle. To study the framework for tiny breaks and to balance out the outcomes, the spread break model was combined with the Risk examination approach. The H combination was joined with the contrast between the outer work done and the strain energy thickness of the framework to obtain the desired arrangement. The heap avoidance plots obtained from the FEM investigations were compared to those obtained from the exploratory results, revealing a tight relationship.[4]

Shreedhar R and Shreedhar S studied Multi cell Box Culvert of the larger thickness of the slab and sidewalls, multi-celled reinforced box culverts are an appropriate structure if the discharge in a drain crossing the road is not considerable and the bearing capacity of the soil is low, while single-celled box culverts are not economical. Using traditional methods such as moment distribution methods, slope deflection methods, and so on, it is extremely difficult for the designer to determine the coefficient for moments, shear forces, and axial thrusts for various loading scenarios and varied L/H ratios for multiple cell box culverts. As a result, design coefficients assist designers in determining the best combination of loading situations to arrive at the critical design forces at the critical section, saving time and effort. The study's findings revealed that the essential portion to consider is the center of the span of the top and bottom slabs, the support sections, and the center of the vertical walls, because these sections experience the highest design forces due to various loading patterns. The greatest positive moments in the center of the top and bottom slabs when the culvert is full of water and the sides of the culvert do not carry the LL. For the situation that the culvert is empty and the top slab supports the dead and live load, the critical negative moment arises at the support sections of the bottom slab. When compared to single-cell box culverts, multi-celled box culverts are more cost-effective for longer spans since the maximum bending moment and shear force values are lower, necessitating thinner sections.[5].

ChijwaNobuhiro and Zhu Xiaoxu in this study reveals the long-term stress on culverts. It deals with the massive deformation of the underground RC, which had previously been kept under wraps, and analyze it. Monitoringcarried out for the next 20 years, and the results were analyzed. It has a synergistic impact on long-term culverts that may fail for various reasons. The reason for this is that culverts that are subjected to vertical soil pressure develop shear cracks later in their lives. They are subjected to time-dependent creep and shrinkage, and delayed cracks are experimentally constructed, developed in the laboratory, and a multi-scaled simulation is performed subsequently.[6]

K KSahu and Shradha Sharma examined box culverts made of RCC with one, two, or three cells, as well as their operating circumstances and design analysis. The costs of using optimal thickness versus not using optimal thickness were examined. As a result, results are presented that show that the optimum thickness presented here leads to cost-effective culvert design. An attempt is made to construct bending moment comparison charts for top and bottom members. As a result, the values of bending moments can be calculated from these charts at any intermediate aspect ratio. According to the findings, the L by H aspect ratios of 4/3 and 4/2 have lower end moments values and When compared to a L by H aspect ratio of 4/4, there is a greater maximum bending moment. The box culvert with an L/H aspect ratio of 4/2 will be more cost-effective because the percentage savings in velocity, hydraulic mean depth, water depth, perimeter, concrete area volume, and end moments will be lower on the top slab, bottom slab, vertical side wall portion, and maximum bending moment of this section will be greater than other sections.[7].

Patil Anike and Galatage Abhijeet in their report depicts a reinforced concrete box culvert with varied aspect ratios. It was examined utilizing several types of cushioning as well as non-cushioning. The behavior of box culverts when subjected to various loading types as per the IRC regulations, as well as numerous combinations that can affect the box culverts up to the worst limit, has been given important relevance for safe structural design. According to the study, for all studied aspect ratios, the most undesirable combinations are observed when empty boxes are subjected to load combinations. The bending moment was found to be different for all investigated load combinations, as well as the pressure of water and soil taken into consideration, for aspect ratios of 1 and 1.5. For aspect ratios of 1 and 1.5, bending moments found constant for all evaluated load combinations as well as soil and water pressure have become inconsequential.[8]

Saurav and Pandey Ishaan Conducted an analytical analysis on Box Culverts using the Finite Element Method and ANSYS software to minimize Flexural Stresses by examining the impacts on the haunches. To obtain accurate stresses that emerge after loading, modelling was done utilizing two properties: Poisons Ratio and Modulus of Elasticity. The analysis is carried out by modelling a Box culvert without haunches at first, and then using haunches of varying sizes later. On the basis of the findings from the examination of various situations, a comparative research was conducted. The fluctuation of Flexural Stresses with Bending Moment was visualized using graphs. Exact Reinforcement required has been determined using bending moments, and a cost study for various sizes has been given. A comparison research was also carried out using different software such as STADD Pro and ANSYS 15, which revealed a significant difference in Shear Stress, equivalent stress, and deflection in identical structures.[9]

Patel R and Jamle Sagar presented in their study that Box culverts are architecturally described as a structure used when water flows from numerous pathways such as roadways, railway lines, and so on. They are significantly less expensive than bridges and a natural stream flowing through multiple channels. On the subject of box culverts, a comparison of software and manual approaches, as well as the author's perspective on design and analysis, is also established. IS standards for roads and bridges are also required for designing concrete box culverts. Paperwork and IRC class research finally have an impact on the loading cases. The structure's design takes into account pressure cases as well as parameters like impact load, braking force, live load, effective width, and so on. For maximum bending moment and shear force, the structural elements are essential. This paper contains all information on the provision in the codes, consideration, and justification, as well as the pros and disadvantages of all areas, in today's study period. This paper contains all information on the provision in the codes, consideration, and rationale, as well as the pros and disadvantages of all areas, in today's period of study.[10]

III. Analysis and Results

There are multiple methods of calculating stresses Created in structures using various methods but the most well-known and extensively used method is the Finite Element Method. FEM provides a more precise way for estimating the reduction in stresses in box culverts utilizing various sizes and shapes of haunches.

Finite Element Method-The Finite Element Method has a number of advantages. It provides a model foundation for the analysis of complex shapes, as well as generic loading and boundary conditions for structural analysis. Model Bodies made of Composite and Multipurpose Material are also available. By altering Element size and type, as well as integrating time dependent and dynamic effect components, it improves accuracy. ANSYS software is a mechanical finite element analysis programmed that is generally used to drive computer models that determine various structural parameters such as strength, elasticity, electromagnetism, toughness, temperature distribution, stresses, and bending moments. Apart from normal stresses and bending moments, using ANSYS over other software allows you to develop industry specific built environments and complex loading on models and provide accurate results that are not possible to determine using conventional methods. It also allows you to study the hydrodynamic factor on the structure. The acronym ANSYS stands for Analysis of Systems, and it provides more accurate and reliable findings.

Analysis was done using a Box Culvert Model in ANSYS with a critical top load by using Straight and Circular Haunches of different Sizes and Parameters like Stress Intensity and Total deformation was observed. The results obtained were as follows.

Results for 0.3m Straight Haunches-The analysis was performed on Box culvert using 0.3m Straight Haunch with critical load acting on the top.

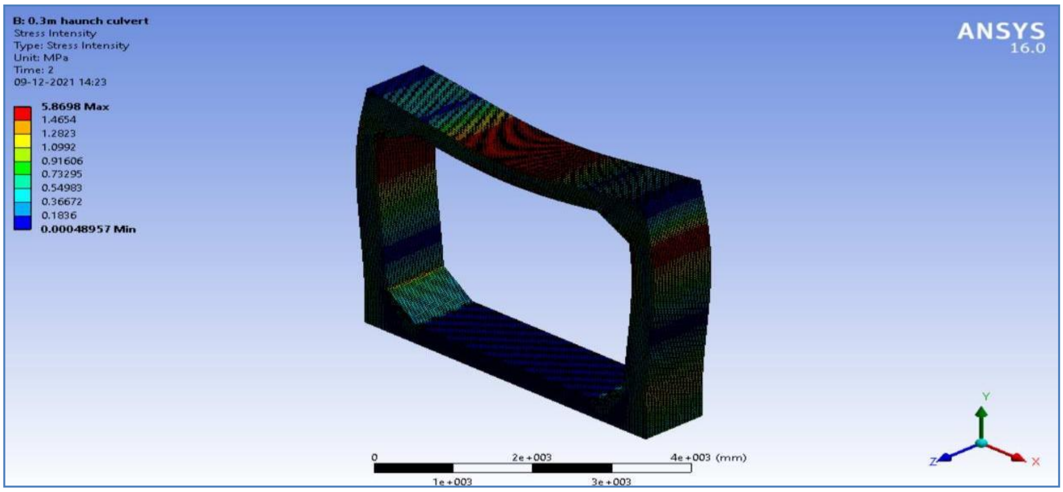

Figure 1: Stress Intensity for 0.3m Straight Haunches.

The above figure shows the stress intensity trends obtained for Box Culvert under loading, Stress Intensity of 5.869N/mm2 occurs for 0.3m Straight Haunches at a distance X=0.725m which is the location where top horizontal slab and side vertical wall meets.

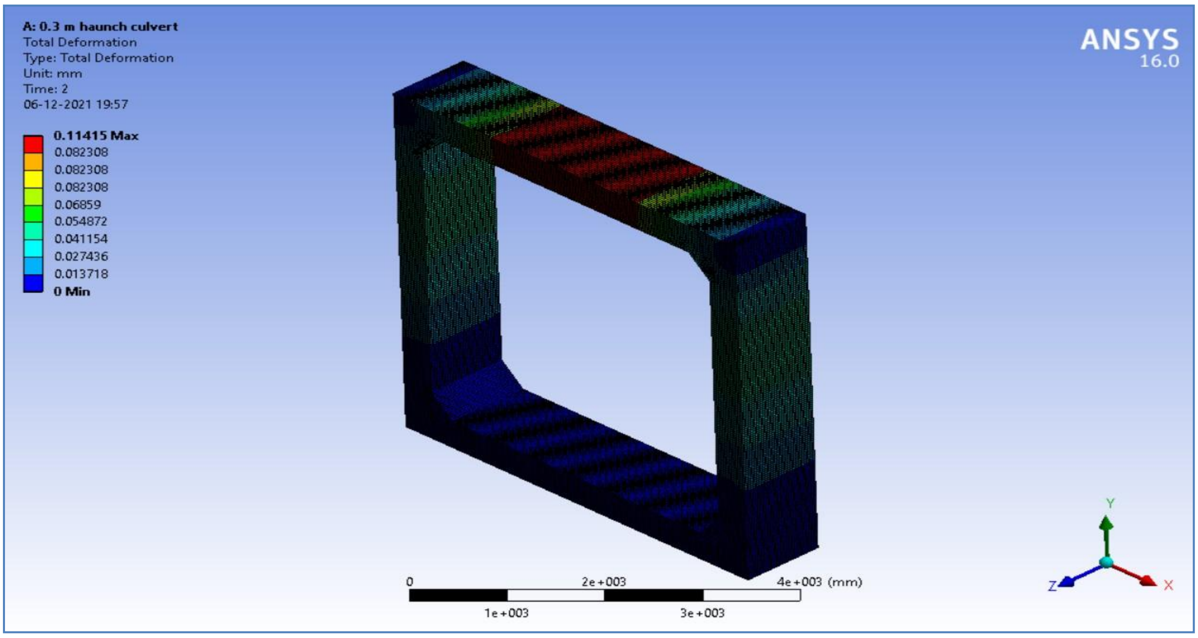

Figure 2: Deformation for 0.3m Straight Haunches

The Figure 2 shows the Total Deformation obtained for Box Culvert under loading, Stress Intensity of 0.11415 mm occurs for 0.3m Straight Haunches.

Results for 0.3m Circular Haunches- The analysis was further performed on Box Culvert with same conditions and loading but with circular haunches of radial size 0.3m and parameters were compared for Stress Intensity and Total Deformation.

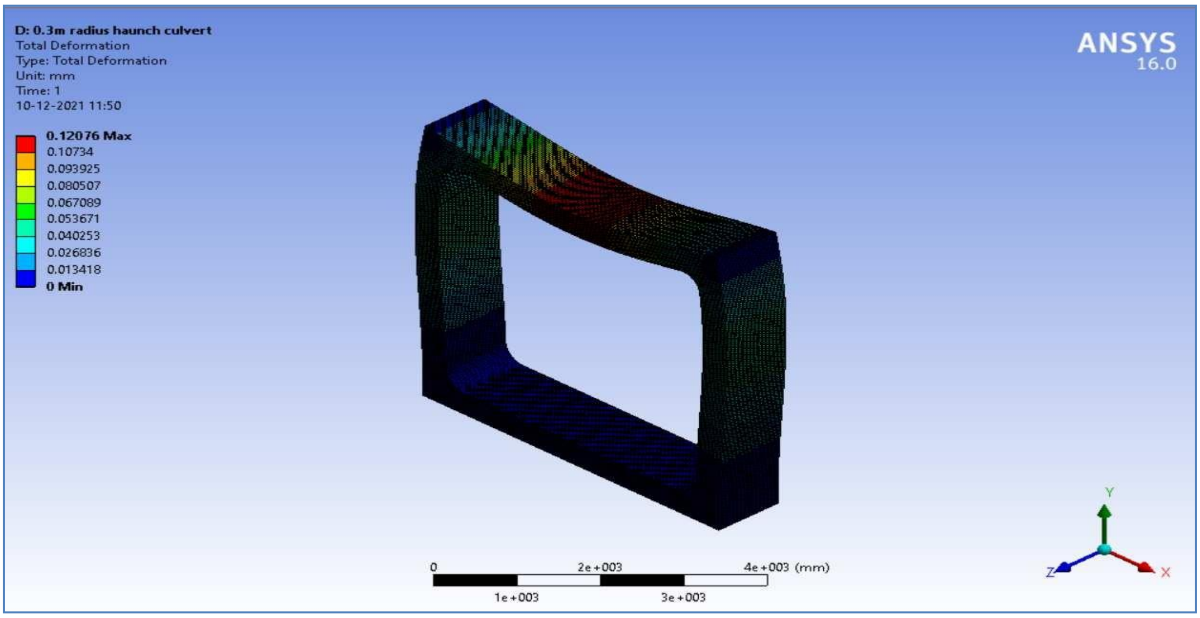

Figure 3 Total Deformation for 0.3m Circular Haunches

The Figure 3 shows the Total Deformation of the Box Culvert for Circular Haunches of 0.3T, Maximum Deformation Occurs at Centre as the Maximum Compressive Stress occurs.

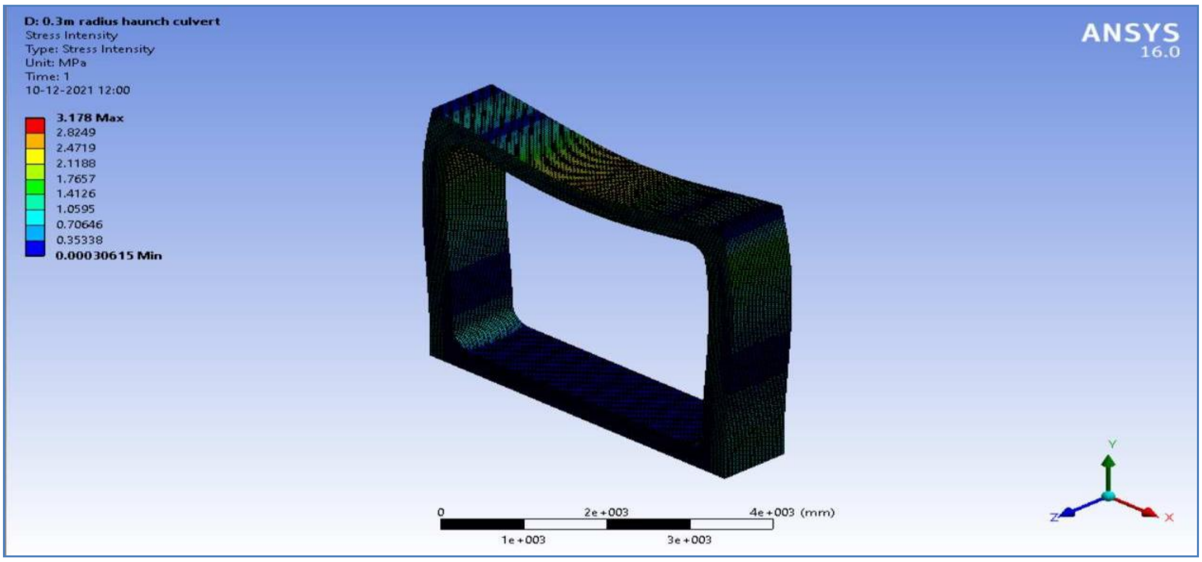

Figure 4 Stress Intensity for 0.3m Circular Haunches

The Figure 4 shows the Stress Intensity for the Box Culvert for Circular Haunches of 0.3T, Stress Intensity reduced to 3.178N/mm2 occurs for Circular Haunches**.**

Results for 0.5m Straight Haunches-The analysis was then performed on Box Culvert by changing the size of haunches this time with 0.5m straight haunches with same conditions and loading and same parameters were compared for Stress Intensity and Total Deformation.

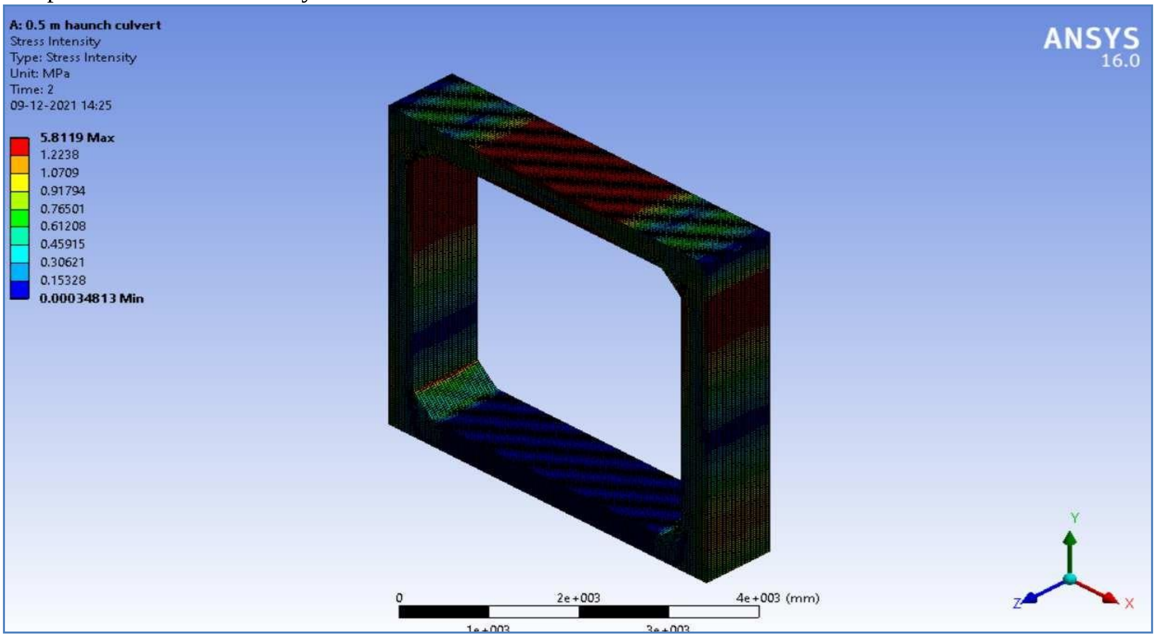

Figure 5 Stress Intensity for 0.5m Straight Haunches

Figure 5 Depicts the Stress Intensity of 5.812 N/mm2 occurs just at the location where the Horizontal Slab meets the Vertical Walls.Maximum Compressive Stress occurs at the Corner just near the end of the haunch.

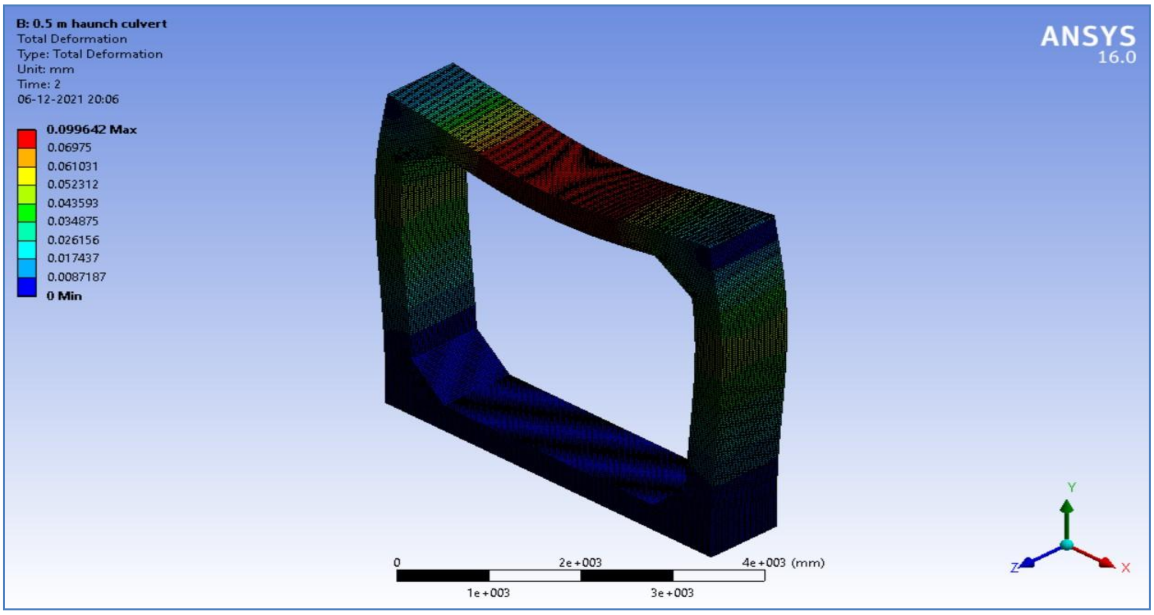

Figure 6 Total Deformation for 0.5m Circular Haunches

Figure 6 Shows the Total Deformation obtained for 0.5m Straight Haunches under Loading. Maximum Deformation of 0.009964 mm Occurs at the center on application of critical loads.

Results for 0.5m Circular Haunches- The observation were then recorded by changing the size and shape of the haunches with radial dimension of 0.5 for circular haunches keeping loading and under conditions same. Same parameters Total Deformation and Stress intensity were then compared.

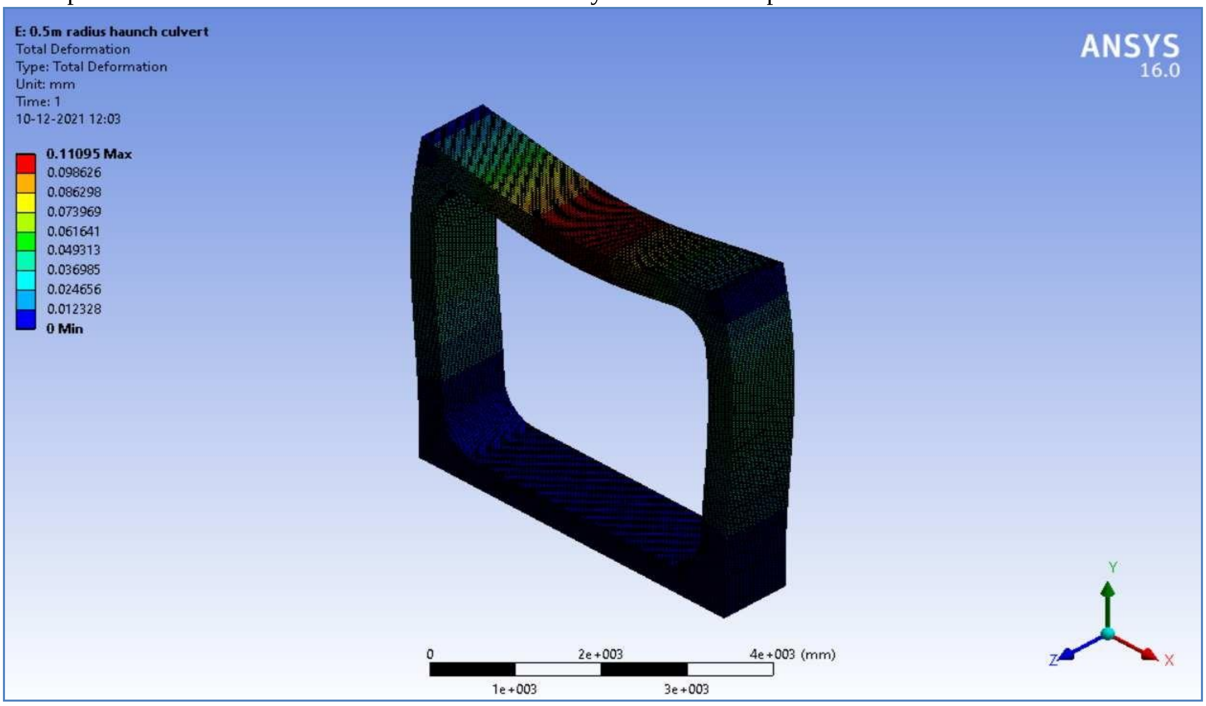

Figure 7 Total Deformation for 0.5m Circular Haunches

Figure 7 Shows the Total Deformation obtained for 0.5m circular Haunches under Loading. Maximum Deformation of 0.1095 mm Occurs at the center on application of critical loads.

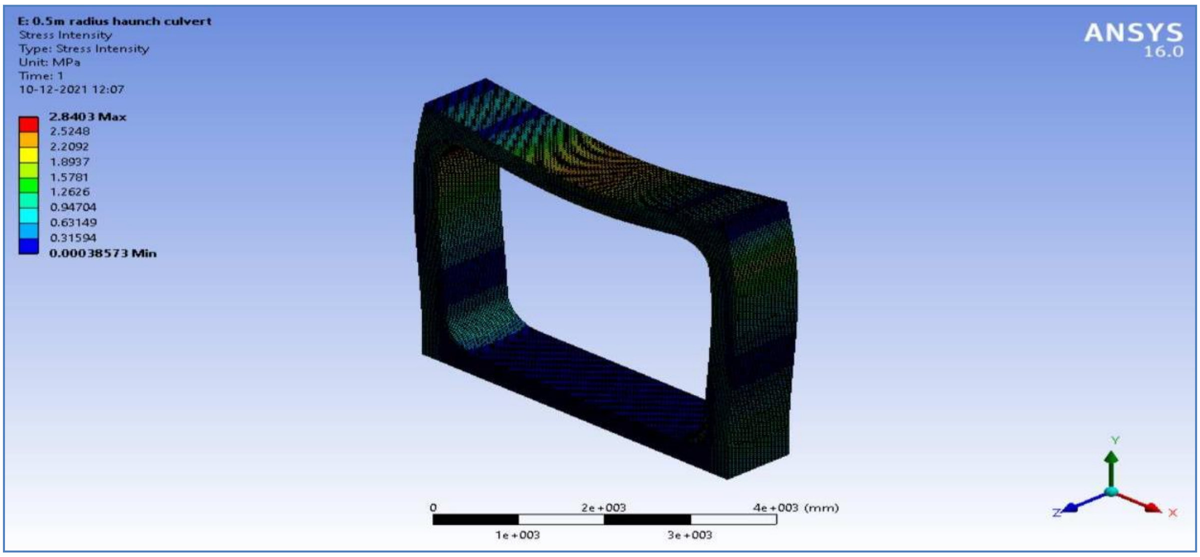

Figure 8 Stress Intensity for 0.5m Circular Haunches

The Figure 8 shows the stress intensity trends obtained for Box Culvert under loading, Stress Intensity of 2.84N/mm2 occurs for 0.3m Circular Haunches at a location where top horizontal slab and side vertical wall meets.

IV. Conclusion

We conducted the analysis of RCC box Culvert with Straight and circular haunches by changing the size of haunches and the results obtained are so presented.

Stress Variant	Straight haunch size		Circular Haunch size	
	0.3	0.5	0.3	0.5
Total Deformation (mm)	0.11415	0.0996	0.12076	0.11095
Stress Intensity (N/mm^2)	5.869	5.812	3.178	2.840

The study carried out with detailed analysis of Box culvert under critical loading with different shape and sizes of haunches and observe the effect of loading with different parameters like Stress intensity and total Deformation of structure. The results obtained for straight haunches show a trend that the values for the Stress Intensity for straight haunches for different size are as for 0.3m Straight Haunchesstress Intensity so obtained under the critical loading was 5.869N/mm2 which further decreased significantly for 0.5m to 5.812N/mm2 with percentage decrease of 0.98%. Further the loading was done to Box culvert with circular haunches for radial dimension of 0.3m and stress intensity so obtained was 3.178 N/mm2 and later on increasing the size of haunches for radial dimension of 0.5m the stress intensity reduced to 2.84 N/mm2 with percentage reduction of 10.63%. Thus, Comparison can be drawn that the Stress reduced on increasing the size of Haunches from 0.3m to 0.5m and also on changing the shape of haunches from Straight Haunches to circular haunches.

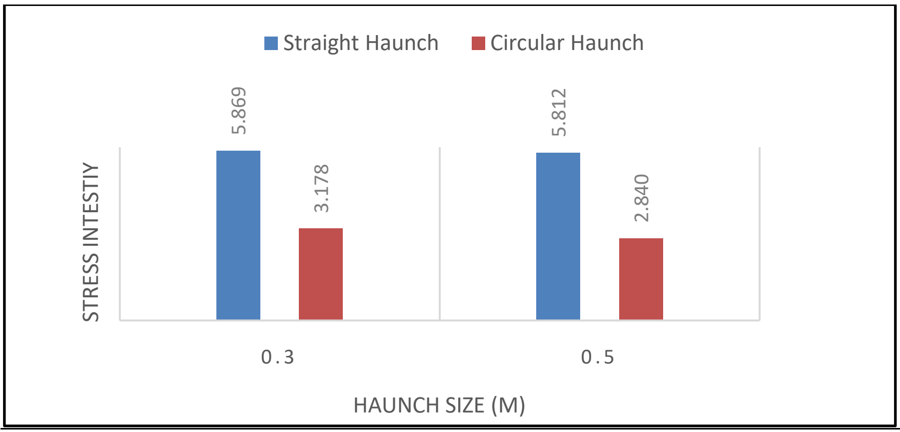

Figure 9 Stress Intensity Comparison for Straight and Circular Haunches.

The above Figure 9 shows a clear comparison of Stress Intensity for both straight and circular haunches on changing the size of haunches under critical loading, The stress Intensity showed a significant reduction by changing the shape and size of the haunches.

The results obtained for straight haunches show a trend that the values for the Stress Another Parameter of Total Deformation was observed for straight haunches for different size are as for 0.3m Straight Haunches the total deformation obtained under the critical loadingwas 0.11415mm which further decreased significantly for 0.5m to 0.0996 with percentage decrease of 12.74%. Further the loading was done to Box culvert with circular haunches for radial dimension of 0.3m and Total Deformation so obtained was 0.12076 mm and later on increasing the size of haunches for radial dimension of 0.5m the deformation reduced to 0.11095 with percentage reduction of 8.124%. Thus, Box culvert under loading for Straight and Circular Haunches shows a varying results for Total Deformation straight haunches provided much lower stress intensity with low values of deformation as well on increasing the size of Haunches. However, Circular haunches shows some different trends as compared to straight haunches. Stress Intensity reduced for the Circular haunches on increasing the size of the haunches for 0.3m to 0.5m with percentage reduction of 10.63%, whereas the deformation showed reducing trend on increasing the size of circular haunches but the values of deformation were higher for circular haunches as compared to straight haunches.

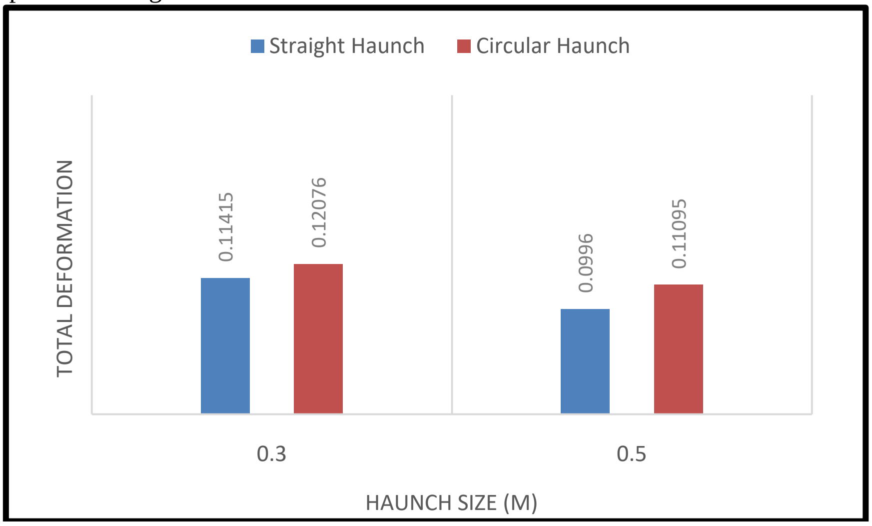

Figure 10 Total Deformation Comparison for Straight and Circular Haunches.

The above Figure 10 shows a clear comparison of Total Deformation for both straight and circular haunches on changing the size of haunches under critical loading, The Deformation showed a significant reduction by changing the Size of Straight and Circular haunches but the Deformation was more prevailing for circular haunches as compared to straight haunches.

Thus, the study also provided a scope for further investigation of Box culvert by changing shape and sizes of haunches. Also changing the Pattern of reinforcement can also be studied for observing the impact on stress intensity and other parameters which presents the future scope of this Project.

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