



IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

e-ISSN: 2319-8753 | p-ISSN: 2320-6710



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 7, July 2021

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.569



9940 572 462



6381 907 438



ijirset@gmail.com



www.ijirset.com

Design of Box Culvert by Using Computational Methods

Surbhi S. Kadyalwar¹, Prof. Girish Sawai²

PG Student, Department of Civil Engineering, V M Institute of Engineering & Technology, Nagpur,
Maharashtra, India¹

Assistant Professor, Department of Civil Engineering, V M Institute of Engineering & Technology, Nagpur,
Maharashtra, India²

ABSTRACT: Box culverts are economical due to their rigidity and monolithic action and separate foundation are not required since the bottom slab resting directly on the soil, serves as raft slab. For small discharges, single celled box culvert is used and for large discharges, multicelled box culverts can be employed. The barrel of the box culverts should be sufficient length to accommodate the carriageway and the kerb. Box Culverts are ideally suitable monolithic structures across a highway or railway embankment to balance the flood water on both sides. It consists of top slab, bottom slab and two vertical side walls. It is most economical due to monolithic action and no separate foundation required since bottom slab serves as a mat foundation. In this paper we present a complete study of box culvert by using computational methods such as Grillage analysis and Finite element method. Grillage analysis is versatile in nature and can be applied to verify of bridge decks having both simple and complex configurations with ease and confidence. Grillage analysis has done by most commonly using software STAAD Pro. Finite Element analysis is a discretized solution to a continuum problem using Finite element method. Finite element method is a numerical procedure for solving differential equations associated with field problems, with an accuracy acceptable to engineers. It gives more accuracy to the Engineers. Finite element method has done by most accurate and emerging software SAP 2000. In FEM we model the structure by using shell element. In this paper we find out stresses such as bending moment and Shear force of the structure under railway loading and these stresses were computed by computational methods and also compared with conventional method. Design parameters are also computed based on Indian Railway Standards. In this paper we also study about design of box culvert and comparative study of reinforcement details.

KEYWORDS: Box Culvert, Computational methods, IRC, STAAD PRO

I. INTRODUCTION

Culvert is defined as a tunnel structure constructed under roadways or railways to provide cross drainage or to take electrical or other cables from one side to other. It is totally enclosed by soil or ground. Pipe culvert, box culvert and arch culvert are the common types used under roadways and railways. The design of culvert is based on hydraulic, water surface elevation, and roadway height and other conditions. These are used for water flow in a controlled way.

Box culverts are types of bridges used when the discharge in a natural stream crossing a road is small, and where the waterway is on relatively high embankment. They are generally cheaper than bridges, which make them the best solution when the natural streams intersect roadways.

Culverts are available in many and shape like round, elliptical, flat-bottomed, pear-shaped, and box-like constructions. Culverts are by their load and water flow capacities, lifespan and installation of bedding and backfill. The type is based on a number of factors including hydraulic, upstream elevation, and roadway height and other conditions.

Following are the different types of Culvert:

- Pipe culvert (single or multiple)
- Pipe-Arch culvert (single or multiple)

- Box culvert (single or multiple)
- Arch culvert
- Bridge culvert
- Metal box culvert

Pipe Culvert:

Pipe culverts are the most common types of culverts due to competitive price and easy installation. They are found in different shapes such as circular, elliptical and pipe arch. Generally, their shapes depend on site conditions and constraints. Pipe culverts on a small scale represent normal pipes like concrete pipes.



(Fig.1.1:Pipe culvert. Source: metal-culvert.com)

Advantages of Pipe Culvert-

- The main features of pipe culverts are:
- It can be constructed of any desired strength by proper mix design, thickness, and reinforcement.
- They are economical.
- These pipes can withstand any tensile stresses and compressive stresses.
- The crossing of water is under the structure.

Disadvantages of Pipe Culvert-

- The main disadvantage of pipe culvert is that it can be easily corroded at the crown because of bacteria's organic matter and release of harmful gas, which is known as Crown corrosion.

Pipe-Arch Culvert (Single or Multiple):

Arch culverts are suitable for large waterway opening where fishes can be provided with a greater hydraulic advantage. Moreover, they provide low clearance and are definitely, much artistic. Pipe arches are particularly useful for sites where headroom is limited and also have a hydraulic advantage at low flows.



(Fig.1.2 :Pipe arch culvert. Source: <http://www.theconstructor.org>)

Advantages of Pipe-Arch Culvert-

- The features of pipe arch culverts are:
- Limited headroom condition
- Improved hydraulic capacity at a low flow
- Aesthetic shape and appearance
- Lightweight
- Easy to install

Box Culvert:

Box culverts are made up of concrete and especially, RCC (Reinforced Concrete). The most challenging part in constructing a box culvert is that dry surface is needed for installing it. However, due to the strength of the concrete floor, water direction can be changed when a large amount of water is expected. This feature makes box culverts, one of the most commonly found types of the culvert.



(Fig.1.3 :Box Culvert. Source: miller-miller-inc.com)

Advantages of Box Culvert-

- Box Culverts are economical for the reasons mentioned below:
- The box culvert is a rigid frame structure and very simple in construction
- It is Suitable for non-perennial streams where scrub depth is not significant but the soil is weak.
- The bottom slab of the box culvert reduces pressure on the soil.
- Box culverts are economical due to their rigidity and monolithic action and separate foundations are not required.
- It is used in special cases, weak foundation.

Arch Culvert:

An arch culvert is made up of metal, stone masonry, concrete, RCC etc. Construction does not take a lot of time and unlike box culvert, water diversion is not necessary, as it can be installed without disturbing the water current. Thus, it can be termed as a Low Profile Culvert. This type of culvert maintains the natural integrity of the wash bed.



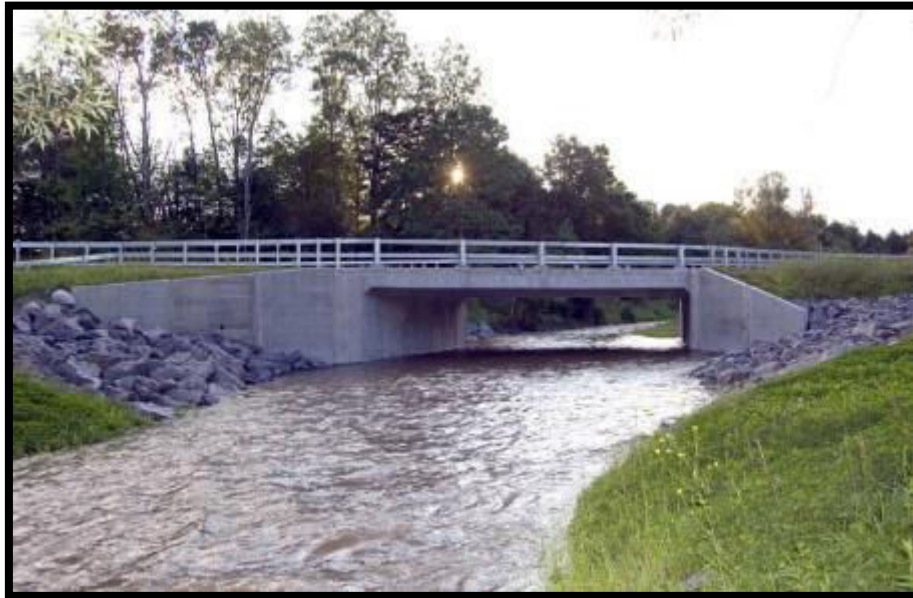
(Fig.1.4 :Arch culvert. Source: <http://www.visitgrey.ca>)

Advantages of Arch Culvert-

- The advantages of using arch culverts over traditional box culverts and pipe culverts are as follows:
- Cost savings
- Accelerated construction schedule
- Greater hydraulic efficiency
- Pleasing aesthetics
- Design-build advantage

Bridge Culvert:

Bridge culverts serve a dual purpose. It acts both as a bridge and a culvert. Generally, rectangular in shape, bridge culverts are constructed on rivers and canals. A foundation is laid under the ground level and pavement surface is laid on top of the series of culverts. Generally, we can term it as a Multi-Purpose culvert.



(Fig.1.5: Bridge culvert. Source: binghamtonprecast.com)

Advantages of Bridge Culvert-

- Extension of the network by acting as a repeater
- Very strong
- Allows traffic to pass on it
- Highly strong foundation
- Most expensive river crossings

Metal Box Culvert:

The metal box culvert is the economic alternative of the bridge. These bridges are manufactured from a standard structural plate or deep-corrugated structural plate. They are the perfect bridge replacement maintaining the same road grade level.



(Fig.1.6 :Metal Box Culvert. Source: conteches.com)

Advantages of Metal Box Culvert-

The advantages are as follows:

- Durability
- Shorter construction period and easy installation
- Deformation ability
- Long service life

Historical Background:

Historical records include many references to engineering feats undertaken by ancient civilizations to collect and convey water. Archeological explorations indicate that an understanding of drainage principles existed very early in history. For example, a sewer arch constructed about 3750 B.C. was unearthed in an excavation at Nippur, India. Another excavation in Tell Asmar, near Baghdad, exposed a sewer constructed in 2600 B.C.

Most renowned of these early construction efforts were the aqueducts of Rome. The water carried by these aqueducts was used primarily for drinking. The aqueducts were also used to carry sewage through Rome's main sewer, the Cloaca Maxima. Built in 800 B.C., and constructed mainly of stone masonry and natural cement, the Cloaca Maxima was the first known man-made waterborne method of sewage disposal. After 2800 years, sections of this concrete sewer are still being utilized.

During the first 5000 years of recorded history, the need for sewers, water supply, and drainage was recognized and practical methods of handling the flow of water were developed. From the remains of the ancient structures, it is apparent that the building materials progressed from relatively simple applications of natural materials to cast concrete. In many applications, permanency was a major requirement and concrete was one of the earliest substitutes for natural stone. While not all stone and concrete structures were able to survive the ravages of time, weather and warfare, concrete has an ancient and noble heritage.

Public health requirements for water and sewage treatment set the beginnings of the concrete pipe industry in the late 19th and early 20th centuries. Plants were established to manufacture pipe for sewers, transportation facilities, irrigation and drainage of agricultural land, and urban storm water drainage. In 1900 Steel reinforcement in pipe wall represents the single most important advance in concrete pipe technology. 1960 Changes to the joint geometry lead to the use of a variety of rubber gaskets for bottle tight joints that significantly reduce leakage and infiltration. 1970 Shorter plant-manufactured junctions used for service connections to facilitate hook-up. 1980 New specifications for precast concrete box culverts and sewers provide pre-approved drainage systems for environmentally sensitive areas, roadways, and mature neighbourhoods. 1990- 2000 On the leading edge of software development for engineers and purchasers of drainage systems the advance life cycle costing analysis, trench material estimating and load analysis software is continued.

II. COMPUTATIONAL METHODS

In this paper we are going to look at the computational methods in Analysis of Box culvert. Computational method indicates that solving complex problems by using computer methods. Over the years ago engineers solving complex problems by using numerical methods. Due to development took place in structures and materials problems become more complex. They can't solved those structures by using numerical methods. So they are going to solve those methods by using computational methods.

Here, we are going to discuss about Grillage analysis and Finite element analysis. Grillage analysis is one of the most familiar computer aided methods for analyzing bridge decks. In this method deck slab or a structure like culvert is converted in to equivalent grillage of beams. These beams are rigidly connected at discrete nodes. Beam deformations are related to torsional and bending moments. The beam stiffness is chosen so that the epitome and equivalent grillage of beams are subjected to indistinguishable deformations under loading. For simple and complex configurations of bridge decks this method is adoptable. Finite element method is most preferable method for the analysis of simple and complex problems without errors and accuracy. For a continuum problem it a discrete solution. A continuous complex problem is divided into separate entities referred as finite elements, connected together at a number of nodes.

III. PROPOSED METHODOLOGY

3.1 LOADS ON BOX CULVERTS

Dead Load-

Box Culverts are subjected to dead load comprising of self-weight of top and bottom slab of the culvert and two side walls of the structure. Super imposed dead load consisting of rail weigh, sleeper weight, ballast cushion and formation layer. Theses loads are applied on the transverse beams in grillage analysis by using effective area method. Directly applied on the top slab in Finite element method. Self-weight is calculated based on clear dimensions of the culvert and thickness of the culvert. Super imposed dead load is calculated from IRS Standards and Specifications code of practice.

Data Collected from IRS Code Specifications and Standards-

Weight of Rail = 52 kg/m

Weight of Sleeper = 285.4 kg/Sleeper

Spacing between consecutive Sleepers = 600mm

Quantity of ballast = 1.682 m³ /m

Live load-

Live load on culvert is vehicular loading. The vehicular live load consists set of wheel loads moving on top slab of culvert. These loads are distributed through sleepers and ballast cushion which is on top slab of the culvert. For that loads we are calculating the results.

Indian Railway Standards (IRS) recommends different types of loading. Here, we considering the broad gauge of 1676mm width of rails. For broad gauge IRS given two types of loading. One is 25t Loading – 2008 and another one is DFC Loading (32.5t axle load). In 25t loading maximum axle load is 245.2 KN and train weight of 91.53 KN/m and in 32.5t loading maximum axle load is 245.25 KN and train weight of 118.93 KN/m. In this paper we study the structural responses by applying 25t loading – 2008

For manual method and grillage analysis we have to apply EUDL (Equivalent Uniformly Distributed Load) on the generated models. These are recommended by IRS Bridge rules. EUDL is converted into uniformly distributed load. Whereas in finite element method applying truckloads of double headed diesel loco.

3.2 GRILLAGE ANALYSIS

In this method deck slab or a structure like culvert is converted in to equivalent grillage of beams. These beams are rigidly connected at discrete nodes. Beam deformations are related to bending and torsional moments.

Steps for Analysis

- Bridge deck or slab of the culvert is split into equivalent grillage of beams.
- Calculating the numerical value of equivalent elastic inertias of the members.
- Loads to be applied and transfer to various nodes of grillage
- Evaluation of stresses and design envelopes.
- Explanation of results

3.3 FINITE ELEMENT ANALYSIS

Finite Element analysis is a discretized solution to a continuum problem using Finite element method. Finite element method is a numerical procedure for solving differential equations associated with field problems, with an accuracy acceptable to engineers. For stress analysis of problems the FEM was first used, and has since been applied to many other simple to complex problems. Sometimes we may have to find out variables like displacements in stress analysis. It is done by dividing the problem domain into discrete elements. Physical properties are applied to each discrete element.

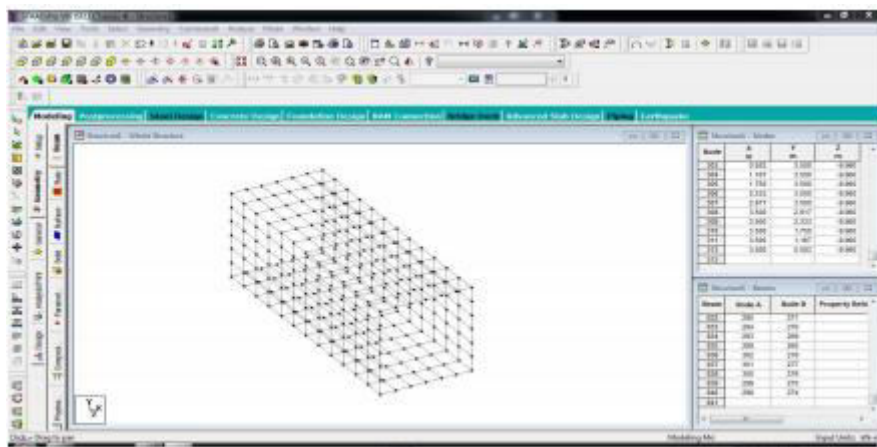
The variation of stresses in a system depends upon the geometrical property or effective area of the system of the system, the material property or surrounding environment, the boundary conditions and loading conditions. The domain

and geometry are very complex in an engineering system. After that, the initial and boundary conditions are also be complicated. So generally it is difficult to get solution of governing differential equation by analytic methods. Numerical methods are most frequently using to get those solutions of the problems. So we are discretizing the problem by using Finite element techniques because of its practicality and versatility.

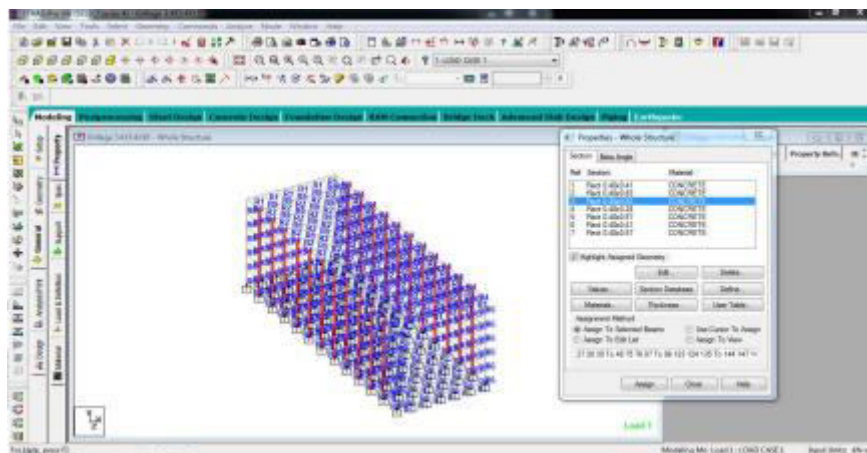
3.4 ANALYSIS MODELLING STEPS

Grillage Analysis modelling using STAAD Pro:

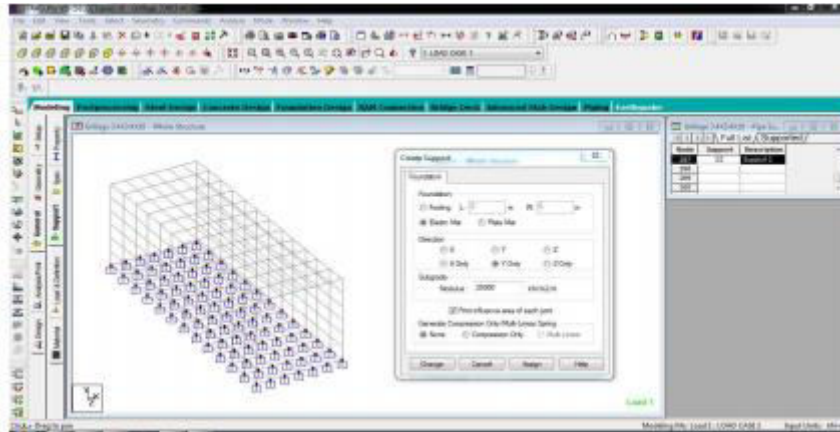
Step 1: Idealization of slabs into equivalent grillage



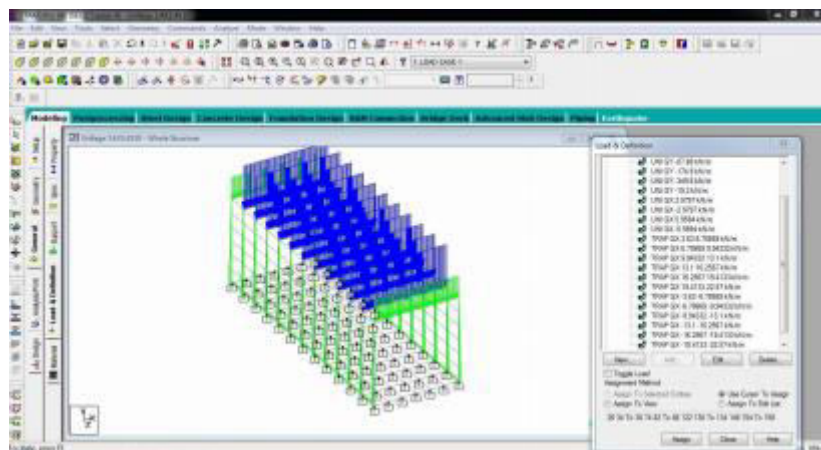
Step 2: Assigning Properties



Step 3: Assigning Subgrade modulus for elastic Mat

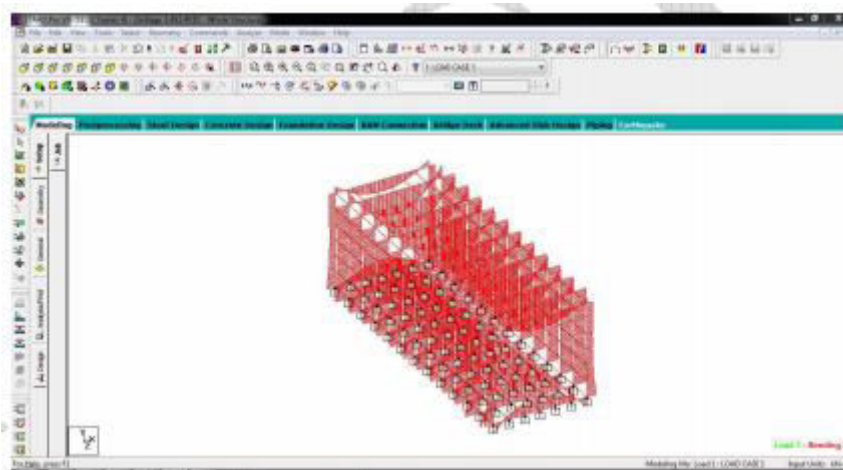


Step 4: Assigning Loads on Grillage beams

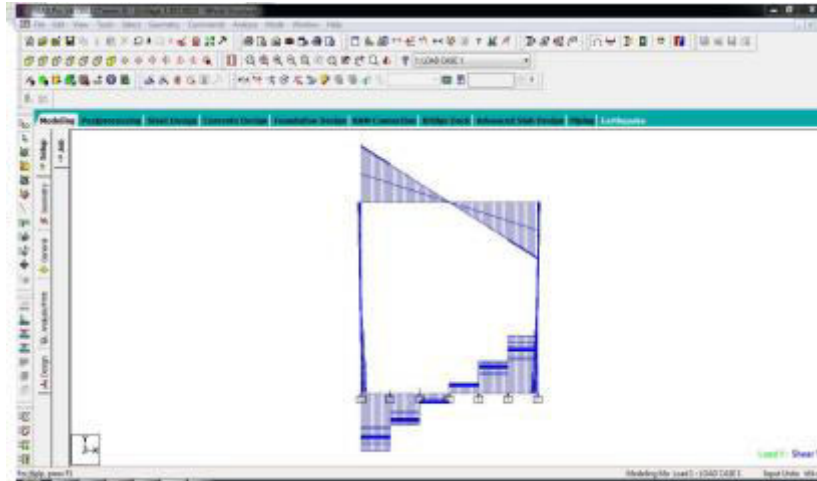


Step 5: RESULTS

1. Bending Moment

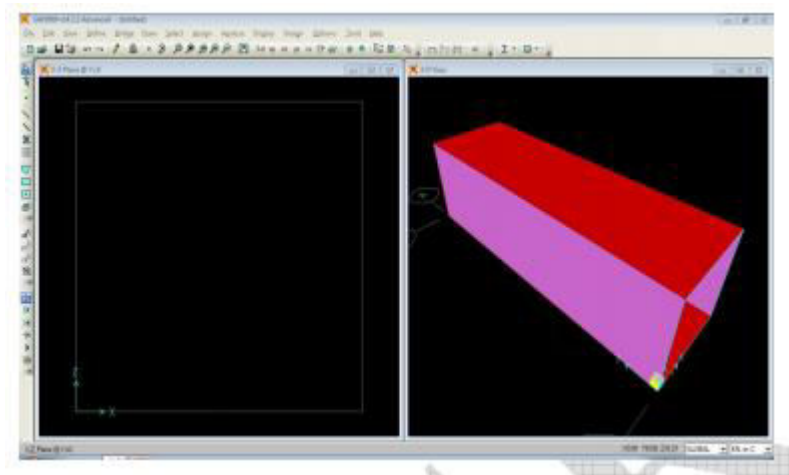


2. Shear Force

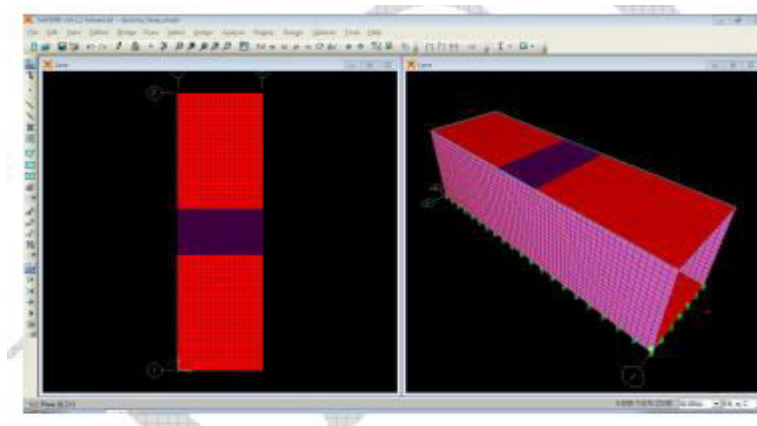


Finite Element Modelling using SAP 2000:

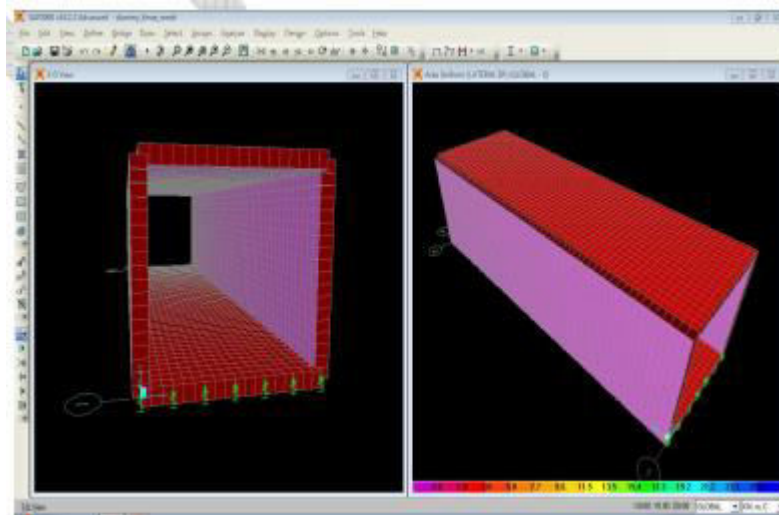
Step 1: Preparing model



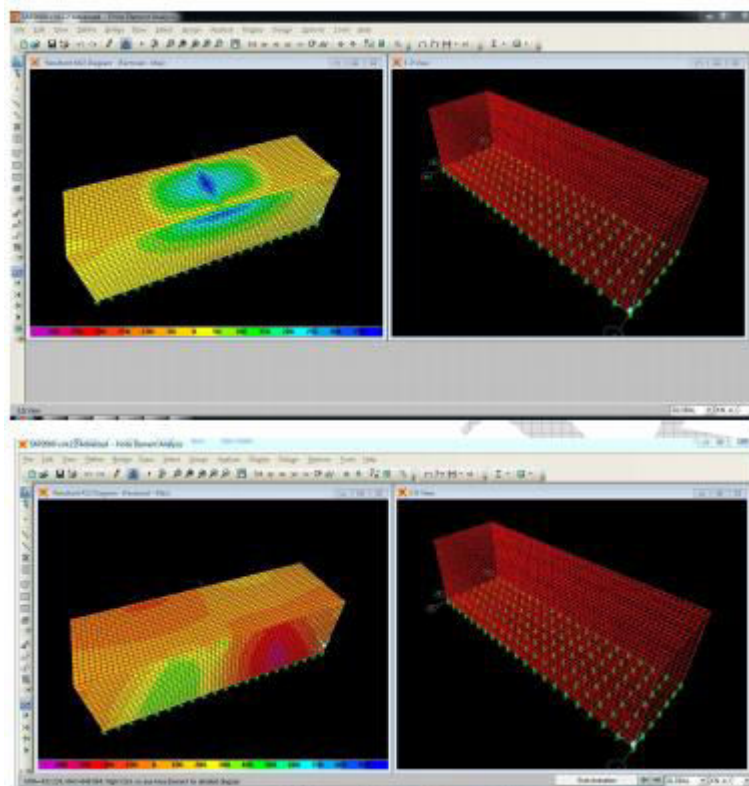
Step 2: Meshed model with defined LANE



Step 3: Extrude view

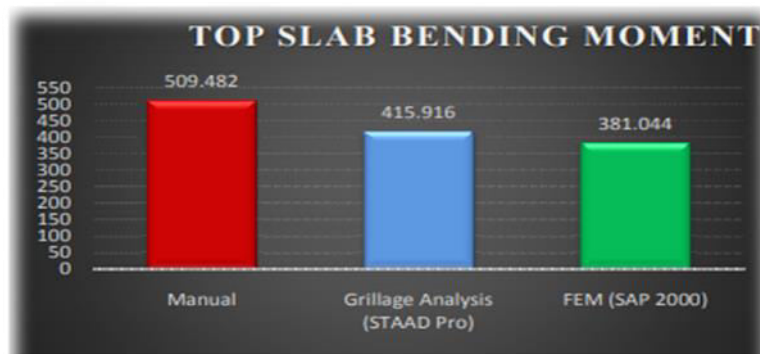


Stress Diagrams (Moment Diagram and Shear diagrams)



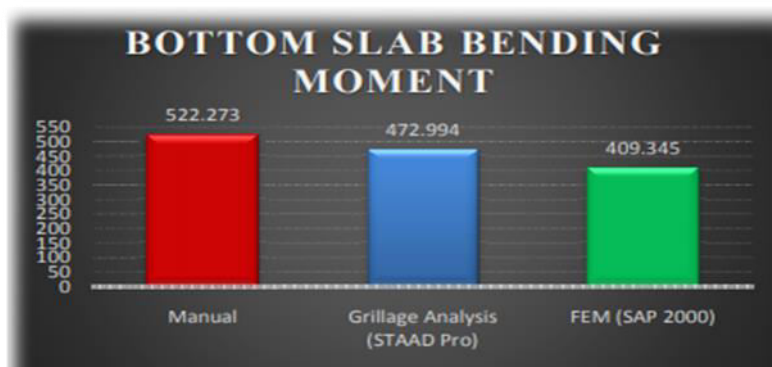
IV. RESULT AND DISCUSSION

1. Bending Moment (Maximum Bending Moment on Top Slab)



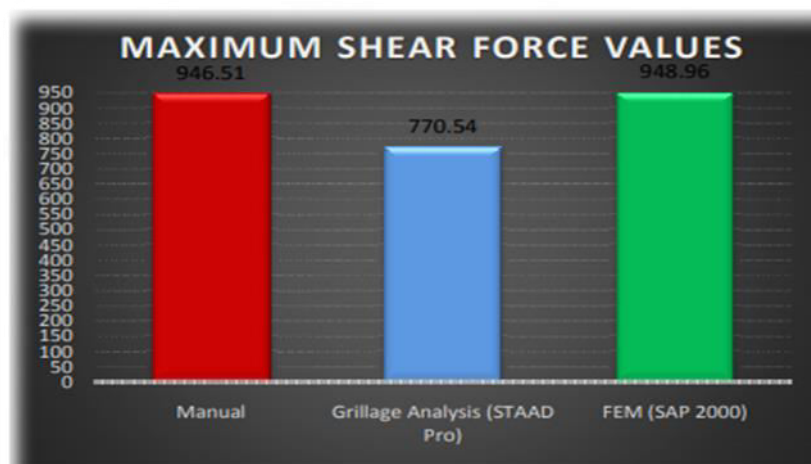
Graph 1: Variation of Bending Moment on Top Slab

2. Bending Moment (Maximum Bending Moment on Bottom Slab)



Graph 2: Variation of bending moment on Bottom slab

3. Shear Force (Maximum Shear Force)



Graph 3: Maximum Shear Force



V. CONCLUSION

The main objective of this paper is to know the behaviour of box culvert and variation of stresses in terms of shear force and bending moment values. Comparative study of computational methods with conventional method. Computational methods modelling and analysis done by using STAAD Pro and SAP 2000. So from analysis and design we conclude that

1. Finite Element Method gives the less value of
2. Area of reinforcement is decreased
3. So we could achieve economical design from this result.
4. Grillage analysis is easy for modelling of structure.

VI. FUTURE SCOPE

Based on the experience of present study, work can also be extended for the other type of bridges such as (i) Slab Culvert Bridge (ii) T-Beam Bridge and (iii) Plate Girder Bridge. The study may be carried out for the bridge abutment, bridge pier & bridge foundation also.

VIII. ACKNOWLEDGMENTS

The authors are grateful to the V M INSTITUTE OF ENGINEERING & TECHNOLOGY, NAGPUR, MAHARASHTRA, INDIA, for providing guidances and resources to carry out this work.

REFERENCES

1. Neeta K. Meshram and P.S.Pajgade 'Comparative Study of Water Tank Using Limit State Method and Working Stress Method' International Journal of Research in Advent Technology, Volume 2, Issue 8, 2014
2. Neha Kolate, Molly Mathew and Snehal Mali 'Analysis and Design of RCC Box Culvert' International Journal of Scientific & Engineering Research, Volume 5, Issue 12, 2014
3. Paul Tom P. 'Analysis and Design of RCC Bridges and Box Culvert' Research Report, 2015
4. Shivanand Tenagi and R. Shreedhar 'Comparative Study of Slab Culvert Design using IRC 112:2011 and IRC21:2000' International Journal for Scientific Research & Development, Volume 3, Issue 05, 2015
5. Y. Vinod Kumar and Chava Srinivas 'Analysis and Design of Box Culvert by using Computational Methods' International Journal of Engineering & Science Research IJESR, Volume 5, Issue 7, 2015
6. Sudip Jha, Cherukupally Rajesh and P. Srilakshmi 'Comparative Study of RCC Slab Bridge by Working Stress (IRC: 21-2000) and Limit State (IRC: 112-2011)' International Journal & Magazine of Engineering, Technology, Management and Research, Volume 2, Issue 8, 2015
7. IRC: 6 - 2000 Standard Specifications and Code of practice for Road Bridges Section-II Loads and Stresses (Fourth revision)
8. IRC: 21 - 2000 Standard Specifications and Code of practice for Road Bridges Section-III Cement Concrete (Plain and Reinforced)
9. IRC: 6 - 2014 Standard Specifications and Code of practice for Road Bridges Section-II Loads and Stresses (Revised edition)
10. IRC: 112 - 2011 Code of practice for Concrete Road Bridges
11. IS: 456 - 2000 Plain and Reinforced Concrete- Code of practice (Fourth revision)
12. Ravindra Bhimarao Kulkarni and Rohan Shrikant Jirage 'Comparative Study of Steel Angles as Tension Members Designed by Working Stress Method and Limit State Method' International Journal of Scientific & Engineering Research, Volume 2, Issue 11, 2011
13. B.N. Sinha and R.P. Sharma 'RCC Box Culvert - Methodology and Designs including Computer Method' Paper no. 555 Journal of Indian Road Congress, 2009
14. B.H. Solanki and M.D. Vakil 'Comparative Study for Flexure Design using IRC 112:2011 & IRC 21:2000' International Journal of Scientific & Engineering Research, Volume 4, Issue 6, 2013
15. Sujata Shreedhar and R. Shreedhar 'Design Coefficients for Single and Two cells Box Culverts' International Journal of Civil and Structural Engineering, Volume 3, Issue 3, 2013



17. Paul Tom P. 'Analysis and Design of RCC Bridges and Box Culvert' Research Report, <https://www.researchgate.net/publication/275272796>, 2015
18. ShivanandTenagi and R. Shreedhar 'Comparative Study of Slab Culvert Design using IRC 112:2011 and IRC21:2000' International Journal for Scientific Research & Development, Volume 3, Issue 05, 2015
19. Neeta K. Meshram and P.S.Pajgade 'Comparative Study of Water Tank Using Limit State Method and Working Stress Method' International Journal of Research in Advent Technology, Volume 2, Issue 8, 2014
20. Neha Kolate, Molly Mathew and Snehal Mali 'Analysis and Design of RCC Box Culvert' International Journal of Scientific & Engineering Research, Volume 5, Issue 12, 2014
21. SudipJha, Cherukupally Rajesh and P.Srilakshmi 'Comparative Study of RCC Slab Bridge by Working Stress (IRC: 21-2000) and Limit State (IRC: 112-2011)' International Journal & Magazine of Engineering, Technology, Management and Research, Volume 2, Issue 8, 2015
22. N Krishna Raju, 'Design of Bridges, Oxford and LBH publishing co. Pvt. Ltd., New Delhi, Fourth edition.



**Impact Factor:
7.569**



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 **9940 572 462**  **6381 907 438**  **ijirset@gmail.com**



www.ijirset.com

Scan to save the contact details