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Parametric study of multicell box culverts using STAAD Pro

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Abstract: *The present Paper presents the behavior of culverts with varying skew angles, for this study 3 cell culverts are studied with skew angles varying from 0 to 70 degree, with 10-degree interval. STAAD Pro software isused for analysis, skeweffect on bottom slab, sidewall, top slab of culverts isstudiedusingvariousloads (dead load, live load, live load surcharge and earth pressure) and load combination using IRC 6 :2017. Parameters used for this study are shear force, longitudinal moments, transverse moments and torsional.*
Results*: While designing box culvert extreme caution and measures must be taken even at lower and also try to minimize the skew where it's possible, the box culverts with higher skew angles greater than 20 degrees must be examined properly so that the higher bending moments and shear forces shouldn't go un noticed or neglected. This behaviour is unlike bridge structure where the change in moments and forces doesn't change abruptly even at lower angles.*
Key Word**: Culverts, Box culvert, skew,**

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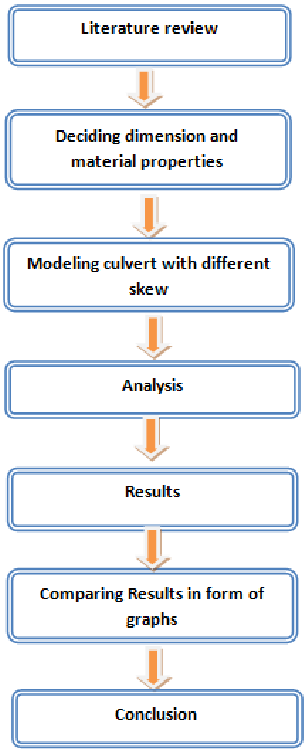
I. Introduction

A culvert is a structure used to direct underground waterways or to divert water past obstructions. A culvert is often built of a pipe, reinforced concrete, or another material that is surrounded by earth and is immersed in the ground. Culverts are frequently used to transport water beneath a road at natural drainage and stream crossings as well as crossdrains to ease drainage of ditches along the roadside. Oftentimes, they are empty when discovered beneath highways. A culvert may also resemble a bridge and be built to let vehicles or pedestrians cross over a canal while providing the water with enough room to move through. The top, bottom, and two vertical side walls of a reinforced concrete box culvert are all built in one piece to create a closed, hollow rectangle or square single cell or several cells. Currently, in order to build and pass roads or trains underneath earth embankments, culverts must be constructed to allow water to cross from both sides of the embankment. Fish, animals, and other aquatic life that needs in-stream passage can move more freely when culverts that allow for proper aquatic creature transit are present. Replacement of culverts that allow for the passage of aquatic organisms is a common method in stream restoration. This method has enhanced fish passage and a decreased likelihood of catastrophic failure as long-term advantages. The aquatic biology will not be significantly affected in the short term if optimal management measures are used.

II. Methodology

I. Choosing culvert dimensions based on prior research and the load cases to be utilized for modeling and analysis in the STAADPRO program.
II. Culvert modeling and analysis with various skew angles.
III. Comparing the outcomes based on the moment and the shear force.



III. Modelling

A. Staad pro:

Structural Analysis and Designing Program is referred to by its full name, STAAD Pro. STAAD Pro is a computer program for structural analysis and design that was created in 1997 by Research Engineers International (REL) in Yorba Linda, California. STAAD Pro is one of the most well-known and commonly used programs for structural analysis and design by civil engineers today. It supports all common design regulations for steel, concrete, and wood. Civil engineers can create any kind of structure with STAAD Pro, and the entire design team can then access the synchronized model data. It guarantees the timely and cost-effective execution of structures and designs connected to projects including steel, concrete, wood, aluminum, and cold-formed steel. STAADPRO assists structural engineers in automating their jobs by getting rid of the time-consuming and laborious manual processes. STAAD pro is widely used by Structural engineering organizations, consultancies, various construction company departments.

B. Procedure:

- Start STAAD Pro
- Select new project and space
- Fill in the project name
- Select SI units or units that are preferable
- Insert nodes and then use translational repeat tool with dimensions selected for modal
- Add beam
- Add plate element then meshing of plates must be done
- Add dummy beams
- Assign spring supports
- Assigning loads
- Generating load combinations
- Run analysis
- Analyze results and draw graphs with the data

C. Parameters:

- Clearspanofeachcell–7m

- No.ofcells-3cell
- ClearHeight–5m
- Totalwidthofstructure–14m
- SkewAngle–0◦,10◦,20◦,30◦,40◦,50◦,60◦and70◦
- Thicknessofwearingcoat–70mm
- Densityofwearingcoat–22Kn/m3
- Densityofsoil(γ)–20Kn/m3
- Angleoffriction(ϕ)–30◦
- Coefficientofearthpressure, considering soilatrestcondition
- (Ka)=1-sinϕ=0.5
- Strengthofconcrete–M25
- Tensilestrengthofsteel–Fe500

- Sectionproperties:

SL.NO	PARAMETERS	DIMENSION(M)
1	THICKNESSOFTOP SLAB	0.7
2	THICKNESSOFBOTTOMSLAB	0.75
3	OUTERWALL THICKNESS	0.4
4	INNERWALLTHICKNESS	0.4

➢ STAADPROprogrammodelsandanalysesBoxCulvertsubgraderesponsemodulesas a 3D model utilising plate element. At the slab's base, spring support is designated,and spring stiffness is given in accordance with "Foundation Analysis and Design" byJosephE Bowles.

Ks=40xqoxSF

Where,SF=SAFETYFACTOR=2.50

qo=SBCofsoil

- Dead Loads - In order to design for the critical combinations of various loads, strains,and stresses, the design loading for the box culvert has been taken into account in linewith IRC: 6 -2016 (Loads and Stresses). Total dead load consists of one's own weight,the weightofacoat,andthecrashbarrier.

➢ Live Load Surcharge - According to Article 214.1.1.3 of IRC 6:2016, live load surcharge is taken into account at a height of 1.2 m. For maximum bending moments, the live load surcharge is taken into consideration on both sides of the box.

Live load surcharge (Δ) = ka×γ×h

- Where, Ka = Coefficient of earth pressure h =1.2 m
- Live Loads – For analysis live loads are considered as per IRC.6:2019 (70R wheeled, Class AA wheeled, SV loading) 3-lane are considered.
- Load Combination according to IRC 6:2019

➢ Total No. of Models:8

a) Culverts with 0◦ Skew.
b) Culverts with 10◦ Skew.
c) Culverts with 20◦ Skew.
d) Culverts with 30◦ Skew.
e) Culverts with 40◦ Skew.
f) Culverts with 50◦ Skew.
g) Culvertswith60◦Skew.
h) Culvertswith70◦Skew

➢ Load calculation

a. Self-Weight–Unitweightofconcreteistakenas25KN/M3
b. LoadfromWearingCoat=densityofwearingcoatXthicknessofbitumenlayer

=22X0.070=1.534kN/m2

c. Earthpressureload - EP=K0γZ

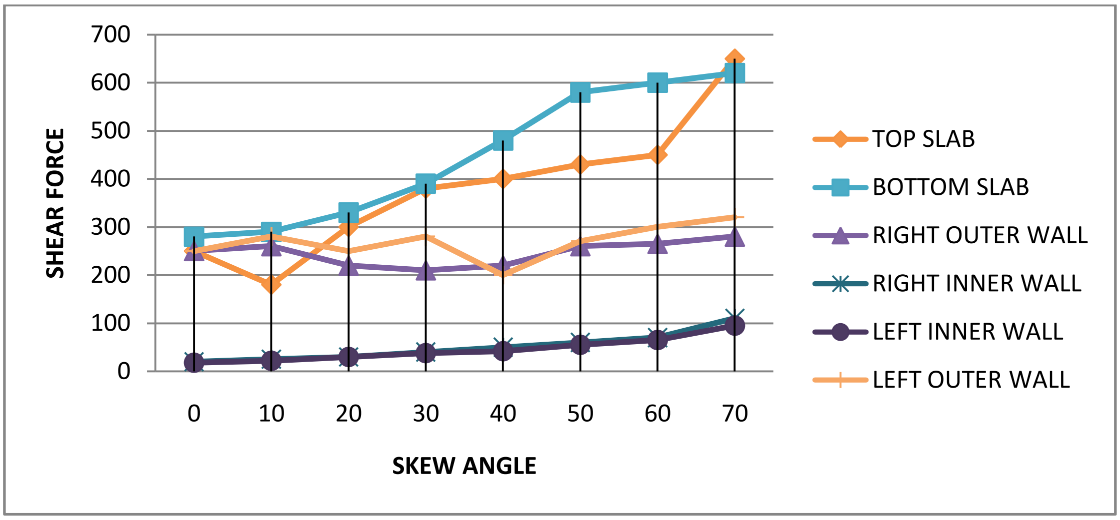
WhereK0=Earthpressurecoefficientatrest

γ =Unitweight ofsoil.

Z=wallheight.
EP=0.5 X20 X 6.75EP=6.45 kN/m2

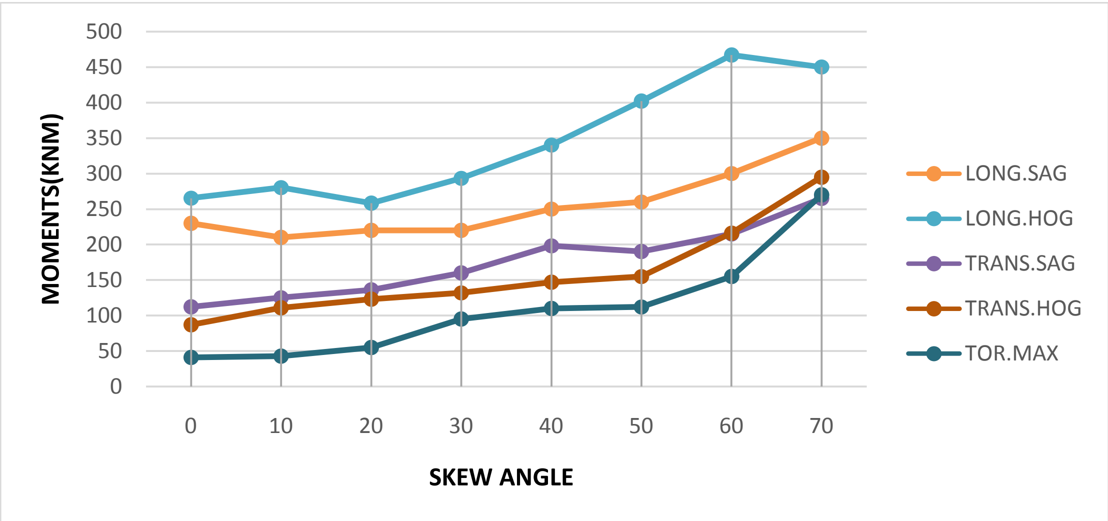
d. LiveloadsurchargeΔ=*heqv*γ
Wherek=lateralearthpressurecoefficientγ= Unitweightofsoil.
heqv=Equivalentheightofsoilforvehicularloading1.2
mΔ= 0.5X20X1.2
Δ=12kN/m2

III. Result



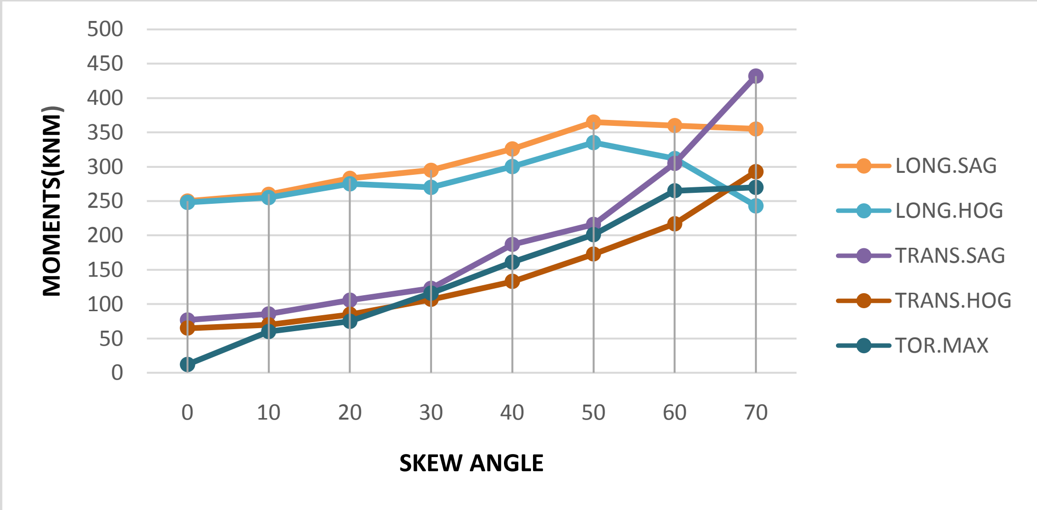
Shear force v/s skew angle

From graph 1: shear force in all slabs increase with increase in skew angle, and also it varies sharply after 10 degrees skew, Bottom slab shear force is maximum. It is also seen that right outer wall and left inner wall have the leant shear force.



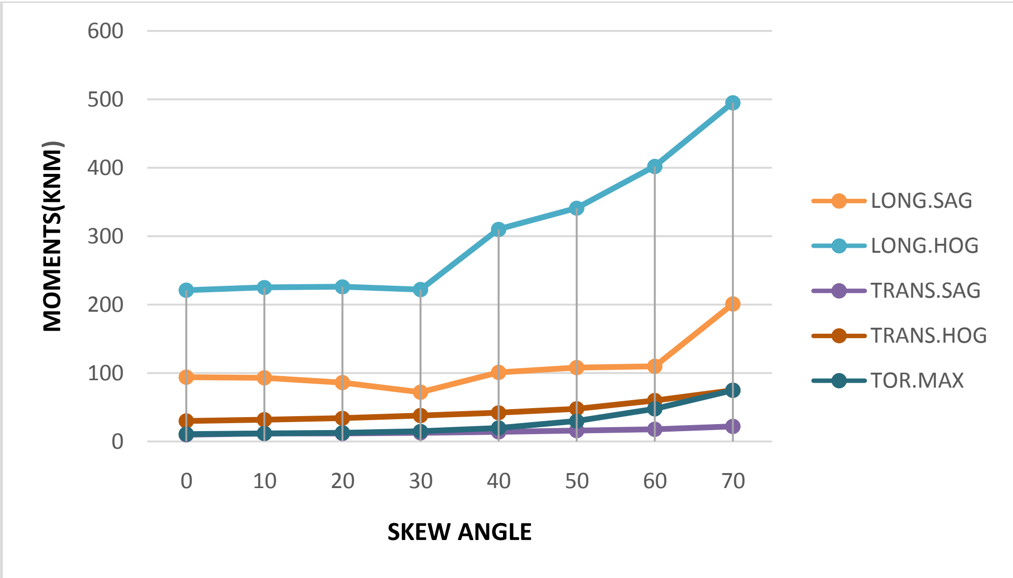
Top slab moments v/s skew angle

From graph 2: It was observed that moments in top slab increases with increase in skew, the sharp increase is seen after 20 degrees skew. Longitudinal hogging moments are maximum. Transverse hogging moments are least.



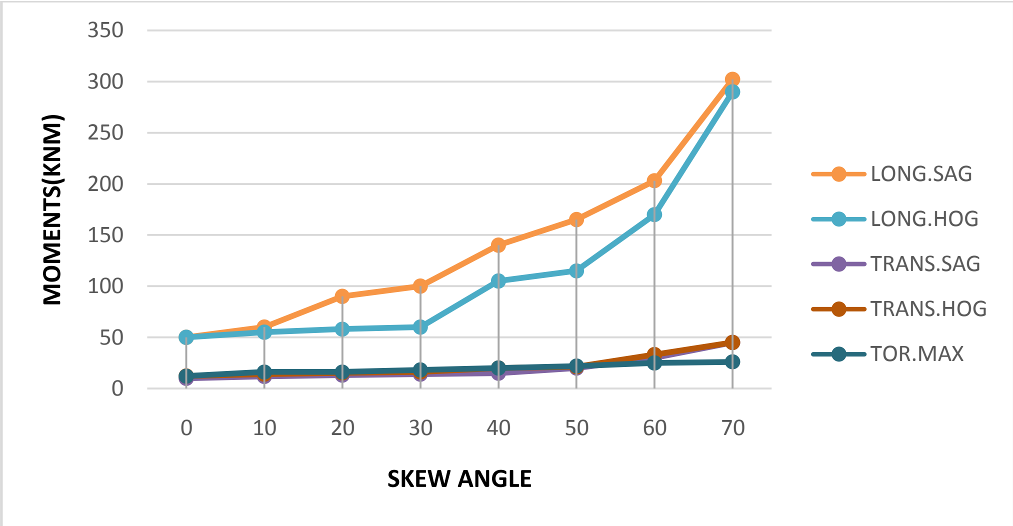
Bottom slab moments v/s skew angle

From graph 3: it was observed that in bottom slab longitudinal moments are larger than transverse moments, increases with increase in skew. Torsion also increases with increase in skew, there is no much variation in moments up to 10 degrees after that it starts increasing.



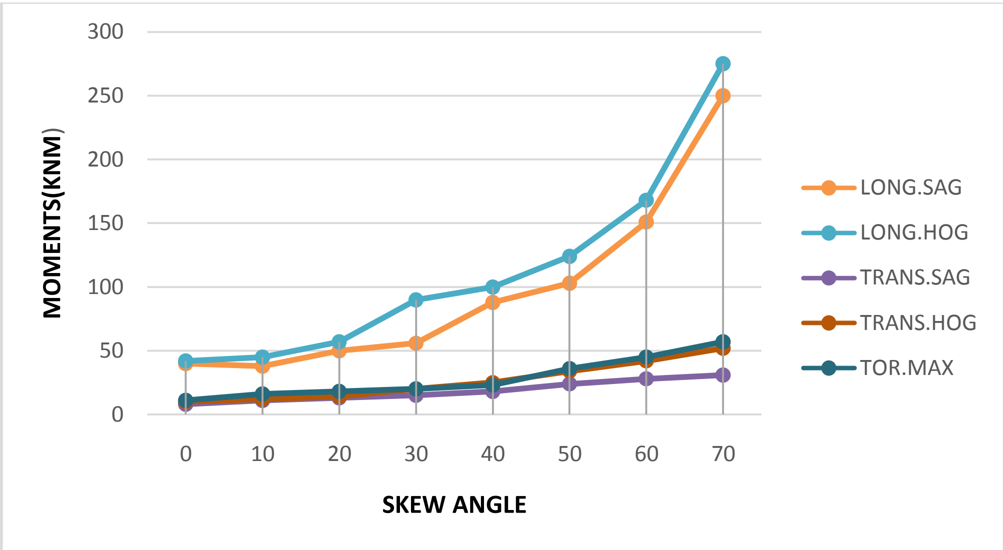
Right outer wall moments v/s skew angle

From graph 4: in right outer wall the moments increase sharply after 30 degrees, and torsion is almost unchanged till 40 degrees then increases after that. Longitudinal moments hogging moments are high



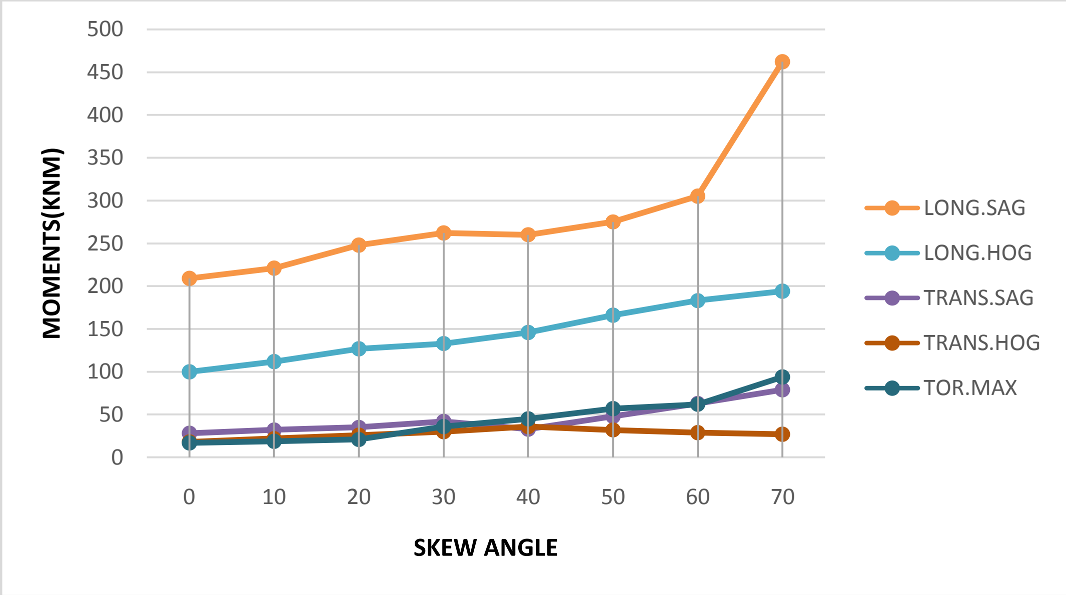
Right inner wall moments v/s skew angle

From graph 5: right inner walls increase with increase in skew but torsion is almost constant with change in skew. Longitudinal sagging moments are highest, Transverse moments are very negligible.



Left inner wall moments v/s skew angle

From graph 6: left inner walls moments increases from 10 degrees skew and torsional moments are negligible. Longitudinal moments are very high transverse moments are less it increases from 40-degree skew.



Graph 7: Left outer wall moments v/s skew angle

From graph 7: left outer wall moment increases with increases skew and torsional moments are negligible. Longitudinal sagging moments are very large when compared to hogging moments. Transverse moments and torsion are less start increasing from 40-degree skew.

IV. Conclusion

In box culverts longitudinal moments, transverse moments, torsional moments and shear forces in all of the slabs rise as the skew angle increases and also It has been noted that from 0 to 20 degrees of skew angle, the moment and shear force grow gradually, whereas at 30 degrees, they climb quickly. Hence while designing engineer should try to minimize skew angle and must pay attention while designing box culvert even at lower angles.

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