Performance Analysis of Precast and Cast-Insitu Skew Culverts

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Abstract— **In past, limited study has been carried out on Precast culverts. In this study the behaviour of precast culverts with hinge joints and cast-in situ culverts (fixed joint) are compared using MIDAS CIVIL software, parametric studies is carried out on 36 models considering different skew angles varying from 0◦ to 45◦ with 15◦ interval, span varying from 3m to 6m and hinge position at 1/3rd from bottom at 2/3rd from bottom are considered to arrive at most optimum hinge position. Analysis is carried out using IRC-6 2016, Models are compared for bending moments and shear forces. The results obtained are given in form of graphs**

Keywords— Box culvert; precast culverts; skew; midas civil

I. INTRODUCTION

Culverts are the tunnel like structures which allow water to flow under a road, railway or any structures. Culverts are designated as important medium of transport of economical value. These are largely used in roadways, railways, sewage conduits, monsoon runoff, pathways of telephone and electrical lines and stock or pedestrian underpass. A culvert is enclosed in soil and it is exposed to earth and vehicular loads. Culverts can either have singular cell or multiple cells. And it can be classified by the construction type as cast-in-place culverts or precast culverts. Advanced technology indicates that the precast concrete culverts are in use last few decades.

A. Precast culverts

Precast concrete box culverts are the most versatile and cost-effective solution for quick-build projects. Cost savings are realised as a result of design flexibility and ease of installation on-site. The applications for pre-cast concrete culverts are limitless. They can be used for service tunnels, underpasses, bridges, stream culverts, cattle passes, and other similar purposes. A Precast Concrete Box Culvert (PCBC) is a simple structure that allows for the passage of roads, pathways, and flowing water (e.g., streams, storm water, or drains) beneath roads, railways, or embankments. Many countries, including India, have used precast concrete box culverts. With innovative and mechanised box culvert production facilities, over 40 - 60 m of culvert section can be produced per day.

B. Shapes of precast culverts

Precast concrete box culvert are manufactured and transported in required shape and size. Bigger box culverts where transporting is difficult as a one unit, so they are constructed in from two ‘U’ sections and connected on-site. Even they are manufactured as two ‘L’ shapes and in between ‘T’ shapes are also been used. These can be provided with rebated joints/V notched to allow sections to be laid open or sealed. They can even be manufactured with precast wing walls and head walls.

Figure No. 01 – Culvert with Hinge Joint at Mid of Wall

Figure No. 02 – Culvert with Hinge Joint at Top

II. OBJECTIVES

- Study of structural behavior of Precast and cast in situ Box culverts with varying degree of skew using Midas civil software.
- Parametric studies of precast and cast-insitu culverts using different span and skew.
- Analysis of Precast culverts with different position of hinges and optimum position of hinge will be studied

III. METHODOLOGY

- Deciding dimensions of culverts based on previous literature and load cases to be used for modelling and analysis in MIDAS CIVIL 2022 software.
- Modeling and analysis of Cast in situ culverts with different skew and span condition.
- Modeling and analysis of precast culverts with different position of hinges, different skew and span condition.
- Comparing the results obtained on the bases of moment and shear force.

IV. MODELING AND ANALYSIS

A. *Modelling*

The modeling and analysis is carried out using MIDAS CIVIL software which uses finite element analysis .The slab and walls were modeled as 4 nodded plate elements. Total 36 models were prepared in which 12 models with no hinge joints, 12 models with hinge position at 1/3rd from bottom of culvert and 12 models with hinge position at 2/3rd from bottom. With different span and skew condition..

B. Parameters for modelling

- Clear span - 3m , 4.5m &6m
- Clear Height – 3m
- Total width – 6.4m
- Carriageway width – 5.5m
- Skew Angle – 0°, 15°, 30°& 45°
- Hinge Position – ⅓& ⅔of height from bottom
- Crash barrier width – 0.45m
- Wearing coat thickness –80mm
- Density of wearing coat – 22Kn/m^3
- Density of soil(γ) – 20Kn/m^3
- Angle of friction(ϕ) – 30°

- Coefficient of earth pressure ,considering soil at rest(Ka)=1-sinϕ=0.5
- Strength of concrete – M30
- Grade of steel – Fe500
- Modules of subgrade reaction – Spring support is assigned at base of slab and spring stiffness is provided as per “Foundation Analysis and Design” by Joseph E Bowles.

Ks = 40 x SF x qo

Where, SF = Factor of safety = 2.50,

qo= Safe bearing capacity of soil

- Dead Loads - The design loading for the box culvert has been considered in accordance with IRC: 6 -2016 (Loads and Stresses), so as to withstand the critical combinations of various loads, forces and stress. Total dead load includes self-weight, weight of wearing coat and crash barrier.
- Live Load Surcharge - As per IRC 6:2016, clause 214.1.1.3, live load surcharge is considered at a height of 1.2 m. The live load surcharge is considered at both sides of box for maximum bending moments.

Live load surcharge (Δ) = ka×h×γ

Where, Ka = Coefficient of earth pressure

h =1.2 m

- Live Loads – For analysis, wheel loads are taken. The following live loads are considered for the design.

1. Case I - IRC Class A-2 Lane
2. Case II - IRC Class 70R (Wheeled)-1 Lane

As per IRC: 6-2016/ Table no. B.2. Basic Combination is used for verification of structural strength and serviceability of limit state.

- Model Cases

  1. Culverts with all fixed joints (Cast In-Situ Culvert).
  2. Culverts with Hinge joint at 1/3rd position from bottom (Precast).
  3. Culverts with Hinge joint at 2/3rd position from bottom (Precast).

RESULTS

A. *Bending moments results*

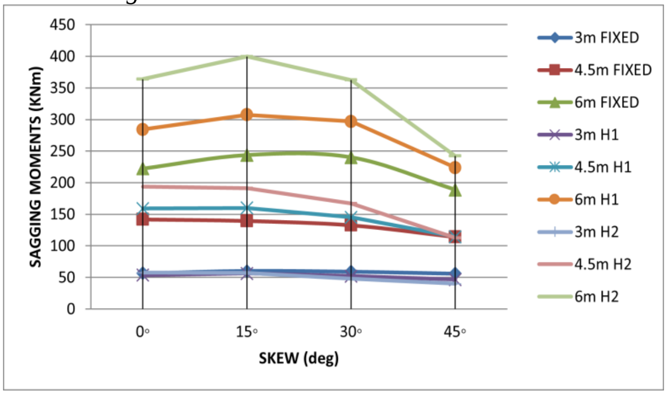

Fig No. 03 – Top Slab Sagging Moments v/s Skew

In all graphs 3m fixed refers to culverts with 3m span and with no hinge joints, 3m H1 refers to 3m span with hinge position at 1/3rd from bottom and 3m H2 refers to 3m span with hinge joint at 2/3rd from bottom. Follows similarly for all span condition

From fig 03 top slab sagging moments increases up to 15° skew and then starts decreasing with increase in skew for all span and hinge conditions. Overall we can consider as their will be 30% increase of moments in hinge at 1/3rd when compared with fixed and 60% increase in hinge at 2/3rd when compared to fixed.

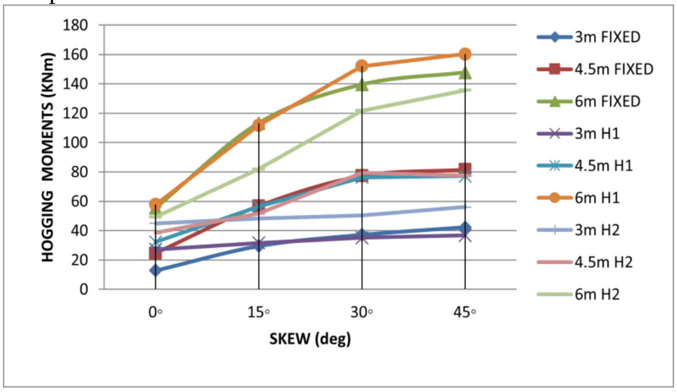

Fig No. 04 – Top Slab Hogging Moments v/s Skew

From fig 04 top slab hogging moments increases with increase in skew and span. Overall we can consider as their will be 10% increase in moments in hinge at 1/3rd when compared with fixed and there is 20% reduction in moments in hinge at 2/3rd when compared with fixed.

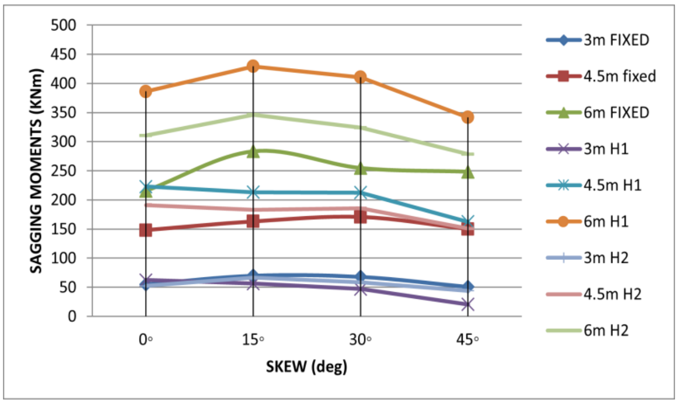

Fig No. 05 – Bottom Slab Slab Sagging Moments v/s Skew

From fig 05 bottom slab sagging moments increases with increase in span for fixed and hinged condition. It even increases with increasing skew angle upto 15° skew and reduces from 15° skew for fixed and hinged condition, we can consider that there is 50% increase in moments in hinge at 1/3rd when compared with fixed and 25% increase in moments in hinge at 2/3rd when compared to fixed condition.

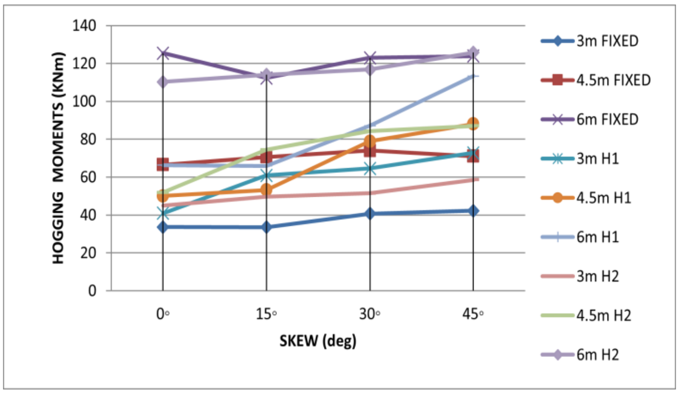

Fig No. 06 – Bottom Slab Hogging Moments v/s Skew

From fig 06 bottom slab hogging moments increases with increase in skew and span. Approximately we can consider as their will be maximum 40% decrease in moments in hinge at 1/3rd when compared with fixed and there is maximum 10% reduction in moments in hinge at 2/3rd when compared with fixed.

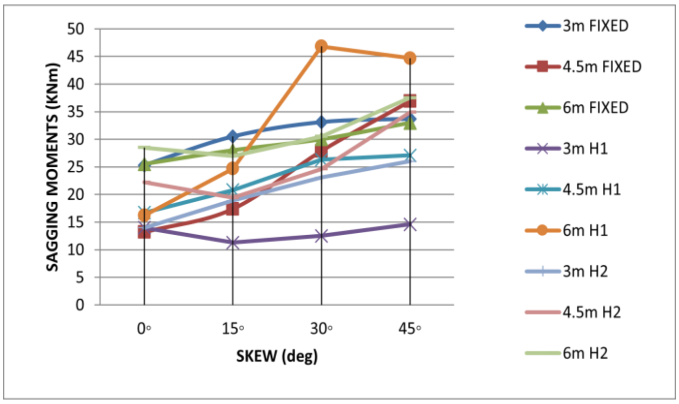

Fig No. 07 – Side Wall Sagging Moments v/s Skew

From fig 07 side wall sagging moments increases with increase in skew and span. Approximately we can consider as their will be maximum 40% decrease in moments in hinge at 1/3rd when compared with fixed and there is maximum 15% increase in moments in hinge at 2/3rd when compared with fixed

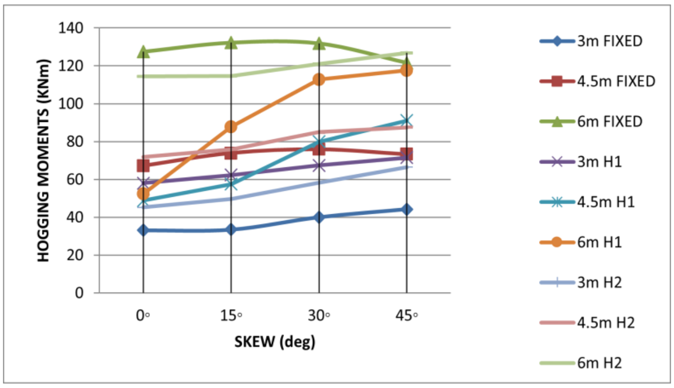

Fig No. 08 – Side Wall Hogging Moments v/s Skew

From fig 08 side wall hogging moments increases, with increase in skew and span. Approximately we can consider as their will be maximum 60% decrease in moments in hinge at 1/3rd when compared with fixed and there is maximum 15% reduction in moments in hinge at 2/3rd when compared with fixed.

B. Shear force results

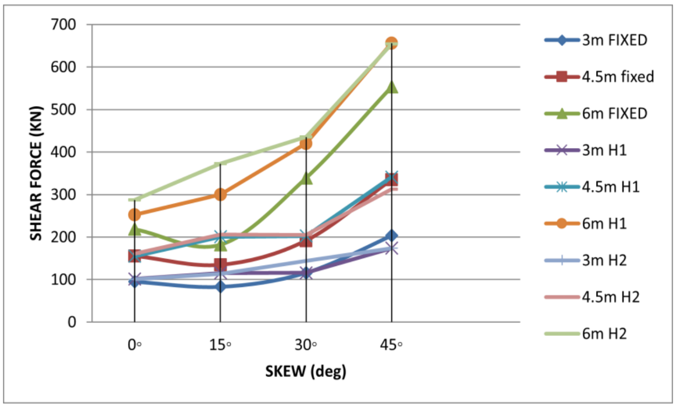

Fig No. 09 –Top Slab Shear force v/s Skew

From fig 10 top slab shear force decreases up to 15° skew and then increases from 15° skew for fixed condition, for hinged condition it increases with increase in skew. Shear force increases with increase in span in all condition. Approximately there is maximum 50% increase in shear in 1/3rd hinge condition and 2/3rd hinge condition than fixed condition. Shear force values in 2/3rd hinge condition are slightly larger than 1/3rd hinge condition.

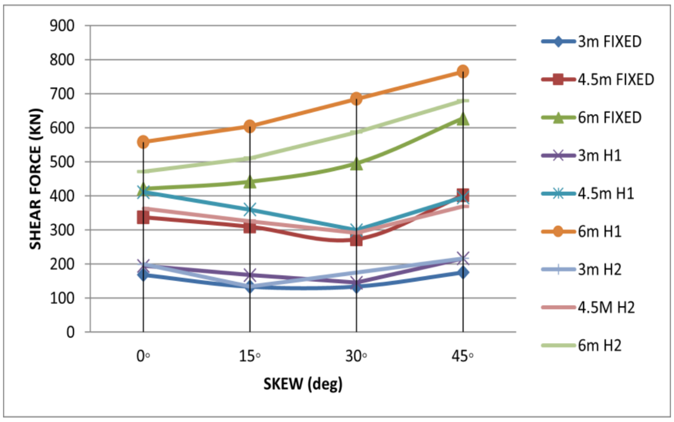

Fig No. 10 –Bottom Slab Shear force v/s Skew

From fig 09 shear forces in span 3 and 4.5 in fixed and hinge condition reduced upto 30° skew and increase at 45° skew. Shear force increases with increase in span. There is 20% increase in shear force in hinge at 1/3rd when compared with fixed and 15% increase in shear force in hinge at 2/3rd when compared with fixed. Shear force for 1/3rd hinge condition is about 15% higher than 2/3rd hinge condition.

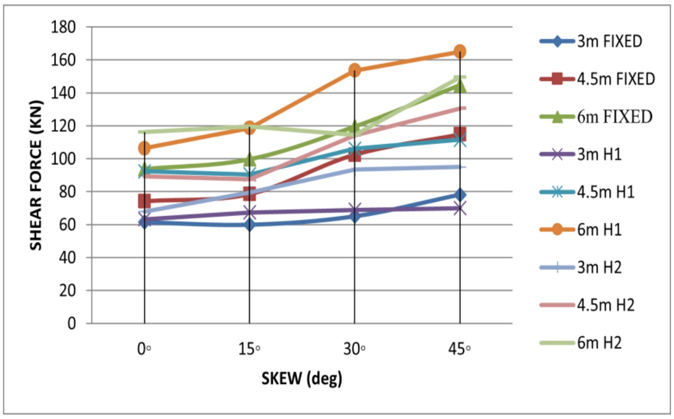

Fig No. 11 – Side wall Shear force v/s Skew

From fig 11 side wall shear force increases with increasing span and skew. There is maximum 20% increase in shear force in hinge at 1/3rd position when compared with fixed, and maximum 40% increase in 2/3rd hinge condition.

V. CONCLUSIONS

- All moments, shear force increases with increase in span.
- Longitudinal sagging moments in top and bottom slab decreases with increase in skew angle.
- Hogging moments in top slab and bottom slab increases with increase in skew.
- Side wall moments and shear force for all components increases with increase in skew angle.
- Box culverts with fixed condition are safest in comparison with hinged condition with 1/3rd and 2/3rd ,culvert with1/3rd hinge condition is better.

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