Determination of the Symmetrically V-Shaped Folded Plates

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Abstract

Folded plates are widely used as a structural system for roofing large floor areas which are to be unobstructed by the presence of interior column supports. The design of symmetrically V-shaped folded plate of the central angle is varied as 60 º, 90 º and 120 º, the plates were subjected to a uniformly distributed load and Analyzed by using iteration method. All the designs have been carried out by incorporating the recommendations of IS: 2210-1988. The deflection, stresses and moments has been calculated at different angles 60 º, 90 º and 120 º and stated at which angle resists higher moment.

Keywords: Folded plates, Stresses, Deflection, Moment

I. INTRODUCTION

V-shaped folded plates are ideally suited for a variety of structures such as factory buildings, assembly halls, godowns, Auditoriums and gymnasia, requiring large column free area. Folded plates were first used for large coal bunkers by G.Ehlers of Germany in 1924-25.The structural behaviour of folded plates resembles that of shells and they can be considered as examples of stressed skin construction. Folded plates belong to the class of stressed-skin structures which, because of their geometry and small flexural rigidity of the skin, tend to carry loads primarily by direct stresses acting in their plane. Folded-plate roof structures have become widely used in recent years and several acceptable methods for analyzing such structures have been developed [1]. In addition, several experimental studies have been reported [2]-[4] which indicate satisfactory agreement between measured and predicted values of strains and stresses induced in such structures by the presence of transverse applied loads. Folded plates resist the system of transverse loads by 'plate' and 'slab' action .The loads acting normal to each plate cases transverse bending between the junctions of the plates, which can be considered as imaginary supports of a continuous slab. This transverse bending is termed as 'slab action'. The transverse moments developed in the plate can be determined by a continuous beam analysis assuming the supports to be at the junctions of the plates. The plates begin supports at their ends on transverses, bend under the action of loads in their own plane.The longitudinal bending of the plates in their own action plane is termed as 'plane action' .The bending stresses resulting from plate action may be considered to have a linear distribution across each plate,with maximum intensity at the centre of span section.The salient features of iteration method of analysis of folded plates are outlined in the following sections.

The iteration method developed by Brielamaier offers a simple means of analyzing symmetrically v-shaped folded plates.However this method is not universally applicable to folded plates of all types .The analysis of the folded plates is based on the following assumptions:The structure is monolithic with rigid joints.The material is homogeneous,elastic than twice and isotropic.The lenght of each plate is more than twice its width.Plate sections remain plate after deformation in all the plates

II. ITERATION METHOD

The iteration method is applicable for symmetrical V-shaped folded plates with simpler computational effort in comparison with the Whitney and Simpson's methods. However this method is not applicable for all types of folded plates. The following steps are involved in the analysis of folded plates by iteration method.

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- The folded plate is analyzed for slab action as a continuous beam and the rigid loads are computed the reactions.The longitudinal stresses developed in the plate are computed assuming the plates to bend in their own plane due to the action of plate loads. The stresses at the junctions are computed and the no rotation solution obtained by the stress distribution procedure as in the case of Simpson's method.
- The plate deflections corresponding to the no rotation solution is computed and from these the relative displacements of the joints can be obtained.
- The transverse moments developed due to the relative joint displacements are computed and the moments are distributed to estimate the ridge loads and plate loads. The longitudinal stresses due to the plate loads are computed and corrected by stress distribution procedure. The resulting stresses are compared with those obtained from the no rotation solution. If the corrections are relatively small, the iteration process is stopped at this stage and the final moments and stresses are obtained by adding the results of the no rotation solution and those due to the first cycle of iteration.
- If the corrections are not small, the deflections caused by correction stresses are computed and the cycle of iteration repeated until the desired results are obtained.
- The convergence of the iteration method depends up on the relative rigidities of longitudinal plate action and transverse slab action and on the geometry of the structure. The iteration method has been found to converge rapidly for symmetrically V-shaped folded plates while it diverges when applied to north light folded plates

III. MATERIALS

A. Concrete (M20):

Controlled concrete shall be used for all and folded plate structures. The concrete is of minimum grade M20. The quality of materials used in concrete, the methods of proportioning and mixing the concrete shall be done in accordance with the relevant provisions of IS: 456-1978.

NOTE- High cement content mixes are generally undesirable as they shrink excessively giving rise to cracks.

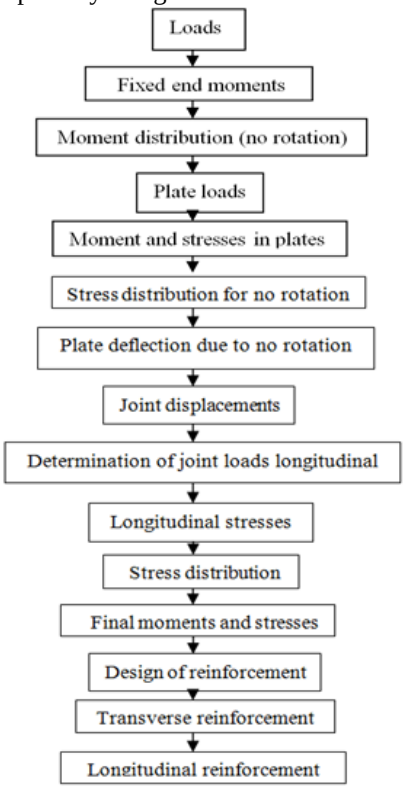
B. Steel (Fe415):

The steel for the reinforcement shall be:

1) Mild steel and medium tensile steel bars and high yield strength deformed bars.
2) Hard-drawn steel wire fabric.

IV. METHODOLOGY

Determination of symmetrical V-shaped folded plate by using iteration method



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V. DESCRIPTION

Analysis of symmetrical V-shaped folded plate using following data:
Span of folded plate = 20m
Thickness of plates = 100mm
Live load = 0.6 KN/m
Concrete = M-20 Grade
Steel = Fe-415 HYSD bars

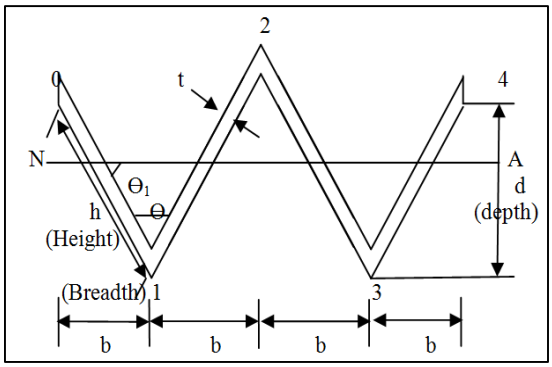
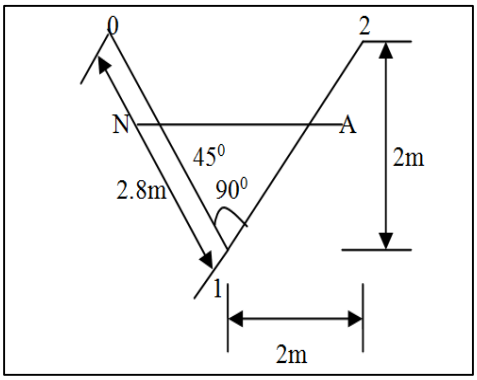


Fig. 1: V-shaped folded plate

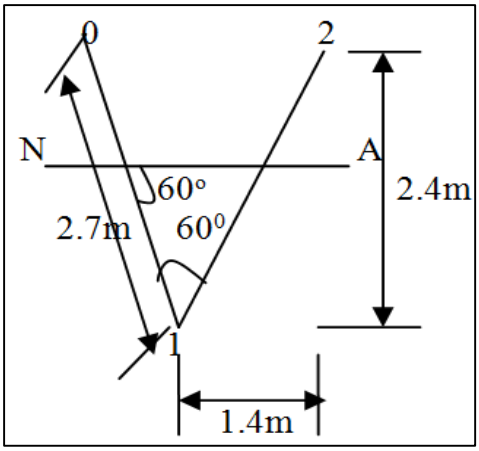
A. Loads:

Self-weight = 2.4 KN/m
Live load = 0.6 KN/m
Total loads = 3.0 KN/m

Case - 1:



Case - 2:



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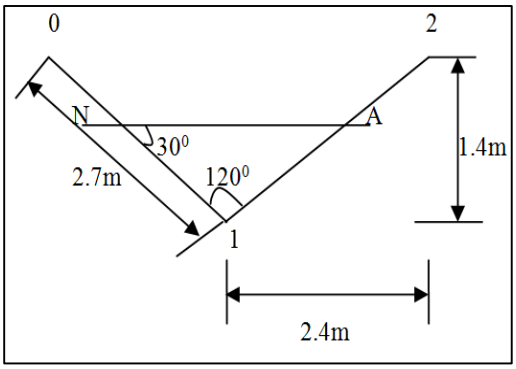
Case - 3:



B. Fixed end moments:

Considering the transverse section of the folded plate as a continuous beam on rigid supports as shown in fig.2, the fixed end moments are computed and tabulated as shown below:

Plate	*Loads KN/m*	*Fixed end moments KN.m*			*Remarks*
		Case 1	*Case 2*	*Case 3*	
0-1	*3.0*	*6.0*	*2.94*	*8.64*	*Cantilever*
1-2	*3.0*	*1.0*	*0.49*	*1.44*	*Fixed beam*
2-3	*3.0*	*1.0*	*0.49*	*1.44*	*Fixed beam*
3-4	*3.0*	*6.0*	*2.94*	*8.64*	*Cantilever*

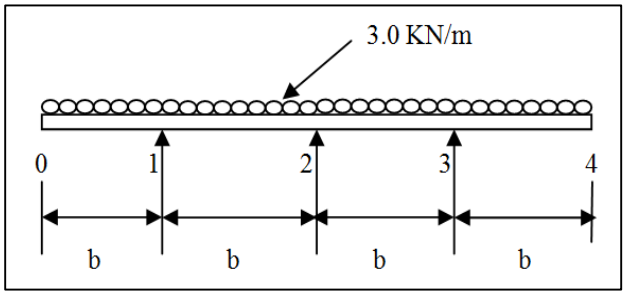


Fig. 2: analysis for slab action

VI. RESULTS

The maximum deflection of a plate of length 'L' and depth 'h' can be computed as detailed below:

Deflection= $$\frac{5}{384} \times \frac{wL^4}{EI}$$

Table – 1
Plate deflection due to no rotation

Cases	*Angles*	*Deflections $10^8/E(m)$*	
		Plate 1,4	*Plate 2,3*
1	*90 º*	*1*	*0.9*
2	*60 º*	*0.37*	*0.36*
3	*120 º*	*3.48*	*3.27*

Table – 2
Final transverse moments (values in KN.m)

Joints	*Case 1 90 º*	*Case 2 60 º*	*Case 3 120 º*
2	*+6.00*	*+4.2*	*+7.20*
3	*-1.188*	*-0.569*	*-3.141*
4	*+6.00*	*+4.2*	*+7.20*

+compression *-tension*

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Table – 3
Final longitudinal stresses (values in N/mm^2)

Joints	*Case 1 90 º*	*Case 2 60 º*	*Case 3 120 º*
0	*+3.277*	*+1.238*	*+11.96*
1	*-3.198*	*-1.219*	*-11.38*
2	*+3.119*	*+1.202*	*+10.72*
3	*-3.198*	*-1.219*	*-11.35*
4	*+3.277*	*+1.238*	*+11.96*

+ compression *- tension*

A. Design of reinforcements:

The design of reinforcements in the folded plate should confirm to the recommendations made in IS: 2210-1962. The transverse reinforcement is designed to resist the moments in the transverse direction computed at mid span section. For greater economy, the spacing of the bars may be increased from mid span to the support section based on the magnitude of the transverse bending moment.

The longitudinal reinforcements in the direction of the span are designed to resist the total tensile force developed in the tension zone. However minimum percentage of reinforcements as recommended in the codes should be provided at all cross sections.

The shear reinforcements are designed to resist the principal tensile stresses. When principal tensile stress exceeds 1.7sqrt(f_{ck}) , reinforcement will be necessary to take up the entire tension; elsewhere, nominal reinforcement at spacing not exceeding five times the thickness of the plate is to be provided. The maximum shear stresses are likely to develop at quarter span sections.

1) Transverse reinforcement:

At joints 1 and 3, the transverse moments cause tension at top of slabs.
Thickness of folded plate slab = 100mm
Assuming effective cover = 25mm
Effective depth d = 75 mm

Cases	*Maximum Bending Moment (KN.m)*	*Area of steel (A_{st}) (mm^2)*
1	*6*10^6*	*368*
2	*4.2*10^6*	*270*
3	*7.2*10^6*	*463*

Provide 10 mm diameter bars at 200 mm centres.
At joint-2, the transverse moment causes tension at bottom of slab.
But minimum percentage of steel is

Therefore 0.3% = (0.3*1000*100)/100
= 300 mm^2

Provide 10 mm diameters at 200 mm centres.

2) Longitudinal reinforcement:

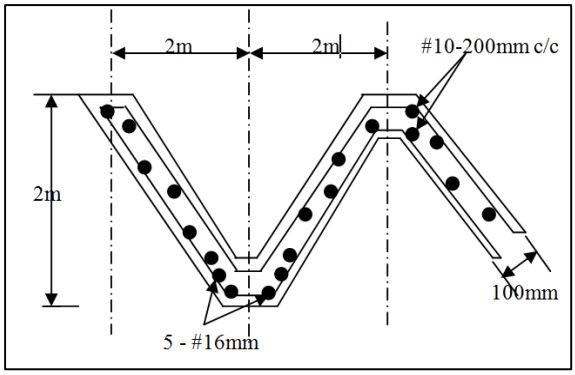
The maximum tensile stresses develop at joints 1 and 3.
Reinforcement in the tension zone is

Cases	*Final stresses (N/mm^2)*	*Area of steel (A_{st}) (mm^2)*
1	*3.198*	*973*
2	*1.219*	*371*
3	*11.38*	*3463*

Provide 16 mm diameter in the tension zone. For the compression zone portion , provide 10 mm diameter bars at 200 mm centers.

3) Reinforcement details in folded plate:

Case – 1



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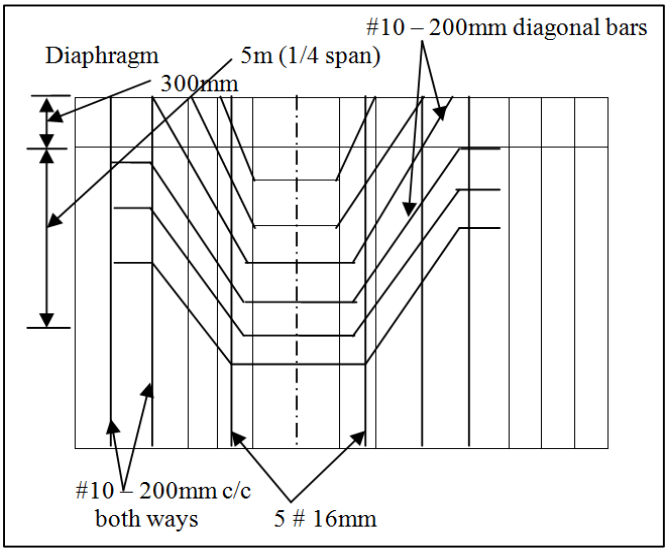
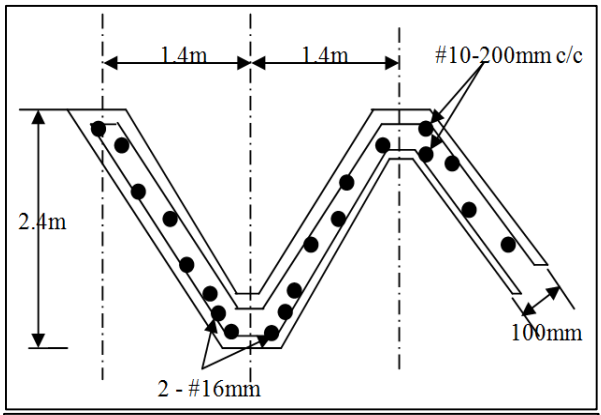
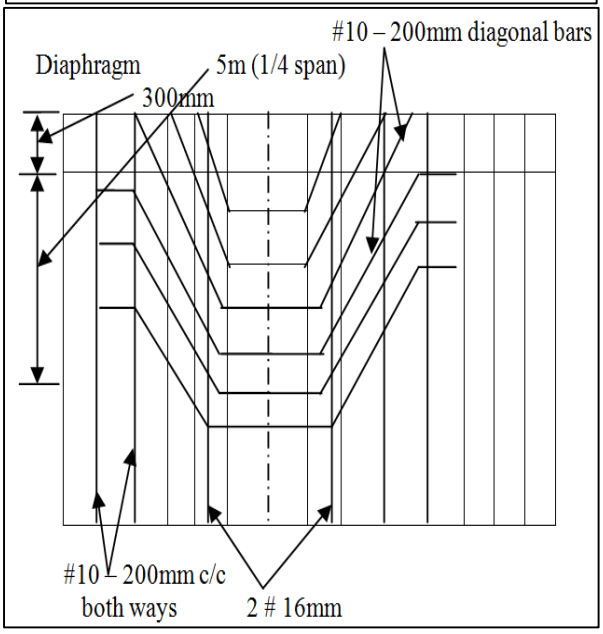


Cases	*Maximum Bending Moment (KN.m)*	*Area of steel (A_{st}) (mm^2)*
1	*$1.5*10^6$*	*97*
2	*$0.525*10^6$*	*34*
3	*$3.6*10^6$*	*232*

Case – 2





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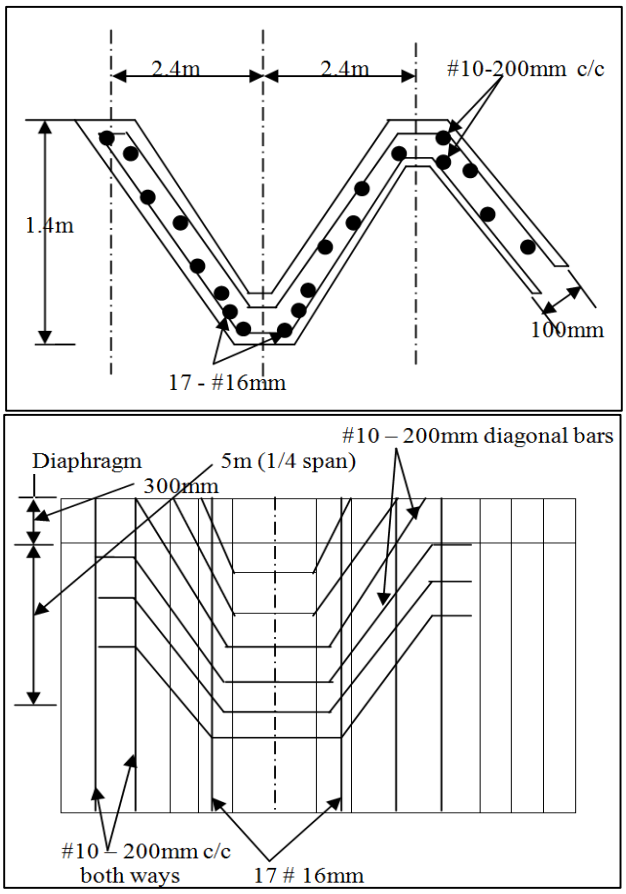
Case – 3



VII. CONCLUSION

This study deals with an experimental research carried out for symmetrically V-shaped folded plates for the calculation of stresses, deflection and moments. The following conclusions were derived based on the results.

1) As the angle decreases the deflection, stress and moment also decrease, as the angle increases these all increase proportionally.
2) Regarding the cost considerations the folded plates with an angle of 90^0 is preferable and also when compared with the strength it is so stable.

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