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COST OPTIMIZATION OF V-TYPE FOLDED PLATE ROOF

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Abstract- *In India, folded plates are a very useful form of structure for roofing large column free area. Folded plates, or as they are sometimes called hipped plates, provide a useful and economical method of construction for roof and floor systems in a wide variety of structures. They are competitive with other construction methods for short spans and have proven exceptionally economical where relatively large spans are needed as for auditoriums, gymnasiums, industrial buildings, hangers, department stores and parking garages. The folded plate shape of roof structure has come into wide usage because of its low cost of construction for long span, high load carrying capacity, rigidity, and aesthetic interest. It quite popular in U.S.A and its introduction to India are rather recent. The different parameters of the folded plate roof i.e. span, thickness, width, inclination angle, height are important to lead economy in cost and functional suitability. In this study, different types of the folded plate roof designed and analyzed by classical methods. Make effort for optimization of the weight and cost for different design parameters. Excel programming is used for the design and analysis for smart solution. This smart solution helps the designer to reach the economy and structural functionality, which help to save the time and laborious repetitive design calculations.*

Keywords-Roof, Folded Plate Roof, Cost Optimization of Roof, V - Shape Roof.

I. INTRODUCTION OF FOLDED PLATE ROOF

Folded plates are a very useful form of structure for roofing large column free area. Folded plates, or as they are sometimes called hipped plates, provide a useful and economical method of construction for roof and floor systems in a wide variety of structures. They are competitive with other construction methods for short spans and have proven exceptionally economical where relatively large spans are needed as for auditoriums, gymnasiums, industrial buildings, hangers, department stores and parking garages. The folded plate shape of roof structure has come into wide usage because of its low cost of construction for long span, high load carrying capacity, rigidity, and aesthetic interest. Folded plate floor or roof construction consists of a series of repeated units, each of which is formed by two or more flat plates intersecting at an angle. The plates act as a continuous slab transversely and as beams in their own planes. Their structural behavior resembles that of shells. In fact, a cylindrical shell can be thought of as a folded plate in limit. The structural action of a folded plate consists of transverse "slab action" by which the loads are carried to the joints and longitudinal "plate action" by which the loads are finally transmitted to the transverses. Because of its great depth and small thickness, each plate offers considerable resistance to bending in its own plane. This "plate action" explains the remarkable rigidity of folded plate construction.

Types of Folded Plate Roof

A folded plate structure is composed of a series of thin plates monolithic along their common longitudinal edge and supported by transverse diapharms, frames or columns.

A folded plate may be prismatic or non-prismatic.

- Prismatic Type: This type of folded plates consists of rectangular plate elements each of constant width and thickness.
- Non-Prismatic Type: This type of folded plates is characterized by its variable plate width along with the span.

Figure 1: Different V Shape Roof

Advantages

Folded plates have certain advantages over shells. These advantages are:

1. The shuttering required is relatively simpler as it involves only straight planks.
2. Shuttering can be stripped at the end of seven days, if not earlier, because of their greater rigidity; this results in quicker turnover which, in turn, cuts down construction time.
3. The design involves only simple calculations which do not call for a knowledge of higher mathematics.
4. Movable formwork can be employed for their construction with greater ease than with cylindrical shells.
5. Simple rectangular diaphragms take the place of complicated transverses required for shells.
6. Their light reflecting geometry and pleasing outlines make then comparable with shells in their aesthetic appeal.

Interest in and use of this type of roof has increased considerably in this country. Considerable additions have been made to our analytical and experimental knowledge in the last decade. The purpose of this report is to solve typical problems and discuss procedures which may be employed for the analysis of a single-span folded plate structure.

Problem Summary

For a clear understanding of the problem summary, it is necessary to know the behavior of folded plate and its structural action.

The structural action of folded plate consisting of **two parts, the "Slab action" and "Plate action".**

- **By the slab action,** the loads are transmitted to the joints by the transverse bending of the slabs. Slabs having their large depth and relatively small thickness, offer considerable resistance to bending in their own planes and flexible out of their planes.
- **By plate action**, the loads carried to the end diaphragms by the longitudinal bending of the slabs in their own planes.

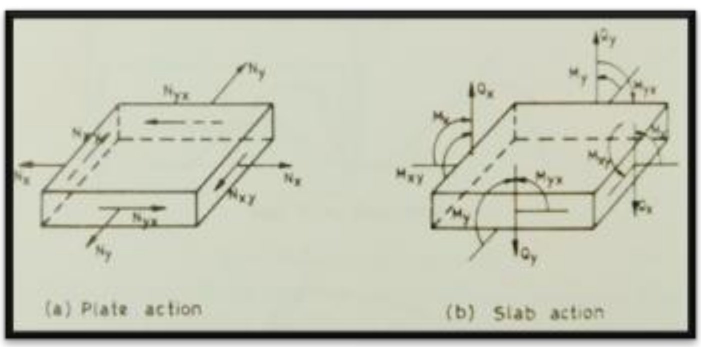


Figure 2: Plate action & Slab action

- **Transverse Slabs Action Analysis**: The transverse action of the slab, of unit length, is analyzed as a continuous beam on rigid supports. The joint loads obtained from this analysis are replaced by their components in the planes of slabs and these are known as plate loads.
- **In Plane Plate Action Analysis**: Under the action of "Plate Loads" obtained in slab action, each slab is assumed to bend independently between the diaphragms, and the longitudinal stresses at the edges are calculated. Continuity demands that the longitudinal stresses at the common edges of the adjacent slabs be equal. The corrected stresses are obtained by introducing edge shear forces.

The Design of economic section for different span, angle, width, thickness and height of the V-shaped and Trough shaped folded plate roof are various parameters to be consider during the design process.

An effort is made to generate a design aid to get ready reference for economic design with various variable parameters of span, shape, thickness etc.

II. METHOD ADOPTED

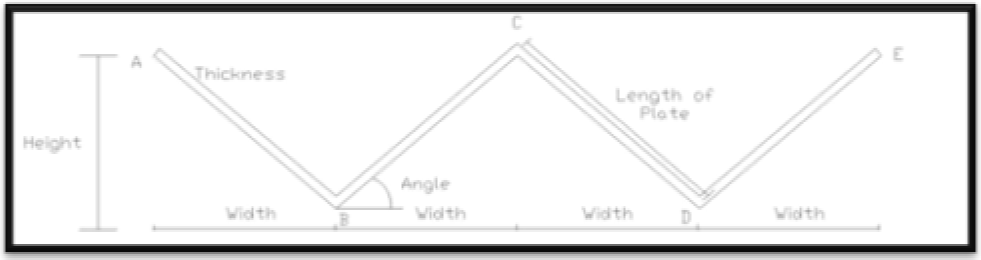
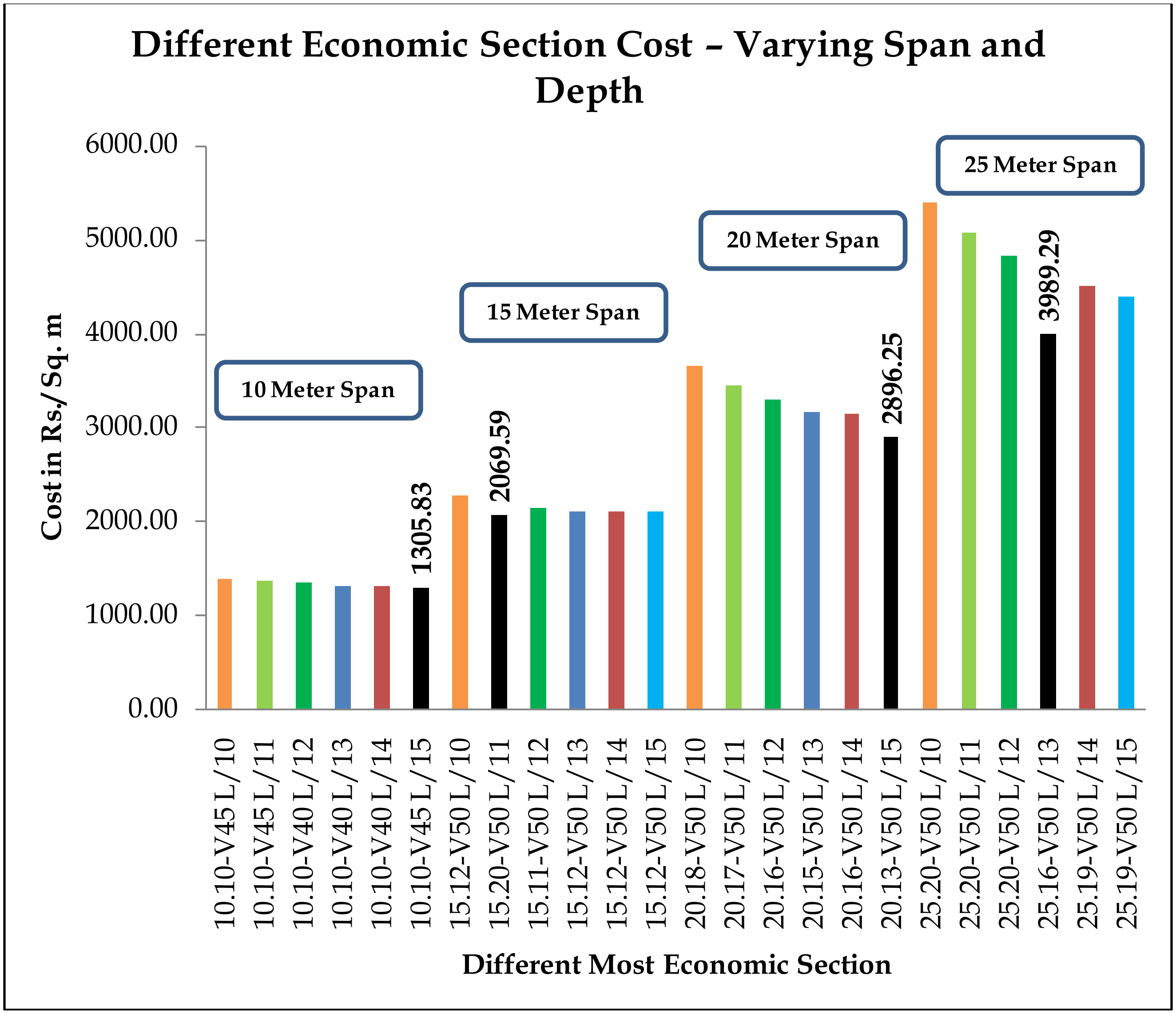


Figure 3: A typical layout of Symmetrical V type folded Plate roof

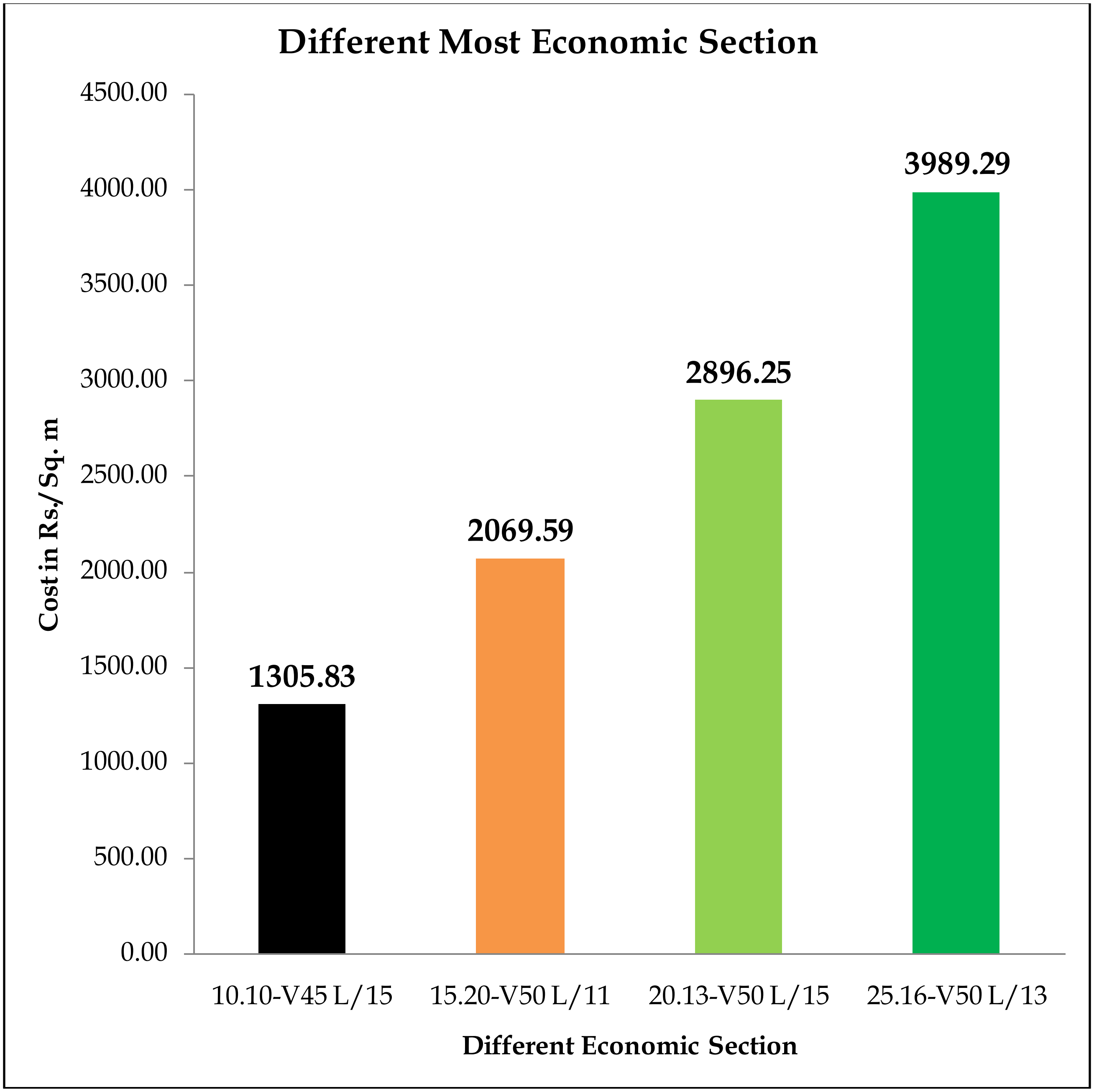
In this study,for symmetrical V-shape folded plate roof, the Iteration method is adopted and referred through **IS 2210-1988**.

The iteration method is applicable for symmetrical V-type folded plates with simpler computational effort in comparison with other rigorous methods. The following steps are involved in the analysis of folded plates by iteration method.

1. The folded plate is analyzed for slab action as a continuous beam and the ridge loads are computed from the reactions. The longitudinal stresses developed in the plates are computed assuming the plates to bend in their own plane due to the action of plate loads.
2. The plate deflections corresponding to the no rotation solution is computed and from these the relative displacements of the joints can be obtained.
3. 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.
4. 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 upon the relative rigidities of longitudinal plate action and transverse slab action and on the geometry of the structure. The iteration method has been found converge rapidly for symmetrical V-type folded plates.



Graph 1: Different Economic Section Cost – Varying Span and Depth



Graph 2: Different Most Economic Section Cost – Varying Span and Depth

III. CONCLUSION

From the above study, derived matrix of economic sections with different span, height, thickness and angle as for 10 meter span 0.1m thickness, 45 degree angle, and L/15 height is economical. Similarly, for 15 meter span 0.12m thickness, 50 degree angle and L/11 height, for 20 meter span 0.13m thickness, 50 degree angle and L/15 height, for 25 meter span 0.16m thickness, 50 degree angle and L/13 height are economic sections.

Table 1: Cost Matrix Thickness vs. Span (With Economic Cost)

Span / Thickness	10	15	20	25

0.10	45-L/15	50-L/14	50-L/15	50-L/15
	1305.83	2162.77	3467.71	5319.36
0.11	35-L/15	50-L/14	50-L/15	50-L/15
	1334.29	2121.01	3337.97	5059.85
0.12	35-L/15	50-L/14	50-L/15	50-L/15
	1361.89	2102.11	3249.81	4867.53
0.13	35-L/15	50-L/15	50-L/15	50-L/15
	1392.55	2111.34	**2896.25**	4724.11
0.14	35-L/15	45-L/15	50-L/15	50-L/15
	1425.79	2125.54	3154.98	4616.62
0.15	35-L/15	45-L/15	50-L/15	50-L/15
	1460.91	2156.15	3135.09	4537.17
0.16	35-L/15	45-L/15	50-L/15	50-L/13
	1497.51	2189.34	3128.27	**3989.29**
0.17	30-L/15	40-L/15	50-L/15	50-L/15
	1530.67	2222.38	3131.88	4438.57
0.18	35-L/15	40-L/15	50-L/15	50-L/15
	1511.99	2216.46	3173.79	4412.07
0.19	30-L/15	40-L/15	50-L/15	50-L/15
	1600.00	2280.08	3212.09	4397.49
0.20	30-L/15	50-L/11	50-L/15	50-L/15
	1636.24	**2069.59**	3253.01	4401.30

(Cost in Indian Rupees)

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