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# OPTIMIZATION OF CELLULAR BEAM BY SPANS, LOADS AND OPENINGS AS VARIABLE PARAMETERS

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## *ABSTRACT*

*Providing circular openings in the web of standard I-sections is a well-established method of fabricating cellular beams. The depth of the original I-section is increased without changing its self-weight, which improves both the bending and shear strengths. The diameter of the openings and their centre-to-centre spacing govern the maximum strength developed by the cellular beam. In this paper, three different spans — short (6.0 m), medium (9.0 m) and long (12.0 m) — are considered. To investigate the maximum strength, uniformly distributed loads of 10 kN/m, 15 kN/m, 20 kN/m and 25 kN/m are applied on ISMB 250, ISMB 350 and ISMB 450 sections respectively. Adopting the concept of one span – one section – four loadings, bending strength, shear strength and deflection are computed for all three spans. A total of 84 cases are obtained and compared with the standard permissible values. The results, presented in tabular form, are intended to be useful to practising field engineers, working contractors and students of structural engineering.*

***KEYWORDS:*** *Cellular Beam; Mode of Failure; Deflection; Spacing of Holes; Bending Moment*

***Article History***

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## INTRODUCTION

Cellular steel beams, recognised by the circular openings in their web, are widely used in modern construction because of their structural efficiency and functional advantages. The introduction of web openings reduces the self-weight of the section, increases the effective depth of the beam and allows building services such as ducts and pipelines to be routed within the structural depth. Cellular beams are particularly suitable for medium-span industrial and commercial structures.

The presence of web openings, however, significantly affects the structural behaviour of the beam. The reduction in effective web area lowers the shear capacity and the stiffness of the section, leading to increased deflections and potential local effects around the openings. The diameter of the opening therefore becomes a critical design parameter. In normal practice, the diameter of the opening is limited to between 0.5 and 0.6 times the overall depth of the beam. It is hence important to study the behaviour of cellular beams under different loadings and span lengths.

In the present study, optimisation is approached through a parametric investigation aimed at identifying efficient combinations of span, load and opening diameter that satisfy structural requirements. Three spans are selected — 6.0 m, 9.0 m and 12.0 m — covering short, medium and long ranges. Each span is analysed under uniformly distributed loads of 10 kN/m, 15 kN/m, 20 kN/m and 25 kN/m. The corresponding I-sections selected for the three spans are ISMB 250, ISMB

350 and ISMB 450. The performance of each combination is examined against the moment criterion, the shear criterion and the deflection criterion. The objective is to identify the optimal ranges of opening diameters and the corresponding limits of bending moment, shear force and deflection.

## METHODOLOGY

The analysis is carried out for three spans: a short span of 6.0 m, a medium span of 9.0 m and a long span of 12.0 m. The selected I-sections are paired with the spans as shown below:

- Span = 6.0 m: ISMB 250; Loads = 10, 15, 20 and 25 kN/m
- Span = 9.0 m: ISMB 350; Loads = 10, 15, 20 and 25 kN/m
- Span = 12.0 m: ISMB 450; Loads = 10, 15, 20 and 25 kN/m

For each span and each load combination, the following parameters are computed:

$M_D$ = Required bending moment

$M_u$ = Actual bending moment

$V_D$ = Required shear strength

$V_u$ = Actual shear force

$Def_p$ = Permissible deflection

$Def_a$ = Actual deflection

A total of 84 results are obtained and presented in tabular form. The detailed specifications of the three sections used are as follows:

ISMB 250: Total depth 250 mm, $b^f$ = 125 mm, $t^f$ = 12.5 mm, $t_v$ = 6.9 mm, A = 4750 mm²

ISMB 350: Total depth 350 mm, $b^f$ = 140 mm, $t^f$ = 14.2 mm, $t_v$ = 8.1 mm, A = 6670 mm²

ISMB 450: Total depth 450 mm, $b^f$ = 150 mm, $t^f$ = 17.4 mm, $t_v$ = 8.4 mm, A = 9230 mm²

For the 6.0 m span, the 9.0 m span and the 12.0 m span, 28 results are obtained respectively, giving 84 results in total. These show the magnitudes of bending moment, shear force and actual deflection of the cellular beams for the chosen combinations of span and loading.

## RESULTS AND DISCUSSION

**Table 1: Results for 6.0 m span (ISMB 250)**

| Load (kN/m) | $M_D$ (kN·m) | $M_u$ (kN·m) | $V_D$ (kN) | $V_u$ (kN) | $Def_p$ (mm) | $Def_a$ (mm) |
|---|---|---|---|---|---|---|
| 10 | 245 | 45 | 121 | 30 | 18.46 | 6.47 |
| 15 | 245 | 67.5 | 121 | 67.5 | 18.46 | 9.60 |
| 20 | 245 | 90 | 121 | 90 | 18.46 | 12.75 |
| 25 | 245 | 112.5 | 121 | 112.5 | 18.46 | 16.18 |

**Table 2: Results for 9.0 m span (ISMB 350)**

| Load (kN/m) | $M_D$ (kN·m) | $M_u$ (kN·m) | $V_D$ (kN) | $V_u$ (kN) | $Def_p$ (mm) | $Def_a$ (mm) |
|---|---|---|---|---|---|---|
| 10 | 521.3 | 101.25 | 128.8 | 30 | 27.7 | 12.36 |
| 15 | 521.3 | 151.8 | 128.8 | 45 | 27.7 | 18.52 |
| 20 | 521.3 | 202.6 | 128.8 | 60 | 27.7 | 24.90 |
| 25 | 521.3 | 253.0 | 128.8 | 112.5 | 27.7 | 30.90 |

**Table 3: Results for 12.0 m span (ISMB 450)**

| Load (kN/m) | $M_D$ (kN·m) | $M_u$ (kN·m) | $V_D$ (kN) | $V_u$ (kN) | $Def_p$ (mm) | $Def_a$ (mm) |
|---|---|---|---|---|---|---|
| 10 | 116.5 | 180 | 126.4 | 60 | 36.9 | 17.48 |
| 15 | 116.5 | 270 | 126.4 | 90 | 36.9 | 26.40 |
| 20 | 116.5 | 360 | 126.4 | 120 | 36.9 | 35.50 |
| 25 | 116.5 | 450 | 126.4 | 150 | 36.9 | 43.70 |

It is observed that in only two cases — both at the highest load of 25 kN/m — the calculated deflection exceeds the permissible limit, by 3.2 mm and 7.8 mm respectively. These deviations are minor compared with the allowable deflection limits and occur only at the worst span–load combinations. The deviation of 3.2 mm is marginal and does not significantly affect the structural performance or the serviceability of the beam. The deviation of 7.8 mm, although comparatively larger, remains within a reasonable range and may be addressed through minor design modifications such as a slight enhancement of the stiffness if required. Overall, the selected cellular-beam sections are adequate for practical applications, with only negligible serviceability concerns under extreme loading conditions. The results indicate that the design of cellular beams is governed mainly by deflection rather than by strength: all analysed sections are found to be safe in bending and in shear for every combination of load and span considered.

If the deflection exceeds the permissible limit, the section need not be replaced by a heavier one — which is often impractical because of restrictions on floor height — but steel plates of suitable thickness can be welded to the top and bottom flanges of the selected section to enhance its stiffness.

It is mandatory in the design of a cellular beam to observe the magnitude of the deflection at every load step. To study the deflection behaviour of an individual beam, the 6.0 m span beam is considered first. The maximum deflection due to a load of 10 kN/m over the full span is recorded; the maximum deflections under loads of 15 kN/m, 20 kN/m and 25 kN/m are then noted in turn. Deflection values are taken from Tables 1, 2 and 3 (column 7 in each table).

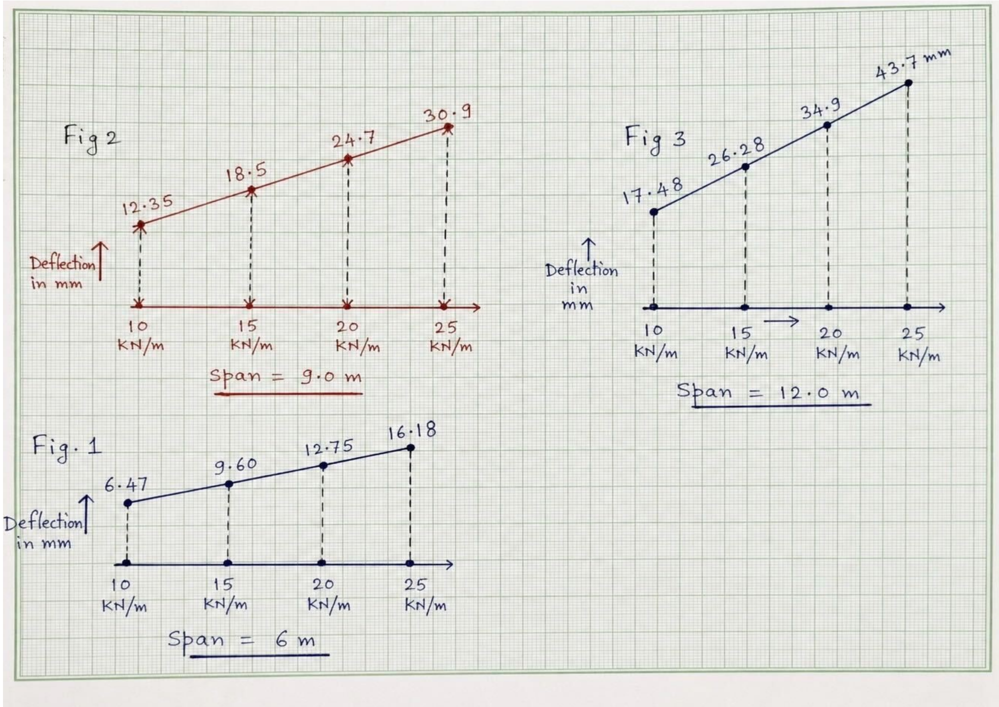


**Figure 1: Showing load/deflection for span 6.0 m**
**Figure 2: Showing load/deflection for span 9.0 m**
**Figure 3: Showing load/deflection for span 12.0 m**

The variation of deflection with span is found to be significant. For an increase in load from 10 kN/m to 15 kN/m, the corresponding increase in deflection is approximately 3.2 mm for the 6.0 m span, 6.4 mm for the 9.0 m span and 9.6 mm for the 12.0 m span. This clearly indicates that the rate of increase in deflection becomes more pronounced with increasing span. The observed behaviour is consistent with classical beam theory, in which the deflection is highly sensitive to the span length.

## CONCLUSION

To cover all common ranges of span, the paper considers three spans — a short span of 6.0 m, a medium span of 9.0 m and a long span of 12.0 m. Uniformly distributed loads ranging from light to heavy (10, 15, 20 and 25 kN/m) are applied to each span. For these spans, the I-sections ISMB 250, ISMB 350 and ISMB 450 are used respectively. For each combination, the actual deflection is calculated and compared with the permissible value.

It is observed that the deflection at any given load can be predicted from the deflection at the previous load step using simple incremental relations:

- For the 6.0 m span: Deflection at any load = Deflection at previous load + 3.2 mm
- For the 9.0 m span: Deflection at any load = Deflection at previous load + 6.4 mm
- For the 12.0 m span: Deflection at any load = Deflection at previous load + 9.6 mm

For the 12.0 m span at a load of 25 kN/m, two cases are observed in which the deflection exceeds the permissible limit by 3.2 mm and 7.8 mm respectively. The deviation of 3.2 mm can be neglected for practical purposes; the deviation of 7.8 mm can be remedied by welding 10 mm or 12 mm thick steel plates to the top and bottom flanges of the section.

In cellular-beam design, the diameter of the openings and their centre-to-centre spacing are critical; the present study respects the limits prescribed by the relevant code, which are incorporated into the spreadsheet program developed for the analysis.

A total of 84 cases are considered: three spans, four loads on each span, and six parameters ($M_D$, $M_u$, $V_D$, $V_u$, $Def_p$ and $Def_a$). Out of these, only two cases marginally exceed the permissible deflection — a failure rate of 2.38 %. In practical terms, only the case with an additional 7.8 mm of deflection requires attention, and a remedy has been proposed above.

## REFERENCES

1. *Deshmukh, M. M., "A design comparison of castellated beams between IS 800-1984 and IS 800-2007," 2013.*
2. *Kurlapkar, R. and Kulkarni, D. B., "Behaviour of castellated beam with sinusoidal openings," International Research Journal of Engineering and Technology, vol. 6, no. 4, 2019, pp. 2478–2483.*
3. *Morkhade, S. G. and Gupta, L. M., "An experimental and parametric study on steel beams with web openings," International Journal of Advanced Structural Engineering, vol. 7, no. 3, 2015, pp. 247–260. doi: 10.1007/s40091-015-0095-1*
4. *Girija, K., Narayanan, S. and Anupriya, B., "Strength study of stiffeners on castellated beam for circular and hexagonal openings using ANSYS," National Journal of Multidisciplinary Research and Development, vol. 3, no. 2, 2018, pp. 20–23.*
5. *Jamadar, A. M. and Kumbhar, P. D., "Parametric study of castellated beam with circular and diamond shaped openings," International Research Journal of Engineering and Technology (IRJET), vol. 2, 2015, pp. 715–722.*
6. *Vishal Kumar Arekar, "Parametric study on castellated beam with arch shaped openings," International Journal of Civil Engineering, vol. 8, no. 5, May 2021, pp. 1–6. doi: 10.14445/23488352/IJCE-V8I5P106*
7. *Zaarour, W. and Redwood, R., "Web buckling in thin webbed castellated beams," Journal of Structural Engineering, ASCE, 1996.*
8. *Bedi, K. and Pachpor, P. D., "Moment and shear analysis of beam with different web openings," International Journal of Engineering Research and Applications, 2011.*
9. *Redwood, R. and Demerdjian, P., "Castellated beam web buckling in shear," Journal of Structural Engineering, 2011.*
10. *Bower, J. E., "Experimental stresses in wide-flange beams with holes," Journal of the Structural Division, ASCE, vol. 92, no. 5, pp. 167–186.*
11. *Chan, P. and Redwood, R. G., "Stresses in beams with eccentric web holes," Journal of the Structural Division, ASCE, vol. 100, no. 1, pp. 231–248.*
12. *Cheng, J. J., "Design of steel beams with end copes," Journal of Constructional Steel Research, vol. 25, no. 1, pp. 3–22.*