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THE MODELLING OF SLAB SYSTEMS

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Abstract

The finite element method (FEM) has been an essential tool for engineers for decades, yet, like any tool, its limitations must be understood and accounted for. The quality of results heavily depends on the model's accuracy. This study aims to establish best practices for correct structural modeling, focusing on slab and beam systems.

Keywords: *slab, FEM, finite element method.*

1. Introduction

In modern structural engineering practice, the accurate modelling of slab systems is crucial for designing safe and cost-effective structures. Slabs not only play a role in transferring vertical loads but also contribute to the overall stiffness of the building system. Proper modelling methods enable reliable prediction of load distribution and of structural behaviour.

Common errors include engineers failing to verify results with traditional methods, incorrect model setup, improper reduction of the moment of inertia and inaccurate joint stiffness assumptions.

Additionally, results are often misinterpreted because beams and columns are treated as one-dimensional (linear) elements, while slabs are two-dimensional (surface) elements, leading to point discontinuities at their intersections.

2. Beams

2.1. Support conditions

Beam analysis considers axial alignment and cross-sectional/material properties (Young's modulus, area, moment of inertia). For a simply supported beam, manual calculation is straightforward: the span is measured between wall axes, and the beam axis rests directly on supports.

$$M = \frac{P}{2} \times \frac{L}{2} = \frac{P \times L}{4} \tag{1}$$

For a 40 kN point load applied on the middle of a 6 m long beam, the bending moment is: $M = 60$ kNm.

The simplest modelling approach involves supporting the beam at its axis with point supports. As shown in **Fig. 1** this matches the results of manual calculations.

When modeling the 30 cm thick support wall by including both edge supports in addition to the central axis support, the resulting bending moment diagram becomes unrealistic. **Fig. 2.** demonstrates how the maximum moment decreases to

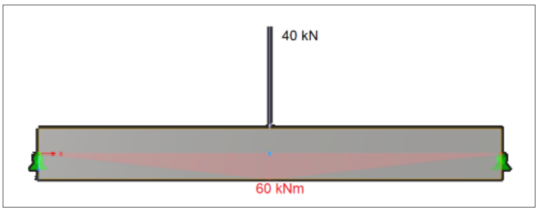


Fig. 1. *Bending moment diagram of a simply supported beam.*

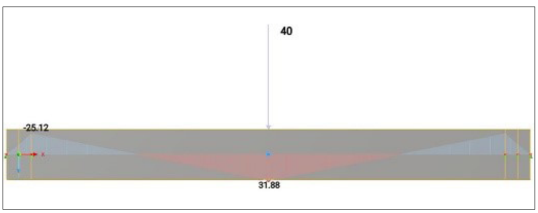


Fig. 2. *Bending moment diagram with multiple point supports.*

31.88 kNm, while moments of 25.12 kNm appear at supports that previously had zero moment.

The GUI may deceive engineers unfamiliar with the software. Under the assumption that supports are actually located at the beam bottom, they introduce an offset to the neutral axis via the “offset” function, resulting in a maximum moment of 37.5 kNm and support moments of 22.5 kNm. (Fig. 3)

When offset application is necessary, creating a rigid link between the support location and beam neutral axis provides a more accurate solution . (Fig. 4)

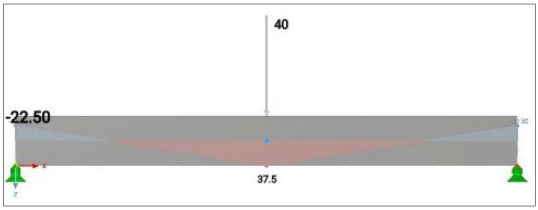


Fig. 3. *Bending moment diagram with axial offset of the beam.*

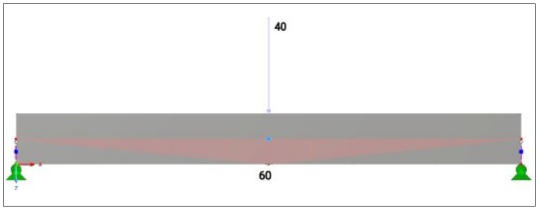


Fig. 4. *Bending moment diagram using rigid links.*

2.2. Frame joint stiffness

Simplified models assume beams span between column centrelines, requiring moment adjustments. The *M'* adjusting moment shall be subtracted from the original moment:

$$M' = V * d \tag{2}$$

where *V* represents the shear force at the beam end, and *d* equals half of the support length (i.e., half the column width).

However, the resulting forces obtained this way are not entirely realistic: while the theoretical model treats columns and beams as one-dimensional elements without considering their height and width, actual structural behaviour differs significantly. Consequently, frame structure joints prove substantially stiffer in reality than what these simplified models assume (Fig. 5.).

Joint stiffening can be properly implemented through two approaches [1]. One method is to connect nodes within 2·d distance via rigid truss elements to enforce compatible displacements (marked “A” in Fig. 6). Another possibility (marked “B” in Fig. 6) is to install rigid links between collinear nodes. This stiffened region alters mid-span moments by 10% but achieves 50% reduction in maximum deflection [1, 2].

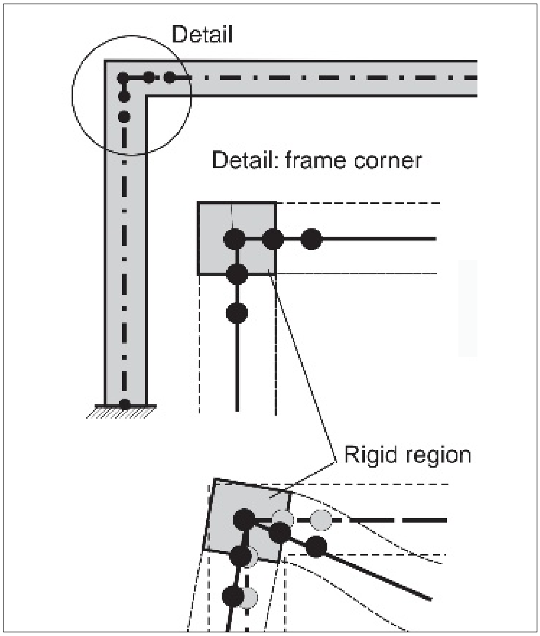


Fig. 5. *Rigid regions between columns and beams.*

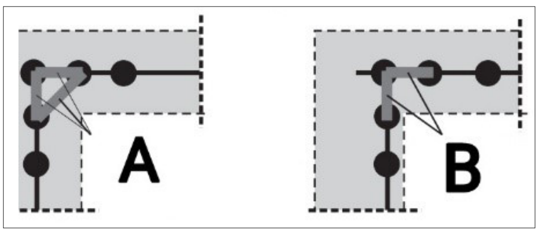


Fig. 6. *Methods of mimicking the rigidity of these regions.*

3. Slabs

3.1. Support conditions

Accurate slab design requires applying multiple load patterns to the structural element. Since applying these loads to the entire structure would be inefficient in terms of time and computational resources, standard practice dictates creating a separate model. This raises a key question: how can we achieve the most realistic model while minimizing computational demands? The following results were obtained for a 5×5 meter slab subjected to uniformly distributed loading.

Fig. 7 shows the principal bending moments for a 5×5 meter slab under uniformly distributed load, supported on all 4 edges by linear supports.

Fig. 8 presents results for the case incorporating 3.00 m high supporting walls beneath slab edges with continuous line supports, showing 13-18% variation compared to the baseline model.

The most common refined approach following basic modelling involves incorporating half-story elements above and below the slab. Supports placed at the extremities of the 1.50 m high walls yield a simplified yet realistic structural model. When benchmarked against Fig. 7. e7 results, this method shows merely 4-10% variance, demonstrating that basic models can achieve satisfactory accuracy (Fig. 9.).

3.2. Material property: Poisson's ratio

Poisson's ratio represents the ratio between longitudinal and transverse material deformation. According to Eurocode 2, $\nu = 0.2$ should be used for compression zones and $\nu = 0.2$ for tension zones. [3] While this approach proves useful for columns, it offers limited practical value for slabs, which are primarily designed for bending and consequently always contain both compressed and tensioned regions.

Bittner's 1965 test results [4] demonstrated that $\nu = 0.0$ represents the most appropriate value for reinforced concrete slab design. Although this assumption leads to conservative estimation of compression forces in the slab, this limitation proves inconsequential since reinforcement design is governed by tensile forces.

Furthermore, Eurocode 2 specifies that transverse reinforcement must constitute at least 20% of longitudinal reinforcement, rendering the Poisson's ratio discussion largely irrelevant for practical design purposes.

3.3. Uplift on slabs

When slab uplift at supports is permitted, the resulting moment distribution significantly deviates from linear finite element analysis predictions.

In Table 1 the following values are displayed: the torsional moments above supports, mid-span bending moments, peak bending moments, shear forces (per meter width) and uplift forces. The first column contains the results of Czerny's test results [5].

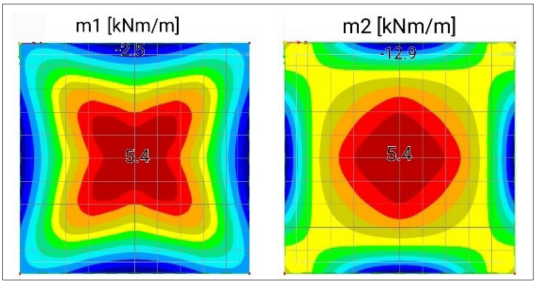


Fig. 7. *Principal bending moments for line supported slabs.*

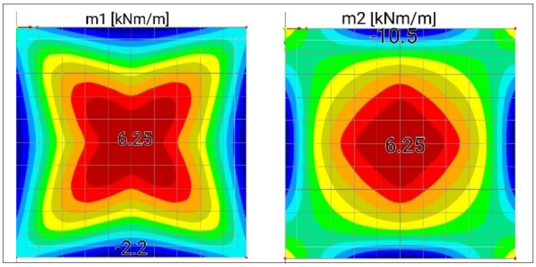


Fig. 8. *Principal bending moments for wall-supported slabs.*

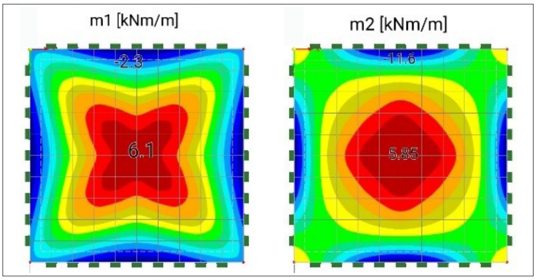
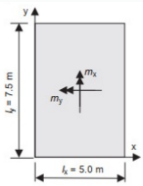


Fig. 9. *Principal bending moments for slabs between two half-storeys.*

Table. 1. *Moment variation due to uplift effects*



		Czerny (1999)	Finite Element analysis simply supported slab (= 100%)	Finite Element analysis slab can uplift
m_{xye}	in kNm/m	15.3 (132%)	11.6	7.1 (61%)
m_{xm}	in kNm/m	18.3 (98%)	18.7	21.0 (113%)
m_{yn}	in kNm/m	7.0 (97%)	7.2	7.5 (104%)
$m_{y,max}$	in kNm/m	7.2 (96%)	7.5	9.1 (121%)
v_{yrm}	in kN/m	18.2 (102%)	17.9	23.9 (134%)
$\bar{v}_{yrm}$	in kN/m	26.5 (106%)	25.0	34.5 (138%)
v_{xrm}	in kN/m	21.2 (98%)	21.6	23.3 (108%)
$\bar{v}_{xrm}$	in kN/m	25.6 (97%)	26.5	28.0 (106%)
F_e	in kN	30.7 (124%)	24.8	– –
f	in mm	24.5 (105%)	23.4	27.3 (117%)

4. Conclusions

Precise modelling of beams and slabs plays a pivotal role in modern structural engineering, ensuring both safe and cost-effective construction. For beam systems, particular attention must be paid to the support conditions (boundary constraints), to joint stiffness (rigid/semi-rigid connections) and moment redistribution effects. These factors critically influence the bending moment distributions (±15-25% variance possible), the deflection magnitudes (up to 50% reduction with proper detailing) and the shear force transitions at connections.

For more accurate results in slab design, key modelling considerations include applying proper support stiffness, Poisson's ratio selection and uplift potential assessment (20-30% moment redistribution in unrestrained systems). In order to avoid common errors and to ensure the required behaviour of the structure, it is always advisable to check it with manual calculations in addition to software modelling.

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