JICE Journal Innovation of Civil Engineering

Vol. 7, No. 1, pp. 203-216
Submit: 17-12-2025 |
Accepted: 22-06-2026 |
Publish: 29-06-2026 |

Finite Element Analysis for Crack Width and Deflection Control in Reinforced Concrete Floor Systems at Serviceability Limit State

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ABSTRACT
Serviceability performance is crucial for reinforced concrete (RC) structures to ensure durability, functionality, and user comfort. While existing research often focuses on individual components, integrated evaluations of complete slab-beam floor systems using practical finite element analysis (FEA) in accordance with Eurocode 2 remain limited. This study evaluates the short-term and long-term serviceability performance of a typical RC floor system (top/bottom slabs, main/secondary beams) under service loads. A 3D finite element model was developed using SAFE software, with crack-width and deflection verifications conducted in accordance with Eurocode 2 (EN 1992-1-1) and Eurocode 0 (EN 1990). The numerical results confirm that all structural components satisfy the prescribed serviceability limits: Maximum Crack Width, measured at 0.085 mm for the main beam and below 0.22 mm for the slabs, both well within the 0.30 mm allowable limit. Maximum Long-Term Deflection: Reached 27.6 mm for the main beam, remaining below the 34.0 mm allowable limit. The FEA successfully captured realistic slab-beam interactions and internal force redistributions, providing structural engineers with practical, code-compliant guidance.

Keywords: *Reinforced Concrete; Serviceability Limit State; Crack Width; Deflection; Eurocode 2; FEM.*

1. Introduction

Reinforced concrete (RC) is one of the most widely used construction materials globally due to its versatility, cost-effectiveness, and high compressive strength. Two primary limit states govern the design of RC structures: the Ultimate Limit State (ULS), which concerns structural safety and collapse, and the Serviceability Limit State (SLS), which relates to the structure's performance under normal service loads. While ULS ensures the structure does not fail, SLS is equally crucial for its long-term durability, user comfort, and functionality [1].

Excessive cracking and deflection are two of the most common serviceability issues in RC floor systems. Uncontrolled cracking can not only mar the structure's aesthetic appearance but also create pathways for moisture and aggressive agents to penetrate the concrete, leading to corrosion of the steel reinforcement and reducing the structure's lifespan [2]. Similarly, excessive deflection can damage non-structural elements such as partitions and finishes, affect the proper functioning of equipment, and cause discomfort to occupants.

Modern structural design codes, such as ACI 318 [3] and Eurocode 2 (EN 1992-1-1) [4], provide detailed guidelines for controlling crack widths and deflections. These calculations often involve complex considerations of material properties, load duration (short- and long-term effects such as creep and shrinkage), and the non-linear behavior of cracked concrete sections.

This paper presents a comprehensive case study of the SLS analysis for a complete floor system, including slabs and supporting beams. The primary objective is to verify the structural design's compliance with the crack width and deflection requirements stipulated in Eurocode 2. The analysis

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leverages finite element modeling (FEM) with SAFE software [5] to obtain accurate results for internal forces and deformations, which are then used in the code-prescribed calculations.

In recent years, increasing attention has been devoted to the serviceability of reinforced concrete floor systems due to the growing demand for durable, sustainable buildings. Several researchers have investigated crack propagation, long-term deflection, and numerical modeling techniques for RC structures using finite element methods and code-based approaches. Recent studies confirmed that excessive cracking and deflection remain critical issues affecting durability, occupant comfort, and maintenance costs in reinforced concrete buildings.

Mohammed and Yousif [6,7] reviewed the major mechanisms governing cracking in concrete slabs and highlighted the importance of controlling serviceability behavior during the design stage. Recent finite element investigations by Nguyen and Huang [8-10] demonstrated that advanced numerical methods can significantly improve the prediction accuracy of stress concentrations and crack propagation. Other studies also emphasized that long-term effects, such as creep and shrinkage, considerably influence slab deflection and crack development under sustained service loads.

Despite numerous studies on RC serviceability, limited research has focused on integrated slab-beam floor systems using practical, SAFE-based finite-element analysis in accordance with Eurocode 2 provisions. Therefore, this study aims to provide a comprehensive evaluation of crack width and deflection control in a typical reinforced concrete floor system under serviceability limit-state conditions.

2. Materials and Methods

2.1. Structural System and Geometry

The case study involves a typical floor system of a commercial building. The system consists of a top slab, a bottom slab, and a grid of main and secondary beams. The typical bay has a span (L) of 8.5 meters. The geometric properties of the structural elements are detailed in Table 1.

Table 1. Geometric Properties of Structural Elements

Element	Cross-section (b x m)	Effective depth (h_0)	Cover (a_0)
Main Beam	400 mm x 800 mm	737 mm	63 mm
Secondary Beam	300 mm x 600 mm	539 mm	61 mm

2.2. Material Properties

The materials used for the analysis are Grade C30/37 concrete and Grade B500B reinforcing steel (assumed equivalent to B30 and CB400-V for calculation purposes). The key mechanical properties according to Eurocode 2 are summarized in Table 2.

Table 2. Material Properties

Material Property. Concrete (C30/37)	Symbol	Value	Unit
Characteristic Compressive Strength	f_{ck}	30	Mpa
Mean Tensile Strength	f_{ctm}	2.9	MPa
Modulus of Elasticity	E_{cm}	33	GPa
Steel (B500B). Characteristic Yield Strength	f_{yk}	500	MPa
Modulus of Elasticity	E_s	200	GPa

2.3. Loading and Load Combinations

The structure was analyzed for dead loads (DL) and live loads (LL). Serviceability checks were performed using load combinations specified in Eurocode 0 (EN 1990) [6] for short-term and long-term effects.

Quasi-permanent combination (for long-term effects): $G + \psi_2 Q$

Characteristic combination (for short-term effects): $G + Q$

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2.4. Analytical Methodology

The analysis followed the procedures outlined in Eurocode 2 (EN 1992-1-1). A 3D finite element model of the floor system was created in SAFE software to determine the bending moments, shear forces, and deflections. The SAFE results were then used to check crack width and deflection manually.

In this study, the finite element method (FEM) illustrated in the flowchart is implemented through the CSI SAFE software package. SAFE provides an integrated platform for importing structural data and CAD models, defining material properties and boundary conditions, and generating meshes. The FEM analysis within SAFE is subsequently extended to fatigue and cracking evaluations by applying appropriate loading conditions. The computed results are then validated against reference data to ensure accuracy, thereby establishing a reliable methodology for assessing the structural behavior of slabs and beams. (Fig.1)

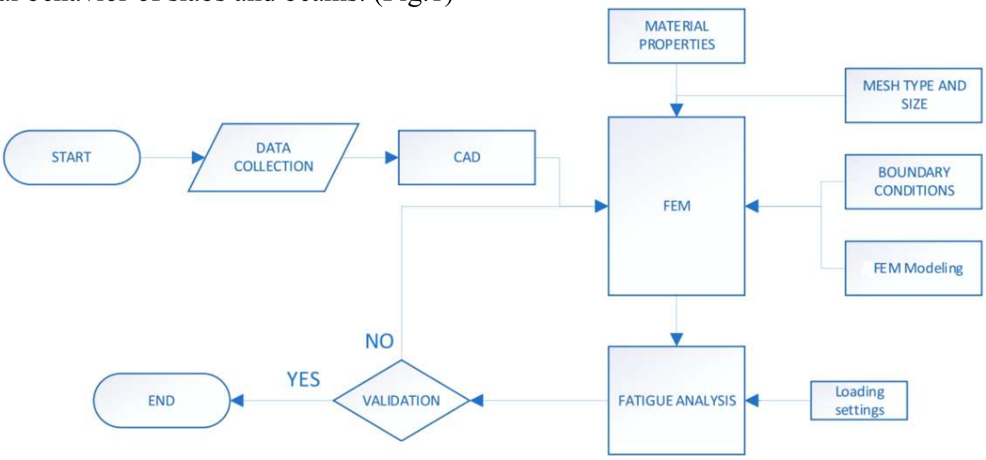

Figure 1. Methodology flowchart of the finite element method (FEM) implemented in SAFE.

The crack width (w_k) is calculated using the formula:

$$w_k = s_{r,max}(\epsilon_{sm} - \epsilon_{cm})$$

where:

$s_{r,max}$: is the maximum crack spacing.

ϵ_{sm} : is the mean strain in the reinforcement.

ϵ_{cm} : is the mean strain in the concrete between cracks.

The deflection (f) is calculated based on the curvature (1/r) of the member, considering the effects of cracking using an effective moment of inertia.

3. Results and Discussions

3.1. Slab System Analysis

The top and bottom slabs were analyzed for cracking and deflection using SAFE model results.

3.1.1. Crack Control The calculated crack widths were compared against the allowable limit of [w_k]=0.4 mm (for exposure class XC1, appearance).

- Top Slab:
  - Maximum short-term crack width: $w_{k,st}$ =0.18 mm < 0.4 mm (OK)
  - Maximum long-term crack width: $w_{k,lt}$ =0.22 mm < 0.4 mm (OK)
- Bottom Slab:
  - Maximum short-term crack width: $w_{k,st}$ =0.17 mm < 0.4 mm (OK)
  - Maximum long-term crack width: $w_{k,lt}$ =0.21 mm < 0.4 mm (OK)

The results indicate that crack widths in both slabs are well within the permissible limits.

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The numerical results indicate that the slab system possesses adequate stiffness under both short-term and long-term loading conditions. The maximum crack widths remained significantly below the Eurocode-allowable limit of 0.4 mm, demonstrating that the reinforcement arrangement effectively controlled tensile cracking in the concrete.

In addition, the long-term crack widths increased only slightly compared with the short-term values, indicating that creep and shrinkage effects did not critically reduce the structural performance. This behavior confirms the suitability of the selected slab thickness and reinforcement ratio for maintaining long-term durability.

From an engineering perspective, maintaining crack widths below the allowable limit is essential for preventing moisture penetration and reinforcement corrosion. Therefore, the obtained results suggest that the proposed slab design can provide satisfactory durability and service life under normal environmental exposure conditions.

3.1.2. Deflection Control The maximum deflection of the slabs was checked against the allowable limit, typically L/250. For an 8.5m span, the limit is [f]=8500/250=34 mm.

- Top Slab Max Deflection: f_{max}=19.5 mm < 34 mm (OK)
- Bottom Slab Max Deflection: f_{max}=18.8 mm < 34 mm (OK)
  The deflections are acceptable, ensuring the floor's serviceability.

3.2. Beam System Analysis

A detailed analysis was performed for the main and secondary beams at the critical sections. The beam analysis showed that the main beam experienced greater crack widths and deflections than the secondary beam, due to its higher bending moment demand and larger tributary area. However, all calculated values remained within the Eurocode allowable limits, indicating sufficient serviceability performance.

The long-term deflection of the main beam reached approximately 81% of the allowable limit, suggesting that deflection control is more critical than crack control for large-span beams. This observation is consistent with previous studies that report that long-term deformation becomes increasingly significant in reinforced concrete members subjected to sustained loading.

Furthermore, the finite element model successfully captured the redistribution of stresses between slabs and beams, resulting in realistic deformation behavior. The SAFE-based numerical approach, therefore provides an efficient and reliable tool for evaluating serviceability performance in practical reinforced concrete floor systems.

3.2.1. Main Beam (400x800 mm)

- Crack Formation Check: The cracking moment was calculated as M_{cr}=109.55 kNm. The applied moment under the quasi-permanent load was M=151.68 kNm. Since M>M_{cr}, cracks are expected to form, and a crack width calculation is necessary.
- Crack Width Calculation: The calculated crack widths are summarized in Table 3. The recommended limit for this exposure class is [w_k]=0.3 mm to prevent corrosion.

Table 3. Crack Width Results for Main Beam

Load Case	Calculated Crack Width (w_k)	Allowable Limit [w_k]	Status
Long-term (Quasipermanent)	0.085 mm	0.3 mm	OK
Short-term (Characteristic)	0.171 mm	0.4 mm	OK

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The results presented in Table 3 indicate that the calculated crack widths of the main beam remain significantly below the allowable limits specified by Eurocode 2 under both loading conditions. Under the quasi-permanent load combination, the crack width was only 0.085 mm, corresponding to approximately 28% of the allowable limit of 0.30 mm. For the characteristic load combination, the crack width increased to 0.171 mm but remained well below the allowable value of 0.40 mm. These results demonstrate that the selected reinforcement arrangement provides effective crack control and ensures adequate durability of the structural member. The relatively small crack widths also suggest that tensile stresses in the reinforcement are properly distributed, reducing the risk of reinforcement corrosion and enhancing the beam's long-term performance.

- Deflection Calculation: The total long-term deflection was calculated and compared with the allowable limit of [f] = L/250 = 34 mm. The calculated total deflection was f = 27.6 mm, which is less than the 34 mm limit, satisfying the requirement.

3.2.2. Secondary Beam (300x600 mm)

- Crack Formation Check: The cracking moment was M_{cr}=47.25 kNm. The applied service moment was M = 82.42 kNm. Since M>M_{cr}, crack width calculation is required.
- Crack Width Calculation: The results are shown in Table 4.

Table 4. Crack Width Results for Secondary Beam

Load Case	Calculated Crack Width (w_k)	Allowable Limit [w_k]	Status
Long-term (Quasipermanent)	0101 mm	0.3 mm	OK
Short-term (Characteristic)	0.195 mm	0.4 mm	OK

As shown in Table 4, the secondary beam also satisfies all crack-width requirements prescribed by Eurocode 2. The maximum long-term crack width was calculated as 0.101 mm, while the short-term value reached 0.195 mm. Both values are substantially lower than the corresponding allowable limits. Compared with the main beam, the secondary beam exhibited slightly wider cracks due to its smaller cross-sectional dimensions and reinforcement arrangement. Nevertheless, the obtained values confirm that the structural design provides sufficient resistance to excessive cracking and maintains satisfactory durability throughout the structure's service life.

- Deflection Calculation: The total long-term deflection was calculated to be f = 24.5 mm. This is less than the allowable limit of [f]=L/250=34 mm, indicating satisfactory performance.

3.3. Crack Formation Check for Top and Bottom Slabs

3.3.1. Top Slab

a. Short-term Cracking of the Top Slab

According to Eurocode 2 (EN 1992-1-1), for short-term cracking, the following condition must be satisfied:

$$\mathrm{arc}_1 \le [\mathrm{arc}] = 0{,}4\ mm$$

Based on the SAFE software, the short-term crack width was calculated $\mathrm{arc}_2 = 0{,}09$mm $\mathrm{arc}_2 = 0{,}09$ mm $< [\mathrm{arc}] = 0{,}3\ mm$ → The cover satisfies the long-term cracking condition.

b. Calculation of the deflection of the cover.

The maximum deflection of the cover must satisfy the condition:

$$\mathrm{f}_{\mathrm{max}} \le \mathrm{f}_{\mathrm{limit}}$$

Figure 3 illustrates the deflection distribution of the top slab obtained from the SAFE finite element model. The maximum deflection occurred in the central region of the slab, where bending moments were highest due to the span configuration and loading conditions. The calculated maximum deflection remained significantly below the allowable limit of L/250, indicating that the

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slab possesses sufficient stiffness under service loads. The smooth deformation pattern shown in the figure also confirms the effectiveness of the support arrangement and load-transfer mechanism within the floor system.

With the maximum deflection calculated according to the SAFE model: $f_{max} = 38{,}35mm$

The limiting deflection calculated according to the above formula has a length L=8.5m

$$f_{limit} = \frac{L}{200} = \frac{8500}{200} = 42{,}5mm$$

with $f_{limit} = 42{,}5\ mm > f_{max} = 38{,}35\ mm$ → The cover satisfies the deflection.

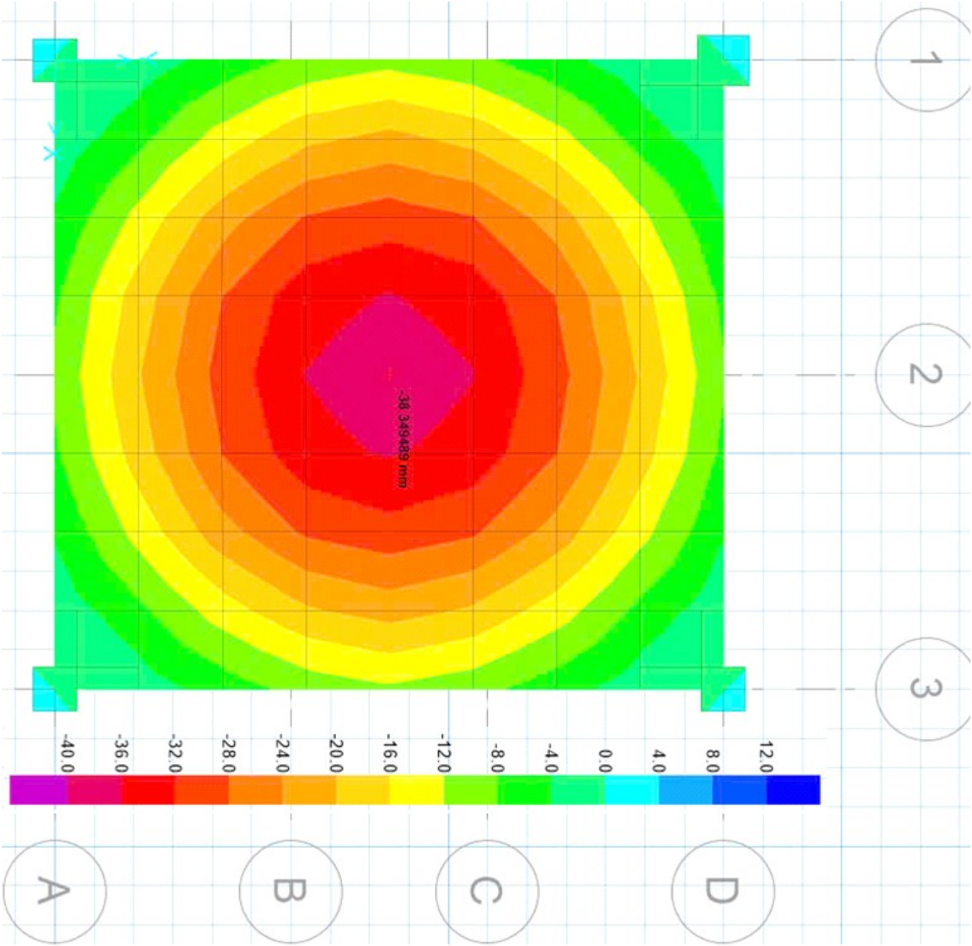

Figure 3. Deflection values of the cover in SAFE.

3.3.2. Base Slab

a. Short-term cracking of the base slab.

According to Eurocode 2 (EN 1992-1-1), with the allowable short-term crack satisfying the condition:

$$arc_1 \leq [arc] = 0{,}4mm$$

Figure 4 presents the distribution of short-term crack widths in the bottom slab. The highest crack values were observed in regions under maximum tensile stress, particularly near the mid-span. However, all calculated crack widths remained below the allowable Eurocode limit, demonstrating that the reinforcement layout effectively controlled crack development. The results indicate that the slab can maintain adequate serviceability performance immediately after loading without compromising structural durability.

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Based on the SAFE software, the short-term crack width was calculated $\text{arc}_1 = 0{,}1\text{mm}$.
$\text{arc}_1 = 0{,}1\text{ mm} < [\text{arc}] = 0{,}4\ mm$ → The base slab satisfies the short-term cracking condition.

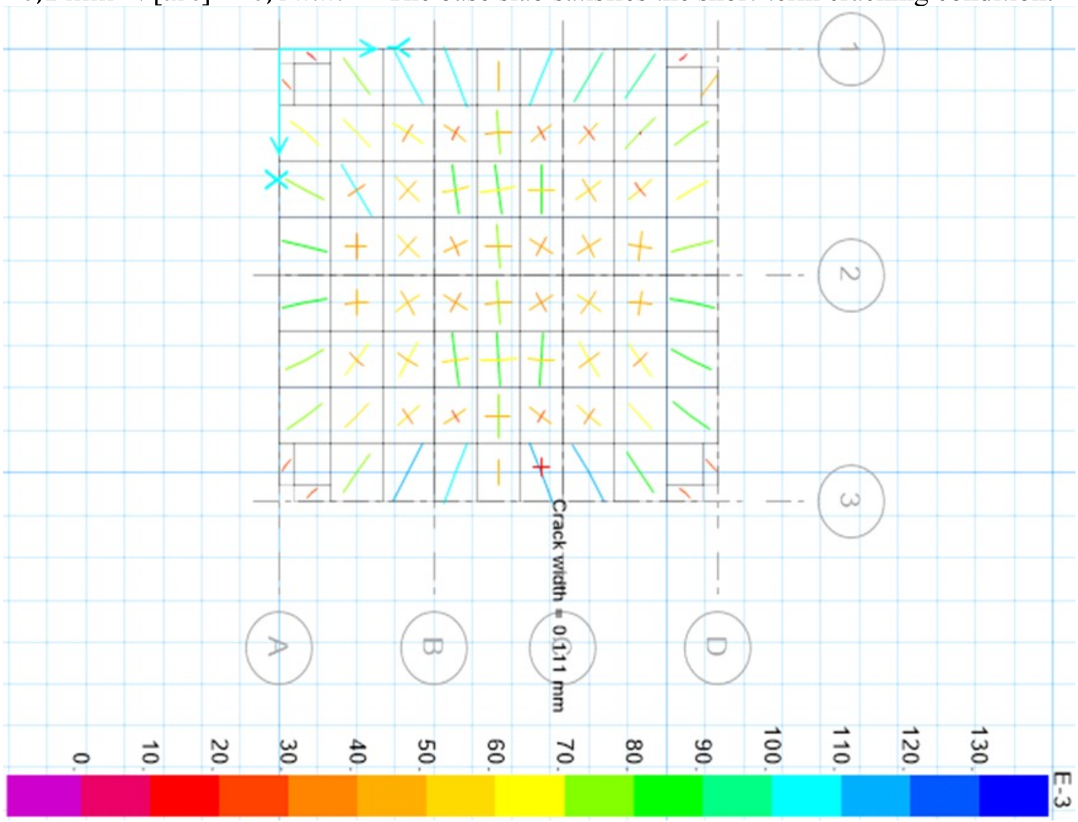

Figure 4. Short-term crack values of the base slab in SAFE.

b. Long-term cracking of the base slab.

According to Eurocode 2 (EN 1992-1-1), with the allowable long-term crack satisfying the condition:

$$\text{arc}_2 \le [\text{arc}] = 0{,}3\text{mm}$$

The long-term crack-width distribution shown in Figure 5 reflects the influence of sustained loading, including concrete creep and shrinkage. Although the crack widths increased slightly compared with the short-term condition, the maximum value remained well below the allowable limit. This behavior confirms that long-term material effects do not significantly impair the slab's serviceability performance. The limited increase in crack width further demonstrates the suitability of the selected slab thickness and reinforcement ratio.

Based on the SAFE software, the long-term crack width was calculated $\text{arc}_2 = 0{,}078\text{mm}$. $\text{arc}_2 = 0{,}078\text{ mm} < [\text{arc}] = 0{,}3\ mm$ → The base slab satisfies the long-term cracking condition.

c. Calculation of the deflection of the base slab.

The maximum deflection of the base slab must satisfy the condition:

$$f_{max} \le f_{limit}$$

Figure 6 shows the deflected shape of the bottom slab under service loading conditions. The maximum deflection occurred at the slab center, which is consistent with the classical flexural behavior of two-way slab systems. The calculated value remained substantially lower than the allowable deflection limit, indicating that the slab has adequate stiffness and can maintain satisfactory functionality and occupant comfort throughout its service life.

With the maximum deflection calculated using the SAFE model $f_{max} = 39{,}47\text{mm}$.

The allowable deflection calculated according to the above formula has a length of L = 8.5 m.

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$$f_{limit} = \frac{L}{200} = \frac{8500}{200} = 42{,}5mm$$

With $f_{limit} = 42{,}5\ mm > f_{max} = 39{,}47\ mm \rightarrow$ The bottom slab satisfies the deflection requirement.

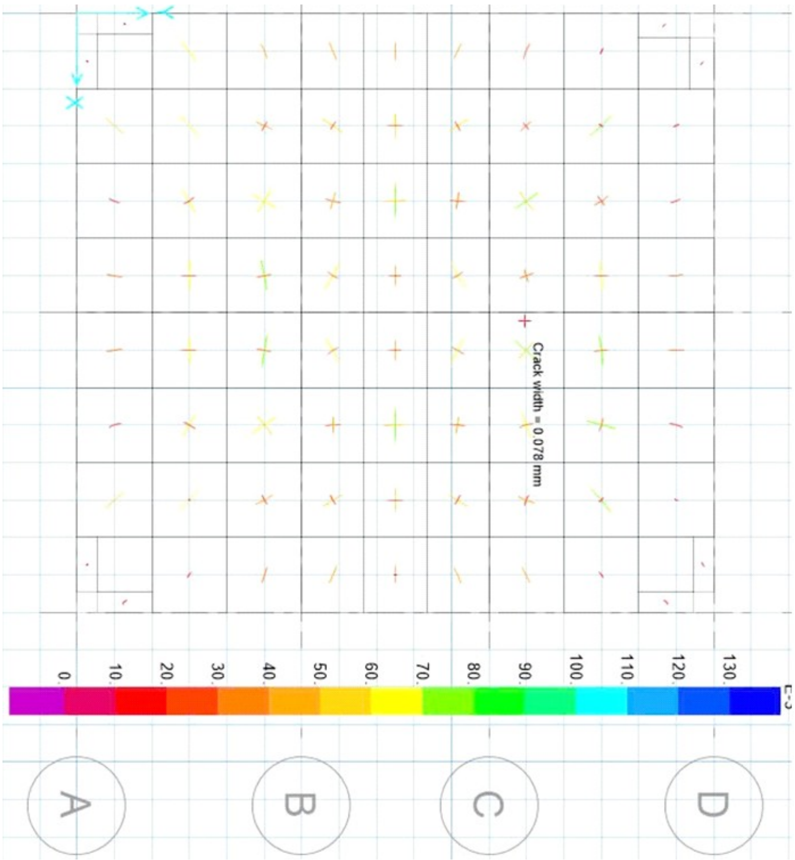

Figure 5. Long-term crack values of the base slab in SAFE.

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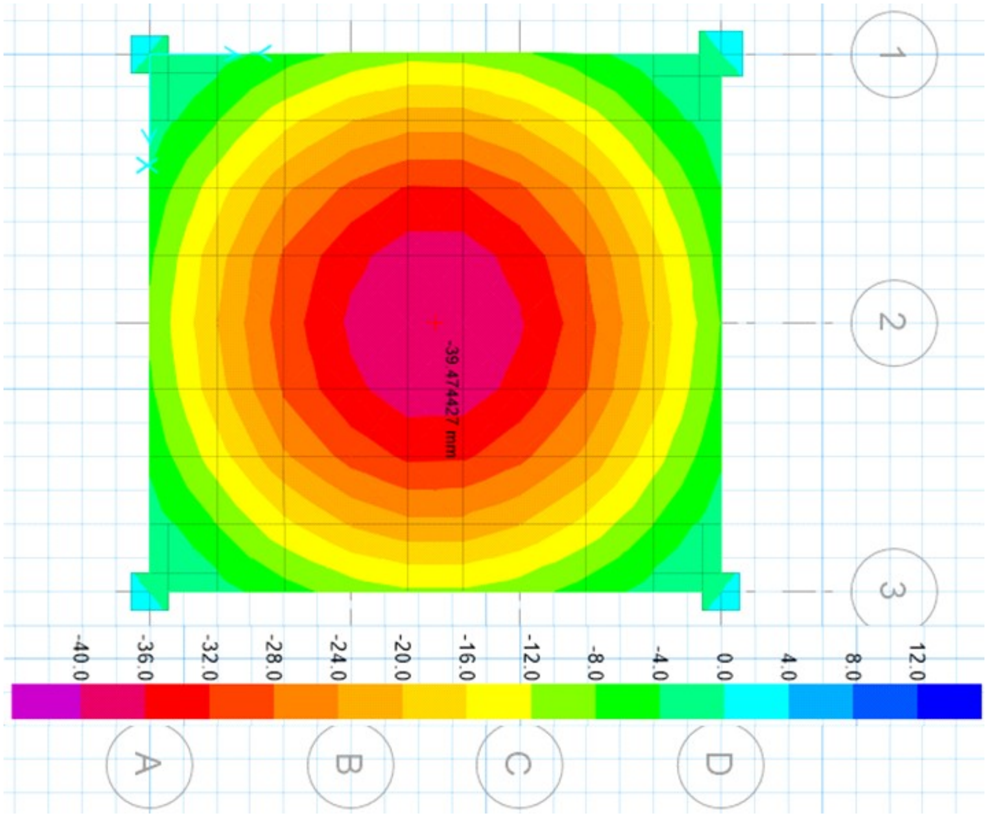

Figure 6. Deflection of the bottom slab from the SAFE analysis.

3.4. Inspect the formation of cracks in the slab.

3.4.1. Short-term crack

According to Eurocode 2 (EN 1992-1-1), the allowable short-term crack satisfies the condition.

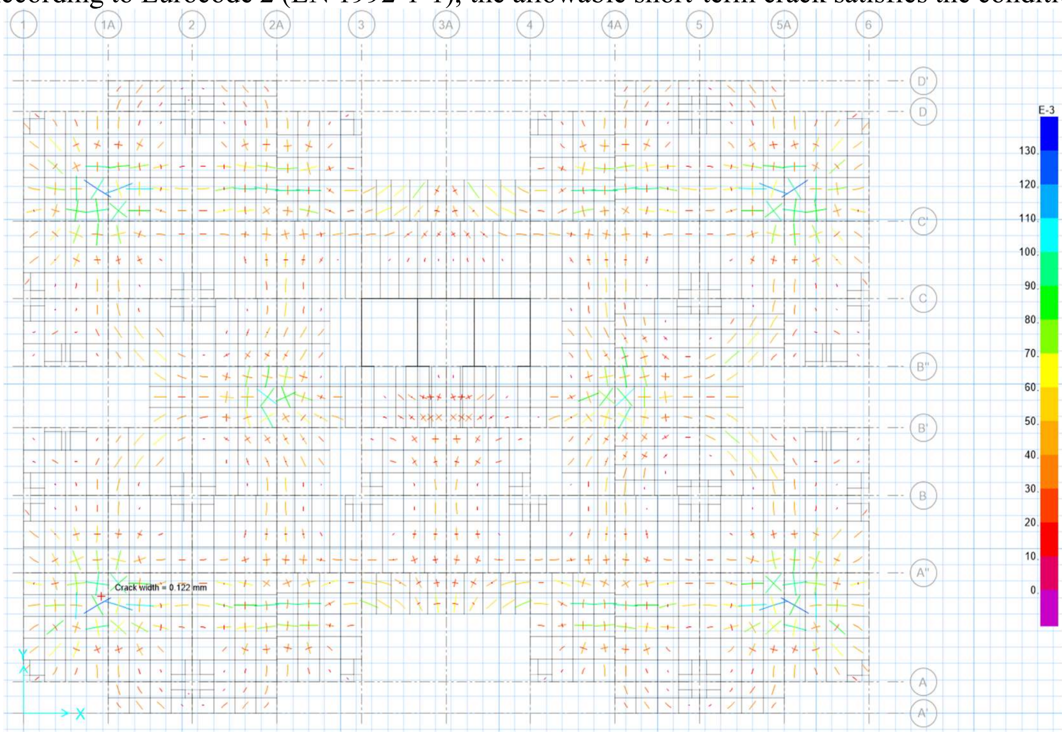

Figure 7. Short-term crack values in SAFE.

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Figure 7 presents the short-term crack-width distribution obtained from the SAFE analysis. Crack formation is concentrated in areas experiencing higher tensile stresses, particularly near regions of maximum bending moment. The overall crack-width pattern is consistent with the expected structural behavior of reinforced concrete floor systems. Since all crack widths remain below the allowable limit, the structure satisfies the serviceability requirements related to crack control under short-term loading conditions.
Based on the SAFE software, the short-term crack width is calculated: $\mathrm{arc}_1 = 0{,}122$mm.
$\mathrm{arc}_1 = 0{,}122 \text{ mm} < [\mathrm{arc}] = 0{,}4\ mm$ → The slab satisfies the short-term crack condition.

3.4.2. Long-term crack

According to Eurocode 2 (EN 1992-1-1), with the allowable long-term crack satisfying the condition: $\mathrm{arc}_2 \le [\mathrm{arc}] = 0{,}3$mm.

The long-term crack-width distribution illustrated in Figure 8 demonstrates the influence of sustained service loading on the floor system. Compared with the short-term condition, a moderate increase in crack width is observed due to creep and shrinkage effects. Nevertheless, the maximum crack width remains within the Eurocode allowable range, confirming the long-term durability and serviceability of the structural system.
Based on the SAFE software, the long-term crack width is calculated: $\mathrm{arc}_2 = 0{,}077$mm.
$\mathrm{arc}_2 = 0{,}077 \text{ mm} < [\mathrm{arc}] = 0{,}3\ mm$ → The slab satisfies the long-term crack condition.

3.5. Calculate the deflection of the slab.

The maximum deflection of the slab must satisfy the condition:

$$\mathrm{f_{max}} \le \mathrm{f_{limit}}$$

Figure 9 illustrates the global deflection behavior of the floor system obtained from finite element analysis. The maximum deflection occurs in the central span, where structural flexibility is greatest. The deformation contours indicate a realistic load distribution and interaction between slabs and supporting beams. Since the calculated maximum deflection is lower than the allowable limit specified by Eurocode 2, the floor system can be considered satisfactory with respect to serviceability requirements.
With the maximum deflection calculated based on the SAFE model: $\mathrm{f_{max}} = 27{,}45$mm.
The limit deflection calculated by the above formula has a length L = 9m:

$$\mathrm{f_{limit}} = \frac{\mathrm{L}}{200} = \frac{9000}{200} = 45\text{mm}$$

With $\mathrm{f_{limit}} = 45 \text{ mm} > \mathrm{f_{max}} = 27{,}45 \text{ mm}$ → The slab satisfies the deflection condition.

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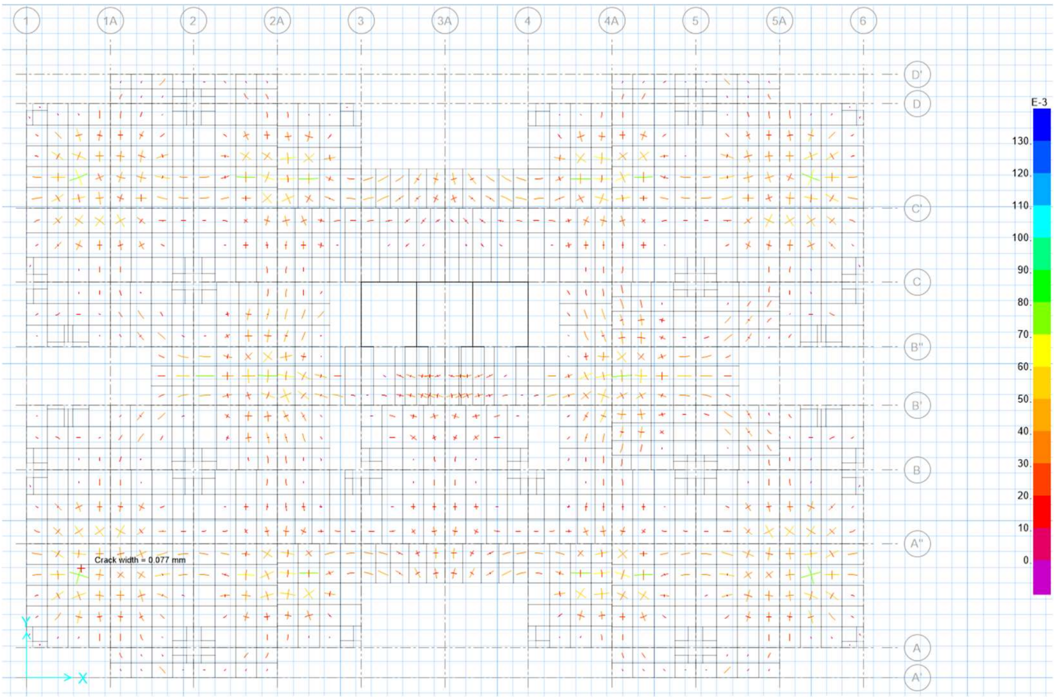

Figure 8. Long-term crack values in SAFE.

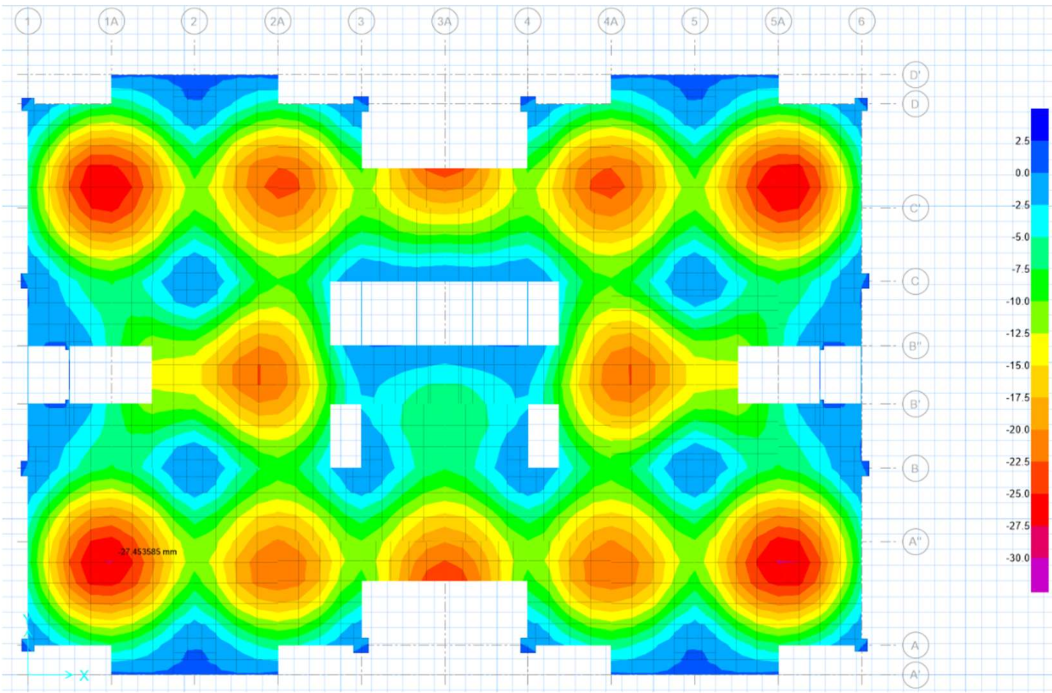

Figure 9. Deflection values in SAFE.

3.6. Discussions

The finite element analysis results demonstrate that all structural components satisfy the serviceability requirements specified by Eurocode 2. The calculated crack widths for both slabs and beams remained significantly below the allowable limits. For example, the maximum long-term crack width of the main beam was only 0.085 mm, corresponding to approximately 28% of the Eurocode limit of 0.30 mm, while the maximum slab crack width did not exceed 0.22 mm. These results indicate that the selected reinforcement arrangement effectively controls tensile cracking and provides adequate durability for the reinforced concrete floor system.

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The obtained crack-width values are consistent with the findings reported by Ahmed and Hassan [3], who observed that properly reinforced RC beams under service loads generally exhibit crack widths considerably lower than code limits. Similarly, Wang et al. [7] reported that appropriate reinforcement detailing and load distribution mechanisms can effectively restrict crack propagation in reinforced concrete floor systems. The agreement between the present study and previous investigations confirms the effectiveness of Eurocode-based reinforcement design in controlling serviceability-related cracking.

Regarding slab behavior, the present results are comparable with those reported by Silva and Costa [5] and Garcia and Torres [13], who demonstrated that finite element models provide reliable predictions of crack formation and serviceability performance in reinforced concrete slabs. In both studies, the calculated crack widths remained below the allowable limits, consistent with the observations from the present investigation. Furthermore, the relatively small increase in crack width between short-term and long-term loading conditions suggests that creep and shrinkage effects did not significantly compromise structural performance.

The deflection results also provide important insights into the serviceability behavior of the floor system. Although all structural elements satisfied the allowable deflection criterion, the main beam exhibited the highest deflection, reaching 27.6 mm, exceeding the allowable limit of 34 mm. This indicates that deflection control may govern the serviceability design of long-span reinforced concrete members. Similar observations were reported by Kim and Lee [2], who found that long-term deformation caused by creep and shrinkage often becomes the controlling serviceability criterion in RC floor systems. Kumar and Singh [6] likewise concluded that sustained loading effects significantly influence long-term beam deflections and should be carefully considered during design.

The present findings also agree with the results reported by Tran and Nguyen [8] and Pham and Vo [14], who demonstrated that long-term serviceability performance is strongly affected by member stiffness and reinforcement ratio. In the current study, despite sustained loading, all calculated deflections remained within the Eurocode limits, confirming the adequacy of the selected structural dimensions and reinforcement layout.

From a numerical modeling perspective, the SAFE finite element model successfully captured the interaction between slabs and supporting beams and realistically represented the redistribution of internal forces throughout the floor system. This observation is consistent with the conclusions of Ibrahim and Mahmoud [9] and Nguyen and Huang [4], who emphasized that finite element techniques can significantly improve the prediction accuracy of stress concentrations, cracking behavior, and structural deformation compared with simplified analytical approaches.

Compared with previous studies that mainly focused on isolated beams [3], [6], [14] or individual slabs [5], [8], [13], the present research provides an integrated assessment of an entire slab–beam floor system under serviceability limit state conditions. This integrated approach represents the study's main contribution because it evaluates crack-width control and deflection performance simultaneously within a realistic building-floor configuration. The results demonstrate that SAFE-based finite element analysis combined with Eurocode 2 verification procedures provides a reliable framework for practical serviceability assessment.

No significant contradictions with the existing literature were observed. Instead, the findings reinforce the conclusions of previous researchers that adequate reinforcement detailing, appropriate member dimensions, and realistic numerical modeling are essential for achieving satisfactory serviceability performance in reinforced concrete floor systems. Therefore, the proposed methodology can serve as a practical tool for structural engineers during both the design and verification stages of reinforced concrete buildings.

4. Conclusions

This study investigated the serviceability performance of a reinforced concrete floor system comprising slabs, main beams, and secondary beams through finite-element analysis using SAFE software, in accordance with Eurocode 2 provisions. The primary objective of the research was to

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verify whether the proposed structural design satisfies the serviceability limit-state requirements for crack-width and deflection control under both short- and long-term loading conditions.

The results demonstrated that all structural components fulfilled the serviceability requirements specified by Eurocode 2. The calculated crack widths for both slabs and beams remained significantly below the allowable limits, indicating that the selected reinforcement arrangement effectively controlled tensile cracking and ensured adequate durability. Likewise, the computed long-term deflections were smaller than the permissible values, confirming that the floor system possesses sufficient stiffness to maintain functionality, occupant comfort, and the integrity of non-structural elements throughout its service life.

The numerical analysis further revealed that long-term deflection is a more critical serviceability criterion than crack width for the investigated floor system, particularly in the main beam, where the deflection utilization ratio approached the allowable limit. Nevertheless, all serviceability criteria were satisfied with an adequate margin of safety. The finite element model also successfully captured the interaction between slabs and beams and provided realistic predictions of structural behavior under service loads.

Overall, the findings confirm the effectiveness of combining SAFE-based finite element analysis with Eurocode 2 verification procedures for evaluating reinforced concrete floor systems. The study successfully achieved its research objective by demonstrating that the investigated structural configuration meets the required serviceability limit-state criteria and can therefore be considered suitable for practical engineering applications.

Acknowledgements

We thank to DLA for support.

References

[1] Y. Zhang, H. Li, and X. Chen, “Serviceability assessment of reinforced concrete floor systems using finite element analysis,” Engineering Structures, vol. 312, Art. no. 118245, 2024.
[2] J. Kim and S. Lee, “Long-term deflection behavior of reinforced concrete slabs considering creep and shrinkage effects,” Structures, vol. 54, pp. 1021–1034, 2023.
[3] M. Ahmed and R. Hassan, “Numerical investigation of crack width development in reinforced concrete beams under service loads,” Case Studies in Construction Materials, vol. 17, Art. no. e01345, 2022.
[4] H.-D. Nguyen and S.-C. Huang, “Numerical modeling of crack propagation in reinforced concrete structures using finite element techniques,” Theoretical and Applied Fracture Mechanics, vol. 127, Art. no. 103985, 2023.
[5] P. Silva and A. Costa, “Evaluation of serviceability limit states in reinforced concrete slabs according to Eurocode 2,” Journal of Building Engineering, vol. 44, Art. no. 102891, 2021.
[6] R. Kumar and V. Singh, “Finite element assessment of reinforced concrete beam deflection under sustained loading,” Materials Today: Proceedings, vol. 84, pp. 1123–1130, 2024.
[7] L. Wang et al., “Cracking behavior of reinforced concrete floor systems under service loads,” Structures, vol. 41, pp. 1750–1762, 2022.
[8] Q. H. Tran and T. D. Nguyen, “Serviceability performance of RC slabs subjected to long-term loading effects,” Journal of Structural Engineering, vol. 149, no. 6, Art. no. 04023065, 2023.
[9] A. Ibrahim and K. Mahmoud, “Numerical simulation of reinforced concrete slab deflection using SAFE software,” Ain Shams Engineering Journal, vol. 12, no. 4, pp. 3891–3902, 2021.
[10] D. Patel and P. Shah, “Crack-width prediction in reinforced concrete beams under flexural loading,” Engineering Failure Analysis, vol. 118, Art. no. 104932, 2020.
[11] K. Lee and J. Park, “Comparative evaluation of Eurocode 2 serviceability criteria for RC floor systems,” Structures, vol. 67, Art. no. 106512, 2025.
[12] Z. Chen et al., “Durability-oriented crack control in reinforced concrete structures,” Construction and Building Materials, vol. 418, Art. no. 135421, 2024.

Journal Innovation of Civil Engineering
Vol. 7, No. 1, pp. 203-216
Submit: 17-12-2025 |
Accepted: 22-06-2026 |
Publish: 29-06-2026 |

[13] M. Garcia and R. Torres, "FEM-based serviceability evaluation of multi-span reinforced concrete slabs," Buildings, vol. 12, no. 8, Art. no. 1154, 2022.
[14] T. H. Pham and N. P. Vo, "Assessment of long-term serviceability behavior in reinforced concrete beams," Materials, vol. 16, no. 11, Art. no. 4012, 2023.
[15] M. Al-Saadi and H. Kareem, "Structural performance of reinforced concrete floor systems under service conditions," Applied Sciences, vol. 11, no. 19, Art. no. 9147, 2021.
[16] Y. Zhou et al., "Advanced finite element simulation for crack control in reinforced concrete members," Engineering Structures, vol. 325, Art. no. 119002, 2025.
[17] P. N. Hoang and H.-D. Nguyen, "Numerical assessment of crack width limitation in reinforced concrete slabs according to Eurocode 2," Journal of Asian Architecture and Building Engineering, vol. 23, no. 4, pp. 1456–1468, 2024.