PRINCIPLES OF STRUCTURAL DESIGNS

Table of Contents

Introduction

Structural engineering is one of the core branches of civil engineering. Structural engineering ensures that buildings and other infrastructures are able to resist the loads applied to them in a stable way and ensure long-term sustainability and durability. Modern multi-storey buildings often use steel and reinforced concrete structures, as such materials possess high strength, good design capabilities, fire resistance, and are cost-effective (Islam *et al.* 2025). Steel structures have great tensile strength, quick erection process and low structural weight, while reinforced concrete structures are characterised by great compressive strength and stiffness. The present report aims to produce a comprehensive technical report for conducting a structural analysis and preliminary design of the "Lawan Project". The project entails constructing sixteen six-storey residential buildings using steel and reinforced concrete structures. Being a junior structural design technician at Alanint Consultants Ltd., my task is to show how principles of structural design can be applied, following all the rules and requirements of the UK Building Regulations and Eurocodes. The report will consider the design of bending moments, shear forces, beam deflections and column load capacities before designing beams and columns. In addition, design approaches, materials used, building information modelling and engineering drawings will be discussed in order to make right decisions about the design of structures. The study also examines the behaviour of structures with varying loads and supports. It also analyses the comparison between the performance of steel structures and reinforced concrete. The suggested structural design will take into account the structural aspects of safety, serviceability, durability, and economic viability for meeting the functional requirements of the housing development. This will be done by incorporating appropriate engineering principles, designing standards, and material selection.

2. Task 1: Bending Moments, Shear Forces and Safety Factors

2.1 Bending Moment and Shear Force Calculations

Structural beams are mainly designed to prevent externally implemented loads through the development of the internal shear forces and bending moments (Foraboschi, 2022). Shear force shows the internal transverse force acting on a beam section, while the bending moment shows the internal resistance built against the beam curvature. The distribution and magnitude of these forces govern the structural safety, serviceability, and member selection. In terms of the simply supported beams, equilibrium situations are used in order to identify the support reactions before constructing the Shear Force Diagrams (SFDs) and Bending Moment Diagrams (BMDs). These diagrams are the important tools in the structural designs as they determine critical sections subjected to increased stresses.

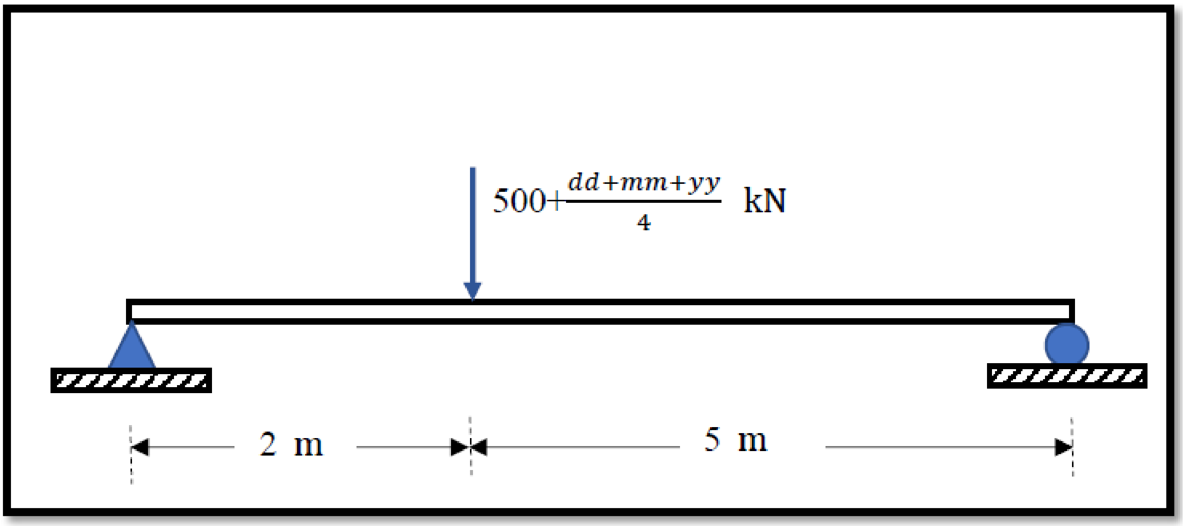

Figure 1: Simply Supported Beam with Point Load

Span:

$$L = 15m$$

Load position:

$$a = 5m$$

Distance from right support:

$$b = 10m$$

Taking moments about support A:

$$RB\ (15)\ = 529(5)$$

$$RB = 176.33\ kN$$

Using vertical equilibrium:

$$RA + RB = 529$$

$$RA = 529 - 176.33$$

$$RA = 352.67\ kN$$

Maximum bending moment occurs directly beneath the load:

$$Mmax = RA(5)$$

$$Mmax = 352.67 \times 5$$

$$Mmax = 1763.35\ kNm$$

SFD values:

$$V = +352.67\ kN$$

At load position:

$$V = 352.67 - 529$$

$$V = -176.33\ kN$$

BMD characteristics:

- Zero moment at supports.
- Linear increase to maximum value beneath load.
- Linear decrease towards right support.

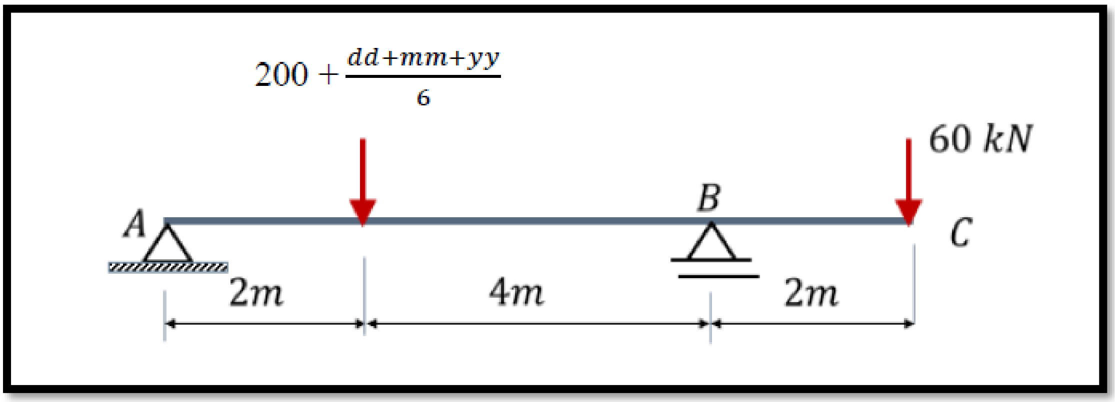

Figure 2: Overhanging Beam with Point Load

Overhang:

$$2m$$

Main span:

$$10m$$

Total length:

$$12m$$

Taking moments about support A:

$$RB\ (10) = 219.33(12)$$
$$RB = 263.20\ kN$$

Using equilibrium:

$$RA + RB = 219.33$$
$$RA = -43.87\ kN$$

Negative reaction indicates uplift at support A caused by the overhanging load.

Maximum negative bending moment occurs at support B:

$$MB = -219.33(2)$$
$$MB = -438.66\ kNm$$

SFD characteristics:

- Constant negative shear between supports.
- Sudden drop at load application point.
- Negative bending develops over support B.

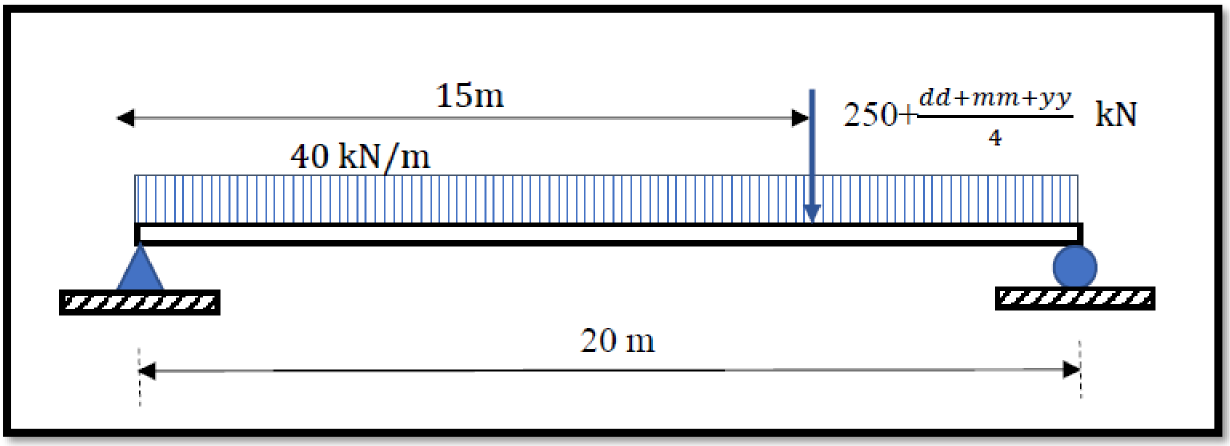

Figure 3: Beam Subjected to UDL and Point Load

Equivalent UDL load:

$$W = wL$$

$$W = 40(20)$$

$$W = 800\,kN$$

Total load:

$$WT = 800 + 279$$

$$WT = 1079\,kN$$

Assuming point load acts at midspan:

$$RA = RB = 1079/2$$

$$RA = RB = 539.5\,kN$$

Maximum bending moment:

$$MUDL = wL2/8$$

$$MUDL = 40(20)/28$$

$$MUDL = 2000\,kNm$$

Moment due to point load:

$$MP = PL/4$$

$$MP = 279(20)/4$$

$$MP = 1395\,kNm$$

Therefore:

$$Mmax = 2000 + 1395$$

$$Mmax = 3395\,kNm$$

Because of the uniformly distributed loading, the SFD is linear and the BMD is parabolic and for uniformly distributed load the BMD has a maximum value at the midpoint. Figure 3 provides the greatest bending moment and is hence the design condition for the three cases analysed. The results show that increasing the span length has caused a significant increase in flexural demands, which is automatically translated into the need to use bigger beam sections with greater moment resistance and stiffness to meet structural safety and serviceability criteria, particularly under distributed loading (Bagheri *et al*. 2025).

2.2 Statutory Requirements

Structural design in the United Kingdom is regulated by statutory requirements and accepted design codes for the structural strength, stability, durability and safety of a structure during its service life (Vagtholm *et al.* 2023). Approved Document A – Structure – of the Building Regulations states that buildings must resist overturning, progressive collapse, wind and accidental loads, and resist excessive movement or collapse to the foundations.

The structural design process for the Lawan Project are based on BS EN 1990 (Eurocode 0) which sets out the principles of reliability, limit state design and load combinations and forms the basis of structural design. Eurocode 0 lays down the usage of the Ultimate Limit States (ULS) and the Serviceability Limit States (SLS) to make sure that structures are safe to use and perform well in their intended use.

The design of reinforced concrete members has been laid out in the following applied standards:

BS EN 1992 (Eurocode 2): It offers recommendations for flexural strength, shear resistance, crack control, durability, reinforcement detailing and column design. Concrete members should be designed to meet both strength and serviceability requirements and should be sufficiently fire resistant.

BS EN 1993 (Eurocode 3): Applies to the design of structural steelwork including designing beams, columns, connections and stability verification. For steel members, the following considerations for overturning, buckling, lateral torsional instability and excessive deflection should be discussed.

ULS verifies the load structures against the collapse state because of factored loading. The deflections, vibrations and cracking at the SLS are restricted to ensure functionality and passenger comfort (Xie and Hua, 2024). Structural robustness provisions extend this further as a localised failure does not lead to disproportionate collapse, adding the capacity to strengthen resilience of the building frame.

2.3 Factors of Safety

Factors of safety are used in structure design to allow for factors such as uncertain material properties, tolerances for construction, variability in loadings, and conditions that are unknown at the time of design (Gaidai *et al.* 2026). The dead loads (causes of those loads which are present in construction permanently or for a period much longer than the design life of the structure that they load) are symbolized by Gk. The live loads (causes of those loads which are present in construction for a time considerably shorter than the design life of the structure on which they are imposed) are symbolized by Qk.

For Ultimate Limit State design, the recommended partial safety factors are:

γG=1.35
γQ=1.50

where:

- γG = partial factor for permanent actions.
- γQ = partial factor for variable actions.

For the Lawan Project:

$$Gk = 7\ kN/m2$$
$$Qk = 3\ kN/m2$$

The design floor load is calculated as:

$$qd = (1.35Gk)\ +\ (1.5Qk)$$

$$qd =\ (1.35 \times 7)\ + (1.5 \times 3)$$

$$qd = 9.45 + 4.50$$

$$qd = 13.95\ kN/m2$$

Therefore:

$$qd = 13.95\ kN/m2$$

This figure indicates the design load based on which the beam, slab, and column dimensions are determined at the ultimate load level. The use of partial factors in the design aims at achieving a conservatively safe margin of the structure while still keeping the reliability level at acceptable limits. These factors are mainly determined through probabilistic methods and correspond to a reliability level that meets the safety requirements of present-day structures.

2.4 Economic and Safe Beam Selection

The assignment specifies a maximum bending moment of:

$$MEd = 200\, kNm$$

According to Eurocode 3, the selected Universal Beam must possess a design moment resistance greater than the applied design moment:

$$MRd \geq Med$$

Assuming structural steel grade S355:

$$fy = 355\, MPa$$

The required plastic section modulus is:

$$Wpl, req = fyMEd \times 106$$

$$Wpl, req = 355200 \times 106$$

$$Wpl, req = 563{,}380mm3$$

UB 356×171×51 is a standard steel table section that fits well the physical and mechanical properties of the steel member section requirements such as plastic section modulus, bending resistance and stiffness. The beam can sustain the required bending moment while its self-weight is quite low as compared with bigger sections. From the economical point of view, choosing the beam size beyond the necessity will lead to an increase in the amount of steel, fabrication costs, transportation and carbon embodiment (Damtsas *et al.* 2025). On the other hand, a beam that is too small in size will either fail in moment capacity or will deflect beyond the limit. However, the selection of a beam must be a compromise between structural performance and material efficiency. Besides, the chosen UB section can also meet serviceability requirements by restricting deflection to the Eurocode limit for:

$$L/250$$

floor beams. A further reduction in deflection enhances the comfort of occupants and reduces the cracking of finishes. Besides, meeting Approved Document A and Eurocode 3 assures the safety of the structural member against yielding and instability. In other words, the UB 35617151 section is a cost-effective and technically well-founded solution that fulfils strength stiffness durability and safety requirements of the Lawan Project.

3. Task 2: Deflection and Support Methods

3.1 Deflection Calculations

Deformation of beams is another factor that should be taken into account when designing a structure due to possible adverse effects on its performance, comfort of its users, and the durability of non-structural elements. Deflections beyond certain limits lead to issues related to the functionality and appearance of the structure, as well as damages to the finishes and non-structural parts of the building (Bado, 2021). In order to comply with the task's requirements, deflection of the simply supported steel beam (fig. 4) and the reinforced concrete beam (fig. 5) was calculated according to the set loads.

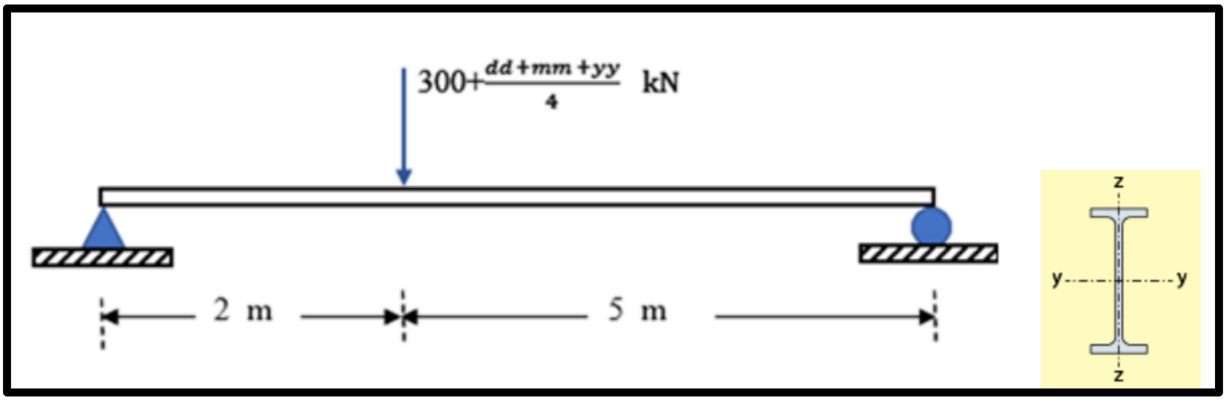

Figure 4: Simply Supported Steel Beam (UB 406 × 140 × 53) Subjected to an Eccentric Point Load for Deflection Analysis

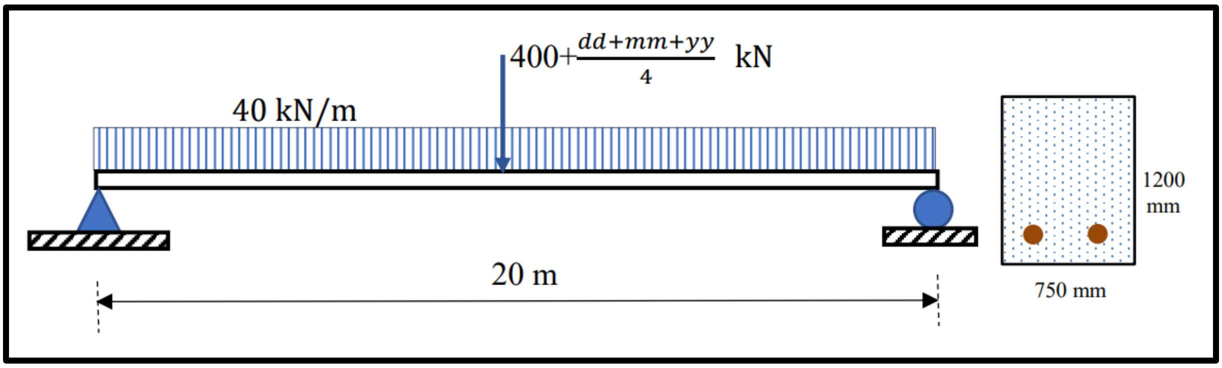

Figure 5: Simply Supported Reinforced Concrete Beam Subjected to a Uniformly Distributed Load and Central Point Load for Deflection Analysis

Based on the chosen date 29/04/1983, the value of load increment can be calculated as $dd + mm + yy = 29 + 04 + 83 = 116$, resulting in an additional load of $116/4 = 29$kN. Thus, the applied point loads are 329 kN for the steel beam and 429 kN for the reinforced concrete beam. Calculation of the maximum deflection of the steel beam UB 406 × 140 × 53 span = 7 m, point load = 329 kN, position of load – 2 m from the left support. Modulus of elasticity = E = 200,000 N/mm², second moment of area = I = 185.57 × 10^6 mm⁴ (from UK Steel Section Properties). Maximum deflection of the simply supported beam subjected to eccentric point load was calculated as:

$$y_{max} = \frac{P\,a\,(L^2 - a^2)^{3/2}}{9\sqrt{3}\,L\,E\,I}$$

With these new design values substituted, the maximum deflection became 49.05 mm. The permissible serviceability limit was assumed to be L/250, and therefore, the allowable deflection is equal to:

$$\frac{7000}{250} = 28 \text{ mm}$$

As the calculated deflection value exceeds the allowable one, it means that the chosen section does not meet the serviceability criterion and needs to be redesigned into a larger Universal Beam section or a different structural configuration. It is stated in Eurocode that deflections of structural elements must be controlled such that serviceability and protection of neighboring structural and non-structural elements are achieved (Honfi *et al.* 2012). The reinforced concrete beam has a rectangular section 750 mm × 1200 mm with a 20 m span, and it is loaded by the uniformly distributed load of 40 kN/m and a 429 kN central point load. As there is no information about the effective cracked-section stiffness provided in the assignment, the gross section moment of inertia was used for the preliminary design evaluation:

$$I = \frac{bh^3}{12} = \frac{750 \times 1200^3}{12} = 1.08 \times 10^{11}\ \text{mm}^4$$

The maximum deflection was calculated using the superposition principle, which implies that the deflections caused by the uniformly distributed load and the central point load should be added. They amounted to 3.86 mm and 3.31 mm, respectively; the total maximum deflection is 7.17 mm. With the application of the same serviceability criterion, the allowable deflection is:

$$\frac{20\,000}{250} = 80\ \text{mm}$$

As the calculated deflection value is considerably less than the allowable one, it means that the reinforced concrete beam meets the serviceability criteria. A comparison of the two structural elements demonstrates that the deflection of the reinforced concrete beam is much smaller as a result of its considerably higher second moment of area. Thus, the reinforced concrete section meets the chosen Eurocode serviceability criterion, while the chosen steel section needs to be redesigned.

3.2 Effect on Structural Stability

The structural stability is highly dependent on the deflection in the beams, as any deflection may negatively influence the serviceability and durability of the construction. Despite the fact that the beam has enough strength to withstand the load, it is possible that the deflection will cause the serviceability failure before reaching the ultimate limit state. According to the Eurocode recommendations, it is required to control vertical deflections to prevent any damage to both the structural and non-structural elements and maintain their integrity and aesthetic appeal (Honfi *et al.* 2012). The excessive deflection in the beam will lead to cracking of the partition walls, ceilings, and floors, as well as distortions of doors and windows, affecting the usability of the structure. Moreover, the excessive deflection may cause unevenness of the floors, thus increasing the discomfort for the occupants. Apart from the immediate problems related to serviceability, the deflection may cause the deterioration of the building during its exploitation. In particular, repeated loads and deformations of the members will cause the redistribution of the stresses, acceleration of the creep and shrinkage of reinforced concrete, and reduction of the effectiveness of the load transfer between beams and supporting elements.

Moreover, the deformation will cause additional maintenance works and decrease the design life of the construction. Thus, it is essential to design the structural members in accordance with the requirements concerning strength and deflections.

3.3 Analysis of Support Methods

The choice of a proper support method is one of the key factors that affects the structural behavior, stiffness and serviceability of a beam. One can compare how the support conditions affect beam deflection based on standard beam deflection equations. For a uniformly distributed load, the maximum deflection of a simply supported beam is:

$$\delta_{SS} = \frac{5wL^4}{384EI}$$

whereas the corresponding maximum deflection for a beam fixed at both ends is:

$$\delta_{Fixed} = \frac{wL^4}{384EI}$$

Therefore, a fixed beam has only 20% of the deflection that a simply supported beam has for the same loading, which means an 80% decrease in vertical displacements. For instance, if a simply supported beam deflects 50 mm, a fixed beam will deflect about 10 mm and a continuous beam about 18–22 mm since the internal supports redistribute bending moments and increase stiffness. The analysis of a continuous beam is necessary for the accurate determination of bending moments, shear forces and maximum deflections when designing a structure (Almayah, 2018). In addition, the behaviour of beams depends greatly on boundary conditions and flexural rigidity, and greater stiffness leads to smaller deflections and improves the beam's response prediction when loads are applied (Niiranen *et al.* 2019). Therefore, the continuous support system is preferable when designing multi-storey buildings made of steel and reinforced concrete.

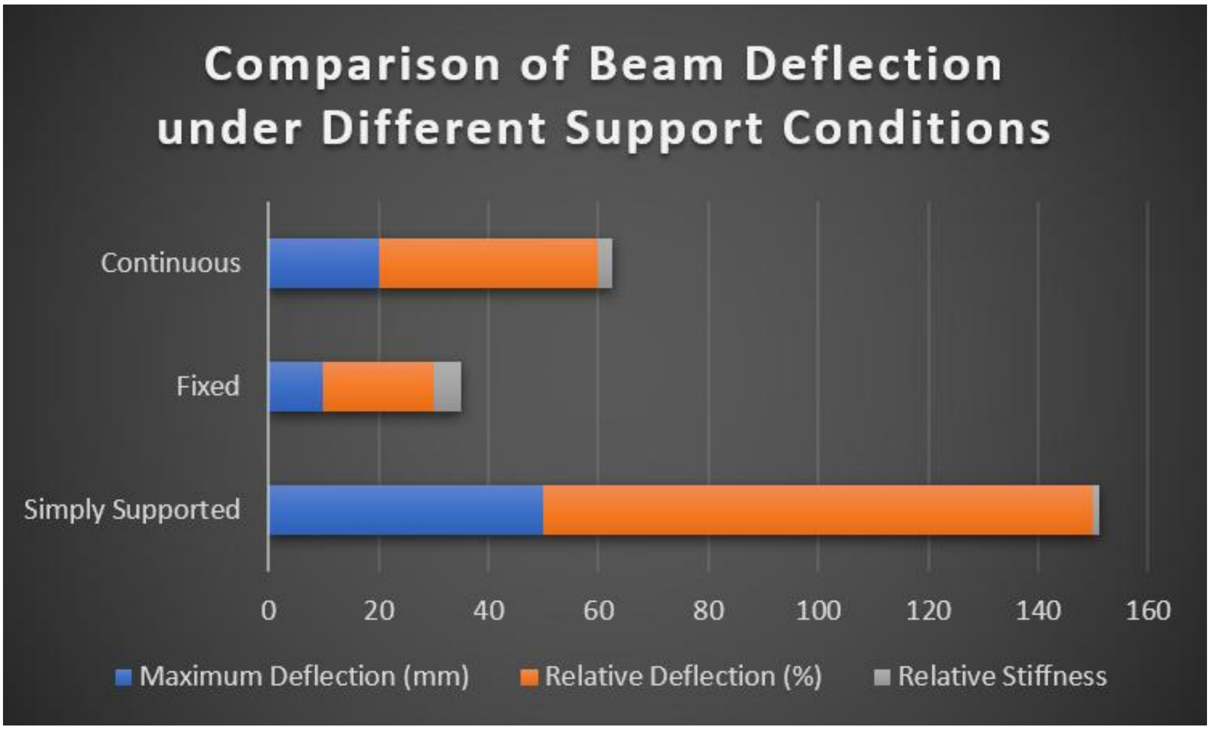

Figure 6: Comparison of Beam Deflection.

3.4 Most Effective Support Method

The choice of the most appropriate support method is determined by the structural needs, loading and serviceability criteria of the structure. The comparative analysis shows that the most appropriate support method for the Lawan Project will be the continuous beam. Unlike a simple supported beam, a continuous beam transfers loads through several spans, reducing the value of positive bending moments and preventing beam deflections (Ghasemi *et al.* 2015). Better load distribution improves the stiffness of the building and increases its overall stability by using construction materials more effectively. In comparison with a fixed beam, the continuous beam makes it possible to reach a good compromise between performance and cost of the building. Continuous beam reduces deflection without applying the restraints to the beam, which are needed in the case of fixed support (Foster *et al*. 2015). That is why continuous beams are used widely in reinforced concrete and steel frames of multi-storey buildings. It is noted from the comparative analysis that the deflection experienced by a simply supported beam could be up to 50mm. However, the use of fixed support and continuous beam support reduces the deflection to about 10mm and 20 mm.

4. Task 3: Axial Load Capacity of Columns

4.1 Slenderness Ratio and Effective Length

The load carrying capacity of a compression member is greatly affected by its slenderness ratio and effective length (Uslu and Taşkın, 2024). These factors decide how likely a column is to buckle and fail before the material actually reaches its compressive strength. Based on Euler's elastic buckling theory, a column that is very long and slender will fail mainly by becoming laterally unstable, while a short one fails because the material is crushed or yields.

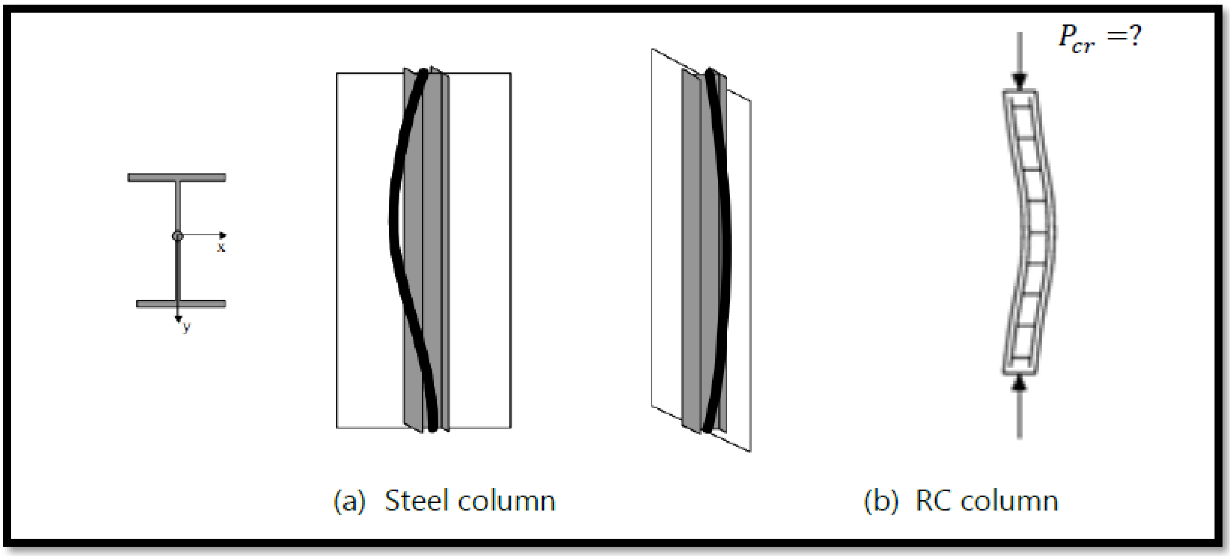

Figure 7: Effective length

The slenderness ratio is defined as:

$$\lambda = rLe$$

Where:

$$Le = Effective\ Length\ (mm)$$

$$r = IAr = \backslash sqrt\{\backslash frac\{I\}\{A\}\}r = AI$$

I is the second moment of area and A is the cross-sectional area.

For a pinned-pinned column:

$$Le = L$$

Given:

$$L = 3.75m = 3750mm$$

For the 450 mm × 450 mm reinforced concrete column:

$$A = 450 \times 450$$

$$A = 202{,}500mm2$$

Moment of inertia:

$$I = 12bd3/12$$

$$I = 12450(450)3/12$$

$$I = 3.42 \times 109mm4$$

Radius of gyration:

$$r = 202{,}5003.42 \times 109$$

$$r = 129.9mm$$

Therefore:

$$\lambda = 129.9/3750$$

$$\lambda = 28.9$$

4.2 Axial Load Capacity Calculations

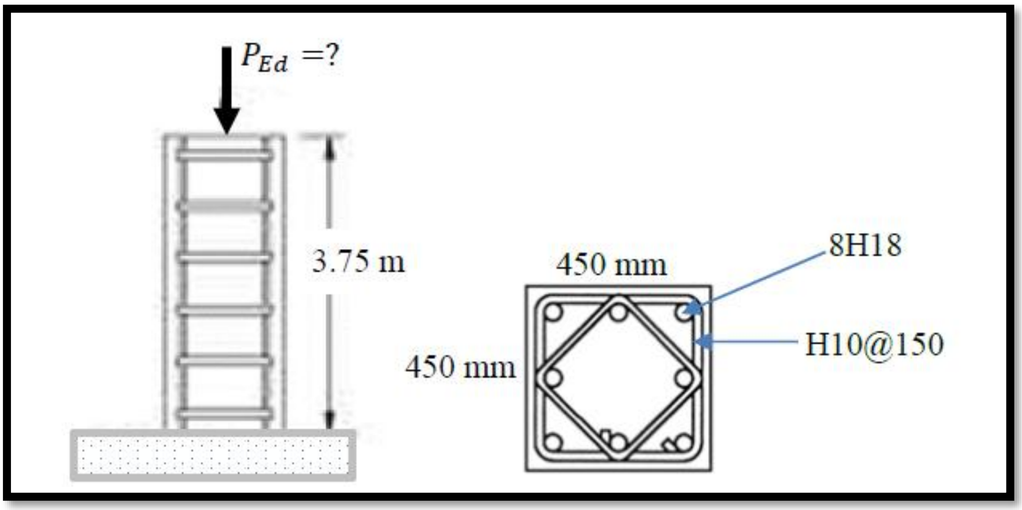

Figure 8: Cross section of the RC column

Reinforced Concrete Column

The assignment specifies a reinforced concrete column with dimensions of 450 mm × 450 mm reinforced with 8H18 longitudinal bars using concrete grade C30/37 and steel grade 500 MPa.

Verification of Short Column

Previously calculated:

$$\lambda = 28.9$$

Since:

$$\lambda < 40$$

the column can be classified as a short column.

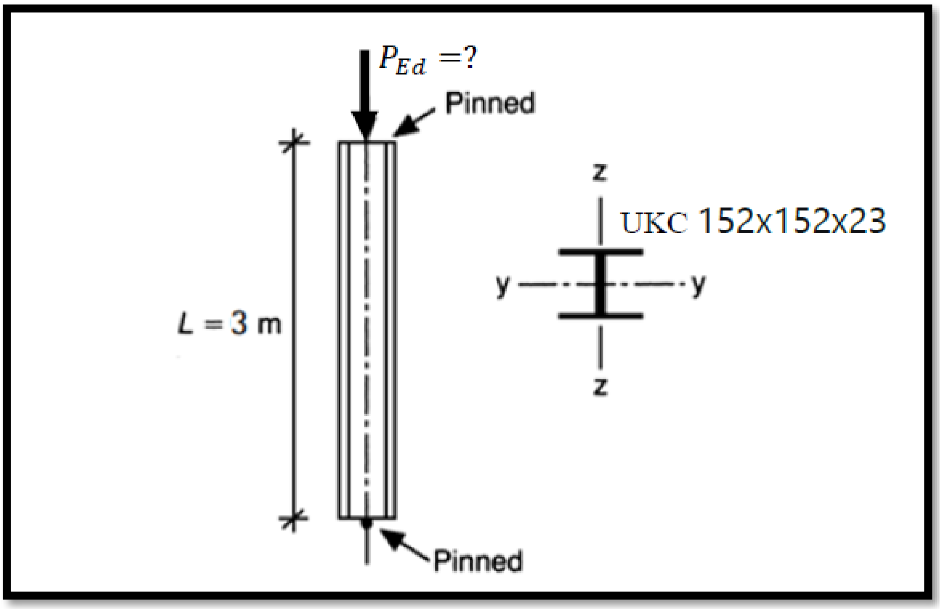

Figure 9: Steel column

Steel Reinforcement Area

Area of one 18 mm bar:

$$As = 4\pi d2$$

$$As = \pi\ (18)24$$

$$As = 254.47mm2$$

Total reinforcement:

$$Asc = 8(254.47)$$

$$Asc = 2035.8mm2$$

Concrete area:

$$Ac = 202{,}500 - 2035.8$$

$$Ac = 200{,}464mm2$$

According to Eurocode 2, axial design resistance is:

$$NRd = 0.4fckAc + 0.67fyAsc$$

Substituting:

$$NRd = 0.4(30)\ (200{,}464)\ + 0.67(500)\ (2035.8)$$

$$N\_\{Rd\} = 2{,}405{,}568 + 682{,}000$$

$$NRd = 3{,}087{,}568NN$$

$$NRd = 3088kNN$$

Steel Column (UC 152×152×23)

The steel column has a length of 3 m with pinned end conditions.

Typical properties:

$$A = 2930mm2$$

$$rmin = 39mm$$

Slenderness ratio:

$$\lambda = 39/3000$$

$$\lambda = 76.9$$

Since:

$$\lambda < 90$$

the member is considered a short-to-intermediate column.

Using structural steel grade S355:

$$fy = 355MPa$$

Axial design resistance:

$$NRd = Afy\,NRd = 2930(355)$$

$$NRd = 1{,}040{,}150N$$

$$NRd = 1040kN$$

Engineering Interpretation

The reinforced column has an axial capacity of around 3088 k N which is over three times that of the UC 152×152×23 steel section. The major differences are largely due to the much larger cross-sectional area of the reinforced section and the benefit of composite action. The steel section has a much slenderer, lighter section but has a much lower axial resistance. For heavily loaded lower-storey columns, reinforced concrete is usually used as steel columns are not as efficient for this application.

4.3 Material Property Analysis

The most conventionally used structural materials within modern multi-storey buildings are reinforcing concrete and steel (Tenório *et al.* 2024). The advantage of each system will be determined by the loading requirements durability fire performance, sustainability expectations and costs. Steel has a better strength-to-weight ratio and quick construction time whereas reinforced concrete demonstrates formidable compressive strength, fire resistance and historical stability.

Table 4.3.1 Comparison of Steel and Reinforced Concrete Columns

Property	Reinforced Concrete	Structural Steel
Load Capacity	Very high compressive capacity	High tensile and compressive strength
Self-Weight	High	Low
Strength-to-Weight Ratio	Moderate	Excellent
Corrosion Resistance	Good due to concrete cover	Requires protective coating
Durability	Excellent in normal environments	Dependent on maintenance
Fire Resistance	Excellent	Requires fire protection systems
Construction Speed	Slower due to curing	Faster erection and installation
Sustainability	High thermal mass, recyclable reinforcement	Fully recyclable material
Maintenance	Low	Moderate to high
Initial Cost	Generally lower	Higher material cost

The reinforced concrete column of the previous analysis was able to support an axial capacity of about 3088 kN, compared to 1040 kN for the steel UC section. Reinforced concrete is clearly appropriate for heavily loaded foundations and lower-storey columns, but steel columns produce the same structural capacity with smaller cross-sectional area, increasing space efficiency inside the building. From a durability viewpoint, reinforced concrete is better suited to aggressive environments, since it is the concrete cover which brings protection for reinforcement against corrosion (Coppola *et al.* 2022). Steel structures must be coated, galvanised or applied with intumescent paint systems to ensure durability. In a fire scenario, concrete However offers a natural insulation, with steel losing strength quickly above 550C.

5. Task 4: Design Solutions and BIM

5.1 Beam and Column Design Solution

The suggested structure for the Lawan project is based on the use of different alternatives of steel and reinforced concrete structure for the internal column B2 and beam C-23 of the ground floor. The design axial load for column B2 is estimated at 2700 kN, while beam C-23 is to span 8 m and bear a permanent load at 25 kN/m and an imposed load of 15 kN/m. In terms of a steel design option, the ground-floor internal column (B2) is to be formed from a Universal Column (UC) made of the high compressive strength S355 structural steel, allowing for minimizing its cross-section size and quick assembly due to its prefabrication. Also, the beam C-23 is expected to be designed as a Universal Beam (UB) capable of withstanding combined loadings and to minimize bending stress and deflection according to Eurocode 3 requirements. Simple beam-column connections facilitate the manufacturing and installation of steel beams and columns (Bishay-Girges, 2020). An alternative design of the ground floor internal column (B2) and beam C-23 is to utilize a reinforced concrete structure designed using the appropriate class of concrete. For example, C40/50 for the column and suitable longitudinal reinforcement and C35/45 concrete with proper tensile reinforcement to resist bending moments and shear forces for the beam C-23. Reinforced concrete structures have good fire-resistant properties and provide better stiffness and durability. Comparing both design options, steel construction allows for fast erection, lighter structures, and smaller sections. However, it usually involves a higher cost of materials and fire protection measures, while reinforced concrete requires less initial cost of materials, has good fire resistance, and lower cost of maintenance. Therefore, reinforced concrete design is preferred due to its optimal combination of safety, durability, fire performance, and low cost.

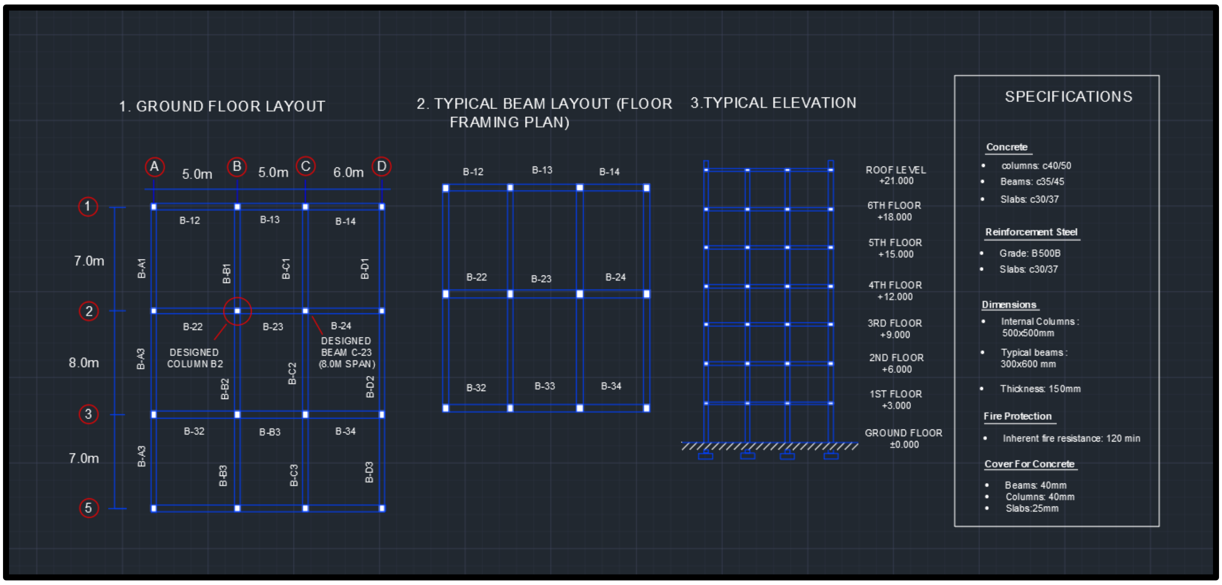

Figure 10: CAD Floor Layout, Beam Arrangement, Column Layout and Structural Specifications for the Lawan Project

Table 5.1.1 Comparison of Steel and Reinforced Concrete Design Solutions

Criteria	**Steel Design**	**Reinforced Concrete Design**
Column B2	UC section (S355), high compressive strength, smaller section	RC column (C40/50), high stiffness and fire resistance
Beam C-23	UB section with simple connections, lightweight and efficient	RC beam (C35/45), high rigidity and durability
Construction Speed	Fast due to prefabrication	Slower due to formwork and curing
Initial Cost	Higher material and fire protection cost	Lower material cost
Maintenance	Moderate	Low
Recommended Application	Fast-track projects	Multi-storey residential buildings (Recommended)

5.2 Alternative Material Evaluation

Glulam timber is a material that may be used as an alternative to steel as a material for the structure of the Lawan Project because of its high strength and low weight as well as environmental benefits due to lower embodied carbon (Abed *et al.* 2022). In comparison with structural steel, glulam requires less energy during production and promotes sustainable construction. Moreover, glulam has good fire performance due to protective char layer, which retards its structural degradation. However, glulam is more vulnerable to water damage and biodegradation without proper protection. Despite the higher carrying capacities and spans, glulam is an environmentally friendly solution for low- and medium-rise constructions.

5.3 Building Information Modelling (BIM) Assessment

Building Information Modelling (BIM) is a holistic digital approach that involves the development of intelligent three-dimensional models. This includes both geometry and engineering data that facilitate the planning, designing, construction and operation of the building (Yang *et al.* 2021). In the Lawan Project, BIM technology may be used for coordination of structural, architectural and building services disciplines, which will improve collaboration between designers, contractors and other project participants. One of the key advantages of BIM is clash detection, which reveals possible conflicts between the structural members, mechanical services, electric systems and plumbing before the start of construction. Clash detection helps reduce the number of design conflicts that may cause delays, additional costs and reduce the quality of the building. An example is the use of Autodesk Revit and Navisworks technologies, where the three-dimensional structural models are coordinated with architectural and MEP systems to detect clashes, revise designs and plan the construction process. Thus, BIM improves design accuracy, project coordination, reduces the risks of the construction process and increases the efficiency of project delivery.

6. Conclusion

This report has provided a thorough structural analysis and initial design of the Lawan Project of 16 six-storey residential buildings with steel and reinforced concrete structures. As part of the structural analysis bending moments, shear forces, beam deflections, column slenderness and capacity to axial loadings was analyzed per UK Building Regulations and relevant Eurocode standards. The beam analysis established the importance in the calculation of shear force and bending moment for the identification of critical loading and the selection of adequate structural members. The implementation of partial safety factors and load combinations guaranteed the satisfaction of the ULS provisions and the achievement of the required margins of safety to the structure. The deflection analysis gave further importance on the serviceability issues demonstrating that the designed reinforced concrete beam satisfied the deflections limitations, while the selected steel beam demanded for reconsideration of its design. In addition, the support system comparison revealed that the continuous beam configurations were the most successful solution due to their great effectiveness in reducing the deflections and distributing the applied loads. Lastly, the axial capacity analysis of the typical reinforced concrete column was much greater than that of the steel column and Because of this the former can be used in heavily loaded structures.

References

Abed, J., Rayburg, S., Rodwell, J. and Neave, M., 2022. A review of the performance and benefits of mass timber as an alternative to concrete and steel for improving the sustainability of structures. *Sustainability*, *14*(9), p.5570. https://doi.org/10.3390/su14095570

Almayah, A.A., 2018. Simplified analysis of continuous beams. *International journal of applied engineering research*, *13*(2), pp.922-928. https://www.academia.edu/download/83023286/ijaerv13n2_16.pdf

Bado, M.F., 2021. Distributed sensing for serviceability analysis of reinforced concrete structures. https://etalpykla.vilniustech.lt/bitstream/handle/123456789/107056/M_F_Bado%20disertacija.pdf?sequence=1

Bagheri, M., Malidarreh, N.R., Ghaseminejad, V. and Asgari, A., 2025, November. Seismic resilience assessment of RC superstructures on long–short combined piled raft foundations: 3D SSI modeling with pounding effects. In *Structures* (Vol. 81, p. 110176). Elsevier. https://www.academia.edu/download/124795211/1_s2.0_S2352012425019915_main.pdf

Bishay-Girges, N.W., 2020. Improved Steel Beam-Column Connections in Industrial Structures. *Engineering, Technology & Applied Science Research*, *10*(1). https://pdfs.semanticscholar.org/f29c/1dcee8f2157a0154cee9c0777fd61489b7ba.pdf

Coppola, L., Beretta, S., Bignozzi, M.C., Bolzoni, F., Brenna, A., Cabrini, M., Candamano, S., Caputo, D., Carsana, M., Cioffi, R. and Coffetti, D., 2022. The improvement of durability of reinforced concretes for sustainable structures: A review on different approaches. *Materials*, *15*(8), p.2728. https://doi.org/10.3390/ma15082728

Damtsas, E., Nieto Jiménez, A., Konstantatou, M., Herrmann, M. and Grigoriadis, K., 2025. The design, fabrication, and structural and embodied carbon analysis of the world's first manufactured topologically optimised multi-metal I-beam. *Architectural Intelligence*, *4*(1), p.23. https://link.springer.com/content/pdf/10.1007/s44223-025-00100-8.pdf

Foraboschi, P., 2022. Strengthening of reinforced concrete beams subjected to concentrated loads using externally bonded fiber composite materials. *Materials*, *15*(6), p.2328. https://doi.org/10.3390/ma15062328

Foster, A.S.J. and Gardner, L., 2015. Ultimate behaviour of continuous steel beams with discrete lateral restraints. *Thin-Walled Structures*, *88*, pp.58-69.

https://www.researchgate.net/profile/Andrew-Foster-6/publication/301559738_Ultimate_behaviour_of_continuous_steel_beams_with_discrete_lateral_restraints/links/582d86c608ae004f74bc912d/Ultimate-behaviour-of-continuous-steel-beams-with-discrete-lateral-restraints.pdf

Gaidai, O., Elkelity, A., Wang, F., Cao, Y., Zhang, T., Abo-Raya, M.H., Kamel, B.M., El-Wazery, M., Seleman, M.M.E.S. and Elshaghoul, Y.G., 2026. Bivariate safety assessment for welded AA5083 aluminium alloys by the Gaidai multivariate reliability method and the Belyaev formulation. *Materials & Design*, p.116030. https://www.sciencedirect.com/science/article/pii/S0264127526006039

Ghasemi, S., Maghsoudi, A.A., Bengar, H.A. and Ronagh, H.R., 2015. Flexural strengthening of continuous unbonded post-tensioned concrete beams with end-anchored CFRP laminates. *Struct. Eng. Mech*, *53*(6), pp.1083-1104. https://www.researchgate.net/profile/Habib-Akbarzadeh-Bengar/publication/277648682_Flexural_strengthening_of_continuous_unbonded_post-tensioned_concrete_beams_with_end-anchored_CFRP_laminates/links/566d8f5d08ae430ab4fff9c0/Flexural-strengthening-of-continuous-unbonded-post-tensioned-concrete-beams-with-end-anchored-CFRP-laminates.pdf

Honfi, D., Mårtensson, A. and Thelandersson, S., 2012. Reliability of beams according to Eurocodes in serviceability limit state. *Engineering Structures*, *35*, pp.48-54. https://www.researchgate.net/profile/Daniel-Honfi/publication/256967997_Reliability_of_beams_according_to_Eurocodes_in_serviceability_limit_state/links/5a0dec65aca27244d2858411/Reliability-of-beams-according-to-Eurocodes-in-serviceability-limit-state.pdf

Islam, M.M., Abir, A.R. and Chanda, A., 2025. Illustrative Structural Comparison of RCC and Steel Structures Based on Numerical Analysis: An Educational Perspective. https://doi.org/10.46610/IJSAACT.2025.v01i02.005

Niiranen, J., Balobanov, V., Kiendl, J. and Hosseini, S., 2019. Variational formulations, model comparisons and numerical methods for Euler–Bernoulli micro-and nano-beam models. *Mathematics and Mechanics of Solids*, *24*(1), pp.312-335. https://research.aalto.fi/files/30231141/ENG_Niiranen_et_al_Variational_formulations_model_comparisons_Mathematics_and_mechanics_of_solids.pdf

Tenório, M., Ferreira, R., Belafonte, V., Sousa, F., Meireis, C., Fontes, M., Vale, I., Gomes, A., Alves, R., Silva, S.M. and Leitão, D., 2024. Contemporary strategies for the structural design of multi-story modular timber buildings: A comprehensive review. *Applied Sciences*, *14*(8), p.3194. https://doi.org/10.3390/app14083194

Uslu, F. and Taşkın, K., 2024. Experimental and Finite element method investigation of axial load carrying capacity of concrete filled circular steel tube columns according to different slenderness ratios. *International Journal of Steel Structures*, *24*(3), pp.619-634. https://www.researchgate.net/profile/Kivanc-Taskin/publication/380408287_Experimental_and_Finite_Element_Method_Investigation_of_Axial_Load_Carrying_Capacity_of_Concrete_Filled_Circular_Steel_Tube_Columns_According_to_Different_Slenderness_Ratios/links/6687a08a0a25e27fbc27bc92/Experimental-and-Finite-Element-Method-Investigation-of-Axial-Load-Carrying-Capacity-of-Concrete-Filled-Circular-Steel-Tube-Columns-According-to-Different-Slenderness-Ratios.pdf

Vagtholm, R., Matteo, A., Vand, B. and Tupenaite, L., 2023. Evolution and current state of building materials, construction methods, and building regulations in the UK: Implications for sustainable building practices. *Buildings*, *13*(6), p.1480. https://doi.org/10.3390/buildings13061480

Xie, W. and Hua, Y., 2024. Structural vibration comfort: A review of recent developments. *Buildings*, *14*(6), p.1592. https://doi.org/103390/buildings14061592

Yang, A., Han, M., Zeng, Q. and Sun, Y., 2021. Adopting building information modeling (BIM) for the development of smart buildings: a review of enabling applications and challenges. *Advances in Civil Engineering*, *2021*(1), p.8811476. https://onlinelibrary.wiley.com/doi/pdf/10.1155/2021/8811476