Final Year Project Showcase Batch 2022
Year 2026

Department: Urban and Infrastructure Engineering
Programme: B.E. (Civil Engineering Specialization in Urban)

1	**Project Title** Residual Strength Estimation of Reinforced Concrete Sections Under Multi-Face Fire Exposure
2	**Project Idea** This project addresses the field of structural fire engineering by developing an automated methodology for estimating the residual strength of reinforced concrete (RC) sections subjected to multi-face fire exposure. Conventional fire assessment methods, including Eurocode 2 simplified procedures, primarily consider single face fire exposure, whereas actual buildings often experience fire acting simultaneously on two, three, or more faces, leading to complex temperature distributions and severe material degradation. The project integrates Eurocode 2 provisions, MATLAB programming, and SAP2000 fibre-based sectional analysis to automate thermal analysis, material degradation calculations, and residual structural capacity estimation. The developed computational approach enables engineers to assess fire-damaged RC members efficiently and accurately, reducing reliance on time-consuming manual calculations while supporting performance-based structural assessment. It promotes safer rehabilitation decisions, minimizes unnecessary demolition, and contributes to sustainable urban infrastructure through improved post-fire structural evaluation.
3	**Process** **1. Literature Review and Eurocode Study** Relevant literature on reinforced concrete behaviour under elevated temperatures and Eurocode 2 fire design provisions was reviewed to establish the theoretical basis for temperature distribution and material degradation. **2. Thermal Analysis** Eurocode temperature profiles for three-face fire exposure were digitized using PlotDigitizer and imported into MATLAB. Interpolation techniques were implemented to generate temperature distributions for various beam sizes, slab thicknesses, depths, and fire durations. **3. Strength Degradation Analysis** Temperature-dependent reduction factors specified in Eurocode 2 were implemented in MATLAB to determine the residual compressive strength of concrete and residual yield strength of reinforcing steel throughout the cross-section.

	4. Model Validation The MATLAB-generated temperature contours and strength reduction results were validated against Eurocode graphical data to ensure computational accuracy. **5. Fibre-Based Section Analysis** Reinforced concrete cross-sections were discretized into 25 mm × 25 mm fibres. Residual material properties were assigned to each fibre into SAP2000 Section Designer. **6. Structural Performance Analysis** Moment–Axial Load (M–N) interaction curves and Moment–Curvature relationships were generated in SAP2000 for fire exposure durations of 30, 60, 90 and 120 minutes. **7. Case Studies** An RC beam and an RC frame were analysed under various fire durations to evaluate structural demand, residual capacity, stiffness degradation, and post-fire safety.
4	**Outcome** The project successfully developed an automated MATLAB-based computational framework capable of estimating the residual capacity of reinforced concrete sections exposed to multi-face fire conditions. The thermal analysis demonstrated highly non-uniform temperature distributions across RC sections, with the greatest material degradation occurring near exposed corners and edges. Fibre-based analysis enabled accurate estimation of residual concrete and steel properties throughout the cross-section. Structural analysis showed that although material degradation increases with fire duration, properly designed RC members retain significant residual strength after severe fire exposure. For a standard 300 mm × 600 mm RC beam subjected to 120 minutes of fire exposure, approximately **95.4%** of its original bending moment capacity remained available, maintaining an adequate structural safety margin. The developed methodology significantly reduces analysis time while improving the reliability of post-fire structural assessment. It provides engineers with an effective tool for evaluating damaged structures and supports informed decisions regarding repair, rehabilitation, or reuse instead of demolition.

5	**Evidence (Theoretical Basis)** Urban fires pose serious risks to reinforced concrete structures by reducing the mechanical properties of both concrete and reinforcing steel. While Eurocode 2 provides procedures for evaluating fire-damaged structures, these procedures mainly address single-face fire exposure and require extensive manual calculations. Real fire incidents frequently expose structural members to multiple faces simultaneously, resulting in complex thermal gradients and non-uniform strength degradation. Existing manual approaches are computationally intensive, time-consuming, and susceptible to human error. This project addresses these limitations by combining Eurocode 2 provisions with automated MATLAB programming and SAP2000 fibre analysis. Temperature profiles were digitized, interpolated, and converted into residual material properties before performing sectional capacity analysis through M–N interaction diagrams and Moment–Curvature relationships. The developed methodology validates Eurocode provisions while extending their practical application to realistic multi-face fire scenarios, providing engineers with an accurate, automated, and performance-based assessment tool for post-fire structural evaluation.
6	**Impact on Sustainability of Urban Regions or SDG-11 "Sustainable Cities and Communities"** The project directly contributes to **United Nations Sustainable Development Goal 11: Sustainable Cities and Communities** by improving the resilience and safety of urban infrastructure following fire events. Instead of assuming that fire-damaged buildings require demolition, the developed methodology enables engineers to accurately determine the remaining structural capacity of reinforced concrete members. This encourages rehabilitation and adaptive reuse, reducing construction waste, conserving natural resources, and minimizing the environmental impact associated with reconstruction. The computational framework also enhances public safety by improving the reliability of post-fire structural inspections and supporting evidence-based engineering decisions. By promoting resilient infrastructure, resource conservation, and sustainable rehabilitation practices, the project contributes to safer and more sustainable urban development.

7	**Competitive Advantage or Unique Selling Proposition** (Cost Reduction, Process improvement, Attainment of any SDG (Sustainable Development Goal), increase of market share or capturing new market or having superior performance over a competitor. In summary, any striking aspect of the project that compels the industry to invest in FYP or purchase it. Some detailed description is required in terms of how, why when what. You can select one or more from the following dropdown and delete the rest of them). Please keep relevant options, delete the rest of them, and correct the sequence **a) Attainment of SDG:** Supports **SDG 11 (Sustainable Cities and Communities)** by enabling safe post-fire rehabilitation, reducing unnecessary demolition, improving urban resilience, and promoting sustainable infrastructure management. **b) Environmental Aspect:** The methodology promotes sustainable construction by extending the service life of existing reinforced concrete structures after fire exposure. Reduced demolition leads to lower construction waste, reduced carbon emissions, and conservation of construction materials. **c) Cost Reduction:** Automated analysis significantly reduces engineering time required for post-fire structural assessment. Rehabilitating structurally adequate buildings instead of demolishing and reconstructing them can result in substantial savings in labour, material, and reconstruction costs. **d) Process Improvement:** Traditional post-fire assessment requires lengthy manual calculations and simplified assumptions. This project automates thermal analysis, material degradation estimation, fibre modelling, and structural capacity evaluation, resulting in faster, more reliable, and code-compliant engineering assessments. **e) Expanding Market Share:** The developed methodology has applications in structural consulting firms, fire safety engineering companies, infrastructure maintenance agencies, insurance investigations, forensic engineering, and government rehabilitation projects, expanding opportunities within the structural assessment industry. **f) Capture New Market:** The project addresses the growing demand for **performance-based structural fire assessment**, post-disaster infrastructure evaluation, and digital engineering tools. It also supports emerging smart infrastructure and resilience-focused engineering services.

a	**Attainment of any SDG** (e.g. How it is achieved and why it is necessary for the region) The developed methodology supports **United Nations Sustainable Development Goal (SDG) 11: Sustainable Cities and Communities** by improving the safety, resilience, and sustainability of urban infrastructure through reliable post-fire structural assessment. ■ **Goal 11:** The MATLAB-based computational tool enables engineers to accurately evaluate the residual strength of fire-damaged reinforced concrete structures using Eurocode 2 provisions. This supports informed rehabilitation decisions, reduces unnecessary demolition, and enhances the resilience and safety of buildings after fire incidents. Key aspects of the methodology aligning with SDG-11 include: ■ Safer Infrastructure: Enables reliable post-fire structural assessment. ■ Resilient Communities: Supports rehabilitation instead of premature demolition. ■ Sustainable Urban Development: Extends the service life of fire-damaged structures. ■ Efficient Decision-Making: Provides automated and code-compliant structural evaluation. By contributing to SDG-11, the methodology promotes safer, more resilient, and sustainable urban infrastructure.
b	**Environmental Aspect** (e.g. carbon reduction, energy-efficient, etc.) **Reduction of Construction Waste and Carbon Emissions:** The methodology promotes the rehabilitation of fire-damaged reinforced concrete structures instead of unnecessary demolition and reconstruction. Reusing existing structures reduces construction waste, conserves raw materials, lowers embodied carbon emissions, and supports sustainable infrastructure management.
c	**Cost Reduction of Existing Product** The developed methodology reduces the cost of post-fire structural assessment by automating temperature analysis, material degradation evaluation, and residual strength estimation. It minimizes manual calculations, reduces inspection time, and helps avoid unnecessary repair or replacement costs through accurate structural evaluation.
d	**Process Improvement which Leads to Superior Product or Cost Reduction, Efficiency Improvement of the Whole Process** (e.g. What is the issue is current process and what improvement you suggests) Traditional post-fire assessments rely on time-consuming manual calculations and engineering judgment, which may lead to inconsistent results. The developed MATLAB-based methodology integrates Eurocode 2 thermal analysis with SAP2000 structural analysis, providing a faster, automated, and more reliable process for evaluating residual structural capacity and supporting effective rehabilitation decisions.

e	**Expanding of Market share** (e.g. how it expand and what is the problem with the current market The developed methodology can expand its market by serving: ■ Structural engineering consultancy firms ■ Fire safety engineering consultants ■ Government and municipal infrastructure authorities ■ Building inspection and rehabilitation agencies ■ Insurance and forensic engineering organizations By providing a reliable and automated post-fire assessment tool, it can increase adoption across the structural engineering and infrastructure sectors.
f	**Capture New Market** (e.g. Niche market or unaddressed segment) The methodology can capture new markets by targeting: ■ Disaster management and emergency response authorities ■ Infrastructure asset management companies ■ Universities and research institutions ■ Engineering firms specializing in structural rehabilitation and resilience By addressing the growing need for rapid and reliable post-fire structural assessment, the methodology opens opportunities in emerging resilience-focused infrastructure and research sectors.
g	**Any Other Aspect (Please tag it like above options)**
8	**Target Market** (Industries, Groups, Individuals, Families, Students, etc) Please provide some detail about the end-user of the product, process, or service The target market for the developed post-fire assessment methodology includes: ■ **Industries:** Structural engineering consultancy firms, fire safety consultants, infrastructure asset management companies, and insurance and forensic engineering organizations. ■ **Groups:** **1.** Government infrastructure authorities and municipal rehabilitation departments. **2.** Building inspection agencies and disaster management authorities. **3.** Universities and research institutions involved in structural and fire engineering research. ■ **Individuals:** Civil and structural engineers involved in the assessment, rehabilitation, and design of fire-damaged reinforced concrete structures. ■ **Students and Educators:** Those in civil, structural, and fire safety engineering interested in post-fire structural assessment and rehabilitation.

9	**Team Members** (Names along with email address	Sheikh Mahpara Ashraf (mahparaashraf786@gmail.com) Maryam Rashid (maryamrashid.0551@gmail.com) Nazia Ajaz (nazajaz0820@gmail.com) Areeba Ali (areebaaliqadri@gmail.com)
10	**Supervisor Name** (along with email address)	**Prof. Dr. Muhammad Masood Rafi (rafi-m@cloud.neduet.edu.pk)**
11	**Video (If any)**	You may please provide the link of the video to be accessible

Pictures (If any)

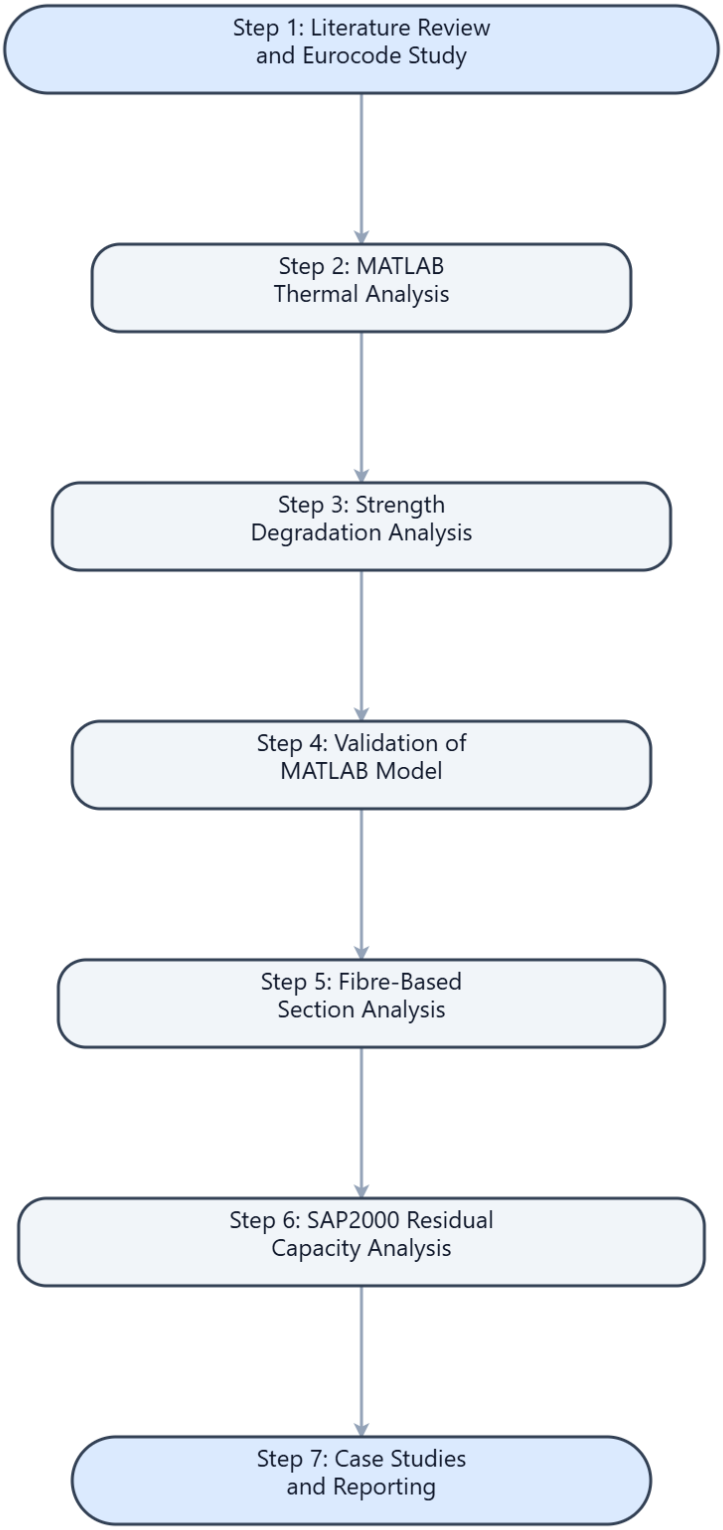

Figure 1: Flow Chart of Methodology

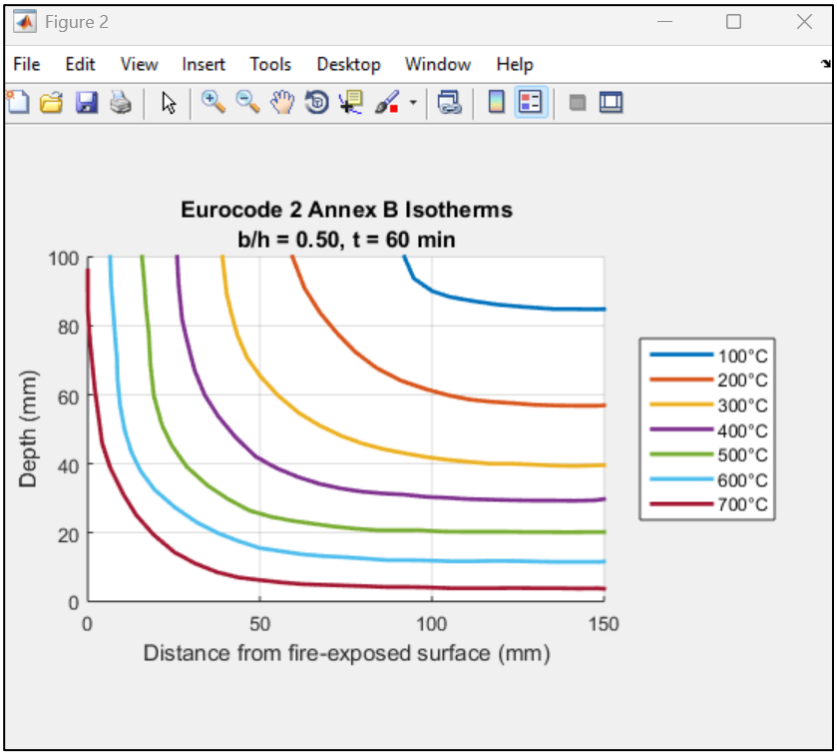

Figure 2: Temp Profile of Beam generated from Matlab script of Beam of thickness for 300/600 beam size ratio at 60 min fire exposure

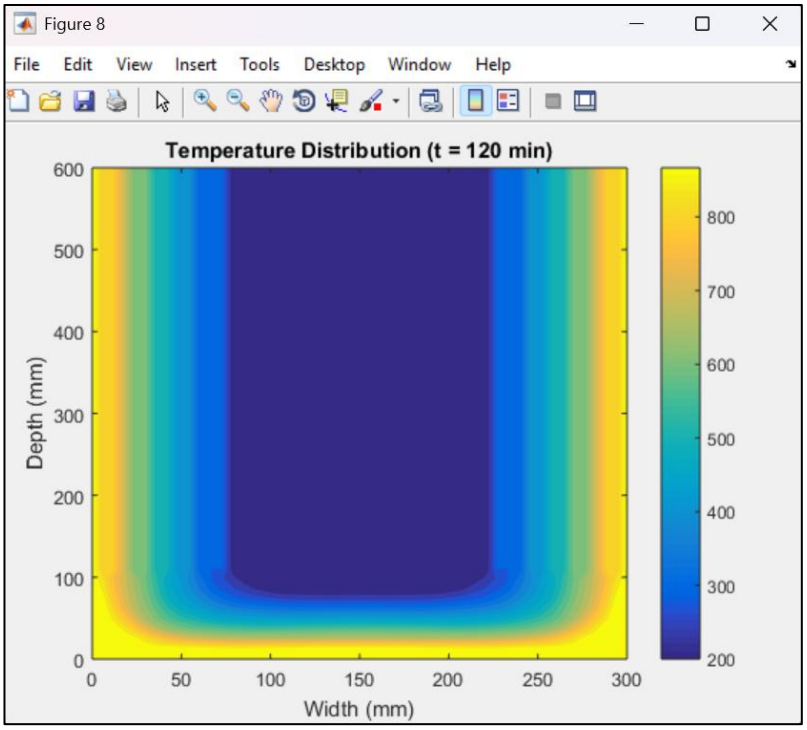

Figure 3: Full Section Temperature Distribution for 300 mm by 600 mm Beam at 120 min fire exposure

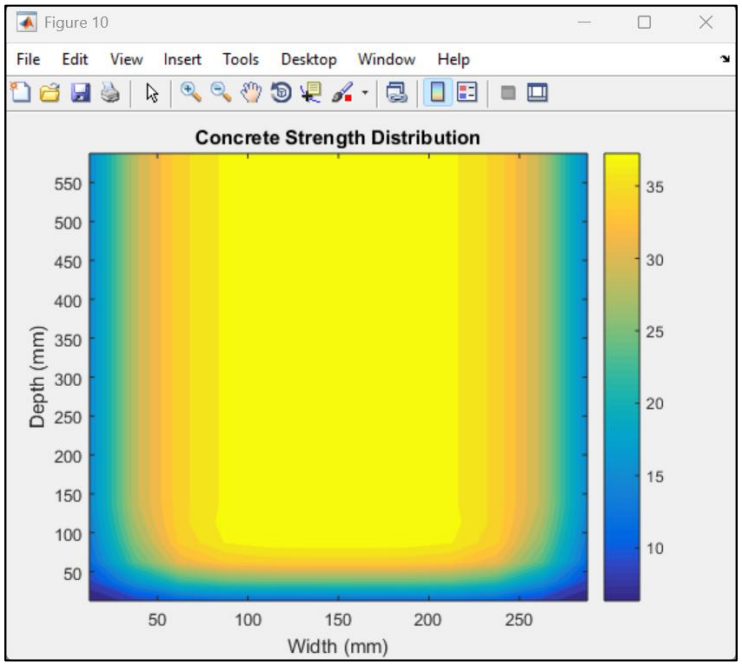

Figure 4: Full Section Residual Concrete Strength Distribution

Table 1: Residual Strength of Steel Reinforcement Calculated Using MATLAB

Width_mm	Depth_mm	Temperature_C	Residual_fy_MPa
62.5	62.5	426.65	235.34
237.5	62.5	426.65	235.34
62.5	237.5	300	250
237.5	237.5	300	250

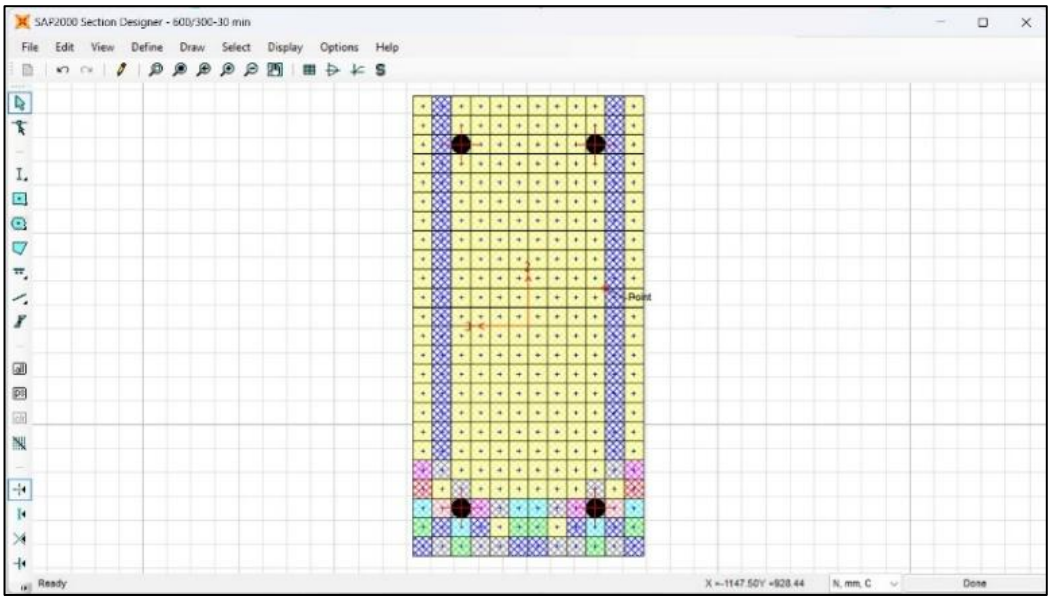

Figure 5: RC section of 300 mm x 600 mm in Section designer Using SAP2000

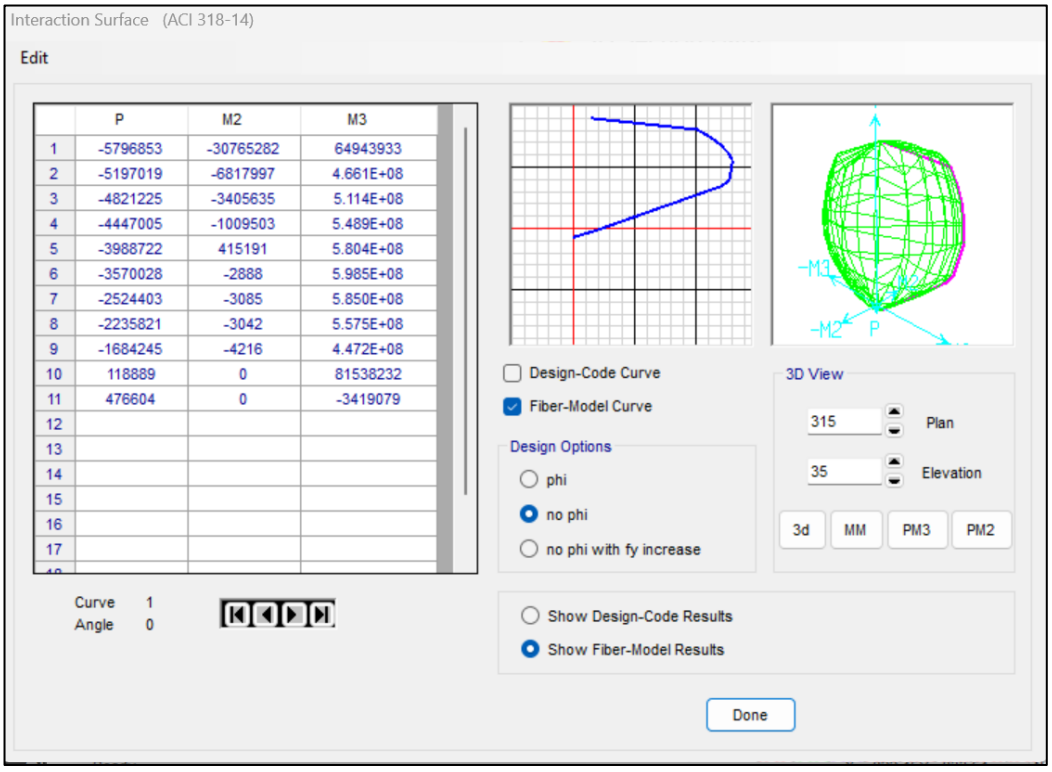

Figure 6: M–N Interaction Curves at fire duration of 120 min Using SAP2000

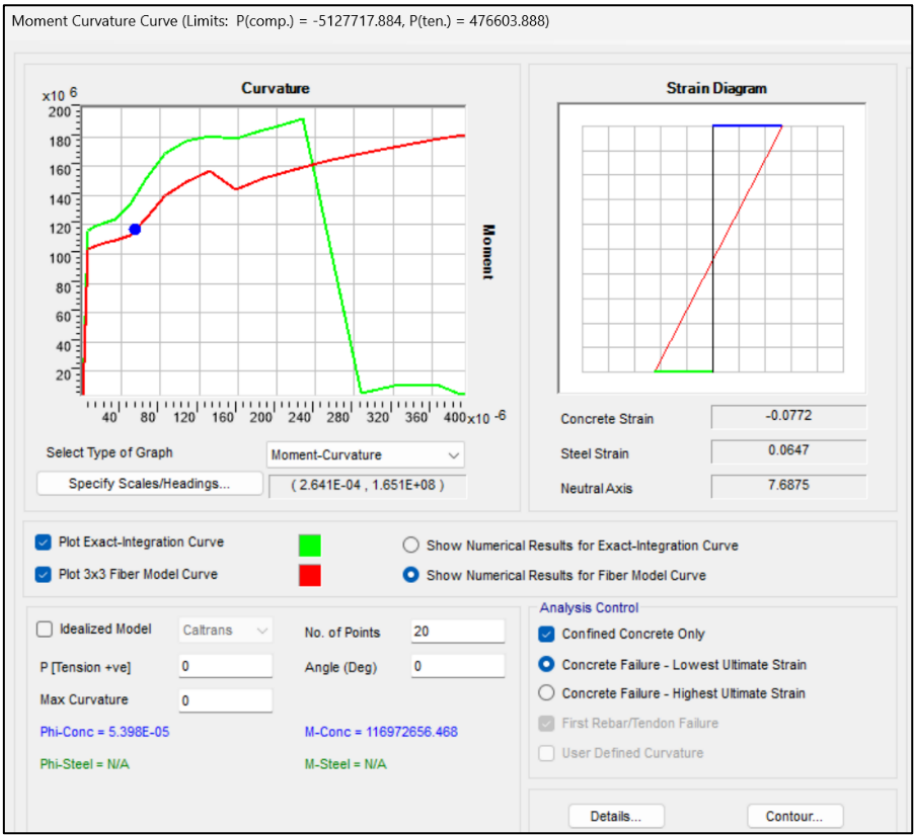

Figure 7: Moment–Curvature at 120 min fire duration Using SAP2000

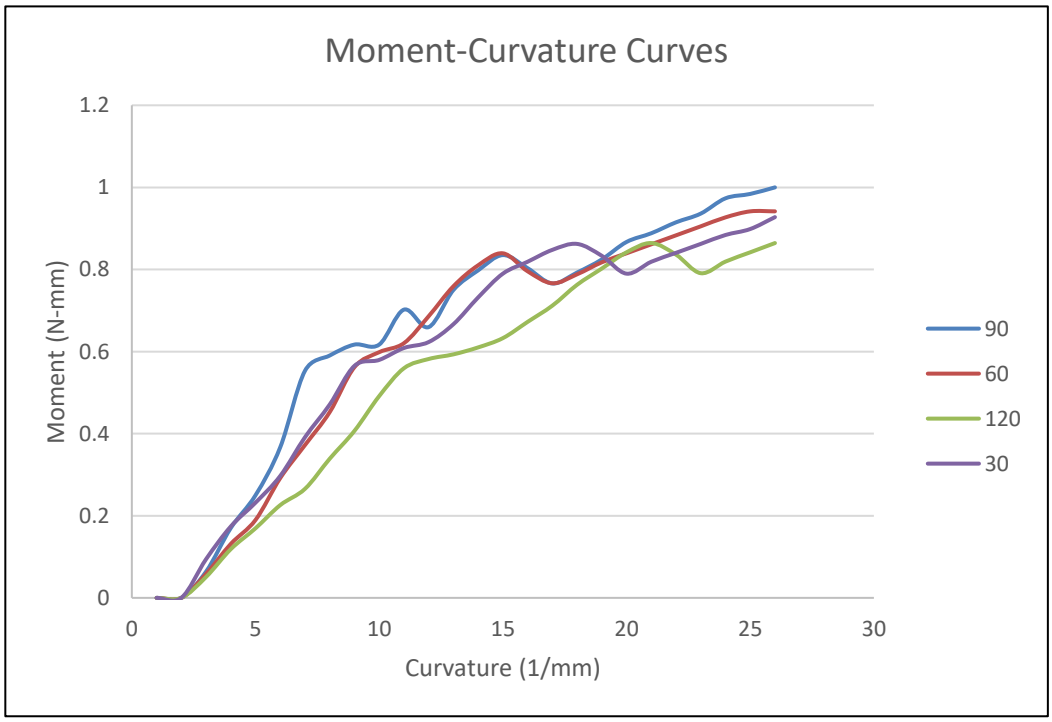

Figure 8: Merge Curves for Moment-Curvature graphs at different fire durations Using Excel

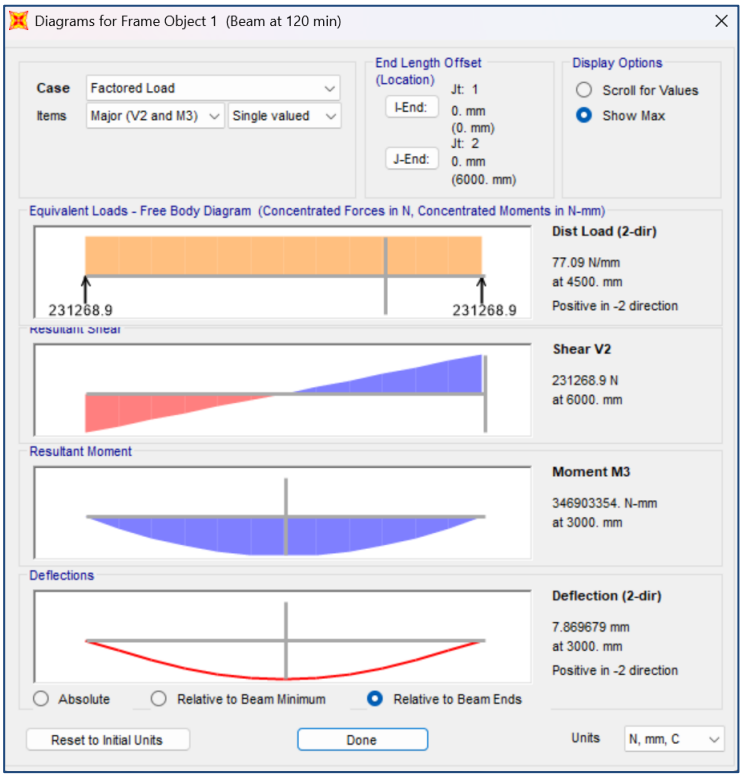

Figure 9: Forces and Deflection of Beam at 120 min Fire duration

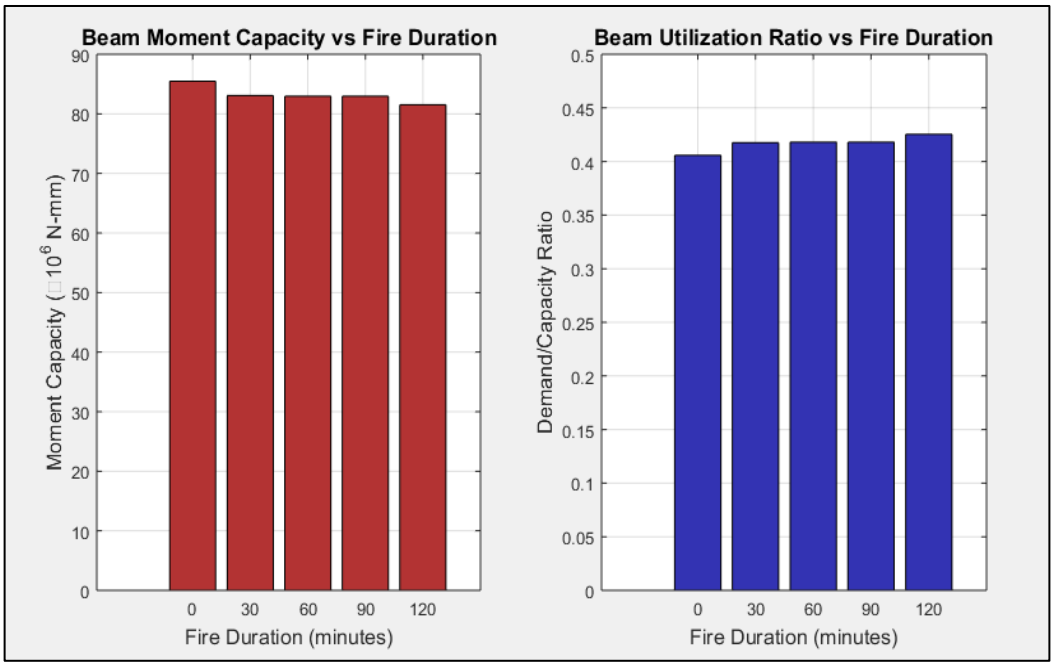

Figure 10: Beam Moment Capacity & Beam Utilization Ratio