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Response Spectrum of PSC Structural Elements

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Abstract

Response spectrum analysis evaluates seismic performance of reinforced concrete and Prestressed concrete beams using ETAB software, following IS 456:2000 and IS 1343:2016 standards. This study compares beams of sizes 230x450mm,300x450mm and 300x600mm under various boundary conditions and zone II 9seismic loads, revealing PSC beams exhibit reduced deflections and moments due to prestressing effects. Results validate software outputs against theoretical calculations, confirming PSC superiority for seismic resilience.

Keywords-Response spectrum analysis, Prestressed concrete(PSC), Reinforced cement concrete(RCC), ETABS.

1. Introduction:

Earthquake causes rapid ground shaking from energy release in the earth's crust, threatening structures in seismic zones. Earthquakes continue to pose significant threats to the built environment, particularly in regions with high seismic activity. To withstand the seismic forces, buildings are designed with a strong framework. Columns bear the weight of the building, while the beams help evenly distribute the load. In a framed structure, slabs, beams, and columns are the load-transferring members. They are the main structural elements. In structural engineering, the analysis of a structure is performed according to the codes, which include static analysis, where only live and dead loads are considered. The other is dynamic analysis, in which, along with live and dead loads, wind loads, seismic loads, and other relevant loads are considered.

One of the dynamic analysis methods used in structural engineering is the response spectrum analysis. Response spectrum is a fundamental concept in structural engineering. Response spectrum analysis is a technique used to estimate how a structure will respond at its peak during the sudden dynamic events, spectrum is widely adopted in building codes and seismic design standards. It is an indispensable tool for understanding and optimizing the dynamic performance of structural elements under seismic and other dynamic loads. where response spectrum analysis assesses dynamic responses via acceleration spectrum, this method suits PSC beams by accounting for prestress losses and tendon effects under is 1343.

2. Objective:

This project aims to analyze and compare the structural behaviour of reinforced

concrete and restressed concrete beams under various loading and boundary conditions according to IS456:2000 and IS 1343:2016 standards.

3. Literature Review:

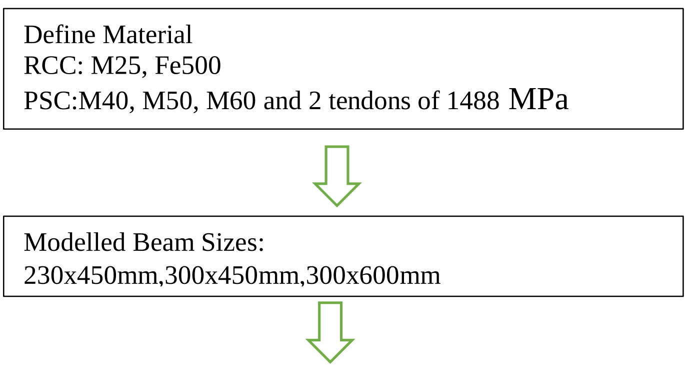
Aherkar, P.S. et.al (2025) "Response Spectrum Analysis for Soft Storey Determination". This study analyzes the impact of soft story using IS1893:2002 and IS1893:2016 by modelling a 15-story structure in ETABS. Infill walls were modelled using diagonal struts as per IS1893:2016, not considered in IS1893:2002. Key parameters like stiffness, displacement, drift, and magnification factors were compared to highlight the updated code's influence. Introduces reduced stiffness and increased seismic vulnerability. The absence of masonry infills at certain levels leads to significant lateral weakness.

Gupta, P. et.al (2024) "Seismic performance evaluation of reinforced concrete flat slab buildings using ETABS". This analysis of various flat slab configurations demonstrates that adding drop panels, column heads, and the area of beams enhances base shear capacity and reduces displacements and drift, improving seismic resilience.

Siva Kumar et.al (2023) "Seismic analysis of RC building (G+9) by response spectrum method". ETABS software is used in the research. Using response spectrum methods, this study confirms the necessity of ductile material and proper structural detailing to ensure robustness under seismic loading, especially in mid-rise RC buildings.

4. Methodology:

The methodology employs ETABS software for detailed response spectrum analysis of isolated PSC and RCC beams spanning 8m, adhering to IS 456:2000, IS 1343:2016and IS 1893:2016 standards. The beam of 8 m is analysised. For IS 1893: 2016 zone II spectrum, importance factor 1.0, response reduction 3.3for beams, soil type II.



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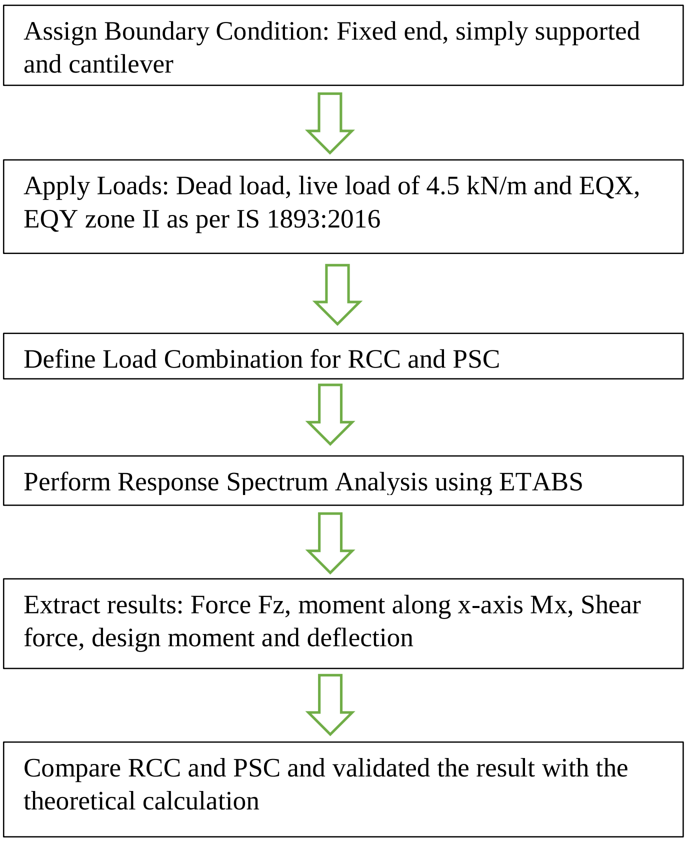


The beam elements are simulated with accurate conditions. Analysis runs response spectrum via modal combination, extracting envelopes for force, moment, shear force and deflection.

5. Validation: Theoretical deflection for simply supported beams is given by

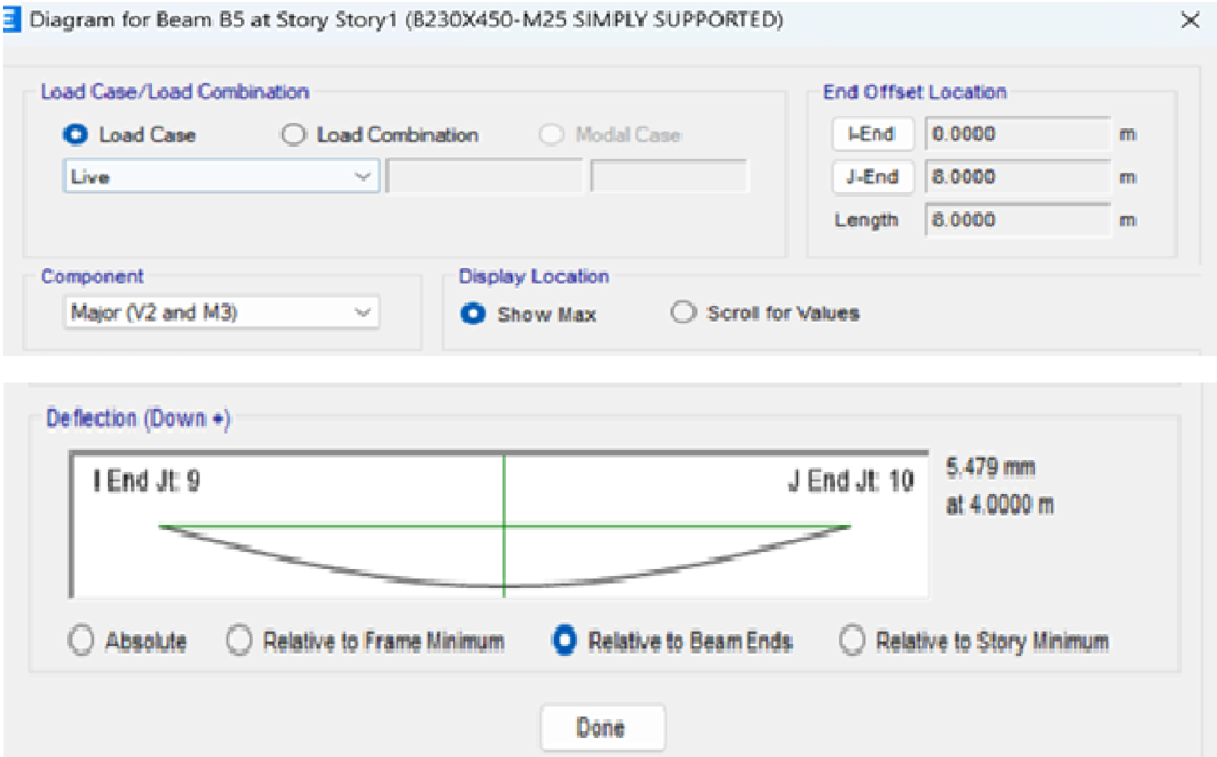
$$\delta_{max}=5wL^4/384EI$$

Results match within 0.4% error for the theoretically calculated result from the above given formula

TABLE 1: Comparison of deflection value from software and theoretical calculation.

Beam size	**Deflection value for software in mm**	**Theoretical deflection value in mm**	**Percentage error**
230x450	5.479	5.496	0.36%
300x450	4.201	4.214	0.31%
300x600	1.771	1.778	0.39%

Figure 1: Deflection in 230x450 beam due to live load in ETABS

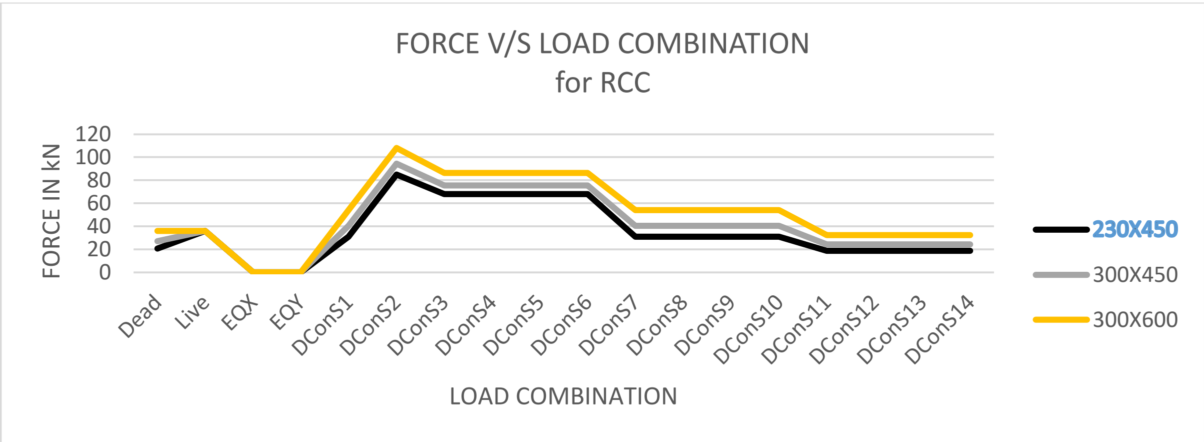


6. Result and Discussion:

The dynamic analysis i.e. response spectrum conducted in ETABS demonstrates that internal force distribution is heavily influenced by prestressing force.

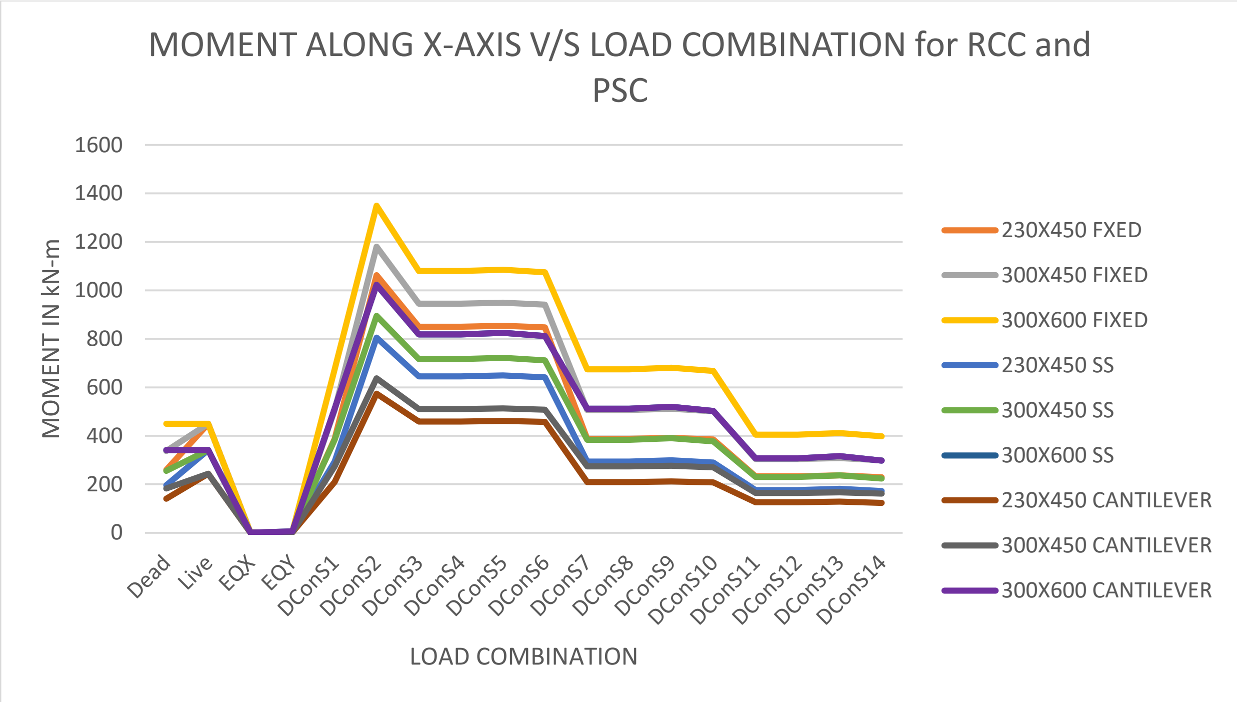
6.1 Force: There is no variation in the force along z- axis for both the beams whereas forces in the other direction is very minimal. From the graph we can say that for both RCC and PSC the Fz is maximum at Dcon S2 and its 110kN.

Figure 2: Comparative graph shows the variation of Fz in RCC and PSC beams.



6.2 Moment along x-axis: There is no variation in the moment along X-axis for both the beams whereas moment in the other direction is very minimal. From the graph we can say that for both RCC and PSC the Mx is maximum at Dcon S2 for the beam size of 300x600 fixed at both the ends is 1300 kN-m. For all the grades of Prestressed concrete and RCC concrete the Mx value is same.

Figure 3: Comparative graph shows the variation of Mx in RCC and PSC beams**.**



6.3 Shear Force: The below graph shows the variation of shear force along the different size and end condition of the beam. For all beams the maximum shear occurs at Dcon S2 load combination. The PSC beam with greater section shows reduced shear force compared to RCC. Fixed end beams exhibit higher shear force, while cantilever beams show maximum shear near the fixed support. PSC configurations yield 10-20% lower shear demands, enhancing the seismic resilience.

Fig.4: Comparative graph shows the variation shear force in different size of beams and end support for M25 grade of RCC.

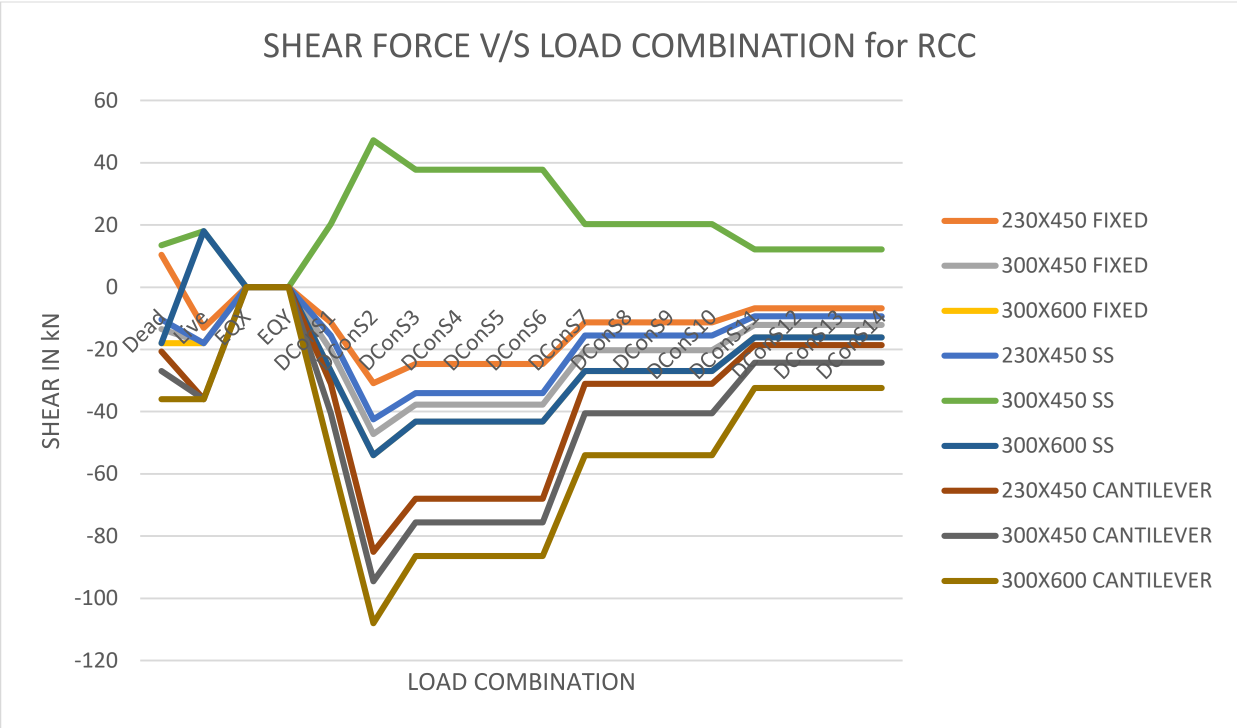


Figure 5: Comparative graph shows the variation shear force in different size of beams and support for M40 grade of PSC.

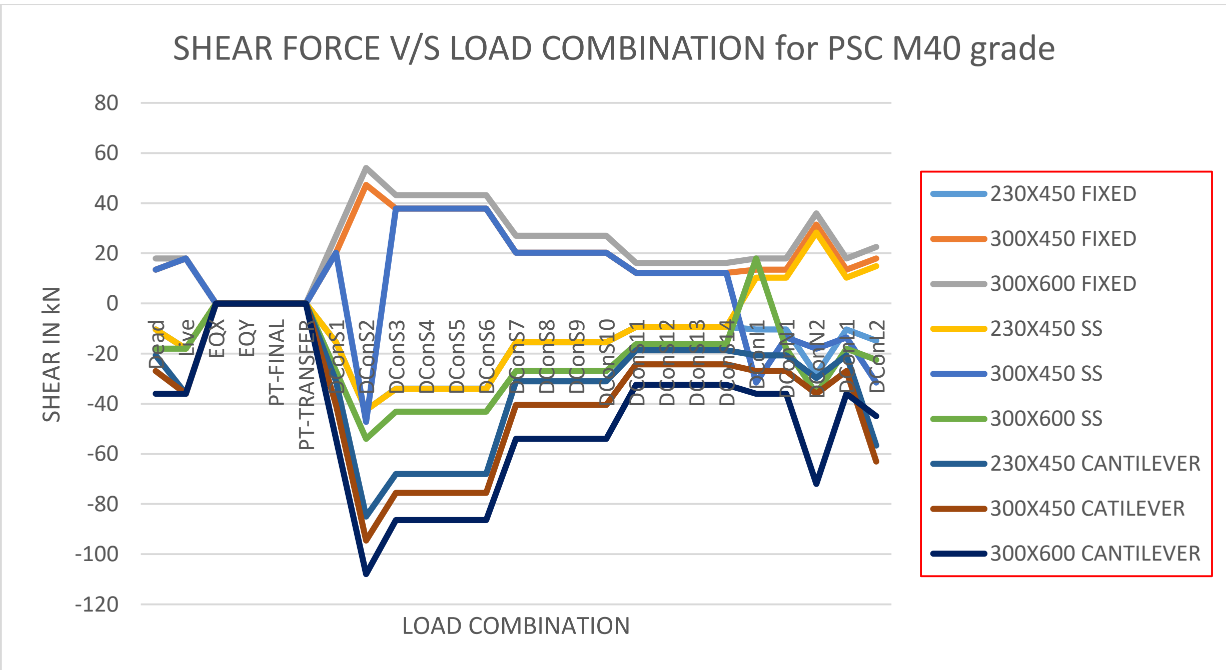


Figure 6: Comparative graph shows the variation shear force in different size of beams and end support for M50 grade of PSC.

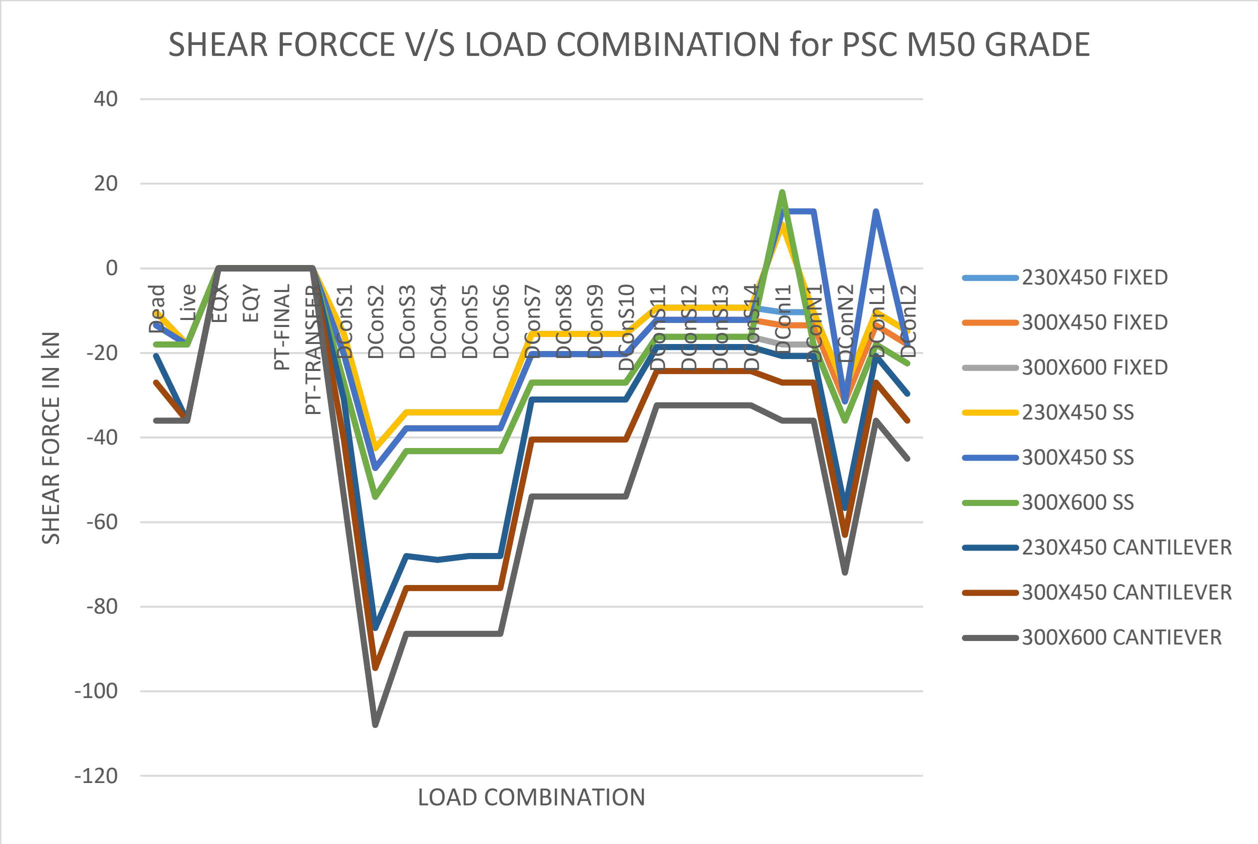
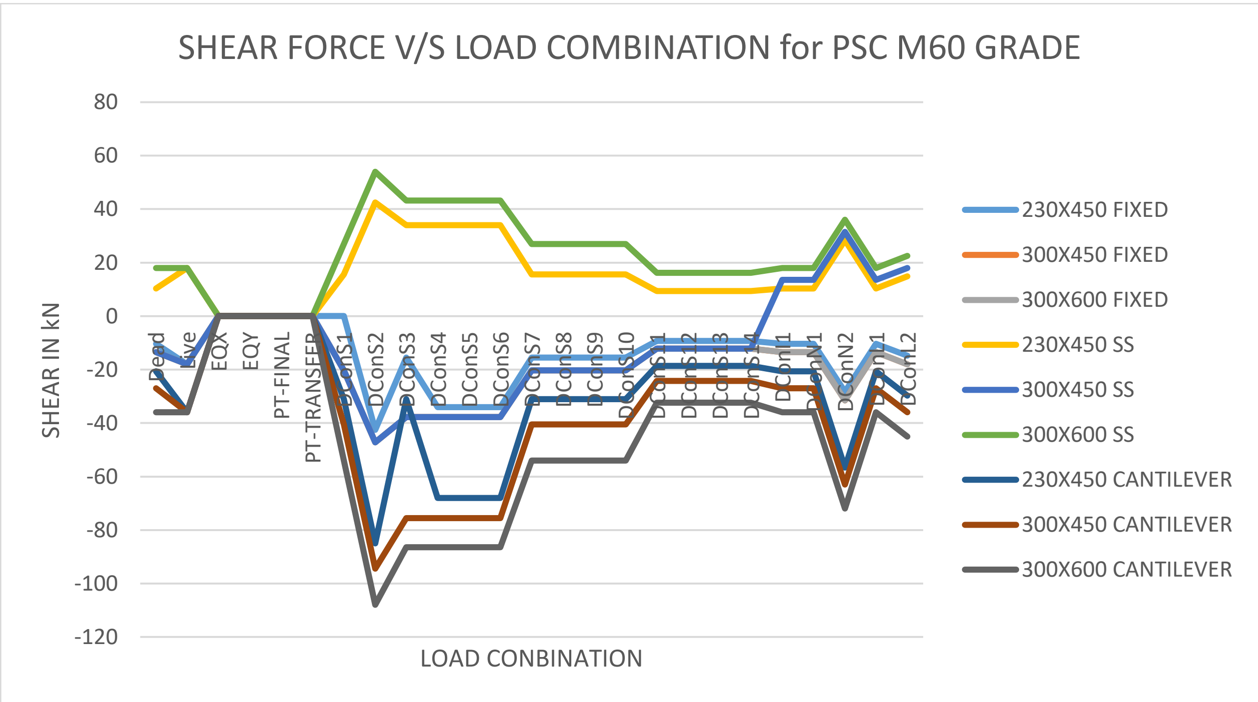


Figure 7: Comparative graph shows the variation shear force in different size of beams and end support for M60 grade of PSC.



6.4 Design Moment:

The design moment graph highlights the moment demand considered for structural design. PSC beams shows reduced design moment when compare to RCC beams indicating more efficient structural behaviour under seismic loading. The design moment is maximum in all the case is in Dcon S2. This reduction directly contributes to optimized reinforcement or tendon requirements. Larger beam section with higher grades of concrete demonstrate further reduction in moment, make them more suitable for earth quake resistant design. Whereas fixed support escalate conservative end hogging for ductility. Simply supported prioritize central governances. Cantilever enforce root critical design.

Figure 8: Comparative graph shows the variation design moment in different size of beams and end support for M25 grade of RCC.

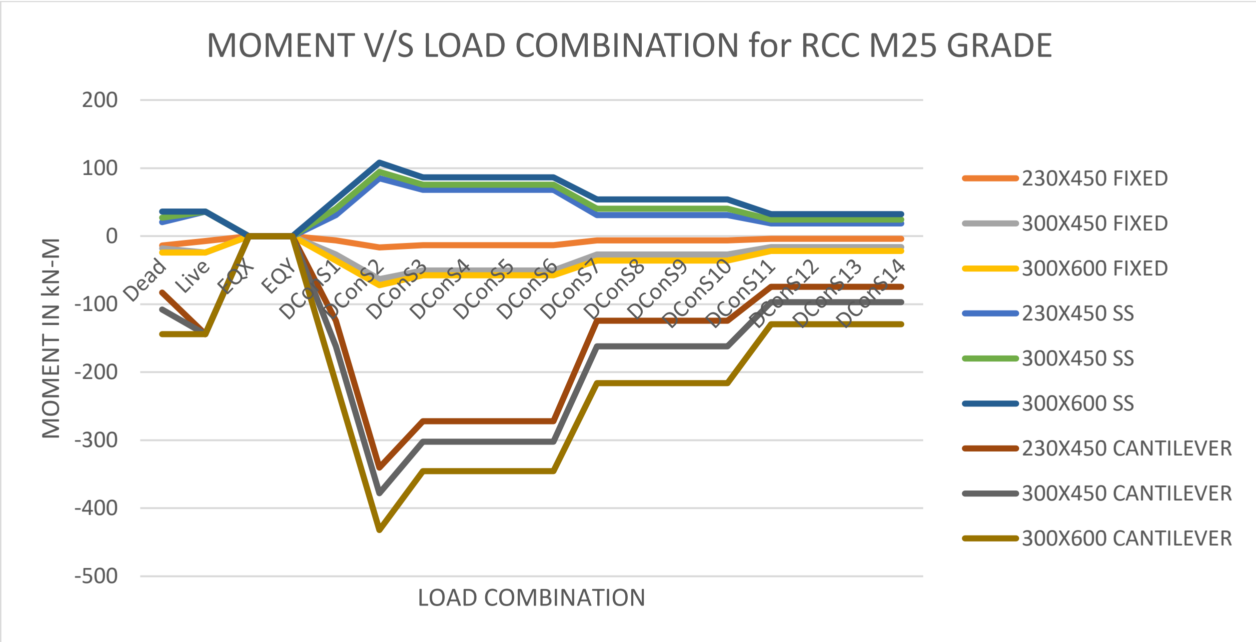


Figure 9: Comparative graph shows the variation design moment in different size of beams and end support for M40 grade of PSC.

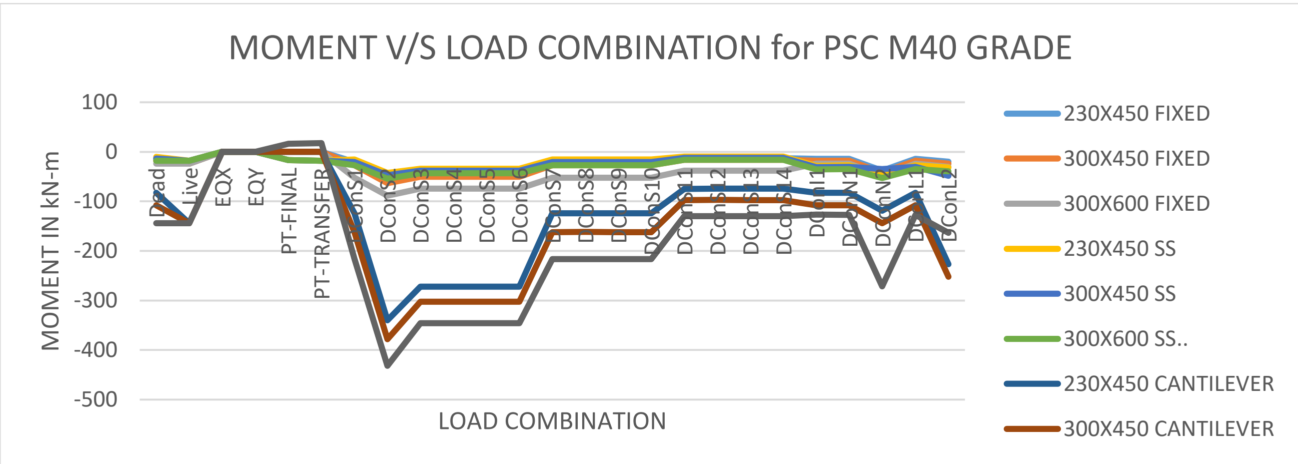


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Figure 10: Comparative graph shows the variation design moment in different size of beams and end support for M50 grade of PSC.

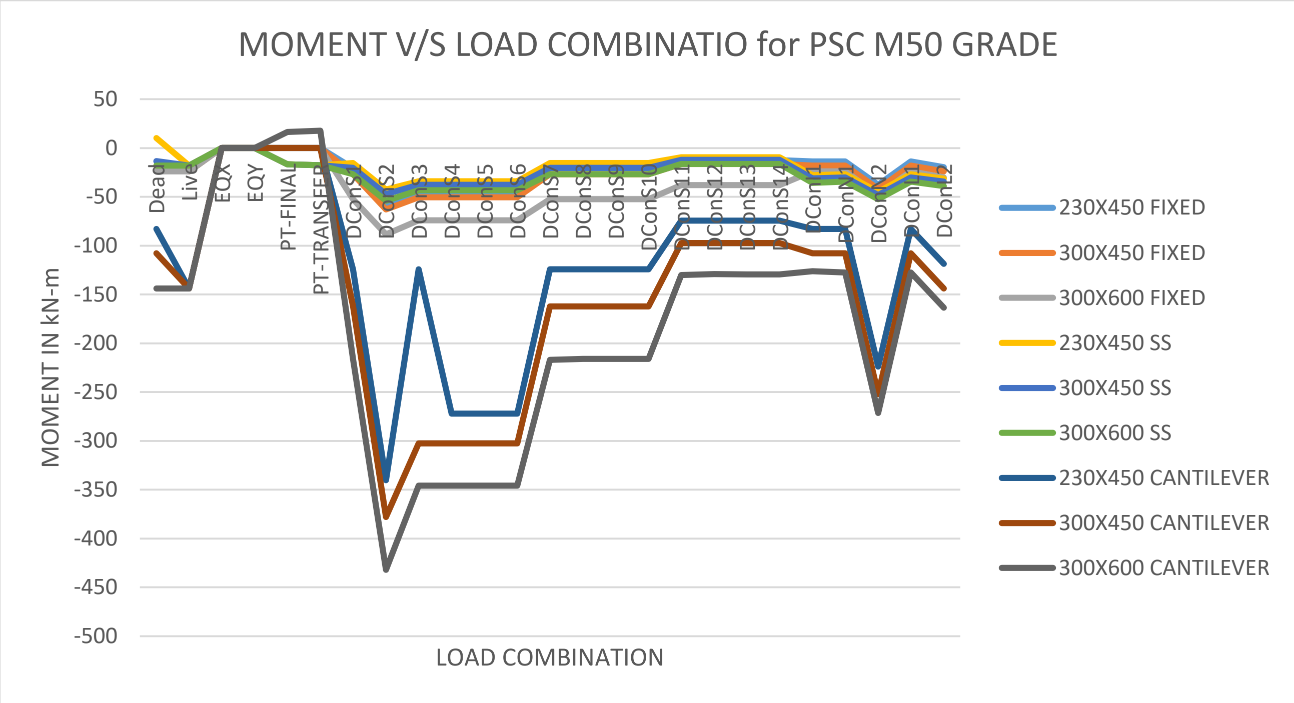
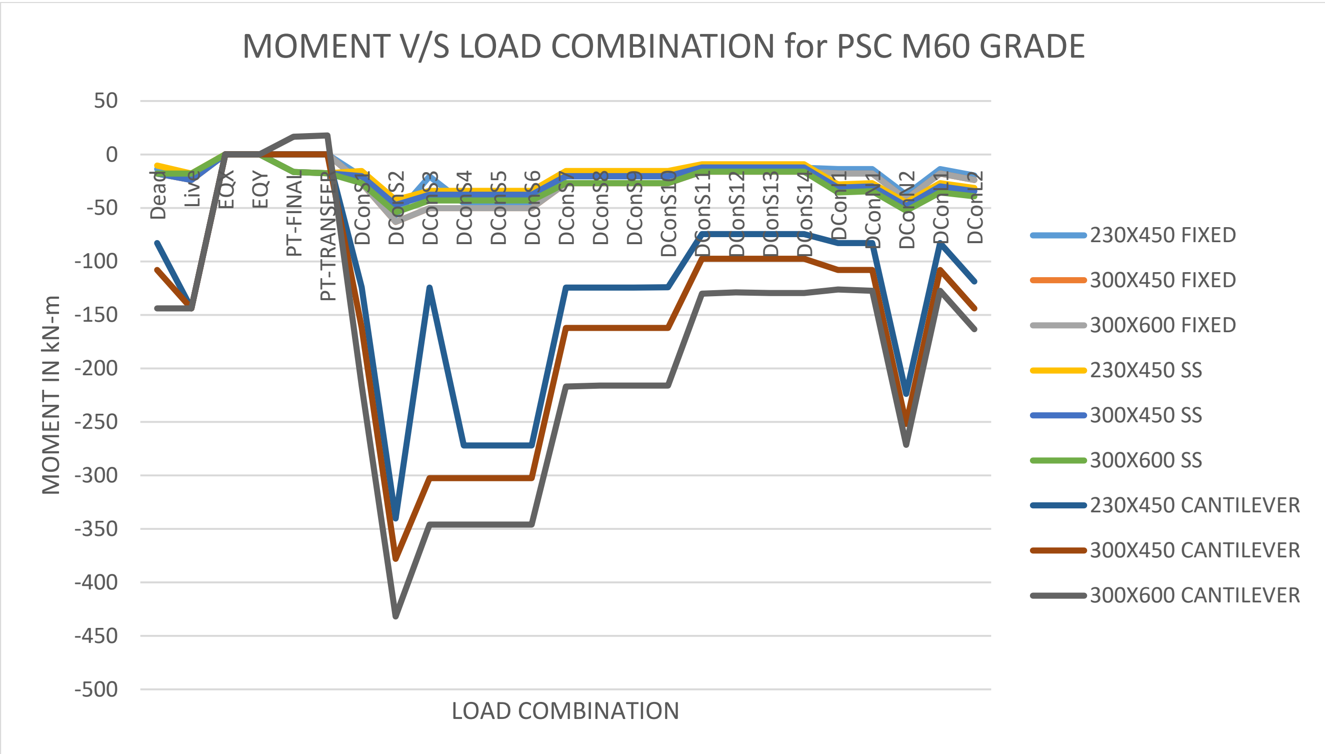


Figure 11: Comparative graph shows the variation design moment in different size of beams and end support for M60 grade of PSC.



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6.5 Deflection:

The deflection graphs illustrate the displacement response of the beams subjected to seismic excitation. RCC beams exhibits higher deflection than the PSC. PSC beams show significantly reduced deflection due to the upward camber. This camber offsets the downward deflection caused by external load. For all the beams the maximum deflection occurred at DConS2 load combination. Among all beam size, higher beam size with higher grade of concrete yield minimum deflection. Confirming that increased beam depth enhances stiffness and limits deflection.300x600mm yields shallowest curvatures with superior stiffness, boundary condition as fixed support yield less.

Figure 12: Comparative graph shows the variation deflection in different size of beams and end support for M25 grade of RCC.

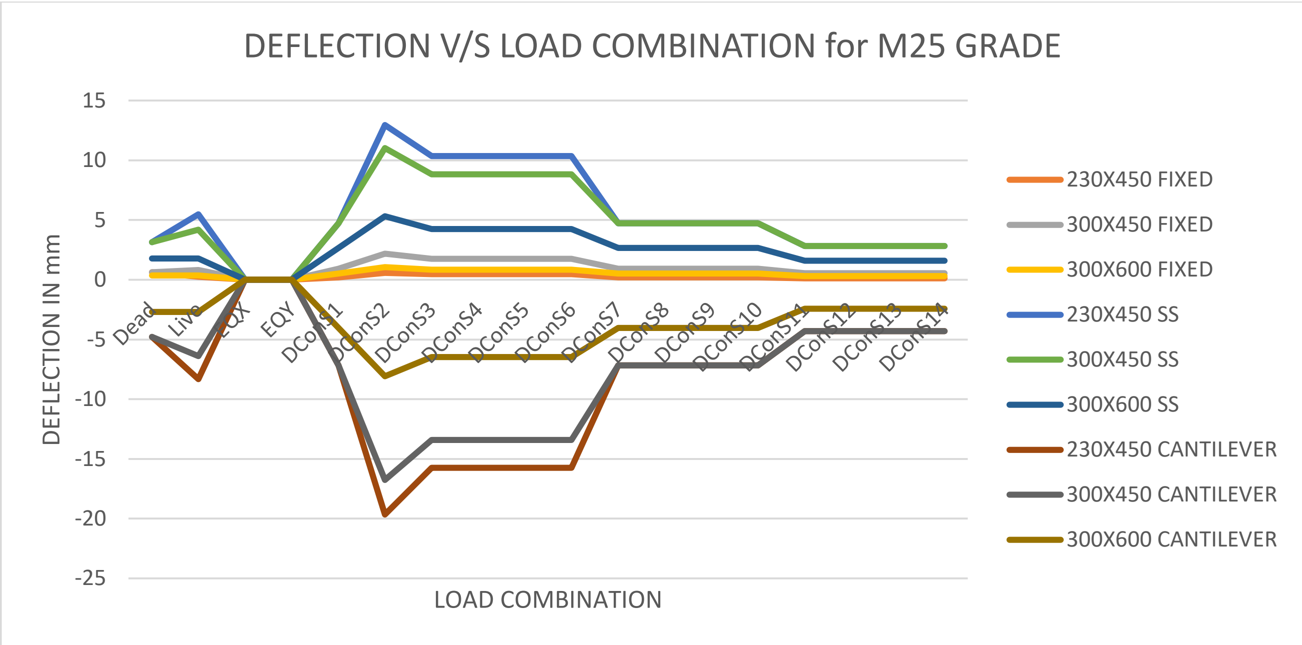


Figure 13: Comparative graph shows the variation deflection in different size of beams and end support for M40 grade of PSC

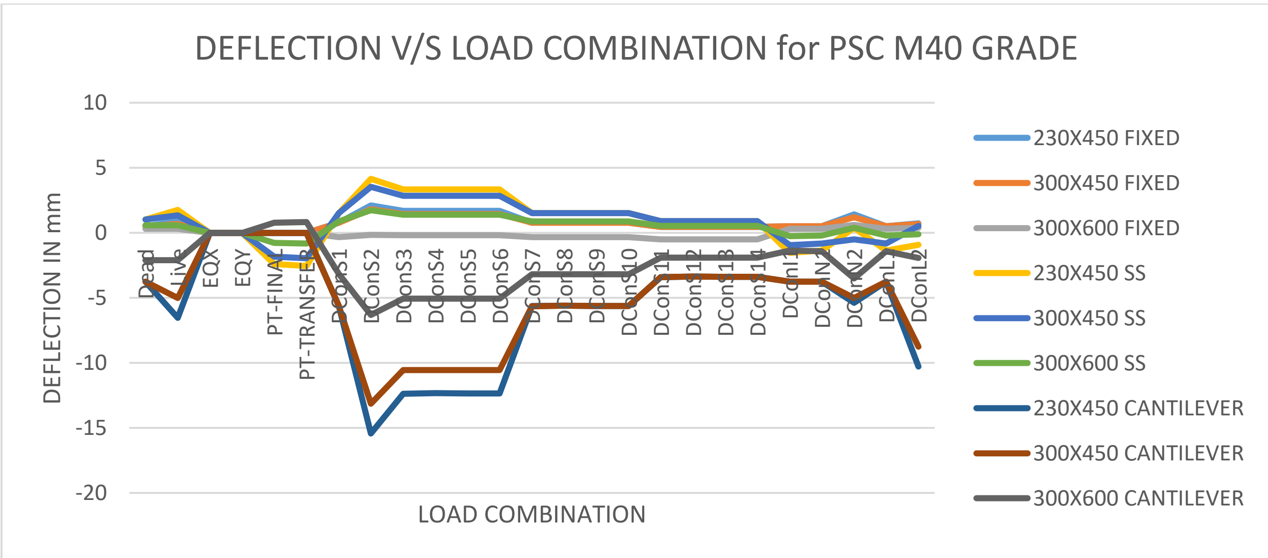


Figure 14: Comparative graph shows the variation deflection in different size of beams and end support for M50 grade of PSC.

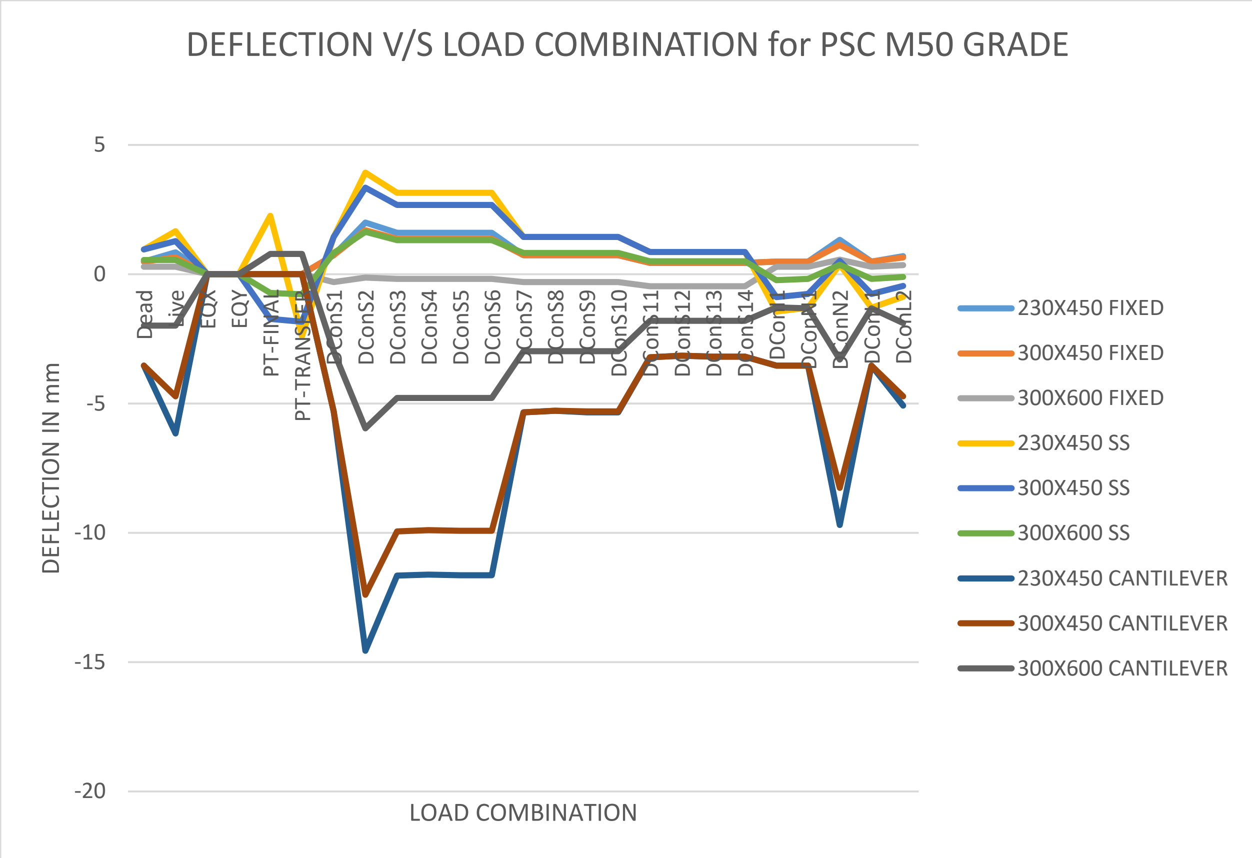
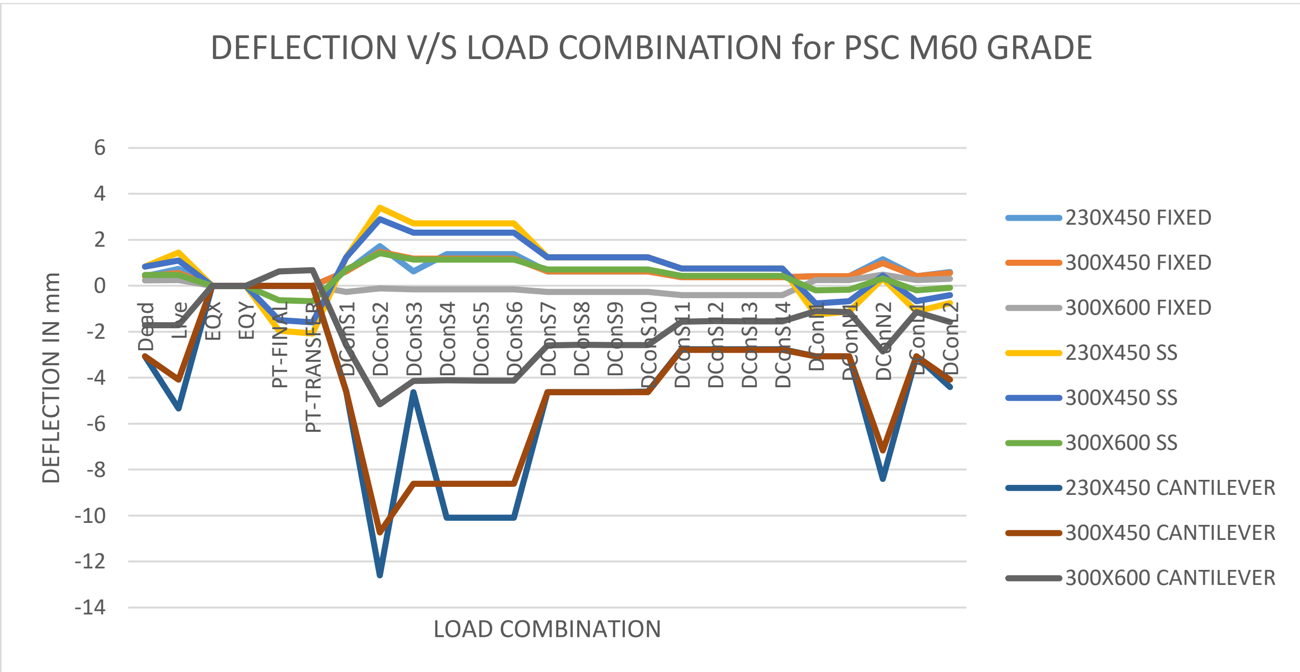


Figure 15: Comparative graph shows the variation deflection in different size of beams and end support for M60 grade of PSC.



Conclusion:

This study presented a comparative response spectrum analysis of RCC and PSC beams using ETABS. The results indicate that Prestressed concrete exhibits lower deflection, shear fore and improved moment performance compared to RCC beam under seismic loading. increased beam depth with higher concrete grades significantly enhanced stiffness and seismic resistance. Fixed end condition yield better results compare to others. prestressing mitigates dynamic tensile effects, crack propagation, and serviceability limits, and advocating PSC for moderate seismic framed structures to enhance the ductility of the structural member.

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