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Comparing Contemporary Realistic Load Demands and Design Performance with Code Minimum Loads for Residential Floors

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Abstract: The Indian standard code specifications for the design of residential buildings provides guidelines and sets minimum required loads to be considered for safe and durable performance of the building. The engineers design the floor slabs using these minimum design loads and performance specifications unless special requirements are listed on the contract drawings. However, these minimum mandated loads were derived decades back based on the socio-economic conditions at the time of their drafting. The changed socio-economic conditions vary very significantly from those days. Contemporary residential building floors carry a wide array of loads due to various mechanical, electrical, and electronic choices which are offered to consumers in the form of machines for easier and comfortable living style. However, there is no revision of design loads from Indian Standards for the design of floors in the last few decades. This study originated from this idea to evaluate the impact of these heavier household loads on the floor slabs. In this study, residential imposed and live loads are created based on the revised intensities, types and layout of the building usage based on equipment footprint and use. Finally, analysis and design of the floor slabs are performed for the upgraded residential loads and layouts. The sufficiency of floor slabs designed with revised current load layouts is evaluated and compared to that of conventional loads specified by Indian standard codes.

Keywords: Floor, Loads, Design, Infrastructure, Sustainability, Resilience

1. Introduction

The minimum load requirements specified in standard code bodies across the world for structural design are based on load types and intensities that closely replicate the typical lifestyles of individuals and societies which are in turn linked to existing socio-economic conditions. However, as the socio-economic conditions change, life stye changes inevitably follow [1, 2]. The advent of new machines and new lifestyles change the way we layout our residences and offices. The new equipment and new comforts bring in bigger items that not only take up more space but also add extra weight. This paper is written in the context of Indian housing, the socio-economic and lifestyle changes in India. In the last two decades India grew tremendously. Its Gross Domestic Product (GDP) is fourth largest in the world and with a large majority of its population young the country is rapidly repositioning itself technologically and economically [3]. This naturally improved the financial standards of the people and led to higher consumer buying. These days vitrified tiles that are about 10 to 15mm thick are commonly laid out on floor slabs. Bigger beds, bigger sofa sets, washing machines have become common additions to households. Though new and novel methods of construction evolved [4], and so are the new materials [5] with very high strengths and performance [6], the loads did not evolve in line with the socio-economic changes.

The original residential floor imposed and live loads currently still in the specifications by the Bureau of the Indian Standards [7, 8] are based on equivalent uniform loads created based on mechanical and electrical commodities commonly in use during those days. However, the advent of larger and heavier equipment into our homes brings a natural question; are our building floors still subjected to the same intensity as the loads? How do the performance parameters such as deflections and stresses in the slabs compare to the code-based loads? To answer these questions, the authors attempted to analyze a typical residential floor slab subjected to a layout of point loads and uniform loads derived based on contemporary realistic loads that our residential floor slabs are being subject to because of these bigger commodities, machines, and devices in our homes.

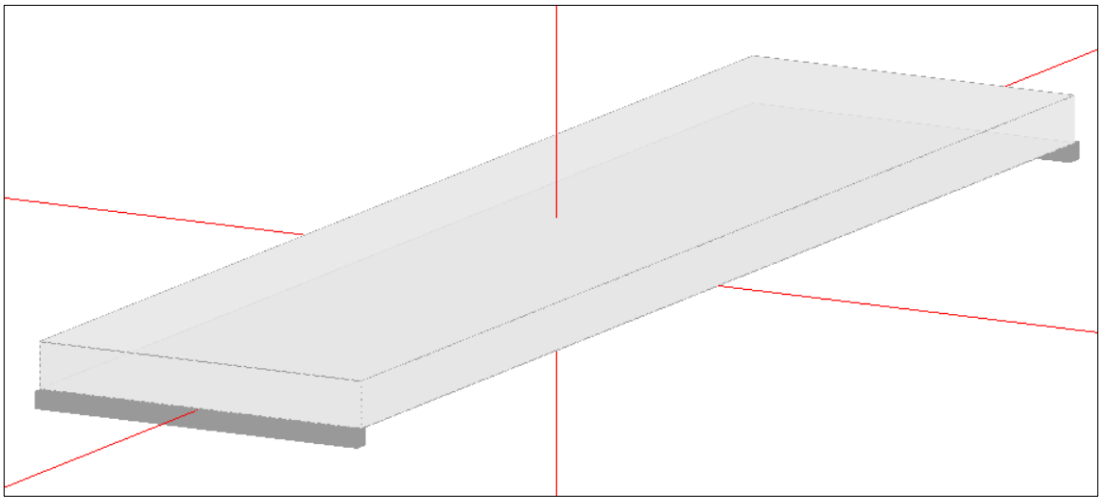

Figure 1: Model of Floor Slab Member (Concise Beam®)

2. Structural Analysis of Floor Slabs with Contemporary Realistic Loads

In this study a standard floor slab member for a typical residential building layout is chosen. The room dimension in the direction of the slab span is about 4m. The typical slab thickness for reinforced concrete slabs for Indian single-family slabs is 130mm. The typical materials and properties of the slab used in actual design and construction of these floor slabs is considered for the sake of analysis of the slab. The geometry of the slab member is detailed in Table 1 below whereas the material properties are shown in Table 2 below.

Table 1: Geometry of the Slab

Geometry Property	Value
Span	4 m
Slab Thickness	130 mm
Width of Slab	1 m
Cover	25 mm

Table 2: Material Properties of the Slab

Material	Property	Value
Concrete	Grade	M25 (25 MPa)
	Density	2500 Kg/m^3
	Youngs modulus (E)	26713 MPa
	Modulus of Rupture	3MPa
Steel	Grade	Fe 500
	Yield Strength	500 MPa
	Density	7850 Kg/m^3

	Youngs modulus (E)	210,000 MPa
Reinforcement Details	Bar size	10mm
	Bar spacing	190 mm
	Cover	25 mm

The slab is analyzed for three different cases of loading. The following are the scenarios analyzed and checked for designs to enable comparison of the designs and performance of the slab. A dead load factor of 1.2 and live load factor of 1.6 are taken for the sake of analysis and design comparisons.

1. Superimposed dead load of 0.2 kN/m^2 + Uniform live load of 2kN/m^2 all over slab as per IS 875
2. Superimposed dead load of 0.2 kN/m^2 all over slab + Point load of 1.8kN at midspan as per IS 875
3. Contemporary realistic superimposed dead load of 0.5kN/m^2 + Contemporary realistic dead load from furniture applied as point loads* + Realistic Uniform live loads*. Four points loads of 0.5kN and four point loads of 0.25 kN are considered as realistic dead point loads whereas realistic uniform live load of 1.7kN/m^2 is applied all over the slab.

   **The points loads are based on the sizes and weights of current commercially available Bed (Cot) and Sofa (Couch) transferred to slab. Each leg of the Cot is applied as 0.5kN and each leg of Sofa is applied as 0.25kN. The uniform live load is based on occupational resident human weight of 85kg per person and resident density of 2 people per square meter in the room.*

3. Design of Slab with Realistic Loads and Code Loads

The slab member is analyzed and designed using Concise beam software. The loads are applied on the slab members as per the configuration, material properties and loads mentioned in the previous section. The results of the analyses are elaborated for each of the three load scenarios mentioned in the previous section. The bending moment demands, the shear demands, the stresses and the deflections in the slab are compared with that of each other scenarios. Limit state design methodology is used with a flexural resistance factor of 0.9 and shear resistance factor of 0.75.

Load Case 1: ***Superimposed dead load of 0.2 kN/m^2 + Uniform live load of 2kN/m^2 on the whole slab as per Indian Standard IS 875 (2008a, 2008b)***

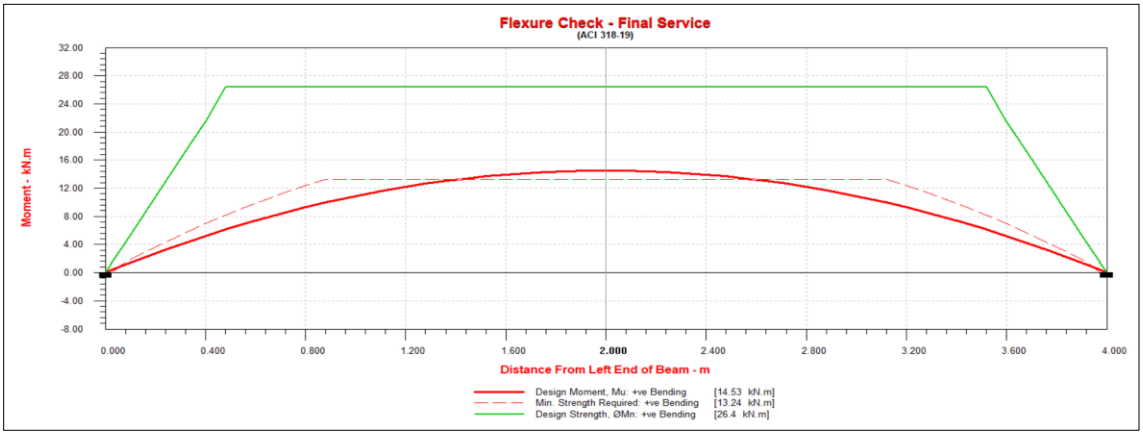

Figure 2: Flexural Moments and Capacity (Load Case 1- Uniform Load IS 875 based)

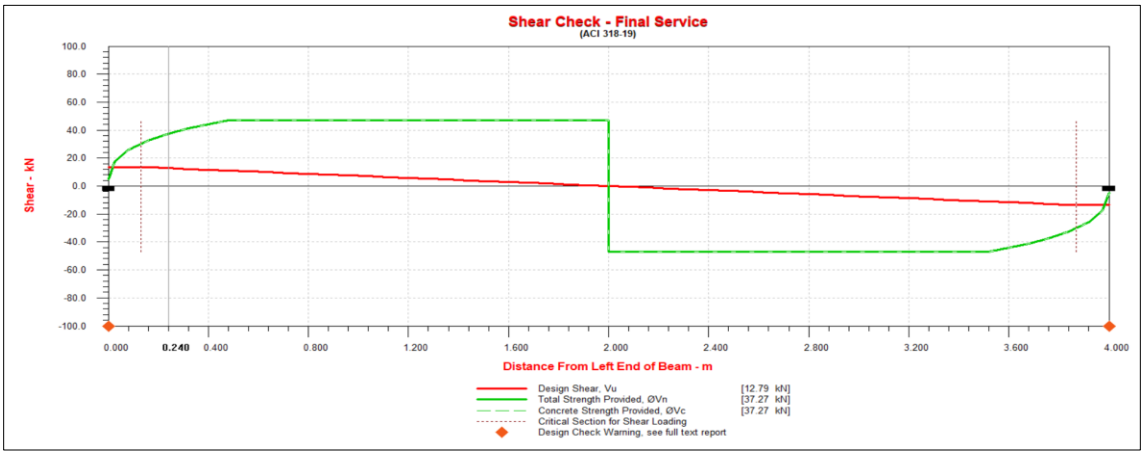

Figure 3: Shear Force and Capacity (Load Case 1- Uniform Load IS 875 based)

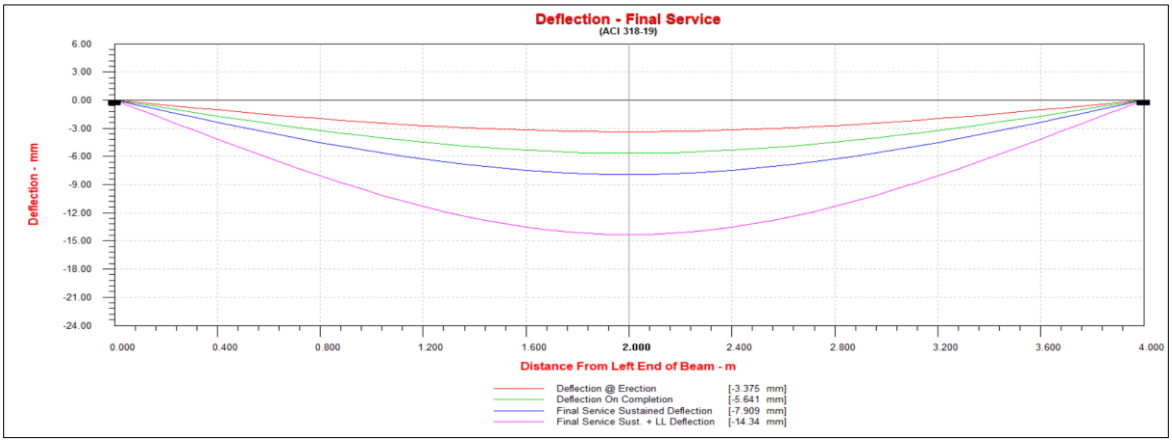

Figure 4: Slab Deflections (Load Case 1- Uniform Load IS 875 based)

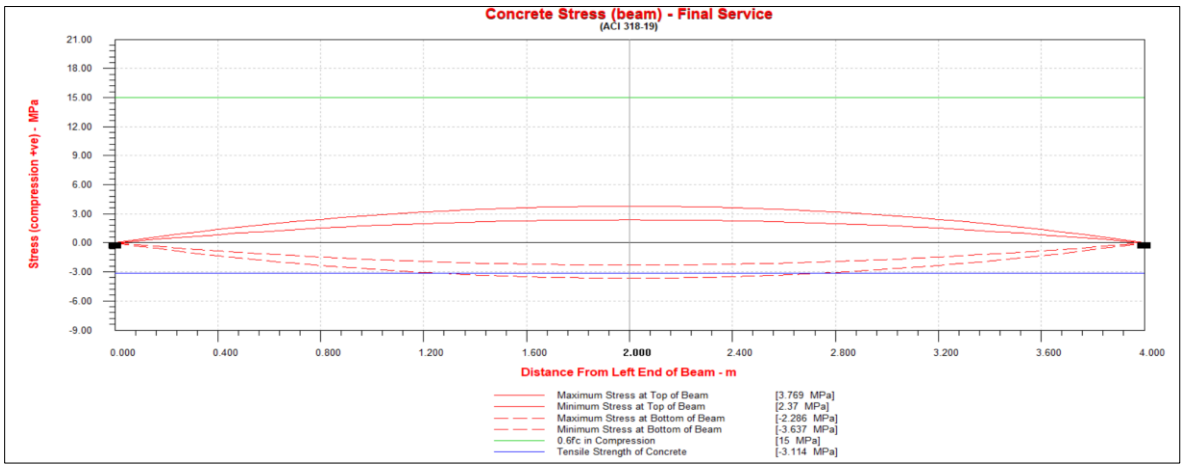

Figure 5: Slab Stresses (Load Case 1- Uniform Load IS 875 based)

Load case 2: ***Superimposed dead load of 0.2 kN/m2 on the whole slab + Point load of 1.8kN at midspan from the end of the slab as per IS 875***

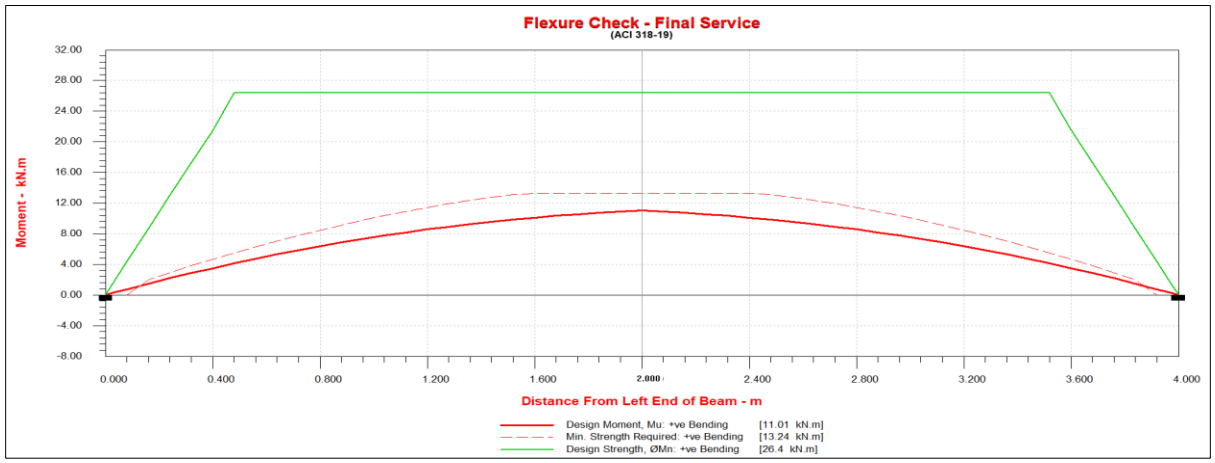

Figure 6: Bending Moments and Capacity (Load Case 2- Point Load @Midspan IS 875 based)

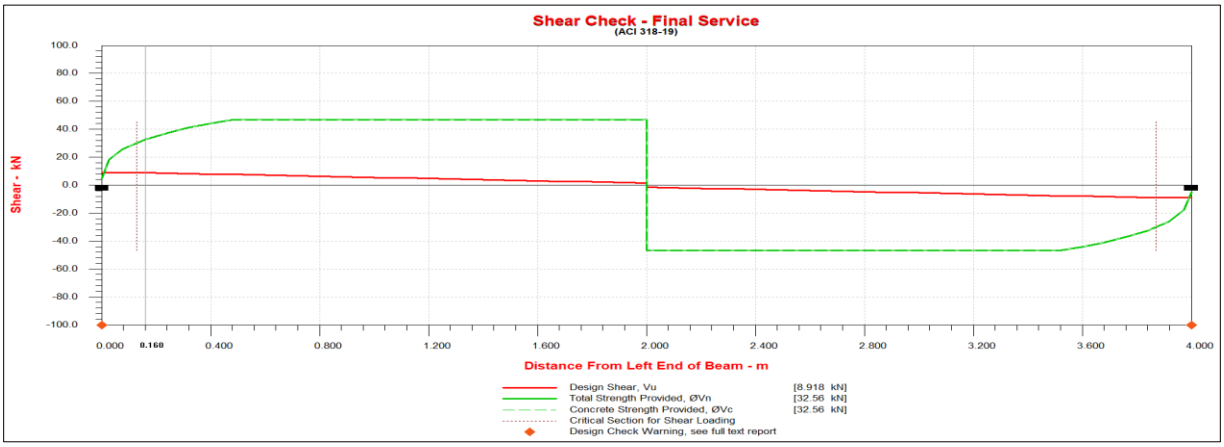

Figure 7: Shear Force and Capacity (Load Case 2- Point Load @Midspan IS 875 based)

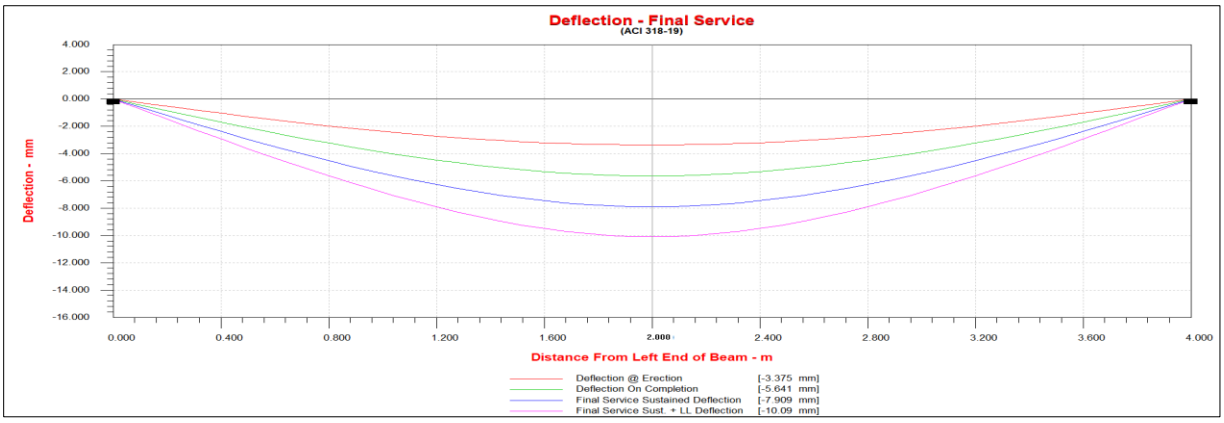

Figure 8: Slab Deflections (Load Case 2- Point Load @Midspan IS 875 based)

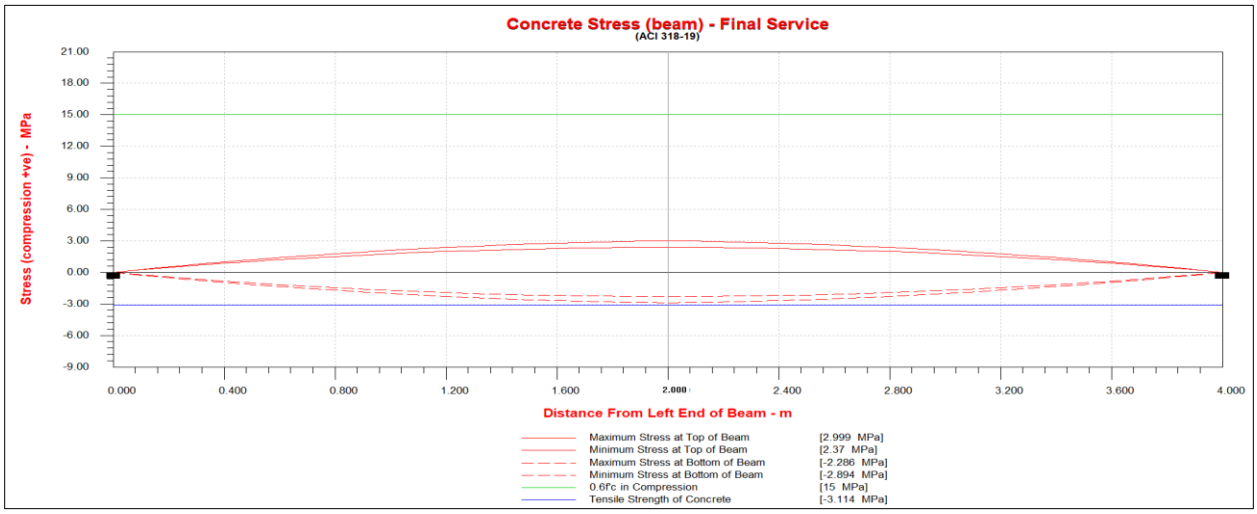

Figure 9: Slab Stresses (Load Case 2- Point Load @Midspan IS 875 based)

Load case 3: ***Contemporary realistic superimposed dead load of 0.5kN/m² + Contemporary realistic furniture dead loads applied as point loads + uniform live loads 0f 1.7 kN/m²***

In this load case, four points loads of 0.5kN and four-point loads of 0.25 kN are considered whereas a uniform live load of 1.7kN/m² all over the slab is used. The points loads are based on current commercially available Bed (Cot) and Sofa (Couch) sizes and weights transferred as point loads to slab. Each leg of the Cot is applied as 0.5kN and each leg of Sofa is applied as 0.25kN. The uniform live load of 1.7kN/m² is based on occupational resident human weight of 85kg per person and resident density of 2 people per square meter in the room.

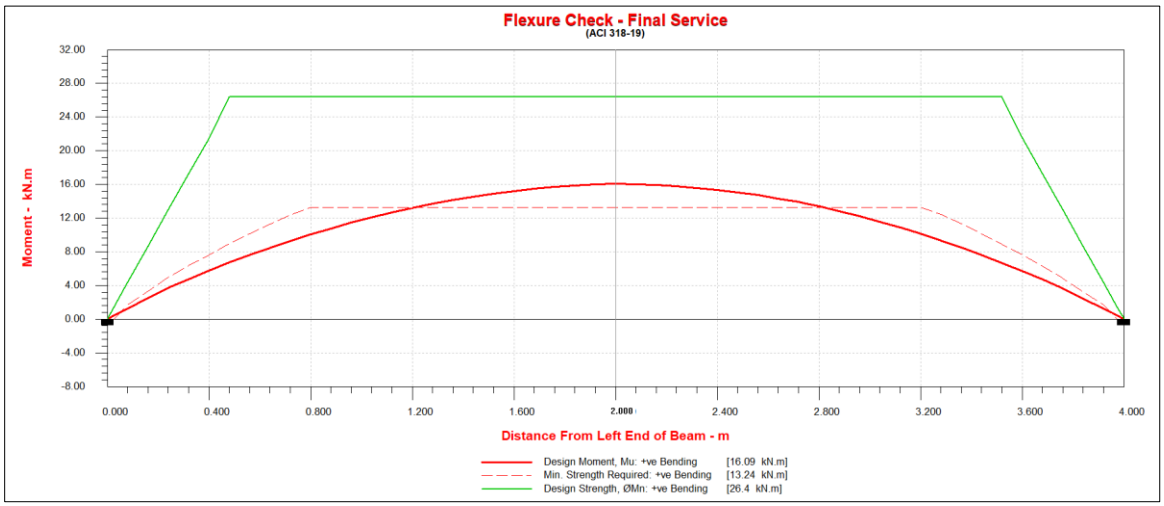

Figure 10: Bending Moments and Capacity (Load Case 3- Contemporary Realistic Loads)

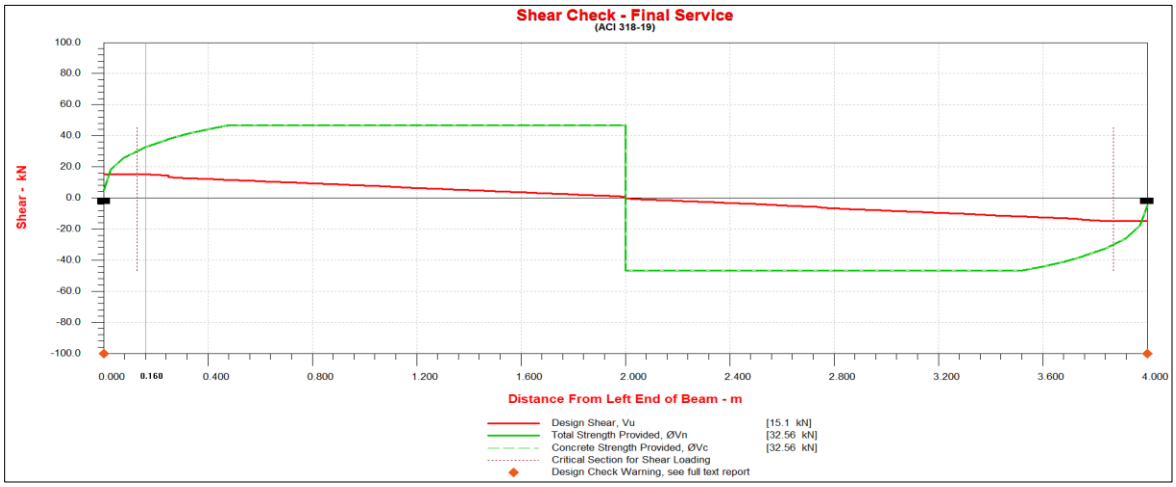

Figure 11: Shear Force and Capacity (Load Case 3- Contemporary Realistic Loads)

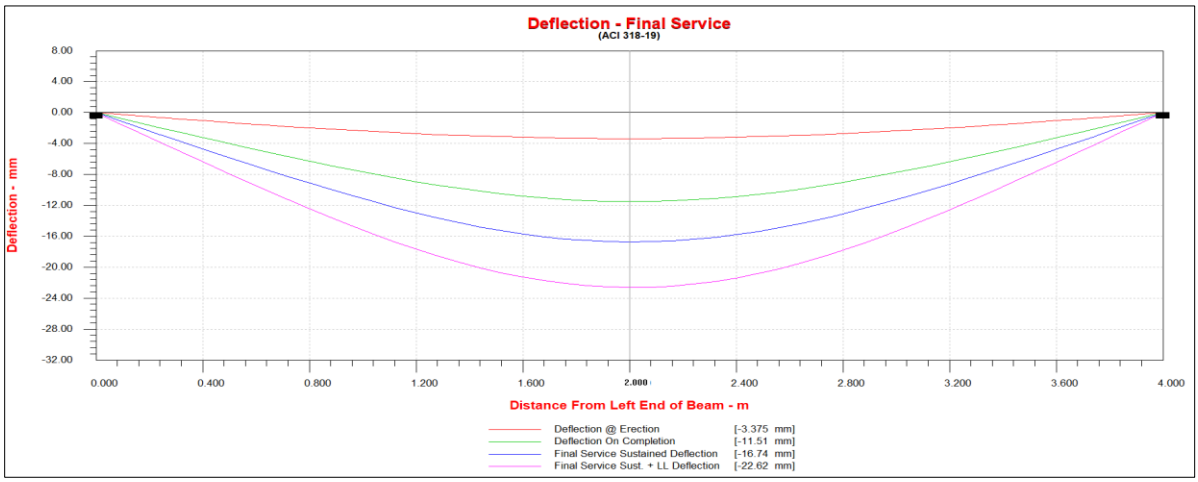

Figure 12: Slab Deflections (Load Case 3- Contemporary Realistic Loads)

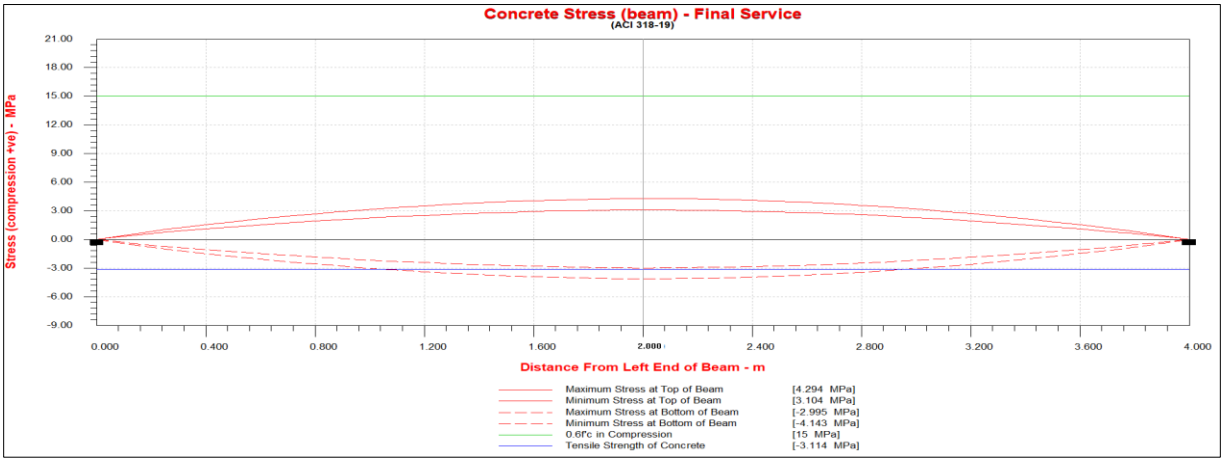

Figure 13: Slab Stresses (Load Case 3- Contemporary Realistic Loads)

4. Comparisons of the Slab Performance and Conclusions

Looking at the results of the three analyses cases above, some important observations can be made. The bending moment in the slab member subjected to contemporary real loads (16 kNm) is 10% more than the IS 875 code based uniform moment (14.5kNm). In case of shear force demands, It (15 kN) is 18% more than the shear force produced by IS 875 code based shear force (12.8kN).

The deflections in the slab which is the main controlling parameter for the design of these residential floor slabs are compared. In the case of conventional IS 875 uniform load-based design, the maximum deflection at the middle of the span is 14.3mm. This value for IS 875-point load-based design is 10.1mm. However, in the case of contemporary realistic load-based design, this deflection shot up to 22.6 mm which is 57% higher than conventional designs based on IS 875. This is equivalent to a span-deflection ratio of 177. As per IS 456 [9], this is expected to be above 250. Similarly, tensile stresses in concrete along with deflections are a major indicator of the long-term performance of the slab. The tensile stress at the bottom of the slab during service is about 3.7 MPa in the case of the conventional IS 875 uniform load-based design and about 2.9 MPa in the case of conventional point load based design. However, the tensile stress at the bottom of the slab under contemporary realistic loads shot to 4.1MPa. This is much higher than the permissible tensile stress in concrete of grade M25 which is 3.5 MPa [9].

It is very evident looking at the above analyses and designs that the contemporary realistic loads are producing much higher load and performance demands on the residential floor slabs in Indian markets. The deflections in the slab subjected to contemporary loads are much below the span to deflection threshold of 240. The tensile stress at the bottom of the slab also exceeded the permissible tensile stresses in concrete. This clearly indicates that the changing socio-economic conditions in India which lead to availability of bigger and heavier household items is causing destress on the conventionally designed slab members based on IS 875 code based standard loads.

This is a call for the code committees of the Bureau of Indian Standards to conduct thorough research on the load demands created by the new age furniture and household utility items as well as the human lifestyle changes and develop new guidelines for selection of load intensities for the design of the floor slab members. Otherwise, designs of floor based on conventional code-based load demands would lead to construction of building slabs that perform poorly in the long-term leading to substantial deflections and cracking and rapid early deterioration of the structure. These evolving loads when combined with the effects of extreme weather events due to climate change would further accelerate the structural deterioration [10, 11]. This adversely impacts the sustainability goals of infrastructure development [12, 13, 14]. In view of these observations, it is suggested that the minimum design loads for residential floor slabs be revised by the Bureau of Indian Standards to adequately reflect the contemporary living conditions.

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References

[1] Gollapudi, P. R., Dendukuri, S. C., & Brahmalla, S. (2024). Impacts of Local Socio-Economic-Political Constraints on the Selection of Bridge Type, Form, and Aesthetics. *International Journal of Scientific Research in Engineering and Management (IJSREM),* 8(1)

[2] Gollapudi, P. R., & Dendukuri, S. C. (2024). The Bridge Through the College (Part-1): Conception and Construction of Reinforced Concrete Bridge Across College Campus. *International Journal of Scientific Research in Engineering and Management (IJSREM),* 8(1)

[3] Jonnalagadda, S. & Vemuri, S. (2023). Challenges in Traditonal Concrete Slab Construction for Housing Buildings in Developing Countries and Critical Need for Novel Methods. *International Journal of Advances in Engineering and Management, 5*(5), 176-186.

[4] Jonnalagadda, S. & Vemuri, S. (2023). Novel Methods and Materials for Concrete Floor Slab Construction for Small Family Housing Buildings in India. *International Research Journal of Engineering and Technology, 10*(7), 1048-1056.

[5] Jonnalagadda, S. & Vemuri, S. (2023). Choosing Conventional Concrete, Ultra-High-Performance Concrete or Steel as Material of Construction: An Opinion. *European Modern Studies Journal, 7*(4), 280-288.

[6] Jonnalagadda, S., & Chava, S. (2023). Ultra-High-Performance Concrete (UHPC): A state-of-the-art review of material behavior, structural applications and future. *Electronic Journal of Structural Engineering*, 23(4), 25-30.

[7] IS 875. (2008). *Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures. Part 1: Dead Loads--Unit Weights of Building Materials and Stored Materials (Second Revision),* Bureau of Indian Standards

[8] IS 875. (2008). *Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures. Part 2: Imposed Loads (Second Revision),* Bureau of Indian Standards

[9] IS 456. (2000). *Indian Standard Plain and Reinforced Concrete)* Bureau of Indian Standards

[10] Vemuri, S., & Jonnalagadda, S. (2023). Wind Analysis of Tall Buildings Using Codal Provisions, Stochastic Approach and CFD – A Comparative Study. International Journal of Advances in Engineering and Management, 5(7), 58-68.

[11] Vemuri, S., & Jonnalagadda, S. (2023). Analyses of Box Bridge and Comparison of Structural Behavior using 3D Finite Element and Typical 1D Line Models. International Journal for Research in Applied Science & Engineering Technology, 11(8), 488-497.

[12] Jonnalagadda, S. (2016). Artificial Neural Networks, Non Linear Auto Regression Networks (NARX) and Causal Loop Diagram Approaches for Modelling Bridge Infrastructure Conditions. All Dissertations, *1725. https://tigerprints.clemson.edu/all_dissertations/1725*

[13] Ram, G. P. (2021). Background of Double Tee Construction and Need for Standardized Precast Double Tee for Indian Building Industry. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(11), 2978-2989.

[14] Jonnalagadda, S., Jonnalagadda, V., & Jonnalagadda, N. (2023). The Adverse Impacts of Climate Change on Infrastructure and Proposed Adaptation Framework for Residential Structures: Part 1, *European Modern Studies Journal, 7*(5), 20-34