

LOAD BEARING RCC SHEAR WALL SYSTEM FOR TALL RESIDENTIAL BUILDINGS IN INDIA – A GLOBAL PERSPECTIVE ON MINIMUM WALL THICKNESS REQUIREMENTS

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Abstract

Through the last decade, India has seen unprecedented developmental changes with rising standard of living amongst the masses. Significant and sustained increase in housing demand, coupled with considerable shrinkage in skilled workforce, have challenged the construction industry with sizeable shortfall of housing units. The recently announced “Housing for All by 2022” campaign by the Indian Government has also put additional pressure on the construction industry to deliver projects in record time frames. Traditionally, residential houses in major cities of India have been multi-storied high-rise apartments suitable for modular construction. Modular construction using Load Bearing Shear Wall (LBSW) System with rapid construction methodologies such as Aluminium/Tunnel Formwork or Precast Concrete fits perfectly as an alternative for traditional construction with shorter construction duration and reduction in labor, while exceeding quality standards of conventional construction practices in India. Thus, LBSW system is becoming increasingly popular for several tall buildings projects of Mass Housing in Metro as well as Tier 1 cities. This paper focuses on current guidelines for the minimum wall thickness for LBSW System in terms of structural design and Fire Resistance Rating (FRR). FRR requirements are looked at in more detail as these guidelines govern wall thickness requirements for Tall Buildings in the range of 70 -100 m for LBSW Systems – typical height range for Mass Housing projects. FRR provisions of International Codes are compared to IS Code provisions. In the interest of economical design of LBSW Buildings, it is proposed to adopt international FRR provisions without affecting the design intent and structural integrity of the building.

Keywords: Tall Residential Buildings, Mass Housing, Load Bearing Shear Wall System, Fire Resistance Rating, Minimum Wall Thickness

1. BACKGROUND

Tall Residential Buildings have been traditionally built using a beam/column moment frame system in India over the last three-four decades. Generally the buildings have been 12-14 levels tall with the exception of Metro Cities. Thus, the mainstream RCC IS codes such as IS 456 and IS 13920 have been mostly used for the beam/column moment frame system as a primary system. Although these codes discuss design and detailing requirements for the shear walls and load bearing walls, typical projects so far have systems where a few walls are used in the overall framed system, whether load bearing or lateral load resisting shear walls (Refer Figure 1).

Recent construction methodology trends in the residential sector, however, have seen an unprecedented shift in the choice of structural system. This has been further fueled by end users' inclination towards improved productivity and efficiency, and supported by the technology advent in terms of state-of-the-art formwork systems such as Aluminum Formwork Systems, Tunnel Formwork System and Precast Large Concrete Panel (PLCP) systems; such systems have

gained significant momentum in the industry over the last decade. At the core of all these technologies lies the RCC Load Bearing Shear Wall (LBSW) System that provides key advantages of faster completion and reduced workforce requirements, coupled with superior quality and low maintenance for residential buildings. The Indian Design Codes, however, have lagged behind in updates where such systems are addressed specifically for design requirements relevant to the technology. Even though structural design provisions of the existing codes still apply to the LBSW system, the structural integrity, serviceability and construction methodology requirements related to Fire Resistance Rating, Crack Control Measures, High Early Strength Concrete and Formwork Removal recommendations have not been updated in tandem with the global industry trends. In search of cost effective construction methodologies, the construction industry has therefore relied on adopting International Codal Provisions for, at least, the parameters that are independent of the geographical locations or design loads. In fact, in cases where the Indian Design Codes do not specifically address any particular design criteria or system, leading

International Codes such as IBC, ACI and ASCE have been referred to, with appropriate approvals from premier educational institutes in India to validate such adoptions. The minimum wall thickness for RCC walls required as per the specified FRR for tall buildings using LBSW system is one such critical parameter that needs attention.

As noted above, although the RCC LBSW System has been a popular choice in recent years, the Indian Design Codes do not specifically include codal requirements for the system based on the efficiency and redundancy provided by the system. In general guidelines provided by the RCC codes, mainly IS 456 and IS 13920 are followed. While these codes are best fit for overall structural design approach, the empirical and/or nominal provisions of these codes greatly impact various other parameters beyond the structural design parameters. For instance, for a typical high-rise building (at 70 m or less above ground), a 2 HR FRR is required by the Mumbai Chief Fire Officer (CFO)- as per the Fire No Objection Certificate (NOC) received for recent projects under construction in Mumbai). The same FRR is revised to 3HR by the Mumbai High Rise Committee (HRC) (as per the CFO recommendation in the 2011 Mumbai HRC Draft Guidelines) for High-Rise buildings taller than 70 m above ground. Thus, in general, for buildings less than 70 m tall, a 160 mm minimum wall thickness is sufficient for both structural demand as well as the fire resistance rating demand. Whereas, in buildings taller than 70 m, the minimum wall thickness needed for 3 HR fire resistance rating becomes 200 mm (with 0.4 to 1 % steel range) even if the structural design demand for RCC LBSW System could be 160 mm thick walls. This usually is not observed in the conventional system, as 200 mm thick walls are anyway provided (since fewer walls take the overall lateral load) even based on the Structural Design demand. Moreover, for RCC LBSW System buildings more than 100 m tall, the wall thickness demand based on structural design considerations also becomes 200 mm or more and thus matches with the FRR consideration thickness. Thus, in general, buildings in the range of 70 to 100 m only have the wall thickness controlled by Fire Resistance Rating instead of Structural demand and need additional attention in the interest of economical design.

2. OBJECTIVE

The primary objective of this paper is to compare the minimum wall thickness provisions of IS 456 and IS 13920 to similar provisions of International Codes. Based on the information provided, the intent is to propose adoption of minimum 160 mm thick walls in RCC LBSW System for 3HR Fire Resistance rating. The proposed adoption is based on the International Building Code – 2015 and Eurocode 2 requirements for RCC Walls and similar information provided by ACI and PCI publications. Individual structures

will then be analysed for required/optimum wall thickness based on structural design demand.

3. REFERRED CODES

3.1 Indian Codes

1. IS 456-2000^[1]
2. IS 13920 – 1993^[2]
3. CED 38 – WC – Draft Standard Criteria for Structural Safety of Tall Buildings^[3]

3.2 International Codes

1. IBC 2012^[4]
2. ACI 318 – 2014^[5]
3. PCI Design Handbook 7th Edition^[6]
4. Eurocode 2 (BS EN 1992)^[7]

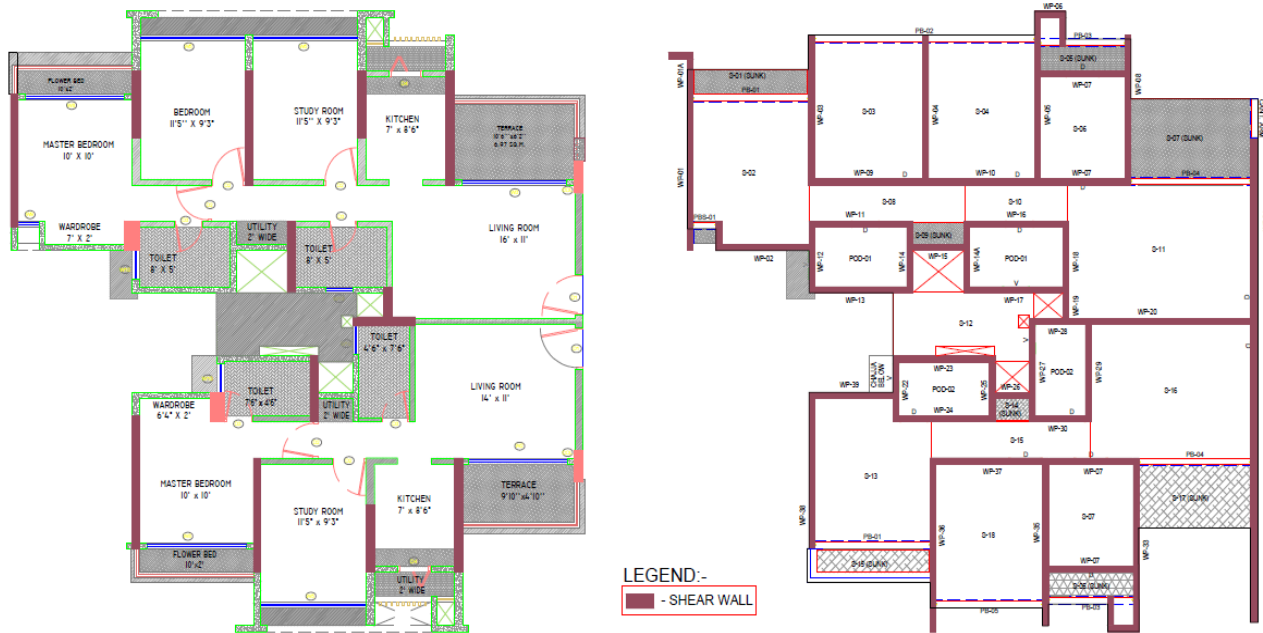
4. RCC LOAD BEARING SHEAR WALL (LBSW) SYSTEM

The key difference between the conventional framed system (with or without shear wall system) and the RCC LBSW system is the significant inclusion of more load bearing walls. Figure 1 shows a typical floor plan of a conventional system and the same when adopted by the RCC LBSW system indicating the wall percentage. Generally, the conventional system will have 10-15% of load bearing walls. Whereas, the RCC LBSW system will typically have 70-80 % load bearing walls (and as high as 95-98 % of walls in a few cases). Thus, the RCC LBSW system has an inherent redundancy in the system compared to the conventional system in terms of load path to transfer gravity or lateral loads. Overall gravity loads are also evenly distributed where the system has rarely any members that carry significantly larger loads compared to other gravity load bearing members. Due to the presence of longer walls with higher stiffness in response to lateral loads, a well-detailed RCC LBSW system provides exceptional rigid buildings at satisfactory ductility. Several structures with RCC LBSW System have performed exceptionally well around the world during times of natural calamities by providing the expected structural integrity and life safety.

5. PREVALENT INDIAN DESIGN CODE REQUIREMENTS OF MINIMUM WALL THICKNESS OF RCC WALL

5.1 For Specified Fire Resistance Rating

IS 456 – 2000: For RCC structures, IS 456 provides minimum wall thickness requirements based on the specified Fire Resistance Rating. Figure 2 indicates the current requirements for specified FRR.



Conventional Beam/Column Frame System w/
Shear Walls **Shear Wall Length – 29.3 m (0.18
m/sqm)**

Load Bearing Shear Wall System

Shear Wall Length – 134 m (0.78 m/sqm)

Note: Only a portion of the building floor plate is shown and compared for clarity

Fig-1: Comparison between Conventional Beam/Column Frames with Shear Wall System vs. LBSW System

Fire Resistance h	Minimum Beam Width b	Rib Width of Slabs b_w	Minimum Thickness of Floors D	Column Dimension (b or D)			Minimum Wall Thickness		
				Fully Exposed	50% Exposed	One Face Exposed	$p < 0.4\%$	$0.4\% \leq p \leq 1\%$	$p > 1\%$
	mm	mm	mm	mm	mm	mm	mm	mm	mm
0.5	200	125	75	150	125	100	150	100	100
1	200	125	95	200	160	120	150	120	100
1.5	200	125	110	250	200	140	175	140	100
2	200	125	125	300	200	160	—	160	100
3	240	150	150	400	300	200	—	200	150
4	280	175	170	450	350	240	—	240	180

NOTES

1 These minimum dimensions relate specifically to the covers given in Table 16A.

2 p is the percentage of steel reinforcement.

FIG. 1 MINIMUM DIMENSIONS OF REINFORCED CONCRETE MEMBERS FOR FIRE RESISTANCE

Fig – 2: IS 456 – Fig. 1 on Page 34 – Minimum Dimensions of RCC Members for Fire Resistance

Based on typical design considerations for high-rise buildings in the range of 70-100 m, the reinforcement requirement in the walls generally ranges from 0.25%–0.8% except for the base level walls of the first few floors. Thus, considerations for a reinforcement ratio of 0.4 – 1.0% are looked at. For 2 HR FRR, minimum wall thickness is

noted at 160 mm. Whereas, for 3 HR FRR, the minimum thickness needed is 200 mm. Figure 3 notes the related minimum cover requirements. Cover requirements specific to RCC walls, however, are not noted. Provisions as noted in Section 26.4.2.1 for walls 200 mm thick or less are followed.

Table 16A Nominal Cover to Meet Specified Period of Fire Resistance (Clauses 21.4 and 26.4.3 and Fig. 1)							
Fire Resis- tance	Nominal Cover						Columns
	Beams		Slabs		Ribs		
	Simply supported	Continuous	Simply supported	Continuous	Simply supported	Continuous	
h	mm	mm	mm	mm	mm	mm	mm
0.5	20	20	20	20	20	20	40
1	20	20	20	20	20	20	40
1.5	20	20	25	20	<u>35</u>	20	40
2	<u>40</u>	30	<u>35</u>	25	45	<u>35</u>	40
3	60	<u>40</u>	45	<u>35</u>	55	45	40
4	70	50	55	45	65	55	40
NOTES							
1 The nominal covers given relate specifically to the minimum member dimensions given in Fig. 1.							
2 Cases that lie below the bold line require attention to the additional measures necessary to reduce the risks of spalling (see 21.3.1).							

Fig – 3: IS 456 – Table 16A on Page 47 – Nominal Cover in RCC Members for Fire Resistance

5.2 Minimum Wall Thickness per Structural Design

Guidelines

IS 456– 2000: Section 32.2.3, Page 61 (Figure 4) specifies the minimum wall thickness for RCC Shear Walls. For a typical floor to floor height of 2900 mm, the minimum wall thickness is calculated at 96.67 mm (considering no fixity).

32.2.3 Maximum Effective Height to Thickness Ratio

The ratio of effective height to thickness, H_{we}/t shall not exceed 30.

Fig. 4: IS 456 – Section 32 – Minimum Thickness for RCC Walls

IS 13920 – 2004: For structures in Seismic Zone 3 and above, IS 13920 applies for achieving appropriate ductility. For LBSW, Section 9.1.2 (Figure 5) recommends minimum thickness of 150 mm based on structural requirements for buildings in high seismic zones.

IS CED 38 (Draft – IS – Code of Practice for Design of Tall Buildings): The draft IS code CED 38, which is to be released (in draft circulation for comments), provides guidelines for tall buildings in the range of 45 m to 250 m in height. The code is being specifically prepared to

bridge the gaps between IS 456 provisions and specific requirements, as per the Tall Building design considerations. The code, however, only addresses structural design considerations. In the proposed code, the IS 456 guidelines are changed with increased requirement on thickness of walls. Per section 8.5.1 (Figure 6), for a typical floor-to-floor height of 2900 mm, the minimum thickness of structural RCC wall is calculated at 145 mm (considering no fixity). Thus, the minimum thickness of 160 mm governs even for tall buildings. Only for buildings in very high seismic zones (Zones IV and V), a minimum thickness of 160 mm is revised to 200 mm, as per Section 8.5.14 (Figure 6).

9 SHEAR WALLS

9.1 General Requirements

9.1.1 The requirements of this section apply to the shear walls, which are part of the lateral force resisting system of the structure.

9.1.2 The thickness of any part of the wall shall preferably, not be less than 150 mm.

Fig. 5: IS 13920 – Section 9 – Minimum Thickness for RCC Walls

8.5 Structural Wall Systems

8.5.1 The thickness of structural wall shall not be less than 160mm or $H_w/20$, whichever is larger.

8.5.14 Special requirements for Seismic Zone IV and Zone V

- Structural walls shall be continuous to the base without being transferred in plane or out of plane at any level;
- The thickness of structural wall shall not be less than 200mm;

Fig. 6: CED 38 – Section 8.5 – Minimum Thickness for RCC Walls

6. INTERNATIONAL DESIGN CODE (IBC 2015) REQUIREMENTS OF MINIMUM WALL THICKNESS OF RCC WALL FOR SPECIFIED FIRE RESISTANCE RATING:

The International Code Council (ICC) is a member-focused association. It is dedicated to developing model codes and standards used in the design, build and compliance process to construct safe, sustainable, affordable and resilient structures. Most U.S. communities and many global markets choose various International Codes that are published by ICC as the code of practice.

About ICC

<http://www.iccsafe.org/>

ICC - I Codes Adoption

<http://www.iccsafe.org/international-code-adoptions/>

The International Building Code (IBC) is published for residential and commercial buildings. This code is updated every three years. The current version is 2015. However, the 2012 version is currently accepted industry-wide. The requirements for the FRR under considerations here are same in both versions. The code recommends both prescriptive as well as design specific approach. The prescriptive requirements are referred here as the FRR requirements in the IS 456 adopt the prescriptive approach. Chapter 7 of the IBC provides requirements for Fire and

Smoke Protection Features. Section 721 provides minimum thicknesses required for various building materials for specified FRR based on a prescriptive approach. Table 721.1(2) (Figure 7) specifies minimum thickness required at specified FRR for Walls and Partitions. For a 3 HR FRR, the minimum thickness of RCC wall, for Siliceous Aggregates, is noted at 6.2 in (157.5 mm).

Note: Footnote “i” of Table 721.1(2) requires that the RCC walls should be reinforced vertically and horizontally with temperature reinforcement as required by Chapter 19 – Concrete (in turn referred to ACI 318 for the design requirements). Chapter 19 – Section 1905 also notes modifications to ACI 318. However, none of the modifications are related to the FRR. Thus, the structural design requirements (in terms of reinforcement provided and nominal covers) will be as per ACI 318 (Figure 8). ACI 318 requires the reinforcement provisions, as per gravity and lateral loads. ACI 318 – 2014, Chapter 11 specifies minimum reinforcement for Structural/Non Structural Walls.

In addition, Section 722 of Chapter 7 discusses the calculated fire resistance approach. Although, this approach is not in the scope of this paper, Section 722.2.1.1 (Figure 9) notes the minimum thickness of load bearing or non-load bearing walls in line with the discussion above.

SECTION 721 PRESCRIPTIVE FIRE RESISTANCE

721.1 General.

The provisions of this section contain prescriptive detail or assemblies. The materials of construction listed in Table 721.1(2) to have the *fire-resistance ratings* prescribed therein. Where dissipation are incorporated into a fire-resistance-rated wall, the details shall be made available to the *building official* to show that the rating is not reduced.

TABLE 721.1(2) RATED FIRE-RESISTANCE PERIODS FOR VARIOUS WALLS AND PARTITIONS^{a, o, p}

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE ^b (inches)			
			4 hours	3 hours	2 hours	1 hour
4. Solid concrete ^{h, i}	4-1.1	Siliceous aggregate concrete.	7.0	6.2	5.0	3.5
		Carbonate aggregate concrete.	6.6	5.7	4.6	3.2
		Sand-lightweight concrete.	5.4	4.6	3.8	2.7
		Lightweight concrete.	5.1	4.4	3.6	2.5

Fig. 7: IBC 2015 – Section 721 – Prescriptive FRR for Solid Concrete

11.6—Reinforcement limits

11.6.1 If in-plane $V_u \leq 0.5\phi V_c$, minimum ρ_t and minimum ρ_l shall be in accordance with Table 11.6.1. These limits need not be satisfied if adequate strength and stability can be demonstrated by structural analysis.

Table 11.6.1—Minimum reinforcement for walls with in-plane $V_u \leq 0.5\phi V_c$

Wall type	Type of nonprestressed reinforcement	Bar/wire size	f_y , psi	Minimum longitudinal ^[1] , ρ_l	Minimum transverse, ρ_t
Cast-in-place	Deformed bars	\leq No. 5	$\geq 60,000$	0.0012	0.0020
			$< 60,000$	0.0015	0.0025
		$>$ No. 5	Any	0.0015	0.0025
	Welded-wire reinforcement	\leq W31 or D31	Any	0.0012	0.0020
Precast ^[2]	Deformed bars or welded-wire reinforcement	Any	Any	0.0010	0.0010

11.6.2 If in-plane $V_u \geq 0.5\phi V_c$, (a) and (b) shall be satisfied:

(a) ρ_t shall be at least the greater of the value calculated by Eq. (11.6.2) and 0.0025, but need not exceed ρ_t in accordance with Table 11.6.1.

$$\rho_t \geq 0.0025 + 0.5(2.5 - h_w/\ell_w)(\rho_l - 0.0025) \quad (11.6.2)$$

(b) ρ_l shall be at least 0.0025

Fig. 8: ACI 318 – 2014 – Section 11.6 – Minimum Reinforcement Provisions for Walls

TABLE 722.2.1.1 MINIMUM EQUIVALENT THICKNESS OF CAST-IN-PLACE OR PRECAST CONCRETE WALLS, LOAD-BEARING OR NONLOAD-BEARING

CONCRETE TYPE	MINIMUM SLAB THICKNESS (inches) FOR FIRE-RESISTANCE RATING OF				
	1 hour	1½ hours	2 hours	3 hours	4 hours
Siliceous	3.5	4.3	5.0	6.2	7.0
Carbonate	3.2	4.0	4.6	5.7	6.6
Sand-lightweight	2.7	3.3	3.8	4.6	5.4
Lightweight	2.5	3.1	3.6	4.4	5.1

Fig. 9: IBC 2015 – Section 722 – Minimum Wall Thickness for LB/NLB Walls using Calculations Approach

7. PRECAST/PRESTRESSED CONCRETE INSTITUTE (PCI) HANDBOOK 7TH EDITION - REQUIREMENT OF MINIMUM WALL THICKNESS OF RCC WALL FOR SPECIFIED FIRE RESISTANCE RATING:

Precast Concrete Institute (PCI) has conducted several fire tests for various building systems over the years. Several of these test reports are used by the Underwriters Laboratory (UL) to issue listings. The tests were conducted as per ASTM E119 with the Structural End Point, Flame Passage

End Point and Heat Transmission End Point criteria. It has been documented that several RCC systems that pass the Structural End Point and Flame Passage end Point criteria do not pass the Heat Transmission Criteria. Thus, for typical RCC members detailed for in service structural loads, the Heat Transmission End Point becomes the governing criteria. Chapter 10, Section 10.5 (Figure 10) provides the prescriptive criteria for the Heat Transmission Requirements for specified FRR.

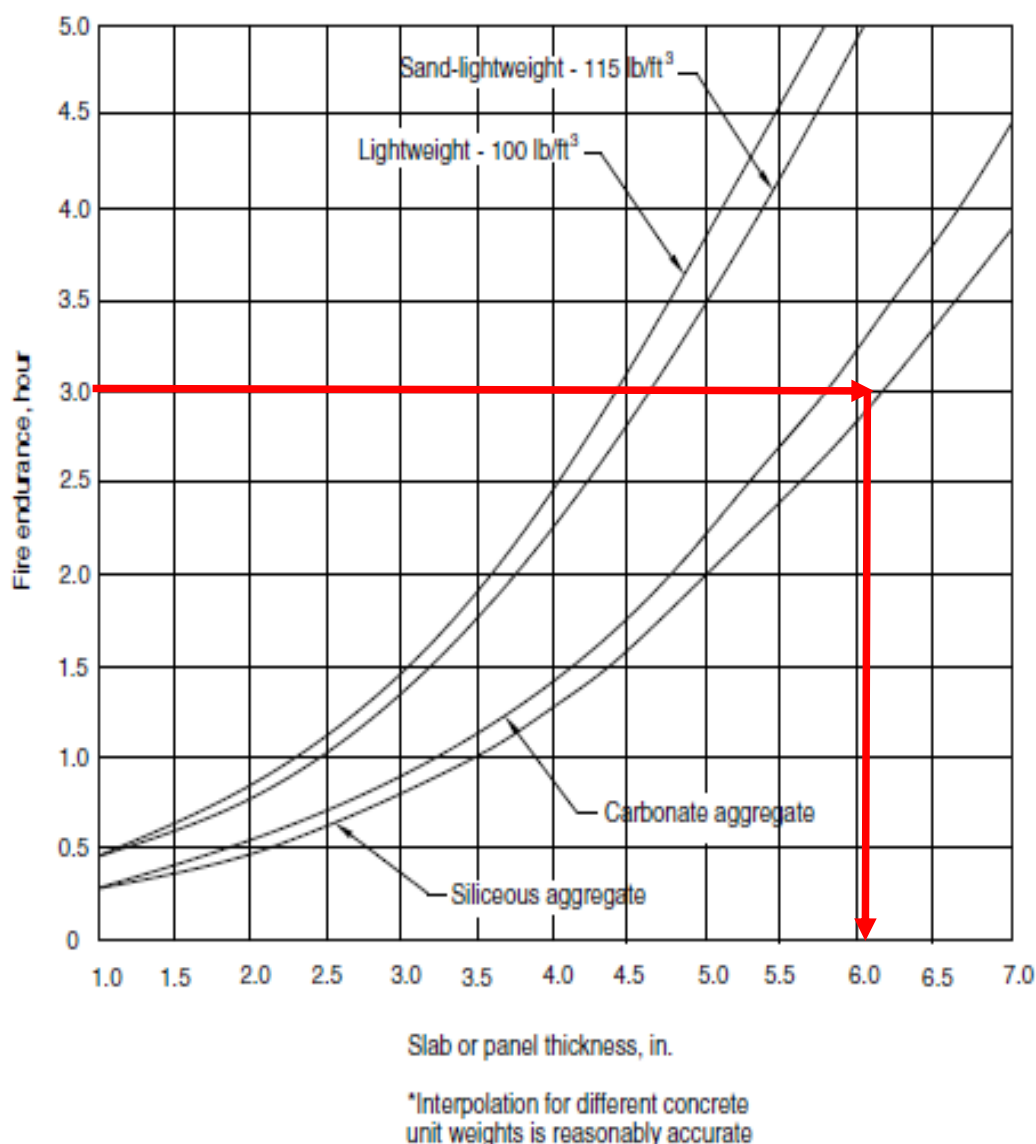


Fig. 10.5.1 Fire endurance (heat transmission) of concrete slabs or panels.

Fig. 10: PCI Design HB 7th Edition – Section 10.5 – Minimum Thickness of RCC Elements for Specified FRR

8. EUROCODE 2 (BS EN1992) - REQUIREMENT OF MINIMUM WALL THICKNESS OF RCC WALL FOR SPECIFIED FIRE RESISTANCE RATING:

Eurocode 2 (BS EN 1992-1-2 (2004)) provides guidelines for fire resistance design of reinforced concrete structures. Similar to American codes, Eurocode 2 also requires primarily fire resistance against Load Bearing Function (R), Integrity Function (E) and Insulation Function (I) as noted in Sections 1.6 and 2.1.2. Criterion R is required for Mechanical Resistance under fire exposure and Criteria E and I are followed where compartmentation is required. Also, in general, Tabulated Data, Simplified Calculations and Advanced Calculations methods are followed as noted in Table 0.1 based on a Prescriptive or Performance Based approach, as per the project's requirement. Per Section 4.1, any of the above methods, within the given constraints, is acceptable. Thus, Simplified Method could be adopted over the Tabulated Data option, if it yields economical design.

Focusing on the scope of this paper, Section 5.4.1- Table 5.3 (Figure 11) specifies the minimum thickness required for Non-Load Bearing Walls for the E and I criteria. Although this table specifies the requirements for Non Load Bearing Walls, Section 5.2 (1) notes that the requirements noted in Table 5.3 will satisfy the E and I criteria for walls and slabs in general. In addition, the ratio of wall height to thickness is restricted to 40 to avoid excessive thermal deformation.

Standard fire resistance	Minimum wall thickness (mm)
1	2
EI 30	60
EI 60	80
EI 90	100
EI 120	120
EI 180	150
EI 240	175

Fig. 11: Eurocode 2 – Section 5.4 (Table 5.3) – Minimum Thickness of NLB Walls for Specified FRR

With respect to the Load Bearing (R) criterion, Section 5.4.2 (Figure 12) specifies the minimum thickness requirements for Load Bearing Walls. For typical residential buildings' requirements, per the provisions of this table, a minimum thickness of 210 mm and cover (from center of rebar) of 50 mm would be required for a 3 HR FRR. This is similar to the IS 456 requirements noted above ($\mu_{fi} = 0.7$).

Standard fire resistance	Minimum dimensions (mm)			
	Wall thickness/axis distance for			
	$\mu_{fi} = 0,35$		$\mu_{fi} = 0,7$	
	wall exposed on one side	wall exposed on two sides	wall exposed on one side	wall exposed on two sides
1	2	3	4	5
REI 30	100/10*	120/10*	120/10*	120/10*
REI 60	110/10*	120/10*	130/10*	140/10*
REI 90	120/20*	140/10*	140/25	170/25
REI 120	150/25	160/25	160/35	220/35
REI 180	180/40	200/45	210/50	270/55
REI 240	230/55	250/55	270/60	350/60

* Normally the cover required by EN 1992-1-1 will control.

Note: For the definition of μ_{fi} see 5.3.2 (3).

Fig. 12: Eurocode2 – Section 5.4 (Table 5.4) – Minimum Thickness of LB Walls for Specified FRR

It should be noted, however, that Eurocode 2 further allows adoption of Simplified and Advanced Calculations method here for Load Bearing criterion that could provide lower wall thickness based on the project specific calculations. The E and I criteria noted in Section 5.4.1 then governs as the minimum thickness criteria. This provision, over the years, has not been adopted by the IS codes, restricting the wall thickness requirements to the nominal provisions only.

9. SUMMARY AND CONCLUSION

The current residential construction industry is favoring RCC Load Bearing Shear Wall (LBSW) Construction in lieu of the conventional beam/column frame or local shear wall construction in recent years. The presence of considerably more shear walls is a key characteristic of the RCC LBSW system that results in a significant redundancy in the system to redistribute loads in the events of natural disasters. The RCC LBSW system, however, is not specifically addressed in the current IS 456 version and often gets compared to the Framed System with a few Shear Walls system. In addition to the redundancy offered by the RCC LBSW system, the overall structural design demand is also lesser for the Load Bearing Walls in the LBSW system, as compared to the Shear Walls in the framed system. Thus, in several cases, for buildings in the range of 70 to 100 m in height, the prevalent requirements of minimum wall thickness for specified Fire Resistance Rating (FRR) start governing in the LBSW system instead of structural design demand. In the interest of economical design, in such cases, it is proposed to refer to International Codal Provisions, namely, the International Building Code (IBC 2015) and Eurocode 2 (BS EN 1992) for the specified FRR that will still provide expected FRR performance and Structural Integrity. Table 1 summarizes the comparison of IS 456 provisions that are currently expected to be adopted by the RCC LBSW system for specified FRR vs. IBC 2015 and Eurocode 2 provisions for ready reference along with nominal structural minimum thickness provisions noted in Table 2.

Table 1: Minimum RCC LB Wall Thickness Comparison based on 3 HR FRR Considerations

IS456:2000		IBC2015		PCI Design Handbook 7 th Edition		Eurocode 2	
Clause No.	Details	Clause No.	Details	Clause No.	Details	Clause No.	Details
Fig.1, Page 34	Minimum wall thickness of 200 mm with 0.4% $<p<1\%$	Table 721.1(2)	Minimum thickness = 6.2 inch = 157.5 mm	Fig. 10.5.1	Minimum thickness= 6.2 inch = 157.5 mm	5.4.1 5.4.2 4.2 and 4.3	150 mm for E and I 210 mm (50 mm cover) for R Per calculation but not less than 150 mm

Table 2: Minimum RCC LB Wall Thickness based on Structural Considerations – Indian Codes

456:2000		IS 13920		Draft –Indian Standard Code of Practice of Design of Tall Buildings (CED 38)	
Clause No.	Details	Clause No.	Details	Clause No.	Details
32.2.3	Ratio of effective height to thickness H_{we}/t shall not exceed 30	9.1.2	The thickness of any part of the wall shall preferably, not be less than 150mm	8.5.1	The thickness of structural wall shall not be less than 160mm or $H_w/20$, whichever is larger.
				8.5.14	For seismic zone IV and V, The thickness of structural wall shall not be less than 200mm

REFERENCES

- [1]-IS: 456 – 2000 - Code of Practice for Plain and Reinforced Concrete, Bureau of Indian Standards.
- [2]-IS:13920–1993-Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces - Code of Practice, Bureau of Indian Standards
- [3]-CED 38 (10639) WC – Draft Standard Criteria for Structural Safety of Tall Buildings
- [4]- IBC 2015 – International Building Code, ICC
- [5]- ACI 318-2014 - Building Code Requirements for Structural Concrete
- [6]- PCI Design Handbook 7th Edition - Precast/Prestressed Concrete, Precast/Prestressed Concrete Institute, USA
- [7]-Eurocode 2 (BS EN 1992-1-2) - Design of Concrete Structures-Part 1-2: General Rules – Structural Fire Design

BIOGRAPHY



Mr. Amit Barde heads the Precast Design Group of the Residential Buildings Strategic Business Unit under the umbrella of Buildings & Factories Independent Company of Larsen & Toubro Ltd. Previously, he has worked with a leading precast concrete manufacturer in the United States for about ten years and has extensive experience in residential, commercial and industrial precast concrete structures. He has designed and managed several precast concrete projects such as data centers, office buildings, schools, warehouses, industrial plants, stadiums and parking structures. He graduated from Purdue University with Master's Degree in Civil Engineering. He is a Registered Professional Engineer (MI-USA) and a LEED Certified Professional (USGBC).