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Study of Minimum Dimensions for Concrete Structural Members against Fire Resistance including Cover Provisions in Different Countries Standards

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ABSTRACT

It is important to understand the overarching requirements for structural performance in the case of Fire. The building shall be designed and constructed so that in the event of fire its stability will be maintained for a reasonable period and this defines the fundamental performance requirements for the structure of a building in fire. How this functional requirement is met may be interpreted in different ways? The loss of any element in fire results in the structure losing its stability if each element possesses sufficient resistance in fire, this ensures that the structure has sufficient load bearing capacity, Fire is an emergency, from which no structure, remains unaffected. Due to increased incidents of major fires in buildings; analysis, repairs and rehabilitation of fire damaged structures has become a topic of interest. R.C.C (Reinforced cement concrete) in relation to fire is relatively less explored because of the lesser use of Reinforced concrete structures in Europe/USA as compared to steel structures. In India, there is more use of Reinforced concrete structure as compared to steel and composite structure. There is an urgent need to collect more data & lay more emphasis on design oriented 'Passive measures' rather than just relying on fire-fighting measures known as 'Active measures'. Ignorance on part of the consultants & civic authorities has resulted in structures that are sub-standard from fire resistance view point. There is an urgent need to gather additional information about performance of R.C.C. under fire in order to create a general awareness & improve the existing practices & Code provisions.

Keywords: Structural member, Beam cover, Slab cover, Fire resistance, Reinforced concrete structures and spalling of concrete

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INTRODUCTION

Fire can cause irreparable losses, particularly to any hospital. Hospitals are structures with a high density of life in terms of patients, doctors staff etc. Therefore, utmost care needs to be taken while designing. The hospital as an infrastructure has many heat dissipating equipment's, combustible gasses, fuel chemicals and a lot of electrical wiring etc. The case of AMRI hospital in Kolkata there were 160 people died inside the hospital on Dec. 09 2011, (space) External glass Façade made of double glass panes were very difficult to break and the building had no operable windows to dissipate smoke which resulted in many deaths due to suffocation / asphyxia. Second case reported from Tamilnadu, India fire mishap at a private mental hospital there were 28 mentally ill people were killed in a fire mishap on Aug 06, 2001.The third case reported from Royal Marsden Hospital London, a fire mishap in a specialist cancer hospital. The study will be the structural assessment of available Building codes and standards against fire by considering Hospitals buildings from different countries Like India Australia, United States, Canada, Japan and New Zealand. We are also going to consider common agreed Consensus based code like International Building code and professional bodies like Society of Fire Protection Engineers, The National Fire Protection Association (NFPA) and American society of civil Engineers, The American Concrete Institute International ACI, The Pre-Cast Pre-stressed concrete Institute, The Indian standards IS 1641(1988) [1] and IS 1642 (1989) [2] and National building code (NBC) of India [3].

It is also necessary to study these above said codes for the specifications and guide lines used for obtaining parameters. We are going to consider both prescriptive and performance based standards and results data. The structural materials which are going to be considered are steel, concrete and composite of steel and concrete. The assessment identifies gaps in Indian codes and standards for the design of structures against fire and also knows the structural performance of Hospital buildings in fire and also studies the parameters for loss of strength by fire under time period consideration, Table -1 Shows different fire incidents in hospital buildings around the world.

Table -1 Major Fire Accidents on Globe

Hospital	Country	Year of incident	Main Cause	Main Damage
AMRI Hospital, Kolkata	India	2001	Short circuit at basement	
SUM Hospital, Bhubaneswar, Orissa	India	2016	Short Circuit	
Royal Marsden Hospital, London	United Kingdom	2008		
North London Forensic Service, Chase Farm Site Hospital	United Kingdom	2008		
The central core of the CESP building, Sao Paulo reinforced concrete framing with ribbed slab floors (was no sprinklers system)		1972		Partial collapse
Joelma building, Sao Paulo Reinforced concrete		1974	Flammable materials had been used to furnish the interior	Spalling of exterior concrete of walls which cause partial collapse.
One New York plaza, New York Reinforced concrete without sprinklers system	USA	1970	Wrong thermal activates in the security system	Failure of the steel filler beams on the 33 - 34th floors. Shear of connection bolts during the fire.
MGM Grand Hotel, Las Vegas Reinforced concrete with sprinklers system	USA	1980	Fault inside a wall soffit at electrical ground	There was no major collapse. However, the casino and restaurants floors suffered of few hours of burning.
Textile factory, Alexandria, Egypt Sprinklers system was not provided	Egypt	2000	Shortage room at the ground floor	Total collapse.

CONCRETE STRUCTURE IN FIRE

The effect of fire on concrete depends upon the higher temperature reached during fire, the length of the fire period, the rate of temperature and properties of concrete [4]. The resistance of concrete under fire depends upon the type of cement, aggregate, w/c ratio, cement content, microstructure and thickness of cover to concrete. Concrete and masonry as a structural material is inherently superior in fire resistance in comparison to wood and steel. Concrete is poor conductor of heat. Thermal conductivity reduces as the temperature increases. Concrete is able to retain its strength for longer periods; Steel however loses its strength at this high temperature [5]. Concrete has intrinsic fire resistance when possibly exposed to elevated temperature nevertheless; the mechanical properties such as strength, modulus of elasticity and volume stability of concrete are significantly reduced during fire exposure and its result in undesirable structural failures. Random spread of fire provides a tough job for fire fighters during rescue work [6].

Table -2 Comparison of Structural Member Minimum Dimensions for Fire Resistance

Country	**Hour**	**Slab**		**Beam**		**Column**	
		Restrained		**Unrestrained**		**Restrained**	
USA	4	168	-	178	76	305	-
	3	145	-	178	44	279	-
	2	117	-	178	19	254	-
	1.5	102	-	178	19	229	-
	1	81	-	178	19	203	-
	0.5	-	-	-	-	-	-
JAPAN	4	-	-	-	-	-	-
	3	-	-	-	30	400	30
	2	100	20	-	30	250	30
	1.5	-	-	-	-	-	-
	1	70	20	-	30	-	30
	0.5	-	-	-	-	-	-

Components	Hour	Slab		Beam		Column	
Country		**Thickness**	**Cover**	**Thickness**	**Cover**	**Thickness**	**Cover**
India	**4**	170	55	280	80	450	35
	3	150	45	240	70	400	35
	2	125	35	200	60	300	35
	1.5	110	25	150	40	250	30
	1	95	20	120	30	200	25
	0.5	75	15	80	20	150	20
Britain	**4**	170	55	280	80	450	35
	3	150	45	240	70	400	35
	2	125	35	200	50	300	35
	1.5	110	25	150	40	250	30
	1	95	20	120	30	200	25
	0.5	75	15	80	20	150	20
New Zealand	**4**	165	50	280	90	500	70
	3	140	40	240	80	450	70
	2	110	25	200	65	350	55
	1.5	95	20	150	55	350	50
	1	75	15	120	45	250	45
	0.5	60	10	80	25	200	30

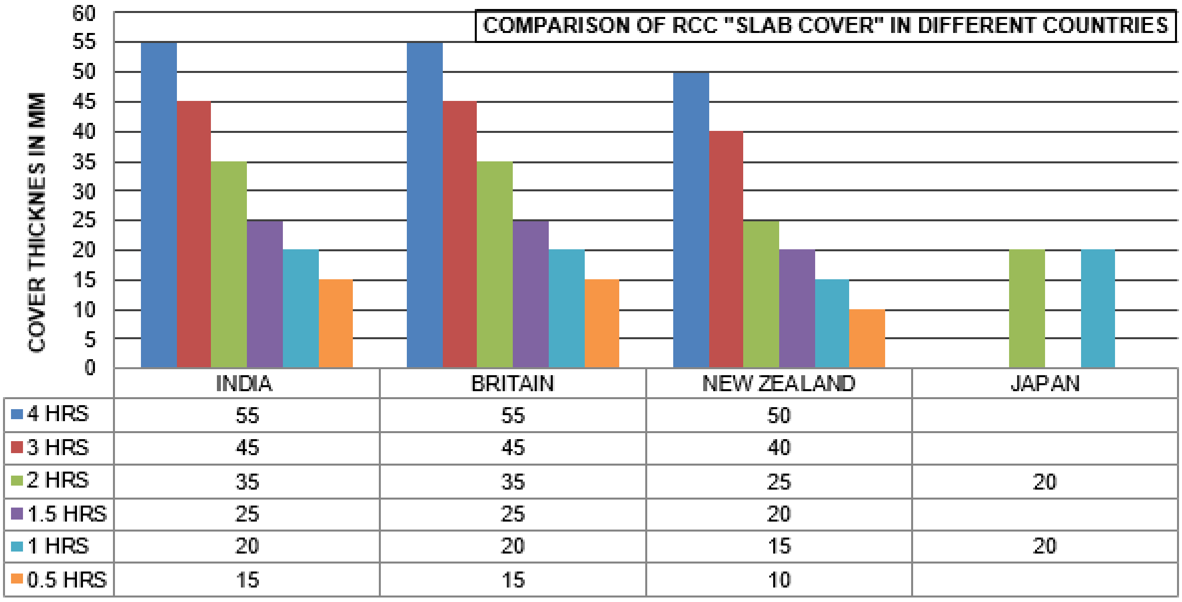


Fig. 1 Comparison of RCC slab cover thickness in different countries

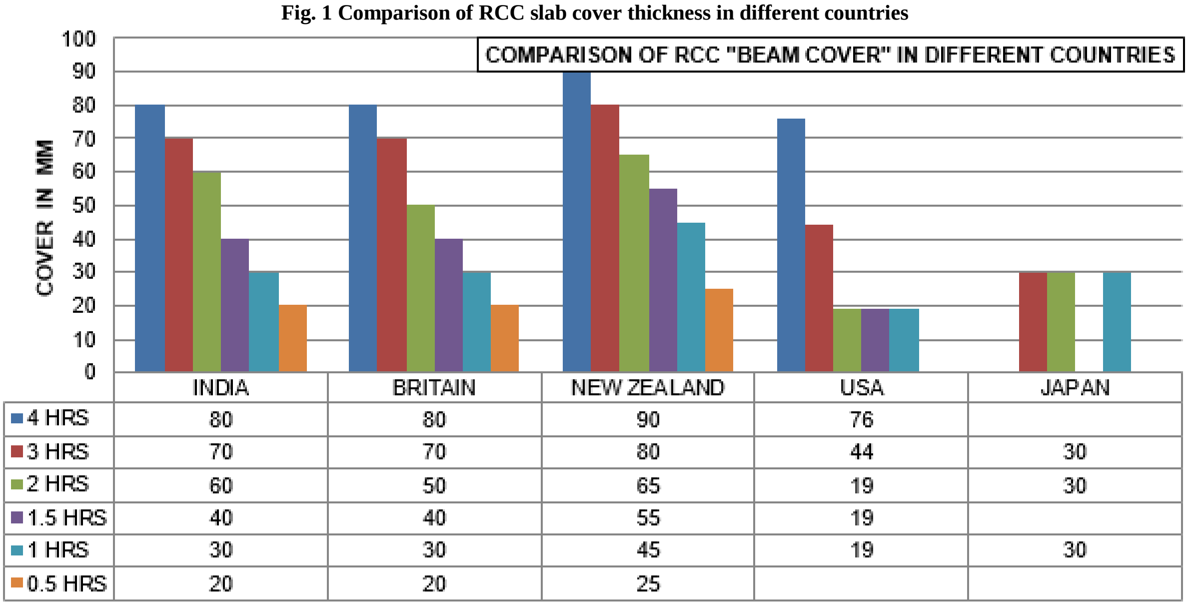
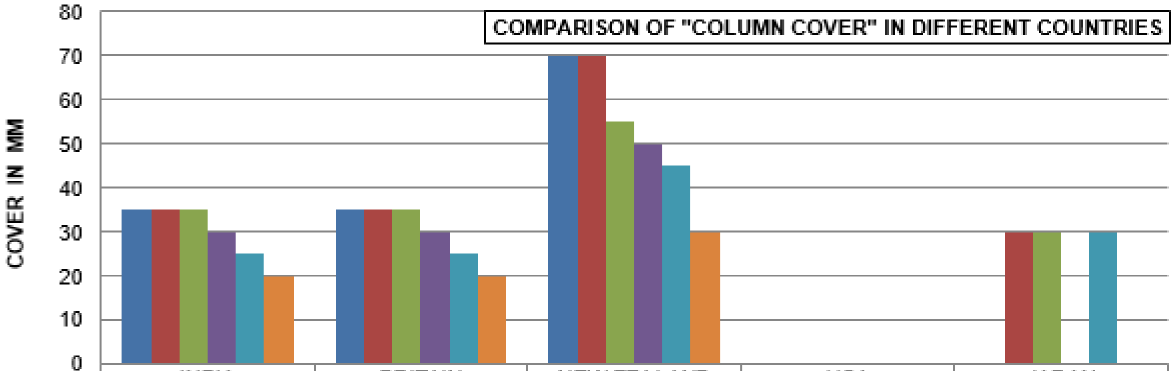
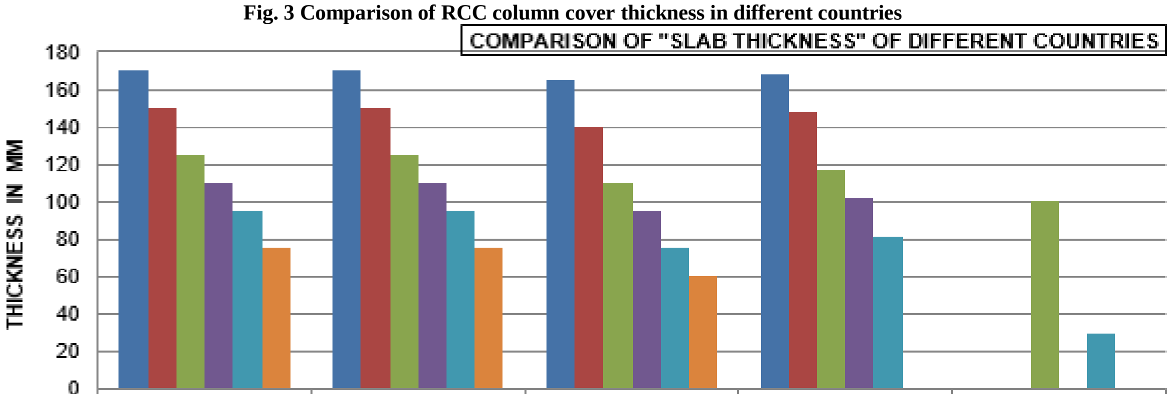


Fig. 2 Comparison of RCC beam cover thickness in different countries



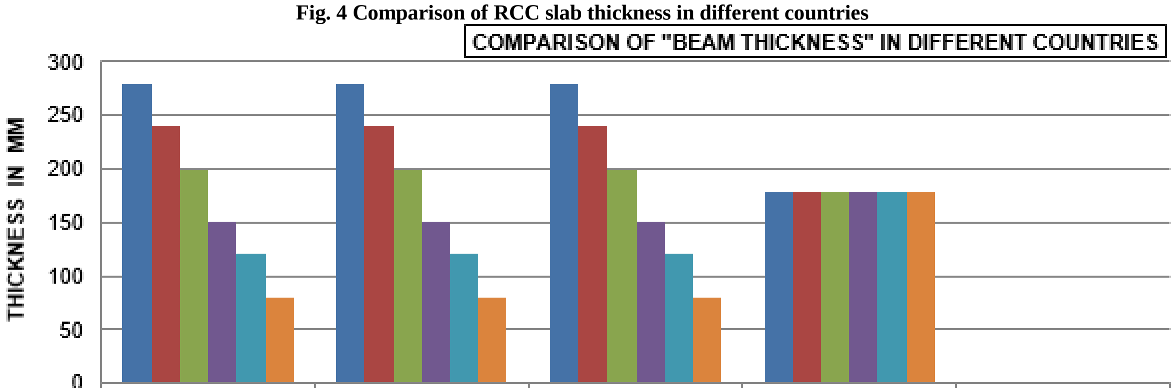
	INDIA	BRITAIN	NEW ZEALAND	USA	JAPAN
4 HRS	35	35	70		
3 HRS	35	35	70		30
2 HRS	35	35	55		30
1.5 HRS	30	30	50		
1 HRS	25	25	45		30
0.5 HRS	20	20	30		

Fig. 3 Comparison of RCC column cover thickness in different countries



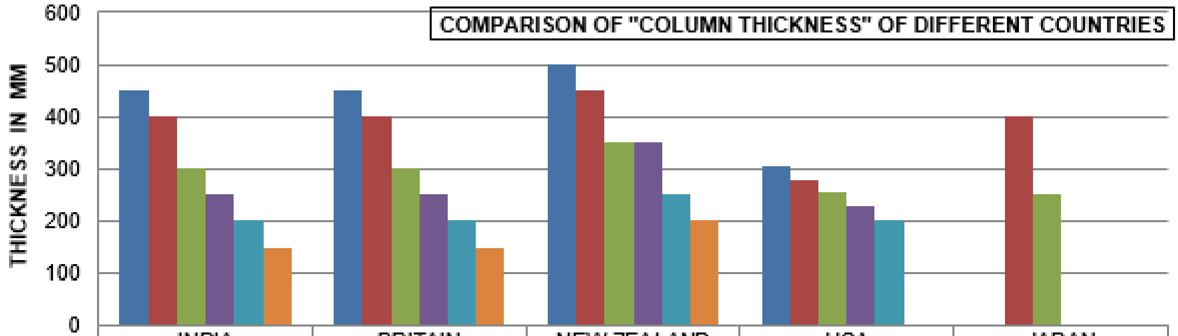
	INDIA	BRITAIN	NEW ZEALAND	USA	JAPAN
4 HRS	170	170	165	168	
3 HRS	150	150	140	148	
2 HRS	125	125	110	117	100
1.5 HRS	110	110	95	102	
1 HRS	95	95	75	81	30
0.5 HRS	75	75	60		

Fig. 4 Comparison of RCC slab thickness in different countries



	INDIA	BRITAIN	NEW ZEALAND	USA	JAPAN
4 HRS	280	280	280	178	
3 HRS	240	240	240	178	
2 HRS	200	200	200	178	
1.5 HRS	150	150	150	178	
1 HRS	120	120	120	178	
0.5 HRS	80	80	80	178	

Fig. 5 Comparison of RCC beam thickness in different countries



	INDIA	BRITAIN	NEW ZEALAND	USA	JAPAN
4 HRS	450	450	500	305	
3 HRS	400	400	450	279	400
2 HRS	300	300	350	254	250
1.5 HRS	250	250	350	229	
1 HRS	200	200	250	203	
0.5 HRS	150	150	200		

Fig. 6 Comparison of RCC column thickness in different countries

*Missing data is not available in the code.

OBSERVATION FROM LITERATURE REVIEW AND CODAL STUDY

Concrete, which has reached a temperature greater than 699^{0}C, is unlikely to have any useful compressive strength. This reduction in strength of concrete at high temperatures is caused due to changes in the strength and deformability of the constituent materials of concrete, the changes in the cross-sectional dimensions and weakening of the bond between the steel reinforcement and concrete. The aggregate in concrete except some lime stones and sintered lightweight materials, contains minerals that are chemically bound with the crystalline water inside concrete. The concrete when exposed to heat from the fire causes the boiling of this crystalline water. The resulting vapour pressure burst the minerals and causes rapid inwardly progressing spalling of the concrete. The loss of this chemically combined water is accompanied by a reduction in strength of concrete and changes in the chemical nature of cement paste. It is observed that during this range of temperature the concrete shows distinct colour change, whereby it turns pink at about 300^{0}C and yellow-grey above 450^{0}C.

CONCLUSIONS

- The change that takes place in concrete properties at different peak temperatures is as follows:
- Up to 120^{0}C, i.e., oven drying temperature, there is no effect on microstructure or the pore system of concrete. Except for the loss of free moisture within the microstructure of concrete, no significant change in colour is noticed at this temperature.
- The exposure of 250^{0}C, on concrete is characterized by localized cracks and dehydration of the cement paste with complete loss of free moisture accompanied by reduction in volume of the paste. This is the stage where the reduction in strength of cement paste gets commenced.
- Between 300^{0}C-600^{0}C, the colour of concrete changes to pink. Significant cracking is observed in both cement paste and aggregates due to expansion.
- At temperatures greater than 400^{0}C, the calcium hydroxide presents in concrete starts getting decomposed.
- Complete dehydration of the cement paste along with considerable shrinkage cracking, honey combing is seen in the concrete exposed to a fire temperature greater than 600^{0}C. Concrete at this temperature become friable, very porous and can easily break down. The colour of the concrete at this temperature changes to grey. Apart from compressive strength, the flexural strength and modulus of elasticity of concrete also reduces under high temperature. This can be attributed to the micro-cracking that is formed in the transition zone of concrete due to fire.
- At the fire temperature greaterthan 900^{0}C, colour of concrete changes to buff.
- Various components of concrete begin to melt at elevated temperature greater than 1100^{0}C.
- The concrete melts completely at temperature greater than 1400^{0}C.
- Type of distress seen in concrete structures under fire includes expansive spalling, strength reduction in concrete and steel, loss of anchorage of reinforcing steel, excessive deflection of slabs, beams, and distortion of the whole structural framing.

- In codal comparison of different countries with respect to cover of different structural elements some values regarding time and temperature are same and some having different values but Euro Code and Indian code having very much similar values.
- The excessive spalling of concrete exposes the steel reinforcement to the heat, which causes it to soften as the temperature approaches 600^0C, at this temperature the bars loses their yield strength about 50% which in turn reduces their capacity to resist the axial thermal restraining forces imposed by the surrounding construction and this causes the steel bars to buckle.

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