Energy Conservation Building Code & its effect on building envelopes

Currently in draft form, the new code is likely to be adopted by the Bureau of Energy Efficiency as a mandatory requirement for new buildings as well as for additions to existing buildings.

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Builders and property developers all over India are now getting interested in terms such as U-factor and SHGC (Solar Heat Gain Coefficient) with the same level of enthusiasm as they had earlier with terms such as FSI (Floor Space Index) and TDR (Transfer of Developmental Rights), the latter term used mainly in the congested island city of Mumbai.

This awareness can be attributed to two reasons. Firstly, all building developments above certain specified limits have to necessarily obtain clearance from the Union Government. The Ministry of Environment and Forests of the Government of India, which is empowered to grant this clearance, has constituted committees of experts who among other parameters also evaluate building envelope issues. Secondly, the Energy Conservation Building Code (ECBC), which is currently in a draft form, is likely to be adopted by the Bureau of Energy Efficiency of the Government of India as a mandatory requirement for new buildings as well as for additions to existing buildings. This code when it is adopted can be the basis for evaluating the energy efficiency of a building and even for approval for construction of the building by local authorities.

The ECBC covers the following aspects of the building :

1. Building envelope
2. Mechanical equipment including HVAC (Heating, Ventilating and Air Conditioning)
3. Service hot water heating
4. Lighting, electric motors and all other power operated devices.

In this article it is proposed to examine the issues related to the building envelope only as enumerated in the Code with special reference to their impact on air conditioning or otherwise of the building.

Building envelope has not been a subject of study in India for its thermal performance. Plot configuration, aesthetics sometimes limited by cost, uniqueness and ultimate saleability are factors driving the building envelope. Thermal performance and annual energy demand have little influence. In the past, buildings of 10,000 or 20,000 m^2 have been common and located in metropolitan cit-

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ies like Mumbai and Delhi. Floor plates were seldom larger than 1000 to 2000m^2 and total power demand ranged from 0.6 MVA to 1.2 MVA. Today, the number of large buildings has increased tremendously and building sizes are normally 50,000 to 100,000m^2 with floor plates of 2500 to 5000m^2. Such buildings require an energy demand of 4.0 MVA to 10 MVA each and have become unbridled energy consumers.

It is to control and regulate such energy consumption, that the Govt. of India has constituted the Bureau of Energy Efficiency (BEE). The BEE has evolved a draft entitled Energy Conservation Building Code (ECBC) which when adopted would become mandatory for all buildings with an energy demand of over 0.60MVA - that is a building of about 10,000m^2 built up area. It is recommendatory for smaller buildings. The intention of the Code is to benchmark energy consumption levels in large residential and commercial buildings and introduce a level of awareness for energy conservation.

Exemptions from the ambit of the Code are manufacturing processes and unconditioned storage spaces and warehouses as well as all single-family buildings and multifamily buildings of three or fewer stories.

The Code will also be applicable to additions, alterations and modifications to existing buildings. Applicability to existing buildings is subject to several riders and exclusions, which are set out in the draft Code. However the broad requirements of the Code with respect to the building envelope are the same for new buildings as well as for extensions and modifications.

Building Envelope

Whereas a simple envelope has only two sides, a building envelope has a minimum of six sides, that is a roof, a floor and four sides (more in some designs). A roof may be opaque or transparent or a combination of both. Floors are only opaque. Sides, have a combination of opaque and vertical fenestrations (windows and doors) to provide physical and visual communication with the outside environment. A building envelope helps provide a stable and sustaining indoor environment of choice and renders it immune to diurnal and seasonal variations in the outdoor environment. During winter, when the indoor environment is heated, the building envelope causes heat loss and during summer cooling, the envelope causes heat gain. Behavior of the envelope has the following characteristics :

- In heating mode, the envelope causes heat loss and during cooling mode, it causes heat gain.
- Solar radiation causes heat gain both in heating and cooling modes.
- Transmission causes heat loss in heating mode and heat gain in cooling mode.
- Internal loads like lighting, equipment and people cause heat gain both in heating and cooling modes.

Except for a small part, all buildings in India have cooling as the dominant requirement and the percent impact

	Parameter	Unit	ECB Hot and Dry Zone		ASHRAE 90.1		Remarks
			24 hour area	Day time area	Climate Zone 1 Residential	Climate Zone 1 Non Residential	
1	**Roof assembly**						
1.1	U-factor of overall assembly	W/m^2°C	0.261	0.409	0.360	0.360	Lower values in 24 hr areas could be justified only in cold climates.
1.2	R Value of insulation alone	m^2°C/W	3.5	2.1	2.6	2.6	
2	**Opaque walls**						
2.1	U-factor of overall assembly	W/m^2°C	0.369	0.352	0.857	3.293	ECBC demands U-factor which is too low for economic justification.
2.2	R Value of insulation alone	m^2°C/W	2.20	2.35	1.0	NR	
3	**Vertical fenestrations**						
3.1	U-factor Non- North	W/m^2°C	3.177	3.177	6.93 (Fixed) 7.21(Operable)	6.93 (Fixed) 7.21(Operable)	U factor is not influenced by surface orientation and ASHRAE correctly recognises this.ECB code specifies different values for North/ Non- North.Leads to uneconomic construction.
3.2	U- factor - North	W/m^2°C	6.922	6.922	ASHRAE 90.1 does not differentiate between U factor based on orientation of surface		
3.3	Maximum SHGC - Non-North		0.25	0.25	0.25 (30 to 40% WWR)	0.25	No significant difference.
3.4	Maximum SHGC- North		0.40	0.40	0.44 (30 to 40% WWR) WWR : Window to wall ratio.	0.44	

Table 1: Comparision between values specified in draft ECB Code and ASHRAE 90.1

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of the building envelope on the total cooling and heating loads depends on the area of the envelope over the total floor area and the percent glass area in the envelope. It is the building envelope which lends itself to engineered energy conservation and all energy codes lay down minimum requirements for each element of the envelope, so as to achieve a total energy package which is most economical for that envelope, consistent with cost and aesthetics. All codes integrate the nation's dominant outdoor climate. The first draft of such a Code in India is in place.

Energy Conservation Building Code (ECBC)

The ECBC covers essentially the following elements of the building envelope:

- Roof — Opaque
  Opaque + Skylight
- Sidewall — Opaque + Fenestration
- Floor — Opaque (No significant reference)

The performance of different materials, elements or assembly of elements of construction, is compared through parameters like K-value, R-Value, U-factor, SHGC and SC which are broadly defined below:

K - Value is the thermal conductivity of a material per cubic meter with a temperature gradient of one degree C. (W/m°C)

R - Value is the thermal resistance of a material or an assembly to a steady -state heat flow across unit area of an element or assembly of elements with one degree C temperature gradient across the two surfaces (m^2°C / W). It is the inverse of U-factor.

U - factor is the rate of heat transmission through unit area of an element or assembly of elements including the transmission across the air film on both sides with one degree C temperature gradient across the two surfaces (W/m^2°C)

SHGC Solar Heat Gain Coefficient is the ratio of heat gain by direct radiation or absorption and re-emission through a glazing or glazing system to the total incident radiation. It is a dimension-less fraction.

SC Shading Coefficient is the ratio of solar heat gain of a glazing or glazing system to that of a 3mm thick double strength clear glass in identical placement .A dimension-less fraction.

ECBC Mandates

'1. Both U factor and SHGC of a fenestration is to be determined including sash and frame as specified in ISO 15099. These are to be certified by the manufacturer or a rating agency and in case of an unrated product a default value given in a table is to be adopted.

2. Air leakage for fenestrations and doors shall not exceed 2 l/s m^2

3. U factors for opaque construction may be adopted from ASHRAE Handbook of Fundamentals 2001 or the values given in the default table in the Code.

4. Building envelope is to be sealed at the following locations to minimize leakage :

- Joints around fenestrations / door frames
- Openings between walls and foundations and walls and roof.
- Openings at penetrations made for utility services.
- Any other openings in the envelope.

ECBC and ASHRAE 90.1

The draft ECBC (the portions relating to building envelope) seems to have been extensively borrowed from ASHRAE Standard 90.1 the *Energy Standard for Buildings except low-rise residential buildings*. "Although Standard 90.1 is not a code, it is intended to be adopted as a code by Governmental agencies that are empowered to enact codes through legislative or regulatory processes." *(Section 2. User's manual: Scope)*. Some modifications to meet Indian conditions are made in the Code.

ASHRAE 90.1 addresses building envelope issues with respect to the energy spent on HVAC and its cost. Clause 2.2 relating to the scope of the standard states as under :

"The provisions of this standard apply to :

The envelope of a building provided that the enclosed spaces are :

1) heated by a heating system whose output capacity is greater than or equal to 10W/m^2 or

2) cooled by a cooling system whose sensible output capacity is greater than or equal to 15W/m^2."

While heating and cooling system loads are more evenly balanced in US, in most parts of India ,heating systems are not applicable while the cooling systems output capacity could be anywhere from 100 W/m^2 to 160 W/m^2. Such predominance needs to be taken into account in an energy code.

The users manual issued by ASHRAE goes on to state that "Investments in insulation or energy efficient windows can result in smaller HVAC systems which will help pay for the better envelope". Cost versus benefit is an age old criteria for any investment and this important consideration is absent in the ECBC paving the way for Governmental agencies empowered to enforce the code and to give building sanctions, to demand compliance with the code provisions with no consideration to costs and benefits.

ASHRAE 90.1 specifies separate exterior building envelope requirements for three categories of conditioned space.

1) Non residential conditioned space

2) Residential conditioned space

3) Semi heated space

In other words the parameters specified in ASHRAE 90.1 would apply to the building envelope only if the

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building falls under the category of conditioned space. This aspect has been missed in the ECBC, which is currently demanding wall insulation and double glazed fenestrations even in the case of non-conditioned buildings. Discrimination between conditioned and non-conditioned spaces seems appropriate. It is hoped that the draft Code addresses these issues before final adoption.

Table 1 illustrates some of the parameters of the ECBC vis a vis values of ASHRAE 90.1 - 2004.

Though it is not specifically mentioned anywhere in the Standard, ASHRAE 90.1 is dominated by winter heating and the performance criteria leans towards winter conditions.

The concept of the "buildings balance point temperature" i.e. the temperature at which losses through the building envelope balance the internal heat gains is an important consideration for envelope design as per ASHRAE 90.1 Standard. This situation is virtually non-existent in India where it is the cooling loads which dominate the design. In India the accent should be on measures to reduce cooling loads consistent with cost-benefit scenerios.

Building Envelope - Influence of Climate

Since climate is an important factor which influences building envelope, the parameters specified in the code are dependent on the climatic zone in which the building is located. The code recommends adaptation of the following climatic zones as detailed by Prof. N K Bansal and Germot Minke in their 1988 publication *Climatic zones and rural housing in India.* (Publishers KFA Julich GmbH)

Climate Zone	Some of the major cities falling in the zone
a) Composite	Delhi, Bhopal, Lucknow, Patna, Nagpur
b) Hot and dry	Ahmedabad, Hyderabad
c) Warm & Humid	Mumbai, Kochi, Chennai, Kolkata
d) Moderate	Bangalore, Pune
e) Cold and Cloudy	Srinagar, Shimla, Dehradun
f) Cold and Sunny	Mount Abu

For the purpose of determining building envelope requirements ASHRAE has introduced the concept of Cooling Degree Day (CDD)and Heating Degree Day (HDD).

Cooling Degree Day base 10°C (CDD 10) for any one day when the mean temperature is more than 10°C is the degree Fahrenheit temperature difference between the mean temperature for the day and 10°C. Similarly Heating Degree Day base 18°C (HDD 18) for any one day when the mean temperature is less than 18°C is the degree Fahrenheit temperature difference between the mean temperature for the day and 18°C.(Though the base temperature is expressed in degree Centigrade, computation is done in degree Fahrenheit).

The annual Cooling / Heating Degree Days are the sum of the degree days over a calendar year. CDD 10 and HDD 18 are a fair reflection of the cooling or heating requirement of a particular place.

We shall have a look at the CDD 10 and HDD 18 for some of the important Indian cities and how ECBC classifies these cities into climate zones.

Name of City	CDD 10@	HDD 18@	Classification of climate zone as per ECBC draft
Ahmedabad	6471	17	Hot and Dry
Bangalore	5227	1	Moderate
Mumbai	6318	1	Warm & Humid
Kolkata	6147	14	Warm & Humid
Chennai	6891	0	Warm & Humid
Nagpur	6263	10	Composite
New Delhi	5589	267	Composite

@ Source ASHRAE 90.1 - 2004.

It may be seen that inspite of the differing classifications used in ECBC the requirement in all these cities is predominantly cooling and heating is hardly a consideration. It is therefore suggested that with the exception of the cold regions in North India such as J & K, Himachal Pradesh etc, the whole country may be classified as one climatic zone at least for the purpose of building envelope assessment. In contrast,ASHRAE classifies the whole of India as "Climate Zone 1". This will make the prescription of parameters and compliance more uniform and easy to define as well as to monitor across the country.

ECBC also differentiates between buildings for 24 hour use such as hospitals, hotels and call centers and other building types. Code requirements are generally more stringent for buildings which are in use for 24 hours. In a country, where HDD 18 is negligible, such stringency is not justified. At any rate, the temperature differential between inside and outside in the night hours is much lower than in daytime which does not warrant stringency.

Building Envelope - Roof Assembly

A roof structure is made up of several materials. The individual resistance of the components are added to arrive at the overall barrier resistance. In addition to the resistance of various components of the barrier, the resistance offered by the film of air which is close to the barrier is also to be considered. The heat transmission capacity of the film is independent of the thickness of the film and the reciprocal of this is the thermal resistance of the film. Outside film resistance is based on a wind velocity of 12 km/hour (3.4 m/s) and decreases with higher velocities.

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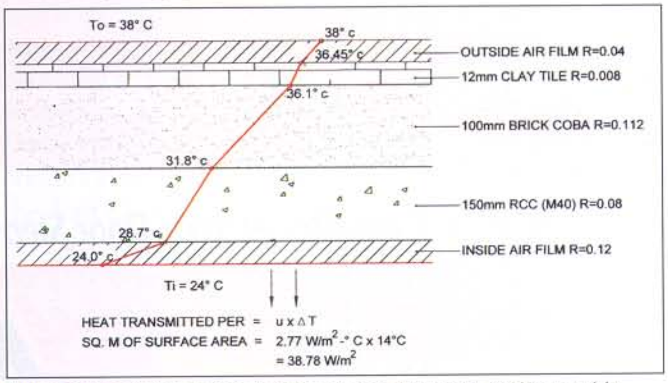

Figure 1: Heat transmission through non-insulated roof assembly.

Figure 1 shows a typical roof assembly with an RCC slab of 150mm thick on top of which brick bat coba of 100mm thick is laid and finished with 12mm clay tile.

The thermal resistance of the roof assembly is arrived at as shown in *Table 2*.

Sr. No.	Code no.	Description	Conductivity k W/m° k	Depth l m	Resistance R m²°k/W
1	F 01	Outside film	-	-	0.04
2	F 14	Clay tile	1.59	0.012	0.008
3	M 01	Brick Coba	0.89	0.100	0.112
4	M 14	Heavy weight concrete	1.95	0.150	0.08
5	F 02	Inside film	-		0.12
		Total Thermal Resistance			**0.360**

Table 2: Thermal resistance of roof assembly
(Code numbers are from Table 19, Page 30.27 ASHRAE Fundamentals 2005)

In this case the overall heat transmission through the roof assembly is the inverse of the resistance i.e., 1/0.360 = 2.77 W/m²°C.

However, ECBC requires a U- factor of 0.409 W/m²°C for all climatic zones for daytime occupied buildings. This will be possible only with the use of insulation material used either over deck or under deck. Adding 75mm thick insulation (expanded polystyrene 16kg / m³) changes the U- factor of the roof assembly as shown in *Table 3* and 4.

The addition of the insulation material to the roof assembly satisfies the Code requirement of 0.409 W/m² °C (maximum). The insulation alone also satisfies the minimum R - value of 2.1 m²°C /W specified in the Code.

The same end result can be achieved by using alternate insulation materials of adequate thickness. For example expanded pearlite (K = 0.045 W / m. °C) 100mm thick applied over deck will result in a U -factor of the roof assembly of 0.38 W/ m²°C and R value of the insulation alone of 2.22m²°C/W.

Hitherto, economic roof insulation was taken as 50mm thick expanded polystyrene and applied as a matter of routine. This insulation applied to the roof assembly in *Figure 1* yields an R- value of (1.67 +

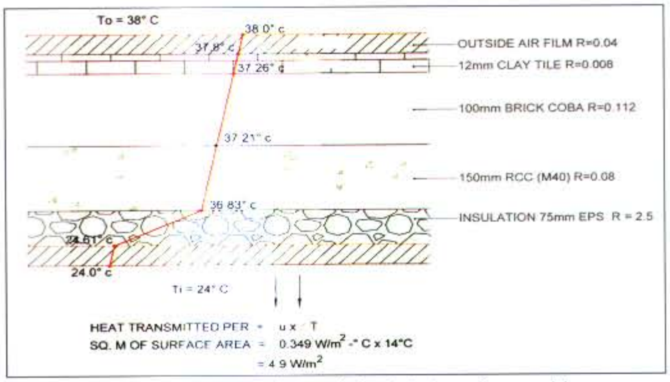

Figure 2: Heat transmission through insulated roof assembly.

a)	Total roof assembly R value as Calculated in Table 1	m² °c/W	0.360
b)	K value of EPS (16 kg/m³)	W / m² °c	0.03
c)	Thickness (Depth)	m	0.075
d)	R value of insulation alone	m² °C /W	2.5
e)	Total R value of the roof assembly (a) + (d)	m² °c /W	2.86
f)	Resulting U factor of the Roof assembly (1/ R)	W/m°C	0.39

Table 3: Thermal resistance of insulated roof.

0.36)=2.03 m²°C/W and a U-factor of 0.49 m²°C/W. This falls short of ECBC mandate by 0.09 W/m²°C in U-factor and 0.07 m²°C/W in R-value.

Thus we have three roof assemblies for comparison:

	Uninsulated roof	Insulated to 75mm thick	Insulated to 50mm thick
R-value m²°C/W	0.360	2.86	2.03
U-factor W/m²°C	2.77	0.349	0.49

Roof heat gain is driven by the gradient of roof surface temperature (Solair) at a given time to the indoor temperature. Many people take maximum Solair temperature occurring at 1300 hours as the criteria for establishing the roof insulation .Mumbai with a DB of 34°C at 1% incidence and 5.2°C daily range has a 24 hour average outside

	Uninsulated roof	Insulated to 75mm thick	Insulated to 50mm thick
U-factor W/m°C	2.77	0.349	0.49
Average annual Solair °C	32.5	32.5	32.5
Inside temp °C	25	25	25
Temperature gradient °C	7.5	7.5	7.5
Heat gain W/m²	2.77×7.5 2.61	20.77 0.49×7.5	0.349×7.5 3.61
Annual heat gain kW/m²(8760 hours)	182	22.8	31.6
Power consumption with water cooled screw chiller (COP 3.45) kW/m²	52.7	6.6	9.1
Power Cost per annum @Rs 5/kWh	Rs 264	Rs 33	Rs 46

Table 4: Comparison of savings with and without insulation

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DB of 31.4°C and a Solair average temperature of 34.3°C. Annual averages would be around 29.5°C outside DB and 32.5°C Solair temperature .These are approximate values which represent the economic value of the insulation in a 24 hour conditioned space. For the typical roof assemblies the energy losses will be as shown in *Table 4*.

Insulation certainly pays off in a very short time but whether it should be 50 mm thick is the question.

Building Envelope - Wall Assembly

The ECB Code stipulates a maximum assembly U- factor ranging from 0.352 W/m^2°C for severe climates to 0.431 W/m^2°C for moderate climates. Alternatively the Code requires a minimum R-value of the insulation ranging between 1.80m^2°C/W to 2.35 m^2°C/W. By a similar calculation as in the case of roofs, U - factor for a wall assembly consisting of outside and inside air films and a concrete wall 250mm thick may be seen to be 3.45 W/m^2°C. Polyurethane foam insulation of 60mm thick which has a conductivity of 0.024 W/m°C used on a single wall 250mm thick will bring down the U - factor to 0.358 which satisfies the above requirement. The insulation has a standalone R- value of 2.5m^2°C/W which exceeds the requirement.

A popular misconception is that a double wall with an air gap in between will reduce the U- factor to a significant extent. However providing an air gap between two walls each of 125mm thick reduces the assembly U factor only to a level of 2.22 W/m^2°C which is far from the Code requirement of 0.352 to 0.431 W/m^2°C. In order to achieve the specified U- factor there is no option but to use insulating material such as expanded polystyrene or polyurethane foam.

In other words, no amount of civil construction will bring about the required thermal resistance. Insulation materials in one form or the other have to be employed to bring about compliance with the Code.

Economics of wall insulation is shown in *Table 5*.

			Conventional	ECBC	ASHRAE 90.1
1.0	**Place and Climate**				
1.1	Place		Mumbai Lat 18.90 N Long 72.82 E	Mumbai Lat 18.90 N Long 72.82 E	Mumbai Lat 18.90 N Long 72.82 E
1.2	Attitude		11.00 m	11.00 m	11.00 m
1.3	Climate Zone			Hot & Humid	1A
1.4	Max Dry Bulb Temp	°C	34.3	34.3	34.3
1.5	Mean Co incident Wet Bulb	°C	23.3	23.3 (1% incidence ISHRAE Weather data)	23.3
1.6	Yearly Average Dry Bulb	°C	24.9	24.9	24.9
2.0	**Air conditioning Design Parameters**				
2.1	Internal room temp	°C	24	24	24
2.2	Light + small power	W/m^2	20	20	20
2.3	Leakage	cm^2/m^2×m^2	1.4 x 40	1.4 x 40	1.4 x 40
2.4	Outside air	litres/second	<-----------------	10	----------------->
2.5	Occupancy	No	<-----------------	Average 1 person in 10 sq.m	----------------->
2.6	Infiltration driving force	litres/second	<-----------------	0.058 @ 8m high @ 35°C	----------------->
3.0	**Base Area**				
3.1	Floor considered		<-----------------	Fifth (Fourth floor is airconditioned)	----------------->
3.2	Room size	m × m	10 x 10	10 x 10	10 x 10
3.3	External wall area	m × m	10 x 4	10 x 4	10 x 4
3.4	Fenestration	m × m	3 x 4 at 30%	3 x 4 at 30%	3 x 4 at 30%
3.5	Opaque external wall	m × m	7x4	7x4	7x4
3.6	Floor area	m × m	10 x 10	10 x 10	10 x 10
3.7	Roof area	m × m	10 x 10	10 x 10=	10 x 10
4.0	**The Building**				
4.1	Construction		<-----------------	RCC framed structure	----------------->
4.2	No of floors		<-----------------	Ground + Five upper floors	----------------->
4.3	Usage		<-----------------	Commercial	----------------->
4.4	Floor to Floor height	m	<-----------------	4	----------------->
4.5	Orientation		<-----------------	Non-North external wall	----------------->
4.6	Fenestration		<-----------------	Single frame 5 mm with 0.6 mm SC	----------------->
5.0	**Cooling Loads**				
5.1	External Wall	W	28m^{2}x3.45W/m^2°Cx(34.3-24) 994	28m^{2}x0.352W/m^2°Cx(34.3-24) 102	28m^{2}x3.293W/m^2°Cx(34.3-24) 950

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			Conventional	ECBC	ASHRAE 90.1
5.2	Internal Walls	W	Nil	Nil (All surroundings area air conditioned)	Nil
5.3	Floor	W	Nil	Nil (Floor below is air conditined)	Nil
5.4	Roof	W	$100m^2$x2.77W/$M^{2\circ}$Cx(34.3-24) 2853	$100m^2$x0.261W/$M^{2\circ}$Cx(34.3-24) 268	$100m^2$x0.360W/$M^{2\circ}$Cx(34.3-24) 371
5.5	Fenestration Solar	West exposure W	12 x 48 x 0.6 346	12 x 48 x 0.25 144	12 x 48 x 0.25 144
5.6	Fenestration Transmission	W	$12m^2$ x 5.7W/$m^{2\circ}$Cx(34.3-24) 705	$12m^2$ x 3.177W/$m^{2\circ}$Cx(34.3-24) 393	12m2 x 7.21W/m^2 0Cx(34.3-24) 891
5.7	Light & Power	W	100 x 20W/ sq.m 2000	100 x 20W/ sq.m 2000	100 x 20W/ sq.m 2000
5.8	People	W	10 persons x 128W/person 1280	10 persons x 128W/person 1280	10 persons x 128W/person 1280
5.9	Leakage	W	$56cm^2$ x 0.058 lit / sec x 3.6 x 1.2 x 35E 491	$56cm^2$ x 0.058 lit / sec x 3.6 x 1.2 x 35E 491	$56cm^2$ x 0.058 lit / sec x 3.6 x 1.2 x 35E 491
5.10	Outside air	W	10 persons x 10 lit / sec x 3.6 x 1.2 x 35E 15120	10 persons x 10 lit / sec x 3.6 x 1.2 x 35E 15120	10 persons x 10 lit / sec x 3.6 x 1.2 x 35E 15120
5.11	Total load	W	23789	19798	21247
5.12	Load density	W/m^2	Total load / area 238	Total load / area 198	Total load / area 213
6.0	**Energy Saving as compared to Conventional building**				
6.1	Percentage reduction on account roof insulation	%	-	11	10.4
6.2	Percentage reduction on account of opaque wall insulation	%	-	3.7	0.2
6.3	Percentage reduction on account of treatment of fenestration	%	-	2.2	0.1
7.0	**Cost Benefit Analysis(Roof insulation excluded)**				
7.1	Saving in cooling load as compared to conventional building	W	Nil	1406	60
7.2	Hours of operation	Hours	10	10	10
7.3	Saving in cooling load per day	kWh	NA	14.06	0.6
7.4	COP (Table 6.8.1 D Ashrae 90.1 - 2004)		2.84	2.84	2.84
7.5	Saving in electical energy	kWh	NA	5.0	0.2
7.6	Cost of energy per day @ Rs 5.00 per unit	Rs	NA	25.0	1.0
7.7	Saving in energy cost per annum	Rs	-	9125	365
7.8	Extra investment in wall insulation	Rs	No wall insulation Nil	60mm Pu foam + GI frame+ 15 mm Gyp board. Rs 1600 per m^2x28 m^2 44800	No wall insulation Nil
7.9	Extra investment on glazing	Rs	6 mm clear plain glass Nil	6mm-12mm-6mm double glazing Rs 2800 per m^2x12 m^2 33600	6 mm clear plain glass Nil
7.10	Total extra cost	Rs	Nil	78400	Nil
7.11	Approximate payback period (Wall insulation +Fenestration)	Years	Not applicable	9	Not Applicable

Table 5: Impact of building envelope factors on air conditioning of a building

Building Envelope - Fenestrations

Heat gain through a fenestration consists of solar radiation and conduction .The solar heat gain is the sum of the radiation transmitted directly inwards and the portion of the absorbed radiation in the glass which flows inward. The solar heat gain depends on the position of the sun with respect to the fenestration and the date and time. However the conduction heat gain is independent of these factors and is dependant only on the U-factor and the outdoor - indoor temperature difference.

However the ECBC specifies widely varying minimum U - factor for North and non-North fenestrations in respect

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of severe climates. For example the maximum U factor for non - North fenestration is specified as 3.177W / m²°C for hot and dry climate whereas the same is permitted up to 6.922W/m²°C for North fenestrations. This clearly defies logic and perhaps will get corrected in the final version of the Code. In respect of moderate climates, however, the U - factor specified is the same for both North and non-North orientations.

Another anomaly in the draft Code is that it allows relaxed U- factor of 6.922 for North fenestrations in case of severe climatic zones where as it is much more stringent at 3.177 for composite climatic zone.

The maximum permissible U factor for non-North fenestrations currently specified in the code at 3.177W/ m² °C is more stringent than what ASHRAE 90.1 specifies without regard to orientation. U- factor as per ASHRAE 90.1-2004 for Climate zone 1 in which India falls is 6.93 W/m²°C for fixed fenestrations and 7.219 W/m²°C for operable fenestrations. Let us hope that when the ECBC is finally adopted, the U -factor for fenestrations will be in line with what ASHRAE 90.1 specifies which will avoid use of unnecessarily expensive types of glass.

A 6mm clear glass used in vertical fenestration has a U factor of 5.7 W/m²°C which will meet the requirement of the Code if the Code gets amended to 6.922W/m²°C for all orientations. However if the Code continues to specify 3.177 W/m²°C as the U factor, double glazing of 6-12-6mm will have to be adopted which results in a U factor of 2.8W/m²°C. The additional cost for providing double-glazing to meet the ECBC requirement of 3.177W/ m²°C will workout to about Rs 2800 per m² of fenestration.

The Code further specifies that vertical fenestration area be limited to 40% of the wall area as a prescriptive requirement. How our glass facade buildings are going to circumvent this requirement defies imagination.

The Solar Heat Gain Coefficient (SHGC) is the ratio of the solar heat entering the space through the fenestration area to the incident solar radiation. Now, the incident solar radiation depends on latitude, and location, date and time and orientation of the fenestration. However surprisingly the code specifies identical SHGC for North and non-North fenestrations in respect of 3 out of 5 climatic zones. Here again the ECBC deviates from ASHRAE 90.1 which specifies a higher value for non-North orientation for all the climatic zones it deals with.

The SHGC specified in the Code varies from 0.25 for hot and dry climate to 0.51 for cold climate. A grey tinted glass with double glazing 6-12-6 mm will meet the requirement of 0.25 SHGC whereas a 6mm thick grey coloured glass with an SHGC of 0.44 will meet less stringent requirements.

Building Envelope - Visible Transmission

ECBC recommends minimum visible transmission of glazing for vertical fenestrations ranging from 0.50 for a window - to - wall ratio (WWR) of 0 to 0.3 coming down to 0.21 for a WWR of 0.61 to 0.7. When the prescriptive requirement of WWR is 40 %, visible transmission ratings go as high as 70%. There is need for consistency.

Testing and Validation

While the ECBC stipulates various values for U-factor, SHGC etc and also specifies certain mandatory requirements, compliance testing and validation of the resulting structure is left wide open. An easy option is to adopt the default table values specified in the Code itself. However whether these values can be achieved and validated with the present level of materials and testing facilities is doubtful.

For example the air leakage rate which is a mandatory compliance is 2l/s.m². How to ascertain compliance with this requirement and a methodology for achieving this is absent.

The same applies to default U - factors, SHGC and other parameters.

It is suggested that accredited agencies should be part of the compliance procedures and validation of the envelope as meeting the minimum Code requirements would go a long way in implementing the Code.

ECBC - Costs and Benefits

In case the building is completely non air conditioned, obviously there are no tangible benefits by way of energy savings. However the roof insulation will bring down the heat transmitted through the roof to a significant extent. Insulating of the opaque walls and using double glazed fenestration will have much lesser impact on the inside conditions. In fact it is common practice in our country to keep the windows open to allow for natural ventilation. This will clearly defeat the use of expensive window assemblies with stringent U-factors and SHGC, when they are kept open.

In a residential building where room or split air conditioners are extensively used, there will be some amount of energy saving by way of reduced heat transmission through roof and external walls. However in such buildings also the general tendency is to aircondition only the bedrooms and to a lesser extent the living rooms. Such air conditioners are not continuously operated but switched on as required. This affects the theoretical economics and pay-back periods and may become an unjustified burden.

In commercial buildings which are either for day time operation or for 24 hour operation there will be definite energy savings by following the Code requirements. *Table 5* shows the comparative merits of a sample building for commercial use situated in Mumbai with conventional requirements, ECBC and ASHRAE 90.1 requirements.

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The impact of roof insulation to bring down heat transfer through the roof to the top most floor is significantly important as it saves almost 11% of the cooling load, of that space considered.

However the wall insulation and treatment of fenestration to bring down U- factor as well as SHGC seems to have very little impact on the reduction of cooling load and consequently on possible energy savings. It should also be noted that *Table 5* presents the savings at peak dry bulb temperature which by definition exists only for 1% of the time. When the outside temperature is lower than the peak and during non-daylight hours the reduction in load and the savings will be still lower. As against this, insulating the walls and providing expensive fenestration has substantial costs associated with it. Even reckoning at peak time savings, it translates to a nonviable pay back period extending to 11 years.

It is worth pointing out here that while ASHRAE 90.1 gives the same importance to roof insulation as the ECB Code does, it does not ask for either wall insulation or fenestration treatment which are demanded in the ECB Code.

However, in buildings where glass is extensively used, there could be a case for using low emissivity glass and / or double glazing to bring down the transmission gain as well as the solar heat gain and each such case should be carefully evaluated giving due weightage to glass orientation.

Conclusion

While the Energy Conservation Code is welcome in this day and age, practical considerations should not be lost sight of while demanding its implementation. It is suggested that as far as building envelope requirements are concerned, roof insulation should be the only mandatory requirement and wall insulation and fenestration treatment should be recommendatory in nature. These should be weighed in each case by the architect or the HVAC designer before the owners are advised to go ahead with the insulation / fenestration treatment or not. It is also necessary to clearly limit the applicability of the Code (sections relating to the envelope) to centrally air conditioned buildings and exempt non air conditioned buildings from compliance.

The Code will be really useful in limiting the energy requirements if the envelope is treated as a study model and thermal performance of the various constituents of the envelope are validated by specified methods and by accredited agencies.

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