A COMPARATIVE ANALYSIS OF BUILDING CONSTRUCTION RULES AND THEIR IMPACT ON INDOOR TEMPERATURE OF MULTISTORIED BUILDINGS

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Abstract

The International Energy Agency projected that global final energy consumption in buildings would grow by 30 percent from 2007 to 2030 if prevailing practices and trends continued. Most of that increase is expected to come from fast growing developing countries. New buildings in Dhaka are being constructed under the 2008 building construction act, termed as 'Dhaka mohanagar imarat nirman bidhimala 2008' focusing more on FAR (floor area ratio) offers vertical expansion than horizontal to accommodate the required floor area through providing more open spaces. Increase in building heights with certain setbacks resulted increase in possibilities of change in natural indoor lighting at the lower level of the structures. As a result, use of artificial lighting in indoor spaces may be increased which may result change in fossil fuel consumption for power generation. Beside the indoor day lighting condition the question arises what would be the situation in terms of indoor temperature due to building to building setback? Is there any impact of indoor temperature due to the setback provided in the construction rules and the building height achieved in this regard? Thus, this paper tries to find out through theoretical investigation whether there are any impact on indoor temperature at different floor levels due to the direct component of solar radiation; and finds out that building setback and building height due to building regulations influences significantly on indoor temperature at different floor levels within a structure due to direct component of solar radiation. Comparisons between 1996 and 2008 imarat nirman bidhimala are presented specially for residential buildings. The southwest facade is analyzed in depeer detail.

Key words: Indoor temperature, building code, building setback, building height, floor levels, south-west

1. Introduction

This paper is the second attempt on this theme, where the author is investigating on *south-west* building facades while in the first attempt the orientation was considered 'west' and it was seen that 'temperature proportion' in terms of 'building side to side' was 76.5% in 5th floor and 67.5% in terms of 'building rear to rear' at the same level.

A country develops through expanding its urban areas. Dhaka the capital of Bangladesh is also expanding which resulted as one of the mega cities of the world. Naturally numbers of buildings are increasing to accommodate the increasing population staying and penetrating this mega city. Energy is used in buildings for various purposes: heating and cooling, ventilation, lighting and the preparation of hot sanitary water are among them. Use of Fossil Fuels has resulted in emission of huge quantity of carbon dioxide causing serious environmental damages. There is still a considerable potential for reducing energy consumption by adopting energy efficiency measures at various sectors of our country (Sayeed, 2005). In 1961 Denmark established one of the first building codes which systematically regulated energy consumption. Since then, building codes have been updated several times, including major changes in 1972, 1979, 1997, and in 2006 (Laustsen, 2008) Mandatory energy efficient design requirements for buildings were first introduced in Europe and North America in the late 1970s and have proven to be an effective policy instrument. Several developing countries began similar efforts in the 1990s, and many more joined the pursuit in the last decade (Liu, Meyer and Hogan, 2010). As the world population increases and cities expand, it is of great importance to design comfortable cities that provide for the needs of the current population without jeopardizing the security of future generations (Ross, 2012). Today, mandatory minimum energy efficiency requirements in the form of building codes or standards exist in nearly all OECD countries (Organisation for Economic Co-operation and Development).

There are too many people in Dhaka and not enough land. As new buildings are being constructed under the 2008 building construction act, termed as 'Dhaka Mohanagar IMARAT NIRMAN BIDHIMALA 2008' (GOB, 2008) Buildings will be tall and close to each other (The Daily Star, 2012). The previous 1996 building by-law which existed from 1996 to 2006 resulted many buildings under the law; as mandatory open space were not present in that law, closely spaced buildings resulted bulk of concrete structures in the city. Using more fossil-fuels to generate power for mitigating darker interior of the lower levels of the structures which demands of the new building code, with a provision open space to penetrate daylight through applying floor area ratio (FAR). The urban building stock in developing countries is expected to more than double by 2030. Demand for energy services in buildings in developing countries will rise substantially in the next two decades, driven by population growth, urbanization, and increased and expanded wealth (Liu, Meyer and Hogan, 2010). Building energy standards and codes have been developed and used in many countries to provide a degree of control over building design and to encourage awareness and innovation of energy conscious design in buildings (Hui, 2002).

This paper is investigating on *south-west* building facades, thus the objective of the paper will be to investigate and find out whether there are any impact in indoor temperature at different floor levels facing 'south-west', considering only the direct component of solar radiation; due to building setback and height of neighborhood structures in terms of the present building code for residential buildings comparing the previous 1996 building by-law.

2. Methodology

To asses the conditions regarding internal temperature comparing two building codes (1996 and 2008 IMARAT NIRMAN BIDHIMALA) several equations were taken to see the situation as this study is based on theoretical analysis rather than field survey nor simulation. As the focus of this paper is to compare the two codes in identical situation, several values were considered to be same because of the identical manner. Among three components of solar radiation only the direct component were taken into consideration. Five katha (335 sq m) plot were taken for the study as in planned residential area such as Uttara model town lying towards the north of the main city comprises five katha plots. While considering this size of plot, floor levels were considered from ground floor to 5^{th} floor as in the 1996 building construction rule the structures were made of six stories, that is- ground + 5 floors. Regarding orientation, south-west of the building is considered. Similar studies can be done with other orientations as well.

Two scenarios are considered in this study as shown in figure 1(a) & 1(b):

1. Two six storey buildings standing side by side having west façade, constructed under 1996 law
2. Two buildings standing side by side were one building constructed under 1996 law and the other building under the new law that is 2008 imarat nirman bidhimala

Fig 1(a): two six storey buildings side by side (b) ten storey building beside six

As building side to side and rear to rear having two different setbacks, this study also tries to see the difference due to the change in setback assuming both the situations are facing west in different situations. Through this, the change in level of obstruction of the neighboring structures due to the difference in building codes along with change in setback and building height can be observed while calculating the indoor temperature. As there are different parameters while calculating the indoor temperature such as orientation, different floor levels, building to building gap, building height, different plot sizes (as there is a relationship with plot size and building set back), in this study the focus will be given for residential buildings facing west, considering ground to fifth floor and buildings setback in terms of side to side and rear to rear for 1996 and 2008 building codes. Considered walls are of west facing, opposite having a building i) constructed under 1996 law, ii) constructed under 2008 building code (ten storey). At each floor the direct solar radiation are considered to enter at sill level which is at 0.6m from each floor level. Each floor height is considered 3m. The direct solar radiation received at south-west façade is considered in the month of April, as April is being identified most representative month of hot-dry summer (Ahmed, 1994). The average amount of solar radiation received at west façade is 43 Wh/sq.m (Ahmed 1994). The average high outdoor temperature is considered 36 deg C in the month of April.

There are three components of the global radiation received at any point on the earth's surface which are as follows:
G(s) = B(s) + D(s) + R (s)……………… (i); where, B(s) = direct (beam) component, D(s) = diffuse component and R(s) = ground reflected component. As this paper focuses on direct component, B(s) will be considered only; while comparing the two codes in identical situation.

To calculate the direct component irradiation on a place normal to the direction of beam (Bn), we know: *B = Bn/SinALT*, considering the irradiation will be on a plane normal to the direction of beam we get:
Bn = B SinALT…………………….(ii) (ALT being the altitude angle)
In terms of mean heat gains from all sources we have:
Qt = Qs+Qc in watts; where

i) mean solar gain, Qs from

Qs = Se G Ag in watts, therefore, *Qs = G(Se Ag)…………….….(iii)*; where Se=mean solar gain factor, G=mean total radiation on relevant face (w/sq m), Ag=area of glazing in sq.m.

As the situation and the materials are assumed to be same in both the situations (1996 and 2008 building construction rules), the only variable will be 'total radiation' (G).

ii) mean casual gain Qc:

Qc = [(qc1xh1) x (qc2xh2)……….]/24 in watts; where qc1 qc2 = instantaneous casual gain in watts, h1 h2= duration of individual casual gains in hours, for same reason Qc will not be applicable for this study.

In terms of mean internal environmental temperature Tei we have:

Qt = (∑Ag Ug + Cv) (Tei-Tao) + ∑ Af Uf (Tei-Teo)………… (iv); where Teo=mean sol-air temperature in degC, Cv=ventilation exchange dependent on ventilation rate, Tao=mean outside air temperature in degC, ∑A= total area of the surfaces bounding the enclosure in sqm.

As, Qt=Qs+Qc, or Qt= [G (SeAg)] +Qc……………. (v),

From (iv) and (v) we have,

[G (Se Ag)]+Qc = (∑AgUg+Cv) (Tei-Tao) + ∑AfUf(Tei-Teo)

or, [G(SeAg)] + Qc = (Tei-Tao) [(∑AgUg+Cv)+(∑AfUf)] [due to vertical surface]

or, [G(SeAg)] = (Tei-Tao) [(∑AgUg+Cv)+(∑AfUf)] [because of identical situation]

or, (Tei-Tao) = [G(SeAg)]/[(∑AgUg+Cv)+(∑AfUf)]

Therefore we get,

Tei = G [(SeAg)/(∑AgUg+Cv)+(∑AfUf)]+Tao………….……..(vi)

2.1 2008 Imarat Nirrman Bidhimala

'Dhaka Mohanagar Imarat Nirman Bidhimala 2008' basically came into action in the year 2006, later there were some corrections in the code which now is in practice from 2008 as cited below in table 1

2.1.1 Building setback and height

	Setback	
Site area	Rear Side of the Building	Both Side of the Building
335sqm-402sqm	2m	1.25m

(Source: 'Dhaka Mohanagar Imarat Nirman Bidhimala 2008')

Table 1: Rear and both side of building setback : 'Dhaka Mohanagar Imarat Nirman Bidhimala 2008'

According to 'Dhaka Mohanagar Imarat Nirman Bidhimala 2008' the focus has been given on FAR (floor area ratio), M.G.C. (maximum ground coverage) and the front road width of the respective plots rather than building heights. The chart given above has been restricted to 10 storey buildings. So this paper focuses buildings up to 10 storey structures.

2.2 1996 Building Construction By-Law

The building construction by-law that was in practice from 1996 to 2006 was known by 'Imarat Nirman Bidhimala, 1996' as quoted below in table 2.

2.2.1 Building setback and height

Site area	Setback	
	Rear Side of the Building	Both Side of the Building
More than 268sqm	2m	1.25m

(Source: Imarat Nirman Bidhimala, 1996)

Table 2: Rear and both side of building setback : 'Imarat Nirman Bidhimala, 1996'

According to this law the height of the buildings were depended upon the front road width. If the front road width were 75' or above then the height of the building could be unlimited or else in most cases the height of the buildings, specially the residential buildings were restricted up to six storey (5+1) structures.

3. Indoor Temperature Due To Daylight Intrusion (Considering Direct Component Of Solar Radiation)

While calculating the indoor temperature due to daylight intrusion, considering only the direct component of solar radiation, building set back due to side to side and rear to rear according to the two different codes calculated separately, which are given below.

3.1 Building side to side

The set back considered in terms of building side to side is 1.25x2=2.5m according to 2008 and the same goes for 1996 building construction rule for 5 katha plots, which is the considered plot size for this study.

3.1.1 Temperature at different floors after applying 2008 building construction code

First of all required angles were calculated, after that respective indoor temperature equation is used to see the difference of temperature at different floors. From equations (ii) and (vi) we get the following calculations shown in figure 2:

Ground floor: $Tei=3.6[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

1st floor: $Tei=3.99[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

2nd floor: $Tei=4.49[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

3rd floor: $Tei=5.16[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

4th floor: $Tei=6.01[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

5th floor: $Tei=7.26[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

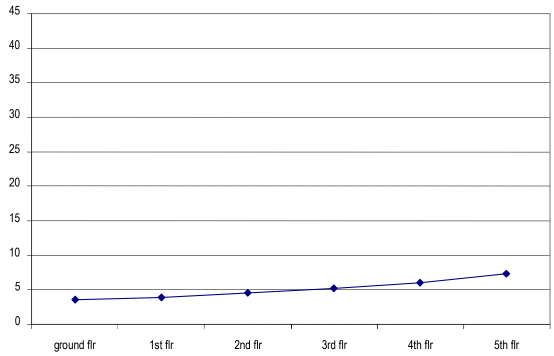

Fig 2: 2008 building code (building side to side)-floor wise comparison

3.1.2 Temperature at different floors after applying 1996 building construction rule

First of all required angles were calculated, after that respective indoor temperature equation is used to observe the difference of temperature at different floors. From equations (ii) and (vi) we get the following calculations in figure 3:

Ground floor: $Tei=6.04[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

1st floor: $Tei=7.25[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

2nd floor: $Tei=9.13[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

3rd floor: $Tei=12.13[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

4th floor: $Tei=17.79[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

5th floor: $Tei=31.02[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

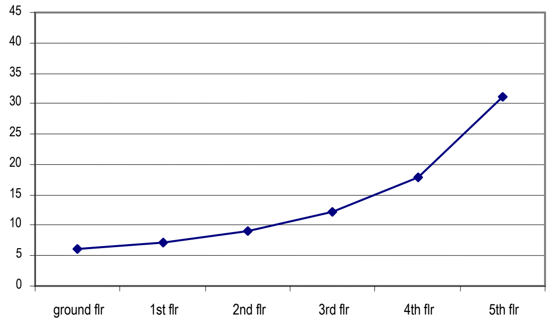

Fig 3: 1996 building code (building side to side)-floor wise comparison

3.2 Building rear to rear

The set back considered in terms of building rear to rear is 2x2=4m according to 2008 and the same goes for 1996 building construction rule for 5 katha plots, which is the considered plot size for this study.

3.2.1 Temperature at different floors after applying 2008 building construction code

First of all required angles were calculated, after that respective indoor temperature equation is used to calculate the difference of temperature at different floors. From equations (ii) and (vi) we get the following calculations as shown in figure 4:

Ground floor: $Tei=5.72[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

1st floor: $Tei=6.35[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

2nd floor: $Tei=7.13[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

3rd floor: $Tei=8.16[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

4th floor: $Tei=9.45[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

5th floor: $Tei=11.36[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

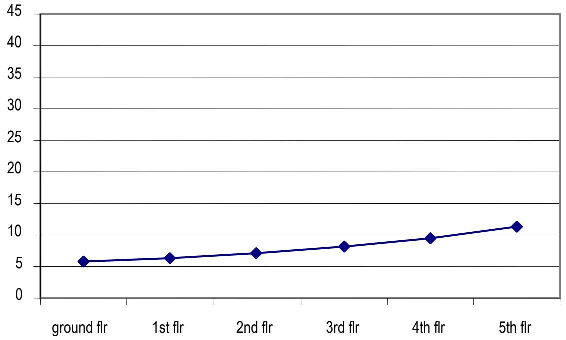

Fig 4: 2008 building code (building rear to rear)-floor wise comparison

3.2.2 Temperature at different floors after applying 1996 building construction rule

First of all required angles were calculated, after that respective indoor temperature equation is used to see the difference of temperature at different floors. From equations (ii) and (vi) we get the following calculations shown in figure 5:

Ground floor: $Tei=9.53[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

1^{st} floor: $Tei=11.36[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

2^{nd} floor: $Tei=14.13[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

3^{rd} floor: $Tei=18.31[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

4^{th} floor: $Tei=25.27[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

5^{th} floor: $Tei=36.86[(SeAg)/(\sum AgUg+Cv)+(\sum AfUf)]+36$

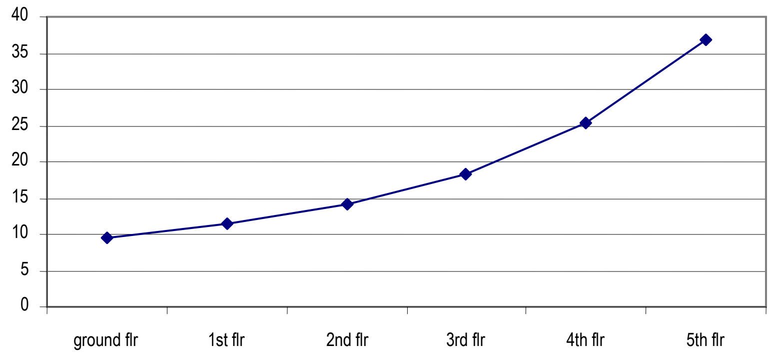

Fig 5: 1996 building code (building rear to rear)-floor wise comparison

4. COMPARATIVE ANALYSIS (Comparing 2008 and 1996 building construction rules)

For comparing the two codes, it has been divided into two parts for better understanding in terms of building to building gap, as there are two aspects in setbacks, which are building side to side and rear to rear setback; but the situations were different, because all time the considered façade of building was selected to be west facing, as the study focuses on west facing facades only. As the situation was considered identical in terms of building material, size of the openings, quantity of glazing materials, environment and so on, only building to building gap and floor levels were considered for both the codes as mentioned above; for comparing, only the variables were considered in the graphs to see the differences for better understanding in terms of indoor temperature.

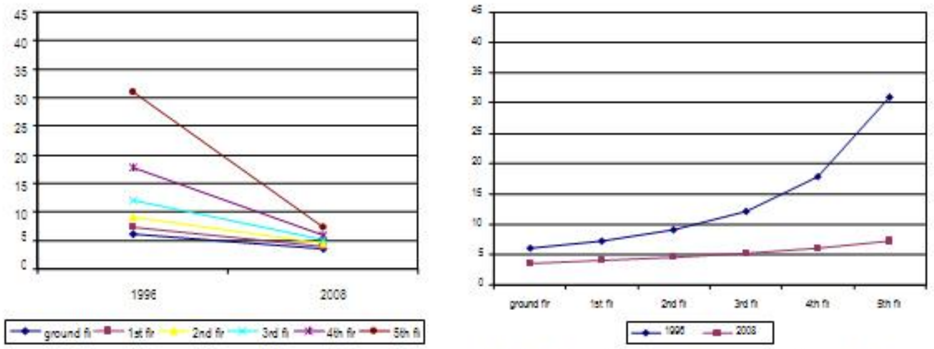

Fig 6: Comparing 1996 and 2008 building code (building side to side) Comparative study

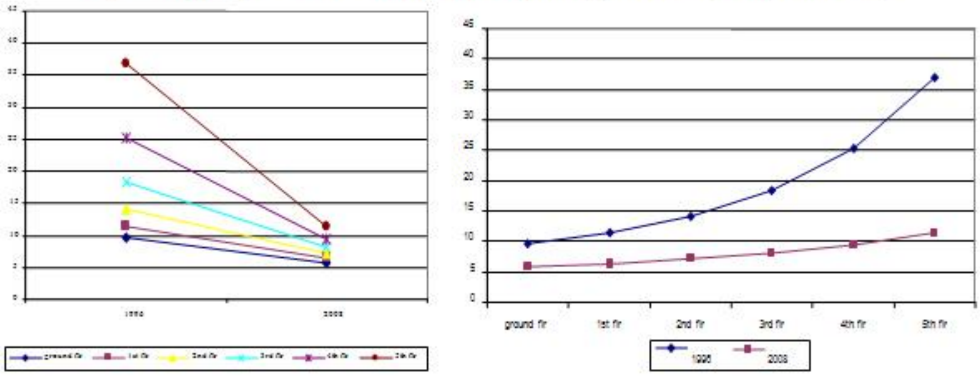

Fig 7: Comparing 1996 and 2008 building code (building rear to rear) Comparative study

5. Findings

It is quiet clear from the graphs above, after comparative study between 1996 and 2008 building code that, as the setback increases the amount of solar radiation intrusion indoor increases which results increase in indoor temperature. More over due to increases in building height after applying 2008 building code, affects the adjacent building in terms of indoor temperature in a huge level. The steepness of the lines in the graph can be observed that, in terms of 1996 building code shifts rapidly from 2nd floor to 3rd floor and above; where as, this remains more over close to each other in terms of applying 2008 building code. Another feature can be observed, in terms of 'building side by side' calculation, there is a sudden jump in indoor temperature from 4th floor to 5th floor when applying 1996 building code, where as in terms of 'building rear to rear' the shift of indoor temperature from 4th floor to 5th floor is not the same.

6. Conclusion

From the above study it is clear that there are changes in indoor temperature between the studied building construction codes. The indoor temperature changes, due to differences in building set back and building height, and the change in the two codes are quiet high in terms of comparative indoor temperature. Further detail studies are required to analyze the indoor temperature at other floors of the buildings constructed under 2008 building construction rules. This study was focused on south-west facing façade only. Similar studies can be done in other orientations with relationship to different floor levels. Various plot sizes can be considered as well, as there is a relationship between plot size and building set back.

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