EVALUATION OF INDOOR THERMAL COMFORT IN SOLAR PASSIVE DESIGNED HIMURJA OFFICE BUILDING, SHIMLA, HIMACHAL PRADESH

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Abstract – The scientists, engineers and building architects, world over, have set forth many approaches for evaluation of indoor thermal comfort temperatures. Few of them are adaptive thermal comfort approaches provided by A. Humphreys 1978; J. Fergus Nicol and Michael A Humphreys, 2002 and Waqas Ahmed Mahar, et al, 2019. The Humphreys, 1978 model provides low ranges of thermal comfort temperatures while the Nicol and Humphreys, 2002 and Waqas Ahmed Mahar, et. al, 2019 provide slightly high temperatures for thermal comfort zone for the same region.

In the present paper the Solar Passive Designed HIMURJA Building has been monitored for evaluation of indoor thermal comfort during winter months of 2020. The monitoring results have been treated against each of the above mentioned adaptive thermal comfort approaches and it has been found that the building remains in comfortable zone under all the above mentioned approaches. The Solar Passive HIMURJA building has been integrated with Thermosyphoning Air Heating Panels, Sun Spaces on the southern its facade. It has an air lock lobby at the entrance; the northern wall is insulated with glass wool and has no windows on this side. All the windows are double glazed. The monitoring results show that these solar passive features are keeping the indoors comfortable throughout the winters.

(Keywords: HIMURJA Building, Thermal Comfort, Solar Passive)

I. INTRODUCTION

The HIMURJA building is located in SDA Complex, Kasumpti, Shimla. Shimla is the capital city of western Himalayas State of Himachal Pradesh. The site of the building is located at an altitude of 2100 meters above mean sea level. The coordinates of the site are latitude 31.10N, longitude 77.06 E. The First Floor Plan of the building is given in Fig. 1. The longer axis of the building is facing the east – west direction, providing a full solar exposure to the southern facade of the building. The narrow eastern part of the building is adjoining to HPSEB building. The small western facade of the building is providing entrance. The Section of the building is given in Fig. 2.

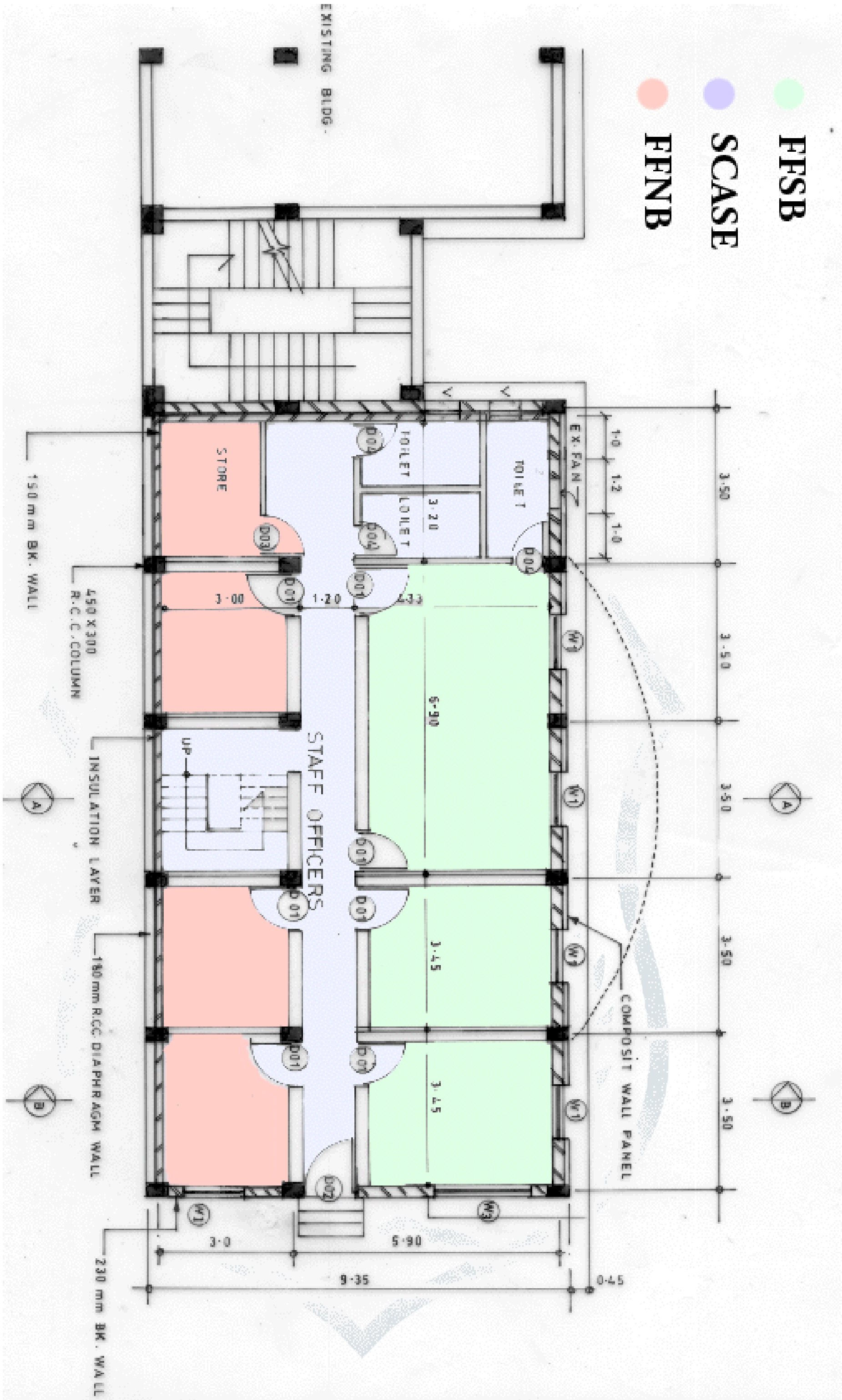

Fig.1: First Floor Plan, HIMURJA Office Building, Kasumpti, Shimla

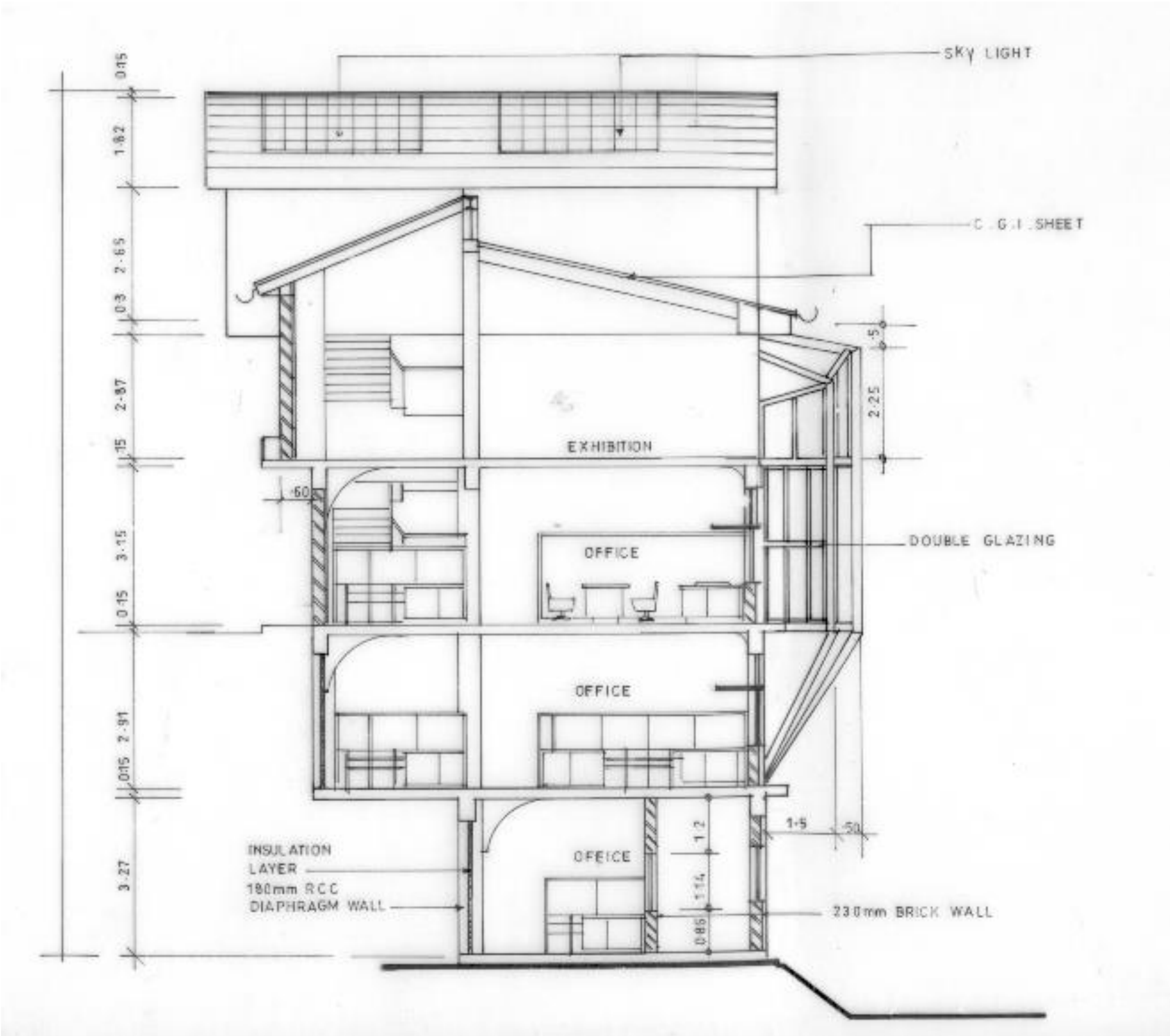

Fig.2: Section of HIMURJA Office building, Kasumpti, Shimla

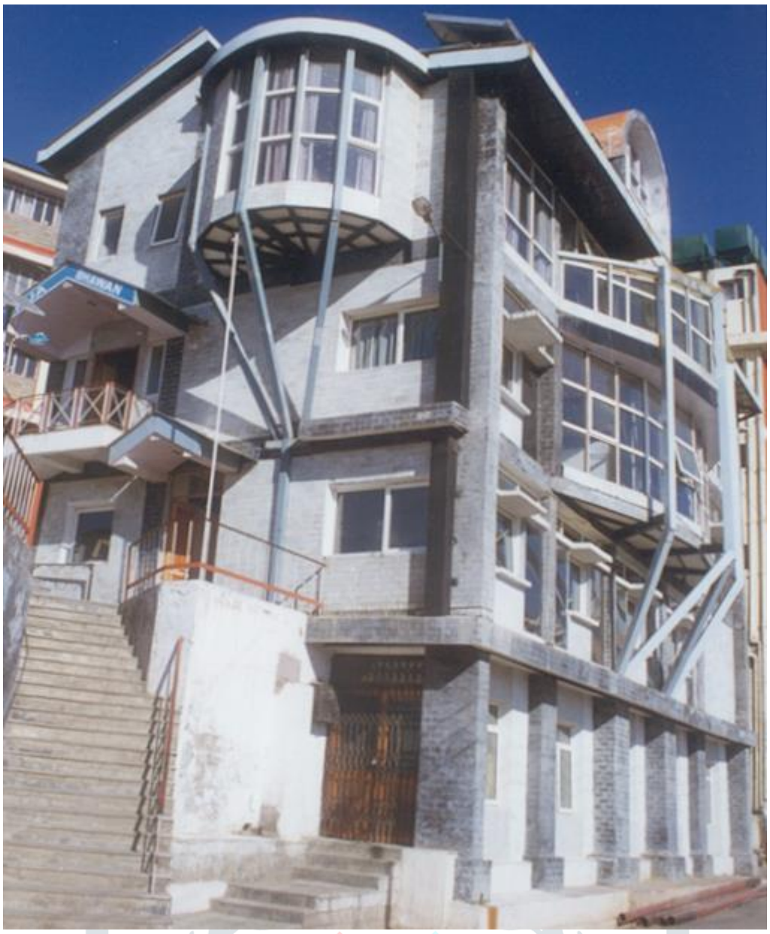

Fig. 3: Solar Passive Designed HIMURJA Building, SDA Complex, Kasumpti, Shimla

II. REVIEW OF LITERATURE

Traditional settlements all over the world are found to be well adapted to local climates which include their surroundings, and respond to human's actual needs, incorporate many eco friendly features in compatibility with local environment, and are hence considered as a model for sustainable building design. It can be easily observed that the traditional houses in the different climates of the world survive for several years. These built forms are spatial in nature and differ according to local geographical conditions (Sarkar 2011).

In cold climatic regions of India, a huge amount of is required for space heating and day lighting in Government offices or other residential buildings. Several parts of Himachal Pradesh in general and the tribal region of Chamba, Lahaul and Spiti, Kinnaur in particular remain covered under snow for more than six months in a year. The residents of these areas are dependent on fire wood, diesel, kerosene for space heating and cooking purposes. The most parts of the State use coal, fuel wood, kerosene, for space heating during these six winter months. The urban populations, however, use electricity and LPG for the above purpose. As the tribal regions are mostly located in the cold desert reason, the state government provides the fuel wood and other fuels subsidized rates to these tribal and remote areas in high altitude regions. Hence in such situations the necessity of solar passive housing and solar passive features in buildings could be realised. Such initiatives could reduce the pressure on conventional sources of energy besides being an advantage to the environmental issues (Chandel S.S, Sarkar A 2014).

The Solar Passive heating strategies in particular make the use of the windows, walls, roof, and other building components to store, collect, and distribute the solar heat to dependency on auxiliary sources of space heating. Generally walls are massive, roofs are insulated and fenestrations are natural which allow heat gain and losses. These typical buildings would have high thermal mass, appropriately shaded, well coupled with ground and shape would be compact in plan (Almusaed 2011).

As per ASHRAE Standard 55 the thermal conditions for inhabitants of a building is to specify the factors or combination of factors responsible for indoor thermal comfort which is acceptable to more than 80% of occupants within that specific space. However it is difficult to precisely define the term acceptability, but it is generally assumed to be a condition of satisfaction where an average occupant is freely exercising his work. It is the sensation of indoor thermal comfort. The ASHRAE model of thermal comfort is based on heat balances model of human body. It states that the thermal sensation of the body is dependent on environmental factors like temperature, humidity, radiation and wind speed and the personal factors of clothing and activity. The ASHRAE has defined the Adaptive Comfort Standards (ACS). The recommendations for ACS should be adopted during the designing stage of the building. However, these could be used for evaluation of existing buildings. The desirable indoor conditions for naturally controlled buildings should be evaluated using simulation models. The ACS could then be applied to assess the acceptability of those indoor conditions. If unacceptable, then design modifications are must, these could be in design and material. If desirable indoor conditions are still not met then the air conditioning measures can

be taken in to consideration. The ACS should be considered as part of operative design guideline. The air conditioning could be used in a limited way to ensure the comfort limits inside the buildings (Richard J. de Deara, Gail S. Brager 2002).
The thermal comfort study is undertaken to assess the level of easiness of doing physical activities. Stable temperature and humidity conditions are required for attaining a level of thermal comfort. The climatic conditions of a particular location are required to be taken into consideration while constructing buildings/ houses. The thermal comfort studies are generally carried out using climate chamber study or based on Adaptive thermal comfort model. The later model is considered to be the best one as it is based on field survey and therefore is bioclimatic specific and comprehensive (Thapa Samar, 2019).

The ASHRAE model gives a wide limit of thermal comfort temperature between 21.5 – 30.5 °C for different conditions. However, In India, the National Building Code (NBC) provides for two sets of temperature ranges one is 23 – 26 °C and other 21 – 23 °C for summer and winter respectively.

The amount of energy being consumed in buildings for attaining a level of thermal comfort needs to be controlled in view of global energy crisis. The buildings world over consume more than 48% of the total energy. Indian scenario is not different where 48% of the total energy is used in buildings and about 73% of it is utilised in residential buildings for space heating/ cooling for providing comfortable indoors. It could be in the form of air conditioning, heating or cooling (Thapa Samar et. al, 2019).

The present paper undertakes an analysis of a Solar Passive Designed HIMURJA Building. The Building is considered as one of the best Solar Passive Buildings in India. Most of the principles of solar passive house designs, passive systems, and strategies for house design have been incorporated in this building. It is expected that the present paper would be helpful in providing a momentum to sustainable building designs approach and energy efficient housing.

III. MATERIALS AND METHODS

Monitoring of Solar Passive Building – HIMURJA Office Building, Shimla:
Improving thermal performance of a building is an issue of concern for builders and architects. The evaluation of the thermal comfort of a building can be carried out in different ways. The thermal state of a building can be assessed visually and by using instruments for the same. Different sets of design parameters is tested against the variations recorded in these instruments. The values of different measured parameters are used in making necessary changes for attaining a level of thermal comfort in buildings. Integrated approach for visual and instrumental methods is required to assess the thermal performance of the building (Sergey Korniyenko 2015).
Under the present study, thermo hygrometers have been used for experimental study of the houses as mentioned above. The thermo hygrometers are of KTJ TA 318 with an accuracy of +-1ºC and +-5%.

Table 1: Building Characteristics – HIMURJA Building, Shimla

Parameters	**Building characteristics/ specification**
Type of Building	Office Building
Name of Owner	HIMURJA (State Energy Development Agency)
Address	SDA Complex, Kasumpti, Shimla - 171009
Altitude	2000 Meters (absl)
Climate	Cold and Cloudy
Outer Walls	9 inches brick walls with black slate outer covers, 40 mm glass wool insulation on North Wall
Interior partition Walls	Wooden Partition
Windows	Double glazed windows with 10 mm air gap, 4mm Glass
Doors	Airlock lobbies at the entrance, wooden interior doors
Roof Type	Concrete slab roof with 40 mm glass wool insulation
Floor height	Ceiling at a level of 10 Feet
Sky lighting	Sky light on roof of top floor

Orientation	Longer Axis of the building is in East – West direction providing full solar exposure to the Southern facade of the building.
Window Size	Solariums on South side, 12 Thermosyphoning Air heating panels, No windows on northern wall.
Flooring	Wooden Flooring
Vegetation	The building is located in SDA Complex, no nearby trees
Veranda	Road in front of South and North facade of the building
Snowfall	1Feet to 1.5 Feet of average annual snowfall during January to February
Monitoring Period	Between January – February 2019

IV. CALCULATION OF INDOOR THERMAL COMFORT

Under the present study, for the purpose of calculation of thermal comfort, adaptive model has been selected. As it is now a well established fact that the human body reacts accordingly to reduce the level of discomfort being caused due to the thermal changes in the surroundings. Adaptive model considers all these changes and takes into account the clothing pattern of the human for adaptation with the changing environment.

The indoor and outdoor temperatures have been plotted against each other to analyse the thermal performance of the monitored building. The thermal comfort for the building have been assessed on the basis of a lower base temperature for cold and cloudy regions of Himachal Pradesh as provided by Chandel S.S and Aggarwa, R 2012. The concept provided by Nicole and Humphreys is working, however, it is not appropriate for all climatic conditions. For cold regions the thermal comfort temperature is lesser than 23.8ºC as calculated by Nicole and Humphrey. The thermal comfort temperatures for winters are assumed as 23.8ºC and for summers it is taken as 29ºC. The Nicole and Humphrey have concluded that the relation between comfortable temperatures and outdoor temperatures in naturally controlled buildings is stable. Both have established a relation expressed in the form of an equation between outdoor temperature and comfort temperature. The equation is as below;

Tc = 13.5 + 0.54To (Nicol J Fergus, Humphreys Michael A 2002), where Tc is the comfort temperature,

To is outdoor temperature. However, the comfort temperatures deviate from the above equation by about 2ºC for artificially controlled buildings.

Another thermal comfort temperature based on survey around the world has been derived as;

Tc= 12.1+0.53To (M. A. Humphreys, 1978).

A similar type of survey conducted in Pakistan provides an equation for thermal comfort as below;

Tc = 17.0+0.38To. (J. F. Nicol, 1998).

Another thermal comfort standard has been evaluated which is based on survey in 5 European Countries. It provides that the running mean outdoor temperature is coupled best with the indoor temperature and it assumes that the clothing insulation level is 0.5, air speed is 0.15m/s, humidity percentage is 50, and the metabolic rate is 1.4 (J. F. Nicol and L. Pagliano, 2007). As per this standard the equation for thermal comfort has been defined as;

Tc = 18.8 + 0.33To.

The month-wise thermal comfort temperatures calculated by above mentioned three comfort standards for Shimla are given below. Comparing the thermal comfort temperatures for above three standards, it was found that the range of thermal comfort temperatures obtained by using the first equation are comparatively low and are ranging between 14.1 °C–18.7 °C. As per second comfort standard equation, the thermal comfort temperature comes out to be 18.5°C–21.7 °C whereas the third equation provides a thermal comfort temperature ranging between 20.5°C–25.3°C for the coldest month of January. The second thermal comfort standard equation has been adopted for the estimation of thermal comfort temperature for different locations in Himachal Pradesh (Chandel S. S, Aggarwal R 2012).

However, under the present study, the thermal comfort temperatures obtained using first equation [Tc= 12.1+0.53To (M. A. Humphreys, 1978)] are found to be in compatibility with field studies in high altitude regions of District Kinnaur and Shimla. Hence for the purpose of this study the adaptive thermal comfort model as provided by Humphreys, 1978 has been accepted and the comfort temperatures have been calculated accordingly.

Calculation of indoor Thermal comfort temperatures in HIMURJA Building (using three models as detailed below)

Table 2: Calculation of indoor thermal comfort temperatures for HIMURJA Office building using Humphreys A 1998, Nicol J.F., Humphreys A 2002 and Nicol, J.F., 1998 – January 2020.

Jan-20	Avg. Indoor temp (°C)	R. Humidity (%)	Daily Maximum Outdoor Temp (°C)	Indoor thermal comfort temperature for HIMURJA Office Building (°C)*	Indoor thermal comfort temperature for HIMURJA Office Building (°C)!	Indoor thermal comfort temperature for HIMURJA Office Building (°C)$
1	21.9	27	10.4	17.6	21.0	18.8
2	18.9	30	11.2	18	21.3	19.2
3	19.4	30	11.4	18.1	21.3	19.4
4	20.6	33.5	5	14.8	18.9	15.9
5	19.3	32.4	6.4	15.5	19.4	16.7
6	14.5	40	4.1	14.3	18.6	15.4
7	15.4	44.7	5	14.8	18.9	15.9
8	17.1	34	1.4	12.8	17.5	14.0
14	18.5	39.5	12	18.5	21.6	19.7
15	20.2	35	14	19.5	22.3	20.8
16	19	37.5	9.5	17.1	20.6	18.3
17	17.8	38.5	9	16.9	20.4	18.1
18	18.6	36	7.5	16.1	19.9	17.3
20	20	31.5	10.9	17.9	21.1	19.1
21	19.5	34	9.5	17.1	20.6	18.3
24	19.9	26.5	14	19.5	22.3	20.8
25	23.1	27.7	14.5	19.8	22.5	21.0
26	23.4	29.3	13.8	19.4	22.2	20.7
27	18.2	32.7	8.9	16.8	20.4	18.0
28	16.6	37.4	5.5	15	19.1	16.2
29	15.5	37.5	6.3	15.4	19.4	16.6
30	17.7	35.7	7.8	16.2	20.0	17.4
31	15.8	35	11.8	18.4	21.5	19.6
Average	18.7	34.1	9.1	16.9	20.5	18.1

***** Humphreys, 1998 (Tc=12.1+0.38 To), **$** Nicol, J. Fergus, Humphreys, Michael A 2002 (Tc= 13.5 + 0.54To), **!** J. F. Nicol, 1998 (Tc = 17.0 + 0.38To)

Table 3: Calculation of indoor thermal comfort temperatures for HIMURJA Office building using Humphreys A 1998, Nicol J.F., Humphreys A 2002 and Nicol, J.F., 1998 – Feba 2020.

Feb-20	Avg. Indoor temp (°C)	R. Humidity (%)	Daily Maximum Outdoor Temp (°C)	Indoor thermal comfort temperature for HIMURJA Office Building (°C)*	Indoor thermal comfort temperature for HIMURJA Office Building (°C)!	Indoor thermal comfort temperature for HIMURJA Office Building (°C)$
1	16.8	34	2.8	13.6	18.1	15.0
2	18.8	32.5	5.7	15.1	19.2	16.6
3	19.5	30.7	7.8	16.2	20.0	17.7
4	18.5	33.5	4.6	14.5	18.7	16.0
5	17.7	35	6.1	15.3	19.3	16.8
6	16.8	37	5.9	15.2	19.2	16.7
7	28.4	52	4.4	14.4	18.7	15.9
10	23.2	26	6.3	15.4	19.4	16.9
11	20.8	30	10	17.4	20.8	18.9
12	21.2	31	12.7	18.8	21.8	20.4
13	24.3	31	15.8	20.5	23.0	22.0
14	23.7	33.7	13.3	19.1	22.1	20.7
15	24.3	28	13.6	19.3	22.2	20.8
17	22.6	27	11.7	18.3	21.4	19.8
18	22.6	27.5	13.3	19.1	22.1	20.7
19	20.5	29	11.8	18.4	21.5	19.9
20	20.5	28.7	13.4	19.2	22.1	20.7
22	18.2	39.7	9.3	17	20.5	18.5
23	19.2	39	9.1	16.9	20.5	18.4
24	16.8	40.5	10	17.4	20.8	18.9
25	17.3	39.7	9.6	17.2	20.6	18.7
26	18.8	39.5	9.7	17.2	20.7	18.7
27	18.6	45.5	10.3	17.6	20.9	19.1
28	17.8	41	11.7	18.3	21.4	19.8
29	17	42	10.7	17.8	21.1	19.3
Average	20.1	34.9	9.6	17.2	20.6	18.7

***** Humphreys, 1998 (Tc=12.1+0.38 To), **$** Nicol, J. Fergus, Humphreys, Michael A 2002 (Tc= 13.5 + 0.54To), **!** J. F. Nicol, 1998 (Tc = 17.0 + 0.38To)

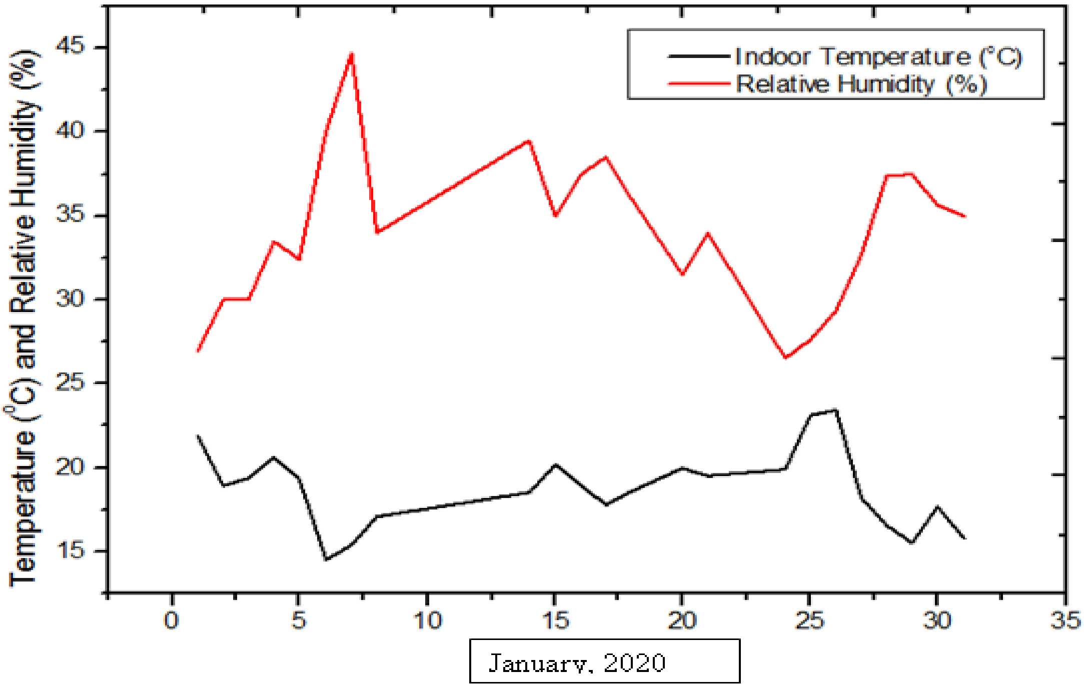

Fig. 4: Plot between indoor temperature and humidity for HIMURJA office Buildings, Shimla.

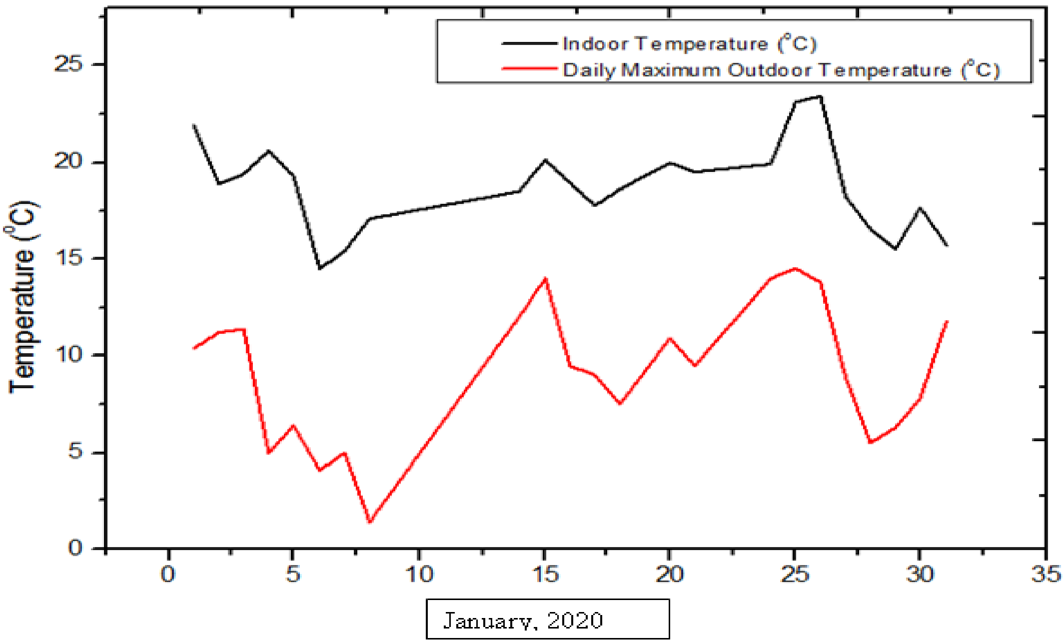

Fig. 5: Plot between indoor temperature and outdoor temperature for HIMURJA Building, January, 2020

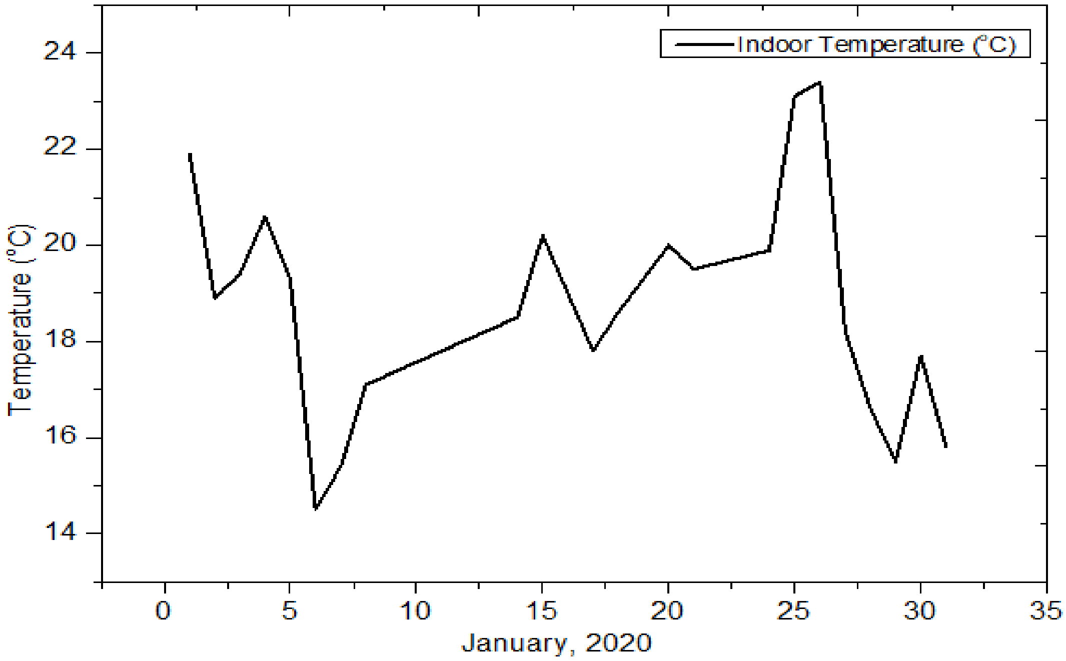

Fig. 6: Indoor temperatures during January, 2020 for HIMURJA Office Building, B-34, SDA Complex, Kasumpti, Shimla - 171009

The comparative analysis of thermal comfort temperatures using different models have been treated against each other in the following graphs

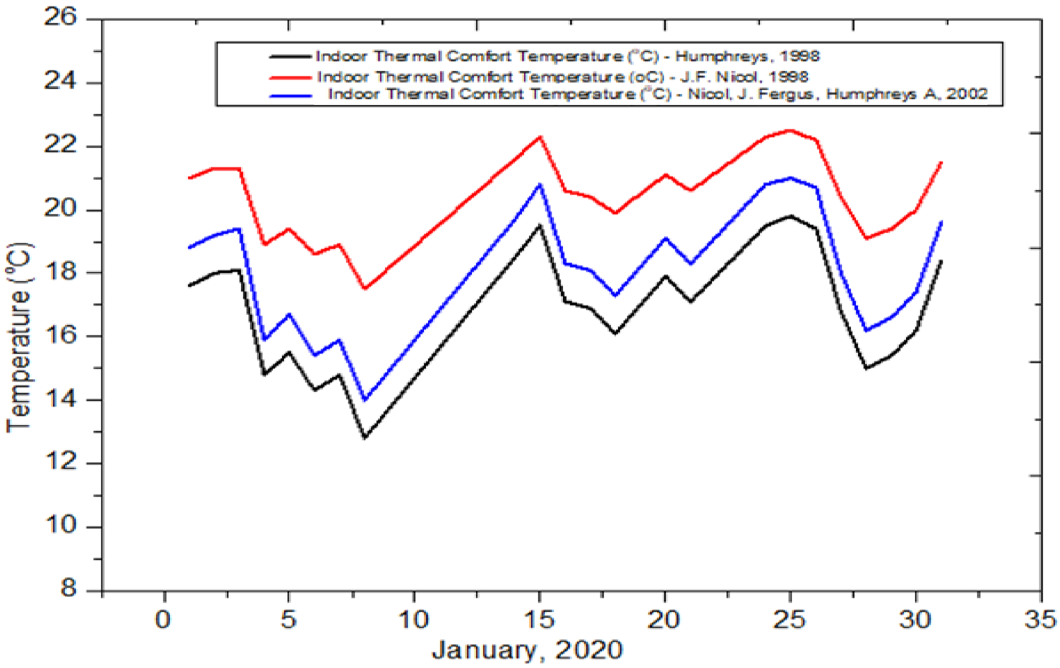

Fig. 7: Comparative analysis of thermal comfort temperatures using above mentioned three models for the month of January 2020 in HIMURJA Office building, SDA Complex, Kasumpti, Shimla – 171009

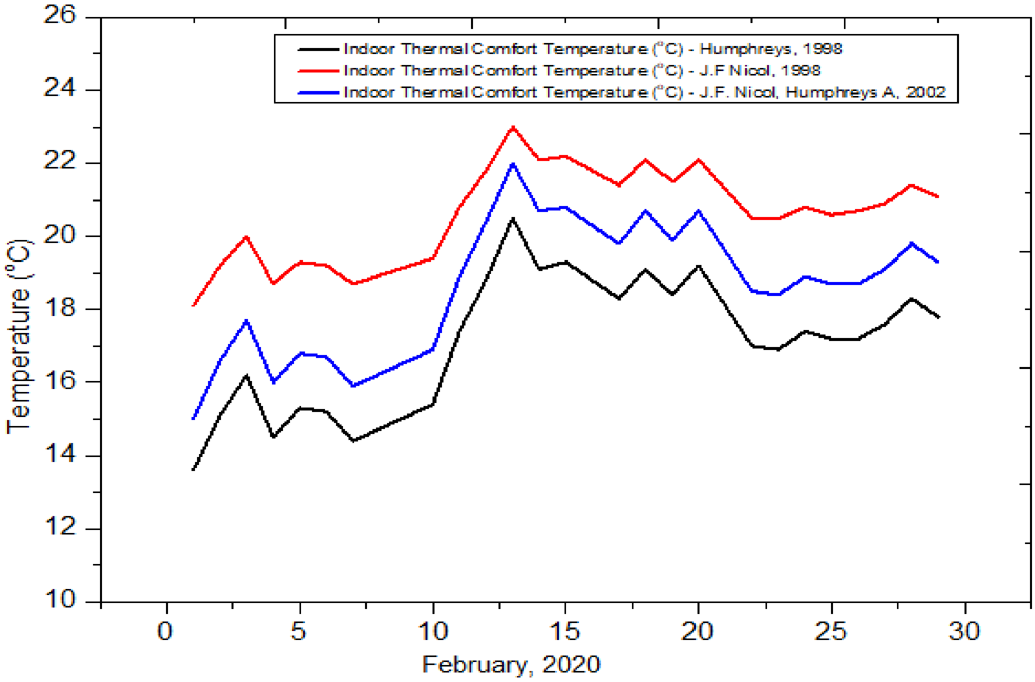

Fig. 8: Comparative analysis of thermal comfort temperatures using above mentioned three models for the month of February 2020 in HIMURJA Office building, SDA Complex, Kasumpti, Shimla – 171009

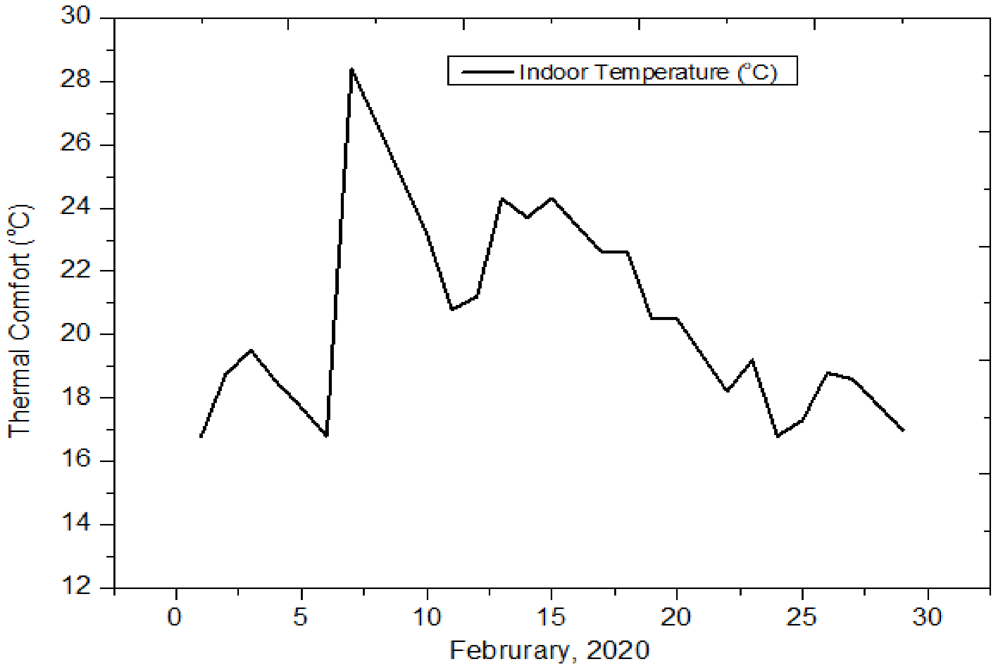

Fig. 9: Indoor temperatures during February, 2020 for HIMURJA Office Building, B-34, SDA Complex, Kasumpti, Shimla - 171009

Results and Discussions:

From the above graph it is inferred that the average indoor temperature of HIMURJA office building fits in all the three afore mentioned thermal comfort models. Throughout the winter months of January and February, 2020 the average indoor temperature is little more than the thermal comfort temperatures as calculated by Humphreys 1998 and J.F. Nicol 1998. However, the indoor thermal comfort temperature for HIMURJA office building is mostly similar to that of calculated using Nicol, J. Fergus, Humphreys, Michael A 2002.

It can be observed from above figures that the Humphreys 1998 model of indoor thermal comfort evaluation gives lowest values for indoor thermal comfort, whereas J.F. Nicol model provides a higher range of thermal comfort temperatures. It is interesting to observe that the indoor temperatures in HIUMURJA Office building is lying within the range of all three models of indoor thermal comfort temperatures. Inference is that the building is providing a condition of indoor thermal comfort throughout the winters without any auxiliary heating.

A similar study conducted on the same building i.e. HIMURJA Office building by the Himachal Pradesh Council for Science, Technology & Environment (HIMCOSTE) corroborate that the indoor temperatures in HIMURJA Office building are ranging between 18ºC to 28ºC when the outdoor temperature is varying between 9ºC to 15ºC. The building has been designed and planned to have maximum solar exposure. Besides, it has day lighting features, all windows are double glazed (Chandel, 2000). The building is integrated with 12 Thermosyphoning Air heating panels fixed in different rooms. The roof and the north wall of the building are insulated with 40 mm thick glass wool. The flooring is wooden and the interior partitions are also of wood. As a result of these ideal solar passive energy saving features, the building is behaving in climate resilient manner and is providing excellent level of thermal comfort which is indirectly enhancing the efficiency of the working staff without any dependence on artificial sources of energy.

However, due to less space availability and constraining design options, it was not an easy task to design and plan HIMURJA Office building in compatibility with passive solar housing features. This building is considered as one of the best example of a Solar Passive building. In such buildings the incremental cost of additional solar passive features ranges between 5-10% of the total cost of the entire building.

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