Assessing Human Comfort Levels in Learning Environments- The Role of Sick Building Syndrome

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ABSTRACT— Human comfort in indoor environments—particularly in schools, universities, and other learning institutions—is a critical determinant of student well-being, cognitive performance, and productivity. Indoor comfort is typically evaluated using parameters such as thermal comfort, air quality, lighting, humidity, acoustics, and ventilation (ASHRAE, 2019). Sick Building Syndrome (SBS) is a condition recognized by the World Health Organization (WHO, 1984), where building occupants experience acute health symptoms such as headaches, fatigue, eye irritation, and respiratory discomfort without a clearly identifiable cause, which improve upon leaving the building. The study aims to find out various parameters that determine the optimum levels of basic human comfort in the learning space. The methodology involves the spatial analysis w.r.t daylighting and ventilation. Environmental simulation softwares- Grasshopper for Rhino and Lightstanza were used to get data and questionnaire surveys were conducted among the user groups involving teachers and students. Teachers who have spent more than 2 years said that for most of them, symptoms do not ease when they leave college. Almost 90% of the students feel their symptoms happened when they were in college. Stress was also a contributing factor for SBS seen in the users. The study proved that students and teachers were affected by SBS symptoms.

***Index Terms*— Sick building Syndrome, Learning spaces, Simulation, Daylight, Ventilation, Spatial Analysis.**

I. INTRODUCTION

The term 'Sick building syndrome' (SBS) is used when occupants in a building feel acute health and comfort issues, which are directly related to the time they spend in the building. SBS could happen in all types of buildings, including schools, houses, nurseries, etc. This could cause reduced performance at work and heightened absenteeism. A report by WHO, in 1984, suggested that up to 30% of newly constructed and remodeled buildings could have issues related to Indoor Air Quality (United States Environmental Protection Agency, 1991). According to the existing body of published literature, Indoor Air Pollution (IAP) has been ranked among the top 10 health risk factors in developing countries. This contributes ~2.6% of the global burden of diseases, 1.6 million premature deaths per year, and ~1.0 million deaths below the age of 5 years according to the latest available estimates. Occupants (children, teachers and staff) at school buildings are four times closer as compared to office buildings; therefore, they need a better quality of indoor air (Shree et al., 2019).

Wind and Daylighting were identified as the main parameters which contributed to the SBS aspects. Ventilation is the movement of air from outside to inside a building or room, and the distribution of air within the room (Koenigsberger et al.,1975). The factors which affect wind flow are Orientation, External features, Cross-ventilation, Position of openings, Size of openings and Controls of openings. Daylighting could be defined as the controlled use of lighting both indoors and around a building. It is the practice of providing effective internal illuminance with natural lighting by placing windows, or any other transparent media or any reflective surfaces during the day. Besides these, personal and psychological factors contribute to the SBS in individuals. Runeson- Broberg and Norbäck (2013) defined personality as the various characteristic sets of behavioral, cognitive, and emotional patterns that are evolved from environmental and biological factors.

II. AIM

To study and find out various parameters of buildings that would determine their optimum level and how sick building syndrome reflects in the Architecture department block and how they further affect health issue risks.

III. OBJECTIVES

1. To define and establish the parameters for sick building syndrome.
2. Analyze the parameters in the department block through simulation models and surveys.

IV. MATERIALS AND METHODS

The study was conducted in the Department of Architecture, T.K.M. College of Engineering, located in Kollam district, Kerala, India established in 1985. The department has approximately 290 students, 28 teachers and 3 non-teaching staffs as on 2019. Simulations were developed to model the natural wind and lighting for the architecture block using rhino Grasshopper software. Figure 1 represents the methodology adopted in the research.

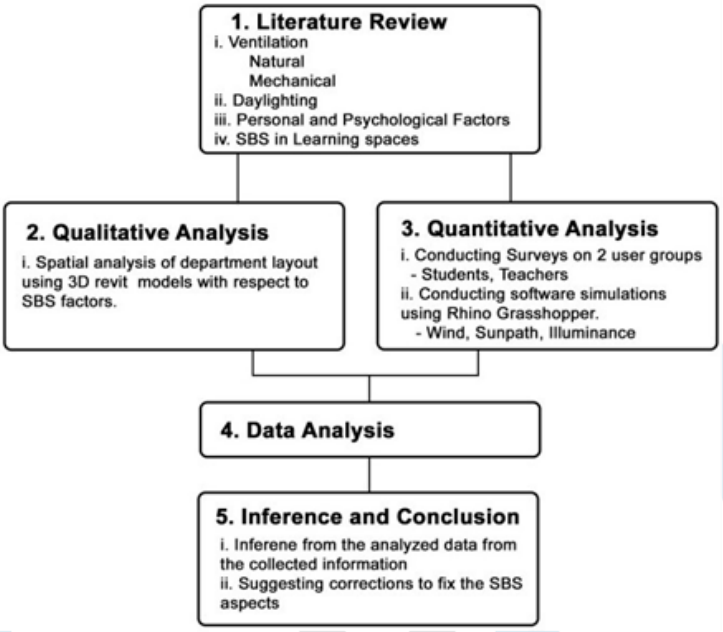

Figure 1. Methodology Flow chart

V. Spatial Analysis

Floors in the department building were spatially analyzed with respect to SBS parameters- daylighting and ventilation. 3D models were constructed in Revit software using the floor plans (Figure 2) Ventilation conditions were analyzed room wise- cross ventilated rooms and rooms with single openings were identified, and marked (Figure 4). Also lighting conditions were analyzed for morning and afternoon session (Figure 3).

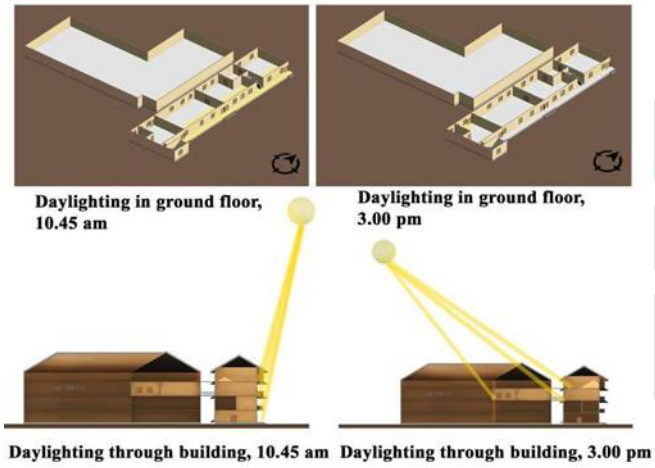

Figure 3. Daylighting through the building

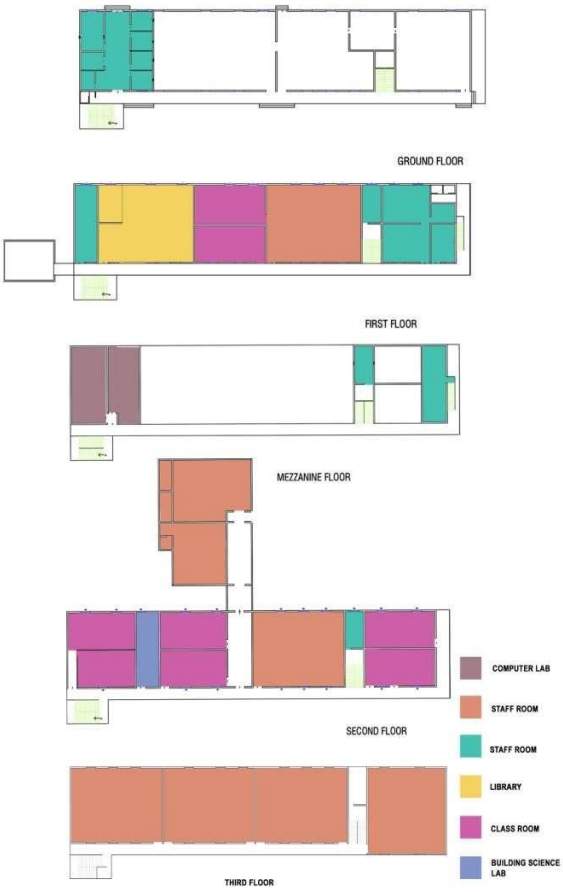

Figure 2. Floor plans showing the spatial configuration of the Department of Architecture, TKMCE

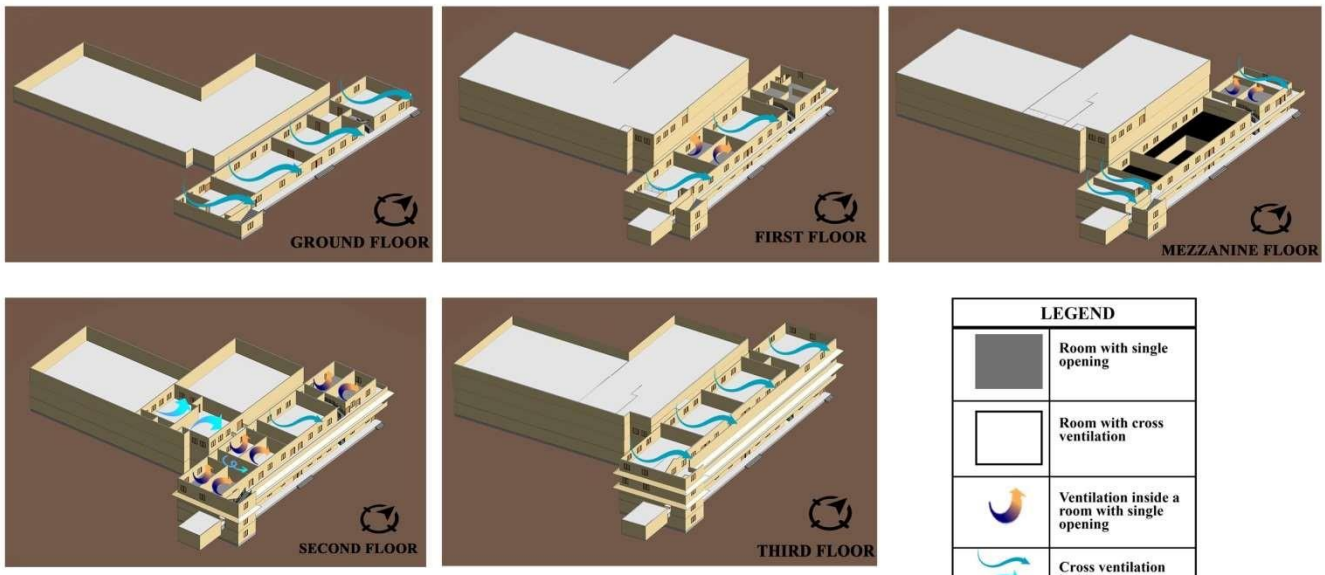

Figure 4. Floor-wise Natural ventilation in the department

Environmental Simulations Ladybug is a plugin for the software Grasshopper, which allows importing weather data into the software to get sun path, wind rose, and adaptation rose diagrams. By exporting Revit models to Grasshopper, the positioning of the Sun was identified from the Sun path diagram and from the Windrose diagram, wind directions and average wind speeds were identified. Lightstanza is online lighting analysis software. The software was used to develop illuminance diagrams by exporting Revit models. For the illuminance study, the chosen time and dates were March 21 and July 21 (2019), a day each from the summer season and rainy season. Data for every 3 hours from 9 am to 5 pm was recorded.

Figure 5. Staff room on the ground floor at 2pm

Figure 6. First floor classroom at 11am (middle) and 2.00pm (right)

Figure 7. First floor studio at 11am (left) & 2.00pm (middle)

Figure 8. First floor Classroom at 11 am

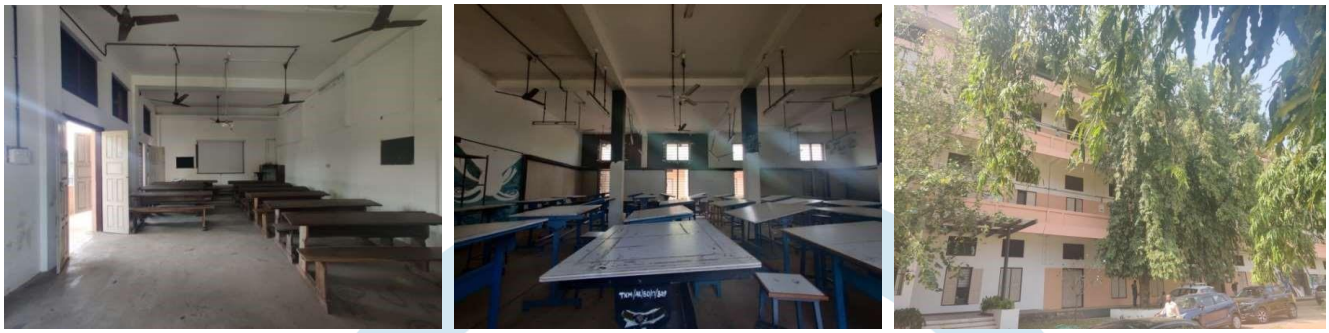

Figure 9.a. Classroom, Second floor at 2 pm (Left),
9.b. Third floor Studio at 2 pm (Middle) and
9.c. False Ashoka Trees in front of the Eastern façade of the building. (Right)

Cross ventilation across the rooms in the ground floor makes them cool throughout the day (figure 5).
On the first floor, the library and the studio have cross ventilation, making them adequately lit, and ventilation is not an issue (Figures 7). But the classrooms and staff rooms have openings only on one side, making them less comfortable during the day (Figures 6).
The classroom inside the studio in first floor becomes hotter by afternoon. Effective cross ventilation is not occurring (Figure 8).
In the mezzanine floor, the rooms are not well ventilated. This causes discomfort in these rooms.

On the second floor, the studios have cross ventilation. But the classrooms and staff rooms have openings on a single side, which further causes discomfort (Figure 9.a). In the third floor, the 4 studios are well ventilated and provisions for cross ventilation are there. This causes in a better comfort level of the users (Figure 9.b).
Since the departmental block is facing the East, during the morning hours, the front of the department and the verandah are lit. During the evening hours, the rear side of the department is lit. The False Ashoka trees (Monoon longifolium) in front of the department building provide sufficient shading (Figure 9.c).

VI. Environmental Simulation

During the working hours of college, the sun would be overhead (figure 10.a.) The lowest temperature recorded was 20.8°C and the highest 35° Celsius. Most of the recorded temperatures were between 28°C and 35°C.

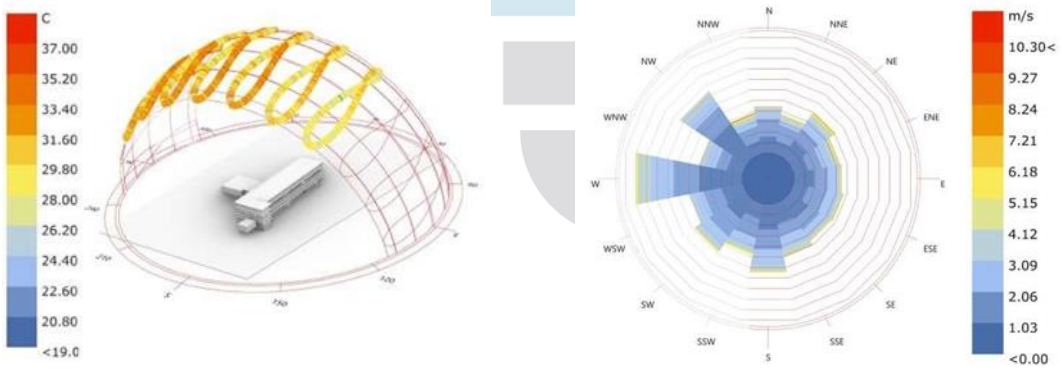

Figure 10.a. Sun-path (left) and 10.b. Wind Rose diagram (right) generated using the Ladybug plugin

The wind is mostly from the South direction, and it is calm for most of the time (figure 10.b.)

- Climate and the geographical location of the site would be the main reason why nonsignificant changes were seen during summer and rainy seasons.
- Most of the recorded illuminances were recorded during the morning hours.
- On the ground floor, the maximum illuminance recorded was at 8 am. During the rainy season, no significant changes were seen in the values, as shown in figure 16.

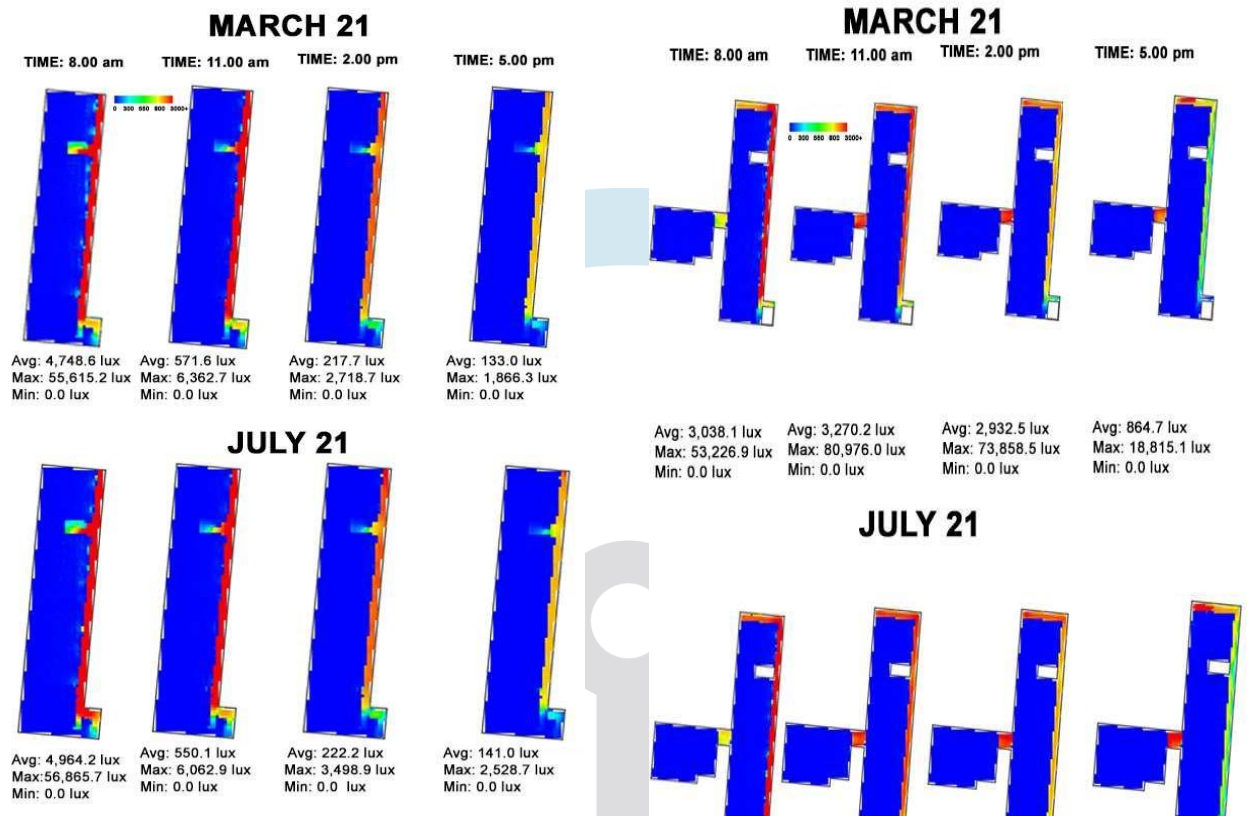

Figure 11.a. Illuminance on the ground floor (left) and 11.b. first floor (right)

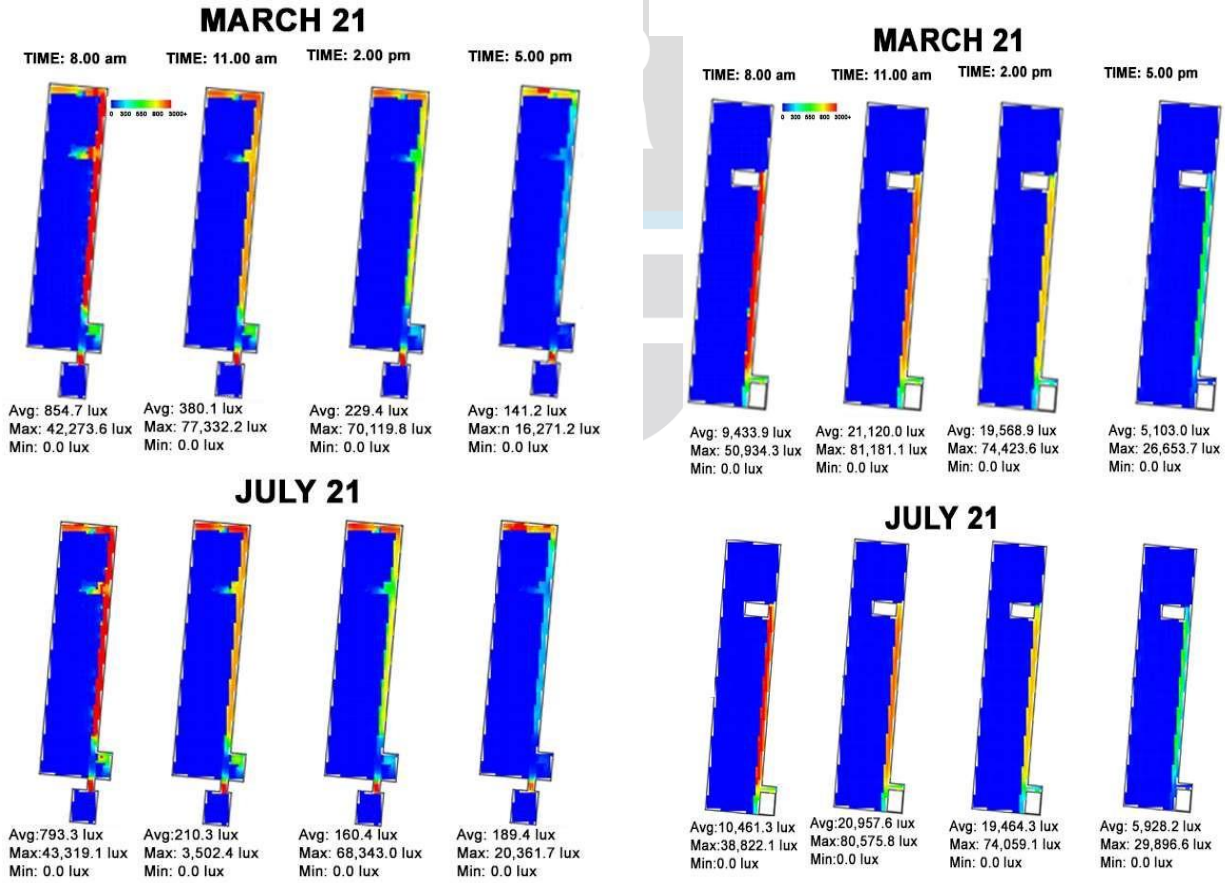

Figure 12.a. Illuminance on the second floor (left) and 12.b. Third Floor (right)

- On the first floor, the maximum illuminance readings recorded were during the morning hours. There were no significant changes recorded during the rainy season, as shown in Figure 11.b.
- On the second floor, the maximum illuminances recorded were also during the morning hours. Significant reduction of illuminance was seen during evening hours, as shown in Figure 12.a.
- On the third floor, the maximum illuminance readings were recorded during morning hours. Significant changes were not seen during the rainy season (Figure 12.b).
- Climate and the geographical location of the site would be the main reasons why no significant changes were seen during summer and rainy seasons.
- Most of the recorded illuminances were recorded during the morning hours.

VII. QUESTIONNAIRE SURVEY

A questionnaire was prepared to further confirm the data collected from the simulation and analysis. Similar studies and surveys were referred to in preparing the survey. Separate studies were conducted for teachers and students. Of the total 28 teachers, 18 teachers (64.5%) participated. 145 students also participated in the survey, ranging from second-year students to newly graduated students. Questions were prepared in 3 sections:

1. general details of the users,
2. classroom/ staffroom conditions, and
3. health conditions after joining the college.

- Majority of the students participated are female students and male faculty.
- For students, 88.3% have spent 2-5 years in college and 11.7% have spent less than 2 years.
- 11.1% of the teachers have worked less than 6 months, 22.2% have worked less than 2 years and teachers who worked 2-5 years and more than 5 years constitute 33.3% and 33.3% respectively.

- Only 9% students felt very comfortable in their classroom. 89% felt no unpleasant odour in class.
- 41.4% felt that the lighting was uncomfortable regardless of time.
- 62.1% felt the glare conditions inside the classroom were fairly bothersome, and so did 49% in the studio.
- 42.1% students felt a lack of airflow regardless of time in the classroom, whereas 38.6% students felt this during the afternoon in the studio.
- 78.6% of students were comfortable in outdoors rather than indoors. 29.7% students were unsure about how often their classrooms were cleaned.
- 68.3% of students were not satisfied with the toilet facilities given in the block. The questionnaire results about classrooms are presented in Table 2.

The questionnaire results are presented in Table 2.

- 61.1% of the teachers shared their rooms with partitions.
- 44.4% commented that the lighting in their workstations is just right. 38.9% said the glare conditions were fairly bothersome.
- 44% felt no lack of airflow in their workstation.
- Half of the teachers said the workstation was slightly warm.
- 66.7% were satisfied with their toilet facilities, and 66.7% experienced unpleasant external sounds during events happening in college or nearby.
- 44.4% of teachers said their staffrooms got cleaned once a week.
  The questionnaire results about workstations are presented in Table 3.

- Tiredness was the most prevalent SBS symptom found in students (62.1%), followed by headache and difficulty in concentration. Among teachers, tiredness (33.3%) and headache (33.3%) were the most prevalent.
- Only 9% of students and 11.1% of teachers never experienced the symptoms when in college. 51% of students and 27.8% of teachers felt their symptoms faded when the left college.
- Among 91% students and 44.4% teachers said their studies involved stress. Teachers and students felt the most stress on Mondays and Wednesdays, due to continuous 6-7 hours of studio works.
- Both students (54.9%) and teachers (43.8%) had trouble in concentration as part of coping stress followed by trouble in sleeping, anxiety, mental breakdown.
  The questionnaire results about general health after joining college are presented in Table 4.

General Details		
Variables	**No. of students (%)**	**No. of Teachers (%)**
Gender		
Female	97 (66.9%)	8 (44.4%)
Male	48 (33.1%)	10 (55.6%)
No. of Years associated with the college		
<6 months		2 (11.1%)
<2 years		4 (22.2%)
2-5 years	17 (11.7%)	6 (33.3%)
>5 years	128 (88.3%)	6 (33.3%)
Health issues before joining the college		
Migraine	29 (20%)	3 (16.7%)
Headache	29 (20%)	5 (27.8%)
Dust allergy	48 (33.1%)	5 (27.8%)
Frequent cold	12 (8.3%)	4 (22.2%)
Asthma	4 (2.8%)	1 (5.6%)
No issues	73 (50.3%)	9 (50%)
Smoking Habits		
Regular	4 (2.8%)	1 (5.6%)
Irregular	14 (9.7%)	1 (5.6%)
Non- smoker	127 (87.6%)	16 (88.9%)
Smoking habits of friends		
Have friends who smoke	62 (42.8%)	6 (33.3%)
Have friends who dont smoke	29 (20%)	6 (33.3%)
Unsure	54 (37.2%)	6 (33.3%)

Table 1. Questionnaire results of general details

Workstation conditions -Teachers	
Variable	**Number of Teachers (%)**
Workstation conditions:	
Private Office	2 (11.1%)
Shared private space	3 (16.7%)
Shared room with partitions	11 (61.1%)
Shared room without partitions	2 (11.1%)
Number of people sharing workspace:	
1	1 (5.6%)
2-3	8 (44.4%)
4-7	8 (44.4%)
8-10	1 (5.6%)
11 or more	0

Table 3. Questionnaire results of workstation conditions

Classroom conditions experienced by Students		
Variable	**Number of Students (%)**	**Number of Students (%**
Class environment		
Very comfortable	3 (2.1%)	
Reasonably comfortable	72 (49.7%)	
Somewhat comfortable	57 (39.3%)	
Very uncomfortable	13 (9%)	
Unpleasant odour inside the class		
Morning hours	0	
Afternoon hours	10 (6.9%)	
Regardless of time	46 (31.7%)	
No such odour	89 (61.4%)	
Uncomfortable lighting		
Morning hours	10 (6.9%)	
Afternoon hours	34 (23.4%)	
Regardless of time	60 (41.4%)	
Not uncomfortable	41 (28.3%)	
	Classroom	Studio
Glare Conditions		
Not bothersome	26 (17.9%)	42 (29%)
Fairly bothersome	90 (62.1%)	71 (49%)
Bothersome	29 (20%)	32 (22.1%)
Lack of airflow		
During morning	5 (3.4%)	45 (31%)
During afternoon	33 (22.8%)	56 (38.6%)
Regardless of time	61 (42.1%)	39 (26.9%)
No lack of airflow	1 (0.7%)	5 (3.4%)
Area more comfortable to spend in		
Indoor	31 (21.4%)	
Outdoor	114 (78.6%)	
Cleaning of classroom:		
Everyday	21 (14.5%)	
More than twice a week	14 (9.7%)	
Once a week	33 (22.8%)	
Irregular	34 (23.4%)	
	43 (29.7%)	
Satisfaction with toilet facilities		
Satisfied	46 (31.7%)	
Not satisfied	99 (68.3%)	

Table 2. Questionnaire results of classroom conditions experienced by the students

SICK BUILDING SYNDROME- EFFECTS IN USER GROUPS		
Variable	**Number of Students (%)**	**Number of Teachers (%)**
SYMPTOMS AFTER JOINING COLLEGE		
Sensitive to odours	6 (4.1%)	1(5.6%)
Sneezing	28 (19.3%)	2(11.1%)
Cough	18 (12.4%)	0
Tiredness	90 (62.1%)	6 (33.3%)
Headache	77 (53.1%)	6 (33.3%)
Dizziness	17 (11.7%)	3 (16.7%)
Difficulty in breathing	14 (9.7%)	1(5.6%)
Stuffy Nose	19 (13.1%)	0
Runny Nose	12 (8.3%)	2(11.1%)
Watery Eyes	21 (14.5%)	1(5.6%)
Dry throat	25 (17.2%)	2(11.1%)
Difficulty in Concentration	62 (42.8%)	3(16.7%)
Tightness in Chest		1(5.6%)
Skin dryness/ irritation	36 (24.8%)	2(11.1%)
No symptoms	0	5(27.8%)
EXPERIENCING SYMPTOMS IN CLASSROOM/WORKSTATION		
Very often	16 (11%)	6(33.3%)
Seldom	19 (13.1%)	10 (55.6%)
Sometimes	97 (66.9%)	0
Never	13 (9%)	2 (11.1%)
EASE OF SYMPTOMS ON LEAVING COLLEGE		
Yes	74 (51%)	5 (27.8%)
No	71 (49%)	13 (72.2%)
EXPERIENCING HIGH WORK STRESS		
Yes	132 (91%)	8 (44.4%)
No	13 (9%)	10 (55.6%)
DAYS WITH THE MOST STRESS		
Monday	128 (90.8%)	9 (69.2%)
Tuesday	38 (27%)	3 (23.1%)
Wednesday	77 (54.6%)	6 (46.2%)
Thursday	22 (15.6%)	3 (23.1%)
Friday	14 (9.9%)	2 (15.4%)
EFFECTS OF STRESS		
Trouble in sleeping	69 (47.9%)	5 (31.3%)
Anxiety	69 (47.9%)	3(18.8%)
Trouble in communication	35 (24.3%)	1 (6.3%)
Mental breakdown	48 (33.3%)	2 (12.5%)
Anger Management	50 (34.7%)	5 (31.3%)
Trouble in Concentration	79 (54.9%)	7 (43.8%)
No effect	12 (8.3%)	3 (18.8%)

Table 4. Questionnaire results on health condition after joining the course

VIII. DISCUSSIONS

The spatial analysis for the classrooms proved that the rooms had no proper openings, leading to less ventilation, more heating up of the room and not too bright lighting. This was further confirmed by the students in the questionnaire. They said the rooms had uncomfortable lighting, lack of airflow eventually leading to discomfort. The studios had proper openings and the higher number of windows allowed cross ventilation across the room. From the students' questionnaires, it was proved that the studios were much more comfortable than classrooms in terms of ventilation and lighting conditions. But glare conditions were uncomfortable for many students.

The spatial analysis in the staffrooms showed that most of the staffrooms had no proper openings- leading to less ventilation and heats up the room more the usual required. This leads to warm conditions in the room, causing discomfort for the users. This was further confirmed by the teachers in their survey- most of them felt the rooms were hot and had a lack of airflow.

Stress among the students and teachers due to the work may also be a contributing factor to the SBS symptoms felt by the users. The long-term exposure has caused the teachers and students to develop chronic symptoms.

IX. CONCLUSIONS

In the study, through simulations and surveys, it was clear that temporality is established; a connection between the putative cause and the outcome is established. Although almost all classrooms and studios have provisions for cross ventilation, they are lacking in thermal comfort. The conditions are hot throughout the day, with people feeling uncomfortable in various aspects. There is clear evidence of the prevalence of Sick Building Syndrome among the users. Factors such as stress, lack of ventilation seemed to have an influence on the users.

X. 6. APPENDIX -1: QUESTIONNAIRE FOR TEACHERS

GENERAL INFORMATION

1. Name: Gender: Age:
2. How long have you been working in the college?
   a. Less than 6 months b. 6 to 12 months c. Less than 2 years d. 2-5 years e. More than 5 years

3. Have you had these issues before joining college?
   a. Migraine b. Headaches c. Dust Allergy d. Frequent cold e. Asthma f. No, I haven't had any.

4. Do you smoke?
   a. Yes, I'm a regular smoker.
   b. Yes, I smoke sometimes
   c. No, I don't smoke

5. Do any of your friends smoke?
   a. Yes b. No c. I don't know

WORKPLACE CONDITIONS

1. Which best describes the space in which your current workstation?
   a. Private office b.Shared private office c.Shared room with partitions d.Shared room without partitions
   e. Other (specify)

2. Pick out your staff room: (Figure 20)

   a. 101 B b. A 201
   c. A 202 d. A 203
   e. A 204 f. A 205
   g. A 206 h. A 307
   i. A 308 j. A 302

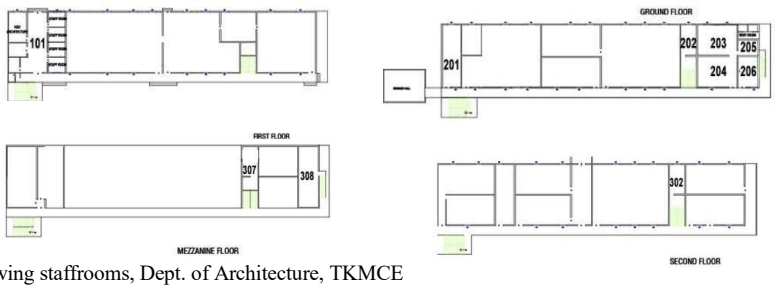

Figure 20. Floor plans showing staffrooms, Dept. of Architecture, TKMCE

3. How many people work in the room in which your workstation is located (including yourself)?
   a. 1 b. 2–3 c. 4–7 d. 8–10 e. 11 or more

4. How would you rate the lighting in your workstation?
   a. Much too dim b. A little too dim c. A little too bright d. Much too bright e. Just right

5. How would you describe the glare conditions in your classroom?

a. Not at all bothersome b. Not very bothersome c. Fairly bothersome d. Bothersome

6. Do you experience a lack of airflow in your workstation?
a. Yes, especially during morning b. Yes, especially during night c. Yes, regardless of time d. No

6. Comment on the thermal comfort in your classroom
a. Hot b. Slightly Warm c. Neutral d. Cool

5. Are you happy with the toilet facilities provided in the department building?
a. Yes b. No

6. Do external sounds bother you when inside the building?
a. Yes, during morning hours b. Yes, during evening hours c. Yes, during events happening nearby
d. No, it doesn't bother me

7. Does your workstation get cleaned regularly?
a. Yes, every day b.Yes, more than twice a week c .Yes, once a week d.No

HEALTH CONDITIONS

1. Have you experienced these symptoms after joining the college?
a. Sensitivity to odors b. Sneezing c. Coughing d. Tiredness
e. Headaches f. Dizziness g. Difficulty in breathing h. Stuffy Nose
i. Runny Nose j. Watery Eyes k. Dry throat l. Difficulty in concentration
k. Tightness of the chest l. Dryness and/or irritation in skin

2. Do you feel any of these while in the building?
a. Very often b. Seldom c. Sometimes d. Never

3. Do you find these symptoms higher on Mondays and Tuesdays?
a. Yes b. No

4. Do you feel at ease or do these symptoms fade when you leave the building?
a. Yes b. No
5. Does your work have high amount of stress?
a. Yes b. No.

6. On Which day do you feel stress the most?
a. Monday b. Tuesday c. Wednesday d. Thursday e. Friday

7. How does stress affects you?
a. I have trouble sleeping at night b. I have high anxiety issues
c. I have trouble in communicating with other people d. I'm always breaking down mentally
e. I have issues managing anger f. I have trouble in concentration
g. Stress doesn't affect me

7. APPENDIX -2 QUESTIONNAIRE FOR STUDENTS : GENERAL INFORMATION

1. Name: Gender:
2. Age
3. How many months/ years have you spent in the college?
a. Less than 2 years b. 2 years c. 3-5 years

4. Have you had these issues before joining college?
a. Migraine b. Headaches c. Dust Allergy d. Frequent cold
e. Asthma f. No, I haven't had any.

5. Do you smoke?
a. Yes, I'm a regular smoker. b. Yes, I smoke sometimes c. No, I don't smoke

6. Do any of your friends smoke?
a. Yes b. No c. I don't know

CLASSROOM CONDITIONS

1. How much do you like the class environment?
a. Very comfortable b. Reasonably comfortable c. Somewhat uncomfortable
d. Very uncomfortable

2. Do you experience unpleasant odour when inside the class?
a. Yes, especially during morning b. Yes, especially during afternoon c. Yes, sometimes
d. No

3. Do you find the lighting uncomfortable?
a. Yes, especially during morning b. Yes, especially during afternoon
c. Yes, regardless of time d. No

4. How would you describe the glare conditions in your classroom?
a. Not at all bothersome b. Not very bothersome c.Fairly bothersome
d. Bothersome

5. Do you experience a lack of airflow in your classroom?
a. Yes, especially during morning b.Yes, especially during afternoon c. Yes, regardless of time
d. No

6. Do you experience a lack of airflow in your studio?
a. Yes, especially during morning b.Yes, especially during afternoon c.Yes, regardless of time
d. No

7. Comment on the thermal comfort in your classroom
a. Hot b. Slightly Warm c. Neutral d. Cool

8. Do you find it comfortable to stay overtime? Why?
a. Yes b. No

9. In which space would you like to spend most of the time?
Why?
a. Indoors b. Outdoors

10. Do your classroom/ studio get cleaned regularly?
a. Yes, every day b. Yes, more than twice a week
c. Yes, once a week d. No

11. Are you satisfied with the toilet facilities given?
a. Yes b. No

HEALTH CONDITIONS

1. Have you experienced these symptoms after joining the college?
a. Sensitivity to odors b. Sneezing c. Coughing d. Tiredness
e. Headaches f. Dizziness g. Breathing Difficulty h. Stuffy Nose
i. Runny Nose j. Watery Eyes k. Dry throat l. concentration issues
m. Tightness of the chest n.Dryness and/or irritation in skin

2. Do you feel any of these while in the building?
a. Very often b. Seldom c. Sometimes d. Never

3. Do you find these symptoms higher on Mondays and Tuesdays?
a. Yes b. No

4. Do you feel at ease or do these symptoms fade when you leave the building?
a. Yes b. No

5. Does your work have high amount of stress?
   a. Yes b. No.

6. On Which day do you feel stress the most?
   a. Monday b. Tuesday c. Wednesday d. Thursday e. Friday

7. How does stress affects you?

a. I have trouble sleeping at night
b. I have high anxiety issues
c. I have trouble in communicating with other people
d. I'm always breaking down mentally
e. I have issues managing anger
f. I have trouble in concentration
g. Stress doesn't affect me

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