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Assessing the Indoor Environmental Quality in Shopping Areas with a Focus on Shopping Arcades Case of Pune, India

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Abstract

With increased environmental awareness and standard of living, aspects such as built environmental quality and thermal comfort have gained importance. The role of built environment is not limited to just providing shelter but has expanded to providing comfortable healthy environment. The indoor environmental quality and thermal comfort directly affect the health of occupant and utilisation of the space. Moreover, the built environment quality is directly proportional to energy efficiency and sustainability in buildings. Indoor environment quality is an important aspect to be considered in large commercial developments such as shopping centres, where there is a huge footfall. Shopping trends have changed over the years from shopping markets, plazas, arcades, shopping complexes to malls. The change is heading towards a more enclosed and air conditioned environment as compared to the older forms of shopping centres such as arcades and plazas. These arcades and plazas were designed as spaces that opened out and were naturally lit and ventilated; thereby were more energy efficient unlike the malls. However the changing trend is influencing developers and designers towards building malls which would eventually wipe out the arcades and plazas completely from the market. The commercial success of retail buildings is also dependent on the environment that is created. In order to continue using these older energy efficient forms, it is important to evaluate them and identify the associated problems. These problems can then be nullified through appropriate design solutions, upgrading theses spaces to the level of malls. In addition, it is in such typology of buildings where design is crucial as it is more dependent on the climate and environment outside. Pune is a city where various forms of shopping centres exist, such as street markets, shopping arcades, malls etc. The aim of the research is to evaluate the environmental quality in shopping arcades in Pune. Field measurements of environmental quality parameters such as temperature, humidity, wind speeds, light levels, CO_2 levels were carried out in various shopping arcades. The study also explores whether lower ground floors can work as shopping spaces. The research identifies problems and design challenges associated with shopping arcades. The above study would give insights as to how environmental quality can be improved through design.

Keywords: Aspect Ratios, Daylight, Orientation, Indoor Air Quality, Openings, Shopping-arcades, Thermal Comfort

1. Introduction

1.1 Evolution of Shopping Areas

Shopping areas have evolved from a long establishes history of trade and commerce. Initially goods were organised outdoors forming open market areas and bazaars. These spaces did not offer protection from the outdoor environment. With expansion of the range of goods and increase in demand, the physical structures of the markets began to evolve into shopping streets. The shops were integrated into the ground floors of buildings along a street providing

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enclosed space for the display of goods. In this typology, the transition spaces i.e. the streets did not provide protection from the outdoor environment. With technological advancements, smaller streets and lanes could be covered; which resulted into development of arcades and plazas. These were semi open shopping areas that provided protection from the environmental elements as well as connected with the outdoor streets.

Further, increase in demand for larger store spaces and new methods of manufacturing lead to development of departmental stores. This form incorporated double-loaded interior corridors with atrium spaces. The atriums provided access to natural light but little emphasis was given to natural ventilation and connection to the outdoor environment. Change in lifestyle, modernisation and further technological advancements brought about development of malls. Malls integrated theatres, food joints and other entertainment activities along with shopping. These buildings were developed as inward-looking forms isolated from the outside world. In this building form, stores were organised along internal corridor which terminated with large anchor shops. While designing, aspects such as display and aesthetics gained more importance over environment quality[1].

Today, the shopping environments are developing into high consumption areas of electricity as a result of introvert design approach. The energy consumption is rising because of minimum or no use of natural daylight and ventilation. Thermal comfort in malls is achieved through air conditioning. In older forms, thermal comfort was achieved by enhancing natural ventilation in spaces through design. The users of these older forms adapted to more varying environmental conditions. Thus the older forms provided comfort and good environmental quality without utilising energy.

The growing mall culture would eventually wipe out the older energy efficient forms such as arcades and plazas completely from the market. The commercial success of retail buildings is also dependent on the environment that is created. In order to continue using these older energy efficient forms, it is important to evaluate them and identify the associated problems. The present study assesses the environmental quality in shopping arcades to help designers understand the various design challenges. This would give insights to developers and designers as to how the environmental quality in these spaces can be upgraded to that in an air conditioned space through use of natural ventilation and daylight.

1.2 Indoor Environmental Quality

Indoor Environmental Quality is any factor of the built environment that affects the health and comfort of building occupants.

Some of the factors that determine indoor environmental quality are thermal comfort, indoor air quality, daylight, etc. BS EN ISO 7730 defines thermal comfort as that condition of mind which expresses satisfaction with the thermal environment, i.e. the condition when someone is not feeling either too hot or too cold. Thermal comfort is determined by six factors namely temperature, mean radiant temperature, humidity, wind speed, human activity level and clothing insulation. Indoor Air Quality (IAQ) refers to the quality of the air inside buildings as represented by concentrations of pollutants and thermal (temperature and relative humidity) conditions that affect the health, comfort, and performance of occupants.

Thermal comfort and indoor air quality are important factors to be considered while designing shopping spaces as these are crowded areas. Enclosed spaces inhabited by humans with inadequate ventilation can lead to increase in CO_2 levels, temperature and humidity. This in turn would cause discomfort to the occupants and pose health hazards as a result of poor indoor quality and lack of thermal comfort. Poor indoor air quality can cause headache, dry eyes, nasal congestion, lung disorders, nausea, fatigue, etc. Improving indoor environmental quality helps to retain occupants, increase productivity, improve health and raise property values and income. Natural light has proved to be beneficial for the health and productivity of building occupants. Shopping areas with natural light tend to be gathering places. Utilizing natural light can lead to substantial energy savings.

2. Methodology

On site studies were carried out in five shopping arcades in Pune, in the month of February for a period of 8 days. The selected shopping arcades are Light house, Clover centre and Wonderland; these are mixed used multi-storey buildings with shopping areas on the ground, first and lower ground floor. The other two buildings are Kalpataru arcade and Kumar plaza; these are single storey, top lit shopping arcades with ground, first and lower ground floor. All buildings are oriented east-west, except for Clover centre which is oriented north- south. The plans of the above mentioned case studies are given in Figure 1.

Field measurement included measurement of air temperature, relative humidity, wind speed, CO_2 levels and daylight levels. Air temperature, relative humidity and wind speed were measured using an anemometer, CO_2 levels were measured using a portable indoor air quality monitor and light levels were measured using a lux meter. The measurements were carried out in three time intervals, i.e. morning (10 am to 12 pm), afternoon (2 pm to 4 pm) and evening (6 pm to 8 pm), on both weekdays and weekends. The measurements were taken at various test points in the passages and were performed 1.0 m above the floor level. Average morning, afternoon and evening values were used for analysis. The average values are compared with standard recommended values and ranges. The indoor air quality is evaluated by comparing CO_2 levels with the ASHRAE standard 62.Thermal comfort is evaluated by comparing temperature and relative humidity values with ASHRAE standard 55. To predict thermal comfort conditions, the tool developed by Centre for the Built Environment (CBE) was used. Conditions at average wind speed, temperature and relative humidity were plotted. The clothing level was considered as indoor summer clothing (0.5 clo). The metabolic rate considered was 1.2 met as the occupants were standing and relaxed.

The data such as temperature, humidity, clothing level and metabolic rate was kept constant whereas wind speeds were changed. Minimum desirable wind speed required to achieve comfort conditions was found out with the help of the tool[2].

The light levels were compared with the standard illumination levels recommended by National Building Code of India. The shops being artificially lit and ventilated have not been considered for analysis.

3. Results and Discussions

The data gathered through field studies, standard ranges and the thermal comfort predictions as per the thermal comfort tool developed by Centre for the Built Environment (CBE) are given in the Table 1.

It was observed from the study that design aspects such as orientation of the building, aspect ratios and location of openings, play an important role in determining the comfort conditions inside the buildings. These design aspects have an effect on the wind movement inside a building. The wind movement in turn has an effect on the

Figure 1. Floor plans. (a) Clover centre; (b) Wonderland; (c) Kumar Plaza; (d) Light house; (e) Kalpataru arcade.

humidity levels, CO_2 concentrations, and perceived thermal comfort which determines the environmental quality in a building.

It was seen from the study that increased wind velocities caused the humidity levels to drop and also reduced the CO_2 concentration, thus maintained the indoor air quality. It can be observed from the (Figure 2), that the CO_2 concentrations were higher in the central areas of the lanes where the wind velocities were lower.

Comparatively, the CO_2 levels were lower at the test points near the entrances of the lanes where there were higher wind velocities. In Light house, the CO_2 levels were constant because the building was newly constructed and had few visitors. Hence, the graph for Light house has not been plotted. Similarly, the CO_2 levels in Kalpataru arcade were lower despite of inadequate ventilation because of few visitors.

CO_2 levels need to be maintained below 1000 ppm as per ASHRAE standard 62[3]. The CO^2 levels in Clover centre do not meet the requirement of the standard due to inadequate ventilation. Relatively the CO^2 levels in Kumar plaza and Wonderland were lower and met the requirement of the standard due to higher wind velocities. (Table 1).

Table 1. Field Measurements and Thermal comfort prediction as per CBE tool

		Thermal Comfort					IAQ	Light levels
Sr.No	Case studies	Temperature (Comfort range for summer as per ASHRAE 55 :(22.8 deg C to 26.1 deg C)	Relative humidity (Comfort range as per ASHRAE 55: (30 to 65%)	Wind speed as per field measurements. (m/s)	Desirable wind speed for average temperature and relative humidity as per CBE tool(m/s)	CBE tool prediction at average temperature, relative humidity and wind speed.	Carbon dioxide levels (To be maintained below 1000 ppm as per ASHRAE 62)	Light levels (As per NBC, illumination levels to be maintained between 100 to 200 lux in passages)
1	**Clover centre**							
	Ground floor	29.7-30.2	29.3-39.2	0.1-0.8	0.6	Not comfortable	439-1112	120-630
	Lower ground floor	29.9-30.6	31-39.8	0.1-0.6	0.7	Not comfortable	634-1264	80-490
2	**Wonderland**							
	Ground floor	29.4-29.9	27.5-30.6	0.3-0.9	0.5	Comfortable	430-655	90-260
3	**Kumar plaza**							
	Ground floor	29.6-29.8	28.6-29.7	0.6-1.2	0.5	Comfortable	450-629	388-705
	Lower ground floor	28.9-29.3	31.1-31.5	0.2-0.8	0.5	Comfortable	554-832	459-810
4	**Kalpataru arcade**							
	Ground floor	29.1-29.4	31.5-32	0.2-0.6	0.6	Not comfortable	435-512	100-320
	Lower ground floor	30.1-31	33.8-36.5	0	0.7	Not comfortable	527-622	125-220
	First floor	29-29.7	31.6-32	0	0.6	Not comfortable	462-532	103-208
5	**Light house**							
	Ground floor	27.7-29.2	30.5-31.1	0.1-0.4	0.3	Not comfortable	380	30-510
	First floor	27.8-28.4	29-31.5	0.1-0.6	0.3	Comfortable	380	35-690

As per ASHRAE standard 55, the recommended temperature range perceived as comfortable in summer is 22.8 deg C to 26.1 deg C[4]. There was not much variation in temperatures throughout the passage area. The temperatures in the passages of all five buildings were higher than the standard range. (Table 1). As per ASHRAE standard 55, the relative humidity levels need to be maintained in the range of 30% to 65%[4] . The relative humidity levels met the requirement of the standard in morning and evening hours, whereas the afternoon humidity levels were slightly lower.

Even though the temperatures were higher than the recommended ASHRAE range, thermal comfort conditions were achieved in the buildings where average wind velocities were higher than the minimum desirable wind speed required. As per the CBE tool prediction, the conditions were thermally comfortable in Kumar plaza and Wonderland compared to other arcades due to higher wind velocities. (Table 1).

The effect of design aspects on the wind movement inside the buildings is discussed below.

3.1 Orientation

The prevailing wind direction throughout the year is west for Pune. The lanes oriented with its longer axis in

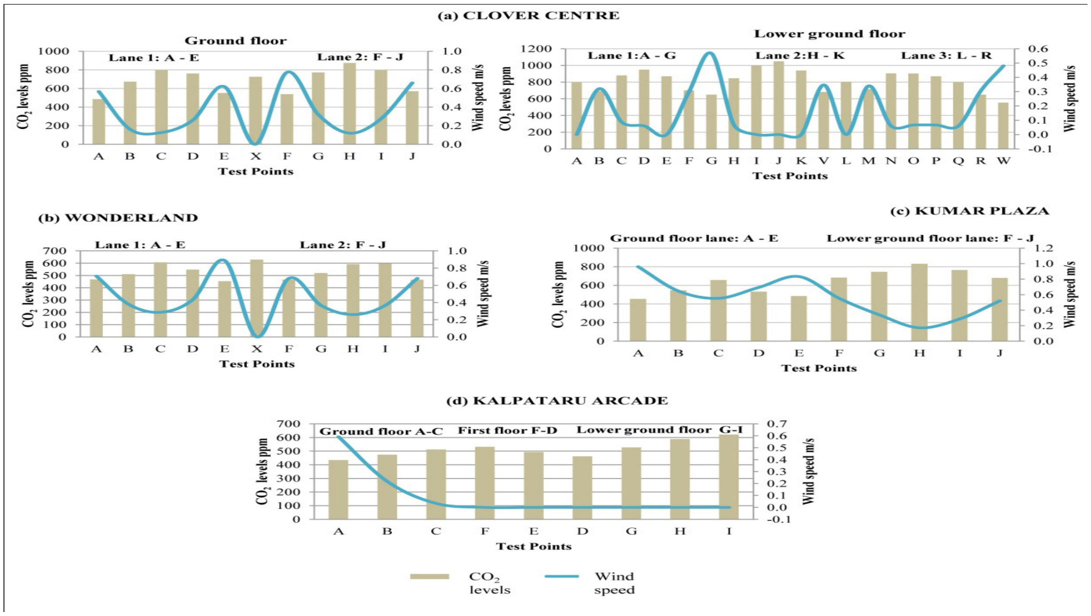

Figure 2. Graphs showing relation between Carbon dioxide levels and Wind speed. (a) Clover centre; (b) Wonderland; (c) Kumar Plaza; (d) Kalpataru arcade.

east-west direction performed better in terms of ventilation as compared to those oriented with its longer axis in north-south direction. Out of the five case studies, Wonderland, Kumar plaza, Kalpataru arcade and Light house were oriented with its longer axis in east-west direction whereas, Clover centre was oriented with its longer axis in north-south direction. Higher wind velocities and lower CO_2 concentrations were recorded in Wonderland and Kumar plaza as compared to Clover centre. In Light house, lower wind velocities were recorded despite being oriented in east- west direction due to longer passage length and smaller openings on the east and west ends. Similarly lower wind velocities were recorded in Kalpataru arcade as the one of the ends of the lane was kept closed. Kalpataru arcade did not work efficiently despite of east- west orientation due to lack of cross ventilation (Figure 1).

3.2 Aspect Ratios

Arcades being longitudinal in form, the length to height ratio is an important aspect to be considered. The building lanes which had a lower length to height ratio worked more efficiently in terms of ventilation. The ventilation rate decreases as the building length increases owing to the internal friction, which produces a sluggish zone with low wind speed in the central areas of the lanes. The ventilation rate increases with increase in the height of the building. Higher wind velocities were recorded in building lanes which were taller in height and had a lesser width. This was due to the Venturi effect created by tall masses on either side of the lanes.

The Kumar plaza ground floor lane worked efficiently in terms of ventilation as it had lower length to height ratio. The lane was taller in height and had a lesser width as compared to other buildings. The wind velocities recorded at most of the test points in the lane met the requirement of the standard. There was good wind movement even in the central areas of the Kumar plaza lane. Therefore the CO_2 concentrations were low and thermal comfort was achieved throughout the lane.

Relatively Clover centre ground floor lanes had a higher length to height ratio and shorter lane height. A larger sluggish zone was produced in the central areas of the lanes owing to building proportions. Thus, lower wind velocities and higher CO_2 levels were recorded. The thermal comfort conditions were achieved only at the ends of the Clover centre lanes near the entrances. (Table 2).

3.3 Location of Openings

Arcades with entrances as wide as the lane width allowed for better circulation of wind. Comparatively, arcades

Table 2. Aspect ratios: Passages

Building name	Length	Height	Width	L/H	H/W	Wind speed m/s	CO2 levels ppm
Clover centre	95	2.7	3	35.2	0.9	0.1-0.8	439-1112
Wonderland	58	2.7	3.2	21.5	0.8	0.3-0.9	430-655
Kumar plaza	**57**	**7**	**2.4**	**8.1**	**2.9**	0.6-1.2	450-629
Kalpataru arcade	31	6	2.4	5.2	2.5	0.2-0.6	435-512
Light house	85	8.7	8	9.8	1.1	0.1-0.4	380

that had smaller entrances as compared to the lane width obstructed the wind flow. In Light house, the ends of the passages had a glazed facade with a door opening on ground and first floor. As the door opening was placed in the centre, there was lesser wind movement in the peripheral areas of the passage. Relatively, wonderland lanes had openings as wide as the lane width which allowed for circulation of wind in the peripheral areas.

Openings placed opposite to each other performed better in terms of cross ventilation as compared to those placed diagonally in relation to each other. The entry and exit of the Kumar plaza lower ground floor were placed opposite to each other, which allowed for circulation of wind through the lane. Relatively, the entry and exit of the Clover centre lower ground floor were placed diagonally in relation to each other which obstructed the wind flow.

3.4 Stack Effect

Stack effect is movement of air inside buildings due to pressure difference between the outside and inside air caused by difference in air temperatures. As air flows into the buildings, it gains heat from the surroundings and rises. If this warm air is allowed to escape out through an opening at a higher level, the pressure at the base of the building is reduced and cooler air is drawn in through openings at lower level. In Kumar plaza, the staircase was located in the direction other than the prevailing wind. Hence, the staircase openings acted as outlets for warm air to escape out at higher level, allowing cooler air inside the lane. This phenomenon accelerated the wind flow inside the lane which resulted in lower concentration of CO_2.

The Kumar plaza lower ground floor lane worked effectively in terms of ventilation as compared to Clover centre lower ground floor lane due to the stack effect. In Clover centre, the staircases were located on the west and east side, in the direction of prevailing wind. These staircases acted as inlets for wind to flow into the lanes, but the velocities achieved were less. The CO^2 concentration was lower in Kumar plaza lower ground floor lane as compared to Clover centre lower ground floor lane. (Table1).

In case of Wonderland and Kalpataru arcade, the staircases did not have openings and hence neither acted as wind inlets nor as stacks.

3.5 Light Quality

As per National Building code of India, the recommended illumination levels for arcades range from 100 to 200 lux[5]. Arcades with a skylight were well lit compared to those which were completely closed. Skylights of translucent material performed better as compared to those with a transparent material.

In Kumar plaza, light level as high as 900 lux was achieved through the transparent skylight, resulting in glare. Comparatively more diffused light was received through the skylight in Kalpataru arcade as stained glass was used. The light levels in Kumar plaza and Kalpataru arcade were above the standard range. (Table 1). The light levels recorded in Clover centre, Wonderland and Light house were low owing to mixed-used typology and absence of skylight. These arcades were artificially lit throughout the day.

4. Conclusion

The design of arcades should be such that aspects such as orientation of the building, aspect ratios, location of openings, etc; will enhance natural ventilation, daylight and indoor environmental quality inside the buildings. This would result into development of sustainable buildings which not only satisfy occupant comfort but are also energy efficient.

Some design recommendations to enhance natural ventilation and daylight are given below:

4.1 Orientation

The arcades could be oriented with its longer axis parallel to wind direction to enhance circulation of wind through the lanes. In case the arcade needs to be oriented with its longer axis perpendicular to the wind direction, inlets and outlet could be organised in a staggered pattern. The inlets could be smaller as compared to the outlets. Outlets could be designed as staircase blocks which would behave as stacks, thereby enhancing the wind movement.

4.2 Aspect Ratios

The rule of thumb for effective wind-driven cross ventilation suggests that the building length L should be less than or equal to five times of ceiling height H[6]. Therefore considering L/H =5, the length of the arcade could be broken in between incorporating openings to avoid development of sluggish zone with low wind speeds in the central areas.

4.3 Openings

Instead of placing two smaller opening on each floor of a double height single storey arcade, the lane could have one large opening across the entire height of the arcade. A larger opening would allow for larger volume of wind to flow inside the arcade.

A smaller inlet and a larger outlet would accelerate the wind velocity, as same volume of wind has to pass through different sizes of openings. The form of the arcade could be designed such that the cross sectional area of the lane narrows towards the windward side and widens towards the leeward side. This form would further increase the velocity of the wind due the ceiling inclination.

The entry and exits of an arcade could be planned such that the openings allow for cross ventilation. Openings placed diagonally to each other with an obstruction in between would reduce the wind velocities due to internal resistance. Therefore, openings could be placed across each other to enhance cross ventilation.

4.4 Stack Effect

The staircase blocks could be positioned in a direction other than that of the prevailing wind, so that they could act as stacks. The shops could be provided with openings on upper level on the internal as well as external facade. The openings on the upper level would further enhance the stack effect by allowing the warmer air to escape outside and inducing cooler air to flow through the shops. This phenomenon would further enhance the circulation of wind through the lanes.

4.5 Light Quality

Side lighting or clerestory could be used instead of a skylight which would provide diffused light in the interiors. The shops could be provided with openings at upper level along with light shelves to enhance daylight in the shop interiors.

4.6 Lower Ground Floors

Lower ground floors could be incorporated with ground floor passages overlooking on to the lower ground floor passage, such that the arcade has a double height. The double height arcade would allow the lower ground floor passage to be naturally lit and ventilated. The lower ground floor shops could be raised 1.5 m above the ground where openings with light shelves could be integrated. The openings could be designed for daylight and ventilation.

5. References

1. Collin A. Evolution of Retail Street scapes. Australia: 2012.
2. CBE Thermal Comfort Tool. Centre for the Built Environment. Available from: http://www.cbe.berkeley.edu.
3. Trane. Indoor Air Quality: A Guide to Understanding ASHRAE Standard 62-2001. American Standard inc; 2002.
4. Sharma S, Suresh R. Indoor Air Quality: Issues and Concerns in India. GRIHA Summit; 2014.
5. National Building Code of India. Bureau of Indian Standards. 2005.
6. Chu C-R. Wind-driven Cross Ventilation in Long buildings. Taiwan; 2014.