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A CASE STUDY ON TOTAL BUILDING PERFORMANCE EVALUATION OF AN "INTELLIGENT" OFFICE BUILDING IN SINGAPORE

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ABSTRACT

The importance of understanding the performance of a building in a holistic sense is undeniable. This paper presents a method of total building performance evaluation, which has been widely used in many developed countries including Singapore. An office building with apartment and commercial retails called "intelligent building" is selected for building diagnosis.

The occupant surveys and physical walkthroughs are carried out as subjective evaluations, while some objective measurements of indoor air quality and visual quality are also introduced in this study. The results indicate that generally, the occupants are satisfied with the quality of the building despite some insignificant indoor air quality and visual symptoms due to low temperature and glare problem in the office.

Keywords: building performance, building diagnostic, intelligent building, sick building.

INTRODUCTION

The sick buildings have been a much talked-about issue nowadays and literature studies have revealed the relationship between interior environmental conditions and productivity [1].

There are six performance criteria in building performance evaluation, namely: spatial (functional) comfort, indoor air quality, visual comfort, thermal comfort, acoustic comfort and building integrity (structural and material performance). The problems arising out of the six performance criteria will affect the occupants to various degrees of seriousness, depending on occupant sensitivity and activity. The composite of these problems will contribute to building related illnesses and to concerns related to the "Sick Building Syndrome".

The concept of total building performance and their evaluation has been studied by researchers over the years and an attempt is being made here to review some of the findings and recommendations. Hartkopf et.al. [2], suggested the use of physical trace records to evaluate and identify the signs of stress in each of the six performance measures by conducting a walk-through of the office. Atkin B. [3], compiles the reports and papers from various researchers, giving an overview of intelligent buildings and discussing the impact of intelligent building features on total building performance and how the office environment may be evaluated and diagnosed. Kan [4], uses both objective and subjective techniques in the evaluation of indoor air quality in Singapore. Such framework can be modified for use in other investigations as well. Hartkopf et.al. [5], presented five levels of evaluation measurement and seven of evaluation assessments. These measurements and assessments together form an integral part of a typical diagnostic process (Figure 1).

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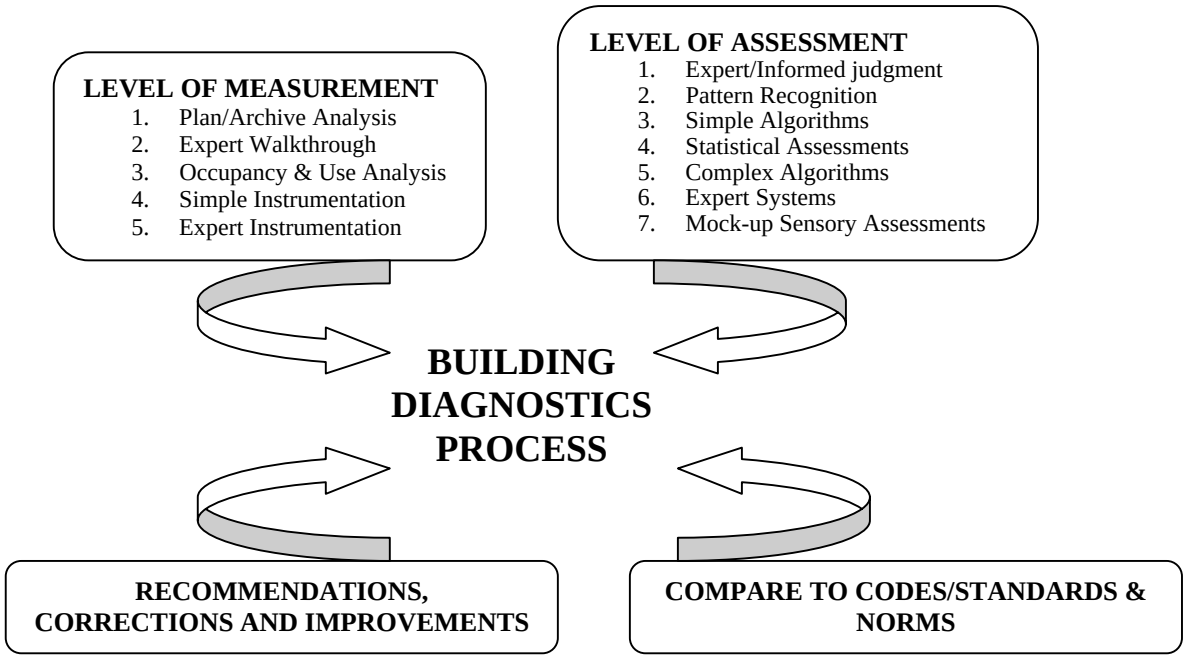

Figure 1. Simplified Process of Building Diagnosis

The study of building performance introduced in this paper reviews various ways of building diagnostic process of an 'intelligent building' in Singapore. The data are obtained by focusing on the expert walkthrough analysis, occupancy and use analysis, and some measurement analysis using simple instruments. Questionnaires are used to get information about characteristics, attitudes and activities of the various user groups in the building. The analysis of survey results are presented and compared with results of simple measurements.

SITE DESCRIPTION

One of 'intelligent buildings', selected in this study is a mixed used office buildings with apartments and commercial retails (open plan office = 834 m^2). Two office towers serve by 2 lift banks with 6 passenger lifts. The residential block is on top of a retail podium and the basements are for parking and Mechanical and Electrical plants. The building envelope is composed of reinforced concrete structure and metal cladding, granite panel, double/triple glazing, and shading devices.

OCCUPANT SURVEY RESULTS

Questionnaire surveys and physical trace records are two means of subjective analysis employed. Answers obtained will assist in grossly qualifying the extent to which the physiological, psychological and social needs of occupants are met. In the survey, the six major attributes of Total Building Performance are rated on a five-point scale in terms of its spatial comfort, thermal comfort, indoor air quality, visual comfort, acoustic comfort and building integrity.

Spatial Comfort

Most of the occupants are satisfied with spatial performance of the building (Figure 2). More than 90 % of the occupants consider that the performance is good and satisfactory.

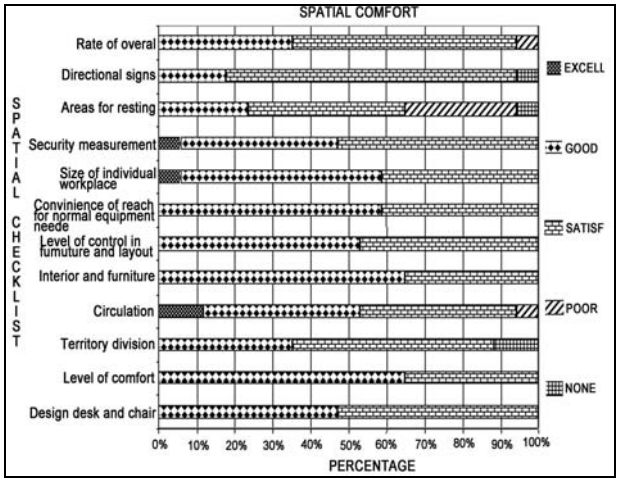

Figure 2. The rate of overall level of spatial comfort and spatial items performance provided in the office

Acoustical Comfort

The disturbing noise source in the office can be seen in Figure 3, the conversation comfort and privacy in Figure 4 and the noice control and acoustical environment in Figure 5.

Most of the occupant are not disturbed frequently (< 25%) and the sound level measurement indicated that the noise level about 50 dBA (Figure 3). This does not exceed the recommended limit of 52 dBA [6].

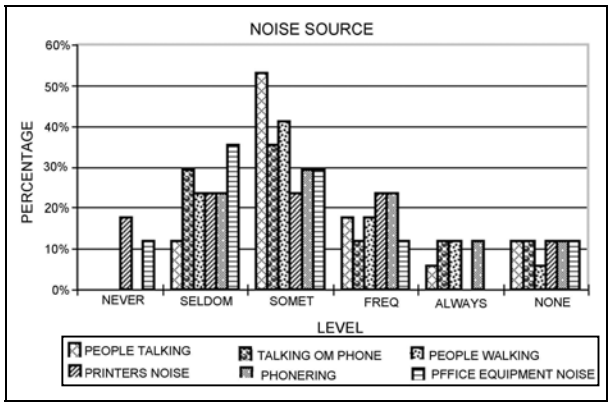

Figure 3. The Noise Source in The Office

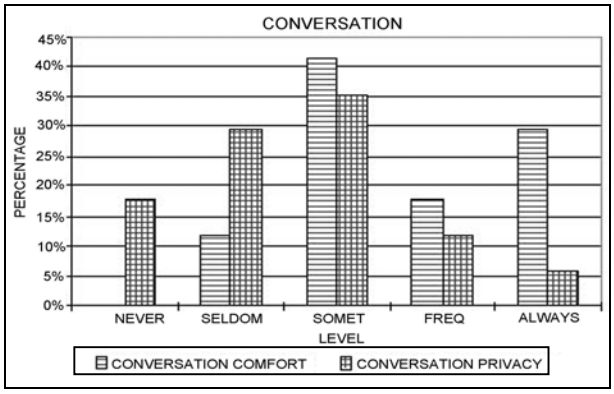

Figure 4. The Conversation Comfort and Privacy

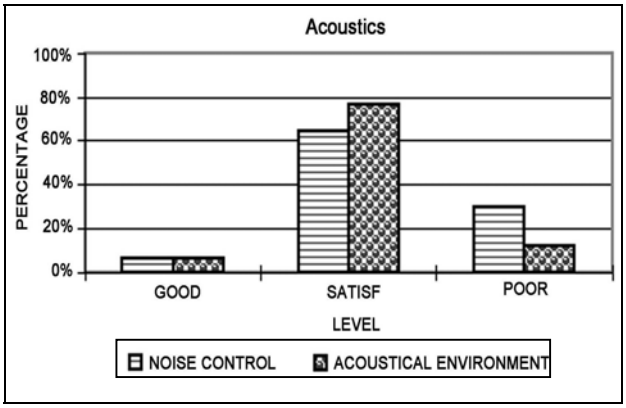

Figure 5. The Noice Control and Acoustical Environment

The open plan concept with zoning of people working with intensive relations together adopted in this building is still giving a good conversation comfort, nevertheless it may result lack of conversation privacy.

Figure 4 shows about 82% of the occupants have no privacy in their conversation (due to the use of open plan office), 47% of the occupants can conduct a decent conversation without having raise their voice or strain to hear and 41% of them sometimes feel difficult to have a normal conversation (sociological needs). Figure 5 shows that the poor noise control (29%) and acoustical environment (12%) should be considered in this building although most of the occupants are still satisfied (psychological needs).

Thermal Comfort

Figure 6 shows that most of the occupants feel that the temperature is satisfactory. However 47% of the occupants note that the temperature is cold. From the measurement results (Table 1), the average air temperature is 20.5°C. In guidelines for a good Indoor Air Quality (IAQ) in office premises, IEE, 1996 [7], the recommended range of temperature is 22.5°C-25.5°C, hence it is still below the recommended temperature.

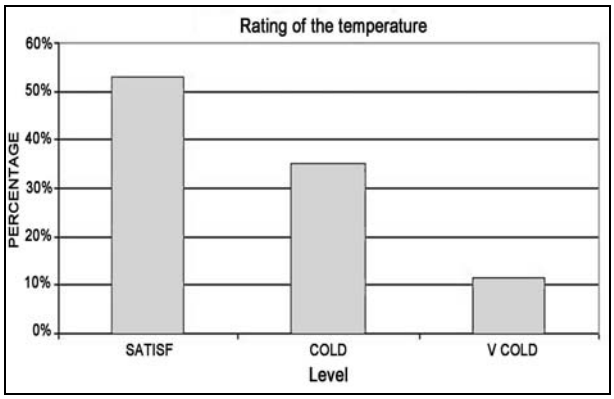

Figure 6. The Rating of The Temperature in Office

Table 1. The Range of Temperature

	Dry Bulb Temp, °C	Wet Bulb Temp, °C
Average temperature within office	20.5	17.2
North-East Window	25.8	-
North-West Window	25.6	-
South-West Window	25.8	-
South-East Window	26.2	-

In Figure 7, the humidity level of air in the office is found in average condition according to the occupants. The measurement result shows that the level of humidity is about 72 % R.H.

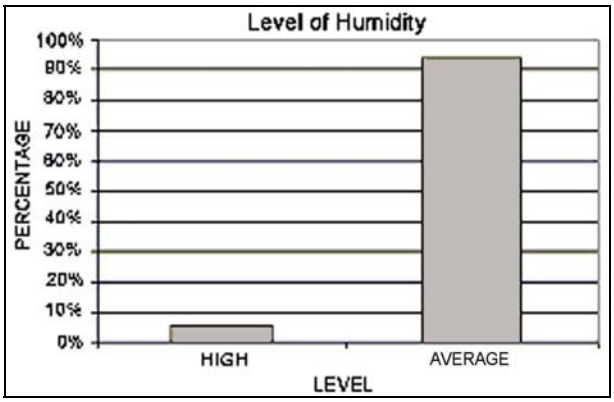

Figure 7. The Level of Humidity

As a result of the good condition of temperature, there are only a few occupants experiencing stiff necks, cold feet, arthritis, rheumatism, numbness or drowsiness (Figure 8).

The temperature in the office is found to satisfy the physiological needs (physical health and safety) of the occupants (Figure 9). Generally the thermal condition in the office is satisfactory.

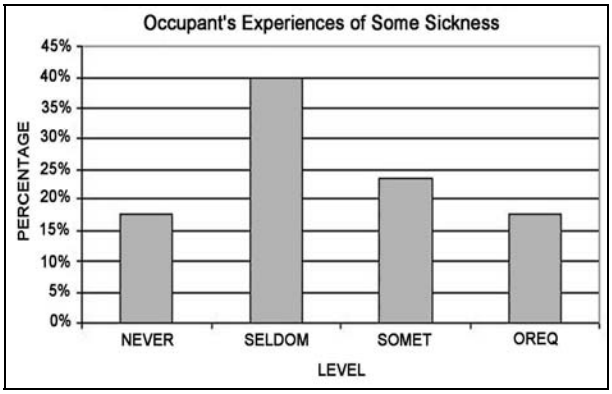

Figure 8. The Percentage of Occupants Experienced of Some Sickness

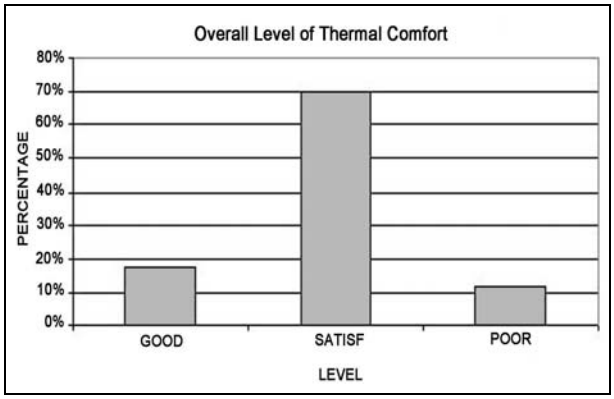

Figure 9. The Overall Level of Thermal Comfort (Air Temperature, Humidity, Radiation and Air Movement).

Visual Comfort

The visual aspect of building is examined from building plan (luminaire layout, types of lamp and their armature, window positions, building envelope, and shading device), expert walk-through (illuminance level/brightness), glare, view, inside and outside view, visual privacy), measurement (measurement point: 3x3 m^2 grid points, corridor, service room, exit room; daylight used as ambient lighting, no obstructions at three side, no ground reflectance), and occupant survey.

The glare problem level of lighting control lighting level and level of visual comfort are shown in Figures 10, 11, 12 and 13 respectively.

The site measurement indicates that average lighting level of this office is over 1000 lux, which is much higher than the recommended level of 500 lux [8]. This condition may cause glare problem experienced by the occupants (Figure 10).

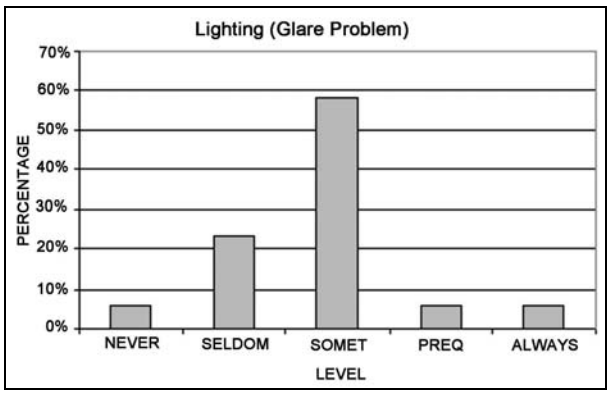

Figure 10. The Glare Problem Experienced by The Occupants

Most of the occupants (64%) are satisfied with the level of lighting control, although there is no individual control device (Figure 11).

A very high percentage of occupants perceive that the lighting level is too bright which is possibly causing glare problem (Figure 12).

There are 59% of the occupants satisfied with the overall of visual quality. The presence of plants and warm colored furnishings added to the ambience of the office. Some of the occupants have also window view to the outside environment (Figure 13).

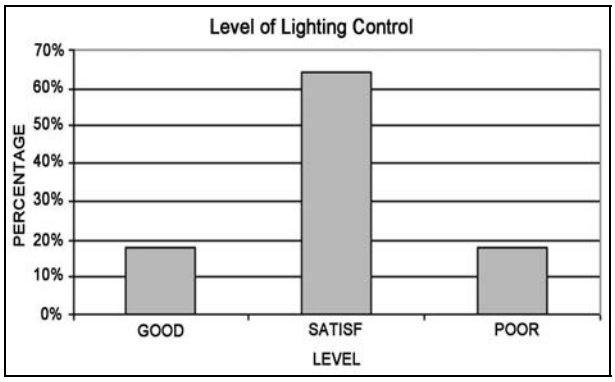

Figure 11. The Level of Lighting Control

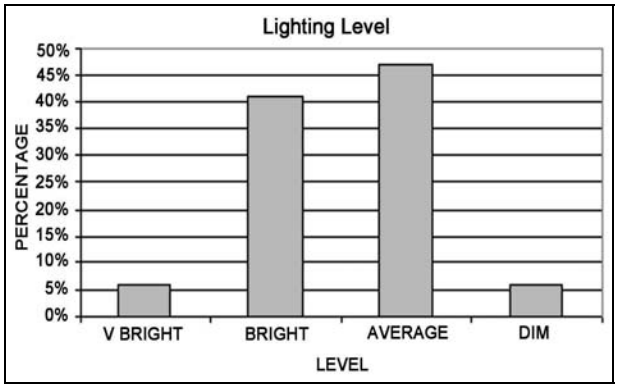

Figure 12. The Lighting Level

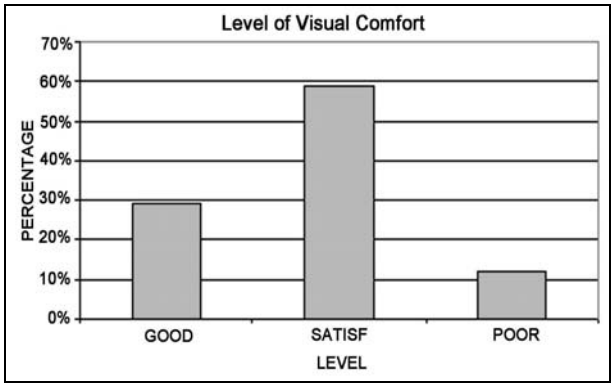

Figure 13. Level of Visual Comfort

Indoor Air Quality (IAQ)

The indoor air quality is audited by the occupant survey and the building environment measurement results. Some IAQ instruments used in this measurement are biological collector and particulate instruments.

The biological pollutants investigated are bacteria and fungus (yeast and mold). The concentration levels of two biological pollutants are measured at the occupant and on the ceiling level. The results are tabulated in Table 2, as follows:

Table 2. Biological Pollutants

Point	Location	Fungus (CFU/m^3) PDA		Bacteria (CFU/m^3) TSA	
		Occupant level	Ceiling level	Occupant level	Ceiling level
1	Office	198	123	420	202
2	Office	242	151	431	352
3	Office	211	132	396	185
4	Lift Lobby	123	299	114	158
5	Office Corridor	114	70	167	79

The concentration of both the bacteria and fungus pollutants are within the recommended guidelines of 500 CFU/m^3. According to the survey result (Figure 14), the "colds and coughs" symptom felt by the occupants is possible due to the low temperature in the office.

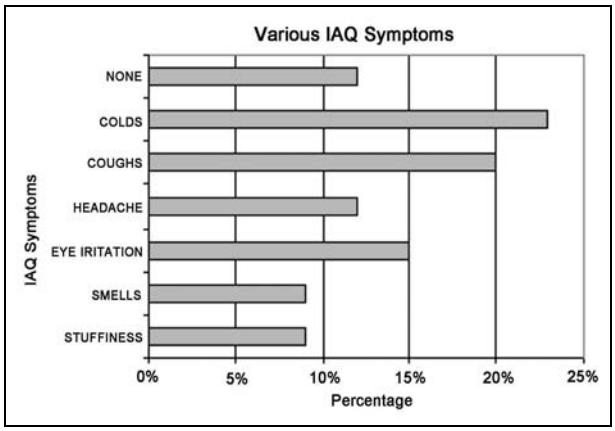

Figure 14. The Various IAQ Symptoms

The air quality does not influence much on the occupants. Only a few of the occupants feel the symptoms frequently (Figure 15).

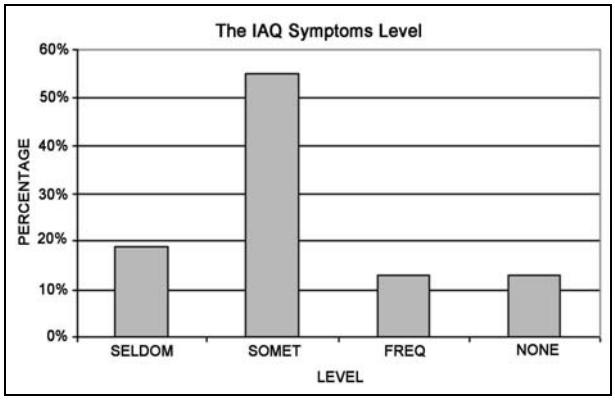

Figure 15. The IAQ Symptoms Level

From the particulate measurement, the maximum total particulate concentration obtained from summing the three individual particulate type concentrations is computed and tabulated in Table 3.

Table 3. The Maximum Total Particulate Concentration Measured at Three Different Locations

Location	Time	Dust (μ/m³)	Inhalable (μ/m³)	Thoracic (μ/m³)	Alveloic (μ/m³)
A (working table)	1:42:00	37.5	39.7	26.0	9.8
B (working table)	1:59:00	66.2	91.6	51.9	14.1
C (next to kitchen & toilet)	2:21:00	65.8	106.1	55.7	15.3

The air velocity at occupant level is mostly below 0.25 m/s. The occupant will experience air draught with air velocity higher than 0.25 m/s. Velocity of 0.75 m/s is measured at supply air diffuser level. In some perimeter location, the air velocity recorded reaches 0.27 m/s. The measurement also shows that no Total Volatile Organic Compound (TVOC) is found in the office space. The proper zoning of mailroom and service area is considered to be the main factor of the zero results of TVOC. However, from the survey result (Figure 16), some of the occupants still felt poor in air movement control (41%). The psychological need not satisfied probably is due to no openable windows in the office. The ventilation and air quality are still satisfactory.

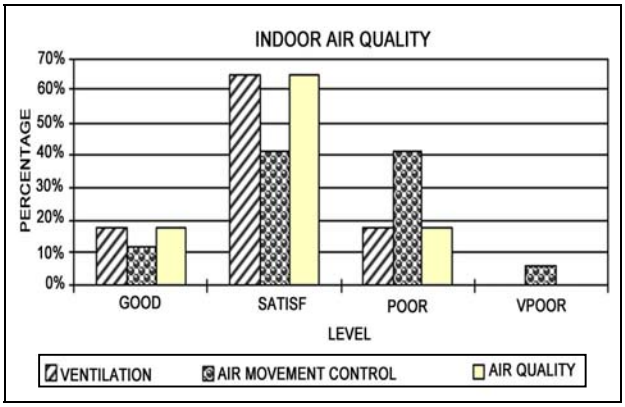

Figure 16. The Ventilation, Air Movement Control, and Air Quality

Building Integrity

This aspect will cover widely point of view in structural, design, and material analysis. However, this paper is limited in general aspect of building integrity such as the status/ appearance of the building, the symptoms of building collapses due to structural instability, safety, serviceability of the building, and adequate provision for some floors that are structurally designed to carry heavy loads (Figure 17). The survey result shows that the occupants are satisfied with the performance of the building. For physiological needs, minimal building defects are noted.

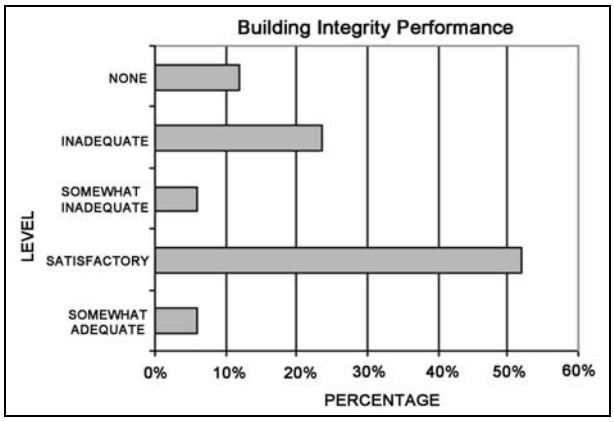

Figure 17. The Building Integrity Performance

CONCLUSION

A simple building diagnostics results can be summarized below:

1. Most of the occupants perceive satisfied in their spatial performance, 59% in satisfactory and 35% in good result.
2. For acoustical comfort, most of the occupant are not disturbed frequently (< 25%), about 82% of the occupants feel no privacy in their conversation, 47% of the occupants still can conduct a decent conversation without having raise their voice or strain to hear but 41% sometimes feel difficult to have a normal conversation (sociological needs). The poor noise control (29%) and acoustical environment (12%) should be considered in this building although most of the occupants still satisfied (psychological needs).
3. Generally, the thermal condition in the office is satisfactory. The temperature in the office is lower than recommended guidelines. As a result, the occupants sometimes feel numbness. The relative humidity of the air is moderate.
4. The visual comfort in this office is available for the occupants, though there is a glare problem, which does not fit the physiological and economic needs. Some of the lighting control devices (such as dimmer) can be adopted here in order to reduce the luminance, the electrical consumption and cooling load can me minimized.
5. A good result is found both in survey form and site measurement for IAQ of the building. Some of the indoor air quality symptoms that occupants experienced are probably due to low temperature and glare problem in the office.

6. For building integrity, the occupants note that the building is stable and safe. Minimal deterioration of the structure and building materials are found. The occupants also note that the building has sufficient provision of structural floors for heavy loads.
7. The occupants are satisfied with the quality and performance of the office in terms of its spatial comfort, indoor air quality, thermal comfort, visual comfort, acoustics, and building integrity (59%).

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