Assessment of thermal comfort inside primary governmental classrooms in hot-dry climates Part I – a case study from Egypt

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The provision of primary schools in Egypt is one of the demanding issues facing the government since the earthquake of 1992. In the aftermath of the quake, the government has built a substantial number of primary schools around the country in an attempt to replace schools lost in the disaster. This work aims to investigate the environmental performance of governmental primary schools in Egypt as an example of a hot-dry climate. The study is presented in two parts. In this paper the results of the subjective assessment of the case studies is discussed. Work was done on three stages; the first and the second investigated the environmental problems inside 19 case studies in al-Minya Governorate. The third stage further investigated the thermal comfort of occupants inside three case studies. The results suggested that the majority of the occupants were thermally discomfort for most of the time during the academic year. In the second part, the results of a field study aiming to objectively assess the thermal performance of a small sample of classrooms were discussed. This study will inform future work investigating the potential of passively enhancing the thermal comfort of occupants inside primary governmental classrooms in Egypt.

Keywords: assessment, building, environmental assessment

1. Introduction

Schools can act as regeneration catalysts by contributing to the development of the area around them. This was evident through the project of the 100 schools initiated by the Government in some areas of Greater Cairo, where the school buildings were refurbished and were opened to the community boosting by such the sense of pride of both the children and the society.

Internal environmental quality (IEQ) of schools can significantly affect the occupant's perception of space as well as their health, performance, physical comfort and mental wellbeing. Unhealthy classrooms with poor IEQ, including thermal performance, are known to cause absenteeism among staff and pupils, and negatively affect the performance of children. Children are at particular risk since they are more susceptible than adults to the effects of poor air quality, which can be "subtle and do not always produce easily recognisable impacts on health and wellbeing" (Lee & Chang, 2000). Moderate heat stress can affect children's mental performance. This was suggested when a sample of young people's mental performance was significantly affected by the slight temperature increase of only a very few degrees within the range likely to be found in a typical classroom (Wyon et al. 1979).

A child inside a classroom collects the majority of information about their surroundings through their auditory and visual systems. The later is stimulated by light reflected off surrounding surfaces. The quantity of light affects the child's nervous system and neuroendocrine hormonal system (Edwards and Torcellini 2002) while the quality will profoundly affect the children psychologically and physiologically. Poor acoustic performance of classroom affects the occupants and increases the strain on the teachers' voice (Stansfeld and Haines 2002). Children in primary classrooms are particularly vulnerable to noise effects because it can interfere with the learning process during a critical developmental period. Children exposed to noise in schools showed "deficits in sustained attention, visual attention, concentration, poorer auditory discrimination and speech perception, memory impairment and poor reading ability and (decreased) school performance" (Stansfeld and Haines 2002).

2. Previous work

Previous work conducted across several countries in the area of schools' internal air quality (IAQ) found that most of the case studies were inadequately ventilated and were high energy consumers. In the UK, the Building Research Establishment (BRE) in an attempt to assess the performance of the current stock of new school buildings monitored the ventilation and indoor air quality inside a representative sample of primary schools in England (BRE 2003). Results showed that 50% of the measurements were under the minimum rate required by the British Standards. Another study looked into the recommended suitable ventilation rates for classrooms and examined the suitability of the air quality guidelines for classrooms (Clements-Croome et al. 2005). A recent comprehensive study in the UK found that the attention of children inside a poorly ventilated school was significantly slow (Clements-Croome et al. 2008). Other studies (Cook 1990; Galasiu and Veitch 2006; Stewart 1981) looked into the behaviour and attitudes of children towards the visual environment of classrooms and the effect of artificial lighting on energy consumption. They found that many primary classrooms in the UK and abroad fail to meet the minimum requirements of the illuminance and glare protection recommendations given by different lighting codes.

Studies that looked solely into the thermal performance of classrooms (Corgnati et al. 2007; Kwok and Chun 2003; Lin et al. 2005) showed that the occupants of the majority of cases were not thermally comfortable most of the time. Only few studies (Becker et al. 2007; Gado et al. 2005; Kruger and Zannin 2004; Wong and Jan 2003) looked into a combination of more than one environmental factor.

Previous work in general is limited to cold and temperate climates. Knowledge about the environmental performance of schools in hot-dry climates is very limited. In Egypt, the majority of the researches approached school design from social, educational, economical or theoretical points of view and very few looked into their environmental design. Toulan focused on the conceptual design of primary schools (Toulan 1982). Abdalla studied the impact of new educational tools on both conceptual design and human dimensions in schools (Abdalla 1994). Others studies (El-Mola 1999; Shalabi 1996) investigated different ways of architecturally responding to the educational process. El-Nashar studied the physical setup of the educational spaces and its impact on children's behaviour (El-Nashar 1998). Noufal studied factors affecting schools built in overcrowded districts of Cairo (Noufal 1998). El-Hefnawy investigated health and safety issues in educational buildings and especially in primary and preparatory schools (El-Hefnawy 2002). The Housing Building and Urban Planning Research Centre conducted a research aiming to formulate guidelines for designing fundamental schools in Egypt (Housing Building and Urban Planning Research Centre HBURC 1987). This study looked into the quality of educational spaces, their occupants' responses and their environmental performance. The most recent research was conducted by the Institute of Environmental Studies and Research (Institute of Environmental Researches and Studies (IERS) 1992) investigating the conceptual design of schools, landscape, materiality, and solar shading but failed to investigate their environmental performance.

It is clear that only few studies have touched on the environmental performance of primary schools in Egypt. The majority of work has been oriented towards other aspects of primary school design. This gap in the body of knowledge was identified and is being approached in this research project.

3. Research background and problem

The demand for primary schools in Egypt is one of the stressing issues facing the Egyptian Government since the earthquake of 1992. This demand had considerably doubled during the last fifty years when the 1952 Revolution provided the members of all sectors of the community with free education and abolished fees for public schools. The Ministry of Education's budget was doubled in one decade and the expenditures on school construction increased by 1000% between 1952 and 1976 (Metz 1990). Providing free education to children from all social sectors dramatically increased the demand for educational infrastructure including school buildings. In the early 1990s the Egyptian Ministry of Education increased the number of primary school years from 5 to 6 and subsequently the demand increased again (Gado et al. 2005). This demand had also substantially increased after the 1992 earthquake that hit Egypt with a magnitude of 4.7 on the Richter scale (Farag 2002). The tremor affected 3964 buildings including a considerable number of schools. In response, the Egyptian Government established the General Authority of Educational Buildings (GAEB) to design new schools around the country.

GAEB uses the same prototypical designs to build schools across the different climatic design regions of Egypt without any consideration to the variation in climatic conditions (Figure 1-A).

All prototypes are designed in cellular fashion using standardized structure and construction systems on a very low budget. By the mid 1970s the “public investment in new educational infrastructure has declined in relation to total educational expenditures; about 85 percent of the Ministry of Education's budget has been designated for salaries” (Metz 1990).

Although this approach could have allowed rapid build, the new classrooms are rigid and uncomfortable. Previous work (Gado et al. 2005) suggested that the internal environmental quality of classrooms in new Governmental schools in Egypt is very low. This can prove damaging and can bread resentment for the space. The design hinders the activities occurring within, and do not respond to the changing needs of primary education imposed by the Government new reforms. Classrooms are arranged along long corridors in an age hierarchy with no common spaces or activity halls. Bad primary school design is of a great concern since children in Egypt up to the age of twelve spend from around 22% of their time in mainstream schooling, with primary schools representing 44% of all pre-university education (Ministry of Education 2005).

4. Research Methodology

This work aims to investigate the environmental performance of governmental primary schools in Egypt. In this part of the paper, the subjective assessment of nineteen case studies representing the three most common prototypes used by GAEB in al-Minya and represent 80% of the primary schools built across the country (GAEB 2004). Al-Minya Governorate lies in the desert climatic design region; the largest region in Egypt (Figure 1-A). The case studies included 5 schools of the six classrooms prototype (T6) single Row Form and double Row Form, 9 schools of the twelve classroom prototype (T12) single Row Form, double Row Form and L-shape plans and 5 schools of the eighteen classrooms prototype (T18) double Row Form. The case studies are located in seven different towns of al-Minya Governorate, twelve were built in rural context and seven were built in urban context (Figure 1-B).

The field study was conducted on three stages. The first stage collected information about the environmental performance of 18 case studies. Ten factors indicating the environmental performance of school buildings were observed across the case studies. These were: the water use, energy consumption, land use, health and safety, environmental impact of materials, internal air quality, thermal performance, visual performance, noise control, space acoustics. Analysis of results indicates that all schools performed very poorly across all investigated factors. However, thermal, visual and acoustic comforts inside classrooms were found to be the major problems (Gado et al. 2005).

In the second stage, the subjective response of 108 occupants (29% were females) inside 54 classrooms were gathered during May 2005; the hottest month of the year in al-Minya during the academic session (mid September to early June). Six occupants were chosen randomly from each school, three pupils and three teachers. Observation and semi-structured interviews with closed ended and open ended questions had been employed to investigate the thermal, visual and acoustic comfort inside the classrooms. The interviews were used to collect data related to the occupants' state of comfort inside the classrooms. Interviews used open ended questions to explore the subjective response of the occupants, while closed ended questions were used to allow the application of statistical analysis on the results. Analysis of results suggested that the thermal comfort is the most critical issue across the case studies. (Gado et al. 2005).

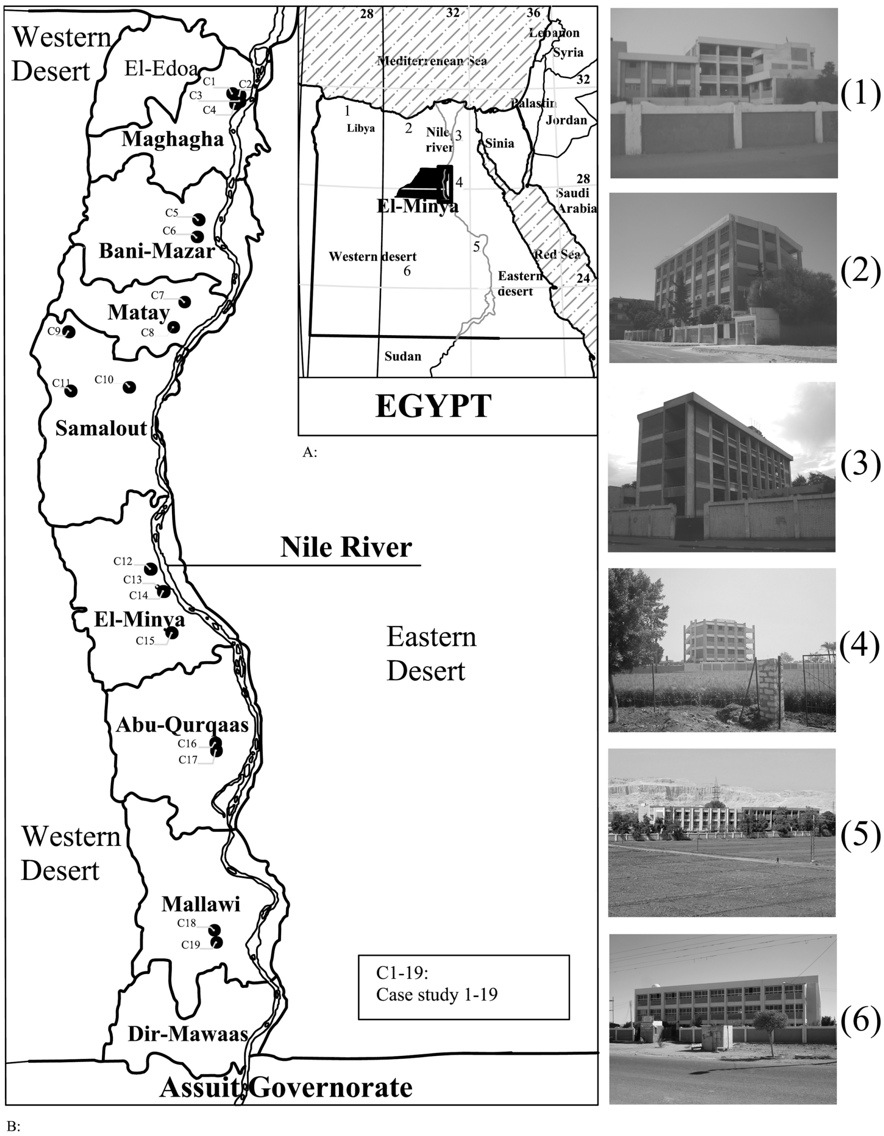

Figure 1: A: Examples of prototypical schools in different climatic zones / **B**: Location of the case studies in al-Minya Governorate

In the third stage, the thermal comfort inside five classrooms of three schools was investigated in details. Two schools were chosen from the 18 cases previously studied and an additional school was employed. The three schools were; Omar ebn al-Khatab primary school (leaner single Row Form), al-Lamaty primary school (leaner double Row Form) and al-Shaheed primary school (L-shape) (Figure 2 - Figure 4) These schools represent the three prototypes commonly built in al-Minya.

Figure 2: Omar ebn al-Khatab primary school

Figure 3: Al-Lamaty primary school

Figure 4: Al-Shaheed primary school

Multi-approached techniques were employed to collect data from 168 occupants (87% were pupils and 43% were female) inside the 5 classrooms during May 2007. Semi-structured interviews and questionnaires were employed. The questionnaire was used to collect data from occupants inside several classrooms at the same time. This allowed the comparison of data collected from different spaces within the same school but have for example different solar and wind orientations. However, since not all young children are capable of using conventional thermal comfort rating-scales (Humphreys 1977), interviews were used with children under 9 years old. Interviews included 24 closed ended questions and 7 open ended questions. Questionnaires included 24 closed ended questions. All the questions were related to the sensation of thermal comfort inside the classrooms. ASHRAE seven point scale (ISO 1998) was used to allow the interviewee to rate their perception of the thermal environment. Any difficult expression such as 'thermal comfort, slightly warm…etc' were explained to the subjects prior to the interviews or the questionnaires.

5. Results and discussion

Analysis of data collected from the first and second stages suggested that the majority of occupants were in discomfort for most of the academic year. 78% of the occupants were thermally uncomfortable, 58% were visually uncomfortable and 21% reported that the acoustics of the classrooms were poor (Figure 5).

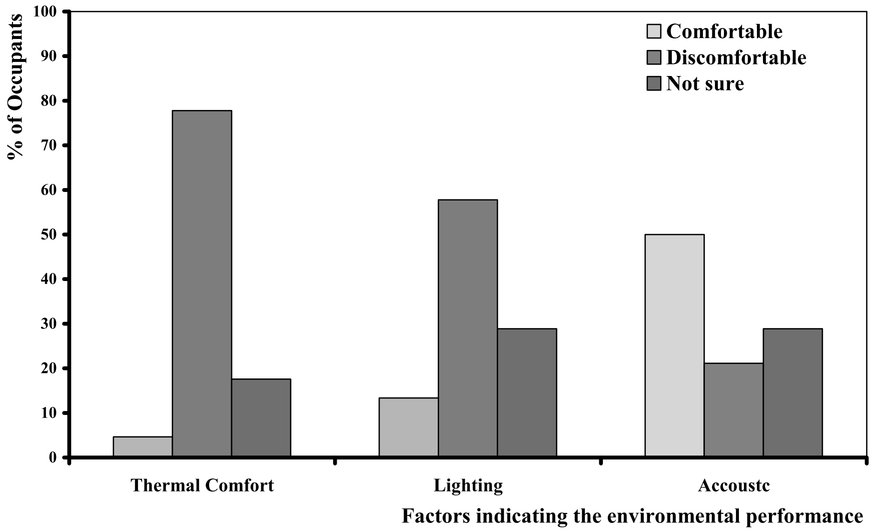

Figure 5: Percentages of occupants reporting discomfortable, comfortable or not sure

Analysis of data collected from stage three indicated that 86% of the occupants were thermally uncomfortable with only 14% reporting to be neutral. 34% of the uncomfortable subjects were hot, 18% were warm, 33% were slightly warm (Figure 6).

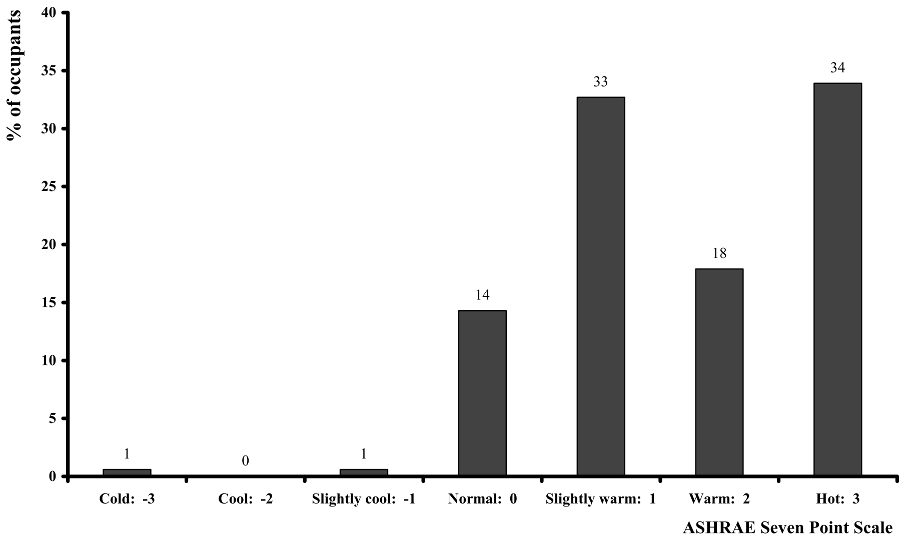

Figure 6: Percentage of occupants' response at each point on ASHRAE Seven Point Scale

Predicted Percentage Dissatisfied (PPD) was calculated using the data collected and was found to be 53%. This suggests that the majority of the occupants inside the case studies are thermally uncomfortable during the overheated period of the academic year. Observations and analysis of the case studies suggest that this could be due to several reasons:

- High occupancy density reaching 0.8 m^2/person in comparison to the average density in British classrooms that ranges from 1.8 to 2.4 m^2/person;
- The building envelope has a very low insulation capacity that ranges between 2.8 and 5.1 W/m^2.K with all external walls and roofs not thermally insulated;
- The high solar heat gain coefficient (SHGC) caused by the relative high window to wall ratio reaching 32% plus high incident solar radiation on windows (ex: incident solar radiation typically ranges between 327 and 900 w/m^2 on the 24^{th} April at 2.00 pm);
- Inadequate solar orientation causing high solar gain through windows. This plus the high outdoor air temperature pushes the conditions inside the classroom outside the thermal comfort zone;
- High shading coefficient (SC) values due to the use of large un-shaded areas (8 m^2) of glazing. This caused almost 25% of the pupils occupying the classroom to be hit by direct solar radiation for prolonged periods of time during the overheated month. This beside the high indoor air temperatures reaching 36^{o}c can lead to thermal discomfort and can cause sunstroke in severe cases;
- Windows are single glazed and poorly constructed with very high levels of air permeability. This caused high levels of heat gain through ventilation during overheated periods and cold draughts during under heated periods;
- The design of windows does not allow natural ventilation;
- In some cases children and teachers had to paint the windows in dark colour or stick newspapers to avoid discomfort and disability glare caused by the direct solar radiation. (Figure 7). This consequently led to a severe drop in the levels of natural light and the use of artificial lighting during daylight hours consuming unnecessary energy. In most cases the informants confirmed that they can not open the windows any way to induce natural ventilation because of the high levels of air and sound pollution outside the schools. This lead to very low internal air speeds reaching less than 0.1 m/s with no simple mechanical ventilation provided. This also led to low levels of air change and consequently caused the classrooms to be stuffy and smelly;

Figure 7: Windows covered and painted by the occupants after Gado and Mohamed (Gado et al. 2005)

- In very few cases, when the occupancy density is low, children move places to avoid direct solar radiation disturbing by such the educational process. This does not solve the problem any way since overcrowding at shaded areas contributes to the children's thermal discomfort (Figure 8).

Figure 8: Directed solar radiation falling on the children, after Gado et. al. (Gado et al. 2005)

Sunny areas Shaded areas

6. Conclusions and further work

This research was concerned with the subjective assessment of thermal comfort inside governmental primary schools in Egypt as a representative context of hot dry climate. Semi-structured interviews and questionnaires were employed and 276 subjects were used. The results suggested that the majority of the occupants are thermally uncomfortable in most of the cases during most of the time.

Work is conducted to objectively assess the thermal performance of the classrooms and to further investigate the causes of the problem. Results of this work are presented in the second part of the paper.

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