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RESEARCH ARTICLE

Acoustic improvement on two lecture auditoria: Simulation and experiment

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Abstract
Based on the commonly used indicators for speech intelligibility, this work acoustically evaluates the two largest auditoria in the Faculty of Engineering, Helwan University, Cairo, Egypt, using experimental and digital simulation techniques. Design treatments were also suggested to improve the acoustic performance of the auditoria, where the impact of these treatments was checked using the simulation as well. The models that were analysed using the CATT software were first validated utilizing the results of the field work in the unoccupied rooms. The results showed that the acoustic quality of the two auditoria are far from the optimal conditions due to their improper acoustic characteristics and the high noise levels as well. The results of improvement proposals showed that altering the ceiling shape and adding efficient absorptive materials to the rear surfaces successfully reduced the excessive reverberation time to the optimal values, increased the early reflections and eliminated the shadow zones. In addition, decreasing the noise levels by 20 dB due to improving the window insulation noticeably improved the speech intelligibility at all receivers.

1. Introduction

Due to frequent complaints about the low sound quality in many lecture auditoria in the Faculty of Engineering at Helwan University, particularly in large rooms, the authors have been asked by the administration of the Faculty to investigate this problem and propose feasible and economic solutions. The faculty was first established in 1955 as an industrial institute of higher education. Later, in 1975, it joined Helwan University as the Faculty of Engineering. It is located in a dense residential district to the north of Cairo City and is surrounded on three sides by narrow and congested streets. The faculty occupies approximately 12.4 acres (52.000 m^2), shown in Figure 1, and contains six departments. The faculty contains more than 70 auditoria of different areas and volumes; 54 of

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them are small rooms (less than 265 m^2), while the rest are large rooms (more than 265 m^2).

Thus, the scope of this work includes two of the large rooms in the faculty, namely, room C and the Abdolraseq room (RAZ). Room C, the second largest room in the faculty, is one of four typical lecture rooms in the department of civil engineering, building 3 in Figure 1; hence it represents 25% of the large auditoria in the faculty. It is a square room in which the benches have been arranged diagonally, see Figure 2. The slope of the audience area is approximately 7°, which agrees with the minimum slope required for sight lines (Elkhateeb, 2003).

1 Departments of Architecture, Math and Physics
2 Department of automotive and locomotive, Library, Theatre and administration.
3 Civil department auditoria
4 Main auditorium
5 Civil Departments and Automotive& Locomotive Workshops
6 Mechanical Power Department and Laboratories.
7 New Building Under construction
8 Mosque

Figure 1 Layout of the Faculty of Engineering.

Room RAZ, the largest auditorium in the faculty, is the main lecture room for the preparatory level, Building 4 in Figure 1. It is a trapezoidal room, as shown in Figure 3. The slope of the audience area is approximately 9°, which provides a good sight line and grants a direct sound path for every student. Similar to most auditoria in the faculty, the two rooms utilize natural ventilation via open windows. These windows directly overlook a crowded, noisy street, parking areas and buildings 2 and 7 (see Figure 1). The main architectural features of both auditoria are summarised in Tables 1 and 2. Speech intelligibility (SI) in lecture rooms is a major concern in educational spaces not only to support the learning process (Reich and Bradley, 1998) but also for lecturers' comfort. Recent studies indicate that improper acoustic conditions in lecture rooms cause severe vocal problems for approximately one-tenth of teachers (Brunskog et al., 2009). Speech intelligibility is a single measure for both room acoustics and the speech-to-noise ratio (S/N) (Reich and Bradley, 1998); it can be governed by different indicators, such as the useful to detrimental sound ratio (U_{80}), speech transmission index (STI) or its common variant, the rapid speech transmission index (RASTI) (Reich and Bradley, 1998; Shams and Rama krishnan, 2012). SI is considered to be a function of reverberation time (T); early reflection energy can increase the S/N by up to 9 dB (Bradley and Sato, 2003), while an S/N of +15 dB can raise SI scores by up to 100% (Bradley, 2002). Thus, the optimal reverberation time (T_{opt}) is an important criterion supporting SI (Shams and Rama krishnan, 2012). Background noise level (L) is another important acoustic indicator (Bradley

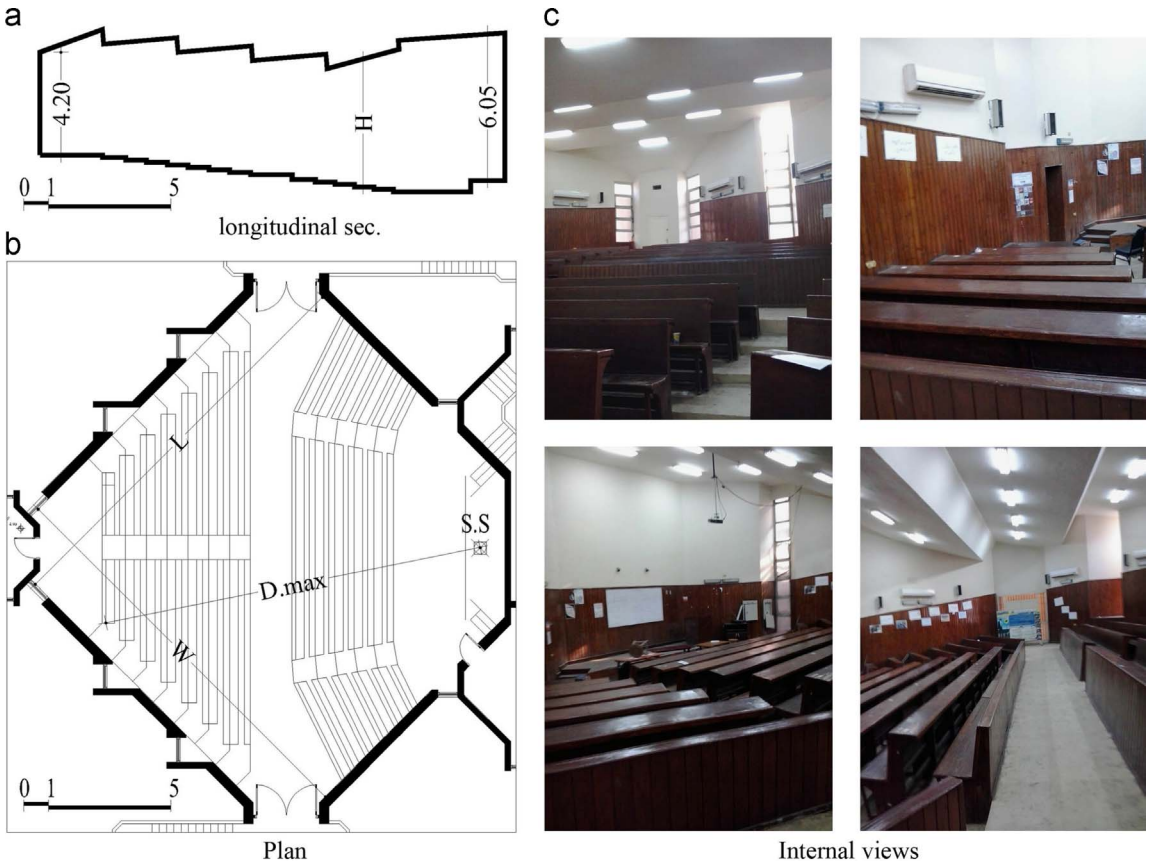

Figure 2 Typical lecture auditorium of the Civil department, room C.

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