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Enhancement of Acoustical Performance in Universities' Educational Spaces

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Abstract

Acoustic and thermal performance greatly affect in lecture halls as, acoustic, architecture and thermal treatments play an important role to enhance acoustic and thermal performance in space and therefore increasing sentiment of acoustic and thermal comfort in space.

This research get down to the role of acoustic, architecture and thermal treatments to enhance acoustic and thermal performance of internal acoustic and thermal environment for main lecture hall of Tanta engineering whereas, the hall suffers great acoustic and thermal problems, all because of several reasons, most important it, sky light of ceiling, integration work done between acoustic and thermal treatments to achieve best acoustic and thermal performance and using ODEON software to evaluate suggested treatments acoustically and selection the best then evaluate it by DESIGN BUILDER software to calculate the range of energy consumption reduce in hall after these suggested treatments.

It helped to enhance acoustic and thermal performance level in hall and increasing sentiment of acoustic and thermal comfort in hall. RT value of lecture hall reduce from RT=3.5 Hz to RT=0.95 Hz and the range of energy consumption reduce in hall after these treatments 70%.

Keywords: Acoustic performance; Acoustic comfort; Thermal comfort; Energy consumption; Reverberation time; Lecture halls; ODEON

Introduction

Acoustic comfort and thermal comfort are basic substrates in lectures halls design [1-3]. Acoustics performance plays an important role in internal environment comfort of space users, especially the spaces that need to good speech and listen as educational spaces in the university buildings [4-8]. Expert experiences in acoustics field show that one third of the students lose about 33% of the current speech in educational space [9-12]. Speech intelligibility is the most important determinant for quality acoustic performance in speech halls [13-15]; many factors affect the speech intelligibility in room as:

- Level of speech in hall
- Distance from speaker
- Directivity of Sound Sources
- Sound Reflections in Room
- Reverberation Time
- Space shape
- Dimensions space
- Internal surface
- Internal finishing
- Acoustic treatments
- Sound absorption and insulation
- Noise

While thermal performance is achieved through a good study of thermal space scarcity, extent of external climate impact on space, and extent of space scarcity to provides internal energy consumption.

In this sense there are many ways to evaluate the space acoustically and thermally, whether these methods by using laboratory measuring equipment and using simulation software, in this study, field measurements were made in one lecture hall and used Simulator program ODEON to evaluate the hall acoustically and calibrate the program by Comparison program results with field measurements [16-18]. Used "DESIGN BUILDER" to evaluate the saving range of energy consumption in hall.

Main lecture hall of Tanta engineering, it located in ground floor of college building (Workshop building), next to workshops halls and classrooms that depend on lecture hall in ventilation [19-21] as in Figure 1.

Where;

1. Preparatory Building, Department of Electrical powers and Administration
2. Architecture Department and Administration
3. Library, Mechanical Power Department, Math and Physics Department
4. Building and Construction Building
5. Civil Department

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6. Workshops
7. Lecture hall 1 and 2 (Case study)

Table 1 show the description of lecture hall 2.

Desks: 19 wooden row, with 1 m (W), 1 m (H), 10 cm the row higher from row previous.

Stage: Concrete, 2.65 m (W), 13.10 (L), the distance to first row is 2.35 m.

Hall: Divided into 6 modules, width of each about 5 m.

Interior surface: Covered up with hard finishing, ceiling has skylight in each hall.

Sound system, amplifier, microphone and 8 loudspeakers, 4 at each side. All we can see in Figures 2-5.

Acoustic and thermal performance of the environment impacts the outcome of learning process, from hall 2 acoustic study; there are many acoustics problems in it whereas internal acoustic environment inappropriate for education process and background noise of hall Larger than the limit, has negative effect on acoustic performance in hall, also range of energy consumption in hall in basic case is very high, on assumption the hall is air conditioned, all because of several reasons, most important it, sky light of ceiling, so suggested some acoustic and architecture treatments to solve these problems and achieve acoustic and thermal comfort for hall users [22-24]. These suggested treatments depended on replace the main ceiling with acoustically treated fallen ceiling and wall binding with acoustically treated materials [25].

Figure 1: Main lecture hall of Tanta Engineering.

Dimensions				
L (m)	W (m)	H (m)	Area (m²)	Volume (m³)
29.7	19.3	10.6	573.2	6076

Table 1: Table description of Lecture hall 2.

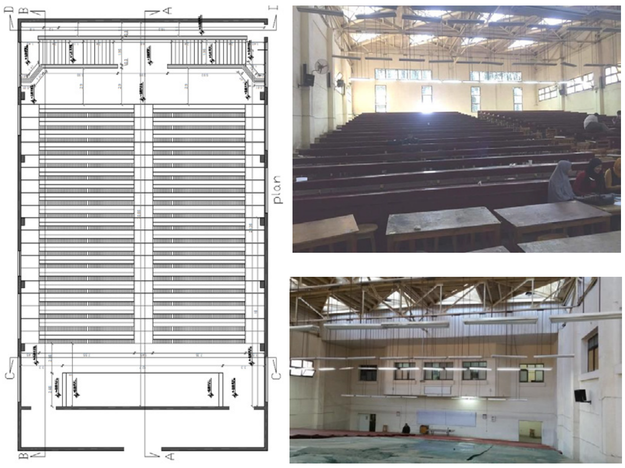

Figure 2: Showing Desk, Stage and Hall Dimensions.

Methodology

- Survey on acoustic performance in lecture halls, the factors affected on it, and the ways of evaluate by measuring and simulation programs.
- Field survey to specify architecture features of selected hall.
- Analysis of hall `acoustic performance and energy consumption, assuming the hall was air condition (basic case).

1. Field measurements for RT, Noise level, Acoustic performance level generally.
2. Evaluate hall acoustically by ODEON software and calibrate the program by Comparison program results with field measurements
3. Calculation of optimal reverberation time $T30$, $C50$ and SPL for hall.
4. Evaluate the saving range of energy consumption in hall by DESIGN BUILDER software.

- Analyse the results to specify acoustic and thermal problems to suggest acoustic and architecture enhancement modifications for hall.
- Evaluate the treatments acoustically by ODEON, identify the best then calculate range of energy consumption in hall after these propose enhancement modification, identify the best.

Results

Figures 6-10 shows the results obtained. From Figure 10:

- The reverberation time and energy consumption values are very big and unsuitable for education process in basic case; this was one of reason for that study.
- There isn`t big different between reverberation time values of basic case in measurement and simulation.
- Happening a sensible change for reverberation time and energy consumption in hall started at increasing the ceiling down (3 m) and use sound insulation and absorption materials in ceiling and walls.

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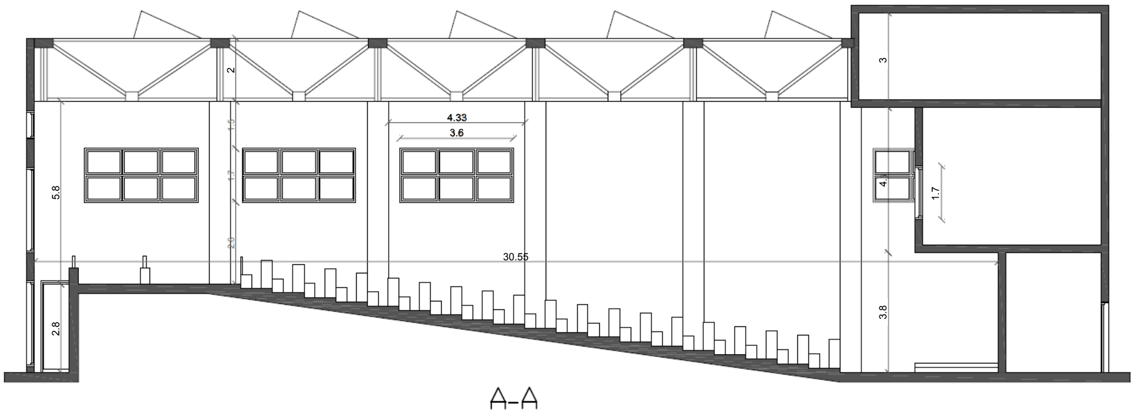

Figure 3: Interior surface are covered up with hard finishing.

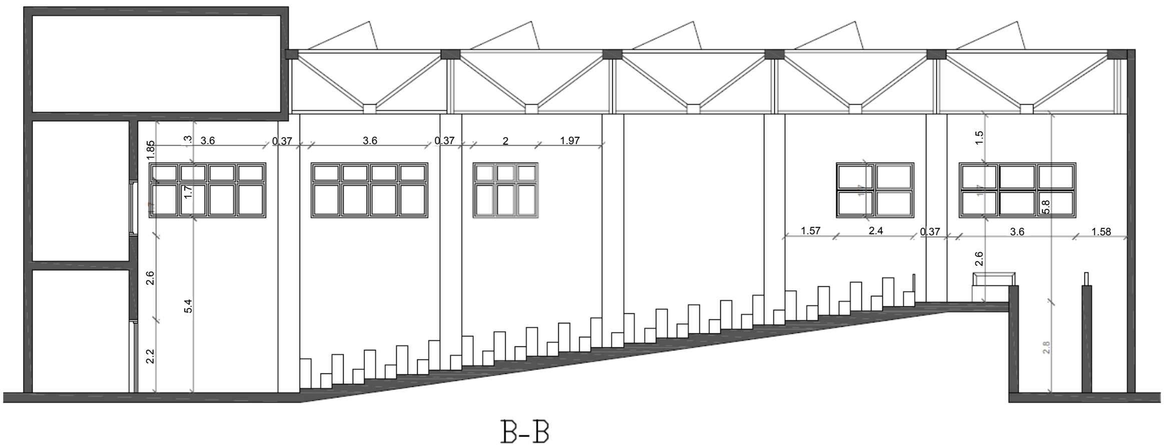

Figure 4: Interior surface ceiling has skylight in each hall.

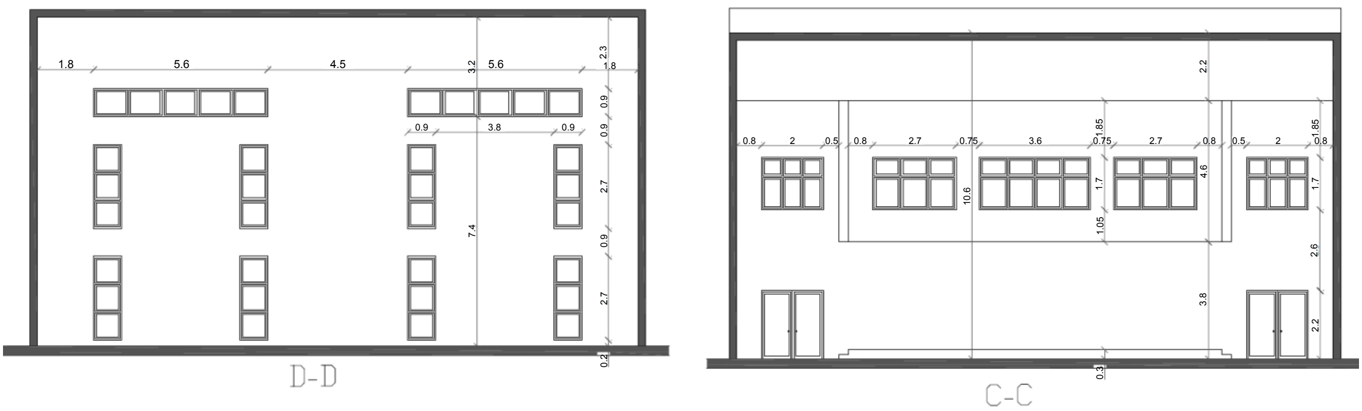

Figure 5: Sound system, amplifier, microphone and 8 loudspeakers, 4 at each side.

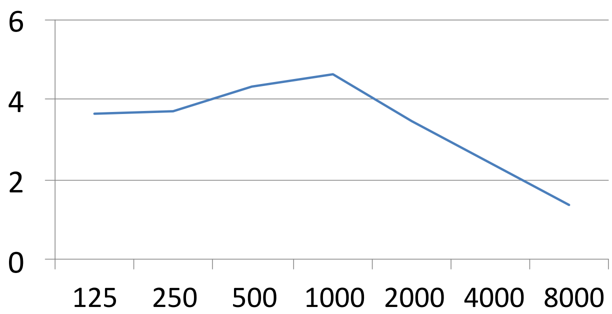

Figure 6: Average reverberation time in lecture room 2 by acoustic field measurement, so RT is very large (basic case).

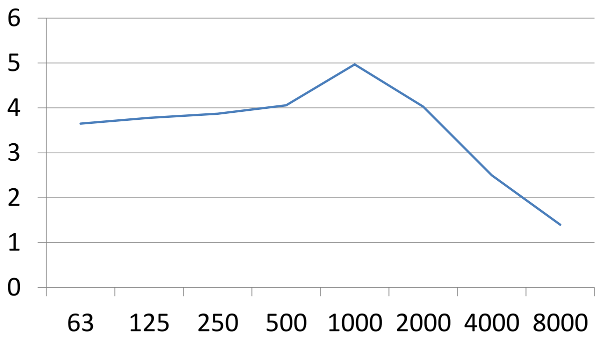

Figure 7: Average reverberation time in lecture room 2 before any treatments By ODEON simulation (basic case).

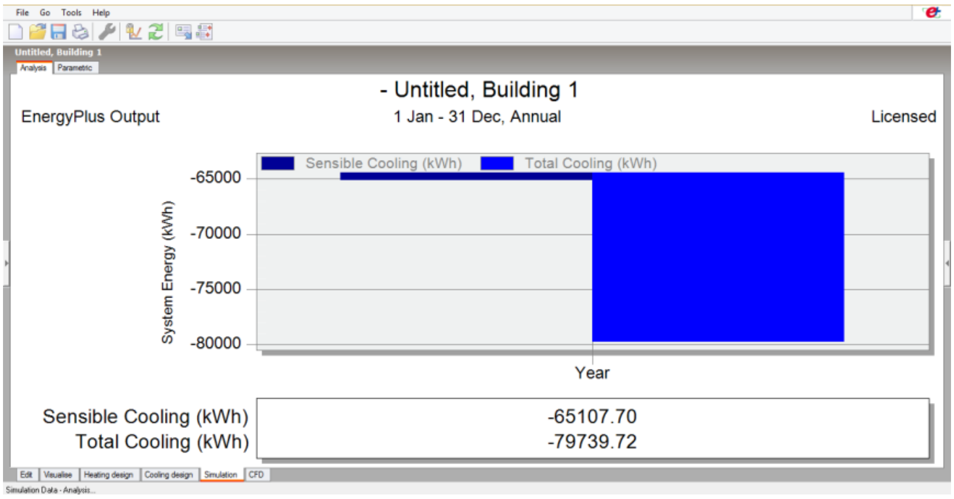

Figure 8: The value of energy consumption in hall Basic case.

- Treatment 2-C, 3-A, 3-B are the best reverberation time values and suitable for education spaces. But treatment 3-B is the best and less energy consumption value. So treatment 3-B is the most appropriate treatment to solve acoustic and energy consumption problems in lecture hall (case study). This is main aim from this research.

Conclusions

- Acoustic design is important for education spaces to avoid a cast adjustment after construction.
- Choosing the internal finishing materials for education space, compatible with acoustic and acoustic performance.

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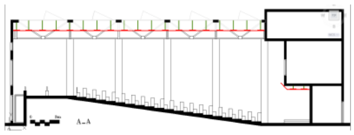
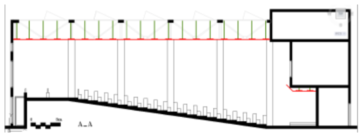
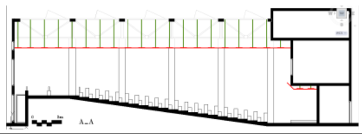
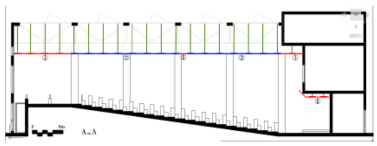
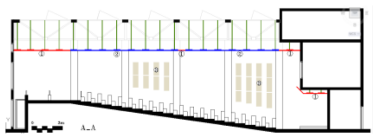
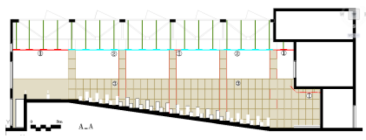
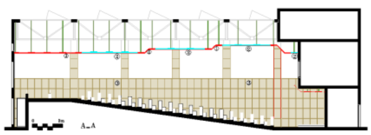
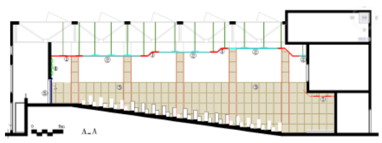
		Architecture Treatments	Acoustic Treatments	Hall Form
Treatment 1		- Ceiling down 1m	-------	
		- Ceiling down 2m	-------	
		- Ceiling down 3m	-------	
Treatment 2	A	Straight Ceiling down 3m	Used glass wool 2.5 cm as sound insulation ceiling materials.	
	B	Straight Ceiling down 3m	- Used glass wool 2.5cm as sound proof ceiling materials. - Covered all walls except front wall with normal wood	
	C	Straight Ceiling down 3m	- Used rook wool 5cm as sound proof ceiling materials. - Covered walls half except front wall with treatment wood	
Treatment 3	A	Step down Ceiling	- Used rook wool 5cm as sound proof ceiling materials. - Covered walls half except front wall with treatment wood	
	B	- Step down Ceiling - Building new rear wall (sub-entrance)	- Used rook wool 5cm as sound proof ceiling materials. - Covered walls half except front wall with treatment wood	

Figure 9: Table of acoustic and architecture treatments in hall to enhancement acoustic and thermal comfort.

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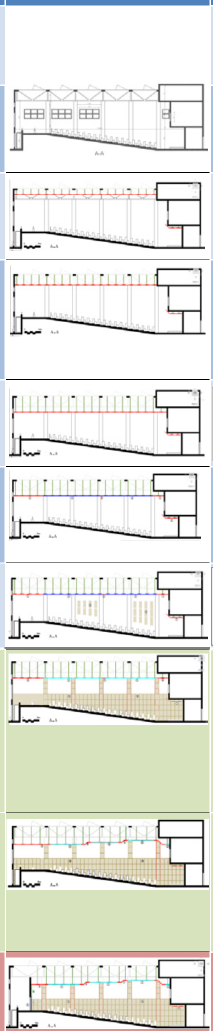

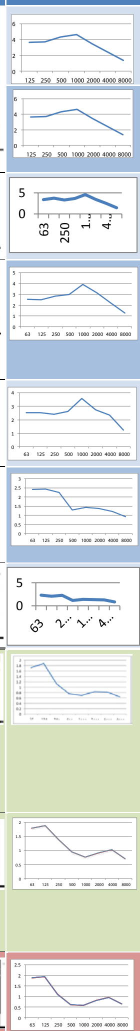

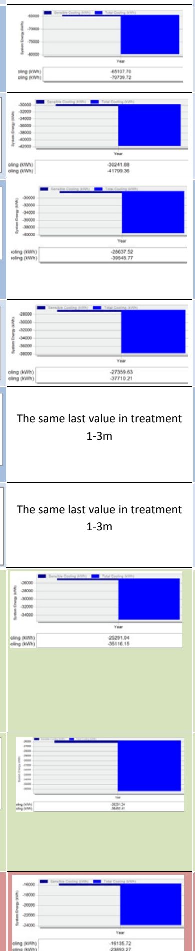

		Description	T30 (s) Average / Freq. (HZ) 63	125	250	500	1000	2000	4000	8000	Energy consumption values	Hall Form	Chart of Reverberation Time	Chart of Energy Consumption	Notes
Basic case	measure	No Acoustic and Architecture treatments	3.55	3.68	3.73	4.36	4.62	3.46	2.4	1.36				----------	Largest values
Basic case	simulate		3.65	3.78	3.87	4.06	4.97	4.03	2.5	1.4	79739.72 / 65107.70				
Treatment 1	1m	- Ceiling down - No Acoustic Treatments	3..39	3.74	3.31	3.66	4.58	3.44	2.50	1.45	41799.36 / 30241.88				
Treatment 1	2m	- Ceiling down - No Acoustic Treatments	2.56	2.50	2.86	3.00	3.91	3.15	2.19	1.26	39545.77 / 28637.52				
Treatment 1	3m	- Ceiling down - No Acoustic Treatments	2.52	2.53	2.42	2.63	3.60	2.73	2.36	1.24	37710.21 / 27359.63				
Treatment 2	A	Glass wool Straight Ceiling down 3m	2.42	2.44	2.25	1.29	1.44	1.38	1.20	0.92	The same last value in treatment 1-3m			The same last value in treatment 1-3m	
Treatment 2	B	Glass wool Straight Ceiling down 3m +all walls normal wood	2.31	2.07	2.27	1.16	1.39	1.33	1.29	0.83	The same last value in treatment 1-3m			The same last value in treatment 1-3m	
	C	Rook wool Straight Ceiling down 3m +all walls half acoustic wood	1.73	1.88	1.13	0.75	0.7	0.83	0.82	0.64	35116.15 / 25291.04				Good value
Treatment 3	A	Rook wool step Ceiling down 3m +all walls half acoustic wood	1.79	1.89	1.39	0.95	0.76	0.92	1.03	0.71	36450.41 / 26251.24				Good value
Treatment 3	B	Rook wool step Ceiling down 3m +all walls half acoustic wood + building new rear wall	1.89	1.95	1.1	0.62	0.59	0.81	0.96	0.65	23893.27 / 16135.75				Best and Less value

Figure 10: Treatments for achieving acoustic and thermal comfort.

- Studying noise sources (internal and external) in design stage and avoiding it to achieve good acoustic environmental, suitable activates in education space.
- Choose acoustical and architectural treatments in education spaces to enhancement acoustic performance and reverberation time in space.
- Use sound insulation and absorption materials in education spaces to achieve good acoustic environmental.
- Work on developing the Egyptian Code for acoustics to cover all aspects of space acoustics, and not limited to work of sound insulation.

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