Renovating a lecture hall with a glass roof: A case study of performance based design

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Architects at the design stage can achieve high-performance buildings by considering

.climatic conditions,

.users' needs and

. technological options

with an appropriate integrated design strategy.

- In current architectural practice, performance analysis of building designs is not done due to time constraints and is left up to the engineers.

- ENGINEERS get involved later in the detailed design stage

and are not allowed to alter most of the design decisions vital to a building's performance.

- With the rapid progress of information technology in all areas of engineering, we now have access to a large number of building performance simulation tools.
- Some examples:

DesignBuilder	Radience
DIALux	Fluent
Catt	ODEON
Ecotect	Energy Plus

- However, the use of simulation tools in the design phase is still limited.

The Main Objective of this study

is to reveal that architects can get reliable results with existing tools

- without having to input detailed information
- and adjusting only basic parameters for simulation.

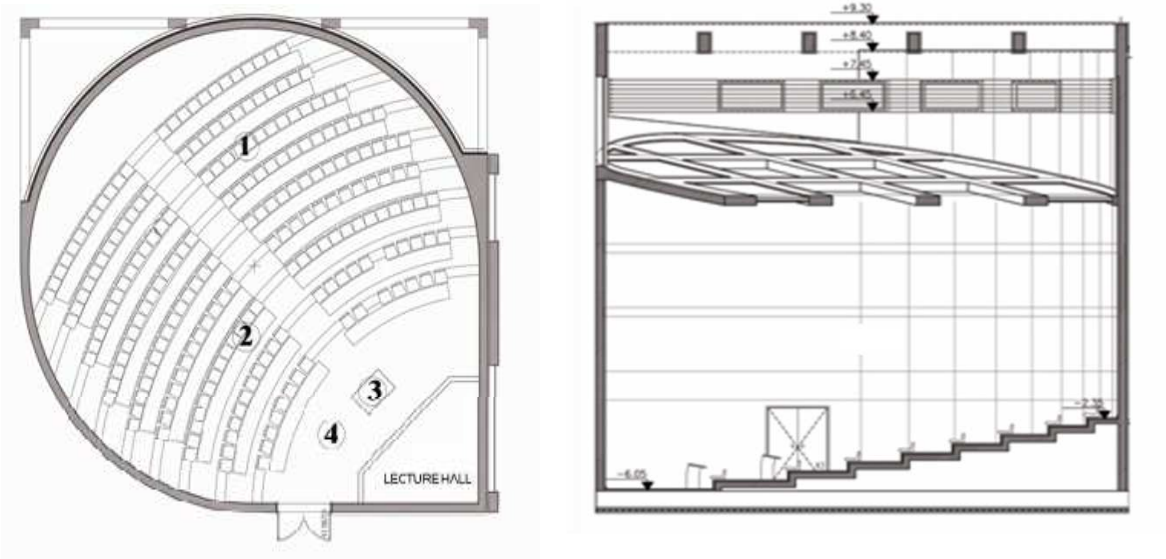
If the designer had used the tools in early design, problems could have been foreseen.

Department of Mathematics at Izmir Institute of Technology Lecture Hall

In this study, a new lecture hall in the Department of Mathematics at Izmir Institute of Technology is examined.

External view of the lecture hall roof.

GEOMETRY OF THE LECTURE HALL



Plan and Section of the lecture hall.

- The lecture hall has a cylindrical mass
- Seating capacity of 220 people arranged in a circular plan
- Diameter is 14.60 m. Ceiling height at the back of the hall above the back row is 7 m. Ceiling height above the stage is 11.75 m

THE GLASS ROOF

Glass skylight

- Reflective glass is used to cover the whole roof.
- The four squares in the center are used as a large (40m^2 total) skylight.
- The rest of the roof has thermal insulation and suspended ceiling underneath the reflective glass cover.
- The hall is placed along the northeast-southwest axis, the plane of the roof slopes down approximately 8 degrees to the southwest

MATERIALS

Interior of the lecture hall.

- The walls of the hall are plastered aerated concrete blocks.
- The floor is covered with natural stone.
- The desks are wood.

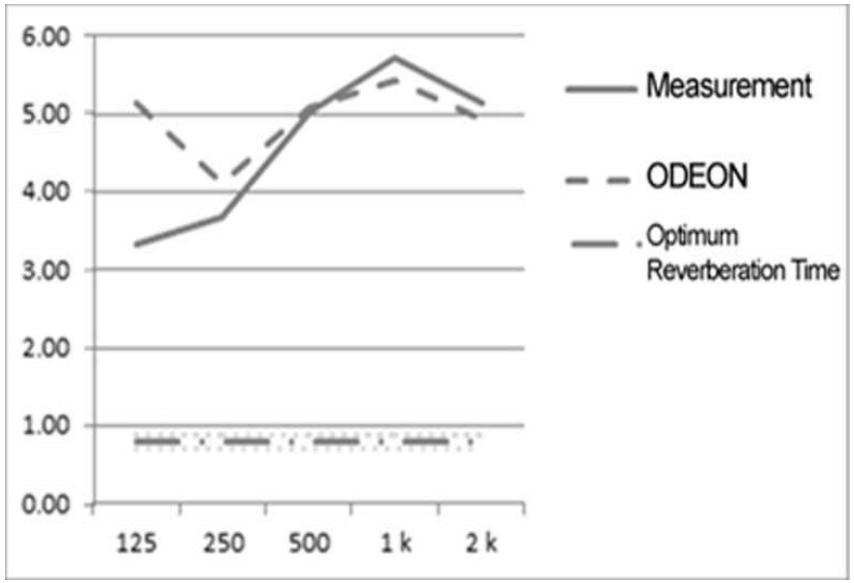
ACOUSTIC ANALYSIS

- The recommended maximum volume for a lecture hall for 220 people is 1100 m^3.
- The ceiling, for the cylinder is designed too high for a lecture hall. As a result the volume of the hall is 1875 m^3.
- The only sound absorbing material is the suspended ceiling tiles.

- Reverberation time is too long. The recommended reverberation time is between 0.7s – 0.9s. However, actual reverberation times are between 3.0s – 5.9s.

ACOUSTIC ANALYSIS

- Measurements were taken while the hall was empty.
- The acoustics is modeled and simulated in ODEON software.



Reverberation times [s]

DAYLIGHTING ANALYSIS

- The skylight provides opportunity to maximize the use of natural light.

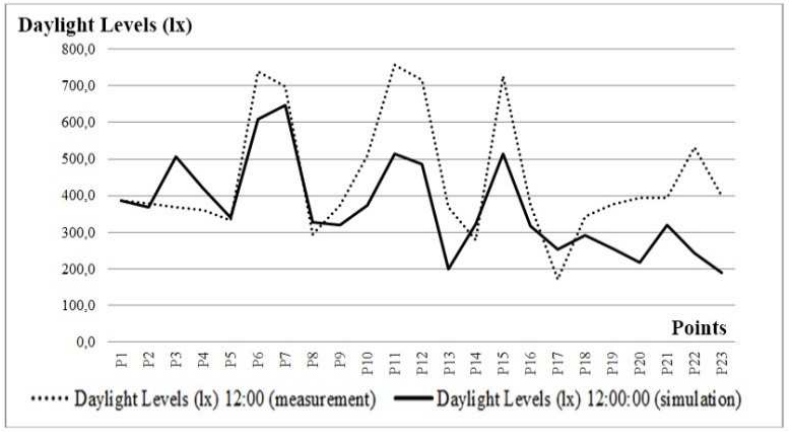
- There are no shading devices and the abundance of daylight has a negative impact on projection systems.

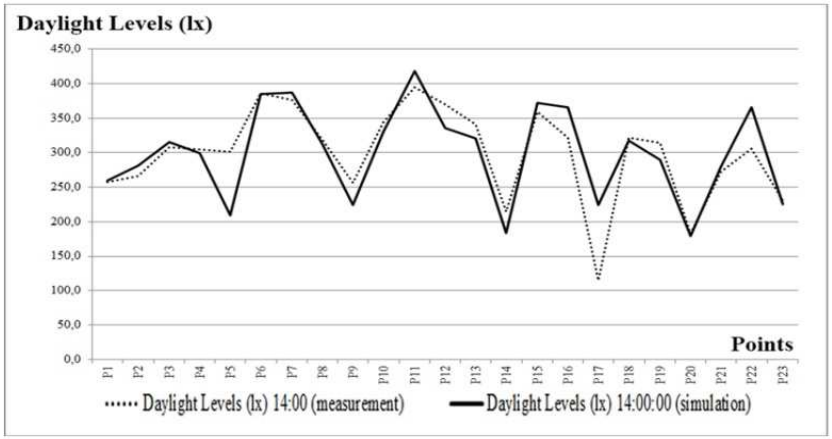
- The stage and the whiteboards are place in the northeast corner and the roof slopes down towards the southeast. As a consequence, direct sunlight shines on the whiteboards causing glare.

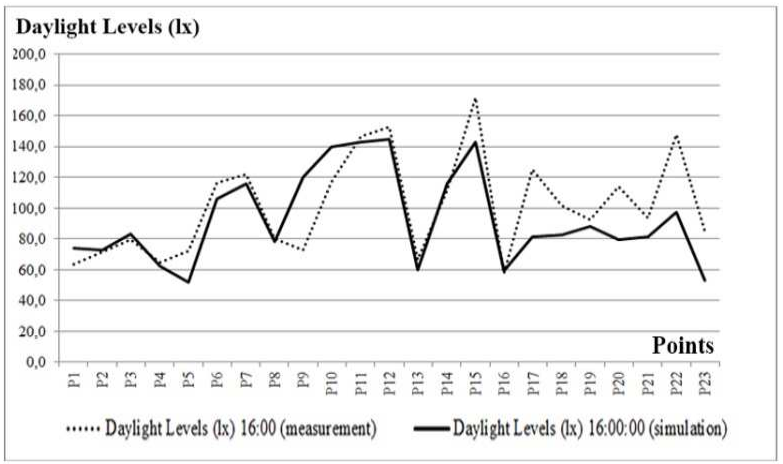
- The exposed ventilation ducts in the ceiling creates dark shadows under direct sunlight.

DAYLIGHTING ANALYSIS

- Daylight levels were measured on December 20, 2012 at 12:00, 14:00, and 16:00
- Daylight in the hall is simulated (for the same date) in 3ds Max Design.

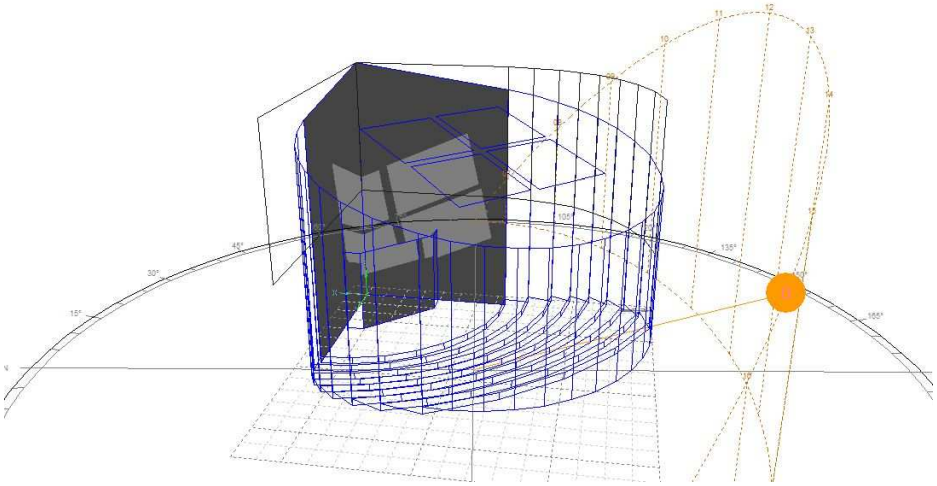






DAYLIGHTING ANALYSIS

- Analysis with Ecotect software shows that direct sunlight hits the whiteboard and the projection screen all year long except December.
- Only in December, direct sunlight remains above the level of whiteboard / screen.



Daylight incidence on the whiteboard / projection screen (March 21, 15:30).

DAYLIGHTING ANALYSIS

- 3ds Max Daylight Analysis tool, commonly used by designers, also reveals the direct sunlight hitting the whiteboard and the projection screen all year long.

Daylight incidence on the whiteboard / projection screen (March 21, 15:30).

ENERGY EFFICIENCY

- Due to the glass roof, cooling and heating loads are increased.
- Long term measurements in the hall have not been completed, however:
- The implications of designing a roof surface with a skylight oriented to southwest in Izmir have been explored with Ecotect software. Monthly heating and cooling loads have been estimated for the current situation with a reflective glass skylight, as well as the alternative which is a closed concrete roof with standard insulation.

	Roof with skylight			Skylight with high performance glass		
	HEATING	COOLING	TOTAL	HEATING	COOLING	TOTAL
(kWh)	630.5	13889.5	14520.1	721.3	10504.6	11225.9
Per m^2 (179.4 m^2)	3.5	77.4	80.9	4.0	58.5	62.6

Comparison of heating and cooling loads.

RESULTS

ACOUSTIC

- Surface absorption is insufficient.
- The lecture hall volume is 1.7 times greater than the recommended volume.
- Reverberation times are more than four times the optimum values, severely reducing speech intelligibility.

DAYLIGHTING ANALYSIS

- The skylight oriented towards the southeast is clearly the most important feature that adversely affects user comfort.
- In the afternoons, direct sunlight is able to fall onto the whiteboard and the projection screen and cause glare.
- There is no system to control direct sunlight.

ENERGY EFFICIENCY

- The glass roof creates additional heating and cooling loads.

PROPOSAL FOR RENOVATION:

To improve visual comfort and the acoustics,

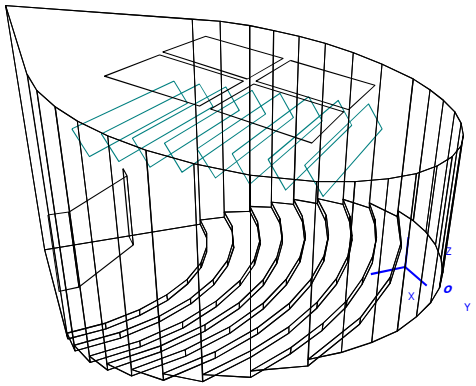
- a series of sound absorption panels are proposed to be placed under the skylight .

- ODEON simulations indicated that the 130 m^2 of absorbing surface provided by the baffles was insufficient and more absorption was required.

PROPOSAL FOR RENOVATION

To improve visual comfort,

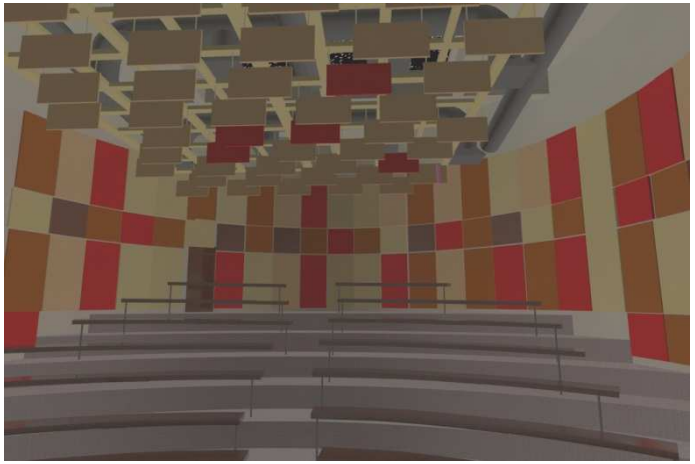
- the sound absorption panels are designed as a series of louvers that will act as shading devices to prevent direct sunlight to reach the whiteboard and projection screen surfaces.



The proposed acoustic baffles under the skylight.

PROPOSAL FOR RENOVATION

- Sound absorption panels can be mounted on the rear wall (behind the audience). It can also composed with the use under the skylight.
- Various color arrangements of these panels enable various design approach.



Use of baffles under the skylight and rear wall.

PROPOSAL FOR RENOVATION

To improve visual and thermal comfort,

Use of rolling roof system over the skylight, is an alternative design approach. Motorized system provides folding and sliding movement . Louvres turning around its axis obstruct the direct sunlight and solar heating . Louvres can be completely closed down during projection.

Rolling roof system

PROPOSAL FOR RENOVATION

- To improve thermal performance,

- Option of replacing the reflective glass with a high performance low-e glass with solar heat gain coefficient has been explored.

- Ecotect estimates a savings of 22% over the existing skylight.

RESULTS

Three important reasons are offered to explain why architects do not utilize simulation tools in their design process:

1) Numerous problems exist with data transfer (interoperability) from CAD tools to analysis tools;

2) The time required for evaluation of alternatives using simulation tools extends the design process.

3) Analysis tools are too complicated and require expertise.

RESULTS

In this study detailed models are not prepared only simplified models are created. Also, only basic simulation settings are entered none of the advanced simulation settings are adjusted. The aim has been to obtain results quickly without too much effort, emulating early design stage.

The results clearly demostrate that the problems could have been foreseen during the design stage. Renovation proposals for acoustic, visual and thermal comfort are examined by simulation tools.

The renovations in the brand new hall require additional cost.

- This case study shows that exploring design alternatives should be carried out by designers early in the design process and existing tools can provide invaluable results even to the novice user.

»THANK YOU