

# Design Project

## Kresge Auditorium Lighting Studies and Acoustics

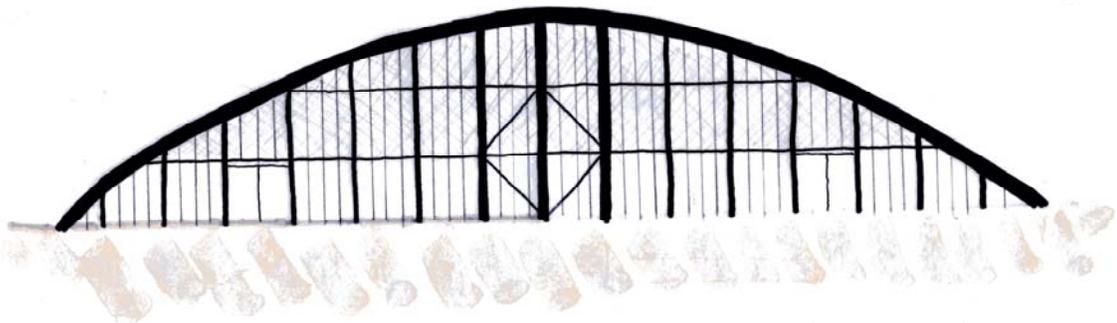


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Due to the function of Kresge Auditorium, the main stage space does not receive any natural light. Thus, the lighting studies on the building are done within the front entrance space which consists of a glass façade and a roof structure which meets the ground level on two sides of the studied space. A picture of the space is shown below showing the façade of study on the right, the roof meeting a structural element at a point, the extrusion of the theater creating a lower ceiling and walls that make the entrance to the theater on the left.

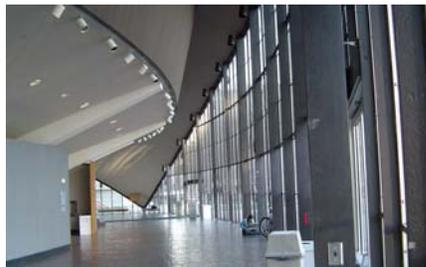
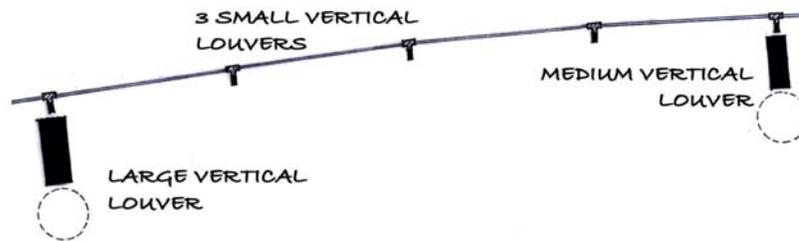


The glass façade seen on the right of the photograph consists of large, 2'-6" x 5' x 1/8" single glass panes which make up about 95% of the total area, and the last 5% are taken by the steel frames and supports. A detail of the windows is seen in the drawing below drawn as a layout of the window program.



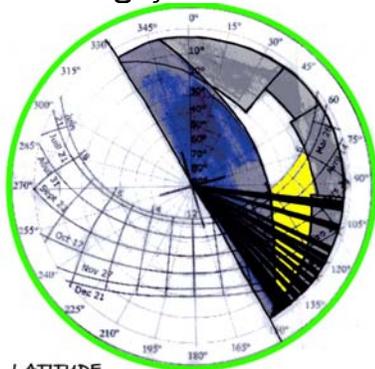
This large area covered with glass provides a great amount of natural light within the space during the day. However, with this natural light comes a lot of solar heat gain during the summer and heat loss during the winter, especially due to the single glazing of the windows. The top two rows of glass panes, which take up about 75% of all windows, are covered by a thin coating, possibly a reflective film, where the rest 25% are of clear glass. The coating layer is used to prevent a great amount of solar gains during hot summer days by reflecting some of the solar rays. The coating is only seen on the higher rows of windows since the summer sun is high in the sky and its rays hit the higher windows at a higher angle and therefore produce more heat gains but low enough such that the early morning sun doesn't penetrate much. With the use of these coatings this heat gain is somewhat controlled.

Other important elements of controlling light penetration are the vertical shading louvers along the inside of the building's façade as an alternative to horizontal overhangs or other more obvious seeming conventions. They are of the same height as the façade (varying due to the roof structure) and vary from 1" as mullions to 4" thick in the middle of the facade and 2"-1' wide respectively. These vertical louvers are placed so that they are perpendicular to the direction of sun rays when the sun is due south and therefore the strongest and in perspective almost create a wall along the south side. Ultimately, They provide shading during the warmest part of the summer days. The following illustrations show a sectional plan and a 3-dimensional picture of their arrangement. This arrangement is continued about 1 4 and a half times along the façade with varying areas of window surface due to the falling roof. The small louvers are along the inside of all the vertical mullions and the three total large vertical louvers are found only in the middle of the façade where it faces almost due east.



The roof structure, the surrounding buildings, and the vertical louvers contribute to most of the shading in the space. The site plan and stereographic charts below show the lighting analysis of shading due to these obstructions at two significant points inside the space with the

amount of sunlight they receive over the course of the year. The first space (blue dot) is what can be described as the middle of the lobby where the lighting/shading is effected by as many elements as possible. This point also serves as an entrance into a smaller theater. The second point (green dot) is significant because this is where the vertical louvers seems to align, form a wall and keep a large amount of direct light in when the sun is near/due South and at its highest intensity. The grey areas of the charts represent the surrounding buildings and some trees, the purple areas shows the roof, and the black areas show the vertical (medium and large) louvers.



LATITUDE  
42 DEGREES

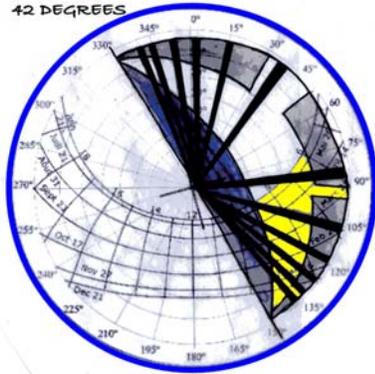


Image based on Kresge floorplan removed due to copyright restrictions. The removed image shows a blue dot at the center rear of the auditorium, and a green dot in one of the rear corners.

From the stereographical analysis we notice that the Kresge lobby entrance was designed to allow minimal direct sunlight as a flat façade regardless of its 120 horizontal angle. The overall design and delicate consideration for everything makes for a comfortable passing as people enter and move through the lobby facing south. The most noticeable difference in moving around the lobby is where the sun penetrates and how much diffuse light is available to make the apparent glare on the ground if the sun isn't already causing some glare. In looking at the stereographs, it is apparent that Kresge was designed to be position the way it is with a specific intention as far as lighting. If the façade faced the opposite direction, sun penetration would double and if Kresge was below

the equator, the louvers would become unimportant with light coming from the north in high intensities.

In terms of solar heat gain during the winter, the space acts almost as a greenhouse, where the heat inside it is transferred to the auditorium further within the building. The heat loss during the cold winter nights is also great but since the building is not used late at night and also because the space is acting only as a lobby, this is not a significant problem.

Another important issue involving the lighting of a space is the level of contrast and glare. Because of the large amount of glass surrounding the space, there aren't any far away areas where the contrast level is greater than 1:10, or any close areas where the ratio is greater than 1:3. Based on this information, the contrast levels within the space do not cause discomfort to the eye.

The glaring issue, however, is a bit different. Although the walls of the lobby are of a fabric material or a brown paneling that has almost no reflectivity and the ceiling does not create any glare because it is never exposed to direct sunlight or light in general since artificial lights are hung pointing down, the highly reflective floor might be a discomfort on bright sunny days. The floor is a continuation of the outside brick foundation but is covered by a very highly reflective coating. When the sun rays hit this surface, most of the light would bounce up and reach the level of peoples' eyes. This might cause a lot of discomfort. However, since little direct sunlight will ever hit the ground this glaring effect is kept to a minimum and discomfort levels are found to be rare and only occur in the morning. The picture below (left) shows the glaring floor at 6PM in spring. On the right, it is seen how the glared light travels through section due to the coated floor and white ceilings.



It is also important to mention the electrical lighting of the space. During the dark hours, the space is lit by a series of lights attached to the lower ceiling's edges, outside along the roof at the top of the major louvers creating an architectural gesture of contrast; what takes away light during the day, provides at night. The lights along the roof provide for balancing light inside and outside the windows to avoid glare. During evenings, the space receives enough electrical lighting for its purpose of

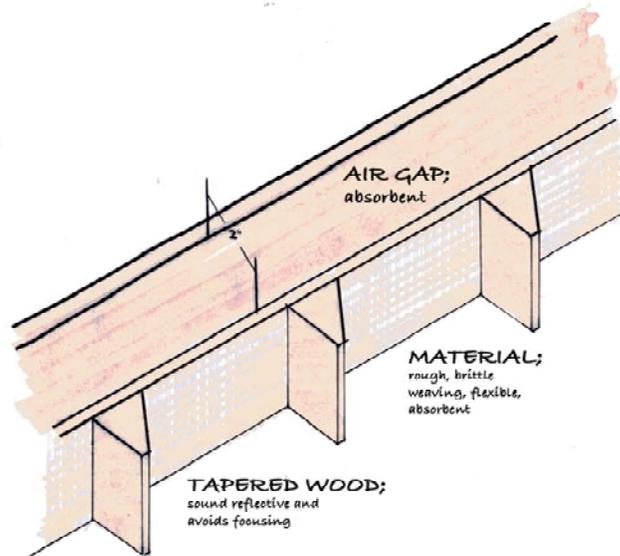
an entrance lobby to a theater. As to the reflective surfaces, the dark colors/material of the walls and ceiling would leave the space with low levels of diffuse lighting but due to the amount of lighting fixtures, about 28, enough light is made available. As a whole, the lobby space of Kresge is very well lit throughout the day for its purpose with a balance between energy savings in the day and energy consumption at night, regardless of the expected energy consumption assumed of a theater.

Another important aspect of a space is its acoustic performance. The large theater of Kresge Auditorium is a space designed for the performing arts and also for lectures and speeches of sometimes important leaders in our society. Therefore, the space has various opportunities to provide the space with elements to improve the quality of sound inside.

To start with, all of the walls inside the auditorium are slightly curved and covered by a very smooth reflective wood finish in order to distribute the sound throughout the space through sound wave reflections. A diagram of this effect is shown below.

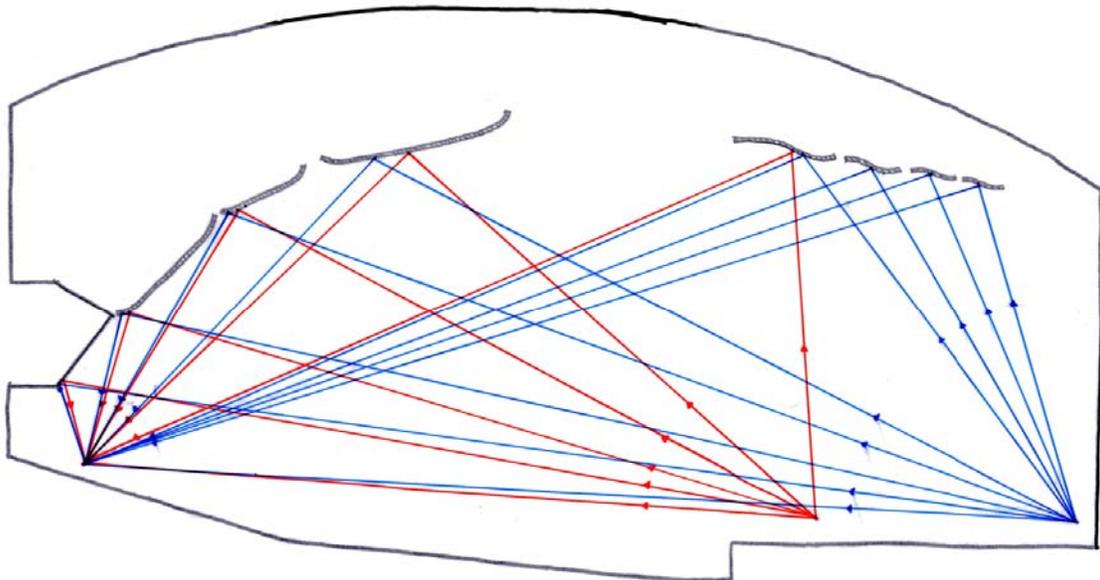
Image based on Kresge floorplan removed  
due to copyright restrictions.

This type of configuration will allow for the least amount of focusing in all directions. Well thought out curvature allows for additional sound waves to accumulate into the corners and at all relative distances so as to recreate the sound of being closer, but just later. In plan, we can see that direct sound versus reflective sound will not prove to be discomforting, as their relative distances are close enough to equaling. It would also be expected that a wall such as the one shown in plan in the back would create multiple focusing points and sending much delayed sound back to the stage, however, the back wall is made of a repeating system of material and tapered wood as pictured below.



The back of the theater is a custom wall covered by a series of vertical 5" sound absorbent texture with 1.5" tapered wood vertical structures in order to reduce focusing. The texture absorbs most of the sound waves and the wooden structures reflect the rest in various directions resulting in sound waves not traveling back to the sound source.

In section of the auditorium reveals the importance of addressing the extreme heights of large, spherical ceilings, which can lead to discomfort.



Panels, nicknamed Clouds, create a lower ceiling which displaces soundwaves such that ones they would die out into the ceiling or the backwall are pushed down sooner and reach more of the audience and

lowers the amount of echoes heard because most soundwaves are controlled using these panels. This control also makes the room ideal for music. In music setting an orchestra can go as deep as 8 rows or the whole entire stage. With this control of sound, people seated in the back or on the sides where sound usually isn't as managed will have better blend with the rest of the musicians because of their soundwave's reflected distances to the audience with the other musicians. This raise in intelligibility makes Kresge ideal for music. For speech, reflected distances may be more controversial as speakers sometimes tend to walk around, speed in their speech, or vary in tone cause intelligibility to fluctuate in and out of a comfortable intelligibility causing general discomfort.

Reverberation time at 500Hz for example should vary greatly with what is going on in the theater because 1 000 people will be absorbing a lot of the sound or all the empty seats will have to try and make up for the loss in absorption from actual people. In calculating reverberation, we will consider all absorbing materials such as the wood and wool back wall, the concrete ceiling, the panels, and the people in seats. After going through the equation of  $RT=V/ABS$  it comes out that there is only a difference of about 4db.

The above section can be viewed from a different perspective. What if the source was coming from the audience? The same reflected distances would apply but what you notice is that many soundwaves focus in certain areas causing echoes in various places throughout the auditorium. While doing this assignment and analyzing Kresge on site, we were lucky enough to have a cellist practicing front and center on the stage. From the cellist, sound was very clear as we moved around the space from one corner to 5 feet away from them. However, what surprised us more was that as we made verbal notes to each, no matter how low the whisper, it seemed as if sound were exaggerated. While sitting in the very back the loudest of whispers would even come with an echo seeming to come from the front of the theater, just as the above diagram read backwards would illustrate.

An important element in an auditorium like Kresge is the seating, both for practical purposes and acoustic reasons. The seating spaces in the auditorium are covered by a rough cushion material (filled with air pockets) that absorbs most of the sound waves that reach it. This way, the seats prevent a lot of echo effect that would otherwise disturb performances.

Image of seats removed due to copyright restrictions.

Something else which is very important for a performing space is its sound insulation. A successful design is a space where outside noise is absent. Kresge Auditorium is very successful in that aspect. Because of the layer of air all around the main theater, the interior space is very well protected from outside noise.

For an auditorium, Kresge meets some pretty high standards for performance while expecting a very tame and quiet crowd. Being a student at MIT shades us from know the truth about Kresge's ability to control sound and light, we just see it as a theater we go into a few times a year. In reality, Kresge is a building able to tell the audience when they are too loud or tell you when it's a sunny day. For a building in general, Kresge makes a huge impact with its shape, form, and visual aesthetics. However, when looking at official drawings, it looks as though the panels/Clouds were not designed to be curved. Every single drawing, even the most detailed of construction drawings show that they were designed without curves in mind. And with construction it seems that the curves do create a 'better' aesthetic presense, but since the original design hadn't called for curves, some of the extra sound received from the clouds can be unnecessary. As a whole however, the auditorium is very good building based on function.