PITTSBURGH GLASS MUSEUM AND RESEARCH CENTER

AN INVESTIGATION OF A BUILDING MATERIAL

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The following project is a museum and research center dedicated to the exploration of glass technology. I chose this project because my goal for this year was to expand my personal knowledge about glass as an architectural material and designing a project of this type enabled me to tie together the wide variety of facts and insights I was gathering through my research.

In the center visitors are to be exposed to the many aspects and glass in the same building that scientists, artists, and designers are exploring further potentials and capabilities. The museum is meant to be used by people of all ages and walks of life who come to be both educated and entertained. Many of the museum's exhibits will be of a participatory nature and will include information on the work taking place in the research center. Further exposure to the research will be provided through tours, lectures, and workshops. The research center will be open for use by both professionals and amateurs who are trying to investigate or promote the many uses of glass materials.

The center contains approximately 130,000 square feet of space. About 20,000 of this is research space, 40,000 is exhibit space, another 40,000 is storage space and the remaining area is the building support facilities. The center is located along the Allegheny River in Pittsburgh, Pennsylvania, an industrial city with ties to the glass industry.
Throughout my years of school I have felt a void in my technical knowledge of how buildings are put together and, at the same time, a lack of confidence in my ability to actually create the spaces I envision. I chose to use my thesis year to address this issue and to try to expand my understanding of the built products of architecture. My method of doing this was to break buildings down into their most basic components, the materials they are built from, and to investigate the materials as a way to understand the architecture they create. Each material used in building has a unique combination of physical qualities that, when understood, can be used to produce a wide variety of spacial effects.

I felt that the best way to get a grasp on understanding the effects materials can have on an environment was to pick one material and investigate it by a variety of methods. Because of the exciting potentials I felt it had, I chose glass as the material I would research. Wanting to look at as many aspects of the material as possible I began by familiarizing myself with a wide variety of information on glass. I looked into the history of glass, its technical properties, the ways it has been used in a variety of building types, and the perceptual effects that had been desired or achieved in these building types. After researching these issues I was able to take the obvious unique quality of glass, its transparency, and break it down into the three separate issues of light, view and enclosure.

Next I took each of these issues and tried to understand the variety of ways each can be used to affect space and the perception of space. Studying a variety of building types I arrived at six categories of view types; no view, controlled view, panorama, variable view, distorted view and repetitive views. While categorizing these view types I drew conclusions about the reasons for using each type and explored the variety of effects views can give to a space. I investigated the issues of light and enclosure in a similar manner. By looking at built examples and doing a series of photographic light studies I drew some basic conclusions about the more commonly used methods of using light to create spacial division, hierarchy and movement. Studying enclosure I looked at the effects of enclosure in the sky, wall, and ground plane of a space as well as the various methods for achieving degrees of enclosure in a glazed opening.

These studies were used to aid me in deciding upon the use of glass in my project. By breaking up the spacial effects of glass into these series of categories I was able to express and analyze the intentions and results of my design in a cohesive manner. I feel that this was helpful in the development of the spacial qualities I wished to produce and, at the same time, led to consideration of further spacial or perceptual effects. I feel that this process of categorizing and analyzing will continue to be helpful as I pursue a career in architecture. Eventually I hope to come up with a more complete vocabulary of architectural issues which relates directly to my understanding of architectural materials and their spacial potentials.
ROOF FRAMING PLAN
GENERAL PUBLIC

This group will consist of people who are visiting for entertainment, education, or out of an interest in a particular exhibit. They will mainly be visiting the exhibit galleries. Changing exhibits and lectures will be held to encourage return visits. The building will need to allow for a variety of interests and participation levels.

CHILDREN

Special consideration will need to be given to children who will mainly be interested in participation style exhibits and should be able to move conveniently through other areas. Spaces will be designed to accommodate school groups of about thirty students.

PROFESSIONALS

People in fields using or related to glass or glass technology (architecture, interior design, art, construction, science etc.). Exhibits will need to be specific enough to interest them. Many of them will use the library and attend seminars and workshops.

RESEARCHERS AND TEACHERS

This group consists of people exhibiting or working on projects. They will have something to share with visitors (objects, processes, experiments etc.). The building will need to allow them to regulate their display or work space and their amount of interaction with visitors.

EMPLOYEES

The employees will need a separate parking area, easy entrance to where they belong, and ways to get around the building to do their work without fighting crowds.
PROGRAM

Library  2000 sq. ft.

Shelves/cabinets/study areas/ lay out spaces
A collection of books, samples, and other objects dealing with glass. Open to any interested person.

Auditorium  2500 sq. ft.

A small auditorium for school or tour groups, seminars et. Must be able to be used comfortably by both large and small groups and be adaptable to lecture, stage, and film use.

Workroom  1000 sq. ft.

To be used for classes or workshops dealing with various uses or aspects of glass (art, construction, science etc..). Needs to be equipped for a wide variety of situations.

Eating Area  4000 sq. ft.

Seating area/service line
A cafeteria style restaurant with the tables having views to areas of interest within the museum.

Kitchen  500 sq. ft.

Food preparation/storage/delivery

Storage  40,000 sq. ft.

Shelves/cabinets/inventory system
Storage area for items not currently on display or in use. Must allow for easy delivery/removal of objects and access to exhibit areas.

Restrooms
Located throughout the building.

Entry Area

Seating for 20-30 people/ticket and information area
Will serve as a hub to a variety of spaces. Must be easily understood from the exterior as being the main entry.

Shop  800 sq. ft.

Display shelves/cabinets/service counter/storage area.

Administration  1000 sq. ft.

Administrative area to contain two officers and a reception space.
Exhibit Areas

The exhibit halls will be based on the historical sequence of glass usage and discoveries. The exhibits will start with objects of nature-made glass and progress to man-made glass and glass in architecture. The various physical properties; acoustical, structural, thermal, and visual will be explored through participatory exhibits in the galleries. Connecting halls will be used to explore the issues of light, view, and enclosure as well as display items.

Sequence

Hall of Objects

Natural glass, hand made glass and blown glass items arranged in historical sequence up to 1200 AD.

Acoustical Gallery

This gallery represents the Gothic era which was the first time glass was used as a major building component and will contain participatory exhibits to explore the acoustical properties of glass.

Hall of Views

Display of glass items dating from 1200 to 1900.

Structural Gallery
Thermal Gallery
Visual Gallery

Each of these galleries will contain participatory exhibits, as well as displays, explaining technical advances in glass usage. The curtain wall construction of these areas is representative of today's building techniques.

Aesthetic Gallery

This gallery will be used to display various artistic and design objects made from or with glass. From this area visitors will be able to observe artists from the research center as they work and to participate in workshops and classes.

Outdoor Areas

Exterior patios and plazas will be used for further display and observation.
Research Stations

These areas will be used by visiting researchers who will be exploring various capabilities and potentials of glass. The researchers will be given some control over their amount of interaction with museum visitors as they work. However, they will be encouraged to hold lectures or workshops explaining their work and to present their findings in a museum exhibit. Each station will have its own equipment storage area as well as an office for visiting researchers.

Structural

This area will center on an open area where walls and structural systems can be built, developed, and tested. It needs to be in close proximity to equipment and storage areas and must allow for control of visitor access.

Thermal

This station will be used to research active and passive solar abilities of glass types and systems as well as insulation potentials. It will need exposure to direct sunlight as well as exterior exposure on all sides.

Acoustical

This station will concentrate on the testing of sound reflection, absorption, and reverberation of building systems. This area will be internally oriented with a high degree of construction flexibility.

Aesthetic

Art forms incorporating glass will be explored and taught in this area. This will be the area in which there will be the most researcher (artist)/visitor interaction and will be used as the blending point of the building's research and museum components. Finished work will be exhibited in various galleries and the sculpture garden.
I chose Pittsburgh, Pennsylvania as the site for my project because of its industrial character as well as its historical and current connection with the glass industry. Pittsburgh is the home of the Pittsburgh Plate Glass Company, one of the nation's largest producers of architectural glass products.

Pittsburgh, Pennsylvania

Pittsburgh is located at the point where the Allegheny and Monongahela Rivers meet to become the Ohio River. The main downtown area, referred to as "The Golden Triangle," is located on the peninsula formed by the intersection of the rivers. Downtown development has historically concentrated in this area with little extension across the rivers, but the current crowded conditions and high rents are changing this trend. Very little development is possible on the south bank of the Monongahela because of the steep ridge which runs near the river's edge. Because of this the Pittsburgh Department of City Planning is concentrating its expansion efforts along the north bank of the Allegheny, and on the advice of the planning department I picked this area for my site.
A major step in this expansion effort will be the completion of the parkwall which will circle the downtown. This parkway will ease the shore's accessibility problem and allow it to become a vital part of downtown. The numerous projects being developed on the north shore are also a part of this effort. Among the projects being considered are office complexes, a recreational shopping center in the spirit of Quincy Market, and a convention facility. One of the larger projects is the Three Rivers Stadium Project which will include hotel and retail facilities, a children's theme park, a technology mart as well as a science and technology center. These projects on the north shore are also part of the city's efforts to develop its river banks which are currently neglected.

At the suggestion of Fred Swiss, the architect for the department of city planning, I chose as my site the area just to the east of the proposed parkway. In order to design my project I am treating this parkway as an already built given. This site is bordered to the east and north by the parkway, to the west by an old railroad bridge, and to the south by the river. There is a steep ridge running along the northern end of the site with the rest of the area being fairly flat.

Access

Entrance onto the site would be off a road running parallel to the parkway on the north side of the site. Being fairly close to parkway exits will make it easy to get to from all portions of the city, and being highly visible, its location will be well known to the people of Pittsburgh.
Visibility

Bordering on the parkway and the river gives a high degree of visibility to the site. It will be seen from all directions and from a variety of levels. The height of the parkway as well as views from downtown buildings will make the roof plane a very visible part of the building. The river edge, which can be seen from downtown, will be of major importance.

Views from the site, with their varied levels of desirability will pose many questions in terms of enclosure and view. The river bank, with its view to the skyline, will be an asset while the parkway will demand solutions which demand controlling and directing views.

River Connection

Access to the river, both visual and physical will be of major importance to my project. The city is currently trying to create a green belt of land along the river. I see in my project the potential both to provide access to this green belt and to create an area where this belt expands to become a more usable space.

Also of importance will be the river's reflective potential and the ways it can be combined with glass and light to create an exciting river front view. I will use the river as a place to explore the various levels of physical and visual interaction glass can provide.
Day/Night

One other aspect I wanted to consider was the difference in the daytime and nighttime views both to and from the site. Interior and exterior lighting as well as the reflectance of both the river and the glass could make this a very exciting consideration.

Possibilities for using this potential include using a variety of materials near the waters edge, casting beams of light and shadows on the water, and projecting parts of the building into or above the water.
SCHEMATIC DESIGN

There were three main ideas which determined the overall form of the museum. The first related to the varied degrees of enclosure within the building. The north and east sides of the site required a high level of enclosure to serve as visual and acoustical barriers along the parkway. The south side of the site, on the other hand, needed to be very open to take advantage of its river contact, views to downtown and solar exposure. This contrast of needs worked well with my thoughts on the potentials of glass and led me to conceive of the whole building as an exploration into the issues of enclosure.

Secondly, I divided the various areas and functions of my building into three levels of understanding or knowledge. The highest level, that of research was grouped into one area while the next highest level, that of education served as a blending place between research and exploration, the third level.

Next the idea of arranging the exploration or exhibit gallery portion of the building along a time line was overlaid with the idea of specific nodes to study the various physical properties of glass.

The combination of these three ideas resulted in this schematic concept and served as the catalyst for my next design decisions.
Orientation

The issues dealt with here included site access (both visual and physical), solar orientation, river interface, and views to and from the Golden Triangle. Also of interest was the need for separate parking for the research center and the idea of using the ridge to block views of the parking lots from the road.

Enclosure

At this point I began to investigate how the enclosure needs of my program and my site could complement each other. I arrived at a scheme where two very enclosed areas buffered the less enclosed entry and south side of the building.
Structure

The idea of variations of enclosure evolved into the use of two separate structural systems in the building—concrete bearing wall and curtain wall.

Circulation

This shows how the building has two separate circulation systems. The system for the research center is very simple, while the museum system allows for many different patterns of movement.
DESIGN DEVELOPMENT

At this point I began to incorporate my thoughts about light, views and enclosure into the further development of my design. The following pages are my thoughts and sketches, investigating the effects I wanted to achieve in various portions of the building and the methods of achieving these effects.

Hall of Objects

Since this hall is the beginning of my museum sequence I felt it needed to create a draw to and through it. I wanted the visitors' journey through this hall to begin fairly slowly, giving them time to observe each item on display as a separate unique experience, in response to the handmade way they were created. Following the historical sequence of glass production the items are placed closer together as glass became more common with the advent of blown and molded glass. The only light in this hall will be from the cases containing the displays so that attention will focus on the cases and items on display rather than the space. This will also cause the hall to become brighter as it nears the end and the cases are placed closer together. The hall terminates in a wash of light against the back wall which will draw visitors to the adjoining acoustical gallery.

Increasing speed of experience
Acoustical Gallery

I felt a tribute to Gothic Cathedrals was needed in my museum because they represent the first major use of glass as a building material and are also a very strong and unique usage of glass. Among the most noticeable effects of Gothic Cathedrals is their use of light and color and the almost translucent appearance of their thick glass with its many imperfections. I wanted this space to be more an abstraction of Gothic Architecture than a direct translation, so I have made it a very simple space with emphasis on light, color, verticality, and materials.

I felt that by making a strong statement with this space and using the ability of stained glass to enclose and cut one off from the outside world, I could create an exciting, interest generating space in which to begin the exploration of the properties of glass. Aside from the strong visual statement it makes, the combination of glass and stone in Gothic Architecture has a unique acoustical impact. For this reason I chose to house the participatory exhibits on the acoustical qualities of glass in this space. There will be a strong acoustical contrast between the adjoining carpeted and plastered halls and the glass and concrete gallery, so visitors will be exposed to the acoustical variations materials can produce even if they choose not to participate in the exhibits.
Hall of Views

Up to this point no views to the outside have been allowed into the exhibit sequence. I introduce the idea of penetrating the wall surface with small windows punched out of thick surfaces in a random manner. At varied intervals views will be allowed. These views will be strongly controlled by the placement and size of the openings as well as the thickness of the concrete bearing wall. All of these methods will allow me to penetrate the wall facing the parking lot without ruining the aesthetic quality of the views. The hall will be well lit at eye level but become dimmer overhead so the wash of light from the highly placed openings can be perceived and appreciated. On display in this hall will be glass items produced from 1200 to 1900.
These galleries introduce the idea of curtain wall construction and the lack of visual and physical enclosure it allows. In order to fully explore this openness, I wanted to allow views to take place between a variety of different interior spaces as well as between interior and exterior areas. Openings of floor and ceiling planes were also desired in order to reinforce this openness. Removable panels are used in parts of these walls so that different glass types can be displayed within the context of the building.
Hall

I felt the main hall in the research center should somehow reflect or enhance the movement of the people traveling through it. For this reason I decided to use tall thin windows to take advantage of the direct south light to cast beams of light across the floor and opposite wall. This will create a sense of rhythm and, at the same time, these openings will cause the views one sees to mirror one's own movement. I wanted to create a variation in the light pattern across from the administrative offices in order to provide a sense of destination for people entering the hall from either end and used a large sliding glass door in order to do this. By providing this opening I created the only full view of, as well as access to, the courtyard adding to the sense of destination.

Library

In the planning with the architects in order to provide a view with a view to the south we decided to open the east wall to maximize the views. I also wanted to provide the maximum view from the interior of the highly stressed heavy poster adjoinin...
Library

In this space I wanted to combine good lighting with a very enclosed, private atmosphere. In order to do this I used glass block on the south wall to diffuse the direct light coming in to the adjoining hallway. On the north and west walls I placed windows high in the wall to maximize light penetration into the space. I also used windows placed at eye level to provide views. In order not to distract attention from studies I used these windows in a highly controlled manner. Low walls are used inside the space to block the window and its adjoining study area from general view, and heavy planting is used outside the window to contain the view and limit viewing distance.

Diffusion of light

Deep penetration of light
Conference Room

I wanted this room to feel like it was more a part of the courtyard than a part of the rest of the building. In order to do this I extended the room past the adjoining rooms and made it glazed on the garden side. Wrapping the glass around the corners and keeping all the doorways to the building side of the room enhances the sensation of protruding out of the building and into the garden.

Control of views by opaque walls

Control of views by translucent walls

Control of views by position

Storage Spaces

Shielding these areas from public view was one of my main concerns in their design. This was done by using either opaque walls, glass block walls (which allowed for light transmission without allowing for visibility), or as in the case of the research delivery area, counting on the placement of the plane to prohibit views.
BIBLIOGRAPHY

Technical and Historical Research


Programming


Building Examples Research


APPENDIX

This appendix contains overviews of the various subjects which were part of my preliminary research. Through these studies I became familiar with the potentials and uses of glass and was able to identify the factors which I decided were most pertinent to my thesis.
LIGHT

One special quality of glass is its ability to transmit light. Light can be used in many ways to create spacial division, spacial hierarchy, and visual or physical movement through space. While looking at building examples I identified a few of the basic methods by which glass is used to create these spacial definitions.

Hierarchy

The light source in a space will generally attract attention and can therefore be used to place emphasis on particular items or areas within a space. The reverse can also be true and an area shielded from light can become the focus.

Division

Contrasting light levels within a space will result in spacial division.

Movement

These areas or light sources can be used to create a sense of movement either by repetition or using the light as a destination.

Divisions in the glass area and their resulting shadow effects can be used to enhance this sense of movement.
VIEW TYPES

Allowing views to take place between spaces is one of glass' most important contributions to architecture. In my research I saw many different ways in which views were used to achieve a variety of architectural effects. In order to further understand these usages I looked for similarities in purpose and arrived at six categories of basic view types: no view, controlled view, panorama, variable view, repetitive view, and distorted view. For each view type I made observations as to why they were used and the methods by which they were achieved. This breakdown gave me a method by which to analyze my use of views and the ways in which they affect the spaces within my building.

No View

Glass is used in ways which let in light while providing no view in order to maintain sense of enclosure, privacy or protection or to avoid unpleasant views. Two ways by which this is done is to place windows in a manner which hides the views or to use a glass type which blocks the view or distorts it to the extent that it becomes unrecognizable.

CONTROLLED VIEW

Views which are controlled or directed are used for a few different reasons. One of these is to emphasize a particular view. By controlling a person's view you can control the aspect of time at which a specific thing is seen. Another reason to control a view is to limit stimuli in order to keep a view from distracting or interfering in a space's activities. This type of view can be frustrating if you want or need to see more than you are allowed, but it can also be a great asset when used to provide unexpected and exciting views. The following are a few samples of the way views can be controlled.

Viewer Control

Opening Control
Panorama

A panorama is a view which offers a wide field of vision in one or more directions. It can be used to allow the view observed to become either a continuation/extension of the viewing area or to serve as a backdrop to that area. A panorama view can reduce feelings of enclosure and seem to open up cramped spaces.

Distorted View

There are a wide variety of glass types available that produce visual distortion. By affecting the clarity, color, brightness, or size of seen objects, these glass types allow various degrees of privacy and enclosure to be created. One great asset of these glass types is that they can alter or disguise views to allow privacy while still maintaining a visual connection with another space, lessening the sense of enclosure.

Degrees of Distortion

Variable View

A variable view is a view that can change in appearance for a variety of reasons. This type of view is used to give variety to a space or to suggest a hierarchy of positions within the space. It can also be used as an incentive for or a recorder of movement.

Repetitive View

Any view type or combination of view types can be used in a repetitive manner. This repetition can be used to enhance the sense of movement through a space or to aid in orientation.

Orientation

Sense of Movement
ENCLOSURE

The transparency of glass and the view and light transmission it allows results in its very unique ability to effect the visual and psychological enclosure of space.

Investigating the issue of enclosure I looked at the three building planes to see how the effects of enclosure varied from plane to plane.

Wall Plane

Wall planes can be manipulated in many ways to create spacial containment. This is the most important plane to consider when dealing with privacy or movement and is also the plane most often associated with views.

Ground Plane

Enclosure in this plane is very important because it relates to a feel of stability. Lessening the enclosure in this plane can be good for creating excitement or making a strong impact but if done improperly can result in nervousness.

Containment

Sky Plane

This is the plane which relates to the idea of shelter. The more private a space is the more overhead enclosure is needed. Variations in this plane using light and views can create very strong spacial effects.

Stability

Shelter
The degree of enclosure created by a glazed opening in a plane can be affected by a variety of issues. The following are four of the more common methods used for altering enclosure.

**Transparency of opening**

**Placement of opening**

**Size of opening**

**Divisions in opening**
Solar

Glass is unique in its ability to directly admit solar energy into spaces. This can be either a positive or negative feature depending on how it is used and controlled. Orientation, shading devices and various kinds of glass are used to alter and control solar heat gain.

Well controlled heat gain can make spaces comfortable and produce warm, friendly surfaces, while poor control can result in extreme discomfort.

Thermal

Glass is very conductive to heat. Because of this it is impersonal or even uncomfortable to the touch. The thickness of a glass pane does not affect a window openings R rating much at all. The air space between panes of glass is what produces the major differences in thermal efficiency.

Thermal Glass Types

Single Glazed

Triple Glazed

Non-reflective low emissivity coatings

Tinted and reflective glass which control heat gain and loss.

Glass fibers used as an insulation material.

Acoustical

Acoustically glass is a highly reflective material. Too much glass, if not used in combination with absorptive materials can create acoustically harsh spaces. The reflectiveness of glass can be an asset however, when used to avoid a feeling of acoustical deadness in highly absorptive spaces. The sound absorption of glass can be altered, but only slightly, with plastic composites.

The sound transmission of a pane of glass depends on the thickness of the glass and the air leakage around it.
Strength

Glass has a very unique molecular composition. Unlike other solids which have a sharply defined structure, glass atoms are joined together in an almost random fashion resembling the structure of a liquid. This random structure causes variations in strength both within a piece of glass and between various pieces. Because of this strength measurements of glass are based on statistics or probability of breakage. For most purposes 8 breakages per 1,000 panes at a set maximum stress is the accepted standard.

Glass has 8 to 10 times the strength in compression that it does in tension. Some people hold the theory that glass always fails in tension (when tension in some point is high enough to make it fail).

There are three basic strengths of glass; annealed, heat strengthened, and tempered.

Annealed
5,000-6,000 psi
Remains in frame if broken
Breaks into sharp shards

Heat strengthened
Is twice as strong as annealed
Remains in frame if broken
Resists thermal stress
Cannot be fabricated in the field

Tempered
Is five times as strong as annealed
Crumbles into small particles if broken
Resists thermal stress
Cannot be fabricated in the field
Used as a safety material

Other strengths can be achieved by reinforcing with other materials.

Laminated: two or more glass panes with vinyl inner layer.
Glass stays in frame when broken
Used for sloped or overhead glass

Glass with metal screens
Does not increase strength of pane
Remains in frame if broken

Durability

The durability of glass is one of its most distinctive qualities. Glass is a non-porous, non-absorptive material and is impervious to common elements and many harsh chemicals. Alkaline solutions however, will attack glass and cause changes in the surface. Glass will retain its color and shape over long periods of time and is very resistant to abrasion and surface scratches.

Because glass does not show wear it does not become shabby with age, but at the same time, it does not convey the "human" or comfortable feel some materials can when they show patterns of use. Glass is good for formal, efficient, sanitary surfaces.
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<td>3000 BC</td>
<td>Man learns how to make glass: used for glazing, jewelry, glass jars, glass is considered a luxury item</td>
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<tr>
<td>300 BC</td>
<td>Phoenician's discover blowpipe. Glass becomes cheaper, more available</td>
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<tr>
<td>200 BC</td>
<td>Begin blowing into molds</td>
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<td>100 BC</td>
<td>Romans first to use glass for windows: very rarely done</td>
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<td>1 AD</td>
<td>Romans produce first glass that is mainly transparent, colorless and fairly free of bubbles</td>
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<td>700</td>
<td>Syrians discover a new way to make sheet glass. Product is called Crown Glass. This is the most common method used to produce sheet glass until the 1800's</td>
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<td>1000</td>
<td>Venice becomes center of glass manufacturing. Best glass blowers</td>
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<td>1200</td>
<td>Use of glass in Gothic Cathedrals. The glass is fairly crude, its many faults and bubbles adding to its luminous quality</td>
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<td>1500</td>
<td>Tudor windows, small panes and mullions used in many combinations. Elaborate fenestration in many large Elizabethan Houses. Made from Crown Glass—the slight curvature of this glass produced interesting visual effects.</td>
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<td>Venetians produce &quot;Cristallo,&quot; forerunner of optical glass. It is very transparent and colorless</td>
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<td>1590-1610</td>
<td>Europeans develop principals of microscopes, telescopes, and thermometers</td>
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<tr>
<td>1700's</td>
<td>French perfect method of casting sheet glass</td>
</tr>
<tr>
<td>1790</td>
<td>Learn how to achieve homogeneity in glass by stirring molten glass with ceramic rod (annealing)</td>
</tr>
<tr>
<td>1800</td>
<td>Begin use of glass pavement light. Able to direct path of light</td>
</tr>
<tr>
<td>1800's</td>
<td>Greenhouses, conservatories, winter gardens become popular. Industrialization of parts results in cheap, quick construction</td>
</tr>
<tr>
<td>1810-1818</td>
<td>Ridge and furrow glazing method developed</td>
</tr>
<tr>
<td>1850</td>
<td>Crystal Palace built in London (Joseph Paxton)</td>
</tr>
<tr>
<td>1889</td>
<td>Galerie des Machines built in Paris (contamin)</td>
</tr>
<tr>
<td>1896</td>
<td>Tietz Department Store built in Berlin. Four story plate glass facade</td>
</tr>
<tr>
<td>1890's</td>
<td>Glass block introduced. Breaks up direct sunlight—gives good distribution of light</td>
</tr>
<tr>
<td>1900</td>
<td>Scientific and mechanical era of glass making begins</td>
</tr>
<tr>
<td>1903</td>
<td>Owen's automatic bottle machine developed</td>
</tr>
<tr>
<td>1907</td>
<td>Keppler system of glass and concrete construction potential, can make concrete with almost the same expansion coefficient as glass</td>
</tr>
<tr>
<td>1910</td>
<td>Heat resistant glass developed</td>
</tr>
<tr>
<td>1913</td>
<td>Insulated glass lens patented</td>
</tr>
<tr>
<td>1918</td>
<td>Hallidie Building—San Francisco W.J. Polk First plate glass facade in U.S.</td>
</tr>
<tr>
<td>1920</td>
<td>Mass production becomes possible because of new methods of continuous melting and automatic shaping</td>
</tr>
<tr>
<td>1930's</td>
<td>Glass becomes used as a heat insulation material.</td>
</tr>
<tr>
<td>1930's</td>
<td>Production of green tinted glass which absorbs solar heat and reduces amount of heat transmitted to interiors. Distorts colors</td>
</tr>
<tr>
<td>1936</td>
<td>Glass fibers for textiles marketed</td>
</tr>
<tr>
<td>1940's</td>
<td>Tempered glassware becomes available. Increases strength of glass 300-600%</td>
</tr>
<tr>
<td>1945</td>
<td>Double glazed insulating units with sealed airspace marketed. Reduce heat loss by about one half</td>
</tr>
<tr>
<td>1947</td>
<td>Electrically conducting glass produced</td>
</tr>
<tr>
<td>1950</td>
<td>United Nations Secretariat Building</td>
</tr>
<tr>
<td>1951</td>
<td>General Motors Technical Center</td>
</tr>
<tr>
<td>1952</td>
<td>Lever House. First use of tinted glass as a design and environmental control method. Twenty-one stories</td>
</tr>
<tr>
<td>1955</td>
<td>Gray and bronze tinted glass produced, darkens but does not distort colors</td>
</tr>
<tr>
<td>1963</td>
<td>Reflective glass introduced</td>
</tr>
<tr>
<td>1970</td>
<td>Structural silicone glazing methods</td>
</tr>
</tbody>
</table>
BUILDING TYPE STUDIES

In these studies I read about and looked at a few selected building types. I collected information and analyzed the ways glass was used in these buildings and the reasons behind the various uses and innovations. This served as a starting point for understanding the many potentials and unique capabilities of glass.
Gothic Churches

Gothic Churches were built at a time when light was equated with good and knowledge, so the buildings were made to admit large amounts of light without interrupting the enclosure of the space.

<table>
<thead>
<tr>
<th>Topic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximize glass</td>
<td>Use large areas of glass—made possible by new construction techniques—pointed arches, flying buttresses. First introduction of glass as a major building component. Connect small pieces of glass with lead.</td>
</tr>
<tr>
<td>Color and Irregularities</td>
<td>Rigid iron bars hold small panes in place No visual connection to exterior.</td>
</tr>
<tr>
<td>Luminous quality of glass</td>
<td>Caused by irregularities in glass. Bubbles and flaws could not be eliminated by crude technology available—used by artist, gave subtlety and variety to windows.</td>
</tr>
<tr>
<td>Attempt to simulate gems</td>
<td>Weathering—roughened exterior surface of glass enhanced its effect. Most common colors—ruby-red and sapphire-blue.</td>
</tr>
<tr>
<td>Communicate Stones/ideas</td>
<td>By pictorial arrangement Used almost as billboards for guilds.</td>
</tr>
</tbody>
</table>
Arcades

Arcades were built as a way to get people away from the heavy traffic of the city and into a place where they could shop. They also protected people from the elements and closed or glazed arcades, which were usually used for the sale of luxury items, needed to promote a luxurious atmosphere. It was "not enough to save pedestrians from the distress and anxiety of the street...had to catch him up in the magic and forget everything else" dependent on the ability to "build an arcade as bright as an open space, warm in winter, cool in summer, always dry and never dusty."

Provide protection from the elements while still providing daylight

Widen arcade

Skylights
Central skylight---center spaces of arcades
Oblong skylight
Continuous skylight---appropriate for transitional nature of arcade

Admit more daylight

Wrought iron construction instead of wood

Use vault form---able to cover space without tall supporting members
Greenhouses

Greenhouses were originally developed to allow for the single purpose of growing plants in the winter and in foreign climates. As they evolved they also became social spaces used for entertaining and hobbies and were a symbol of high social status. Their ability to use standard parts, and to cover areas quickly, cheaply and aesthetically led them to be used as public buildings and later to be mass produced and used in the homes of the middle class.

Admit direct sunlight

Large, operable windows on the south side of the building

Slope glass wall to admit more light—best sun penetration when wall is perpendicular to sun. Slope varied with latitude.

Curvilinear glass roof—perpendicular to sun at various times

Ridge and furrow glazing—perpendicular to both morning and afternoon sun

To admit more sunlight

Domes and semidomes—
Wrought iron structure—less area for structure, more area for glass
Larger panes of glass

To retain heat

Oil paper on glass to act as double glazing
Canvas curtains on windows
Massive masonry back walls

For enjoyment, moral benefits

Attached conservatories, make greenhouse an extension of the parlour

For prestige

"Architectural" conservatories—incorporate plasters, cornices, friezes etc. in design. Some become very elaborate

Economy

Mass production of parts—glass panes and iron of standard sizes
Dry glazing techniques
Shops

Shops are built with the major intentions of attracting attention, displaying goods and producing imagery which appeals to potential clients.

<table>
<thead>
<tr>
<th>Display of goods</th>
<th>Use of bay or curved windows to gain display space</th>
</tr>
</thead>
</table>
| Exterior viewing | Use of larger and larger panes of glass in shop windows as technology makes them available  
Non-reflective glass and glass set at angles to avoid reflectance |
| Interior viewing | Glass display cases |
| Attracting attention | Variable facade: display or facade which can change easily and always seem "new" |
| Visible at night  | Interior lighting--see display at night  
Changes in illumination can make glass seem either solid or transparent |
| Persuade customer to enter--smooth transition from street to shop | Glass doors  
Vestibules |
| Persuade customers to stay | Add to visibility of goods |
| Illusions | Mirrors--increase apparent size of space  
Lights |
| Security | Screens, shutters, security glass |
Office Buildings

Office Buildings are usually built with maximum economy in mind, occasionally however, this is less important than the presentation of a certain image. Also important in design considerations is the provision of an environment which is healthy and conducive to productivity.

Maximize economy

- Fenestration based on the breaking down of bay size. (also good for flexibility)
- Try to eliminate glass size variations in the building
- Production of standard window sizes

Avoid direct sunlight in spaces

- Long axes run west to east giving south and north exposure
- Transom to direct light to ceiling
- Sun blocks outside of building (moving or fixed)

Thermal protection

- Thermopane
- Double glazing (3/4" airspace good)
- Weather stripping

Ventilation

- Fixed windows
- Forced air

Cleaning
I spent quite a bit of time thinking about what the idea of a thesis meant to me and what I wanted to gain from this year before deciding upon a thesis project. I feel that thesis is not just an opportunity to do a larger or more complex project than I have done before. Although, in the end I will design a project, the real importance of my thesis is what I will design the project from and the conclusions and body of knowledge I will arrive at through the research of a certain area. It is also the investigation of what I believe to be important in architecture. This attitude led me to decide two things. First, that a good portion of my time should be spent investigating and evaluating my thesis both as it involves my project and separately from the project. Second, that my thesis should involve an area of study which will be directly applicable to a wide variety of projects, not just the one I chose as an example. Being given three quarters to investigate a subject is a rare opportunity and should be used in a way which will contribute to my general as well as specific knowledge of architecture. Recently I have felt a void in my knowledge of building materials, how buildings go together, and the impact of specific materials in the making of architectural space. I feel this knowledge is essential to the ability to create good architecture, and therefore have decided to base my thesis on an investigation of building materials.

My thesis is that, through variations in usage, one material can take on different qualities. Where a material is placed, what it is used with, and how it is used affect both its architectural abilities and the way it is perceived by people. My research will concentrate on how a material can be used in a variety of ways to create changes in the perception of itself and of space. My research will involve library research, visiting of spaces, the use of large and small scale models, and interviews.
In order to narrow the scope of my project I have chosen glass as the material I will investigate. Glass has been used as a building material since Roman Time, but its use as a major building component began with Gothic Cathedrals. Used mainly for its decorative abilities in Gothic Architecture it has since been used in a wide variety of ways which exploit its many other unique qualities. Forcing houses, such as those built by Joseph Paxton took advantage of the ability of glass to transmit light while early storefronts changed style in order to exploit the increasing visual clarity improved glass technology was producing. Semi-prism blocks were used in sidewalks to direct the path of light deep into basement areas. This usage as well as many glass and concrete roofs, such as the porte cochere at the Savoy Hotel, explored the structural abilities of glass. As the acoustical and thermal abilities of glass were improved architects became free to use glass in increasing amounts. Many houses of the Modern Movement, such as those by Phillip Johnson and Mies van der Rohe, show this new freedom. Also important at times has been glass' reflective ability. One of the unique qualities of glass which is becoming increasingly important in architecture today is its ability to resist corrosion. This asset, along with other factors, has led glass to become a popular material for building skins. Many skyscrapers, such as those by S.O.M. and The Los Angeles Silvers, are examples of this usage.

My research will begin with looking into the various uses of, and technology associated with, architectural glass. I will investigate the development and evolution of glass in architecture, its present uses, and projections for the future. These specific uses will then be evaluated in terms of their effect on the sensory properties of the material (touch, acoustics, visual, lighting, thermal, degree of enclosure, etc...) and how these properties contribute to the overall architectural experience of the space. The information will be divided further into the three building planes (wall, floor, ceiling) and the impact the placement of glass in these different planes has on its perception. My end evaluation of the effect of separate uses will be based on both subjective and objective issues. During the investigation process subjective opinions will be obtained through responses of people to questions asked while visiting buildings and viewing models, samples of materials and perhaps videos.

A museum of glass technology is the project I have chosen as the design method of investigating my thesis. The museum will be organized along a progression through time and technological change. Exhibit space may be provided for the showing of glass and its history, but the main exhibit will be the building itself. Participation or "hands-on" spaces and exhibits which will allow visitors to interact with the building will be provided for. These spaces will be designed to create a greater awareness of glass as a material and of its potential and past uses.

I felt that a museum of this type should be located in a fairly large city in order to attract visitors. I also felt that the city needed to be one that had some connection to the glass industry. For these reasons I am currently considering Pittsburgh, Pennsylvania as the location for my museum. I have not yet picked a specific site, but I will be looking for an area inside the city so it will be accessible but also on a site large enough that the unique indoor/outdoor relationships glass offers can be explored.