SACRED LIGHT

Lighting Sacred Islamic Architecture

Hochschule Wismar

MASTER THESIS
In Architectural
Lighting Design

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2010

ACKNOWLEDGEMENT

Above all, I thank Allah (GOD) for granting me the sense of sight and vision. Without them it would have been impossible to appreciate light which is one of Allah's greatest creations.

I would like to thank my parents, my wife, and every onewho helped me for their great support throughout my entire studying period.

Special thanks and respect to:

Prof. Thomas Römhild
Ralf wershoven
Volker Von kardorff
Hosam Abdulkarim

LETTER OF DECLARATION

To whom it may concern,
By this letter I confirm that the content of the following Master Thesis was written by me,

Abdulaziz Al-Azem

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01 Abstract

ABSTRACT

Light is one of Allah's (God) greatest creations. Because of light we can see and perceive the beauty of nature and get inspirations to invent, build and even to write. Without light there will be no life.

The relationship between light and the religion of Islam is as old as Islam. The impact of light on Islam lies behind its significant importance on both the religious and social aspect. Muslims needed to know the times of the daily prayers that depend on the sun's position; and the moon's cycle for the Muslim lunar calendar.

From these religious motivations, light became a main concern for Muslims scholars a thousand years ago and what they produced lasted for centuries.

Since the birth of Islam, the mosque was the most important building due to its function where Muslims perform the second pillar of Islam which is praying.

After defending the mosque and its Major architectural characteristic, a deep analytical study of historical mosques from different periods and locations focusing on the Middle East region, and an overview of the use of natural and artificial lighting will give the best impression on how mosques were lit and how they should be lit in the present day.

After case studies and analysis, we can conclude with a comprehensive light guide which can be used as a design tool to create a proper lighting design for existing mosques and future ones. There will be no future without a past. By learning from the past, a better future is perceived.

02 Introduction

IDENTITY OF LIGHT
Light In History

Light has become a fundamental definition of our human lives since the dawn of humanity on earth. The cycle of the day and night has fascinated the early humans who started thinking about the nature and true substance of light. Greek philosophers spent years observing light movement and trying to analyze it origin and its components. Islamic scholars have added to these studies precious observations that helped the western scientists in defining rules for the movements of lights. Since the discovery of light, humans tried to control the flow and intensity of the light to use it in everyday life. Many attempts to understand light were made in the 16th and 17th centuries by reputable scientists such as Galileo Galilei, Johannes Kepler, and Renes Descartes. Descartes, for example, developed the law of refraction that corroborated with other finding of other scientists independently. In everyday life usage of lights, house windows were directed to the direction of the sunrise to capture the highest amount of light possible. During the night, history has provided different type of artificial lighting (lamps and other instruments of lighting, for example candles that date back to about 400 A.D.) that the humans used and developed to conquer the absence of light during night times. In current times, light has two sources 'artificial' and 'natural'. The endeavor of the lighting designer is to make the best use of the combination of both in creating a perfect combination of light revealing spaces.

Light And Religion

Early humans observed that the sun is the source of all life on earth. For that, they regarded themselves children of the sun and started to worship it throughout the early civilizations. For example, Stonehenge that was built on the Salisbury Plain (England) between about 20001500- BC was regarded as an important icon for early religions. In the ancient scripture of the Jews, we can find references to the sacred light on the face of Moses having spent time praying in the mountains for God. These references indicate a close relation in the ancient human thought between God and light (Sun). Coming closer in history, Christianity lays a clear unification between religion and light. In many of the Christian scripture, we can find “God is light”, “Let there be light”, and “Light of life” sayings and many other references that indicate the importance of light in Christian religion. Also in the Christian architecture of the churches, the architectures used mosaic and gold to create what is referred to as ‘inner light’ that gives a special effect of the presence of sacred moments. Coming to our central subject, light in Islam is referred to in many of the Islamic scriptures. A Surah for the light “Sourat Al-Nour” refers to Allah as the light of the heavens and the earth. The architectural side of Islamic lighting shows innovation and appreciation of using an appropriate combination of artificial and natural lighting to provide for the illumination of mosques and other Islamic structures. Many of the mosques designers have invested a lot of efforts to build an eye capturing designs of windows and interior reflectors to create the desired effects for peacefulness and calmness.

Light as a source was one of the most elements which Muslim scientists focused on, due to its importance in the secular and sacred daily life activities. A list of some contributions to the science of light reflects how important light was in the Islamic society.

> *“Science and technology, in some shape or form, exists and develops within all types of societies in the context of all shades of religions belief. Muslims have made many important and far reaching contributions to the development of our shared scientific knowledge and our technology”.*
>
> ***Sir Roland Jackson**.*

Camera And Vision

> *Light issues in all directions opposite any-body that is illuminated with any light (and of course, also opposite any self-luminous body). Therefore when the eye is opposite a visible object and the object is illuminated with light of any sort, light comes to the surface of the eye from the light of the visible object*.

10th century Ibn al-Haitham from his Book of Optics

Arab astronomer and mathematician Latinized as Alhazen, in full, Abu Ali al-asan Ibn al-Haytham, mathematician and astronomer who made significant contributions to the principles of optics and the use of scientific experiments.

MAJOR WORKS | Ibn al-Haytham's most important work is Kitab al-mana ir "Optics". Although it shows some influence from Ptolemy's 2nd century ad Optics, it contains the correct model of vision: the passive reception by the eyes of light rays reflected from objects, not an active emanation of light rays from the eyes. It combines experiment with mathematical reasoning, even if it is generally used for validation rather than discovery. The work contains a complete formulation of the laws of reflection and a detailed investigation of refraction, including experiments involving angles of incidence and deviation. Refraction is correctly explained by light's moving slower in denser mediums. The work also contains problem" to determine the point of reflection from a plane or curved surface, given the centre of the eye and the observed point-which is stated and solved by means of conic sections.

In later stages, these discoveries led to the invention of the camera obscura, and Ibn al-Haitham built the first camera, a camera

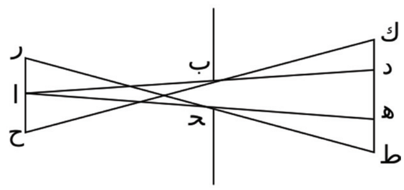


Figure 1: Ibn Al Haytham's observations of light's behavior through a pinhole camera.

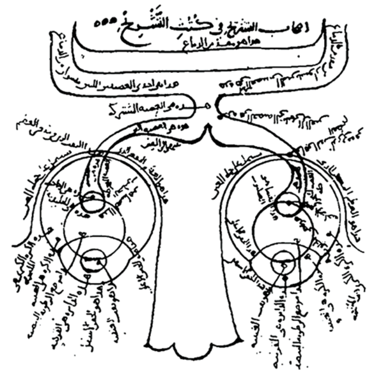


Figure 2: Ibn Al Haytham's studies of the eye gave the first modern understanding of lens, retina and optic nerve, as well as the mechanics of vision and perception

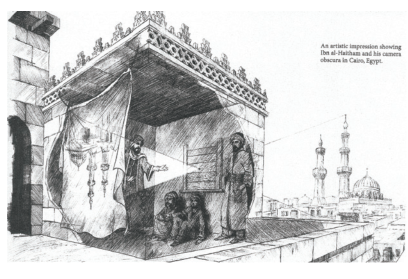


Figure 3: An artistic impression showing Ibn Al-Haitham and his Camera Abscura in Cairo Egypt.

obscura or pinhole camera, in history. He went on to explain that we see objects upright and not upside down, as the camera does, because of the connection of the optic nerve with the brain, which analyses and defines the image.

Time By Light

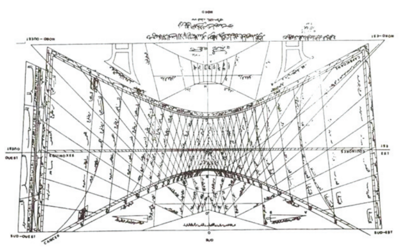


Figure 4: rawing of Sundial in Topkapi Palace, Istanbul, Turky

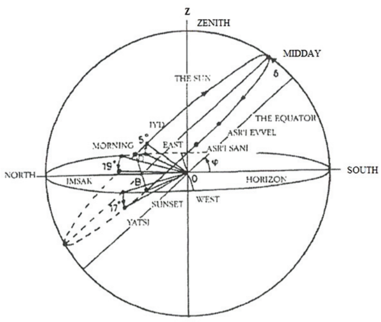


Figure 5: Prayer times according to the Sun.

SUNDIALS I The earliest type of timekeeping device, which indicates the time of day by the position of the shadow of some object exposed to the Sun's rays. As the day progresses, the Sun moves across the sky, causing the shadow of the object to move and indicating the passage of time.

The medieval Muslims were especially interested in sundials, for these provided means for determining the proper times for prayer. Indeed, most Muslim dials contain lines indicating these times, and on a few they are the only lines at all. Although the Muslims learned the basic principles of designing sundials from the Greeks, they increased the variety of designs available through the use of trigonometry. For example, they invented the now-ubiquitous sundial with the gnomon parallel to the polar axis of the Earth. At the beginning of the 13th century ad, Abu al-Hasan al-Marrakushi wrote on the construction of hour lines on cylindrical, conical, and other types of sundials and is credited with introducing equal hours, at least for astronomical purposes.

CANDLE CLOCK | A candle clock is a thin candle with consistently spaced markings (usually with numbers), that when burned, indicate the passage of periods of time. While no longer used today, candle clocks provided an effective way to tell time indoors, at night, or on a cloudy day. A candle clock could be easily transformed into a timer by sticking a heavy nail into the candle at the mark indicating the desired interval. When the wax surrounding the nail melts, the nail clatters onto a plate below.

The most sophisticated candle clocks known to date, however, were those of Al-Jazari in 1206.

Donald Routledge Hill described one of al-Jazari's candle clocks as follows:
The candle, whose rate of burning was known, bore against the underside of the cap, and its wick passed through the hole. Wax collected in the indentation and could be removed periodically so that it did not interfere with steady burning. The bottom of the candle rested in a shallow dish that had a ring on its side connected through pulleys to a counterweight. As the candle burned away, the weight pushed it upward at a constant speed. The automata were operated from the dish at the bottom of the candle.

Figure 6: Al-Jazari's candle clock in 1206.

Astronomy

> *"It is He who made the sun a shining light and the moon a derived light and determined for it phases-that you may know the number of years and account [of time]"* ***10:5 Holy Quran***

By the 9th century, the new Abbasid capital of Baghdad was the world centre of scientific activity, especially in astronomy and mathematics.3 Scholars in that flourishing cosmopolitan city had adopted the knowledge they found in Indian, Persian and Greek sources. Also, in the mid 8th century, the Muslims encountered the astrolabe, a two-dimensional representation of the three-dimensional heavens, and by the early 9th century they were devising new types of instruments (several of which are currently thought to have been European inventions of the 15th and 16th centuries). With remarkable rapidity they created a new science that well merits the appellation “Islamic science” for two reasons. Firstly, the principal universal language of serious innovative science from the 9th century until the 15th was Arabic, and secondly, some of the interests of the Muslim scientists were directed towards the complicated problems of (1) regulating the Muslim lunar calendar, (2) calculating the precise times of the five daily prayers that depend on astronomical phenomena and local latitude and vary from one day to the next, and (3) determining the sacred direction (qibla) towards the Kaþba in Mecca. In particular, the times of Muslim prayer are defined in terms of phenomena that depend on the altitude of the sun above or below the local horizon.4 From the 8th century to the early modern period, Muslim astronomers were foremost in the science of astronomical timekeeping (‘ilm al-miqat in Arabic), of which the determination of the times of prayer constitutes a small but highly significant part. The tools of the astronomer were, in addition to the mathematics of spherical and planetary astronomy, handbooks full of astronomical tables and explanatory text,5 and astronomical observational instruments and mathematical computational devices.6 In particular, Muslim astronomers produced all sorts of tables relating to timekeeping and instrument construction, some serving specific latitudes and others serving all latitudes.

THE ASTROLABE OF NASTULUS | This remarkable astronomical instrument was made by the Muslim astronomer known as Nasᵭulus, who was active in Baghdad between 890 and 930. Its rediscovery brings our knowledge of the activities in that flourishing scientific centre a substantial step further. This type of instrument was previously not known to exist, although sundials based on the same principle are described in Arabic treatises datable to ca. 950 and ca. 1280. It is essentially a mathematical device providing a graphic solution to a problem that was of interest to Muslim astronomers, namely, the determination of the time of day as a function of the solar altitude throughout the year, here specifically for the latitude of Baghdad. The instrument reveals a level of mathematical competence and sophistication that is at first sight astounding. However, with a deeper understanding of the scientific milieu from which it came, it can be seen to be fully within the theoretical competence of the scientists of that environment.
Nevertheless, the spectacular accuracy of the engraving of the principal curves on the instrument is completely unexpected. The instrument also features the earliest known solar and calendrical scales from the Islamic East; the origin of these was previously thought to be in the Islamic West.

Figure 7: The front of Nastulus Astrolabe.

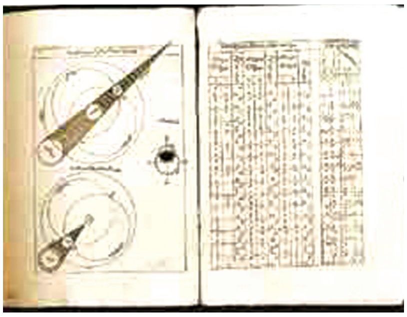


Figure 8: Al-Battani astronomical hand

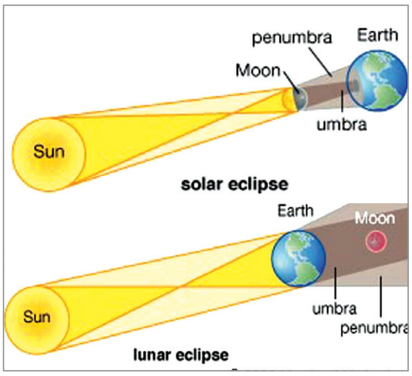


Figure 9: Solar and Lunar Eclipse explained earlier by Al-Battani's astronomical hand book.

ECLIPSES | Al-battani was an arab astronomer and mathematician who refined existing values for the length of the year and of the seasons, for the annual precession of the equinoxes, and for the inclination of the ecliptic. He showed that the position of the Sun's apogee, or farthest point from the Earth, is variable and that annular (central but incomplete) eclipses of the Sun are possible. He improved Ptolemy's astronomical calculations by replacing geometrical methods with trigonometry. From 877 he carried out many years of remarkably accurate observations at ar Raqqah in Syria. Al-Battani was the best known of Arab astronomers in Europe during the middle Ages. His principal written work, a compendium of astronomical tables, was translated into Latin in about 1116 and into Spanish in the 13th century. A printed edition, under the title De motu stellarum ("On Stellar Motion"), was published in 1537.

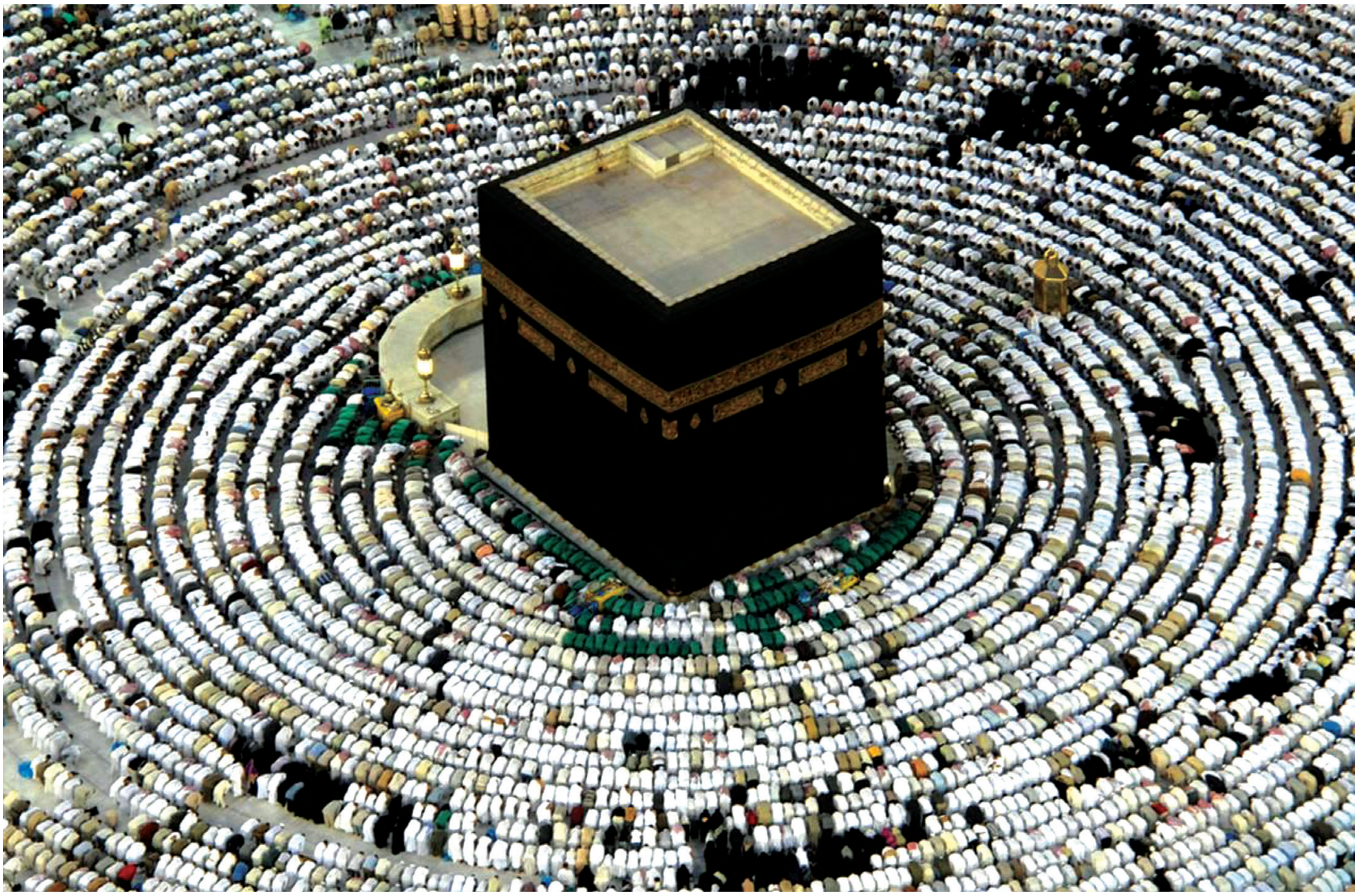


Figure 10: The Kaaba, Holy Mosque of Makkah, Saudi Arabia

03 Theoretical Analysis

The Mosque

The Mosque is a building used for Muslim prayer, the principal unit of Islamic architecture.

The first mosque was the house of the Prophet Muhammad in Medina.

This was a simple rectangular (53 by 56 m) enclosure containing rooms for the Prophet and his wives and a shaded area on the south side of the courtyard which could be used for prayer in the direction of Mecca.

The word 'Mosque' is an English translation of the Arabic term 'Masjid,' which translated literally means 'a place of prostration.
Since worship of God has always been the cornerstone of every religion, places of worship occupy an important position in the daily life of a religious community. This is why the Muslim community has always been attached to the Mosque throughout history in some way or the other.

Several features which were later to become standard features of mosques were introduced at an early stage.

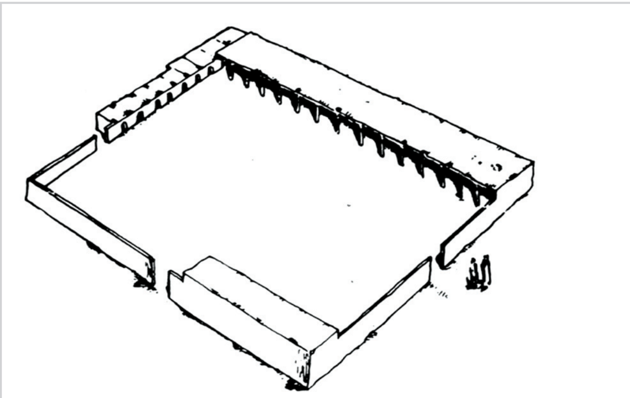


Figure 11:The house and the Mosque of Prophet Muhammad, Medina 622 AD, Saudi Arabia.

Major Architectural Characteristic

PRAYER HALL | The most important room in a Mosque is its main prayer hall. It serves as a centre of spiritual activities.

Since bowing and prostration are essential parts of Muslim worship and prayer, seats are not placed in it. In hot countries mats made from palm leaves are usually used to cover the floor, but in cold countries and in the rich states of the Middle East, it's halls are fully carpeted.

The pattern on the carpet usually has lines running through it to mark the rows in which worshippers stand.

MIHRAB | A niche or marker used to indicate the direction of prayer usually in a mosque.

A mihrab is usually a niche set into the middle of the qibla (the direction of Mecca which determines the direction of prayer.The qibla is the prime factor in the orientation of mosques and is usually marked by a mihrab) wall of a building in order to indicate the direction of Mecca. Within the Mosque it is the site where the Imam stands to lead the congregational prayer. 'Mihrabs' indicate the exact direction for prayer. They are usually decorated beautifully with patterns and calligraphy. This, however, is not essential. In some small house-Mosques it may assume the form of a special mark on the wall to indicate direction.

MINBAR | A type of pulpit usually found in mosques from which prayers, speeches and religious guidance are given.

The Minbar is situated to the right of the Mihrab and consists of a raised platform reached by a set of steps, often there is a door at the entrance to the steps and a dome or canopy above the platform.

The Minbar is one of the earliest architectural features to be identified with Islam. The earliest historical reference to a Minbar states that in 629 the Prophet made a Minbar from which he used to preach to the people. This Minbar consisted of two steps and a seat and resembled a throne.

DOME | A circular vaulted construction used as a means of roofing. Because of its distinctive form the dome has, like the minaret, become a symbol of Islamic architecture.

It seems likely that the dome originated as a roofing method where the absence of suitable timber meant that it was impossible to make a flat timber roof. Domes keep the inside of the building cool and airy. Perhaps architects thought it useful for transmitting clearer communication to the congregation also because when the speaker speaks his voice gets amplified through the dome enabling the congregation to hear him clearly.

SAHN | It's the courtyard of a mosque which plays a very important function in terms of circulation and acts as one of the main sources for gathering daylight.

RIWAQ | Arcade or portico open on at least one side, located on both sides of the courtyard.

ABLUTION FOUNTAIN | Located mostly at the center of the Sahn(courtyard). Its main function is to allow Muslims to perform ablution before prayers.

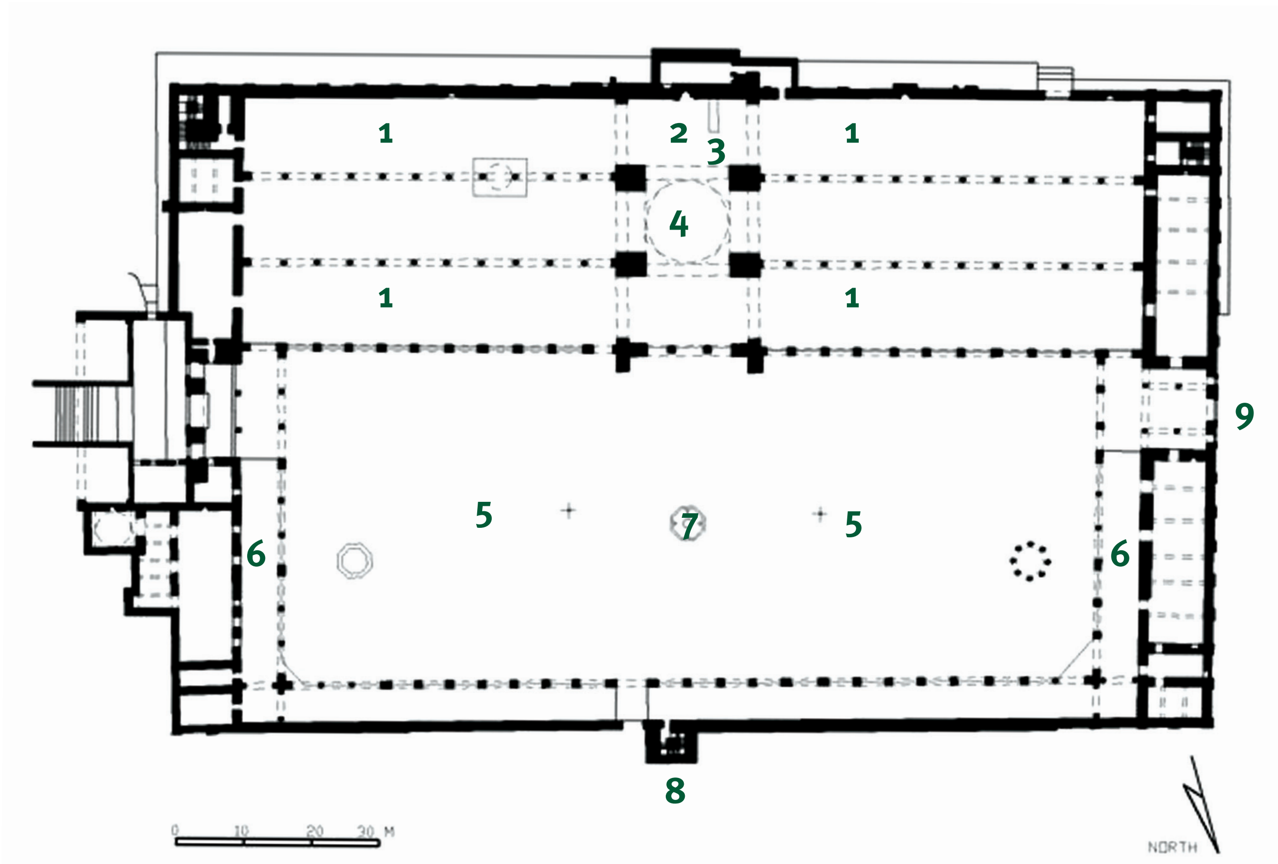
MINARET | A tower-like structure usually associated with mosques or other religious buildings. It often capped with a miniature dome, attached to a Mosque. It used to make the call to prayer (Azan) and nowadays, in the Muslim world, loud speakers are installed at this site to amplify the voice of the 'mua'dhdhin.'Although there are Mosques with four minarets, the common practice is to build one or two minarets only. It is a distinctive feature of a mosque, and one can identify a Mosque by its minaret. Most minarets have a balcony just under the top. In some Mosques the minaret used to make the call to prayer from the balcony.

PORTAL | Mosque main entrance. It is sometimes decorated with Muqarnas projections.

The muquarnas is a system of projecting niches used for zones of transition and for architectural decoration.

Muqarnas is one of the most characteristic features of Islamic architecture and is used throughout most of the Muslim world. Muqarnas is usually associated with domes, doorways and niches, although it is often applied to other architectural features and is sometimes used as an ornamental band on a flat surface.

There are several theories about the origins of muqarnas. Generally the decorative origin and function is favored over the suggestion that muqarnas was the solution to a particular structural problem.



1. Prayer hall
2. Mihrab
3. Minbar
4. Dome
5. Sahn
6. Riwaq
7. Ablution fountain
8. Minaret
9. Portal
10. Muqarnas

Figure 12:Prayer Hall, Al-Azhar Mosque,

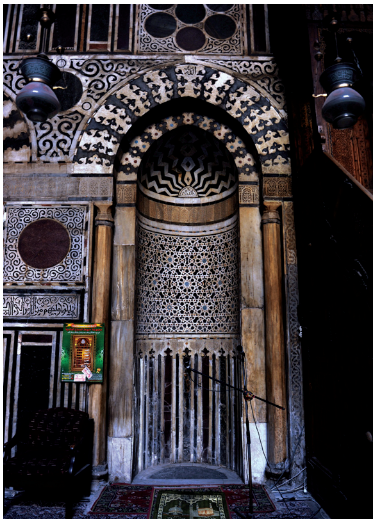


Figure 13: Mihrab, Al-Ghuri Complex,

Figure 14: Minbar, Muradiye Mosque,

Figure 15: Dome, Qaitbay Complex,Cairo, Egypt.

Figure 16:Sahn, Ummayad Great mosque Damascus, Syria.

Figure 17: Riwaq, Sultan Ahmed 1st Complex,

Figure 18:Ablution Fountain, Amr Ibn Al-As Mosque, Cairo, Egypt.

Figure 19:Minarets, Selimiye Mosque Edirne,Turkey

Figure 20: a. Portal, Al-Mu`ayyad Shaykh mosque, Cairo, Egypt

Figure 20: b. Muqarnas detail, Al-Mu`ayyad Shaykh mosque,Cairo, Egypt.

Spatial Behavioral Settings

It is useful to examine the impor tance the Mosque had in Muslim society through its long history. Throughout Muslim history, the Mosque played a central role in the cultural and social life of Muslims as an institution. Although its role has undergone changes from the position it held during the Prophet’s time, it still has a great impact on the life of Muslims, even today. The Mosque, in certain respects, is different from the places of worship of other communities due, mainly, to its inf luence on each and every aspect of Muslim society. The most obvious roles are as: a place of wor ship and a centre of education.

It was, therefore, natural for the Mosque, as a symbol of morality and piety, to become the centre of all activities, color ing the social and mater ial life of the community.

Due to the fact that the major function of the mosque is per forming different group prayers, such as the five daily prayer s and other impor tant ones throughout the year , a clear change in the spatial behavior of the mosque is directly linked to the different number of people enter ing the mosque throughout the different times of the day, giving the space a continuous changing atmosphere.

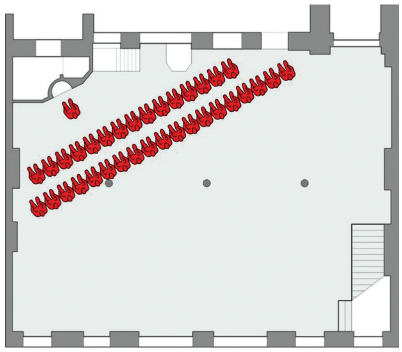
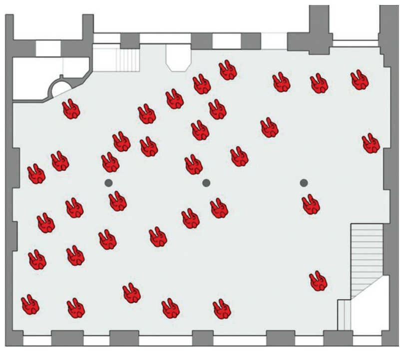


Figure 21: seating distribution during prayers top and before prayers bottom



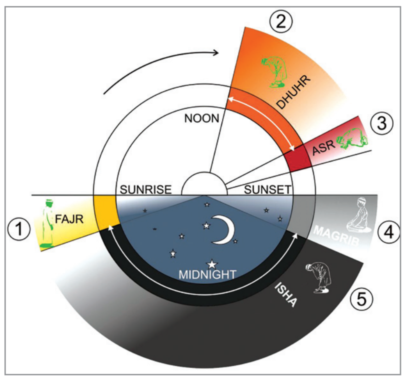
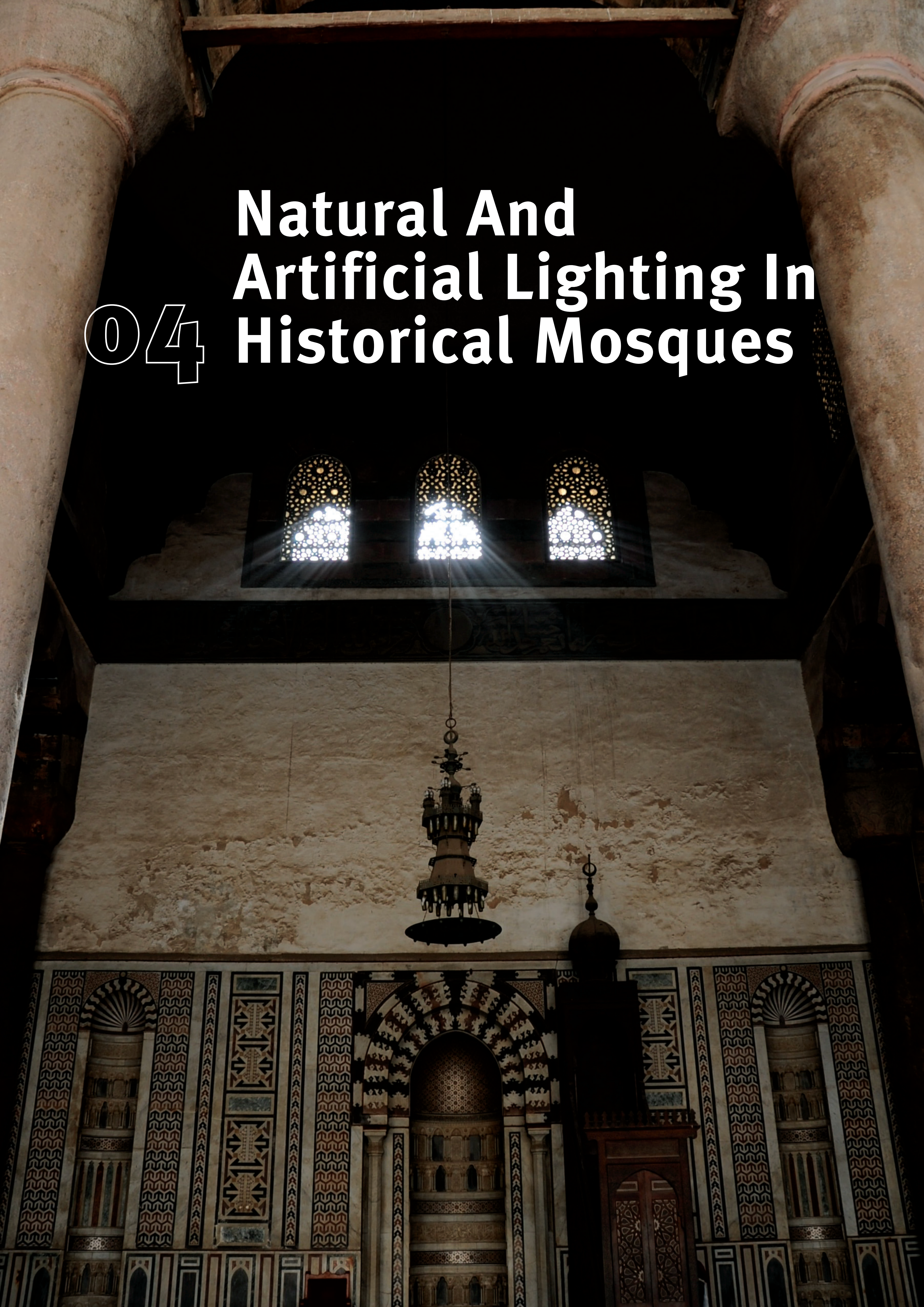


Figure 22:The daily five prayers

04 Natural And Artificial Lighting In Historical Mosques



Light And Visual Performance

> *“Allah is the Light of the heavens and the earth. The example of His light is like a niche within which is a lamp, the lamp is within glass, the glass as if it were a pearly [white] star lit from [the oil of] a blessed olive tree, neither of the east nor of the west, whose oil would almost glow even if untouched by fire. Light upon light. Allah guides To His light whom He wills. And Allah presents examples for the people, and Allah is knowing of all things”.*

24:35 Holy Quran

PHYSIOLOGY OF THE EYE | One of the most remarkable properties of the eye is its ability to adapt to different lighting conditions. We can perceive the wor ld around us by moonlight or sunlight, although there is a difference of a factor of 105 in the illuminance. The extent of tasks the eye is capable of per forming is extremely wide - a faintly glowing star in the night’s sky can be perceived, although it only produces an illuminance of 10- 12 lux on the eye.

This accomodation is only influenced to a very small extent by the pupil, which regulates incident light in a 1:16 ratio Adaptation is per formed to a large extent by the retina. The rod and cone system hand les different levels of light intensity. The rod system comes into effect in relation to night vision (scotopic vision), the cones allow us to see dur ing the daytime (photopic vision) and both receptor systems are activated in the transition times of dawn and dusk (mesopic vision).

Although vision is therefore possible over an extremely wide area of luminances there are clearly strict limits with regard to contrast perception in each individual lighting situation. The reason for this lies in the fact

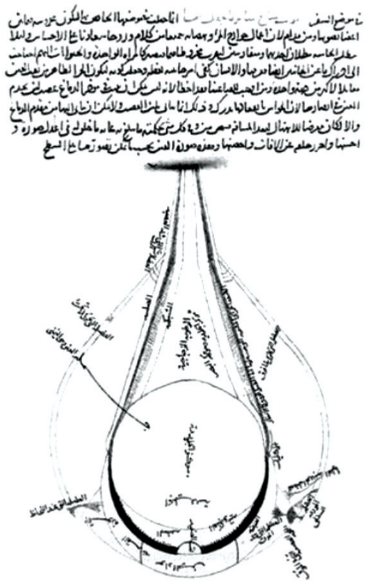


Figure 23: The anatomy of the eye by 13th century Kamal al-Din al-Farasi, based on Ibn al-Haitham's ideas. The Arabic text is referring to the role of the brain in interpreting the image on the retina of the eye.

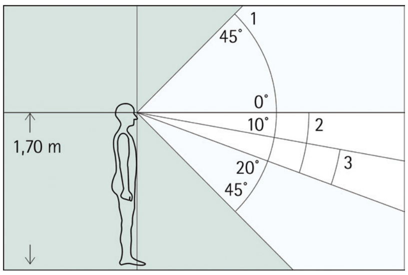


Figure 24: Visual field

that the eye cannot cover the entire range of possible luminances at one and the same time, but adapts to cover one nar row range in which differentiated perception is possible.

Objects that possess too high a luminance for a par ticular level of adaptation cause glare, that is to say, they appear to be extremely bright. Objects of low luminance, on the other hand, appear to be too dark.

The eye is able to adjust to new luminance conditions, but as it does so it simply selects a different but restr icted range. This process of adaptation does take time. Adapting from dark to light situations occur s relatively rapidly, whereas adapting from light to darkness requires a considerably longer time. A good example of this is how bright we find it outside having come out of a dark cinema auditor ium dur ing the daytime, or the transitory per iod of night blindness we experience when entering a very dark room. Both the fact that contrast in luminance can only be processed by the eye within a certain range, plus the fact that it takes time to adapt to a new level of lighting, or br ightness, have an impact on lighting design: the purposeful p lanning of different luminance grades within a space, for example, or when adjusting lighting levels in adjacent spaces

GLARE | In many cases where light impairs vision, it is because it dazzles. This can be caused by either direct glare or reflected glare.

- Direct glare is caused by excessively high luminance, e.g. inappropriate or incorrectly positioned luminaires, unshielded lamps or even windows.
- Reflected glare is caused by light reflecting from shiny surfaces such as monitor screens, art paper or wet roads.

Glare should always be avoided. Both direct and reflected glare undermine visual comfor t and affect our sense of wellbeing (discomfor t glare); glare also impair s visual per formance(disability glare). The effect of direct and reflected glare is similar : both impair perception of the contrasts needed for trouble- free vision. Direct glare can be avoided by adequately shielding lamps and darkening windows. Ref lected glare is reduced by positioning luminaires cor rectly in the room, by limiting the luminance of luminaires and by the use of matt sur faces.

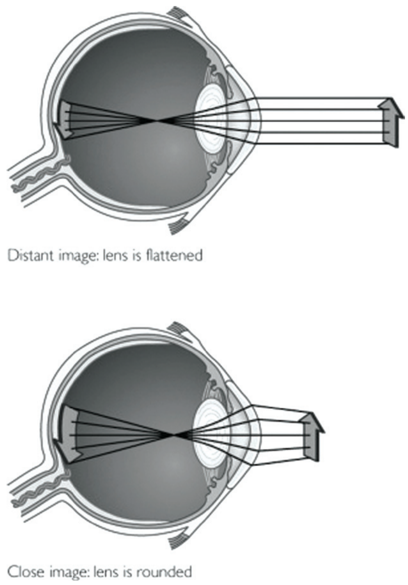


Figure 25: Human eye adaptation to different light levels

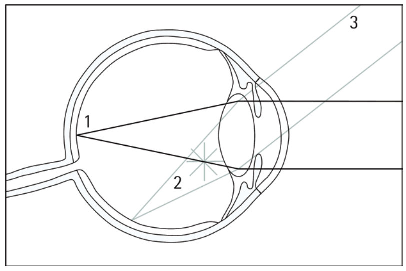


Figure 26: In the case of physiological glare the retinal image of the object being viewed (1) is superimposed by luminances that occur in the eye from the dispersion (2) of the light produced by a glare source (3).

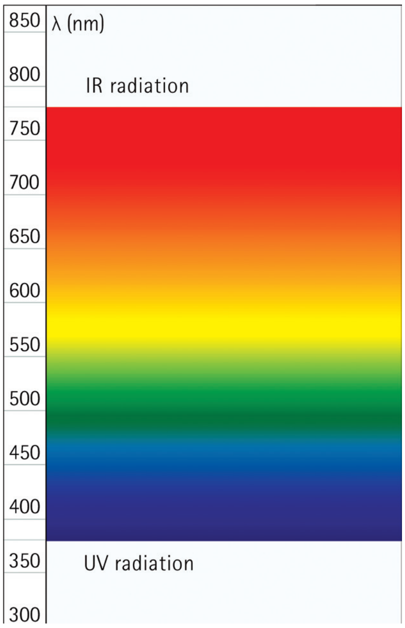


Figure 27: The spectrum of visible radiation comprises the narrow band 380 -780 nm.

LIGHT AS A NATURAL SOURCE | Light, the basis for all vision, is an element of our lives that we take for granted. We are so familiar with br ightness, darkness and the spectrum of visible colour s that another form of perception in a different frequency range and with different colour sensitivity is difficult for us to imagine. Visible light is in fact just a small par t of an essentially broader spectrum of electromagnetic waves, which range from cosmic rays to radio waves.

It is not just by chance that the 380 to 780 nm range forms the basis for our visible light". It is this very range that we have at our disposal as solar radiation on ear th in relatively uniform amounts and can therefore serve as a reliable basis for our perception.

The human eye therefore utilizes the par t of the spectrum of electromagnetic waves avai lable to gather information about the world around us. It perceives the amount and distr ibution of the light that is radiated or reflected from objects to gain information about their existence or their quality; it also perceives the color of this light to acquire additional information about these objects.

The human eye is adjusted to the only light source that has been availab le for millions of years the sun. The eye is therefore at its most sensitive in the area in which we exper ience maximum solar radiation. Our perception of colour is therefore also attuned to the continuous spectrum of sunlight.

> *Have you not considered your Lord-how he extends the shadow, and if He willed, He could have made it stationary? Then we made the sun for it an indication*

25:45 Holy Quran

DAYLIGHTING | Daylight is one of the key elements for mosque lighting. Without proper daylighting, a mosque’s space wi ll not function properly. Due to the fact that two of the five prayer s are per formed during the day, proper day lighting techniques are strongly required. Since the beginning of Islam, daylight and the mosque were always strongly linked. We can see this in the first mosque that was bui lt by Prophet Muhammad and his follower s, where daylight was enter ing the prayer hall from the cour tyard as a direct source.

Throughout history the architecture of the mosque has evolved and changed rapidly due to different factors such as:

- Architectural styles: Depending on which Islamic dynasty the mosque was built, e.g. Ummayads, Tulunids ,Fatimids...etc, the interpretation of the mosque’s space was always changing.
- Geographical location: solar path diagram and climate.
- Usage and function: The amount of people praying in the mosque and the function of the space played a big role in the evolution of the mosque’s plan such as: the Hypostyle Mosque, the Madrasa or the Domed Mosque.

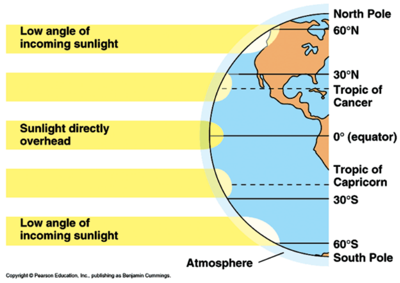


Figure 28:Latitude solar radiation

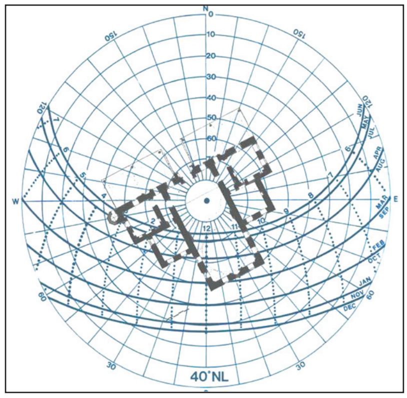


Figure 29 :The sunpath diagram overlaid on a mosque

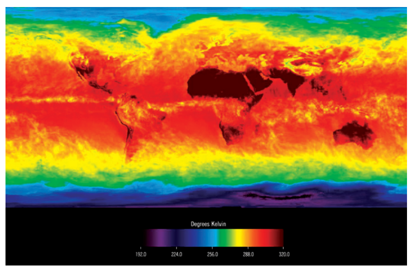
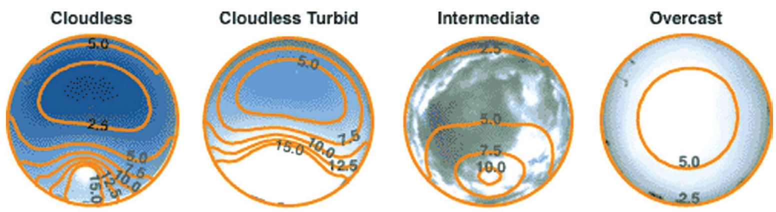


Figure 30:Solar radiation wor ld map



ASRC -CIE Luminance distribution for the four basic models (kcd/m^2)

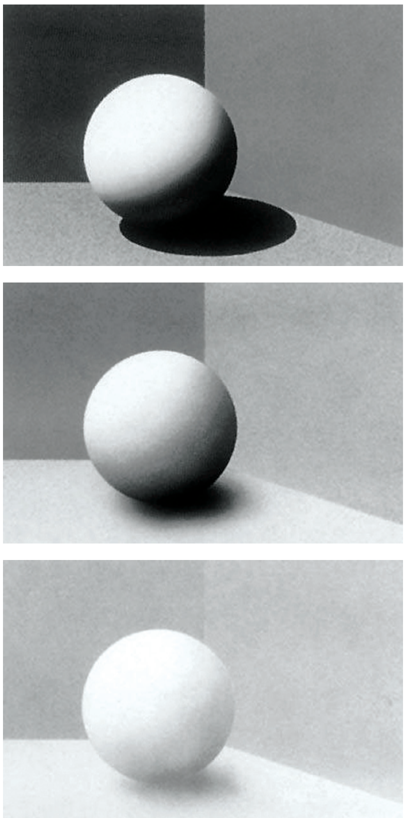


Figure 31: (1) directed light produces strongs hadows. (2), diffuse and directed lighting produces soft shadows. (3), diffus e lighting produces small amount of shadows

Figure 32:Light color tempareture

In every historical Dynasty different Day lighting techniques and methods were applied and used to achieve a certain atmosphere in the internal and external architectural elements of the mosque. Due to the fact that the prayer hall of the mosque is the most important part, different designs of windows and other elements such as the Mashrabiya were in great use in order to achieve a naturally lit space.

Environmental needs of a mosques space rely on different factors. They can be identified and listed as follows:

- **Change:** The variation of color and intensity due to the different prayer times through the seasons of the year. Change is at the hear t of daylighting; the human body has a capacity for adaptation. Entering the prayer hall from the cour tyard, the illumination of the prayer hall should not be bright nor dark, in order to allow a natural process of adaption to be achieved.
- **Orientation:** All mosq ues are oriented towards to the direction of Mecca, great knowledge of the or ientation of the sun path is required in order to take advantage of daylight.
- **Color:** The color of natural daylight inside the mosque's prayer hall can be one of the main reasons in creating a certain atmosphere and mood.
- **Modeling:** How different architectural styles are reveled through the presence of different lighting conditions: diffuse or direct light.

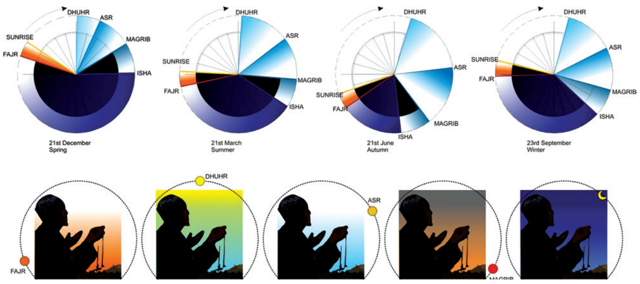


Figure 33: Prayer times through different seasons

THE WINDOW | Throughout the evolution of mosque architecture, windows played a big role in allowing natural daylight to penetrate and to light up the interior of the mosque. Different types, shapes, sizes and materials of window were introduced from the earliest examples of mosques. From the Umayyad until the Ottoman dynasty, different types of windows were introduced. By doing so, the whole atmosphere of the mosque's interior changed through time.

Several Factors affect the performance of the window inside a mosques space, they can be summarized in four main points:

- **Size:** The bigger the opening of the window is, the greater amount of light is gathered.
- **Position:** Different locations of a window can control the direction of sun light inside a mosque space, e.g. windows that are located in a mosque's dome allow sun light to illuminate the internal part of the dome creating the effect of a luminance ceiling.
- **Glass material:** Windows with colored glass allow less light to enter the space, where a clear glass allow more light to penetrate the space sometimes causing glare. The right choice of glass material depending on the function of the window can be the result of creating a naturally lit mosque.
- **Function:** A function of mosque's windows can be divided into two main categories: functioning windows and decorative windows. By combining both types, a mosque can't be regarded only as a lit space, it is a space that is glorifies the presence of Allah (God) through light.

Figure 34: 1548 Süleymaniye Complex minaret opening allows daylight to enter the shaft of the minaret from narrow opnings.

Figure 36: 970 Al-Azhar Mosque vertical recessed windows reduce the amount of contrast between interior and exterior spaces.

Figure 35: 1568 Selimiye Complex difusing glass windows reduces direct sun light penetrate the space.

Figure 37: 1295 Sultan Ibn Qala'un Complex Color ed glass windows reduses the strength of sunlight through color filtration mostly used as a decorative element.

Figure 38: 1295 Sultan Ibn Qala'un Complex Mashrabiyas main function is to scater sunlight in order to reduce its strength.

Figure 39: 1568 Selimiye Complex Open work grilled windows main function is deflecting sunlight to cr eate a shading effect.

THE COURTYARD | Acting as a light well, the cour tyard of the mosque plays a big role in gather ing direct sun light and transmitting it to the inter ior par t of the mosque. The relationship between the cour tyard and the prayer hall is directly affected by the different openings and the depth of the prayer hall. The deeper the prayer hall is less light is transmitted from the courtyard. Courtyards such as the open cour t yard and the roofed cour tyard depend on the type of the mosque plan (hypostyle, four iwan, and domed mosque).

Figure 40: 641Amr Ibn Al-As Mosque Open courtyard.

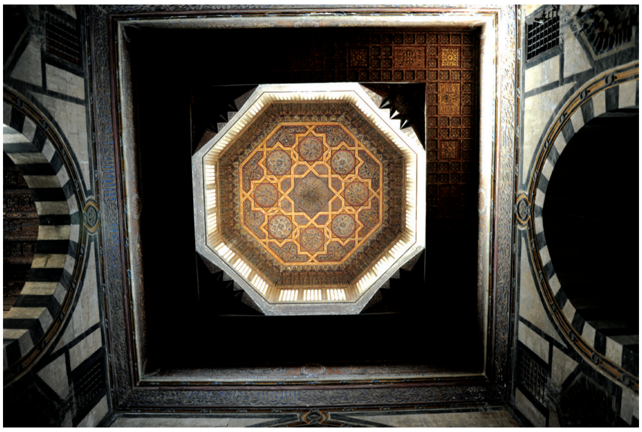


Figure 41: 1472 Qaitbay Complex Roofed courtyard with fenestration.

Figure 42: 1270 ear ly Mamluk period, Pierced globe brass inlaid with silver.

Figure 43: Umayyad Oil lamp

Figure 44: 1495 Mamluk, Mosque lamp.

ARTIFICIAL LIGHTING | Artificial lighting in a mosque is as important as the daylighting due to the fact that three of the five prayers are at night time or in a time where daylight is not enough to light up the inter ior of the mosque. Different types of ar tificial lighting and their implementations in the prayer hall can be one of the best ways to show how every dynasty in Islam wanted to reflect their identity through a ce tain lighting effect. We can say that the major factor s effecting ar tificial lighting are:

- **The source (candles, Oi l lamps, Glass lamps):** Every single type of ar tificial lighting can create a different mood and atmosphere.
- **Size:** The size of each light source can be the reason of how much light is focused in one area.
- **Quantity:** The repetition of every single source can show how is the intention to light up the interior of the mosque dark or br ight even or concentrated on cer tain areas.

MOSQUE HI STORICAL LI GHTI NG SOURCES | Different and special techniques from simple ar tificial lighting sources were applied throughout the historical evolution of mosque lighting. Examples from the early stages of Islamic dynasties until the peak of the Ottoman Empire can clear ly show a different lighting atmospheres.
Major mosque ar tificial lighting sources can be listed as follows:

- **Oil lamps:** One of the most primitive artificial lighting tools. Some oil lamps were portable and could be carried around poorly lit areas such as the shaft of the mosque minaret where no lighting fixtures are installed.
- **Brass globes:** Spherical carved brass globe containing a candle inside it. Little light is emitted in order to highlight circulation areas such as the mosque corridors.
- **Candle sticks:** Usually big in scale in order to hold a s ingle large size candle that can reach

a height of three meters, it is commonly used to highlight the mihrab area.

- **Polycandelons:** One of the main light sources of the prayer hall poly candelons are hanging ring structures that contain more than one small cone shaped glass oil lamps, generating general lighting distribution effect.
- **Mosque g lass lamps:** Hanging glass lamp containing water covered with oil, topped by a floating cotton wick. One will known method was that the wick holder, a metal S-shaped hook fixed to the lamp`s rim. In this floating-wick system the oil was continuous ly absorbed upward by the wick, the top of which was lit. As soon as the oil was completely finished, water extinguished the remaining flame. It is likely that the light seen through the water- like rock crystal lamp was unders tood in medieval times as an allegory for the sparkling water in the legendary source of life. In the lighted rock crystal lamp it was impossible to differentiate between water and light; water looked like waving rays of light, and rays of light looked like streams of water. The main advantage of the rock- crystal lamp lies behind its ability to create different lighting effects depending on the water level inside the lamp. A study conducted by scholars from the Univers ity of Pennsylvania and the University of Warwick, where a recreation of an early Islamic glass lamp combined with computer analysis is clearly showing the different capabilities of the lamp.

Figure 45: 1543 Sehzade Mehmed Mausoleum, Ottoman polycandelon.

Figure 46: 16th Century, Ottoman candlestick.

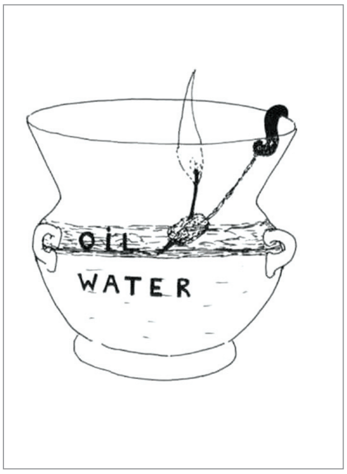


Figure 47: Drawing of early Islamic rock crystal lamp.

Figure 48: 1329 Mamluk, Rock crystal mosque lamp.

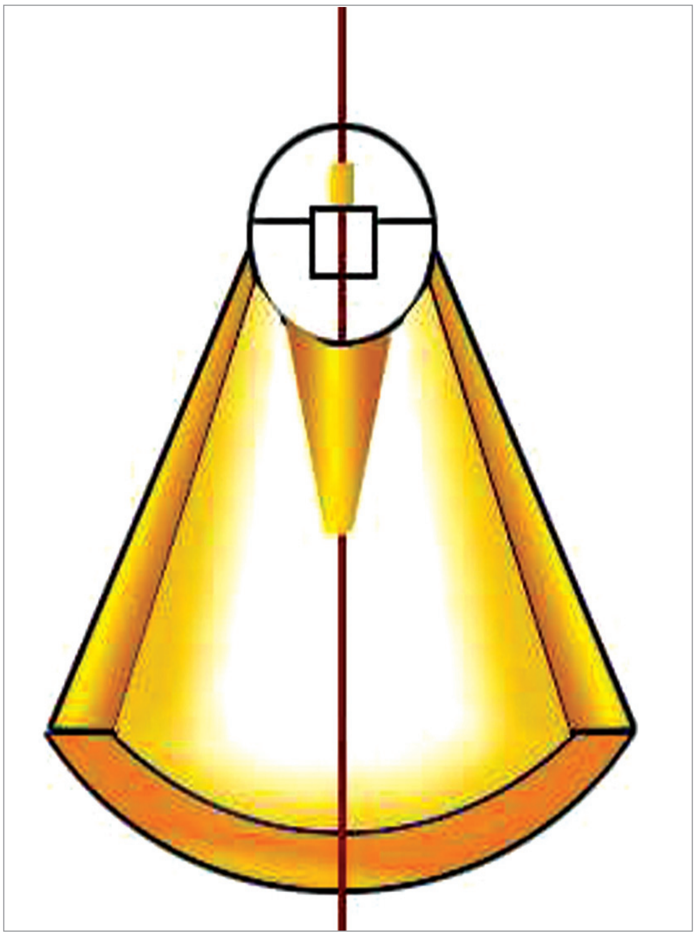


Figure 49: diagram illustrates a cross -section view that was cast o a paper hung across the diameter of the fixture perpendicular to the camera. This s hows two cones are cast in the vertical crosss ection. Thes e cones will vary based on flames' intensity and position. (The red line indicates the optical axis .)

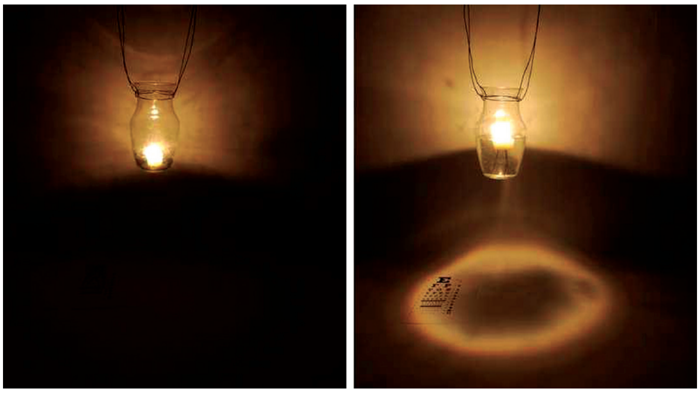


Figure 50: Having a higher water level produces illumination underneath the lamp fixture that facilitates navigation and reading. The fixture on the left contains no water; the fixture on the right contains a high level of water

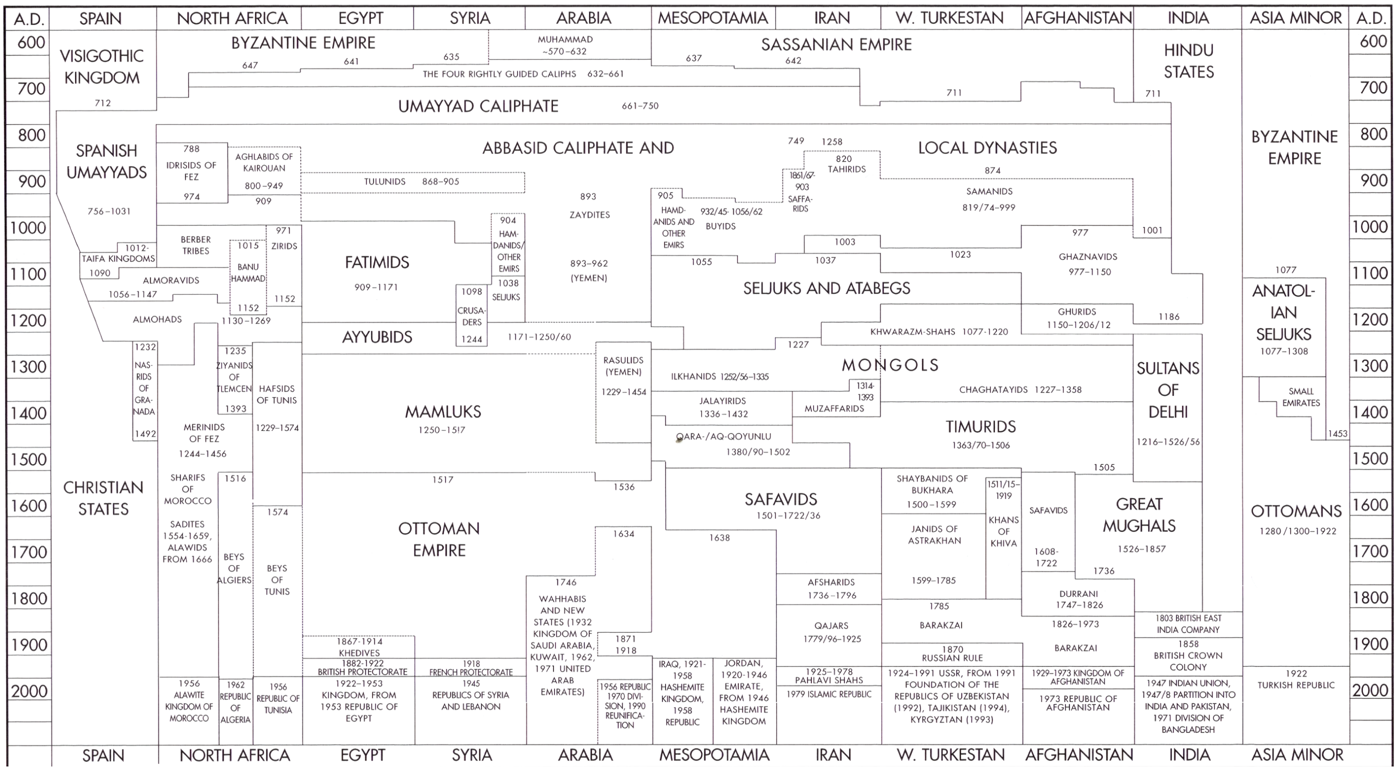


Figure 51: Time chart of Islamic dynasties.

05 Case Studies

Case Studies

A case study of six different mosques from five different dynasties can give us a clear view on how the techniques of ar tificial and daylighting were developed throughout different Islamic dynasties.

The Great Mosque of Damascus | Umayyad
Ahmad Ibn Tulun Mosque | Tulunid
Al- Azhar Mosque | Fatimid
Great Mosque of Tripoli | Mamluk
Sultan Hasan Complex | Mamluk
Selimiye Complex | Ottoman

Islamic Dynasties

Throughout history the architecture of the mosque has evolved and changed star ting from the Umayyads till the Ottoman dynasty. Every single dynasty had its own unique architectural style, which gave the mosque a different design approach by focusing on every single detai l of the major mosque elements. A brief overview of different Islamic dynasties which were used in the case studies covering countries of Syria, Lebanon, Egypt and modernday Turkey.

UMAYYADS (661- 750) | The dynasty of Umayyad caliphs was based in Syria. Under the Umayyads the Islamic state was transformed from a theocracy to an Arab monarchy. At its height Umayyad rule extended from the Atlantic coast of North Africa to India and from Central Asia to the Yemen. The most important building projects under taken during the Umayyad era included mosques, palaces and cities. Mosques were an essential par t of early Islamic government as they provided a meeting place at which important announcements could be made. The bui lding techniques employed by the Umayyads were as diver se as the regions they conquered, so that major projects would employ workmen of several different nationalities. At its most conservative Umayyad architecture is indistinguishable from either Byzantine or Sassanian work but usually there is a combination of eastern and western elements which produce an unmistakably Islamic bui lding.

TULUNIDS (868- 905) | Dynasty which ruled over Egypt and Syria in the late ninth and early tenth century. The dynasty was founded by Ahmed ibn Tulun the son of a Turkic soldier from Bukhara who was based at the Abbasid capital of Samarra. Architecturally the most significant member of the dynasty is Ahmed ibn Tulun who established a new city as his capital in Egypt. The only monuments remaining are the congregational mosque of Ibn Tulun and an aqueduct. The mosque displays certain similar ities to the congregational mosques of Samarra, in particular the minarets.

FATIMIDS (909- 1171) I Caliphs who ruled North Africa, Egypt and Palestine from the tenth to the twelfth century. The Fatimids were a religious dynasty who c laimed descent from the prophet's daughter Fatima. The conquest of Egypt began a new phase in Fatimid history with the foundation of Cairo as the imperial capital. For ideological reasons their mosques had no minaret, a feature which remained absent until the last years of Fatimid rule in Egypt.

MAMLUKS (1250- 1517) I Term applied to the architecture of Greater Syria and Egypt between 1250 and 1516. During this period the area was ruled by the Mamluk sultans based in Cairo. The word 'mamluk' is an Arabic term for slave. The Mamluk sultanate had its or igins in such slave soldier s, usually of Turkic or Mongolorigin, who were used as guards by the Ayyubid sultans and pr inces. The Mamluk sultanate can be divided into two periods; the first is known as the Bahri (sea- based) Mamluk per iod because the dominant Mamluks were based on Roda island in the Nile delta. The second period is known as the Burji Mamluk period because those in power came from the Citadel in Cairo (burj is Arabic for tower). Mamluk architecture reflects the confidence derived from its military successes and is one of the most distinctive Islamic styles of building. The main source for Mamluk architecture was the buildings of the Ayyubids, they were also influenced by other styles, inparticular Italian and Andalusian architecture. There are, however, several features which are characteristic of buildings throughout the area under Mamluk control. These can be considered under three headings: surface decoration, layout and planning, and structural elements. Building Types some of the most distinctive buildings of the Mamluk per iod are the many religious foundations. More typical of the period are the many religious institutions such as madrassas. Madrassas became a common feature in most cities and were used to train administrators.

Ottomans (1299- 1923) | Major Islamic dynasty based in Turkey which at its height controlled a vast area including all of modem Turkey, the Balkans and much of the Middle East and North Africa. The or igins of the Ottoman dynasty can be traced back as far as their thir teenth century founder Othman (Osman). The major event of the fifteenth century was the capture of Constantinople (later known as Istanbul) and the defeat of the Byzantine Empire by Mehmet the Conq ueror in 1453.

1. The Great Mosque of Damascus

NAME | Great Umayyad Mosque
LOCATION | Damascus , Syria
DATE | 709- 715 (8th Century)
STYLE | Umayyad
BUILDING USAGE | Mosque
PLAN TYPE | Hypostyle

The Great Mosque of Damascus is the first monumental work of architecture in Islamic history. The Umayyad mosque's religious significance was reinforced by its renowned medieval manuscripts and ranking as one of the wonders of the world due to is beauty and scale of construction. The plan of the mosque is formed by a 97m x 156m rectangle with the courtyard on the northern side. The courtyard is punctuated by three major elements: the ablution fountain, the treasury dome, The clock dome the courtyard is wrapped around three sides with double height Riwaqs and the prayer hall. Three bays, parallel to the qibla, form the prayer halls interior space; they are supported by two rows of columns. Each bay has two levels, the first with large semi circular arches and the second with double arches. The three bays intersect in the middle with a larger, higher one that is perpendicular to the qibla wall and faces the mihrab and minbar. The main octagonal dome is supported on this wide bay and it is 36m high. The dome has apertures around its parameter.

Daylighting

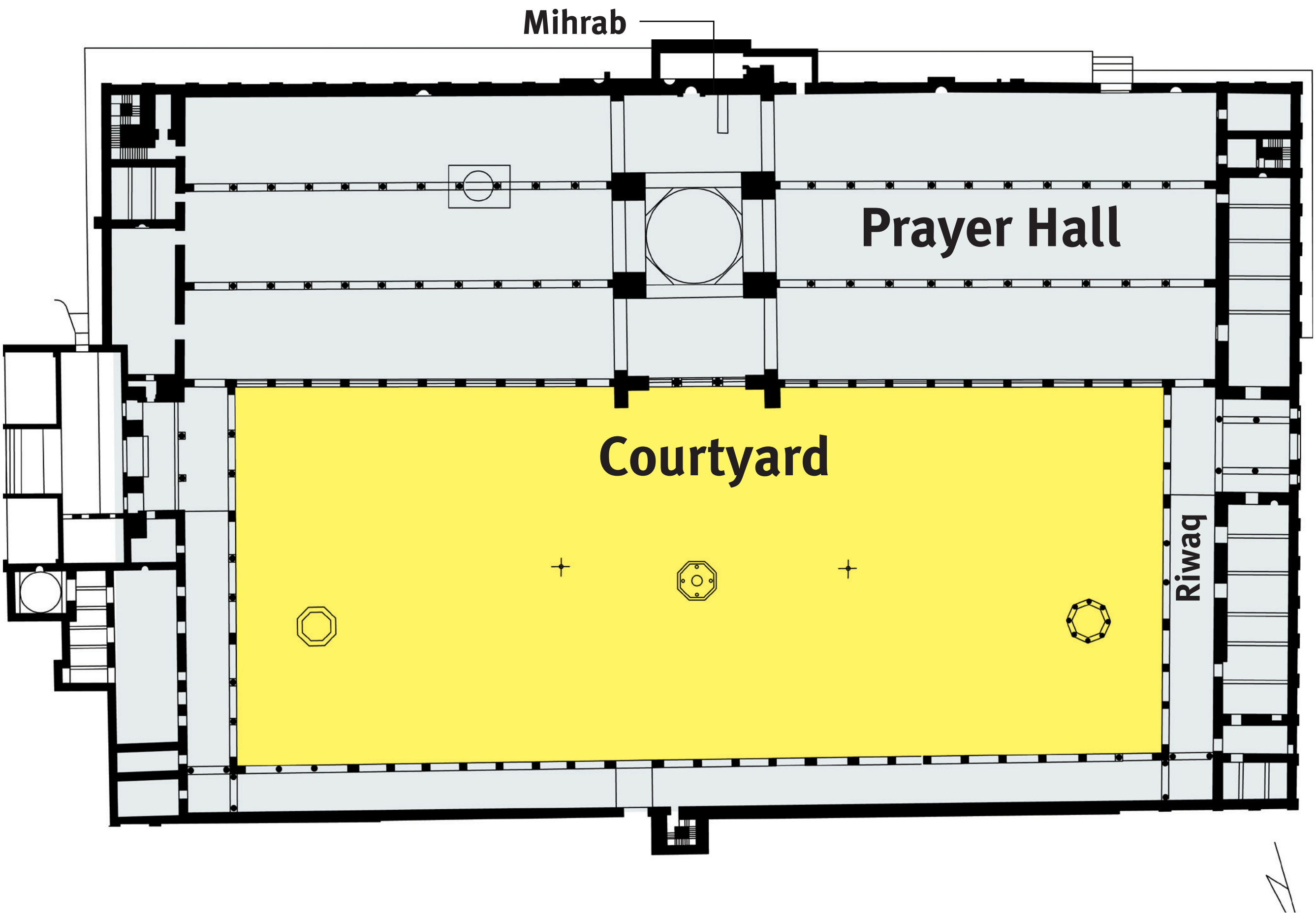


Figure 52: Mosque plan showing covered areas in grey and open courtyard in yellow.

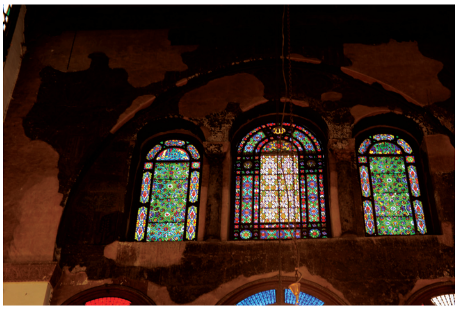


Figure 53: Courtyard windows: located directly next to the courtyard. These windows are allowing most of the daylight to enter the prayer hall divided into two positions: high with small colored glass windows and low with bigger colored and clear glass windows.

Figure 54: Mihrab windows: bigger windows are located above the mihrab area in order to allow daylight to enter the space from the higher ceiling where the mihrab area is located.

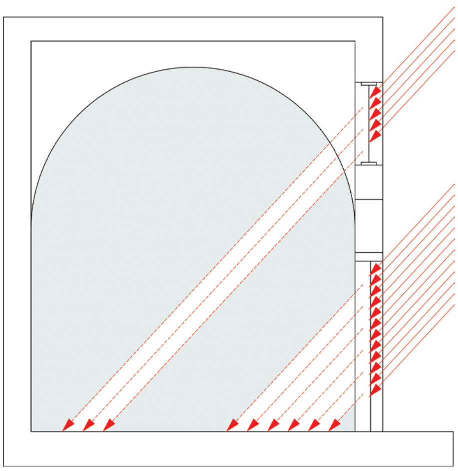


Figure 55: Diagram showing reduced daylight penetrating the prayer hall through colored glass windows.

Figure 56: Dome windows: two rows of small windows are wrapping the dome giving it a luminous effect.

Figure 57: Qibla wall colored glass windows: located at the upper part of the wall allowing reduced daylight to enter the first few rows of the prayer hall, in order to avoid glare.

Artificial lighting

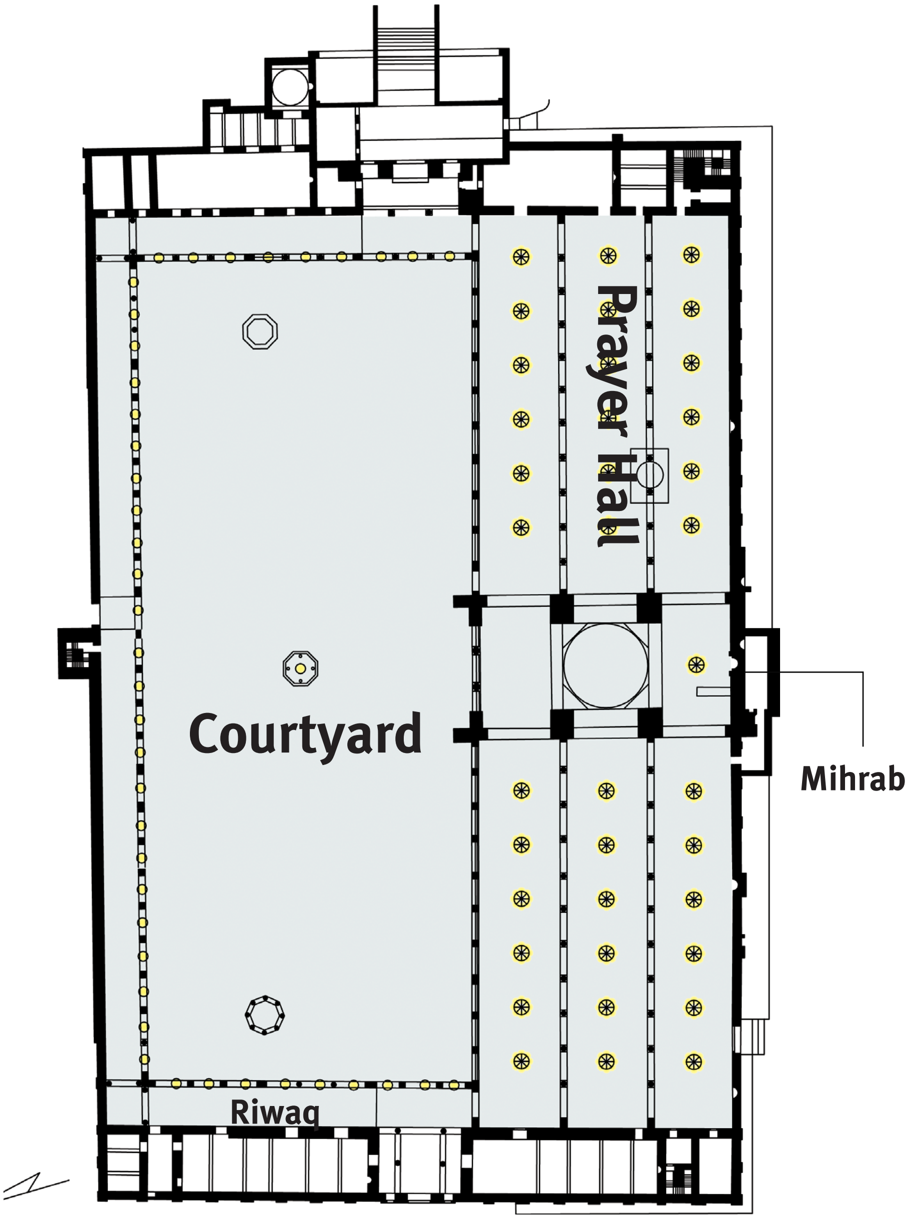


Figure 58: Mosque general lighting layout.

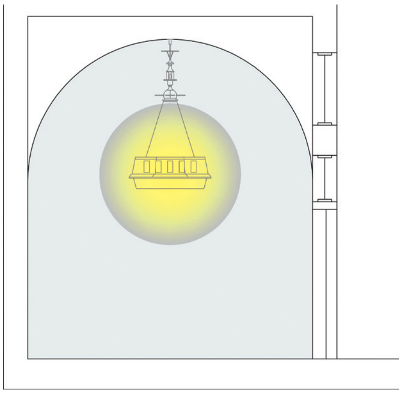


Figure 59: General lighting distribution is created through the use of candles, visible contrast between dark and lit spaces due to the wide spacing between the Candelons and the high ceiling of the prayer hall.

Figure 60: Picture showing a reproduction of a historical Candelon.

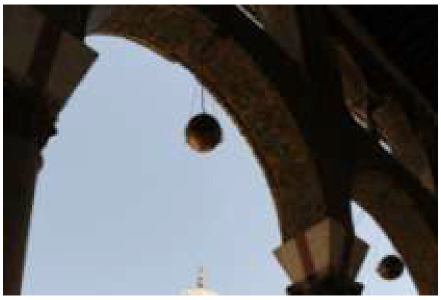


Figure 61: Pierced brass globes, located between the columns of the Riwaq, where light is just needed for highlighting the external pathways.

2. Ahmad Ibn Tulun Mosque

NAME | Ahmad Ibn Tulun Mosque
LOCATION | Cairo, Egypt
DATE | 870- 879 (9th Century)
STYLE | Tulunid
BUILDING USAGE | Mosque
PLAN TYPE | Hypostyle

Ibn Tulun mosque is an architectural masterpiece. It is the largest, oldest, and in terms of grandeur, dignity and monumental simplicity, the finest in Egypt.

It is a hypostyle mosque with a sahn surrounded by four riwaqs, five aisles deep on the qibla side and two aisles deep on each of the other three sides. The sahn is square with an arcade of thirteen pointed arches on each of the four sides, and the arcades of the prayer hall are made up of seventeen arches that run parallel to the qibla wall.

The solid mass of the arcades is further relieved where the spandrels of each arch are pierced by a window framed with colonnettes. All four walls of the mosque are pierced by over 120 pointed arched windows containing delicate filigree grilles from many periods. The room behind the mihrab is supported by wooden corbels with small windows on each side.

Daylighting

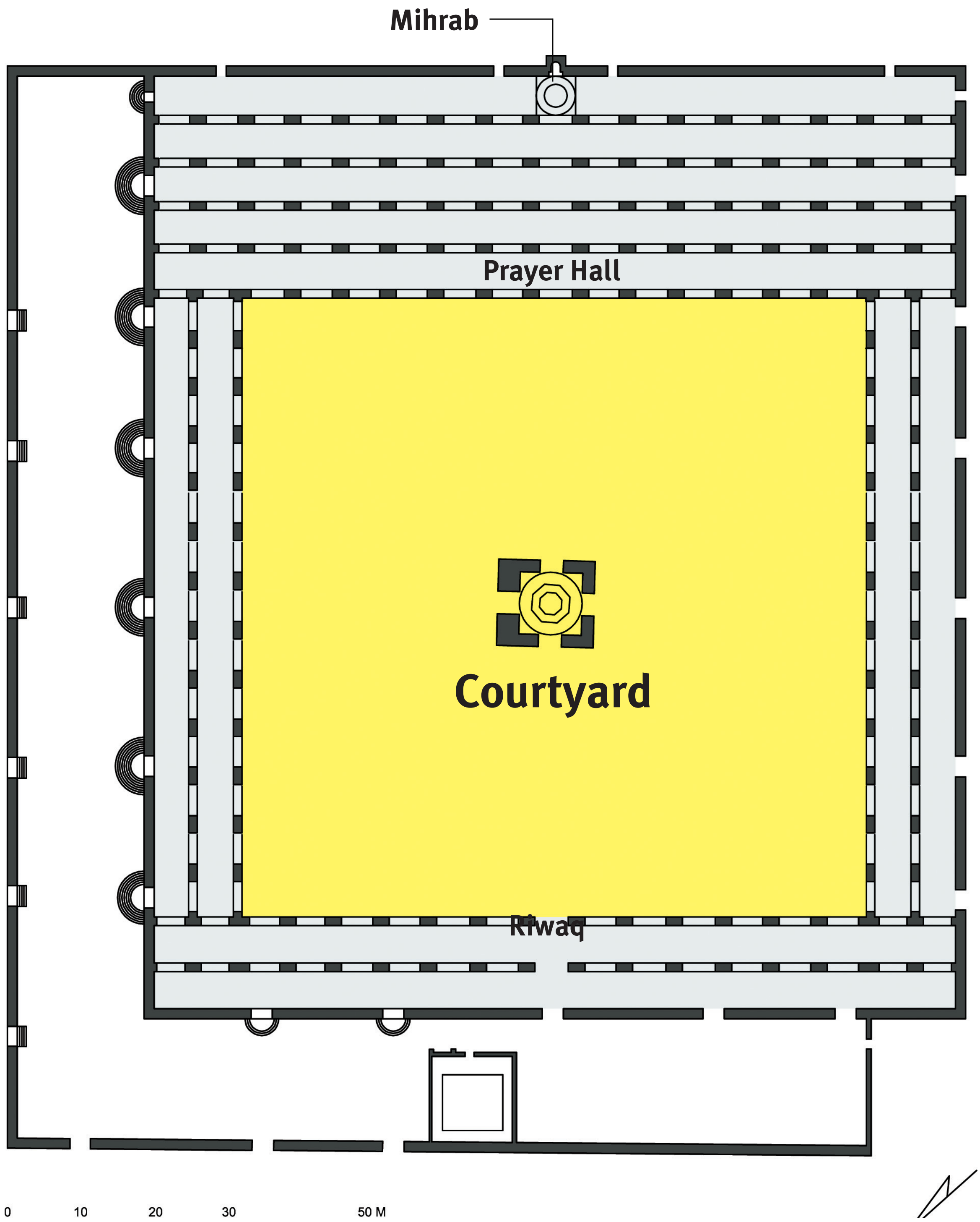


Figure 62: Mosque plan showing covered areas in grey and open courtyard in yellow.

Figure 63: Open arcade of the prayer hall allowing direct sunlight to enter the space, great contrast of shadow and light is clearly visible due to the presence of huge piers.

Figure 65: Mihrab dome

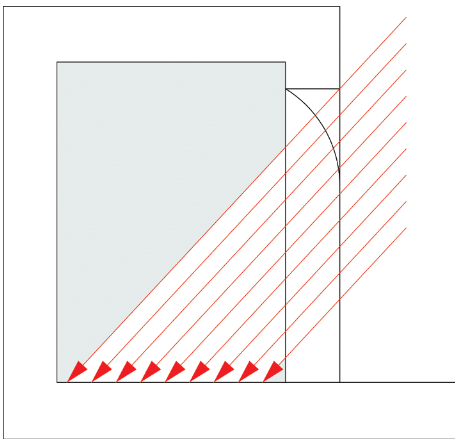


Figure 67: Diagram showing direct sunlight entering the prayer hall, creating a highly lit space with high contrasts of shadow and light.

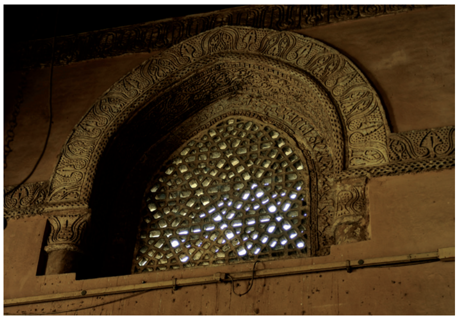


Figure 64: All four walls of the mosque are pierced by over 120 pointed arched windows containing delicate filigree grilles, allowing diffused light enter the prayerhall.

Figure 66: Mihrab flanked on both sides by grilled windows and topped by a small wooden dome with fenestrations, in order to emphasize the importance of the Mihrab area.

Artificial lighting

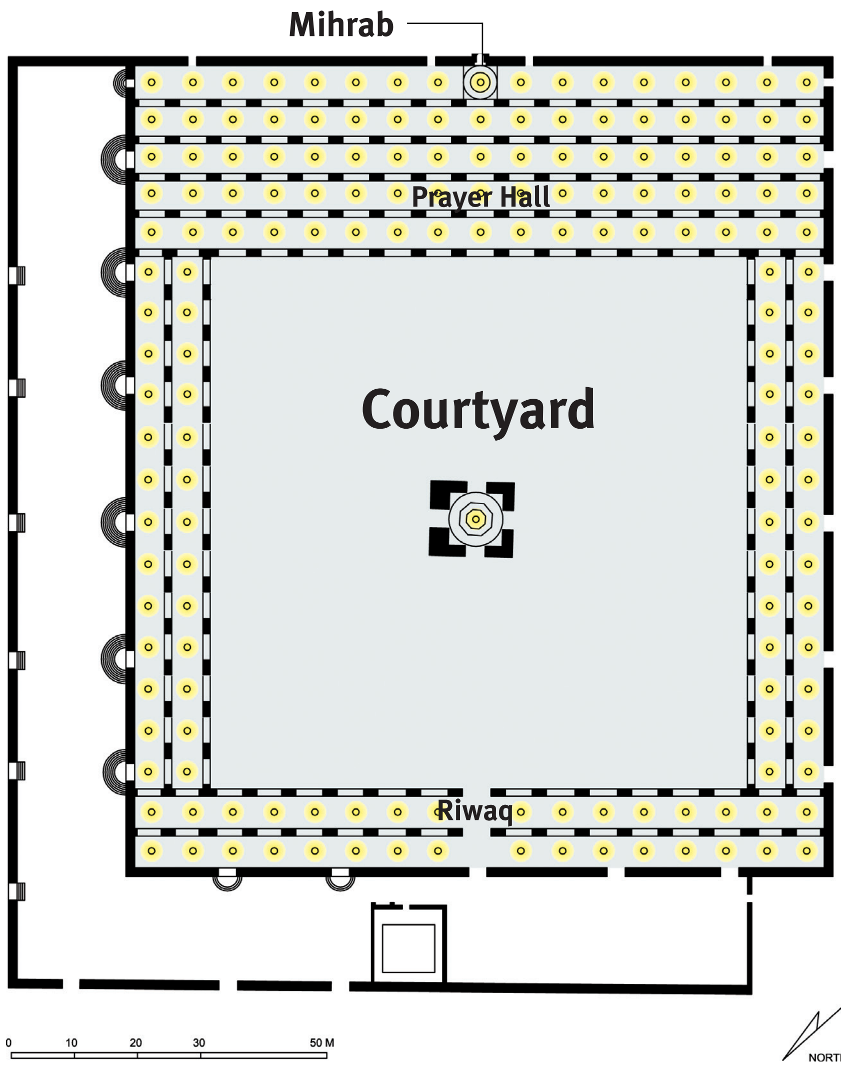


Figure 68: Mosque general lighting layout.

Figure 69: Repeated number of rock crystal lamps, hanged in every single bay of the prayer hall.

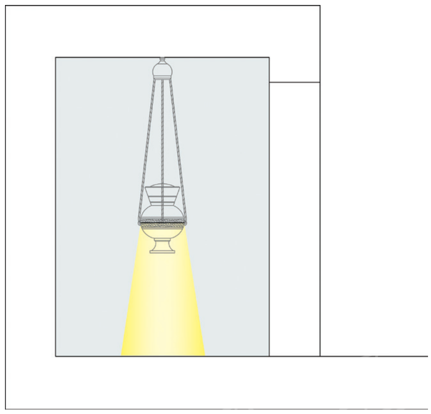


Figure 70: Maximum performance of the rock crystal lamp is achieved, by repeating an equal pattern of centralized hanging lamps, giving the prayer hall even lighting distribution with small evidence of dark areas.

3. Al-Azhar Mosque

NAME | Al-Azhar Mosque
LOCATION | Cairo, Egypt
DATE | 970- 972 (10th Century)
STYLE | Fatimid
BUILDING USAGE | Mosque
PLAN TYPE | Hypostyle

The Mosque of **Al-Azhar** was founded by Jawhar al-Siqilly, the Fatimid conqueror of Egypt, in 970 as the congregational mosque for the new city of al-Qahira. The first khutba was delivered from its minbar in 972 and a university was established there in 988.

The original structure is a hypostyle mosque, with the aisles defined by round arches on pre-Islamic marble columns with Corinthian capitals, and with the axis to the mihrab emphasized by a wide longitudinal aisle (transept), higher than the rest of the prayer hall. The other aisles are transverse, running parallel to the qibla wall. The termination of the transept at the mihrab is marked by a dome.

Among the original decorations are stucco panels and a window screen in the original qibla wall, stucco representations of a palm tree on the piers of the wall facing the original qibla wall. Also original are the stucco decorations on the inside of the northeast wall of the sanctuary, including bands of Kufic inscriptions framing windows with geometric stucco grilles, and the Kufic inscriptions and stucco carving in the hood of the mihrab.

Daylighting

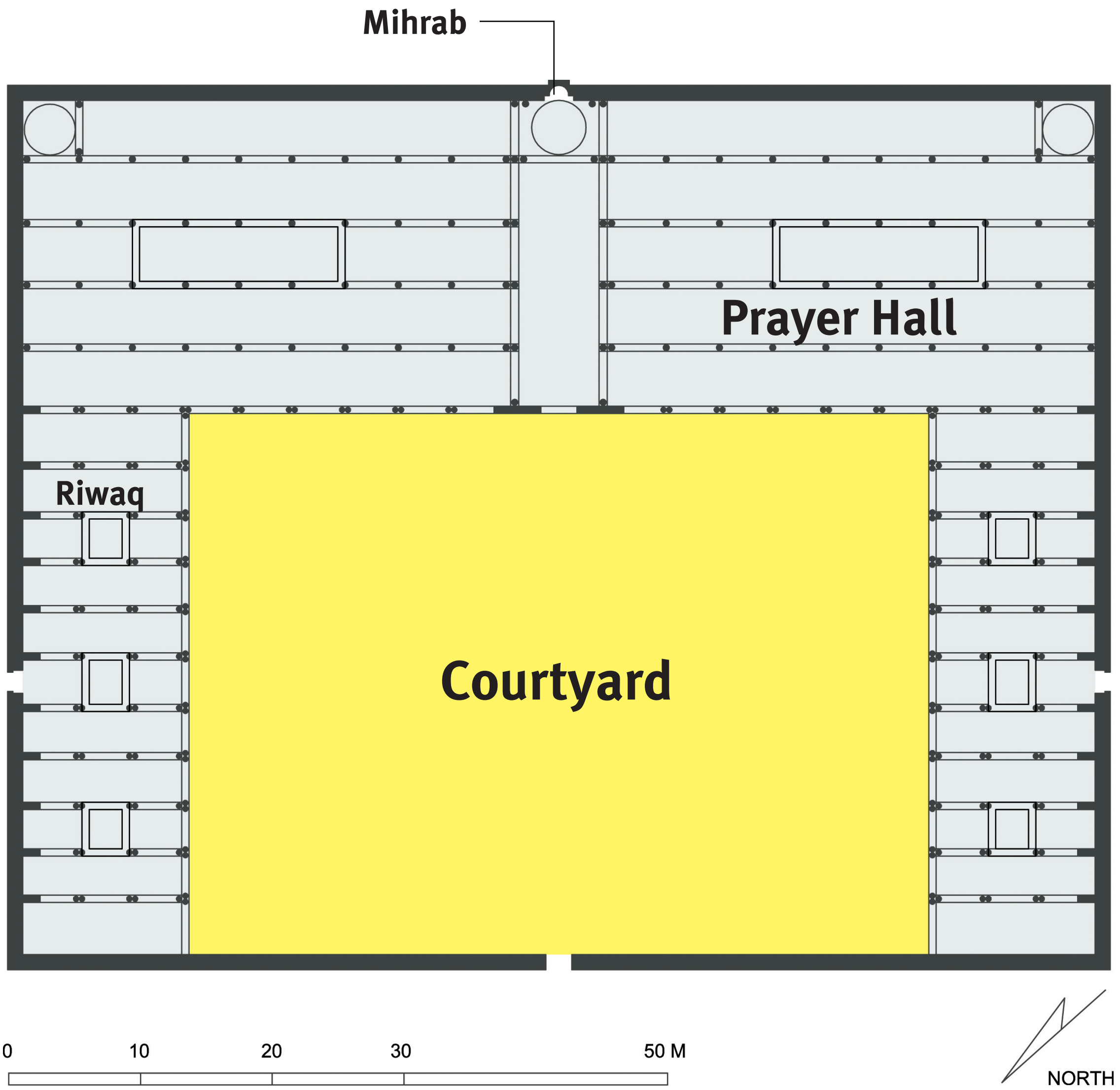


Figure 71: Mosque plan showing covered areas in grey and open courtyard in yellow.

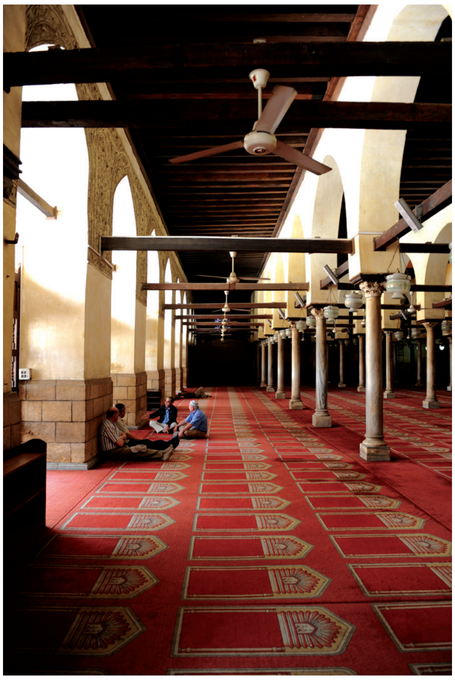


Figure 72: Interior view of the Mashrabiya opening.

Figure 73: Masrabiyas located at the opening of the prayer hall arcades next to the courtyard.

Figure 74: Muqarnas dome with colored glass fenestration, located on top of the Mihrab area.

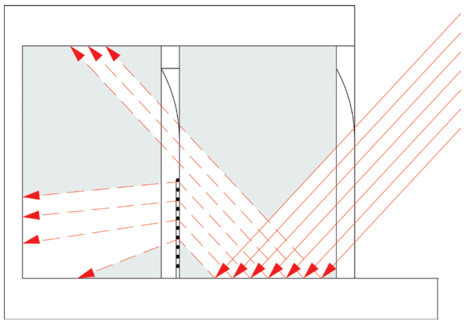


Figure 75: Diagram showing how the Mashrabiya is deflecting the indirect daylight (center), in order to highlight the lower part of the prayer hall. Low lighting levels is achieved due to the deep prayer hall and the additional Riwaq behind the prayer hall(right).

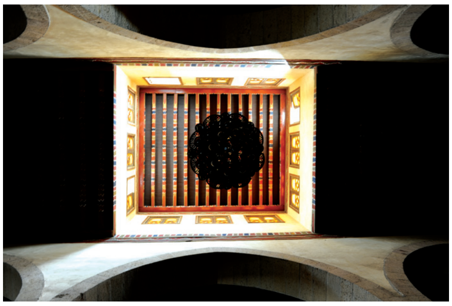


Figure 76: Extruded ceiling wrapped with colored glass windows allowing reduced daylight enter the prayer hall.

Artificial lighting

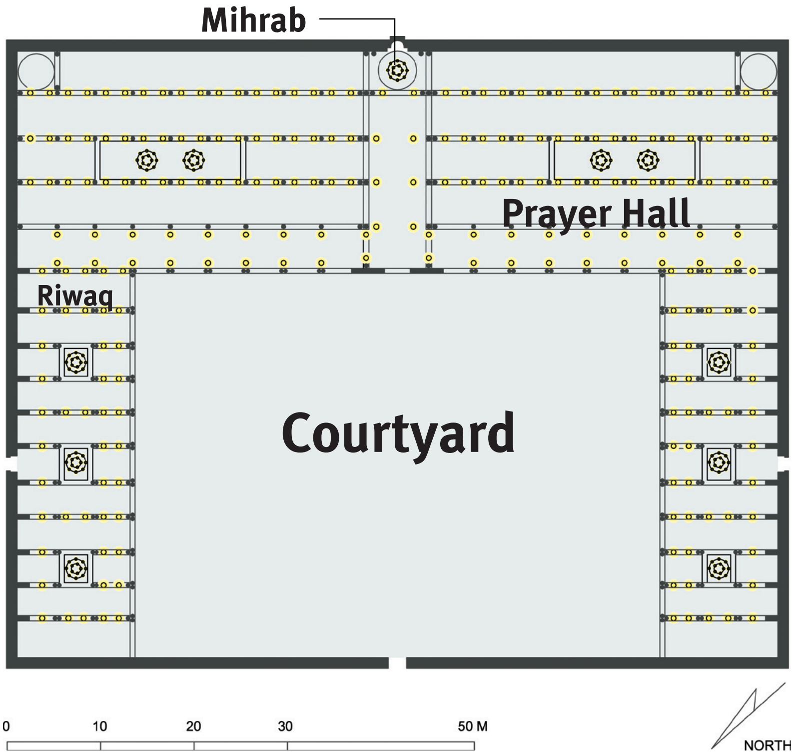


Figure 77: Mosque general lighting layout.

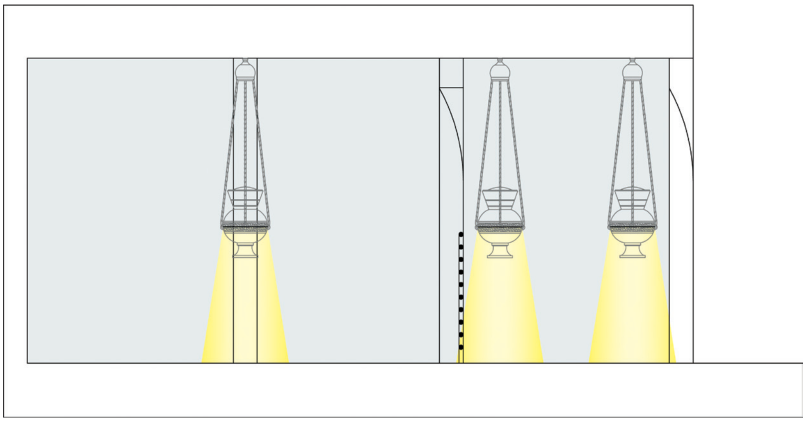


Figure 78: in order to highlight the vertical structures of the prayer hall, two hanging mosque lamps are position between the columns (left). Two rows of hanging mosque lamp are placed all around the Riwaq to highlight the circulation area (right).

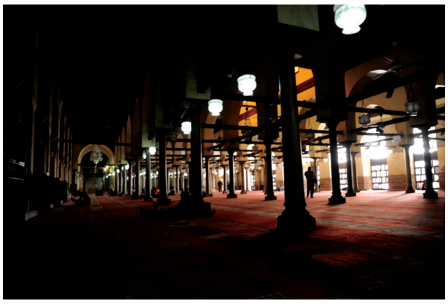


Figure 79: Interior view of the prayer hall showing the location of the mosque lamps.

Figure 80: Exterior view of the Riwaq, with hanging mosque lamps.

4. Great Mosque of Tripoli

NAME | Great Mosque of Tripoli
LOCATION | Tripoli, Lebanon
DATE | 1294- 1314 (13^{th}-14^{th} Century)
STYLE | Mamluk
BUILDING USAGE | Mosque
PLAN TYPE | Hypostyle

The Great Mosque occupies an area of about 50 by 60 meters in the middle of the city. It does not have an elaborate facade, but is readily identifiable from the outside by its minaret and its main northern gate, the two controversial elements responsible for the theory that it is a remodeled Christian church.

The plan of the Great Mosque shows a traditional arrangement with a central courtyard, single porticoes on three sides, a deeper qibla side for prayer, and a central fountain. In traditional fashion the mosque has three axial entrances set to the north, east, and west, but there are also two others on either side of the prayer hall.

The courtyard which dominates the building is enclosed by porticoes to the north, east, and west, and by the closed prayer area to the south. The porticoes display a rhythmic arrangement of identical low arches in the courtyard, and a continuous corridor-like area of simple cross-vaulting behind. These are the riwaqs built by al-Malik al-Nasir in 1314, when he completed the mosque.

Daylighting

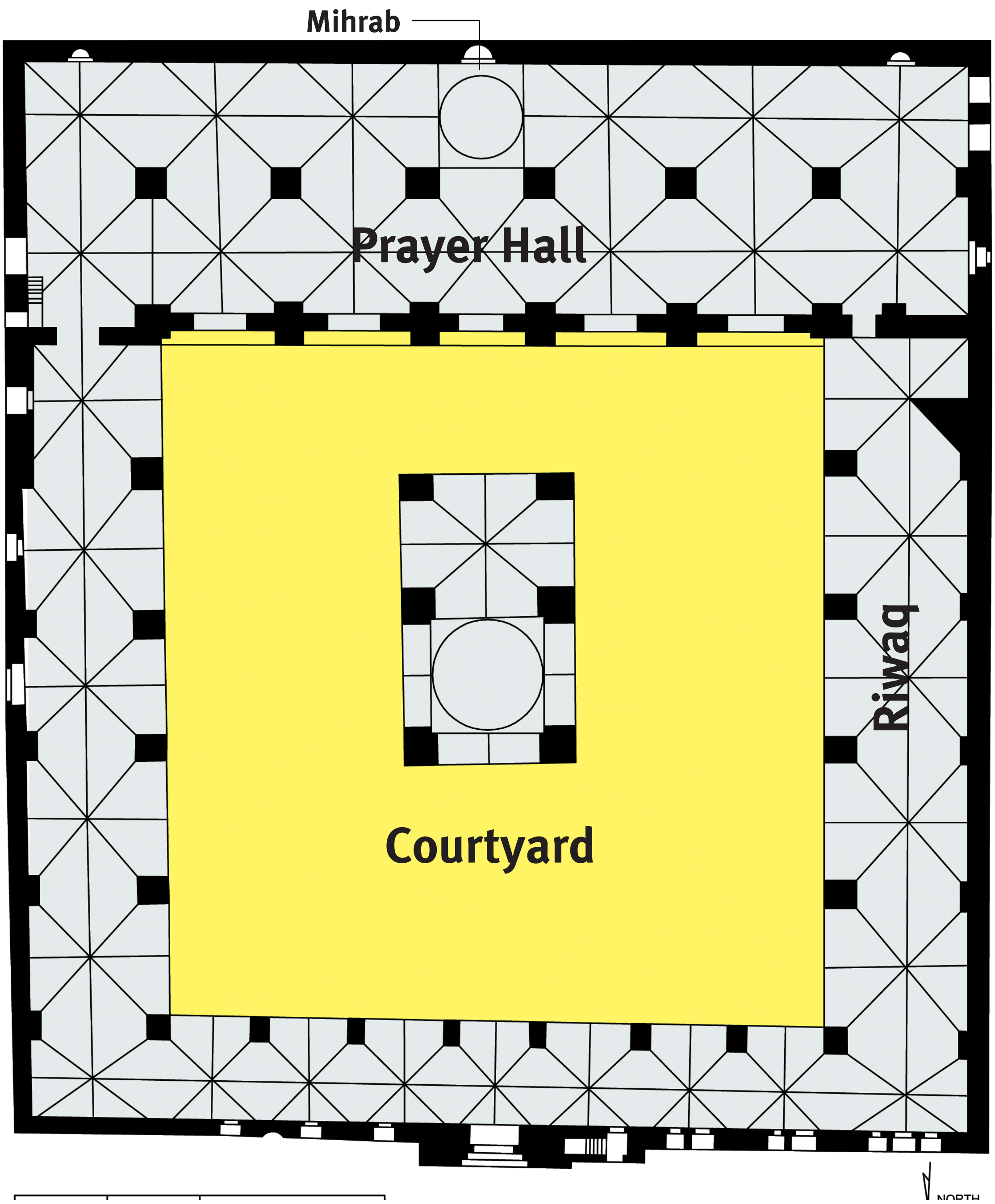


Figure 81: Mosque plan showing covered areas in grey and open courtyard in yellow.

Figure 82: Mihrab dome with colored glass windows.

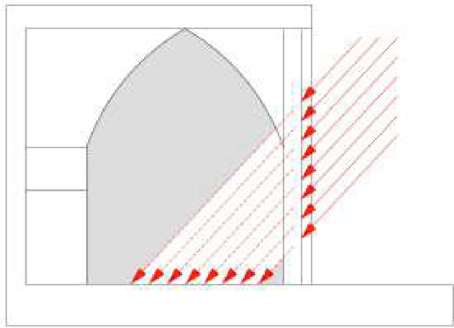


Figure 83: Diagram showing the quantity of daylight entering the prayer hall. The overall lighting distribution can be regarded as high lighting levels with uniform lighting distribution.

Figure 84: Vertical clear glass windows at the northern part of the prayer hall, where most of the daylight is entering the space.

Figure 85: Colored glass fenestration located at the Qibla wall to avoid glare.

Figure 86: Small recessed windows, located at the western part of the prayer hall, allowing daylight to enter the space in the afternoon.

Figure 87: Ablution fountain view at 18:00 (sunset-maghreb) prayer

Figure 88: Ablution fountain view at 16:00 (after noon-asr) Prayer

Figure 89: Ablution fountain view at 12:00 (Noon-Zuhur) Prayer

Figure 90: Riwaq view at 16:00 (after noon-asr) Prayer

Figure 91: Riwaq view at 18:00 (sunset-maghreb) prayer

Figure 92: Riwaq view at 12:00 (Noon-Zuhur) Prayer

Figure 94: Mihrab view at 12:00 (Noon-Zuhur) Prayer 400 -150 lux

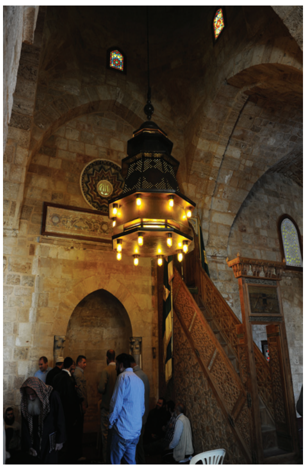


Figure 95: Mihrab view at 16:00 (after noon-asr) Prayer 200- 100 lux

Figure 93: view at 18:00 (sunset-maghreb) prayer 50 lux

Artificial lighting

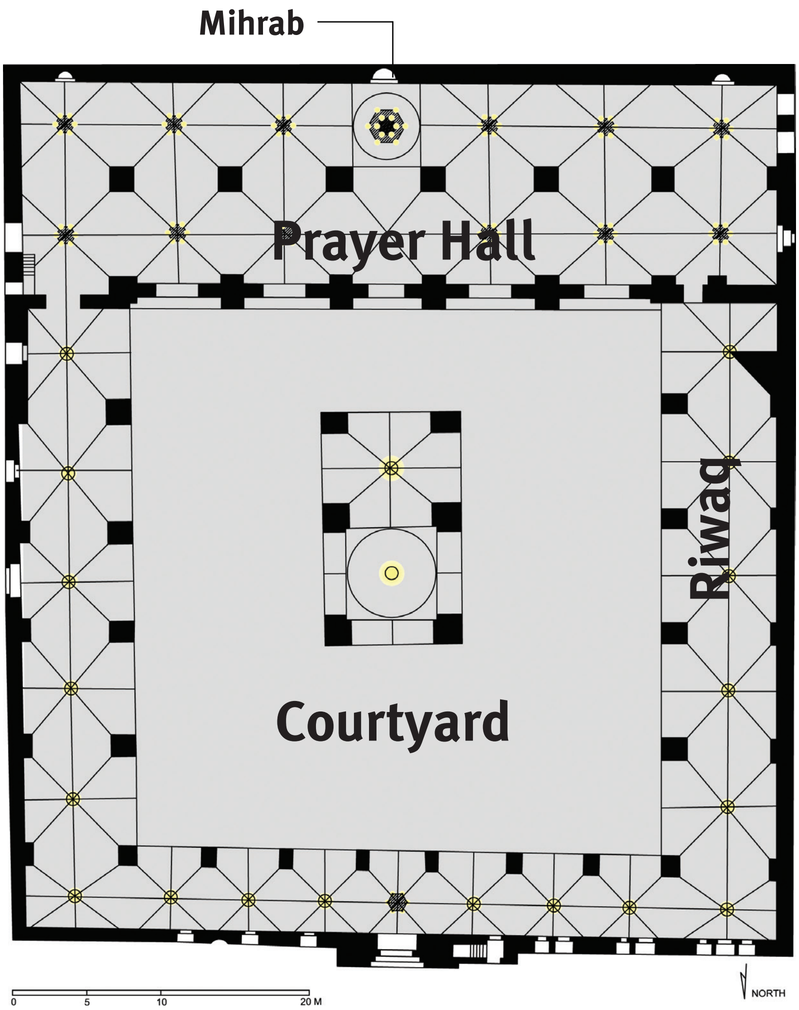


Figure 96: Mosque general lighting layout

Figure 97: close-up view of Mihrab lamp.

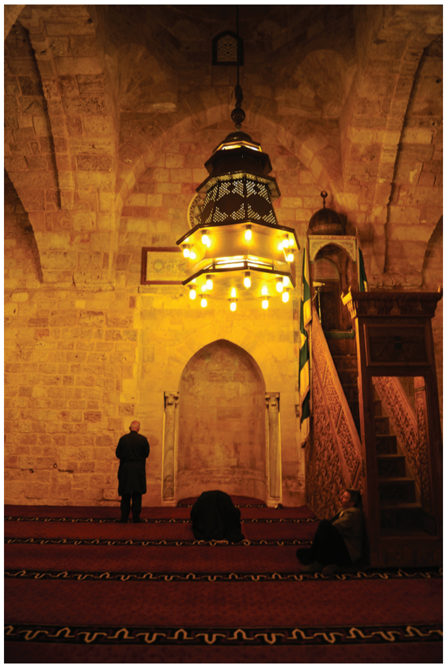


Figure 98: Mihrab area lit by two leveled Mamluk brass lamp.

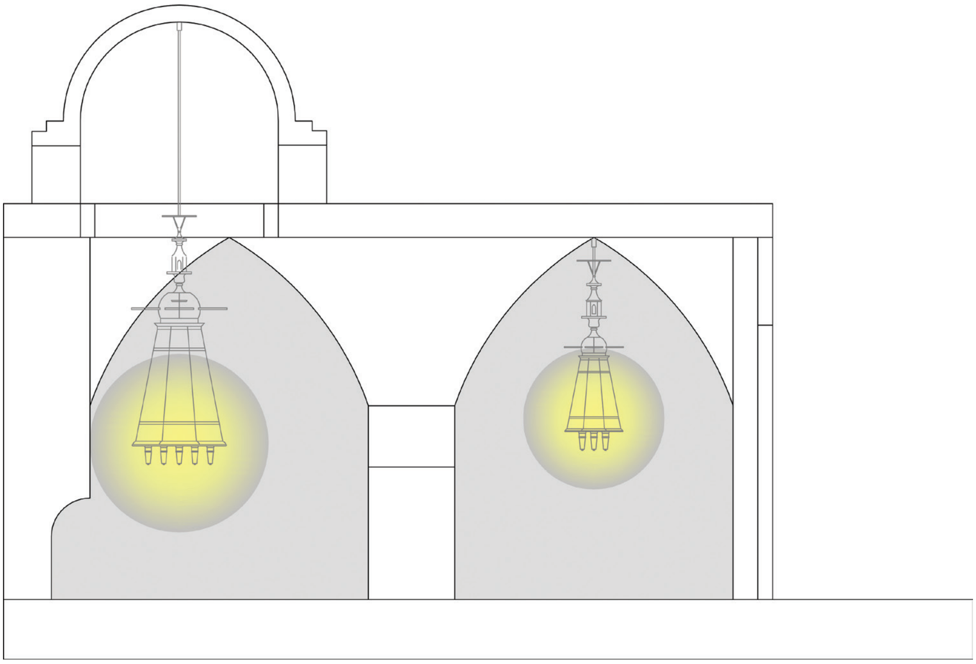


Figure 99: Diagram showing how the Mihrab area(left) is emphasized by placing a bigger Mamluk brass lamp with stronger lighting output.

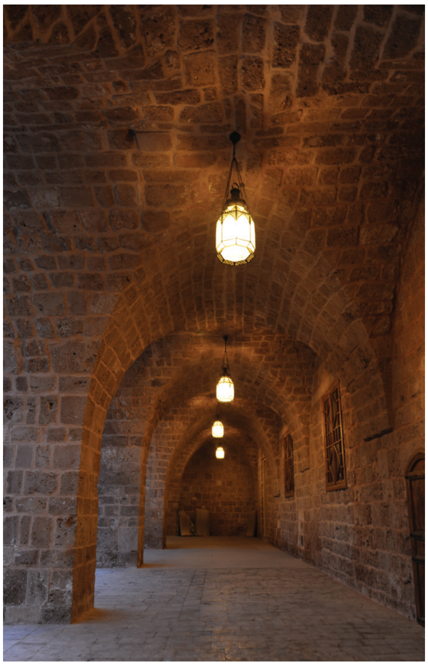


Figure 101: Repeated row of centralized small single source lamps are placed in the Riwaq.

Figure 100: Smaller Mamluk brass lamps are used to lit the prayer hall

5. Sultan Hasan Complex

NAME | Sultan al-Nasir Hasan Funerary Complex
LOCATION | Cairo, Egypt
DATE | 1356- 1363 (14th Century)
STYLE | Mamluk
BUILDING USAGE | Madrasa, Mausoleum, Mosque
PLAN TYPE | Four Iwan

The Complex of Sultan Hasan was built between 1356 and 1363, and included a madrasa, congregational mosque, and mausoleum. The free-standing complex, which had a monumental domed mausoleum flanked by minarets, only one of which survives, is located in a prominent position below the Citadel, toward which the monumental portal is oriented. The muqarnas-hood portal occupies the entire length of the façade. The height of the exterior walls and the arrangement of the windows give the facades a strongly vertical emphasis.

The four iwan arrangement of the madrasas takes up the center of the plan, with an ablutions fountain in the center of the courtyard and the four madrasas accommodated in the corners of the plan. The qibla iwan is significantly larger than the remaining three, which are also monumental in size and scale. Rather than integrating the students' cells into the central space, the cells were arranged along the street facades and their windows comprise an integral part of the architecture of the facades.

Daylighting

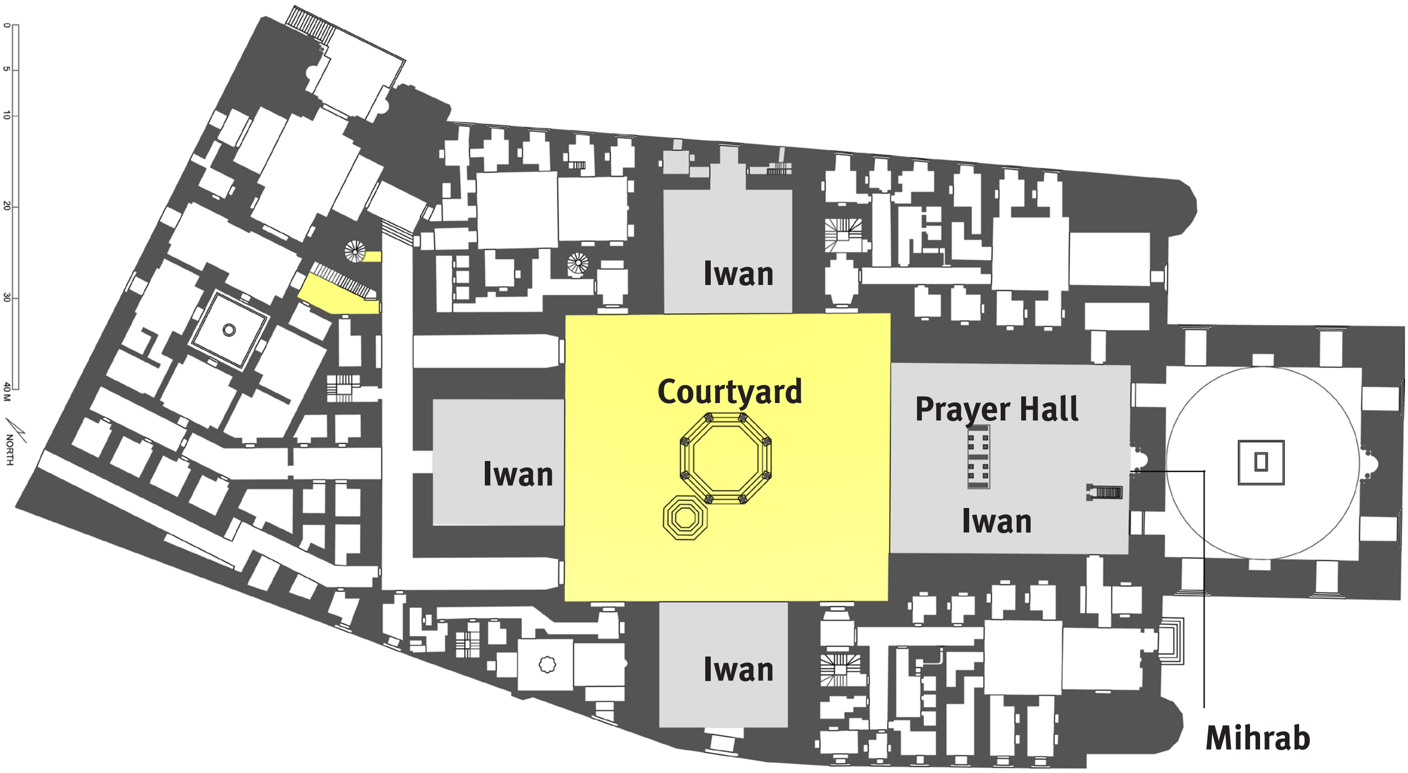


Figure 102: Mosque plan showing covered areas in grey and open courtyard in yellow.

Figure 103: Interior view of the prayer hall Iwan.

Figure 104: View of the ablution fountain and the western and northern Iwan, having different natural lighting levels due to their different orientation around the courtyard.

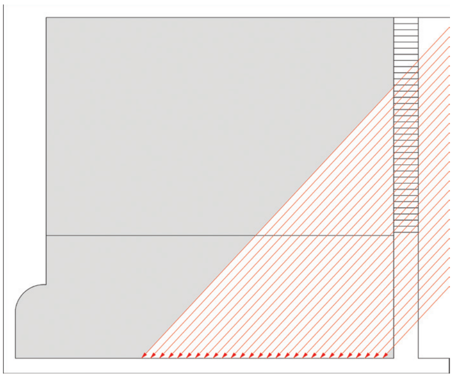


Figure 105: Due to the high ceiling of the Iwan, large amount of direct daylight is entering the prayer hall, creating bright lighting levels.

Figure 106: View of the dome located at the main entrance hall, allowing daylight to enter the space through its windows.

Figure 107: Light shaft allowing daylight to enter the corridors.

Artificial Lighting

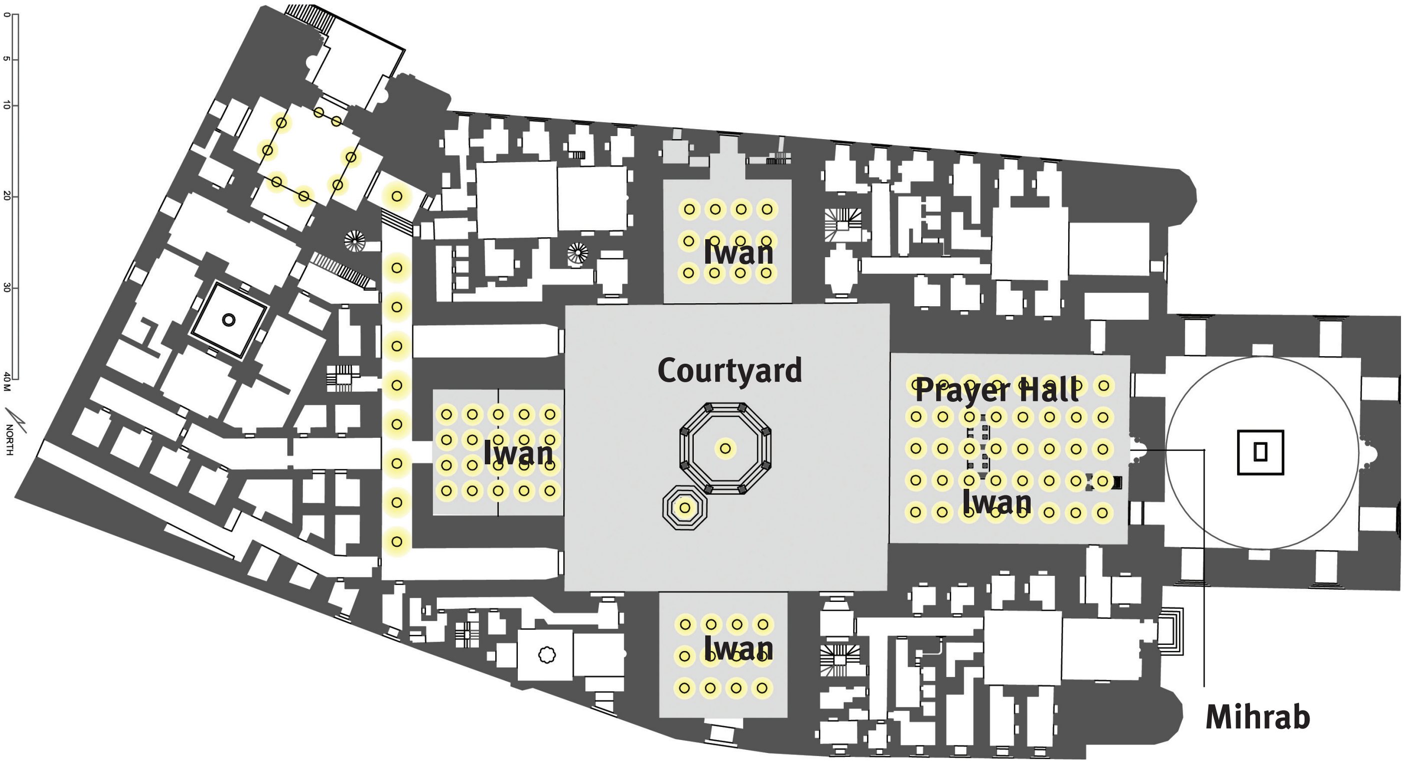


Figure 108: Mosque general lighting layout.

Figure 109: Hanging mosque lamps located at the complex's corridors.

Figure 110: Hanging mosque lamps located at the complex's corridors.

Figure 111: five rows of eight hanging rock crystal lamps, are placed in the prayer hall to achieve even lighting distribution.

Figure 112: Hanging mosque lamps at the main entrance hall.

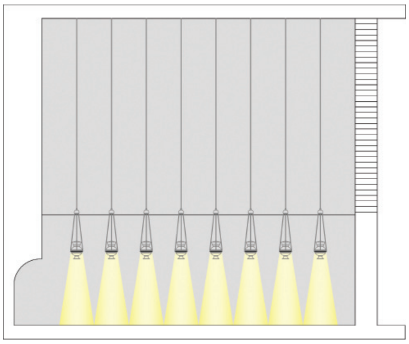


Figure 113: Diagram showing the lighting layout of the prayer hall.

Due to the great advantages of the rock crystal lamp different lighting effects were applied, in order to fit the different special functions of the Sultan Hasan Complex.

6. Selimiye Complex

NAME | Selimiye Complex
LOCATION | Edirne, Istanbul
DATE | 1568- 1574 (16^{th} Century)
STYLE | Mamluk
BUILDING USAGE | Madrasa, Hadith school, Mosque
PLAN TYPE | Square based domed mosque

Situated on a small hill in the center of Edirne, the complex is composed of the mosque, a madrasa, a hadith school and a timekeeper's room. With its dome and four minarets, the mosque can be seen from a long way as one approaches the city, which it has come to symbolize. The dome has a diameter of 31.22m and a height of 42.25m), with the addition of a protruding Mihrab, producing the most acclaimed work in Ottoman architecture. The single dome covers the whole depth of the mosque while the salient Mihrab and lateral spaces add an extra perspective. The dome covers some 30% of the mosque's floor surface (2000m2).

The outer Riwaq is not confined to the flanks but, for the first time in mosque architecture, continues also along the Mihrab wall. As we have seen, in the octagonal plan, the arch spans are reduced. Moreover, the increased number of props also reinforces the building's resistance to potential earthquakes. The octagonal frame rests on the sidewalls surrounding the Mihrab on the southern front, on the two other fronts on large buttresses (4x16m together with the pillars) and large pillars on the entrance front. None of the elements gain sufficient importance to enter in competition with the dome, as would be the case with suspended arches in a square-based system, so that it left to dominate the whole interior space. Finally, the light penetrating from eight sides defines the visual balance of the space.

Daylighting

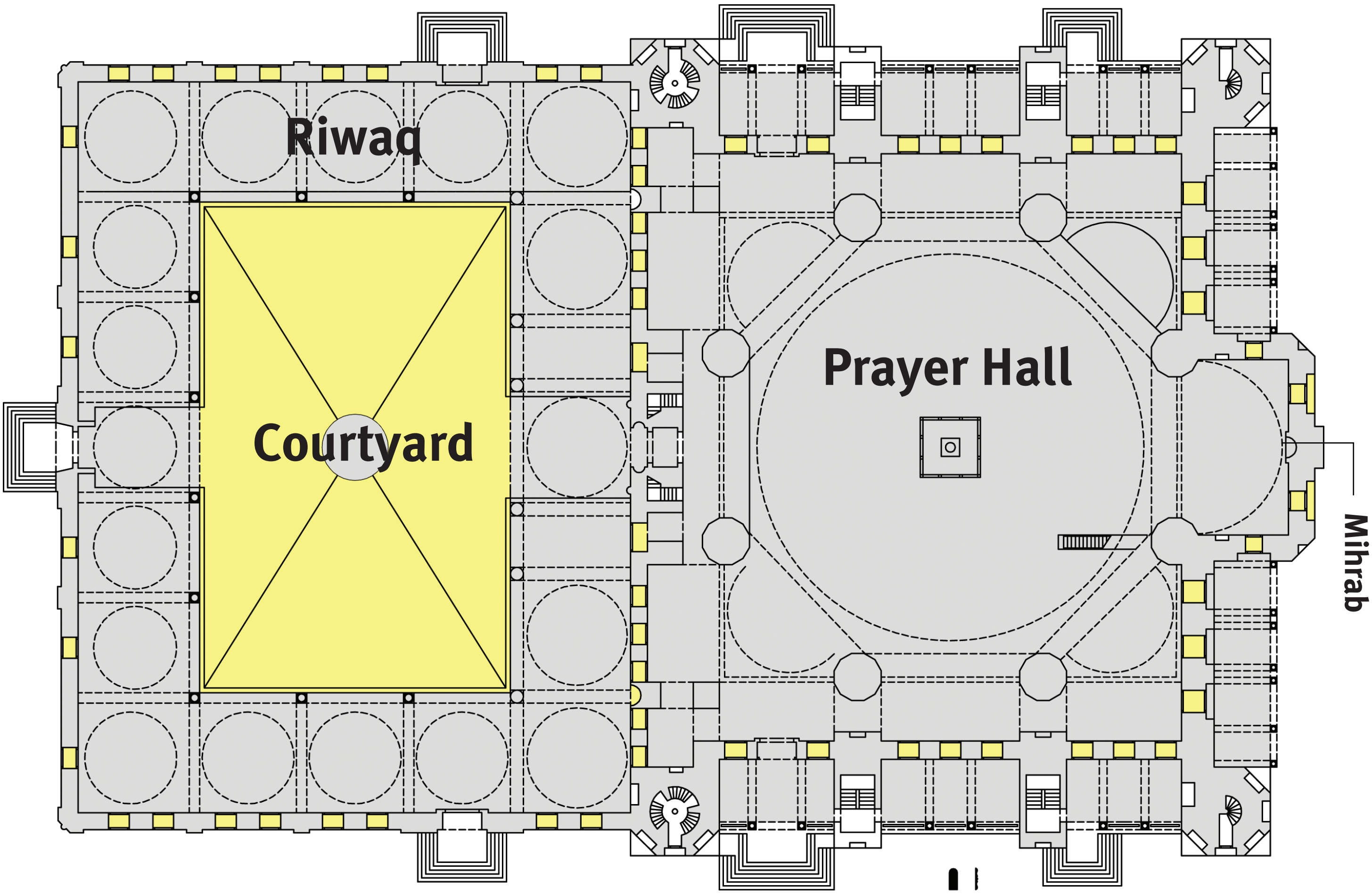


Figure 114: Mosque plan showing covered areas in grey and open courtyard in yellow.

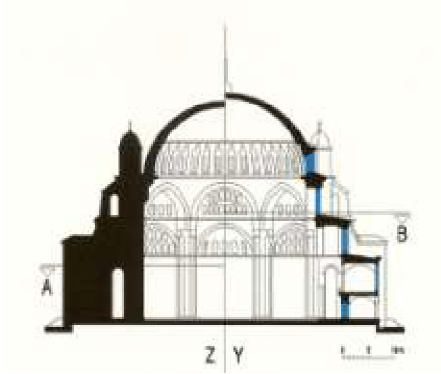


Figure 115: Structural scheme section

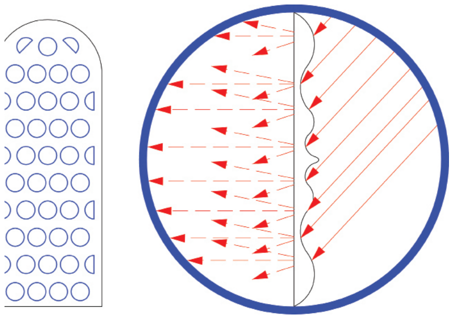


Figure 116: Diagram showing the function of the textured glass. Scattered diffused light is lighting the interior of the mosque, achieving highlighting levels and reduced glare.

ure 117: View of Qibla wall with three fenestration levels.

Figure 118: General interior view of the mosque prayer hall

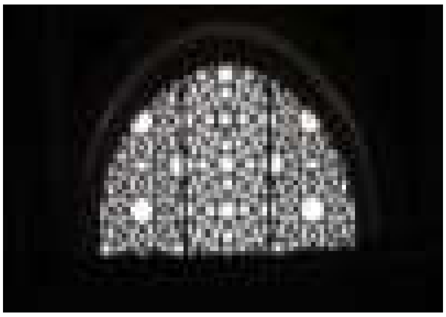


Figure 119: Grilled window with geometric decorations.

Figure 120: Close up view of the diffusing glass window where most of the day light is allowed to enter thespace.

Figure 121: Single piece of the textured glass that is used for most of the windows

Figure 122: colored glass window.

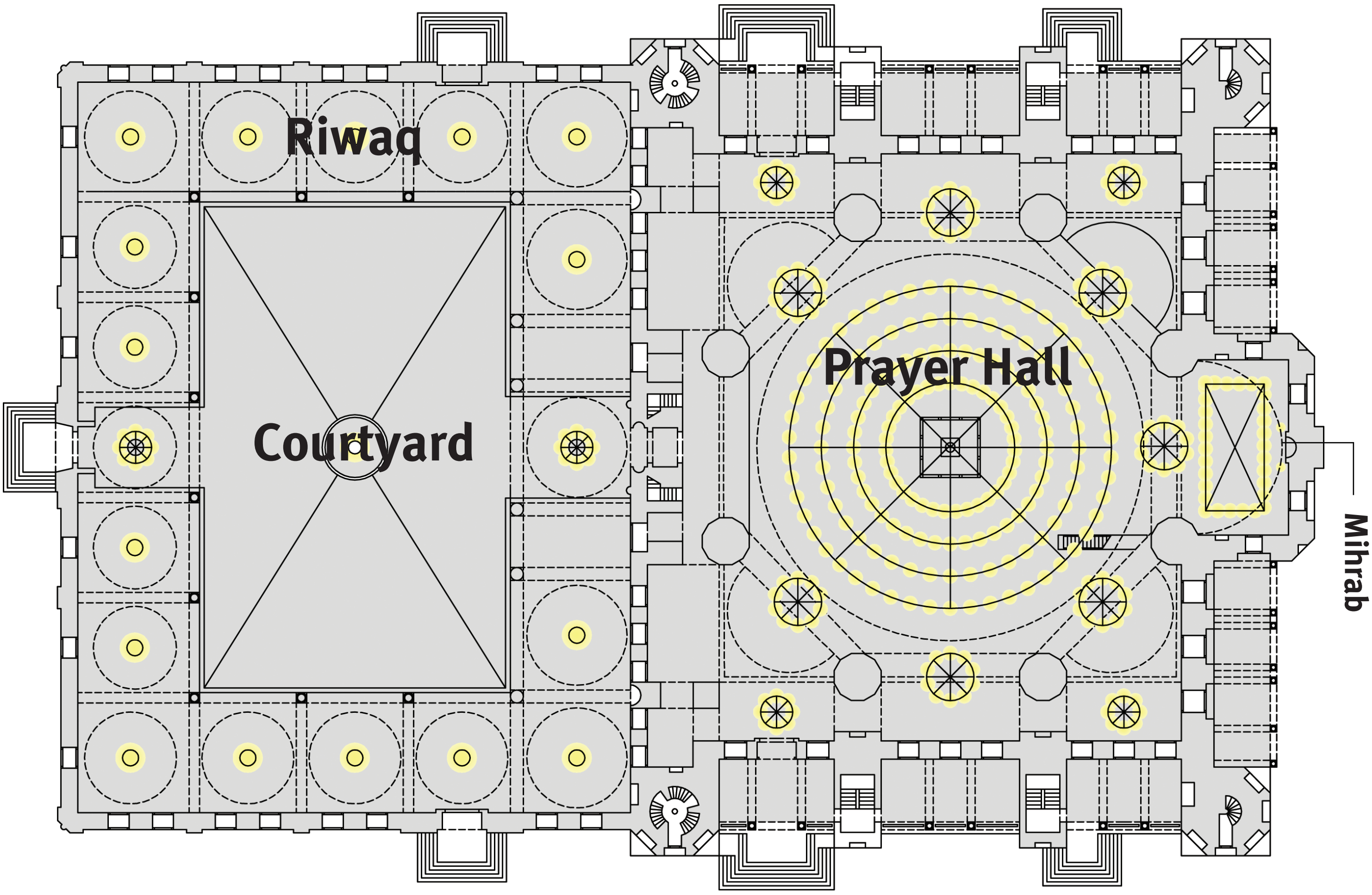


Figure 123: Mosque general lighting layout.

Figure 124: By carefully repeating the rings of light throughout the interior space of the mosque, in different dameters nad height levels. An atmospphere of warmtha and serenity is created.

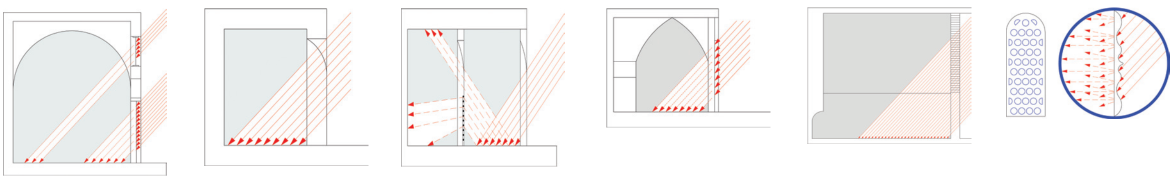
Figure 125: Close up view of showing low suspended rings holding a large number of small glass lamps.

Figure 126: Candle sticks flanked on both sides of the Mihrab, creating a visual emphasis on the Mihrab area.

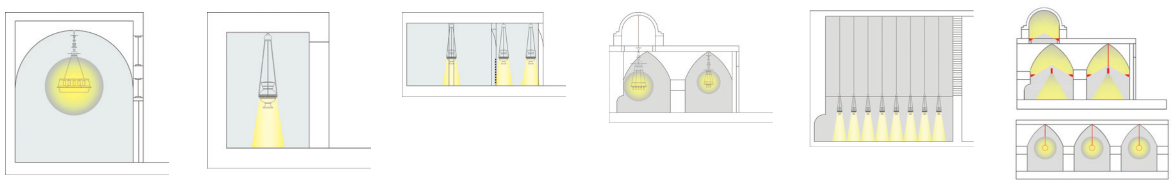
06 Conclusion

Analytical Comparison

vertical colored glass windows facing the courtyard	open arch prayer hall arcades wrapped around the courtyard	mashrabiya fenestration facing the courtyard	vertical clear glass windows facing the courtyard	open iwan	vertical clear glass windows diffusing glass windows located nearly in everywhere
dome windows qibla wall windows	grilled windows wrapped around the prayer hall walls	dome colored glass windows raised sailing colored glass windows	qibla Colored glass windows Dome Colored glass windows	grilled windows at qibla wall and the other three weans	grilled and colored glass windows



even lighting distribution with low lighting levels		low light levels	high lighting levels with uniform lighting distribution	high lighting levels with clear contrast of shadow and light	high lighting levels with uniform lighting distribution and reduced glare
- prayer hall Candle -chandeliers riwaq brass globe	rock crystal mosque lamps	rock crystal mosque lamps prayer hall & riwaq	mamluk brass lamps	rock crystal mosque lamps	circular polycandelons



low lighting levels uneven lighting distribution	uniform lighting distribution with emphasis on horizontal surfaces lighting distribution	highlighted vertical surfaces clear perception of different spaces	low lighting levels with clear perception of different spaces	uniform lighting distribution with clear perception of different spaces	even lighting distribution with clear perception of different spaces

Analytical Results

From the analytical comparison of the case studies, we can conclude that Artificial and Daylighting in historical mosques have changed and evolved throughout history.

From the Umayyad to the Ottoman dynasty, unique lighting atmospheres were created through different Daylighting and Artificial lighting tools, used as method to create the identity of every architectural style.

It is true that every dynasty had its own unique lighting atmosphere, especially regarding lighting levels, on the other hand a clear emphasis on creating uniform lighting levels through ambient lighting distribution in order to light the prayer hall, simple lighting tools are used to create enough lighting levels to fit the function of other spaces, such as the corridors of the Riwaq, the ablution fountain, and the main portal were few light is needed.

What the Ottomans have learned from all the past dynasties, is the main reason behind the great lighting quality of the Ottoman mosques, both by day and by night, where diffused light of illumination levels reaching 400lux during the day, and uniform ambient lighting levels with an emphasis creating different lighting effects to separate the architectural spaces of the mosque.

From this observation we can say that by following the steps of how mosques were lit in the past. Modern lighting tools should be used as an enhancement method in order to maintain the architectural identity of the mosque and to create a sacred architectural lighting atmosphere.

07 Modern Mosque Lighting Design

Mosque Lighting Design Steps

Mosque lighting design can be achieved through a proper design steps. An attempt of creating a design guideline can be a great help to achieve the desired concept.

MOSQUE LIGHTING DESIGN STEPS

BUILDING ANALYSIS | Before getting deep into the lighting design steps, a proper analysis of the mosque in different perspectives should be done:

- Geographical setting
- Daylight analysis through solar path angle.
- Architectural design: how the spaces of the mosque are defined in respect to style, scale and function.
- Location of windows: how daylight is penetrating the prayer hall of the mosque.
- Building material: understanding the characteristics of the building material and its reaction to natural and artificial light.

CONCEPT | By understanding the natural setting of the mosque and the cultural background of the society where the mosque is located. For examples people in the Arabian Gulf region have tendencies to like bright light, so lighting levels in the mosques of the Arabian Gulf region can be brighter than the mosques located in other parts of the world.

LIGHTING DESIGN

- Daylighting

The handling of daylight in a mosque is very dependent on the climate conditions of its location. In very hot climatic zones, daylight is only admitted through very small opening or filtered, for example by transcend as can be seen in the Umayyad Mosque in Damascus.

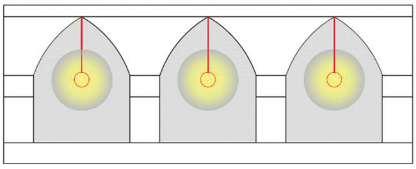


Figure 127: Diagram showing the Riwaq with ambient lighting effect.

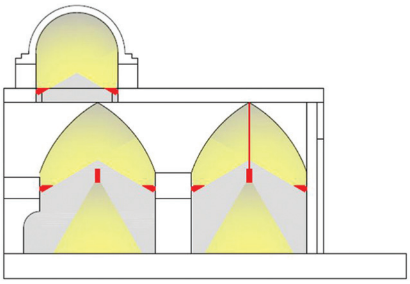


Figure 128: Diagram showing wide angle down lights and ceiling washlights.

In temperate climatic zones, more natural light is admitted into the interior of mosques through clear (rarely colored) glass windows. For the ottoman type of central-dome mosque, which commonly serves as a model for new mosques built in a traditional style or reinterpretations thereof, the following apply: The entire prayer hall and the enclosing walls of the room should be brightly and evenly lit. Direct sunlight and strong shadows should be avoided. Central areas such as the Mihrab or Minbar should not be emphasized through the use of light. The room can be illuminated via clear glass windows above floor level, likewise the rim of the dome but not the vertex of the dome itself, in order to avoid bright spots in the prayer hall.

- Artificial lighting:

\- Prayer Hall

Uniform lighting distribution of the prayer hall horizontal surfaces, can be achieved by using luminaires such as downlights with diffused wide angle lighting distribution.
In order to achieve uniform lighting for the mosque prayer hall ceiling, luminaires such as ceiling washlights can be used.
To give the dome the luminous ceiling effect, luminaires with grazing effect can be applied.

\- Circulation Areas

Areas such as the Riwaq and the portal can be lit with luminaires of ambient lighting characteristics.

\- Ablution Area

A high level of uniform lighting is needed to avoid slipping accidents in the ablution area, where the possibility of spilled water is possible.

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