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**Courtyard Floor of
Sultan Hassan Complex, Cairo, Egypt:
Full Documentation and Geometric Analysis**

By

Muhammad Moussa, B. Arch.

**A thesis submitted to
the Faculty of Graduate Studies
in partial fulfilment for the requirements
for the degree of**

Master of Architecture

**Carleton University
Ottawa, Ontario
May 11, 2001**

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Chair

Department

Thesis Supervisor

ABSTRACT

This study's focal point is the courtyard floor of the Mamluk monument: Sultan Hassan *madrassa* and mosque (1356-1361), Cairo, Egypt. The thesis presents the first accurately measured and drawn documentation of the floor pattern of the 32mX34.6m courtyard. The documentation process includes the line geometry as well as the color information of the floor patterns. The second phase of the thesis is a geometrical analysis aimed at the possible classification of the floor patterns as types of symmetry groups.

The final phase of this study summarizes the discoveries about the geometrical relationships and operations that are possibly involved in the generation of the entire floor design. The complexity of geometrical operations makes drawing a primary medium of presentation and visual argument.

The scope of the study mainly concentrates on the geometrical aspects of the floor as the main spine that binds the body of the thesis together. Sultan Hassan is a vast complex that has much to yield to the students of Islamic architecture, and more specifically Mamluk artistic tradition.

Acknowledgements

Field measurement of the Sultan Hassan courtyard floor was done during the months of December- January 1992-93 by a small group of Carleton University architecture students led by Prof. Gulzar Haider. Since then the desire to accurately draw and understand the morphology and possible intentions of this Mamluk architectural masterpiece has gone through different phases depending upon students' availability and interest. I acknowledge the hard work of all those who preceded because in many ways I sense I am harvesting the fruits of what they planted. With respect I wonder if any one of them could have foretold the nature of fruits that have come forth. The work presented here is a form of a conclusion, which hopefully is bringing a new beginning.

In our necessity to revisit the site to correct and complete the 1992-93 measurements I like to acknowledge the crucial contributions of the Cairene youth Omar Moussa, Mohammed Derbala., Osama Moussa, Mourad Youssry and Neviene Wafaay.

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To Sajida's memory, who sought spirals signifying the journey of self in my drawings long before I discovered the dance of rotational symmetry, I offer this.

Finally I like to profess my deeply felt gratitude to God who created me and gave me curiosity to search beyond appearances and to His Messenger Muhammad and all the scholars of His Way who through their example made the pursuit of knowledge a duty for me.

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Introduction

Computer generated image of Sultan Hassan Courtyard, Cairo, Egypt.

IV.1. Background on Mamluk Period and Culture

The architectural achievements of the Mamluk¹ period² (1250-1517) have certainly played a role in earning a place for Cairo among UNESCO's list of "Cities of Human Heritage."³ Approximately one thousand mosques were constructed in the comparatively short period of the Mamluk rule, majority of which were in the magnificent capital city. The famous 14th century Andalusian social theorist/historian, Ibn Khaldun (1332-1406), in several instances in his "*Muqadimah*" (1377), refers to Cairo as a manifestation of a highly developed civilization of his time: "Today no city has a more abundant sedentary⁴ culture than Cairo. It is the mother of the world, the great center (*iwan*) of Islam, and the mainspring of the sciences and crafts."⁵ In fact, not only the practice of the sciences and crafts, represented as mosques/schools, and Sufi colleges was viewed by Ibn Khaldun as a sign of cultural flourishing, but also the marriage between 'sciences', or more precisely, knowledge (*ilm*) and crafts (*hiraf*), was a sign of the advancement of a civilization: "When civilized people have more labor than they need for mere subsistence, such labor is used for activities over and above making a living. These activities are man's prerogative; they are the sciences and the crafts... We, at this time (14th century), notice that the sciences and scientific instruction thrive in Cairo, because the civilization is greatly developed and its sedentary

¹ They were a dynasty of slaves, mostly Turkish in origin or Central Asian, who ruled over the Islamic world between Egypt and Syria, the word 'Mamluk' means "the owned".

² The Mamluk rule spanned two periods in the history of the Egypt and the Middle East. First is the *Bahri* Mamluk period (1250-1381), this name was given because the main barracks was on the banks of the Nile River. (*Bahr* (بحر) is Sea in Arabic). The second is *Burji*, or Circassian (1381-1517), the name *Burj* (برج) means tower in Arabic. The name changed when the main barracks shifted; the Mamluk Sultan Qais'un quartered a group of bodyguards (Mamluks) at the towers of the citadel; they became known as *Burji* as their power grew to rule Egypt.

³ Doris Behrens-Abouseif, page 3.

⁴ As opposed to nomadic culture in Ibn Khaldun's terms.

⁵ *Muqadimah*, Ibn Khaldun (مقدمة ابن خلدون), Vol. III, Page 315.

culture has been well established for thousands of years, therefore the crafts are firmly established there and exist in many varieties. One of them is scientific instruction.”⁶

“Scientific instruction,” just as any production of an artisan, was considered a craft because of the similarity in the adopted attitude; using Ibn Khaldun’s term: “the scientific habit”. A ‘habit’ in the sense of the thoroughness of practice⁷, a scientific method. This practiced attitude has also produced a certain cultural homogeneity within the different student groups, Sufi guilds and craft practices. “This (state),” Ibn Khaldun adds, “has been strengthened and preserved in Egypt by the events for the last two hundred years (1200-1400) under the Turkish (Mamluk) dynasty... They built a great many colleges, hermitages, and monasteries, and endowed them with mortmain endowments that yielded income. They saw to it that their children would participate in these endowments, either as administrators or having some other share in them. In addition to the fact that they were inclined to do good deeds and hoped for (a heavenly) reward for their aspirations and actions. As a consequence, mortmain endowments became numerous, and the income and profit increased. Students and teachers increased in numbers, because a large number of stipends became available from the endowments. People traveled to Egypt from the Iraq (north east of the middle east) and

⁶ *Ibid.*, Vol. II, Page 435. To capture Ibn Khaldun from an architectural point of view and in contemporary terms; the history of humanity viewed through the lens of Architecture, becomes the finest argument of the role of architecture as a container and a shaper of the human beyond the apparent physical dimensions. Architecture, at the height of Civilizations, transforms beyond being the simple container of the human body, as a shelter and a shell. Perhaps it is through the craftsmen/women and scholars and their interchange that a civilization is able to communicate its inner essence to its forthcoming generations. In turn, the human presence transforms from the simplistic existence of a physical body to become a vessel and a language for humans to transform their spirits, collectively and individually.

⁷ “Habit is different from understanding and knowing by memory. Understanding of a single problem in a single discipline may be found equally in someone well versed in the particular discipline and in the beginner, in the common man who has no scientific knowledge whatever, and in the accomplished scholar. Habit, on the other hand, belongs solely and exclusively to the scholar or the person well versed in scientific disciplines.” *Ibid.* Vol. II, page 427.

⁸ *Ibid.* Vol. II, page 435.

the Maghrib (west Africa and Morocco) in quest of knowledge. Thus, the sciences were very much in demand and greatly cultivated there.”⁸

Bearing this general cultural context in mind when examining architecture, Mamluks seem to have developed different types of ‘religious’ architecture bestowing different shades of the concept of the sacred and knowledge on each one. Three main categories of religious architecture could be identified as types of space structure; each having functions in addition to and beyond that of prayer (*masjid*), these are briefly presented below:

1. The *riwaq*⁹ congregational mosque (*Jami*):

The congregational mosque was a center for major events in the city. This type was, and continues to be the place for the collective noon-prayers held every Friday. It therefore attracts a great number of people from all over the city. (Fig. 1)

Fig. 1: Congregational mosque of Baybars (1266-1269) after Hoag

2. The four *ivan*¹⁰ *madrasa*: During Mamluk period, education was understood as the acquiring of the sacred knowledge using the inspiration of the Quran¹¹, even the sciences that could be considered today as most secular of sciences were

Fig. 2: Plan of madrasa Sarghatmish (1356). After Aly Gabr.

⁹ (رواق) A space organization of the mosque in aisles or rows of columns carrying a roof, which is sometimes elevated in some way to indicate the Qibla axis. This model is formally the closest of all three types to the prophet's mosque in Medina.

¹⁰ (ايوان) A deep niche or a vault, which is usually elevated from a central space, and sometimes, uncovered courtyard.

¹¹ Quran is believed by Muslims to be the Divine word revealed to the Prophet Muhammad through the Archangel Gabriel.

related to Quran and taught as sacred sciences¹². (Fig. 2)

It is revealing to find that in some of the *iwan madrasa* type, usually consisting of four *iwans*, which are often understood to be divided into four sections for the functional teaching of the four schools of Sunnite Islamic law, only two or three of the four were taught. (Fig. 3) This raises an intriguing question about the nature of the relationship between this architectural formula and the *madrasa* as a building type.

Furthermore, in some cases the four *iwans* go through an architectural transformation of a sort; for example some *iwans* become too small in size to accomodate any classes, and sometimes they are only architecturally implied. (Fig. 4)

Although the main function of the *madrasa* is a college/mosque, usually the program encompassed other functions to accommodate different needs of the students and the immediate community around it: hostels, hospitals, water fountains etc. These functions were architecturally distinguished from the main function of a mosque and a college through having an indirect relationship with the main courtyard.

Fig. 3: Madrasa/mosque of Prince Ijaj al-Yusufi (1373). An example of a four *iwan* plan, teaching only two schools of Islamic law. (after Aly Gabr)

Fig. 4: Madrasa/mosque of Sheykhu (1349). An example of a four *iwan* type plan with two of the *iwans* are implied. (after Aly Gabr)

¹² The Islamic sciences which were taught in the Mamluk madrasas according to Ibn Khaldun included: The Quranic sciences and its divisions including Hermenutics and interpretation. Jurisprudence and its divisions, including inheritance laws. The sciences of speculative theology. The science of Sufism. The science of dream interpretation. The rational sciences. The sciences concerned with numbers including the craft of calculation, Algebra and arithmetic. The geometrical sciences including spherical figuers, conic sections, survey and mechanics. Optics. Astronomy. The science of logic. Physics. The science of medicine. The science of agriculture. The science of metaphysics. Alchemy. and the science of the secrets of letters. Ibn Khaldun's "Musaqadimah".

3. The *khulwat*¹³ and the *khanqah*:

This type is similar in some ways to the *madrasa* in its function as a 'school', however there are some distinctions between the two types, which gives them the different architectural character. Traditionally the students in the *khanqah* usually are more committed to the practice of a specific Sufi Path (*tariqa*), and therefore their rooms/cells are arranged around the courtyard and were directly related to it. As a result, sometimes one or more of the *iwans* disappear from the space arrangement. (Fig. 5) In some examples, a merging of the function of *madrasa* and *khanqah* as one building would maintain both the *Sufi* cells and the four *iwans* opened onto the courtyard. (Fig. 6)

Fig. 5: Khanqah of Sheykh (1355). An arrangement of khulwat (Sufi cells) around the courtyard. (after Aly Gabr)

Fig. 6: khanqah/madrasa and mausoleum of Sultan Baybars (1307). (After Creswell).

Having briefly reviewed three main types of religious Mamluk architecture, it is evident that the courtyard is a central element in all three types. Even more specifically, during the Mamluk period we find that the centred courtyard of the *madrasa* type has been furnished with a geometrical marble patterned floor, which seems to be a rather consistent architectural formula integrated with the four *iwan* plan in the architecture of the Mamluk

¹³(خلوات) Hermitages and solitary prayer place for the Sufis, which also could be compared to a monastery.

madrasa. This re-composing of the same elements suggests a form of a physical and a spiritual exercise performed by the Mamluk culture in search of an “archetypal space”. The epitome of this development, as regarded by the majority of historians through different times, is the mosque-*madrasa* complex of Sultan Hassan; the courtyard with its patterned marble floor is the largest in size and perhaps the most complex in its geometry.

This thesis primarily comprises the documentation of the geometrical floor pattern of the courtyard of Sultan Hassan *madrasa* in Cairo (1356-1361), which historically belongs to the *Bahri* Mamluk period (1250-1381). Through a critical analysis of the geometry of the marble patterns, the thesis builds towards an exploration of the architectural and cultural significance of the floor. The absence of specific manuscripts on architectural theory from the Mamluk period raises questions about the sophisticated works they left for us. But perhaps the precise nature of the geometrical operation would lead to critical insights into the approach and development of the attitudes of craftsmen/artists/builders of this important period.

IV.2. The Approach of the Study

Any serious examination of an historical work of architecture cannot be divorced from a theoretician’s, a philosopher’s, or an art historian’s attitude. They are justified in the interest of the seriousness of the inquiry into the work of architecture. Understandably, the search often revolves around the making of architecture, its genesis and the process of

becoming in the world of appearance. Questions, in turn, are raised about how that shapes the people, whose hands, eyes, and imagination touch it. “Architecture”, Hassan Fathy suggests, “is the most important element in culture because a building is like the shell of a snail. The soft, living part secretes calcium carbonate and by mechanical forces it takes the shape of a spiral, but once the shell is formed it turns on the living soft part and gives it shape.”¹⁴

Through being cognizant of, and intimate with, this process of ‘the making’¹⁵ one can gain critical insights into the meaning and significance of a work of architecture. In other words the attempt is to let the actual work of architecture set the choreography of its architectural and cultural significance, through a form of a replay of its genesis. This approach is perhaps an application of George Steiner’s approach which he argues by illustrating three principal senses of ‘interpretation’: “An interpreter is a decipherer and communicator of meanings. He is a translator between languages, between cultures and between performative conventions. He is, in essence, an executant, one who ‘acts out’ the material before him so as to give it intelligible life. Hence the third major sense of ‘interpretation’. An actor interprets Agamemnon or Ophelia. A dancer interprets Balanchine’s choreography. A violinist a Bach partite. In each of these instances, interpretation is understanding in action; it is the immediacy of translation.

Such understanding is simultaneously analytical and critical. Each performance of a dramatic text or musical score is a critique in the most vital sense of the term: it is an act

¹⁴ These ideas were discussed in the Aga Khan award seminar held in Fez, Morocco 1979.

¹⁵ The making in this instance is meant to express a process that stretches before and after the physical making; the process of the making could be a process of discovery, thinking and realization as well. The physical making then becomes a sign of its presence. The physical object as a sign, a manifestation of the process of ‘making’.

of penetrative response which makes sense sensible. The ‘dramatic critic’ par excellence is the actor and the producer who, with and through the actor, tests and carries out the potentialities of meaning in the play. The true hermeneutic of drama is staging (even the reading out loud of a play will, usually, cut far deeper than any theatrical review). In turn, no musicology, no music criticism, can tell us as much as the action of meaning which is performance. It is when we experience and compare different interpretations, this is to say performances, of the same ballet, symphony or quartet, that we enter the life of comprehension.”¹⁶

Therefore when presenting this thesis, the pursuit is to communicate in the same ‘performing’ manner. In other words, to reenact the geometry of the floor as the process of its making distinct from its construction—which is an important study in the context of the history of technology. Our interest is to seek the possible understanding of the collective intentions of the builders when applying the ordering principles of space. The very nature of the geometrical operations gives us an advantage to carry out this kind of a reading. Different intentions can render themselves clear. For instance, an application of reflection is quite different from that of rotation. The implication of the application of these distinct operations could be viewed as travelling the path of the maker, the replaying of the music from the musical notes. Through the geometry, perhaps one would be able to access this work of architecture and its cultural connotations, to examine the different stages and layers of its construction—that which is being constructed?

¹⁶“Real Presences” Stienen, George, page 8.

IV.3. History of the Documentation of the Floor

In 1895, Hertz Bey¹⁷ produced what has become the ‘standard’ documentation of "The Mosque and *Madrassa* of Sulatn Hassan". The publication comprised a complete set of measured drawings; detailed sections, elevations and plans, site indication and location of the monument; a review of historical references to the monument in the manuscripts of oriental and western historians and travellers; a critical study of the monument from the point of view of style and its technical aspects; a report on the actual state of the edifice at that time; and an evaluation of repair work that was needed and its cost estimate. Sultan Hassan *madrassa* was one of the few buildings that were fully surveyed and documented in this thorough manner.

Fig. 7: Photo in Herz Bey's publication

There is no evidence of any geometrical documentation of the floor patterns of the courtyard, except one photograph taken from an upper floor. (Fig. 7) Hertz Bey, after observing other Mamluk monuments in Cairo, deduced that the floor, because of its fine mosaic like details non characteristic of other Mamluk floors, is of a later period than that of the Sultan Hassan's. Based on this assumption he then suggested in his publication that "to restore the floor tiles according to the actual design is useless, furthermore, a design with small pieces is very expensive and would damage quickly because of weather changes. It

¹⁷Chief Member and Architect of The Committee of Conservation of Monuments of Arabic Art founded in 1881.

therefore would be better to be content with a design with bold lines (gestures or strokes), which another monument can help give clues for.”¹⁸ In the footnotes Hertz Bey suggested to look at the court of Barquq mosque. (Fig. 8)

fig.8: Barquq mosque/madrassa (1386).

Hertz Bey’s work served as a foundation for the complete restoration of the monument twenty years after its publication. The floor was then thoroughly restored in 1915 under the supervision of “The Committee of Conservation of Monuments of Arabic Art.”¹⁹

Consulting more photographs and other documentation done at the time of the restoration, which might be archived in Cairo or Paris, would reveal whether the restoration process has completely restored or replaced the original floor pattern. However, comparing the only photograph of the court from Hertz Bey’s publication with the existing design, the overall design seems to have not changed much. Though, some patterns appear to have been simplified and some of the details were eliminated. Also it seems that there were some motifs added, which are not present in the photograph.

It is one issue if some specific patterns have been substituted, but it is a different and a far more serious matter if the design philosophy, which generated the original design, has

¹⁸“La Mosque du Sultan Hassan au Caire” 1899

¹⁹“La Mosque du Sultan Hassan au Caire”, Publication by The Committee of Conservation of monuments of Arabic Art, publishing Press of the French Institute of Oriental archaeology, 1899.

changed. It would then be necessary to further search for and consult other documentation of the restoration process to find or suggest the philosophy of the restoration itself. To find if the restoration committee and the craftsmen who restored the floor had indeed studied other examples of floor patterns from Mamluk Cairo to reconstruct the floor to its current design. If no evidence becomes accessible, perhaps a study of different floors of Mamluk Cairo would help shed some light on the approach of the Committee of Conservation.

To the best of our knowledge, this study is the first to present a full documentation of the floor pattern in its restored state. It would also be the first that is solely dedicated to the attempt of understanding the floor of the courtyard in its specific nature, to consider its geometry as a guide to give insight into the floor as an important architectural element.

IV.4. The Plan of the Study

Chapter One aims to establish a context for the project and introduce the documentation phases. First, the intent is to establish an historical context; a review of the history of construction and restorations. Second, a review of the architecture of Sultan Hassan *madrasa* aiming to locate the floor in the context of the overall physical and architectural experience. Third, an introduction of the documentation phases and the presentation of detailed line drawing of the floor patterns.

Chapter Two becomes the main body of the thesis; it includes a review of the definitions of geometrical terminology, and a taxonomy of symmetry groups. Based on this, every pattern of the floor is considered: starting with an analysis of its line geometry, its group designations as a motif, then considering the pattern colors in terms of its influence on the geometry as an operation, and finally an analysis of the geometric process of repetition in the floor.

Chapter Three: The intent is to capture an overall sense of the choreography led by the geometrical analysis of the floor through a set of drawings. This set would then act as a visual argument, based on which relationships and connections with culture and tradition could be further explored.

Chapter One

Section detail of nine sections that compose the floor of Sultan Hassan Complex.

V.1. A Brief Historical Context

Fourteenth century historian, Al-Maqrizi¹, is probably the earliest to document a detailed history of Sultan Hassan *madrasa* and locate it within the historical events of its time. In his book “Lessons and Morals by Remembering the Heritage of Monuments and Plans”², he describes the *madrasa* of Sultan Hassan as a manifestation of many wonders of the art of building; to the extent that he declares: “no other temple³ is known to resemble it in the countries of Muslims.”⁴

According to al-Maqrizi the Mamluk Sultan: Hassan, was approximately 26 years old when an impressive palace⁵ was dismantled in anticipation of the magnificent edifice to stand opposite to the citadel of the hill. Perhaps the foundations of the palace played a role in the way the irregular parameters of the building were laid out. The building was conceived as a complex including a *madrasa*, a mosque, an orphanage, and the mausoleum of the patron king: Sultan Hassan. Its four *iwan* space organization shows

Fig. 9 Plan drawing after (Hertz Bey)

¹ (المقريزي) Al-Maqrizi died approx. 1467. He is by far the most quoted I found during my research, majority of those who intended to write a detailed history about the monument referred to his work.

² “كتاب المواعظ والإعتبار بذكر الخطط والآثار”, a short title used is “*al-Khitat*” (الخطط)

³ He used the word *ma'bad* which means a “place of worship”, the odd use of the word is probably to include all sizes and types of mosques.

⁴ *Al-khitat*, al Maqrizi, page 316.

⁵ Al Maqrizi says this palace was Yalbugha El-Yahyawi's, one of the Mamluk princes of the 14th century.

a *madrassa* type (Fig. 9), but because of its sheer size it has also been regarded as a “*Jami*” (congregational mosque). The construction began in 1356. Master builders, geometers, and craftsmen were commissioned from across the Mamluk Empire for the construction. This might help clarify the apparent integration of different influences in the main composition and the motifs which comprise the surfaces of the building. Aside from the four-*iwan* layout of the *madrassa*, a clear Seljuk⁶ influence is evident in the original design where the entrance was flanged with two minarets. (Fig. 10) The construction of these two minarets was abandoned after the collapse of one of them. (Fig. 11) There are also some apparent characteristics in the decorative motifs of the facades which suggest that the craftsmen builders were familiar with the Chinese artistic tradition.⁷

Fig. 10: The facade as intended. (after Aly Gabr)

Fig. 11: The final portal design. (After Osman Rostam 1970)

Based on a calligraphic inscription in the Hanafi school in Sultan Hassan, where it praises the patron Sultan for the great achievement, it is hinted that the one who “constructed its architecture” was Muhammad Belbik Al-Husseiny. Tarek Waly understands this to be a tribute for the chief architect. Doris Behrens-Abouseif however, interprets it as

⁶ Seljuk were a dynasty of Muslims rulers, Turkish/Persian in origin, who governed over Persia between mid-eleventh century and mid-twelfth century.

⁷ The Hertz Bey's publication found the architectural style to be of diverse traditions, even suggested a European/Byzantine involvement in the construction of the edifice. The Chinese influence has been understood by many historians as a result of the flourishing of trade with the Chinese empire at that time.

an acknowledgment of a supervisor Mamluk prince's efforts.⁸ The construction of the basic structure required five continuous years (1356-1361); another three years for detailing, which was never fully completed. Though, the work was concluded in 1365. The marble floor was a part of the second phase, which extended after the death of the Sultan in 1361; the fountain structure was completed in 1363.⁹ After the sultan's death, Al-Maqrizi attributes the completion of the details of the construction to its final state to Al-Tawashy and Besheir Al Gomdar¹⁰

Repairs and restorations over the years were mostly done on the main structure of the building. Ibrahim Pasha rebuilt the dome and the second minaret in 1669-70 as their present appearance after the collapse of the original minaret in 1660, and the dome in 1661. The appearance of the floor as it is today is the result of the latest restoration in 1915 by "The Committee of Conservation of Monuments of Arabic Arts" as mentioned before.

In the specific case of the floor, it seems that since the last restoration a more recent replacement of a few pieces has occurred. These pieces could be easily identified because of the kind of marble and its state. Al-Maqrizi's documentation shows that most of the Mamluk building materials of marble and wood has been often imported from Syria; the quality of marble is usually more uniform and plain in terms of color and grain, unlike the majority of the marble produced by Egypt. However after a thorough geometrical analysis perhaps we would be more confident as to suggest which of the marble pieces is a recent replacement.

⁸ "Islamic architecture in Cairo", Doris Behrens-Abouseif, page 127.

⁹ "The Mosque of Sultan Hassan in Cairo", Osman Rostam, page 59.

¹⁰ Tarek Waly and Al Maqrizi

V.2. Locating the Floor in the Context of the Overall Architectural Experience

The *madrasa* of Sultan Hassan is situated in the heart of Cairo, at the foot of the Muqattam hill, which is magnificently surmounted by the Citadel of Salah-u'Din (1183-84) (Fig. 12), and later, Mohammed Ali Mosque (1830-48). The edifice echoes the side of the Muqattam hill and stands asserting its presence. Historically, for more than five hundred years the edifice has stood alone with its Mamluk style minarets challenging the Citadel of the hill and the pyramids far on the horizon¹¹. (Fig. 13) Today, its unchallenged dignity has not changed, though modern Cairo has completely re-modeled the horizon. Al-Riffai Mosque (1869-1912) extends the mass of the building creating an alley in between, which has recaptured the majesty of the building. (Fig. 14 and 15) The timeless character of the exterior elevation—articulated through the vertical recessed strips in which the apertures are located—sets

Fig. 12: Cairo from the west looking east, in the background Sultan Hassan Mosque (left) and the citadel (right). Close up from a lithograph by David Roberts (1796-1864).

Fig. 13: Cairo from the east looking west, in the background Sultan Hassan Mosque (left) and the Giza pyramids (right). Close up from a lithograph by David Roberts (1796-1864).

Fig14: Sultan Hassan (right), And al-Riffai (left) viewed from the citadel.

¹¹ The pyramids are still visible on the horizon from the minarets of Sultan Hassan.

up the skewed entrance for full effect. As one approaches the portal along the sidewalls, progressively the scale is emphasized. A flight of stairs then elevates the visitor to the niche, which is crowned by a complex of stone *muqarnas*

Fig. 15: The alley way between Sultan Hassan and Al-Riffai, Sultan Hassan's great portal tilts about 30 degrees from the facade into the alley and is about 37.7 meters high. The level of entrance relative to the street is 5.7 meters.

Fig. 16: The muqarnas of the entrance underneath which the calligraphic band runs.

that are unsurpassed in its intricacy and geometrical articulation. Fig. 15. It also embraces the visitor with a calligraphic inscription in the flowing *naskh* style: "In the name of God the Compassionate the Merciful. In Houses God has permitted that they be raised and His name be commemorated in them, praising Him by in the mornings and evenings."¹² (Fig. 16)

As one steps into the vestibule, the whole physical condition dramatically shifts. The bright white sunlight becomes a soft colored dim light filtering through eight triangular windows suspended approximately 24 meters high. The sound effect shifts by the acoustic quality of this chamber;

Fig. 17: The dome and muqarnas of the vestibule.

from the busy streets of Cairo to a quiet whisper, which echoes the quality of light. (Fig. 17)

¹² "بسم الله الرحمن الرحيم. في بيوت أذن الله أن ترفع و يذكر فيها اسمه يسبح له فيها بالغدو والآصال. صدق الله العظيم" Quran, Sura al-Nur "النور" (24): 36.

Crossing the threshold of the main door, a cool breeze embraces the skin coming from the depth of the mosque as opposed to the heat of Cairo streets; as if this threshold aims to erase the memory of the elements of the physical experience of the outside, only to prepare for a subtle use of the senses. As soon as the eyes adjust themselves to the cooler and dimmer environment, the sight of subtle natural light attracts the attention where a passage shows its beginning. Following the hanging lamps and the subtle natural light, one goes through two turns –one to the right and another to the left– which will bring the visitor to the threshold of the light filled courtyard beyond. (Fig. 18 and 19)

Fig. 18a: The plan drawing showing the main passageways leading to the courtyard.

Fig. 18b: Sultan Hassan plan drawing (after Hetz Bey, with the floor drawing add to the courtyard).

Fig. 19: Passage to the main courtyard.

The central courtyard is an awe-inspiring void (32 x 34.6 x 40 meters). From this central court, four vaulted halls project into the heart of the monolithic mass. These four niches serve as prayer halls; they basically compose the function of the ‘mosque’ (*masjid*).

There are four different portals which lead to four different *madrasas* and their student residences; two to the right and two to the left. These doorways are slightly different from the two that bring the visitors into the court. From the great niche there are two other doorways which lead to the mausoleum, one's experience is altered once more to the subdued light and the silent emptiness of the mausoleum. (Fig. 20)

Fig. 20: The space of the Mausoleum

Fig. 21: The space of the court viewed from the qibla side.

Strikingly, arriving at the court, one is overwhelmed by light as it pours into the spatial heart of the monolithic body of stone. In an imaginative sense, it seems as though the sky is the only way from which to enter the space, the top aperture of the court being the only major opening to the outside. (Fig. 21) One loses the sense of the outside ground level as it begins to feel as if surrounded by earth from all sides; at the bottom of a well where the horizon is at the top edge of the court wall. The threshold between heaven and earth becomes a thin membrane of light, and we stand at this moment where heaven kisses the earth, and breathes its light into its opaque mass. (Fig. 22)

Fig. 22: Different planes subtly establish different horizons

Fig. 23: Light softened and enriched by the depth of the court and its different materials.

Polar to the ceiling of light is the floor, literally called "*Sahn*" in arabic, the 'plate', which receives the light of the sky. (Fig. 23) The

illuminated spatial 'heart' of the court emits its light to the four niches projecting in the darkness of the opaque stone. Light reflects off the walls, the central fountain pavilion and the floor of the court, its harshness is softened into an ambient light, which illuminates the deepest corners, as if the light is inhabiting the void; a soft and gentle vapor which fills the emptiness of the court rather than being forcefully injected into it. As the sun sets, the niches emit light back to the court through a hovering plane of light; a dense grid of hanging oil lamps. (Fig. 24) The floor then captures the light, dim yet captivating in its eloquence, and reflects it amplifying its intensity– definite to be breathtaking if one is to be located in the highest floor or overlooking from the roof. Yet only a being, free of gravity, locating itself hovering above the center would delight with the best view.

Fig. 24: The court at the time of sunset

The floor of the central court is kept empty and is sunken from that of the four prayer niches. The floor pattern colors are shades of pomegranate red, sky blue gray, olive green, light stone yellow, black and white with natural shades and variations. The marble's natural feel is quite different in nature from the earth quality that the stone color of the four niches gives to the whole structure of the building. (Fig. 25) Through its texture and color, the

Fig. 25: floor detail.

floor brings a sense of liveliness into the heart of the building; like a flowered valley of a stone canyon. This impression is accentuated through the geometry of the floor that gives an order like that of a flower arrangement in a formal garden carpet.

In the center of the floor, a domed octagonal pavilion manifests an impressive presence. Eight thin columns encircling the octagonal pool and water fountain carry an octagonal drum, which then carries a spherical dome with a wooden calligraphic band marking its great equatorial circle. (Fig. 26) The calligraphic inscription quotes the famous Throne verse from the Quran: “God, there is no god but He, The Living, The Everlasting. Slumber seizes Him not, neither sleep; to Him belongs all that is in the heavens and the earth. Who is there that shall intercede with Him saves by His leave? He knows what lies before them and what is after them, and they comprehend not anything of His knowledge save such as He wills. His Throne encompasses the heavens and the earth; the preserving of them oppresses Him not; He is The All-High, The All-Glorious.”¹³

The relation between the center of the fountain and the center of the spherical dome floating above it creates an extrusion of a vertical axis. As this axis marks the center of the

Fig. 26: The fountain pavilion dominates the void of the court.

Fig. 27: View from court entrance.

¹³ “بسم الله الرحمن الرحيم. الله لا إله إلا هو الحي القيوم لا تأخذه سنة ولا نوم له ما السموات وما في الأرض من ذا الذي يشفع عنده إلا بإذنه يعلم ما بين أيديهم وما خلفهم ولا يحيطون بشئ من علمه إلا بما شاء وسع كرسيه السموات والأرض ولا يئوده حفظهما وهو العلي العظيم. صدق الله العظيم” Quran, Sura al_Bakara (البقرة) (2):256.

space, it also establishes the impossibility of situating oneself in it. One's path across the court curves either positively or negatively around the center. The visitor will either be attracted inwards towards the center to experience the fountain with space above it created by the dome, or centrifugically curve outwards acknowledging the presence of this invisible vertical axis. (Fig. 27)

Fig. 28: View from the main *ivan*.

Fig. 29: Longitudinal section. (After Hertz Bey)

The tension between the ascension of the four pointed niches and the hanging lamps equalizes into a horizontal imaginary plane hovering in the space on which the top section of the fountain structure would float. (Fig. 28)

Through the principal Mecca oriented niche there are two symmetrical entrances around the *qibla* axis. These simple openings finally take the visitor to the impressive mausoleum, which plays a major role in giving the building its character from the exterior. When one compares the space of the court to that of the mausoleum, a remarkable difference is evident in their sense and quality of space. The space of the mausoleum seems to be defined as if stone arranged itself around a monumental mass of non-matter (Fig. 29).

Whereas in the courtyard, one feels more the sense of space as a subtraction of matter. An absence of solid mass that once resided in its center; as if the stone has been carved and pushed aside to make a space within. (Fig.30)

Fig. 30: the court from the minaret.

This idea becomes more evident as one recalls the memory of the exterior. A formal analysis of the exterior shows a difference between the main mass of the edifice, which is an extrusion of the site and the domed cubical mass projecting from the extruded mass. One can easily relate the space of the tomb to the monumental domed

Fig. 31: Exterior view shows the main formal features of the *madrasa*.

cube experienced from the exterior; it seems to be a logical expectation that such a space would exist inside. In contrast, the void of the court and the four niches are totally unpredicted and the least expected from the exterior, which is heavy, solid and opaque. (Fig. 31)

Although in the sectional drawing (Fig. 29) the space of the mausoleum seems to be a peak point of the formal architecture, but at an experiential level the mausoleum quietly sits marginal to the living activities. Thus one feels the presence of the spatial court as the essential heart of the building. The main

Fig. 32: After a Friday prayer.

prayer spaces pour not only its light but also the people after their prayer into the court as this pulsating journey is performed five times a day. (Fig. 32) It also forms an interior “public” space for the students of different schools to socialize without leaving the sacred environment of knowledge. If one recalls the journey through the building this realization becomes more evident. First, the journey from the outside seems to aim at preparing the visitor for the peak of the architectural experience: encountering the court of light, imbued with the imagery of paradise through the Quranic calligraphy embracing the court from the four sides; on the door supports which lead in and out the court: “The Pious are amid gardens and springs (of clear flowing water).”¹⁴... “Their Lord doth give them glad tidings of a Mercy from Himself, of His good pleasure, and of gardens for them, wherein are delights that endure; eternally dwelling therein, verily in God’s presence is a reward, the greatest (of all).”¹⁵ As for the frequent visitor, it seems that the architecture brings this vision to the imagination every time one thinks of revisiting. So that as the cool breeze envelopes the skin every time one is entering the building, it directly re-awakens the memory of this journey towards the garden of light, perhaps even increases the longing for it. (Fig. 33)

Fig. 33: The courtyard and the main prayer iwan, behind which the mausoleum quietly sits.

¹⁴ “بسم الله الرحمن الرحيم. إن المتقين في جنّات و عيون. أدخلوها بسلام مامنين. صدق الله العظيم.” Quran, Sura Al-Hager (الحجر): 45-46

¹⁵ “بسم الله الرحمن الرحيم. يبرئهم ربهم برحمة منه و رضوان و جنّات لهم فيها نعيم مقيم. خلدين فيها أبداً إن الله عنده أجر عظيم. صدق الله العظيم.” Quran, Sura Al-Tauba: (التوبة) 21-22

Arriving at this conclusion, the architectural significance of the floor introduces itself through the central architectural role of the court as a function as well as a spatial experience. Accordingly, the architectural treatment of all horizontal surfaces in this building has been limited to this floor area. In that sense the idea of “decorating” could be critically challenged; when ‘crafting’ is exercised discretely and in a selective manner, it reflects a possibility of a deeper involvement of intentions. This point could potentially be argued based on a criterion that may well be considered for the criticism of “decoration” in the first place. Presumably it is the ‘superficiality’ of decoration that presents a weakness, its detachment from the rigorous pursuit of a more meaningful ‘spatial’ experience. Yet can we consider any surface treatment as a decoration? Can the serious exercising of calligraphy be considered as decorating the text?

Perhaps it is when a surface connects, relates and plays a role within the greater scheme of the work of architecture that one starts to wonder whether this is not just the mundane application of ‘aesthetics’ and the consumption of time and effort. In that sense, superficiality is not considered according to the physical depth of the work of art, rather the intentions and formative energies behind it. The geometrical analysis of the floor patterns in the following chapters attempts to lead to and establish a

Fig. 34: The courtyard of Sultan Hassan madrasa; a sense of selectivity of textures, materials and light.

foundation of possible relationships which could be further expanded and explored within the spatial and cultural contexts. The inner strength of these relationships is mainly drawn from, and relying on, the detailed accuracy of documentation and recording process, as well as the precise nature of the geometrical operations.

V.3. Documentation and Field Measurement Phases

The documentation of the floor pattern has been compiled through five stages:

1992-93: The measurement of the floor pattern was initiated through a field trip to Cairo in December-January of that year. Five students from Carleton school of Architecture: Dominique Morazan, Laura McKendrik, Rosita Nikfas, Katherine Ircha, and Tariq Aziz, architect Zainab El-Hamida of Ottawa, all led by Prof. Gulzar Haider. Their field measurements and photographs have played a vital role in the birth of this thesis. (Fig. 35 and 36)

1993-96: Students Morazan, McKendrik and Nikfas took lead in early scaled drawing of the floor. It was student Karl Kantaroff who over 1995-96 completed the final drawings of eight sections of the floor at 1:20 scale. During that period it was discovered that the

Fig. 35: Carleton University students at Sultan Hassan courtyard, Dec. 1992.

Fig. 36: Sketches brought back from the field trip, Dec. 1992

measurements for the central section needed correction and completion.

go to Cairo for the re-measuring of the central section (assisted by Omar Moussa). On return to Carleton I embarked upon digital conversion of Kantaroff's work and assembly of one complete AutoCAD model of the floor.

1999: In December there was the third field trip to Cairo to make a final check of connectivities and adjacencies of the pattern as drawn in comparison with the actual floor. The work of Cairo assistant Muhammad Derbala was crucial in this stage.

2000: As the research objectives of the thesis emerged the colors of the marble pieces making the pattern became crucial. As a result a further field check was made in August through correspondence with a Cairene group of assistants: Muhammad Derbala, Osama Moussa, Neveen and Mourad Youssry.(Fig.37)

Fig. 37: Last phase of checking the color information. Aug. 2000.

The following set of drawings (Drawing sheet no. 1 to 1.9) are based on the initial three stages of the geometrical documentation of the floor patterns. The floor is presented as nine sections, the basis of this division will be further discussed in chapter two.

* The complete Floor patterns as documented by the third stage; Aug. 1999.

* The position of the drawing is in reference to the Qibla orientation. The vertical direction in the floor drawing would actually run East west, However we have chosen to keep the Mecca orientation as a north for this drawing, because it is more accurate and more influential in the overall space of the mosque.

Drawing Sheet No. 1

**Section
A1**

* The basic dimensions of this section measured from the corners of the patterns, starting from the lower right corner moving counterclockwise, are ; 10.60, 9.05, 10.60, and 9.05 m.

* Bordered from the lower side by the main entrance to the courtyard, the doorway is off center to the left. And from the left, it is bordered by the doorway to the Maliki School.

Drawing Sheet No. 1.1

©

**Section
A2**

* The basic dimensions of this section measured from the corners of the patterns, starting from the lower right cornered moving counterclockwise, are : 10.65, 12.40, 10.60, and 12.40 m.

* Bordered from the top side by the west iwan, which is the smallest of all four iwans, and from the top by the central fountain pavilion.

Drawing Sheet No. 1.2

©

**Section
A3**

* The basic dimensions of this section measured from the corners of the patterns, starting from the lower right corner moving counterclockwise, are ; 10.65, 8.94, 10.65, and 8.95 m.

* Bordered from the lower side by the secondary entrance to the courtyard, which is off center to the right. And from the right, it is bordered by the doorway to the Hanbali School.

Drawing Sheet No. 1.3

**Section
B1**

* The basic dimensions of this section measured from the corners of the patterns, starting from the lower right corner moving counterclockwise, are : 12.42, 9.02, 12.40, and 9.05 m.

* Bordered from the left by the north iwan, and from the right by the central fountain pavilion.

Drawing Sheet No. 1.4

**Section
B2**

* The basic dimensions of this section measured from the corners of the patterns, starting from the lower right cornered moving counterclockwise, are : 12.42, 12.40, 12.42, and 12.40 m.

* This section houses the octagonal fountain basin, encircled by eight thin columns carrying an octagonal drum and a spherical dome. The columns are shown as a section-cut in the drawings.

Drawing Sheet No. 1.5

**Section
B3**

* The basic dimensions of this section measured from the corners of the patterns, starting from the lower right corner moving counterclockwise, are : 12.40, 8.90, 12.40, and 8.93 m.

* Bordered from the right by the south iwan, and from the left by the central fountain pavilion.

Drawing Sheet No. 1.6

**Section
C1**

* The Basic dimensions of this section measured from the corners of the patterns, starting from the lower right corner moving counterclockwise, are : 10.50, 9.02, 10.50, and 9.02 m.

* Bordered from the top side, almost up to the half, by the main Mecca iwan. And from the left, it is bordered by the doorway to the Shafie School.

Drawing Sheet No. 1.7

©

**Section
C2**

* The basic dimensions of this section measured from the corners of the patterns, starting from the lower right corner moving counterclockwise, are : 10.40, 12.40, 10.48, and 12.40 *m*.

* Bordered from the top side by the main Mecca iwan, and from the bottom by the central fountain pavilion.

Drawing Sheet No. 1.8

**Section
C3**

* The basic dimensions of this section measured from the corners of the patterns, starting from the lower right corner moving counterclockwise, are : 10.40, 8.90, 10.40, and 8.90 m.

* Bordered from the top side, almost up to the half, by the main Mecca iwan. And from the right, it is bordered by the doorway to the Hanafi School.

Drawing Sheet No. 1.9

©

Chapter Two

Exploration drawing of geometric operations performed on one the floor patterns.

Detail of an exploration drawing of geometric operations performed on one the floor patterns.

VL1. An Approach to the Geometric Analysis

For an architect, sketching and drawing are basic tools for comprehension and communication. Drawing in the design process is a means to think and realize the designers imagination, but it also becomes a method to comprehend and absorb the world.

Drawing, in the study at hand, was used at an initial level for the recording the design. This first approach revealed a sense of a set intentions, which through the making of a geometric pattern aspires beyond the simplistic decorating or the filling of the surface. For instance, one cannot help but notice that the corner sections of the floor, which at a first glance seem to be simply repeated through two axes of symmetry, are slightly different so that they only repeat as diagonal pairs. This level of observing through the act of drawing then leads to a second level of investigating also via drawing. In this case, drawing becomes an instrument for the 're-playing' of the musical piece as discussed through Steiner's approach earlier. The final mode of drawing, which this thesis addresses, becomes a form of a dialogue between the two above mentioned modes; drawing as a means for imagination and drawing as a method of comprehension.

In defining drawing as a tool or a method, an issue concerning mathematical accuracy and geometric precision should be addressed. The main interest of the study is the reading of geometry as an operation, a 'performance'. The classification of patterns and their group designation enables us to understand the floor geometry as a set of principles that can denote the specificity of movement. It also makes possible the examination of the

composing of specific phrases of movements. The group designations, which are basically three sets of groups: points, lines and planes, in themselves could be viewed as formulas of growth: the point groups radiate from a center like stars, line groups grow along an infinite line, and plane groups are like a grid where each node could be the center of the pattern and therefore one can imagine it filling the whole plane. In the two-dimensional space these formulas are not infinite; line groups only exist in seven 'formulas', and seventeen in the case of the plane groups. The fact that these two-dimensional formulas are finite in number facilitates our approach and our attempts at analysis. It allows for a system of classification of all the patterns. The breaking down of these formulas into four, and only four, geometrical operations could specifically point at distinct characteristics of movement. The difference in carrying out the operation of reflection is distinctly different from that of rotation. Reflection requires flipping in the three dimensional space, while rotation moves in the same plane.

Another approach to the geometry is the symbolism of numbers and proportions, which is mainly based on the geometrical shapes, their proportions and ratios with respect to each other. It can be conjectured that there is an echo between geometries and the cultural context of 14th century Cairo but the current scope of the study cannot afford to fully consider the possibility and more important the accuracy of such ideas.

Since this chapter is dedicated to the geometrical analysis of the floor, therefore it becomes important to briefly define geometrical operations and the composition of patterns in two-dimensional space, also to introduce the terminology used for the classification of

patterns. Geometrical operations and symmetry groups have been specifically explored and discussed by Peter Stevens in His book “The Regular Handbook of Patterns”¹⁶, which became the main reference for this thesis concerning pattern classification and the geometrical analysis of the floor patterns.

VL2. A Review of Symmetry Groups

There are only four geometrical operations that could be identified in 2D space: translation, rotation, reflection and glide reflection, or as Stevens puts it: “two dimensional motifs can repeat in only four different ways.” On a flat surface we can simply identify the four symmetry operations by applying our hands as also implied by Stevens.

Translation: If one is able to trace the shape or image without changing the orientation and without lifting one’s hand off the surface. (Fig. 38) Lines, which represent the motion of the points to become their images, indicate the operation of translation.

Rotation: Using the same hand, the orientation changes restricting one’s hand from lifting off the surface. (Fig. 39) The change in orientation will always have a center, which could be

¹⁶ “The Regular Handbook of Patterns”, Stevens, Peter. The MIT Press, Cambridge, Massachusetts. 1980.

located by connecting two sets of corresponding points on the object and its image. Each line that connects a point with its image acts as a chord in a circle. The intersection of the lines that perpendicularly bisect each chord is the center of rotation. Marking the center indicates the operation of rotation.

Note: “Pure translation is a special case of rotation—rotation around a center that lies infinitely far away.”¹⁷

Reflection: In our body, one hand is the reflection of the other, the idea of mirror is also illustrated if the object is turned inside out; it will produce its reflected image, like a glove. To indicate this operation the line that represents the “mirror line” is drawn. (Fig. 40)

Glide reflection: This operation happens in two steps, one is reflection and the second is as if the 2D space breaks at the mirror line and slides against each other keeping the same common edge of the mirror line. To indicate the glide reflection we indicate the mirror line, which also indicates the direction of gliding. (Fig. 41)

Note: Reflection is a special case of glide reflection where the displacement is zero. “Thus the four symmetry operations could be reduced to only two— rotation and glide reflection.”

¹⁷ *Ibid.* page 5

Note: Double reflection where the mirror lines are parallel is a translation.

Note: Double reflection where the mirror lines are not parallel is a rotation around the intersection point of the mirror lines.

Note: all 2D conditions or operations are obtainable through a series of reflections. Thus all operations are achievable through a set of reflections. Though there has to be intermediate images between the original and the final image.

Based on the previous definitions, we will assign indications for the four symmetry operations so as to identify them on our illustrations.

Translation: dotted line tracing the object's motion to its image.

Rotation: pivot point, which indicates a pin like vertical axis intersecting the plane around which things rotate.

Reflection: continuous mirror line, which is perpendicular on the axis of motion of the shape.

Glide Reflection: dashed mirror line: same as reflection line but dashed.

Definition of Proper and Improper operations: Symmetry operations are divided into two kinds of operations: Proper and Improper. The Improper operations are the ones where the stages between the object and its image is not traceable in the same 2D plane. In translation and rotation a shape glides in the same plane as its image, "and the image at the

start can be directly superimposed on its image at the finish or anywhere along the way.”¹⁸

This is not the case in the operation of reflection nor glide reflection; in order for an object in 2D to reflect, it has to move through the 3d space. Therefore the process of the production of the image is untraceable in the 2D space—an improper operation.

We can define proper and improper operation using our hand as well; the operations that involve the two hands are improper, and when only one hand is able to achieve the final pattern—that is called a proper operation. This means that the operation is achieved only in the domain of two-dimensional space.

* * *

Definition of Symmetry: For a shape to become symmetric, it has to repeat a certain part to produce the whole.

Definition of Symmetry group: A symmetry group is a collection of symmetrical operations which together share three characteristics

1. Each operation could be followed by a second operation to produce a third, which in itself is a member of the group; like a loop of movements.
2. Each operation could be undone by another operation: as if to pack and unpack.
3. The position of a pattern after an operation can be the same as before the operation, the ability to “fold”.

¹⁸ *Ibid.* Page 6

Two-dimensional patterns are three categories, as mentioned earlier: **point groups**, **line groups** and **plane groups**. The following is a brief review of the details of their geometrical operations, which in different compositions produce a limited number of iterations.

Images in this section are mostly after Stevens unless mentioned otherwise. In this section the indications of geometrical operations are a key to understand how to distinguish one group from another.

Point groups

Group 1: This group contains asymmetric shapes, it is a member of point groups because a 360 rotations for the object will superimpose it back on itself; there is no part of the motif that is repeated in any way, like a hand for example. (Fig. 42)

Bilateral symmetry (*m*): This group is called: “bilateral symmetry”. It symmetrically folds through one mirror line, and it also has 360 degree rotations. (Fig. 43)

Group 2: 180 degree rotation about a central point brings the pattern to coincide with itself. Like playing cards or like an (S) oval, or a double barred spiral galaxy. This group does not contain any mirrors. (Fig. 44)

Group 2mm: 180 degree rotations, plus the mirroring through the

center of rotation of the group 2. It contains two-fold center and two perpendicular mirrors. (Fig. 45)

Group 3: Three-fold 120 degree rotations; three rotations for the image to superimpose on its origin. (Fig. 46)

Group 3m: Three-fold rotation center, plus three mirrors which run through the center of rotation. (Fig. 47)

Group 4: 90 degree rotations, that is: four rotations for the image to superimpose on its origin. (Fig. 48)

Group 4mm: 90 degree rotations, plus four mirrors through the center of rotation. (Fig. 49)

Group 6: 60 degree folds. (Fig. 50)

Group 6mm: 60 degree rotations, plus six mirrors through the center of rotation. (Fig. 51)

The (*m*) is doubled in the groups with even numbers to indicate the presence of two-types of mirrors. One set is through vertices and the other are bisectors of sides. In odd numbered polygons, one mirror would bisect from one end and is on a vertex from the other.

Practically all regular polygons could become symmetry groups when viewed from the number of folds they produce. The problem arises when they have to repeat to fill the surface. Only the groups that we mentioned above are able to repeat in this way: to close pack and fill the surface.

Definition of Unit Cell: it is the minimum area in a pattern that can only repeat through translation. (Fig. 52)

Definition of The Fundamental Region: the minimum area of a motif that can repeat through any of the four-symmetry operations to form one Unit Cell. (Fig. 52)

Definition of Mesh: is the Fundamental Region for the pattern operations. (Fig. 52)

Fig. 52: An example of unit cell, mesh and fundamental region from a p4mm pattern. (Pattern from Sultan Hassan floor).

* * *

Line Symmetry groups

To make line groups we will join translations, rotation, reflections, and glide reflections with groups 1, m , 2, and $2mm$. Four line groups appear into existence as a result of the marriage with 1 and m , and three when united with 2 and $2mm$.

1. **Group t :** Successive translation of an asymmetric motif. (Fig. 53)

2. **Group tg :** Successive translations of a glide reflection, this is also a variation of group 1. (Translate the guide reflected). (Fig. 54)

3. **Group tm :** Translate Mirrored, successive two alternating mirroring across and perpendicular to the translation line. One way to identify this group is to notice that the fundamental region is always between the two mirrors and the border of the pattern. (Fig. 55)

4. Group mt : Mirror Translated. One mirror line parallel to the direction of translation. (Fig. 56)

1. Group $t2$: Translating two-folded. Two-fold is 180 rotations. (Fig. 57)

2. Group $t2mg$: This is one of two of the line groups that contain all four operations. It contains within itself groups t , $t2$, tm , and tg . (Fig. 58)

3. Group $t2mm$: This group consists of two alternating $2mm$ roto-centers. (Fig. 59)

Plane Groups

1. Group $p1$: Basically like Group 1 point symmetry, but it has a lattice that when shifted does not contradict the pattern. (Fig. 60)

2. Group pg : Repeats in one direction by translation and the perpendicular by glide reflection. (Fig. 61)

3. Group pm : Repeating in one direction by translation and the perpendicular as a tm linear pattern. (Fig. 62)

4. Group cm : Repeating in one direction by translation and the other is an alternating reflection and glide reflection. (Fig. 63)

* * *

1. Group $p2$: The fundamental region rotates both direction. (Fig. 64)

2. Group $p2mg$: Mirroring in one direction and glide reflection. The pattern also produces two fold roto-centers between mirror lines and on the glide reflection lines. (Fig. 65)

3. Group $p2gg$: A glide reflection in both directions of a two-fold. (Fig. 66)

4. Group $p2mm$: A rectangular enclosure of four mirrors. (Fig. 67)

5. Group $c2mm$: This group can look like staggered arrangement of $2mm$ motifs, or reflected arrangement of two folds centers, or row upon row of either $t2mg$ or $t2mm$. An alternating reflection and glide reflection in two perpendicular directions. At the intersection of the mirror lines one finds two distinct types of $2mm$ centers, and where the glide reflection intersects two simple two-fold centers. (Fig. 68)

* * *

1. **Group $p3$:** This group consists of rotation without reflection of a three fold motifs. All three roto-centers lie on a straight line and each roto-center of the same type and have the same orientation. Therefore it is easily identifiable by three crossing orientations. (Fig. 69)

2. **Group $p3m1$:** Three mirrors enclosing an equilateral triangle. The three fold rotation lines project from the center to the vertices of the equilateral triangle of the mirror lines. (Fig. 70)

3. **Group $31m$:** Three mirrors enclosing an equilateral triangle with a threefold roto-center in the center; the three fold rotation lines projects from the center and bisects the mirror lines forming the equilateral triangle. (Fig. 71)

* * *

1. **Group $p4$:** Four and two-fold centers alternating along perpendicular lines. (Fig. 72)

2. Group $p4gm$: The four fold centers come in mirrored pairs. The pairing is because the mirror lines run through two-fold centers. In other words a two fold center in the center of a square enclosure of mirror such that the axis of the two-fold bisects the mirror edge. (Fig. 73)

3. Group $p4mm$: This pattern could be generated by three mirrors enclosing a triangle 45,45,90. In this pattern we can find all symmetry operations. (Fig. 74)

* * *

1. Group $p6$: Six-fold centers without any mirroring. (Fig. 75)

2. Group $p6mm$: Three mirrors enclosing a 30-60-90 triangle. (Fig. 76)

* * *

VL3. Introduction to the Geometrical Analysis of the Floor Patterns

The documentation and presentation of the floor patterns in this thesis involve two stages: the line geometry and color configuration. For the first stage, lines between marble pieces of the same color were ignored. As for the colors, only six colors, of which there are different variations, were identified: wine red, stone yellow, sky blue-grey, olive green, black, and white. The colors have a very earthy and natural feel, and because of the subtle variations of the marble colors, in this study, these six categories become color codes and do not represent their actual natural appearance.

For pattern classification, a prototype sheet has been devised for every pattern in the floor. It demonstrates the details of the geometry of the pattern, the frequency and the location of the pattern in the floor, and finally the group designation to which each pattern belongs. This reading or classification is based on the line drawing of all the patterns of the floor. The page that follows this first level of classification provides the detailed geometrical analysis of the pattern in different contexts. Then, it is followed by another layer that adds the color information to see what shifts occur in terms of the geometry of the pattern and the relationship between the repetition in the overall context of the floor. Observations, then, will be summed up in point format on the first sheet of every pattern.

VL4. Pattern classification

A primary classification is proposed to differentiate between what is a pattern and what is not. The drawings sheet no. 2 and 2.1 attempt to illustrate this by imagining a dark paint being poured at one corner of the floor and allowed to flow and fill between the patterns. All the filled area is actually covered with white marble only. Yet the color white is repeated in other areas of the floor and in different sizes. The white color seems to work on three different levels: first it is a filler between all the patterns of the floor. The second level is filling within the patterns themselves. These differ from the first kind because their shapes are more defined and whole. The third is participating in the motifs that compose the patterns, as if it tries to represent emptiness between the motifs so as to bring out the details of the design. Therefore, black and white representation drawings of the colors, where all the colors are represented as black except the white color, can prove to be helpful in demonstrating and revealing certain geometrical qualities of a design.

The patterns have been outlined based on the separation from the first two understandings of using the white color, the third is included in the patterns as motif filler.

Based on drawing sheet no. 2.1, we can see that the areas between patterns are clearly divided by four continuous strips, which separate nine areas. This separation becomes the basis for the nine quadrilateral grid which is divided as: A1, A2, A3, B1, B2, B3, C1, C2, and C3. We will refer to this basic division when pointing at the different sections of the floor.

* A primary classification is the distinction between pattern and background. This was achieved through the imagined pouring of a darker color at any edge of the floor, which when let to flow defines the edges of the patterns.

* The darkened area is classified as a first of three levels of backgrounds. These three levels were identified in the introductory discussion of chapter two.

Drawing Sheet No. 2

* When examining the first of the three levels of backgrounds, four strips become the only continuous dividers in the floor. They basically divide the floor into nine sections

* Each of the eight sections around the central one has a similar suggestion of four continuous strips, yet none continues through the entire floor.

Drawing Sheet No. 2.1

©

1m 0 1m 5m 10m

* Color representation of the floor patterns.

* Six color categories: dark red, black, light blue, olive green, stone yellow & White.

Drawing Sheet No. 3

©

**Section
B2**

* Black and white representation of colors. The five main colors are represented as black except the white color, which basically acts as a filler. It is represented as the emptiness of the white sheet of paper.

Drawing Sheet No. 4

The Floor Patterns:

**Pattern
no. 1**

- * Group designation: (m), also remains unchanged after considering color information.
- * The pattern performs a double rotation around the center of the floor (drawing sheet no. 5.1)

Drawing Sheet No. 5

a.

b.

c.

d.

I. Geometrical analysis of the repetition of the motif in the floor.

The sequential study explores the rotation of the motif in the floor:

Figure (a) shows the motif as it repeats in the floor. If we connect the vertices of four corners of the motif, which are images of each other through the operation of rotation, a square appears. This square relates to another square that inscribes the octagon of the fountain also through the operation of rotation, figure (b). In figure (c), this rotation is inversed so that the two squares become congruent. To trace the rotation of the vertices, figure (d) connects the vertices that are images of each other, which shows two rotated squares that rotate creating a circle, the inner octagon of the fountain. Figure (e) rotates the patterns back to their final places while holding the relationships established in the previous diagrams.

What is suggested here is that a first rotation establishes the relationship between motifs and the fountain, then another which rotates the whole system in its final place.

e.

Drawing Sheet No. 5.1

©

II.a. line drawing

II.b. Black and white representation of colors.

III.a. Yellow selection.

III.b. Black selection.

- * Considering color information, the geometrical relationships remains unchanged.
- * Only two colors other than the white of the background are present in this motif.

**Pattern
no. 2**

* Group designation of the pattern is (*group p4mm*), which remains unchanged after the consideration of color information.

* The pattern establishes an axial tilt due to the difference in scale. This also implies a (*group 2*) rotational geometry.

I. Geometric analysis of the pattern.

Unit cell.

Fundamental region.

Group designation of the pattern is (*group $p4mm$*).

The different compositions of the pattern in the floor form (*group $2mm$*) each on its own, as well as when assembled in each section, (A2&C2) except one pair in section C2 where the two compositions form (*group $4mm$*), being square in shape with equal number of nodes in both directions.

II.a. Yellow selection, Section A2.

II.b. Black selection, Section A2.

II.c. Yellow selection, Section C2.

II. Black selection, Section C2.

II. Group designation remains the same when considering colors.

Drawing Sheet No. 6.1

III. Difference in scale and dissimilarities between the two sections, which results in an axial tilt in the floor

Section A2 and C2 carry some resemblance in the way the patterns on the left and right correspond in their number of units. However, at the top and the bottom areas, in the case of section A2 have a pair less in number by a column of three units. Another dissimilarity is the apparent difference in scale between the side areas in each section. In section A2, the left side areas are larger than the right side, while it is the opposite in the case of section C2. This establishes two things: first, the relationship between the two sections is a 180 degree rotations around the center of the floor. Second, since in section A2 the left side larger than the right, therefore the center of the section is slightly shifted to the right in relation to the center of the floor, while in section C2, it is shifted to the left. This produces a slight tilt to the main axis of the floor. This slight rotation seem to acknowledge the operation of rotation discovered in pattern no. 1. (Drawing sheet no. 5.1)

**Pattern
no. 3**

* The group designation of this design as line geometry is (*group 4mm*). After the consideration of color, it transforms to (*group 4*).

* The repetition of the motif forms another (*group 4*) around the center of sections A2 and C2. However, it further shifts as we consider the color information; the pattern in section A2 remains a (*group 4*), while in section C2 it becomes (*group 2*).

Drawing Sheet No. 7

I. Geometric analysis of the pattern.

Unit cell.

Fundamental region.

Group designation of the pattern is (*group 4mm*).

II.a. Line drawing of a unit motif, (*group 4mm*).

II.b. Black and white representation of color, (*group 4*).

III.a. Yellow selection, Section A2 & C2.

III.b. Black selection, Section A2 & C2.

III.c. Red selection, Section A2 & C2.

Group designation changes when considering color; the motifs transform to belong to (*group 4*).

III.a. Yellow selection, section C2.

III.b. Black selection, section C2.

III.c. Red selection, section C2.

III.d. Yellow selection, section A2.

III.e. Black selection, section A2.

III.f. Red selection, section A2.

IV.a. Geometrical analysis based on color selection, section C2.

IV.a. Geometrical analysis based on color selection, section A2.

* While the motifs in both sections are similar in using a four fold rotation, the two sections use different ways to repeat them:

In section C2, the motifs form (group 2), a set of translations, and a set of glide reflections.

In section A2, the motifs form (group 4), and a set of translations.

**Pattern
no. 4**

* The group designation of this design as line geometry is (group 2mm). After the consideration of color, it transforms to (group 2).

* The motif is repeated in the floor through translation. The path of the operation of translation forms an isosceles triangle with a thin base relative to its height, which emphasizes the central axis.

Drawing Sheet No. 8

I. Geometric analysis of the pattern.

Unit cell.

Fundamental region.

Group designation of the pattern is (*group p4mm*).

If we look at the motif as possibly growing vertically as a line pattern, the group designation would be (*group t2mm*).

II.a. Line drawing of a unit motif, it forms (*group 2mm*)

II.b. Black and white representation of color.

III.a. Black selection, Section A2. (*group 2*).

III.b. Red selection, Section A2. (*group 2*).

Group designation changes when considering colors; the motif shifts to belong to (*group 2*).

IV. repetition of the pattern in the floor, section A2.

IV. Repetition of the pattern in the floor through the operation of translation, gives emphasis to the qibla axis midst the central arrangement of the section.

Drawing Sheet No. 8.1

©

**Pattern
no. 5**

* Group designation of the motif, as line geometry, is ($p4mm$). But when viewed as a pattern it is ($p6mm$). After consideration of color information a motif it transforms to (*group 2*), and as a pattern it transforms to ($p3/m$) (drawing sheet no. 9.1).

* The motif is repeated in the floor through translation along the qibla axis.

Drawing Sheet No. 9

©

I. Geometric analysis of the pattern.

Group designation of the line pattern is (*group p6mm*).

The line drawing of the motif as a unit forms a (*group t2mm*).

Unit cell.

Fundamental region.

II.a. line drawing of a unit motif, it forms (*group 2mm*)

II.b. Black and white representation of color.

III.a. Black selection.

III.b. Red selection.

Group designation changes when considering color information; the motif shifts to belong to (*group p31m*).

Looking at the motif as a unit, it becomes (*group 2*); supports the operation of rotation only.

IV. The repetition of the pattern in the floor is possible through the operation of translation along the qibla axis, or a reflection perpendicular to the qibla axis. The operation of translation would give emphasis to the qibla axis midst the central arrangement of the section. It also extends the operation of translation from the corresponding motif in section A2. (drawing sheet no. 8.1)

IV. Repetition of the pattern in the floor, section C2

Drawing Sheet No. 9.1

©

**Pattern
no. 6**

- * The group designation of the line pattern is (*group 12mm*). It could also compose a plane pattern of (*group 4mm*).
- * After considering color information, the line pattern shifts to (*group 12mg*).
- * The pattern as a motif belongs to (*group 2mm*) when viewed as line geometry; it can rotate around the center of the floor or translate along the qibla axis. As we consider the colors, it will only translate.

Drawing Sheet No. 10

Group designation of the line pattern is (*group t2mm*).

II. Black and white representation of color.

III.a. Black selection.

III.b. Red selection.

Considering the color information, the group designation of the line pattern transforms to (*group t2mg*).

IV. Geometric analysis of the generation of the pattern.

V.a. A diagram of geometrical operations on one color. Group designation of the line pattern after considering color information is (*group 12mg*), a group which contains all the geometrical operations.

VI. The origin of the pattern which can become a plane pattern that fills the surface. Group designation of this pattern is (*group p4mm*).

VII.a. Black selection, section A2

VII.b. Black selection, section C2

VII.c. Red selection, section A2

VII.d. Red selection, section C2

* Considering the color information, each section forms a (*group m*), that is to say they have one orientation as they follow 360 degree rotations.

VIII. Repetitions in the pattern geometry

The line pattern grows to form a ring around the center in both sections A2 and C2. When considering color, the relationship between the two sections could be established through a translation along the tilted qibla axis

**Pattern
no. 7**

* Group designation of the geometry is (*group 12*), (drawing sheet no. 10.1). The group designation remains unchanged after the consideration of the colors.

Group designation of the line pattern is (*group t2*).
 Group designation does not change when considering colors.

III.a. Light Blue selection, section A2

III.b. Light Blue selection, section C2

III.c. Red selection, section A2

III.d. Red selection, section C2

III.e. Yellow selection, section A2

III.f. Yellow selection, section C2

* Considering the color information, a few inconsistencies appear, which makes it difficult to classify the pattern. However, the yellow selection might be a clue as to how the pattern is transforming.

**Pattern
no. 8**

* Group designation of the pattern is (*group 2mm*) of a pair of (*4mm*) motifs. The pattern repeats in the floor through two pairs of (*group 2mm*), divided between section A2 & C2.

* Once adding the color information the patterns pair in each section diagonally. The group designation of the motif does not change, though the relationship between them in the floor changes from (*group 2mm*) to (*group 2*). (drawing sheet no. 12.1)

Drawing Sheet No. 12

I. Geometric analysis of the motif.
Group designation is (*group 2mm*).

II. black and white representation of color.

II. On the level of the single motif, the group designation does not change after considering color. Rather, it happens on the over all context of the floor.

III.a. Black selection.

III.b. Red selection.

III. a&b. The color selection shows a (*group 2*) in both sections individually, then another (*group 2*) in the over all floor. The relationship between the two sections could be established through a rotation around the centre of the fountain considering the shift in scale between the left and right following pattern no. 2.

**Pattern
no. 9**

* Considering the line geometry, the motif belongs to (*group 4mm*). It also forms a (*group 4mm*) in each of the corner sections, and it repeats in the floor forming (*group 2mm*) as a result of the slight elongation of the floor in the qibla axis.

* When considering color, the single motif remains as a (*group 4mm*), but on the level of the single section it pairs diagonally maintaining only the diagonal mirrors. This forms (*group 2mm*). In the over all context of the floor, it further eliminates the mirror to belong to (*group 2*); 180 degrees rotational geometry.

Drawing Sheet No. 13

I. Geometric analysis of the pattern: (group 4mm).

I.a. Marble assembly of the corners of the motif shifts the motif from (group 4mm) to (group 4).

II. Black and white representation of color. Two types could be identified.

IV. Black and white representation of color in the over all context of the floor. The motifs form pairs in each section. Also each section pairs diagonally across the floor because of the slight elongation of the floor in the qibla direction. Details of the pairing becomes more evident when considering the colors individually (drawing sheet no. 13.2)

Group designation changes when considering colors on the level of a section and over all context of the floor, however not on the level of the single motif.

III.a. Red selection.

III.b. Black selection.

III.c. Light Blue selection.

III.d. Yellow selection.

V.a. Red selection.

V.b. Black selection.

V.c. Yellow selection.

V.d. Light Blue selection.

**Pattern
no. 10**

- * The Group designation of this design as a "motif" is (*group 2*). As a line pattern it is (*group 1*); note worthy is that the growth through translation springs from the intersection of the line of translation with the bisector axes of the motif. * The motif assembles itself in the context of one section to form (*group 2mm*), which also repeats in the rest of the floor based on (*group 2mm*).
- * The motif maintains its group designation after considering the colors; only in the context of the overall floor the four corner sections clearly pair diagonally by having different color sequence.

Drawing Sheet No. 14

Group designation of the line pattern is (*group 1*).

Considering the color information, the group designation does not change except in the over all geometry of the floor; sections pair diagonally, details (drawing sheet no. 14.2).

V.a. Red selection

V.b. Black selection

V.c. Yellow selection

* Details of color information showing the pairing of sections A3 with C1, and A1 with C3. Yet there is a slight defiance of this pairing in the second pair due to the subtle difference in the use of the yellow color.

- * The group designation of this design when considered as a motif is (group 2mm). As a line pattern it is (group 12mm).
- * The group designation remains unchanged after considering the color information since the pattern is monochromatic.
- * The pairing of the motifs is emphasized, which helps imply a rotational geometry the overall context of the floor.

I. Geometric analysis of the pattern.

Group designation of the line pattern is (*group 2mm*).

Unit cell.

Fundamental region.

III. Black and white representation of color.

Color information does not change the group designation of the pattern. The pattern uses only the color red other than the white color of the background.

VI. The Pattern forms a (*group 2*) in the context of the whole floor, but if considered only in terms of the seven ring long strip, it forms (*group 2mm*), which basically borders the corner sections A1, A3, C1 and C3. The other four singular units are split between sections B1 and B3 to form a (*group 2*).

Drawing Sheet No. 15.1

**Pattern
no. 12**

- * The group designation of this design when considered as a motif is (*group 2*). As a line pattern it is (*group t2*).
- * The group designation remains the same after considering color information.
- * The subtle variation of the geometry of the motif stresses a rotational geometry (*group 2*) in the over all context of the floor.

Drawing Sheet No. 16

©

Group designation of the line pattern is (*group t2*).

II. Black and white representation of color. Two variations of pattern assembly could be identified.

III.a. Black selection.

III.b. Red selection.

III.c. Yellow selection.

Considering the color information does not change the group designation of the line pattern.

V.a. Red selection.

V.b. Black selection.

V.c. Yellow selection.

* Details of color information shows the pairing of sections; A3 with C1 and A1 with C3. Yet there a slight defiance of this pairing in the second pair mostly evident in the subtle difference in the Yellow color.

**Pattern
no. 13**

* The group designation of this design when considered as a motif is (*group 2*). As a line pattern it is (*group 12*).

* In the context of a section, it forms a (*group 4*). And in the overall context of the floor it forms a (*group 2*).

* The group designation in all the above contexts remains unchanged after the consideration of the color information.

Drawing Sheet No. 17

Group designation of the line pattern is (group 12).

II. Black and white representation of color. .

III.a. Black selection.

III.b. Red selection.

*The motif repeats in the floor in four sets of four pairs. The four sets are in the four corner sections. It was difficult to find a constant geometrical relationship between them because of a slight shift in the orientation of the "S" like shape in the motif.

*The color information does not the group designation of the motif.

**Pattern
no. 14**

- * The group designation of this design when considered as a motif is (*group 4mm*). As a line pattern it is (*group 12mm*). The repetition of the motif in the floor forms (*group 2mm*).
- * The group designation after considering color information transforms to (*group 2*) when viewed as a motif. As a line pattern it becomes (*group 1*).
- * It became difficult to find a relationship between the four sections, since one of them uses a different method to wrap around the center; section A3 uses mirrors in the corners while the rest use rotation in the corners. (drawing sheet no. 18.2)

I. Geometric analysis of the line pattern.

Group designation of the line pattern is (*group 12mm*).

Unit cell.

Fundamental region.

II. The line pattern assembled as a motif, which belongs to (*group 4mm*). The motif repeats in the center of each of the four corner sections: A1, A3, C1 and C3.

III.a. Black and white representation of color.

III.b. Black and white representation of color in the over all context of the floor.

Drawing Sheet No. 18.1

©

IV. Details of color information shows two variations of color assignment; sections A1, C1 & C3 on one hand, and section A3 on the other. The key difference lies in the way the line pattern make the corner turn. The first group use rotation while section A3 uses 45 degree mirroring.

Also noticable is a form of duality the red and the black colors, which already is detectable in the majority of the patterns of the floor. This patterns shows a further duality between sections. In the black selection, if we impose section A1 on C3 it completes the motif. However for the above mentioned difference in the geometry, section C1 and A3 do not have the same relationship.

Adding the color information subtly relates to the alternating motion fond in pattern no. 6 (drawing sheet no. 10.2).

In general the motif shifts when considering color information o belong to (*group 2*).

**Pattern
no. 15**

* The motif belongs to (*group 4mm*). It repeats in the floor to form (*group 2*).

* The group designation of the motif remains unchanged after considering color information.

I. Geometric analysis of the motif.
Group designation is (*group 4mm*).

II. black and white
representation of color.

III.a. Black selection.

III.b. Red selection.

Black selection.

Red selection.

The group designation of the motif does not change when considering color information. Also the repetition of the motif in the floor remains unchanged, which (*group 2*).

**Pattern
no. 16**

* The motif belongs to (*group 4mm*). It repeats in the floor to form (*group 2*).

* The group designation of the single motif remains unchanged after considering color information, yet a slight dissimilarity in the application of color defies the initial geometrical relationship that was established through line geometry.

Drawing Sheet No. 20

©

I. Geometric analysis of the motif.
Group designation is (group 4mm).

II. Black and white
representation of color.

III.a. Black
selection, section
C1

III.b. Green
selection, section
C1

III.c. Green
selection, section
A3

The group designation of the
motif does not change when
considering color information.

IV.a. Black selection.

IV.b. Green selection.

**Pattern
no. 17**

* The group designation of the line pattern is (*group 12mm*). It repeats in the floor forming a (*group 2*).

* The above group designations remains unchanged after considering color information.

Drawing Sheet No. 21

©

Group designation of the line pattern is (group 12mm).

The color information does not the group designation of the motif.

**Pattern
no. 18**

- * The group designation of this design when considered as a motif is (*group 2mm*). As a line pattern it is (*group 12mm*). The repetition of the motif in the floor forms (*group 2*).
- * The group designation after considering color information remains unchanged.
- * This pattern is one of the patterns where there is a certain consistency in the laying of marble pieces. If considered, the line pattern forms a (*group 12*).

Drawing Sheet No. 22

I. Geometric analysis of the line pattern.

Unit cell.

Fundamental region.

Group designation of the line pattern is (*group 12mm*).

II.a. Black and white representation of color. The pattern is found in two mono-chromatic variations, Black and Red.

II.b. The single motif unit forms a (*group 2mm*). After considering the color information, this group designation does not change because of the single color application, other than the white background.

III.b. Red selection.

III.a. Black selection.

The original formation, (*group 2*), which is the pattern of repetition of the motif in the floor, did not change after considering the color information. Yet on the level of sections A2 & C2, the shift of scale is emphasised by the addition of color to form a (*group 2*) in each section individually.

Drawing Sheet No. 22.1

**Pattern
no. 19**

* The group designation of this design when considered as a motif is (*group 4mm*). As a line pattern it is (*group 12mm*). The repetition of the motif in the floor forms (*group 2mm*).

* The group designation after considering color information remains unchanged.

I. Geometric analysis of the line pattern.

Unit cell.

Fundamental region.

Group designation of the line pattern is (*group t2mm*).

II. Black and white representation of color . .

III.a. Black selection.

III.b. Red selection.

The color information does not the group designation of the motif.

**Pattern
no. 20**

- * The group designation of this design when considered as a motif is (*group m*). As a plane pattern it is (*group p4mm*). The repetition of the motif in the floor forms (*group 2mm*).
- * The above group designations after considering color information transforms in a special way; it seems that most of the mirror lines are transformed to a separation of duals, yet the operation of rotation is maintained. However, there are a few dissimilarities that makes it difficult to find a consistant group designation. (drawing sheet no. 24.2).

Drawing Sheet No. 24

I. Geometric analysis of the pattern.

Unit cell.

Fundamental region.

Group designation of the pattern is (group $p4mm$).

II.a. Section B1, the four pairs form (group $4mm$).

II.b. Section B3, the four pairs form (group $4mm$).

III.a. Black and white representation of color, section B1.

III.b. Black and white representation of color, section B3.

The motif repeats as a Pair of four pairs, which form a (group $2mm$).

Drawing Sheet No. 24.1

©

IV.a. Black selection, section B1

IV.b. Black selection, section B3

IV.c. Red selection, section B1

IV.d. Red selection, section B3

* An emphasized sense of duality appears when color is considered; between the red and the black colors, as well as between sections B1 and B3.

* Despite the minor discrepancies, the shift in the geometry becomes evident through the color selection; the mirroring (*group 2mm*) transforms to become the rotating (*group 2*).

**Pattern
no. 21**

- * The pattern is composed of a pair of eight sections. The group designation of each section on its own is (*group 1*).
- * The pattern emanates four rings of nodes from a center in the case of section B3, while in section B1 it produces only three rings (drawing sheet no. 25.2).
- * The composition of each set of eight sections suggests a (*group 4mm*). However, the slight shift in the ring before the last, in both compositions, defies this pattern classification.
- * The suggested mirror lines in section B3 perform a dual separation similar to one discussed in pattern no. 20.

Drawing Sheet No. 25

Both sections B1 & B3 suggest four mirror lines, however there is slight inconsistency in the orientation of the square inscribed in the star node in each sector, which also prevented a bisecting mirror to pass through each of the eight sectors. The orientations of all polygons of the star are multiples of 45 degrees, this will become more evident in the analysis of color. Thus each sector as a motif belongs to (*group 1*).

I.a. Section B1.

I.b. Section B3.

II.a. Section B1.

II.b. Section B3.

III.a. Black selection, section B1.

III.b. Black selection, section B3.

III.c. Red selection, section B1.

III.d. Red selection, section B3.

A few discrepancies in the color selections further defies the geometry suggested by the line drawing, more so in the case of section B3.

IV.a. Alternating Black and Red selections, section B1.

IV.b. Alternating Black and Red selections, section B3.

IV.c. Alternating Black and Red selections, section B1.

IV.d. Alternating Black and Red selections, section B3.

Alternating the color selection reveals the role of the mirror lines in section B3 suggested by the line drawing (drawing sheet no. 25.1). Again a sense of duality between the red and the black selections, which present in other patterns as well (pattern no. 20 & 6). Alternating the color selection in Section B1 reverses the duality found in section B3, which could be understood as another form of duality between section B1 & B3-(compare with drawing sheet no. 25.3).

This suggests a rotational geometry of (*group 4*) despite the inconsistencies in the color of the fine pieces of the marble

**Pattern
no. 22**

* The pattern group designation as a line drawing is (group 8mm), once color is considered it transforms to (group 4).

Drawing Sheet No. 26

I. Geometric analysis of line drawing.

II. Black and white representation of color.

III.a. Red selection.

III.b. Green selection.

*Group designation of the motif as a line drawing is (*group 8mm*).

* When color is considered it transforms to (*group 4*).

**Pattern
no. 23**

* The pattern group designation as a line drawing is (*group 4mm*), and remains unchanged after the consideration of color.

Drawing Sheet No. 27

©

I. Geometric analysis of line drawing.

II. Black and white representation of color.

III.a. Black selection.

III.b. Green selection.

*Group designation of the motif as a line drawing is (*group 4mm*).

* Group designation remains unchanged after considering color information.

**Pattern
no. 24**

* The pattern as a motif forms (*group 2mm*). The line pattern group designation is (*group 12mm*). The presense of the motif in the floor forms a (*group 2*).

I.a. Geometric analysis of the pattern.

Unit cell. _____
Fundamental region. _____

Group designation of the line pattern is (group $12mm$).

I.b. The line pattern forms a unit motif, which belongs to (group $2mm$).

II. Black and white representation of color.

III.a. Black selection.

III.b. Red selection.

Considering the color information does not change the group designation of the line pattern.

Drawing Sheet No. 28.1

**Pattern
no. 25**

* The group designation of this design when considered as a motif is (*group m*). As a line pattern it is (*group ml*). Through the repetition in the floor the motif forms a (*group l*) since it repeats through translation only.

* The translation path of the single pattern runs along the qibla direction, while as a motif it runs perpendicular to it.

* The group designation of the pattern remains unchanged since the it is monochromatic.

Drawing Sheet No. 29

I. Geometric analysis of the pattern.

Unit cell.

Fundamental region.

Group designation of the line pattern is (*group mt*).

19 units

II.a. Section B1.

19 units

II.b. Section B1.

19 units

II.c. Section B3.

21 units

II.d. Section B3.

The motif translates across the floor to produce two pairs. It is worth noting that the two pairs slightly deviate from their similarity not just by the difference in proportions but also the number of units in each pattern.

Considering the color information does not change the group designation of the line pattern, since it is also monochromatic. The motif uses the color red other than the white color of the background.

Drawing Sheet No. 29.1

©

**Pattern
no. 26**

* The pattern as a motif forms (*group 2mm*). The line pattern group designation is (*group 12mm*). The presense of the motif in the floor forms a (*group 2mm*).

* The pattern remains unchanged when considering color information since it uses only the color red beside the white color of the background.

Drawing Sheet No. 30

I. Geometric analysis of the pattern.

Group designation of the line pattern is (*group m*).

Unit cell.

Fundamental region.

11 units

II.a. Section B1.

11 units

II.b. Section B1.

12 units

II.c. Section B3.

12 units

II.d. Section B3.

The motif translates across the floor to produce two pairs. It is worth noting that the two pairs slightly deviate from their similarity through an inconsistency in the number of units in each pattern. Considering the color information does not change the group designation of the line pattern, since it is also monochromatic. The motif uses the color red other than the white color of the background.

Drawing Sheet No. 30.1

©

**Pattern
no. 27**

* The motif group designation is (*group 4mm*). The repetition in the floor forms (*group 2mm*).

* Once color is considered, the patterns re-group into two sets of two pairs, which forms a (*group 2*) instead of (*group 2mm*).

Drawing Sheet No. 31

I. Geometric analysis of the motif.
Group designation is (*group 4mm*).

II. Black and white
representation of color.

III.a. Black selection.

III.b. Red selection.

The group designation of the single motif does not change when considering color information. The motif splits into two monochromatic variations, Black and Red. This transforms the original (*group 2mm*) repetition of the motif in the floor into (*group 2*).

**Pattern
no. 28**

- * The pattern as a motif is (*group 2mm*). As a line pattern the group designation is (*group 12mm*).
- * The pattern repeats in two sections of the floor (B1&B3) in two different ways: in section B1 it forms a (*group m*), while in section B3 it forms a (*group 2*).
- * Group designations remain unchanged when considering color information.

Drawing Sheet No. 32

I. Geometric analysis of the pattern.

Group designation of the line pattern is (*group 12mm*).

Unit cell.

Fundamental region.

II. Black and White representation of colors.

III.a. Yellow selection.

III.b. Black selection.

The group designation of the single motif is (*group 2mm*)

The group designation of the motif does not change when considering color information.

The repetition of the motif hints at a rotational geometry established through two sets of three pairs. However, the relationship between pairs is not consistent in both sets. Though each of the pairs within the set has a rotational relationship.

Drawing Sheet No. 32.1

©

**Pattern
no. 29**

- * The pattern as a motif is (*group 2mm*). As a line pattern the group designation is (*group 12mm*).
- * The pattern repeats in two sections of the floor (B1&B3) in two different ways: in section B1 it forms a (*group m*), while in section B3 it forms a (*group 2*).
- * Group designations remain unchanged when considering color information.

Drawing Sheet No. 33

I. Geometric analysis of the pattern.

Group designation of the line pattern is (*group* $t2mm$).

Unit cell.

Fundamental region.

II. The group designation of the pattern as a motif is (*group* $2mm$).

III.a. Yellow selection.

III.b. Black selection.

The group designation of the motif does not change when considering color information.

The repetition of the motif hints at a rotational geometry established through two sets of two pairs. However, the relationship between pairs is not consistent in both sets. Though each of the pairs within the set has a rotational relationship.

IV.

Drawing Sheet No. 33.1

©

Patterns no. 30 to 42

* In section B2 there is a unique quadrilateral ring of patterns, which creates a border for the central section as well as for the octagonal fountain structure.

* To consider the ring of patterns as a unit in addition to the single patterns, the following section is presented in a slightly different manner: (I) line drawing shows the geometric pattern details of the ring. Motifs are grouped according to their line geometry (a-m), and are then examined in details in (drawing sheet no. 35, 36 & 37). (II) Black and White representation of colors, which are Black and Red beside the white background. (III) The colors are separated in Two drawings, which then help re-group the motifs according to their specific color configuration.

Drawing Sheet No. 34

©

<p>Pattern no. 30. (a).</p> <ul style="list-style-type: none"> * Group designation is (<i>group m</i>). * Like pattern no 10, this pattern has a calligraphic quality to it, which will be discussed further in the final chapter.
<p>Pattern no. 31. (b).</p> <ul style="list-style-type: none"> * Group designation is (<i>group m</i>). * (<i>group 2mm</i>) relationship between the pairs.
<p>Pattern no. 32. (c).</p> <ul style="list-style-type: none"> * Group designation is (<i>group m</i>). * (<i>group 2mm</i>) relationship between the pairs.
<p>Pattern no. 33. (d).</p> <ul style="list-style-type: none"> * Group designation is (<i>group m</i>). * (<i>group 2mm</i>) relationship between the pairs.
<p>Patterns no. 30, 31, 32 & 33</p>

<p>Pattern no. 34. (e).</p> <ul style="list-style-type: none"> * Group designation is (<i>group m</i>). * (<i>group 2</i>) relationship between the pairs, except one pair (<i>group 2mm</i>). 		
<p>Pattern no. 35. (f).</p> <ul style="list-style-type: none"> * Group designation is (<i>group m</i>). * (<i>group 2mm</i>) relationship between the pairs. 		
<p>Pattern no. 36. (g).</p> <ul style="list-style-type: none"> * Group designation is (<i>group m</i>). * (<i>group 2mm</i>) relationship between the pairs. 		
<p>Pattern no. 37. (h).</p> <ul style="list-style-type: none"> * Group designation is (<i>group m</i>). * (<i>group 2mm</i>) relationship between the pairs. * The pattern exists in two scales, in the side opposite to qibla the pattern has larger details, as if focused on a section from the other three. 		
<p>Patterns no. 34, 35, 36 & 37</p>		

<p>Pattern no. 38. (i).</p> <ul style="list-style-type: none"> * Group designation is (<i>group m</i>). * The motif exists as one pair in the floor, (<i>group 2mm</i>) relationship. 		
<p>Pattern no. 39. (j).</p> <ul style="list-style-type: none"> * Group designation is (<i>group m</i>). * The motif exists as one pair in the floor, (<i>group 2mm</i>) relationship. 		
<p>Pattern no. 40. (k).</p> <ul style="list-style-type: none"> * Group designation is (<i>group m</i>). * (<i>group 2mm</i>) relationship between the pairs. 		
<p>Pattern no. 41. (l).</p> <ul style="list-style-type: none"> * Group designation is (<i>group m</i>). * The motif exists as one pair in the floor, (<i>group 2mm</i>) relationship. 		
<p>Patterns no. 38, 39, 40 & 41</p>

* An alternating rhythm of motif borders is starting to appear even though there are some inconsistency.

IV. Study of the rhythm of repetition.

- * Based on the color study the 13 motif designs (a-m) further regroup into 26.
- * This study is more focused on the geometric relationship between rhythmic repetition of motifs. In this drawing, the dotted line helps illustrate the relationship between the phrases of repetition, which form (*group 2*), a 180 degree rotations around the center of the floor. As for the small circles they show two cases of mirroring, which interrupts the phrases of rotation.
- * The difference in the number of motifs in each side of the quadrilateral ring also plays role in not having a consistency in the rhythmic relationship of the patterns. One of the four sides has an extra pair of motifs; each side contains 14 pairs except the side opposite to qibla, it contains 15 pairs. This was achieved by having the width of the ring slightly narrower at that side.

I. Black and white representation of solid pieces in the floor.

As a final class in pattern classification is the category of solid pieces of marble that are not included as geometric patterns themselves. Yet, their repetition in the floor might be of importance in our geometric analysis of the floor as a whole.

The drawing here presented is a black and white representation of color. It is evident the 180 degrees rotational geometry that is established in the floor.

II.a. Black selection.

II.b. Red selection.

II.c. Light blue selection.

II.d. Yellow selection.

II.e. Green selection.

The color selection shows some discrepancies, especially between section A2&C2. However, the rest of the floor reinforces the diagonal pairing and rotation in the floor.

The solid pieces still present a curious and interesting presence in the floor, as to what is the distinctions between solid pieces and patterns?

This concludes all the patterns of the floor.

What is presented next is a summary of color as each section is separated into the five colors.

Drawing Sheet No. 43.1 ©

As a conclusion for this chapter on the geometrical analysis of the floor patterns, also aiming for a more comprehensive understanding of the geometry in the floor, every section of the nine sections of the floor is here below separated into the basic color categories. It is interesting to see the operation of rotation work in a larger context as well. We have seen how numerous patterns defied the line geometry through the color configuration. When the patterns are assembled together as one section, the colors seem to be operative in the same manner; defying an initial suggestive axial symmetry through color configuration.

This observation will be further expanded on and studied in chapter three.

a. Black and white representation

b. Black selection

c. Red selection

d. Yellow selection

e. Light blue selection

f. Green selection

Color selection, Section A1

Drawing Sheet No. 44.1

©

a. Black and white representation

b. Black selection

c. Red selection

d. Yellow selection

e. Light blue selection

f. Green selection

Color selection, Section A2

Drawing Sheet No. 44.2

©

a. Black and white representation

b. Black selection

c. Red selection

d. Yellow selection

e. Light blue selection

f. Green selection

Color selection, Section A3

Drawing Sheet No. 44.3 ©

a. Black and white representation

c. Red selection

e. Light blue selection is empty

Color selection, Section B1

b. Black selection

d. Yellow selection

f. Green selection

Drawing Sheet No. 44.4 ©

a. Black and white representation

b. Black selection

c. Red selection

d. Yellow selection

e. Light blue selection is empty

f. Green selection is empty

Color selection, Section B2

Drawing Sheet No. 44.5

a. Black and white representation

b. Black selection

c. Red selection

d. Yellow selection

e. Light blue selection is empty

Color selection, Section B3

f. Green selection

Drawing Sheet No. 44.6

a. Black and white representation

b. Black selection

c. Red selection

d. Yellow selection

e. Light blue selection

f. Green selection

Color selection, Section C1

Drawing Sheet No. 44.7

©

a. Black and white representation

b. Black selection

c. Red selection

d. Yellow selection

e. Light blue selection

f. Green selection

Color selection, Section C2

Drawing Sheet No. 44.8 ©

a. Black and white representation

b. Black selection

c. Red selection

d. Yellow selection

e. Light blue selection

f. Green selection

Color selection, Section C3

Drawing Sheet No. 44.9 ©

I. Red selection in the floor.

I. Black selection in the floor.

I. Yellow selection in the floor.

I. Light blue selection in the floor.

I. Green selection in the floor.

Chapter Three

Detail of an exploration drawing of geometric operations performed on the complete floor.

VII.1. Conclusion Part 1: A Sense of Geometric Choreography in the Floor

In concluding the work that has been done so far, the intent is to posit the possible geometric evolution of the floor—a choreography of symmetry operations leading to its unique geometric form. One seeks to ‘perform’ the specific geometric operations in the floor, in attempt to unveil for us the subtle presence of the floor as a work of architecture. After examining each and every pattern on its own, it is important to see how the floor comes together as a single entity. This could be viewed as yet another level of ‘performance’ with the objective of understanding a credible morphogenesis of the floor.

The approach to the geometric analysis as a musical or a theatrical ‘performance’ has yielded a number of discoveries that were somehow inherent in the analytical process itself. The fact that the floor was first considered as a mere line drawing and later analyzed as juxtaposition of color groups opened a set of doors through which to approach possible new understandings of the floor. It is worth recognizing that this process as a ‘performance’ has played a vital role in shaping our conception of this work of architecture. This does not necessarily mean nor can it be conclusively claimed that the floor was conceived in this manner. Yet, as Steiner has argued, this ‘performance’ approach has critically revealed certain aspects of this work of art that otherwise might have remained hidden. Specifically ones that would have been rather impossible to discover if the floor was not measured, drawn, re-checked, and its geometric “genes” carefully studied. It is also important to point

out that without the aid of high speed digital tools, most of these discoveries about the nature of the floor would have not been visible to the eye, perhaps even to the makers of the floor themselves. In other words, the ‘performance’ is very much dependent upon the speed of geometric computation and drawing, not unlike the movements discovered when still frames are run at a certain speed to achieve the simulation of movement. This, however, does not mean that the craftsmen who masterly composed this floor did not experience these realities in their own way with their own tools, whether physical, intellectual or spiritual. One can only hope that this investigation would act as a catalyst for serious speculations about the nature of the experiences that the ‘designers and makers’ of a floor like Sultan Hassan would have gone through.

Maintaining drawing as the main vessel of investigation, the arguments of this chapter radiate from a series of diagrams based on the geometric analyses presented in chapter two.

First, it might prove helpful to summarize and recapitulate certain facts about the geometry of the floor that were arrived at from the previous chapter. The scale of the floor proves that, to the human eye positioned at any location on the floor, it is difficult to detect most of the relationships that were discovered in the geometrical analysis. (Fig. 77) Standing on the floor, it would require a masterly skill to

Fig. 77: A view from the roof.

detect the details in the line geometry that indicates the subtle differences between the sections of the floor. For instance, the differences between the four corner sections of the floor and the subtle scale difference in sections A2 & C2, which result in the axial tilt in the floor, are not directly obvious to the viewer (Drawing sheet no. 6.2). This, for us, would present a first level of geometric complexity. Perhaps from a window from an upper floor, a contemplating visitor would be able to notice that level of relationships established in the floor. (Fig. 78) Yet a

Fig. 78: The process of checking the Floor

second level would be the application of color, which further indicates complex relationships within the first set and is therefore more difficult to detect. For example, the way some patterns shift their geometric relationships only after considering their color configuration. (Pattern no. 3 and 14) There might even be a third level of complexity in the geometric relationships that the makers might have known, though not necessarily on a visual level, thus making that level even harder to access. For instance, certain dualities of color in the two central stars of sections B1 and B3, which are too subtle to be deduced without any tools. (Drawing sheet no. 18.2 and 25.4)

It is revealing to find that none of the patterns in the floor require an “improper”¹ geometrical operation in order to repeat. It seems as if it was intentional to eliminate all improper operations from the floor, so that the movements indicated by the geometry of the

¹ As mentioned before a proper geometrical operation is indicated when one is able to trace the path between a shape and its image in the two-dimension: (rotation & translation). That is, an improper geometrical operation is untraceable in the same plane that the shape and its image exist in: (reflection & glide-reflection). (pages 43-45)

patterns remain confined within the two dimensional realm. In fact, it is possible to generate the entire floor through a set of translations and rotations—even more exciting to bear in mind is that translation is a special case of rotation. As if the floor exists in a complete two-dimensional realm that is able to function independently. Amazingly, most of this elimination of improper operations was achieved and maintained through the color configuration.

The drawings presented in this chapter are a series of investigations that could be viewed in their totality as a linked series of explorations, though each drawing could also afford to stand as a single finding. Though we can provide a brief introduction to each drawing as a specific exploration, yet the full discussion would be woven across the entire set of drawings. The attempt is to highlight certain generative and operational themes in the floor, which would serve as stepping-stones for further examination of the floor's architectural and even cultural significance.

1. Rotation phases: The line geometry of the pattern closest to the center of the floor (pattern no. 1) repeats suggesting a rotational geometry. As we carefully follow the line geometry in the floor, we can begin to sense the echo of this one central and most evident rotational operation in the rest of the floor. (Fig. 79) This is suggested through a number of subtle moves, such as the subtle shift in scale in sections A2 & C2, as well as the line

geometry of the center patterns of the four corner sections (A1, A3, C1 and C3) (Fig. 80)

The slight tilt of the main axis as a result becomes an important clue to the direction of the operation of rotation (counter clockwise). Counter clockwise rotations resonate in the natural/physical world; the closest to detect standing on the floor would be the rotation of the planets looking at a night sky above, which in a way could be viewed acting as a ceiling for the deep open court. (Fig. 81) Of more relevance to the floor as a part of the mosque is an echo from within the Islamic tradition: the ritual of circumambulating the Kaba during *Hajj*, the performance of the rite of pilgrimage, which interestingly lies on the axis of the floor (*Qibla* axis). The Kaba also is the center towards which all Muslims orient themselves five times a day for the ritual prayer. (Fig. 82)

This initial motion could be conceived as a spark for the operation of rotation throughout the floor around the center of the fountain, yet a second spark of color would set off each section into a 180 degree rotation around itself.

When viewed from the earth, represented by the dot, the planet Venus is seen to swirl across the sky in a symmetrical loops. (After P. Stevens, P.78).

Fig. 82 : The Kaba, in Mecca.

This brings us to the important examination of color, to consider color information like a color-blind person whose full vision has been restored; the eyes open to an extended presence of color that is operative on multiple scales in the floor.

2. Color transformation and complexity phases:

considering two types of transformations that occur as a result of considering the color configuration, the process of introducing color could be spanned over two stages: The first is a transformation on the level of a single motif; certain patterns change their group designations once color is considered (such as pattern no.14) (Fig. 83) The second is on the level of repetition in the floor, that is patterns that do not change in themselves yet the way they repeat in a single section or the entire floor transforms, for example (pattern no. 9 & 27, drawing sheets no. 13.2 & 31.1).

3. Pattern pairing: When considering color as a transformation, a peculiar phenomenon seems to be operative on multiple levels as well. We have seen that all the patterns of the floor repeat in at least one pair as a line geometry. A strong sense of pairing comes forth as patterns further group as pairs within a single set

Fig. 84: Two levels of pattern pairing.

through color configuration. Also more than once we have seen the same line geometry become rendered in two variations of color configurations. This regrouping through color further influences the phases of color transformation (for example pattern no. 9 & 27). Two scales of operation are most apparent: on the level of each section, and on an overall scale in the floor. (Fig. 84) Oddly enough this pairing also plays a role in setting up the 180 degrees rotations as it operates diagonally across the single section or the entire floor.

4. Synchronization of color and motion phases: A subtle relationship surfaces when relating the different phases of transformation that the first two operations mentioned above bring about (rotation and color transformation phases). The first level of color complexity and transformation introduces the operation of rotation to the central pattern of each section, while the second level becomes the infusion of the operation of rotation to the corners of each section. (Fig. 85) We could then layer these levels of complexity as different stages and express them through drawing. Both operations could be woven together so as to inform each other as a sequence of phases, like a carefully planned out choreography that aims to animate the floor, simultaneously, with color and motion: Color through motion, and motion through color.

Fig 85: Synchronization of color and motion.

In the next set of drawings, the above-mentioned operational themes are interwoven so as to suggest a generating geometric choreography and performance of the floor. A base drawing attempts to establish the fundamental geometrical relationships as a choreography, while on a translucent overlay, sketches aim to graphically perform and animate the operative nature of the geometrical operations.

These four operational and generative themes become the main points in our conclusion for this investigation of the geometry of the floor of the courtyard of Sultan Hassan madrasa and mosque. These points are argued through the act of drawing resulting in the drawings presented in the following pages. It is important to point out that these observations are completely grounded on the basis of the geometric analysis presented in the second chapter, yet in no way do they exhaust the possibilities for further or other readings of this work of architecture.

Drawing Sheet No. 46.1.a ©

Rotational Theme, Phase I:

The pattern closest to the center of the floor becomes the most apparent spark for the operation of rotation in the floor. This initial rotation could be seen echoed in the subtle tilt of the main axis. This, at this stage, is suggested through line geometry. Because of the subtle shift in scale the center of section A2 moves to the right, while C2 to the left, implying a counterclockwise rotation. Further more, the line geometry in Section B1 & B3 form a rotational relationship (*group 2*), which support this initial level of the operation of rotation as seen in the translucent overlay (drawing sheet no. 46.1.a).

Drawing Sheet No. 46.1 ©

Drawing Sheet No. 46.2.a ©

Drawing Sheet No. 46.2.b ©

Rotation, phase 2:

The second fold of the operation of rotation could be considered as a second echo of the initial rotation of the center around itself (Pattern no. 1). Still considering only the line geometry, the eight remaining sections of the floor pair in a 180 degrees rotational relationship around the center of the floor. The four corner sections on a diagonal relate through the central patterns, while the other middle sections relate more through their border patterns. The axial symmetry of the floor is further defied, yet respected by the two fold rotation.

The first overlay (drawing sheet no. 46.2.a) aims to graphically illustrate the location of the operation of rotation, while the second (drawing sheet no. 46.2.b) attempts to demonstrate the influence of the application of the operation of rotation in this phase.

Drawing Sheet No. 46.2 ©

Color transformation and complexity, Phase 1:

Through out the geometric analyses in chapter two, there were a number of ways that the color configuration influenced the final group designations of the patterns. Some were transformed on the level of the motif itself: that is the group designation of the single motif was transformed once color was considered over the line geometry. Other patterns were not affected as single motifs, yet the transformation was in the way they repeated in the floor.

In this first phase of color transformation and complexity the highlighted patterns are the ones that were transformed on the level of the single motif. This is considered as a first phase because these are most affected by their color configuration. Surprisingly these pattern occupy the central areas of the floor section. Furthermore most of these patterns were transformed in such a way that all mirroring symmetries were eliminated. In other words the folding symmetry became only rotational symmetry, which ties back into the two previous phases of rotation: (drawing sheet no. 46.1 & 46.2).

Drawing Sheet No. 46.3 ©

Drawing Sheet No. 46.4.a ©

Synchronization of color and motion, phase 1:

Filtering the color transformation from the previous drawing, (drawing sheet no. 46.3), into the second phase of rotation (drawing sheet no. 46.2) reveals an intricate relationship between motion and color. We can imagine it as a process of motion that is initiated through the line geometry, which results in the rotation of the floor around its center, as this first operation begins to rotate the bordering sections around the central one, color is introduced to the central patterns of each of the bordering sections.

Drawing Sheet No. 46.4 ©

Drawing Sheet No. 46.5.a c

Color transformation and complexity, Phase 2:

As mentioned before, we started looking at color complexity from the most complex, and now working our way to the more simpler ones. The second phase is the transformation on the level of repetition in the floor. Every pattern in the floor repeats at least as one pair, in this case some patterns further grouped and paired within a single set of line geometry. This drawing highlights the patterns which were influenced only on the level of repetition in the floor. That is the patterns which maintained the same group designation as a single motif, but transformed in the way they repeated in the floor.

This phase could serve to extend the relationships established in the first phase of synchronization between color and motion (drawing sheet no. 46.4). The overlay in this phase is super imposed from that previous study (drawing sheet no. 46.4.a); the purpose of the repetition of the overlay is to help project and relate the phases together.

Drawing Sheet No. 46.5 ©

Drawing Sheet No. 46.6.a c

Drawing Sheet No. 46.6.b c

Drawing Sheet No. 46.6.c c

Pairing, Phase 1:

The phenomenon of pairing becomes of a significance since not only there are no patterns that do not have a pair, but also because this operation of pairing extends through color. Most of the patterns that repeated four times were further paired through color as two pairs of two. These also we can group into two categories. One is on the level of each section, here indicated as dashed lines. Another is on the level of the whole floor, here indicated as dotted lines. The diagonal pairing further adds to and supports the operation of rotation in the floor.

The overlays for this drawings aim to demonstrate three main characteristics: pairing on the level of each section, pairing in the context of the floor and combining this grouping with the sense of rotation discovered from previous drawings, since all pairing occurs in some diagonal relationship that establishes a 180 degrees rotations. The group which operate on the level of a section would suggest a rotation of the section around itself, while the ones that operate on the overall scale of the floor would relate to the rotation of the floor around itself.

Drawing Sheet No. 46.6 ©

Drawing Sheet No. 46.7.a c

Synchronization of color and motion, Phase 2 + Rotation, Phase 3:

We can now begin to bring the influence of the later findings upon the operation of rotation in the floor. We can see the initiation of a new set of rotations in the floor based on the color transformation. From the center of each section a new rotation based on color, similar to the first rotation emanating from the center of the floor, yet that initial rotation was based on line geometry. It is possible to follow the echo of this initiation as it resonates in each section.

Drawing Sheet No. 46.7 ©

Drawing Sheet No. 46.8.a c

synchronization of color and motion, Phase 3:

If we imagine how the previous phases established the rotation of the floor around the central section, now we can further picture a flash of color that generates more rotations on a finer level, a rotation within a rotation. Through colors, the border sections suggest a self-rotation, each about its own center. The corner patterns of all sections except B1 & B3, echo the rotation of the floor on a smaller scale. Sections B1 & B3 remain mainly related to the over all rotation of floor.

To sum up the previous phases: the line geometry of the floor suggests a rotational geometry around the center of the fountain, and through color the individual sections suggest a rotation around themselves in addition to confirming the original rotation of the whole floor about itself. We can also bring the pairing as a two way relationship between color transformation and the operation of rotation.

The final phase of synchronicity happens as color infuses from the center of each section to reach the corners. Still employing the pairing as a medium for color and rotation, each section becomes as a reflection of the macrocosm in the microcosm.

Drawing Sheet No. 46.8 ©

Rotation, phase 4:

This drawing filters back the operation of rotation from the color transformation, like ripples caused in water after the stones sink under the surface. We can now imagine the floor continuously rotating, and the motion keeps traveling from the center to the corners. As long as the pattern closest to the center remains with a subtle and an unstable tilt, the floor seems to be still alive and in the process of transmitting its life to the space of the court.

Drawing Sheet No. 46.9 ©

VII.2. Conclusion Part 2: A Hierarchy of Geometric Analyses:

This thesis has revealed that the usual static and restrictive view of geometry is not only unfair and inaccurate but potentially limited in helping us see the “life” beyond a fixed order of points, lines and polygons. Sultan Hassan floor has revealed itself in different ways as the geometry has moved from a mere static order to a full “performance”. Based on this understanding we can recognize multiple shades of geometry: first is the layer of shapes, a packing of flat, regular and semi-regular polygons to fill the surface. This level of understanding of geometry yields only a simplistic, or worse yet, a stereotypical decorative understanding of the floor. At a second and a deeper level, geometry could be the vessel for the application of proportions, where the surfaces are governed by a set of relationships that are hidden. This becomes a static understanding of geometry, a frozen and a universal instant. If this approach to geometry is applied to the understanding of a volume, it results in the reduction of space to a set of planes, like the six faces of a hollow and empty box. The third and last level in our discussion is an understanding of geometry as a mapping and a choreography of movement, and from a similar perspective a formula of growth. This understanding is volumetric and three dimensional in its nature; it is the inhabitation of space. A pattern as such is not the arrangement of shapes, rather an arrangement of a set of movements that are principles, which when applied to any “shape” produces a ‘pattern’, a manifestation of a hidden dance in the physical space. This idea of “pattern” is captured

uniquely in the words of Mahmoud Shabistari (d. 1320):

*"The heavens revolve day and night,
Like a potter's wheel.
And every moment the master's wisdom,
Creates a new vessel. For all that exists
Comes from one hand, one workshop."*²

Fig. 86: The full manifestation of the operation of rotation in the floor

As the 'performance' approach has revealed, this attitude towards geometry is of essential importance and plays a vital role in gaining critical insights into the nature and significance of works of architecture like Sultan Hassan. In our specific case, it is our

² Quoted after Seyyed Hossein Nasr, *Islamic Cosmological Doctrines*. Page 105

position that considering the geometry of the floor adds a more depth to specific questions that could be raised about the nature of the floor and its relationship to the over all architectural context. For example, what are the implications of the fact that the dimensions of the floor (also the courtyard) are slightly elongated (32x34.6 meters), considering that the degree of its subtlety is so fine to the extent that it is hardly noticeable from any view into the court? Even more so when we consider the fact that the capability of achieving precise measurements and geometries are evident in other spaces in the mosque, such as the space of the mausoleum (21x21 meters). In this particular case further questions raised through the geometry of the floor enriches the question and potentially our understanding of the whole complex and the cultural and artistic tradition that produced it. For instance, the floor maintains 180 degree rotations defying the first impression of an axial symmetry, which echoes from the geometry implied by the stone structure. The subtlety in the architectural dimensions is matched with the subtlety in the geometry of the floor, perhaps even reinforced and supported by it. If the dimensions of the court subtly defied four-fold symmetry by an axial symmetry, then what are the implications of the fact that the floor further defies the courts axial symmetry? This further strengthens the argument against any position that would suggest that the floor geometry is “a builder’s whim” or a result of Islamic culture’s obsession with “geometric decoration of surfaces” as a consequence of injunctions against representational icons.

Perhaps it would be appropriate to be content with the present discoveries as a fitting conclusion for this study. It has only proved that this important work of architecture needs to be further explored within the context of the three-dimensional architecture of Sultan Hassan madrasa, (Fig. 87 and 88), as well as compared with other floors produced during the Mamluk period.

Fig 87: A computer generated image of the court of Sultan Hassan complex.

Fig 88: Hassan Fathy's three dimensional visualization of Sultan Hassan floor.

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