Lightweight Interventions as Solutions to the Annual Pilgrimage to Makkah (The Hajj)

The Role of Shading Structures for Pedestrians walkways

A Master's Thesis submitted for the degree of
"Master of Engineering"

supervised by
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Makkah, 30.10.2016

Affidavit

I, **REDA SAUD SIJINY**, hereby declare

1. that I am the sole author of the present Master's Thesis, "LIGHTWEIGHT INTERVENTIONS AS SOLUTIONS TO THE ANNUAL PILGRIMAGE TO MAKKAH (THE HAJJ): THE ROLE OF SHADING STRUCTURES FOR PEDESTRIAN WALKWAYS", 134 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 31.10.2106

Signature

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And

For Shara,
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GLOSSARY of TERMS

Ad'ha (pl. Adahi): the Day of the Feast, the Adahi area in Muna to perform the sacrifice

AH: Anno Hegirae The Islamic calendar starts counting years starting from the time when Muhammad had to leave Mecca and go to Medina, an event known as the Hijra. The first day of the first Islamic year is 1Muḥarram 1 (AH) and corresponds to 16 July 622 (CE).

Arafat: part of what is considered the areas on the outskirts, known as the Holy Precinct (called the Masha'er).the plain of Arafat, located roughly 14 km from Muna. Where the pilgrims goes to the plains of Mount Arafat to stand in vigil.

Dhul-Hijjah: the 12th month of the Islamic lunar calendar, eponymously called `Dhul-Hijjah (literally, (the month of the Hajj)

Eid ul-Ad'ha: the 10th day of the month (the 3rd day of the Hajj), the Day of the Feast.

Haram: A sanctuary, where many acts are prohibited, such as hunting birds or uprooting trees, hence it is also known as a prohibition.

Hegira (Hijrah): Prophet Muhammad's migration Muhammad and his followers' emigration from Mecca to Medina. Literally, "migration". This holiday marks the beginning of the Muslim New Year on the first day of the month of Muharram. The date of Hajj is determined by the Islamic calendar (known as Hijri calendar or AH), which is based on the lunar year.

Ihram: the pilgrims abandon their worldly dress and with it their material desires and develop a state of ihram — physically, the ihram consists of two unsewn sheets of cloth, a loin cloth and a shoulder cover with which the pilgrims cover themselves; spiritually, the ihram consists of many sacred prohibitions: there cannot be any acts of aggression, personal adornments are not allowed and sexual desires and impulses must be sublimated. Once in a state of ihram the pilgrims move towards

Mecca. Pilgrims enrobe themselves in their modest garments the Ihram state that was signified by the enrobing of the pilgrims is the name given to the special spiritual state in which pilgrims wear two white sheets of seamless cloth and abstain from certain actions.

Jabal Al-Rahmah: The sacred “Mountain of Mercy” located in the plain of Arafat, on which pilgrims spend most of the day of the 9th day of the month in prayers and contemplation.

Jamarat: the symbolic pelting of the Devil which takes place at the Jamarat area of Muna.

Kaa’ba: (The symbolic cubic structure constructed of black stone and enshrouded in black cloth in the centre of the Mosque) and the direction of prayer for the Muslims).

Marwah: Al-Marwah (Safa and Marwah) are two small hills now located in the Masjid al-Haram in Mecca, Saudi Arabia between which Muslims travel back and forth seven times during the ritual pilgrimages of Hajj and Umrah.

Masha’er: areas on the outskirts, known as the Holy Precinct (called the Masha’er).

Muna (Mina): narrow plains of the valley at Muna, part of what is considered the areas on the outskirts, known as the Holy Precinct (called the Masha’er).

Mutawwef: A pilgrim guide in Makkah. Traditionally, an essential component of the whole pilgrimage process and a crucial administrator for the successful completion of the rituals by the pilgrim.

Muzdalifah: the flat valley of Muzdalifah located about 12 km east of Makkah. It is where the pilgrims are required to gather a number (49 pebbles) of small pebbles from the ground of Muzdalifah, which will be ritually cleansed, ready to be used for the symbolic pelting of the Devil which takes place at the Jamarat area of Muna

Nafrah: the mass exodus of pilgrims from the sacred mountain, out of the valley of Arafat, towards Muzdalifah. From Arafat after sunset.

the greatest mass movement of the Hajj begins, called the “Nafrah”, towards the flat valley of Muzdalifah. It is the one occasion of the whole Hajj when all pilgrims move at the same time and on the same route; the route the majority have taken earlier in the day going to Arafat. The distance is approximately 7 km

Safa: Al-Safa and Al-Marwah (Safa and Marwah) are two small hills now located in the Masjid al-Haram in Mecca, Saudi Arabia between which Muslims travel back and forth seven times during the ritual pilgrimages of Hajj and Umrah.

Sa’i: Performing the Sa'i, also known as Sa'ee, serves to commemorate Hagar's search for water and God's mercy in answering prayers. It is the back and forth movement between the hills of Safa and Marwah in Makkah. It is an integral part of the Islamic Hajj and Umrah, symbolizing the search for water by Hajar in order to give to her son Ismail.

Tawaf: the circumambulation (called the Tawaf in Arabic) of the Kaa’ba seven times.

Wuquf: one of the most significant rites of Hajj. Literally the “standing” ritual which take place on the 9th day of the month, called the Day of Wuquf -which is the pinnacle of the Hajj rituals- the pilgrims travel to the plain of Arafat, where they stand in contemplative vigil: offering supplications, repentance on and atonement for their past sins, and seeking the mercy of God.

ABSTRACT

The annual Islamic pilgrimage (Hajj) to the holy areas in Western Arabia is unquestionably the largest annually occurring mass congregation of people in one place in the world. Peaking in a five-day period that takes place in the city of Makkah and within areas on its outskirts, known as the Holy Precincts, the Hajj presents one of the largest logistical challenges for the government of Saudi Arabia. However, the Hajj is still relying on crisis management tactics to operate-for reasons that will be presented in the thesis- despite the passing of more than forty years since authorities identified the magnitude of the task and started implementing modern solutions to deal with the rapidly increasing numbers of the pilgrims.

This thesis provides a fresh approach to solving some aspects of the Hajj and its problems by focusing on how lightweight structures as interventions can help minimize this dependence by the Hajj organizers on crisis management.

An introductory section describes the Hajj rituals, showing that it is mainly composed of set of predefined movements in between the Holy Precinct locations. The same section will continue by describing the problems facing the Hajj that have developed as a result of modern conditions. With particular attention focusing on the congestion during the Nafrah is caused by priority given to vehicular transportation over pedestrian movement. This section aims to bring back attention that pedestrian aspect of Hajj is as vital if not more important and needs more attention.

Next, the major section deals with recent research and development in the field of pedestrian movement and analysis and the challenges that face the conventional vehicular transport of the Hajj and focuses specifically on problems obstructing the smooth flow of pedestrian Hajj movement.

The third section explores the role that lightweight structures and innovative building technology can play in solving some of the problems facing the Hajj. A review of several proposals that have been commissioned in the past using this approach is presented. One particularly interesting proposal, a shading structure for the pedestrian walkways, was further analysed and researched and also reconstructed using design software.

It is hoped that in theory, these types of proposals will redirect the debate about pedestrian movement in the Hajj and encourage performing the Hajj on foot. It will also help change the dominant belief that using buses is the only option for transportation in the Hajj, on the contrary, it should be the last option, especially for the Nafrah.

In practice, such kinds of projects, if implemented, will offer a less complicated and less cumbersome alternative to performing the Hajj. It will also give organizers new tools and applications to relieve congestion of vehicular transportation modes, thus achieving a better rate of separation between pedestrian and vehicular circulation in the Hajj.

Key words: Hajj, Pedestrian Movement, Walkway Shading, Canopies for shading, Hajj Research Centre, Lightweight Structures for the Hajj

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

The Hajj is an annual religious event that takes place in the city of Makkah and within areas on its outskirts, known as the Holy Precincts (called the Masha'er). Many of the rituals and rites are performed en masse in a specific sequence, but in its simplest form it is predominantly "the march of hundreds of thousands of pilgrims" following the footsteps of the Prophet Mohammad, who in turn, followed in the footsteps of his ancestor, the Patriarch Prophet Abraham (Rasch, 1980).

However, since the 1950s, the inevitable adoption of modern modes of transportation - most significantly air travel – has led to the tremendous increase in the number of pilgrims able to travel to Makkah to perform the Hajj. From a manageable 200,000 in 1951 to a staggering 2.5 million in recent years. This astronomical increase in the number of pilgrims has become the biggest challenge facing the Hajj organizers and accommodating both shelter and infrastructure needs, especially those of the movement of the massive number of pilgrims performing the Hajj rites simultaneously continues to be a big struggle for all those involved in the operations of the Hajj.

This onslaught of pilgrims and the full capacity condition this has created has inadvertently accelerated the deterioration of the nascent infrastructure of the city of Makkah. An infrastructure that had only started to develop in the late 1960s in a relatively small city, but which is not able to cope with a full doubling if its population in the short span of 3-4 weeks during the Hajj season.

To date almost all the solutions that have been implemented have been conventional or one dimensional, lacking in a sense a holistic overall vision. None of the solutions applied took into consideration an all rounded approach that takes into account the other non-physical aspects of the Hajj; aspects that constitute a major characteristic of the inherent nature of the Hajj, such as the multi-cultural and socio-religious variety of the pilgrims, and also the spiritual component of the Hajj rituals. These new challenges and subsequent problems were so unique to this one annual religious event as to prompt the authorities to create a whole Ministry specializing in the administration and organization of pilgrimage to Makkah; called the Ministry of

Hajj. In a similar spirit, and when it became evident that tackling the worsening problems facing the planning and infrastructure of the city of Makkah would need a customized approach, a movement towards establishing a specialized research institute was voiced by a group of concerned specialists in the early 1970s. Their main worry was the impact of all the developments on the natural and cultural environment. They firmly believed that the Hajj would require solutions that are peculiar to the conditions that are found nowhere else; solutions that would have to be developed from within. This institute was called, the Hajj Research Institute, and it was established in 1975 at the King Abdulaziz University in Jeddah with that specific aim in mind.

The challenges facing the Hajj can be categorized into two categories; accommodation and movement. The latter can be further divided into vehicular and pedestrian. The focus of this research is to explore solutions that would help the pedestrian movement of the pilgrim, not inside the city of Makkah, but at the Holy Precincts (the Masha'er).

This research project will provide an investigation on how lightweight structures and innovative building technology can encourage pilgrims to perform their Hajj on foot and at the same time enhance their pedestrian experience, which would, in effect, alleviate the congestion on the vehicular traffic network and subsequently relieve the organizers of much of the operational pressures. In addition, the study will explore several design solutions to help this cause and also a set of future recommendations.

1.1 Problem Statement

It is the pedestrian aspect of the pilgrimage that many researchers and specialists in the field of Hajj studies have been calling for to be prioritized. Many researchers and experts in the field of crowd dynamics and pedestrian simulation have attested that the best mode of mass transportation between the Masha'er locations given the circumstance and constraints of the Hajj is walking. From as early as 1974, and as part of an international competition that was organized by the Ministry of Finance of Saudi Arabia soliciting solutions to the growing demand on accommodation in the valley of Muna, all the participating teams were unanimous in their declaration that a "*purely pedestrian system is the most productive means of mass transport for*

relatively short distances." (Rasch, 1980) This is a principle still true to this day and shared with anyone who has performed the pilgrimage recently. If one is to experience the Hajj, it is evident that the pedestrian aspect is a fundamental priority. However, due to the dire conditions that have changed the natural geography of the Holy precincts, a large number of pilgrims- especially those on foot- find it difficult to perform, what Bodo Rasch describes as a "*smooth, safe, spiritually uplifting and beautiful Hajj*." (Sijiny, 2010). The pilgrimage rites are still plagued by perpetual congestion in the flow of movement of the pilgrims. Obviously massive over-crowding is the biggest factor. However, car focused roads and hindrances to the pedestrian flow caused by motorcars and their accompanying infrastructure have exacerbated the conditions. (Rasch, 1980). Unfortunately, what many pilgrims experience is a complete disappointment to the expectations they had set out at the beginning of their journey. The strongest memory that many pilgrims end up with is sitting for so many hours inside a car or bus amid fumes and pollution.

Hence, since the 1970s there have been many attempts to provide solutions for the mitigation of the pedestrian flow during the peak periods of the pilgrims' movement. However, the Hajj is still relying on crisis management tactics to operate, as demonstrated by the sheer number of troops from all major security and government departments who are deployed during the Hajj every year. Even though forty years have passed since the first modern solutions were implemented to deal with the rapidly increasing numbers of the pilgrims, there still exists an urgency to deal with the masses of people flowing, especially during the mass exodus from Arafat to Muzdalifah; called the Nafrah.

In summary, there is a need for a better understanding of the challenges and hindrances facing pedestrians in the Hajj and to promote a structured approach to prioritize and provide model solutions to ensure an obstacle-free, "*smooth, safe, spiritually uplifting and beautiful Hajj*" (Sijiny, 2010).

1.2 Overview of the research

1.2.1. Research Hypothesis:

The main research hypotheses states that the a purely pedestrian system is the most productive means of mass transport for relatively short distances, and that priority in the Hajj should be shifted to pedestrians over vehicles. In addition, minimally invasive solutions in the form of lightweight structures should become the main focus of attention underpinning Hajj research and planning.

1.2.2. Research Aims, Objectives and Questions:

The overarching aim that any research related to the Hajj seeks to achieve is to provide an arrangement that will make “walking the Hajj on foot will again become the main means of transport and so attractive that the vehicular traffic will diminish without a need for compulsory restrictions” (Rasch: 1980).

In view of this much sought after ideal, the long term goal of this research is to highlight advantages of performing the Hajj on foot, and bring back a sense of authenticity and a spiritual value of the experience. In other words, the goal is to redirect awareness of the significance of pedestrian movement in mass events such as the Hajj and to encourage the performing the Hajj on foot. In order to achieve this, the study will draw attention to the role that lightweight structures and membrane architecture could play in providing new and innovative solutions. By highlighting the compatibility and symbiotic nature of lightweight structures and interventions with the natural and socio-historic context of the Holy Precincts, the research will show how they have the ability to address all of the required criteria.

In practice, the outcomes of the research will refocus attention towards a simpler, less complicated, and less cumbersome alternative to solving the Hajj problems. Instead of limiting all solutions to concrete and steel, it will give organizers new tools and applications to relieve congestion of vehicular transportation modes, thus achieving a better rate of separation between pedestrian and vehicular circulation in the Hajj. A much sought after ideal called for by almost all those who are involved in the Hajj. In addition, the aim is to encourage solutions that will enhance the

experience for those who opt to perform the Hajj on foot, not only without trouble, but also in the process gain an “uplifting experience” (Sijiny: 2010).

More specifically, the following research questions need to be addressed:

1. What are the typical hindrances and problems facing those pilgrims who perform the Hajj on foot?
2. How can we classify these problems for easier identification and analysis?
3. (with the exception of the massive Jamarat Bridge) Why have most solutions in the past focused on vehicular circulation only and almost entirely ignored pedestrians?
4. What are the current and/or proposed solutions as well as research advancements in pedestrian movements and lightweight structures that could be implemented for pedestrian walkways in the Holy precincts?
5. How can lightweight structures enhance the pedestrian Hajj experience?
6. What innovative building technologies such as membranes or textiles could be used to mitigate the extremities and tough conditions facing the pilgrims and the organizers during the Hajj?

The result of this study will be valuable to the Hajj organizers as well as related consultancy and service providers in developing better practices and solutions for the Hajj management in general, and for pedestrians in particular.

In pursuit of this aim, the research has the following four specific objectives:

1. To provide a comprehensive review of causes and characteristics of the main problems typically hindering a pedestrian pilgrimage.
2. To review current conditions and research in regards to pedestrian movement studies and how they could enhance existing pedestrian walkways.
3. To revisit, analyse and simulate previously proposed sun shading projects and re-evaluate their validity in today’s conditions.
4. To exemplify in what ways can the pedestrian Hajj experience be enhanced by implementing lightweight structures and solutions using innovative building technologies such as membrane and textile architecture

CHAPTER 2

THE HAJJ

2. THE HAJJ

The Hajj; the pilgrimage to the sanctuaries of Makkah and its surrounding, is an age-old ritual that predates Islam (Rasch,1980). However, in its Islamic form it has a well-defined and time specific programme. The Hajj holds a special place in the hearts of the Muslim community since they are enacting a set of rituals which takes them in the footsteps of the Prophet Mohammad (PBUH) tracing his path to the barren plain of Muna and the slopes of Mount Arafat. (Sardar, 1978)

The Hajj is the fifth pillar of Islam, and is a once in a lifetime obligation, and shall only be demanded for those who have the physical and financial ability to perform it in the rightful manner. In ancient times, this entailed the arduous journey, either on land or by sea routes, to and back from the Holy sites and has kept the numbers of pilgrims at a steady rate for more than 1300 years. However, in modern times, the number of pilgrims performing the Hajj has been increasing exponentially. Between 1949 (99,000 pilgrims from abroad) and 1984 (919,000 pilgrims from abroad) it has increased more than tenfold. (AlAfghani, 1987) In recent years, the annual number of pilgrims surpasses the 2.5 million mark and has changed the character of the rituals and sites indefinitely. According to the BBC, the Hajj, is “the biggest yearly mass movement of people on the planet.” (BBC, 2002)

The majority of rites of the Hajj take place in specific sequence for six days outside the centre of the city. The following section presents a brief description of the rituals that take place in the Hajj and their geographic location.

2.1 Brief description of the Hajj

Apart from it being a once in a lifetime obligation for Muslims, the journey nature of the Hajj gives it a very symbolic characteristic. In his introduction to the Hajj, Dr. Ziauddin Sardar, a previous member of the Hajj Research Centre, describes the main impetus that believers have in regard to the Hajj:

> *"… the Hajj is performed not because the pilgrims seek inspiration, but because they are inspired. The Hajj, …… is an expression, and not a search for belief. As an expression of belief the Hajj is the apex of spiritual experience of Muslims, a journey through the enlightened history of Islam". (Sardar, 1978)*

The Hajj is an annual event that takes place during the 12th month of the Islamic lunar calendar, eponymously called `Dhul-Hijjah (literally, (the month of the Hajj). It takes place in the city of Makkah and within areas on the outskirts, known as the Holy Precincts (called the Masha'er). Many of the rituals and rites are performed en masse, but in its simplest form it is predominantly "the march of hundreds of thousands of pilgrims" following the footsteps of the Prophet Mohammad (PBUH), who in turn, followed in the footsteps of his ancestor, the Patriarch Prophet Abraham (Rasch, 1980).

On the 8th day of the month, the pilgrims enrobe themselves in their modest garments signaling their entry into the state of Ihram, after which they visit the sanctuary of the Holy Mosque and perform the circumambulation (called the *Tawaf* in Arabic) of the Kaa'ba (The symbolic cubic structure constructed of black stone and enshrouded in black cloth in the centre of the Mosque) seven times. Following that the majority of the pilgrims make their way to their designated tent camps located in the narrow plains of the valley at Muna, located roughly 14 km South-East of Makkah, and stay there overnight.

On the 9th day of the month, called the Day of *Wuquf* -which is the pinnacle of the Hajj rituals- the pilgrims travel to the plain of Arafat, located roughly 14 km from Muna. This takes place at the crack of dawn, which is crucial for those pilgrims making this journey on foot who want to avoid the blistering heat of the day. In addition, the sooner they arrive to Arafat the more time they can spend there in prayers and spiritual contemplation and vigil. Depending on the season in which the Hajj falls (cool or hot – this differs since the lunar year is 11 days short of the Solar year, and hence an annual shift in season occurs) a not so large percentage, between 12-30% of the pilgrims make the journey on foot, which takes roughly from 2-4 hours (Rasch, 1980) (The fact that none of the pedestrian walkways are shaded is a major contributing factor to this relatively low percentage). However, the majority

of pilgrims travel by vehicles, which in most cases are big transport buses, but also in some cases large SUV passenger cars. Very few of the pilgrims make their way directly to Arafat from their homes in Makkah or Jeddah, and avoid completely the overnight stay in Muna. But this is mostly restricted to pilgrims from the local community and residents. Once the pilgrims arrive to Arafat, they stay there until sunset.

As soon as the sun sets on the 9th day of the month, the greatest mass movement of the Hajj begins, called the "*Nafrah*", towards the flat valley of Muzdalifah. It is the one occasion of the whole Hajj when all pilgrims move at the same time and on the same route; the route the majority have taken earlier in the day going to Arafat. The distance is approximately 7 km, and in such a relatively short distance it is certainly one of the largest mass gatherings and movements of people in one specific location on Earth (BBC, 2002). As can be expected, many of the typical cases of congestion take place during this exodus. The fact that more than 2.5 million people want to leave from the same point at once is in itself fraught with complexity. A larger number of pilgrims opt to make this journey on foot. (Rasch, 1980) (This increase compared to the earlier travel in the opposite direction is due to two factors; 1- the relatively shorter distance between Arafat and Muzdalifah, and 2- it takes place after sunset, which is relatively a much cooler part of the day).

However, a big traffic jam entails in several parts, especially on some of the road for vehicles, where many pilgrims on foot start to walk, either because they are not aware of the presence of specific pedestrian walkways, or access to them was just not possible. Starting from the Hajj season of 2011, a third option had been introduced, that of the Masha'er railway.

The surge to Muzdalifah starts to calm down around 10 pm, and is more or less disappears come midnight. Most of the pilgrims spend their time seated on the sparse space available, either for prayer or a quick meal. Before they continue to the next phase of the Hajj, they are required to gather a number (49) of small pebbles from the ground of Muzdalifah, which will be ritually cleansed, ready to be used for the symbolic pelting of the Devil (represented by stone pillars) which takes place at the Jamarat area of Muna on the morning of the next day. Approximately 80% of pilgrims spend the whole night at Muzdalifah leaving after *Fajr* (dawn prayer) for the

7 kilometer walk to Muna (Happold,1983). The remainders proceed straight away to Muna, mostly on foot (Rasch, 1980).

Already before the sunrise on the 10th day of the month (the 3rd day of the Hajj), the pilgrims who have spent the night in Muzdalifah press on towards Muna. Most go straight to the Jamarat area to perform the symbolic pelting of the pillar signifying Satan. This is usually where the most extreme crowding and congestion takes place.

Once the pelting has been done, many of the pilgrims head towards the Adahi area in Muna to perform the sacrifice, which is not obligatory, but is symbolic of the story of Ishmael, the son of the prophet Abraham. However, many choose to postpone the sacrifice to another day during the Hajj which is permissible. Those who do not perform the animal sacrifice on the 10th day can either head back to their camps in Muna to rest, or if they still have the energy, continue towards Makkah to perform another circumambulation of the Kaa'ba called the *Tawaf Al-Ifada*. This circumambulation denotes the end stage of the Ihram state that was signified by the enrobing of the pilgrims, and culminates with the ritualistic clipping or shaving of the head signifying the Day of the Feast (called Eid ul-ad'ha). After that many pilgrims don their cheery garb and spend the remaining three days in Muna between packing their belongings and the only ritual obligation of pelting the three locations of the devils on a daily basis.

On the 13th day of the month, the sixth day of the Hajj proper, and once they have completed the stoning of the Devils for that day, the pilgrims leave Muna and the Hajj is over. After that, around half of the pilgrims travel to Madinah to visit the Mosque of the Prophet Mohammad where he is buried. The rest either head back to their temporary accommodation either in Makkah or in Jeddah to wait for their travel arrangements taking them back home. It takes roughly about one month until all the pilgrims have left the country (Rasch, 1980).

This brief description of the movements and rites of Hajj shows that a big part of the Hajj is made up of physical rituals in combination with prayers, vigils and contemplation. From the pilgrim's perspective, the Hajj, as Dr. Ziauddin Sardar describes it, forms part of the pathway to "spiritual enrichment"; "a journey towards the assimilation with the will of God." (Sardar, 1978). To achieve this, the pilgrim understands that this leads through the physical process of Hajj: all rites of the Hajj

require a certain amount of physical exhaustion. Described succinctly in his introduction to the Hajj, Dr. Ziauddin Sardar explains that it is "*in the intention of the pilgrims that they would suffer humbly the physical discomforts of the Sacred journey for they know that physical exertion is a way towards spiritual enlightenment*" (Sardar, 1978).

In figure 2.1, the main movements and rites and their sequence are explained in an aerial map that shows all the main locations of the Holy Precincts (Masha'er).

Figure 2.1 The Main Rites of the Hajj (in sequence)

2.2 The Hajj in modern times

Since the 1950s, the Government of Saudi Arabia has spent more than $100 billion for the development of the pilgrimage facilities (Campo, 2009). It has invested heavily in the infra-structure of the city of Makkah, leading to a considerable increase in the housing, transportation, sanitation, and health care facilities provided for both the pilgrims and residents of the city. (Harrison, 2001) In addition, the Government allocates a massive budget for the security of the Hajj, amassing a considerable number of security personnel supplied with the latest state of the art equipment to maintain and oversee a trouble free event. They also set up a special Supreme Hajj Committee to oversee all aspects of security and logistics, and ensuring that all necessary arrangements are taken care of each year. It is no secret that the preparation and overseeing of all the arrangement for the Hajj constitutes one of the largest logistical challenges for the government of Saudi Arabia.

Inevitably though, the sheer number of pilgrims itself-gathering for one event- has always been fraught with danger. With the numbers greatly increasing in recent years, on several occasions numerous accidents and deaths have occurred due to crushing or trampling of pedestrians in an overcrowded situation. (Harrison, 2001)

The fact that this growth has been exponential and not gradual has aggravated the situation. Pilgrims numbers increased from approximately 100,000 in 1924 (roughly half arriving from abroad), doubling to more than 200,000 in 1951 reaching a staggering 450,000 in 1961, and passing the million mark in 1972 (Long, 1979). The number of pilgrims performing the Hajj annually since the early 80s has always hovered between 2.5 – 3 million. This astronomical increase in the number of pilgrims annually has come to the detriment of the infrastructure of the city of Makkah which is not able to cope with a full doubling if its population in the short span of 3-4 weeks.

No doubt there is a dire necessity to develop and implement new and expanding infrastructure and facilities to accommodate to tremendous increase in the number of pilgrims coming for the Hajj. However, it is the manner in which these projects and plans have been implemented that resulted in a growing list of new problems that did not exist before.

In his seminal PhD thesis “Tent Cities of the Hajj”, 1980, the German architect and founding member of the Hajj research centre, Dr. Bodo Rasch highlights that these problems are the result of too many quick fix solutions that have been initiated during the Oil boom years of the 70s by the Saudi Government. It was the intention of these attempts to alleviate the congestion caused by the astronomically increasing number of pilgrims with the onslaught of modern transport means, but at the same time this has unfortunately led to the deterioration of the peace and tranquility that any Pilgrim would expect from this once in a life time spiritual experience (Rasch: 1980).

Since then, the modest infrastructure of the holy sanctuaries has been in a constant race to keep up with this massive increase in the numbers of pilgrims. However, due to rapid deployment and constant changes that take place, these infrastructural solutions, founded solely on modern technology, have been threatening the peace and tranquility, which forms the core nature of the pilgrimage ritual. The main challenge of course, is that the city of Makkah now has to accommodate nearly two million pilgrims who spend less than one month every year within its borders, a 100% swelling of its population in a very short period of time.

2.3 The modern crisis of the Hajj

For more than one thousand and three hundred years, the landscape of the Holy Precincts stood virtually untouched. However, the rapid changes that have been taking place over the past forty years have made a deep and permanent scar to this sacred site. Dr. M. A. Badawi, one of the early members of the Hajj Research Centre, provides a vivid description of the impact of modern planning and construction on the natural setting of the Holy Precincts:

> *“The Hajji almost has the virtue of constancy. The burned hills and the bleak valley suffer no growing plants to alter the scene or eat into the heart of the soil. Being barren means being permanently unalterable. Only when the powerful bulldozers, the noisy and terrifying dynamites were introduced did the face of the Sacred Valley radically change”.*
>
> *(Badawi, HAJJ STUDIES, 1978)*

The core issue of the problems endemic to the Hajj in modern times stems from the balance (or imbalance, to be accurate) between the physical aspect and the spiritual aspect of the Hajj. Writing in the first volume of the Hajj Studies publication, Dr. Ziauddin Sardar explains:

> *"In an ideal Hajj, the physical experience of the pilgrim will be insignificant compared to his spiritual experience. In a non-ideal Hajj, the pilgrim spends most of his time fighting the physical aspects of Hajj which have taken a formidable form. He has little time left for reflection, prayer and meditation. (Sardar, 1978).*

It is the recent prevalence of this "non-ideal" Hajj that has become a dominating factor in all aspects related to performance of the Hajj nowadays. In the above text, the author describes a situation of the Hajj thirty five years ago. Not a lot has changed in this regard; in fact, it has even worsened.

No doubt that the Hajj itself requires from the pilgrim a certain amount of physical exertion. However, if the physical exertion increases beyond its natural limits, the pilgrims become overwhelmed with physical exhaustion. As a consequence, the Hajj now becomes rather more of a physical experience than a spiritual one. If the physical dimension is further increased, the spiritual experience of Hajj diminishes proportionately, inevitably leading to the prevalence of this "non-ideal" Hajj, as explained above. This physical exertion is mostly exacerbated by introducing into the physical process of the Hajj what constitutes a "noise", or aspects affecting the rites which do not belong to the Hajj environment (Sardar, 1978). It has blatantly eroded the spiritual nature of the pilgrimage.

Already in the 1970s there was considerable awareness amongst researchers of the negative impact that modern infrastructural solutions have had on the Hajj. One of the earliest studies to tackle this problem was the PhD thesis of Dr. Solaiman Al-Hamdan, entitled: "The pilgrimage to Makkah: A study of the physical planning problems with special reference to the increasing number of pilgrims and changing modes of travel", which was submitted for dissertation to the Department of Town and Regional Planning at the University of Sheffield, England in 1976. From the title we could discern the core issue of the problems facing the Hajj, his singling out of

the *increasing number of pilgrims* and the *changing modes of travel* as the two main critical factors causing the problems in the Hajj of modern times is an important indication of the level of urgency.

The recent catastrophe which took place in Muna in September 2015 is a clear sign that although there have been significant improvements in the infrastructure facilities of the Hajj grounds (Makkah, Holy Mosque Expansion works, Masha'er facilities, Number of accommodation, etc.) undertaken by the KSA Government, the fact is that the Hajj organizers still rely heavily on "crisis management tactics" during the course of the six days of the Hajj proper (Sijiny, 2010). It is hard to deny that the Hajj nowadays is referred to as an accident prone experience.

As a result of the astronomical increase in number of pilgrims annually since the 1950s, it was inevitable that the authorities would try to accommodate this by developing and expanding the infra-structure and utilities of the city. However, it was clear from an early time that the pace of the infra-structure development could not cope with the steady and exponential rise in the pilgrim's numbers. Simply, the new and modern infra-structure was unable to cope. Indirectly this modern infra-structure although solving one aspect of transportation for example, indirectly also created new problems that did not exist before, related to the secondary infra-structure attached to it, for example car-parking structures, or flyovers that ate up valuable space in confined parts of the city. As a consequence, this has led to the impediment of the "natural flow of pilgrims", i.e. those who opt to move between the different Hajj locations on foot (Rasch, 1980). The outcome of which is a constant state of congestion that grips the city and most of its roads and facilities throughout the whole Hajj period. An outcome that has pretty much shaped what most people's image of the Hajj has become; perpetual traffic jams.

As a consequence, it is unfortunate that every year almost all mainstream literature tends to cover the Hajj from the logistical perspective only. The stereotypical image associated with the Hajj is of traffic jams like no other in the world. In a review of several news reports on the Hajj by some major news corporations, almost all of them mention the traffic jams as if they were an inherent characteristic of the Hajj. For example, in a BBC report in 2002, the highlight of the report is to mention the aspect of the traffic in the Hajj: "*There were mile-long traffic jams as buses left*

Mecca, some with pilgrims riding on top after a day spent waiting in the scorching Saudi sun." (BBC, 2002)

What has made the situation worse was the relatively naïve approach and inexperience with which the authorities dealt with these new and gigantic challenges. To assume that solutions that have worked elsewhere could be simply applied for the Hajj and simply scaled up was a sign of the lack of depth and cohesion that the authorities had in those early years. In what could be described as a period of panic and confusion, by 1965, when the reality of the dramatic increase in the number of pilgrims dawned upon the people in charge, there followed a frenzy of initiatives and proposals from various departments in the Saudi Arabian government of the time. Each with their own mandate and set of goals, it soon became evident that there was no cohesion between these various departments, and many realized that "*a holistic approach to planning was needed to deal with these developments"* (Rasch, 1980).

Instinctively, the first reaction as always was to solicit the expertise of the '*International Consultants*'. However, the Hajj is a very unique and site specific problem, and unless one has both extensive experience in the Hajj and a very high level of technical knowhow, coupled with a comprehensive outlook, all proposals for solving the problems facing the Hajj would be lacking, if not outright detrimental. The result was that the early international engineering and architecture firms that were hired by the authorities caused more problems than solving them. In the course of subsequent studies and implementation, Bodo Rasch puts it succinctly, that by "*unscrupulously adapting the development of Makkah and the Hajj to western standards, they prepared the way for desolate suburbia, multi-storey car parks, ring roads, traffic overpasses and tunnels."* (Rasch, 1980).

The core malady that still permeates the approach to tackling the challenges that face the Hajj is the lack of an encompassing overall vision; which looks at both pedestrian and vehicles. The culture of many Government departments nowadays is to get it over and done with as soon as possible. There needs to be an initiative to look at the Hajj from an overall perspective and make the necessary connections between the different elements of the Hajj. Even as recent as 2006, when a stampede on the last day of the Hajj, shortly after 1pm, killed at least 346 pilgrims, in an interview with Keith Still, one of the world's leading experts on crowd dynamics,

he asserts that "*The primary cause of injury and accidents is failing to understand how design, information and management influence a crowd*." (Graham-Rowe, 2011)

According to Bodo Rasch, the problems facing the Hajj can be categorized into two types:

1. Problems in the ability to perform the rituals
2. Problems in the transport infrastructure

Of course both of these types of problems stem from the inevitable increase in the number of pilgrims annually (Rasch, 1980). The following section gives some examples of each type.

2.3.1 Problems in performing the Rituals:

These are effectively problems that affect the spirituality, comfort, health and safety of the pilgrims. In the earlier times of the Hajj and until the 1960s, the pilgrims would be divided into manageable group sizes each with a pilgrim guide and their staff all focusing on the needs of this one group and facilitating all aspects of their Hajj, both physical and spiritual. This in a sense was a very successful form of de-centralization of the Hajj operations.

The arduous journey to reach the Holy Lands was in itself a filtration process that effectively only enabled those who are truly physically able – or at least accompanied by someone who is- to arrive to Makkah and undertake all the physical exertions expected during the Hajj rituals. However, the increase in pilgrims' numbers due to availability of modern and cheap modes of transport has virtually eroded this filtration process. Combined with the constant race to provide the necessary infrastructure and resulting problems that hinder access to them, has resulted in a growing number of vulnerable pilgrims facing even tougher physical conditions compared to the past.

The sheer increase in numbers would not necessarily have been a major problem if pedestrian movement was a priority for the planners and decision makers during the early planning and development period. However, the fact that all this increase in

numbers was to be accommodated by vehicular transportation only has been the major cause of the crisis nature of Hajj in modern times.

As explained by Dr. Ziauddin Sardar above, the constant pressure that the rituals are subjected to manifests itself in the form of ‘noise’. Noise is anything that is alien to the environment of Hajj and that interferes with the spiritual development of pilgrims. (Sardar,1978)

Figure 2.2 Large tracts of land have been eaten up by the necessity to provide buses with necessary parking spaces, depriving the pilgrims of valuable camping space that would help ease the congestion of pilgrims in their tents.

As explained above, the “non-ideal” Hajj situation arises when “*the physical dimension is further increased, the spiritual experience of Hajj diminishes proportionately*”. (Sardar, 1978) Over the years, this reality has been constantly eroding the spiritual aspect of the Hajj to the point that one could claim that nowadays it has been virtually removed by the “*overpowering physical experience of Hajj*” (Sardar, 1978).

It is quite easy to argue that nowadays, the Hajj has been reduced to a set of mechanical actions; a tragic condition from the spiritual point of view! Spiritual aspect aside, this condition is even affecting negatively the ability of the pilgrims to

perform their physical rituals. For example, parking areas in Muzdalifah cover about 80% of the valley, and leaves hardly any space for a few hours of simple contemplation (Rasch, 1980) This combination of massive over-crowding, hindrance by vehicles over unsuitable roads is the core reason why a large number of pilgrims, are still not able to perform what Bodo Rasch described previously as a “smooth, safe, spiritually uplifting and beautiful Hajj” (Sijiny, 2010). This is the simplest right that any pilgrim deserves and expects when embarking on their once in a lifetime obligation.

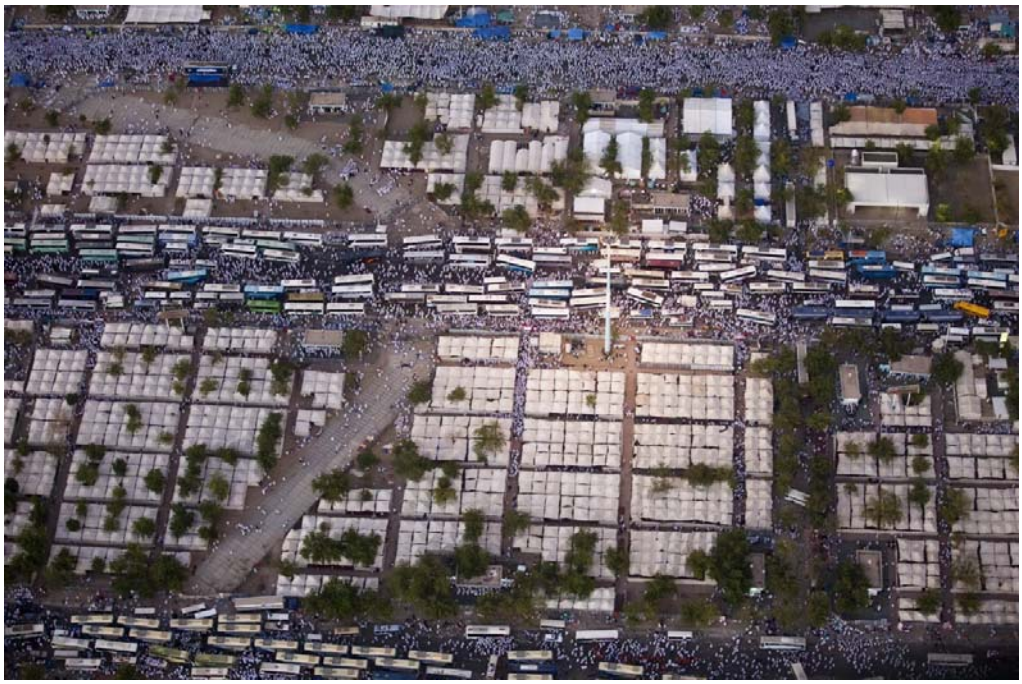

Figure 2.3 What is normally planned as a streamlined and well managed logistical programme turns immediately into chaos once the rush for their camps begins. As pilgrims on foot mingle with buses that already have their motors running trying to reach access to the pedestrian walkways, they stumble upon a mixture of obstacles and barriers.

For many of the faithful worldwide, Hajjis- those who have managed to complete the Hajj rituals- cannot help feel nowadays a sigh of relief for having being able to survive the ordeals of the Hajj. A notion of “We made it!” permeates many a conversation between pilgrims on their journey home. Whereas in classic times it was the complete opposite, the feeling of relief would inevitably occur after having survived the arduous journey to reach Makkah, but the Hajj itself was secure in the relative safety of the sanctuary. Nowadays it is a sufficiently safe journey, while the Hajj itself is fraught with the dangers of collision, stampede, pile-up, pollution, etc.

These Psychological effects are significant, and should not to be under-estimated. While logistical and infrastructural facilities are important, they are not of sole importance.

2.3.2 Problems in the transport infrastructure

These are problems that deal with the efficiency of the facilities that have been provided to date. The main objective of implementing contemporary solutions for the Hajj was always meant to be consistent with an attitude along the lines of what Bodo Rasch puts it; "*you just help the people to do their worship with as little disturbance as possible*" (Sijiny, 2010). What you have now is the complete opposite. The single most destructive intrusion has been the vehicular network of roads and transport infrastructure. Instead of forming an organic whole with the pedestrian movement, the vehicular traffic functions totally independently and so a conflict between cars, pilgrims and traffic police arises. This leads to many accidents and disturbs the peace of mind of all those involved. (Rasch, 1980)

These problems stem directly from the sheer number of pilgrims amassing at one place and also due to the extremely short duration in which all the events of the Hajj take place. This is the single most formidable challenge that the organizers face every year.

Figure 2.4 With the increase of the number of pilgrims used as the official excuse, the multiplicity of infrastructural projects has virtually eroded whatever is left of the natural landscape and has completely covered it in manmade materials.

Not only is the problem a shortage in the availability of facilities, such as accommodation, transportation vehicles, provisions, sewage and waste treatment, etc., but also that even when available, the problem persists due to the lack of efficiency in delivering them or having the pilgrims reach them in such a short period.

Many of the recent solutions implemented for the Hajj are heavy, permanent, invasive and disrespectful of the sanctity of the place. They are also not efficient in the allocation of material and finances, and do not take into consideration the temporality of the Hajj. In the course of implementing all these “engineering” solutions, unfortunately a lot of damage has occurred, both physically; to the geography of the place, and psychologically; to the perception of the modern Hajj.

This echoes the analysis of many experts who worked at the Hajj Research Centre, as Dr. Bodo Rasch explains: “The urban planners of the world … none of them understand Makkah and Madinah, not even the Muslim ones. You cannot divide Makkah into urban zones with schools and markets.” (Sijiny, 2010)

Unfortunately, even when providing the most straight-forward of amenities, for example; an exclusively pedestrian walkway, the incompetence in the execution of these causes many disruptions to the smooth flow of the pilgrims. In many cases it is such simple deficiencies- such as the lack of signage directing to a secondary pedestrian route- that lead to some of the major accidents that have occurred in recent times. As Bodo Rasch explains, "*of course Muna and many places in the Hajj have seen what they call stampedes. That is not really the right word. A stampede is more of a reaction out of panic. Pilgrims rarely ever panic. But there are pileups. And the pileups happen when there is no space. People push from the back not knowing that there is no way forward*" (Sijiny, 2010).

Other solutions have relied only on conventional planning approaches to deal with the temporary accommodation required by the pilgrims. For example, the planning of the tent city encampment of Muna in a conventional grid-iron layout normally used for urban settlement, instead of the common sense approach to respect the natural topography, causes many problems to this day.

To overcome this predicament, Saudi authorities have stretched out over the Holy Precincts an extensive network of roads, bridges, crossings, motorways and other traffic arrangements, without having been able to eradicate the problems created by them. These efforts have not been successful because of the fact that a motorcar requires a hundred times more traffic space than a pedestrian and because it is impossible to build enough roads for nearly two million motorized pilgrims who must all go to the some places at the same time. (Rasch, 1980)

Consequently, the city of Makkah and its surrounding face a constant battle to keep up with this challenge.

2.3.3 Tackling the problems: The Hajj Research Centre

The Hajj is a microcosm of the Muslim World. If the Hajj is not feeling healthy, then that is a reflection of the state of the Muslim community. With this notion in mind, In 1975 the Hajj Research Centre (HRC) was founded by the architect Sami Angawi, a Makkan and the son of a Pilgrim guide" (Mutawwef). It mission was to address the Hajj's complex dynamics through the use of technology and analysis, and to tackle the problems of the Hajj with scientific methods. The Jeddah-based think tank -

founded at the King Abdul Aziz University- attracted a multi-disciplinary team including architects, plannners, statisticians, engineers, designers, religious scholars and sociologists. He was joined at the inception of the centre, by Bodo Rasch, a Stuttgart-based architect. It was inspired and modelled around the IL Institute which was established in 1962 by Frei Otto at the University of Stuttgart.

They met two years prior to that at the University of Texas in Austin, where Bodo Rasch was visiting lecturer. Following this encounter, a long term friendship was formed, and later Sami Angawi was invited by Frei Otto's team (of which Bodo Rasch was a member) to participate and advise on the competition entry for the international architectural competition for accommodating pilgrims in Muna in 1974.

The establishment of the Hajj Research Centre in 1975 with the fundamental aim of contributing by "means of objective and thorough research, towards appropriate solutions of all problems connected with the Pilgrimage and with the Sacred Cities and Sites" was a significant moment in the history not only of the Holy cities of Makkah and Madinah, but for the whole of Saudi Arabia (Rasch, 1980). Considered to be the first Saudi bred think-tank in the country, the multi-disciplinary approach that the centre took in dealing with the daunting challenges and problems facing the Hajj was exemplary. These were aims which are very much relevant these days, forty years after the Hajj Research centre was established.

The first ten years of the Hajj Research Centre witnessed an unprecedented explosion of ideas and field research into this new field peculiar to the Muslim World. The centre managed to gather the brightest minds from a wide array of specialties to create a truly unique multi-disciplinary team of researchers and experts. This approach was originally implemented by Frei Otto at the IL Institute of Stuttgart University, and championed by him through his architectural career when working on his designs and projects.

The founders of the centre realised from the outset that in the Hajj unparalleled problems have risen and only solutions unique to these conditions can begin to alleviate them. That is why they believed that the Hajj requires its own "kind of engineering". In my interview with Dr. Bodo Rasch in 2010, he explains these early notions regarding the founding principles of the centre:

"By concentrating on the technology that needs to be invented for the Hajj, Saudi Arabia could be a leader in many fields of the technical development. That's basically what ***our aim was at the Hajj Research Centre****, …. The fact is that the engineering for something like the Hajj cannot be bought from overseas. It hasn't been developed. Most government agencies think that you can buy the engineering in America or Europe. In this case, it doesn't work. You have to develop it. Even the scientific foundation for the engineering required is not there"* (Sijiny, 2010).

2.4 The Hajj is a Pedestrian Event: Pedestrian aspects of the Hajj

One of the main misconceptions that the earlier planners succumbed to was to treat the Hajj and the Holy Precinct sites only as a city, applying traditional urban planning theories and conventions. But the Hajj is not a city, it is an event. Even if it takes place within the confines of a contemporary city, it cannot be dealt with using land use and zoning methods. Therefore, the authorities have realized that it is more appropriate to consider event management practices to solve the problems facing the Hajj instead of depending solely on conventional infrastructural design, civil engineering, traffic engineering and city planning efforts (Sijiny, 2015). When one experiences the Hajj, one cannot help but realize that this is a mass crowd event, and that a large percentage of it characteristics relates to pedestrian movement and to the mechanics related to it. In my interview with Bodo Rasch in 2010, he sheds some light on this aspect: "*The other thing was the experience of the pedestrian Hajj. When we did this at the Hajj Research Centre, it was an uplifting experience. From then, it was clear to me that the Hajj was meant as a pedestrian event*" (Sijiny, 2010).

The most obvious aspect of the Hajj that has been overlooked for the longest of times is that it is a pedestrian experience, and that even if some vehicular solution where to be implemented, it is of the utmost importance that a segregation between pedestrians and vehicles should be a high priority. Unfortunately, this was never the case. Attention has always been directed mainly onto the transport infrastructure and the traffic solutions focusing solely on the vehicular movement and circulation. Based on the prevailing tendency in the 1970s worldwide; "a car for every citizen", it seemed that Hajj organizers in those early years were bent on providing each pilgrim the possibility to perform the Hajj using their own car.

Figure 2.5 Tents at Arafat circa 1976. Pilgrims were allowed to park their cars in front of their tents.

In his PhD thesis the “Tent Cities of the Hajj”, 1980, which he submitted after several years of extensive research during the early years of the Hajj Research Centre, the German trained architect Bodo Rasch states that “*The pedestrian traffic is, over short distances, objectively the most efficient means of transport; it is the most important component of the pilgrims’ movement as a whole; it is really a religious act.*” (Rasch, 1980) Already by then, it was plainly obvious, especially to those researchers in the early days of the Hajj Research Centre, what advantages pedestrian traffic had on the overall flow of movement during the Hajj.

In 1974, the Ministry of Finance of Saudi Arabia invited five architectural practices to participate in an international competition, in the hope of intervening in what was then a growing uncertainty over the ongoing development of the Hajj infrastructure. This uncertainty stemmed from an acute discrepancy between predictions and estimations and the reality of Hajj situation. (Rasch, 1980) One of these teams was led by Frei Otto, and included both Bodo Rasch and Sami Angawi – who went on to establish the Hajj Research Center after a short period as a result of this competition. It is worth noting that all the participating teams realized that both the pilgrims’ accommodation in Muna and the traffic of the Hajj were the fundamental problems which must be resolved if the whole situation of the Hajj is to improve in the future.

It is unfortunate that none of the competition entries presented were ever integrated in the planning and development of the Hajj precincts during the course of the past

forty years. However, from the entries that were submitted, what was truly noteworthy is that all the participating teams highlighted the importance that a "*purely pedestrian system is the most productive means of mass transport for relatively short distances*" (Rasch, 1980). This is a tenet still true to this day and shared with anyone who has performed the pilgrimage recently.

It is this pedestrian aspect of the whole pilgrimage that many researchers and specialists in the field of Hajj studies have been calling for to be prioritized, and not just for bottle-neck areas. Hence, since the 1970s there have been many attempts to support the pedestrian flow during the peak periods of the pilgrims' movement. According to Dr. Bodo Rasch, the PhD thesis of Dr. Solaiman Al-Hamdan (see page xx), conducts a thorough research on issues and aspects of the vehicular traffic of the Hajj. Furthermore, Dr. Al-Hamdan presents several necessary solutions, such as the *"widening of the existing pedestrian route which occurs in the middle of the valley to 60m."* In line with what the Hajj Research Centre have also strongly suggested, he also advises that an especially strict segregation of pedestrian and vehicle traffic be enforced. The significance of this early research lies in that while a well worked out traffic system for vehicular movement during the Hajj has been presented, the author still recognises the important status of the pedestrian movement for the Hajj (Rasch, 1980).

Other observations on the problems facing the vehicular movement were presented in the Hajj Walkway Shade Structures report in 1983. This was a report that was prepared by Atmospheric Industries Ltd. and Buro Happold and presented to the Hajj Research Centre highlighting the necessity of providing a shaded walkway for the pilgrims. The authors of the report have noticed that as the buses were becoming the preferred alternative to walking, this has put a constraint on the pilgrims to adhere to a fixed time and route. The result that they found out is that on the return journey from Arafat to Muzdalifah (The *Nafrah*) the percentage of walkers rose by 24% and on the last part from Muzdalifah to Mina by 36%, compared to the numbers who used the bus on the departure journey. This was due to the discomfort the pilgrims felt because of traffic congestion that forced many of them to remain in their bus during the hotter part of the day.

These and many other researches point towards the clear advantages of facilitating the pedestrian movement during the Hajj. It is therefore imperative that a major

effort of the organizers should be spent to encourage solutions that will enhance the experience for those who opt to perform the Hajj on foot. This would be a Hajj on foot not only without trouble, but also in the process one that will bring about an uplifting experience.

In the following chapter I will elaborate on the significance of pedestrian movement in the Hajj along with a brief overview of recent developments in pedestrian studies and simulation.

Figure 2.6 The mass movement of pilgrims on the 9th day of the month is witness to the quintessential nature of walking in the Hajj.

CHAPTER 3

PEDESTRIAN SYSTEMS IN THE HAJJ

3. PEDESTRIAN SYSTEMS IN THE HAJJ

When one considers the earliest systems of distance and length measurement which were based on the human dimensions, especially the foot, it will be apparent that walking is actually the most vital mode of transportation. From the earliest times, cities were organized in a form where all aspects of survival were within a convenient walking distance. However, because it does not employ vehicles or other high tech modes of equipment, walking is not usually considered a transportation mode (Fruin, 1992).

According to John Fruin, one of the world's leading experts on pedestrian movement and the author of "Pedestrian Planning and Design", one of the most referred book in the field of pedestrian movement, "*with the exception of cycling, walking is the only means of human movement by which we can dramatically experience the sensory gradients of sight, sound, and smell that define a place*" (Fruin, 1992). This somehow gives an indication why walking is given much reverence as part of the rituals of the Hajj, the act of marching in fact heightens these "sensory gradients of sight, sound, and smell that define a place" such as the Holy Precinct in the vicinity of Makkah. This is crucial to know when one thinks of the spiritual dimension of the rituals of the Hajj.

Even back in the 1970s, when the car was the dominant and nearly the only dependable mode of transportation, researchers such as John Fruin called for the consideration of pedestrianism as a mode of transport. He lists several advantages for walking when considered as a transportation mode. These are:

- predictable travel times;
- continuous availability;
- ubiquitous and easily maintainable routes;
- reliable and free,
- non-polluting,
- non-energy-consuming service
- healthy and relaxing exercise

He goes on to explain how the pedestrian mode is gaining recognition as a basic building block in urban system design, and how attempts are being made to improve the walking experience, to make it safer, convenient, and attractive (Fruin, 1992).

During my research on the Hajj, I wanted to investigate the importance of walking in the Hajj, and to try to find out if it was just a kind of luxury or option. Throughout the years, while growing up between the cities of Jeddah and Makkah, I have noticed that in almost all discussions that took place about the Hajj amongst my relatives and friends who used to work during the Hajj season, the talk on vehicles, cars, and buses was the most dominant. Questions like; how soon can they be made available? How many of them can be secured? What capacity of people can they handle? What budget could they be secured for? Who will be driving them? All such questions seemed to be in their point of view the most crucial for the logistics and services to be provided for the visiting pilgrims. However, in my mind, I always believed that vehicles were an alien presence in the Holy Precincts. To see the pilgrims packed inside or on top of these buses seemed in a way disrespectful to the values and principles of the Hajj. I realized that many architects, designers, and in fact just many simple human beings shared the same notion. It became evident during my interview with Dr. Bodo Rasch in 2010, where he describes this notion with absolute clarity and assurance:

> *"To walk the Hajj – if you do it – it is so absolutely evident that that's the way it has to be done. If you walk for two hours from Arafat to Muzdalifah, and if you sit in a car for seventeen hours for the same distance, it becomes so obvious that this is supposed to be a pedestrian experience". (Sijiny, 2010)*

It struck me how this clarity and simplicity was highlighted by someone who is a the forefront of high-tech design and technology. As mentioned in the previous chapter, most of the previous solutions have focused on vehicular circulation and almost entirely ignored pedestrians. However, it is evident that all future solutions should indeed give priority to pedestrians. The reason for this is evident when we revisit the Hajj's simplest definition, which is the "*march of hundreds of thousands of pilgrims*" (Sijiny, 2010). This simple act of marching and walking along a path that many prophets, sages and blessed men and women have walked along, constitutes in itself the primordial nature of any pilgrimage. The walking itself becomes part of the sacred gesture and the ritual. To enact the basic human primitive activity. To replace

this activity with cars and vehicles in a way not only contradicts this primordial nature, but also deprives the pilgrim from this connection with a blessed path.

3.1. Recent developments in pedestrian study & simulation

We have seen from the previous chapter that the earliest studies on the Hajj were carried out by the Hajj research centre, and crowd and pedestrian studies and observation constituted the majority of their scientific research and observations. Their team was one of the first to use state of the art technology, such as time-lapse photography, to record and count the number of pilgrims passing in or through the major location of the Hajj rituals, especially the bottle-neck areas. Many of these statistics were utilized for future planning and engineering purposes. For example, a 1982 research by the Hajj research Centre entitled “Pedestrian Footways in the Hajj Areas” was used to establish the total width requirements of the walkways between the various sites of the Hajj (AlGadhi, 1996).

Most of the early studies however where rather qualitative in nature and mostly focused on historic, administration, demographical, logistical and planning aspects. Even the early studies on crowd behavior focused primarily on the socio-psychological aspects. However, in his 1996 review on crowd behavior and movement, AlGadhi mentions that one of the first analytical studies to quantitatively evaluate pedestrian traffic flow, was the one carried out by Eberhard Haug, Bernd Gawenat and Bodo Rasch in 1987, which they applied to study the existing Tawaf area inside the Holy Mosque (AlGadhi, 1996).

However, with the growing number of accidents taking place as a result of the astronomical rise in the numbers of pilgrims and the pressure that puts on the whole flow of the Hajj movements, especially in some of the well-known and re-occurring bottle necks, the Hajj authorities have stepped up their efforts to hire and consult the world’s leading expertise in the field of pedestrian studies and crowd dynamics.

After a series of accidents in the 1990s, the authorities enlisted the expertise of one of the world's leading expert on crowd dynamics, Keith Still, a 52-year-old mathematician from Aberdeen. His research and scientific analysis has been of

great influence in the redesigning of sections of the Hajj (Graham-Rowe, 2011). He advised the authorities on some aspects of the design of the new Jamarat bridge, where the symbolic pelting of the devil takes place. Two years earlier, the pillars had already - with the approval of religious scholars - been enclosed in elliptical concrete walls, as advised by Keith Still in order to increase the area available for stoning (Rauner, 2007). For this he had used a special software that he developed, called the Myriad II, to model how different sizes and configurations of columns and stoning pillars. This would make it easier for the pilgrims to hit them first time and avoid hitting other pilgrims (Graham-Rowe, 2011). Such customized software that was not available until recently is just one of the recent developments that will certainly help Hajj planners and organizers.

In another study, a team led by Eberhard Haug and Rainald Löhner based in Stuttgart, conducted a series of calculations with the pedestrian simulation tool PEDFLOW to study the influence of columns on the pedestrian flow of pilgrims within the confines of the holy Mosque and it's new expansion of the Mataf area. Surprisingly, there was virtually no significant influence on the pedestrian motion passing by the columns. (Löhner, 2014)

Another leading expert, Dirk Helbing of the ETH Zurich has been involved in several projects related to the simulation and quantitative analysis of pedestrian movement and disaster patterns during the Hajj. He was called upon, following the fatal crushing disaster that happened at the Jamarat bridge with a death toll of 364 deaths in 2006. Helbing is a pioneer in the field of panic studies. He has written frequently on the topic of pedestrian flow and cases of stampedes in football. He put together a team of German experts for the Saudi authorities, comprised of traffic planners from Aachen, logistics experts from Dresden and his Post-Graduate students at the University. For Helbing, Mecca is "the biggest pedestrian problem in the world." (Rauner, 2007)

One of the most significant and controversial ideas introduced to the Hajj flow was the one-way traffic. Already the concept of one-way traffic flow for bottle neck places was discussed and proposed from as early as the first few years of the Hajj research Centre. However, it had to wait until 2006 in order to be revived again by Dirk Serwill and Reiner Vollmer, two traffic planners who developed the details of this strategy, along with the Aachen-based engineering company IVV (Rauner, 2007).

All these studies focus on the pedestrian traffic flow, with a special focus on the most problematic bottle-necks, namely the *Tawaf* in the Holy Mosque, and the stone pelting at the Jamarat. My argument is that they are all looked at from a purely physical and mechanical point of view, which without doubt is very important. However, as explained previously, the Hajj is a connected system, and hence other aspects related to the facilities, layout, and design of these walkways are as important. When one looks at the condition of the walkways that are available for the pilgrims to use during the Hajj, one cannot help but wonder at the total lack of urban and landscape consideration that would not only enhance the experience of walking, but also add to the safety and comfort of the pilgrims. For example, many of the accidents of crushing or pile-ups take place when some pilgrims reach a certain point in a total condition of exhaustion. This is due to many factors, some of which are straight forward, for example, 90% of the walkways are not shaded, and when the Hajj falls especially in the summer season that becomes a significant factor in how soon the pilgrim becomes exhausted or dehydrated. Treating the Hajj sites and locations as a landscape and urban design project would certainly add a more human dimension to the austere infra-structural facilities that are being constructed.

3.2. Current conditions of facilities for pedestrian use

It is quite obvious that during the planning stages for the sites of the Hajj, the priority was given to vehicular traffic and the movement of pilgrims via buses and cars. Hence the Holy Precinct's (*Masha'er*) landscape is dominated by vast network of roads, flyovers, tunnels, parking lots and concrete retaining barriers. Even in locations such as Arafat where there is no urgent requirement to have vehicular access to every single tent camp, the pedestrian ways network of its streets is rectilinear and suitable for vehicles but not for pedestrians, who look for the shortest route between any two points - in the most popular case the route between the congregation Mosque of *Namira* and the small hillock that people amass on the day of the *Wukuf*, called *Jabal Al-Rahmah* (Rasch, 1980). This is quite surprising given that the pedestrian movement today still represents a major component of the pilgrim traffic.

In the build-up to the Nafrah on the 9th day of the month, before sundown a great number of people gather at the Western border of the Arafat valley. Without any proper guidance (either way-finding or direct instructions) pedestrians have to force their way through the bumper-to-bumper traffic – which obviously is a very dangerous situation. Even though recently there have been some improvements made to the available walkways in terms of finishing material and provision, it has been observed that the pilgrims do not go out of their way, in order to find the pedestrian way provided, but instead they head straight towards their goal. For a great number of the pilgrims who do the Nafra on foot, this involves some precarious obstacles. (Rasch, 1980) This is a classic case of making available the required facilities but failing in the efficiency to lead the pilgrims to use it. During the Hajj I performed in 2005 along with some relatives including women, we faced the challenge of having to slide down the concrete slopes of the valley's storm water embankment, crossing sometimes very uneven ground of the Wadi's concrete culver and then back up the concrete slope on the other side.

Figure 3.1 As shown in the photo, the angle of the concrete culver is quite steep, and extremely tricky to step upon especially for the elderly. But without any other options, many pilgrims find this to be the only way to perform their Hajj on foot and avoid walking on paths that have been occupied by fuming buses.

As mentioned before, up until about three years ago, the walkways available for the pilgrims were in a condition not really appropriate for pedestrians, in fact since the

designers of this infra-structure were civil and traffic engineers, these walkways were modelled on the highway: asphalted surfaces, crash barriers and flood lights (Rasch, 2010).

Another example that many pilgrims have experienced, is when they arrive in Muzdalifah, they find that it is has been converted into a huge asphalted parking lot with high mast halogen lighting, typically used on highways for vehicles. In fact parking areas in Muzdalifah cover about 80% of the valley once again.

However, one of the worst and perhaps most difficult part of the pedestrian walkway is the road leading from Muna to Makkah. As can be seen in figure 2.1, there lies a towering mountain range between Muna and Makkah, and hence there is absolutely no visual contact with the destination. The traditional seven km route is along Al-Abtah Street winds around the mountains and is a journey of approximately one hour and twenty minutes. However, the route most used nowadays is the mountain tunnel route which has been constructed in the 1970's as part of the massive infra-structural overhaul that the Hajj sites have undergone. The Tunnel Route is the shortest and most popular for pedestrians, taking approximately 40 minutes. However, as expected some considerable congestion occurs at the north end of the tunnel with pilgrims resting in the mouth of the tunnel after having walked from Muna with very little shade. It is worsened by the conditions of the roads leading to and from the tunnels. Here vehicles and pedestrian have to share the road which nearer the Holy Mosque ceases even to have sidewalks. People must compete with vehicles for space in an atmosphere polluted by noise and exhaust fumes. Obviously this is a highly precarious situation and the cause of many accidents.

3.3. Obstacles and challenges facing the pedestrian pilgrims

The challenges and problems facing the Hajj can be divided into two categories; problems with accommodation and problems with the movement. The problems with the movement are in turn divided into vehicular and pedestrian. The focus of this research is to explore solutions that would help the pedestrian movement of the pilgrim, not inside the city of Makkah, but at the Holy Precinct (called the Masha'er).

On the onset, one of the biggest challenges facing pedestrian movement of the pilgrim is the lack of attention it receives when compared to other so-called “priorities”. It has a low rank in the pecking order, so to speak. For example, in a PhD thesis representative of recent research by the Hajj Research Centre (name changed to CTHMIHR) entitled *A system of mobile service units for the large-scale event industry: an implementation for the Hajj, the pilgrimage to Makkah, Saudi Arabia*, the author fails to mention either shade or pedestrian walkways as part of the services needed by the pilgrims. The list he has provided covers only the services that are absolutely crucial, such as food, drink, healthcare, information, security, safety, transportation, accommodation, emergency, administration, communication, toilets and ablution (Othman, 2003). The fact that neither shade nor pedestrian walkways are mentioned goes to show to what degree these two essential needs are neglected in the current research priorities of the Hajj Research centre.

The following is a list of obstacles and challenges facing the pilgrims who perform their Hajj duties solely on foot:

1. Lack of separation between vehicles and pedestrians
2. Inadequancy of walkways specifically catering to pedestrians
3. Absence of Shade
4. Limited information and lack of appropriate signage

Figure 3.2 Prior to the Nafrah, which takes place after dusk, many pilgrims seek to move nearer to the edge of the Arafat Valley, in order to moderate or break down their efforts in preparation for the long march of the Nafrah. However, many pilgrims find that buses have already taken their positions in the starting line-up, blocking their access to reach the pedestrian walkway – paved in red clay color- which appears in the top left corner of the image.

3.3.1. Lack of separation between vehicles and pedestrians

As explained previously, despite the fact that the pedestrian movement still constitutes the largest part of all Hajj circulation, there is an apparent priority currently given to the vehicular traffic. Every year during the *Nafrah* one is always observing the constant conflict between pedestrians and vehicles and wonders why the provision of a purely pedestrian zone isn't given full priority (Rasch, 1980). In my interview with Dr. Bodo Rasch for the Dutch Architecture Journal "Volume", where I asked him about the founding principles of the Hajj Research Centre, he responded with one very important principal, that *"…without separating cars and people, every other effort is for nothing"* (Sijiny, 2010).

This is the elusive goal that many planners and engineers have been calling for. Clearly it is naïve to think that a total separation is ever possible. However, the main premise is to create a network of paths and roads that cater exclusively to their purpose. Especially when it comes to pedestrian walkways, where in almost all of the paths that are officially designated as pure pedestrian, there perpetually takes place an intrusion by buses and large cars into these walkways due to lack of

information, pure ignorance, or out of emergency situations. While it is difficult to guarantee that pedestrians would not avail themselves of the roads and facilities meant for cars and vehicles (there is no stopping a group of disgruntled pilgrims to get off their bus that is stuck in traffic and continue the rest of the journey on foot), the opposite is much more attainable if it becomes priority and policy. If this policy is adopted, then the vehicle traffic should therefore only have a complementary and supporting function. However, according to Dr. Bodo Rasch, *"What you have now in Makkah are people using the tunnels and flyovers, which were meant for cars"* (Sijiny, 2010).

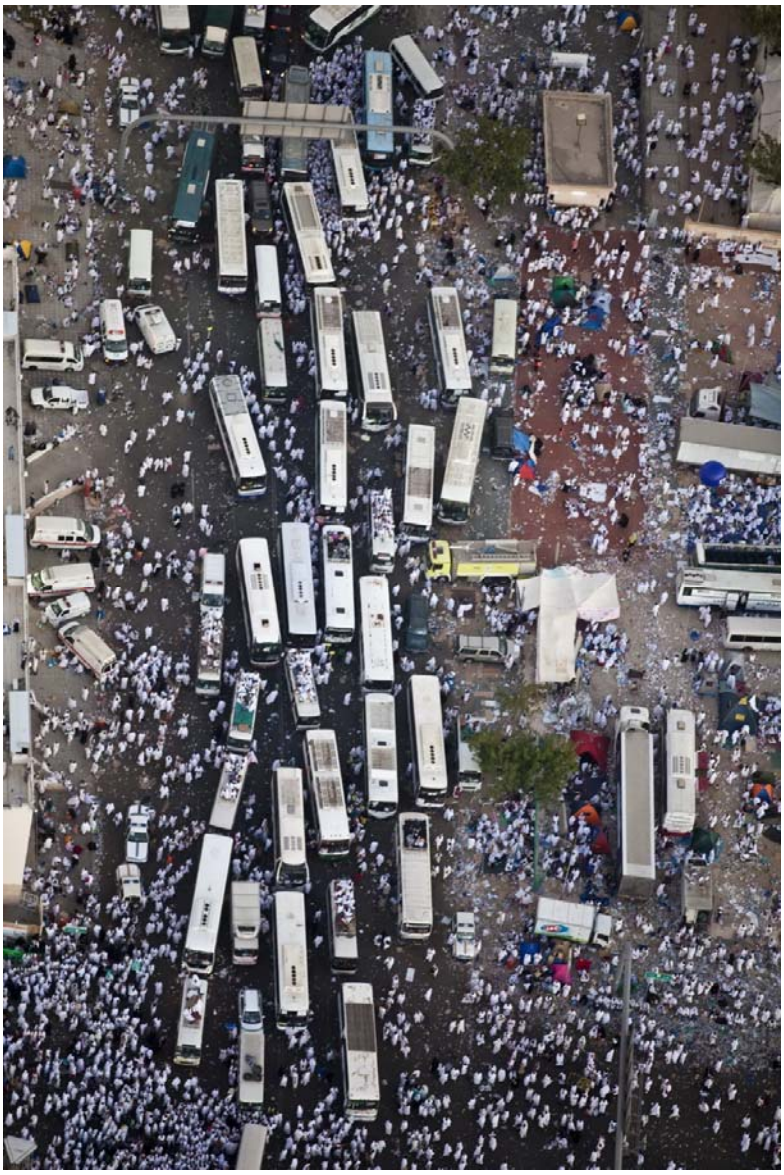

Figure 3.3 At several points along the pedestrian path it seems that the red pavement, especially designated for pedestrians, simply disappears as clear in the top right corner of this photo. It is no wonder that the mixing of pedestrains and vehicles is inevitable.

By prioritizing motorcars and their accompanying infrastructure the pilgrims have to endure perpetual congestion in the Hajj. This apparent priority currently given to the vehicular traffic stems from a misconception. The strategy that any solution for the Hajj has to be mechanical and high tech is obviously causing more harm than good. This bias towards the vehicular traffic is evident when one considers the example of the *Nafrah* where more than 75 % of the entire circulation space is claimed for cars, although about 60 % of the pilgrims are on foot (Rasch, 1980).

3.3.2. Deficiency of walkways catering specifically to pedestrians

As mentioned earlier, when one looks at the condition of the walkways that are available for the pilgrims to use during the Hajj, one cannot help but wonder at the total lack of urban and landscape consideration that would not only enhance the experience of walking, but also add to the safety and comfort of the pilgrims. For example, many of the accidents of crushing or pile-ups take place when some pilgrims reach a certain point in a total condition of exhaustion.

Figure 3.4 Even though there are six major routes for exclusive use of pedestrians, it remains a challenge to reach for two main reasons. First, simply because the pilgrims do not know they exist, or because as can be seen in the image, the way leading to it is fraught with obstacle and vehicular infrastructure that it very hard for pilgrims to traverse.

This is due to many factors, some of which are straight forward, for example, 90% of the walkways are not shaded, and when the Hajj falls especially in the summer season that becomes a significant factor in how soon the pilgrim becomes exhausted or dehydrated.

Another straight forward factor is the provision of resting facilities, the number of benches along most of the walkways constitutes a trickle of what needs to be available, and many of them are made of material that is frankly only suitable for the industrial purposes; i.e. precast concrete. One other important factor is the material that these walkways are made. Until about only as recent as three years ago, almost all the walkways were finished in asphalt, obviously a material only suitable for cars. Recently however, the municipality has started to cover the walkways in concrete interlock tiles, which although better than asphalt, is still not the ideal material for pedestrians. Especially if you take into consideration that many of the pilgrim use very rudimentary foot wear (budget thongs made of plastic), most of which gets lost during their march.

3.3.3. Limited information and appropriate way-finding signage

Given the scale of the problems and incidents that occur during the Hajj season, it is little wonder that proper way-finding signage is given any attention. Even on the purely pedestrian walkways, the only signs that could be seen are the type that was developed in the 1970s for highway traffic and vehicular transportation. Some of the new signposts, e.g. at the edge of Arafat, demarcating the legal boundaries of the valley, are in the style of the Motorway uni-pole advertising which were designed to be observed while seated in a car and traveling at 100 m/hour and are not suited for pilgrims on foot. What little information systems available along the stream of pilgrims are rudimentary to say the least. It is worthy to note the observation of Bodo Rasch, that "*the apparent lack of general and fundamental information makes the pilgrims feel insecure and suspicious, so that when they do find a sign they do not follow it*" (Rasch, 1980).

Figure 3.5 The dire condition and lack of clear information which this lonely way-finding map of Arafat shows adds to the confusion and incompetence of some of the facilities that have been installed.

It is quite obvious that the use of an information system and pictograms developed for events that take place in a western context is not the best course of action for use in the Hajj. The most appropriate approach is to develop a way-finding system that is unique to the Hajj and caters to its specific conditions and needs.

In one of the classic cases where information and signage play an important and crucial role in facilitating the smooth flow of the pedestrian pilgrims is during the *Nafrah* when the pilgrims start to arrive in Muzdalifah, *"where all of a sudden the pedestrian trail ends and there is this massive flow of people that doesn't know where to go. Then it starts slowing down and the flow backs up; a very dangerous situation arises" (Sijiny, 2010).*

Here is a case where you have a "Massive flow of people" reaching a stopping point that has been clearly marked, but inside this wide area (the stopping point) they do not know where to go, and inevitably resulting in pile-ups. A simple analysis of this

example shows that certain basic information has to be conveyed to this stream of pilgrims in order to ensure a safe arrival. Their needs are summarized below:

a. Direction: the pilgrim on foot needs to be given direction, and to be told where to go.
b. Delineation: the pilgrim has to be informed of a designated and demarcated space or zone to be accommodated within.
c. Purpose: the pilgrim wishes to understand where they are and why they are there.

This shortage of information continues at Muzdalifah. During the night of the 9th day of the Month, the pedestrians disperse all over Muzdalifah, to wait for the dawn prayers before they start to move towards Muna. In the morning they face a lot of difficulty to find the way to Muna and only the narrowing mountain slopes help to guide the stream of pilgrims. This is another example where information and signage is in want.

3.3.4. Absence of Shade

The gist of what many have been calling for is that shaded walkways will directly lead to encouraging pilgrims to make the Hajj on foot and increase the number of pedestrians. Shading should not only be looked at as an optional improvement or extravagance, on the contrary, it is in fact as important as the provision of water and food. Whereas the tent itself does provide the necessary shade when stationery, it is the shade during the outdoor activities that is crucial. In many cases it could be the difference between life and death, especially as the Hajj coincides with the summer season and the cases for heat stroke, dehydration, or exhaustion increase significantly.

Figure 3.6 Even though in recent years there has been some progress in allocating walkways exclusive for pedestrians, these lack many of the basic amenities. The most conspicuously absent amenity is shade. These walkways are used throughout the hotter part of the day, and it could be noticed how many makeshift shading canopies are erected on the side.

For example, many of the accidents of crushing or pile-ups take place when some pilgrims reach their designated location in a total state of exhaustion. As their exhaustion weakens any ability to resist dizziness or falling on the ground, or pushing for survival when pressure is upon them causing asphyxiation. In fact it could be argued that their exhaustion could have been the main reason causing the initial pile-up. In this regard, it is quite surprising to know that nearly 90% of the walkways are not shaded. "*The provision of a fully shaded walkway and serviced rest areas between the major sites of the Hajj would upgrade the whole value and experience of walking, strengthening the original concept of the Hajj movement as a meeting and cultural exchange event for Muslims from all parts of the world*" (Happold, 1983). The aim of shading the walkway would be to increase the numbers of pilgrims walking, which will in turn reduce the numbers of vehicles that cause congestion both to themselves and pedestrians. Not only that, but providing shade in the form of a shade structure at high level would relieve the pilgrims of the hassle of carrying an umbrella and will naturally encourage air movement beneath it (Happold, 1983).

For walking to become the preferred option during the Hajj, it is imperative that the walkways are attractive for the pilgrim to use. With the Hajj coming during the extremely hot summer months; it is quite obvious that if the pilgrims feel that performing their Hajj on foot will be fraught with too much exhaustion and risk, they will naturally opt for the bus or car transport. We know from experience that there are many factors that contribute to lowering the percentage of pilgrims moving on foot, such as the long distances, unfamiliarity of the terrain, immediacy of vehicle transport. However, an increasingly dominant factor as the Hajj moves into the hottest part of the year is the lack of shade (Happold, 1983).

The last time the Hajj fell during the hot summer months was roughly thirty three years ago. It was noted in a report by Buro Happold et. al studying the feasibility of erecting shading canopies along the pedestrian walkways of the Hajj that the absence of change was causing considerable changes in the sequence and logistics of the Hajj movement. They have noticed that in relation to the pilgrim's movement towards Arafat "*the figures indicate that with the Hajj taking place in summer the majority carry out this more during night or early morning. The traditional time for starting is after Fajr (dawn prayer) indicating that the intensity of the sun is causing them to change*" (Happold, 1983). With more pilgrims now encouraged to travel on foot from their tent camps in Muna towards Arafat on the 9th day of the month, it is recommended that shading should be provided along the whole of this route.

In addition, not only will the shade contribute to a comfortable and convenient movement for the pilgrims on foot, but because the shaded route will be clearly seen as such from a distance, from the start in Mina, it would also become a much needed orientation landmark encouraging pilgrims to walk, and giving them much needed direction and visual cues to follow (Happold, 1983).

One more useful function for shading structures suggested by Buro Happold et.al is at the tent camps in Arafat. They have observed that up to 95% of movement within Arafat is on foot, however the existing road network is in conflict with the radial movement and causes considerable congestion. Hence they have suggested that the shade structure could be used to separate vehicles from pedestrians in the area (Happold, 1983).

For example, in 1982 the Hajj fell during the month of September (which is considered very much part of the summer in Arabia) only 12% chose to walk to Arafat on the morning of the 9th day in spite of a direct, well-surfaced walkway (Happold, 1983).

The next chapter will review and present several projects that used innovative material and technology to enhance the experience of the pilgrim during the Hajj, including examples of shading structures and pedestrian walkways.

CHAPTER 4

LIGHTWEIGHT STRUCTURES AS SOLUTIONS FOR THE HAJJ

4. LIGHTWEIGHT STRUCTURES AS SOLUTIONS FOR THE HAJJ

In this chapter, I would like to argue that lightweight structures and interventions are the optimum solutions to help mitigate the problems that persist in the Hajj and to provide solutions that would improve the pilgrims in the Hajj. This chapter will discuss aspects of lightweight structures and will argue for the suitability of lightweight structures as a strategy for the Hajj. In addition, to highlight how these attributes are relevant, the latter part of the chapter will present some case studies from many of the efforts and projects that have tried to tackle the problems facing the Hajj using lightweight structures. I believe that implementation of shaded structures would solve many of the challenges to pedestrianisation of the Hajj outlined in previous chapters.

4.1 Attributes of Lightweight Structures for shade (in the Hajj)

The case for lightweight structures as a design philosophy and as a building technique has long been championed by many renowned architects and engineers. The inherent advantages and unique attributes have been proven and put to the test on many significant occasions and for truly landmark and breakthrough projects. Projects such as the Munich Olympic stadium roof by Frei Otto or the Hajj Terminal at Jeddah's King Abdulaziz Airport by the firm SOM have certainly been defining moments in the history of buildings and pivotal in the development of state of the art structures.

I would like to focus on some of the attributes of Lightweight Structures that relate directly to the conditions and problems of the Hajj that have been discussed in the previous chapters. These are attributes that are not only appropriate from a functional point of view but also from a psychological one.

4.1.1 Minimally invasive in their nature

It is evident that any interventions that take place in a sacred location like that of Makkah and its surrounding Holy Precincts should be minimally invasive, in order to preserve this landscape that has been witnessed by millions of pilgrims throughout

the past centuries, foremost by the Prophet Muhammad himself. It is difficult to argue against what is seen as common sense; the importance of preserving sanctity of a sacred location and by extension its natural geography is imperative. Consequently, a minimally invasive approach is merited, and lightweight structures are the type of structures that are least damaging to any given physical environment. As the architects and researchers of the Hajj Research Centre thought it would be the most sensible approach to dealing with problems of the Hajj. Their main guiding principle was "*to use rational methods to ease the suffering of the people who are choked between cars and dust and structures"* (Sijiny, 2010). Their mantra was *"that the most minimally invasive sheltering would be the right approach. With a minimum amount of structural impact, we would have achieved the maximum effect*" (Sijiny, 2010).

4.1.2 Suitability for temporary events

The very fact that almost all pilgrims spend most of their time during the six days of the Hajj inside tents is a tribute to the eternal Bedouin tent and its ephemeral quality. This flexibility and portability is also the main reasons why tents have been deployed throughout centuries for any temporary event. From war camps to Circus tents, they have been one of the most perennial man made items since the existence of man himself. It is therefore no surprise that it has been used in the Hajj ever since the pilgrimage was ordained on the Muslim faithful. Therefore, due to the temporal nature of the Hajj, almost all projects and proposals within the vicinity of the Holy Precincts have considered the compatibility of lightweight and membrane structures either partially or wholly.

4.1.3 Efficient in material usage

The very definition of lightweight structures according to the thinking of Frei Otto, is the minimization and optimization of energy and material resources used on a project. Naturally, if you reduce the mass of a building it would be easier to set it up. Therefore, taking into account the impermanence of the Hajj as an event, lightweight structures meet the two core demands of shelter and shade with the least allocation of material and cost and with the minimum of impact.

Of course shelter and shading structures could be constructed of many other kinds of materials that are economic and available, such as concrete or steel, but for a maximum of just two weeks of use, it is obvious that a solution that uses the minimum mass would be the most efficient way of allocating material.

4.1.4 Ideal as landmarks

Moreover, the unique sinuous forms that are found in lightweight structures provide a strong sense of visual communication, and by extension a crucial way-finding demarcation and sense of direction for the masses who are marching in the landscape. In such a mass event where millions of people gather in such a wide space in a barren terrain, it becomes crucial to provide the appropriate way-finding signage and landmarks. Without necessarily creating specific large scale signage (that would inevitably have to use so many languages), lightweight structures with their organic forms will automatically act as landmarks in the rocky landscape of the Holy Precincts and inadvertently tend to guide pilgrims towards or along them.

Even in the cases when shade is not crucial, such as during the Nafrah which takes place almost entirely at night, there is enough demand for pilgrims to find the walkway they need to take in order to reach their destinations at Muzdalifah, and then further on at Muna valley. In other words, in such cases it is a visual requirement that needs to be fulfilled, and for example the shading canopies could be could be illuminated at a very low level to indicate the route used to direct the pilgrims and maintain the pedestrian flow (Happold, 1983).

4.1.5 Visually harmonious with the environment of the Hajj

In essence, lightweight structures in general and membranes in particular are the natural evolution of the Hajj's most conspicuous manmade object; the pilgrim's tent. These simple textile based canopies and human scaled shelters have been popping up for a very short period in these special valleys and have been true to the nature of the Hajj being a caravan end station in the pre-modern days. Images of the valleys filled with rows and rows of white tents have been ingrained in the pilgrim's memory since Hajj was ordained. To maintain this image has been an unannounced ideal for most planners and designers who have worked on solutions for the Hajj. Therefore, to their advantage, recent developments in membrane structures and

materials have been nothing but a boon to designers working on proposals for the Hajj. Compared to other contemporary materials such as steel as concrete, there is no doubt that membrane and textile structures are the ideal building method for any intervention implemented within the Masha'er precinct.

4.2 Brief History of Lightweight Structures projects related to the Hajj

To present the case for lightweight structures for the Hajj, four projects that have been presented or executed by the Hajj Research Centre for the Hajj will be reviewed. These are:

1. The proposed pedestrian bridge over the tent city of Muna, proposed as part of Frei Otto's competition entry in 1974.
2. Mountain Tents for Muna, developed during the early years of the Hajj Research Centre in 1980.
3. Foldable Mobile Structures for Pilgrims' Accommodation by Yousuf Hijazi in 1984.
4. Hajj Walkway Shading Structures by Atmospheric Industries and Buro Happold in 1983.

4.2.1 Pedestrian bridge proposed in Frei Otto's entry for the 1974 Competition:

The official name of the competition in 1974 was the International Architectural Competition for Accommodating Pilgrims in Muna. It was organized by the Ministry of Finance who felt it had to intervene in the planning process of the Hajj sites after sensing that too many proposals were being developed without any central coordination or overall vision. Four architecture practices and one engineering firm were invited to participate in the competition. The main theme as the title indicates was: "Accommodation for the increasing numbers of pilgrims in Muna". The Ministry realized that in order to improve the overall situation of the Hajj, the focus must be put on solving the two fundamental problems; the pilgrims' accommodation in Muna and the traffic movement of the Hajj. The biggest challenge here was that these two issues fell under the responsibility of two different ministries; the Ministry of Hajj handled the accommodation in Muna, and the Ministry of Communication (later renamed Transportation) was responsible for roads and traffic infra-structure (Rasch, 1980).

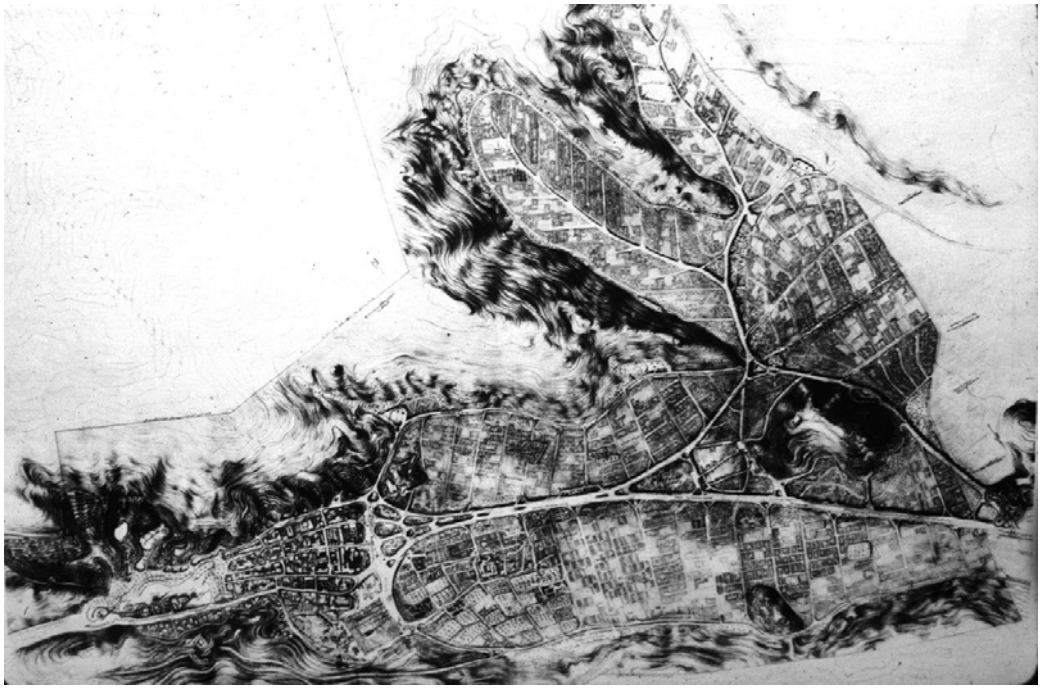

Figure 4.1 Frei Otto's Masterplan for Muna, 1974

The point worth mentioning in the entry by Frei Otto was that even though the theme of the competition referred only to the accommodation of the astronomically growing number of pilgrims in Muna, Frei Otto's team entirely committed on solving the traffic problem and developed a concept which attempts to deal with mass movement on the basis of traditional values. Another point that is very important to highlight is their conviction of the importance of the pedestrian component and that a purely pedestrian system is the most productive "mass transport means" for relatively short distances. In addition, they also demand a ban on private cars, especially in the narrow valley of Muna. In their Master plan they propose an exclusively pedestrian zone between Arafat and Makkah. Most significantly, is how this exclusively pedestrian way is elevated above the vehicular traffic in the form of a lightweight pedestrian bridge when it reaches the confined area of Muna. At that time, many conflicts with cars and buses occurred in the many streets in the narrow valley of Muna, and hence it was Frei Otto’s idea to leave the area underneath it free for roads and camps.

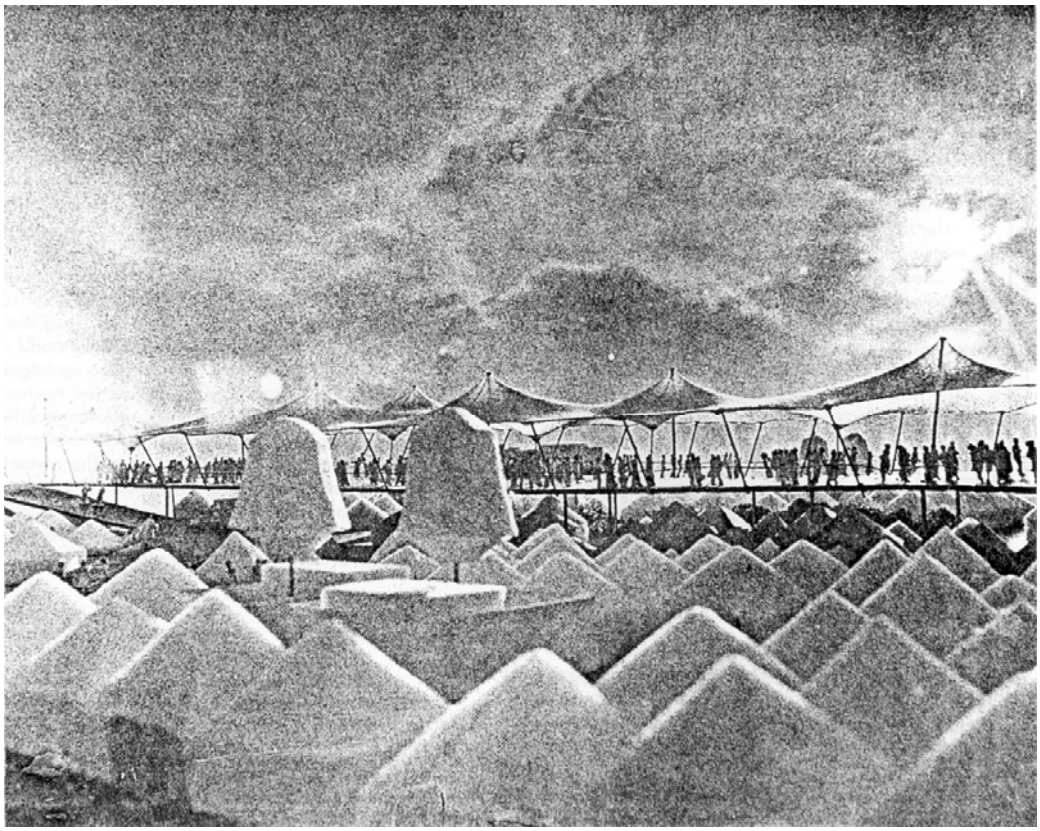

Figure 4.2 Model of pedestrian bridge with shading canopy proposed for the Hajj by Frei Otto,1974

Another aspect of this pedestrian bridge was flexibility to changing requirements, the idea was that it can be taken down, added to or altered. Another advantage was making available about 20 hectares underneath it for camp settlements (Rasch, 1980).

Naturally, being the founder of modern lightweight and membrane structures, he had the pedestrian bridge shaded with a membrane canopy to entice the pilgrims to use it. It was the hope of Frei Otto's team that through this "*arrangement walking the Hajj on Foot will again become the main means of transport and so attractive that the vehicular traffic will diminish without a need for compulsory restrictions and thus traffic problems may solve themselves*" (Rasch, 1980).

4.2.2 Hajj Research Centre Mountain Tents:

The first concept for the mountain tents was originally conceived as part of the projects that Bodo Rasch developed while working at the Hajj Research Centre in Jeddah during the late 1970s. They were one of the first architectural solutions to be adopted and implemented in the Hajj itself by the Hajj Research Centre in 1981. In this design solution it can be seen how a minimally invasive approach, one of the founding principles of the Hajj Research Centre, has been put to action. Conceived as a non-permanent structure, they can be erected at the time of the Hajj and stored away for the rest of the year, leaving almost no trace in the natural landscape.

The premise under which these tents were developed is that the only way to compensate the *main site deficit* of accommodation capacity in the valley of Muna would be by utilizing the mountain slopes more intensively. In addition, and based on what was proposed in the 1974 competition, the idea to introduce changes in the *internal organization of the tent* camps (i.e. multi-level beds) was seen as one of the most efficient solutions to increase the capacity of the pilgrim's accommodation without too much damage to the natural topography of the sites (Rasch, 1980). The germinating idea for this concept apparently stemmed from Frei Otto's experience in the military camps during World War II (Sijiny, 2015).

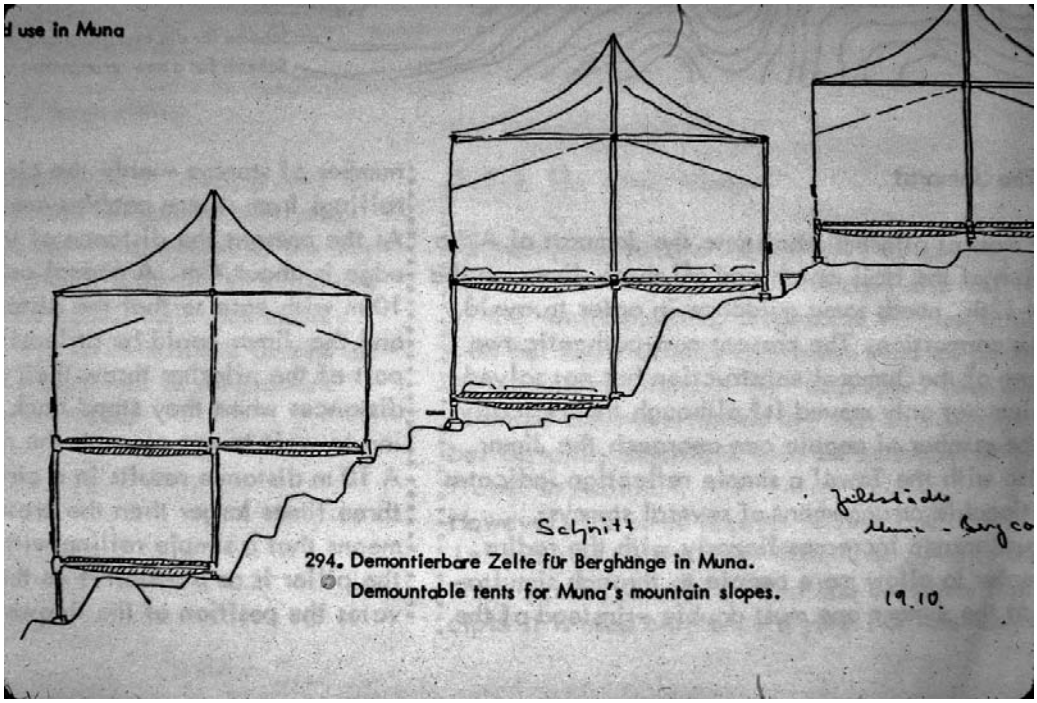

Figure 4.3 Early Sketches for the Mountain Tent in IL 29 Publication, by Bodo Rasch, 1980.

Later on when Bodo Rasch joined the HRC co-founded with the Meccan architect Sami Angawi, they started to develop this initial concept into a working model and prototype after consultation with Frei Otto. The architectural drawings and study models were carried out at Frei Otto's Atelier Warmbronn near Stuttgart. In the spring of 1981, Frei Otto and Bodo Rasch enlisted the help of local firms Kaufmann; manufacturers of steel tubes, and L. Stromeyer & Co.; the famous tent manufacturers to build the first prototypes. Later these five prototypes were erected on nearby hills in the vicinity of Berkheim, in the South of Germany.

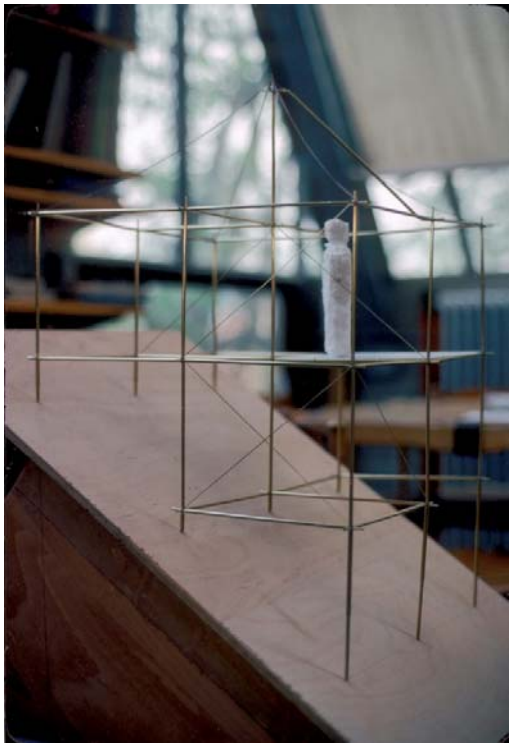

Figure 4.4 Model of the Mountain tent developed at Frei Otto's Atelier Warmbronn in 1981.

Figure 4.5 Study model of the Mountain tent, and in the background could be seen the German architect Frei Otto and the director of the Hajj Research Centre; Sami Angawi discussing the project at Frei Otto's Atelier Warmbronn in 1981

The square tent design follows the basic form of the traditional Hajj tent but due to its structure and lightweight qualities, is both more durable and flexible. In addition, this new construction method allows for the multi-level arrangement that is the concept of the design. The tent is based on a self-supporting framework of aluminium tubes standing on extendable legs, which holds wooden floor panels in the horizontal frame. This creates one full level and one half level, the latter being suitable for a kitchen or storage space. The walls and roof are of canvas with a fire-retardant impregnation, and form four sided pyramids and serve as interior ceilings.

Figure 4.6 Prototypes developed by the German firms Kaufmann and Stromeyer erected in the vicinity of Berkheim, South Germany

Figure 4.7 The tent prototypes installed on the mountain slopes in Muna during the Hajj of 1981.

4.2.3 Mobile Foldable Structures for Pilgrims Accommodation by Yousuf Hijazi:

As part of fulfilling his Master's Degree in Architecture, and while embedded at the Hajj research centre as a researcher, the Saudi architect Yousef Hijazi embarked on developing a very unique and innovative solution for the pilgrim's accommodation in the Hajj. His collapsible tent structure with a frame made out of aluminium was indeed visionary and well ahead of its time. Making use of recent advancement in aluminium structures and their relative light weight, he set out to work on a prototype with manufactures in Germany.

Funded by budget allocated by the HRC, four prototype units were designed, manufactured and tested in Stuttgart, before being shipped to Jeddah for further trials and testing near the premises of the HRC. These four would form the basic module cluster. Later that year, the structures were erected in the Masha'er for the Hajj season 1985. During which it accommodated 350 pilgrims who were hosted by the HRC and its staff.

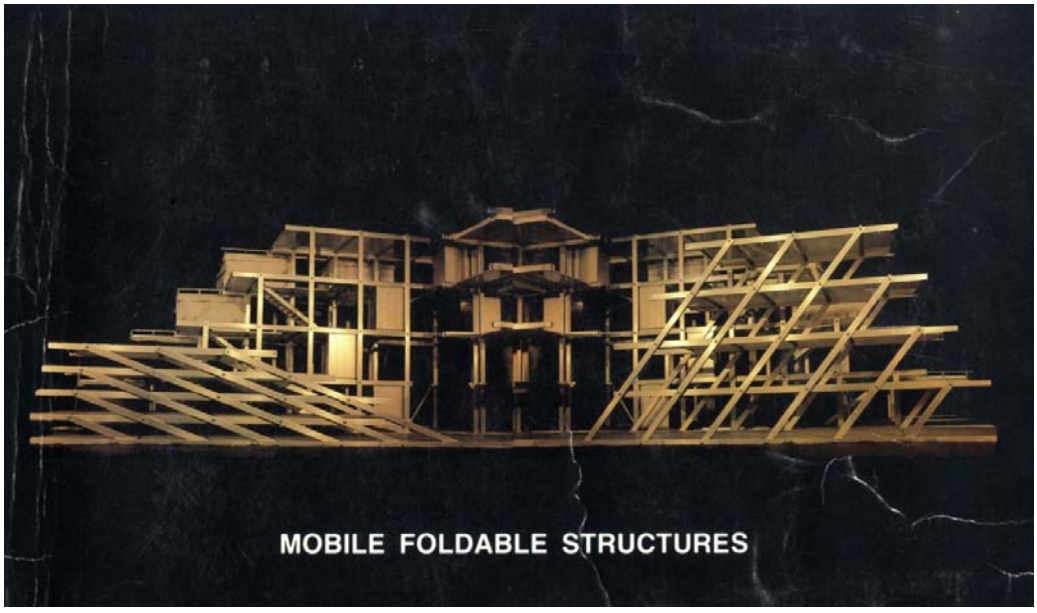

Figure 4.8 Cover page of the report prepared and published by the Saudi Architect Yousuf Hijazi to document and present the project. (1985)

Figure 4.9 The prototype during the erection process in Germany.

Figure 4.10 The prototype in Germany being fitted with the living module canvas.

There were two basic types of locations that the prototypes were tested. The biggest challenge was the mountain slopes of Muna, for which a concrete base platform was prepared and one prototype erected with its back leaning onto the rugged mountain terrain. The second type which the study focused on the most was on a flat tract of land that would be erected on the plain of the valley creating a module for the tent camps. Every two units would be erected so as to create a support by leaning on each other, thereby creating a pyramid form in the process.

It is noteworthy to mention that amongst the main criteria that the author and architects emphasizes is the utilization of the hill slopes for pilgrim shelter without compromising the preservation of the natural topography and environment of the ritual site of the Hajj. This stems from a desire to preserve the traditional Hajj atmosphere of tents and cluster units.

Figure 4.11 The foldable structure being erected near the Hajj Research Centre in Jeddah for testing and demonstration.

Figure 4.12 The prototype installed on top of a hill side podium to exemplify its versatility and adaptability to the mountain terrain.

Figure 4.13 The foldable structure fitted with the canvas to form all the accommodation chambers and other utilities. In the centre of the unit can be seen the vertical circulation cluster which can also be used for storage, 1985.

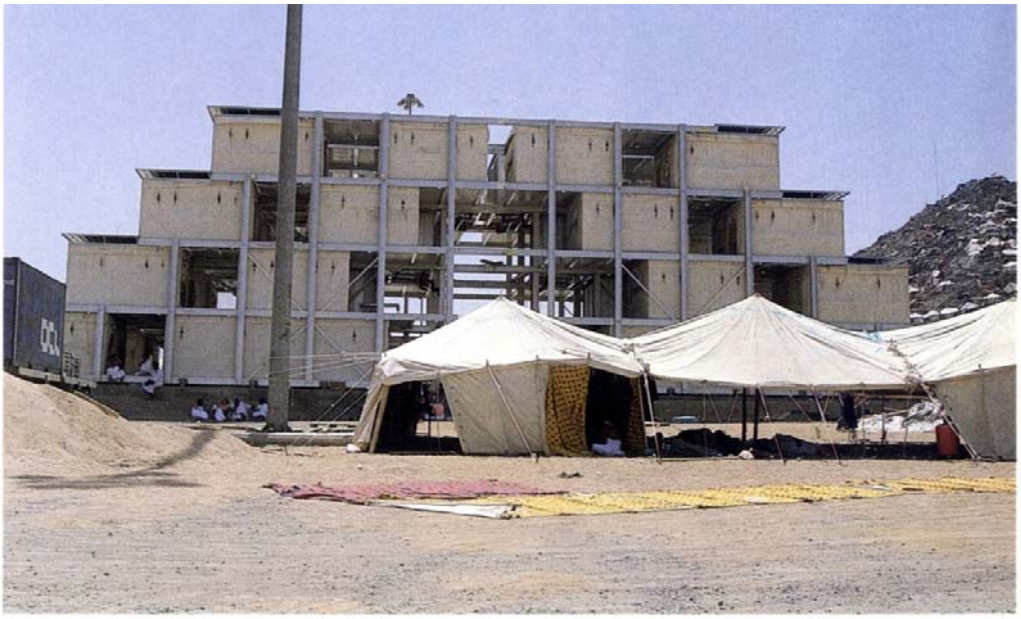

Figure 4.14 A cluster of 4 prototypes forming a typical support arrangement in a pyramid like formation erected in the valley of Muna, 1985.

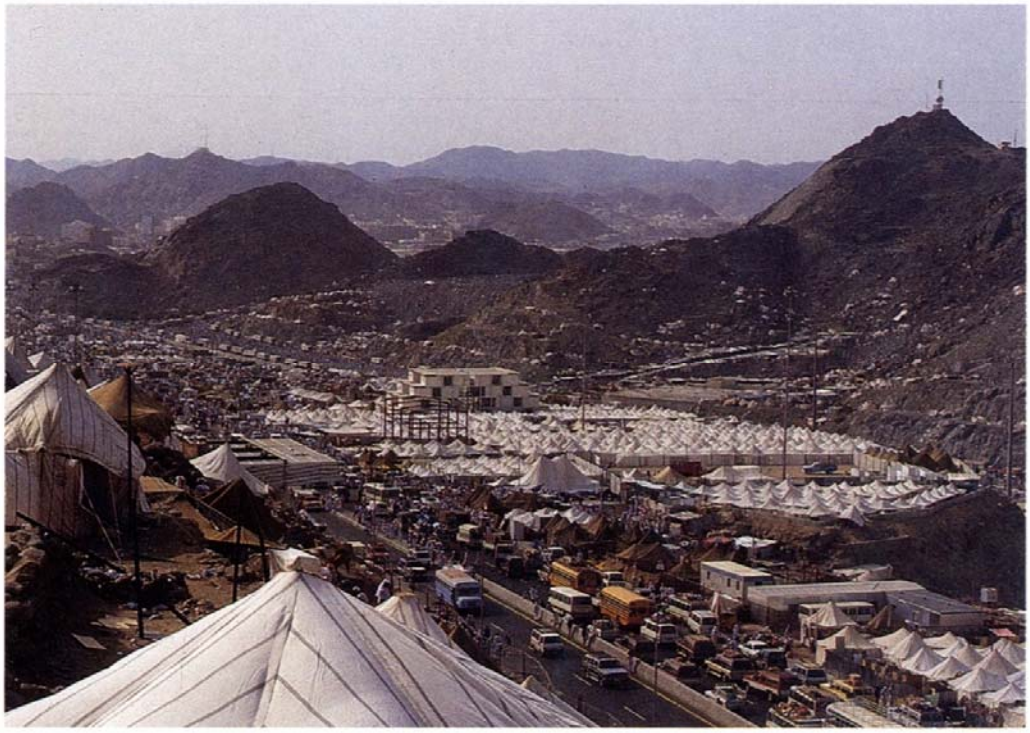

Figure 4.15 Aerial view of the tent camps in the valley of Muna, and in the centre can be seen the cluster of 4 prototypes of the foldable mobile structure which was able to accommodate 350 pilgrims in 1985.

4.2.4 Hajj Walkway Shade Structures by Atmospheric Industries Ltd. and Buro Happold:

In 1983 the Hajj Research Centre commissioned this study from Atmospheric Industries Ltd., led by the English artist Graham Stevens, in collaboration with Buro Happold. This followed a period of extensive study by the Hajj Research Centre of movement of both vehicles and pedestrians within the Holy Areas.

The study was restricted to shade structures themselves and only considered factors directly relevant to them. Although the report gives a commentary on the possible areas of installation, specific layout and site location were left to future phases once the project received approval.

The Atmospheric Industries report highlights the need for shade along the traditional routes of the Hajj to help increase the number of pilgrims walking. Especially when this study was commissioned, the Hajj was already approaching the extremely hot summer season, and hence such study would have been timely.

Figure 4.16 Cover page of the Hajj Walkway Shade Structures Report by Atmospheric Industries Ltd. and Buro Happold, 1983.

The architectural programme called for provision of ‘A shaded walkway from Muna to Arafat’, with a minimum width of 20 m, and rest areas at about 1 km intervals along this route. The Hajj Research Centre director, Dr. Sami Angawi had already been in discussion in previous years with Buro Happold and Atmospheric Industries to determine the design objectives of the shade structures. Together they developed the design brief with criteria specific to the Hajj. The design brief concluded that a 20 m wide walkway shade structure supported by vertical columns on a well spaced rectangular grid shall be adopted for design studies. Six solutions for walkway shading and one solution for area shading were put forward with comparative costs and construction times. These were:

1. Precast concrete louvres on a 16 x 12m column grid.
2. A space deck with aluminium cladding on an 19.5 x 12 m column grid.
3. A cable truss with aluminium louvres on a 40 x 14 m column grid.
4. A traditional canvas awning on steel framing with a 10 x 10 m column grid. The canvas would either have a short life or it could be installed annually.
5. A Teflon/glass canopy with diagonal supporting struts on a 10 m x 10 m column grid.
6. A Teflon/glass canopy with additional radial supporting struts on a l0 x 10 m column grid.
7. Teflon/glass modular canopy on a Hexagonal grid with 7 m side.

This design is only suitable for area shading.

The report was prepared by Atmospheric Industries with assistance from Buro Happold and City University. The bulk of the report present the importance of providing shade for the pilgrims during the Hajj and many statistics that have been gathered from the data collected by the Hajj Research Centre since it started. The latter section of the report contained the basic scaled architectural drawings and some typical section details for each of the six solutions. It was obvious that the decision was already taken to adopt one of the Teflon coated Glass fibre options not only due to its lightweight characteristics, but also because it represent state of the art technology within the construction industry. This is apparent because it is only the Teflon Glass fibre options that had scaled models built for it and presented in the report, as can be seen from the cover page in Figure 4.16. In addition the physical characteristics of various shading materials were presented.

There is an appendix report which describes wind tunnel testing carried out at Bath University and a computer analysis and static calculations by Buro Happold and City University on the Teflon/glass walkway structure. Future Tents (New York) helped with modelling and in discussions with U.S. fabricators. Cost advice was obtained from Symonds Tramor — Quantity Surveyors and Owens Corning Fibreglass Ltd, one of the leading glass manufacturing companies in the world, and who happened to be working at that time on the mega structures of the Hajj Terminal at King Abdulaziz Airport in Jeddah.

The next chapter describes in more detail aspects of this proposal and presents a reconstruction of the two options that use Teflon coated glass fibre membrane for the shading canopy.

CHAPTER 5

Hajj Walkway Shading Structure by Atmospheric Industries & Buro Happold, 1983

5. Hajj Walkway Shading Structure by Atmospheric Industries & Buro Happold, 1983

As explained in the previous section, the design No 5 had been previously presented to Sami Angawi, director of the Hajj research and accepted by him as the most suitable out of a range of fabric designs. As one would expect, providing shade for pilgrims was one of the top priorities of research conducted at the Hajj Research centre. In the build up to producing the final feasibility report, Atmospheric Industries along with Buro Happold developed the main design brief and objectives for the shading structure that would be installed along the pedestrian walkways between Muna and Arafat, passing by Muzdalifah. The following section describes the chosen projects, their design criteria and also the different site conditions that the design team had to deal with.

5.1 Description, criteria and site conditions

The key factors in the provision of shade for the Hajj were listed as follows:

1. Maximising shade area while minimising interference with the movement of pedestrians at ground level.
2. Coordinating the shade structures with the movements and requirements of the pilgrims based on the research by the HRC.
3. Coordinating the shade structures with other services of water, food, ablution, rest and prayer.
4. Introduction of shade structures shall have a positive effect on the behavioural patterns of the flow of pilgrims.
5. Shade structure itself should be economic, easily installed and maintained.
6. The visual and environmental impact be of the shade structures shall complement the spiritual and religious requirements of the pilgrims (Happold, 1983).

As a result of these design criteria, it was decided that any angled bracing or ties would not be acceptable. Hence, it was clear that the walkway shade structure shall have only vertical columns coming down to ground level on a well-spaced rectangular grid. Apparently, there was already provision for pedestrian walkways between Muna and Arafat, albeit in very poor condition, as elaborated by Bodo

Rasch in his thesis(Rasch, 1980). For this reason, the decision has been taken to adopt a shading structure that is 20m, although this width was deemed to be too narrow if more pilgrims decide to walk. The report suggests that the ideal width for the shade structures to be 24m. This would still be valid to this day, as the average width of the current pedestrian walkways is 27 metres. In addition, to maximise solar radiation reaching the ground beneath the structure for sanitary reasons, the height was determined to be 7.5m high. In addition, the performance of each type of material in terms of size of area shaded versus amount of heat radiated and light transmission was assessed, and in this regard it was found that the Teflon glass fabric gives the optimum shading performance.

Of course, the most challenging of the criteria was the visual and environmental impact. It is very difficult to quantify, hence it was essential to consider its influence for the long term development of the Holy Areas. As explained in the report; "*the visual impact affects whether a walk seems long or monotonous and the subjective response to the structure will affect the pilgrims' decision whether or not to walk*". (Happold, 1983) It was determined that the structures using architectural membrane would be the best to give an environmental impact appropriate to the Holy Areas. It is important to note that at that time such criteria were given priority. This could be gleaned from the fact that although the Teflon/glass solutions were more expensive than the precast concrete or metal decking designs, they were the recommended option simply because they were deemed to be the option that related the most with the traditional tents of the Hajj. In addition, as explained in chapter 4, their unique forms have the added value of being visually distinctive as a walkway or a rest area shading, which is crucial for way-finding, and an important requirement in encouraging pilgrims to walk.

At such an early period in the history of membrane structures – almost 35 years ago- it was quite a courageous move on behalf of the Hajj Research Centre to have considered this type of construction. However, this goes to prove to what degree the centre was visionary and far ahead of its time. Via the help and expertise of Buro Happold, wind tunnel testing at Bath University (near to where Buro Happold is located) and structural analysis was carried out on both the Teflon coated glass fibre options to prove their engineering feasibility. Both designs were found to be structurally sound in principle although it was recommended to conduct further work

to develop the connection details and installation procedures.

During that period, the lightweight and membrane industry was dominated by large American companies, and one of the largest developers of glass fibre membrane was the American company Owens-Corning, one of the largest glass manufacturers in the world at that time. For this initial feasibility study report, the authors obtained the property data of three grades of Teflon coated glass fibre membrane manufactured by Owens Corning called “Structo-Fab”. The data sheet of these three fabrics are attached in appendix C.

5.2 Reconstruction of design and 3D modeling

For the purpose of the Master’ Thesis, and as part of the requirement of the Lightweight structures engineering programme, I have attempted to reconstruct the two Teflon coated glass fibre options using current software and methods that we have learnt throughout the Masters’ programme. Apart from the exercise aspect of using the software and form finding tools that have been conveyed to us during the course, the goal of this reconstruction is to simulate the membrane structures and familiarize oneself with the challenges and obstacles that the original designers might have faced during their design phase. Another aim is to compare the process and methods we have applied to the projects covered in the course, with a project that has a completely different set of criteria and requirements.

The biggest challenge I faced during the reconstruction process was the membrane form finding. The first challenge was working from two manual drawings only, that barely showed any details, especially in regards to the membrane form. I realized that what is conveyed in a manual drawing could be interpreted so many ways when reconstructing a 3D computer model. Another aspect in the form finding process was determining the tangential aspect of the curve of the membrane.

Because the framing system is a pre-stressed mechanism, the structure tends to distribute the forces from applied loads uniformly throughout the system by means of relatively large deflections at the point of application, which are controlled by the pre-stress forces in the fabric edge and ridge cables.

5.2.1 Option 05: TEFLON/GLASS CANOPY ON DIAGONAL STRUTS

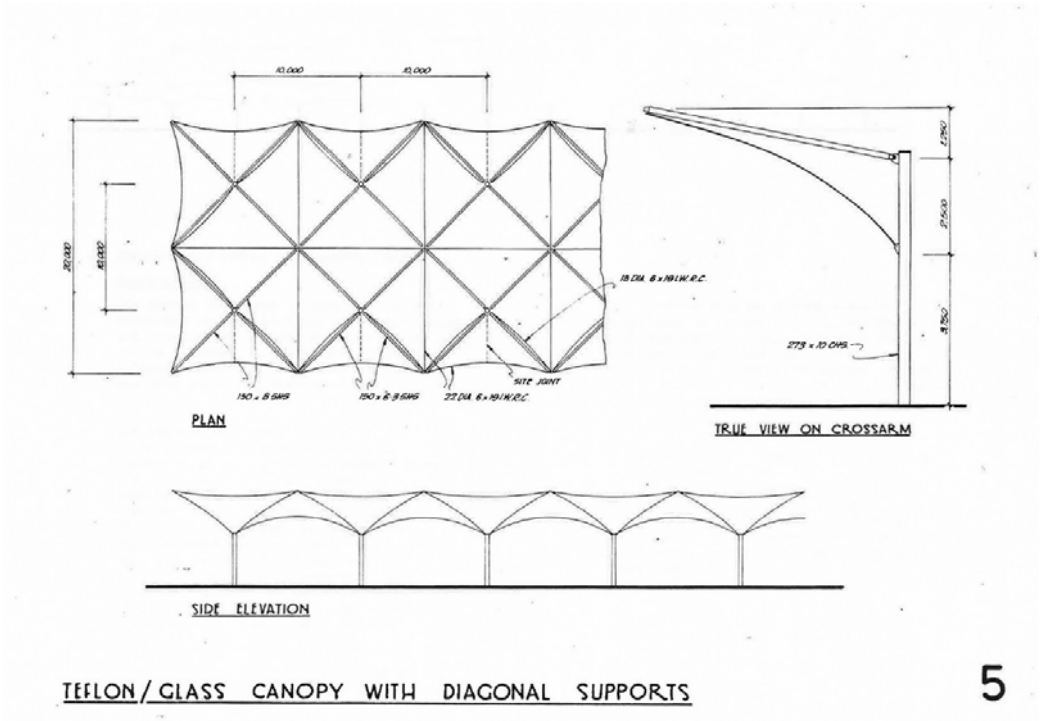

Figure 5.1 Option 05: Teflon/Glass canopy on diagonal struts

Description

The proposed design using Teflon coated glass fibre was developed in both physical models (photographs) and computer model forms (figures) during the feasibility phase of the study, and was approved in design meetings at the Hajj Research Centre as one possible basis for development.

The structural system shown in simple hand drawing fig. 5.1 consists of an elevated framing of struts and ties supported on equally spaced columns with a doubly curved membrane forming the shading surface below the framing. The membrane is pre—stressed with low points at column centres and high points along the scalloped edges and between columns at the crown joints of the framing. For reasons of both fabric patterning and in order to transmit the membrane forces to the crown joints, strong ridge lines are contained within the membrane forming an inflection curve between the low points and the crown joints. Similar ridge lines connect the low points with the framing joints supporting the scallop edge cables.

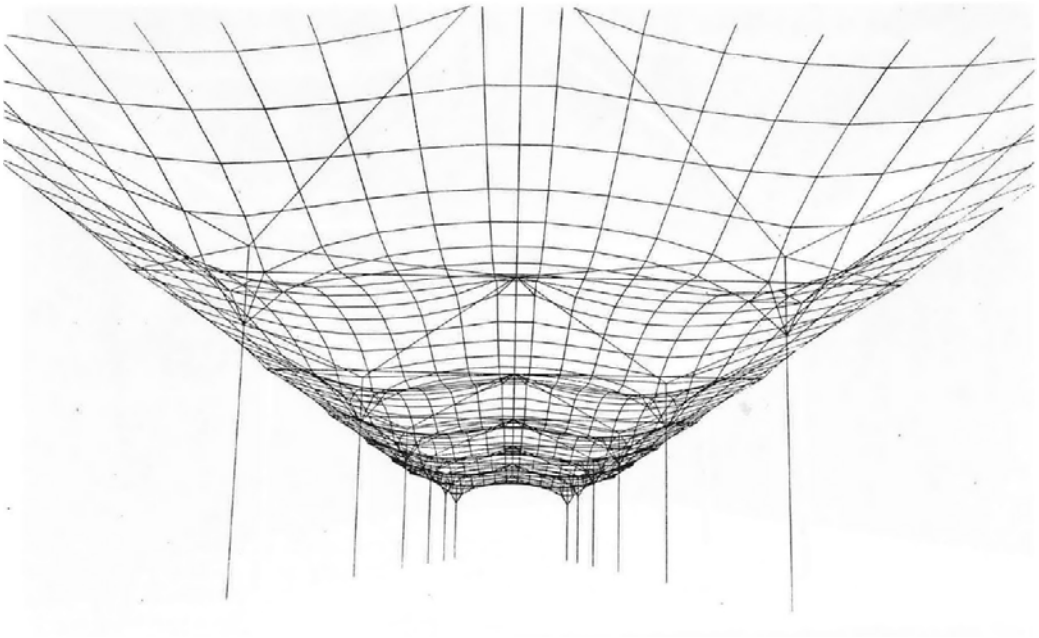

Figure 5.2 Basic 3D mesh computer modeling of the canopy of option 5.

The elevated framing system forms a structural mechanism which is stiffened when stressed in equilibrium with the membrane surface and the tie-cables. Under live load stress variations, due to wind, deformations of the framing joints are limited by the ridge and boundary cables.

Commentary

The advantages of this system are that the number of framing members and joints are kept to a minimum. A disadvantage is the penalty which must be paid in the size of the edge boundary cable, due to the long edge scallops, and the need to keep the sag/ span ratio of these scallops small to maintain stability. In a one-off prototype, the installation would have been quite complex.

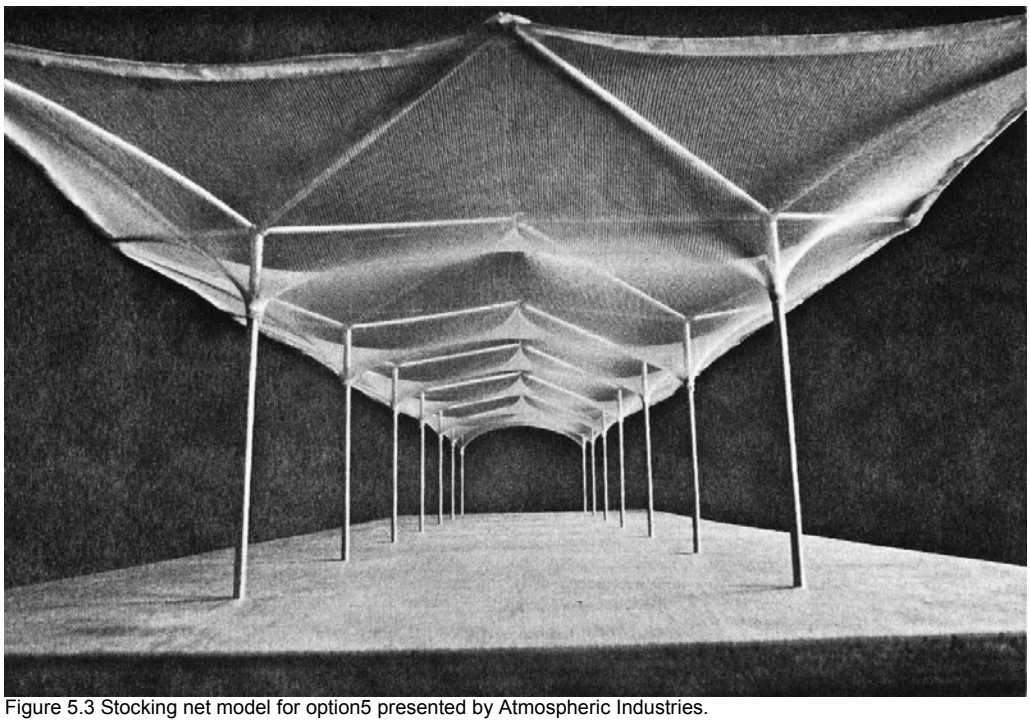

Figure 5.3 Stocking net model for option5 presented by Atmospheric Industries.

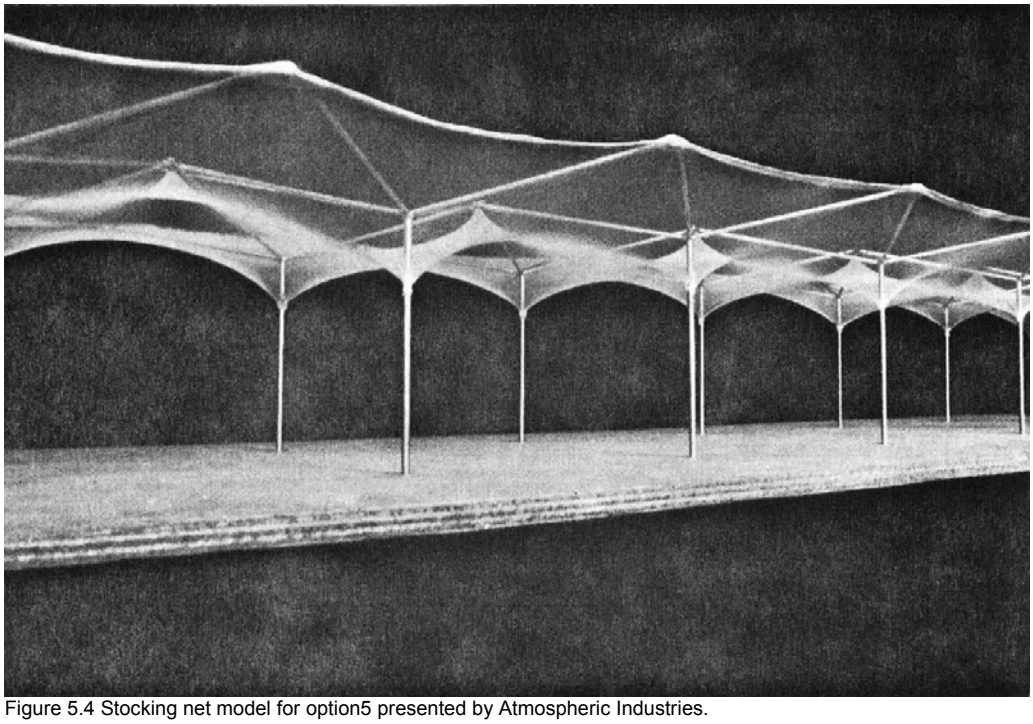

Figure 5.4 Stocking net model for option5 presented by Atmospheric Industries.

Architectural Drawings:

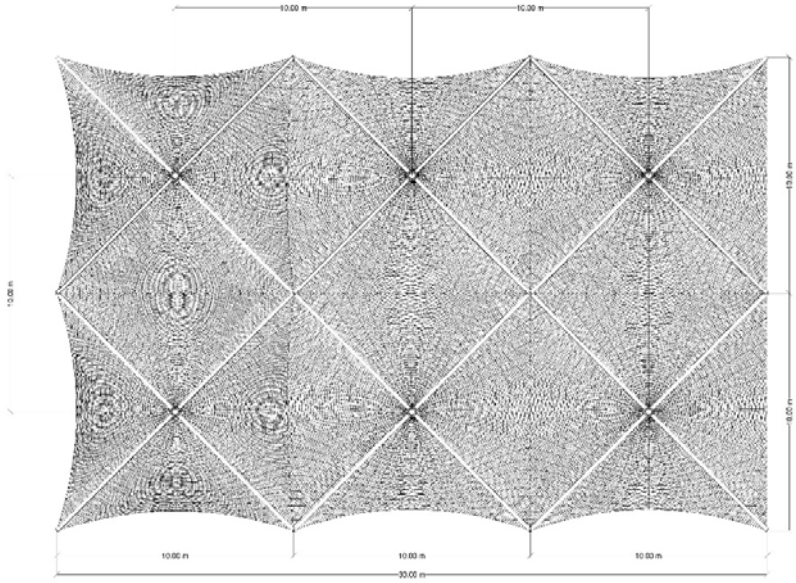

Figure 5.5 Partial plan of option 5 showing a cluster of 6 units (NTS)

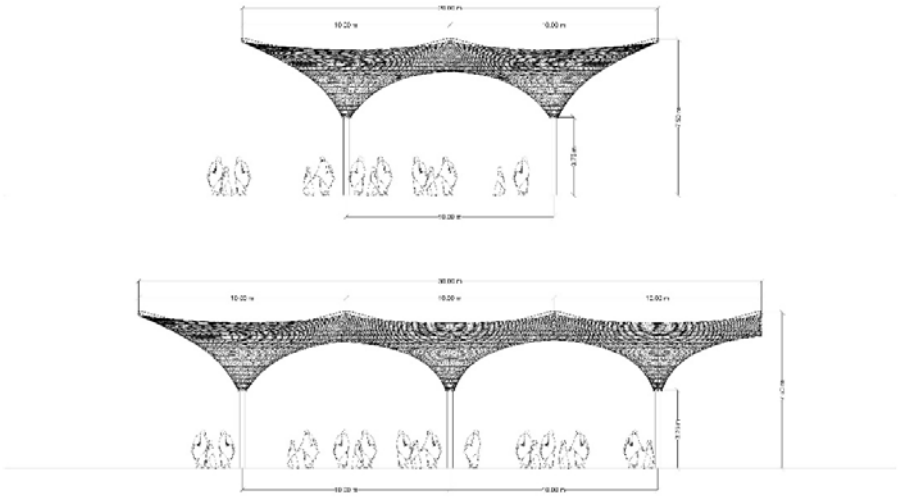

Figure 5.6 Elevation for option 5 showing a cluster of 6 units (NTS).

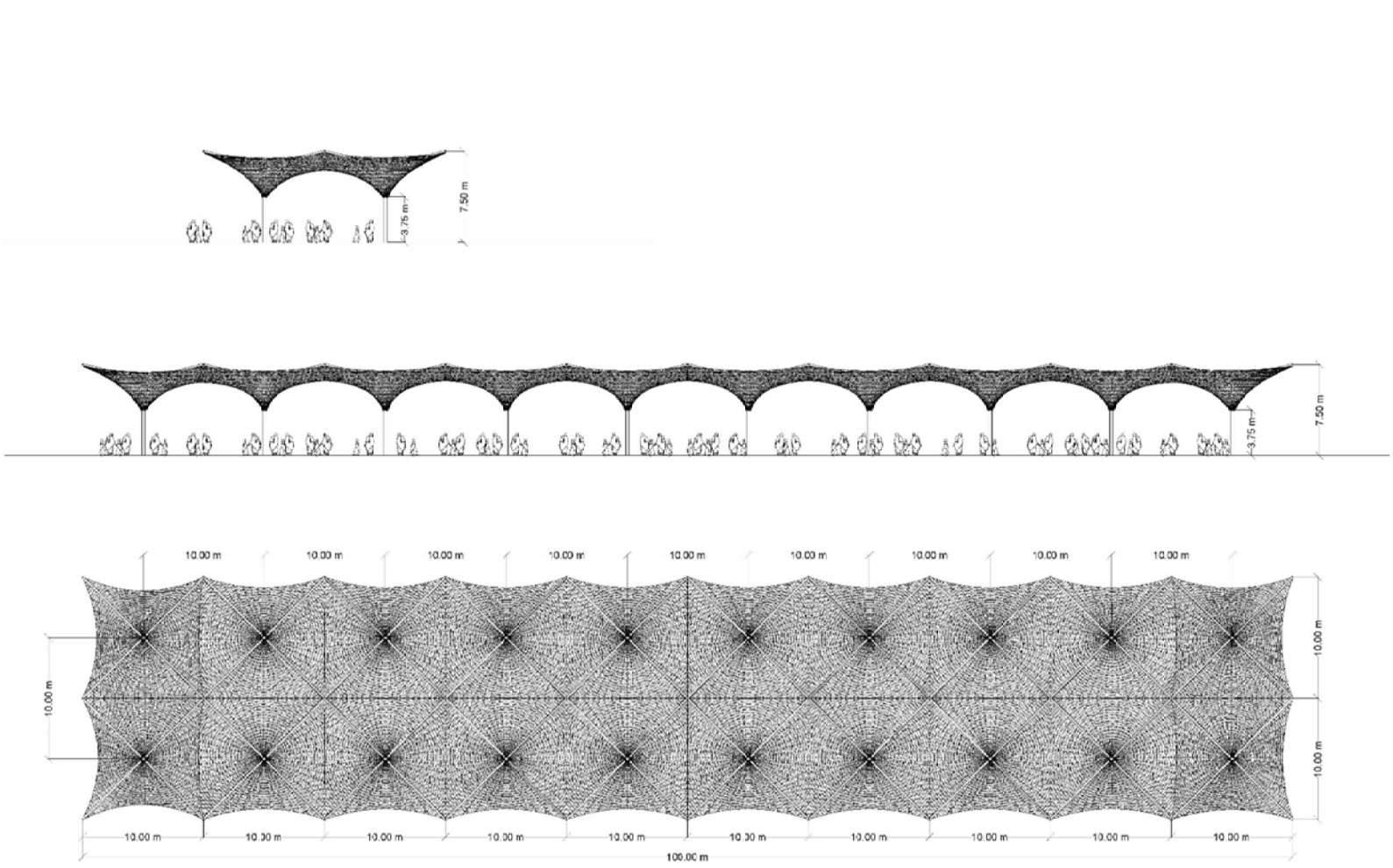

Figure 5.7 Plan of the suggested 100m module walkways (NTS) – Option 5: Cluster of 20 units.

3D Modeling:

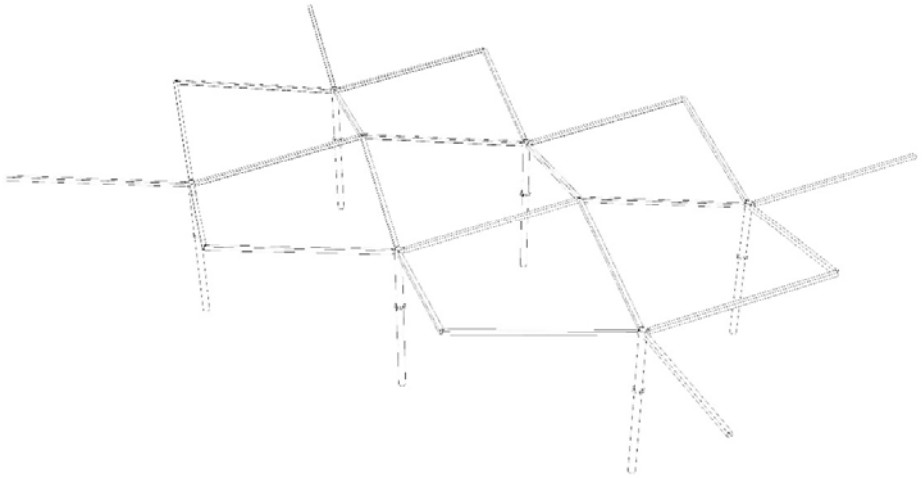

Figure 5.8 3D Model of the main structural elements for option 5. – Cluster of 6 units

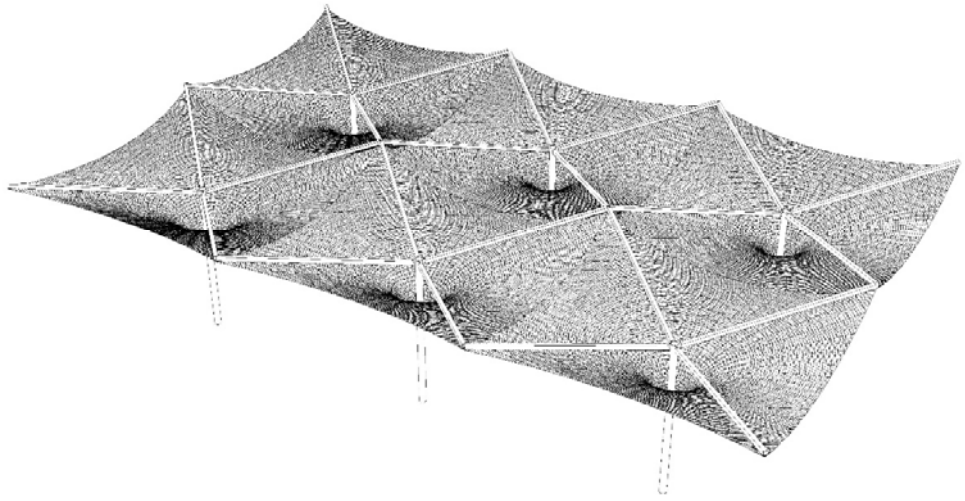

Figure 5.9 3D model of option 5 with membrane after form finding – cluster of 6 units.

3D Modeling

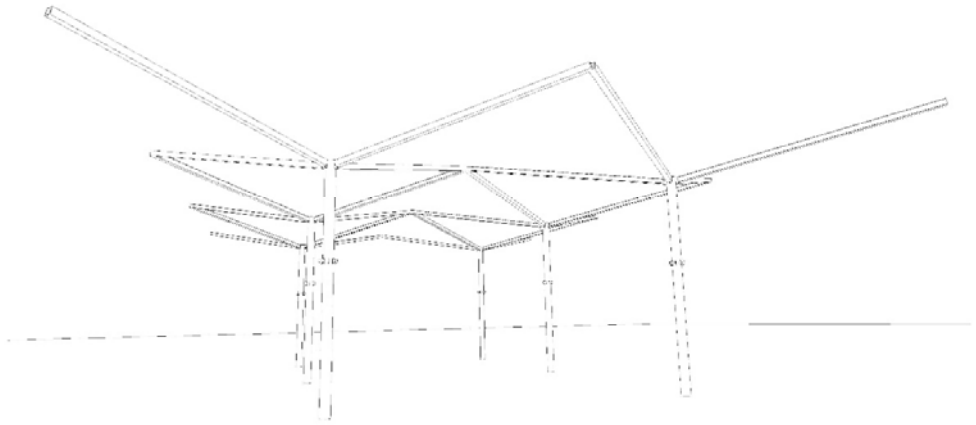

Figure 5.10 3D Model of the main structural elements for option 5. – Cluster of 6 units

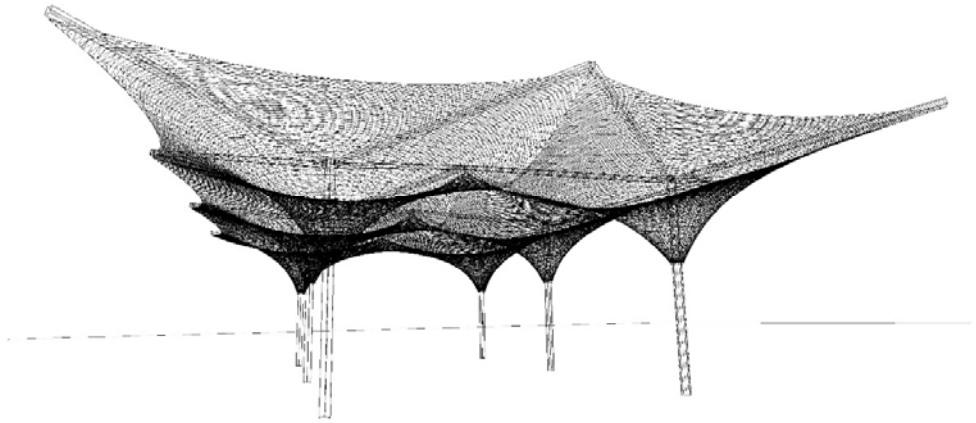

Figure 5.11 3D model of option 5 with membrane after form finding – cluster of 6 units.

3D Renderings

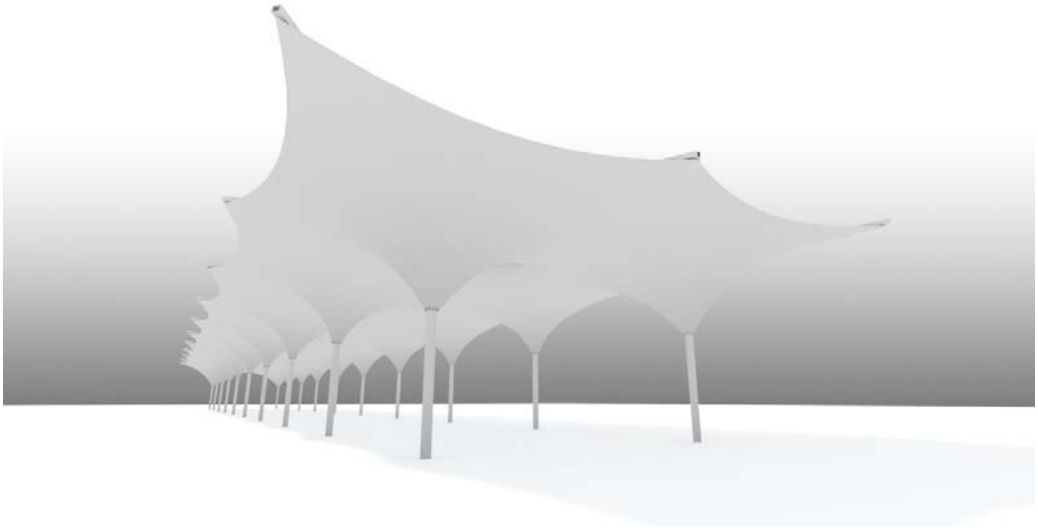

Figure 5.12 3D render of the suggested 100m module for use on the pedestrian walkways- cluster of 20 units.

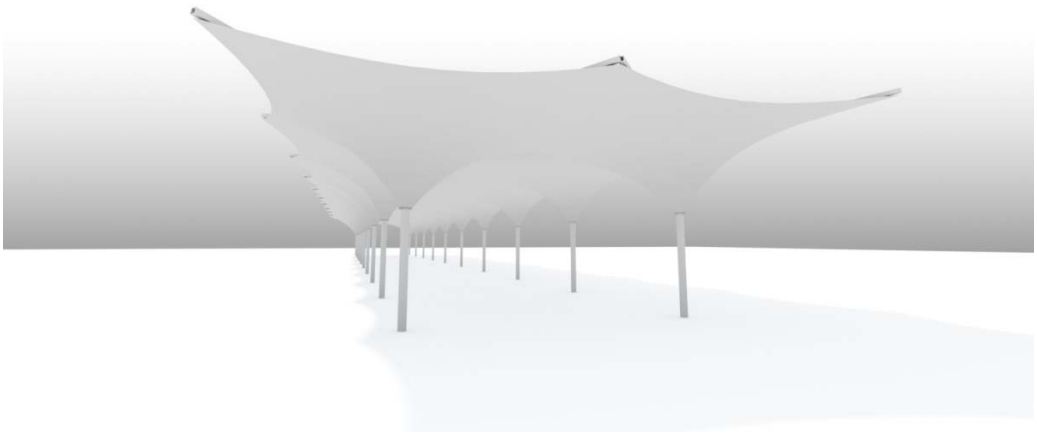

Figure 5.13 3D render of the suggested 100m module for use on the pedestrian walkways- cluster of 20 units.

3D Renderings

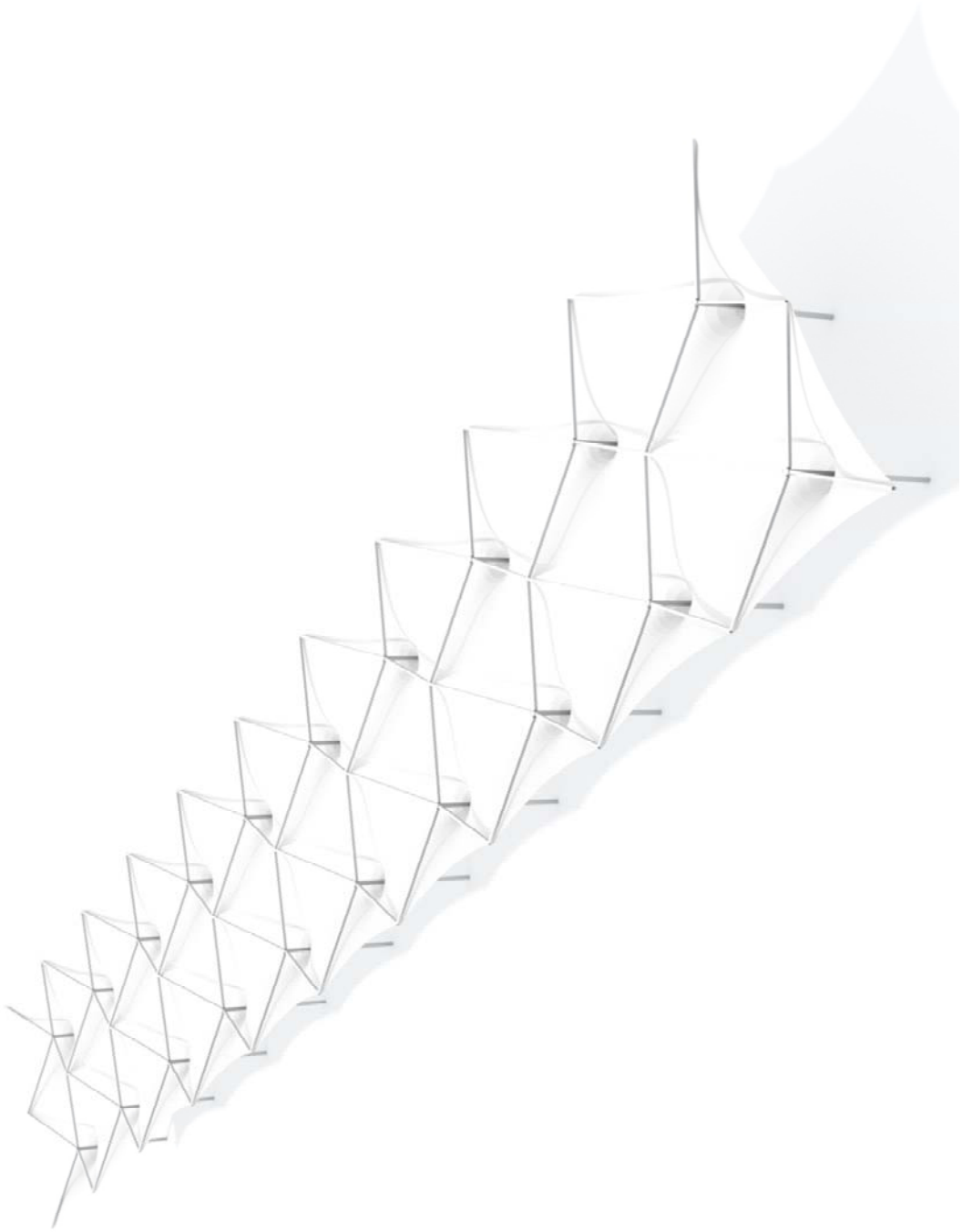

Figure 5.14 3D render of the suggested 100m module walkways- cluster of 20 units.

5.2.2 Option 06: TEFLON/GLASS CANOPY ON RADIAL STRUTS

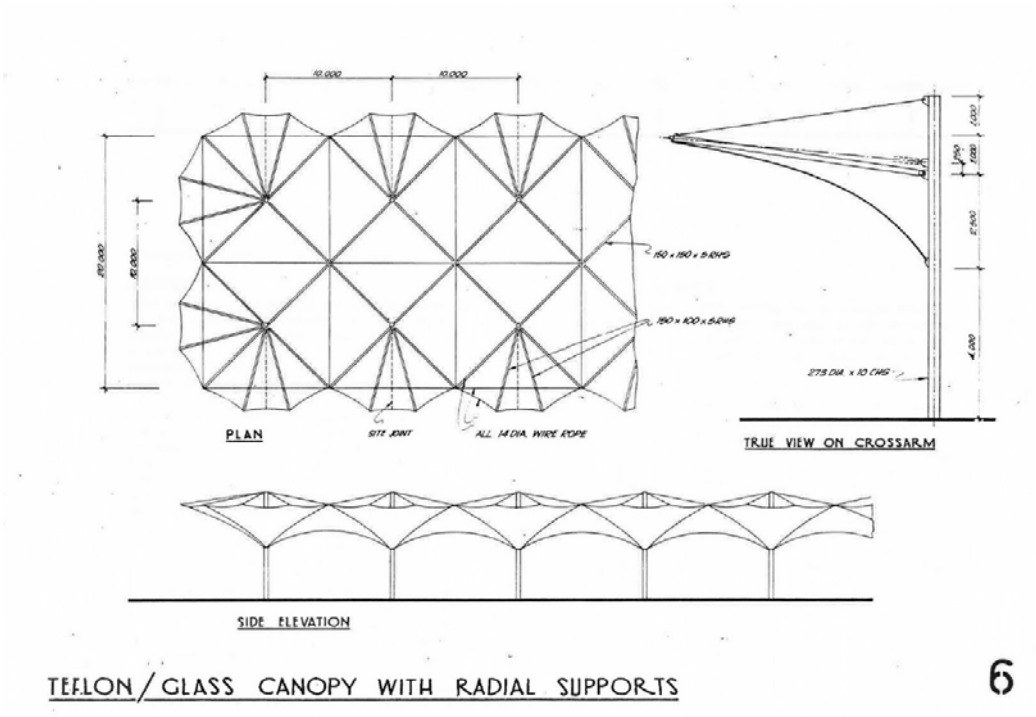

Figure 5.15 Option 06: Teflon/Glass canopy on radial struts

Description

This design is very similar to the previous but has additional radial struts to avoid the problems associated with the long boundary scallops. Other systems of sub dividing the boundary arcs were considered but rejected on the grounds of unnecessary complexity.

In this design the mast is extended above the strut intersection point and the diagonal and radial struts are supported from top of the mast by radial cables. This system has been analysed by Buro Happold and the results are included as the appendix report.

With the boundary cables supported at two intermediate points the maximum tensions are reduced from 130 KN to 40 KN reducing the cable size from 22mm diameter to 13mm diameter. The forces in the radial masts are reduced from 220 KN to 130 KN, but the effect on member sizes is small because of slenderness ratio requirements. The radial cables allow the radial struts to be supported during installation and provides an additional safety feature.

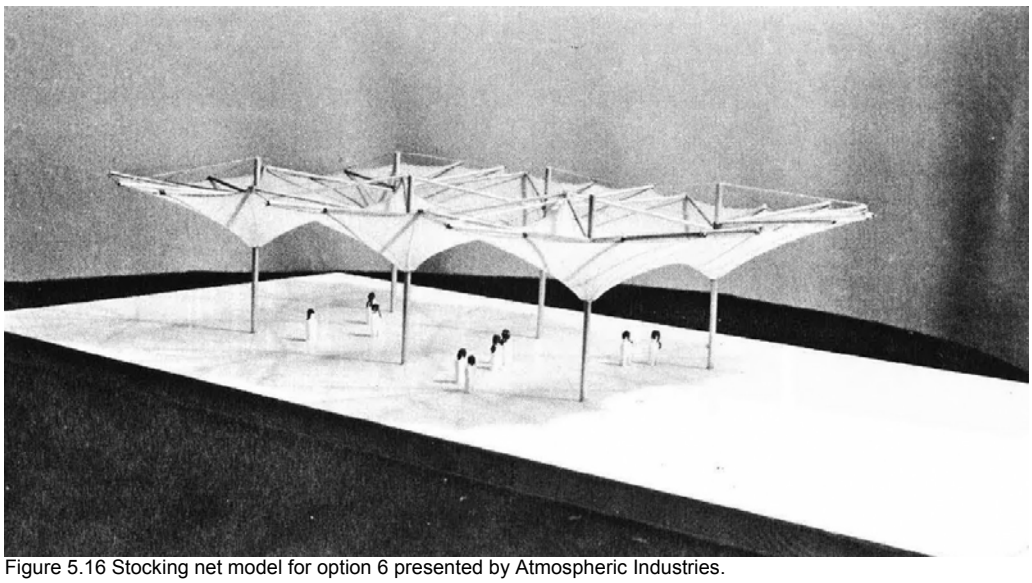

Figure 5.16 Stocking net model for option 6 presented by Atmospheric Industries.

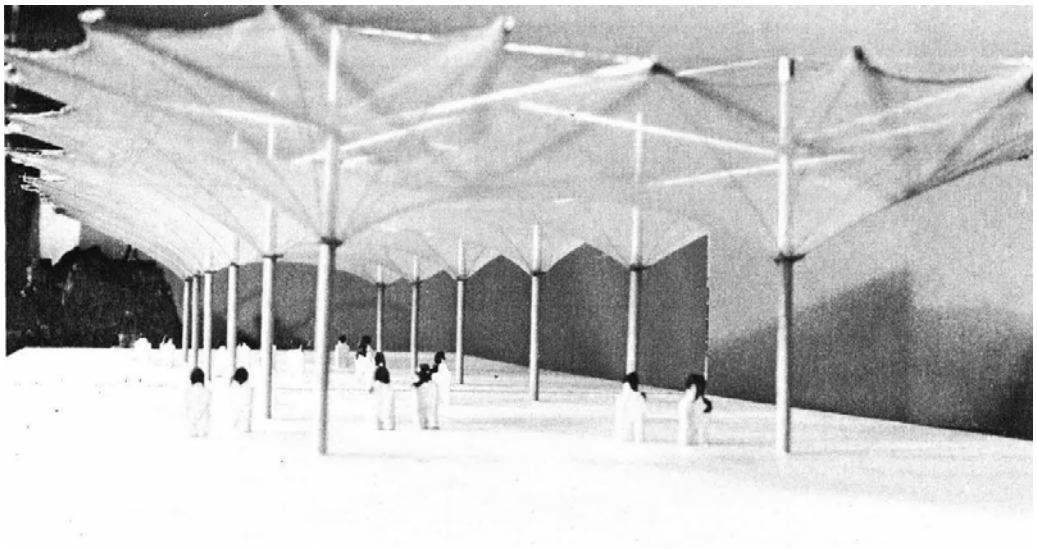

Figure 5.17 Stocking net model for option 6 presented by Atmospheric Industries.

Commentary

There was little to choose between designs 5 or 6 for the walkway structure on the grounds of function or cost. Design No 5 with diagonal supports was preferred on the grounds of simplicity of line, and fewer components.

Design No 6 is a development on this design which subdivides the edge cables, gives the canopy a flatter appearance and reduces the forces in the supporting structure.

Architectural Drawings

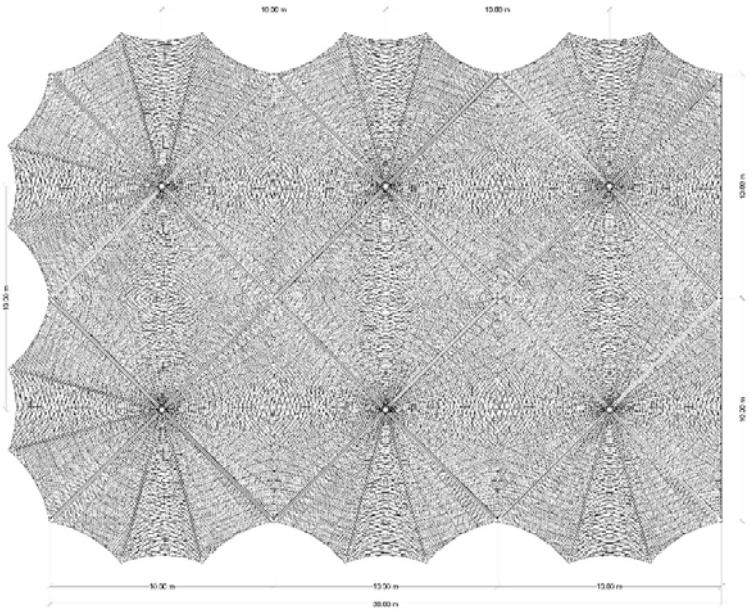

Figure 5.18 Partial plan of option 6 showing a cluster of 6 units (NTS).

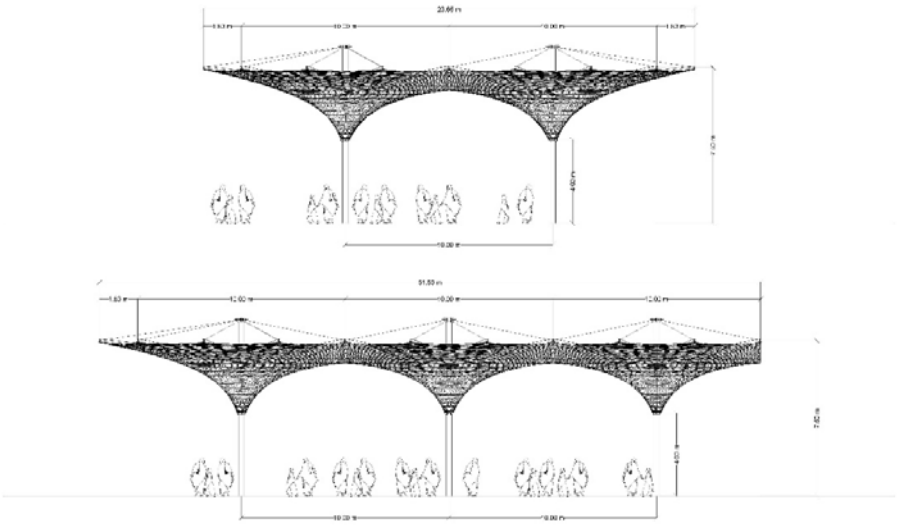

Figure 5.19 Elevation for option 6 showing a cluster of 6 units (NTS).

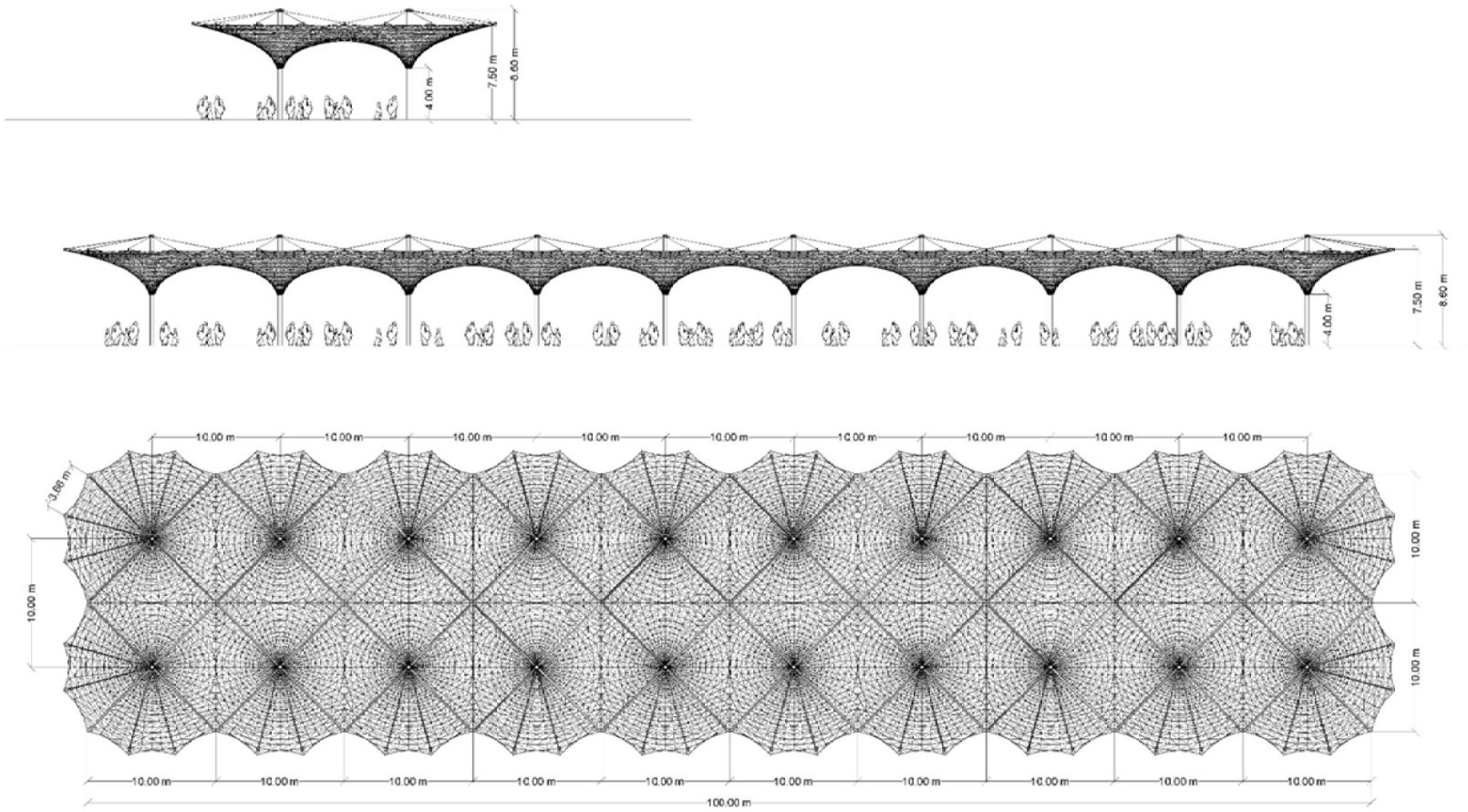

Figure 5.20 Plan of the suggested 100m module walkways (NTS) – Option 6: Cluster of 20 units.

3D Modeling

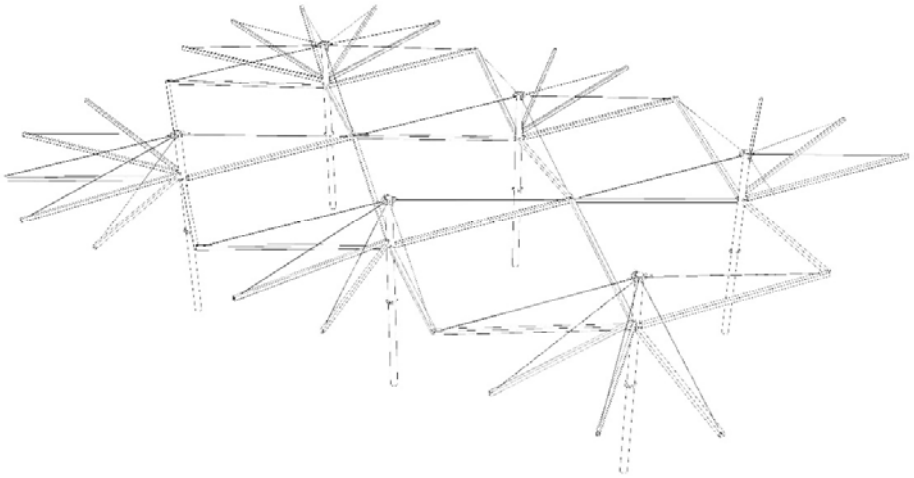

Figure 5.21 3D Model of the main structural elements for option 6 – Cluster of 6 units.

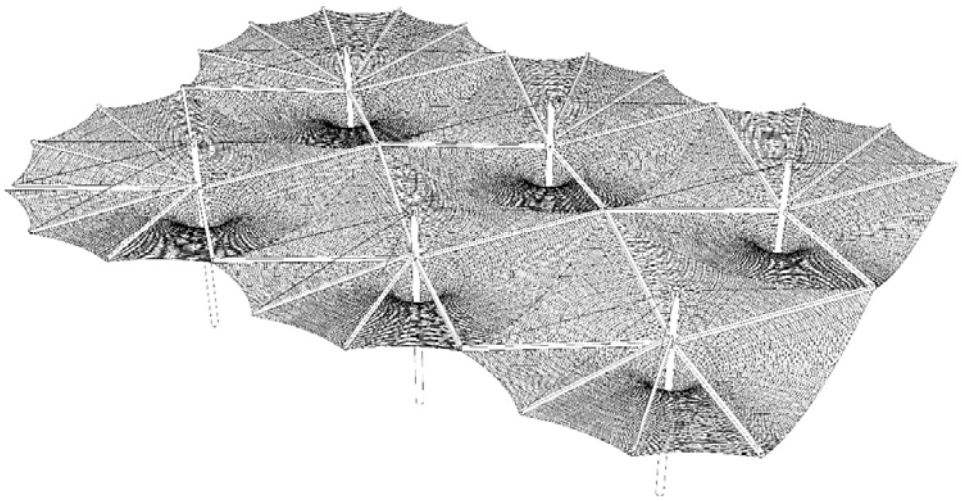

Figure 5.22 3D model of option 6 with membrane after form finding – Cluster of 6 units.

3D Modelling

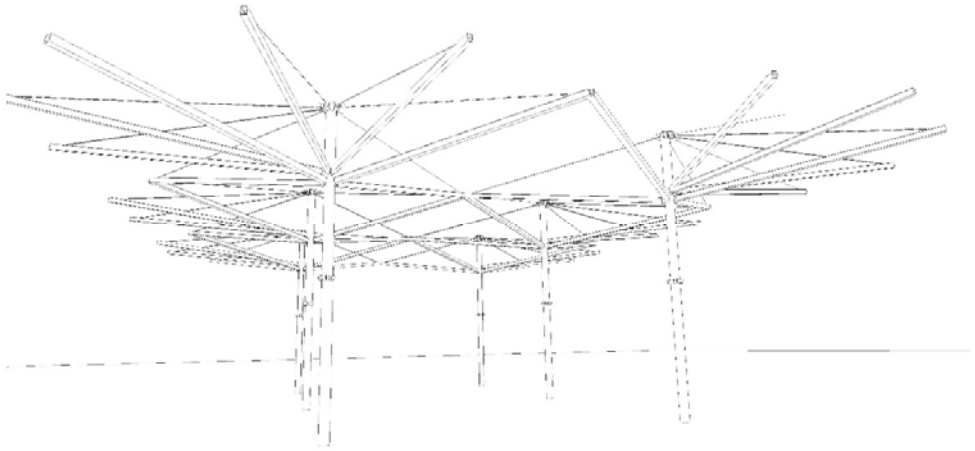

Figure 5.23 3D Model of the main structural elements for option 6 – Cluster of 6 units

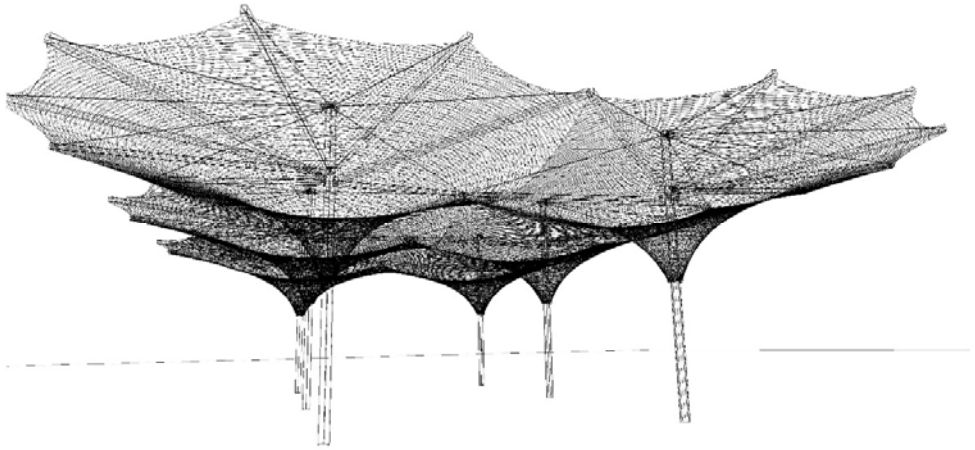

Figure 5.24 3D model of option 6 with membrane after form finding – cluster of 6 units.

3D Modelling

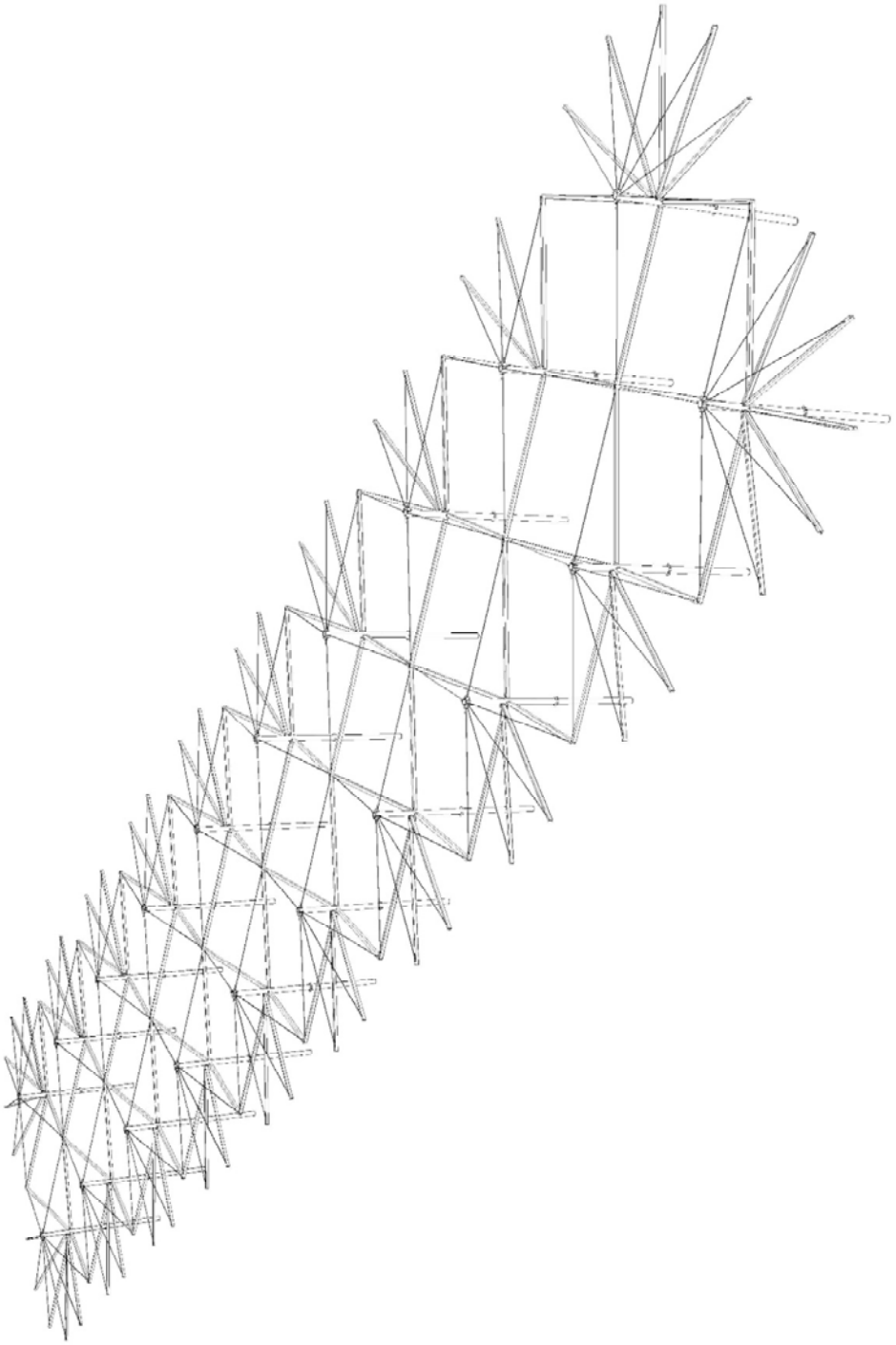

Figure 5.25 3D model of the structural members for the suggested 100m module walkways - Cluster of 20 units.

3D Modeling

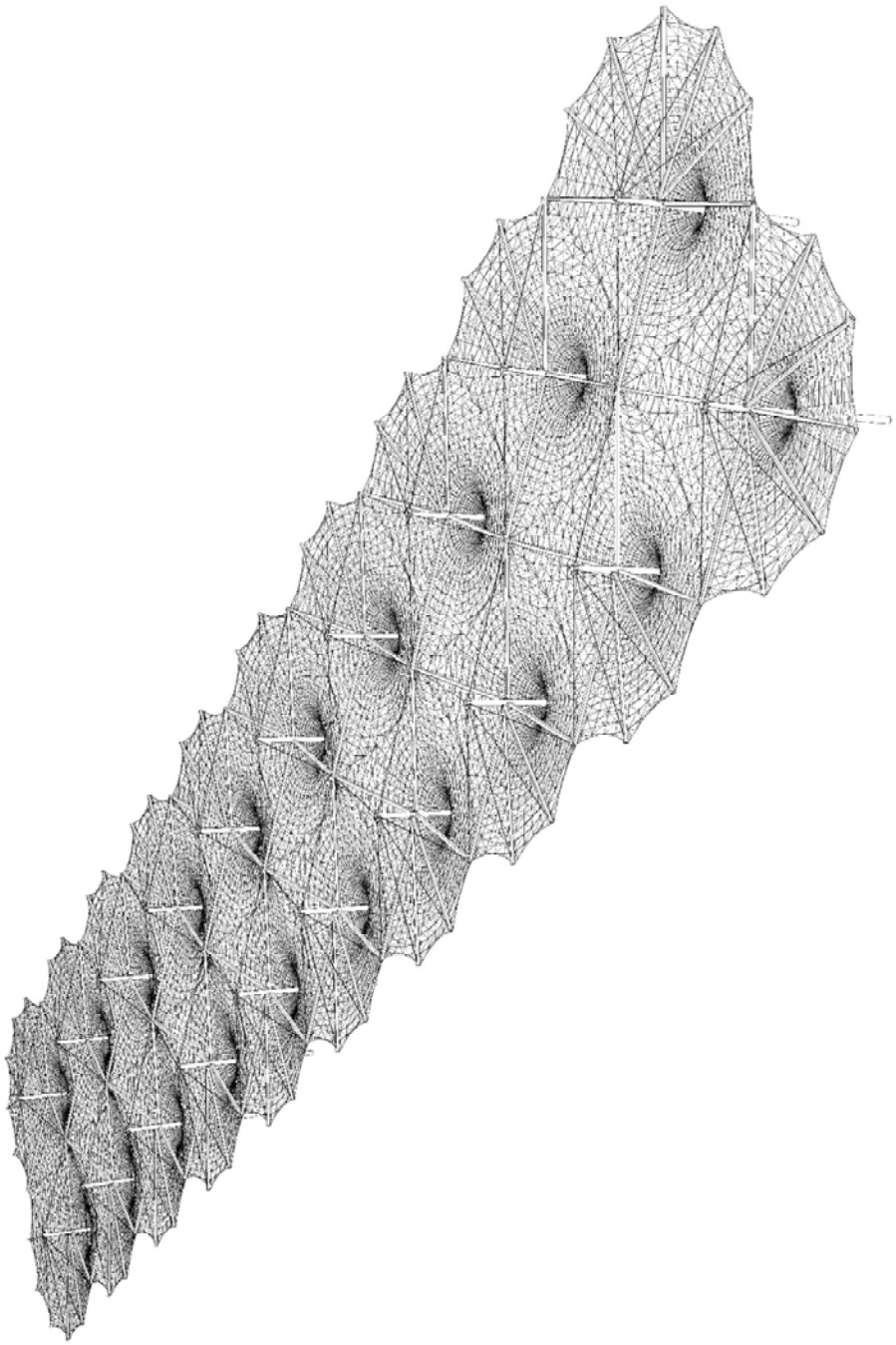

Figure 5.26 3D model of option 6 with membrane after form finding – Cluster of 20 units.

3D Renderings

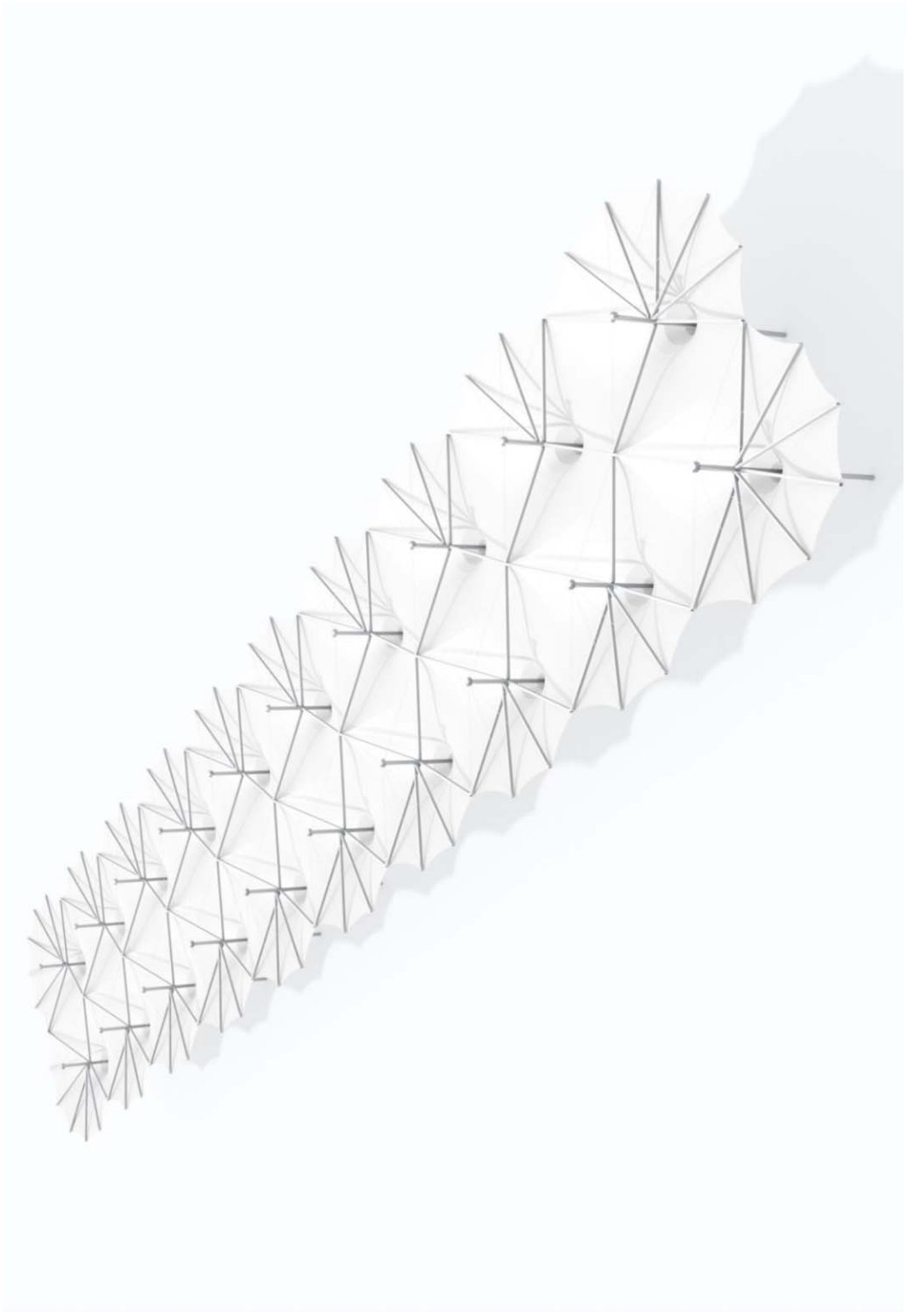

Figure 5.27 3D render of the suggested 100m module walkways- Cluster of 20 units.

3D Renderings

Figure 5.28 3D render of the suggested 100m module for use on the pedestrian walkways – Option 6: Cluster of 20 units.

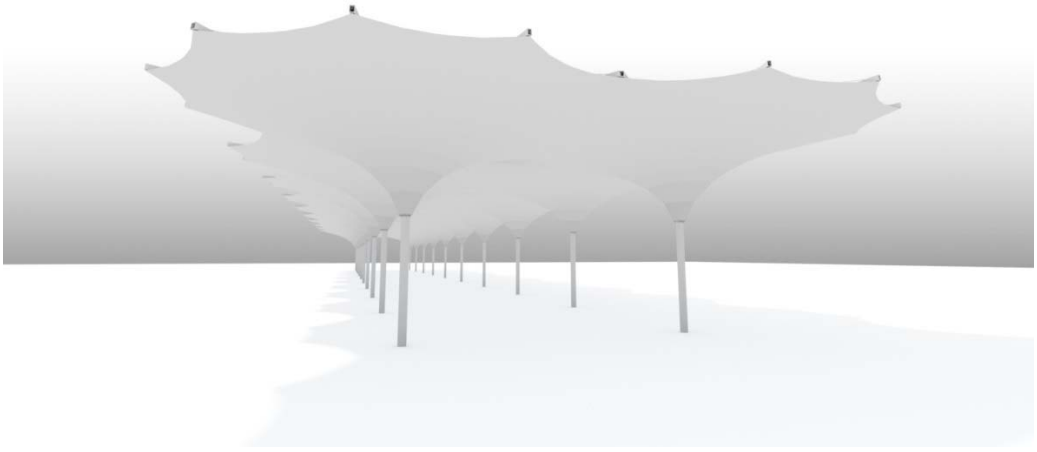

Figure 5.29 3D render of the suggested 100m module for use on the pedestrian walkways – Option 6: Cluster of 20 units.

Photomontage

Figure 5.30 Photomontage of the Option 6 Structure on the walkway between Muzdalifah and Arafat. Photo taken on the 9th day of the month when pilgrims are making their journey in the morning towards Arafat for the Wukuf ritual.

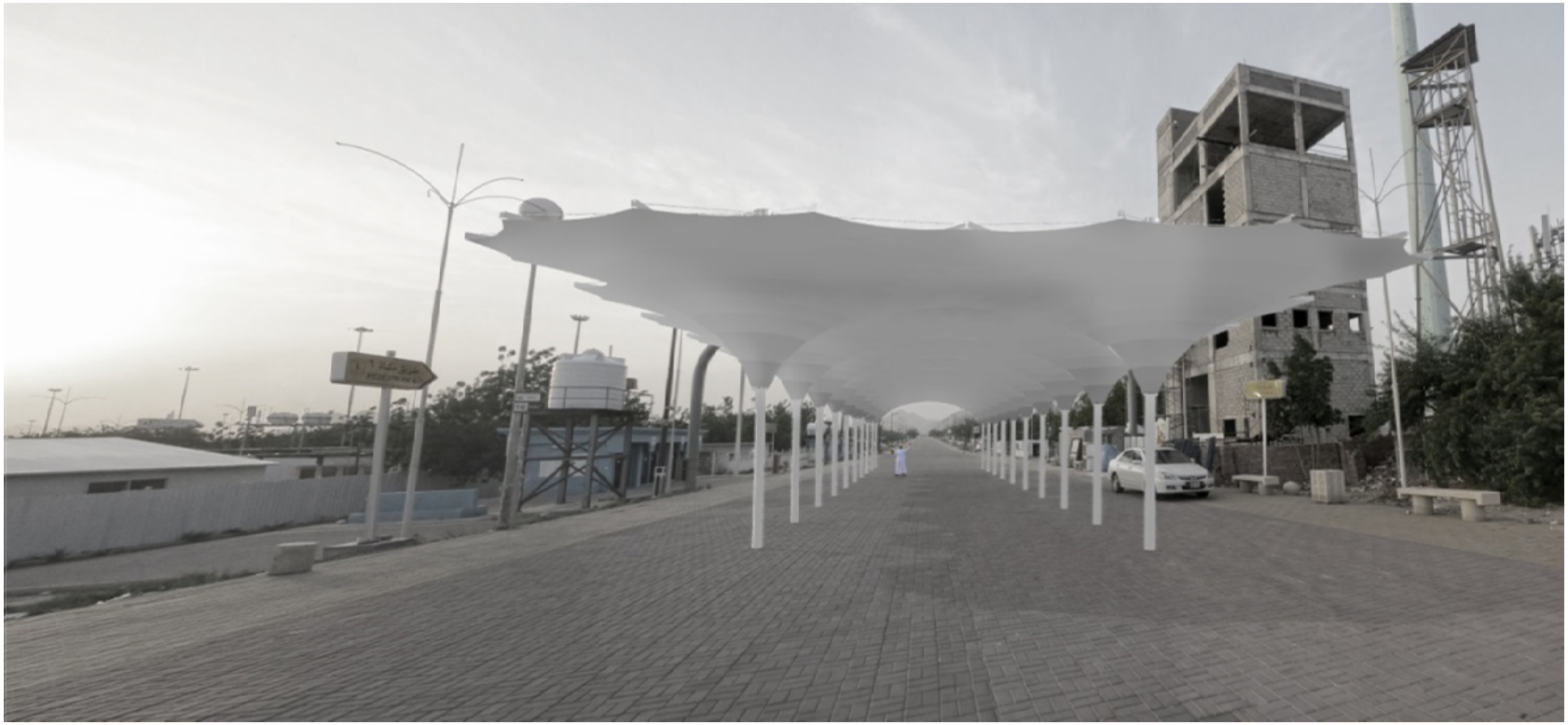

Figure 5.31 Photomontage of the Option 6 Structure on the walkway at the starting point in Arafat.

5.3 Assessment and Future Development

Assessment

The minimal shaped double curved membrane structure consists of 2 membrane surfaces with each two of them connected along a ridge cable. These membrane structures are spanning between curved boundary cables and the central high points. The peripheral membrane edge is supported on columns made of steel. Each high point is supported by four radial arranged lattice masts which are located above the membrane surface and are supported on the boundary columns. The lattice masts a have a rigid connection within each other and with and the columns. The columns are founded on single concrete foundations.

Future Developments

If both structures were built on a 10 m grid the first one would have a mean shaded width of 19m and the second 22 m, so there is an advantage of increased shaded area. If greater shade area is required, the grid spacing in design 5 is increased to 12 m. The costs in this case would not be proportionately increased. The following points are essential to be covered when developing this project further for execution and installation:

1. Integrate new technology with shading structures such as solar cells.
2. Finalize details, connections, steel members and specifications.

CHAPTER 6

SUMMARY AND RECOMMEND-ATIONS

6. SUMMARY AND RECOMMENDATIONS

The Hajj is the Muslim's annual pilgrimage to the Holy Sanctuary in Makkah and the Sacred precincts nearby; Muna, Muzdalifah and Arafat. However, it has undergone considerable/a total transformation/change from its original form in the past 50 years with many negative consequences.

6.1 Summary

After a brief description of the Hajj was presented in chapter 2, a list/summary of the modern day problems and challenges that the Hajj, as an event, faces continuously has been presented along with some of its major causes. It was shown how these modern day factors have created a crisis situation not only for the Hajj organizers during the main event itself, but also for the city of Makkah and its residents. Towards the end of chapter 2, I have highlighted a common denominator/or a recurrent theme/point that many specialists have been calling for to be prioritized during the planning and operation process of the Hajj; namely the inherent Pedestrian aspect of the Hajj. Since the very dry definition of the Hajj is a "march of people along a path", walking is a vital component not only for the ritual, but also for the true meaning of the Hajj proper. In a sense, walking forms part of the meditative nature of the Hajj experience.

As a result, it would seem so evident/second nature that the science and physics of pedestrian flow would play a vital role in the future planning of the Hajj. Therefore, in chapter 3 recent developments in the science of pedestrian analysis and simulation were reviewed and a review of the current conditions, obstacles and challenges facing the pedestrian pilgrim in the sacred precincts of the Hajj were presented. One of the largest obstacles that hinders/impedes the simple/average pilgrim from conducting all of his/her Hajj journeys/circulation solely on foot is the lack of shade on almost all of the pedestrian paths that have been made available on site. Both the pedestrian paths between the main sacred precincts themselves, and also within tent encampments themselves. Chapter 4 presented the major advantages of having lightweight ~~shading~~ structures along these routes, and the role they would play in enhancing the overall experience for the pilgrim. Previously proposed solutions/projects using contemporary lightweight structure technologies were reviewed in this chapter.

In chapter 5, a lightweight shading structure scheme that was presented to the Hajj Research Centre in 1983 was revisited and analyzed to reassess its relevance for the current conditions of the pedestrian walkways of the Hajj. This early hand drawn scheme was reconstructed and modelled using the AutoDesk AutoCAD software for 3D modelling and the Form-Finder software to form find the membrane component of the shading structures. Two themes we originally presented and both were reconstructed and presented in renderings and dimensioned architectural drawings, plus some photomontages o existing conditions. One reason was to revalidate the classic hand drawn design methods used back in 1983. And also to shed some light that such a crucial scheme was being called for already roughly more than thirty years ago, and hopefully refocus/redirect the discussion/debate on such types of projects for the Hajj. These results begin to support and validate the research hypothesis that lightweight interventions are the optimum solutions for the problems facing the annual pilgrimage to Makkah (The Hajj). Furthermore, they bring back the discussion that solutions to the problems facing the Hajj need not necessarily be massive ones, but rather small and simple gestures that encourage a relook at the Hajj as predominantly a landscape design project rather than a purely infrastructural one.

6.2 Recommendations

Clearly the scheme presented is only a preliminary design that needs to be developed and improved further after a well-grounded topographic survey of the site has been conducted. The work on the shading structure itself is not complete. For example, no consideration has been given yet to the water drainage or the wind conditions of the site. Although these could be easily accommodated as drainage pipes within the steel columns connected to a subterranean drainage network. In addition, the next step would see further development of the connection details, steel members specifications, membrane specifications and cutting patterns. Another area that is worth investigating is integrating new technology within shading structures. The use of photovoltaic solar power cells that are sewn or welded onto the membrane surface itself is a very promising prospect. With the large surface area available, these structure will be able to generate a considerable amount of power that could feed into the grid of the Holy precincts. This could potentially at least, provide power for the lighting of the tent encampments and facilities during the five days of the Hajj.

The following is an essential list of recommendations that should feature prominently in any future planning for the Hajj:

- Preserve as much as possible the natural terrain and landscape of the Holy Precincts.
- Revisit the design and planning of the Holy precincts as a public venue and seasonal park with all the necessary landscaping and wayfinding facilities.
- Prioritize the pedestrian aspect of the Hajj via three main routes:
    i. Encourage pilgrims to walk as much as possible during the Hajj, via promotional programmes either in their countries or once they arrive to Saudi Arabia.
    ii. Develop and implement facilities and projects that facilitate and make it easy for the pilgrims to walk during the Hajj.
    iii. Ensuring that a total segregation of the pedestrian paths from vehicular traffic is always achievable and maintained.
- Shade will never hurt anybody. Increase the total shade areas by using plants, umbrellas, lightweight structures as much as possible.
- Redesign landscape of walkways of the hajj
- Develop master plan layout for all walkways

The research presented only explored a shading system with a focus on the pedestrian walkways that are located between the Masha'er locations. It would be a far bigger challenge to conduct a comprehensive study to include how pilgrims would reach the Masha'er locations in the first place. In such a case, would it still be feasible to encourage the pilgrims to access these sites on foot? Would it be logical to provide pedestrian access and walkways from the city of Makkah to the Holy precincts? These inquiries are several unknowns and questions that need to be explored further. Moreover, evidently there is still immense potential that could be expected from implementing deployable and operable shading umbrellas for the walkways.

With the advancement of design and analysis technologies, this research believes that the use of lightweight shading structures in the Hajj is the most promising and economically feasible means to tackle the increasing circulation complexities of the Hajj and to meet the growing operation and organizational demands of the Hajj in modern times.

APPENDIX A

INTERVIEW QUESTIONS

APPENDIX A: INTERVIEW QUESTIONS

Questions for interview with Prof. Frei Otto* on the 1974 Hajj competition for pilgrims in Muna:

1. Can you kindly give some background on how and why were you invited to participate in this competition?
2. What made you take on the competition? And What attracted you the most about this competition?
3. Do you think it was a coincidence that Bodo Rasch happened to teach Sami Angawi just before you were invited to the competition?
4. Can you tell me about how you structured the team?
5. Did you treat the competition as an architectural project, or was it considered more of a planning proposal? In light of the fact that there was no specific major structure to be designed or developed, such as in Montreal or Mannheim.
6. Given the fact that this your first ever experience with projects in the Middle East at that time, and due to the fact that most of the knowledge required for this competition and the site came only through 3rd parties, what would you change or propose if for instance you were invited to a similar competition 5 years ago?
7. Forty years later, the Hajj is still hindered by some of the same problems and challenges you had to tackle when working on the competition, what advice would you give for those now responsible for the Hajj?
8. According to Bodo Rasch in his review of the competition entry in the IL 29 publication, your proposal emphasized the traffic problem of the Hajj, and in fact gave the "problem of the pilgrim's accommodation" secondary consideration, even though the title of the competition was "Competition for Accommodating Pilgrims in Muna". Can you elaborate when had that become evident to you and your team? Was it from the onset, or midway, or more towards the end of your work on the project?
9. Were there any completely different approaches that you considered for the planning of the project?

** It is unfortunate that Prof. Frei Otto passed away during the course of preparing and writing for this thesis. I would like to thank his daughter and some of his ex-students in their help to find answers to some of the questions in the above interview.*

Questions for interview with Dr. Sami Angawi on the Hajj Walkway Shade Structures Study presented in 1983 by Atmospheric Industries Ltd. (Graham Stevens) and Buro Happold:

1. Can you kindly give some background on how and why this study was commissioned?
2. From the title of the study, these were shading structures for Walkways to be used by the pilgrims. Where these walkways already in use? Where they determined prior to conducting the study?
3. Were there any prior studies related to pedestrian in the Hajj or those signifying the importance of providing facilities for pilgrims performing the Hajj on foot?
4. This study was presented approximately 33 years ago, which means that the Hajj occurred in similar season (late September). Was the heat a significant factor in the commissioning of this study?
5. Can you tell us who was participated in this study form the HRC?
6. What was the outcome after the study was presented to the HRC? Was it presented to any other Government Department? MoMRA? Makkah Governorate? Ministry of Hajj?
7. Can you tell us the reasons why none of the proposals in the study were implemented or taken into consideration? Budget? Management? Engineering issues?
8. Would it be acceptable to categorize the problems facing the Hajj into 2 main categories: namely traffic/circulation problems and pilgrim's accommodation?
9. In 1974, the Ministry of Finance of Saudi Arabia invited five architectural practices/teams to participate in an international competition, "Competition for Accommodating Pilgrims in Muna". You participated with the team that was led by Frei Otto, and included Bodo Rasch. One of the main concepts that all five teams focused on was the assertion that a "purely pedestrian system is the most productive means of mass transport for relatively short distances". Is this still a valid statement? Can you kindly elaborate.
10. As part of Frei Otto's competition entry, it was proposed to have a pedestrian bridge over the tent city of Muna. Are there any remnants or relationship between the 1974 Frei Otto pedestrian bridge proposal and the study on Shade structures for the Hajj walkway by Buro Happold?
11. Thirty three years later, the Hajj is still hindered by some of the same problems and challenges you had to tackle when working on this study, what advice would you give for those now responsible for the Hajj?
12. Were there any other similar or related studies or proposals that were commissioned or considered by the HRC?

Questions for interview with Dr. Miraj Mirza on the current situation of Hajj:

1. How important is it to preserve the sanctity of Makkah and the Masha'er and the natural features of the geography of the sanctuary to pilgrims?
2. Is this goal limited to the romanticist's dreams?
3. Is peace and tranquillity during the preforming of the Hajj a legitimate demand? Or just a luxury that you have to pay for?
4. Do you think a minimally invasive approach to building the infrastructure and facilities of the Hajj is a valid cause? Practical? How would you describe it?
5. The organization of the Hajj has been described on several occasions as being a constant "crisis management like nowhere in the world". Do you think this is a reasonable description? Exaggerated perhaps?
6. Do you think it is easy for the pilgrims these days to perform the Hajj on foot? If not, can you elaborate why not?
7. Has there been any priority given to pedestrian aspects of Hajj by the organizing authorities? For example special facilities or amenities to improve their experience?
8. Can you suggest some ideas that would improve the experience of those pilgrims performing the Hajj on foot?
9. What in your opinion are the fundamental problems that are still persisting in the Hajj?
   (infrastructure, planning, communication, management, culture/language/attitude, sheer numbers, density….??)
10. Forty years after the first efforts to establish a comprehensive planning and implementation strategy, the Hajj is still hindered by some of the same problems and challenges the earlier teams had to tackle, what advice would you give for those now responsible for the Hajj?
11. How can the Hajj improve in general?

APPENDIX B

PRELIMINARY STATIC ANALYSIS

APPENDIX B: Preliminary Static Analysis

The following figures are a sample of preliminary static analysis that was conducted on the 3D model developed for the shading structure in Chapter 5. This static analysis was performed using the Tech-Net software EASY 2015. The 3D model used for the static analysis was for a hypothetical 10 unit structure composed of 2 rows of five units each. The caption on each screenshot describes the specific analysis performed at different sequential phases of the whole exercise. These are presented here as examples of the type of static analysis that needs to be conducted in more detail for the structures if at some point in the future they were to be executed. They are by no means conclusive nor exhaustive.

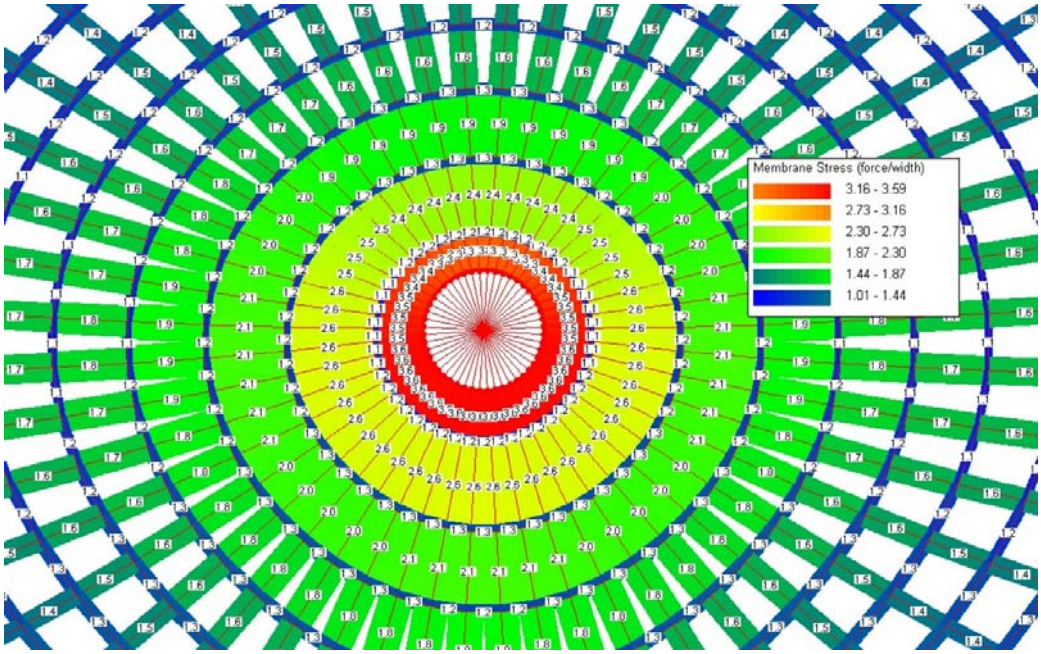

Figure B.1 Membrane Stresses – Only Prestress applied

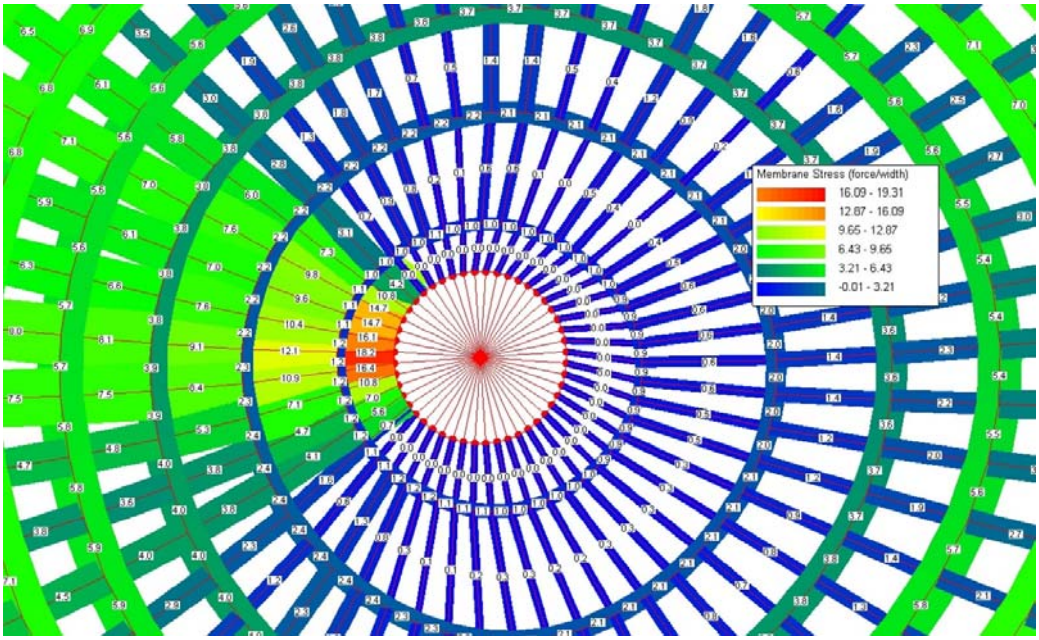

Figure B.2 Prestress+Selfweight+Wind.X.Pressure Fabric Stress Only

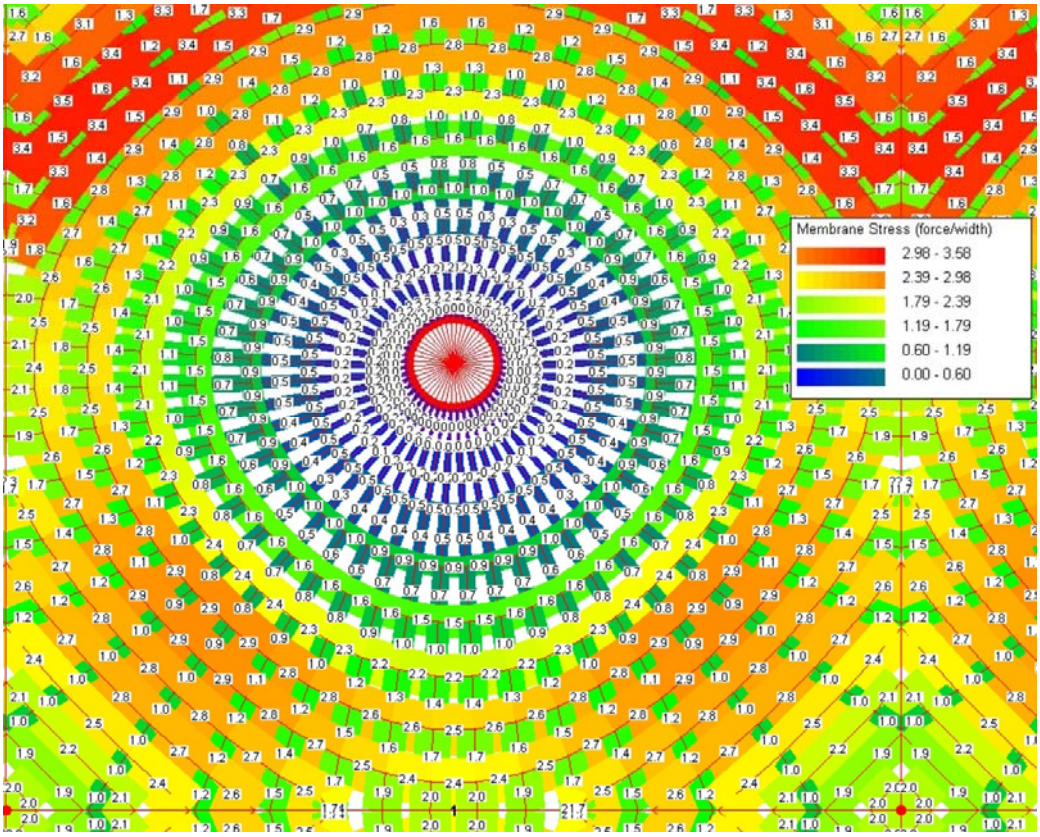

Figure B.3 Prestress+Selfweight+Dead Load-Fabric Stresses

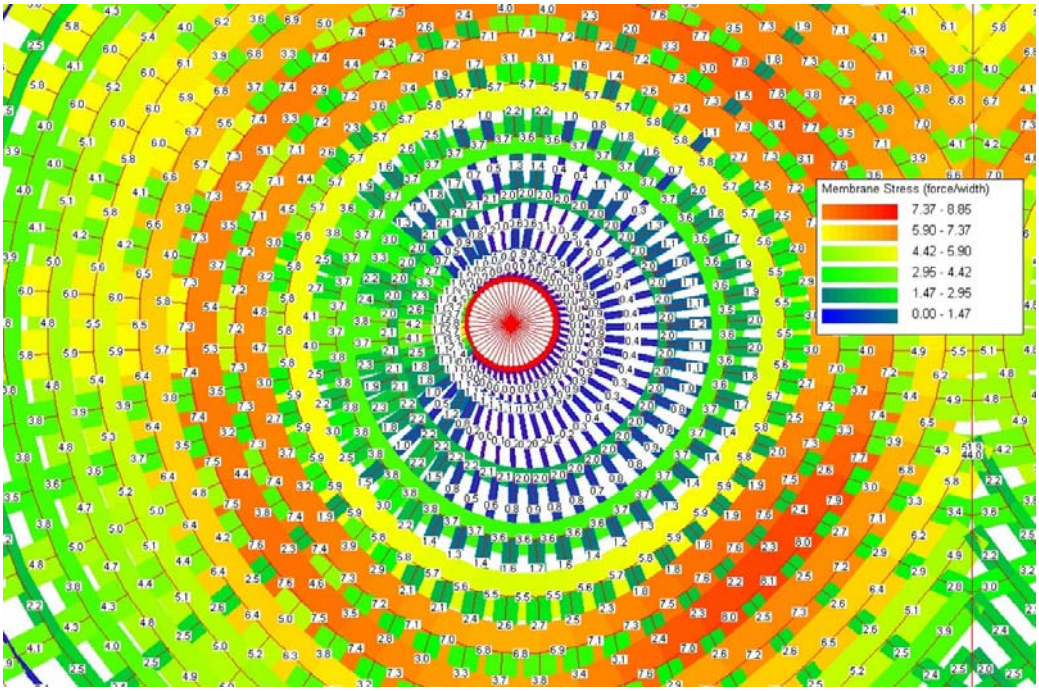

Figure B.4 Prestress+Selfweight+Wind.X.Suction Load-fabric stress

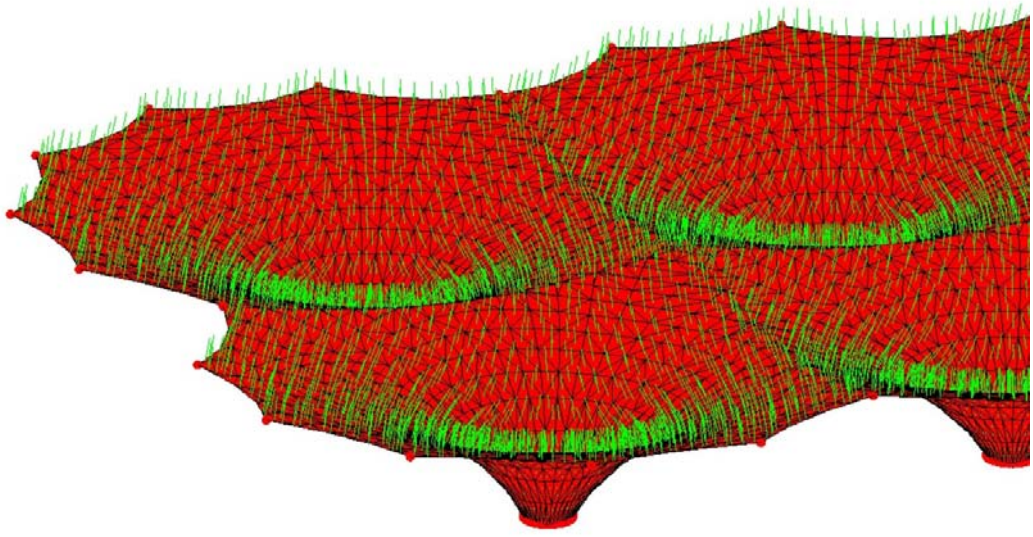

Figure B.5 Normals

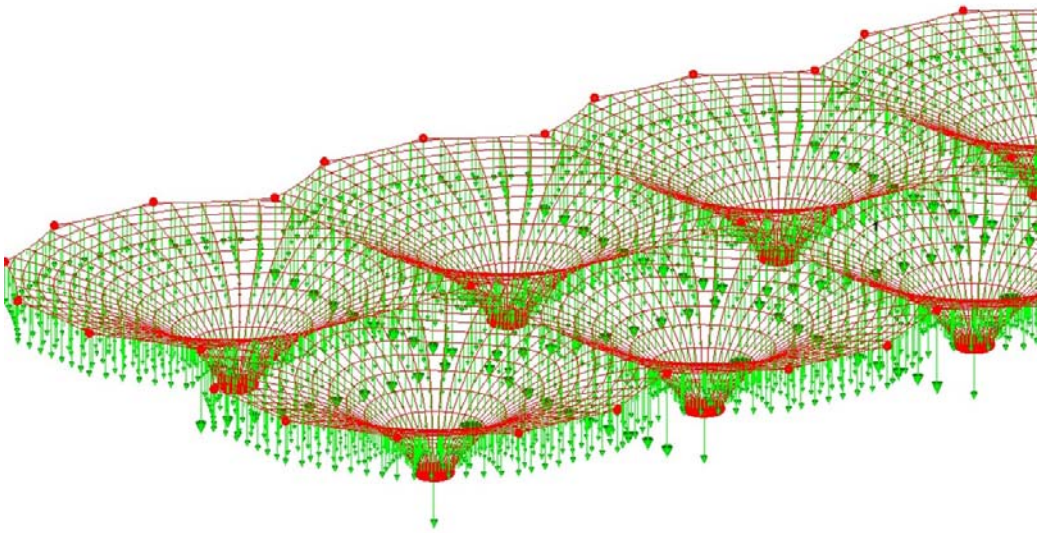

Figure B.6 Prestress+Selfweight

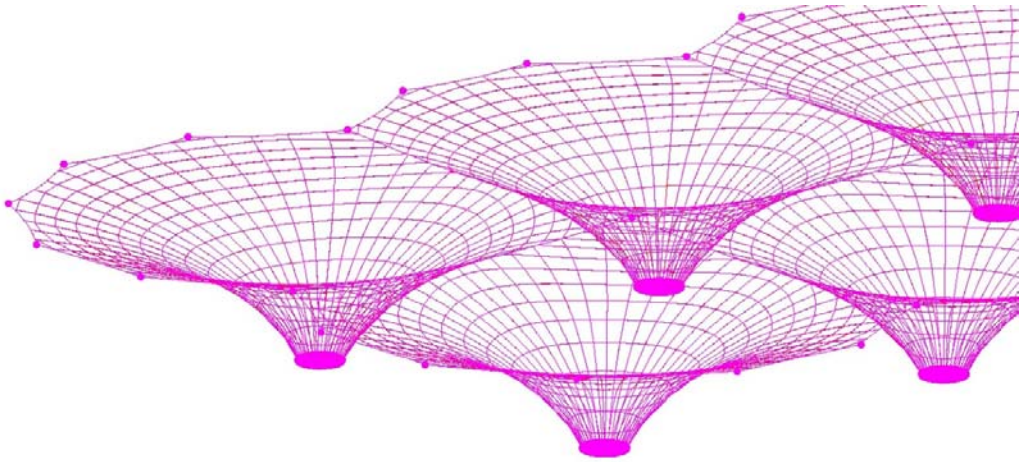

Figure B.7 Prestress+Selfweight-Deflection

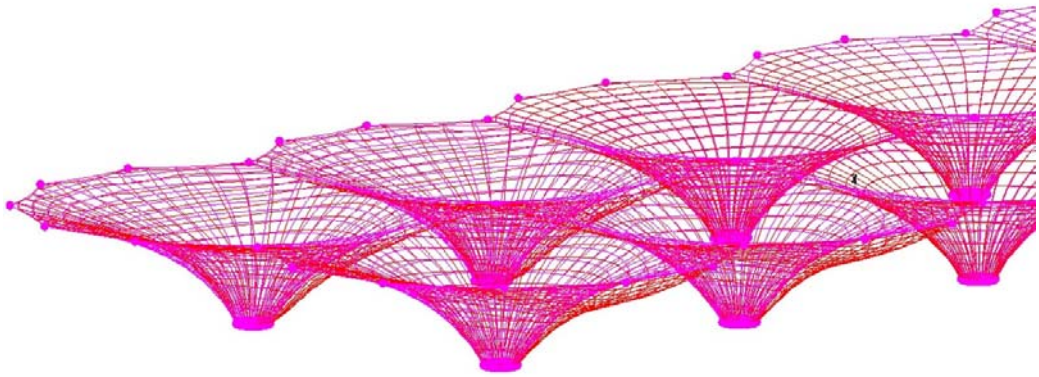

Figure B.8 Prestress+Selfweight+Wind.X.Pressure Load-Deflection

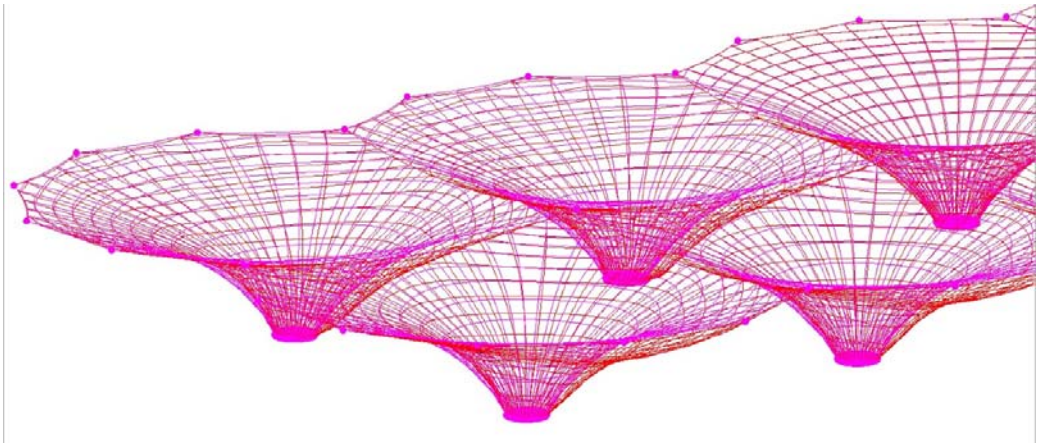

Figure B.9 Prestress+Selfweight+Wind.X.Suction Load-Deflection

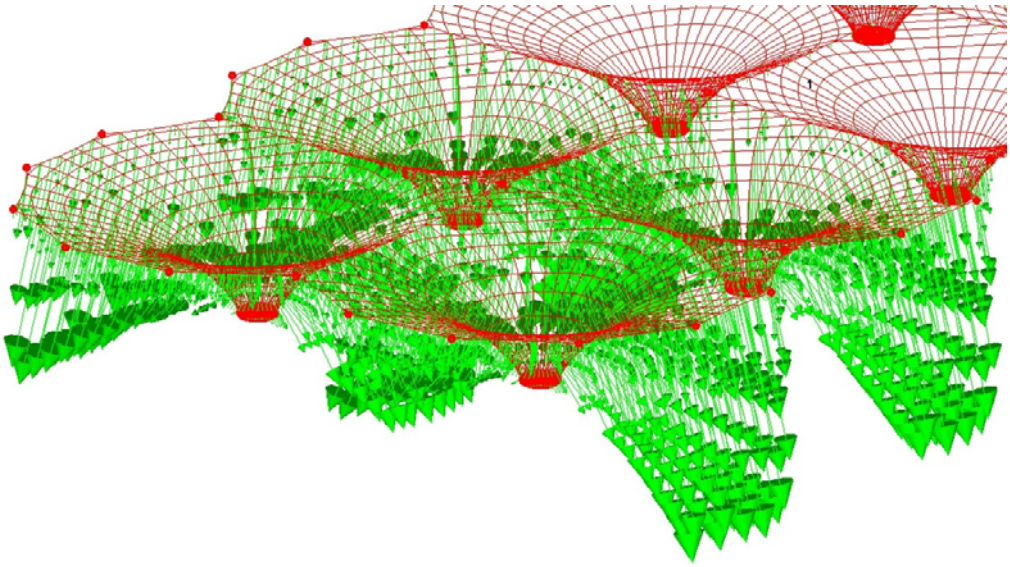

Figure B.10 Prestress+Selfweight+Wind.X.Suction Load-Vectors Only

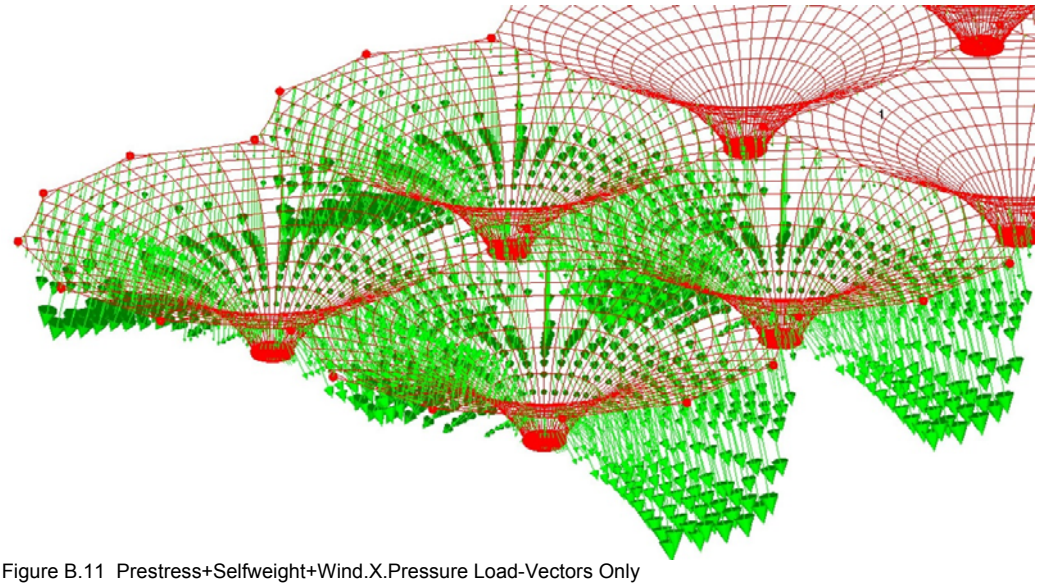

Figure B.11 Prestress+Selfweight+Wind.X.Pressure Load-Vectors Only

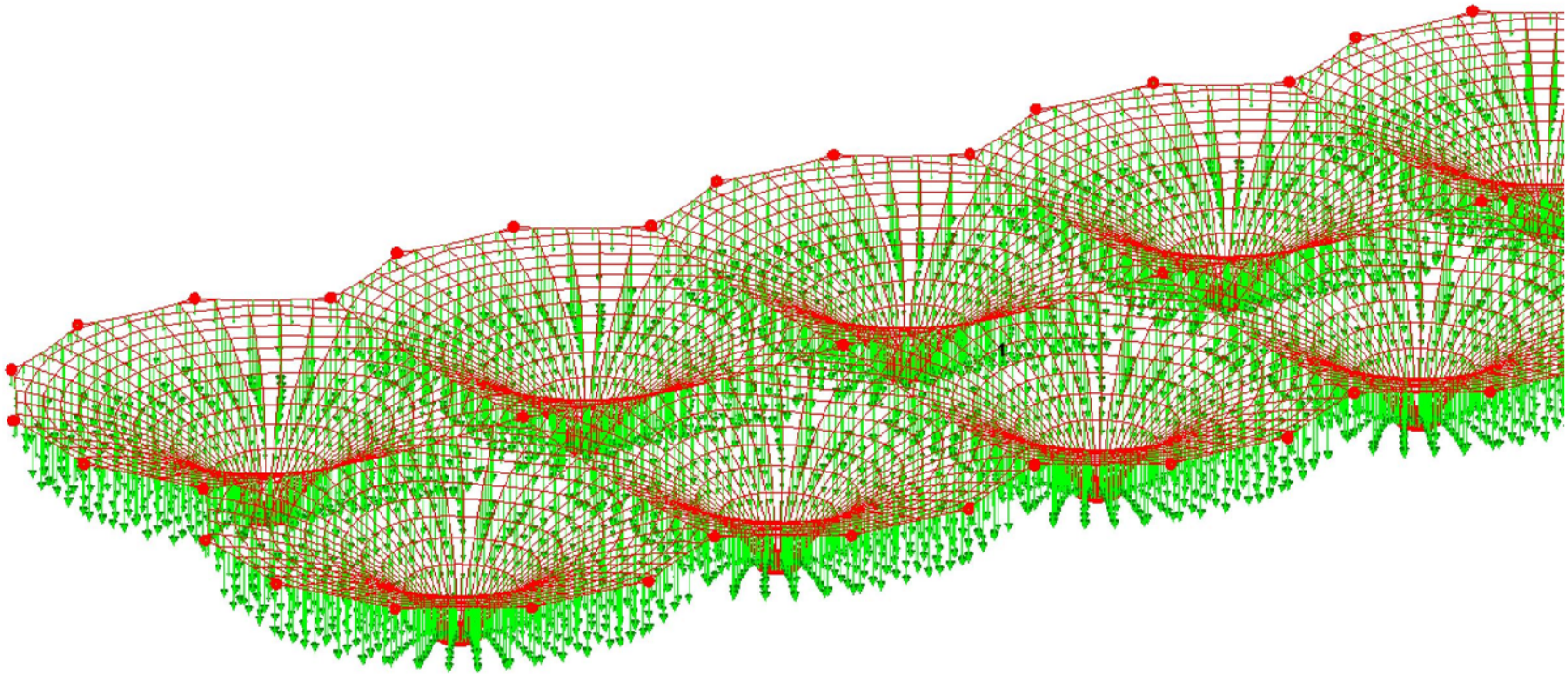

Figure B.12 Prestress+Selfweight+Dead Load-Vectors Only

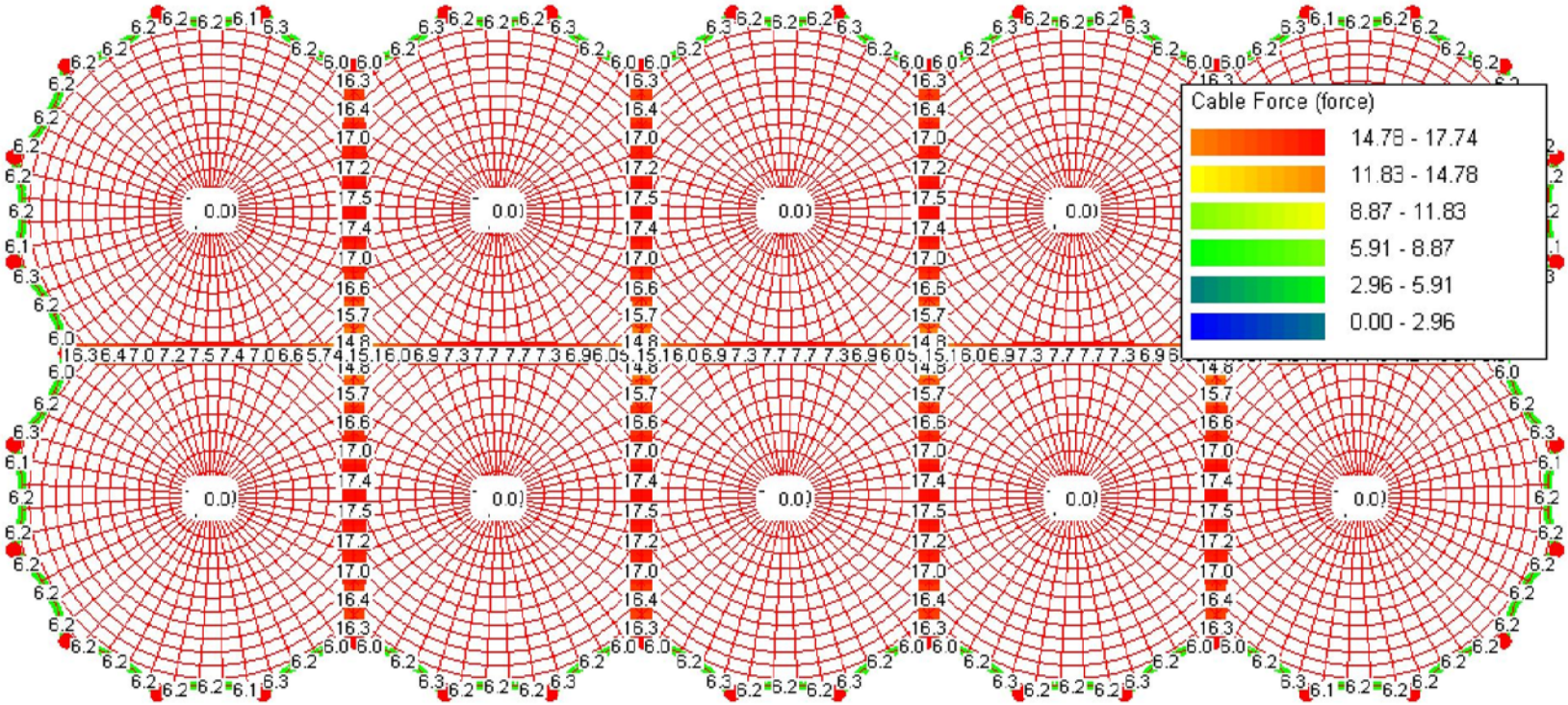

Figure B.13 Cable Forces-only prestress

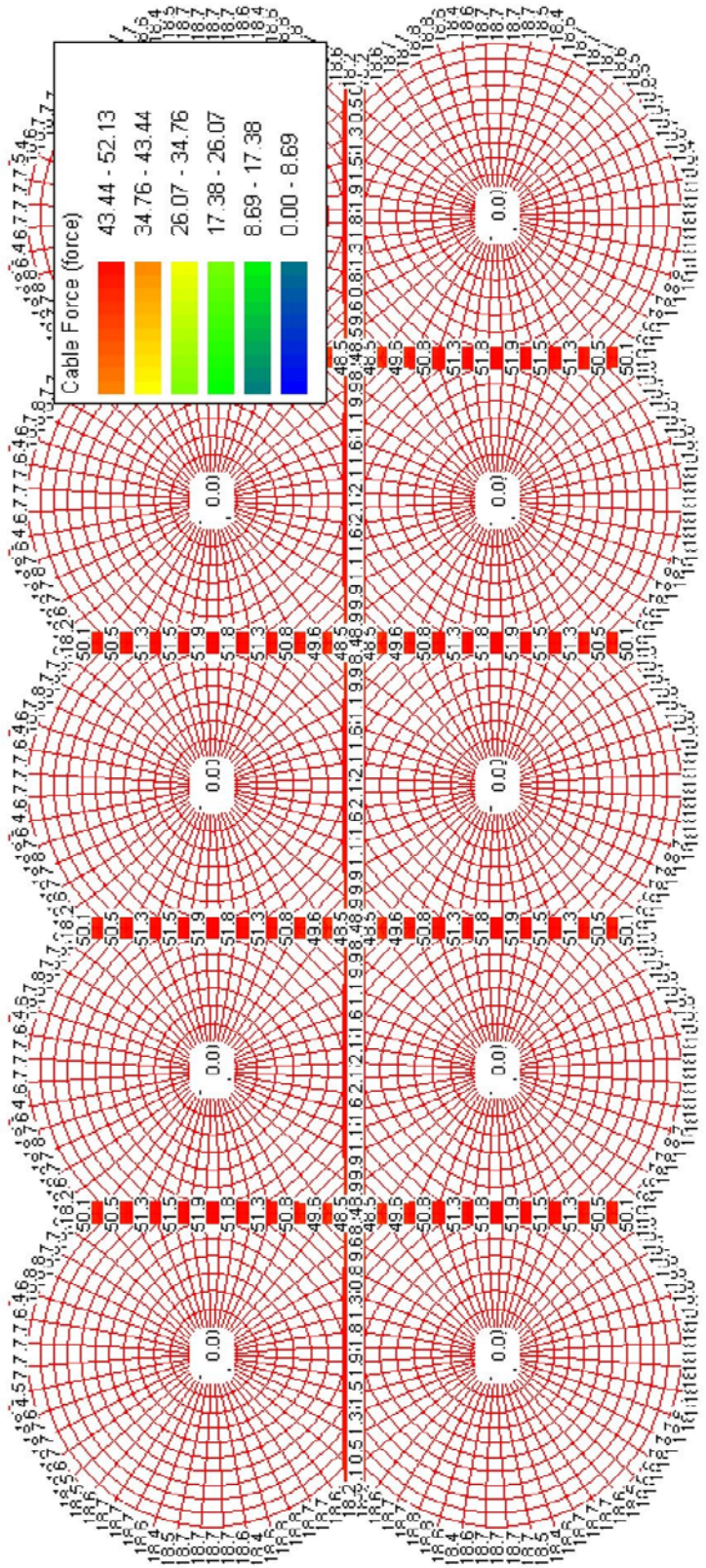

Figure B.14 Cable Forces-PTFE- only prestress

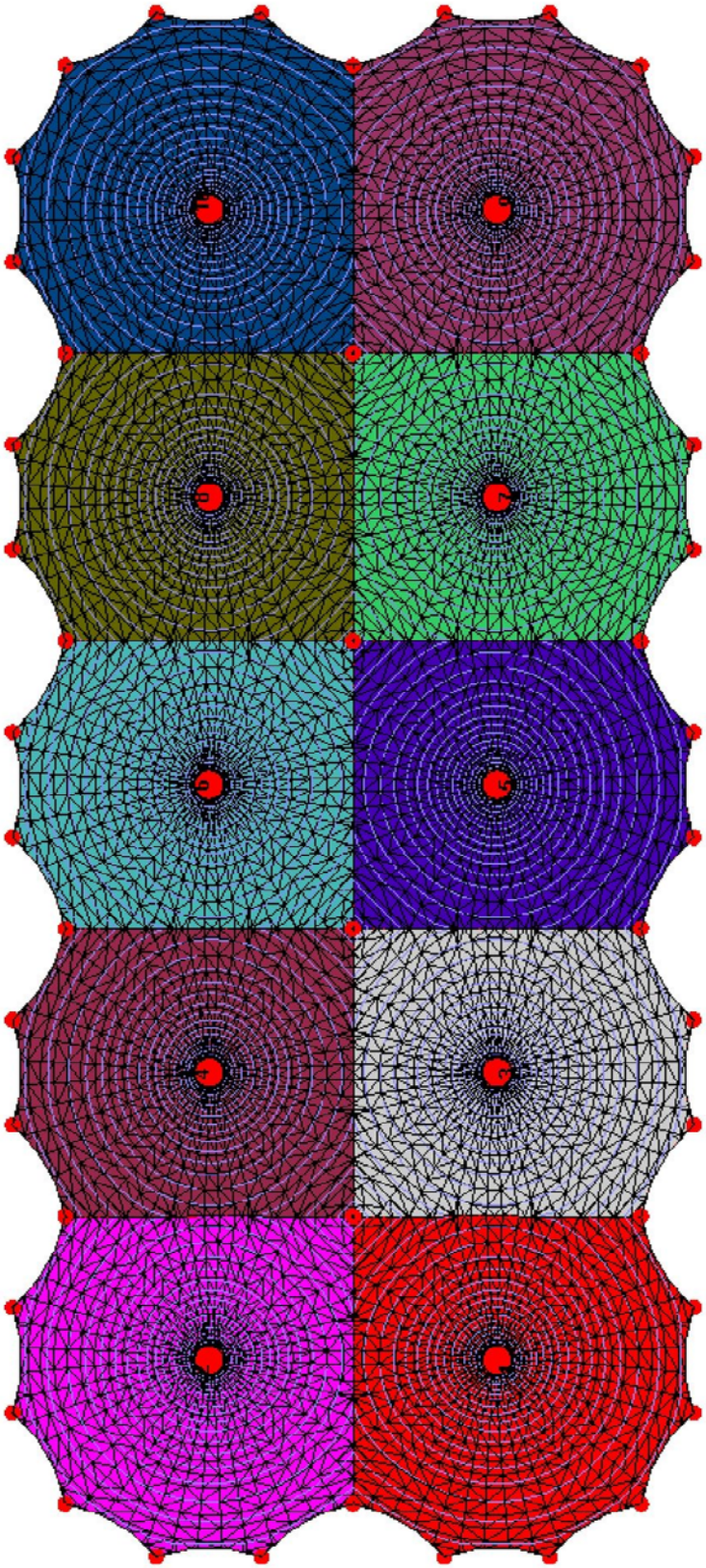

Figure B.15 Contour Lines

APPENDIX C

DATA SHEET OF FABRIC OCF 375

APPENDIX C: DATA SHEET OF FABRIC OCF 375

The two solutions developed for the shading structure in Chapter 5 used Teflon coated woven glass fibre fabric, which normally has a tensile strength of up to 150 KN/m^2. The fabric which was recommended for the shading canopy of both designs was a fabric called Structo Fab OCF 375 and was produced by the American company Owen Corning Fibreglass. (Happold, 1983) The properties of this fabric are listed in the table below and were tested according to Federal Standards and by Owen Corning Fibreglass:

Fabric	**Grade**	**Testing Method**	
Structo Fab	375	Federal	OCF
Weight: Ave. (g/m^2)	1271.465	5041	W-01 Cg
Weight: Min. (g/m^2)	1169.74		
Thickness (mm)	0.8128	5030	D-01 Ja
Strip Tensile (KN/cm)		5102	S-26 C
Dry Warp	0.910		
Dry Fill	0.750		
Wet Warp	0.770		
Wet Fill	0.630		
Trapezoidal Tear (KN)		5136	S-94 Ad
Warp	0.155		
Fill	0.169		

BIBLIOGRAPHY

Bibliography

1. AlGadhi, Saad A.H. (1996). *A Review of Crowd Behavior and Movemement*. Journal of King Saud University, Riyadh, Saudi Arabia.
2. Alnabulsi, H., & Drury, J. (2014). *Social identification moderates the effect of crowd density on safety at the Hajj*. Proceedings of the National Academy of Sciences of the United States of America, 111(25), 9091–9096. http://doi.org/10.1073/pnas.1404953111
3. Alafghani, A. S. (1987). "*Study of the Hajj to the Holy City and a design of the pilgrims accommodation center in Makkah, Saudi Arabia*." Unpublished.
4. Alkhaldy, I. (2009) A critical spatial analysis of residential planning in Makkah, Saudi Arabia.
5. Atmospheric Industries Ltd. and Buro Happold. (1983). "*Hajj Walkway Shade Structures – a Feasibility Study*". Unpublished Professional Report, Hajj Research Centre.
6. Beukers, Adriaan, Ed van Hinte, and Gert Staal. (1998). Lightness: the inevitable renaissance of minimum energy structures. Rotterdam: 010 Publ.
7. Brownson, John A. M. Jamil (1982). *"Hajj Studies: A Meta-geographic Inquiry".* Unpublished Master of Science Thesis. Western Washington University, USA.
8. Campo, J. E. (2009). Encyclopedia of Islam. Infobase Publishing.
9. Fetini, Alyssa (2009). *"A Brief History of the Hajj"*. http://content.time.com/time/world/article/0,8599,1864624,00.html – retrieved on August 27, 2015.
10. Fruin, J. (1992). Designing for pedestrians. Public Transportation United States.
11. Gdoura, Mohammed Khaled, Löhner, Rainald , Haug, Eberhard, Gawenat, Bernhard. (2014) "*On the influence of columns in densely populated corridors*". The Conference on Pedestrian and Evacuation Dynamics 2014 (PED2014). Transportation Research Procedia 2 (2014) 2 – 9.
12. Gibson, J. I. (1978) "*The Framework For Hajj Simulation Models: A Preliminary Report*". Hajj Studies, 2, pp. 39.
13. Harrison, D. (Ed.). (2001). *Tourism and the less developed world: issues and case studies*. Cabi.
14. Hijazi, Yousuf (1986). "*Pilgrim Accommodation System in Mina Valley, Saudi Arabia*". Master's Thesis, Illinois Institute of Technology.
15. Khan, Hasan-Uddin, editor. (1982) "*Frei Otto's New Work*". Mimar 4: Architecture in Development. Singapore: Concept Media Ltd..
16. Koolhaas, R. and Reisz, T. (2010) Al Manakh: Gulf cont'd, Amsterdam: Stichting Archis. Al Manakh: Gulf cont'd.
17. Long, David E. (1979). *"The Hajj Today: A Survey of the Contemporary Pilgrimage to Makkah".* SUNY Press.
18. Makky, Ghazy. (1978) Mecca, the pilgrimage city: a study of pilgrim accommodation,

19. Mirzā, M. N., & SHĀWŪSH, ‘. A. I. S. (2011). The illustrated atlas of Makkah and the Holy Environs: from the 11th century to the present day. Makkah al-Mukarramah, Center of Makkah History.
20. Othman, F. M. (2003) *A system of mobile service units for the large-scale event industry: an implementation for the Hajj, the pilgrimage to Makkah, Saudi Arabia*. Unpublished.
21. Otto, Frei, et al. (1976) “*Zelte – Tents”.* IL 16. University of Stuttgart.
22. Peters, F. E. (1994). “*The Hajj: The Muslim Pilgrimage to Mecca and the Holy Places”*. Princeton University Press.
23. Porter, Venetia and Saif, Liana. (2013 *)“The Hajj: Collected Essays”*. British Museum Research Publication No. 193, December 2013.
24. Rasch, Bodo. “*Die Zeltstädte des Hadsch - The Tent Cities of the Hajj*”. IL 29. University of Stuttgart, 1980.
25. Rasch, B. (1980) The tent cities of the Hajj, Institute for Lightweight Structures. The tent cities of the Hajj.
26. Sardar, Ziauddin. “*Hajj Studies Vol. 1*”. Croom Helm, London, 1979 (UK).
27. Sardar, Z. (1978) The information unit of the Hajj Research Centre. in Aslib Proceedings: MCB UP Ltd. pp. 158-164.
28. Sardar, Z. (1978) The Spiritual and Physical Dimensions of the Hajj: A Systems Overview. Hajj Studies, 1, pp. 27-37.
29. Sijiny, R. (2010) The Hajj is a Myriad of Details—Bodo Rasch. Volume, (1), pp. 138.
30. Hajj Walkway Shading Structure by Atmospheric Industries & Buro Happold, 1983.