



# opportunity to rise

designing a tall building in Cape Town

Design Research Project APG5058S

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Master of Architecture (Professional)

by

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# 1. Introduction

The issue taken on in this project is the design of a tall building in Cape Town. The Cape Town CBD is locked geographically between the mountain and sea, limiting its expansion. This has resulted in an increased land value there and a motivation to build tall. Since 1994 a height limit of 60m has been imposed in the city, which has now been challenged. The first post-Apartheid tall building is currently under construction in Cape Town, reaching a height of 150m. It shows that tall buildings are an issue which architects in Cape Town will have to engage with once again.

Lesley Beedle, founder of the Council for Tall Buildings and Urban Habitat (CTBUH) wrote that a tall building “*is a building whose height creates different conditions in the design, construction, and operation from those that exist in “common” buildings of a certain region and period*” (CTBUH, 2011). The style, height and visibility promote tall buildings as cultural icons (Jencks, 2002). It is for these reasons that the design of a tall building is an interesting topic for an architectural thesis.

The project aims to present a holistic scope of engagement when it comes to the design of a tall building, engaging with the issue at an urban scale as well as in detail. A part of the focus is to show a technical understanding of tall buildings, to show that they are not low buildings extruded vertically but are technically distinct. With the re-emergence of tall buildings, it is an aim to present a next step in tall building design in Cape Town, whilst adding a new landmark to the city’s skyline.

The structure of this report will be to present the design development in a sequential manner, following the design process. The second chapter provides an overview of the research done and the key findings on tall building typologies. The third chapter involves the choice of site as well as site analysis. The fourth, and main body of the report, is the documentation of the design development throughout the year.

## Defining a Tall Building

As a starting point, it is helpful to define what is meant by “*tall building*” or “*high-rise*” or “*skyscraper*”. The definition is not a simple one. Kenneth Yeang argues that the term “*skyscraper*” has more clarity to it than “*high-rise*” or “*tall building*” as it does not imply relativity. However, others would argue that it cannot be seen in isolation but rather in relation to its time and surroundings. A tall building can therefore be defined in relation to its scale in local context, where a tall building is one which is significantly taller than the surrounding buildings. In essence, the technical design differentiation as well as the contextual distinction (Strelitz, 2005) of tall buildings is what set them apart from others.

What is considered tall varies geographically. In Cape Town the tallest buildings are in the range of 120m high. In Asia and North America there are a significant number of buildings exceeding 400m in height. Therefore for the purpose of this project a tall building will be defined in relation to context; one which creates different conditions in the design, construction and operation from those that exist in “*common*” buildings in Cape Town. (Beedle, CTBUH, 2005)



FIGURE 1: Cape Town CBD (google images, edited)

The CBD contains a number of relatively tall buildings, constructed between 1960 and 1993. It shows that the land value of plots and economic booms at certain time periods had motivated developers to build tall.



FIGURE 2: Portside, Cape Town (Karol, 2009)

The Portside tower is expected to be completed next year. It is set to be the first post-apartheid high rise building in Cape Town. It is a mixed-use building consisting of 33 000m<sup>2</sup> office space, a 14 000m<sup>2</sup> hotel and a small retail component of 2 500m<sup>2</sup>. The area of the site is 6 500m<sup>2</sup>, flanked by three wide avenues. It represents a shift away from the typological tall office buildings.



FIGURE 3: Photocollage of Cape Town CBD showing thesis intervention (author)

## 2. The Tall Building Typology

### 2.1 A Brief History of Tall Building Typologies

Tall buildings have existed for a long time. Before the 19th century there were tall buildings such as terraced temple mountains, pyramids, amphitheatres, fortresses, city halls, mosques, cathedrals and towers of various types. This section will however take the first large office buildings built in Chicago at the end of the 19th century as the starting point in the historical overview of tall buildings.

In 1870, Chicago had a population of 300 000, by the end of the 19th century the population had increased to 1.7 million. Building high on the smallest possible footprint was not a demonstration of power but a reflection of economical necessity (Eisele & Kloft, 1999).

Its development was decisively influenced by the inventions of the age; safe elevators and skeleton steel construction made of rolled iron sections. The earliest tall buildings in Chicago did however not seek to express the lightness and power of the steel skeleton but rather adopted a classical appearance with the horizontality of their natural brick and stone facades expressed. New soaring expressions of the vertical structural elements soon began to be theorised. Louis Sullivan (1856-1924) can be considered as the first theoretician of tall building aesthetics, and was influential in formulating the ethos "form follows function" (Eisele & Kloft, 1999).

The new style, which became known around the world as the "Chicago School" helped pave the way for the Modern Movement. The structure as the form giving element was to be made clearly visible from outside. Sullivan also devised the first rules for designing high-rises: the tripartite division. He divided the building into base, shaft and capital to render the scale of tall buildings legible. This can be seen as typological of tall buildings of all epochs, although it was barely seen in Chicago at the time. A law passed in 1893 drastically limited the permissible height of buildings to 40m which temporarily halted the further development of tall buildings in Chicago. New York then became the centre of tall building construction.

At the beginning of the 20th century in New York, speculators demands sent tall buildings to new heights. The designs appropriated historicist forms to in an attempt to soften the futurist image of the high-rise. The vertical elements of gothic architecture proved very suitable for creating a stylised mask to clad the high-rise. Attention was given in particular to accentuating the pinnacles, turning them into symbolic advertisements for the building. In 1916 zoning laws were enforced which prescribed the construction of the so-called "setback building" (Eisele & Kloft, 1999). Tall buildings as a result took the form of three distinct zones, with greatly extended pinnacles. The style created is often referred to as the "wedding cake style".

In the early 1930s, two of the world's most famous skyscrapers were constructed; the Chrysler Building and the Empire State Building, which set the limits of steel skeleton construction with the Empire State Building remaining the world's tallest building for 40 years. It can be considered as the archetype of the skyscrapers constructed in the economic boom of the "Golden Twenties", before economic crisis and a radical change in the spirit and style of modernism brought about a new epoch in tall building design.

In 1937 Gropius was offered a position at Harvard. In that same year Laslo Moholy-Nagy founded the new Bauhaus in Chicago. In 1938 Mies van der Rohe became the director of the Illinois Institute of technology; the modernists had entered the arena of high-rise design and the International Style took shape. Between 1948 and 1969 Mies van der Rohe designed fourteen high-rises in Chicago, which gave him the chance to develop and perfect an archetype. It was based on simple cubic forms showing great attention to detail, rejecting the notion that each individual high rise building had to have a unique character. It became the prototype for the modern office tower, with Mies van der Rohe style towers replicated all over the world.



FIGURE 4: Home Insurance Building, Chicago, William LeBaron Jenney, 1884 (google images)

The early Chicago tall buildings did not strive for verticality and lightness in expression. The heavily clad structure is reminiscent of classical Italian Renaissance compositions.



FIGURE 5: Woolworths Building, New York, Cass Gilbert, 1914 (google images)

Gothic elements were used as part of the architectural expression



FIGURE 6: Seagram Building, Chicago, Mies van der Rohe, 1958 (google images)

The archetype of the International Style. The Seagram Building by Mies van der Rohe was innovatory with respect to urban planning; it was set back from the property line, creating a large plaza in front. This influenced New York's new building legislation, passed in 1961. It permitted greater floor area concentration in return for public space on the site (Eisele & Kloft, 1999). Where the top had once been the most significant element of tall buildings, this new type of tall building focussed attention on the base as the public zone. The greater floor ratios allowed triggered a building boom. A major problem arose however, when several of these buildings were placed alongside one another the plazas would pass into one another uninterrupted, dissolving the property line completely and creating an unsatisfactory urban setting. In 1981 the laws were changed and stipulated a maximum setback of 3m in order to preserve the property line (Eisele & Kloft, 1999).

In the 1970s and 1980s, architects began searching for alternatives to the stereotypical buildings of the modern movement. Post-modern high-rise architecture rejected purely defined forms and technical elements were exaggerated to create decorative details, or alternatively concealed behind historicist or symbolic facades. The tripartite division played an important role in the expression of post-modern high-rise architecture. The tall buildings designed by Michael Graves are characterised by an independent base pushed up against the street edge and the tower set back from the base. The base would house public functions such as retail and other public attractions, distinguishing the tower and base as two separate zones. In addition, post-modern high-rise buildings often had conspicuous thematic expression given to the top of the building. Since the 1970s it has become difficult to consider the typology of tall buildings as a chronological evolution as styles have developed parallel to one another.

In Europe, tall buildings did not feature as a building type until after the First World War. The initial euphoria of tall buildings, the protagonists of which were the early modernist architects such as Le Corbusier, was quickly followed by scepticism; the organically grown European city was less suited for the American model.

Despite the relatively late development of the tall building type, Europe played an important role in the development of new materials and construction methods at the end of the 19th century. In 1851 Joseph Paxton's Crystal Palace, an all skeleton building, became the prototype of the structural mode of construction. The use of iron in combination with glass created the aesthetic for this new building type: the railway, market and exhibition hall. The 300m high tower designed by Gustav Eiffel for the 1889 World Exhibition in Paris marked a new milestone for skeleton construction. The use of rolled iron and sheet section and the use of riveted joints made the structure lighter and easier to calculate, marking the technical and structural preconditions for tall high-rise construction. In France, August Perret and Le Corbusier advocated the concept of high rises as part of large urban development projects, redressing the cramped city with designs involving large traffic axes and green strips between towers.

In Russia, the development of high-rise buildings began with the idea of creating symbolic representations of a new society. In 1919 the Tatlin Tower was conceived, a 300m high spiralling iron and glass building and monument. The tower was never built, but it reflected a strong belief in modern technology. There were countless competitions and architectural experiments in Russia which were never built, but did make a significant contribution to the theory of tall building design.

In addition to Frankfurt, London is one of the few European cities which have seen the successive development of tall buildings in the city centre. As a matter of principle, tall building locations tended to be of both commercial and visual significance. During the past few years tall building developments in London have evolved a powerful dynamic of their own. The building boom in Docklands started in the year 2000, with a number of tall buildings such as the Swiss Reinsurance Building by Norman Foster and the London Bridge Tower by Renzo Piano setting the bar for contemporary tall building design.



FIGURE 10: Docklands and London Bridge precinct (google images)  
The architectural expression is diverse and highly articulated.



FIGURE 7: Humana Building, Louisville, Michael Graves, 1986 (google images)



FIGURE 8: Plan Voisin for Paris, Le Corbusier, 1925 (google images)

In the plan, Le Corbusier proposed to bulldoze most of central Paris north of the Seine, and replace it with his sixty-story cruciform towers from the Contemporary City, placed in an orthogonal street grid and park-like green space



FIGURE 9: Monument to the Third International, Moscow, Vladimir Tatlin, 1920 (google images)

The Thrid International was an organisation that aimed to unite all Communist parties around the world. Steel spirals bear large, variously sized glass cubes which house different rooms, such as meeting rooms at the base.

Currently, the tallest buildings in the world are found in Asia. In 1998, the architect Cesar Pelli designed the Petronas Towers in Kuala Lumpur. At 452m, the twin towers were the tallest buildings of the time, with a total useable floor area of 1.82 million square meters (Eisele & Kloft, 1999). In the social context of an African or European city, a building of this magnitude would have been unacceptable. In Asia however such projects are constructed despite the absence of infrastructure and compensatory space, often causing the collapse of transport systems and a dramatic deterioration in climatic conditions. Asian cities such as Shanghai grow unrestrained, adapting to new economic realities. A study carried out by architect Rem Koolhaas together with Harvard University students in 1996 examined the phenomenon of the explosive overdevelopment in the Chinese Pearl River Delta. The study provided a framework for describing the urban reality found in these megacities and the mega-skyscrapers found there.



FIGURE 11: Petronas Towers, Kuala Lumpur, Cesar Pelli 1998 (google images)  
The twin towers represented the idea of a mega-skyscraper, a city within a building.

## 2.2 Tall Buildings in South Africa

In South Africa, the first building over 80m tall was the Mutual Heights Building in Cape Town, constructed in 1939. The real boom in tall buildings came in the 1970s, with a large number of speculative office developments taking place, particularly in Johannesburg and Durban, inspired by the booming economy. The Mutual Heights building took its aesthetic cues from the early Chicago skyscrapers with classical composition and stone cladding. The next tall building was constructed more than twenty years later in 1962 with the Naspers Centre, also in Cape Town. It represented a shift in architectural expression, where the skeleton frame and lightness of the building was expressed with straight lines. The vast majority of tall buildings in South Africa adopted the skeletal rigid frame construction principle as found in the steel framed buildings in the USA, but simply used concrete as the structural material.



FIGURE 12: Standard Bank Centre, 1968 (google images)

The Standard Bank Centre in Johannesburg by the architects Hentrich-Petschnigg and Partners, constructed in 1968 gained international acclaim for its innovation in concrete construction, using suspension elements to carry the loads.

In 1970 the ABSA Centre in Cape Town was constructed. It mimicked the purist form and aesthetic expression of the International style inspired by Mies van der Rohe, which had gained prominence in the USA at the time. Unlike the American counterparts, the structural frame of the ABSA Centre is of concrete, concealed behind a carefully composed Cartesian façade of tinted glass. Unlike the "miesian" skyscraper, the ABSA Centre is composed of a tower which rests on a block which houses commercial functions and parking. The pure form and slenderness of the tower make it one of the most iconic buildings in Cape Town, occupying a prominent location in the city and its skyline.



FIGURE 13: ABSA Centre 1970 (google images)

The BP Centre by Revel Fox in 1972 is truly modern in its expression, with an exposed concrete superstructure which is articulated and coupled with shading elements which respond to the buildings local climate and orientation. The building expresses aesthetic qualities of the *beton brut* (exposed concrete) architectural language, a derivative of the late Modern Movement in architecture. Circular columns, sculptural shading devices, monolithic with the structure, and filleted corners of the building help express the nature of the material used. Unlike the ABSA Centre, which is composed of a tower and block, the vertical tower of the BP Centre reaches to the ground as a singular form, with a separate building mass which houses the parking below ground floor. The BP Centre represents conformity to the vernaculars of the corporate tower in terms of its spatiality and form, yet at the same time strives to reconcile these with local contextual concerns.



FIGURE 14: BP Centre by Revel Fox 1972 (google images)

In 1973 the Carlton Centre in Johannesburg was completed. It remains the tallest building in Africa at 223m, designed by Skidmore Owings and Merrill (SOM). The structural system is the rigid frame which was the predominant structural system at the time. The perimeter structure took the form of concrete post and beam construction with a closely spaced column grid. Like the ABSA Centre, the Cartesian tower sits on a block housing parking. The tall building boom in Johannesburg happened in the 70's, with 12 tall buildings constructed between 1970 and 1976. Since 1976 there has only been one tall building, the Kwadukuza Egoli Hotel, constructed in 1985 and is 140m tall. 1976 is remembered as a turbulent time politically in Johannesburg with the Soweto uprisings of June 16th marking a turning point in the resistance movement, followed by mass protests, particularly in Johannesburg.

The 140m high Kwadukuza Egoli Hotel has a striking form, with the building mass raised about 30m above ground floor. The structural system used is a core and outrigger, a novel approach to structure in South Africa. A large tapered cantilevering member from the core transfers the vertical loading from the floors above back to the core. The fully glazed façade conceals the structure, emphasizing a monolithic and simple form extruded vertically. At the base a large plaza is created with the central core and cantilever exposed making the structural system legible. The approach taken here reflects a firm belief in the principles of Modern architecture, yet develops an architectural language quite different from the typical tall office buildings of the time.

The Shell House (later renamed the Atterbury House), built in 1976 in Cape Town exemplifies a typological tall building design. The structural system used is a central core with cantilevering floors. Additionally, there are four slender shear walls at each corner of the square envelope to provide lateral stability. The floor plates are roughly 1000m sq, arranged around a central core which allows for the easy subdivision of the floor plate. Because the perimeter is not composed of a rigid frame, the horizontal bands of the floor plates are expressed rather than the vertical members.

In 1993 the Triangle House (also known as Safmarine House) by Louis Karol architects was completed. It is post-modern in its appearance, with historical and symbolic dressing of the façade. The façade is constructed of a mixture of three types of granite, as well as precast concrete cladding upon a concrete frame. Exaggerated and structurally superfluous concrete frames project from the top of the building. The pinnacle of the building is capped by a pyramid shaped roof, oriented 45 degrees from the shaft. The cruciform floor plan allows for shallow office space with good natural light and views. There are roof terraces on the 22nd and 23rd floors and the wings of the building span 53m from tip to tip. This indicates that the cruciform plan employed here is not very economically productive, with distances of less than 25m from the tip of each wing to the central core, when distances of 45m are allowed. In addition, the ratio of building wall to floor area is also not economical as a result of the form. Once again, the visual expression coincides with typological changes and predominant trends in the tall buildings found in the USA at the same period in time. The Triangle House is the last of the tall buildings to be completed in Cape Town. In the early 90s a height restriction of 60m was imposed which halted the development of tall buildings.



FIGURE 15: Carlton Centre, 1973 (google images)



FIGURE 16: Egoli Hotel, 1985 (google images)



FIGURE 17: Shell House, 1976 (google images)



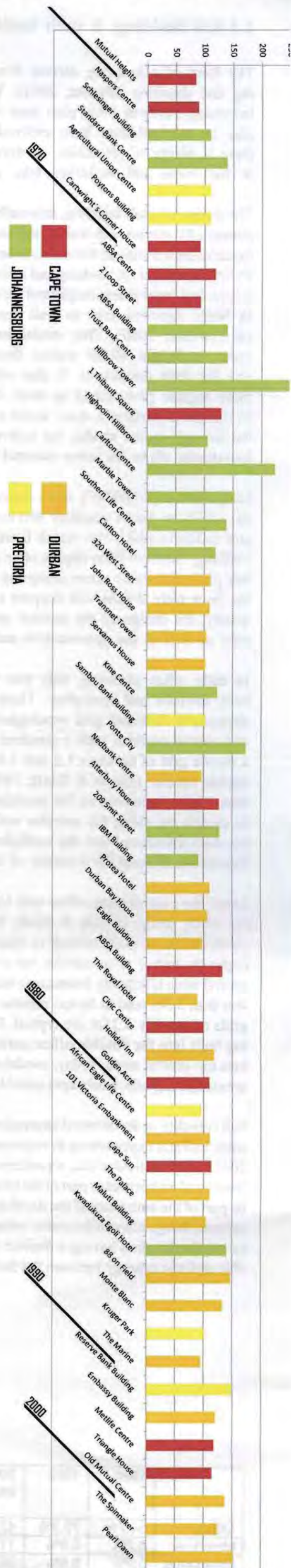
FIGURE 18: Safmarine House, 1993 (google images)

In conclusion, one could say that the tall building type in South Africa died in the early 90s, at the same time of the most significant political and social changes which the country has ever experienced. In terms of typology, it must first be stated every tall building in South Africa has been constructed using reinforced concrete as the structural material. This undoubtedly reflects the skills and economics of the construction climate in South Africa. However, the structural systems employed, to a very large degree, have not explored the structural and formal possibilities of reinforced concrete but rather emulated the steel framed construction principles used for the American skyscrapers. Spatially, central core arrangements have dominated, using modular office plans and uniform rectangular or square floor plates stacked vertically. This largely reflects the market forces which drive tall buildings, with simple forms comprising of repetitive and economically productive floor plates. As such, one can describe the typological developments of tall buildings in South Africa as having largely followed the models found in post World War Two USA.

In contrast to the tall building developments of Docklands in London, the tall buildings found in urban centers of South African cities are not characterized by highly articulated and diverse forms, they to a large degree share a prototypical approach to design based on well established tall office building typologies of the Modern Movement. It must however be mentioned that in South Africa tall building construction reached its end in the early 90s, whereas the Docklands high-rise developments took place from the late 90s onwards. Since the end of the tall building period of South Africa there has been an evolution in the approaches to tall building construction internationally. This could inspire the South African tall buildings of the near future.

BUILDING NAME	HEIGHT (m)	YEAR	CITY
Mutual Heights	24	1973	Cape Town
Naspers Centre	26	1972	Cape Town
Schlesinger Building	110	1965	JHB
Standard Bank Centre	139	1968	JHB
Agricultural Union Centre	110	1968	Pretoria
Poytons Building	110	1968	Pretoria
Cartwright's Corner House	91	1970	Cape Town
ABSA Centre	105	1970	JHB
2 Loop Street	140	1970	JHB
Trust Bank Centre	140	1970	JHB
Hillbrow Tower	270	1971	JHB
1 Thibault Square	128	1972	Cape Town
Highpoint Hillbrow	105	1972	JHB
Carlton Centre	223	1973	JHB
Marble Towers	152	1973	JHB
Southern Life Centre	138	1973	JHB
Carlton Hotel	119	1973	JHB
320 West Street	110	1973	Durban
John Ross House	109	1973	Durban
Transnet Tower	103	1973	Durban
Servamus House	102	1973	Durban
Kine Centre	123	1974	JHB
Sambou Bank Building	102	1974	Pretoria
Ponte City	173	1975	JHB
Nedbank Centre	96	1975	Durban
Atterbury House	107	1976	Cape Town
209 Smit Street	128	1976	JHB
IBM Building	91	1976	JHB
Protea Hotel	110	1976	Durban
Durban Bay House	106	1976	Durban
Eagle Building	96	1976	Durban
ABSA Building	132	1976	Pretoria
The Royal Hotel	89	1977	Durban
Cape Centre	107	1978	Cape Town
Holiday Inn	118	1978	Durban
African Eagle Life Centre	95	1980	Pretoria
101 Victoria Embankment	110	1981	Durban
Cape Sun	117	1981	Cape Town
The Palace	110	1983	Durban
Maluti Building	104	1984	Durban
Kwadukuza Egoli Hotel	140	1985	JHB
88 on Field	147	1985	Durban
Monte Blanc	133	1985	Durban
Kruger Park	100	1985	Pretoria
The Marine	95	1987	Durban
Reserve Bank Building	148	1988	Pretoria
Embassy Building	120	1991	Durban
Maluti Centre	98	1991	Cape Town
Standard Bank	88	1992	Cape Town
Old Mutual Centre	137	1995	Durban
The Spinnaker	124	2007	Durban
Pearl Dawn	152	2010	Durban

FIGURE 19: Tall Buildings in South Africa (author, CTBUH database)



## 2.3 Tall Buildings & their Built Form

The form of a building derives from its height, proportion, massing and detailing (Strelitz, 2005). These are crafted from the relationship between floor plan area and height. Trends and typologies in tall buildings have evolved over the last 120 years and there is plenty of precedent to draw upon. This chapter will look at the forms tall buildings take and their spatial organisation.

The design of a tall building, internally and its external appearance is a combined focus on corporate objectives and individual aspirations. Efficient design is critical; this needs to be balanced with creating high quality environments for working and living. The critical parameters for efficient design are storey height and the size of both the floor plate & core. In North America, core to wall depths of just over 20m are typical (Strelitz, 2005). This model has resulted in a ratio of floor space to height which makes them more economically productive for their developers. It also reflects the availability of larger, more regular plots found in most American cities (Strelitz, 2005). In Europe in particular, there seems to be a more assertive agenda on the internal spatial quality for individuals. Tall buildings with shallow depths allow for better external views and daylight penetration.

Large floors (2-3000m<sup>2</sup>) suit certain organisations. They also have the ability to house ancillary services such as entertainment venues and auditoria which can enrich living and working patterns within a building. Shallow floor depths offer good daylight and views, which has particular value when designing for residential use. Variation in the floor plate depths will support a wider range of activities. Ultimately, the design of the interior space will result from the clients brief as well as the opportunities and constraints offered by the site.

In early office planning, only two types of office were predominant; modular and open-plan. There were correspondingly two fundamentally different grid typologies: Two rows of modular offices and central corridor with a standard building depth of roughly 12m, a facade grid of between 1.2 and 1.8m and office widths of 3.6m for double rooms (Eisele & Kloft, 1999). A Building depth of greater than 13.5m is excessive for modular offices. File storage and built in closets set along the corridor wall were standard before computers were introduced into the workplace. Alternatively, open plan configurations allowed for a variety of facade grids and building depths.

Later, the combination office was introduced, offering new solutions for office design (Eisele & Kloft, 1999). Combination offices are a combination of workstations in single rooms with a direct link to a common central zone suitable for a variety of uses. The size of this central zone ultimately determines the building depth. Central zones of less than 3.5m tend to be too narrow for effective functioning. Facade grids of roughly 1.25m are typical. Glazed corridor walls with shelving built into the flexible office partitions can help bring natural light into the central zone. Today, modular, group and combination offices are competing office concepts suitable for different work requirements.

Individuality in the outward expression of tall buildings is embedded in some cultural expectations in response to their respective sites (Strelitz, 2005). At a particular site, a preference for individualism might come from local authorities as part of the urban design framework. It could also be part of the ambitions of the developers, architects and occupiers. The external image often helps create value for the building. Other approaches see the location having a distinct aesthetic deriving from considerable stylistic synergy between the individual buildings (Strelitz, 2005).



FIGURE 20: Manhattan Street Grid 1811 (Rivera, 2009)

The street grid of Manhattan was planned in 1808 by John Randal Jnr, secretary to the Commissioners of Streets and Avenues in the City of New York. Hills were flattened and rivers were filled in to achieve the grid pattern of Manhattan.

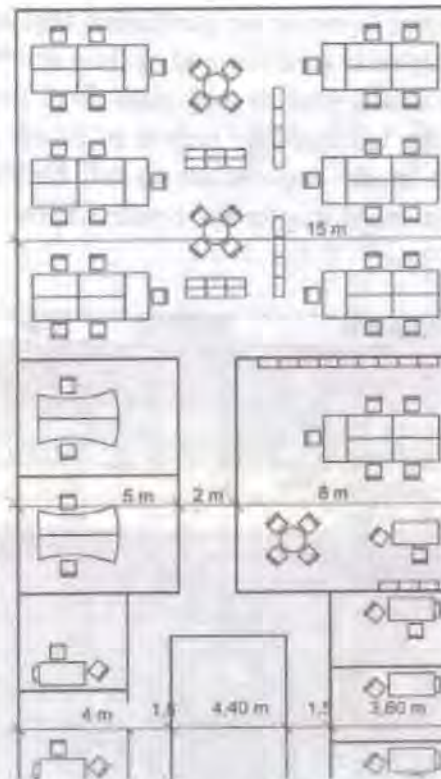


FIGURE 21: Office Arrangements (Neufert, 2009)

The diagram shows a combination of modular, open-plan and combination office modes within a building of 15m depth. A building of 15m depth can however result in excessively large modular offices and in this case it would most likely be composed of predominantly combination and open-plan areas.



FIGURE 22: Canary Wharf, London (Strelitz, 2005)

There is a degree of stylistic synergy between the buildings, giving the area a distinct aesthetic.

	1980	1995	2008 (estimated, including buildings under construction)
Office	84.7%	78.3%	47.3%
Mixed-use	5.2%	6.6%	11%
Residential	5.2%	9.6%	35.3%
Hotel	4.9%	5.5%	6.4%

FIGURE 23: Trends in Tall Building Functions (Woods, 2008)

The study looked at building over 150m in height worldwide. There has been a significant increase in residential and mixed use high-rise development.

Increasingly, we see tall buildings which cater for a number of office workmodes, with the form of the building adapting to depths required for each one. Tapered and stepping forms are often a result. Tall mixed use buildings also often have forms which adapt to the functional requirements. Apartments depths are largely determined by natural light penetration. Living/eating rooms and bedrooms are arranged along the facade as natural light is required, functions such as bathrooms, toilets, storage and kitchens are typically placed deeper in the floorplate and are lit artificially. Generally, good daylight penetration is received by the space within 8m of the facade, but this is influenced greatly by the ceiling height. Together with circulation corridors, a depth from wall to core of about 15m represents the upper limits for comfortable apartments. The shallower the depth, the more scope there is for natural light, however this needs to be balanced with creating sufficient lettable area to make the floorplate economically productive.

One important determinant is whether the building is owner occupied or whether it is a speculative development. With owner occupied buildings the floor plates can be designed according to specific needs and desires to suit a known occupant. Speculative development needs to allow for a far greater flexibility as occupants are likely to change numerous times.

**CORES:**

The service core placement and configuration becomes critical to the design. How the floor plate is split between tenants also has a fundamental impact on core placement as well as the efficiency of the building overall. A single tenant per floor is likely to yield the most efficient floor area ratios, whereas a floor plate configuration which allows for multiple tenants will result in the lowest floor efficiencies (Yeang, 2000). Placing the core at the end of the building will allow for large, unencumbered space but might make multiple tenancy difficult. Also, emergency escape route distances need to be carefully considered. Emergency escape requirements for single tenant and multiple tenants are also different.

The placement of the core can also play an important role in the energy consumption of the building. Using a split core with cores oriented east & west with glazing north & south has a lower cooling load than a central core design (Yeang, 2000). Cores can also be placed according to desired views, either from within the elevator or lobby, or from the internal space.

Service cores typically become the principle structural element for resisting both gravity and lateral loads. The placement of the core will also have structural impacts.

Centre core arrangements maximise the useable space at the buildings perimeter, allowing for more natural light. It is also a structurally efficient location and allows for efficient sub-division of the floor plate. Offset or end core arrangements do not break up the floor plate, and are particularly appropriate for small sites where centre core placements would make the space inflexibly small. Many sites do not offer an outlook in all directions and an end core can act as a parti wall. There are environmental benefits such as shading possible with end core arrangements. In conclusion, the core placement should reflect the nature of the space that is designed.

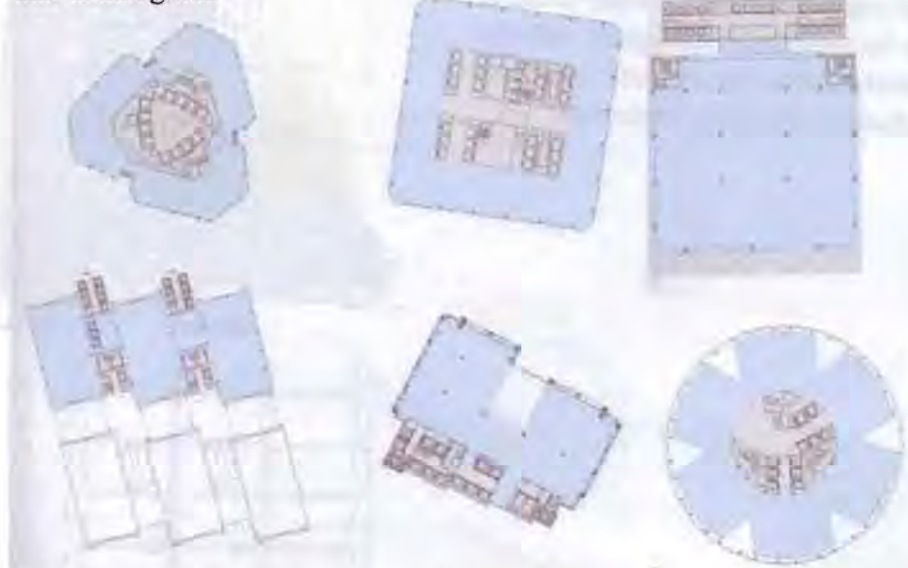


FIGURE 27: Service Core Placements (Strelitz, 2005)  
The image shows various core placements. The plans have a similar scale and orientation. From left to right:  
Top row:  
Tower 42, Richard Seifert and Partners 1980  
HSBC Canary Wharf, Forster and Partners 2002  
122 Leadenhall Street, Richard Rogers, 2007  
Bottom row:  
Grand Union Building, Richard Rogers 2004  
Heron Tower, KPF 2006  
Swiss re HQ, Forster and Partners 2002



FIGURE 24: 122 Leadenhall Street, London, Richard Rogers 2007 (Terranova, 2008)  
The tapered form of the building arose in response to sensitive views of St. Pauls church, but resulted in a form which accommodates a wide range of office work modes.



FIGURE 25: Plan of Commerzbank HQ, Frankfurt, Forster and Partners, 1997 (Howeler, 2003)  
The building features 3 cores placed at each corner of the triangular floor plate. Offices only occupy two sides, allowing the third side to open to multistory sky gardens and atria. Another aspect of this building is that it hardly experiences any sway due to lateral loading as a result of the placement of the split cores.

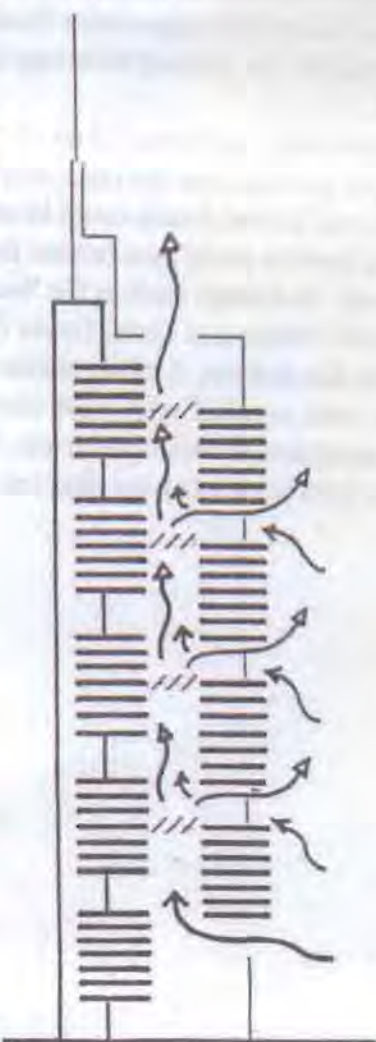


FIGURE 26: Section of Commerzbank HQ, Frankfurt, Forster and Partners, 1997 (Strelitz, 2005)  
The buildings sets a high standard for ecologically sensitive high rise building design. This section shows the natural lighting and ventilation strategy.

## 2.3 Structural Types

### Loads

When looking at gravity loads, the weight of the structure increases almost linearly with the number of floors, assuming the floor plate remains constant. For typical structures between 20-30 floors, the vertical load resistance nearly offsets the effect of lateral forces as only 10% of the total structural material is needed for lateral force resistance. However, with an increase in building height and slenderness, the importance of lateral force effects rises in a much faster and non-linear fashion; the material needed for the resistance of lateral forces increases as the square of the height. Therefore at a certain height considerations of stiffness and sway resistance rather than the strength of the structural material will shape the design of the structural system.

### Wind Loads:

In general, tall buildings are susceptible to oscillation. The building shape has a considerable effect on designing for wind. A round building for example, typically only has to resist about 60% of the wind load on a comparable rectangular building. Vortex shedding occurs when strong winds flow past a building and vortices form alternately on one and then on the other side, causing low pressure areas. If these fluctuations act at intervals close to the natural period of the building, it starts to resonate and loads build up drastically. For very tall slender buildings mechanical dampers may be required to control the vibrations. Wind turbulence acts as a damping agent as it disrupts the formation of vortices. Tall slender round building create less turbulence than rectangular buildings, so despite having to resist less wind loads, the lack of turbulence makes them highly susceptible to oscillation.

### Structures

The first use of the steel skeleton in a tall building was in 1885 with the Home Insurance Building in Chicago, with a height of 55m. Masonry building was however still popular, the Monadnock Building in 1895 consisted of 16 floors of masonry construction and perforated façade, with walls which increase to a thickness of almost 2m at ground floor. This showed the economical limits of masonry construction for tall buildings.

In 1913 the Woolworths building reached a height of 235m using a steel skeleton frame. It was highly mechanized with high speed elevators, air-conditioning, electric lighting and telephone systems. Steel framed buildings continued to dominate tall building construction, even with a shift in the stylistic expression from historical to the modernist forms pioneered by the likes of Mies van der Rohe.

Engineers such as Fazlur Khan of SOM developed new structures by attempting to increase the efficiency of high-rises. So-called tubes were developed; lateral forces could be resisted by rigid tubes on the exterior. The interior could then remain free of shear walls and reinforcement elements. Buildings such as the World Trade Center (New York), John Hancock Center and Sears Tower (both Chicago) were constructed of steel in this fashion. A whole series of combined systems were created; tubes were coupled with rigid cores by means of outriggers, tube-in-tube structures, bundled tubes etc. Steel-reinforced concrete and composite steel elements were also introduced as building materials.

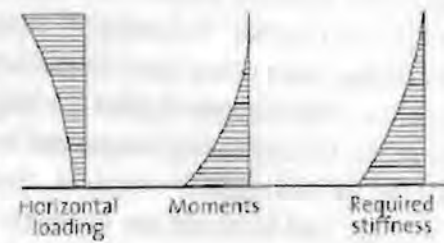


FIGURE 28: Response of Tall Buildings to Lateral Loading (Eisele & Kloft, 1999)

The highest horizontal loading occurs at the top of the building, yet the greatest bending moments are experienced at the base, requiring a greater stiffness there.



FIGURE 29: Airflows in relation to Building Form (Wells, 2005)

Airflows around bluff objects break up into eddies and down-draughts. Tall square buildings can cause gusting at street level. Streamlining a building reduces wind pressures and hence structural weight. It causes less turbulence but can result in high degrees of oscillation.



FIGURE 30: Monadnock Building, Chicago, Burnham & Root, 1895 (Eisele & Kloft, 1999)

The section shows how the heavy masonry walls increase in thickness towards the base

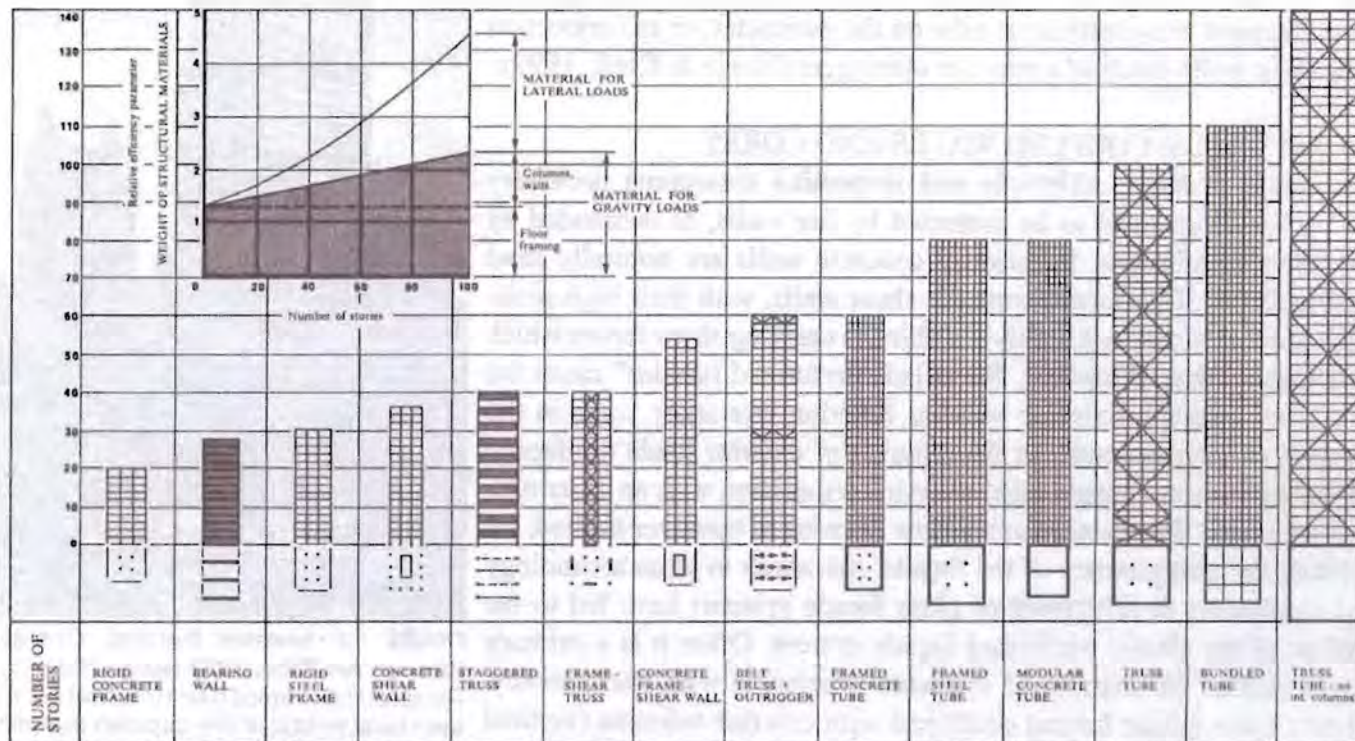


FIGURE 31: Structure Types (Schueller, 1996)

The eminent structural engineer Fazlur Khan of SOM developed this table in 1972. It shows different types of structural systems for office buildings of ordinary proportions and shapes. There are many variables which need to be taken into account when selecting an appropriate structural system, and therefore it is not a simple matter of reading it off a chart. However it may be concluded that there is an optimum solution for any building for a given situation.

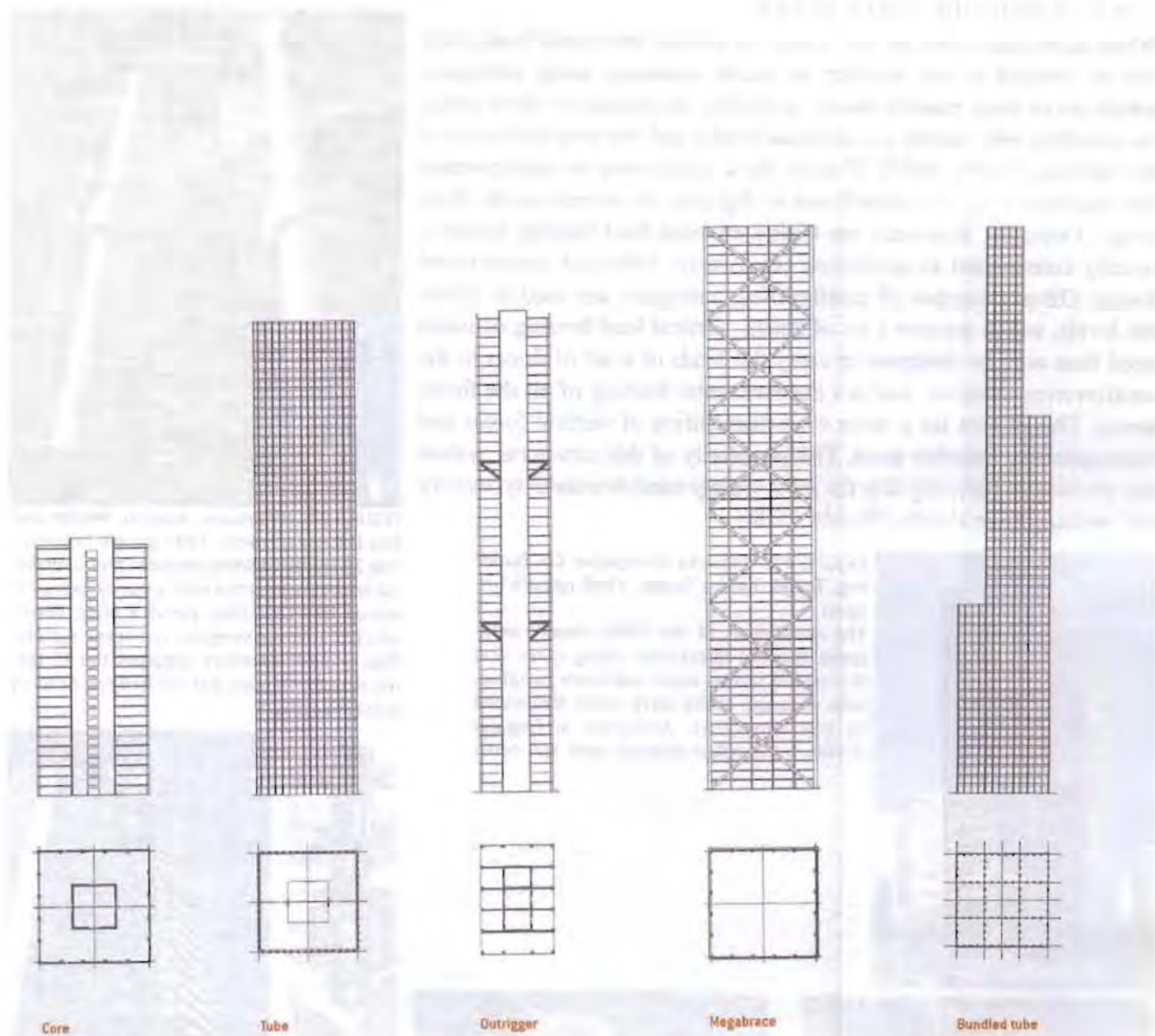


FIGURE 32: Structural Forms (Strelitz, 2005)

The basic structural forms as described by Harry Bridges of Arup.

1. The core: The central core alone provides the rigidity to resist lateral loading.
2. Tube: The perimeter of the building consists of closely spaced vertical members which carry vertical and horizontal loading, acting as a single hollow core.
3. Outrigger: At certain levels in the building cantilever structures extend from the core, they transfer loads from the perimeter structure to the core
4. Megabrace: Much like a tubed structure, the external facade carries the loading. It is a framed structure which is continuously braced on all sides to provide the required rigidity and to act as a single tube. Vertical members need not be as closely spaced as in a tube structure as the shear forces are resisted by the bracing members.
5. Bundled Tube: Much like a megabrace, but the bracing is provided by internal members which link opposite facades as opposed to external bracing members.

## RIGID FRAMES

The floors of the first tall buildings were constructed with closely spaced steel beams. The floor supports are rigidly connected to steel columns to form steel frames. In South Africa, the same system was typically applied using concrete post and beam connections. For structures taller than 25 floors, economic considerations dictate that the framing needs to be arranged as a continuous tube on the perimeter, or in connection with shear walls (such as a core) or outriggers (Eisele & Kloft, 1999).

## SHEAR WALLS, COUPLED WALLS AND CORES

The elevator shafts, stairwells and respective anterooms necessary for tall buildings need to be protected by fire walls, as demanded by fire safety regulations. Reinforced concrete walls are normally used (Yeang, 2000). Reinforced concrete shear walls, with their high resistance to shear stress, are highly suitable for carrying shear forces which arise through lateral loading. So-called "perforated façades" cause the reinforced concrete exterior walls to function like shear walls in the removal of interior loads. In the removal of exterior loads the façade can be said to form a rigid tube, often in conjunction with an inner tube such as a core. The maximum window opening is however limited, restricting the transparency of the façade. Advances in glass technology and continuous development of glass façade systems have led to the decline of the classic perforated façade system. Often it is a primary aim to reduce the number of elements interfering with transparency. Interior cores (shear forces) combined with exterior columns (vertical forces only) often provide an effective solution for this. When shear walls are joined it forms a core, which functions like a bar fixed into the subsoil; a vertical cantilever. The maximum height of these buildings is however limited the maximum practical dimensions of the core.

## CORE-OUTRIGGER STRUCTURES

When individual cores are too slender to assume horizontal loads, they can be coupled to one another, or façade columns, using outriggers which act as large transfer beams or trusses. In contrast to shear walls, the coupling only occurs at individual levels, and not over the height of the building (Wells, 2005). Usually these cantilevers are incorporated into machine or service plant floors so that they do not restrain the floor usage. Outrigger structures are highly stressed load bearing systems, usually constructed in reinforced concrete to withstand concentrated forces. Often a number of cantilevering outriggers are used at different levels, which support a set of floors. Vertical load bearing columns need then only be designed to carry the loads of a set of floors to the cantilevering member, and not the horizontal loading of all the floors above. This allows for a more even distribution of vertical forces and corresponding member sizes. The popularity of this structural system has grown and currently it is the most widely used structural system for tall buildings worldwide (Woods, 2008).



FIGURE 35: Shizuoka Newspaper Co. Building, Tokyo, Kenzo Tange, 1968 (google images)  
The Metabolists of the 1960s clearly separated vertical circulation along cores and the served space. Many multicore buildings with exposed shafts have been influenced by the Metabolists. Archigram in England envisioned utopian schemes with tall cores



FIGURE 37: HSBC, Canary Wharf, Forster and Partners, 2002 (Strelitz, 2005)  
The 200m high building uses floor slabs which are cantilevered from the central core. The vertical members are absent in the expression of the facade, where continuous horizontal bands are articulated.



FIGURE 33: Seagram Building, Chicago, Mies van der Rohe, 1958 (google images)  
The steel rigid framed tube structural system was characteristic of the cartesian skyscraper which was dominant in North America in the 1960s and 70s. The Seagram building is a prime example of this tall building type. The exposed steel frames in this case are however decorative as the load bearing steel had to be covered for fireproofing



FIGURE 34: Hypobank, Munich, Walter and Bea Betz Architects, 1981 (google images)  
The 21 storey building features four cylindrical towers connected with a storey high girders on the 11th floor (service plant floor), which forms an irregular outrigger system. This primary structure supports the 15 storey structure above and the hanging 6 storey portion below.



FIGURE 36: Standard Bank Centre, Johannesburg, Hentrich-Petschnigg and Partners, 1968 (Schueller, 1996)  
Four coupled concrete tubes form the central core, off which storey high concrete beams cantilever at three levels of the building. They support a stack of ten floors each, connected with eight prestressed concrete hangers which carry the vertical loads in tension. This building is a fine example of a concrete suspension structure, using a core and outrigger system showing a high degree of sophistication for its time.

### BRACED FRAMES

With increasing height the bending stresses in the frames become so great that a pure frame system is no longer economical. Stiffening braces are added to reduce the cross section of the vertical members. These braces absorb the lateral loads in the stiffened frame and the frame legs are no longer subject to bending. Attempts should be made to arrange the diagonal bracing so that the connections are always centrally stressed. With complex geometries this is however not always possible and these eccentricities cause secondary stresses which must be factored into calculations. A further design consideration is the shortening of frame columns under high vertical loading. This causes shortening of the diagonal braces and must be carefully accommodated for in the design.

When the bracing is arranged as a continuous tube on the perimeter of the building, as found in the Hancock Centre in Chicago, it can be described as a "megabrace" structure. In theory, megabrace structures can resist lateral loads without the assistance of an interior core.

### BUNDLED TUBE STRUCTURES

Another way of improving the effectiveness of perimeter tube framing is to introduce additional shear resistant "webs" inside the building. This form of structure is only really used for very tall buildings. The Sears Tower in Chicago is the first and most famous example of this. At 443m it was the world's tallest building for a number of years. The building which has a width of approximately 70m is divided into nine cells, which each act as tubes. These rise to various heights, breaking up the form of the building elegantly. Two cells end at the 50th floor, two more end at the 66th floor, three at the 90th floor and the remaining cells rise to the top of the building at 109 floors. The columns are spaced at 4.6m and the floor span in each cell is about 23m. The direction of the span in the individual cells alternates every 6th floor to ensure even vertical loading of the columns (Eisele & Kloft, 1999).



FIGURE 38: Hancock Centre and Sears Tower, Chicago, SOM, 1968 and 1972 (google images)

Both of these buildings represented giant leaps in the evolution of structural systems for tall building design. The braced tube structural concept was introduced for the first time in the Hancock Centre in 1968. The bundled tube system was used for the first time in 1972 with the Sears Tower. These structural systems allowed buildings to be taller than ever before, with both of them being the tallest building in the world at the time of their completion (Iyengar, 2000). In both cases the architectural expression and massing strongly reflected the structural system used

Building Cases	Year	Stories	Height/ Width	psf	Structure System
Empire State Building, New York	1931	102	9.3	42.2	Braced rigid frame
John Hancock Center, Chicago	1968	100	7.9	29.7	Trussed tube
World Trade Center, New York	1972	110	6.9	37.0	Framed tube
Sears Tower, Chicago	1974	109	6.4	33.0	Bundled tubes
Chase Manhattan, New York	1963	60	7.3	55.2	Braced rigid frame
U.S. Steel Building, Pittsburgh	1971	64	6.3	30.0	Shear walls + out-riggers + belt trusses
I.D.S. Center, Minneapolis	1971	57	6.1	17.9	
Boston Co. Building, Boston	1970	41	4.1	21.0	K-braced tube
Alcoa Building, San Francisco	1969	26	4.0	26.0	Latticed tube
Low Income Housing, Brockton, Mass.	1971	10	5.1	6.3	

FIGURE 39: Weight of Highrise Steel Structures (Schueller, 1996)

One way of analysing the structural efficiency of a building is through the quantity of structural material used. This is particularly the case for steel structures. It is measured as the weight of the structural components (Newtons) divided by the gross floor area (psf= per square foot). There is a direct relation between the slenderness ratio (Height/Width) of a structure and the amount of structural material needed. However, selecting the optimal structural system greatly affects the quantity of structural material needed. For example, the Hancock Centre is far more efficient in its use of materials (29.7 psf) than the Chase Manhattan building (55.2psf) despite being more slender and much taller.

All of the tall buildings in South Africa which were studied use a combination of rigid frames, shear walls, cores, and outriggers. There are no local examples of megabraces and bundled tube construction.



FIGURE 40: BP Centre, Cape Town 1972 (google images)



FIGURE 41: Shell House, Cape Town 1976 (google images)

**CORES:**

The BP Centre uses 8 circular columns on the perimeter, tied to each other and the interior core by the floor plates which provide the columns with extra rigidity against buckling. Lateral forces are carried solely by the core.

The Shell House uses four vertical shear walls at each corner, connected to each other and to the interior core via the horizontal floor plates, effectively creating a coupled shear wall exterior tube around the internal core.

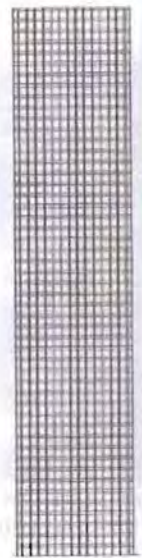


FIGURE 42: Mobil House, Cape Town 1970 (google images)



FIGURE 43: ABSA Centre, Cape Town 1970 (google images)

**TUBES:**

The Mobil House and ABSA Centre both employ the use of rigid frames which form a perimeter tube. The framed structure is expressed in the Mobil House as part of the facade, whereas in the ABSA Centre the structure and facade are separated.

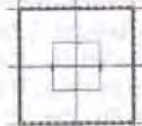


FIGURE 44: Golden Acre, Cape Town 1979 (google images)



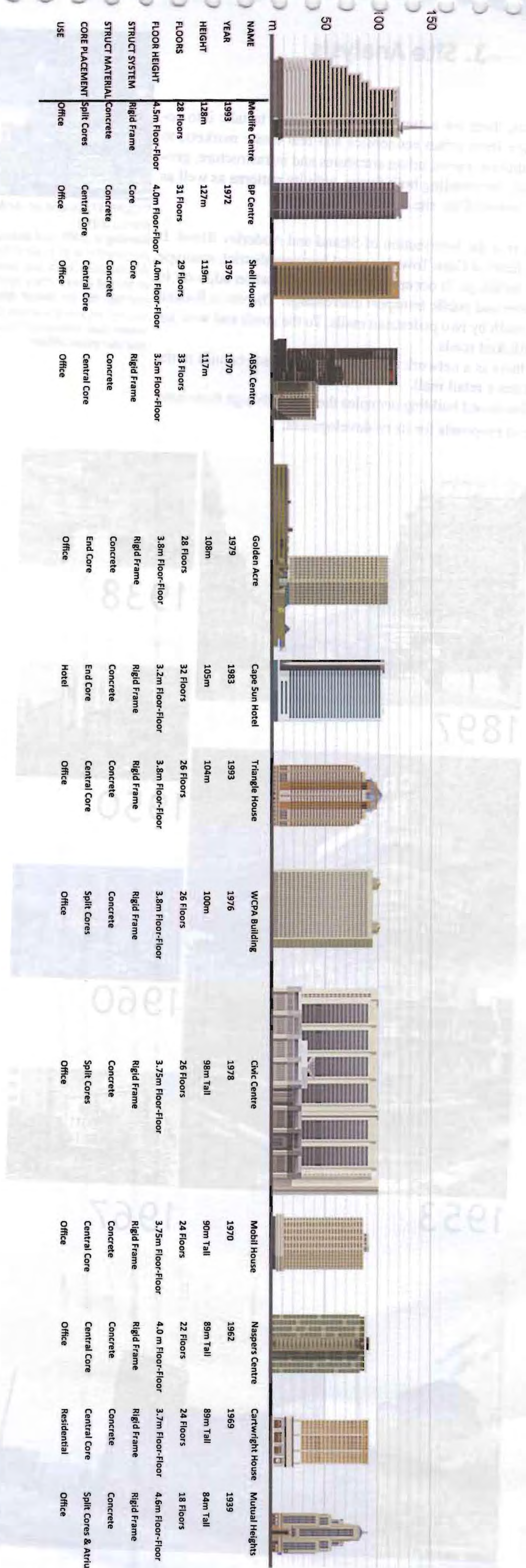
FIGURE 45: Standard Bank Centre, Johannesburg 1968 (google images)

**OUTRIGGERS:**

The Golden Acre tower uses closely spaced exterior vertical columns, tied to the floor beams which act as stiffening elements against buckling. The vertical loads of the exterior columns are transferred to the core at two levels, using concrete outriggers at service plant levels, allowing column free space below where the building mass expands horizontally, catering for a large mall. 4 slender vertical shear walls at each corner extend down to the foundations to assist in lateral stability.

The Standard Bank Centre uses an outrigger system where sets of ten floors are suspended from trusses cantilevering from the core at plant floors.





**FIGURE 46: Cape Towns Tall Buildings** (author, CTBUH database, skyscraperpage.com)  
 All of the buildings are constructed using reinforced concrete as the structural material. They predominantly have a central core arrangement, with the exception of buildings with particularly large floor plates. 7 of the buildings were constructed in the 1970s, two in the 60s and one before 1960. Concrete post and beam construction is the most commonly used structural system, forming a rigid perimeter frame. There are however a few buildings which rely on the central core solely to resist lateral loads, with widely spaced perimeter columns which only carry vertical loads (as found in the BP Centre).

### 3. Site Analysis

In choosing a site, there are a number of components to take into account. They range from urban economics and real estate markets, to the climatic conditions, views, urban armatures and infrastructure, geological conditions, surrounding built forms, activity patterns as well as the physical attributes of the site.

The site chosen is at the intersection of Strand and Adderley Street. It is located in the heart of Cape Town's central business district, amongst a cluster of tall buildings. It occupies a prominent location adjacent to the Central Station and public transport interchange. The site is flanked on the east and north by two pedestrian malls. To the south and west are two heavily trafficked roads.

Below ground there is a network of underground passages built in the 1960's which form a retail mall.

Currently, an abandoned building occupies the site, although there have been a number of proposals for its re-development.



FIGURE 47: Strand-on-Adderley, Cape Town (Karol, 2009)

Starting in 2000, Old Mutual and Woolworths proposed a large scale redevelopment of the intersection, with two towers on either side of Strand street. They appointed Louis Karol and R&L for the sketch design before the recession hit and the project was shelved. One tower was intended to be residential use and the other offices.

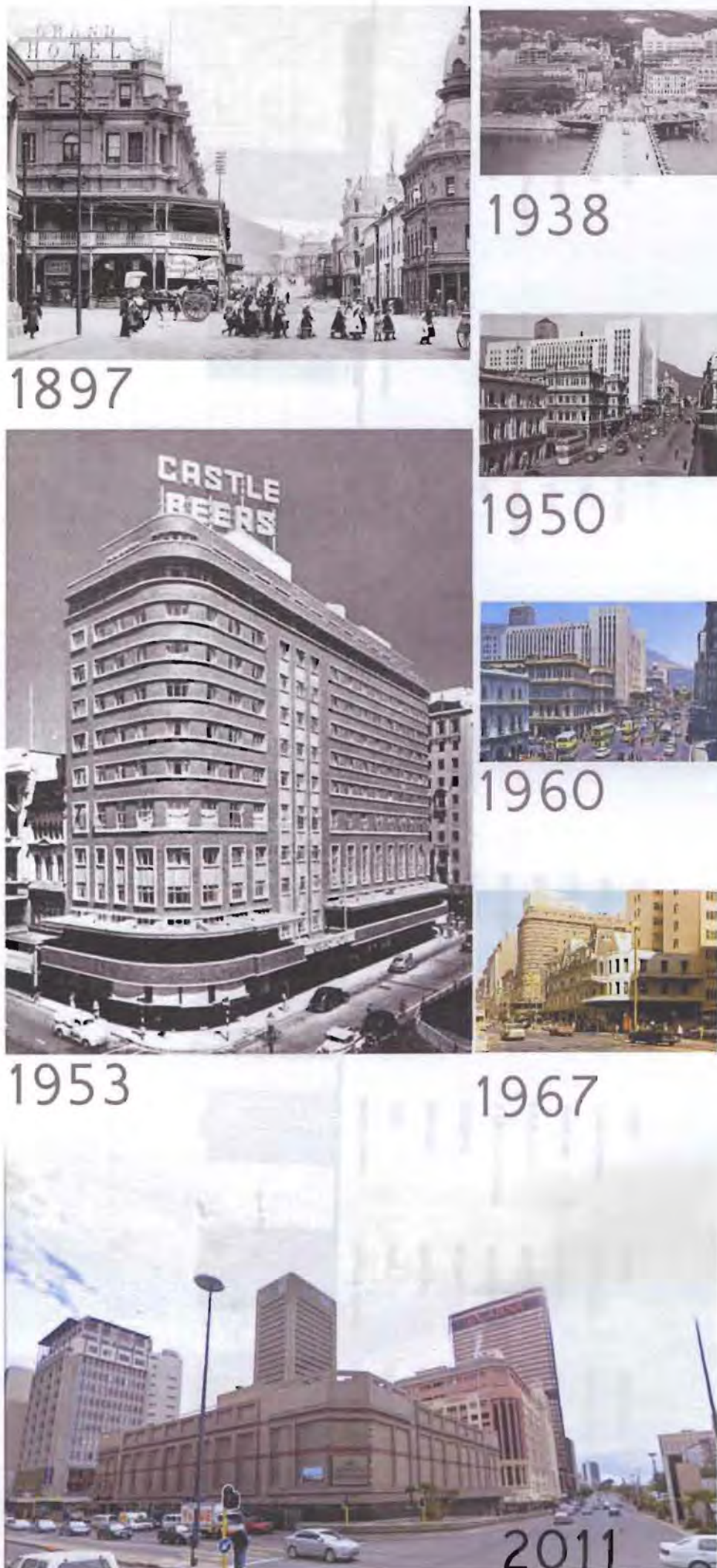
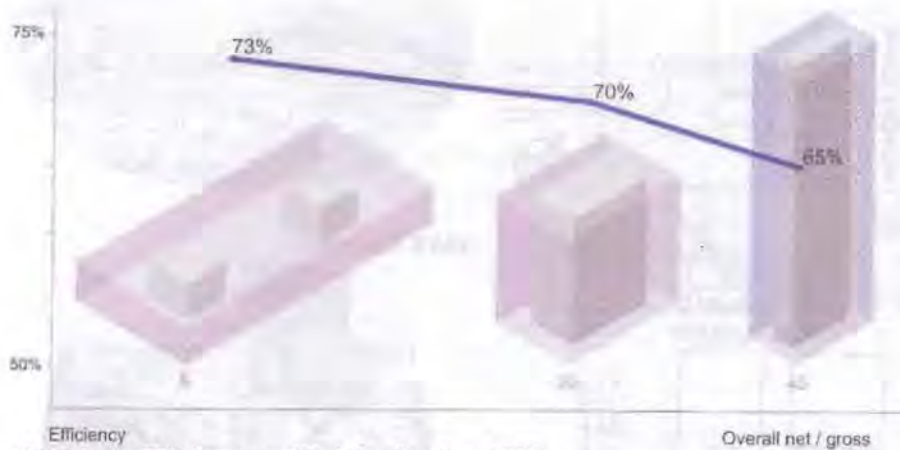


FIGURE 48: Strand-on-Adderley over time (google images)

**Economics**

Tall buildings are significantly more expensive to construct than lower buildings of equivalent floor area, and have lower floor area efficiencies (Watts, 2010). In principle, the commissioning of tall buildings only happens when the rental levels are high enough to recoup the extra capital costs. Tall buildings therefore only cater to an exclusive and compact portion of the real estate market. In the case of Cape Town, the site would need to be located in the CBD, where there is a limited availability of land and the value of and demand for the land is high enough to create rentals which make a tall building economically viable (Ang & Prins, 2003). The chosen site is appropriate in this regard.

One needs to be wary of associating tall buildings with high density, as they will not solve housing problems, especially in the context of South Africa. They cater to exclusive demands where developers are able to seize the economic opportunities afforded by given urban conditions. High rise policy will then look to couple private benefits with public gain where possible.



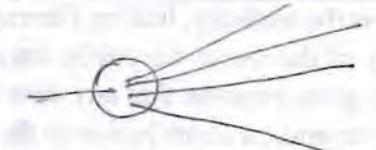
**FIGURE 49: Efficiency and height** (Strelitz, 2005)  
The Floor Area efficiency of a building decreases as the building increases in height. The construction costs of a tall building is also higher than a low building of equivalent floor area.

**Surrounding buildings**

There are a number of tall buildings in the CBD, predominantly constructed in the 1970's. It is also the historical centre of Cape Town containing many heritage assets and buildings. The site is located amongst a mix of tall and short structures. Unlike the carefully preserved centres of many European cities, the Cape Town CBD is characterized by this eclectic mix of building heights. The introduction of a tall building on this particular site is seen as a contribution to the existing cluster of tall buildings and character of the CBD.

Tall building developments in Cape Town need to be considered strategically, finding appropriate forms in relation to the specific character of the location as well as the existing urban infrastructure.

The key considerations are the relationships between a tall building and the city skyline, the urban grain and the relationship to the existing at street level. Tall buildings do not need new theories of urbanism, but need to draw influences from the dynamic and pressures of existing urban conditions (Pedersen, 2004). It is in this regard that building upon the existing can imply bringing about new energy and evolved dynamic to its context.



**CAPE TOWN - DOMINANT CENTRE**  
Distinct CBD with economic clustering.  
High land value.



**LONDON - POLYCENTRIC**  
A number of central hubs with intensified use of space for workplaces, residential purposes, shopping, recreation & culture facilities.



**ROTTERDAM - ABSENCE OF CBD**  
High density-low rise developments spread in uniform manner.  
No distinct CBD traditionally, although one is starting to emerge

**FIGURE 50: City structures** (author)  
This sketch diagrams aim to show the spatial make-up of the cities in a simplified manner. It shows how the urban conditions and spatial make-up of Cape Town provides opportunity for tall building development.



**FIGURE 51: Elevation of Strand Street** (author)  
Unlike the carefully preserved centres of many European cities, where all buildings are of uniform height, one could say that the CBD is characterised by a somewhat eclectic mix of tall and short structures. One could argue that this is the character of the CBD, where small historical buildings are juxtaposed in quite a chaotic manner with the modern structures of the 21st century. What is clear is that one is dealing with a very heterogenous built environment.

**Urban armatures**

The site is located adjacent to the Cape Town train station, making it easily accessible via public transport. Below ground a well served pedestrian concourse runs through the site. On street level the site is flanked by two pedestrian malls; the "Fan Walk" on Waterkant Street which links the train station to Green Point, and St. Georges mall, which cuts across the mid-city, linking Greenmarket and Thibault Square. The proximity of the site to the public transport interchange and pedestrian networks gives impetus that any development on there has a great opportunity to make a contribution to the public domain and feed into the existing urban armatures along with the activities they support.

Tall buildings to a large degree follow an internal set of constraints which form a disciplined biology of building types which can makes linkages to other urban structures difficult. Despite this, if the building is designed well, and in the right location it can make a great contribution to the quality and vitality of their settings



FIGURE 52: Site Plan (author, not to scale)

**Views**

To the west and south of the site one has a view of Table Mountain, in a north westerly direction one overlooks the city towards Lion's Head Mountain. To the east one has a view towards the foreshore and ocean. Another positive attribute of the site is that it is located in the first row of tall buildings in the mid city along Adderley street and therefore the views towards the south and east are almost unobstructed. By virtue of the building height, views to the west and north will also be unobstructed for most portions of the building. The direction of views becomes a important factor to take into account when designing the orientation of the buildings, as it needs to be considered in conjunction with climatic information such as sun position and wind direction. It was however decided that views are of utmost importance in this case and that climate control should be achieved without disturbing the views if possible.

**Climate and environment**

Given the location of the site, and the patterns of use and activities at street level, analyzing the impacts of wind and overshadowing are important. A study of overshadowing showed that the introduction of a tall building would not severely affect the activities at street level. It is important that the square in front of the train station as well as the two pedestrian malls are not overshadowed during the morning and daytime. No provisional wind study was done, but it was taken into account that provisions would need to be made to protect these areas from becoming too windy.

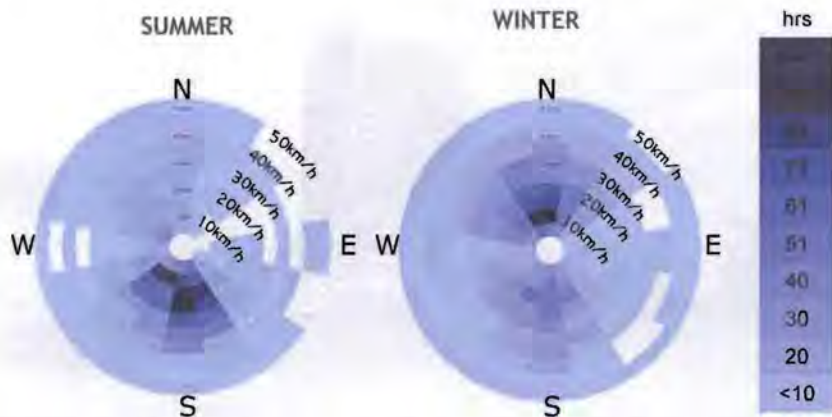


FIGURE 55: Wind Frequencies in Cape Town (Ecotect, 2011)  
In summer the wind is from a south-south-easterly direction, reaching speeds of up to 30km/h. In winter the wind comes from a north-north-westerly direction reaching speeds of up to 40km/h.



SOUTH: Table Mountain



NORTH: Lions Head



EAST: Foreshore



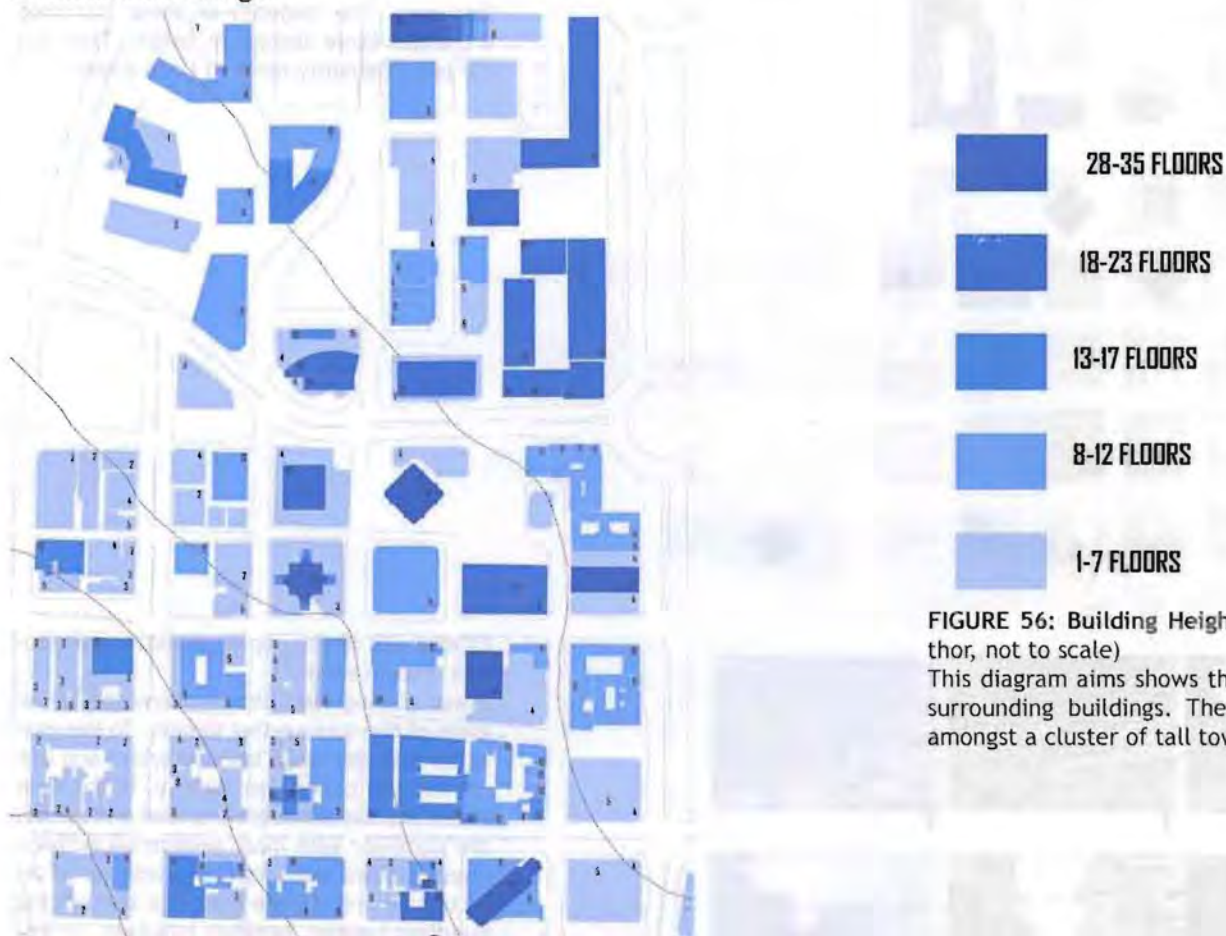
FIGURE 53: Views (google images)



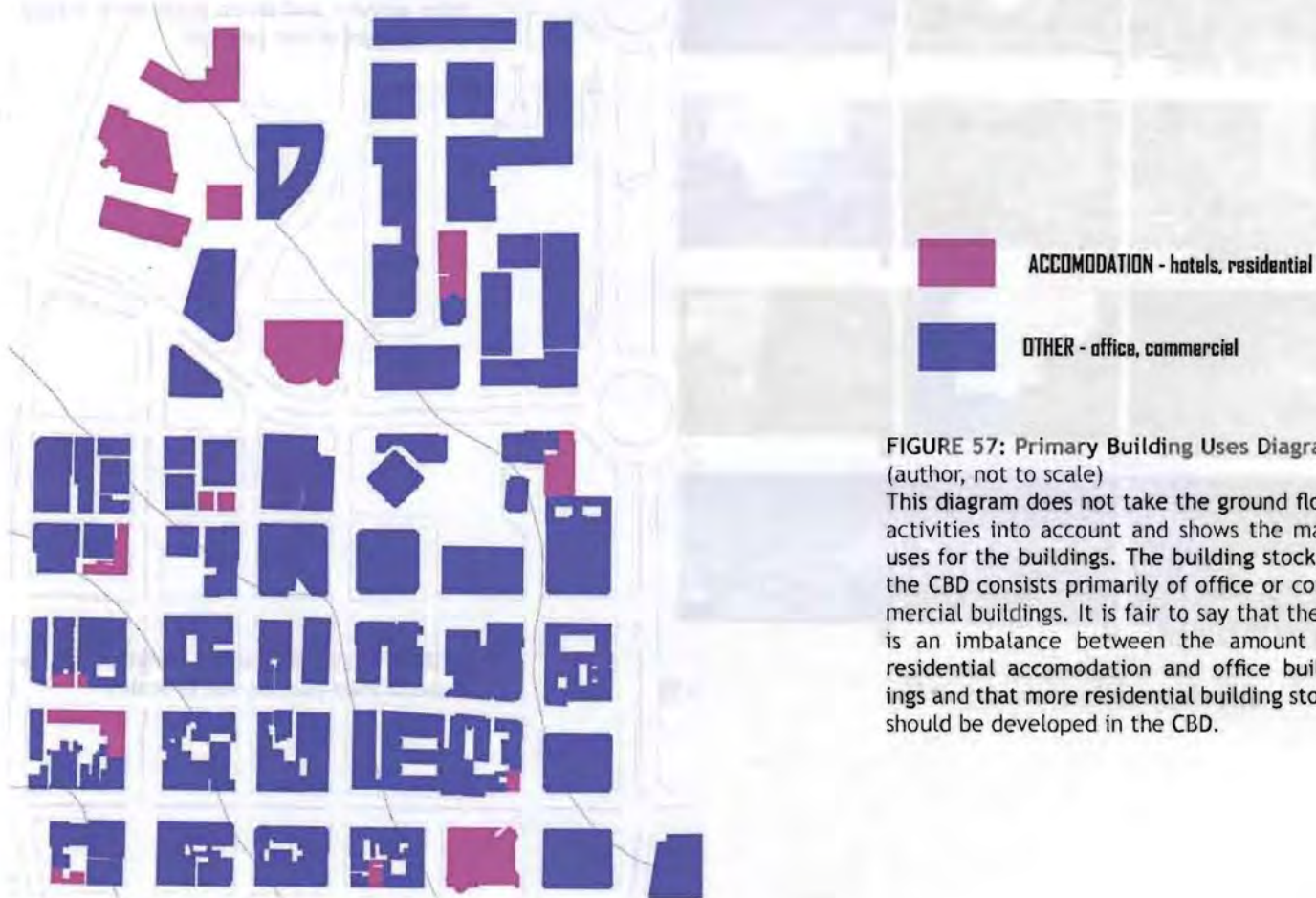
FIGURE 54: Overshadowing Analysis (author)  
The study shows that a proposed tall building should not be a problem in terms of overshadowing.

**Analysis Mappings**

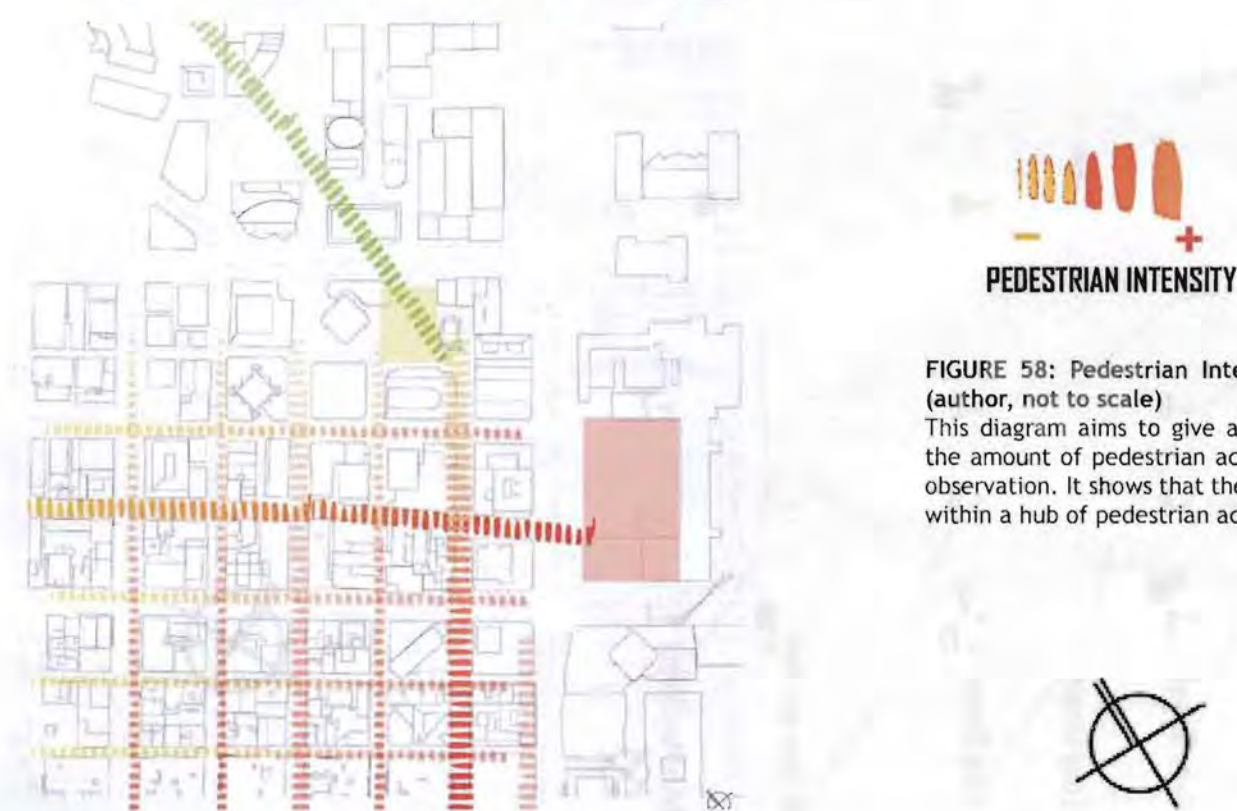
In addition to the impacts on the city skyline, tall buildings are a significant presence in their local environment. They are experienced over a wide area and their impacts need to be considered in relation to range of criterion. It is not only the relation to heritage assets but also the relation to the urban fabric as a whole which needs to be considered. The scale, massing and proportion of a tall building in relation to the existing urban grain will become critical in this regard. Good design practice often involves careful social and environmental analysis such as the understanding of movement patterns as well as the use of wind and shadow simulations to inform the design.



**FIGURE 56: Building Heights Diagram** (author, not to scale)  
This diagram aims shows the heights of the surrounding buildings. The site is located amongst a cluster of tall towers.

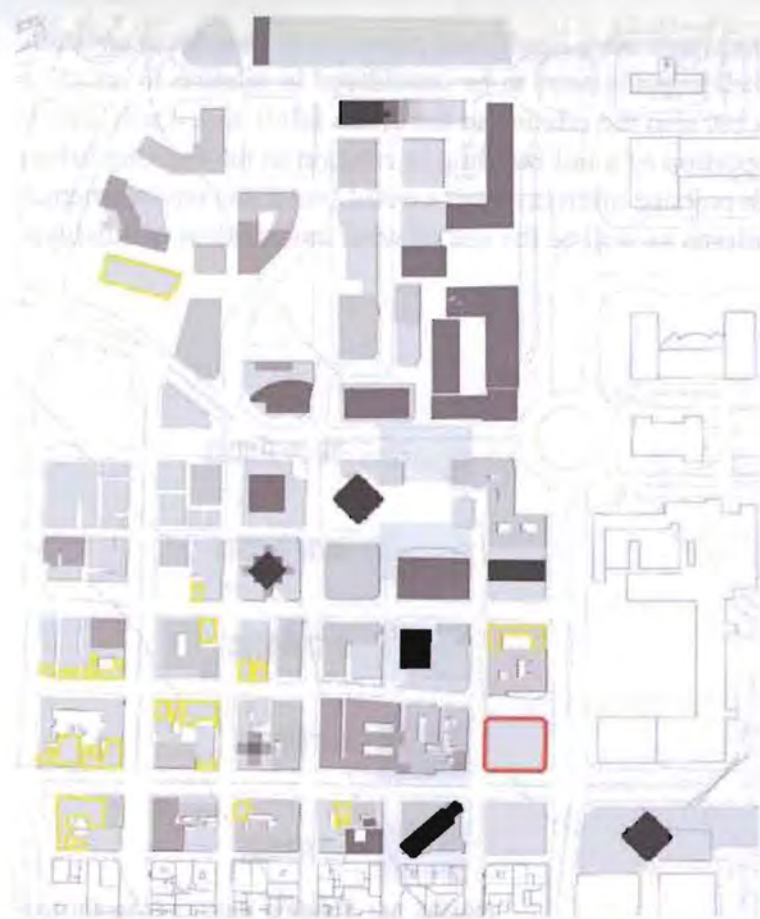


**FIGURE 57: Primary Building Uses Diagram** (author, not to scale)  
This diagram does not take the ground floor activities into account and shows the main uses for the buildings. The building stock in the CBD consists primarily of office or commercial buildings. It is fair to say that there is an imbalance between the amount of residential accomodation and office buildings and that more residential building stock should be developed in the CBD.



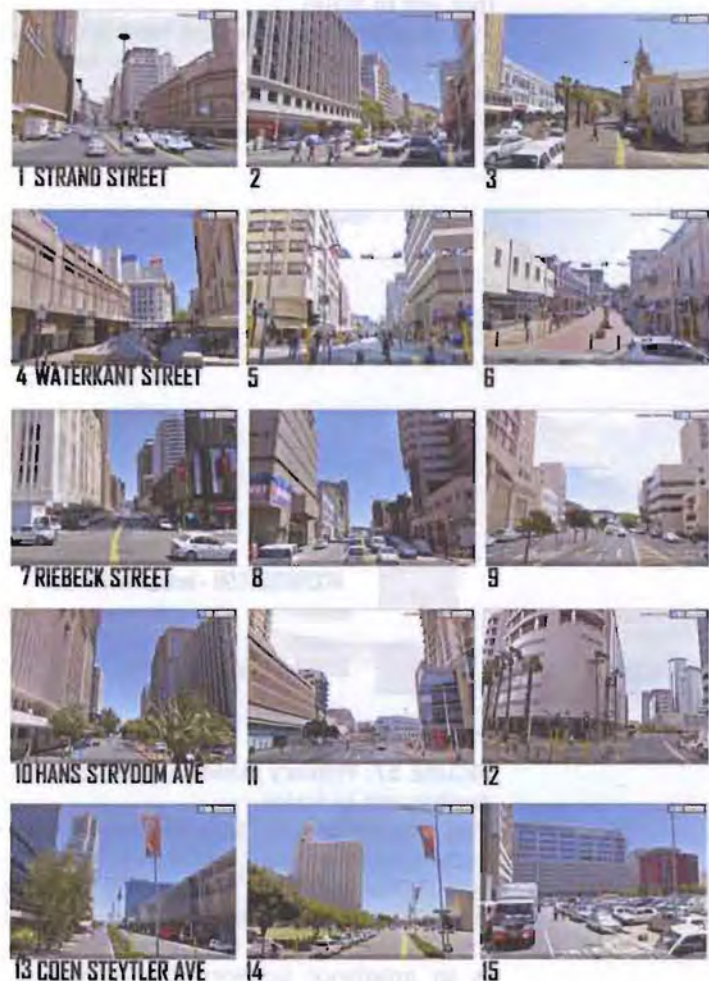
**FIGURE 58: Pedestrian Intensity Diagram** (author, not to scale)  
This diagram aims to give an indication of the amount of pedestrian activity based on observation. It shows that the site is located within a hub of pedestrian activity



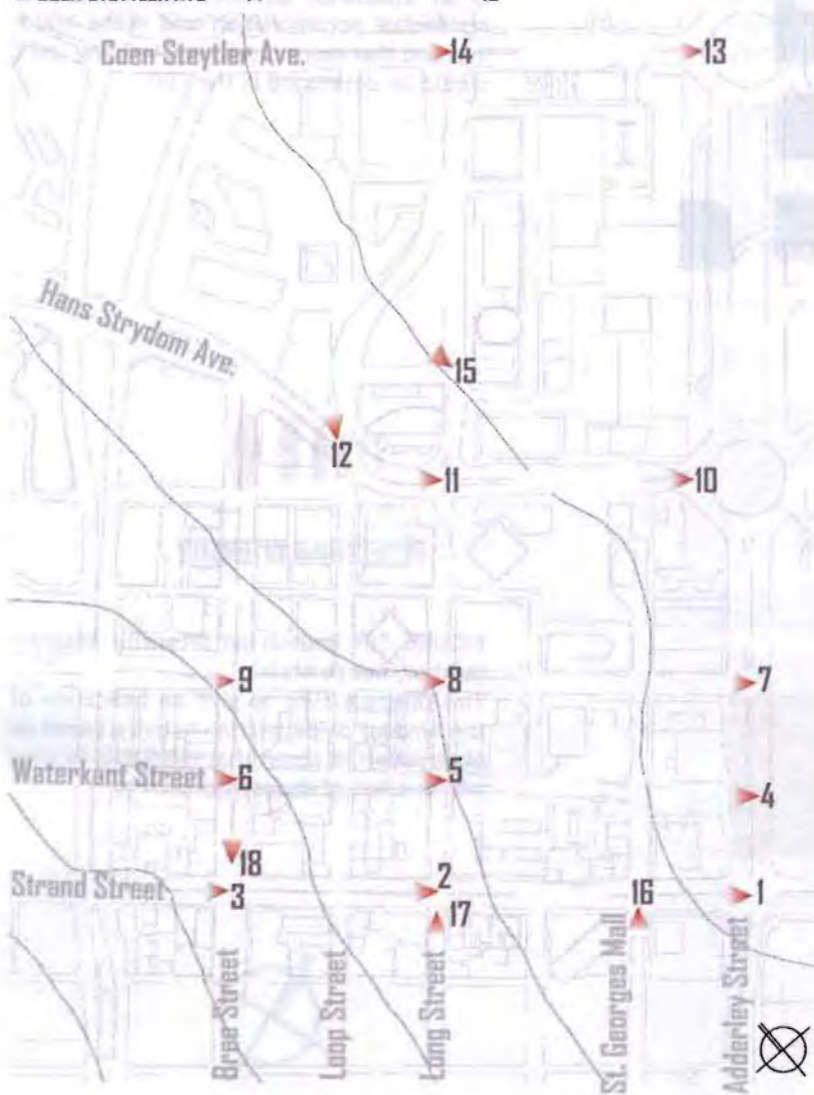


**HERITAGE BUILDINGS**

**FIGURE 59: Pedestrian Intensity Diagram** (author, not to scale)  
 This diagram shows the buildings in the area which are protected by heritage conservation laws. The majority of these buildings are under three storeys in height. They occur predominantly north of Loop street.



**FIGURE 60: Photographic Walkthrough** (author, google earth)  
 These photographs aim to show the urban grain of the surrounding streets. To the east of the site the roads become wider and one notices less pedestrian activity. To the west of the site the urban grain is finer and streets are narrower with more pedestrian activity. These studies were part of a process of selecting an appropriate site. The surrounding buildings heights, heritage buildings, pedestrian activity and urban grain were considered as part of this process.



**FIGURE 61: Photographic Walkthrough reference Plan** (author, not to scale)

**Geology**

A crucial consideration for the projects is the size and complexity of foundation and substructure work. It becomes important because basement construction is a lengthy and time consuming process. In reality, test holes would need to be drilled to gather precise geotechnical information, for this project information was assembled and assumed from available maps and data. The subsoil consists of Greywacke, which is a variety of sandstone (capacity app. 50ksf), quartz, feldspar and stone fragments set in a fine clay matrix. The water table is relatively high and the bearing pressure of the soil relatively low. Spread, raft and mat footings which are not supported by piles are inappropriate because, when they are designed below the water table, hydrostatic uplift pressure would cause problems (Byrne, 1995). These foundations are economical for high rise structures when it is built on rock or soil with very high bearing capacity and when bedrock is situated at excessively deep levels below ground. In the Cape Town CBD bedrock and granite is situated at relatively shallow depths and pile foundations are commonly used. It is also accepted that because of the parking requirements and size of the site the basement structure would need to extend well below the water table, which is pricey but possible. Another consideration taken into account is that because the site is in such a densely built up area and the high water table, boring piles would need to be carefully considered to avoid excessive noise and vibrations, as well as measures to prevent the sidewalls of boring holes from collapsing due to excessive water ingress and pressure.

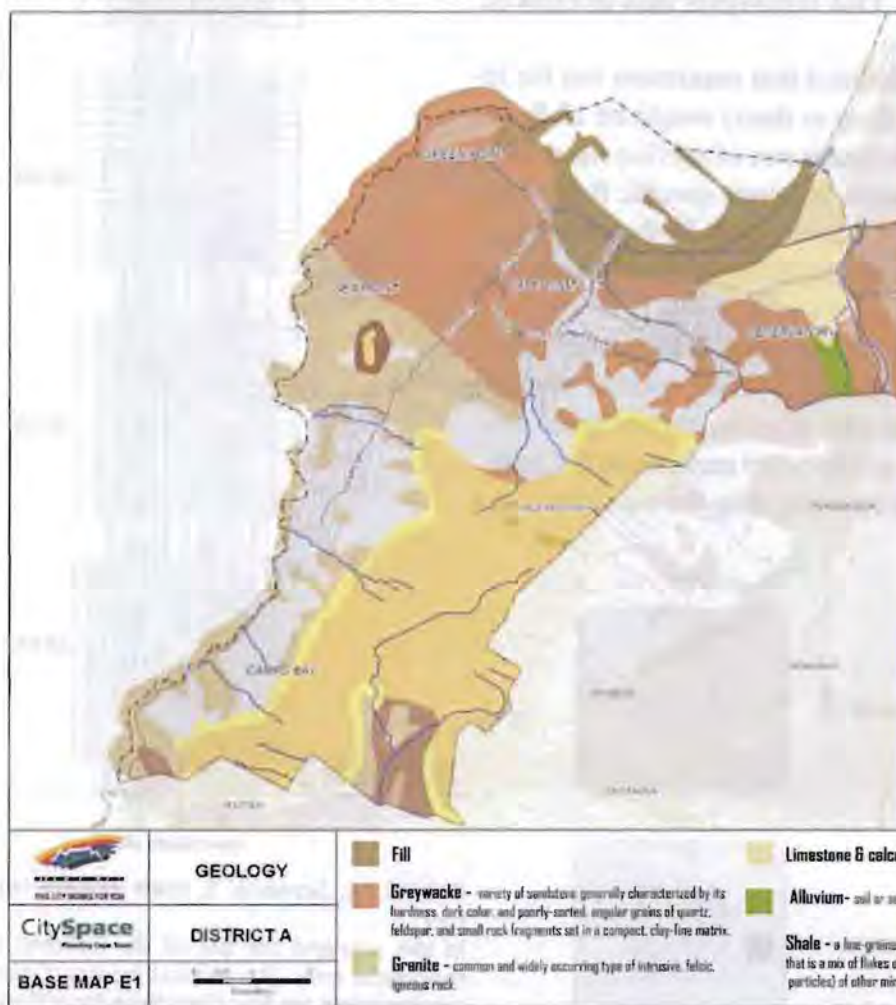


FIGURE 64: Geology map of subsoil conditions (CTOCT, 2008)

**Physical Attributes**

The site is about 3000m<sup>2</sup> in area, with a rectangular shape of approximately 51x59m. The greatest challenges to designing on this site is that it is located on the heavily trafficked intersection of Strand and Adderley streets, which makes vehicular access to the site extremely difficult. By law, one is not allowed to build a vehicular exit to a parking garage within 50m of a major intersection such as this. Waivers on this regulation are allowed, given that they are approved by relevant authorities following a traffic impact assessment. Alternatively, the entire intersection would need to be reconsidered and designed to allow for vehicular access to the site. To add to this, the underground concourse running through the site makes it even more difficult to design for basement parking. It is most likely for these reasons that the existing building on this site stands mostly empty. The size of the site was tested to determine the height to which one could build before the site became too small to make the building practical. This study is included in the next chapter on design development. It was concluded that the site is physically big enough to allow for a tall building.



FIGURE 62: Coastline 1930 (M&R, 1987)  
The site at the corner of Strand and Adderley Street is not located on reclaimed land



FIGURE 63: Underground Concourse (M&R, 1987)

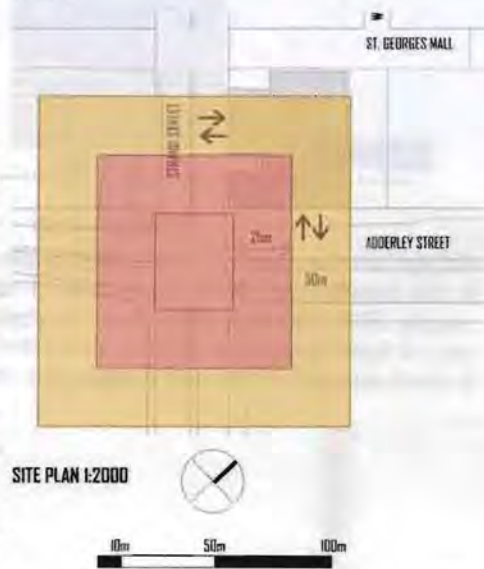


FIGURE 65: Intersection of Strand and Adderley street (author)

The orange square describes a distance of 50m from the intersection. The red square describes a distance of 25m from the intersection. When talking to a traffic planner at the city council he said that a scheme proposing a ramp exit within 25m would most likely be rejected, but within the orange zone would be considered although it is a departure from building regulations

## 4. Design Development

### 4.1 Study to determine maximum size of the building, March 2011

This study started linking the site analysis to the beginnings of form making and massing. The aim of the study was to firstly to validate the site as a suitable one for a tall building, and also to set the constraints to how big and tall the building could be. Usually, the maximum size of a building is determined by building regulations such as bulk factors and height restrictions, but in this case these regulations are disregarded. The limits for this study are set only by the physical dimensions of the site.

#### Method:

Firstly, a point at which the building becomes impractical needed to be established. It was decided that when the ratio of net-gross floor area dropped below 70% the building would be uneconomical.

Therefore an area equal to 30% of the site was taken as the size of the core. Using rules of thumb to calculate core requirements and sizes (including toilets, elevator shafts, elevator lobbies, escape stairs and structure), it was determined how many elevators could be accommodated within the core.

The number of elevators would then determine how much floor area could be served (using rules of thumb). This is however also influenced by the lift strategy.

A lift strategy was taken where it was decided that maximum run for local elevators (elevators which go from floor to floor) would be 18 floors, this also roughly coincides with the maximum run of service risers from plant rooms. Two express elevators (shuttle between specific floors only) would carry passengers from the ground floor to each 18-floor high segment of the building. The size of the core would therefore decrease every 18 floors.

The function of the space also determines how much floor area can be served by each elevator. Using the lift strategy, and the number of elevators which can be accommodated in the core of given size, various scenarios were tested. When the numbers of elevators required at the base were too many to be accommodated in the core, then the maximum size of the building had been reached.

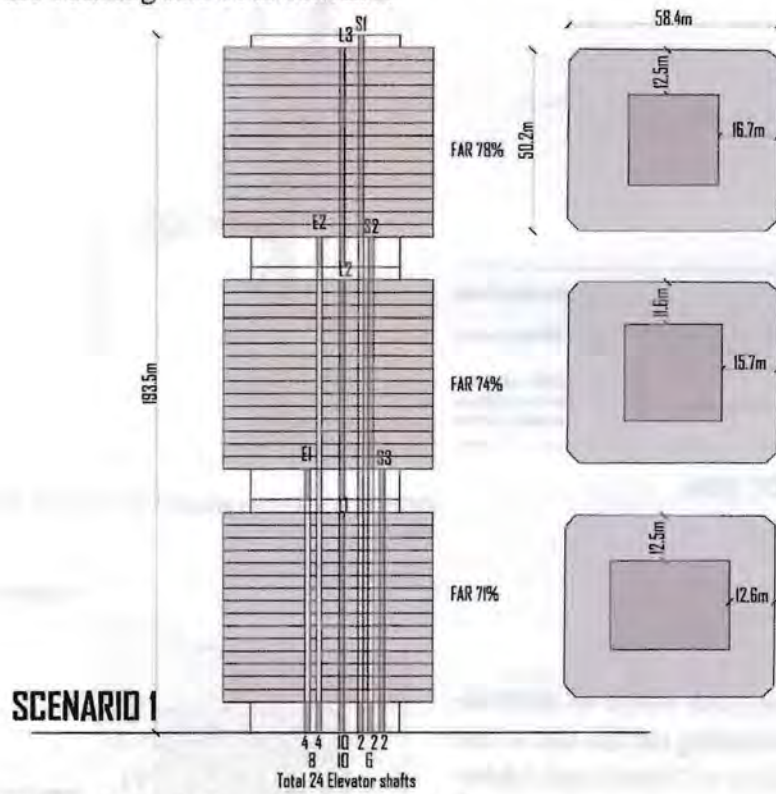


FIGURE 67: Scenario 1, scale 1:2000 (author)  
In this scenario the use of the building is office only. The height of the building is roughly 200m. The floor plans show the depth of the floor plates. In such a scenario natural lighting would be difficult to achieve in the deeper areas of the floor plate. It would also restrict the use to open-plan offices only.



FIGURE 69: Height Comparison (author)  
The diagram shows the height of these scenarios compared to the other tall buildings in Cape Town.

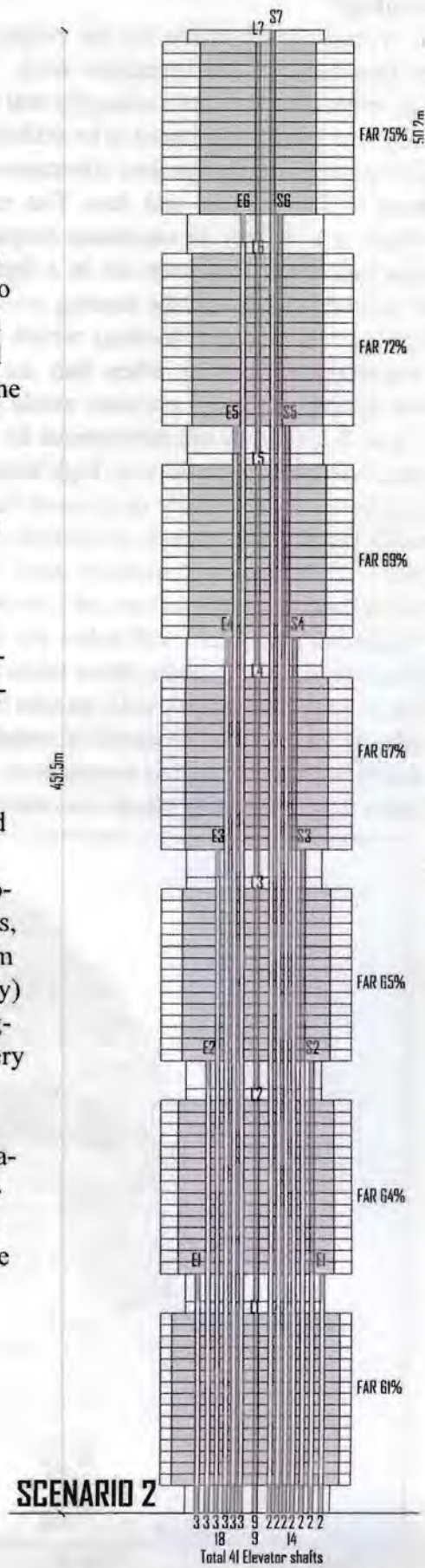


FIGURE 66: Scenario 2, scale 1:2000 (author)  
In this scenario the use of the building is residential only. The vertical transportation requirements are less than those for offices, resulting in a taller building of around 400m

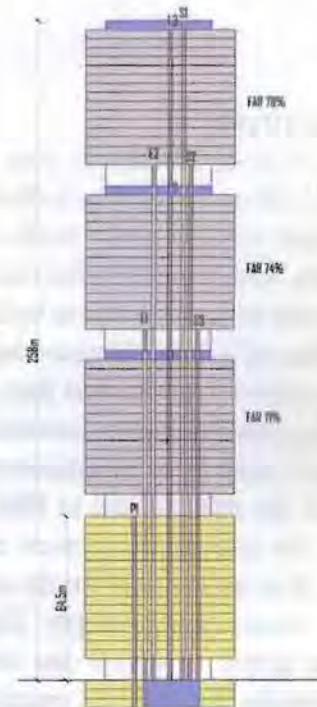


FIGURE 68: Parking Requirement (author)  
If 4 bays/100m<sup>2</sup> (industry norm) were provided for scenario 1, it would take about 18 floors of parking to achieve this (marked yellow). A decision was taken to aim to provide 2bays/100m<sup>2</sup>, given the proximity of the site to the public transport interchange.

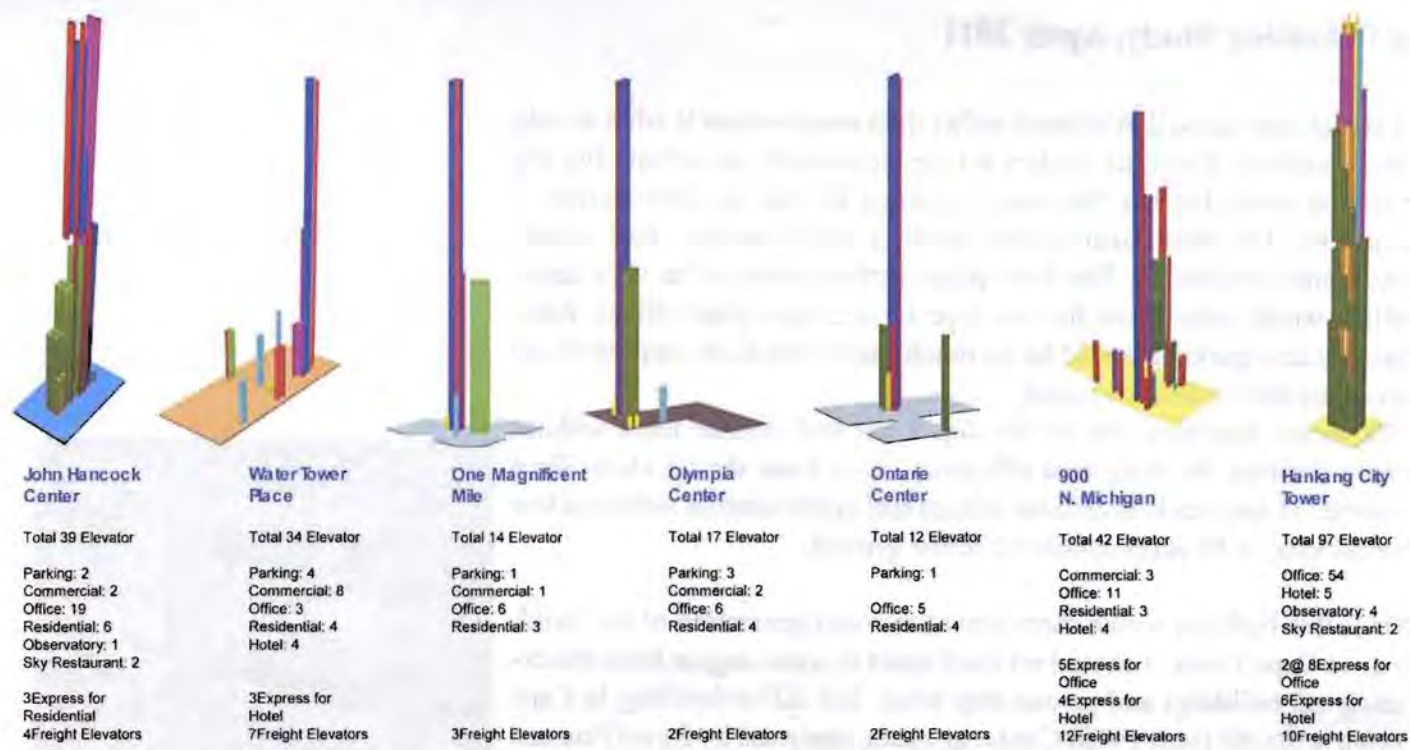


FIGURE 70: Study of Vertical Transportation for mixed-use Tall Buildings (Kim, 2004)  
 This study analysed the vertical transportation in relation to floor area and use for a number of mixed use tall buildings. The analysis was used to help inform the lift strategy for the scenarios.

	LOCAL LIFTS	INSIDE SHAFT SIZE
OFFICE	1 lift/3250m <sup>2</sup>	2540x2032mm (1140kg)
RESIDENTIAL	1 lift/75 units (65m <sup>2</sup> /unit)	2006x2235mm (900kg)

	SERVICE, EXPRESS & FIRE	INSIDE SHAFT SIZE
OFFICE	1 lift/ 24 600m <sup>2</sup>	3300x3250mm (2730kg)
RESIDENTIAL	1 lift / 300 units	3300x3250mm (2730kg)

**ELEVATOR BANKS:**

	% OF FLOOR AREA
INSIDE SHAFTS	40%
STRUCTURE	13%
LOBBY	47%

TOILETS: 1/60 Workstations (0.7m<sup>2</sup>/18m<sup>2</sup>)

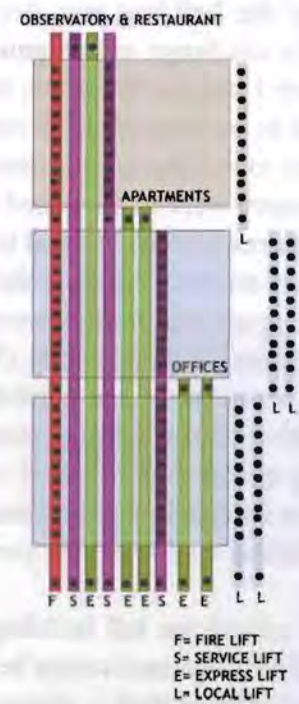


FIGURE 71: Rules of Thumb for Calculation (compiled from Allens, 2009 & Neufert, 2010)  
 This table shows the calculation formulae which were used to conduct the massing study.

FIGURE 72: Lift Strategy (author)  
 The diagram shows the lift strategy. The dots are an indication of where the lift stops and passengers may disembark or enter the lift.

#### 4.2 Exploration of Massing and Form, March 2011

Given the constraints for the maximum size of the building, the next exploration was aimed at developing an idea for the overall form of the building. Concerns over the formal expression and its relation to the surrounding built context were taken into consideration. The hope was to develop a stance on what the shape, orientation and formal language of the building should be.

##### Method:

A series of study models were built at scale 1:1000

FIGURE 73: Site Plan (author, not to scale)

The buildings marked in red are tall buildings rotated from the street grid. Those marked in grey are tall building aligned with street grid. To the south one has a view of Table Mountain, to the north Lions Head, and to the east the Foreshore.

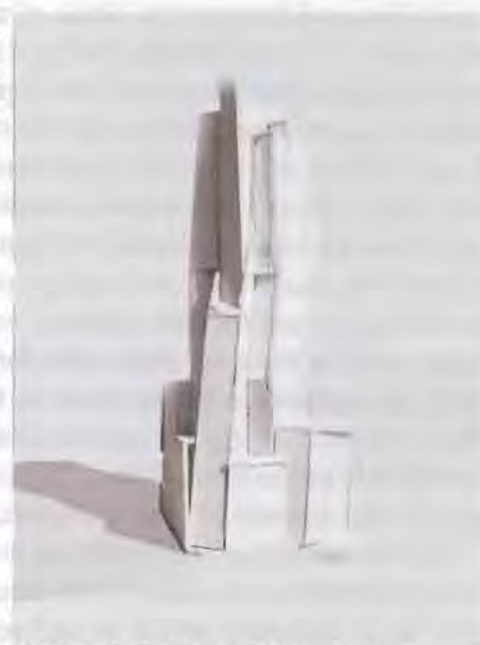
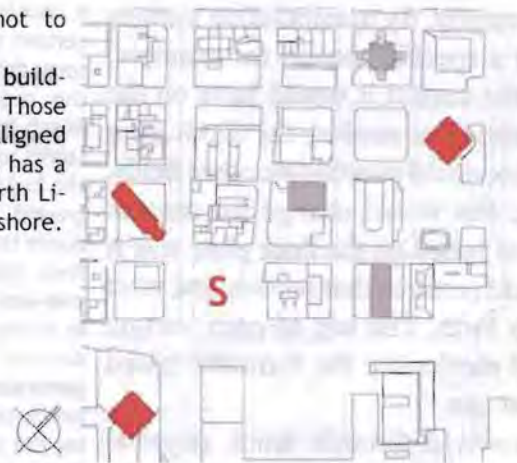


FIGURE 74: Study Model (author)  
 This was the first model built. It shows the mass rotated from the street grid so that the facades are oriented north and south. There are also a number of tall buildings in proximity which are rotated from the street grid.

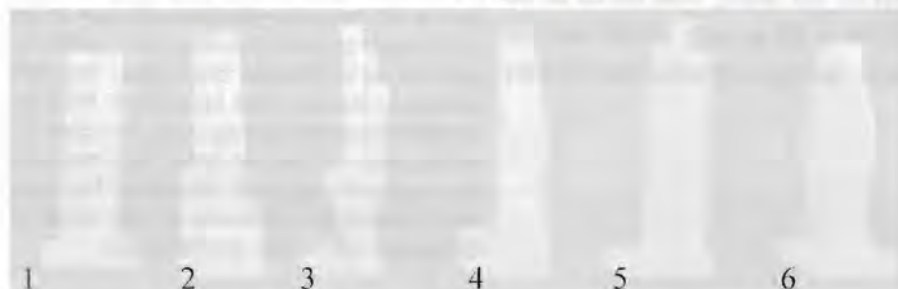


FIGURE 75: Study Models (author)  
 1. Square block  
 2. Spiral and Stepping form  
 3. Bulging Form  
 4. Chiselled Rectangular Block  
 5. Rectangular narrow Blades  
 6. Chiselled Square Block

### 4.3 Massing Study, April 2011

A stance was taken that tallness rather than massiveness is what should be articulated. Previous studies set the constraints as to how big the building could be, but this study is aimed to find out how slender it could be. The theoretical model showing maximum size had certain functional limitations. The floor plate depths tended to be very large, which would only allow for one type of use; open plan offices. Also, the required parking would be so much that it would be impossible to accommodate it below ground.

The vision therefore was to develop a tall and slender form without compromising the floor area efficiency. This form should allow for a number of uses such as cellular offices and apartments as well as allow for parking to be accommodated below ground.

Since this building would form part of the next generation of tall buildings in Cape Town, it should set itself apart to some degree from the existing tall buildings and go one step taller. The tallest building in Cape Town is the BP (now FNB) Centre at 130m, designed by Revel Fox and completed in 1972. Portside by Louis Karol is under construction at the moment and set to be 150m tall. A height of between 150m and 175m was seen as an appropriate height for this tower.

The use of the building was decided to be a mix of apartments and offices. The challenge of designing a mixed-use tall building is something which I wanted to tackle; where vertical transportation and services need to be separated for each use and the required core to wall depths vary to suit the various uses. Additionally, a restaurant and public observatory were to be placed at the very top of the building, which further requires its own vertical transportation. The Hancock Centre in Chicago has an observatory at the top, a study showed that the vertical circulation space required to access that one floor took up 1.6% of the total floor area of the building (Kim, 2004). It therefore makes little economic sense when one considers that one loses more floor area in transportation than what one gains by having the floor, but it could be something special which is well worth it. The observatory at the top of the London Bridge Tower by Renzo Piano, completed in 2005, receives about 2 million visitors a year ([www.theshard.com](http://www.theshard.com), 2011).

Although mixed-use tall buildings are becoming an increasing trend (Woods, 2008), the motivation behind a mixed-use building is more of a design challenge than a statement promoting mixed-use buildings. I believe that there should be a range of day and night-time activities within close proximity to each other, but they need not necessarily be housed in one building.

#### Method:

Much like the study to determine the maximum size of the building, the same core calculation techniques were used. With a height of between 150-175m, and the practical limits of service risers and local elevators of roughly 18 floors (Strelitz, 2005), it seemed logical to split the building vertically into three parts. Two segments would be used for one use (office or apartment), and one for the other.

A spreadsheet was formed where formulae were programmed to take data from various fields and do a range of calculations for each section as well as the building overall. Certain assumptions were made to help simplify the study such as the shape of the building was taken to be a perfect square and the core is placed centrally. By manipulating various fields, such as the floor plate sizes for a specific section for example, quick assessments could be made of the impact it would have on the floor area ratio (FAR), the amount of elevators needed, the depth from core to wall and so forth. Conversely, one could manipulate other fields, such as the amount of local elevators, this would change the amount of floor area which could be served, and based on the floor plate size it would determine how many floors would result in that section and what their floor area ratio would be and so forth. The use of each section could also be changed and this would recalculate the formulae based on the rules of thumb for that particular use.

Many scenarios were tested and simulated through quick physical models until one which satisfied the aims of the study was taken to be developed further. This spreadsheet proved to be a very useful design tool. It provided the base and constraints needed to conduct further explorations into the form.



FIGURE 76: Study Models (author)

A couple of models were built to represent certain scenarios which were tested on the spreadsheet. The tapering form allows for the required change in the core-to-wall depth from office space to residential to be taken up elegantly. The bottom section of the building tapers inwards as it reaches the ground. This allows for more light and reduces the presence of the building at ground floor. Having the largest floor plate roughly mid-way up the building also has advantages in terms of floor area efficiency and slenderness. Tapering inwards from the middle generates more floor area than a building which tapers from the bottom to the top using the same angle of incline. Or conversely, if the building were to taper from the bottom to the top, the taper would have to be much more gradual and less pronounced to achieve an equivalent floor area. The two models to the left (one tapering in both directions from mid-way up, and the other tapering from the bottom to the top) were the favoured scenarios from this study. The form which tapers from mid-way up was taken as the model for further development.

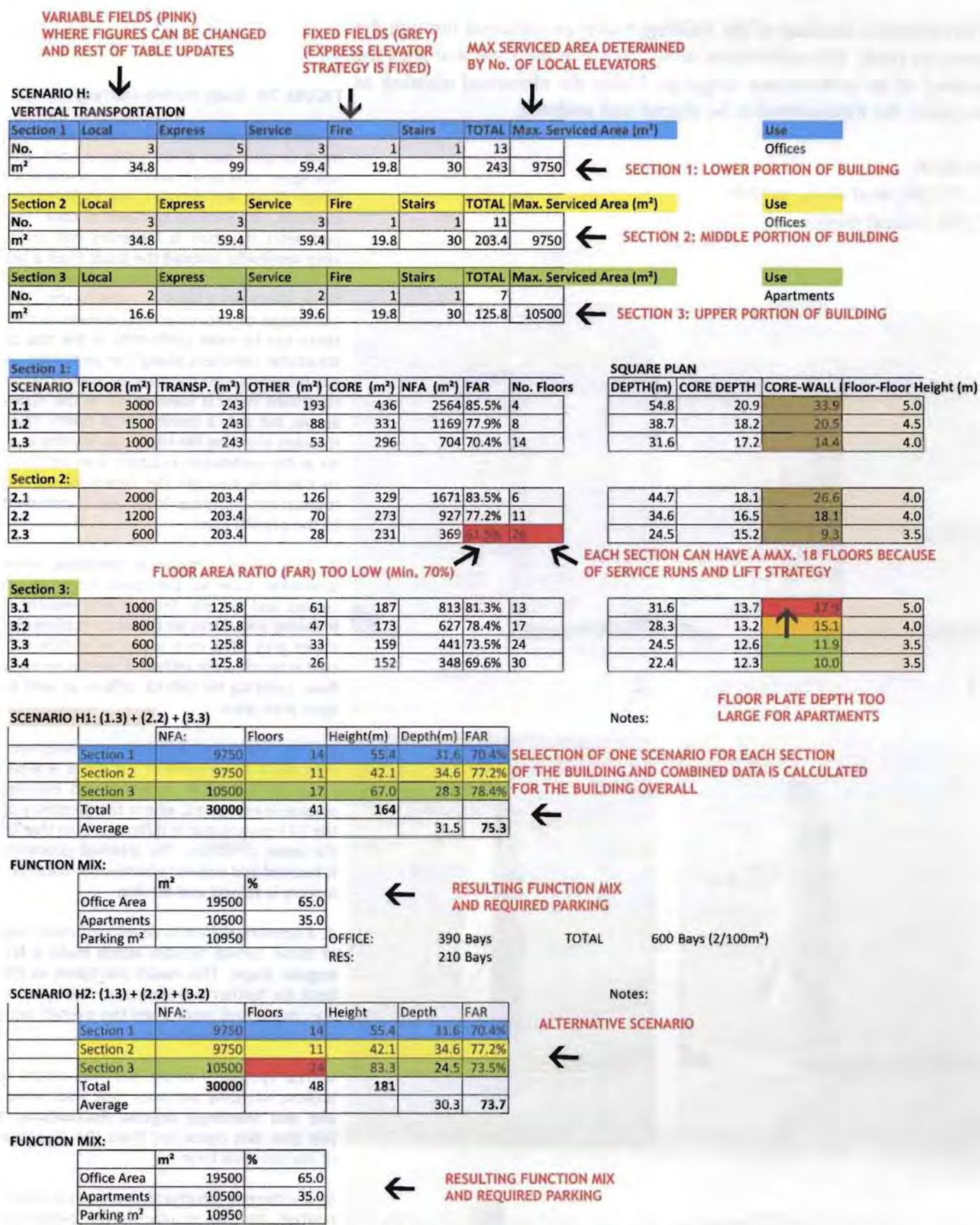


FIGURE 77: Spreadsheet used to assess various scenarios (author)  
The red markings explain the various fields and data which was calculated



FIGURE 78: Precedent Studies (Strelitz, 2005)  
These floor plans were scanned, scaled and measured to determine the floor area ratios for these particular floors. This gave some comparative information to help judge what efficiencies I should be looking to achieve

#### 4.4 Further Development of the Massing and Form, May 2011

The elemental massing of the building had been achieved through the previous study, this exploration aimed to refine the form and start the making of an architectural language. Using the elemental massing as the basis, the form started to be shaped and sculpted.

Method:

1: 500 physical study models

1:500 context model

FIGURE 79: Study Models (author)



1



2



3



4



5



6



8

1. Basic Mass as basis of further studies. The mass is split into three parts. A core and outrigger structural system is envisioned, where three sections are like independent capsules tied back to the central core. The perimeter structure is therefore not continuous vertically, instead the loads from a set of floors would be transferred to the core at three levels using large transfer beams. The advantage of this structural system is that there can be more uniformity in the size of structural members along the perimeter as the members near the base do not carry the combined vertical loads of all of the floors above, but only a limited set of floors. Also, it makes planning the basement parking easier as the perimeter structure does not need to continue through the basement to the foundations as these loads are transferred to the central core.

2. This model explores a continuous outer structural tube as the main structure. A curved and circular form is also explored, breaking away from an orientation along the street grid. The core is placed slightly off-centre to allow for different depths on each floor, catering for cellular offices as well as open plan ones.

3. This model builds on the previous one, with slight differences to the form. A separation of the outer structure and internal volume is expressed, where the geometry of the internal volume is different from that of the outer structure. The internal geometry is faceted and angular whereas the outer geometry is curved and flowing.

4. A symmetrical form is developed consisting of three curved facades which make a triangular shape. This model was taken as the basis for further development. The symmetry, curve and taper gives the overall form elegance and slenderness.

5. The symmetry of the previous model is broken, creating an outer skin with wavy-like and seemingly organic fluctuations. I felt that this detracted from the elegance of the previous form.

6. A different structural approach is investigated. Instead of placing the perimeter structure beyond the facade, columns are placed internally, allowing the facade to be better expressed as a continuous surface, adding to the simplicity and elegance of the form. I liked the expression, but having columns on the inside could be cumbersome and interfere with the practicality of the internal space.

7. A perimeter structure is used consisting of a continuous tube of diagonal braces. It allows for column-free internal space and could be incorporated as an external shading device. The external structure would then also be a form of expression and architectural language. These principles were carried forward in further explorations.

8. Context model from wood. Scale 1:500

By the end of this study, a decision had not yet been reached on what form the outer structure would take and what its materiality would be. The fabrication and construction would still need to be researched and considered before a decision could be made.

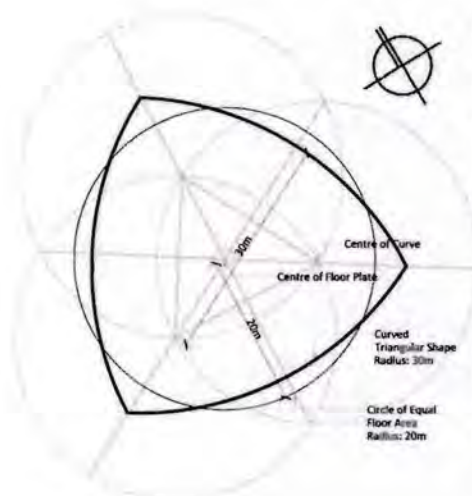


## 4.5 Core and Floor Plan Layout, April- June 2011

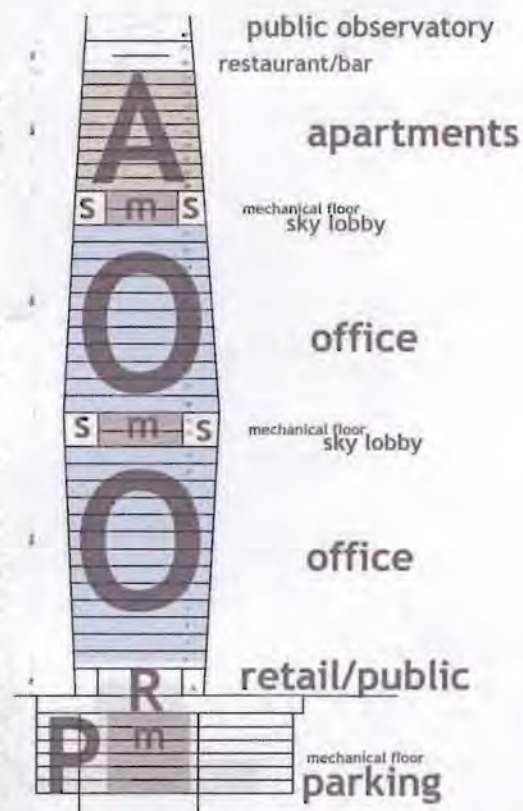
The aim of this exercise was to test the massing studies to see how accurate they were by drawing up the floor plans and comparing the floor area ratios, core-to-wall depths and so on to the theoretical studies. Also, this would be a test of the practicality of the building form.

Method:

Floor plans at scale 1:500. The core was designed first, arranging the elevator shafts, toilets, elevator lobbies, escape stairs and structure. Thereafter selected floor plates were arranged.



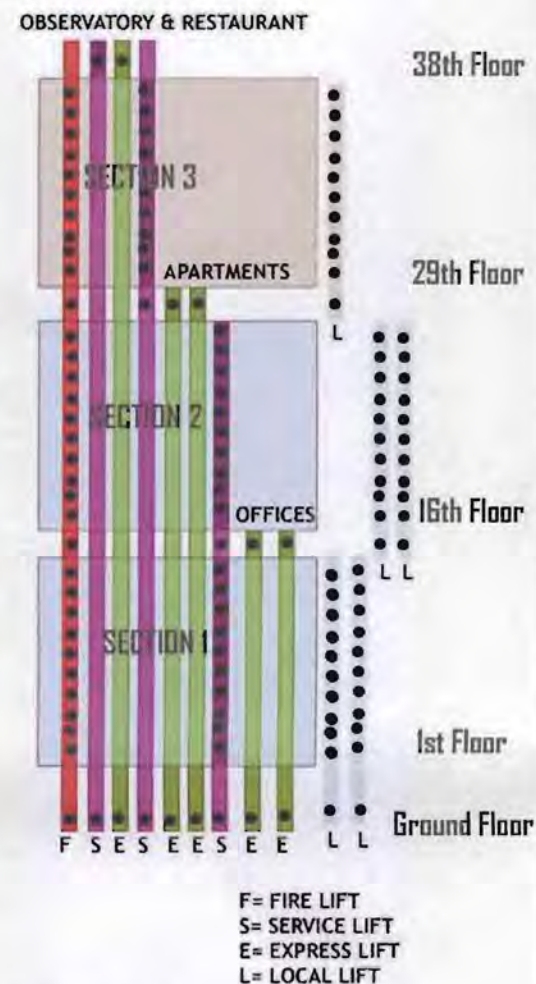
**FIGURE 80: Geometry of the Floor Plates, scale 1:1000 (author)**  
The curved triangular form creates a larger radius for the curve at the perimeter of the building when compared to a circle of equal area, making it easier to inhabit the space. One facade faces due south with the others at oblique angles to east and west. Having one facade facing directly south should assist in the shading strategy later on. Also by virtue of the form and orientation, there should theoretically be less wind turbulence created when compared to a rectangular building form.



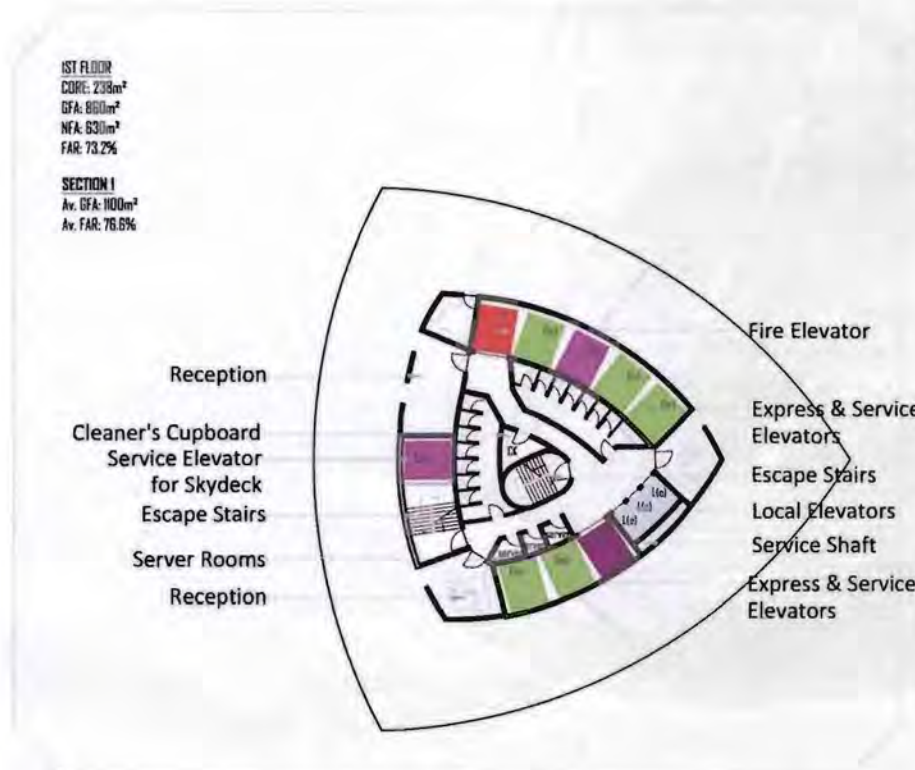
**FIGURE 81: Program 1:2000 (author)**



**FIGURE 83: Ground Floor Core Layout, scale 1:500 (author)**  
2 local elevators shuttle between the underground parking levels and the ground floor lobby. Access to get further into the building can then be controlled.



**FIGURE 82: Lift Strategy (author)**  
The diagram shows the building split into three sections. The size of the core decreases at each section as certain elevator runs end.



**FIGURE 84: 1st Floor Core Layout, scale 1:500 (typical for section 1) (author)**  
The core allows the floor plate to be split into three portions. Toilets and other ancillary rooms are arranged along the shaft walls of express and service elevators which do not stop at that particular floor. At the top left of the plan one sees the floor area ratio for this floor as well as for the section of the building. The values are very similar to the theoretical ones calculated in previous studies.

- (o) = Office
- (r) = Residential
- (u) = Underground Conc.
- (s) = Sky deck/restaurant
- (L) = Local Elevator
- (E) = Express Elevator
- (S) = Service Elevator
- (F) = Fire Elevator
- (P) = Parking Elevator

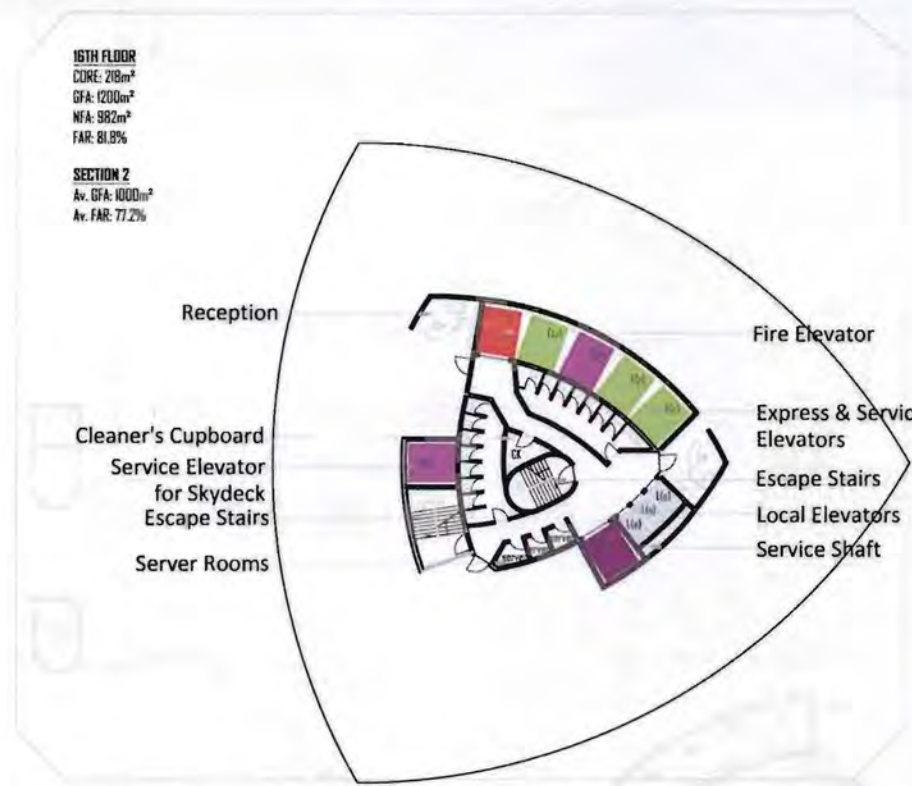


FIGURE 85: 16th Floor Core Layout, scale 1:500 (typical for section 2) (author)  
 Two express elevators fall away

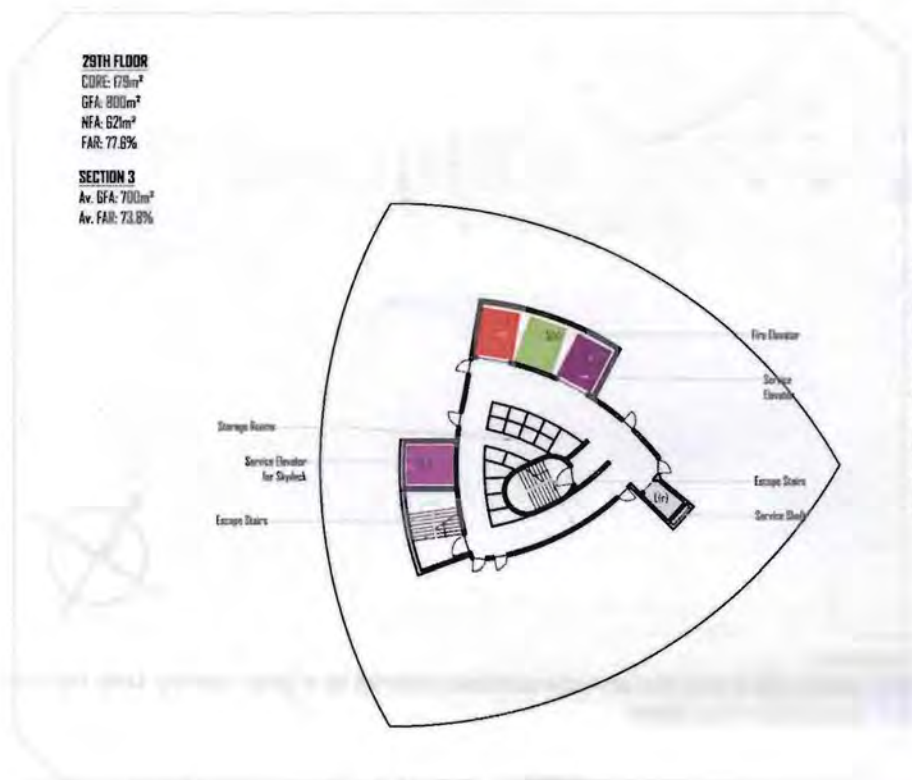


FIGURE 86: 29th Floor Core Layout, scale 1:500 (typical for section 3) (author)  
 At the residential levels two more express elevators and a service elevator fall away. Only one local elevator is needed.

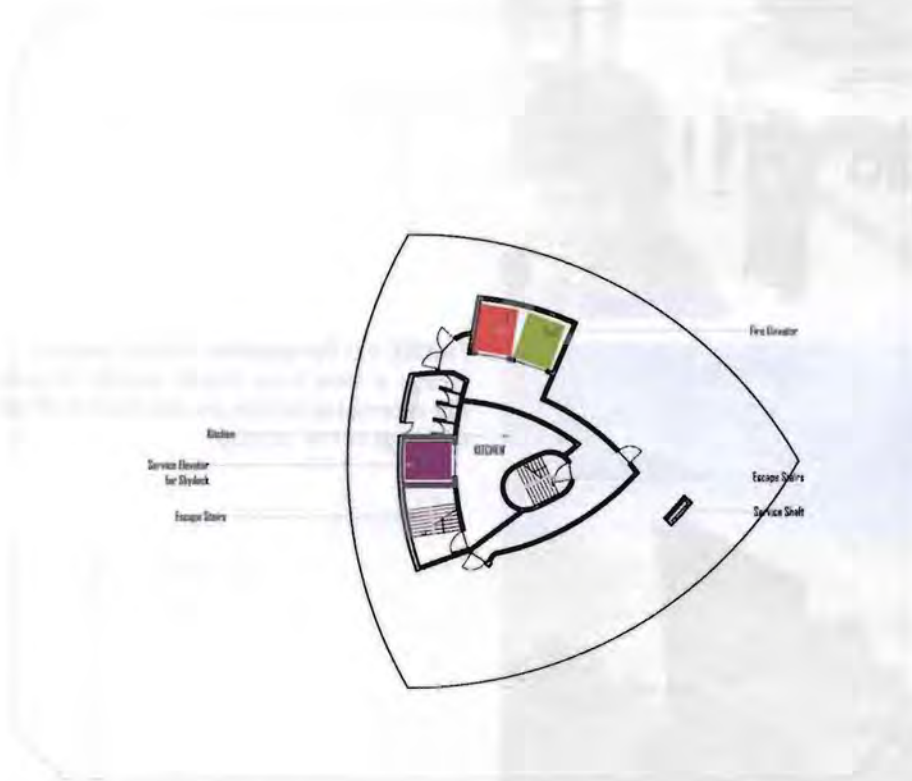


FIGURE 87: 38th Floor Core Layout, scale 1:500 (author)  
 At the very top floor of the building only an express, service and fire elevator remain.

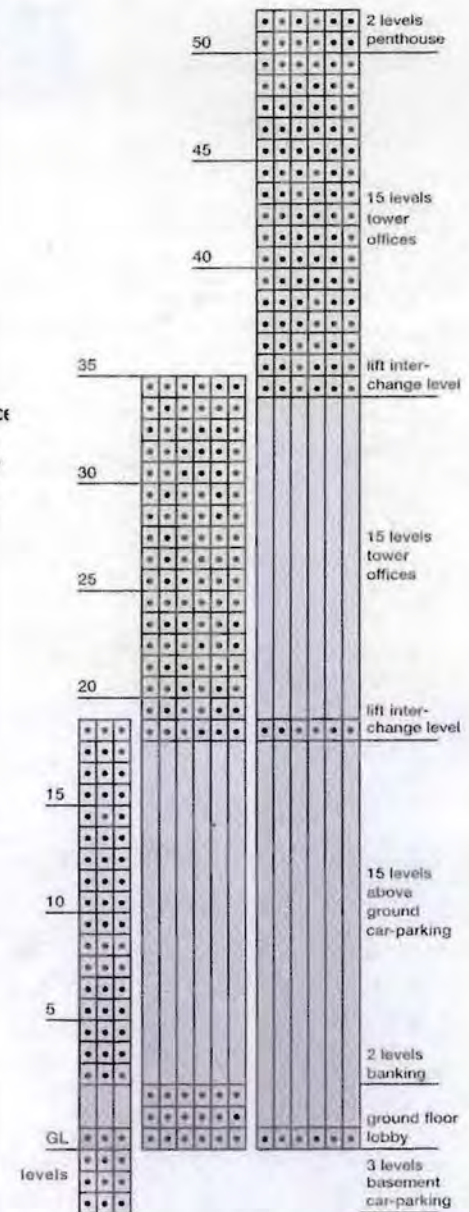


FIGURE 88: Example of Elevator Analysis for a 52-storey Building (Yeang, 2000)  
 The schematic diagram by Ken Yeang in the book "Service Cores" shows the number of lift shafts and proposed openings. The dots indicate door openings. The scheme consists of 3 lift zones, one for car parking below and above ground, one for lower and mid-level offices, and one for the upper offices. This scheme has certain similarities to the one being used for the thesis project.

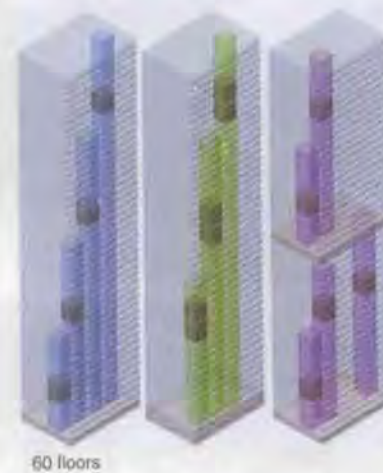
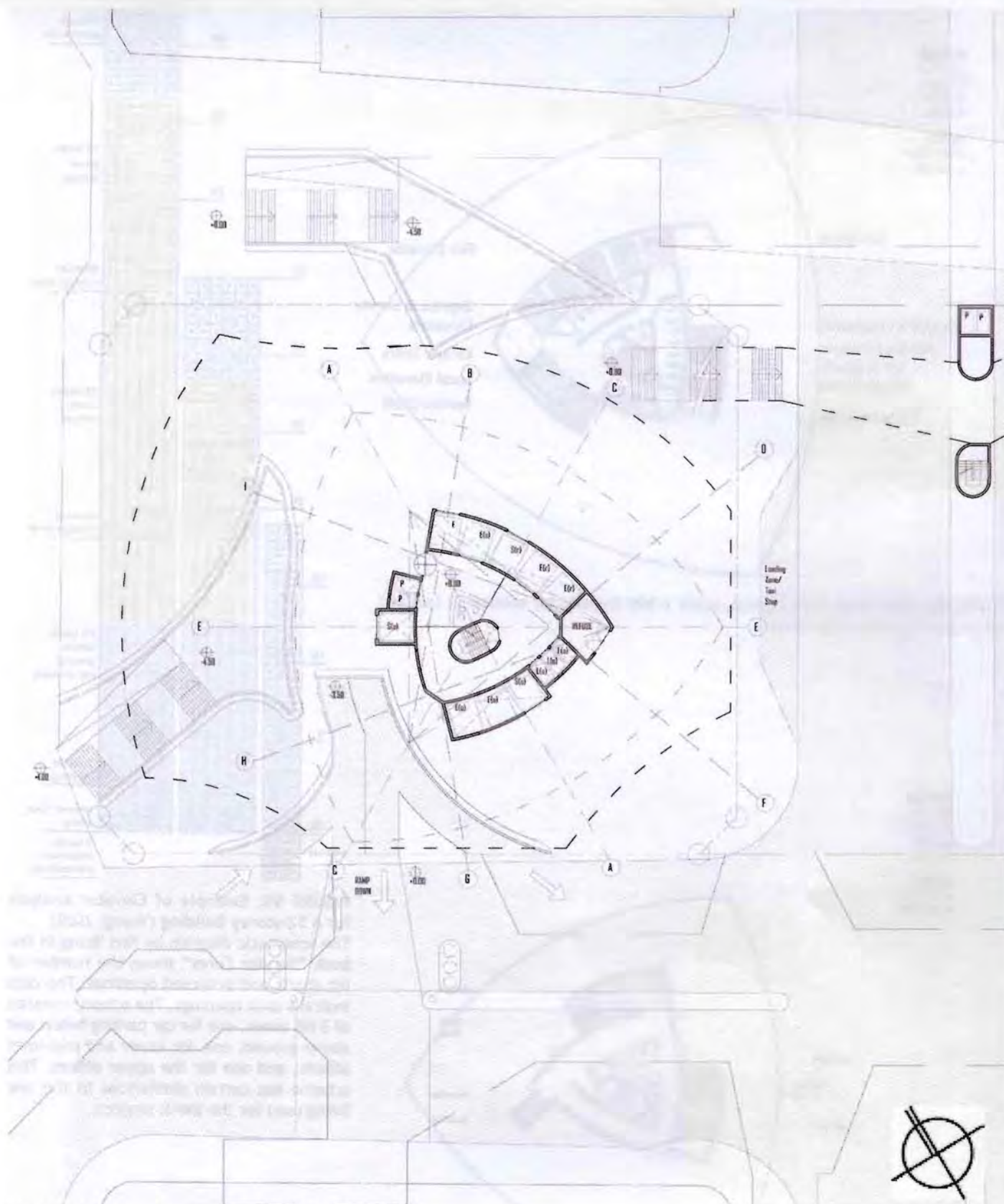


FIGURE 89: Lift Strategies (Strelitz, 2005)  
 The diagram shows a number of plausible alternative lift strategies for buildings of varying height.





**FIGURE 90: Ground Floor Plan, scale 1:500 (author)**  
 The idea was to create a permeable ground floor plane which felt like an open pavillion covered by a large canopy. Only the core of the building would reach the ground with the rest of the mass lifted.



**FIGURE 91: Perspective Sketch (author)**  
 This sketch tries to capture the environment at the base of the building, showing the large canopy which should be designed to shelter the open space at ground floor from downwind.



**FIGURE 92: Perspective Sketch (author)**  
 This is a view from strand street, showing the external structure and the cluster of tall buildings in the vicinity.

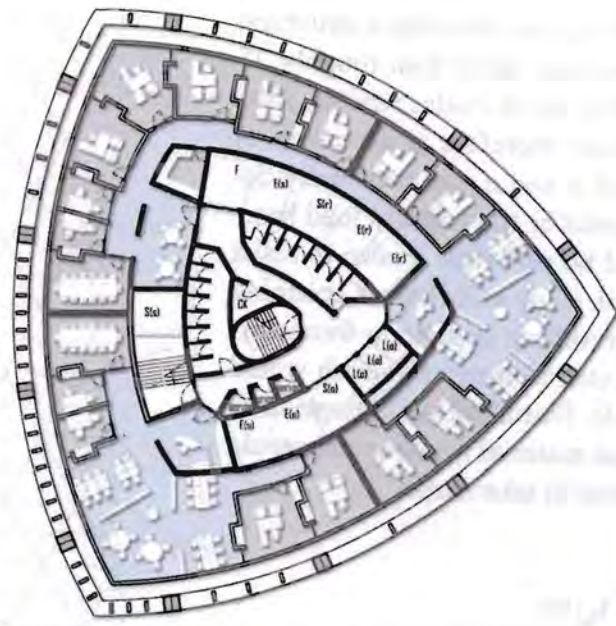


FIGURE 93: 1st Floor Plan, scale 1:500 (typical plan for section 1) (author)  
 At the first floor the core-to-wall depths are still shallow enough to allow for cellular office types as well as open-plan if desired. The partitioning is done in a radial manner, connecting perpendicular to the facade.



GROUND FLOOR

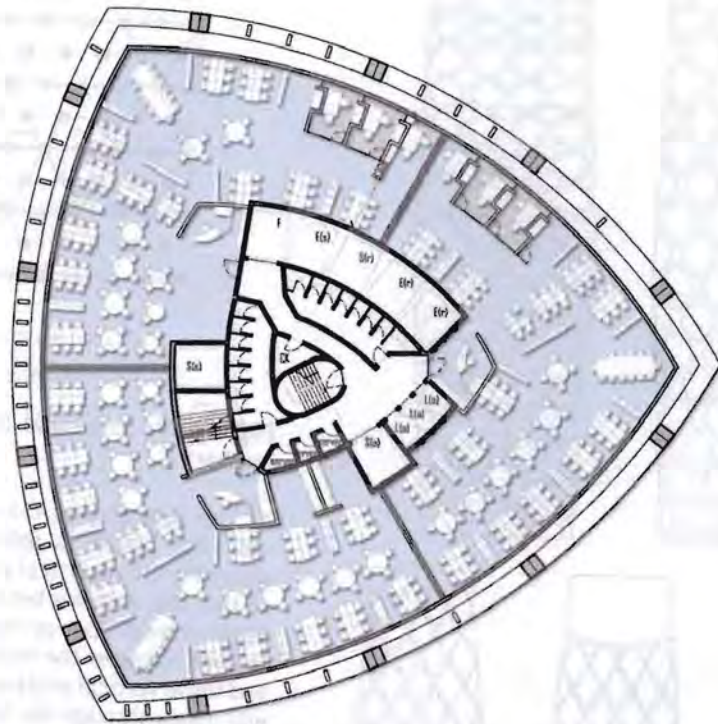
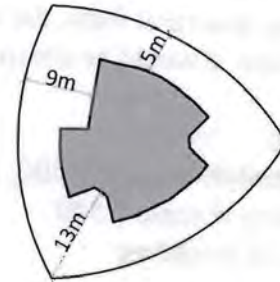
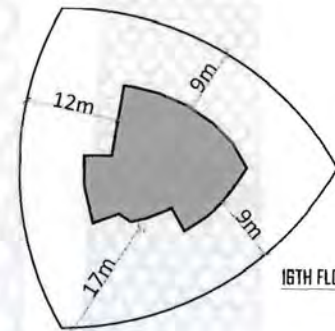
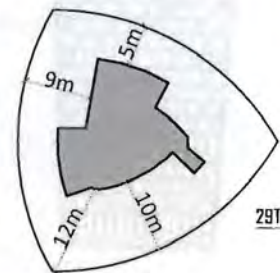


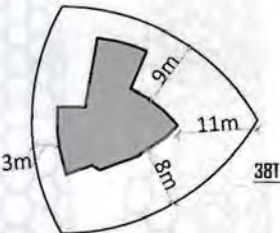
FIGURE 94: 16th Floor Plan, scale 1:500 (typical plan for section 2) (author)  
 This is the largest floor plate. The depths here do not allow for cellular offices. With certain elevator shafts falling away it in effect creates a core which is off-centre, allowing for various arrangements.



16TH FLOOR



29TH FLOOR



38TH FLOOR

FIGURE 96: Core-Wall Depths (author)



FIGURE 95: 29th Floor Plan, scale 1:500 (typical plan for section 3) (author)  
 This is the largest floor plate for apartments. Various sized apartments are arranged in a radial manner. This floor plate represents the upper limit for the depth of apartments before they start becoming unpractical and difficult to light.

- (o) = Office
- (r) = Residential
- (u) = Underground Conc.
- (s) = Sky deck/restaurant
- (L) = Local Elevator
- (E) = Express Elevator
- (S) = Service Elevator
- (F) = Fire Elevator
- (P) = Parking Elevator



#### 4.6 Structure & Skin; Concept, Form & Materiality, June-August 2011

The next step in the design development was to develop a structural concept. Research showed that with structures taller than roughly 35 floors, the core alone is not able to resist the lateral loads (Strelitz, 2005 and Schueller, 1996). A perimeter structure therefore is necessary. A number of structural systems were looked at and it was eventually decided that a continuous tube structure would be the primary load bearing element. The girth of the tube would be sufficient in size to resist lateral loads. It would also carry vertical loads with beams spanning between the core and the external tube, resulting in column-free internal space. The vision was to create an external structure which would add depth and visual richness to the façade. Simultaneous to these studies of the structural form, the idea of what material the structure would be and how it would be constructed started to take shape.

##### Method:

Study models at scale 1:500, 1:200 and 1:100

Elevations at scale 1:500

3D digital modeling

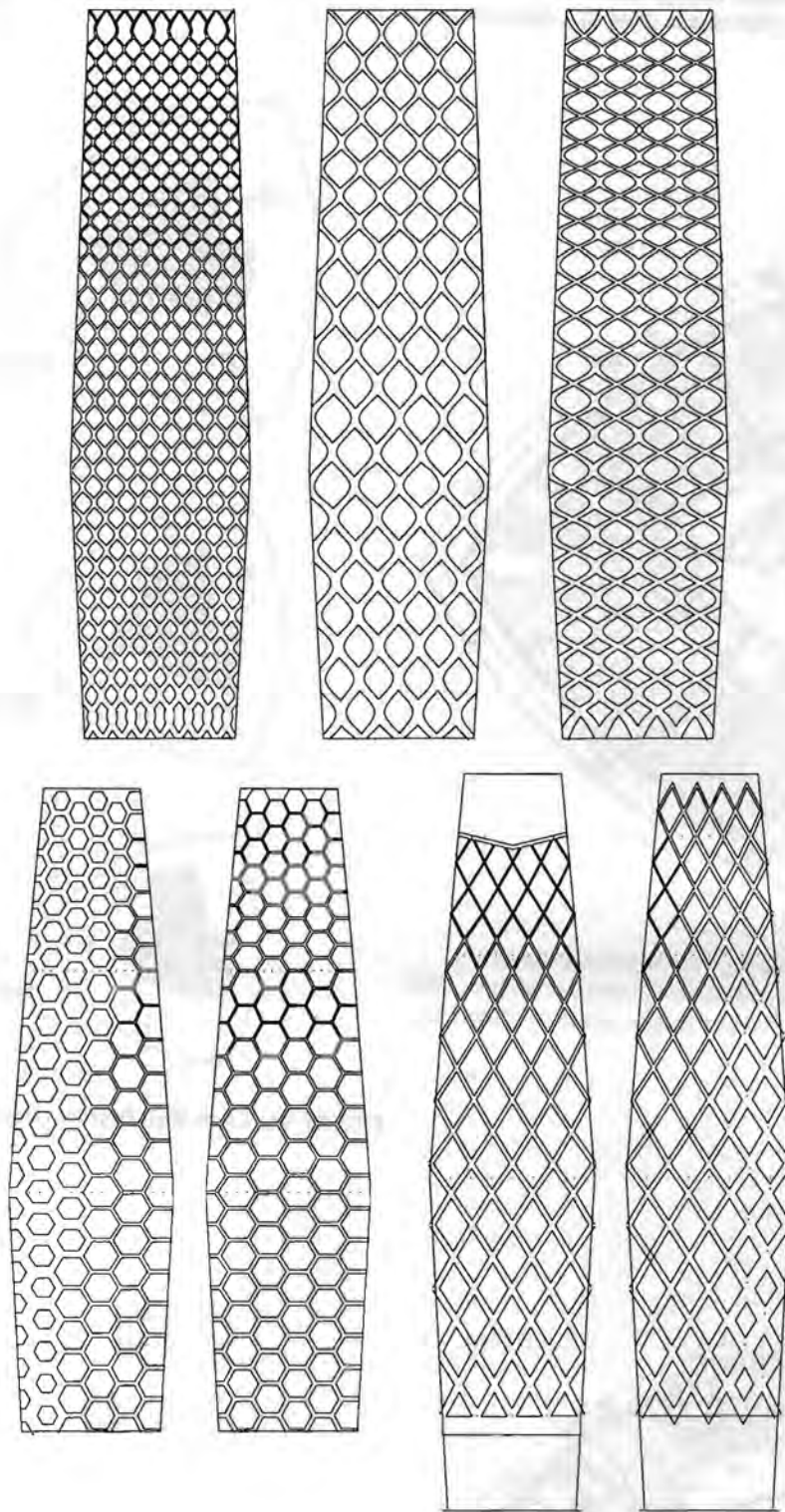


FIGURE 99: Elevations, scale 1:2000 (author)

Using the structural grid which had been established, a number of alternatives were explored. The idea was also to find a system and geometry which could be changed and adapted to suit a particular orientation.

1. Splines, triangulated at a scale of one storey in height and increasing member sizes according to structural load
2. Splines, triangulated at a scale of two storeys in height and increasing member sizes according to structural load
3. Splines, spanning two horizontal bays and two storeys in height and increasing member sizes according to structural load
4. Honeycomb, with increasing member sizes according to orientation and increasing member sizes according to structural load
5. Simple diagonals, with increasing member sizes according to orientation and increasing member sizes according to structural load



FIGURE 97: Structural Grid, scale 1:1000 (author)

1. The geometry of the outer tube is laid out. The facade is split vertically into 8 equal bays. The vertical grid lines are placed so that the distance between them remains equal at each floor of the building. A grid is formed between the horizontal floor plates and these vertical grid lines. The floor beams will pierce through the facade and meet the outer structure at the points where the grid intersects (black dots). The diagonal pattern is created by connecting these points with straight lines. The scale of this pattern was chosen to be so that a triangles of 2-storey height are formed. This means that at every second level there will be floor beams which do not meet the outer structure (grey dots). A transfer edge beam will need to carry the loads so that they meet the outer diagonals (thick grey lines).

The building form is symmetrical which means that the members are identical within each particular floor. But because of the building taper the members from level to level are slightly different in length and their angle of deflection increases or decreases incrementally.



FIGURE 98: Swiss Re. Building, London, Forster and Partners, 2002 (Strelitz, 2005, edited)

The structural grid for the outer tube is also triangulated every two storeys in height, with transfer beams at every second level to pick up a floor beam which doesn't meet the grid.

RESEARCH:

This page shows some of the research on structure and materiality previously done and compiled in an earlier research

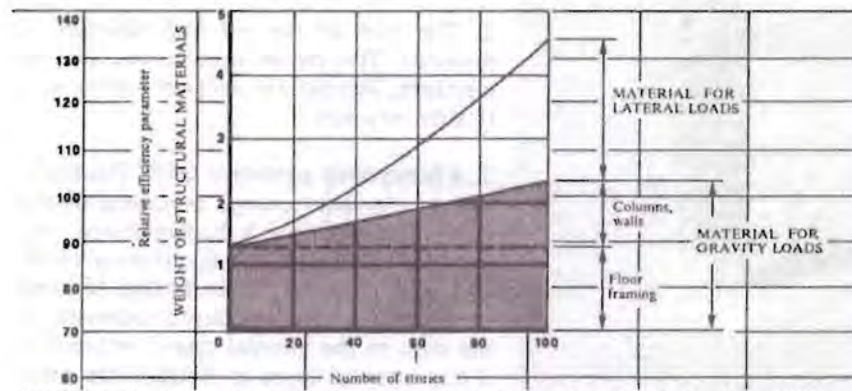


FIGURE 100: Lateral Loads in relation to Building Height (Schueller, 1996)  
The amount of structural material required to resist lateral loads increases as the square of the height, whereas the material required to resist gravity loads increases linearly with height.

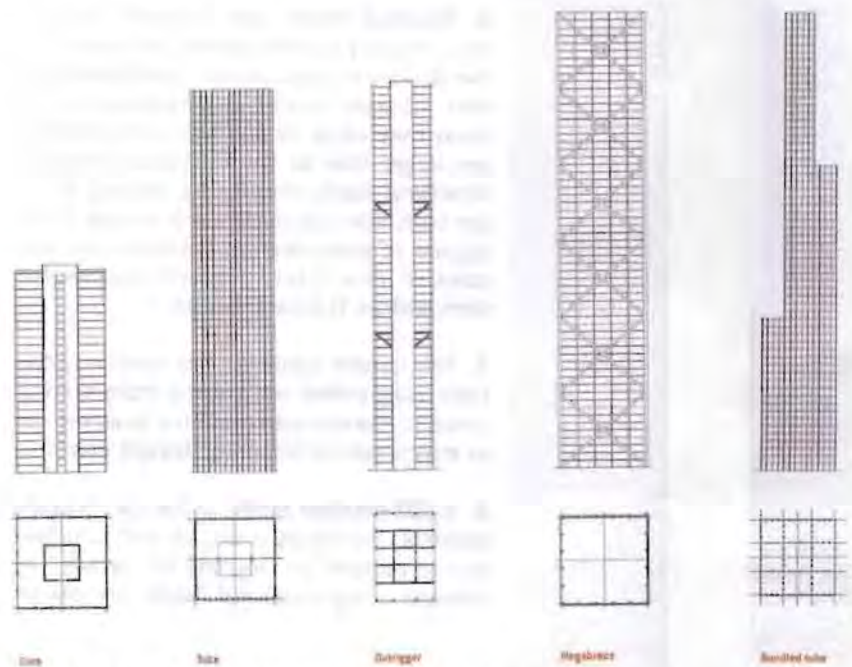


FIGURE 101: Structural Forms (Strelitz, 2005)  
The basic structural forms as described by Harry Bridges of Arup.  
1. The core: The central core alone provides the rigidity to resist lateral loading.  
2. Tube: The perimeter of the building consists of closely spaced vertical members which carry vertical and horizontal loading, acting as a single hollow core.  
3. Outrigger: At certain levels in the building cantilever structures extend from the core, they transfer loads from the perimeter structure to the core  
4. Megabrace: Much like a tubed structure, the external facade carries the loading. It is a framed structure which is continuously braced on all sides to provide the required rigidity and to act as a single tube. Vertical members need not be as closely spaced as in a tube structure as the shear forces are resisted by the bracing members.  
5. Bundled Tube: Much like a megabrace, but the bracing is provided by internal members which link opposite facades as opposed to external bracing members.

The type of structure used in this project can be described according to the diagram above as a tube structure (2). The difference is that the members are not vertical but form a diagonal grid, allowing the members to be spaced further apart as this diagonal form increases lateral stability. Although it might appear to be a megabrace structure because of the diagonals, it is in fact a rigid tube structurally.

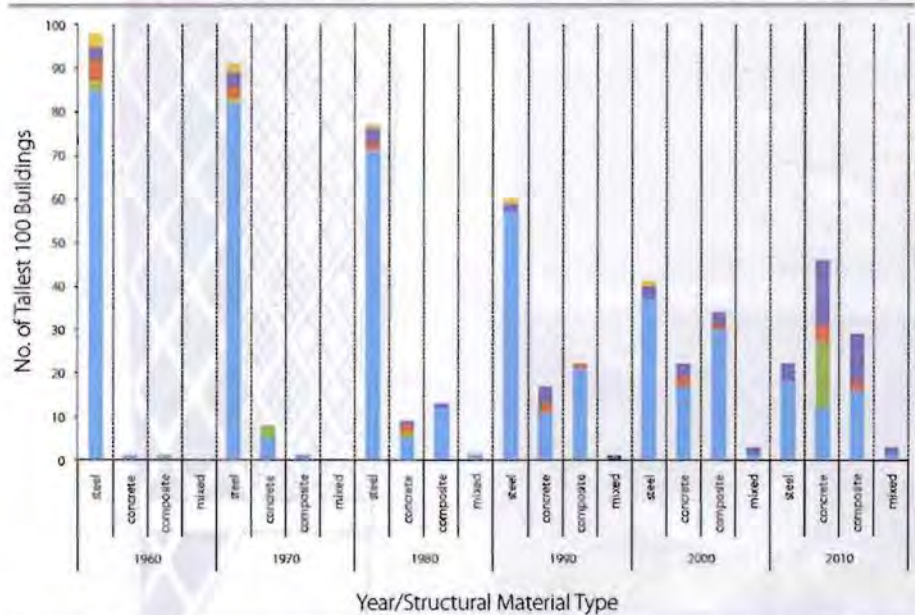


FIGURE 102: 100 Tallest Buildings: their structural materials and function (CTBUH, 2011)  
There is perhaps an optimal material in terms of structural performance for each type of structure, yet there are other considerations which inform the choice of material as well. Skills and economics vary geographically, the local construction environment is crucial in selecting optimal materials for building. In South Africa, all of the 60 tall buildings (over 80m) were constructed using concrete as the structural material (CTBUH database). Of the 100 tallest buildings in the world in 1960, about 90% were built using steel. This figure has reduced by at least 15% each decade since 1970. By the end of 2010, only 22% of the 100 tallest buildings in the world were constructed using steel, with over 40% using concrete and about 30% using a composite of steel and concrete (CTBUH, 2011)



FIGURE 103: Floor system of Swiss re HQ, London, Forster and Partners, 2002 (Strelitz, 2005)  
The steel deck and concrete topping system was used. The steel beams have been fabricated to allow for the overlap of services as well as reduce the weight of the members whilst allowing sufficient structural depth.



FIGURE 104: 88 Wood Street, London, Richard Rogers, 2001 (Strelitz, 2005)  
Precast ribs were installed and connected to the structure by post-tensioning. A reinforcing mesh was laid above the ribs and topped with in situ concrete to form the floor surface



FIGURE 105: Soccer City Stadium, Johannesburg, Boogertman and Partners, 2010 (DSE, 2009)  
Large prefabricated steel sections were manufactured at a workshop in Vanderbijl Park and transported to site as abnormal loads on large trucks. It shows that the expertise and facilities exist in South Africa for large-scale steel construction.

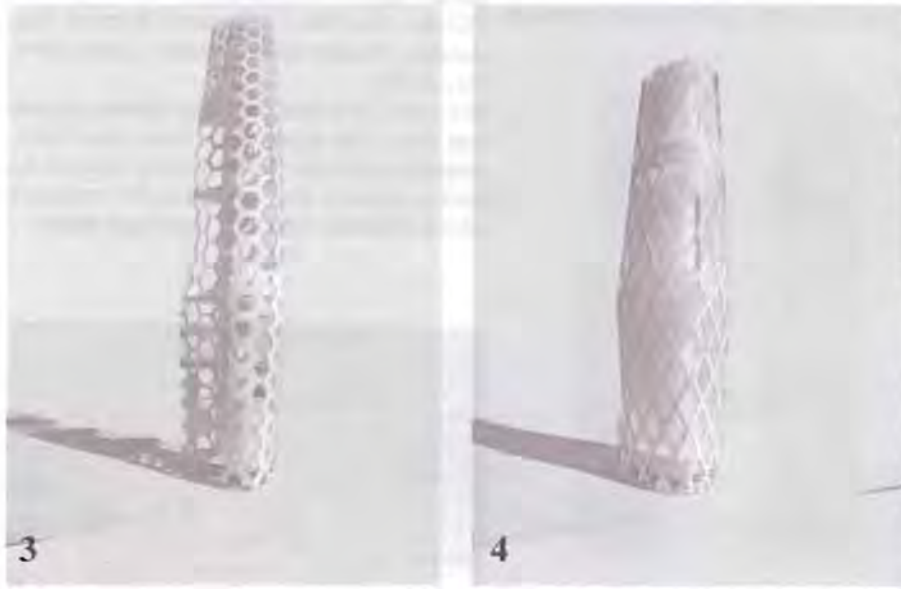
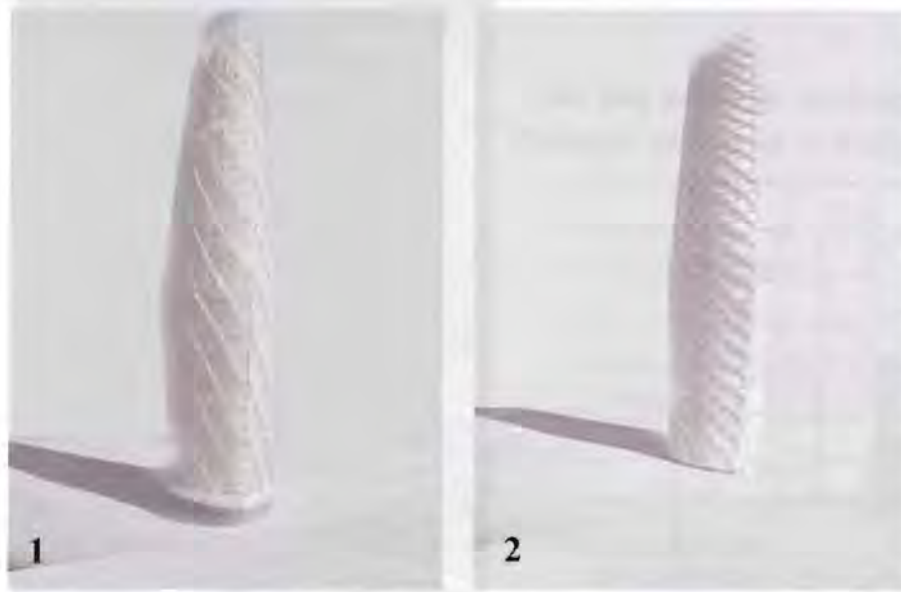


FIGURE 106: Study Models (author)

1. The basis for the investigation is this model, with an outer structure consisting of uniform sized diagonals

2. The form of the external structure is explored. This model uses curved bracing members. This pattern does not express verticality very well.

3. A honeycomb pattern is used. The thickness of members change according to the orientation, acting as a shading device, limiting solar gain and providing thermal mass. This model was not taken further because the member sizes are disproportionate to the sizes of the internal rooms, especially if the internal space is divided into small cellular offices. Although the outward expression would seem harmonious, it would severely hamper views from inside and seem out of scale.

4. Diagonal braces are revisited, as they best respond to and express the nature of the structural loads. In this model the members increase in size in proportion to the loads they carry. At the base the members are larger than at the top. Expressing the structural loads visually by varying member sizes does cause the form to lose its elegance to some degree. From an aesthetic point of view, I felt that uniform member sizes (model 1) looked better.

5. The curved members are revisited, this time using a finer scale and a more vertical pattern. Curved members are however not as structurally efficient as straight ones.

6. 1:100 detailed model of facade. Shading elements are incorporated as well as ledges on the outside for cleaning the facade. Although having horizontal ledges are practi-

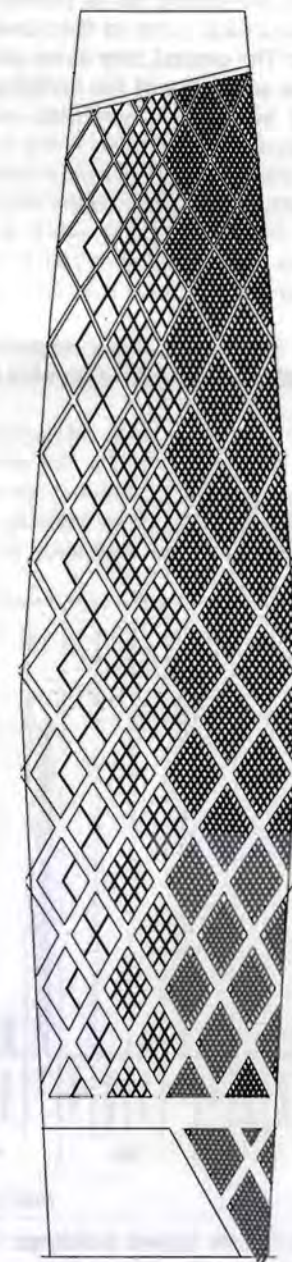


FIGURE 107: Elevation (author)

Eventually it was decided to use simple diagonals to form the structural tube. Secondary shading members would be incorporated which could change in density according to the orientation. Rather than thickening the main structural members, this alternative brings a human scale to the structure and allows for better views from within the building.



FIGURE 108: 1:200 Model (author)

The outer skin is designed with lattice-like shading members. The main structural members increase in size towards the bottom where the forces are the largest. A large ring beam raised above the ground collects all of the forces from the perimeter tube and transfers them to a few large columns which penetrate to the foundations. A wedge-like roof is suspended with chords from the ringbeam. This roof is seen as an extension of the ground plane where people are able to walk on the roof. Beneath this roof there would be the lobby area as well as some retail activities. A large portion of the ground floor is a void, creating an area below ground level which is open to the sky, protected from wind, and connected to the underground concourse.

Now that the geometry of the outer structure had been resolved to a certain degree, deciding on a structural method and material became important. The tall buildings in Cape Town are all constructed using reinforced concrete structurally. It gives an indication of the economy of concrete. Ideally concrete should be the structural material used, but given the form of the structure it was decided not to use concrete but use steel instead. The main factors which came into consideration are listed in the column below

**In-Situ Concrete:** It was decided against concrete because of the complexity of the form, which would require precisely cut formwork. Building the formwork would require so many unique pieces that it would become very time consuming and expensive.

**In-Situ Concrete with permanent steel formwork:** This came into consideration because sheet metal could be fabricated using CNC (computer-numerically-controlled) cutters which would speed up construction and provide a neat finish. Concrete would then be poured into the steel formwork. The concrete would provide the necessary fire resistance.

**Pre-cast Concrete:** Pre-cast concrete would be ideal because of the finish and material properties it has. But this would require too many unique casts to make it feasible.

**Steel with fire-proof (aluminium) cladding:** It can be concluded that the geometry of the structure dictates that it is a job for precise pre-fabrication. One might as well fabricate all of the members in a controlled environment off site and deliver them to site as pieces ready to be assembled. This would be the speediest construction technique. Steel is expensive, but using any of the other techniques would also become unconventionally expensive.



FIGURE 109: View from Adderley Street (author)

The 3d model represented here varies from the 1:200 physical model in that the perimeter structure reaches the ground, piercing through the enclosed space on ground floor. A suspended canopy is also incorporated to protect the traffickable roof from downwinds and rain

With this in mind, the design team decided to create a structure that would be both aesthetically pleasing and structurally sound. The design team decided to create a structure that would be both aesthetically pleasing and structurally sound. The design team decided to create a structure that would be both aesthetically pleasing and structurally sound.

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FIGURE 110: View from Strand Street (author)

As opposed to the physical model, the digital one shows uniform member sizes for the structural members. This can be achieved by over-sizing the cladding at the top as well as adding extra flanges and thickening the steel at the bottom.

Also, the perimeter structure meets the ground. Both changes made in the digital model were preferred to those in the physical model

## 4.7 Revisiting the Floor Plans and Core Layout, September 2011

The task was to make improvements to the preliminary layouts. The aim was to improve on the practicality of the floor plates by re-arranging the elevator banks. Also, the structural system needed to be taken into account and by redesigning the core, the attempt was to optimize the spans and structural system between the core and perimeter tube. The task was also to develop the structural system a bit further.

Until this point, there had already been a few explorations into how the tower reaches the ground and what kind of space is created at street level, underground, as well as the first few levels above ground. The purpose of this part of the design development was to reach a conclusion regarding this part of the design. The importance of a well designed base to the tower cannot be overemphasized. It is the key to the successful integration of the building into the existing urban armatures and public domain.

Method:

Drawings at various scales

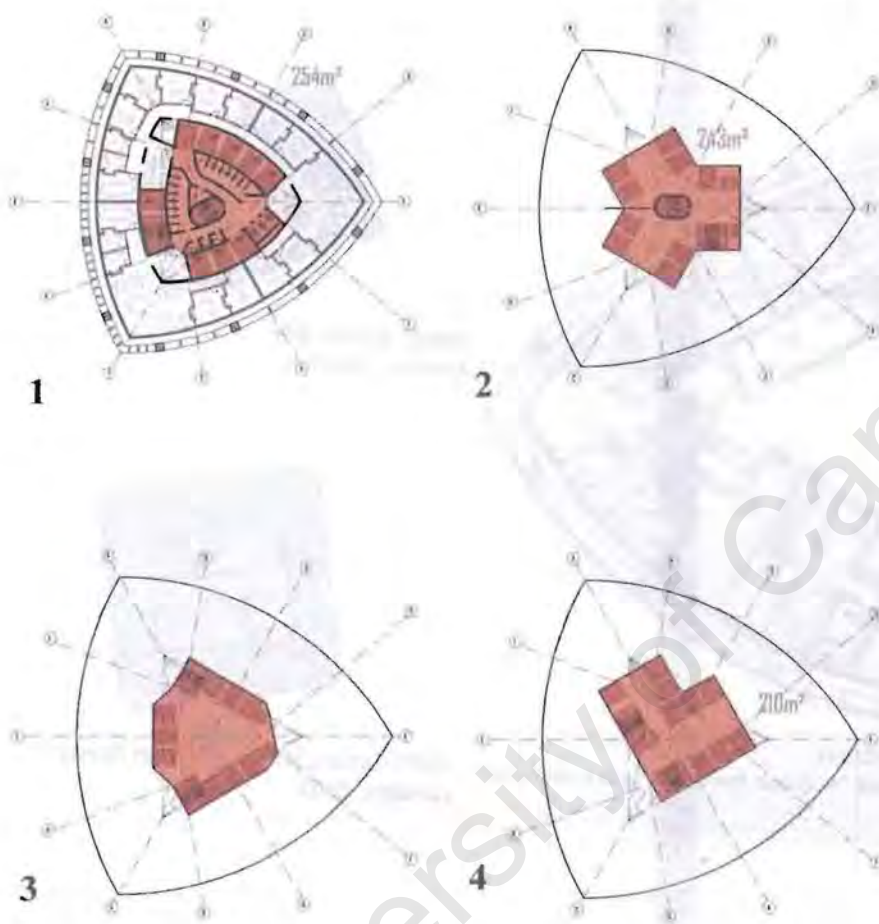


FIGURE 111: Desktop Study of possible core layouts, scale 1:1000 (author)

This was a quick exploration of various core layouts to see which basic organisation should be used. Using the same elevator strategy, the aim was to find an alternative using straight core walls rather than following the curve of the outer facade. This would be more practical in terms of the functioning of things such as elevators and door openings. Also it would be more practical in the use of space, especially for the small rooms such as toilets and offices.

1. Original Layout using curved walls and a radial arrangement following facade curvature.

2. This layout works well in terms of the functioning of the core, but creates awkward spaces between the core and facade

3. Much like the original scheme, but using straight walls with linear elevator banks. This scheme was taken to be developed further.

4. This layout proved the most space efficient when considering the core in isolation but it also creates awkward spaces outside of the core.

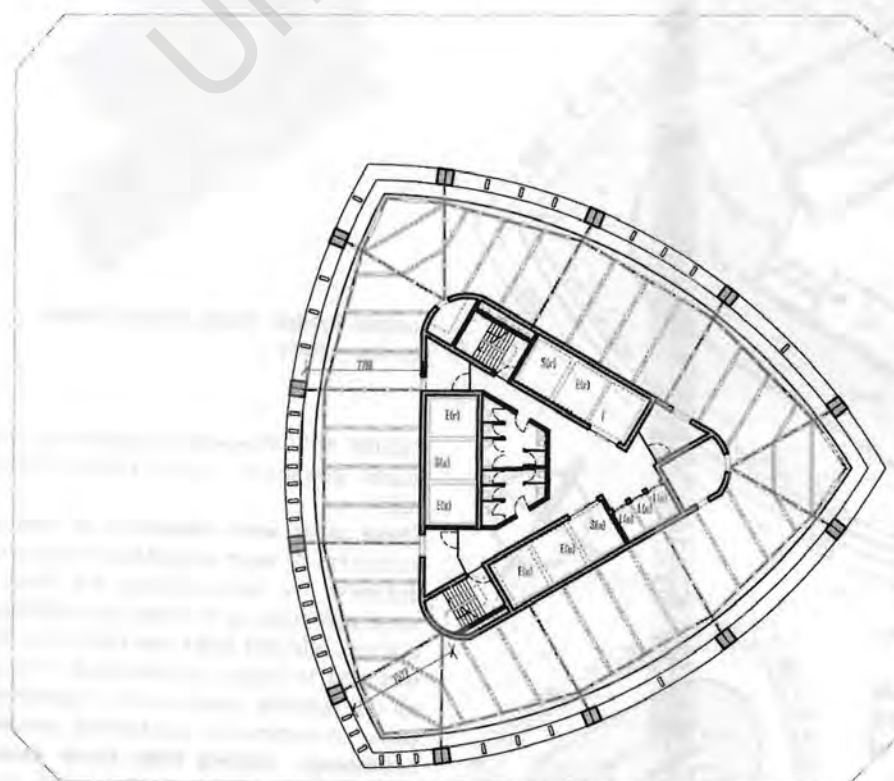


FIGURE 113: 1st Floor Beam Layout, scale 1:500 (author)

Secondary beams of varying length span between the edge beam and the core. Main beams span between the core and perimeter tube. The edge beams span between the primary beams.

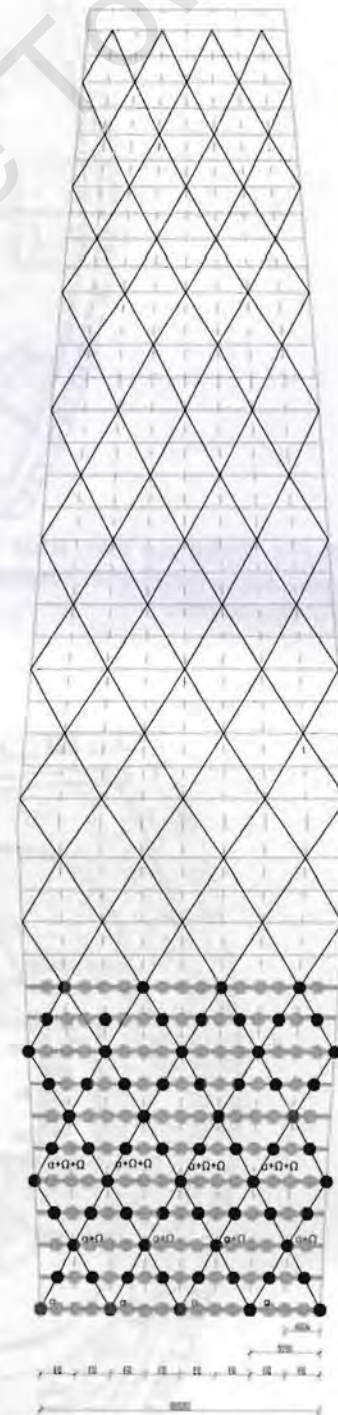
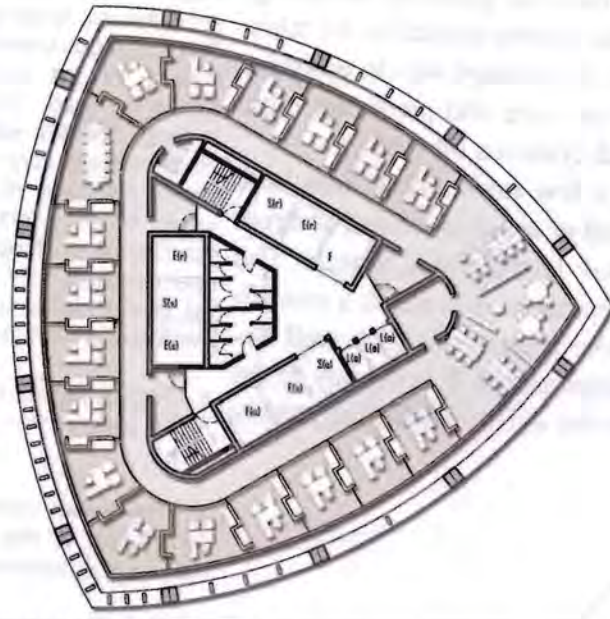


FIGURE 112: Structural Grid, scale 1:1000 (author)

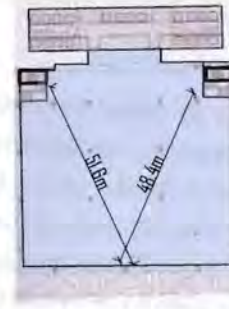
This diagram shows transfer (edge) beams at each level (thick grey lines). The main beams are indicated as black dots, they pierce through the facade and meet the outer tube structure. Secondary beams are indicated by grey dots, they meet with the edge beams on the interior of the facade. If the floor system used is permanent steel corrugated decking with concrete topping and they span between beams, the beam spacing needs to be quite close, resulting in edge beams on each floor.

**Typical Layouts**

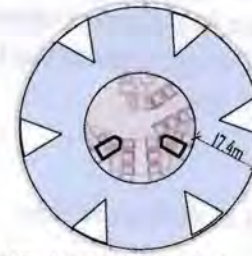
Given the form and massing of the building, each floor plate is different. Selected floor plans are shown below.



**FIGURE 114: 1st Floor Plan, scale 1:500 (author)**  
The layout follows the same principles as the original scheme, with ancillary rooms such as toilets housed in the central area along shaft walls which aren't in use.



122 Leadenhall Street, Richard Rogers  
London, 2004



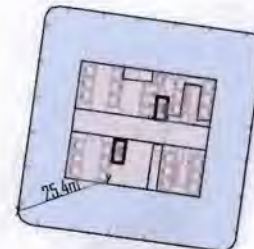
Swiss Re HQ, Norman Forster  
London, 2004



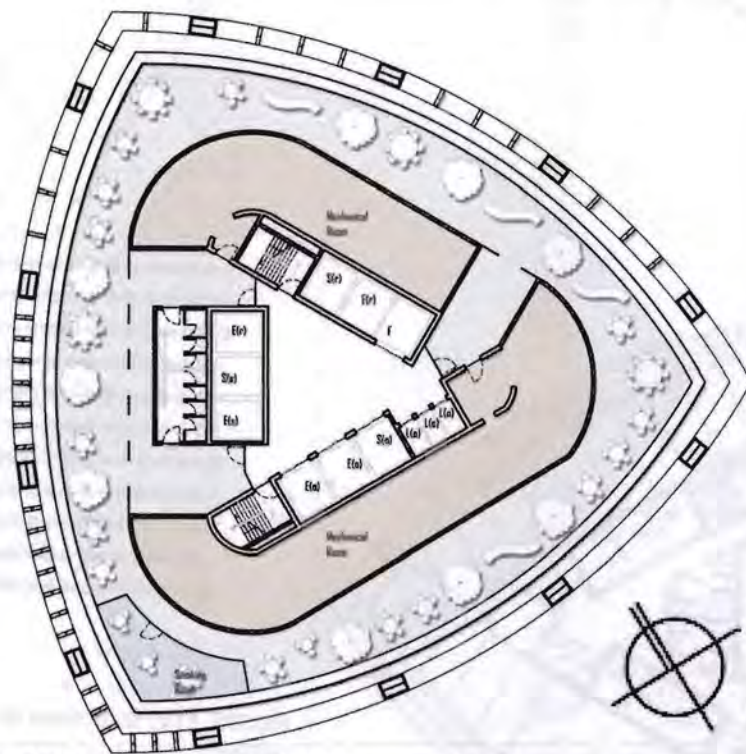
**FIGURE 115: 29th Floor Plan, scale 1:500 (author)**  
A number of apartment sizes ranging from one to three bedroom apartments are shown in this example



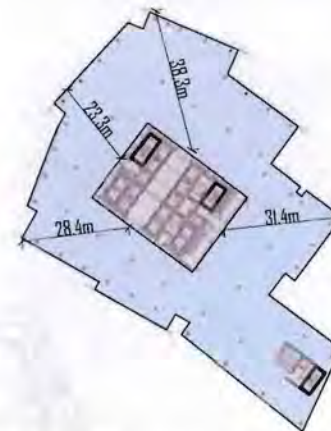
Heron Tower, KPF  
London, 2002



HSBC Canary Wharf, Norman Forster  
London, 2002



**FIGURE 116: 15th Floor Plan 1:500 (author)**  
The sky lobby floor features a narrow double volume along the building perimeter, with seating and a smoking room. The majority of the floor is taken up by mechanical rooms. To the right is a plan of the second level of



London Bridge Tower, Renzo Piano  
London, 2003

**FIGURE 117: Precedent Studies on Escape Route Distances, scale 1:2000 (Strelitz, 2005)**

These plans were measured to find some indication of what acceptable escape route distances for tall buildings are. There was some confusion as to what the building regulations allowed and I therefore felt that it was best to judge by precedent. These are all tall buildings constructed in recent years, using contemporary mechanical ventilation technology. Judging from these examples the escape distances for this thesis project are acceptable as they are shorter than each of the above examples. Research showed that the allowed escape route distances are also dependant on mechanical technology used, such as pressurized stairwell shafts and automatic sprinkler systems in corridors (Eisele & Kloft, 1999).

## Ground Floor

One of the main concerns in designing the ground floor is how to accommodate vehicular access, loading and drop off zones. Pedestrian access, primarily from the pedestrian malls as well as lobby areas needed to be accommodated.

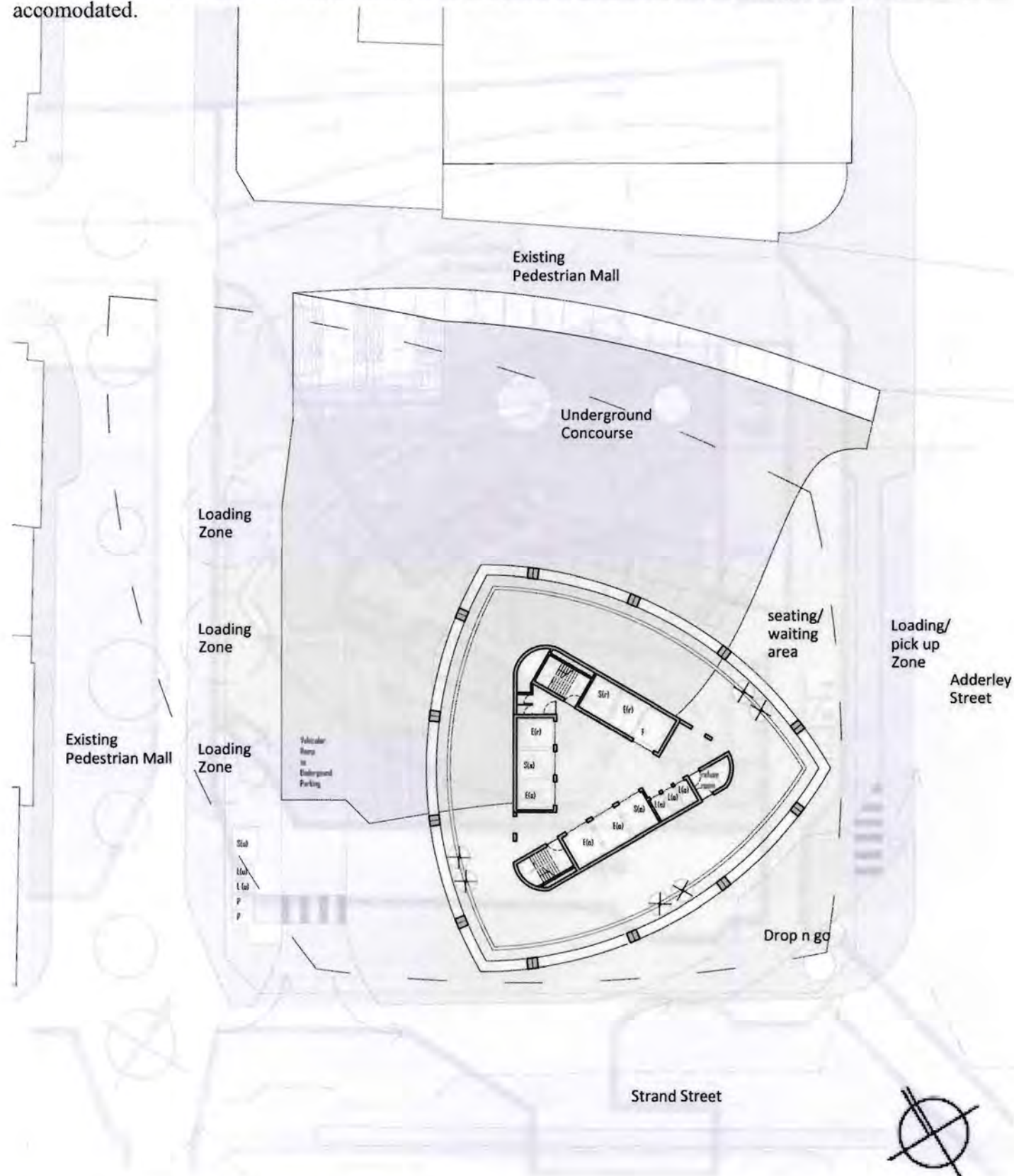


FIGURE 118: Ground Floor Plan, scale 1:500 (author)

Most of the ground floor is left void, with the first underground level seen as having a more important role in connecting and contributing to the urban armatures and public realm. All access to the upper levels of the building is controlled from ground floor, between the ground floor and lower levels separate elevators outside of the building enclosure transport the passengers. Vehicular access to the site is only taken from one direction; southbound along strand street. Exiting from the basement levels is also only in this direction. A 25m long ramp takes vehicles down two levels, bypassing the underground concourse, reaching the parking levels. St. Georges Mall is used for deliveries. An alternative loading/pick-up lane is catered for along Adderley Street. The enclosed area is part of a large permeable lobby which is seen as an extension of the outside space.



FIGURE 119: View from Adderley Street (author)

The idea of a traffickable roof is abandoned and the wind canopy is lowered to provide better shelter. The underground concourse becomes a much more prominent feature. The vertical expression of the building form is also better complimented by not having the large enclosure on ground floor as in previous models. The mass of the building appears to rise from below ground to the skies as one solitary form and gesture.

### Underground Concourse Level

The underground concourse is an existing urban armature which is used by thousands of pedestrians daily. The relationship of the building to this concourse is critical to the success of the building at street level.

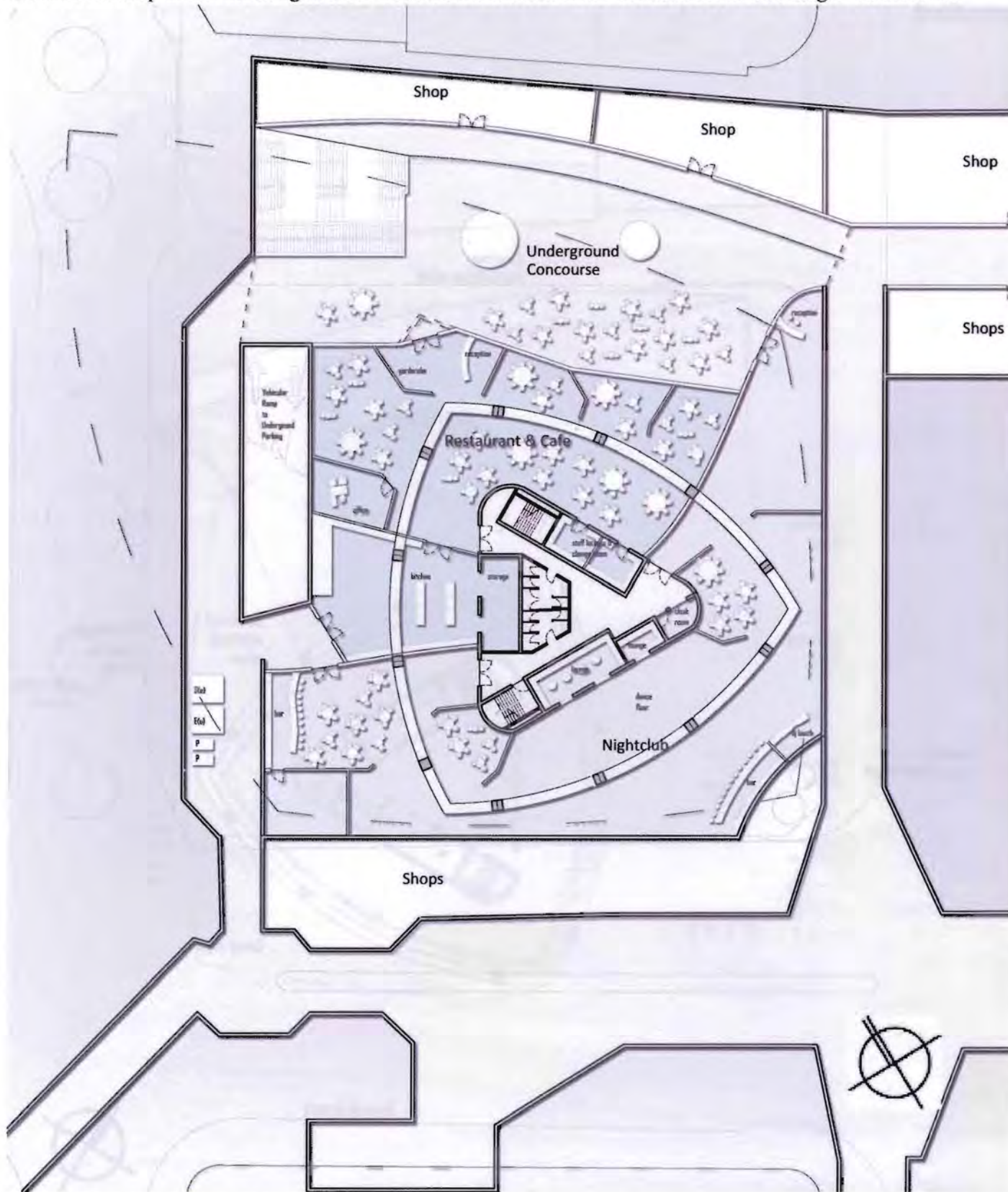


FIGURE 120: 1st Underground Floor Plan, scale 1:500 (author)

The building connects to the underground concourse, creating a large open area below ground which is sheltered from the wind, lit directly with north and east sunlight, and will benefit from the large flow of pedestrians between the train station and the mid city. A restaurant/cafe opens out to this space, which would most likely be a place for users of the building to have lunch. Along the other side retail stores are accommodated as a continuation of the existing mall. Large stairs and an escalator take pedestrians up to street level. A night club (discotheque) is also housed on this level. Toilets in the central core are shared by the tenants, with each having independent doors which lead to the lobby within the core and can be shut between opening hours.



FIGURE 121: View from Underground Concourse (author)

The image shows the open area with outside seating from the restaurant/cafe and shopfronts on the right. Angular planes extend the internal space beyond the perimeter structure and a canopy is seen suspended above.

## Basement Parking

In designing the basement parking, the transfer of the structural loads from above ground, tanking, as well as construction techniques needed to be considered.

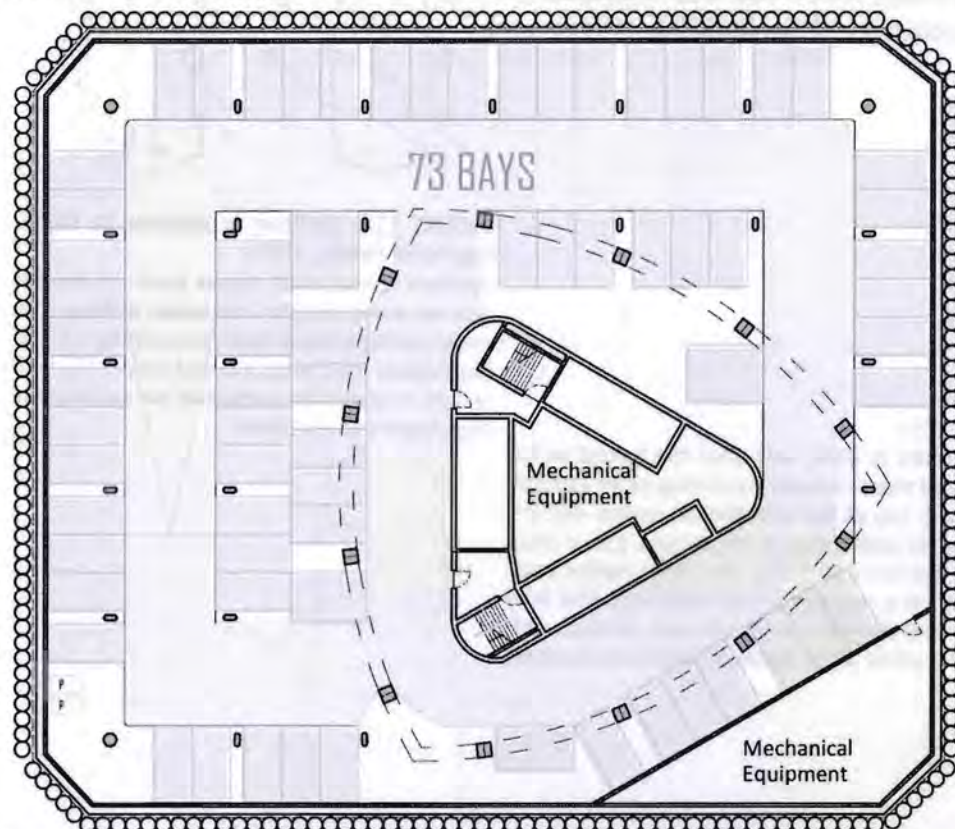


FIGURE 122: Basement Parking Layout scale 1:500 (author)

The configuration of the basement parking is made tricky in that the geometry of the building does not follow that of the street grid. Below the first underground level (public concourse level) the loads from the perimeter structure will be transferred to vertical columns which run plumb through the basements.



FIGURE 125: Basement Parking Scenarios scale 1:1000 (author)

A couple of layouts were tested. The one shown above was found to accommodate the most parking bays. With such a configuration 6 parking levels would be required to reach the target number of parking spaces (2/100m<sup>2</sup>).

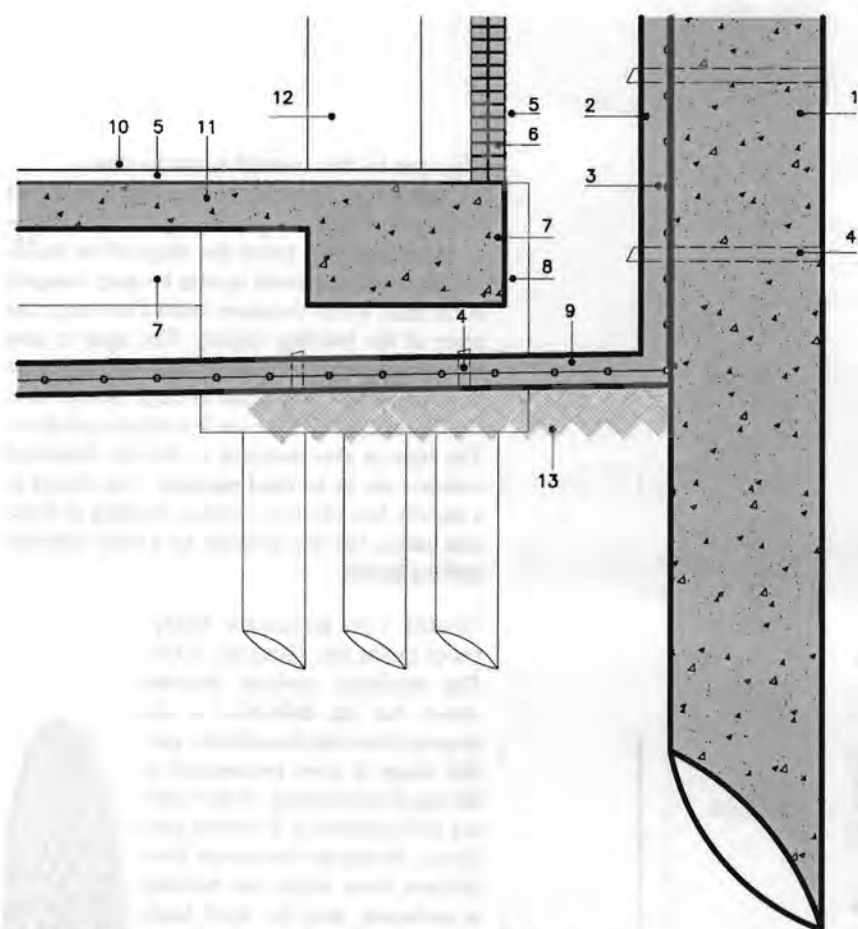


FIGURE 123: Basement Tanking Detail 1:50 (author)



FIGURE 126: Sheraton Hotel, Cape Town (google images)

The hotel, which is not located far from the site, has eight basement floors. Parking and other services are housed below ground, allowing a clean and elegant form above ground

- 1 1m Dia. Pile Retaining Wall
- 2 200mm Bentonite Slurry Wall
- 3 Galvanised Reinforcing Mesh
- 4 25mm uPVC Pipe
- 5 Torch-on Waterproofing Membrane
- 6 Non-load-bearing Brickwork
- 7 RC Floor Beam between Pile Caps
- 8 RC Pile Cap
- 9 Bentonite Slurry Sump Floor
- 10 Screed Finish
- 11 300mm RC Floor Plate
- 12 760x250 RC Basement Column
- 13 Compacted Earth

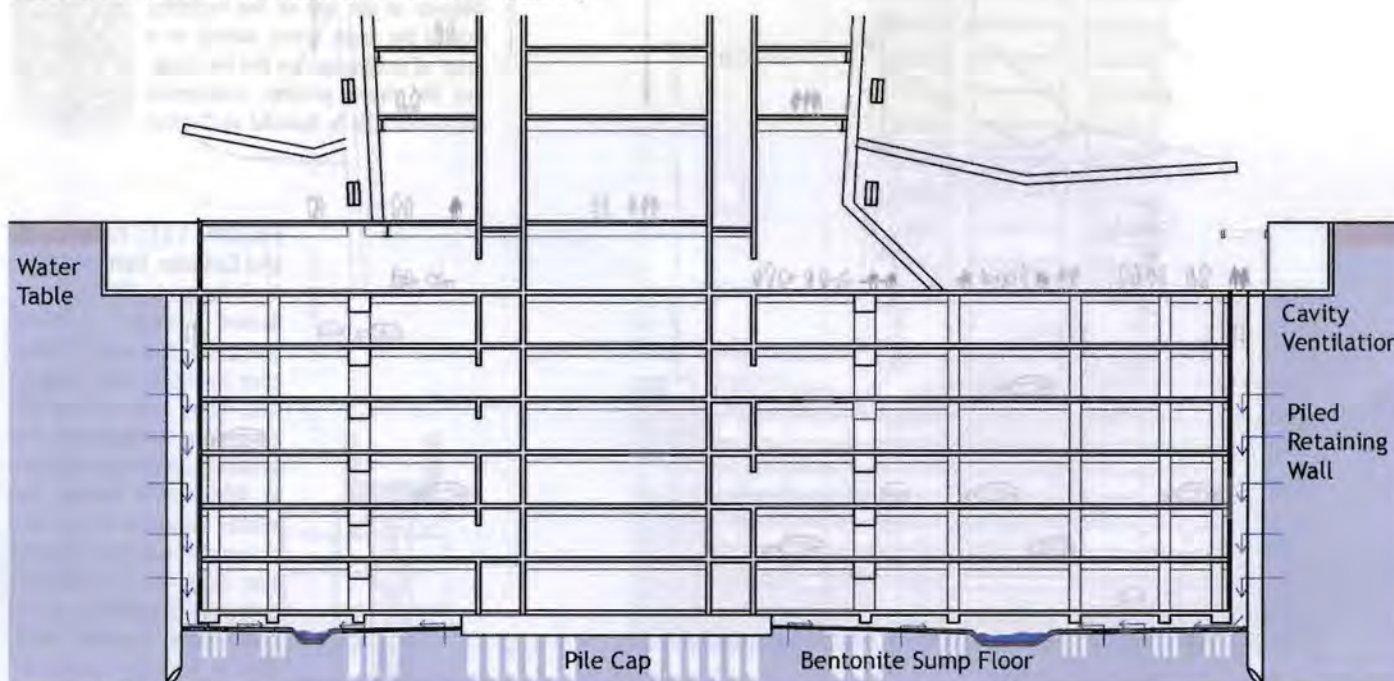


FIGURE 124: Basement Tanking Strategy 1:500 (author)

To reduce water pressure, the piled retaining wall as well as sump floor is designed to allow water ingress. The lowest basement does not rest on the ground, but is carried by beams which run between the pile caps. The pile caps act as stilts which lift the basement from the sump floor. The sump floor is not connected to the rest of the building structurally, its purpose is to redirect the water which is let in to pumps which take the water to the municipal drainage. If the sump floor experiences movement due to water uplift, it should not affect the building structurally.

**Observatory and Damper Structure**

The structural system was developed further, incorporating a tuned mass damper to counteract building sway, which can lead to discomfort and even motion sickness for occupants of the building.



FIGURE 127: Tuned Mass Damper (Eddy, 2005)

The Tapei 101, designed by KPF and completed in 2004, was once the tallest building in the world at 510m. It features a tuned mass damper consisting of 41 circular metal disks assembled piece by piece at the top of the building as cranes are unable to lift such weights. It weighs 300 tonnes and is one of the largest tuned mass dampers in the world. The damper has a diameter of 5.5m, the steel cables have a thickness of 90mm. Such dampers feature in a number of tall buildings. The Burj Khalifa in Dubai has a total of 11 tuned mass dampers. A tuned mass damper was installed at the Hancock Centre in Chicago a while after its construction to increase the comfort for inhabitants.

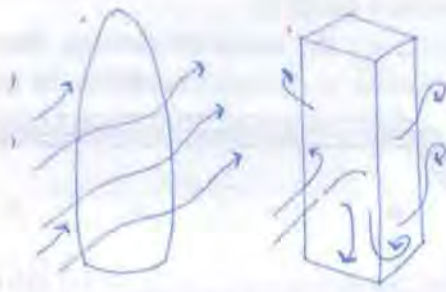


FIGURE 128: Airflows in relation to Building Form (Wells, 2005)

Airflows around bluff objects break up into eddies and down-draughts. Tall square buildings can cause gusting at street level. Streamlining a building reduces wind pressures and hence structural weight. It causes less turbulence but can result in high degrees of oscillation.

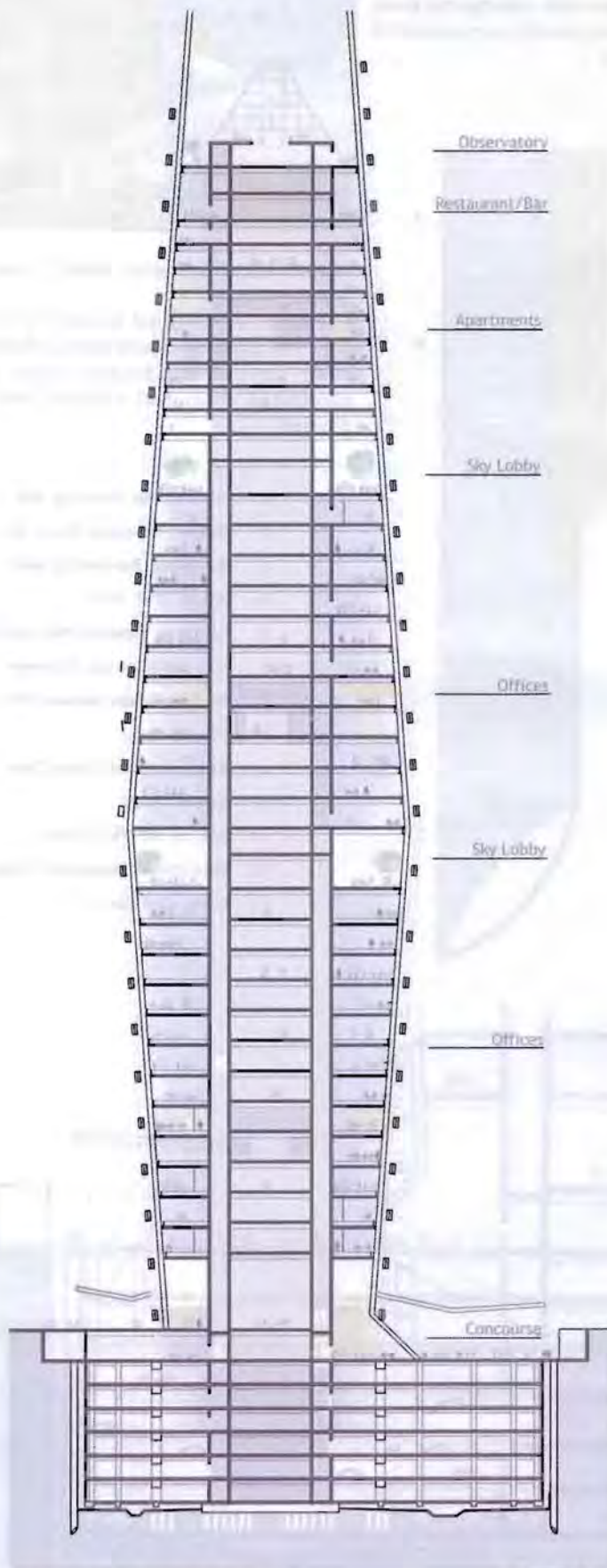
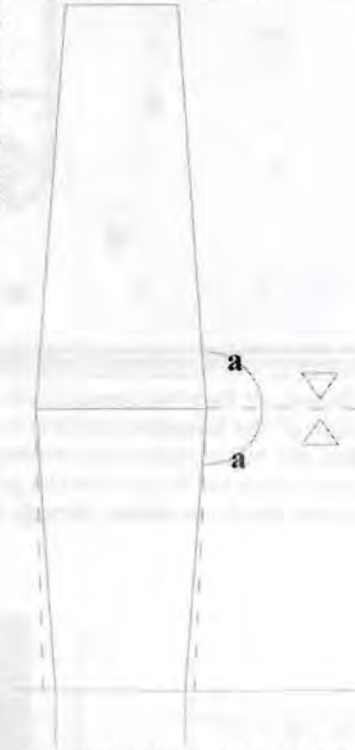


FIGURE 130: 1:1000 Section (author)



Changes to the overall form (author)

The ideal placement of basement columns had been devised with the parking layout. This placement did not quite match the shape of the building, and the form would need to be more compact at the base. It was therefore decided to change the taper of the building slightly. The taper is now mirrored at exactly on either side of the largest floor plate. This will result in large savings during construction as there are less unique members. The taper is also designed so that the basement columns are in an ideal position. This results in a slightly less efficient building in terms of floor-area ratios, but this is offset by a more efficient parking layout.

FIGURE 129: Structural Analysis of Swiss Re. (Strelitz, 2005)

The structural analysis diagram shows that the deflection of the structure from the theoretically perfect shape is most pronounced at the top of the building. If the building is considered as a vertical cantilever, the top has the longest lever distance from where the building is anchored, also the wind loads are highest at the top. Situating a damper at the top of the building makes the most sense, acting as a form of anchorage for the building. For the thesis project, residential accommodation is housed at the top



FIGURE 131: Tuned Liquid Column Damper (Yalla & Kareem, 2003)

Tuned liquid column dampers are an alternative to tuned mass dampers. They use the weight of water to stabilise the building. A U-shaped tube is filled with water, the water moves from the columns on either side of the tube to counteract sway. This method is not commonly used in buildings as it is less space-efficient than mass dampers, yet they have been shown to react quicker to sudden changes in direction than mass dampers (Yalla & Kareem, 2003)





FIGURE 132: View of Upper Level of Observatory (author)

The tuned mass damper is supported by a framed structure and suspended with steel chords. The framed structure lies on top of the walls of the core shafts. The suspended weight is incorporated as a visual feature to add to the experiential quality of the observatory at the top of the building.



FIGURE 133: View of Lower Level of Observatory (author)

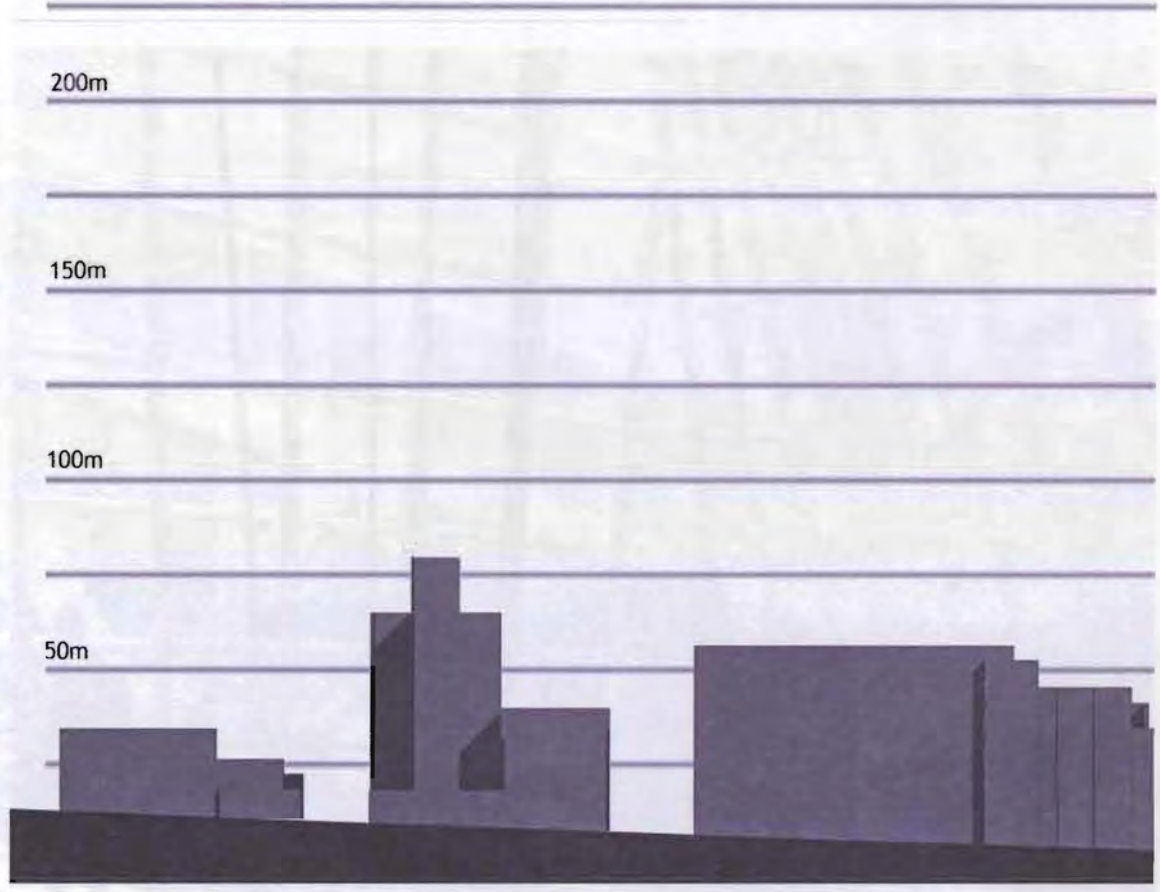


FIGURE 134: Strand Street Elevation 1:2000 (author)

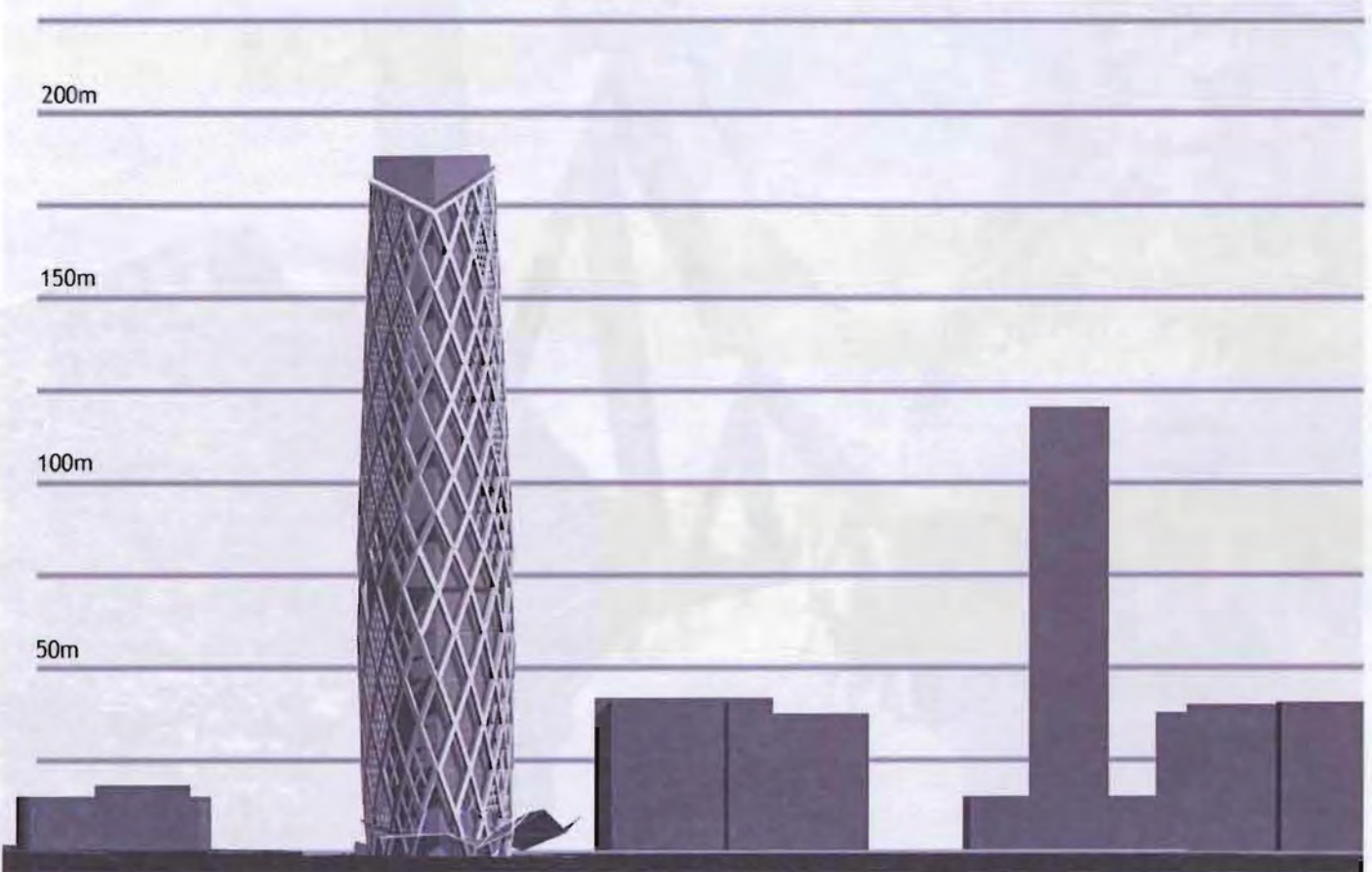
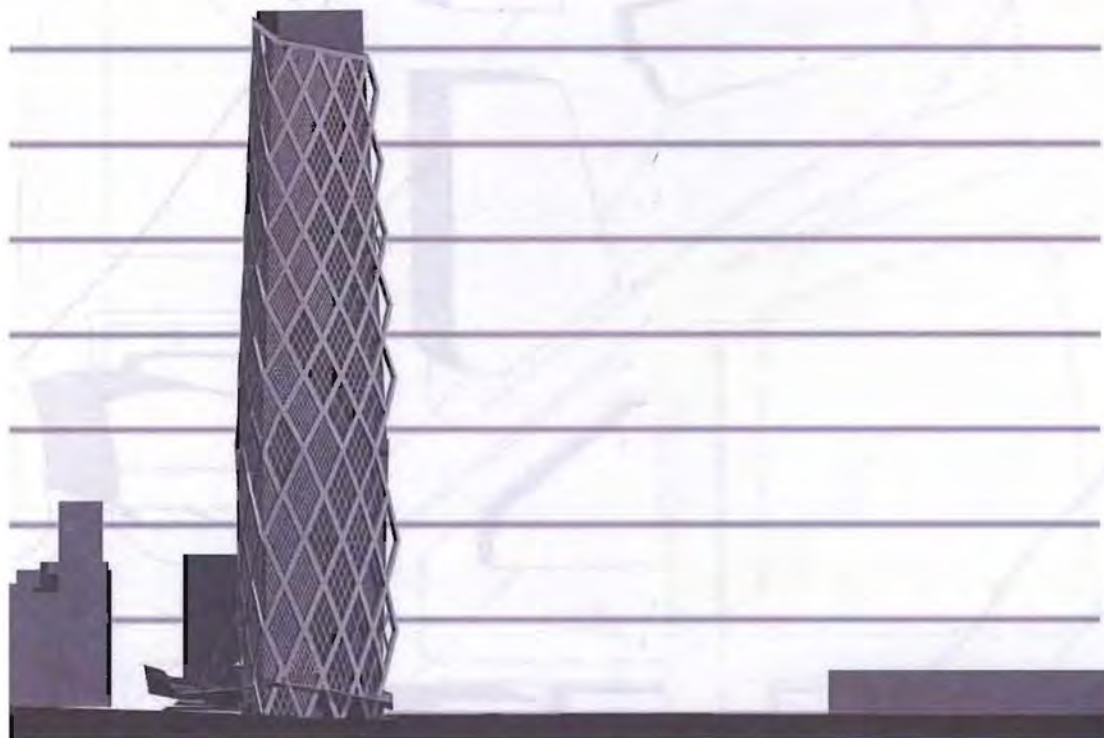


FIGURE 135: Adderley Street Elevation 1:2000 (author)



The tallest buildings in the mid-city are between 120 and 130m metres high. The thesis project proposes a building which is significantly taller. This project represents a new generation of tall buildings which will be built in the CBD in the near future. It is therefore fitting that the intervention sets itself apart from the existing tall buildings and goes one step taller. Regarding the issue of heritage protected and other low buildings in the CBD, I would argue the point mentioned earlier in this paper, that Cape Town CBD is heterogenous and the scale and size of buildings have not been carefully preserved as in many European city centres. This is not necessarily a bad thing, as this eclectic mix and contrast is what characterises the CBD. A building of this height is therefore not seen as detrimental to the skyline but rather as something which enrichens it.

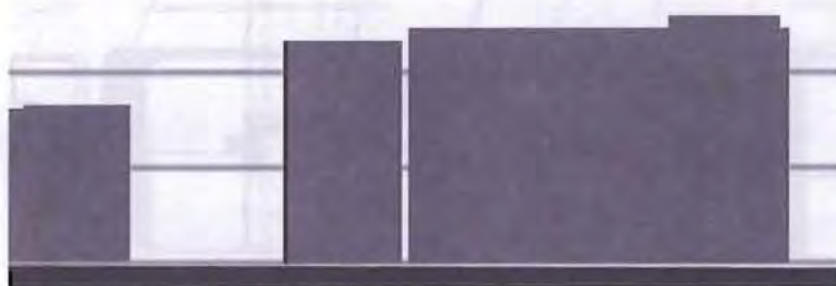




FIGURE 136: Site Plan 1:2000 (author)

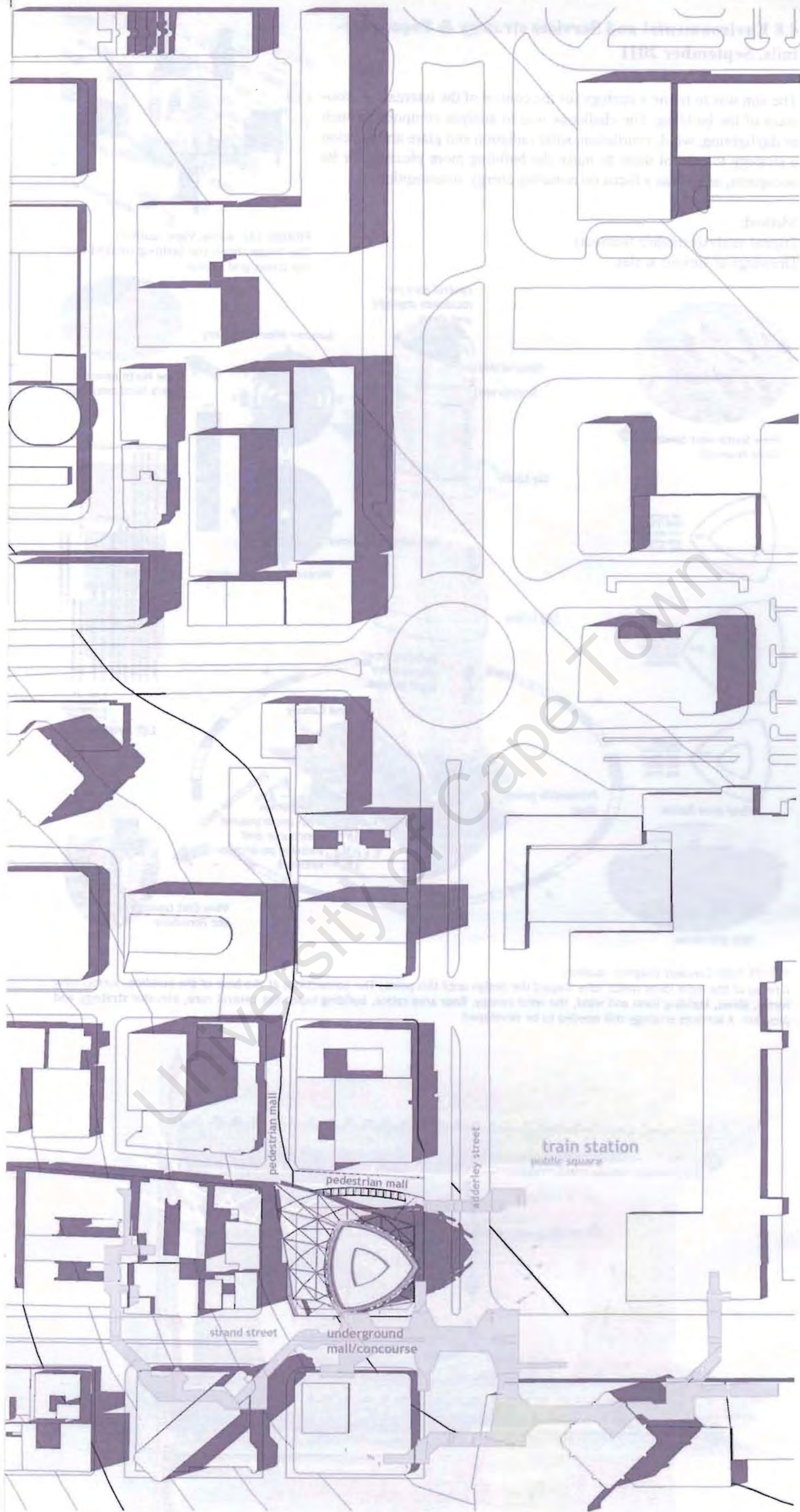


FIGURE 11-10  
 The plan shows the layout of the city center, including the pedestrian mall, the underground mall/concourse, the train station, and the public square. The streets shown are Strand Street, Adderley Street, and the pedestrian mall. The drawing illustrates the spatial organization and connectivity of the urban environment.



## 4.8 Environmental and Services strategy & Façade Details, September 2011

The aim was to refine a strategy for the control of the internal environment of the building. The challenge was to analyze components such as daylighting, wind, ventilation, solar radiation and glare and develop a strategy to control these to make the building more pleasant for its occupants, as well as a focus on reducing energy consumption

Method:

Digital analysis models (ecotect)

Drawings at various scales

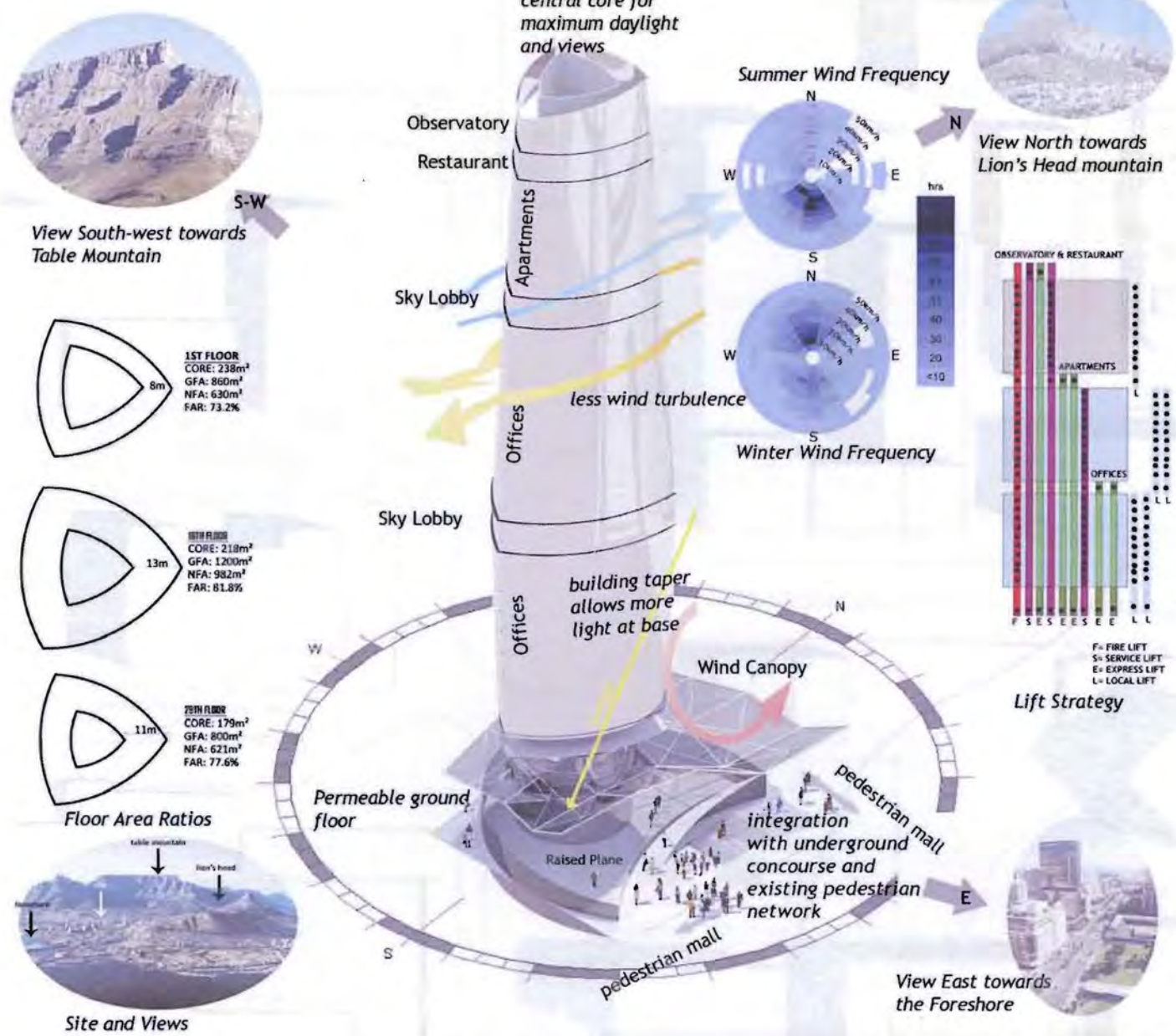


FIGURE 138: Concept Diagram (author)

A recap of the main ideas which have shaped the design until this point; The connections at the base of the building, surrounding forms, views, building form and wind, the wind canopy, floor area ratios, building taper, the central core, elevator strategy, and program. A services strategy still needed to be developed

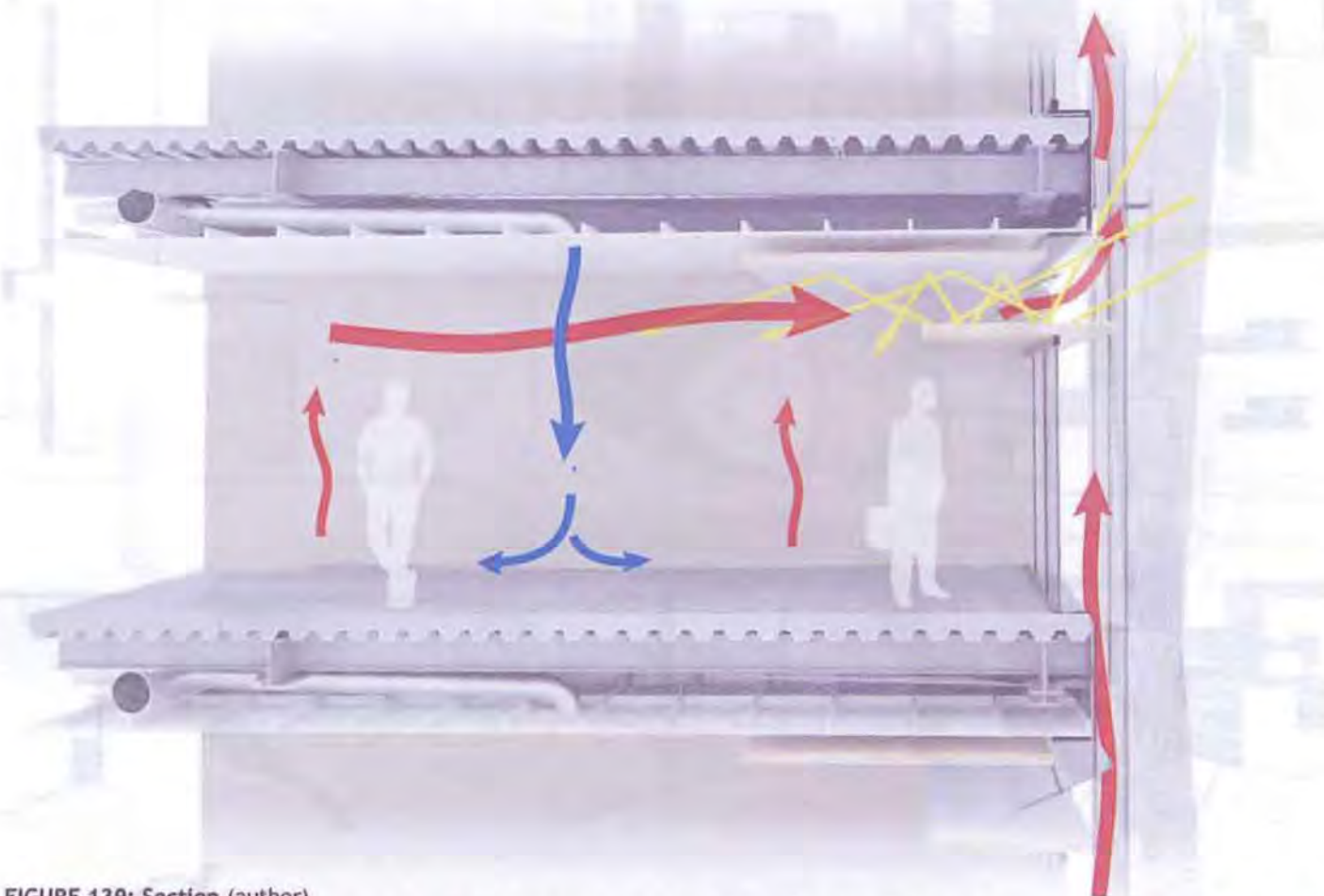
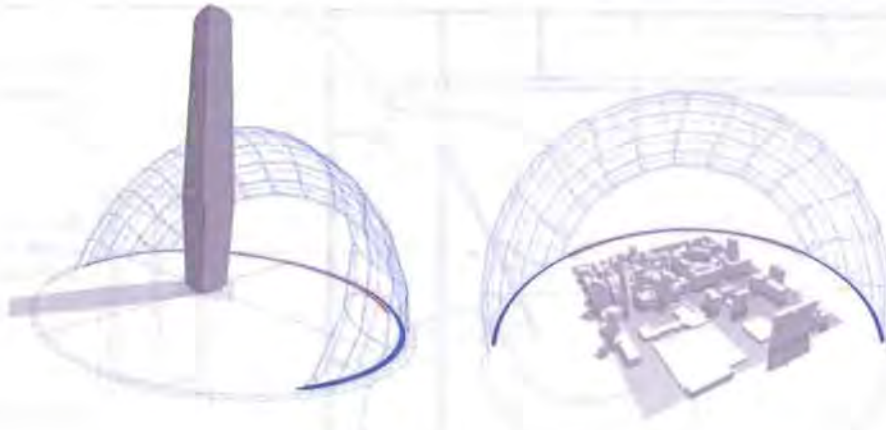


FIGURE 139: Section (author)

This is the initial idea for the services strategy, showing a double-skin of glazing within which air is ventilated. A light shelf is used to bounce natural light deeper into the space. Given the floor plate depths, it is assumed that there will be insufficient natural light in all areas, and artificial lighting will be required in parts, even during the day.

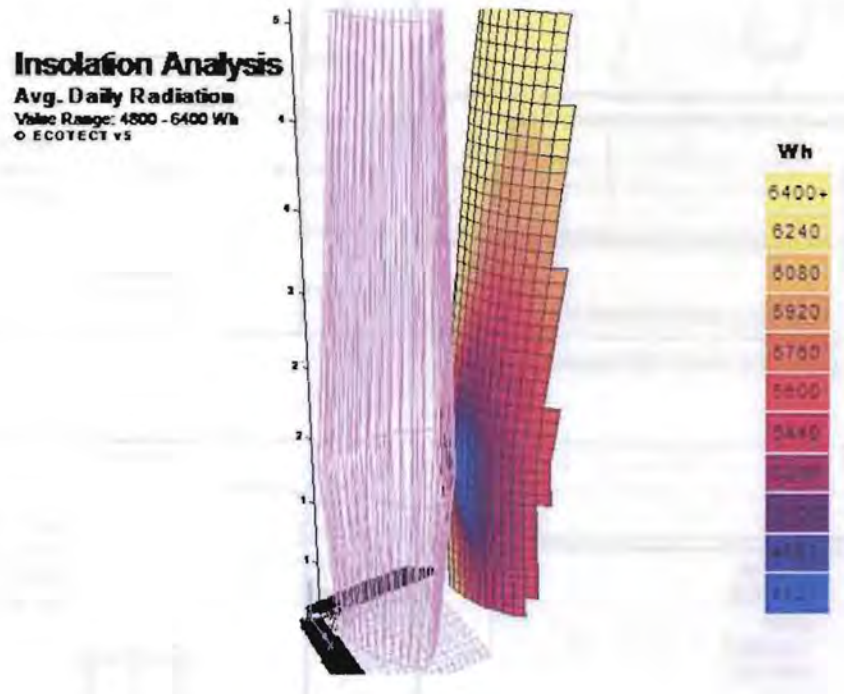
**Solar Studies**

As part of devising a services strategy solar studies were conducted.



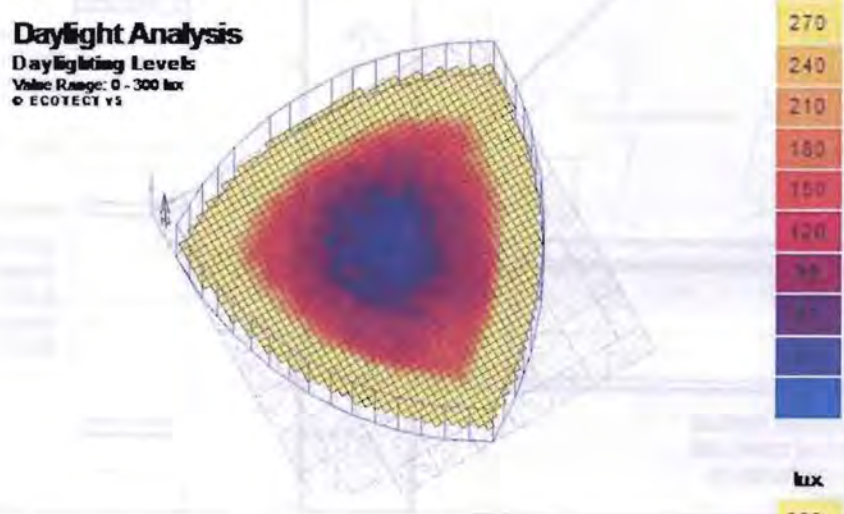
**FIGURE 140: Orientation and Sun Path (author)**

The orientation of the building is such that one facade faces due south, whereas the other facades are at oblique angles to east and west.



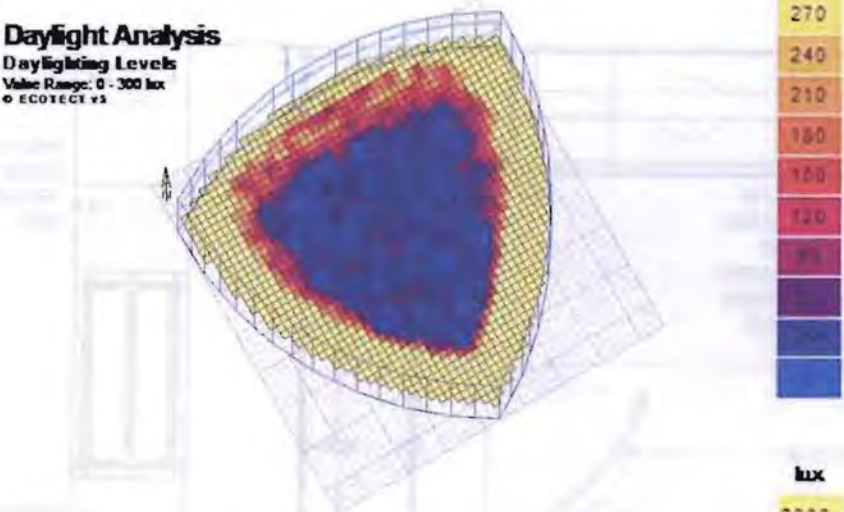
**FIGURE 141: Insolation Analysis (author)**

The insolation analysis gives an indication of the amount of solar radiation the facade receives. It is measured as energy in Watt-hours. The analysis is used to assist in designing shading elements. Although I do not know exactly what the watt-hour values mean and how one should respond to it, it is useful in that one can see which portions of the facade receive more solar radiation than others.



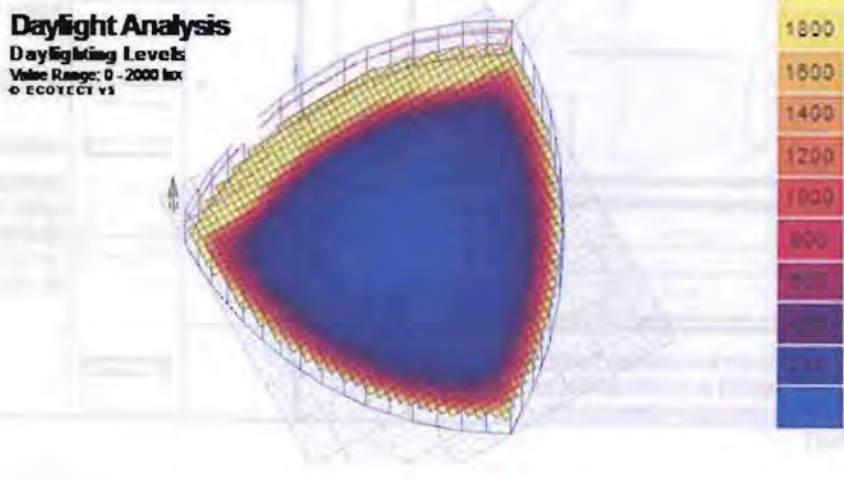
**FIGURE 142: Daylight Analysis (author)**

The daylight levels were tested to see how much natural light penetrates into the spaces. The largest floor plate (16th floor) was used to test this. The measurement scale is set to values between 0 and 300 lux. 300 lux is the required lighting level for office space. The analysis shows that at between 6 and 7m from the facade the daylight levels drop to below 300 lux, requiring artificial lighting



**FIGURE 143: Daylight Analysis (author)**

This scenario incorporates the use of a light shelf along one of the three facades. It shows that the light is more evenly dispersed, yet it does not indicate that light is brought much deeper into the space and as such artificial lighting would still be required.



**FIGURE 144: Daylight Analysis (author)**

The measurement scale is increased to measure between 0 and 2000 lux. It shows that the portion of the facade with the light shelf has dramatically increased lighting levels within the first 7m. Also it shows that along the perimeter of the building the occupants will experience glare (2000 lux). The perimeter structure and shading elements were not modelled for this analysis. Subsequent to this study, it was decided to abandon the idea of using light shelves because based on this analysis they do not bring light significantly deeper into the space but rather intensify the light levels where they already are sufficient. Also, deflected light will be created by the outer structure anyway, making light shelves a bit redundant.

**Environmental Strategy**

Natural and mechanical systems combine to regulate the internal climate

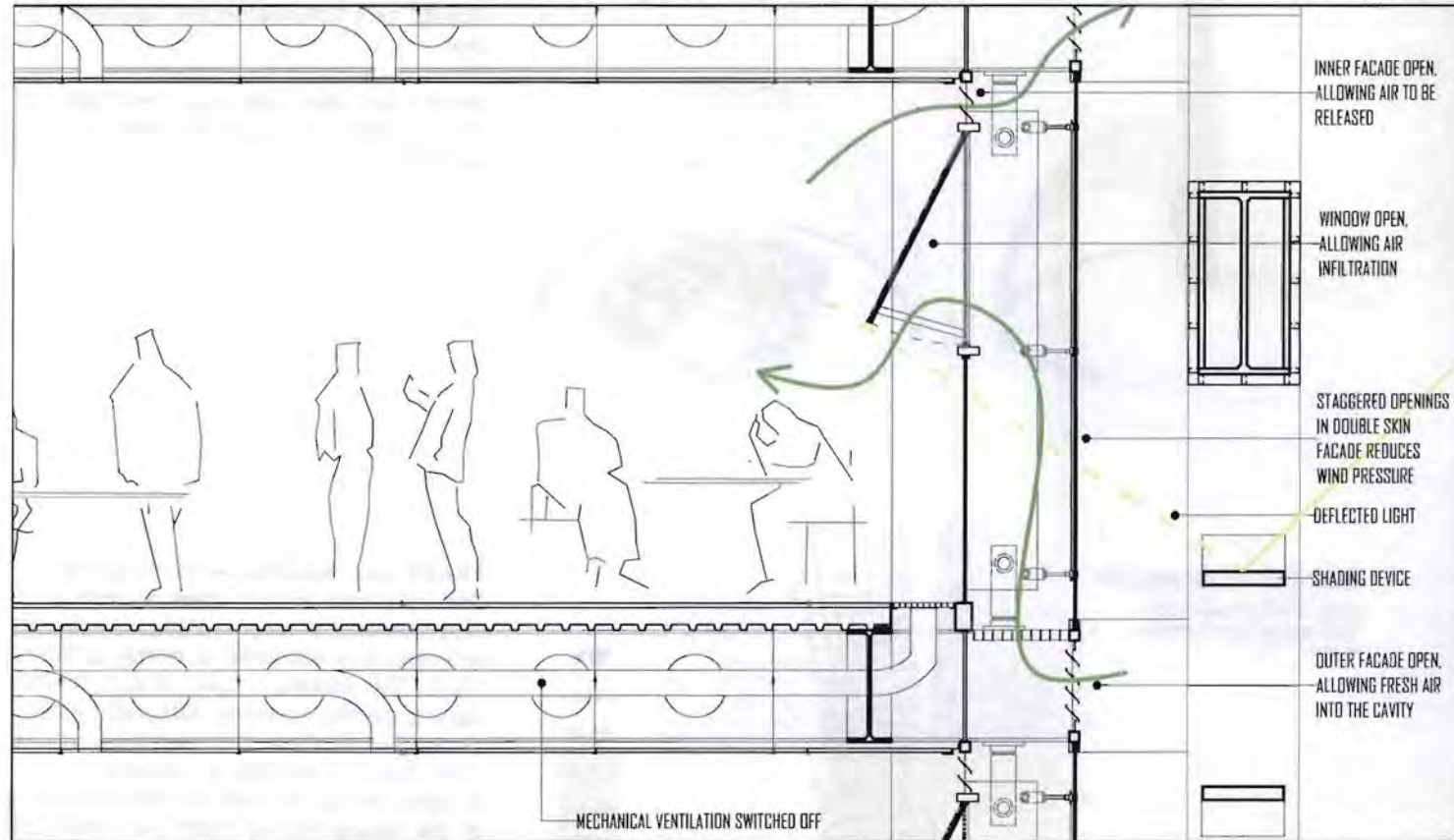


FIGURE 145: Scenario During Mild Temperatures (Spring & Fall) 1:50 (author)  
Both inner & outer facades are open

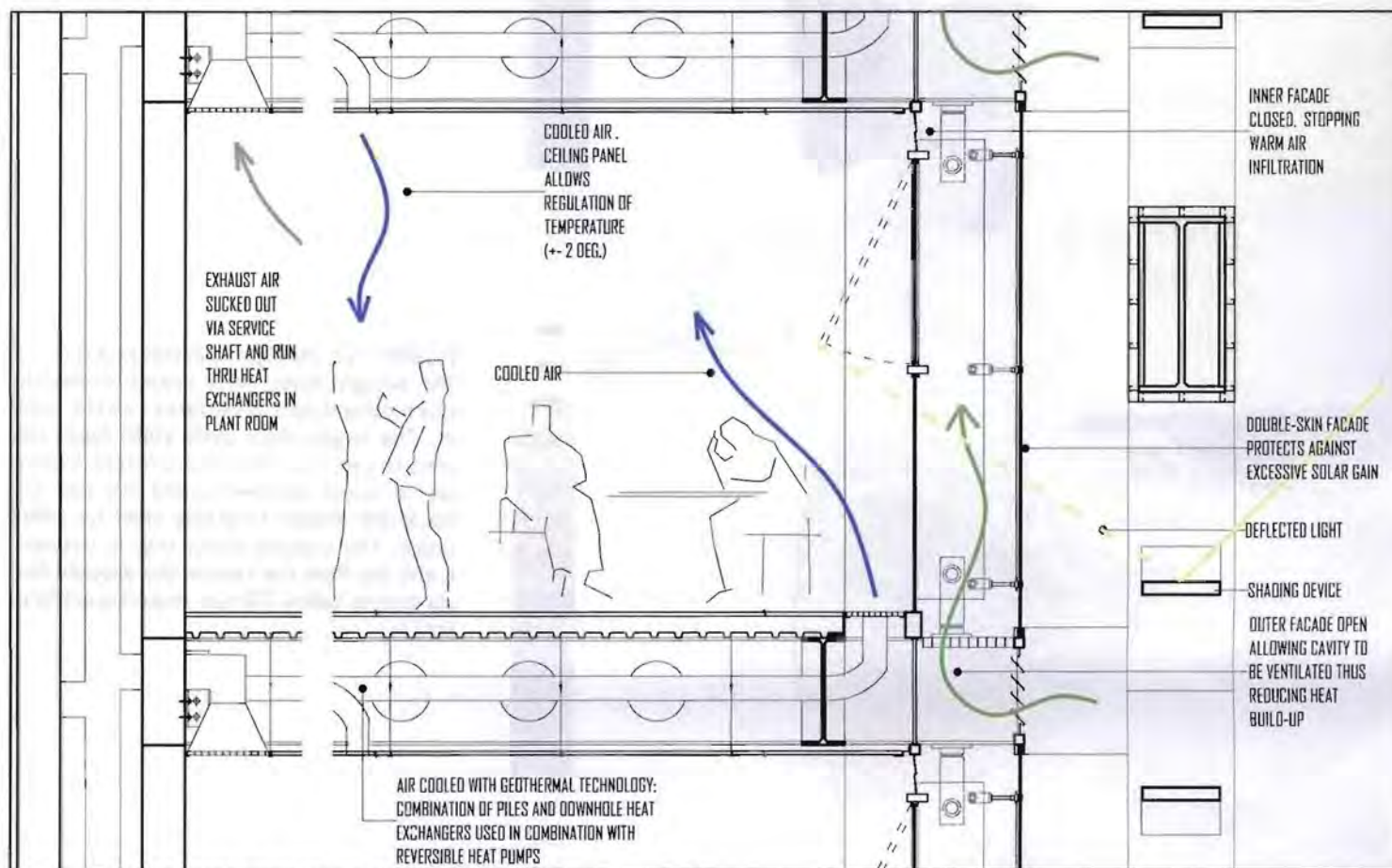


FIGURE 146: Scenario During Summer 1:50 (author)  
Outer facade open, inner facade closed

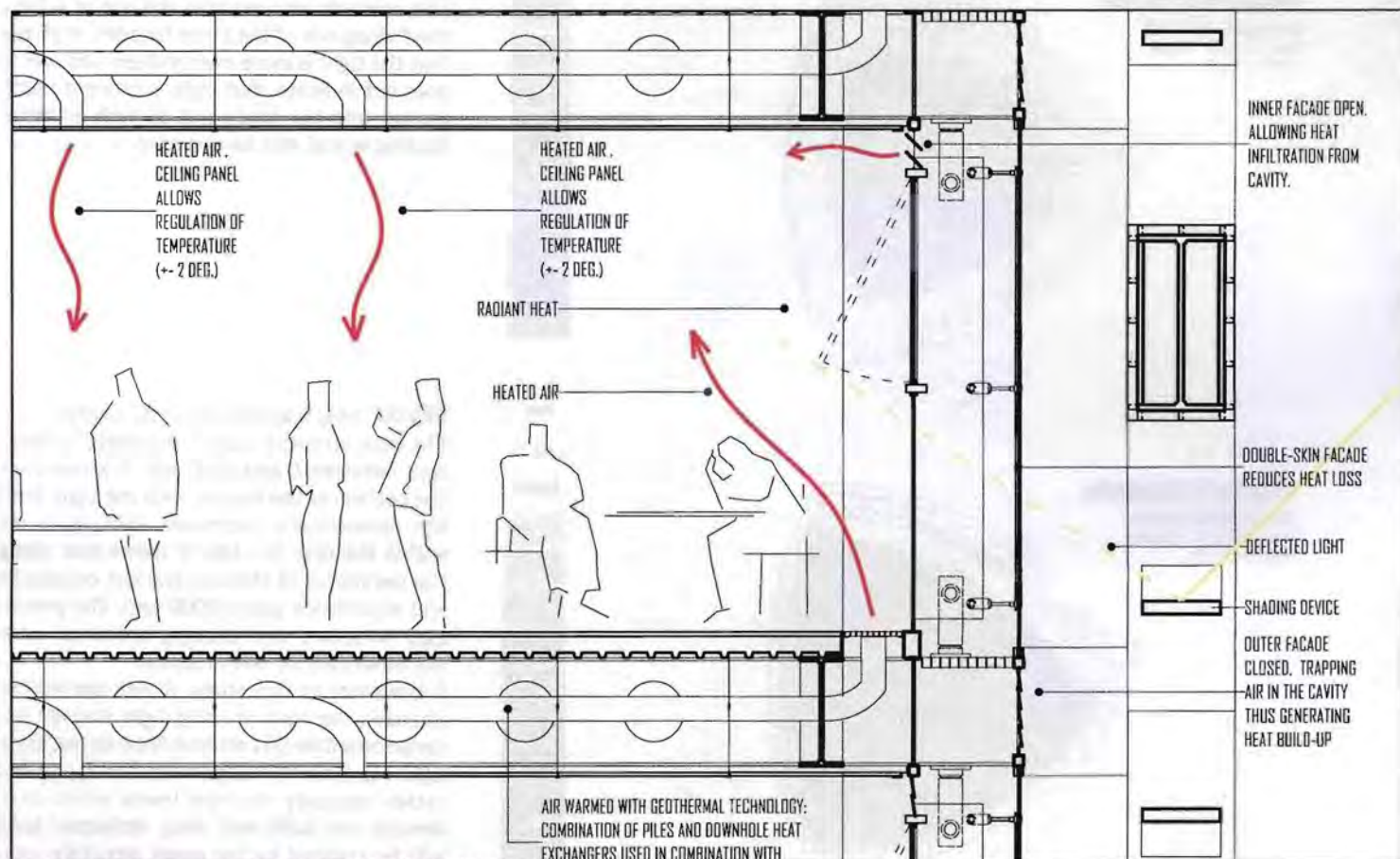


FIGURE 147: Scenario During Winter 1:50 (author)  
Interior facade open, exterior facade closed

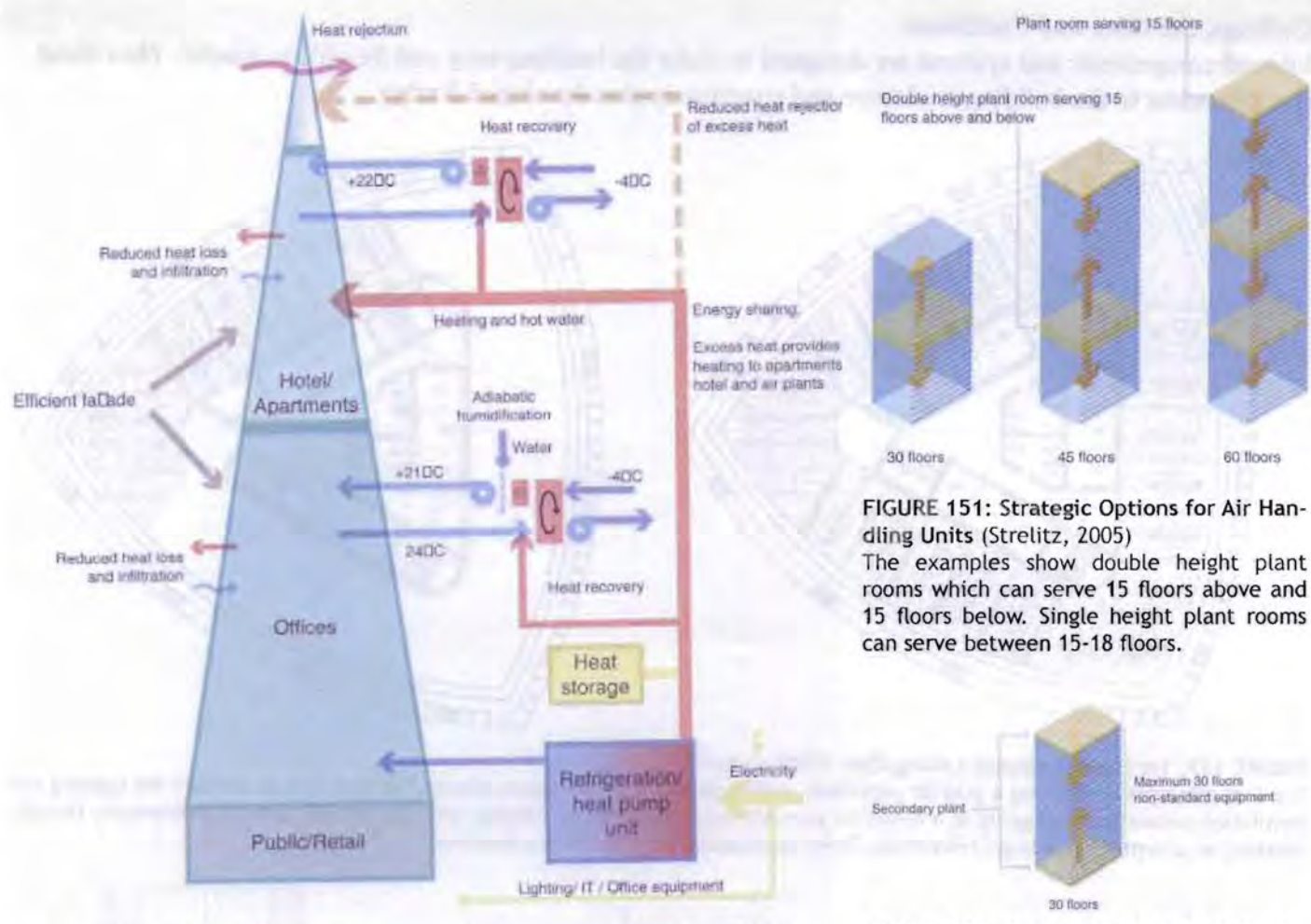


FIGURE 148: London Bridge Tower proposed Services System (Strelitz, 2005)  
The refrigeration/heat pump unit provides cool air to the office and the excess heat is used for heating and hot water for the apartments

FIGURE 151: Strategic Options for Air Handling Units (Strelitz, 2005)  
The examples show double height plant rooms which can serve 15 floors above and 15 floors below. Single height plant rooms can serve between 15-18 floors.

FIGURE 152: Strategic Options for Water Systems (Strelitz)  
Using standard equipment, water risers can be a maximum of 15 floors, if a double height plant room is used, 15 floors below and 15 above can be served. Using non-standard equipment the maximum riser distance can be doubled.

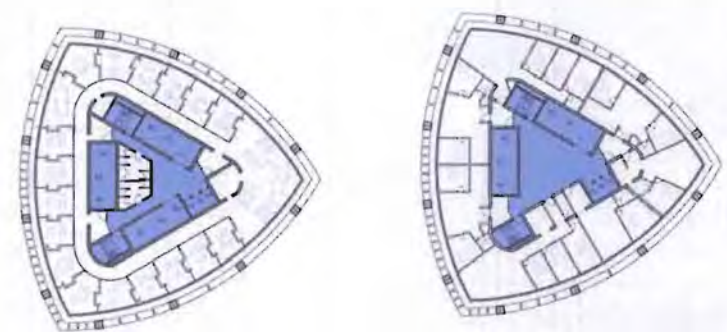


FIGURE 149: Fire Safety Zones (author)  
As a safety measure, the stairwells, lobbies, and shafts need a separate ventilation system. These shafts are pressurized for smoke ventilation and to avoid fire from spreading from one floor to the next via the shafts.

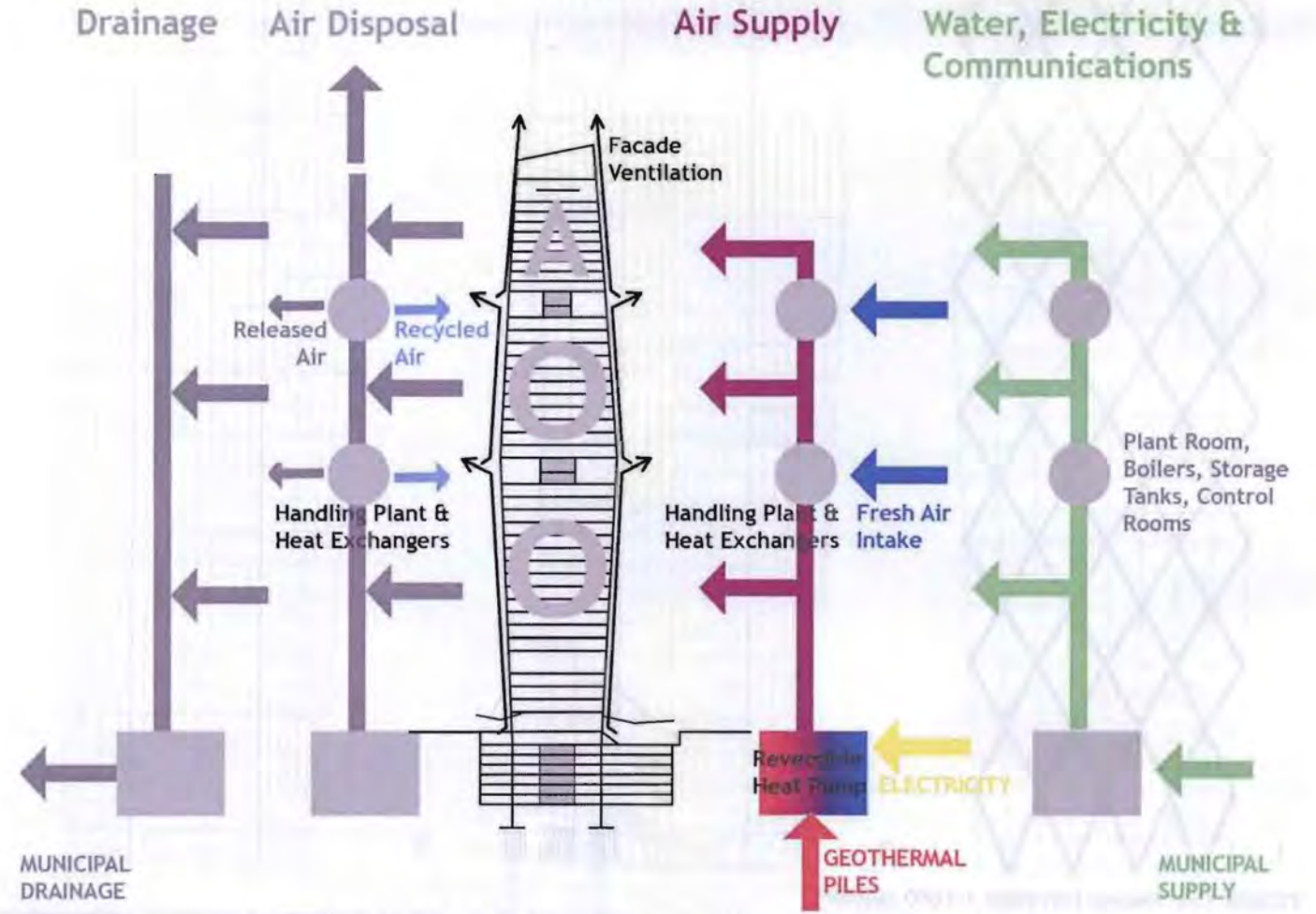


FIGURE 150: Schematic Diagram of Services Strategy (author)  
For the provision of heating and cooling, geothermal piles and downhole heat exchangers in combination with electrical energy will be used to feed the reversible heat pump housed in the basement. Heat Pumps are effective in that 1 kWh electrical energy for the pumps yields 6 kWh heat energy. Air is driven up to plant levels where the air is handled and distributed to each section of the building. Secondary heat exchangers are provided at plant room levels which assist in heating/cooling the air. Exhaust air is sucked up to plant rooms where some of the air is recycled, and the rest released from the building. For other services such as water, electricity and communications, the municipal supply is brought in at the basement, where it is distributed to plant rooms, and then to each section. For water supply it is important to limit the distance of the service risers to avoid static water pressure build-up, the runs are therefore only from one plant room to the next. For electricity and communications it is useful to have separate control rooms for each section to cater to the specific needs of tenants in that respective section.

### Ceilings, Services and Partitions

Internal components and systems are designed to make the building easy and flexible to inhabit. How these systems relate to the building enclosure and structure is also developed further.

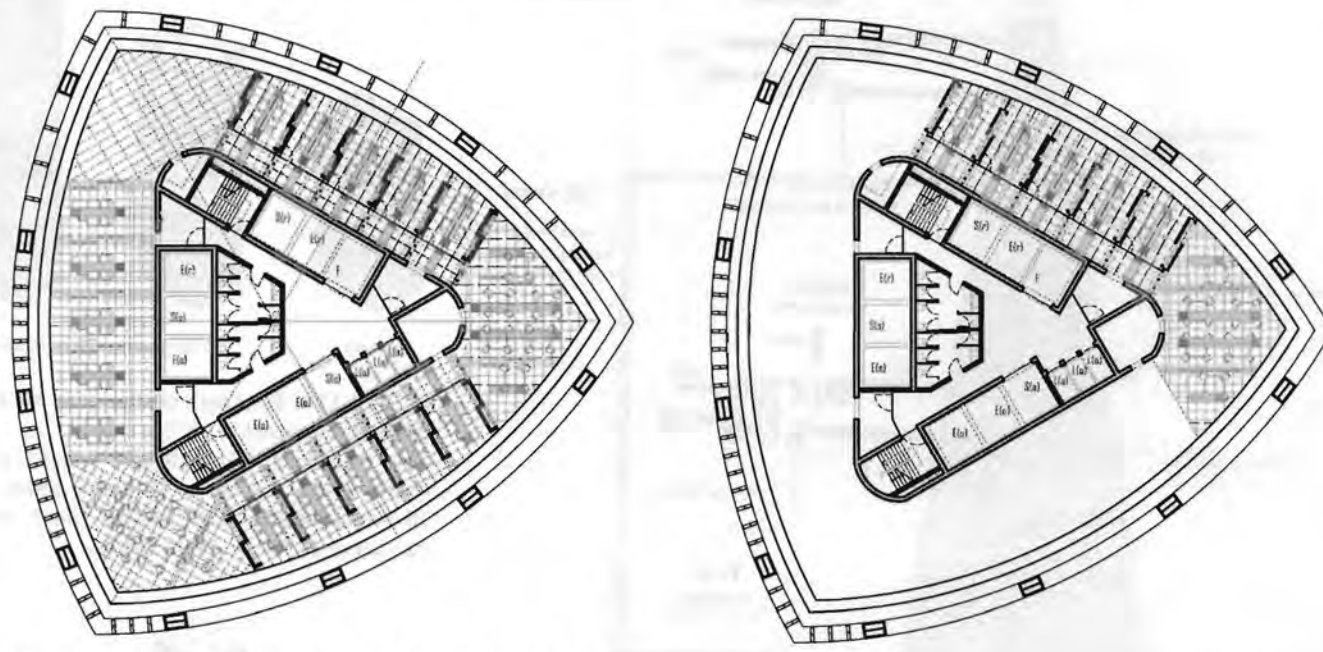


FIGURE 153: 1st Floor Reflected Ceiling Plan 1:500 (author)

The first attempts at creating a grid for partitions, ceiling and facade are shown above. The idea was to arrange the lighting and ventilation panels in strips going in a direction perpendicular to the core. Dealing with the corners proved problematic though, creating an abrupt change in grid direction. Other approaches were therefore explored.

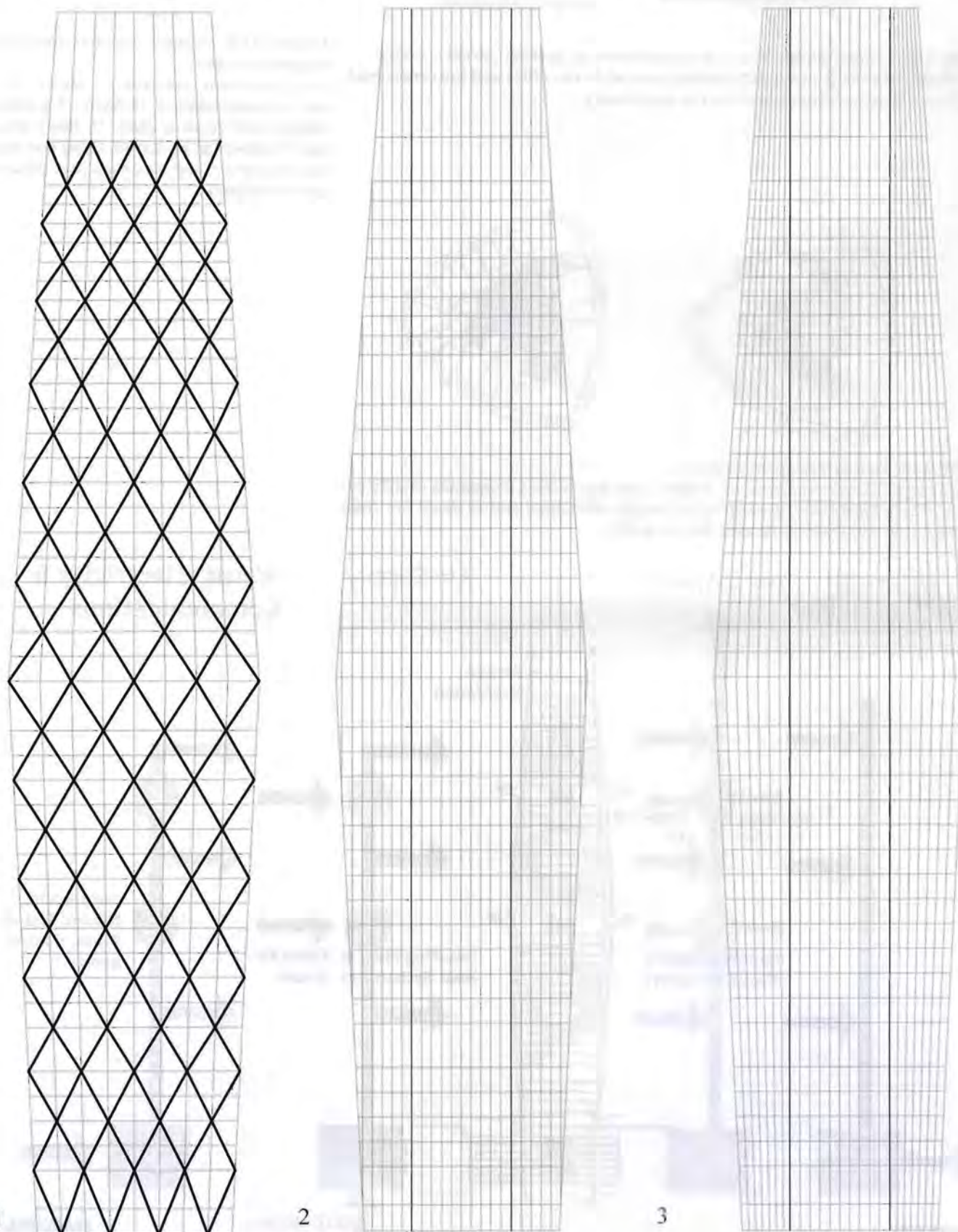


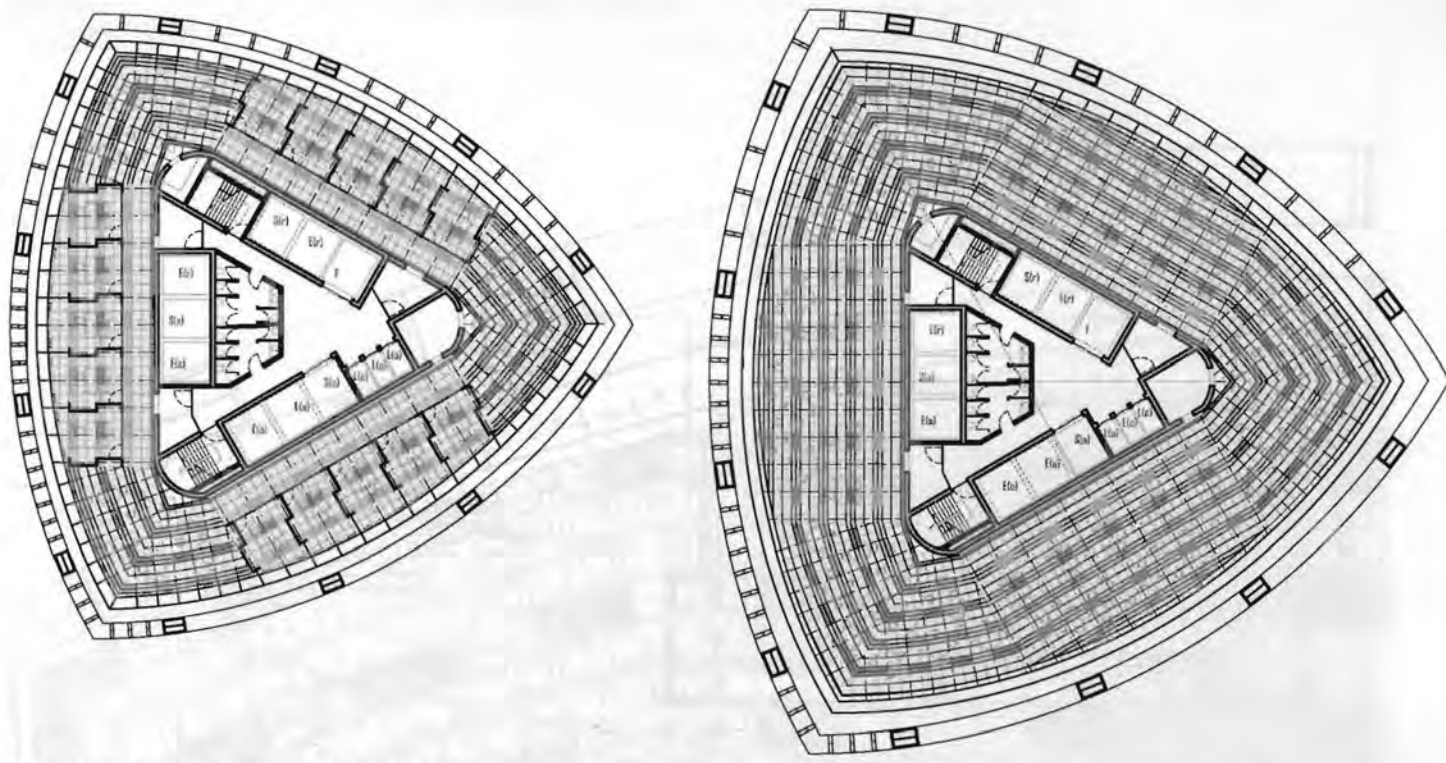
FIGURE 154: Facade Elevation 1:1000 (author)

Mediating between the overall form of the building and the internal layout became quite a challenge. A panelised ceiling system is required for the offices, as this allows for greater flexibility and easier maintenance. Three approaches were considered;

1. Both facade grid and ceiling/partition grid follow form of building. This would mean that ceiling/partition grid changes in size at every level, therefore each levels has differently sized facade and ceiling panels. The vertical grid also is not perfectly vertical.

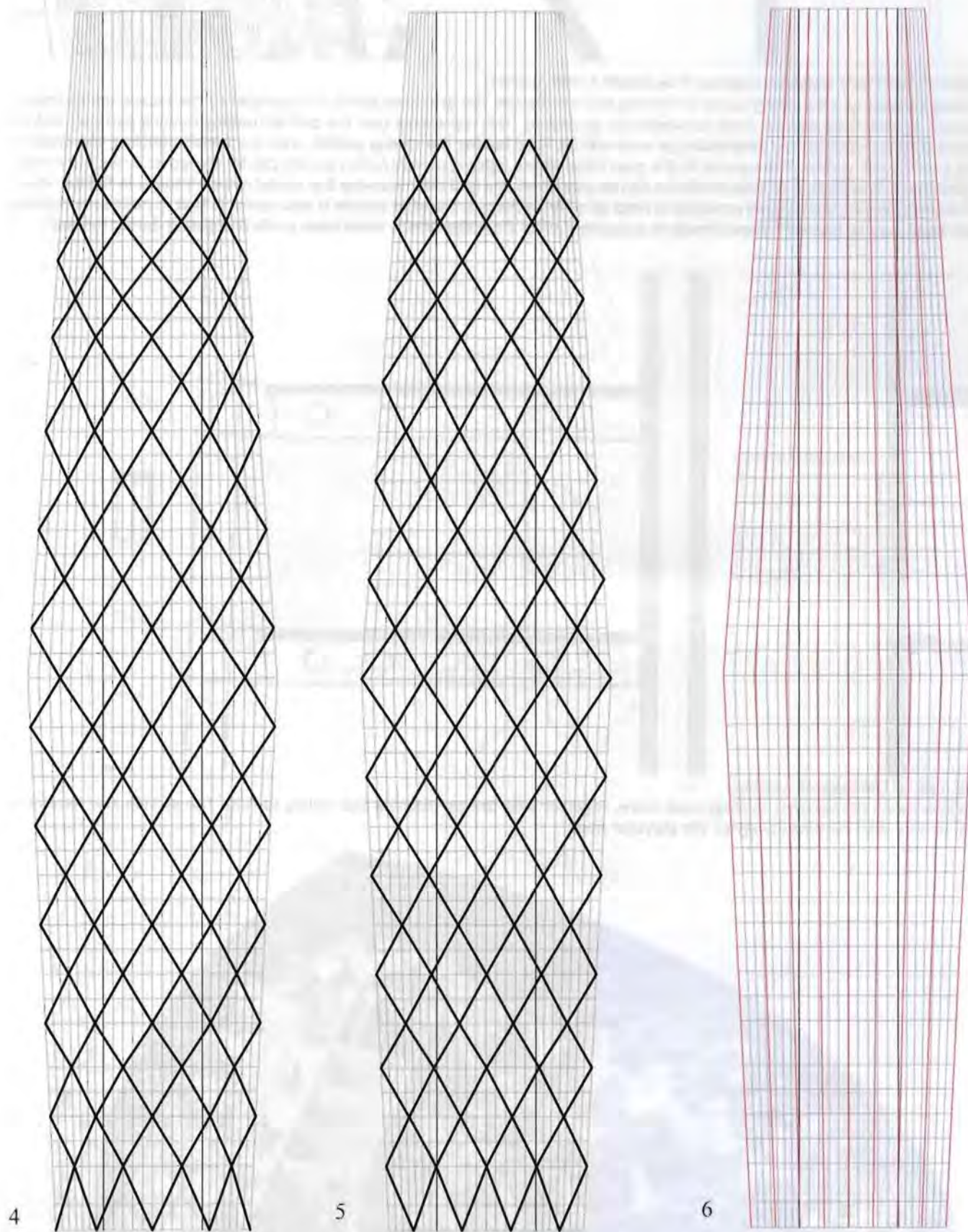
2. The facade grid is changed to match a regular ceiling grid. This would cause awkward junctions at the corners as facade grid no longer follows form of the building. This would be particularly apparent from within the building. Panel sizes are uniform for each section of building, apart from where they break at corners.

3. The corner section of the building follows the approach 1, and the central portion follows approach 2. This option was seen as the best as the corners would in most cases be open-plan (no partitions meeting with facade). The central portion is practical and works well with ceiling/partition grids. Through detailing, the heterogeneity of the facade grid will try to be masked by not expressing vertical mullions but trying to give an expression of the facade as one continuous surface.



**FIGURE 155: 1st & 16th Floor Reflected Ceiling Plan 1:500** (author)

The lighting and ventilation panels are arranged in rings. Along the central portion where the core walls are straight, the ceiling, partition and facade grid follow a regular grid pattern of 600mm x 600mm. At the corners the grid is arranged in a radial manner from core to facade, yet in the other direction it follows the central grid pattern, resulting in the appearance of continuous rings.



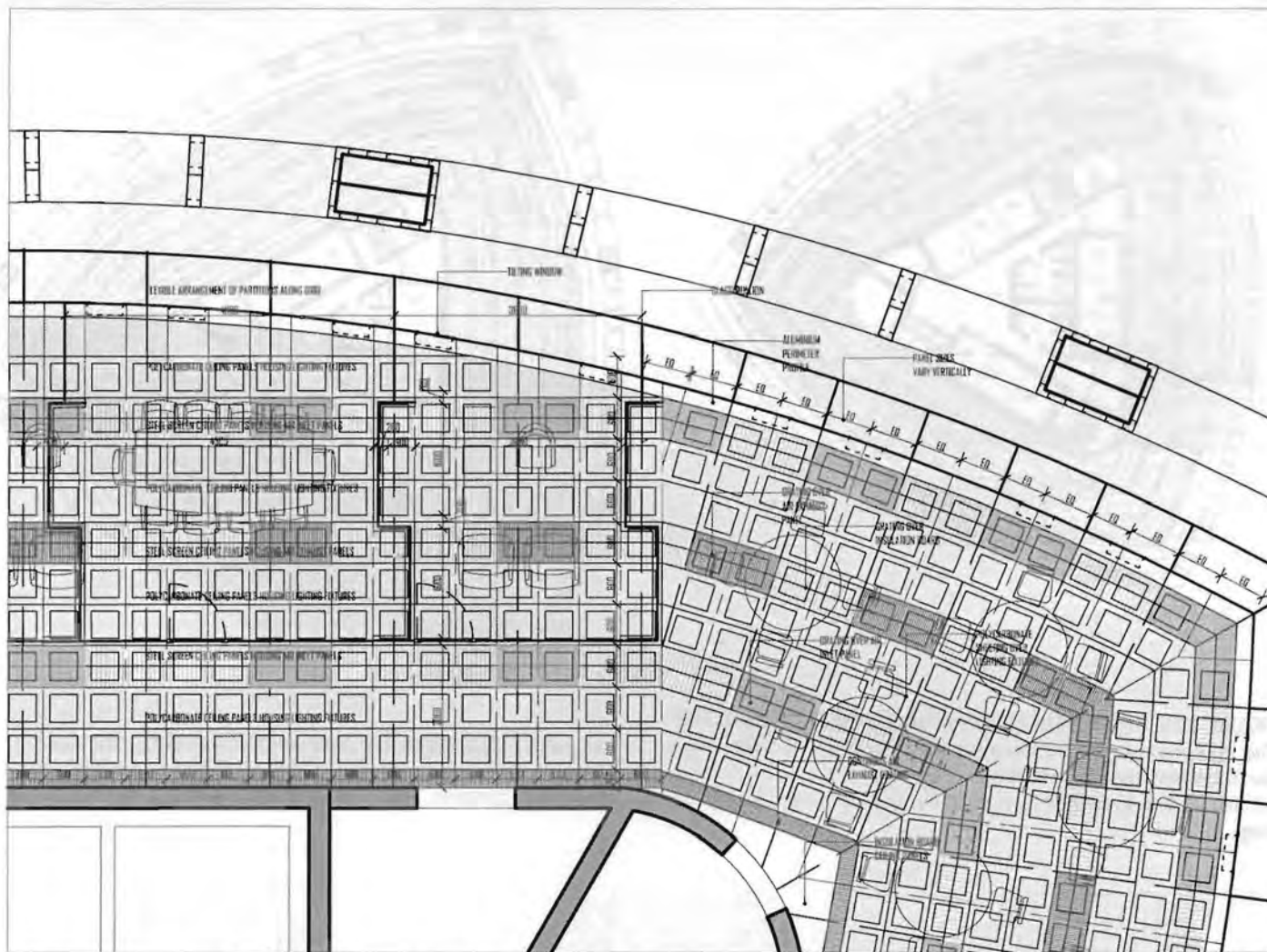
**FIGURE 156: Structure and Facade Elevations 1:1000** (author)

The question now was whether the structural layout (perimeter tube and floor beams) should follow the new facade grid, consisting of a combination of the regular and tapering pattern.

4. The outer structure follows the facade grid, creating a pattern out of sync with the overall form.

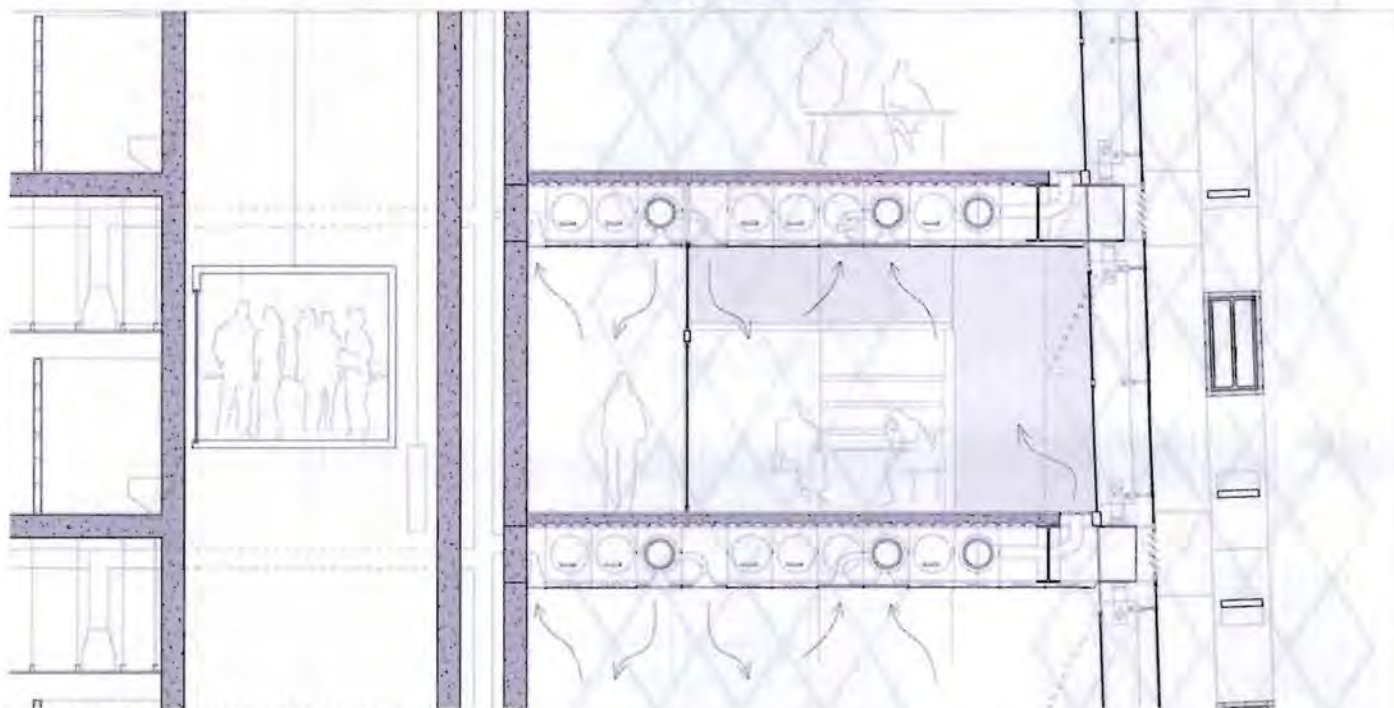
5. The original structure overlaid on the new facade grid. The outer structure follows the form of the building and does not match the facade grid. This was seen as a better option. As long as the tubes grid is aligned to the horizontal levels of the building, the connections to the floor beams will still be at discreet locations. The vast difference in the scales of the facade grid and structural grid will make their non-alignment hardly perceivable. Structurally it also does not create a problem because there is a ring beam running on the perimeter of each floor slab which can be used to support facade mullions.

6. Overlay of facade (grey) and structural grid (red).



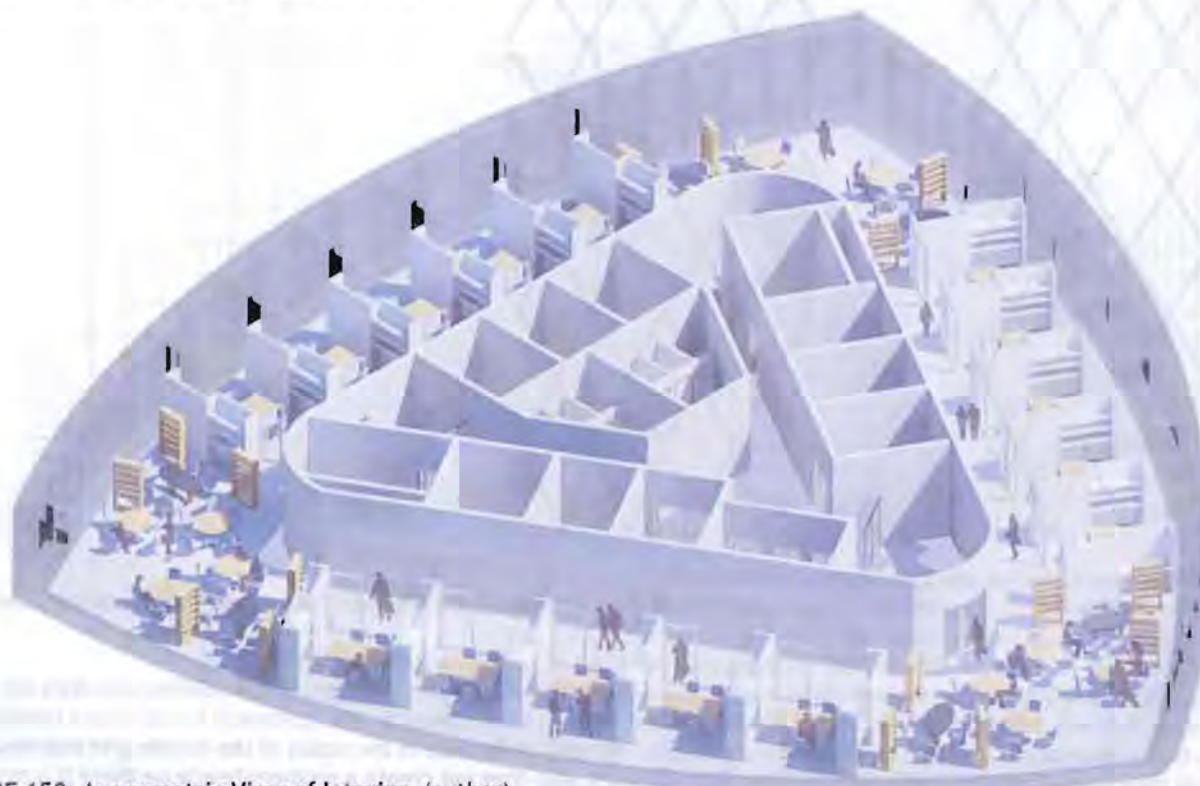
**FIGURE 157: 1st Floor Reflected Ceiling Plan Detail 1:100 (author)**

The ceiling consists of alternating bands of lighting and ventilation. The grid lines which run parallel to the facade are indicated on the plan as solid lines and the ones perpendicular as dashed. This represents that the ceiling framing running parallel will be expressed visually, whereas the perpendicular ones will be fixed behind the ceiling panels, with the panels abutting one another and the framing not visible. The squares in the plan show where lighting or ventilation panels can be placed according to needs. Their placement is organised so that partitions can be placed on any grid line, allowing the rooms to be arranged in flexible modules of 600mm. Having the lighting arranged in rings at varied distances from the facade is also useful in that it makes the lighting for each band easy to control independently (e.g spaces further from the facade need more artificial lighting during the day).



**FIGURE 158: 1:100 Section (author)**

The section shows the services strategy once more, together with the partitioning and ceiling system. The section also shows the vertical service duct running alongside the elevator shaft.



**FIGURE 159: Axonometric View of Interior (author)**

Glazed connections of the partitions and facade allow for almost panoramic views from within the offices. Glazed partitions along the corridor help bring natural light to the corridor.



FIGURE 160: Interior View (author)  
The view shows down the corridor shows the ceiling grid system and partitioning



FIGURE 161: Interior View (author)  
A view from within a cellular office, showing glazed mullions, windows, ceiling and partitioning.

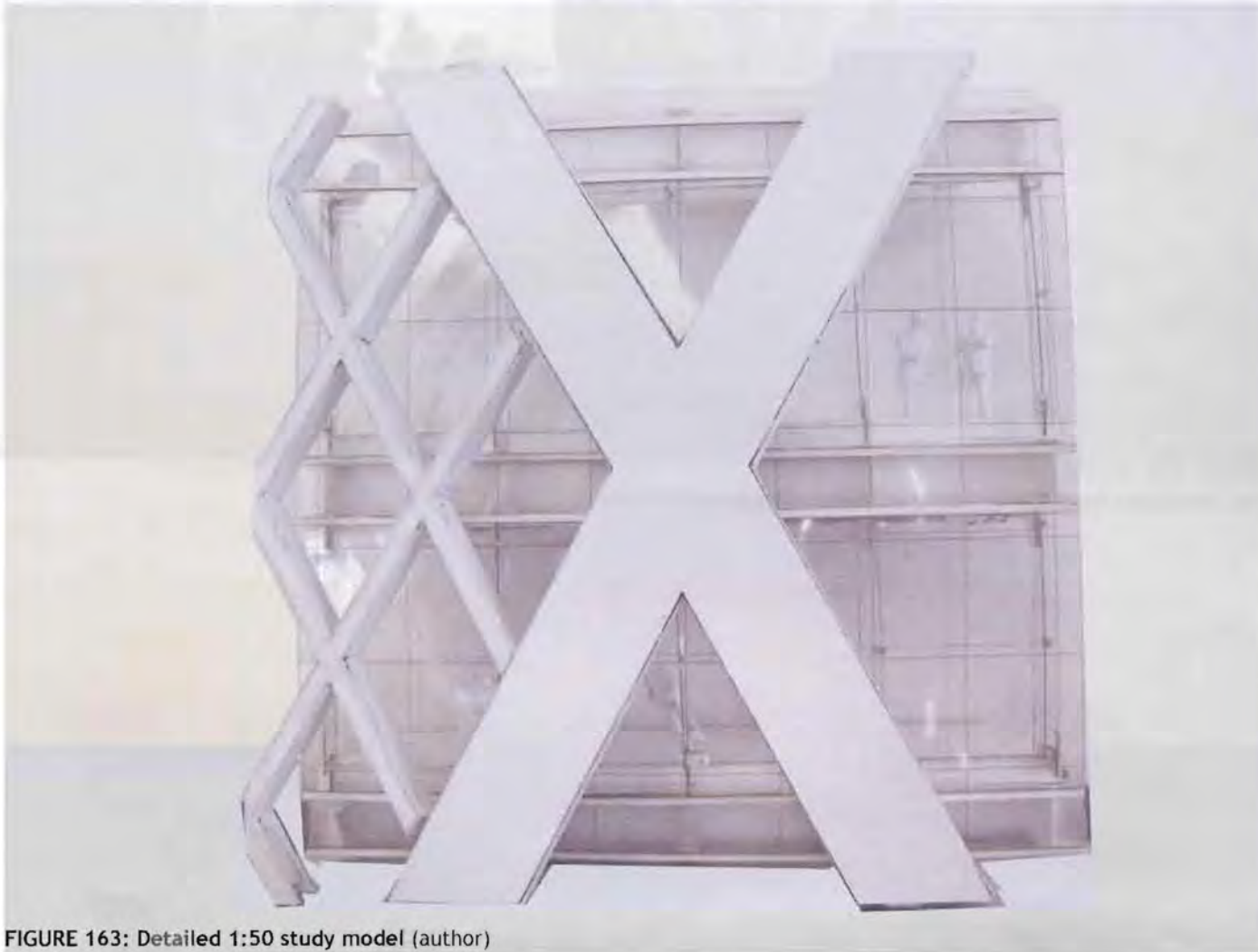


**FIGURE 162: Facade Materiality Precedent** (google images)

On the left is the Sony Center in Berlin by Murphy/Jahn in 2000. Clad entirely in glass, the towers sculptural form seems to dissolve at the edges, where facades extend beyond the building mass. Vertical glass mullions span between floors, taking advantage of new high-performance glass to achieve a crystalline architecture.

To the right is the Trump World Tower in New York by Costas Kondylis & Partners in 2001. Its simple form, slender proportions and minimal facade treatment give the tower a relentlessly rectilinear expression. High-strength concrete and careful planning of the structural members achieved the required structural performance for this building which has an incredible slenderness ratio of 11:1. The architect Costas Kondylis stated "It was designed to look like a slab cut out of one big piece of glass".

The aim is to achieve such monolithic expression in the facade for the thesis project.



**FIGURE 163: Detailed 1:50 study model** (author)



**FIGURE 164: Detailed 1:50 study model** (author)

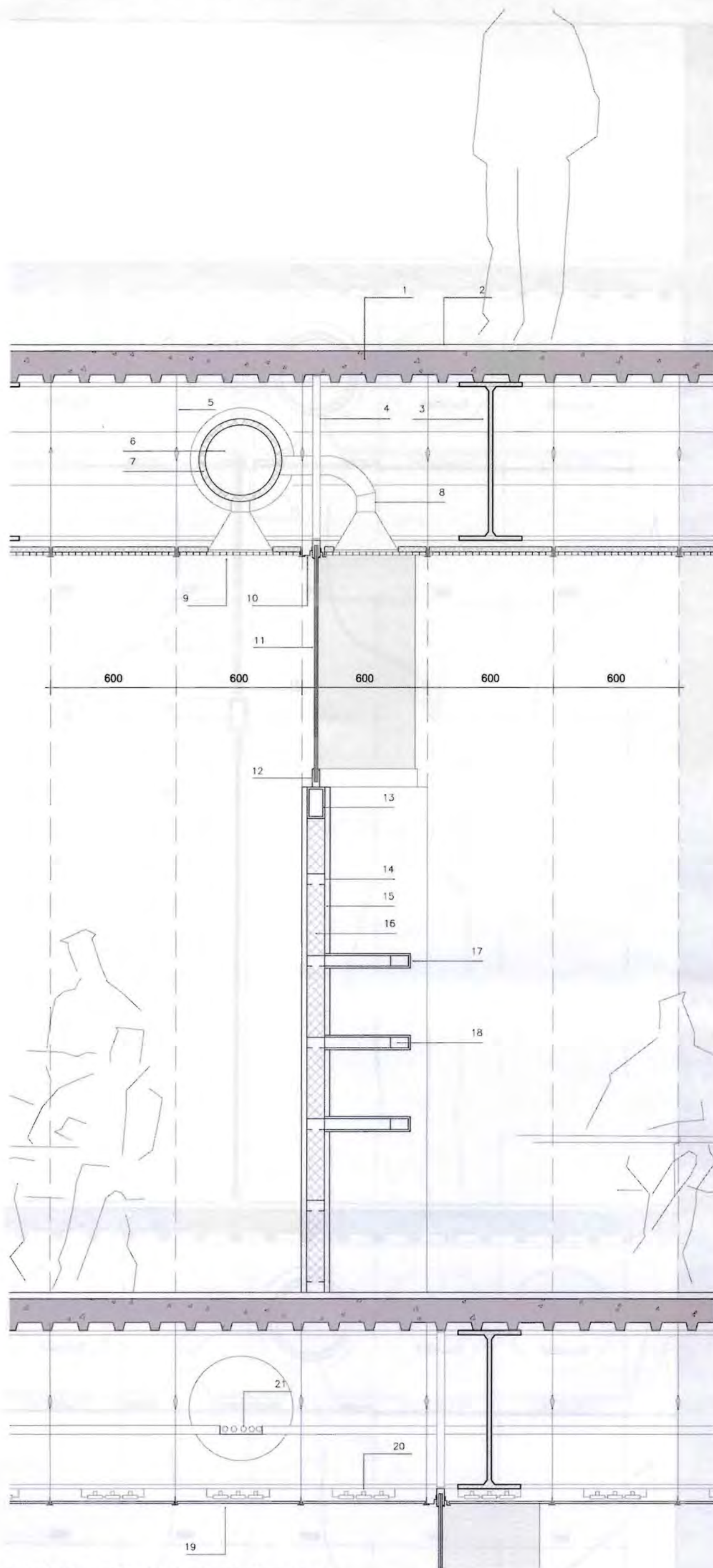


FIGURE 165: 1:20 Section thru Partitioning (author)

The detail shows the connection between partition wall and ceiling. An example of where the partitioning cuts across a ventilation band is shown on the upper floor, and where it crosses a lighting band is shown on the floor below. The partitions are supported from the top by a klet which is attached to the underside of the floor slab. The partitions are designed to lie within the 600mm ceiling grid pattern, and so that as less ceiling panels need to be adapted in size to cater for the partition. The glass sheet therefore lies just within the grid line so that only one ceiling panel instead of two need to be changed where partition meets ceiling.

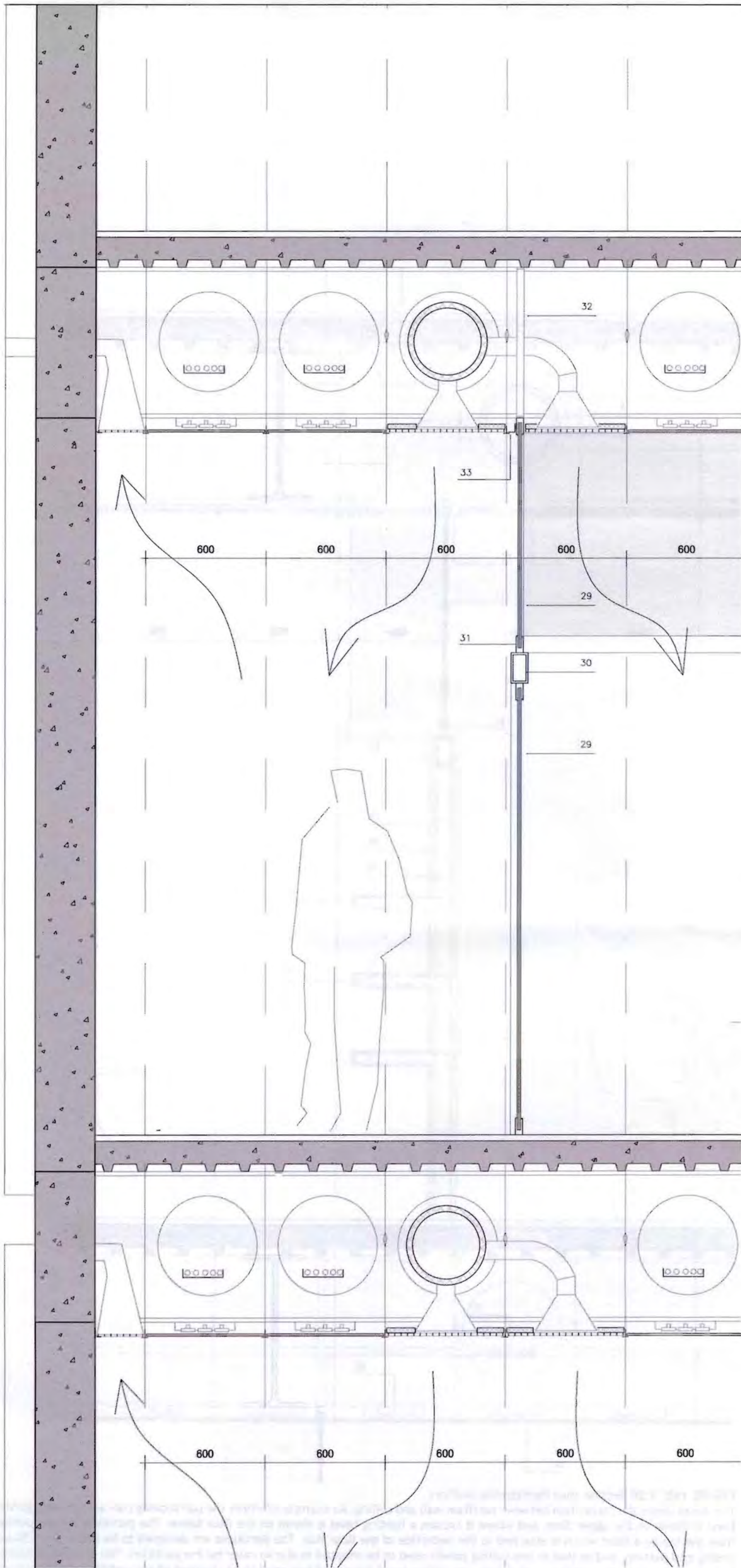


FIGURE 166: 1:20 Section at Corridor (author)

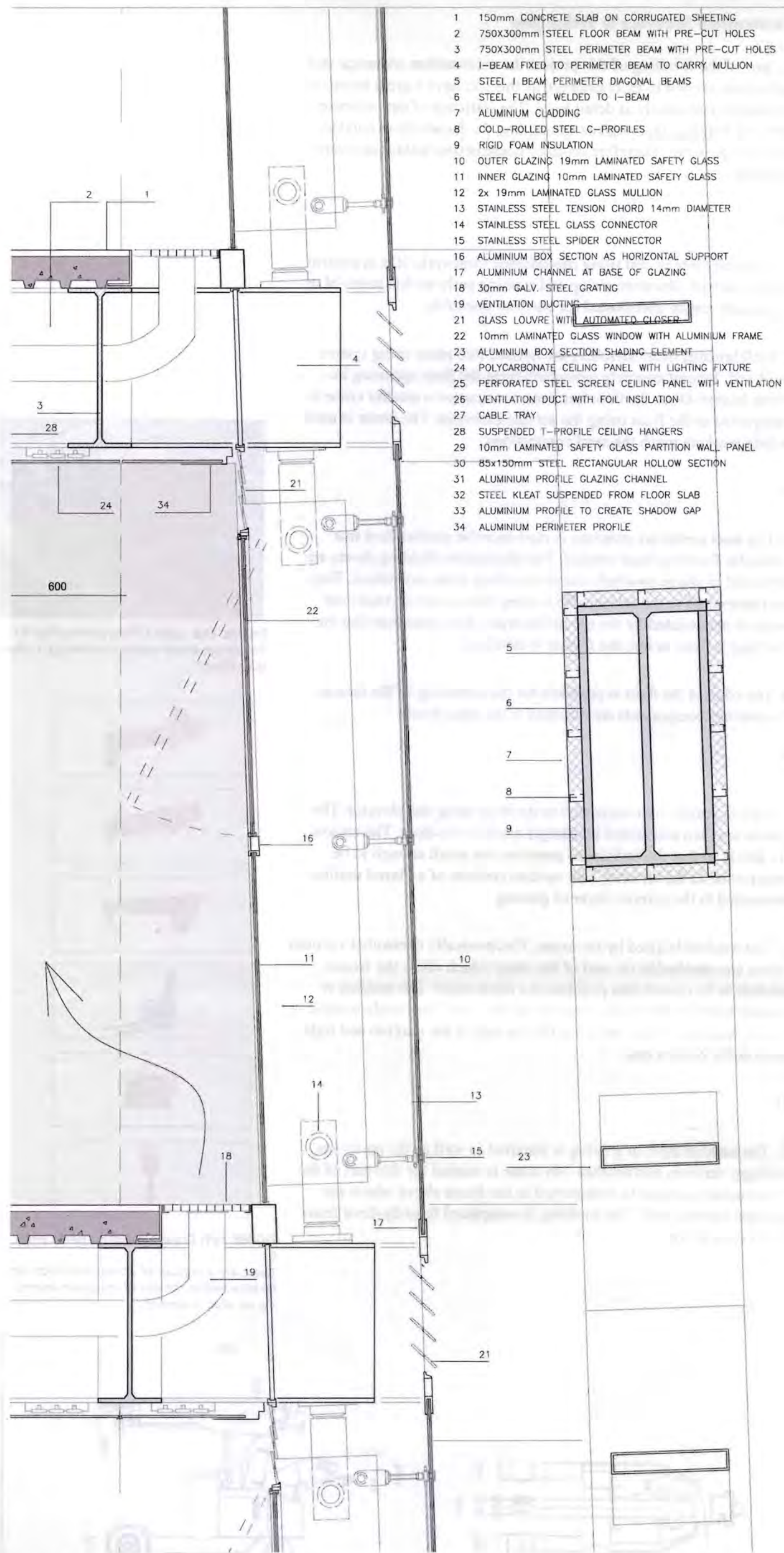


FIGURE 167: 1:20 Section at Facade (author)

Laminated sheets of glass serve as mullions to resist local wind loading on the facade. Short steel beams cantilever from the edge beam wherever a mullion is placed and they connect the mullions to the main structure. Glazed mullions were preferred so that the vertical facade grid is less pronounced from the outside. The glazed mullions simultaneously support the inner layer of glazing, where aluminium channels and glazing span between these rigid members. The facade panels are held by stainless steel connectors which project from the mullions. The joint between glass panels is a silicone bead, joining adjacent glass panels with no frame in-between.

## Construction Sequence & Techniques

As part of the detailing of this project the construction sequence and techniques needed to be considered as this can have a great impact on the design, especially at detail level. The intricacy of the perimeter tube and building taper makes assembling the facade from outside nearly impossible. Therefore on-floor construction techniques were explored.

### A

1. Concrete Core is cast using mechanised formwork. It is important that the service elevators are up and running early so that material and machinery can be transported for on-floor assembly.

2. Prefabricated Steel members are hoisted into place using cranes and fixed. Precast concrete members form the floor spanning between beams. Once the floor has been constructed a smaller crane is transported to the floor using the service elevator. The crane is used to help workers reach the steel connections.

### B

3. The steel perimeter structure is clad once the steelwork at that particular floor has been erected. The aluminium cladding sheets are delivered to site as precisely cut pieces ready to be assembled. They are transported to the relevant floor using the service elevator and workers are assisted by the use of the crane. It is important that the cladding is done before the facade is installed.

4. The edge of the floor is prepared for the mounting of the facade. Connecting components are attached to the edge beam.

### C

5. Facade panels are transported to the floor using the elevator. The panels are then assembled into larger modules on-floor. The reason for this is so that the individual members are small enough to be transported in the elevator. The module consists of a glazed mullion connected to the exterior layer of glazing.

6. The module is lifted by the crane. Electronically controlled vacuum lifters are attached to the end of the crane which allow the facade module to be moved into position at a tilted angle. The mullion is loosely bolted to the steel connector at the base. The facade module is then rotated into place, bolted at the top end of the mullion and tightened at the bottom end.

### D

7. The interior layer of glazing is installed as well as the partitions, ceilings, services and finishes. No crane is needed for this part of the construction and can be transported to the floors above where the process repeats itself. The building is completed floor-by-floor from the bottom to top.



FIGURE 168: Glass Lifting ([www.jekko.it](http://www.jekko.it))  
The image shows workers operating a small glass lifter.



FIGURE 169: Crane Accessories ([www.jekko.it](http://www.jekko.it))  
There are a number of accessories which can be attached to the end of the crane depending on what is needed.

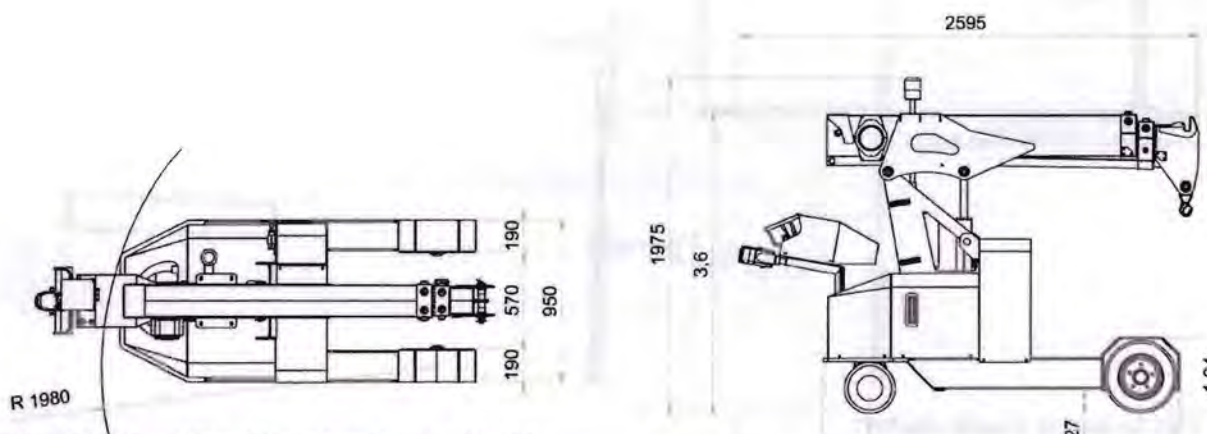


FIGURE 170: Glass Lifter Dimensions ([www.jekko.it](http://www.jekko.it))

The dimensions of the service and express elevator carts used in this project are 2540 x 3050mm. This type of crane can therefore easily fit into the elevator cart. The load which the crane is able to lift is dependant on the distance which the arm extends. This particular model can extend a maximum distance of 2.5m and at that length can lift 400kg. If the crane arm is extended is extended only 1m it can lift 1 tonne. It should be sufficient for the type of loads and distances needed for on-floor assembly in this project.

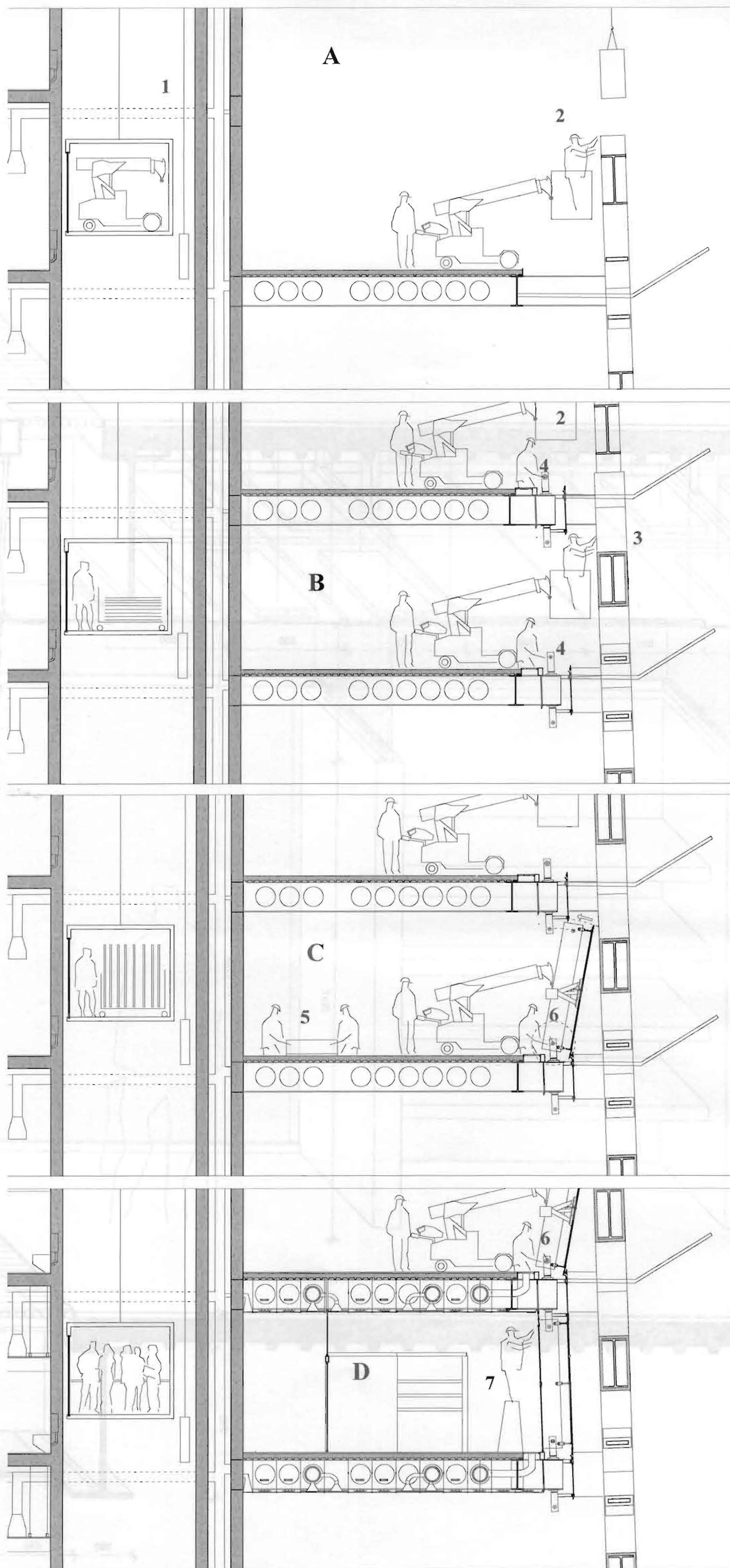


FIGURE 171: Construction Sequence 1:100 (author)

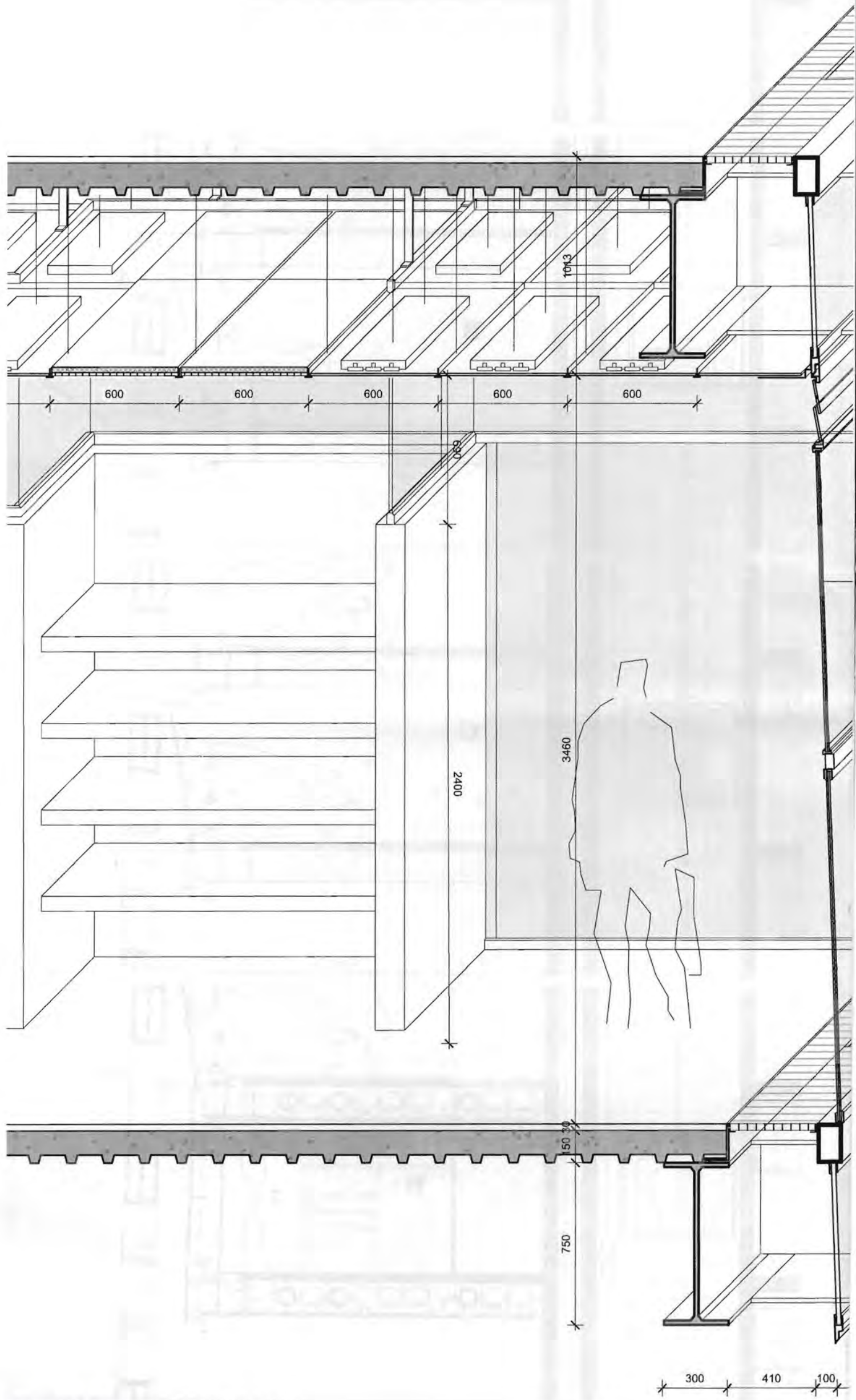
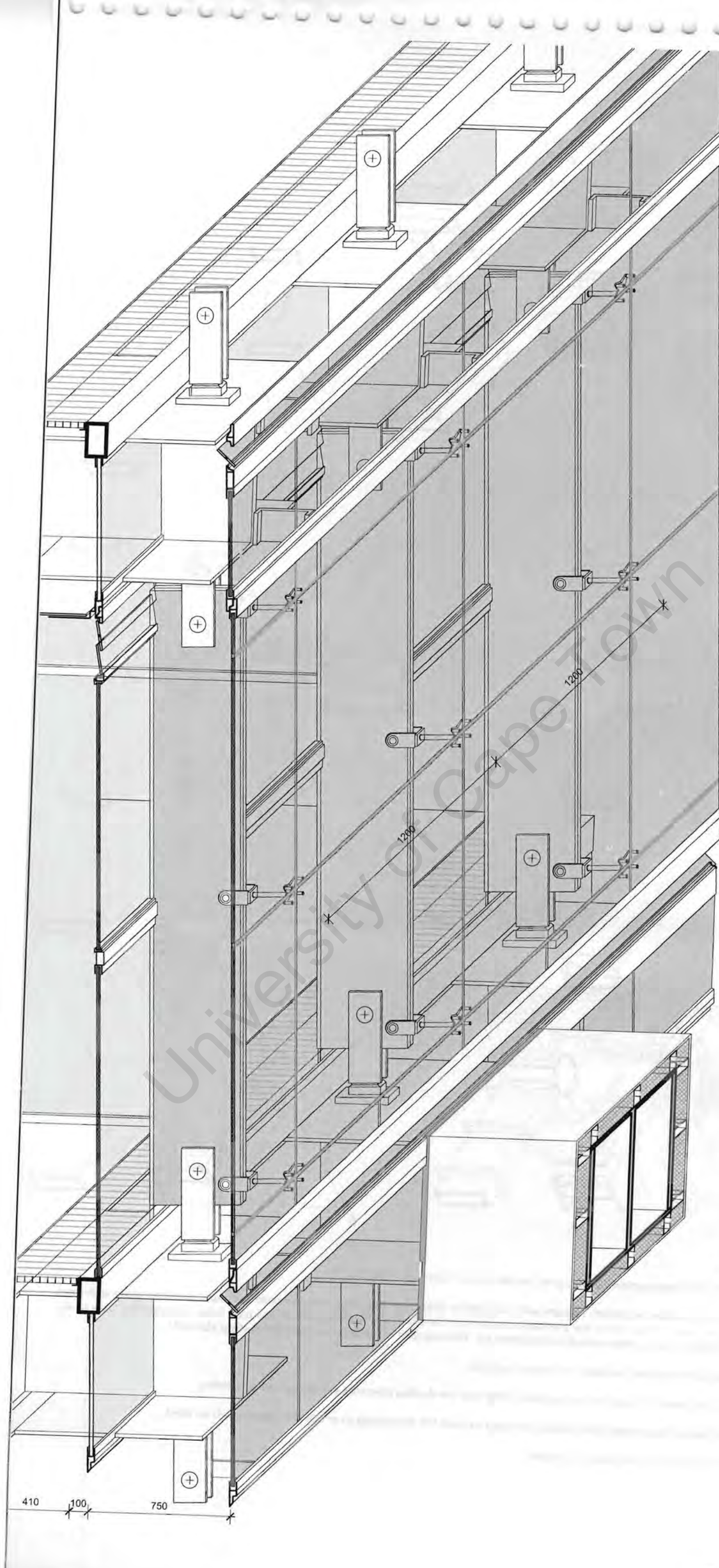


FIGURE 172: 1:20 Axonometric Detail (author)



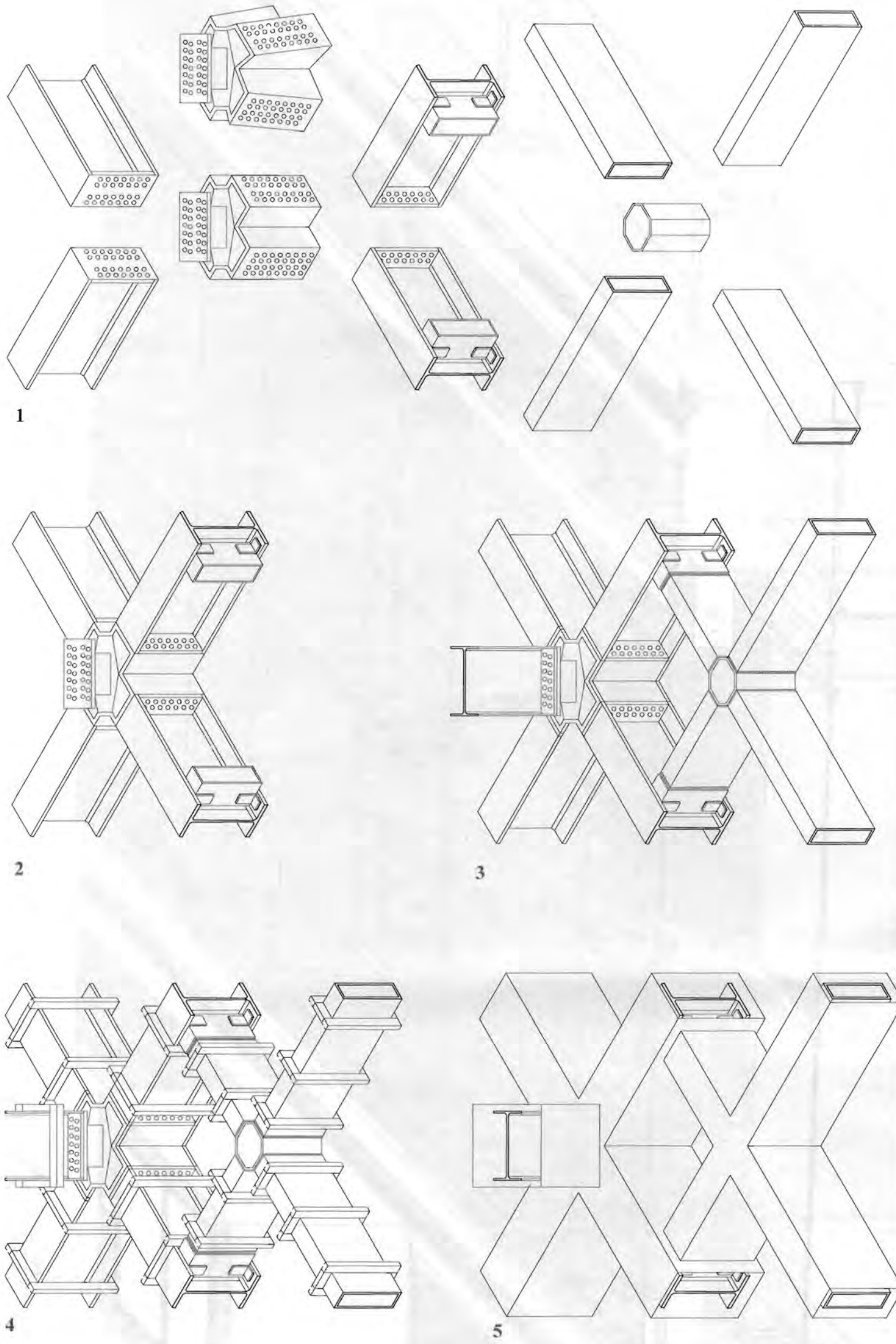
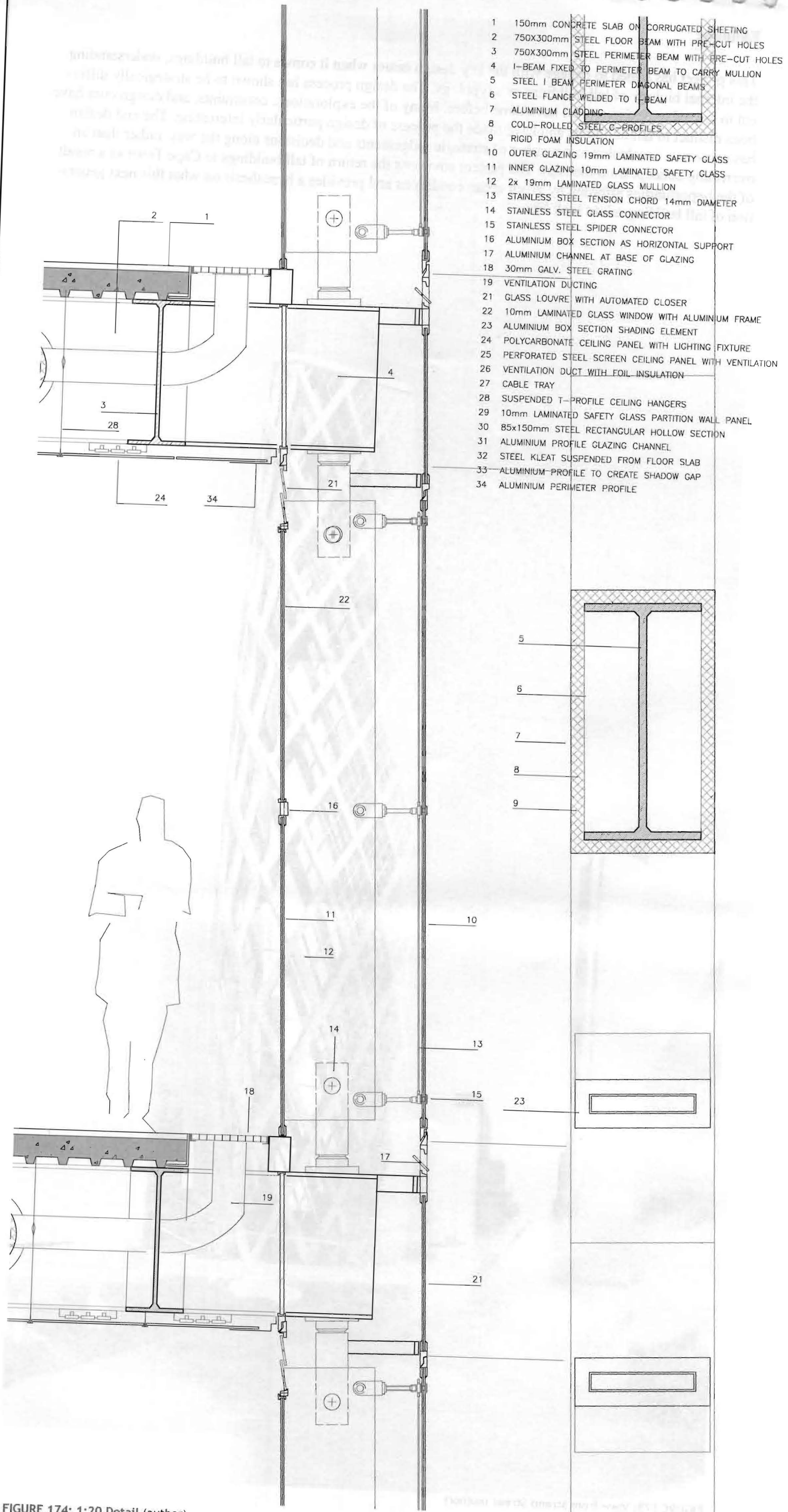


FIGURE 173: Construction Sequence of the Perimeter Tube 1:50 (author)

1. The prefabricated elements. I-Beams with base plates welded to their ends form the main structural members along with steel connector joints. These joints are precisely manufactured and uniquely angled to create the tube form. A connection plate to accept the floor beam is also welded to the connector. Rectangular Hollow Sections form the shading elements.
2. The main structural members are bolted together
3. The floor beam is bolted to the perimeter tube and the shading elements are connected by welding.
4. Cold formed light gauge steel profiles are used to build the bracing to which the cladding will be fixed.
5. The cladding and insulation is installed.



- 1 150mm CONCRETE SLAB ON CORRUGATED SHEETING
- 2 750X300mm STEEL FLOOR BEAM WITH PRE-CUT HOLES
- 3 750X300mm STEEL PERIMETER BEAM WITH PRE-CUT HOLES
- 4 I-BEAM FIXED TO PERIMETER BEAM TO CARRY MULLION
- 5 STEEL I BEAM PERIMETER DIAGONAL BEAMS
- 6 STEEL FLANGE WELDED TO I-BEAM
- 7 ALUMINIUM CLADDING
- 8 COLD-ROLLED STEEL C-PROFILES
- 9 RIGID FOAM INSULATION
- 10 OUTER GLAZING 19mm LAMINATED SAFETY GLASS
- 11 INNER GLAZING 10mm LAMINATED SAFETY GLASS
- 12 2x 19mm LAMINATED GLASS MULLION
- 13 STAINLESS STEEL TENSION CHORD 14mm DIAMETER
- 14 STAINLESS STEEL GLASS CONNECTOR
- 15 STAINLESS STEEL SPIDER CONNECTOR
- 16 ALUMINIUM BOX SECTION AS HORIZONTAL SUPPORT
- 17 ALUMINIUM CHANNEL AT BASE OF GLAZING
- 18 30mm GALV. STEEL GRATING
- 19 VENTILATION DUCTING
- 21 GLASS LOUVRE WITH AUTOMATED CLOSER
- 22 10mm LAMINATED GLASS WINDOW WITH ALUMINIUM FRAME
- 23 ALUMINIUM BOX SECTION SHADING ELEMENT
- 24 POLYCARBONATE CEILING PANEL WITH LIGHTING FIXTURE
- 25 PERFORATED STEEL SCREEN CEILING PANEL WITH VENTILATION
- 26 VENTILATION DUCT WITH FOIL INSULATION
- 27 CABLE TRAY
- 28 SUSPENDED T-PROFILE CEILING HANGERS
- 29 10mm LAMINATED SAFETY GLASS PARTITION WALL PANEL
- 30 85x150mm STEEL RECTANGULAR HOLLOW SECTION
- 31 ALUMINIUM PROFILE GLAZING CHANNEL
- 32 STEEL KLEAT SUSPENDED FROM FLOOR SLAB
- 33 ALUMINIUM PROFILE TO CREATE SHADOW GAP
- 34 ALUMINIUM PERIMETER PROFILE

FIGURE 174: 1:20 Detail (author)

**Endnote:**

This project has aimed to engage with the key design issues when it comes to tall buildings, understanding the internal biology of tall buildings as a typology. The design process has shown to be strategically different to any other design work I have done before. Many of the explorations, constraints, and design cues have been distinct to tall buildings and have made the process of design particularly interesting. The end design has come as a conclusion to a number of strategic judgements and decisions along the way, rather than an overriding concept from the start. The project envisions the return of tall buildings to Cape Town as a result of the opportunities afforded by given urban conditions and provides a hypothesis on what this next generation of tall building might look like.



FIGURE 175: View from Strand Street (author)

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