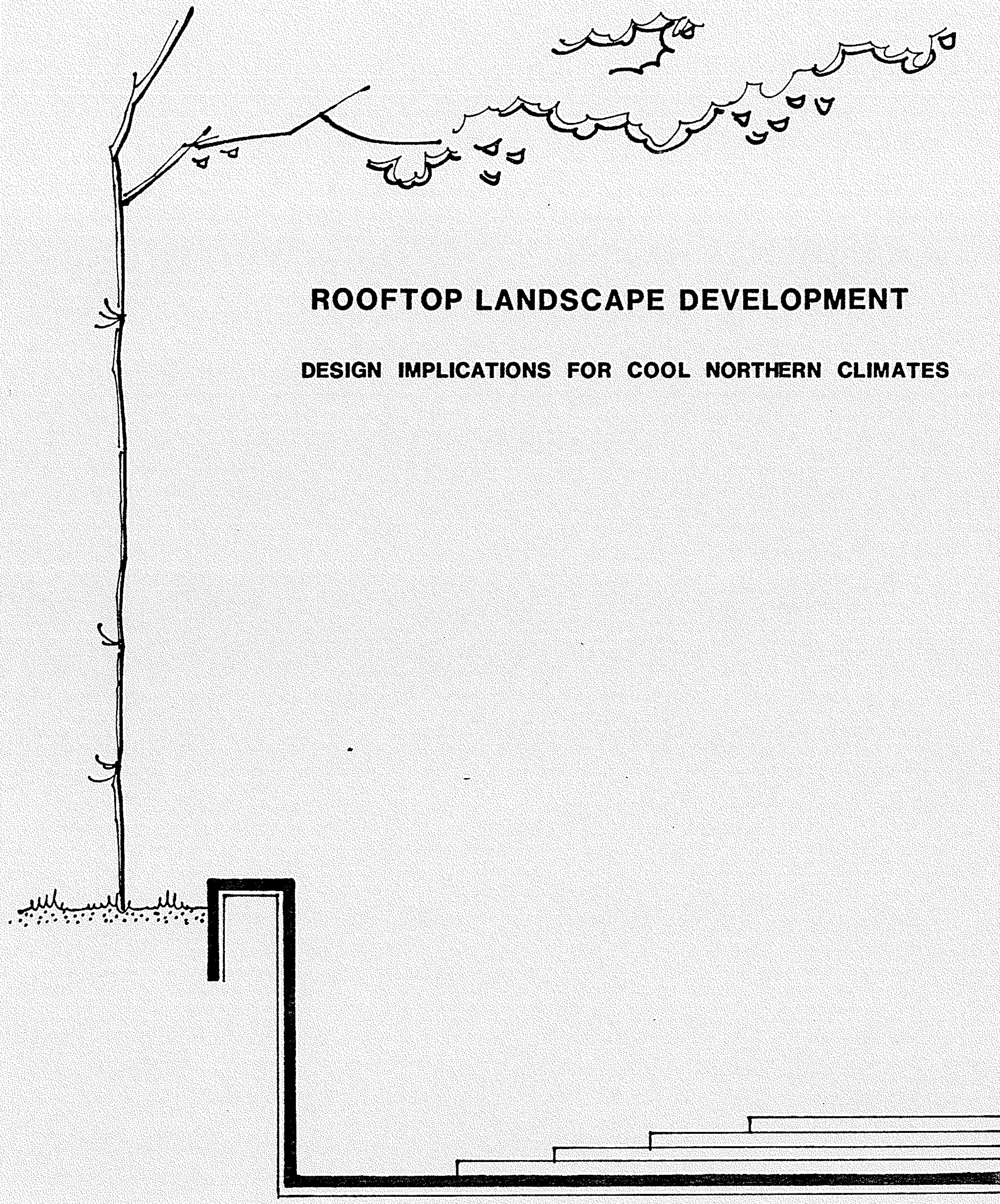
ROOFTOP LANDSCAPE DEVELOPMENT

DESIGN IMPLICATIONS FOR COOL NORTHERN CLIMATES



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A

PRACTICUM

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULLFILLMENT FOR THE

REQUIREMENTS OF

MASTER OF LANDSCAPE ARCHITECTURE

SUBMITTED BY

TING LEE

DEPARTMENT OF LANDSCAPE ARCHITECTURE

UNIVERSITY OF MANITOBA

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ROOFTOP LANDSCAPE DEVELOPMENT

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BY

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A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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ABSTRACT

The purpose of this study is to investigate the historical development of roof gardens and to develop an understanding of current needs and technological capabilities in rooftop landscape development.

The cultural practice of roof gardens throughout historical times was strongly influenced by climate. With today's technological advancements, unforseen possibilities for rooftop landscape development in northern climates are permitted. The significance of rooftop landscape development in our society has become the provision of acceptable alternatives in urban open space and the use of rooftop landscapes as exciting elements in urban design.

This practicum develops a set of design principles and guidelines for rooftop landscape development in the Prairie region. Snow load, snow removal, protection of plant materials and insulation of planters and building structures, as well as treatment of drainage of water is emphasized.

In Winnipeg, rooftop landscape development has not been a popular phenomenon due to economic and population restraints. Present developments such as public podiums or plazas and amenity spaces on new apartment rooftops have enjoyed a certain degree of success. The possibilities and benefits of retrofitting older building for rooftop landscape developments have thus far, however, been markedly overlooked.

The design of the rooftop restaurant terrace for the Brokerage Building in Winnipeg attempts to illustrate the basic design principles and guidelines developed in the practicum. It also serves to demonstrate the possibilities and attractiveness of retrofit with rooftop landscape developments on existing buildings in Winnipeg.

ACKNOWLEDGEMENTS

My sincere gratitude is extended to Professor Charlie Thomsen, for supervising all stages of this study and for critically reviewing the manuscript. The advise and valuable suggestions contributed by Professor Ted McLachlan and Mr. Michael Decter are gratefully acknowledged.

I am also greatly indebted to all the professional and technical staff, expecially Mr. Ed Lach, for their time and assistance during the interviews, as well as their valuable contributions to this practicum.

Lastly, I would like to express my utmost gratitude to my parents Tse-Yu Lee and Yao-Chin Soong, my husband Vincent Chun-Sang Au and friends and fellow students who simply cared.

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

1.0 INTRODUCTION

Variations on the theme of rooftops has, through the course of history produced intricate roofscapes that are as distinctive to a city or a culture as the built environment itself. The utilization of roof areas for something other than shedding water is nothing new as well.

The terms "roof garden" or "sky garden" have been applied loosely to a variety of historical schemes ranging from high level private terraces to truly exotic hanging gardens. Contemporary rooftop developments on the other hand, offer opportunities ranging from residential outdoor terraces, public urban squares and podiums to integrated deck-level commercial complexes and the modern hanging gardens over expressways as in Seattle's Freeway Park *(Figure 1)*.

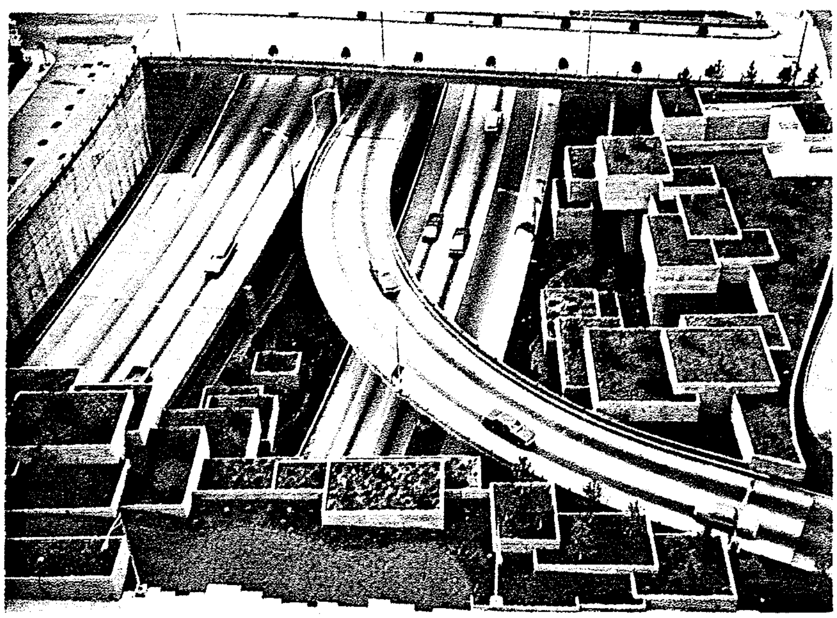


Figure 1

Seattle Freeway Park

(From Landscape Architecture, Sept, 1977)

In view of the diverse opportunities available for potential application of rooftop development today, the term "rooftop landscape" offers a better description. For the purposes of this practicum, "rooftop landscape" is defined as a man-made outdoor environment, designed with or without planting, to serve some of the same functions as a landscaped area at ground, but separated from the ground by man-made structures.

As today's society experiences mounting pressures of increasing urban density, escalating land costs and the resultant squeeze on urban open spaces; it seems only natural that the valuable space provided by rooftops should be utilized whenever possible to improve aesthetic and functional quality in urban environments. Recognizing the potential of this development alternative, the City Planning Commission in New York has stipulated that certain new apartment houses be built with gardens over portions of the roofs to ensure provision of adequate open space *(Kathleen Tinkel, 1977)*. Significant progress in the incorporation of rooftop landscapes in new building developments has been observed in major city centers for the last 50 years. Most older North American buildings at first glance, however, remain dominated by ubiquitous tar and gravel covered flat roofs.

The reluctance on the part of some owners and designers to incorporate rooftop landscape development in new or existing buildings, reflects general concerns for cost and safety or more commonly, lack of familiarity with available technologies that capitalize on rooftops for open spaces in northern climates.

1.1 Objectives

It is the objective of this study to investigate current concepts and available technologies related to various aspects of rooftop landscape development, to analyse such developments in relation to cool northern climates such as those experienced on the Prairies to derive a comprehensive set of principles and to demonstrate and test the implications of these principles through a site specific design.

1.2 Methodology

In order to address the objectives set out for this practicum, the study was divided into three main categories: background research, information systhesis and design application. The principle tasks undertaken in each category are described below, and their interrelationships presented in the Mehtodology Flow Chart *(Figure 2)*.

Background Research - A preliminary literature search on the subject of roof gardens was prepared for a special topics course and a summary of the findings are included in the annotated bibliography at the end of this study. Also involved was the investigation of local rooftop landscape development practices from site visits and interviews with professionals in Winnipeg.

Information Synthesis - A synthesis of the systematic growth of rooftop landscape from historical to current patterns and associated technological progress was developed to enable the identification of design principles and guidelines appropriate to the Prairie climate.

Design Application - Site reconnaissance and investigation of development potentials for the rooftop of the Brokerage Building in Winnipeg. Findings and recommended development process are discussed and illustrated in Section 6.

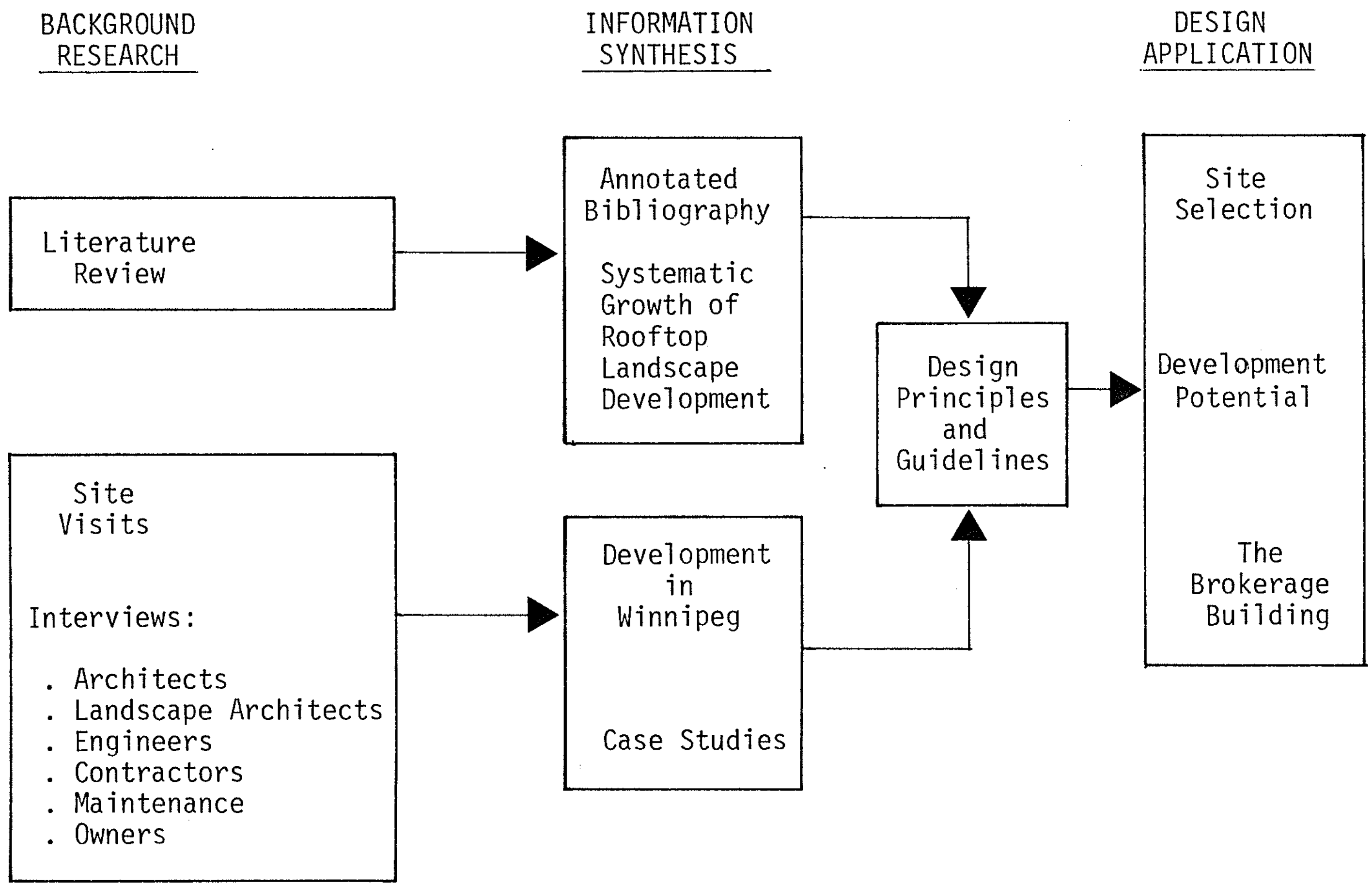
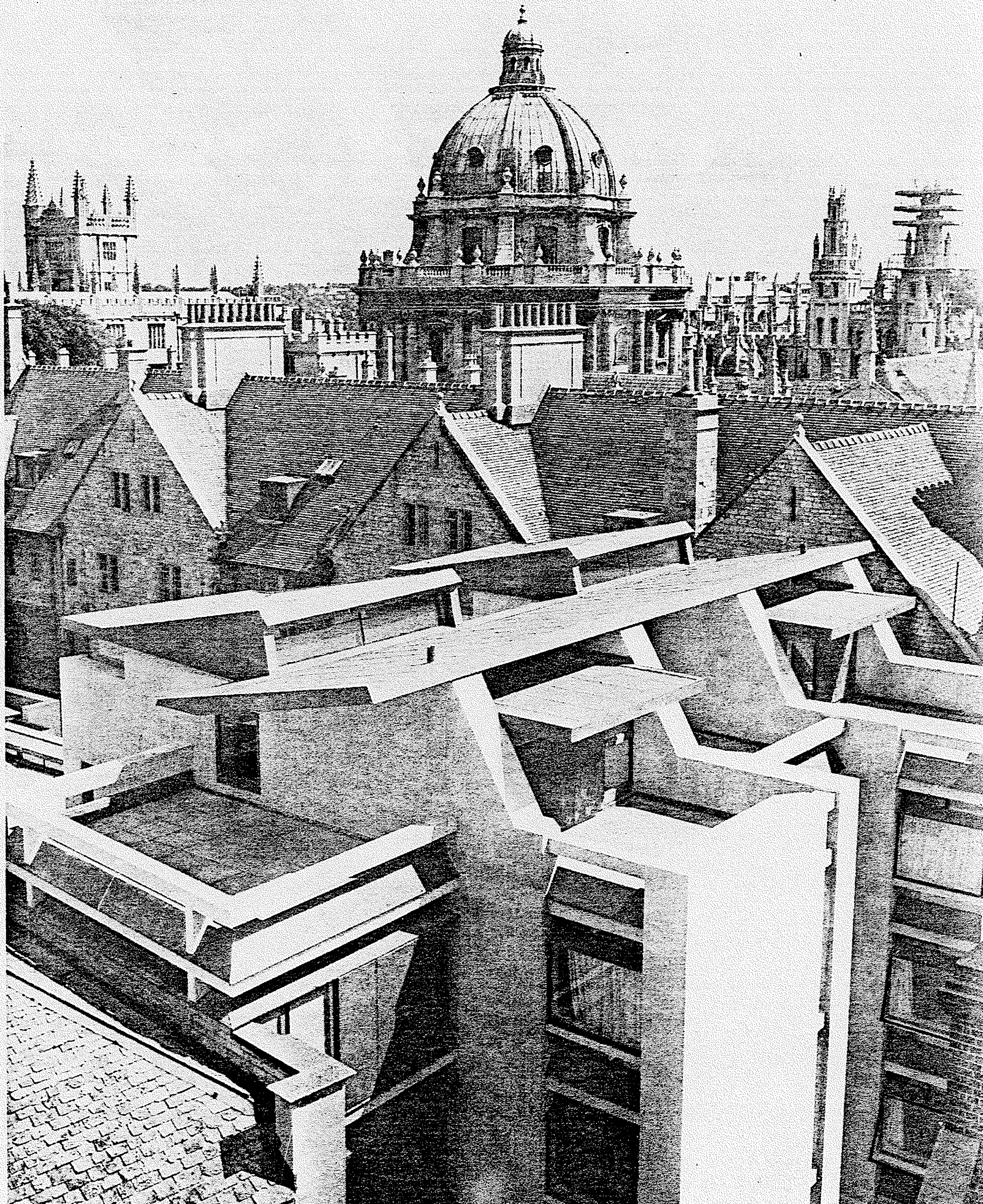


Figure 2 Methodology Flow Chart

2.0 HISTORICAL DEVELOPMENT



2.0 HISTORICAL DEVELOPMENT

This section reviews the historical development of rooftop landscape as a systematic art, focusing on events and attitudes which cultivated the growth of rooftop landscapes.

2.1 Roof Functions and Roof Forms

Roofs, as an essential element of architecture, have traditionally been associated with the concept of shelter. Along with the common expression of 'having a roof over ones' head', a roof has to meet an impressive range of functional requirements in order to protect the inhabitants from the elements. These requirements range from keeping out water, providing thermal insulation, offering protection against the sun, resisting alternate exposure to heat and cold, and moderating heat losses.

Vernacular roof forms often reveal additional functions imposed by local climates. For example, people living in dry, warm climatic regions have long used flat roofs as an extension of outdoor living spaces *(Figure 3)*.

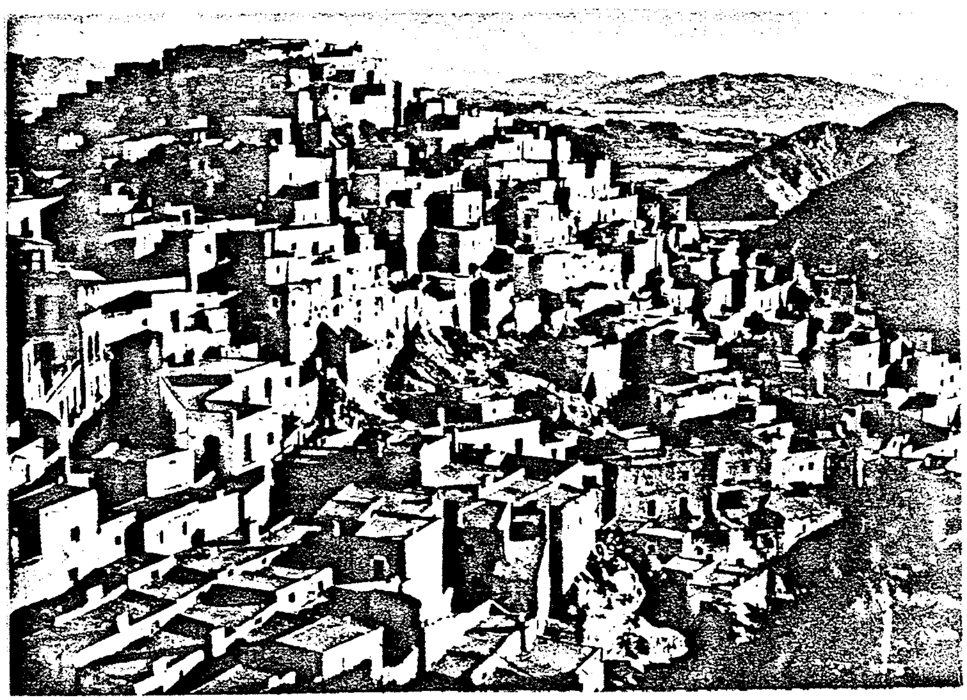


Figure 3 *Mediterranean Hill Town*
(From Architecture Without Architects, 1964)

In areas of colder climate and heavy rainfall, pitched roofs were developed to shed rain and snow. In the Scandinavian region where winters are harsher, neolithic turf layer over a structural pitched roof were adopted for added insulation benefits *(Figure 4)*.

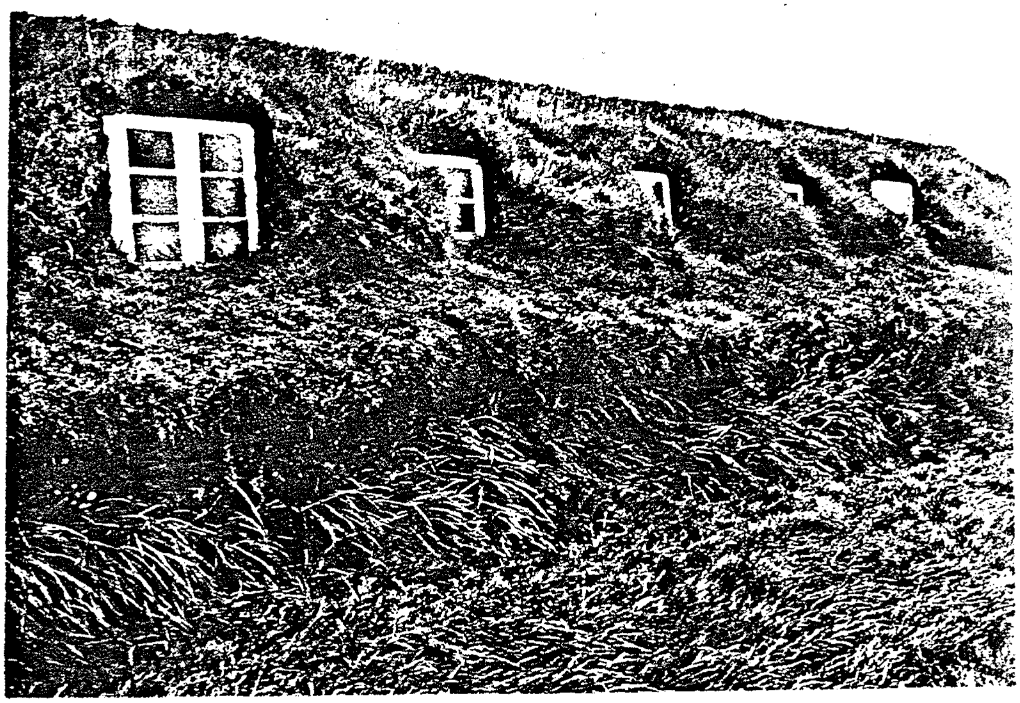
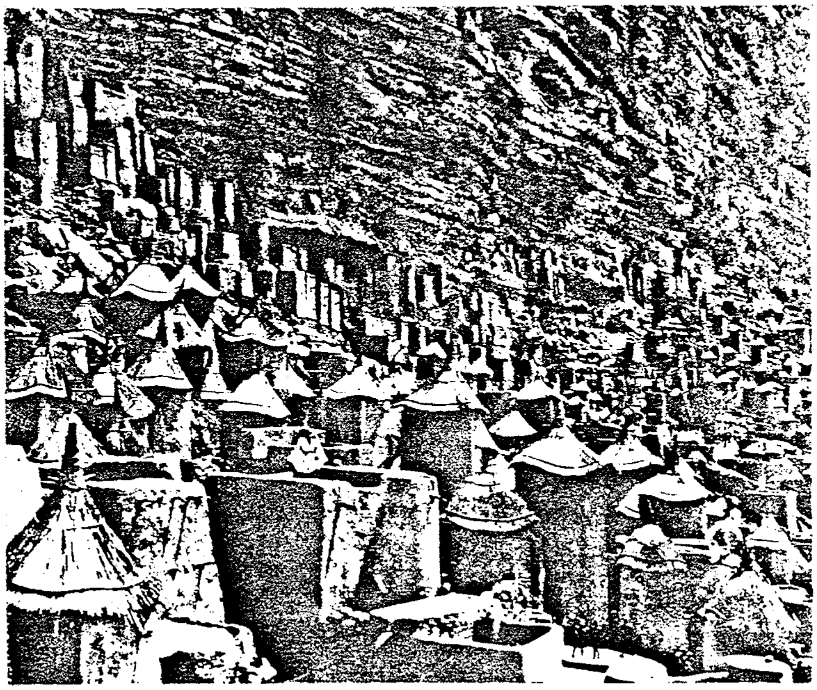


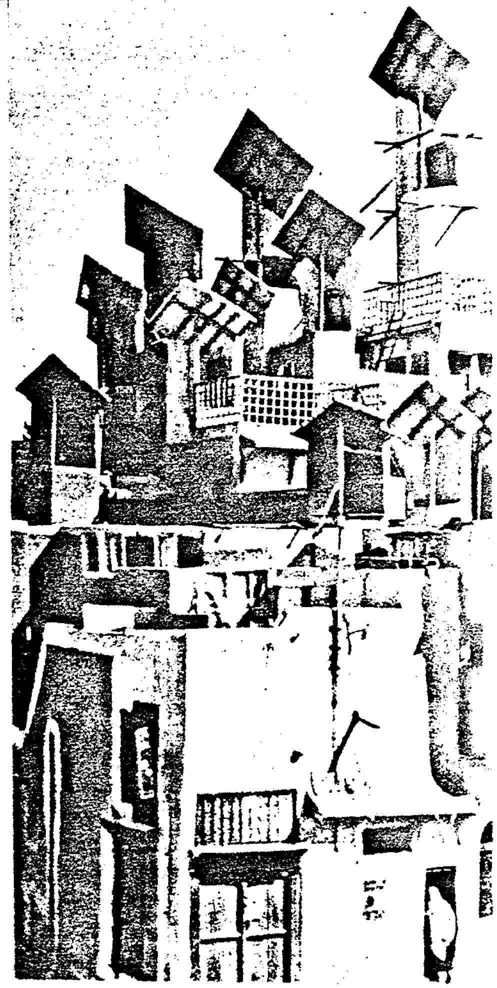
Figure 4 *Icelandic Turf House (From Abitare, 1975)*

Whether flat or pitched, sodded or thatched, vaulted or subterranean, vernacular roofscapes *(Figure 5)* have always contributed an interesting dimension to the living environment in addition to their functional attributes. It seems ironic that with the advent of modern technology, today's roofscapes are limited to the ubiquitous tar and gravel covered flat roofs, featuring only mechanical and electrical equipment. It is evident that both aesthetically and functionally the roof has become a neglected element in our living environment.

Figure 5 Vernacular Roof Forms
(From Architecture Without Architects
1964)

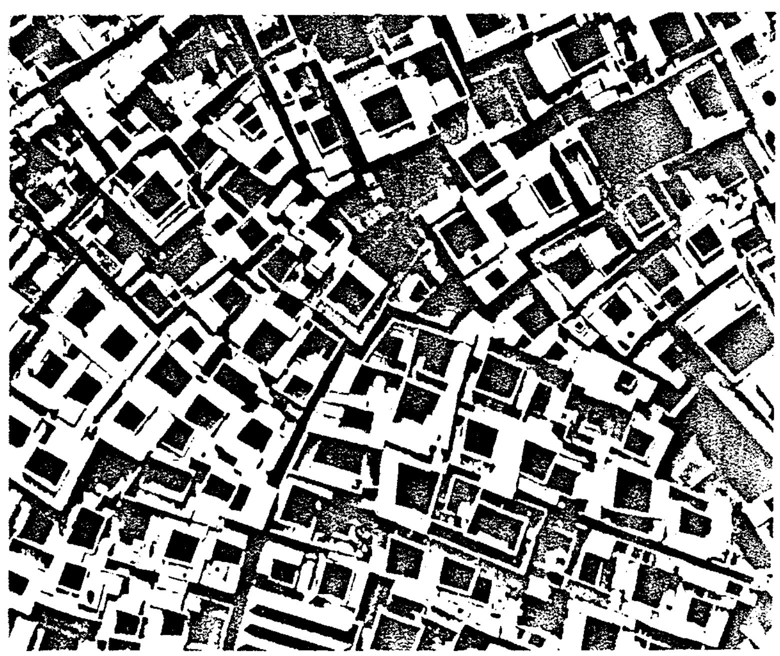


Straw - hatted houses of the Dogons,
Africa.



Permenantly fixed windscoops,
West Pakistan.

Movable Architecture,
Guinea.



Archetype of an Islamic town, Morocco.

2.2 Historical Background

"Roof gardening has existed in Mediterranean countries since the invention of the earthenware pot." *(J. Whalley, 1978: p.7)*

The earliest recorded roof planting effort *(T. Odsmundson, 1979)* dated back to the great ziggurat of the ancient Sumerian city of Ur. Built about 2000 B.C. in what is now known as Iraq, the temple tower had trees planted on the three upper terraces. One may argue, however, if these were true roof plantings as the towers contained solid cores of rubble and soil. Perhaps a more genuine attempt at producing a roof garden was demonstrated in the Babylonian Hanging Gardens built 1500 years later *(Figure 6)*. The highest garden terrace *(T. Odsmundson, 1979)* was estimated to be 23m (75 feet) above ground. A stone building (a rarity in Mesopotamia) with barrel vault supports was specially designed to sustained the weight of the roof garden. Water was transported from ground level wells to the roof for irrigation by a pulley device. Natural asphalt was used to protect the structure from moisture penetration.

The elaborate tradition of classical times was followed in the tree-planted circular terraces of the tomb of Augustus *(Figure 7)* and the Byzantine Balcony Gardens of Justinian. Similar concepts of roof garden and promenade built along the city wall also prevailed in other Middle East countries, such as India and Persia.

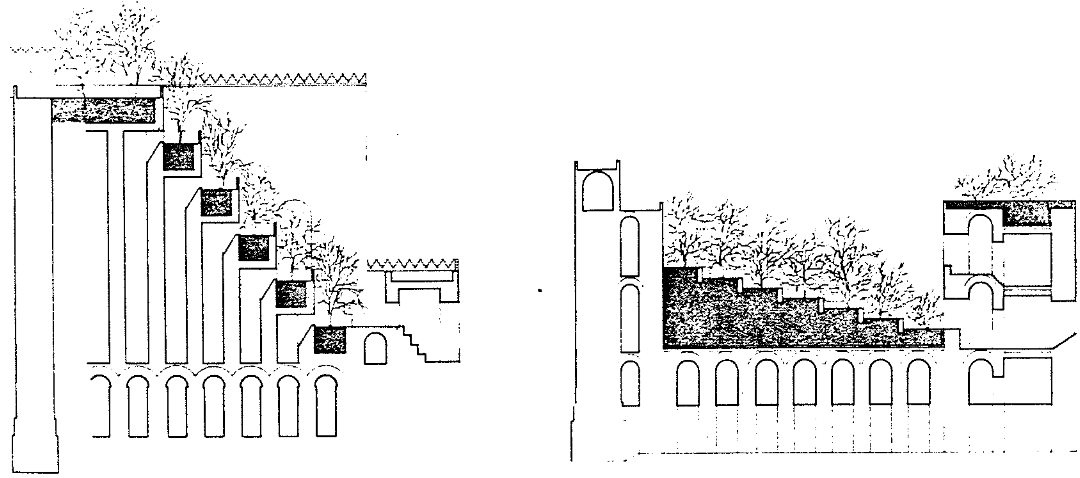


Figure 6 *Reconstructed Sections of The Hanging Gardens of Babylon*
(From Dachgarten & Dachterrassen, 1962)

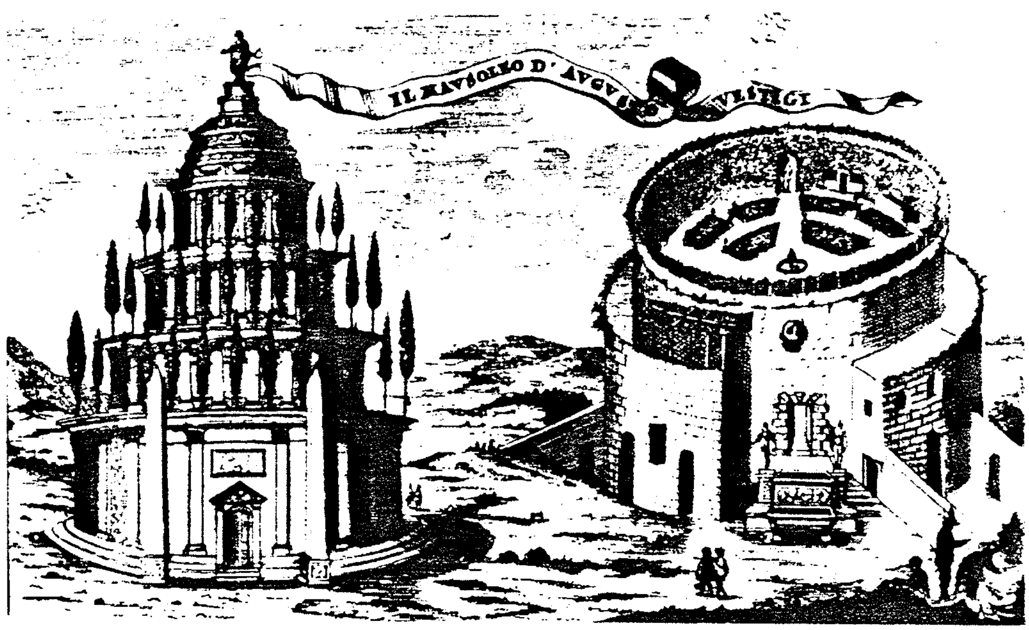


Figure 7 *Tomb of Augustus in Rome, 28 B.C.*
(From Dachgarten & Dachterrassen, 1962)

2.3 Architectural Traditions

Harsh winters, characteristic in Northern Europe, traditionally prohibited the feasibility of flat roofs. A revival of classical architecture during the Renaissance period reversed the trend by a re-introduction of the cantilevered stone balcony. This architectural form allowed external planting space without undue structural and moisture-proofing problems. The infusion of classical precedent and Renaissance taste resulted in products such as Cardinal von Lanberg's roof garden in Passau which reflected High Renaissance ornamental parterre design *(Figure 8)*.

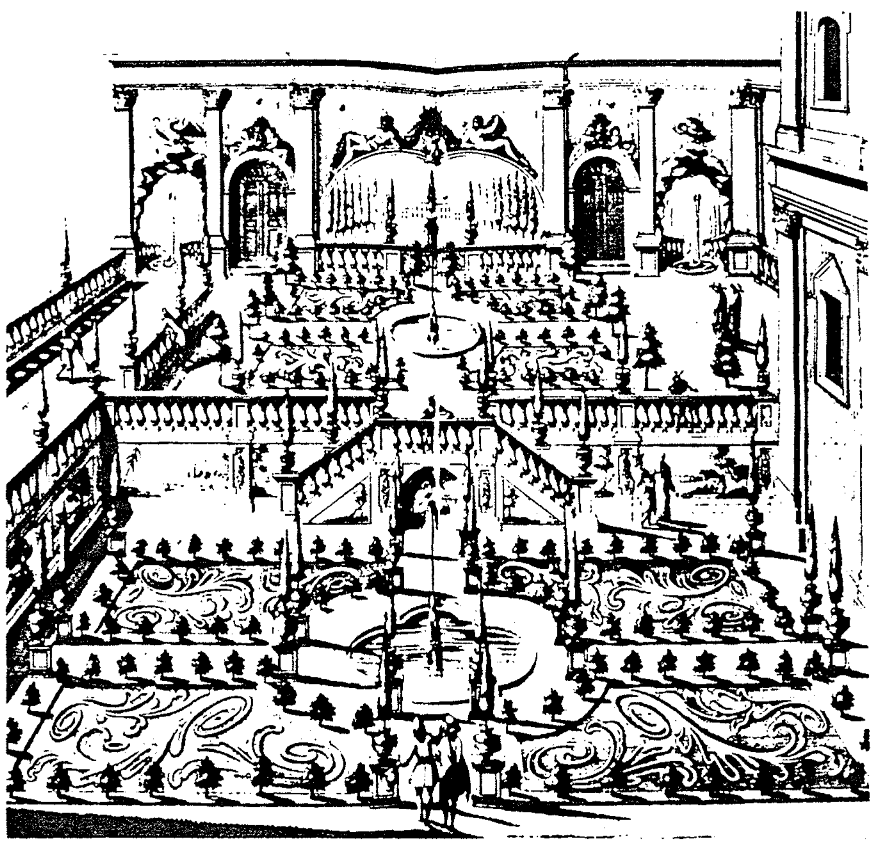


Figure 8 High Renaissance Roof Garden in Passau (From Dachgarten & Dachterrassen, 1962)

The turning point from Renaissance taste came during the Paris World Exhibition of 1867. This was where the German master builder, Carl Rabitz, exhibited the model of "the first bourgeois roof garden *(Fgiure 9)*, set in north Europe, on a purpose-designed flat roof intended principally for leisure use during the Summer months. This roof construction utilized Rabitz's patented invention of vulcanised cement. Widely reported in the papers, reviews of the scheme touched on themes which are still expounded in the cause of roof landscape: beautification of the city roofscape, reserving leisure space from congested city development, increased roof insulation and stabilization of effects of temperature changes on roof structure and the internal environment." *(John Whalley, 1978: p.8)*

Figure 9 *"Modern Hanging Garden" of Carl Rabitz, Berlin, 1860*
(From Dachgarten & Dachterrassen, 1962)

During the modern movement, the flat roof emerged as a dominant design element aimed at reducing the superficial decoration of ninteenth century designs. Le Corbusier "democratized" roofscape from the stern classical traditions in his Five Points to A New Architecture *(John Whalley, 1978)*. The outcome was the instigation of flat roofs on high rise buildings as additional areas for leisure. A noted example is the playground atop Unite d'habitation at Marseilles, France built in the early 1950's. Plant growth, however, was restricted in order to preserve the 'geometric simplicity and cubic purity' of the architecture.

It was not until the time of Frank Lloyd Wright that current concepts of cascading foliage overhung from balconies became popularized and roof landscapes were truly revealed as an integral element in modern architectural design *(Figure 10)*. The concept of heavily planted sections was realized in numerous European and American schemes such as: Gateway House, Basingstoke, Hamshire by AMP Associates *(The AJ Journal, Mar 26 1980: pp. 445-449) (Figure 11)*; the renowned three level terraces of the Oakland Museum, Oakland, California by Kevin Roche *(A. Temko, 1977: pp. 30-37) (Figure 12)*; and countless housing schemes in Switzerland *(L. Burckhardt, 1967)*.

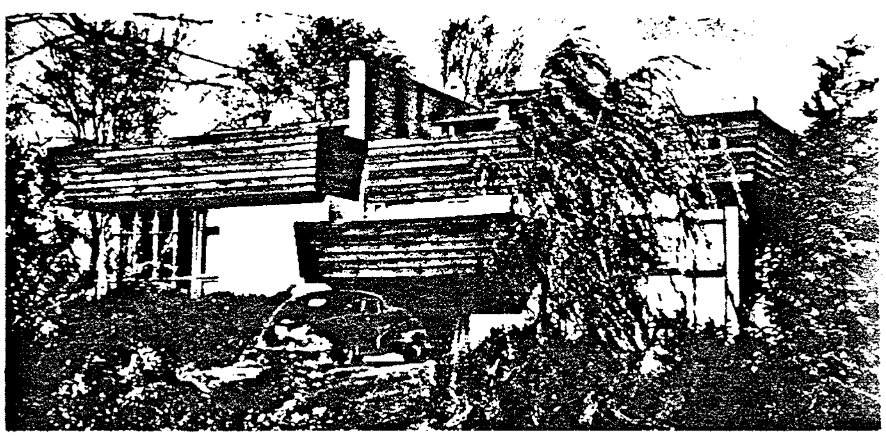


Figure 10 *Residential Roof Garden by Frank Lloyd Wright U.S.A., 1939*

(From Dachgarten & Dachterrassen)

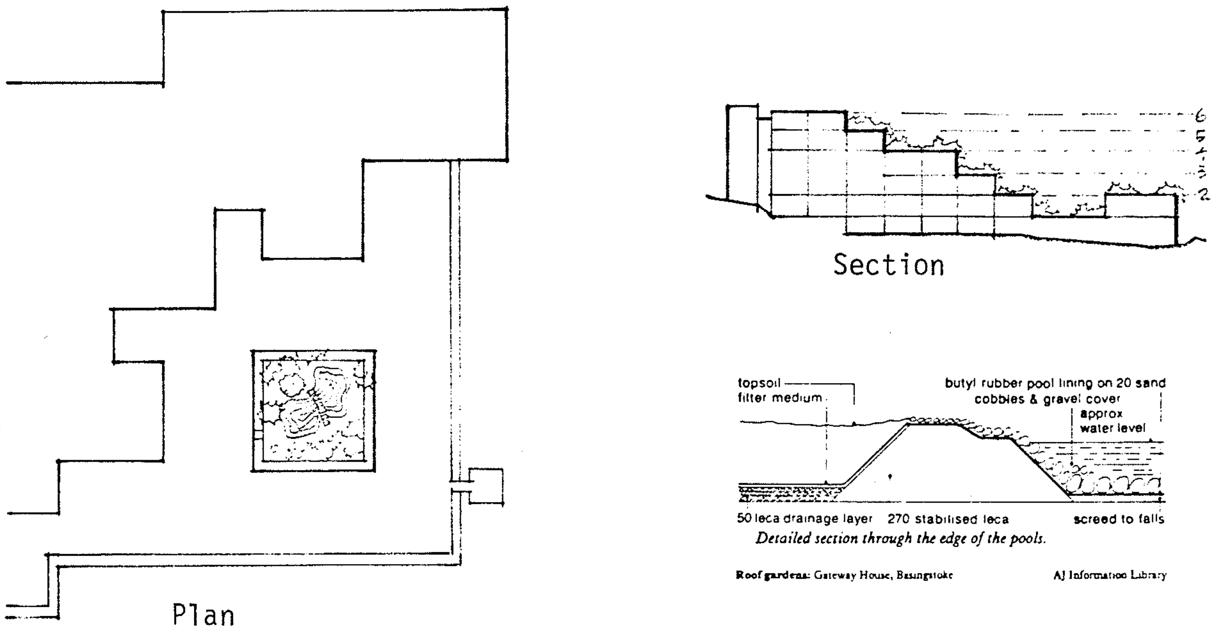


Figure 11 *Plan, Section and Detail of Gateway House, Basingstoke (From AJ Journal, Mar 26, 1980)*

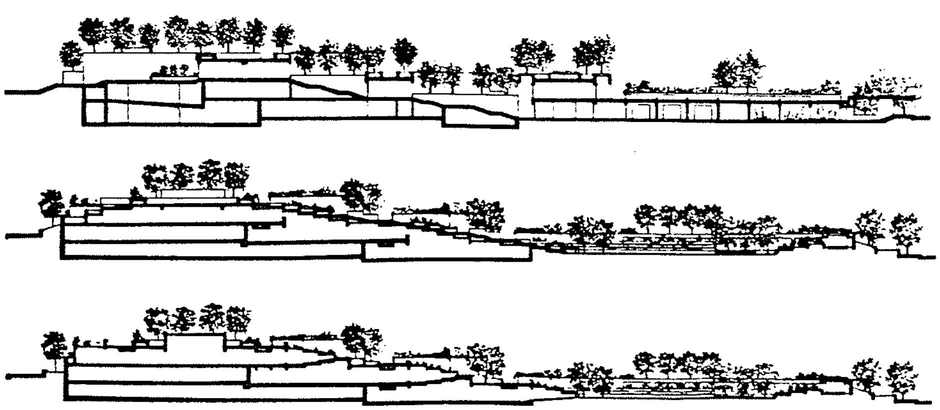
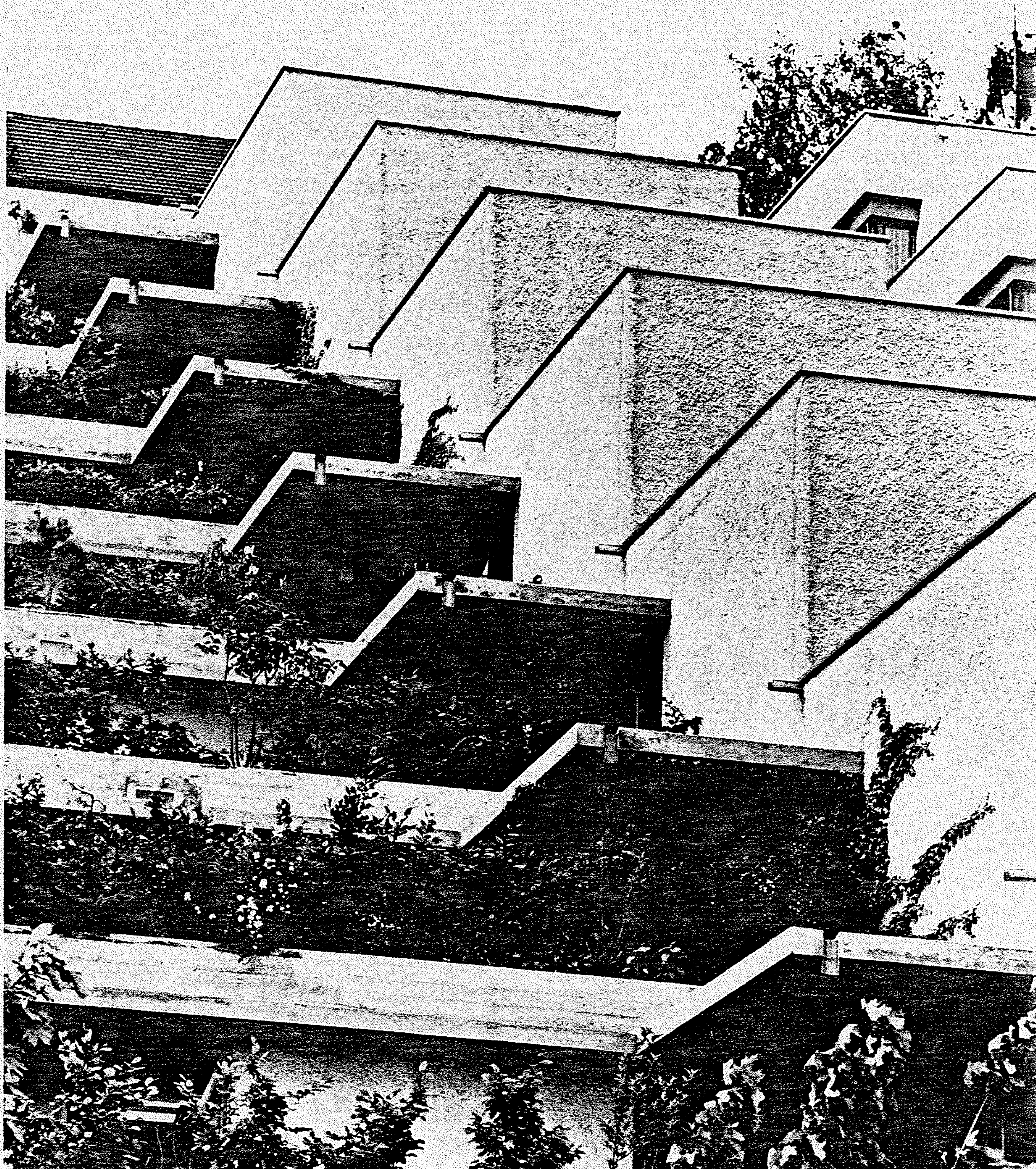


Figure 12 *Diagramatic Sections of Oakland Museum, California (From Roofscape, 1977)*

3.0 CURRENT DEVELOPMENT

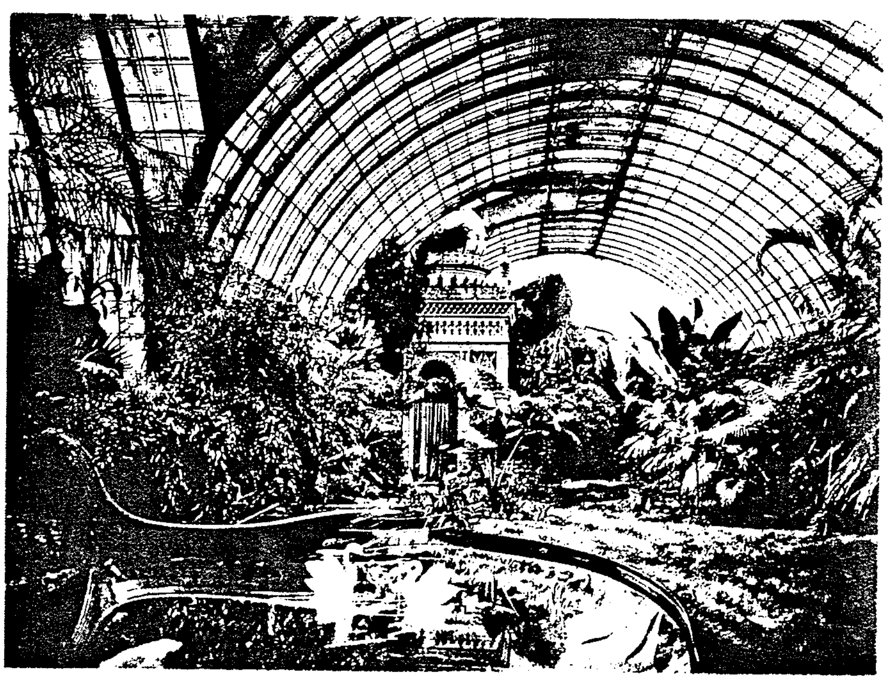


3.0 CURRENT DEVELOPMENT

Section 3.0 sets out to examine the state-of-the art development of current rooftop landscapes in terms of technological progress and world-wide development trends.

5.1 Technological Progress

The widespread enthusiasm for roof gardens, was not paralleled by an equivalent progress in roofing technology. The importance of technological support was all too evident in the experience of Ludwig II's winter garden *(Figure 13)*. Built over a wing of his Munich palace in 1874, the garden was designed to be a tropical paradise containing exotic plants and birds under a glazed roof. In spite of the specially designed system of thick cooper plates laid



Fgiure 13 *Ludwig II's Winter Garden, Munich, 1874 (From Dachgarten & Dachterrassen, 1962)*

over stone vaults, it was not possible to prevent the extensive water seepage which led to the gradual deterioration of the building. The structure was eventually demolished in 1897.*(John Whalley, 1978)*

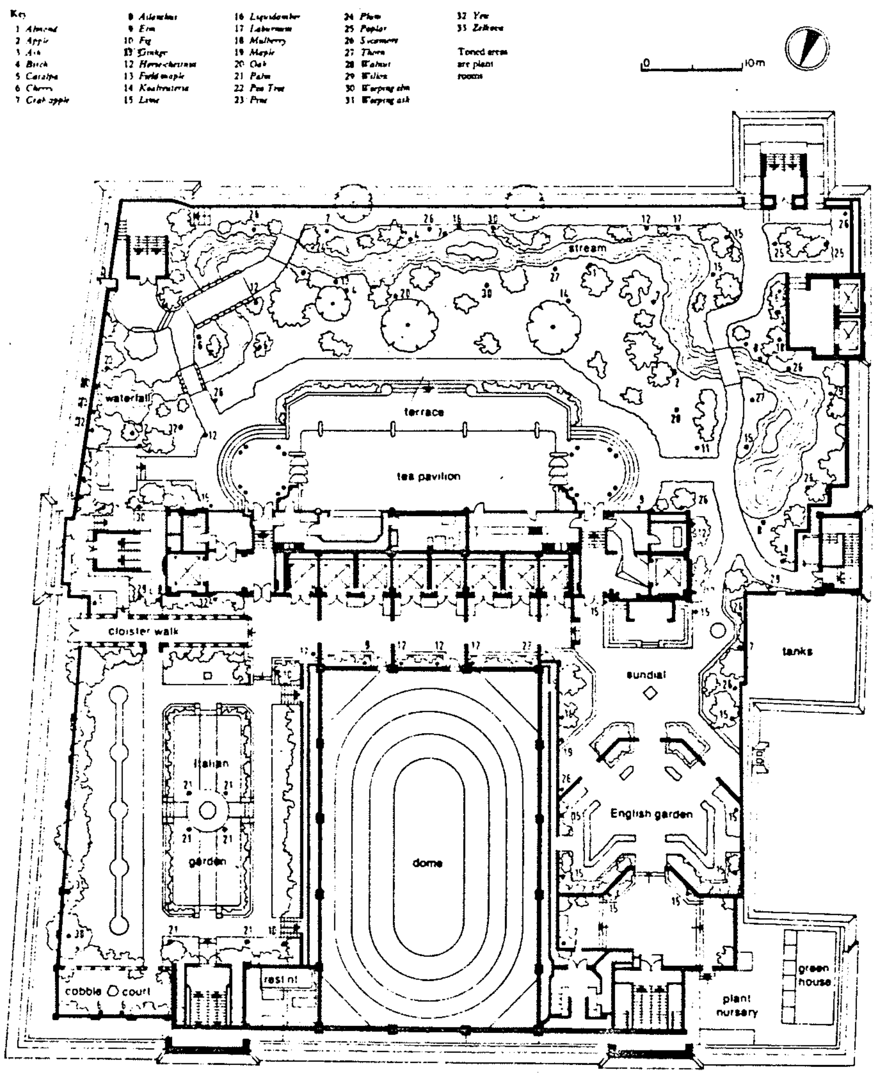
Where flat roofs used to be a luxury reserved for dry warm climates, their popularity in world wide city centers increased dramatically after the introduction of asphalt and similar roofing materials.

During the early 1890's, hotel and theater managers were the pioneers of the 'roof garden movement' in the United States. Hotel and restaurant roofs were utilized for amusement purposes, catering to the luxury of the rich and entertainment of the pleasure-seeker *(Figure 14)*.

"PARADISE" ROOF GARDEN

Figure 14 *Roof Gardens For Entertainment (From Roof Gardens of New York, 1906)*

Limitations in structural techniques, economies of construction and general lack of understanding for plant requirements often limited early attempts at rooftop landscape to treatments with potted plant materials which were not integrated with the roof structure. The exceptions were the Derry and Tom's Roof Garden in London *(Figure 15)* and the Casino Terrace in Berne. Both constructed in the 1930's, Derry and Tom's was considered the largest roof garden in Europe at the time. In both gardens, it was the strength of the underlying building which helped to reduce weight restrictions. In the case of the Casino Terrace, a substantial soil layer of 1.7m (5 ft) in depth, overlaid 0.3m (12 in) of gravel to simulate ground level situations and to create an amiable environment for luxuriant plant growth.



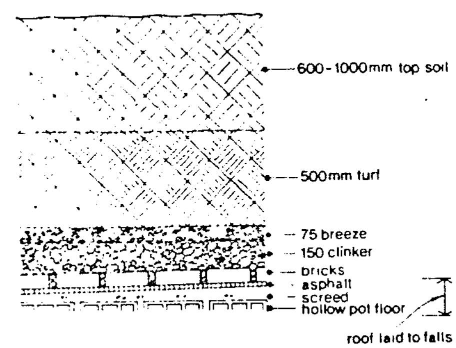


Figure 15

Plan and Section of the Derry & Tom's Roof Garden As Originally Constructed

(From AJ Journal, Oct 15, 1980)

The construction of underground complexes during the 50's brought roofs closer to street level. Rooftop development began to serve a more demanding role of public open space in addition to that of private gardens. The roof garden of the Kaiser Center in Oakland, California, constructed in 1959, represented the contemporary precedent for elaborate rooftop landscape development. *(T. Odsmundson, 1979)* The creation of the lush 1.4 Ha (3.5 acre) park, four to six floors above street level was largely made possible by the landscape architects' (Osmundson and Staley) effort to combat the weight restrictions *(Figure 16)*.

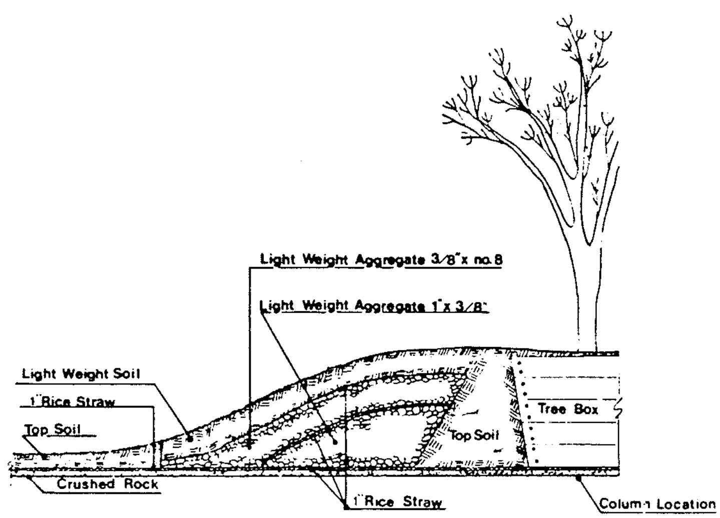


Figure 16

Kaiser Center Roof Fill Section

(From Landscape Architecture, Sept, 1979)

Light weight material and soil mixture were used throughout the park. Soil depths were kept to a minimum of 150mm (6 in) for lawns and 740mm (30 in) for trees. Plants with a shallow and fibrous root system were selected for successful growth in the restricted soil environment with limited soil depth and moisture. Trees were placed at column locations with sub-soil redwood crates for stablity. A layer of rice straw was used to prevent silting from the soil into the drain rock layer.

The European counterpart was carried out in the Grosse Schanze Park *(Jane Back, 1973)* over Berne Central Railway Station in Switzerland. The garden consists of an area of 11,000 m^2 (2.7 acre). Built over the new station building, it was designed to integrate with an existing park and provide public access both to town and to the station *(Figure 17)*. The program consists of planting areas with trees and flowers, a large central lawn area, a peripheral concrete slabbed promenade, a restaurant, childrens' play areas, garden pools and fountains.

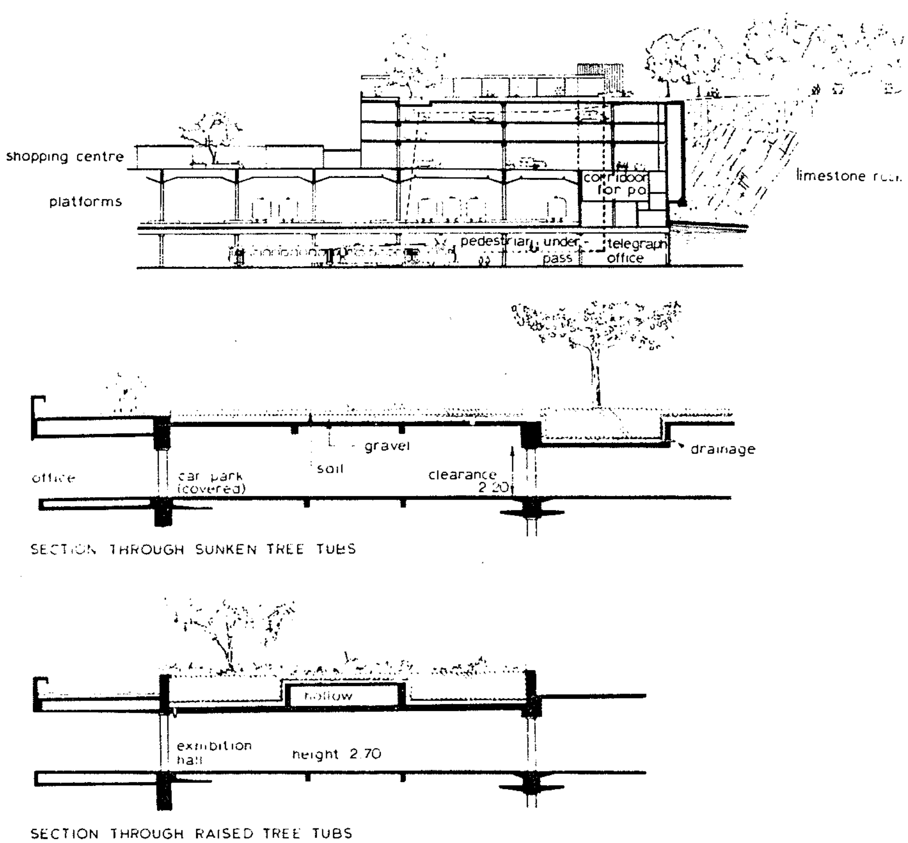


Figure 17 *Section Details of Grosse Schanze Park, Berne (From Concrete Quartely, Jan-Mar 1973)*

The roof section developed has been used as a reference for many subsequent European rooftop developments *(Figure 18)*. An asphalt waterproofing layer was laid on top of the reinforced concrete roof slab with a grade of 1:60 for drainage. A 150-200 mm (6-8 in) thick drainage layer of 30-50 mm diameter (3/16-2 in) gravel was laid directly above. Immediately over this was 15 mm (5/8 in) layer of fiberglass matting which acted as insulation and filter guard to prevent soil fines from clogging up the drainage path. Next came 50mm (2in) of coarse peat to hold a reservoir of moisture for root growth. The rest was made up of sandy loam top soil to a depth of 200mm (8 in) for lawn, 500-600mm (20-30 in) for shrubs and 800-1200 mm (31-47 in) for trees.

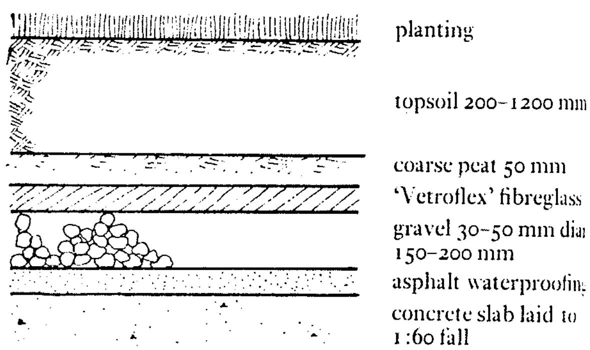


Figure 18

Roof Section of Grosse Schanze Park, Berne

(From Concrete Quarterly, Jan-Mar 1973)

Although, experience and confidence gained from dealing with new products and improved technology have greatly expanded the opportunities for rooftop landscape development since 1960, approaches addressing the fundamental issues of load distribution, protection of plants from exposure from wind and sun, plant anchorage, waterproofing and insulation from the building heat beneath all remain unchanged.

Soil and water (drainage and water supply) remain the two most critical considerations for the establishment of any rooftop landscape. Various light weight soil media have been established to accommodate the weight restrictions presented in most modern structures. Amongst them are the University of California mix of fine, expanded shale (used in place of sand), peatmoss and various fertilizers used in Kasier Center, 1959; the UCLA Plant Mix System of fine, salt-free sand, redwood sawdust and chemical nutrients used in Oakland Museum, 1969; and the standard sandy loam soil mix used in Grosse Schanze Park, Berne, 1960-70.

Peat has become a popular growing medium for rooftop planting, owing to its light weight and water retention qualities. It is commonly used in a mixture of 25% peat, 50% sand and 25% top soil mixture as in the Constitution Plaza, Hartford, Connecticut, see below. *(From Handbook of Landscape Architectural Construction, 1975)*

Planting Soil Mixture used for shade trees:

% By Volume	Material
25%	Screened Topsoil
50%	Coarse Sand
25%	Moss Peat

Nutrients per Cubic Yard	
3 pounds	Bonemeal
4 pounds	"Uramite" or approved equal
3 pounds	Muriate of Potash

Lime as necessary to bring pH to 6.0 - 6.5

Planting Soil Mixture used for shrubs, flowering trees, and groundcover:

% By Volume	Material
25%	Screened Topsoil
50%	Coarse Sand
25%	Moss Peat

Nutrients per Cubic Yard	
5 pounds	Bonemeal
5 pounds	"Uramite" or approved equal
4 pounds	Muriate of Potash

Lime as necessary to bring pH to 6.0 - 6.5

Planting Soil Mixture used for broad leaf evergreen plants:

% By Volume	Material
10%	Screened Topsoil
40%	Coarse Sand
40%	Moss Peat
10%	Oak Leaf Humus

Nutrients per Cubic Yard	
5 pounds	"Uramite"
3 pounds	Superphosphate
1 pound	Muriate of Potash

Lime as necessary tc bring pH to 4.5 - 5.5

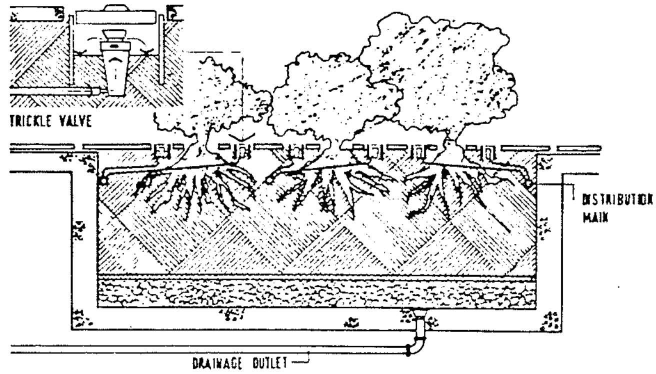
Peat-Sand Mixture used as a six inch layer below grass.

% By Volume	Material
50%	Coarse Sand
50%	Moss Peat

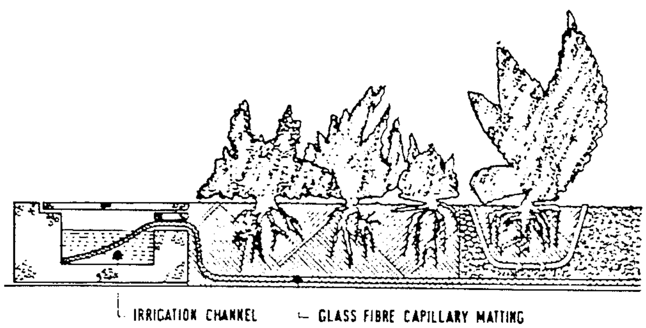
Another approach using a light weight growth medium is the use of hydroponics with expanded mica or perlite as a basic soil. Water and nutrients are added artificially into the soil medium. It is important when a light weight soil mix is employed to pay proper attention to plant anchorage and maintanence of nutrient levels. Because of the high level of maintanence required, application of this system is usually restricted to container food crop production in protected environments. *(H. Olkowski, 1979)*

Additional water supply from artificial irrigation is a necessity on rooftop conditions to supplement natural rainfall. Traditional hand watering by hose is time consuming and labour intensive, but preferable in cases where constant supervision of the plants' water requirements are critical, such as in exposed areas. A variety of manual or automatic sprinkler type irrigation systems are available for large areas of lawn and groundcover areas to save on time and labour.

More sophisticated automatic methods are the trickle-irrigation system *(Baker, Stansfield & Sturdy, 1977)*, and the capillary irrigation system *(Figure 19)*. The trickle-irrigation system is most effective when applied in hot arid climatic regions to save water consumption. The capillary irrigation system uses glass fibre matting to draw controlled amounts of water from an irrigation channel. Variations based on the same principle include the underground irrigation system developed in Israel *(Tony Southard, 1968)*, and the Purr Wick System developed by Dave Bingamen of Purdue University, Indiana during the late '60s and early '70s *(J. Frankhouser, 1980)*. The underground irrigation system uses a precise mixture of soil particles to form a gradient which is able to retain a portion of the water supply in the lower more porous layers. The required moisture is released upwards through capillary action when the top layers dry out.



Tricke-valve Irrigation System



Capillary Irrigation System

Fgiure 19 *Automatic Irrigation Systems (From Landscape Design With Plants, 1979)*

A more dramatic approach in automatic irrigation was the creation of the artificial high water table. This was available in the roof garden of Harvey's Store, Guildford (1958) by flooding the roof with a series of interconnected pools. *(A.E. Weddle ed., 1967)* Island curbs made of permeable precast standard quadrants enabled continual seepage from adjacent pool water to keep soil naturally saturated. A normal weight asphalt covering of double thickness was used to protect against water penetration into the underlying structure *(Figure 20)*.

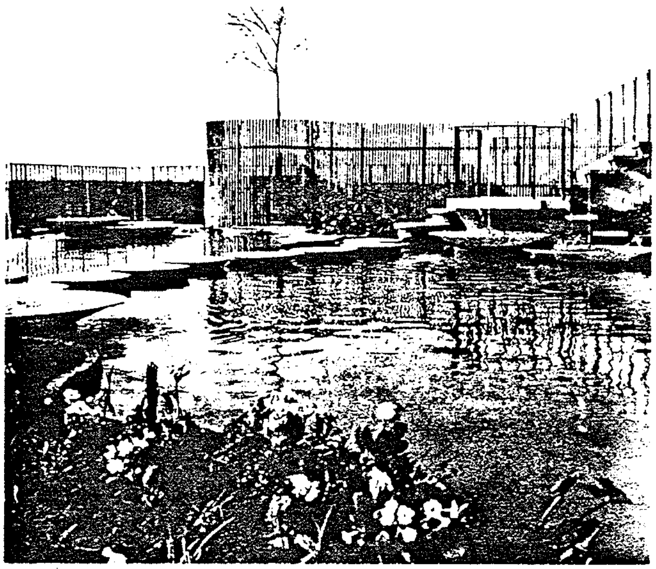


Figure 20

Roof Garden in Guildford, Surrey by G.A. Jellicoe

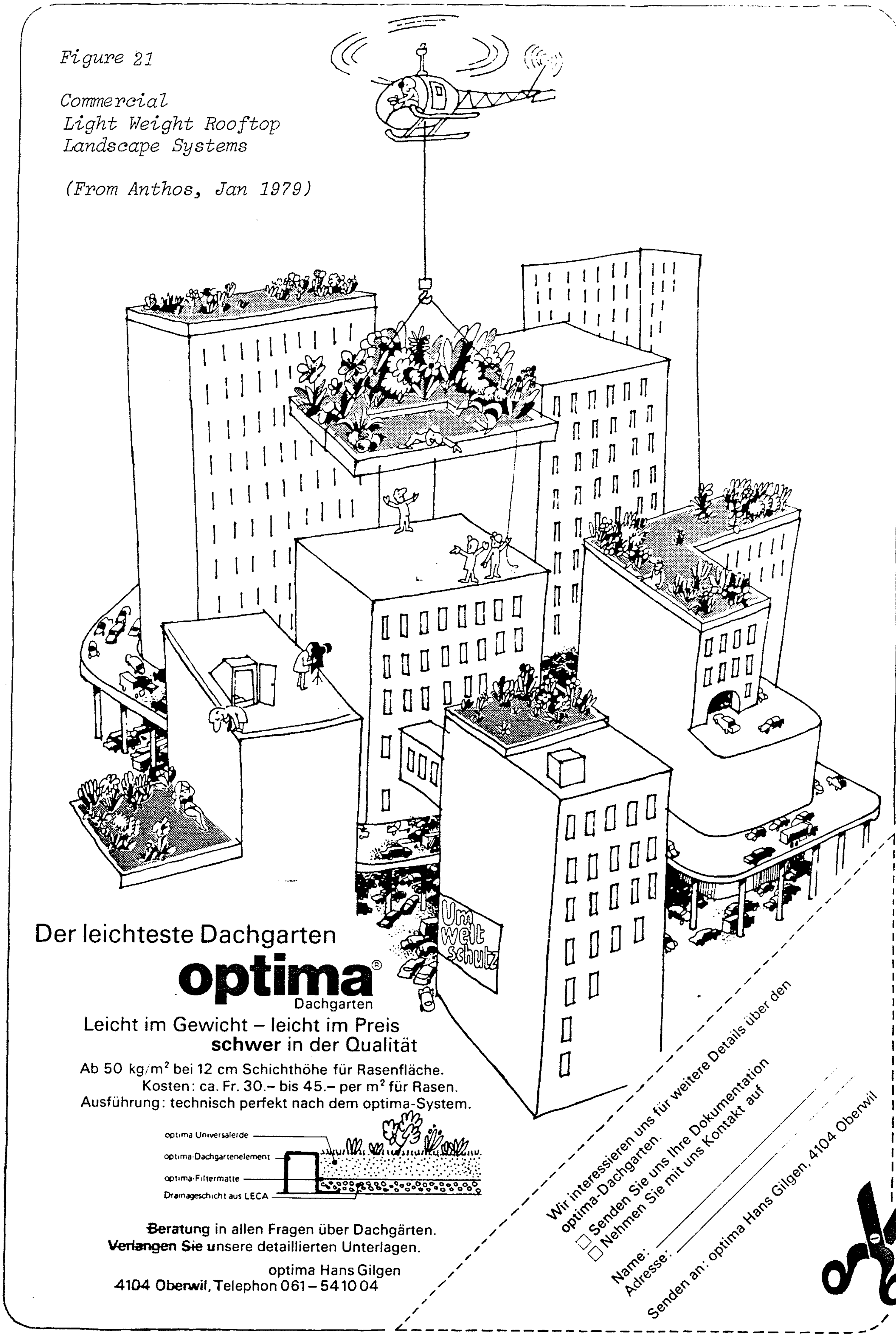
(From Dachgarten & Dachterrassen, 1962)

Modern structural engineering techniques have permitted the elaborate rooftop landscapes observed in the last twenty years. As the technical feasibility of rooftop landscape becomes more widely recognized, it is evident that interdisciplinary efforts are required early in the building process by participating professionals. The input of the landscape architect, is to ensure that the roof slab structure and detailing will permit appropriate scope to accommodate proper planting depth, drainage, irrigation and other services required for landscape development on rooftops. Where the loading capacity of existing buildings becomes the limiting factor to rooftop developments, it is forseeable that, the development of light weight planting media and drainage systems will increase the flexibility of "afterthought" landscape schemes on many existing flat roofs *(Figure 21)*.

Figure 21

Commercial Light Weight Rooftop Landscape Systems

(From Anthos, Jan 1979)



3.2 The Need For Rooftop Landscape Development

2,000 years ago, the Babylonian Hanging Gardens were constructed in an effort to present a theatrical display of power and wealth. In today's society, the needs and means of rooftop landscape development are governed by the combining factors of population density, economic feasibility, available technology, and climate. The value of today's rooftop landscape development lies in the maximum utilization of otherwise wasted open space. As modern society is continually pressed with problems of increasing urban density and lack of open space, the enormous resource of open space potential offered by the exposed roof areas in our cities should no longer be overlooked.

The advantages of rooftop landscape development are obvious. In terms of releasing the pressure of urban congestion, they provide an unexpected oasis of green in the built up area, and contribute to the general well-being of city dwellers by offering places of privacy and seclusion admist the city. They can improve the quality of view from surrounding higher buildings and are readily accessible to upper level tennants. As landscape features in their own right, rooftop developments can add natural beauty to urban forms and add a new dimension to city life with vantage points and expanded views not possible from the ground. From an urban planning standpoint, they facilitate the segregation of vehicular and pedestrian traffic, and have the potential to reduce air pollution if extensively developed.

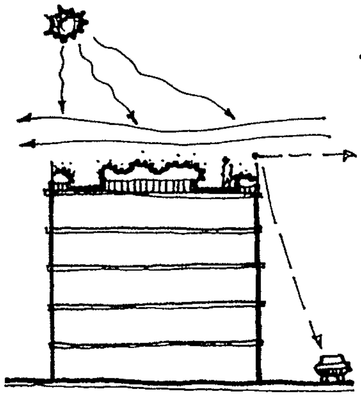
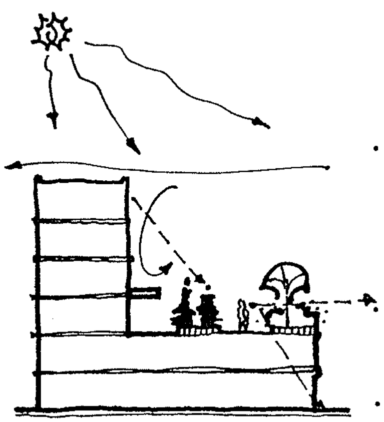
3.3 Rooftop Landscape Development Types

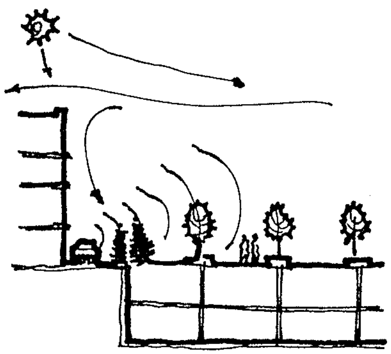
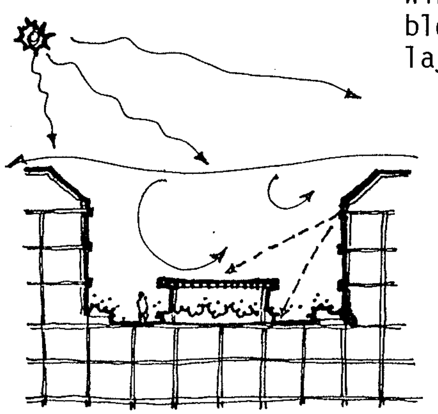
There are multiple reasons for developing rooftops. Depending on user needs and preferences, the intended use may be visual, recreational, ecological or as sheltered nodes within circulation links. Rooftop landscape development types, can be categorized by the degree of complexity or physical positioning as related to the building. The latter refers to the height of the development above ground, and the extent of enclosure.

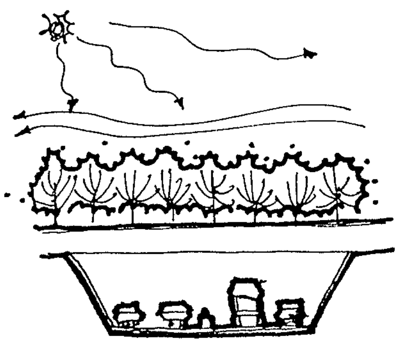
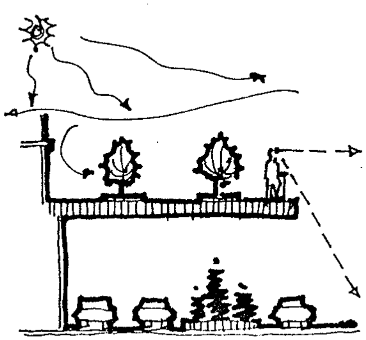
The degree of complexity ranges from sole manipulation of architectural massing, to simple placement of container plants above the structural roof, to the complete integration of the building structure with outdoor space. An example of which is demonstrated in the Robson Square development in Vancouver *(Figure 23)*.

While most low level rooftop developments are open to public access, higher level rooftop developments may be either open or enclosed. The degree of enclosure extends from low parapet walls as used in the rooftop gardens of New York's Rockefeller Center, to internalized courtyard situations as in the case of Place Bonaventure in Montreal.

Based on their physical variations, rooftop landscape developments can be catergorized into six major groups. Each type having specific microclimatic, environmental and visual qualities, as well as maintenance requirements which should be taken into consideration during the design stage. Following is a description of the major considerations for the six rootop landscape development types.

Roof Deck Types	Microclimatic Qualities	Environmental Qualities	Physical/ Visual Access	Maintenance Requirements
1. Building Top Roof Deck 	. Exposure to strong winds and sun. . Prohibites use of tall vertical elements and large trees without support and wind control devices.	. Maximum environmental stress on people and plants due to exposure. . Isolated from street traffic and noise. . Extensive edge treatment for safety and wing deflection is paramount.	. Access restricted from building below. . Privacy and security ensured. . Potential panoramic and distant views from deck.	. Provision for equipment storage required due to limited access. . Program to maintain soil moisture and protection for plants is critical. . Winter use of the roof may be prohibited unless snow removal options can be provided.
2. Deck Level Complex 	. Orientation of building parts towards prevailing wind and sun affects microclimate. . Taller building can provide shade for lower deck or offer shelter from wind. . Balance of sun and shade important. . Potential downdrafts from tall building can create uncomfortable condition at deck level.	. Most common form of rooftop development. . May exist as a contained unit, or as continuous prommenade with open space nodes established around building. . Away from street noise. . Constant interaction with interior spaces.	. Controlled access. . Reduced privacy due to views from above. . Pattern of deck layout as viewed from above should be considered. . Views from deck are partially confined.	. Extra snow drift accummulation on lower deck needs efficient snow removal program to ensure year round use. . Proper building parts orientation for climatic control can effectively reduce plant maintenance requirements.

Roof Deck Types	Microclimatic Qualities	Environmental Qualities	Physical/ Visual Access	Maintenance Requirements
3. Garage Roof Deck 	. Suffer from ground level wind tunnel effect at base of tall building clusters. . May be in constant shade by surrounding tall structures.	. Usually developed as public parks above underground parking garages. . Maintains continuity of surrounding circulation pattern and landscape appearances. . Suffers from traffic exhaust and noise pollution.	. Easy street level access. . Restricted ground level views. . Overlooked by adjacent buildings.	. Ease of maintenance. . Easy snow removal and equipment transport. . Protection needed for plants and street furnishings from vandalism.
4. Enclosed Roof Deck 	. Protected environment. . Sun pockets and wind control possible with proper layout.	. Essentially a raised courtyard. . Partially or fully enclosed by walls or building units. . Potential conflict of privacy and territorial requirements between tennants and deck users. . Sense of confinement and isolation from surrounding context due to enclosure. . Framed distant views can creat illusion of space.	. Restricted access from within building complex. . Direct visual access between building units and deck. . Overlooked by taller units.	. The courtyard situation creates a snow trap during Winter. . Need snow disposal program for year-round use and to reduce snow load accumulation.

Roof Deck Types	Microclimatic Qualities	Environmental Qualities	Physical/ Visual Access	Maintenance Requirements
5. Bridge Deck 	. Usually located in exposed sites due to street rights-of-way regulations. . Experiences high winds and full sun.	. Often appears isolated or detached from surrounding urban fabric. . Suffers from traffic noise and polluted air quality. . High environmental stress on plants due to exposure and shallow soil condition.	. Provide visual relief from monotonous transportation routes. . View to traffic from deck is undesirable. . Visual access from drivers' points of view is an important design factor. . Access controlled by overall pedestrian-traffic system.	. Due to the degree of exposure and isolation, maintenance program should be extra sensitive to plant needs in response to weather changes.
6. Cantilevered Deck 	. Microclimates similar to that of Deck Level Complexes. . Building part offers shelter from sun and wind exposure with proper orientation. . Suffer from down drafts.	. Size and extent of the deck development often restricted by span of overhanging members. . Mimimal soil depth allowed. . Development often extends over passenger drop-off zones in front of buildings.	. Optional access from street is possible with exterior staircases because the development is usually not too high above ground. . Overlooked by upper building units. . Can be oriented to capture distant views.	. Ease of maintenance as development is kept to a minimum due to load restrictions. . Weight of maintenance equipments critically assessed. . Edge protection is important as deck ends abruptly.

3.4 Present Trends and Future Outlooks

Alongside the development of more reliable roofing technology, roofscape concepts are now being exploited extensively in population centers around the world such as in Switzerland, Germany, Japan and the United States.

Roof terraces in Scandinavian countries are widely used to help relieve urban problems of traffic, parking, recreation and planning, and are frequently incorporated in city renewal schemes. The current struggle to design with ecological consciousness and energy efficiency is acknowledged by recent approaches with underground offices and housing projects where architecture is masked by the landscape on top. In Germany, native plant species which can establish themselves easily in shallow soil depths on rooftops are used extensively to reduce plant maintenance efforts. Rooftop landscape has been given a further scientific cause by identifying its oxygen producing capabilities particularly for environments where fresh air is at a premium.

In 1962, the editor of Landscape Architecture, Grady Clay, noted that, the "multi-level city" which is made inevitable by elevator and skyscraper technology is upon us. This can be observed in today's roofscape consisting of gardens, parks, plazas and promenades which are to be viewed from high-rise buildings, soaring expressways, contemporary ziggurats of buildings of stepped profiles, catwalks and balconies *(Figure 22)*.

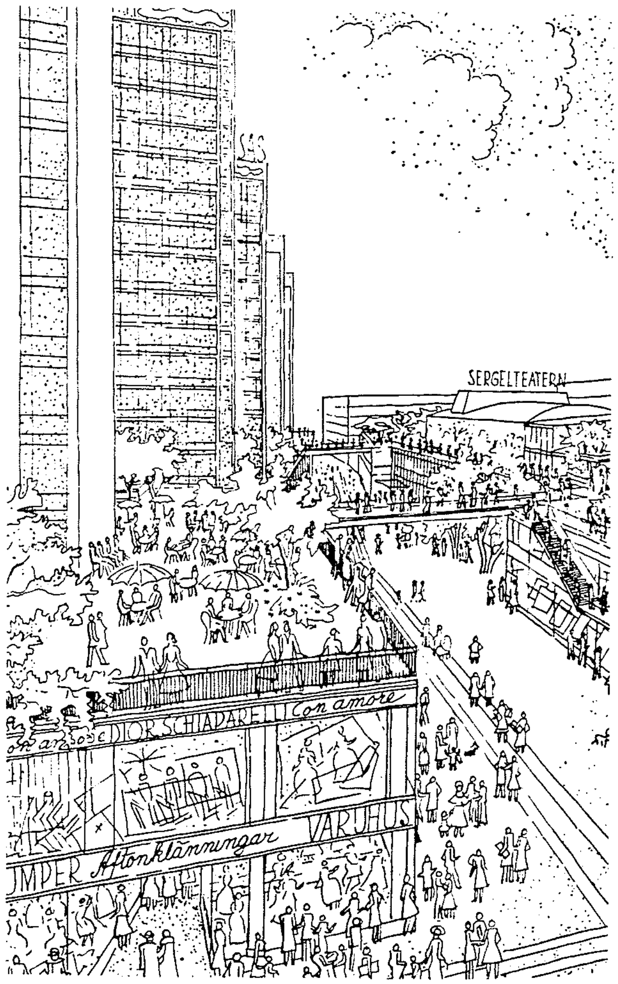


Figure 22

Multi-level Integration in Stockholm's Norrmalm Project

(From Design of Cities, E.N. Bacon, 1974)

English landscape architect Geoffrey A. Jellicoe expressed in the book, Motopia, his version of the future multi-level city. In a model apartment community built on a grid, traffic is to travel on elevated expressways built on rooftops such that the ground will be left free for human recreation and nature.

As long as the requirements of open space in our cities are not being met on the ground level, landscape development on rooftops with regional adaptations will continue to be the most attractive alternative.

4.0 ROOFTOP ENVIRONMENTS OF THE NORTHERN CLIMATE

4.0 ROOFTOP ENVIRONMENTS OF THE NORTHERN CLIMATE

This section assesses the effects of climate on rooftop landscape development trends across Canada. The pattern of development in major population centers across the country and more particularly in Winnipeg is highlighted.

4.1 The Significance of Climate

The variability of climatic conditions from coastal area to the interior, and from Winter to Summer is an obvious fact to all Canadians. To a large extend this variability determines livelihood and social activities. In Canada, where we did not have the need nor the capability to conceive rooftop developments, recent trends towards increasing urban density and successfull development of the "inverted roof system" *(See Section 4.3)* have altered the scene.

Rooftop landscape developments across Canada indicate an occurrence pattern associated primarily with major urban centers, and only secondarily with favorable climatic influences. Research into the applicability of roof decks to various Canadian macro-climatic regions *(CMHC, 1979)* substantiated the fact that only two, Northern/Arctic and Atlantic, out of the five major climatic regions of Canada (Northern/Arctic, Pacific, Prairie, Great Lakes-St. Lawerence and Atlantic) do not have the potential for extensive use of roof decks. While rooftop landscapes render themselves desirable in some parts of Canada rather than in others, because of climatic constraints, they are feasible in most areas if the need ever arises.

As the significance of macroclimate as a sole limiting factor for rooftop landscape development is reduced, microclimate control remains important in planning and design. Cold Winter temperatures combined with high winds, and drifting snow in the Prairies pose special design considerations for rooftop landscape development. Climatic data for Winnipeg illustrates this point in Appendix A.

4.2 The Canadian Context

In Vancouver, prosperity and population growth have led to problems with urban congestion. Multi-family zoning regulations revised in 1961 *(F.Y. Wing, 1967)* encouraged underground parking with proper landscape development in a bonus floor ratio system. Rooftop landscape with pools, gardens, walkways, patios and playgrounds are included as basic components of many major building developments. The popularity of roof decks in Vancouver and Victoria is further enhanced by the mild Pacific climate which features moderate year round temperatures. In addition to the countless private roof terraces and public plazas, recent noteworthy developments include: the roof garden for Kaiser Resources Ltd. (1977), on top of the 18 story Crown Life Place Building designed by Osmundson and Staley; and the downtown Robson Square scheme completed in 1979 under the guidance of architect Arthur Erickson and landscape architect R. Zinser *(Figure 23)* as described in Landscape Architecture, July 1979, pp.377-379.

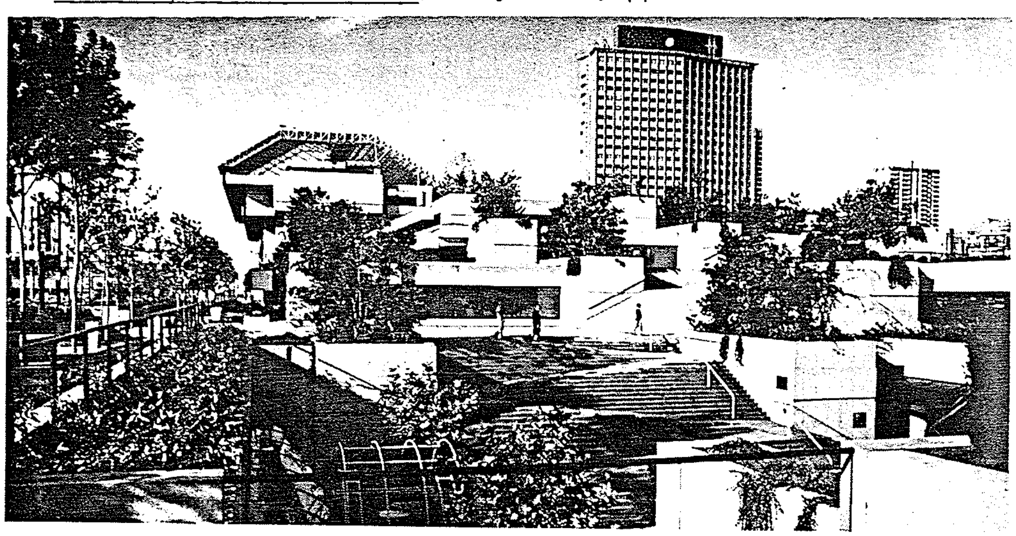


Figure 23 *Robson Square. Vancouver*
(From The Canadian Architect, Nov 1979)

In major urban centers located in the Great Lakes - St. Lawerence region, the enjoyment of rootop landscapes is encouraged by short Winters, mild temperatures, and moderate precipitation and wind speeds. Despite some unpredictable weather and high relative humidity during summer months, population demands have promoted the use of roof decks as long as microclimatic control are provided. The famed rooftop development atop Place Bonaventure in Montreal is only one of the numerous projects reflecting the need to incorporate microclimatic controls for plant and user protection.

Cities in the Prairies have a shorter summer season for use of roof gardens. Low amounts of precipitation and many hours of bright sunlight during the summer period however, enables the enjoyment of roof decks. Attractive winter scenes can be created by designing with snow drift accummulation patterns in mind. Therefore, the potential of a rooftop landscape should not be overlooked simply because of the extended length of the prairie Winter. In comparision, the use of rooftops are more prevalent in Calgary and Edmonton than in Winnipeg presumerably because of their more favorable economy and constant population expansion. The pronounced effects of Chinook winds in southern Alberta which aid in raising winter temperatures, can also be viewed as a contributing factor to prolonging the period of use. Calgary's PLUS 15 downtown planning scheme, which encourages circulation above ground level *(Figure 24)*, is another lift for the popularity of rooftop landscape development in the city.

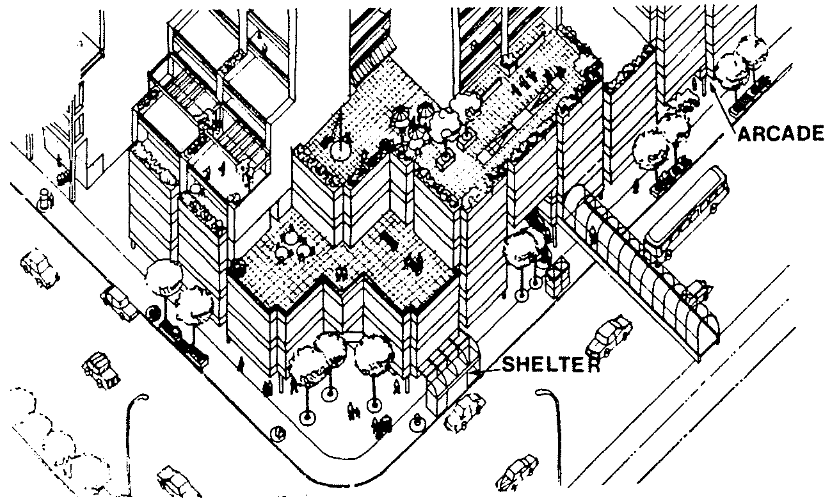


Figure 24 *PLUS 15 Bridge System in Calgary (From The Canadian Architect, Apr 1981)*

The majority of rooftop landscapes developed in Canada to date can generally be described as being concerned with the presentation of formal urban qualities, with plants used for purely ornamental effect. The high cost of maintaining these elaborate man made environments has of late prompted awareness and increased experimentation into more natural and ecologically conscious approaches, such as in the use of low maintenance plant groupings and habitat preservation of the urban avian population.

The potential use of roof decks for children's play space was recently given special attention by CMHC's Children's Environments Advisory Service *(Dan Matsushita Associates Ltd., 1979)*. Based on the assumption that there is a growing trend among families to live within the inner-city, where open space is at a premium, the research justified the concerns of cost and safety in developing rooftop play spaces through careful planning and proper design. Added advantages of easy surveillance and reduction in vandalism were also identified. Thus far in the past

decade, significant rooftop play space development has only taken place under highly supervised situations,such as those observed in the Children's Hospitals of Montreal and Ottawa, and privately financed day-care centers. The research concluded that:
"the use of roof decks as an integral part of residential and family design has remained underdeveloped, although the cities of Montreal, Ottawa, Halifax and Toronto are all said to be examining their potential." *(J. Weston, 1980: p.19)*

4.3 The Inverted Roof System

The greatest difficulty concerning flat roof construction in Canada is the prevention of moisture entry into the assembly from both inside and outside when the structure is exposed to the full onslaught of weather extremes experienced in most parts of the country.

The conventional application of a membrane vapour barrier, rigid insulation and a multiple-ply membrane roofing, bitumen and gravel over the reinforced concrete deck system *(Figure 25)* maintains a relatively constant temperature environment for the deck throughout the year and avoids problems associated with thermal expansion and contraction of structural parts. The roof membrane, however, is exposed to severe thermal variations which contribute to membrane splitting and deterioration. In addition, the positioning of insulation between the air vapour barrier and the roofing membrane creates a water and vapour trap if any moisture does penetrate the system.

Extensive research undertaken by the Division of Building Research, National Research Council of Canada since the early '60s, has led to the introduction of several improved roof assemblies based on thermal and moisture considerations *(Handegrod and Baker, 1968)*. More recently, and particularly for roof terrace applications, a new approach has been suggested *(Baker and Hedlin, 1972)*. Although known by a variety of names such as: 'upside down', 'inverted', 'insulated membrane', and 'protected membrane', the system is simply a rearrangment of the normal elements of the roofing system *(Figure 26)*.

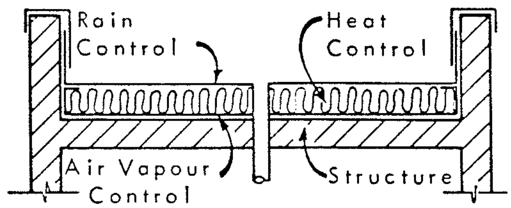


Figure 25 *Convention Flat Roof (From Canadian Building Digest No. 150)*

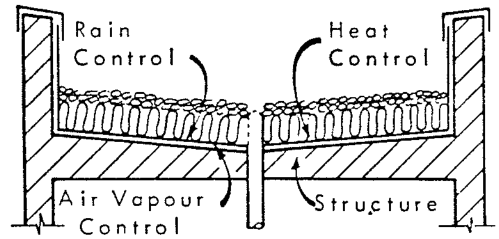


Figure 26 *The Inverted Roof System (From CBD No. 150)*

It is applied with insulation on the cold side of the waterproof membrane to reduce the possibility of roof failure by protecting the membrane from exposure. In practice, the impervious membrane is applied directly to the deck, over which is placed insulation and ballast. Drainage is provided at the interface between the membrane and the insulation by means of a porous layer, or chamfering the bottom corners of board-type insulation. Since warm air inside the building tends to hold more moisture than cold air outside, any moisture leakage from the interior can evaporate easily to the outside through the same passage.

Placement of the insulation on the outside of the waterproof membrane ensures a favorable thermal and moisture environment to protect the watertight integrity of the membrane, hence extending the life and effectiveness of the roof assembly. The system has been proven successful in numerous applications on flat roofs and roof terrace developments across Canada.

4.4 Winnipeg Roofscape

Restricted by extended periods of cold temperature and generally a slower pace of growth when compared with other major Canadian cities, rooftop development in Winnipeg has not achieved a high profile in terms of public awareness and demand. It is not the intention of this practicum to promote further rooftop landscape development for Winnipeg at this point in time, but rather to investigate the amount of activity that has taken place and review future potentials.

A brief survey of existing developments in Winnipeg identifying the distribution and range of rooftop opportunities in the city is presented in Appendix B. The list is compiled based on field survey data, and the CMHC's and land Titles' records. The list is by no means exhaustive, but rather aims at providing a representative sample of the norm on existing developments. The survey reveals that the majority of rooftop landscapes in Winnipeg exist either in the form of ground level public parks overtop underground garages or as amenity spaces atop highrise apartment blocks.

The use of roof decks as amenity spaces in Winnipeg increased rapidly subsequent to the CMHC's acceptance of 'properly' designed roof decks as amenity spaces in the early 1970's:

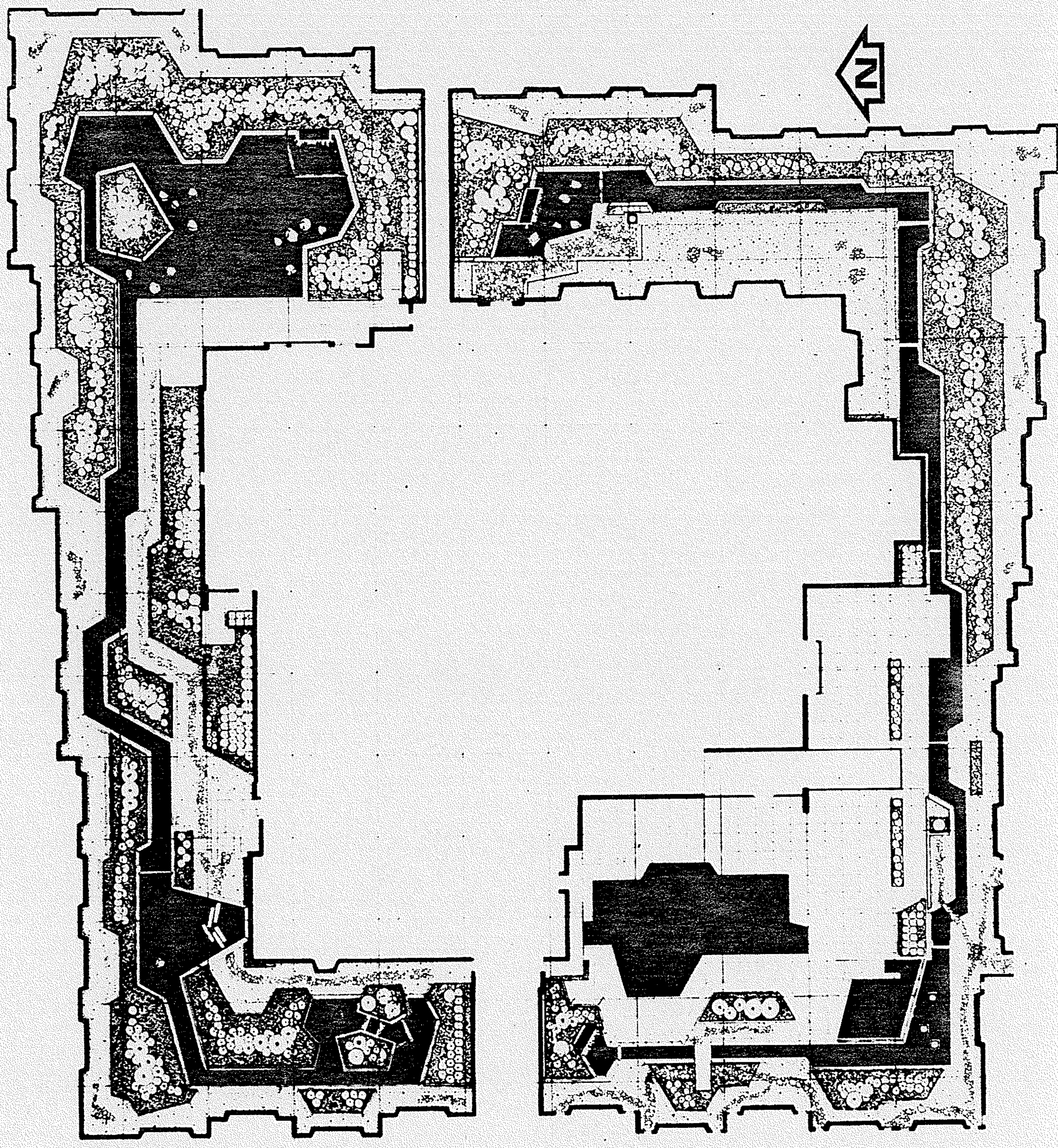
> "The acceptable Amentiy Area may include patios, landscaped areas of the site, balconies, recreational facilities, communal lounges and other developed areas within the site which in the judgement of the Corporation have been specifically designed to serve as useful areas for active or passive recreation of the residents."
> *(Government of Canada, CMHC Site Planning Criteria. 1977: p. 36)*

The CMHC has since published the book entitled Roof Deck Design Guidelines (1979) which deals with problems concerning safety, protection against weather, access and quality of construction details. The key obstacle which maintains skepticism among government agencies with respect to rooftop amenity space provisions is the reluctance on the part of most owners and developers to provide proper upkeep and maintenance. Quite often, residential rooftops are developed only to minimum open space standards, so that the developers can take advantage of buildable land on the ground to increase profit. The results of such haphazard construction, coupled with lack of continual maintenance, often render rooftop amenity areas on apartment buildings unsafe and unpleasant for tenant use.

Four selected case studies are presented in Appendix C to illustrate the potential for rooftop landscapes in Winnipeg. While there are other projects that could have been studied, these were selected because of the complexity involved, the frequency of usage, and the material availability for study. Arranged chronologically by date of construction, they are: a terrace deck developed in conjunction with the University Center Building, University of Manitoba; a triangular shaped rooftop garden atop the Winnipeg Art Gallery; a street level park over a parking facility which forms part of the downtown Centennial Library complex, and a recreational amenity courtyard set between a highrise office and apartment complex.

Three out of the four projects represented here are located in downtown Winnipeg reflecting the greater density pressures for open space in the area. The present pattern of incorporating rooftop landscapes as roof gardens, elevated podiums or street level plazas in downtown's new developments has proven to be a popular and successfull concept for open space provision on premium land. While the populations' preoccupation with low density, single family residential life style does not provide incentive for rooftop landscapes in suburban areas, recent interests in the core area development and rehabilitation of the historic warehouse district provide further opportunities for rooftop landscape developments in the high density area. Rooftop landscape development in conjunction with new commercial and residential contruction and retrofit process of existing buildings can be a useful tool for open space provision and at the same time create an urban image to draw people back to downtown and help guide the direction of core area development.

5.0 DESIGN PRINCIPLES AND GUIDELINES



5.0 DESIGN PRINCIPLES AND GUIDELINES

While roof garden practice is not a recent phenomena, a more economically and sensible use of existing urban open space including rooftops is a renewed interest with the increase of urban land value. Its application requires a close coordination with the entire professional group responsible for the structural design of the building. Ideally, planning for the rooftop landscape should begin early in the building process, so that it can be integrated with the building design from the point of detemining load capacity to the handling of projecting vents and mechanical elements on the roof. Otherwise, opportunities for landscape development on the roof may be limited by various structural and mechanical restrictions imposed by the underlying structure.

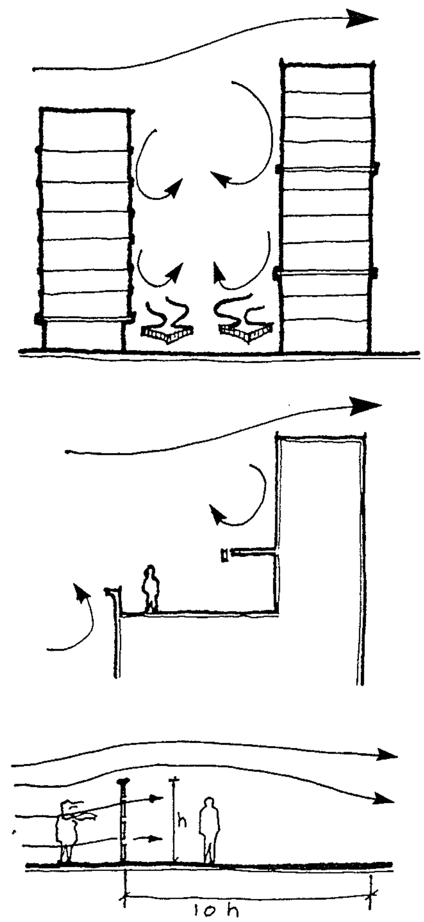
Whether the construction is new or retrofit, the consequence of any failure can amount to great costs, often invloving removal of complex construction under severe weight restrictions; loss of established plant materials and replanting etc. The use of first class materials and cautious planning throughout are strongly recommended. Detail discussions in design principles and guidelines of rooftop landscape construction and planning are well documented in several sources as indicated in the annotated bibliography. The purpose of this section is to summarize design principles and present guidelines bearing relevance to the climatic conditions in the Prairies.

5.1 Climatic Factors

To ensure performace and continual usage of the roof deck, considerations must be given to ameliorate the adverse micro-climates on the roof. Proper micro-climatic control is required to extend the period and the comfort level for the enjoyment of rooftops; as well as to protect plants and the roof assembly itself from the destructive effects of the natural elements. Wind, sun, air temperature, precipitation and relative humidity are all influential factors. Major issues are sun/shade orientation, snow drift and wind control.

Wind

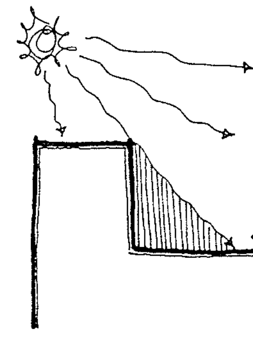
- Design should channel summer SE breezes, and buffer winter NW prevailing winds.
- Wind control can be achieved by proper building orientation and location with respect to surrounding structures; making use of parapets, walls and screens. Plants should not be used as wind buffers when winds are severe.
- Wind speed increases with height, but the speed of downdrafts from tall buildings and wind tunnel effects can also create dangerous and uncomfortable situations at lower deck levels.
- Downdrafts from tall buildings can be prevented by the use of overhangs.
- Strong prevailing and deflected winds should be controlled for human comfort, snow drift control, moisture retention and stability of plants.
- "Screens composed of 2/3 solid and 1/3 void will provide effective protection from direct horizontal winds for a distance five times the height of the screen and a sheltering effect for ten times this height."
  (CMHC 1979: p.23)



(From CMHC, 1979)

Sun

- Exposure and shelter from the sun are preferred at different seasons of the year and depending on the activities.

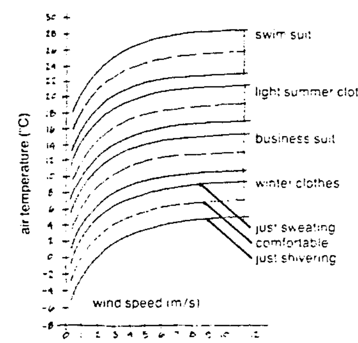


- Provision of sun pockets and warmer areas will extend usage in the late Fall and early Spring season. Some covering such as trellis and awnings are essential during hot summer months. Shadow casted by adjacent buildings and permenantly shaded areas should be properly projected and planned for.

- Plant selection and location should be responsive to availability of natural radiation.

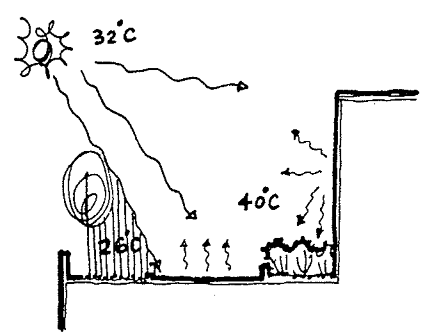
Air Temperature

- Temperature and wind speed combine to influence human comfort level and the usability of roof decks.



(From CMHC, 1979)

- Paved surfaces, walls and mechanical parts retain and reflect heat thus reducing the wind chill factor. However, careful location of plant material from reflective surfaces is required to prevent scorching and over-transpiration.



- The combined effect of internal building heat and external temperature in Winter may result in excess root growth which is not in balance with the dormant plant body above grade. This has a decided effect on plants and proper insulation should be provided on all sides of plant containers to ameliorate the impact.

- The required thickness of the insulation is dependent upon interior and exterior temperatures involved, as well as its co-efficient of heat transmission. The insulating layer can be vermiculite, fiberglass battens or other waterproof insulating materials with the least thickness requirements.

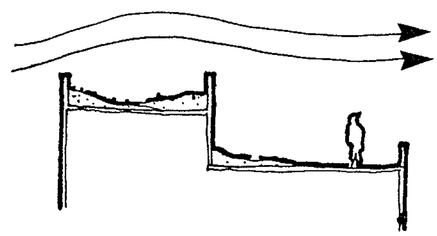
Precipitation

- Rain inhibits deck use, but is necessary for plant survival and cleaning.

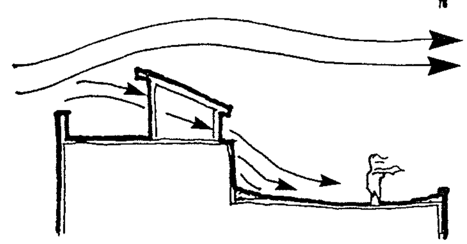
- Snow accummulaiton while undesirable can also be employed to create temporary visual interest and attractions in Winter.

- Small snow blowers can be accommodated on most pedestrian oriented roof decks.

- Automatic snow removal systems such as a fluid heating system embedded in concrete to melt snow and ice on contact reduce maintenance but are costly to repair.



- Slight modifications to building form, building orientation, or control devices such as walls or screens combined with wind flow and snow drift analysis will aid in proper design of deck configuration to prevent formation of snow traps.



- Snow load determination based on the National Building Code of Canada is included in appendix E.

Humidity

- Relative humidity affects human comfort level.

- Provision of adequate water supply and moisture are important for plant survival in the dry Prairie environment.

- Evaporation of moisture from vegetation and water features in turn has a cooling effect on surrounding air.

5.2 Structural Support

The two most critical factors involved in any rooftop landscape construction are adequate structural support and waterproofing. Support of the roof load becomes more difficult with increased building height as the load has to be carried through all floors. Since there exists a limit to tolerable total rooftop landscape weight beyond which the entire supporting structure may become uneconomical, as a general rule, only the lightest material should be selected.

Load Bearing Capacity

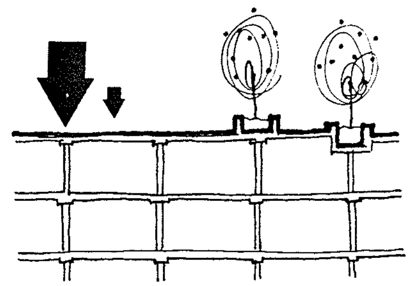
- Seldom is the building's structural system designed to "fit" the rooftop design alone. Usually, the structural system is established for building use and then "beefed up" to accommodate the rooftop landscape. In any case, the weight of the complete development including live and dead loads must coincide with the design load capacity of the supporting structure.

- Live load includes maximum pedestrian traffic, maintenance, and construction machinary, as well as wind loads on tall vertical elements. Design live load for assembly purposes is 100 psf in accordance with the National Building Code of Canada *(Appendix E)*.

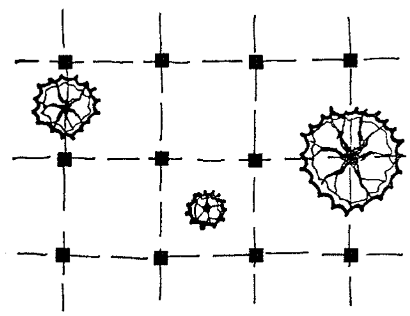
- Dead load includes paving, wet soil, mature weight of planting, pools and the roof assembly itself.

- Examples of some weights of materials are listed in appendix F.

Load Distribution



. The location of heavy elements on the roof should correspond to the position of load bearing members of the underlying structural system.



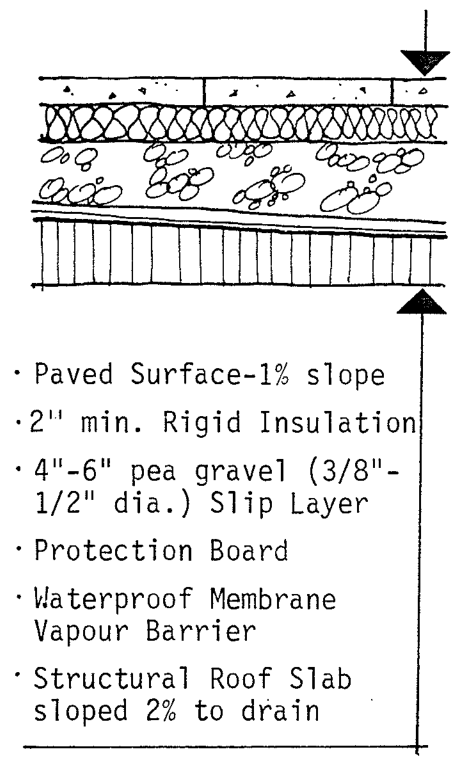
. In the popular 'post and beam' construction, a grid pattern exists for load distribution. The heaviest elements should be placed directly over structural columns or bearing walls of the greatest bearing capacity; decreasing orders of lighter weights can be sustained by areas directly over the beams between the structual columns followed by areas in between the beams and the columns.

5.3 Roof Construction

A roof deck must meet all the requirements for separation of environments as well as provide for traffic and plant growth. The principle of the 'inverted roof' system with a structural deck sloped for drainage, a roofing membrane above it and insulation above the membrane as discussed in section 4.3 is by far the most successful arrangement for the Prairie climate. Proper insulation, drainage and waterproofing are essential to maintain the features of the system intact.

Waterproofing Systems

- Waterproofing is essential not only to protect internal furnishings from moisture but more importantly to protect structural elements from deterioration.
- Choice of membrance is the most crucial factor. Material chosen should be appropriate and suitably protected from weather, mechanical and plant root penetration.
- Membrane-type waterproofing systems such as built-up membranes of bitumen and felts or fabrics are most commonly used to achieve a flat surface.
- The double two-ply membrane system is preferred to provide the required continuous films of bitumen for large areas.
- For inverted roof assemblies, the principle membrane at the roof slab should be sloped, continuous, and sealed around all pentrations. A bitumen-coated base sheet will resist wetting of the membrane by moisture from the heated interior below.
- Bituminous flashings shall extend a minimum of 8" above the roof membrane.
- A protection board should be placed between the coarse drainage layer and the membrane to prevent damage to the waterproof membrane.



Insulation System

- In the northen climate, planting soil on the roof becomes an excellent conductor of heat away from the building. At the same time, the heat passing through has a desiccating effect on the plant materials.

- A water impervious, non-organic, light weight insulation placed below the surface elements and above the waterproof membrane, as well as on all sides of plant containers will act effectively as a buffer to prevent the escape of building heat and protect roof structures from exterior temperature extremes.

Slip Layer

- Because of differential expansion and contraction movements between the rooftop elements and the roof slab and its membrane, it is essential to provide a buffer between these roof layers to reduce breakage.

- A 102mm - 152mm (4-6 in) layer of lightweight crushed rock, fine gravel, clean coarse sand or no fines concrete over the membrane will serve as a subsurface drainage and percolation layer as well as a buffer between surfae elements and the roof slab.

- The slip layer should extend under planting, paved areas, pools, fountains and all roofscape surfaces and structures.

Drainage

- As ponding water adds weight to the roof, and increases the chance for roof damage even with a small split in the roof slab, effective surface and sub-surface drainage are equally important.

- The roof deck shall provide positive slope to the drains - a minimum slope of 2% or 1/4 inch to one foot is recommended.

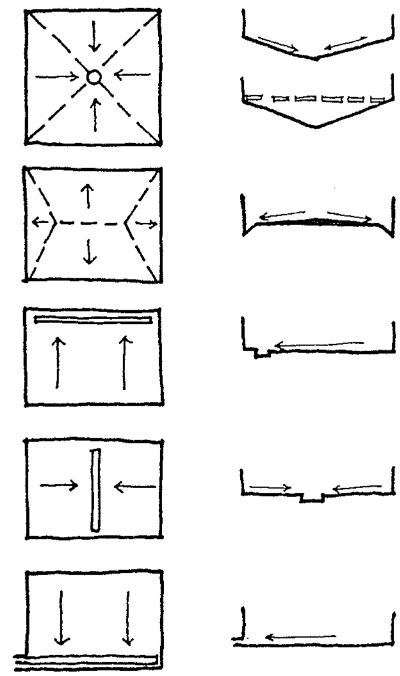
- the roof surface should be shaped in such a manner to encourage free flow of water to roof drains. An adequate number of drains combined with short runs of surface flow will help to keep the roof surface well drained. See illustration for some of the schematic drainage plans.

- Controlled-flow drains which retain part of the runoff on the roof after a heavy downpour are favored by the City of Winnipeg to reduce the size and lower the costs of the storm drainage system. Properly flashed curbs should be used around all openings when control flow drains are in use.

- Catch basins which can be removed for cleaning and roof drains should be located at points of greatest structural deflection such as at mid-span between columns, to preserve the load bearing configuration of the roof slab.

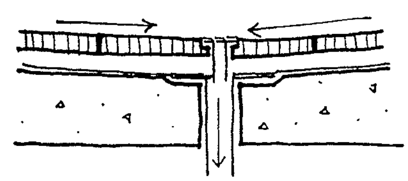
- Sub-surface drainage and ventilation can be provided by a system of voids, or a percolation layer as described in the discussion of Slip Layer, in addition to sloping of the roof slab.
  (M.C. Baker, DBR 151)

- For drainage under planting beds, a minimum of 100 mm of clean gravel placed above insulation is recommended. In planters, a depth of 75-150 mm (3-6 in) of coarse gravel separated from the top soil by soil separator, and bottom sloped to a corner drain is essential.

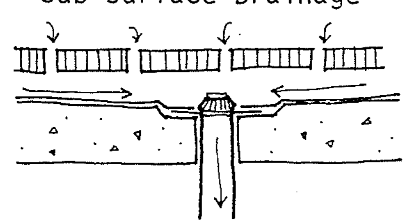


(Adapted from CMHC, 1979, and Rogers, 1975)

Surface Drainage



Sub-surface Drainage



(From CMHC, 1979)

5.4 Planting

"Even on a Babylonian scale, however, a roof garden can never replace a ground-level garden where tap roots sink deep and trees grow tall" *(Grady Clay, 1962: p.13)*. Therefore in order for plants to survive in a simulated growing environment such as that of a rooftop, special care is needed for the provision of proper soil depth, nutrient level, plant selection, drainage, anchorage, plant location and maintenance.

Soil requirements

- Maximum soil depth and minimum soil weight is desired.

- A high quality sandy loam top soil mixture of:

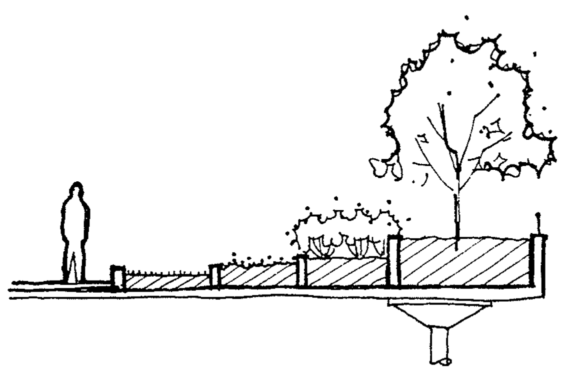
Loam topsoil	25 - 50%	(by volume)
Peat-moss	25%	
Sand	25 - 50%	

  weight 1450-1600 Kg/m3 *(CMHC, 1979: p.45)*. It provides the necessary nutrient, drainage and water retention qualities required in a restricted growth environment.

- A light weight mix, weighing as low as 650-800 Kg/m3 can be obtained by replacing sand with perlite, vermiculite and plastic foam.

- Minimum soil depths required for proper root establishment and anchorage are:

	Min. Depth (mm)	Dry Weight (Kg/m^3) Standard Mix	Light Mix
Grass	150 (6 in)	250	125
Ground Cover	300 (12 in)	500	250
Shrubs	600-750 (12-18 in)	1000-1250	500-625
Trees	900-1050 (3-3 1/2 ft)	1500-1750	750-875



Irrigation

. Good drainage, frequent watering and fertilization are essential to maintain a viable growth medium. The irrigation program either manual or automatic, should respond to the seasonal precipitation level and sudden weather changes, as well as the porous soil conditions.

Installation

. Planting, other than trees, does not necessarily require the provision of planters which ensure root medium depth and root growth restriction.

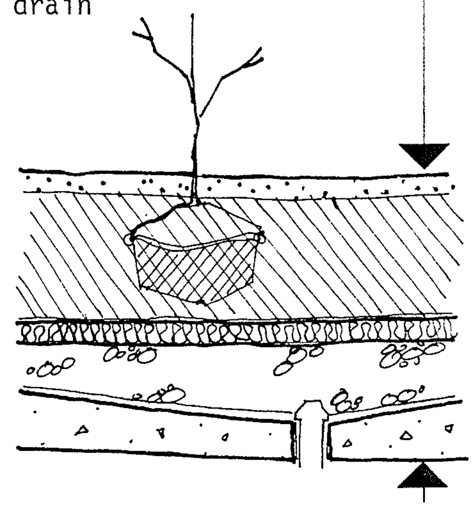
. A planting mound can be constructed by placing a coarse gravel drainage layer (100 mm min.) over the waterproof membrane covered by protection board, followed by a layer of 25 mm (1 in) rigid insulation that is permeable to water. The topsoil is prevented from silting by the placement of a soil separator such as a 13 mm (1/2 in) fibreglass mat between the topsoil and the insulation.

. Because of load restrictions, large trees and planters should be located over columns.

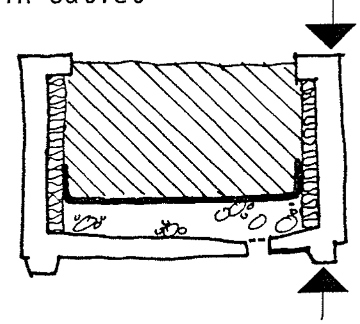
. Permenant roof planters have the same drainage and soil requirements as plant mounds. Rigid and batt type insulation should be placed under the soil at the sides and bottom of the container. Size of the planter should be as large as weight restriction permit. Minimum recommended box dimensions are 1800 x 1899 mm (6 ft x 6 ft).

. Planters can also be depressed within the roof slab as part of the roof structure for stability. Such planters can be drained at the bottom through a layer of crushed rock and screened drainholes connected to the main drainage pipes.

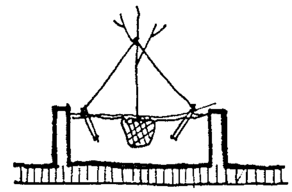
· 50 mm Mulch
· Top Soil Mix
· Soil Separator
· 25 mm min. insulation
· 100-152 mm Gravel (4"-6") Slip Layer
· Membrane with protection board
· Roof slab sloped 2% to drain



· Top Soil
· Rigid Insulation
· Soil Separator
· 75-150 mm Coarse Gravel
· Bottom sloped to drain
· Drain Outlet

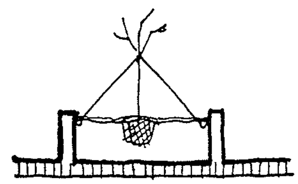


Anchorage



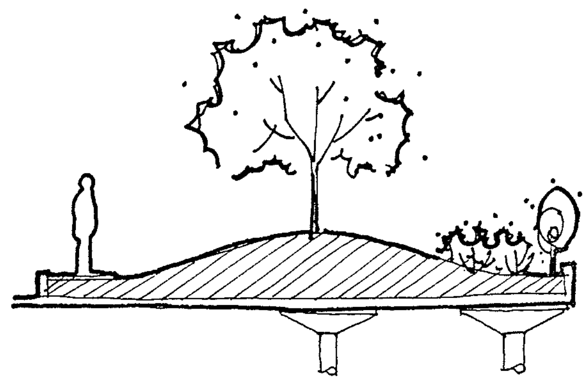
. Anchorage is required for trees due to windy rooftop conditions and weakened anchorage ability of light soils.

. Invisible anchoring methods such as guy wiring to subsoil eys-bolts or stakes, and under soil wooden crate etc., are preferable to staking, for aesthetic and strength considerations.



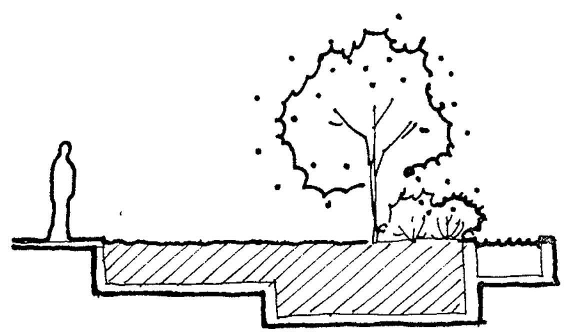
Plant Selection

. Besides functional (shading, screening), aesthetic (color, scale, texture) requirements, plants of compact form for stability; medium to small foliage for moisture retention; fine and shallow root system for establishment in restricted soil depth; and slow growth rate for limited space and weight restrictions, are the best candidates.



. Plants should be located in relation to their particular mircoclimatic needs ie. sun/shade; or in groups for protection from winds and for space defintion.

. Coniferous trees and shrubs should be protected from wind desication and over-transpiration during Winter.



. In a confined rooftop situation, scale rather than size is the important criteria for plant selection.

. For the determination of feasibility of rooftop planting, the weight of the tree can be computed at the rate of 1.3-1.7 Kg/mm (75 to 100 pounds per inch) of caliper *(R. Zion, 1968)*.

. Following is a list of plants suitable for Prairie roof decks based on: CMHC's Roof Deck Design Guidelines; Department of Agriculture, Province of Manitoba, Recommended List of Ornamental Trees, Shrubs, Climbers and Ground Covers For Manitoba; interview with Professor Louis Lenz, Department of Plant Science, University of Manitoba.

PLANT NAME	CONDITIONS	REMARKS
CONIFEROUS TREES		
Larix sibirica (Siberian Larch)	Sun	
Picea glauca densata (Blackhills Spruce)	Sun	Protect from winter wind
Picea pugens cvs. (Colorado Spruce)	Sun	Resistant to wind and salt
Pinus mugho (Mugho Pine)	Sun	Protect from winter wind
Pinus sylvestris (Scots Pine)	Sun	Protect from winter wind
Pinus cembra (Swissstone Pine)	Sun	Protect from winter wind
FLOWERING TREES		
Crataegus spp. (Hawthorn)	Sun	Popular for roof deck, brilliant
Malus spp. (Ornamental Crabapples)	Sun	flowers in Spring, showy fruit in Winter
Prunus maacki (Amur Chokecherry)		
Prunus pennsylvanica (Pincherry)		
Sorbus spp. (Mountainash)		
Syringa reticulata (Japanese Tree Lilac)		
Tamarix pentandra rubra (Tamarisk)		
SHADE TREES		
Fraxinus spp. (Ash)		
Populus spp. (Poplar)		Hardy, fast growing
Hippophae rhamnoides (Seabuckthorn)		Silver foliage
Shepherdia argentia (Silver Buffaloberry)		Silver foliage
Prunus virginiana melanocarpa 'Shubert' (Shubert Chokecherry)		Purple foliage
Salix alba 'sericea' (Silky White Willow)	Sun	Fast growing, branches easily broken by
Salix alba 'Vitellina' (Laurel Willow)	Sun	wind
Tilia americana (American Basswood)	Sun	Self-pruning, fragrant flowers
Ulmus pumila (Siberian Elm)	Sun	Fast growing

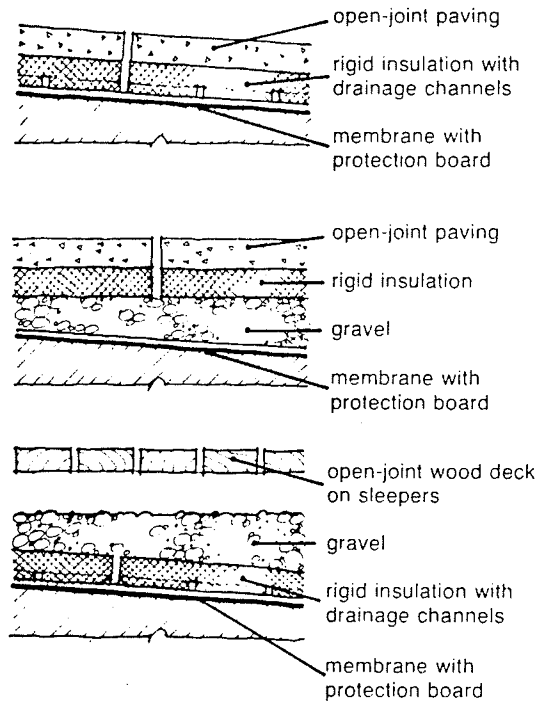
PLANT NAME	CONDITIONS	REMARKS
MEDIUM - TALL SHRUBS		
Acer ginnala (Amur Maple)	Sun	Brilliant red fall color
Amelanchier alnifolia (Saskatoon)		
Lonicera tatarica (Tatarian Honeysuckle)	Sun/Shade	Vigorous, dense, good wind screen
Rhus glabra (Smooth Sumac)	Sun	Red fall color
Prunus triloba multiplex (Flowering Almond)		
Syringa vulgaris (Common Lilac)		
Viburnum spp.	Sun/Shade	Vigorous, dense
Physocarpus opulifolius (Ninebark)		
LOW SHRUBS		
Cornus alba 'Sibirica' (Redtwig Dogwood)	Sun/Shade	Hardy, red winter twigs
Cornus stolonifera 'Flaviramea' (Yellowtwig Dogwood)	Sun/Shade	Yellow winter twigs
Cotoneaster lucida (Hedge Cotoneaster)		
Cytisus spp. (Broom)	Sun	Colourfull masses of blooms
Juniperous horizontalis (Creeping Juniper)	Sun	Evergreen conifer, winter protection
Juniperous sabina 'Skandia' (Skandia Juniper)	Sun	Evergreen conifer, winter protection
Ribes alpinum (Alpine Current)		
Prunus X cistena (Cistena Plum)	Sun	Puple leaves
Potentilla fruticosa cvs. (Pottentilla)		
Syringa meyeri (Littleleaf Lilac)		
Spriaea spp. (Spirea)		
Lonicera coerulea edulis (Sweetberry Honeysuckle)		

PLANT NAME	CONDITIONS	REMARKS
VINES/GROUND COVERS		
Ajuga reptans (Carpet Bugle)		
Arctostaphylos uva-ursi (Bearberry)		
Clematis spp.		
Coronilla varia (Crowvetch)		
Cytisus decumbens (Broom Prostrate)		
Fragaria chiloensis (Sand Strawberry)		
Parthenocissus quinquefolia (Virginia Creeper)		
Vince minor (Periwinkle)		
Mattiuccia struthiopteris (Ostrich Fern)		
Vitus riparis (Wild Grapes)		
Paxistima canbyi (Pachistima Canby)		
Sedums (Dragons Blood)		Dark foliage
(Running)		Green foliage
(Gold Moss)		
Hosta spp.		
Festuca ovina glauca (Blue Sheeps Fescue)		
Hemerocallis (Day Lily)		
GRASSES		
Kentucky Blue (Park Mixture)		
(Fylking Mixture)		

5.5 Surface Treatment

Surfacing materials should be selected based on use, tolerance of intended traffic, resistance to frost damage, protection of underlying membrane, ease of maintenance, costs and weight.

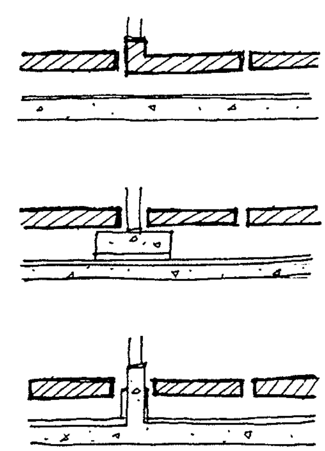
- Wood deck boards resting on sleepers, are light weight, and provide unimpeded drainage and ventilation beneath.
- Stone and precast concrete surfacing need to be kept dry with a 2% slope and frequent control joints to allow for expansion due to moisture/temperature influences. Costs are high. Provision of adequate reinforcing in concrete paving can, however, permit a reduction in thickness. A minimum pavement weight is ensured if combined with the use of light-weight aggregates.
- In general, loose paving units that are able to move independently from the roof slab and provide easy accessibility to layers below for maintenance are preferred.



5.6 Anchorage of Physical Structures

Permanent roofscape structures such as parapets for safety, walls for privacy and space separation, screens for wind buffer, shelters for shade, furniture and game structures should be properly anchored from being blown over by strong winds at roof level.

- Position of all structures that require penetration through the slip layer should not impede subsurface drainage.
- Stability of these structures can be obtained by integration with paving, independent shallow and wide footing on the slip layer, or integrated with structure *(CMHC 1979)*.



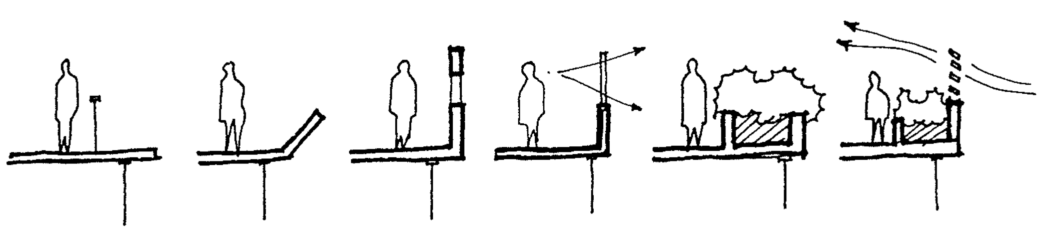
5.7 Pools and Water Features

Pools and fountains are desirable for their aesthetic and cooling qualities. The weight of the water and its container should however, be carefully controlled. The location of the water feature, its size and depth of water should be dependent on the distribution, frequency and bearing capacity of support columns.

- A 50-70 mm (2-2 3/4 in) deep pool with a black bottom is sufficient to provide the reflective effect.
- Waterproofing and drains should be adequate to prevent damage to the roof structure.
- The container should be designed to rest on the structure as a separate unit which moves independently from the roof deck to illiminate cracking as a result of differential movements.
- A recirculating pumping system or an aerator device should be installed to reduce dirt built up and organic growth. A simple submersible pump can be used to handle relatively low volumes of water. Other larger automated pumping systems should be used with consideration given for the placement and access of the equipment storage vault.

5.8 Safety

Parapets, walls and screens are required along the building perimeter on any above-ground development for safety reasons. Design of safety walls can integrate planting to frame views, employ height and distance to prevent vertigo, as well as function as wind screens.



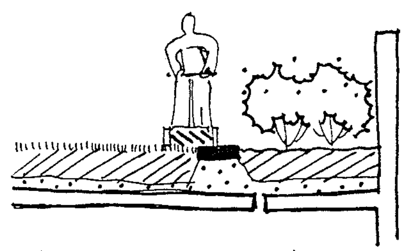
5.9 Access

Unobstructed access incorporating ramps and elevators with stairs should be provided for elderly and handicapped persons in accordance with requirements set forth in the National Building Code of Canada.

5.10 Maintenance

Ease of installation and maintenance are as important a design consideration during the planning of a rooftop landscape as the appearance of the final product itself. The weight and movement of construction and maintenance equipments ahould also be provided for.

. Plant survival and realization of the design effect depends on the efficency of the maintenance program including the following aspects *(CMHC 1979: pp. 252-155)*:
- regular watering
- fertilizing and mulching
- pruning and mowing
- control of diseases, weeds, insects and other pests
- winter protection
- clean-up and replacement



(From CMHC, 1979)

. For larger developments, long term savings from reduced labour costs, far outweigh the initial costs of installing the more expensive maintenance free equipments such as automatic sprinkler systems, snow melting wells, automated pool purification and water supply systems.

5.11 Retrofit

Concerns and requirements regarding rooftop landscape design and construction such as load distribution, drainage, and proper insulation, considered in the original building design stage, become even more severe in the case of retrofit. Opportunities are more restricted when a roofscape is to be constructed over an existing structure not designed to carry traffic and a landscaped surface on its roof.

Economic feasibility determines the extend to which the underlying structure should be strengthened. In most instances, the roofscape should be added with minimal interference to the existing structure and should be sympathetic to the building's appearance and character.

A suspended surface in the form of wood flooring and light structures will keep the existing roof membrane intact and allow drainage to occur beneath the new floor surface to the existing roof drain.

Trees and shrubs, as well as soil and other structures have to be kept to a minimum and are best located near the supporting perimeter walls if the underlying structural members have not been reinforced. Precise evaluation of building structure and loading capacity along with the overall weight of the added roofscape are critical. Construction should not be attempted without a thorough analysis of the existing building capacity and conditon.

6.0 THE BROKERAGE BUILDING

6.0 THE BROKERAGE BUILDING

(The Bain Block)
115/119 Bannatyne Avenue

Built:	1899-1900
Architect:	J.J. McDiarmid
Contractor:	J.J. McDiarmid (Carpentry) Thomas Sharpe (Stone & brick work)
Renovation:	1980
Engineer:	Crosier, Kilgoer & Associates
Architect:	Sedun, McFeetors, MMP Architects Engineers.
Owner:	The Brokerage Building Patnership.

6.1 Site Location and Selection

Located within Winnipeg's historical warehouse district, northeast of the commercial downtown core, the Bain Block is the most easterly building on the north side of Bannatyne Avenue. Originally a wholesale warehouse, built of yellow ochre brick and rough-hewn limestone foundations and trim, the block was recently renovated for commercial ventures and renamed the Brokerage Building.

The building consists of two distinct parts. The east building (#115) is a 3 storey structure while the west building (#119) is 5 storeys. The owner proposes that a restaurant be established on the fourth floor of the taller building with an associated restaurant terraces development on the rooftop of the easterly building.

The site was selected based on the following criteria:

- structural opportunity to demonstrate major rooftop design principles, i.e. structural load capacity, height above ground, physical configuration.
- a realistic client that can generate genuine need requirements for the development such as user profiles, financial restraints and implementation opportunities.

6.2 Site Analysis

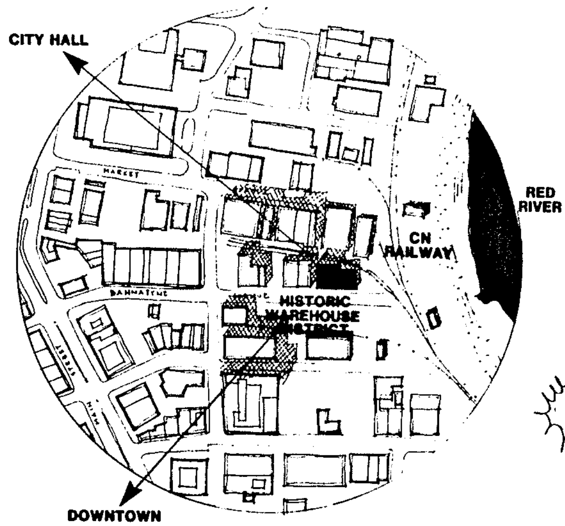
The building is bounded on the east and north by an unpaved parking lot and railway tracks in a service lane respectively. The CN railway mainline concentration located just east of the parking lot, separating the Block from the Red River. The first Marshall-Well Building sits to the west, separated by a service lane.

No structures in the immediate vicinity are tall enough to cast shadows, channel winds or block views at rooftop levels. As a result the lower rooftop of the Brokerage Building is fairly exposed, offering uninterrupted senic views of the Red River and the city skyline east of the river.

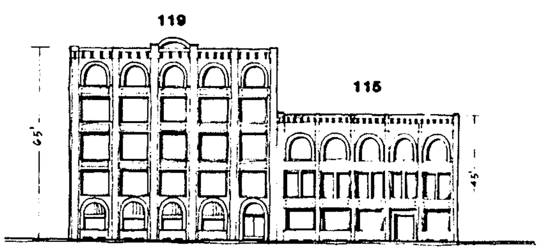
The terrace roof is exposed to the sun throughout the day and is only partially shaded by the westerly building in the afternoon. The tar and gravel covered roof has a central drain. Rooftop of the easterly building is bare except for a 2' high parapet wall, and a mechanical box abutting the center of the westerly building wall.

6.3 Design Objectives

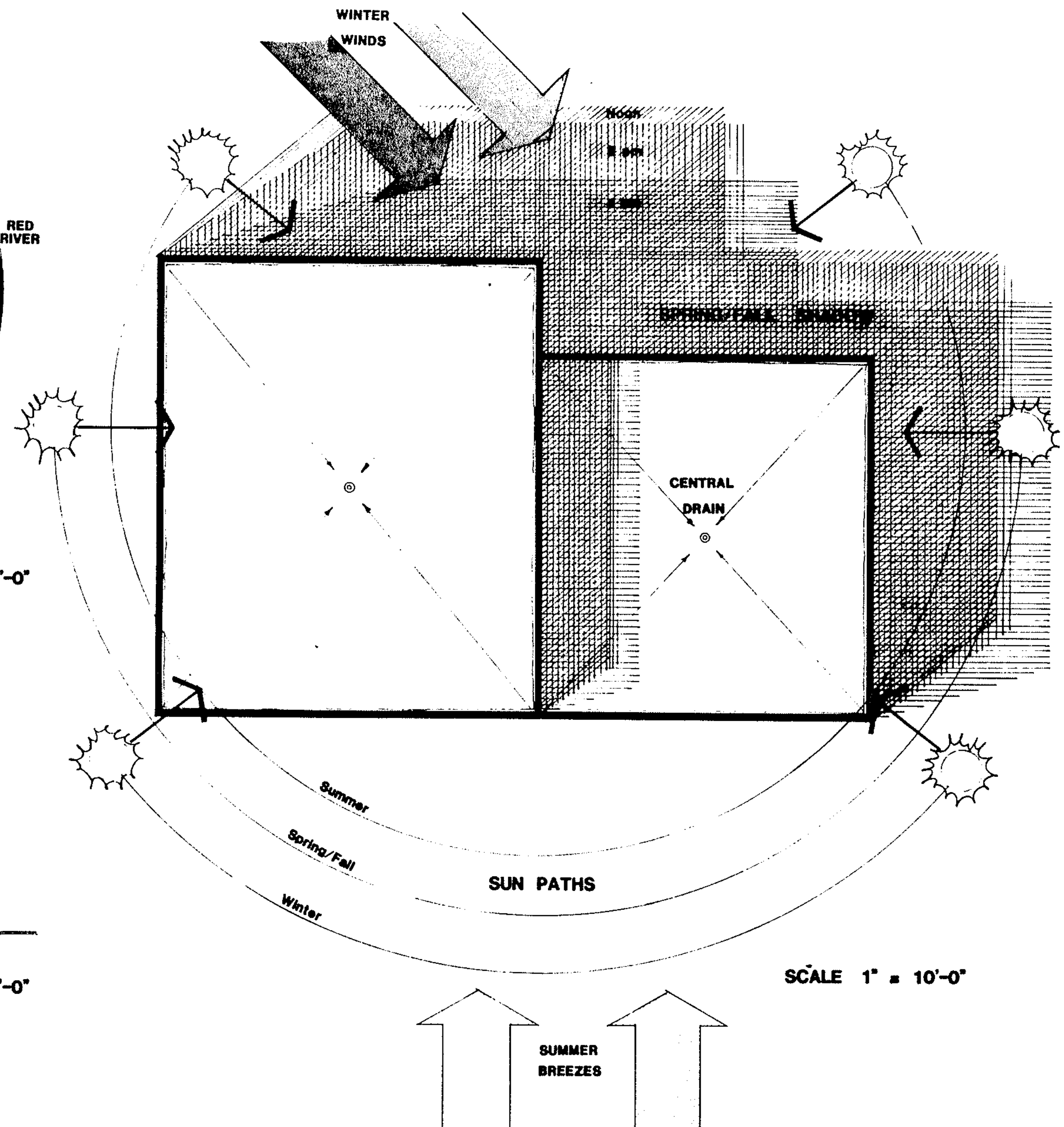
The restaurant terrace is intended to be an attraction to promote the establishment of the restaurant. The terrace's main function is to act as an outdoor extension of the interior dinning space in summer and provide visual focus in winter. The terrace's secondary purpose is to offer open space for passive activities which takes advantage of senic vistas for the other occupants of the building.



SITE CONTEXT SCALE 1" = 200'-0"



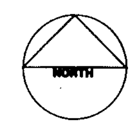
SOUTH ELEVATION SCALE 1" = 20'-0"



SCALE 1" = 10'-0"

THE BROKERAGE BUILDING

L1



SITE ANALYSIS

As with any rooftop landscape efforts over an existing building, the design of the restaurant terrace is strongly affected by the load bearing capacity of the underlying structure. The existing Brokerage Building structure needs upgrading and reinforcement upon any rooftop introductions. For the purpose of this practicum, the design approach followed will be to select the scheme best suited to the design criteria of microclimates, user and activity requirements while catering to the owner's concern for low maintenance and minimal structural renovation based on a reasonable budget.

6.4 Structural Analysis

Physical Characteristics: #115 is 65'x72'x approximately 45' high; #119 is 75'x90'x approximately 65' high. Each building facade is 5 bays wide, #115 with 12' bays and #119 with 14'18" bays.

Foundation: 4'8" exposed rough-hewn limestone veneer.

Wall Construction: Load-bearing brick masonry, veneered in common bond with headers at every 6th course. The brick wall extends above the decorative treatment in the attic and cornice area to form a 2' high parapet around the roofs.

Structural Support: Timber roof consists of 1"x8" decking over 2"x10" joists running north-south at 16" o.c. This is reinforced by 2 rows of 2"x2" cross bracing running east-west between the spans. The building has square timber post and beam interior structural support. 8"x8" wood beams running east-west are spaced 14' apart.

STRUCTURAL REINFORCEMENT ALTERNATIVES

1. JOIST AND BEAM REINFORCEMENT

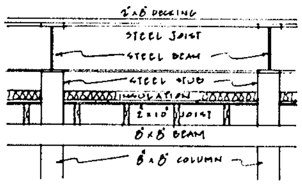
- Add new joist to every joist, reinforce wood beams with steel channels.

- Total load 140 psf
  Total cost $ 25,000.00

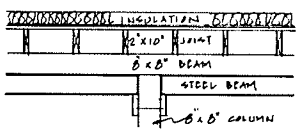
- Not feasible due to inadequate load capacity.

2. STEEL ROOF ADDITION

a). New roof of steel beam and joist, wood decking and steel stub column over existing roof.



b). Reinforce existing timber beam with steel beam underneath.



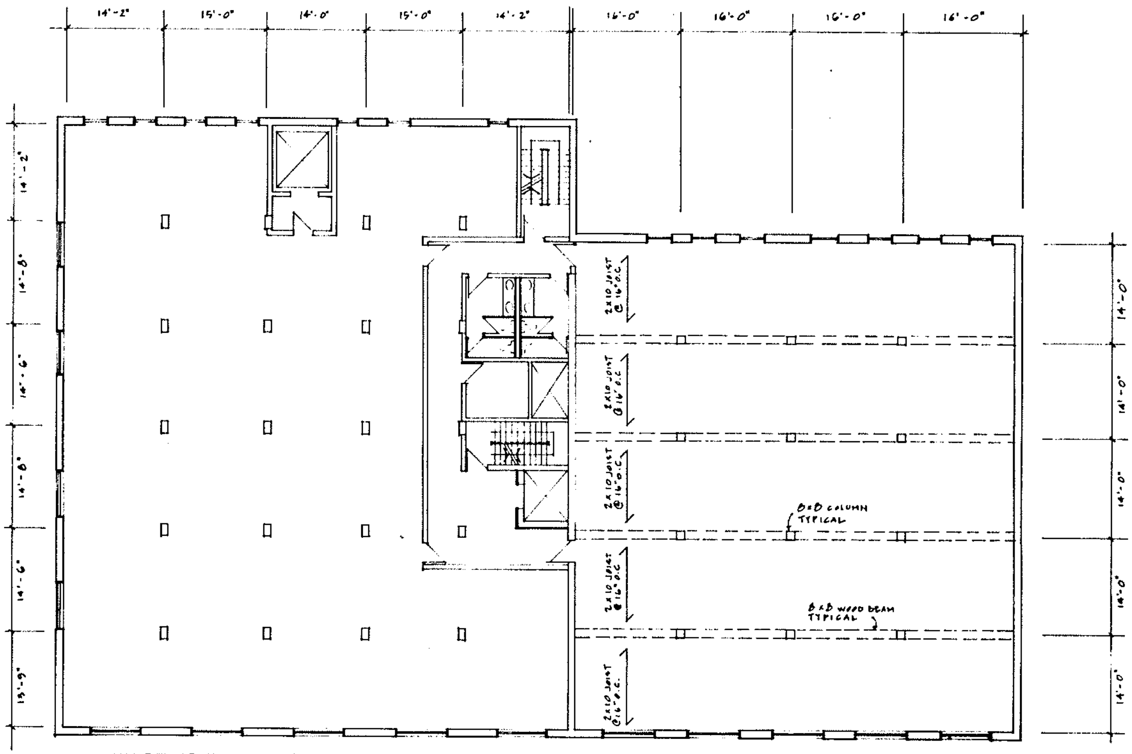
- Total load 225 psf
  Total cost $ 50,000.00

- 2a) is selected over 2b) due to the ease of construction and advantage over for raised level development.

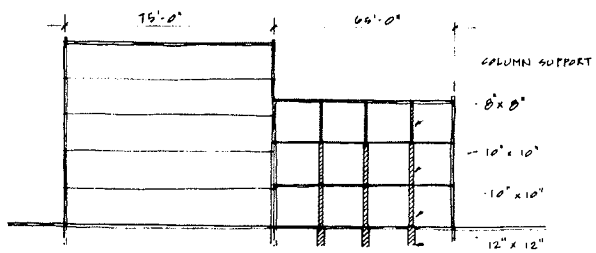
3. COLUMN AND FOUNDATION REINFORCEMENT

- Total load Above 225 psf
  Total cost Unlimited

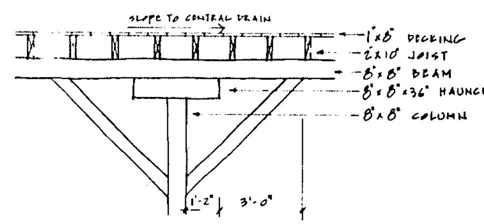
- Not considered due to costs and structural restraints.



EXISTING THIRD FLOOR FRAMING SCALE 1/8" = 1'-0"



COLUMN SUPPORT SCALE 1" = 20'-0"



ROOF STRUCTURE SCALE 1/2" = 1'-0"

THE BROKERAGE BUILDING

L2

STRUCTURAL ANALYSIS

The wood beam rests over a 8"x8"x36" haunch above the 8"x8" timber post. The beams are further secured to the posts by 2"x8" cross bracing. The column support of #115 is 12"x12" at the basement level, 10"x10" at the first and second level, and 8"x8" at the third level. The posts are distributed over a 14'x16' grid.

Load Capacity: Existing roof beam flexural capacity is 36 psf. Joist has flexural capacity at 122 psf and shear capacity at 133 psf. Assuming the foundation is in good condition and free of movement, the existing foundation and column supoort are adequate without further reinforcement. The roof beam presents the most critical load bearing capacity in the existing structural assembly. Since the existing roof is only design for a live load capacity of 36 psf (the minimum snow load requirement for Winnipeg), upgrading of the existing structural system is mandatory upon any rooftop additions. Depending on the extent of rooftop development, reinforcement can take place at the joists and beams level, increasing column support and/or underpinning the foundation for further strengthening.

Structural Reinforcement Altetrnatives: Three strategies for structural reinforcement are presented here to illustrate the rationale behind the chosen system for the roof terrace design. These broad summaries and calculations are based on available knowledge of the building structure. It should be noted that detailed professional engineering analysis and assessment of the existing building structure and condition should be carried out before any plans can be implemented.

1. Reinforce Joists and Beams

Structure	.	Add new joist to every existing joist, i.e. 2"x10" at 8" o.c.
	.	Reinforce wood beams with 2 - C8x11.5 steel channels.
Load Capacity	.	100 psf live load + 40 psf dead load (uniformly distributed loads)
	.	plus concentrated loads directly over existing coulums up to 200 psf.
Cost	.	$ 25,000.00 at $ 5.50/sq.ft.
Comment	.	This alternative is not feasible because its load bearing capacity cannot accommodate the load for a light weight walking surface (180 psf).

2. New Steel Roof Addition Up To Existing Column Capacity

Structure	a)	Build new roof with steel beam and joist with wood deck over steel stub columns on existing roof. New structure is 18" deep with a load of approximately 15 psf.
	b)	Reinforce existing timber beam with steel beam underneath. Less material but difficult steel beam to timber column connection.
Load Capacity	.	Approximately 225 psf total load. (uniformly distributed loads)
Cost	.	$ 50,000.00 at $ 11.00/sq.ft.
Comment	.	Both structures provide sufficient load capacity for development with decks, trellis, shrub planting, light weight walking surface and water feature. Structure a) has a higher floor level than the restaurant which rendered it suitable for raised deck development. Structure b) has a level floor surface with the restaurant and is more attractive for open space and planter developments.

3. Reinforce Column Support and Foundation Underpinning

Structure	. Major structural renovation.
Load Capacity	. Unlimited
Cost	. Unlimited
Comment	. Not considered in this practicum due to the level of complex structural engineering analysis involved and insufficient knowledge of the below grade building condition.

6.5 Design

To fully realize the design intent, the design concept is approached by the efficient use of limited space and materials permitted within the weight constraints. The roof area is intended to provide a pleasant amenity space for the public. In this respect, the roof terrace design should provide an image that is sophisticated yet not intimidating, diverse yet controlled.

Two distinct areas are created to accommodate the unstructured open space activities and the restricted dining functions. Wood is the unifying medium chosen for its light weight and inviting qualities and used consistently throughout for walking surfaces, planters, fencing, screening and trellis construction.

The restaurant terrace occupies the southern portion of the roof, and is consistent with internal access arrangements. It is physically separated from the building edge by 3' high planters for buffer and safety purposes. Privacy from the open area is gained by the use of a 6' high wooden fence and screening combination, planters and a reflecting pool. People watching is possible through an eye-level lattice screen incorporated in the fencing. A wooden trellis is included to provide a sense of permanency and stability in this portion of the roof, in constrast to the portable planter arrangements in the open area. The overhead trellis also provides a framed view of the Red River from within the restaurant.

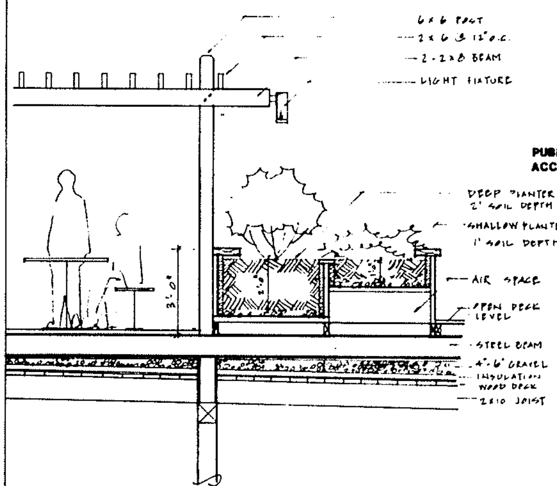
Wooden planters ranging from 2'-3' in height are the major space defining elements in the open area. Shallow 1' compartments for ground cover and annuals are incorporated in some of the 3' planters to reduce the overall weight of the planters due to soil depth. Planter layout carries on the 4'x4' square pattern of the wood decking. Their arrangements create sitting alcoves with built in wooden benches, viewing gallery, aisles and passageways throughout. Placement of art objects such as sculptures and other displays in the open area can generate further interests to attract people.

Due to the addition of the steel roof, a change in level occurred between the exterior and the interior spaces. This is handled from within the restaurant by the creation of a podium near the glass sliding door entrance. The interior podium provides a smooth transition from the interior to the restaurant terrace as well as generating drama in the design of the restaurant interior. There are two access points from the building onto the open deck area. Owing to the confined interior public corridor spaces, the change in level has to be handled at the exterior as sucken entrances. The main entrance is from the elevator corridor. A wheel chair access ramp and low planters are built into this entrance which leads to the central water feature. For the areas occupied by both entrances, reinforcement of the existing wooden roof beam and joist system is required to increase support for the added live and dead loads.

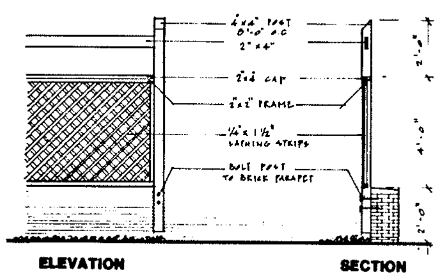
A portable wood decking system of 4'x4' squares resting on 2"x4" sleepers is selected for the weight, scale, texture and ease of maintenance. The walking surface rests above the 2"x8" wood decking which is secured to the new steel roof addition. All wooden planters are laid above and unattached to the walking surface. Planter drainage is through drain holes at the base of planters and through the wood deck to the existing central roof drain below. The reflecting pool with 4" water is constructed essentially as a planter with waterproofing throughout and bottom painted black. It can be emptied from the bottom during winter.

An eight foot high wooden fence is anchored to the brick parapet along the north wall for wind buffering. A lattice pattern is employed to allow view through and reduce wind load on the fence. Access to the building edges is restricted for maintenance purposes only. It is controlled for safety by a series of wooden planters, provision of railings along the viewing gallery and a 1'-2' wide gravel strip located between the parapet and the planters.

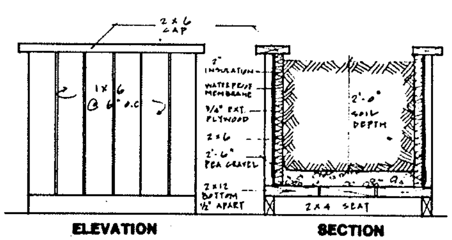
Trees are not included in the planting scheme due to the shallow soil conditions dictated by weight restraints. Low deciduous and coniferous shrubs are placed in 3' planters. Shallow 1'-2' planters accommodate ground cover , annuals, perrenials and the stone/gravel mulch. The plants are selected for their year round esthetic appearances, space defining qualities and most importantly, compact size and their ability to establish and survive in the restrictive environment.



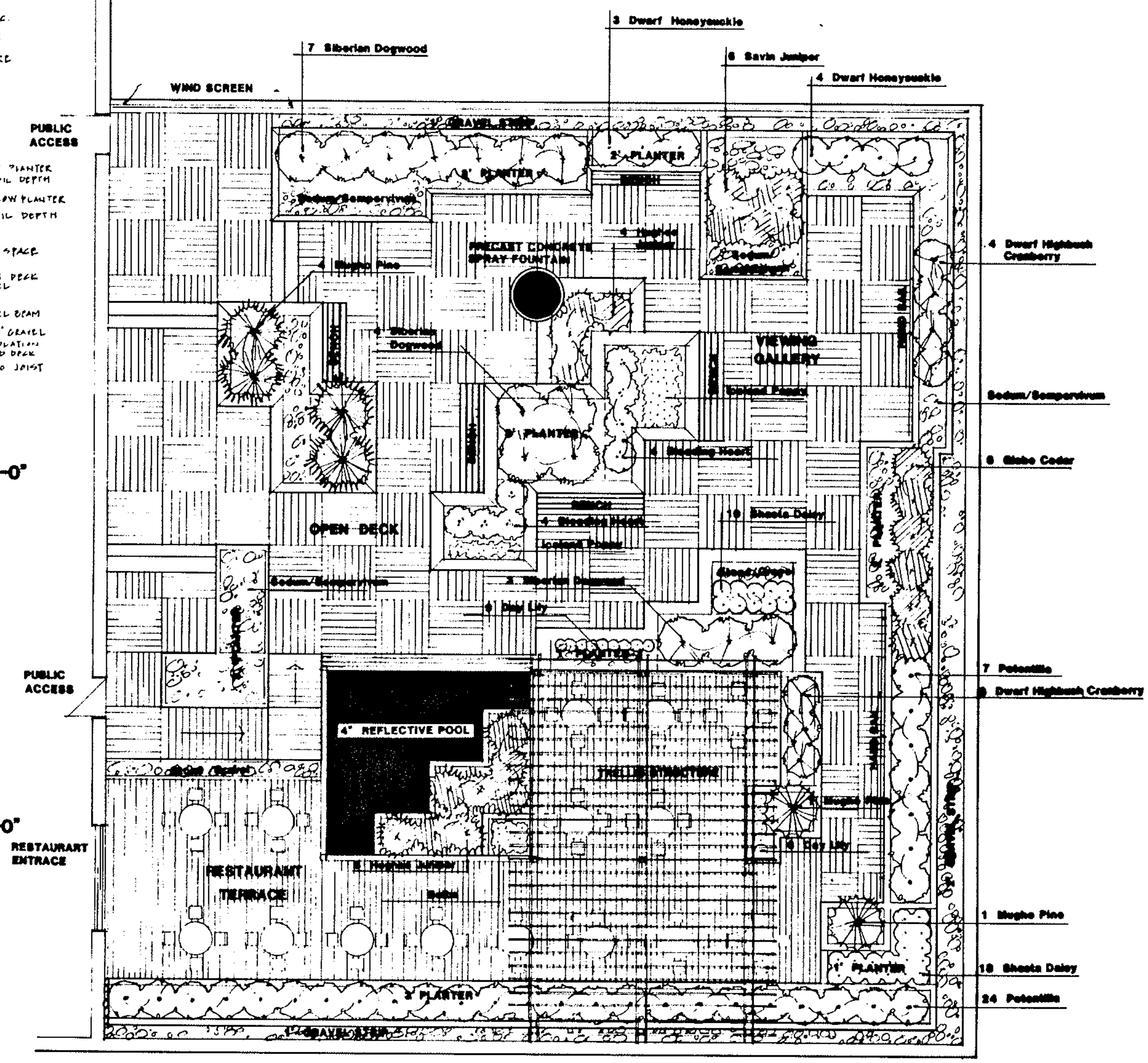
TRELLIS / DECK SECTION SCALE 1/2" = 1'-0"



WIND SCREEN DETAIL SCALE 1/2" = 1'-0"



PLANTER DETAIL SCALE 1" = 1'-0"

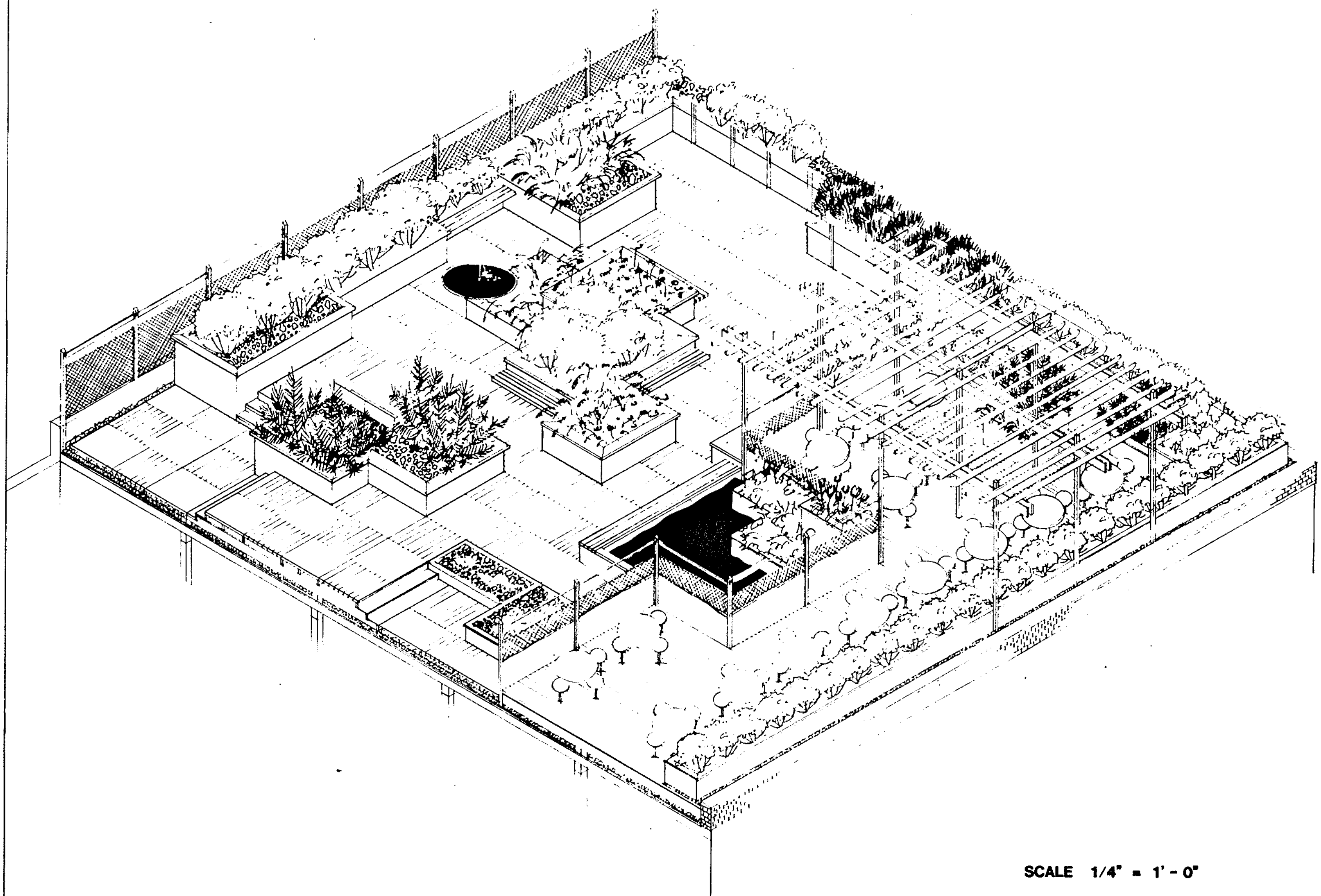


PLAN SCALE 1/4" = 1' - 0"

THE BROKERAGE BUILDING

L3

ROOF TERRACE



SCALE 1/4" = 1' - 0"

THE BROKERAGE BUILDING

L4

ROOF TERRACE ISOMETRIC

6.6 Maintenance Recommendations

In order to retain the attractiveness and usability of the roof deck for its intended activities, regular upkeep and maintenance of the deck appearance, equipment function and plant health are compulsory. While major efforts of the maintenance program will be concentrated on plant care, regular upkeep of the deck surface, pool condition, litter disposal, snow removal for winter access and unimpedded drain passage etc. should not be overlooked.

Plant Establishment:

- Plants should be well watered immediately after planting to let water penetrate well into the root level.
- Mulch should be applied to reduce evaporation.
- Fertilizer should be applied only at the surface to prevent burning of the tender new roots.
- Perform necessary pruning after planting to compensate for root loss during tranplantation.

Watering:

- Since the frequency of watering varies depending on the type of plant, temperature, humidity, wind, rainfall, position of plant etc., a trained person should be employed to take up the critical watering and maintenance program in order to be consistent and ensure provision of proper care and attention.
- Sufficient hose bibs and water outlets should be provided for manual watering.
- Water 3 times a week for the first two weeks after planting and thereafter, twice a week during growing season.
- Daily watering is required during extremly hot weather.
- Watering should be performed during the cooler period of the day and continue watering until the soil around the plant is saturated to the full depth of the roots.
- Soil should not be constantly wet, but should never be allowed to dry thoroughly.

Fertilizing:

- Fertilization should be carried out more frequently than normal planting on grade as soil nutrients tend to leach out due to frequent watering and porous soil texture.

- Apply balanced organic/chemcial fertilizers by surface sprinkling followed by deep watering. Surface broadcasting should be avoided due to high winds.

- Fertilization should be performed twice during the growing season in spring and in summer. Apply 14-14-7 at the rate of 1/4 litre/10 sq m (one cup/100 sq ft) to decicuous shrubs, and 1/8 litre/10 sq m (half cup/100 sq ft) to coniferous shrubs. *(Adapted from Fertilizer Recommendations For The Home Garden, The Manitoba Dept. of Agriculture 1975)*

Weed and Diseases Control:

- Use only sterilized topsoil.

- Mulch planting beds to discourage weed growth.

- Apply liquid or pellet type weed and disease control regularly. Rainfall or irrigation should not occur within 6 hours of herbicide application.

- Maintain strong, healthy plants. Avoid dependence on chemical control.

Pruning:

- Plants should be prunned by annual thinning and pinching to keep them at an appropriate scale for the planter and to remove dead or diseased branches.

- Prunning of deciduous shrubs should be performed in early spring before the buds break,to remove winter-killed branches, unsightly seed pods or dead flowers, and to thin out overgrowth.

- Flowering deciduous shrubs may be pruned after flowering to protect flower buds.

- Prunning of the Mugho Pine should be confined to new growth and undertaken shortly after growth has begun in April. When performed annually for a few years, the density of a branch increases and results in a small, dense, compact specimen as desired.

- Prunning of Junipers should be made before new growth has started but cuts should not be obvious. Branches should be cut back close to a healthy lateral.

- Prunning of both types of coniferous shrubs is generally limited to correcting defects and to cutting back branch tips to ensure symmetry and compact growth.

- Natural needle loss will occur in August and September for most evergreen species.

Winter Protection:

- Water all plants before freeze up.

- Remove dead annual and clean up bed.

- Conifers must be deep watered in late October just before freeze-up and again as soon as the frost is out of the ground to reduce the browning of needles due to warm sun and drying winds.

- Snow accummulation will provide a certain degree of insulation to the plants.

Clean Up and Replacement:

- Weed growth, shrub prunnings and fallen leaves and flowers must be removed regularly.

- Dead plants should be removed immediately and replaced with new plantings.

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No. 99 "Application of Roof Design Principles" by G.O. Handegord and M.C. Baker.
No. 150 "Protected Membrane Roofs" by M.C. Baker and C.P. Hedlin.
No. 151 "Drainage From Roofs" by M.C. Baker.

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APPENDIX A

WINNIPEG CLIMATIC DATA

APPENDIX A . WINNIPEG CLIMATIC DATA

Winnipeg has a "Continental" type climate, with temperatures varying over wide extremes through the year. The normal temperature curve is at its lowest($-1^{o}F$) during the period January 17-27 and its highest ($70^{o}F$) from July 19-27.

The average date of last frost ($32.4^{o}f$ or less) in Spring is May 25 and the first frost in Fall is September 21 giving an average frost free period of 118 days. The average period during which Winnipeg is free from killing frost ($29.5^{o}F$) is 131 days.

The average date of the break-up of the Red River is April 9 and the average date of freeze-up, November 16.

July normally has the most bright sunshine (320 hours) and December the least (81 hours).

Winds predominate most of the year from a southerly direction, as air flow is funneled down the Red River; but during winter months the prevailing direction shifts to northwesterly. April is the windiest month.

Winter snowfall averages 132 mm (52"). Precipitation averages 53mm (21.06") annually. Most of this precipitation falls as heavy showers during the summer months of April to October.

Thunderstorm activity reaches a peak during July, but hail is infrequent.

(Source: Annual Meteorological Summary - Winnipeg, Manitoba
Atmospheric Environment Service
Environment Canada)

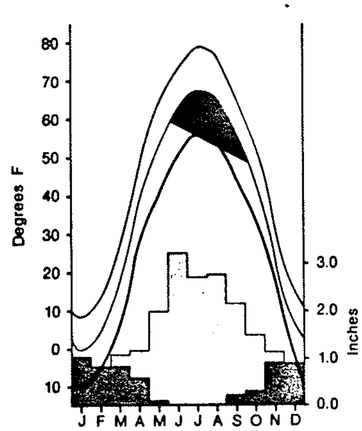
CLIMATE

Winnipeg, Manitoba
50° n. Latitude

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	NOV	OCT	DEC
AVERAGE MEAN TEMPERATURE	°C	-17.7	-15.5	- 7.9	3.3	11.3	16.5	20.2	18.9	12.8	6.3	- 4.9	-12.9
	°F	0.1	4.1	17.7	38.0	52.4	61.7	68.3	66.0	55.1	43.3	23.2	8.7
AVERAGE TOTAL PRE-CIPITATION	cm	2.63	2.1	2.7	3.0	5.0	8.1	5.5	7.0	5.5	3.7	2.9	2.2
	in	1.03	.82	1.08	1.17	1.97	3.19	2.17	2.76	2.16	1.44	1.14	.88
AVERAGE TOTAL RAINFALL	cm	0.03	0.1	0.7	2.0	4.7	8.1	5.5	7.0	5.4	3.0	0.7	0.1
	in	0.01	0.03	0.27	0.78	1.87	3.19	2.17	2.76	2.14	1.17	0.26	0.03
AVERAGE TOTAL SNOWFALL	cm	2.6	2.0	2.0	2.0	0.3				0.2	0.7	2.2	2.1
	in	1.02	0.79	0.81	0.39	0.10				0.02	0.27	0.88	0.85
PREVAILING WIND DIRECTION		NW	NW	NW	N	N	S	S	S	S	S	NW	S

ANNUAL TEMPERATURE AND PRECIPITATION
based on monthly means

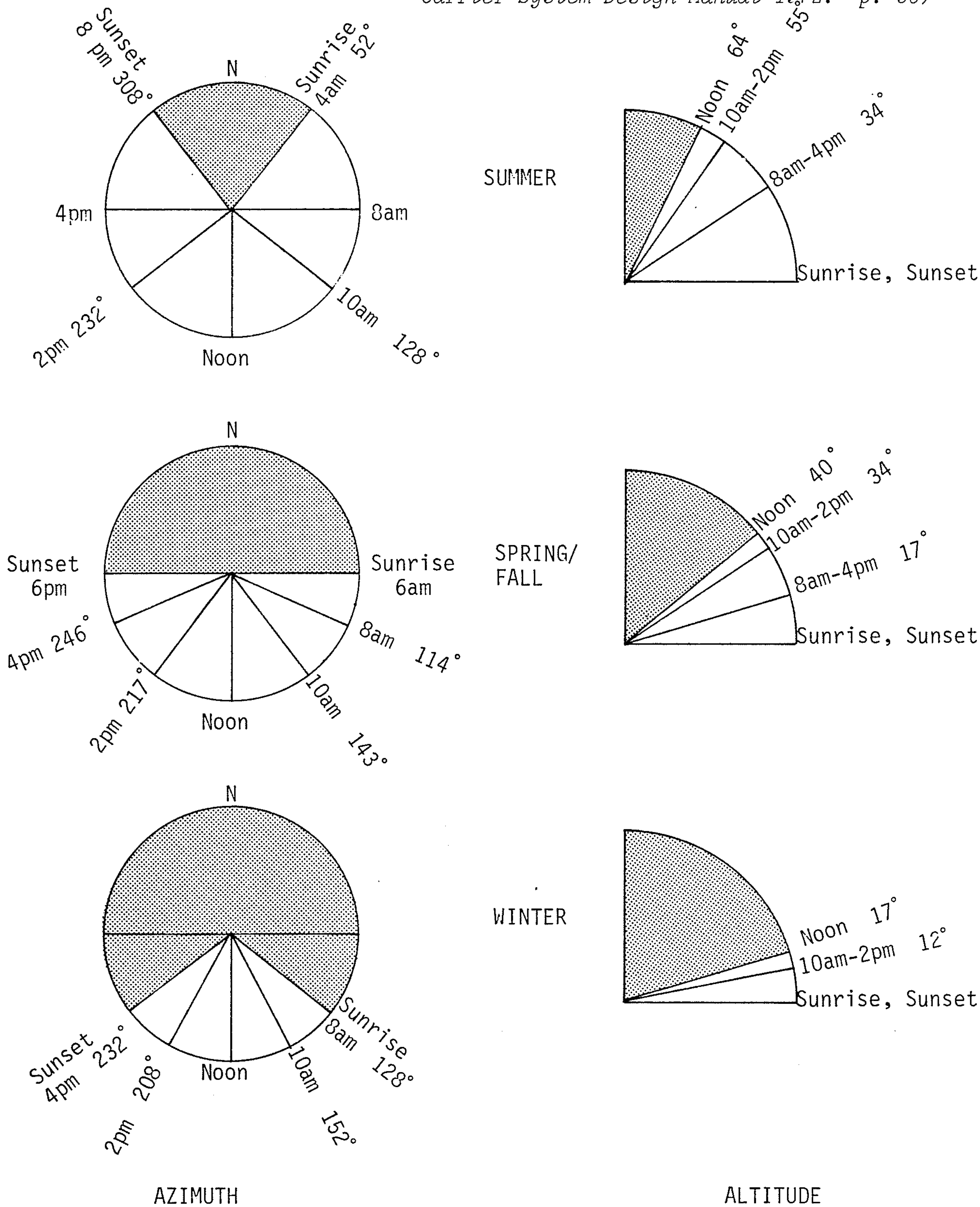
- Mean maximum temperature
- Mean temperature
- Mean minimum temperature
- Average frost-free season (above 32°F)
- Rainfall
- Snowfall (reduced to rainfall equivalent)



SUN ANGLE

Winnipeg, Manitoba 50° Latitude

(Source: Climate of Winnipeg, 1966.
Carrier System Design Manual 1972. p. 58)



APPENDIX B

LIST OF ROOFTOP DEVELOPMENTS IN WINNIPEG

APPENDIX B LIST OF ROOFTOP DEVELOPMENTS IN WINNIPEG

Parking Garage Roof Decks

1. Seven Evergreen (Rosyln Towers) 1980-81
   7-11 Evergreen Place
   Owner - Osborne Towers Ltd.
   Architect - Cooper Rankin Architects
   Landscape Architects - Hilderman Feir Witty & Assoc.

2. Enfield Crescent Apartments 1960
   295 Enfiled Crescent
   Architect - Ikoy Partners
   Landscape Architect - DPR & Assoc. Ltd.

3. Niakawa Tower 1977
   115 Niakawa Road St. Vital
   Owner - Niakawa Tower Ltd.
   Architect -Agassiz
   Builder - R. Massey

4. Wilmont Estates 1979
   585 River Avenue
   Architect - Ikoy Partners
   Builder - M. B. S.
   Owner - Wilmont Estate Ltd.

5. Wellington Arms 1979
   277 Wellington Crescent
   Architect - Ikoy Partners
   Builder - M. B. S.

6. Senior Citizens Apartments (public housing) 1977
355-357 Kennedy Street
Architect - LM Architectural Group

7. Skyview Towers 1972
130 Beliveau Avenue St. Vital
Owner - Ashmore Development Ltd.

8. The Cedars 1974
365 Wellington Crescent
Owner - Winnipeg Condominium Corp.
Builder - R. Massey Builders Ltd.

9. Parkside Plaza 1974
1630 Henderson Highway. North Kildonan
Owner - Burgundy Holidays Ltd.

10. Marina Towers 1975
60-70 Whellams Lane. North Kildonan
Owner - River East Agencies Ltd.
Architect - Design Four Architects

11. Southwood Green Condominium
19-1 Snow Street. Fort Garry
Landscape Architect - Dennis Wilkinson

12. Evergreen Place
1 Evergreen Place
Architect - Ross Blankstein Coop Gillmor Hanna

13. Winnipeg Square 1979
Portage and Main
Owner - Trizic Development Corporation

Roof Decks - Top of Building

1. Hargrave Place (22 storeys) — Uncomplete
   33 Hargrave Street
   Architect - Peter Pun
   Landscape Architect - Hilderman Feir Witty & Assocs.

2. Drury Manor Apartments (hi-rise) — 1974
   1833-39 Pembina Highway. Fort Garry
   Owner - McDonald Grain Co. Ltd.
   Pro-Plan Construction

3. St. Andrews Place (roof terrace at level two) — 1976
   Elgin and Ellen
   Architect - Ikoy Partnership

4. Univillage College Housing — 1973
   99 Dalhousie Drive. Fort Garry
   Owner - College Housing Holdings Incorporated.

5. Ladco Apartments (two buildings)
   2400 Portage Ave. St. James
   Owner - Roman Catholic Archiepiscopal Corp.

6. High Rise Public Housing
   470 Pacific at Princess
   Owner - B. A. Shuckett
   Architect - Smith Carter and Partners

7. Colony Square 1980
555 St. Mary.
Owner - Lakeview Properties Ltd.
Architect - Peter Wreglesworth / Smith Carter Partners.
Landscape Architect - Hilderman Feir Witty and Assoc.

8. Winnipeg Art Gallery 1970
300 Memorial Blvd.
Architects - G. da Roza / Number Ten Architectural Group

9. UMSU Center Deck 1968
University of Manitoba
Architects - Associated Architects for the University Center
Waisman Ross, Blankstein Coop Gillmor Hanna
Roy Sellors, Carl NelsonJr., Claude P. DeForest
Landscape Architect - Man Taylor Muret & Assoc.

APPENDIX C

CASE STUDIES IN WINNIPEG

C - I

UNIVERSITY CENTER 1968

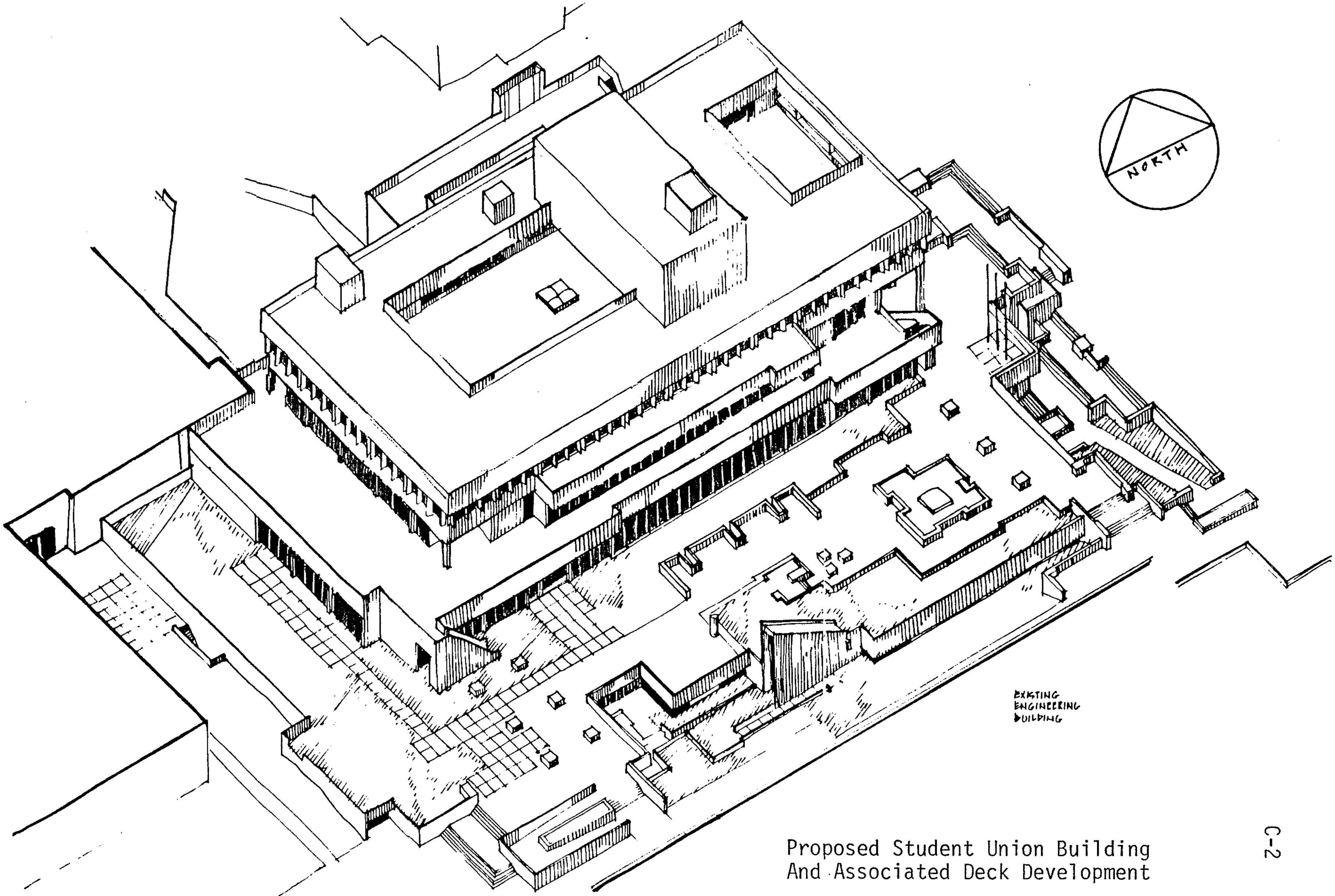
UNIVERSITY OF MANITOBA

Architect	Associated Architects for the University Center: Waisman Ross, Blankstein Coop Gillmor Hanna Roy Sellors, Carl Nelson Jr. Claude P. DeForest
Landscape Architect	Man, Taylor Muret
Engineer	Frank Noffke College - Union Consultant

Project Description

The University Center building is primarily a place for non-academic functions and facilities. The Student Union is its major occupant. Several deck areas and outdoor atriums are incorporated in the building design in order to effectively extend indoor spaces to the outside. While many of these spaces were not developed as a result of budget constraints the deck on the main level on the western side of the building is the most extensively developed and used.

The western portion of the building was sunken below ground level in order to preserve the uninterrupted view to the Administrative Building from the processional entrance drive. The deck developed over this sunken portion acts as an extension of the interior main level lounge spaces. It is also a major passage between buildings and serves as a seating plaza. The deck is comprised of concrete planters, built-in benches and tables, raised planting mounds, and interspersed lawns and paved areas. A fountain feature was dropped from the original plan due to cost restrictions. This deck is overlooked by a balcony deck on the second level. The second level deck, with a wooden plank surface resting on sleepers,was left undeveloped and serves as a promenade deck.



Proposed Student Union Building
And Associated Deck Development

*(Source: Campus Planning Department,
University of Manitoba)*

Technical Data

Roof Construction : The "inverted roof" assembly is applied with paving on 2" leveling sand bed over 2" rigid insulation on a gravel drainage course resting on 8" flat concrete roof slab.

Load Distribution : Dead load capacity ranges between 150 to 200 lb/ft^2 which limits soil depth to a maximum of 3 feet. Large planters are placed on columns with dropheads.

Drainage : The deck surface slopes to drain. Drainage runs towards the center deck and collects at roof deck drains. 3 1/2" diameter non-corrosive perforated pipes imbedded in the gravel course lead the runoff to verticle piping.

Surface Treatment : 1 1/8"x2 1/4"x8" red brick pavers in common running bond and 4" precast concrete slabs are used for paving. There is also a 8"x16" precast paver mowing strip along the perimeter edge. Brick surface upheaving is experienced annually due to improper construction of the sand and gravel layer underneath.

Lawn areas are maintained over 6" of topsoil. A wood false work system ranging in depth from 1' to 3' was once erected to create grass mounds without adding excessive weight. This proved unsuccessfull, as the wood members deteriorated and rotted in the damp air space which led to the collapse of the structure.

Planting : Large trees are placed in concrete planters. Evergreen and deciduous shrubs are planted in sunken plywood planters and planting mounds. Soil depth for trees and shrubs is 3 inches. A standard planting mix was used.

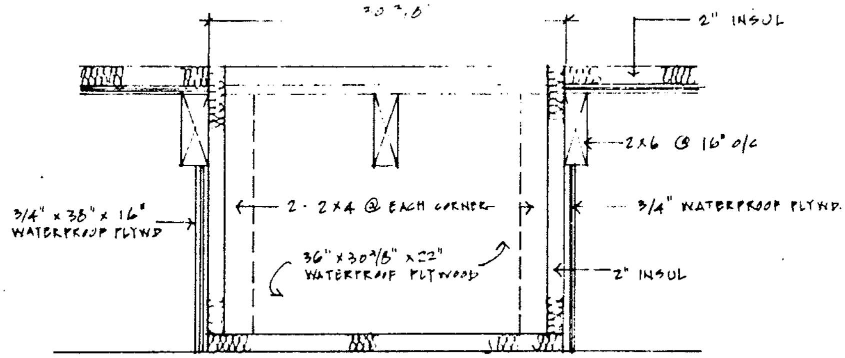
Plant List :

Species	Size
Acer ginnala	10' - 12'
Cerastium tomentosum	4" pot (12" o/c)
Elaeagnus angustifolia	12' - 15'
Euonymous alatus	15" - 18"
Pinus mugo mughus	3' - 4'
Salix exigua	5' - 6'
Sheperdia argentea	6' - 7'
Myosotis sylvatica	3' pots (6" o/c)
Cornus alba sibirica	30' - 36"

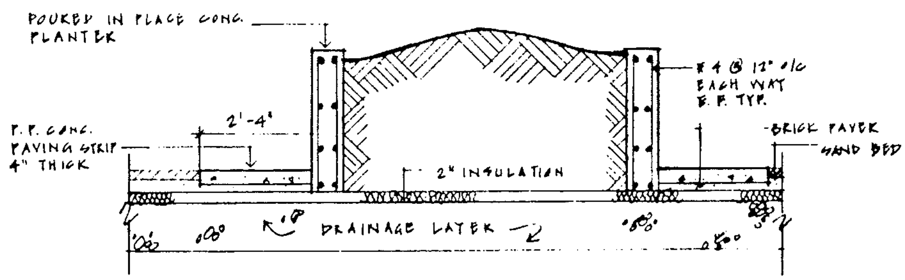
Maintenance : Fertilizers were applied only during installation. Lack of continual maintenance resulted in uncontrolled weed growth and death of trees and shrubs. Planting has been left unpruned. Annuals are planted in planters where trees have been removed. In May 1981, additional low planting beds retained by railroad ties were installed.

Irrigation : Piping and pop-up sprinkler systems placed in all planters, planting beds and lawn areas were replaced by hand watering.

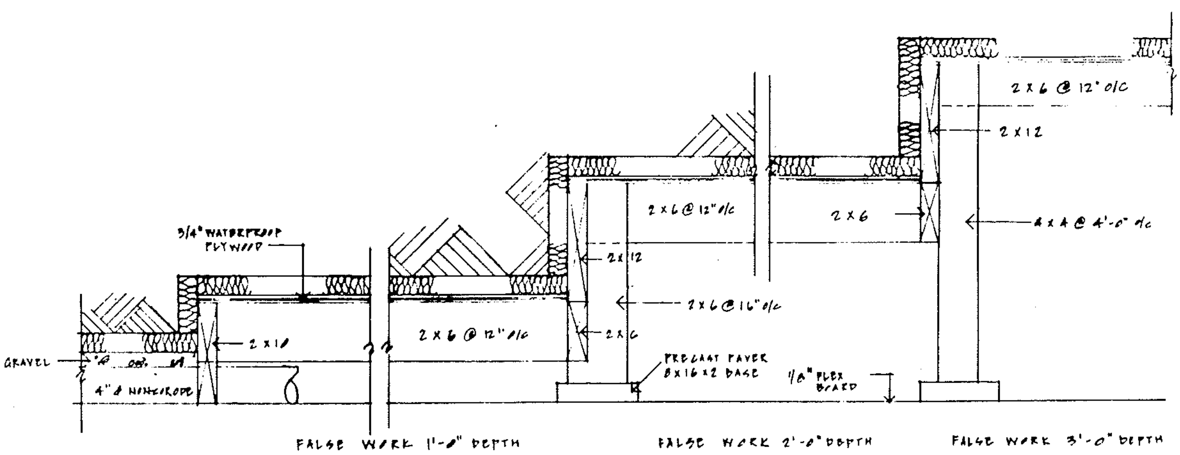
Lighting : Low level walkway lighting,with reliance on light from building interior.



SUNCKEN PLANTER @ 1 FT. & 2 FT DEPTHS 1½" = 1'-0"



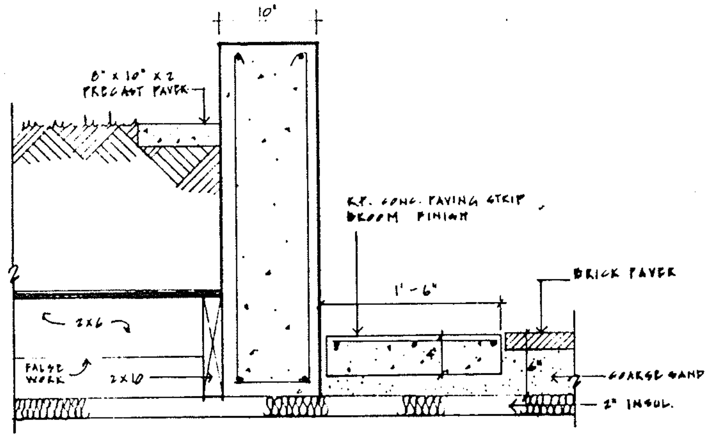
PLANTER SECTION 1/2" = 1' - 0"



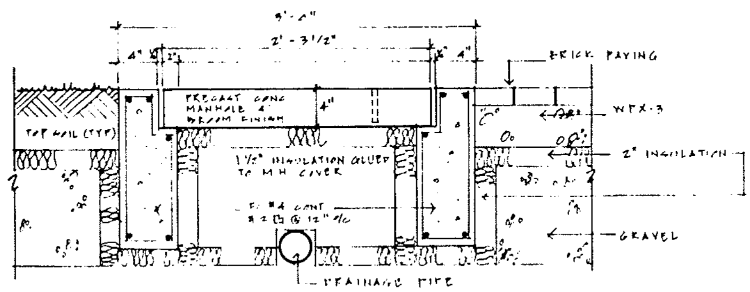
SECTION THRU FALSE WORK 1½" = 1'-0"

University Center Planter Details

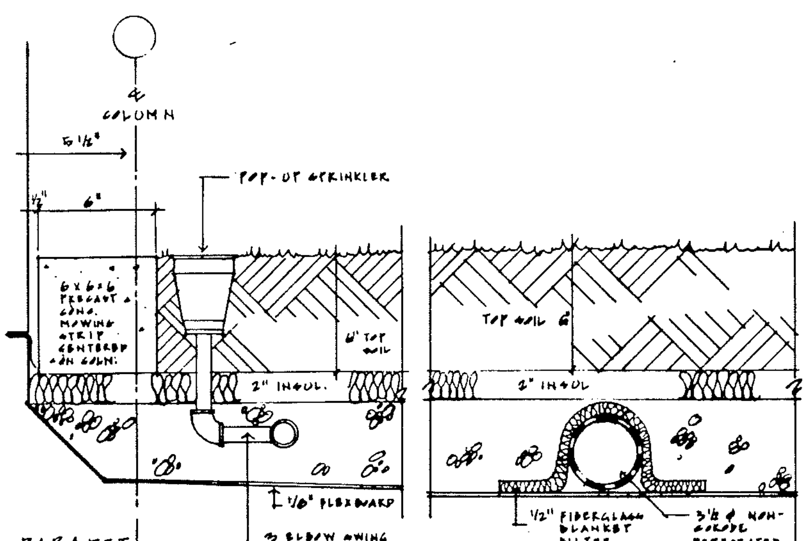
Source: Campus Planning Department, University of Manitoba



10" CONC. WALL SECTION 1½" = 1'-0"



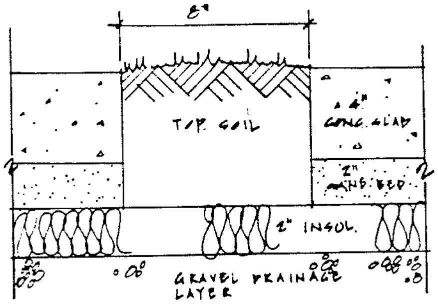
ROOF DRAIN MANHOLE SECTION 1½" = 1'-0"



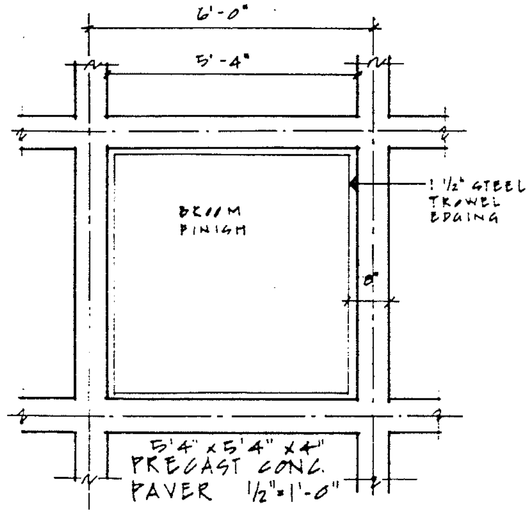
PARAPET MOWING STRIP 3" = 1'-0"

DRAINAGE PIPE

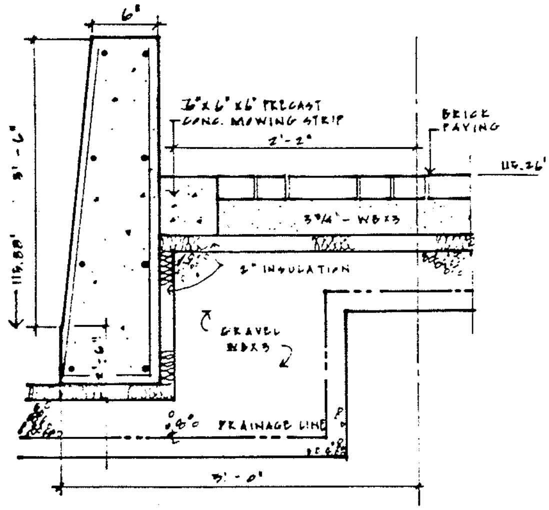
University Center Roof Section Details



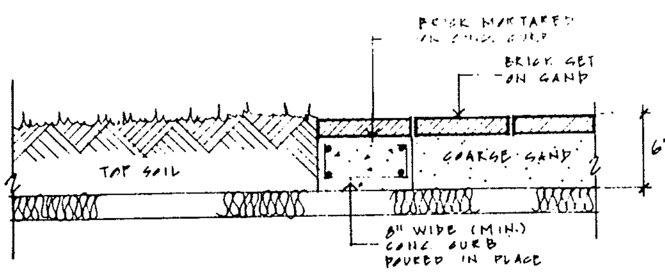
PAVING SECTION 1/4 FULL SIZE



5'4" x 5'4" x 4" PRECAST CONC. PAVER 1/2"=1'-0"



SECTION AT PODIUM SCALE 1 1/2" = 1'-0"



CONCRETE HEADER DETAIL 1 1/2" = 1'-0"

University Center Paving Details

C - II

WINNIPEG ART GALLERY 1970

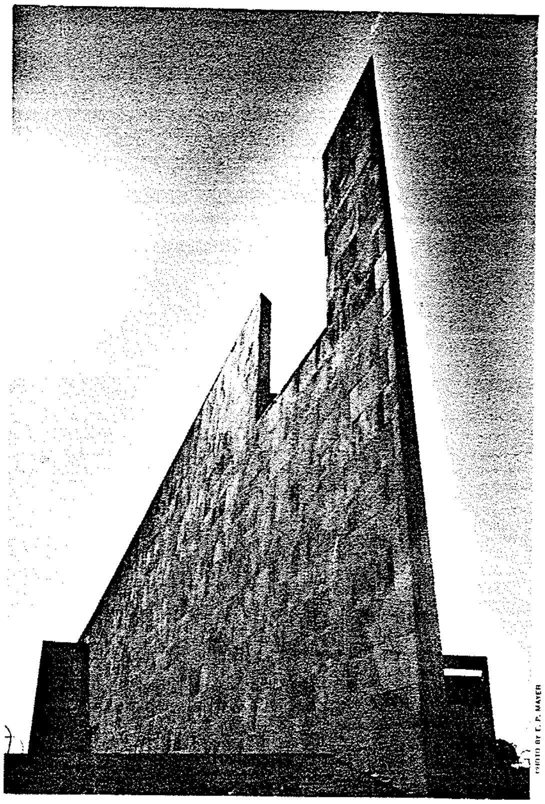
Architects	Gustavo da Roza, Architect The No. 10 Architectural Group, Associates Isadore Coop, Partner in charge Ludwig Bachmann, Project Manager
Structural Engineers	Read Jones Christoffersen Ltd.
Mechanical Engineers	Mechanical Consultants Western Ltd.
Electrical Engineers	K.A. Hand & Associates Ltd.
Lighting Consultants	Edison Price Inc. New York.
Interior Design	Gustavo da Roza, Architect The Number 10 Architectural Group
General Contractor	Bird Construction Co. Ltd.

Project Description

The idea of an art gallery building began immediately after the founding of the Winnipeg Art Gallery in 1912. The actual plan for the building was selected in 1968 from a national competition of 109 entries. The concept for the building design was to fulfill the technical, functional and aesthetic requirements outlined by the late John A. Russel, professional advisor of the building committee. The winning architect 'de Roza' described his plan thus: "The load bearing walls of dressed Manitoba limestone are used to affirm and crystallize the character of this northern Prairie environment. The form of the building points north, inspired by the shape of the site. This affords the individual an opportunity to associate with and participate in the aspirations of our cultural development in Winnipeg, Canada."

The Roof Garden

The fourth floor of the art gallery is developed into a roof garden with associated restaurant facilities. The interior restaurant facilities occupy the southern portion of the roof. The public lounge and the coffee shop are physically and visually



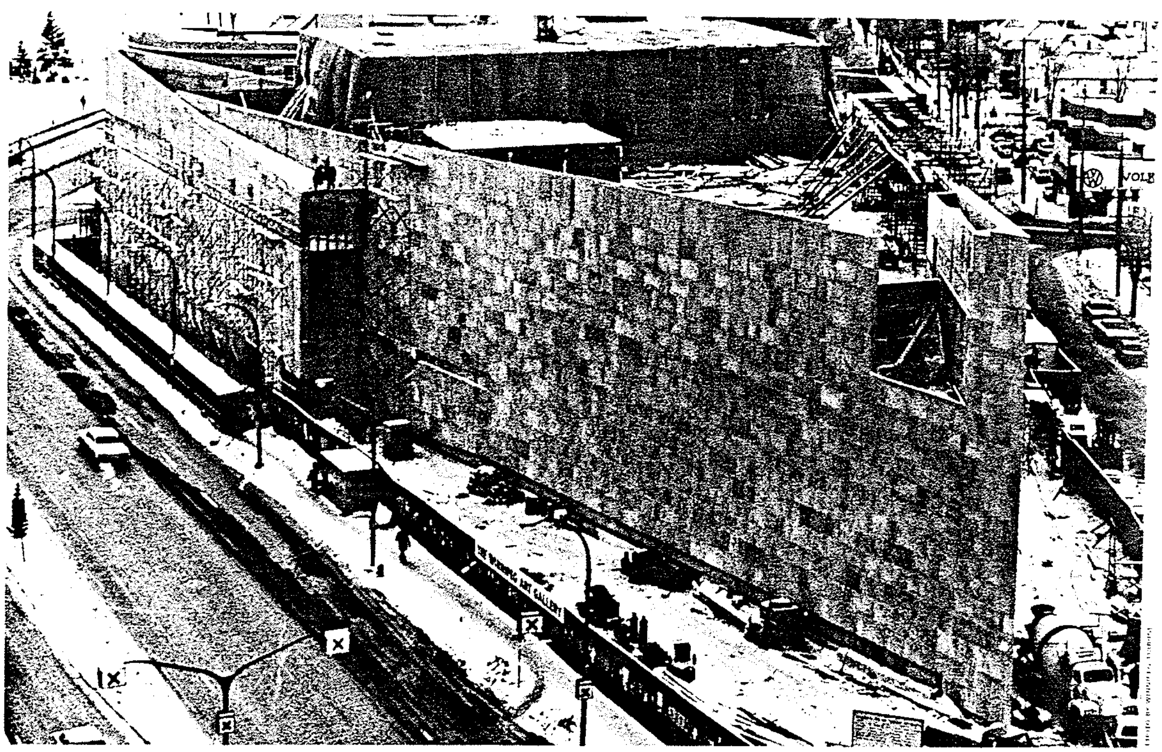
View of Winnipeg Art Gallery During and After Construction

Source: Art Gallery Brochure

AREA	SQUARE FEET
Display galleries	26,000
Work and storage	13,000
Vaults	4,500
Art education facilities	6,500
Lecture and seminar rooms	2,000
300 seat auditorium	4,500
Restoration department	2,500
Gift shop, art rental and volunteer workers area	3,500
Administration areas	5,000
Curatorial, extension, art education and library	5,000
Coffee shop and lounges	3,500

AREA	SQUARE FEET
Net area excluding lobbies, halls, washrooms, mechanical rooms, staff facilities, kitchen, elevators, stairhalls and wall thicknesses	76,000
Total indoor area	120,000
Total outdoor area (roof garden, east platform and ramp way)	25,000
Construction cost	$ 3,300,000
Cost per square foot of total indoor area	$ 27.50
Total cost including furnishings fees and land	$ 4,500,000

Source of funds: Government of Canada Centennial Grant, Province of Manitoba Centennial Grants, Manitoba Centennial Citizens Campaign 1967 and 1970, Private Donations and Gallery Funds



connected to the garden, while the restaurant faces south with a framed view of the Legislative Building.

The roof garden, open and paved with concrete slabs has a central pool feature. Integrated steps and ramps add visual interest and separate the garden into three levels. The lowest section immediately surrounding the indoor facilities is used in the summer as a coffee terrace, the middle section along with the higher level are used for sculptural displays. Access to the roof garden is from interior elevators and stairs. Emergency stair exits are also provided at each of the three corners of the building. The entire roof is surrounded by a vertical extension of the building's "Tyndall" limestone wall. Concrete walls, curbs and paving slabs on the roof garden have sand-blasted finishes.

<u>Technical Data</u>

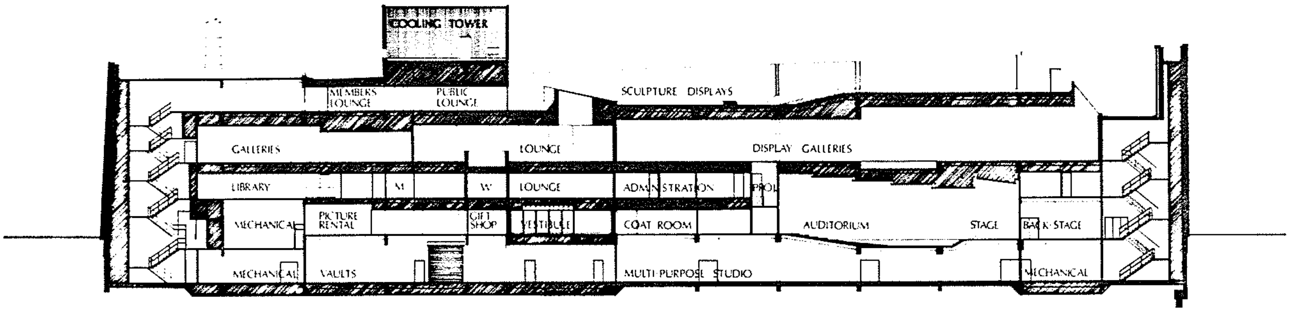
Structure : The building structure consists of reinforced concrete walls, beams, columns and slabs on caissons. Column distribution on the gallery floors below is limited in order not to interfere with display functions. Load capacity therefore, is greatest along periphery walls.

Load Distribution: Permanent plantings in concrete planters are placed along building edges. Pool and skylight structures are supported by 10" x 96" column walls below the center of the floor.

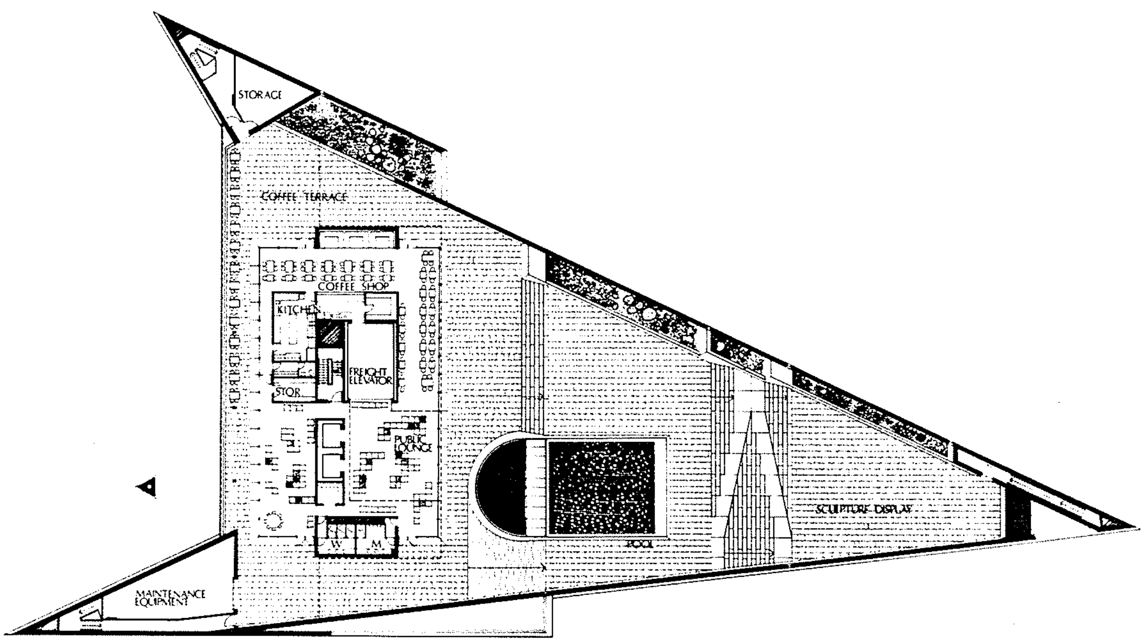
Roof Construction: A concrete roof slab rests on 24" x 45" concrete beams spanning east-west across the building. The concrete roof slab is sloped to drain from the center ridge line to peripheral edges. Thickness ranges from 12 to 4 inches from north-south center line to building edges. The inverted roof assembly,similar to that applied on the UMSU deck is used. 2" precast concrete paving slabs, on 2" of rigid insulation resting on 6 to 8 inches of crushed gravel fill,which provide drainage,and a levelling layer atop the sloping roof slab. The waterproofing membrane is applied between the gravel fill and reinforced concrete roof slab.

Drainage: Surface runoff and excess water from planters are collected along building edges and drained through the gravel fill layer. Perforated non-corrosive weeping tiles 4" in diameter are placed in the gravel layer along the building edges to collect surface runoff. Drainage is carried to 4" dia. rainwater leaders along the structural columns.

Planting: Large trees and shrubs are confined to concrete planters along the west wall to shelter them from prevailing NW winter winds. Annuals, for added color, are planted in portable wooden planters every Summer. A normal planting soil mix is used. Irrigation is by manual hand watering with hose and pipes. While no active maintenance program is followed, plant materials are surviving.



LONGITUDINAL SECTION 0 8 16

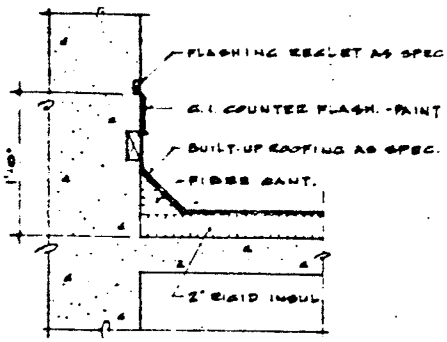


ROOF LEVEL PLAN 0 8 16

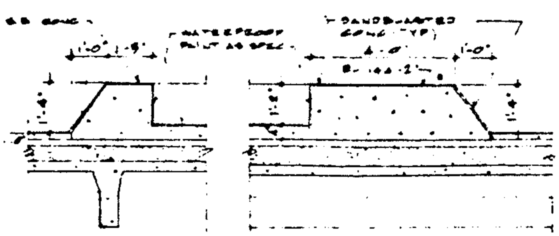
Source: Art Gallery Brochure

Winnipeg Art Gallery Details

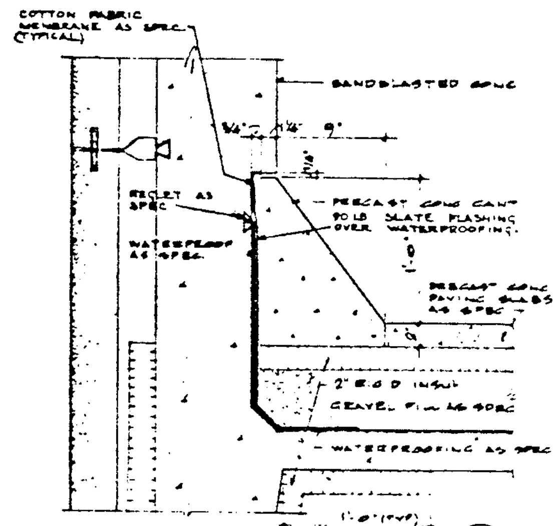
Source: De Roza Architects



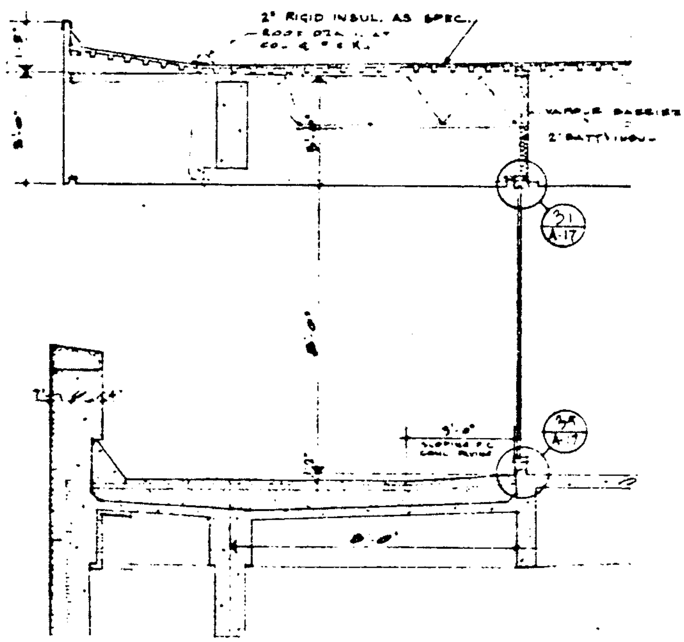
FLASHING DET. 8/A-13



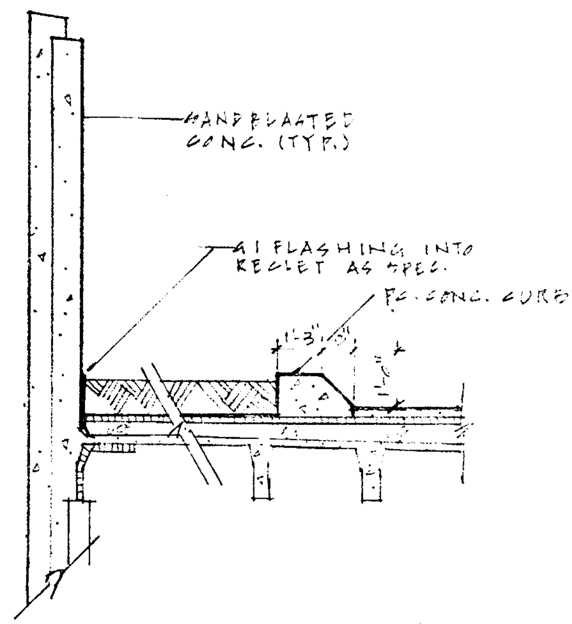
15/A-14 SECTIONS THRU POOL WALL



TYP. PRECAST CONC. CANT 11/A-14



SECTION THRU COFFEE TERRACE



PLANTER DETAIL

C - III

WINNIPEG CENTENNIAL LIBRARY

Architects	McDonald Cockburn McFeetors Tergeson
Design Architect	John Turner
Landscape Architect	The Lombard North Group
Structural Engineers	Krosier Greenberg

Project Description

The Central Library Complex was commissioned in 1974 by the City of Winnipeg to commemorate the one hundredth anniversary of the City. In conjuction with the building, a public park above an underground parking facility was developed to "emphasize the Library's uniqueness by offering relief and contrast in an area where massive commercial and residential buildings predominate". *(The City of Winnipeg, Program of Requirements For The Complex of Library, Car Park and Park. 1972: p. 1:2)*

The Park

The entire project occupies a 2.68 acre site bounded by Donald Street, Smith Street, St. Mary Avenue and Graham Avenue. The park is located at the southern portion of the city block covering approximately 36,000 square feet. The facility provides for passive usage during all seasons and other activities compatible with the library concept.

The park is comprised of paved and landscaped areas broken into small units to discourage boisterous activity. Trees, shrubs, ground cover, and grass mounds are contained by continuous low concrete walls which double as seats. Built-in wooden benches are also provided. Spaces are arranged to create small group seating areas. Zig-zag paths of interlocking pavers are used to connect the various spaces with the public sidewalk. In addition there are permenant metal and concrete sculptures and a reflecting pool situated adjacent the library building. A large geometric shaped fountain pool which is flooded in Winter for skating, is isolated at the St. Mary Avenue, Smith Street corner of the site.

The entire area is lit by standard street lights along the paths. Building floodlights and internal building lights provide for additional evening illumination. Raised grass mounds, plantings and wood and concrete fenestration along the pheripheral site boundaries serve to contain the park and attenuate street noise. These features are designed to provide an aesthetically pleasing sculptural effect which enhances the street scene and allows periodic glimpses of the greenery inside the park.

Technical Data

Roof Structure : A 12" concrete slab supported by 18" x 18" concrete columns which are distributed on a 30' square grid. A 10' x 10' load bearing pad is placed between the slab and columns to disperse point load.

Roof Construction :

Hard Surface Area - Colored interlocking concrete pavers atop 1 1/2" of sand on 2 1/2" of compacted subfill on 1" rigid insulation space boards 1/4" apart on 2"-6" pea gravel (3/8"-1/2" dia.) with a drainage layer over a protection board and a waterproof membrane.

Planting Area - Top soil on 1" fiberglass mat soil separator on 2" rigid insulation on 2"-6" pea gravel over a protection board and a waterproof membrane.

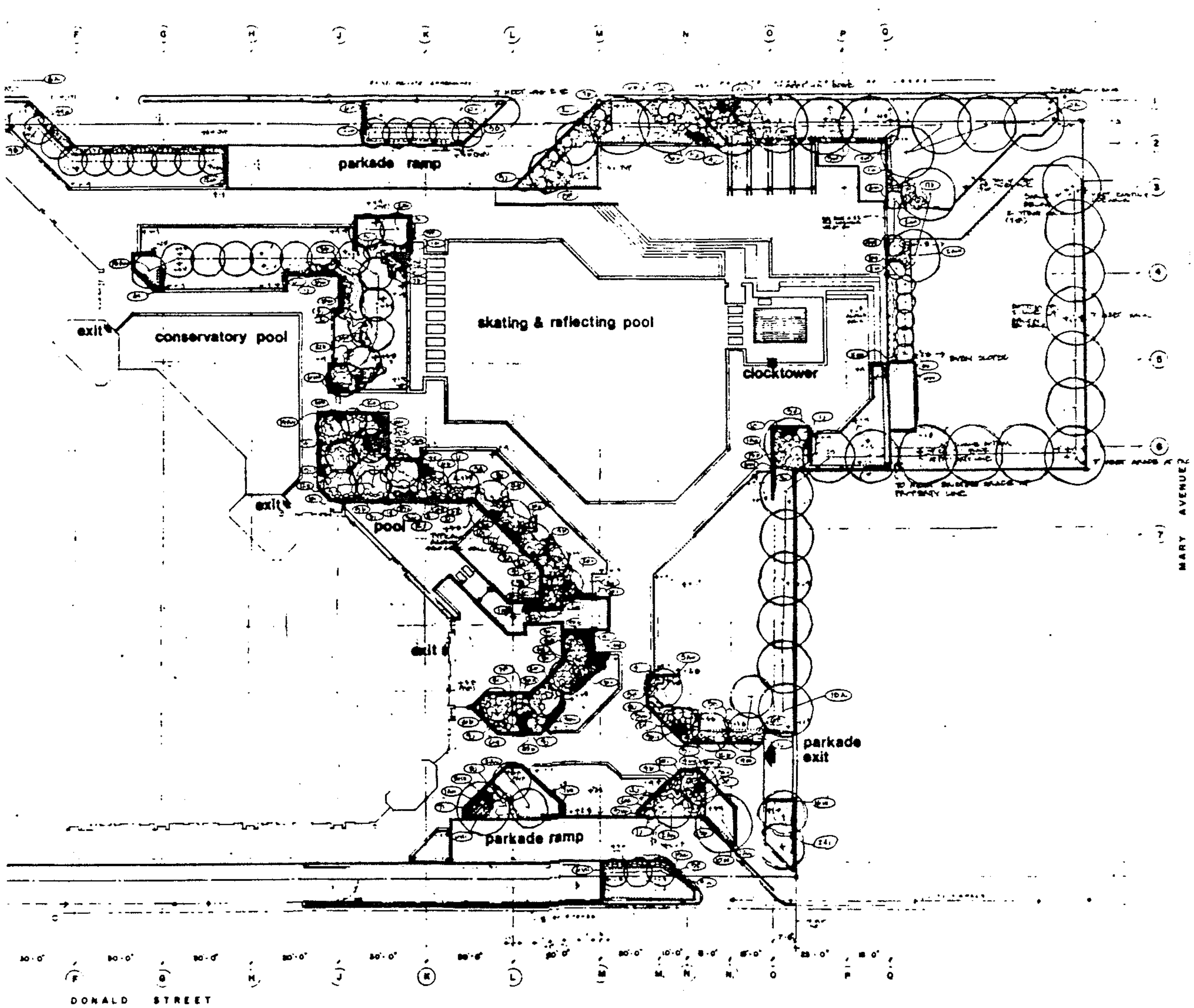


Figure *Centennial Library Planting Plan*
Source: The Lombard North Group

Pool Construction - 4" pool concrete on 1" rigid insulation on 2"-6" pea gravel on protection board and waterproofing membrane over structural slab.

Drainage : Surface runoff is drained locally into 6" dia. surface drain inlets and collects through a pea gravel drainage layer. Planting areas drain through gravel bed to underground drains which link with street storm sewers.

Planting : Standard planting soil mix placed in planters 2' -6" to 4' in height is used for trees and shrubs. Lawns are contained by 1'-6" high concrete curbs.

Plant List :	Trees	Tilia Americana
		Prunus virginiana melanocarpa "shubert"
		Syringa amurensis japonica
	Shrubs	Cotoneaster acutifolia
		Cornus alba sibirica
		Juniperus horizontalis
		Juniperus sabina "skandia"
		Prunus tribola multiplex
		Ribes alpinum
		Salix purpurea nana
		Viburnum opulus
	Ground Cover and Vines	
		Clematis virginiana
		Chrysanthemum maximum
		Hemerocallis
		Polypodium sp.

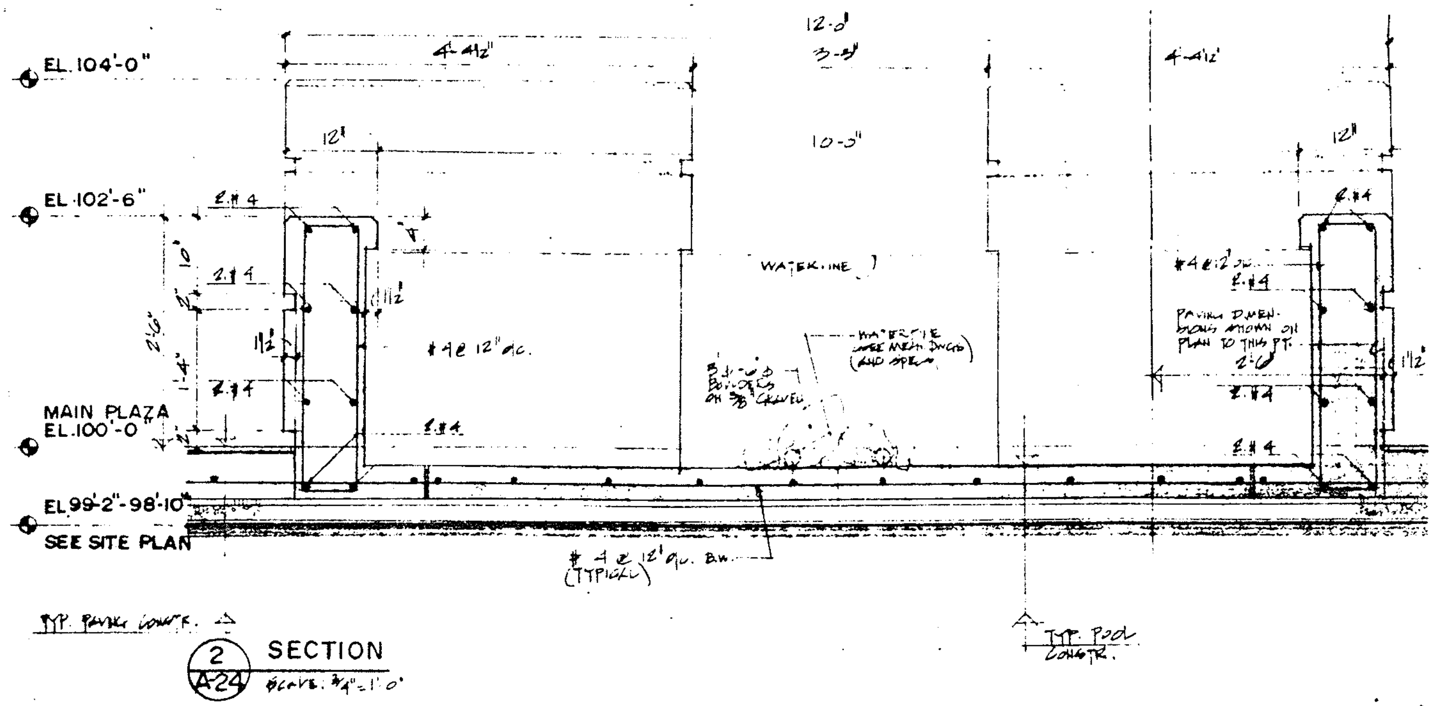
		Iris sibirica
		Convallaria majalis
		Parthenocissus quincefolia
		Vitus vulpina
	sod	No. 1 Nursery grown sod of:
		50% Kentucky Blue
		50% Merion Blue

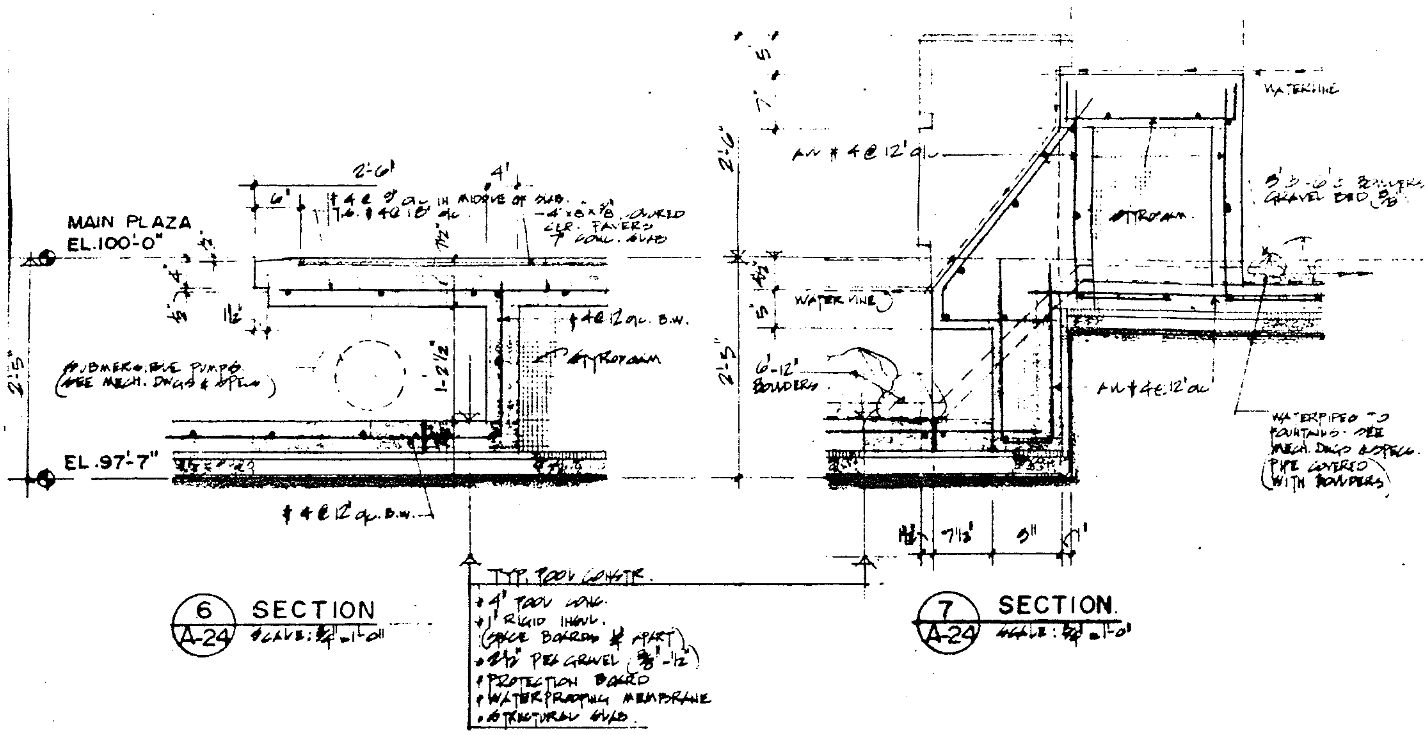
Maintenance : The park is maintained by the City of Winnipeg, Parks and Recreation Department, City Center/ Fort Rouge Division. A regular fertilization, weeding, and pruning program is carried out. A separate crew looks after the pool. Chlorine is applied a minimum of every two weeks at 1 part/ million gallons of water in summer because of depletion due to intensive UV rays from natural radiation.

A sprinkler system is installed for irrigation in all planting areas. Hand watering compliments the system during the summer season.

Milorganit fertilizer is applied to planting areas every Spring.

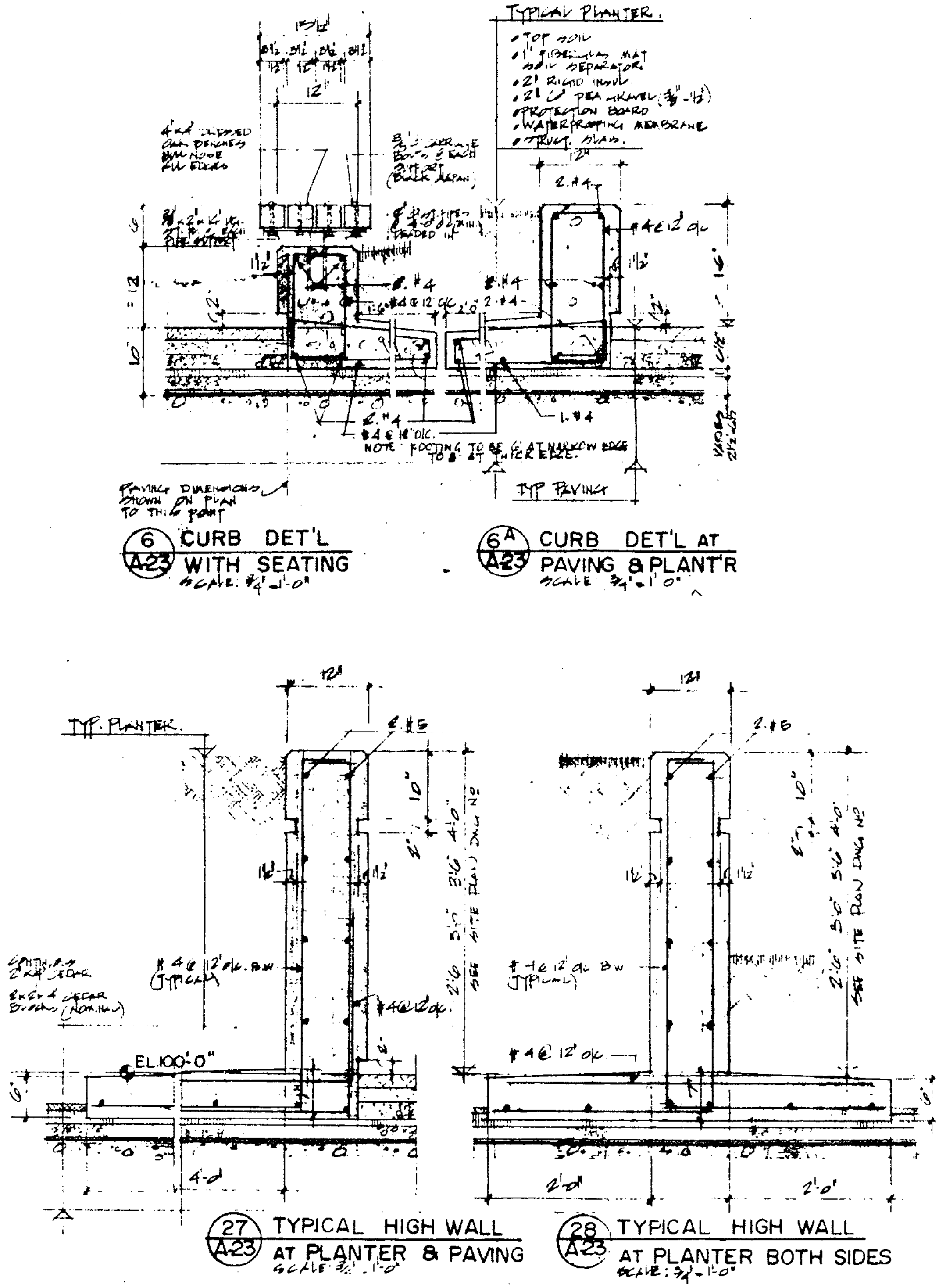
Problems : With the exception of mechanical problems concerning the water pumps in the fountain pool and minor cracks at pool base, the structure has held up well over time and is enjoyed by many users. Fairly steep slopes were created in the lawn areas due to space restrictions. This results in a time consuming task when mowing the lawn to its specified 2" height.





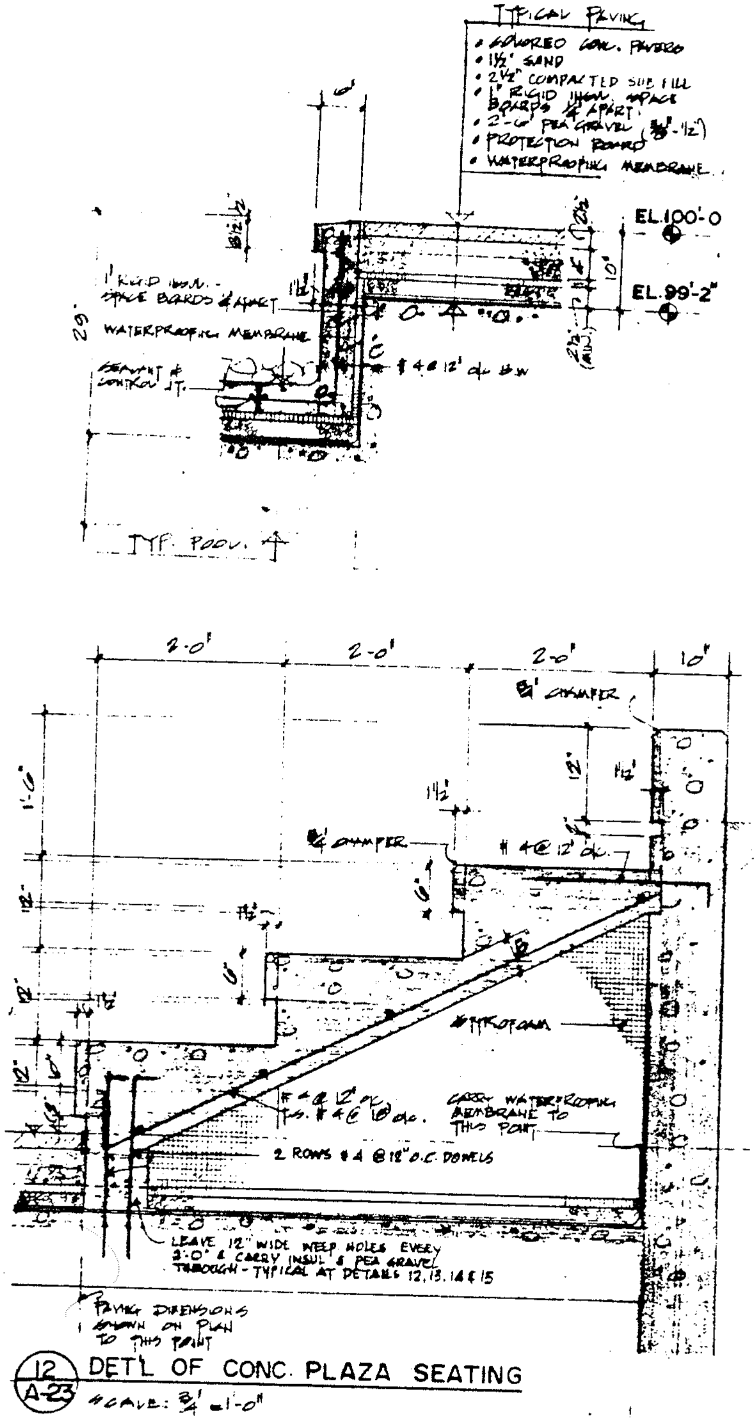
Centennial Library Pool Details

Source: McDonald Cockburn McFeetors Tergeson



Centennial Library Planter Details

Source: McDonald Cockburn McFeetors Tergeson



Centennial Library Stairs and Paving Details
Source: McDonald Cockburn McFeetors Tergeson

C - IV

COLONY SQUARE 1980

Developer	Lakeview Properties Ltd.
Architects & Engineers	Peter Wreglesworth / Architect Smith Carter Partners
Landscape Architect	Hilderman Feir Witty & Assoc.
General Contractor	V. K. Mason Construction Ltd.
Landscape Contractor	Aubin & Russel Landscape Contractor

Project Description

Colony Square is a self-contained commercial, and residential complex being marketed to promote the convenience and vitality of downtown living. The complex is comprised of street level retail shops, two concrete apartment towers of sixteen and seventeen storeys, a six storey office building and underground parking.

Roof Podium

The roof podium above the street level retail shops is surrounded by the three towers. It is developed as the recreation amenity space for the apartment and office tenants.

The "landscaped, terraced outdoor recreation deck" is equipped with a swimming pool, a sunbathing area, two paddle tennis courts and planter-bench units.

Technical Data

Structure : The core floor is 12" concrete slab of precast hollow core units which span 26' x 30' structural bays.

Load Distribution : Combined live load and dead load capacity of the roof ranges between 200 to 300 psf. Plant containers are supported by 120 psf dead load and 100 psf live load capacities.

Podium Floor Construction : 4'-0" x 4'-0" x 3" precast pavers on 3" rigid insulation (R-16), on waterproofing membrane and concrete topping on core floor.

Planter Floor Construction : Standard planting mix on 3" granular fill, 1/2" fibre board on 3" rigid insulation and G.I. flashing and waterproofing on core floor.

Drainage : The roof slab is sloped for drainage. Surface drainage is collected in 3 general areas. Office pheriphery planters have drain holes at the bases to let out excess water as surface runoff, built-in central planters each have their own drainage outlets. The pool has a separate drainage and water supply setup.

Paving : Concrete interlocking pavers and planters are a warm terra cotta colour to compliment the brick facade of the towers.

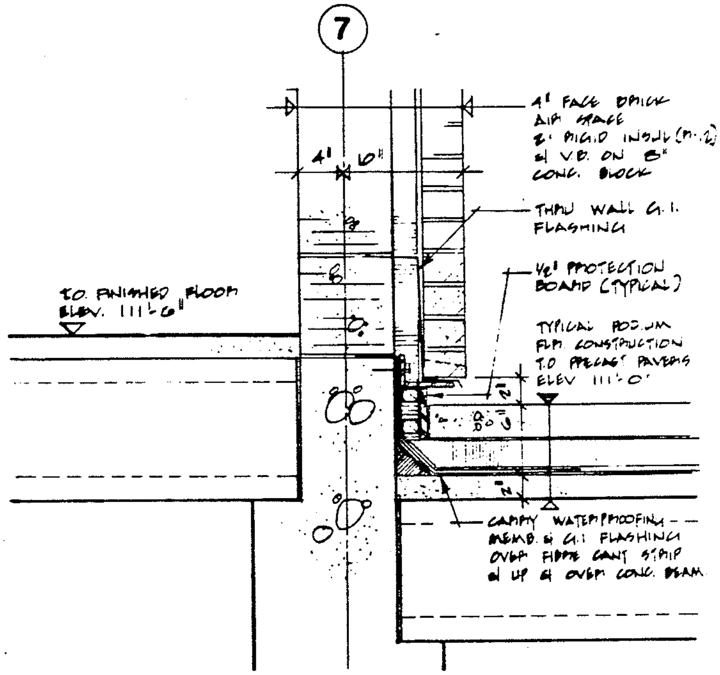
Pool construction : The pool is constructed essentially as a "concrete depression" set into the roof structure. The concept is similar to the interlocking pavers which, during frost action move independently from the podium floor thus preventing damage to the roof structure. The depth of the pool ranges between 5'-6" at the deep end to 2' - 6" at the shallow end. Water is prevented from penetrating the 1 foot thick concrete wall by waterproofing, 2" perimeter insulation and vapour barrier on the dry side of the concrete wall.

Planting : Trees and evergreens 8' ht. and up are guy wired for stability. Sides and bases of planters are insulated for fluctuations in temperature. A standard soil mix with a minimum soil depth of 22 inches is used. The maintenance schedule was prepared by the landscape architect to ensure continual care of the plant material.

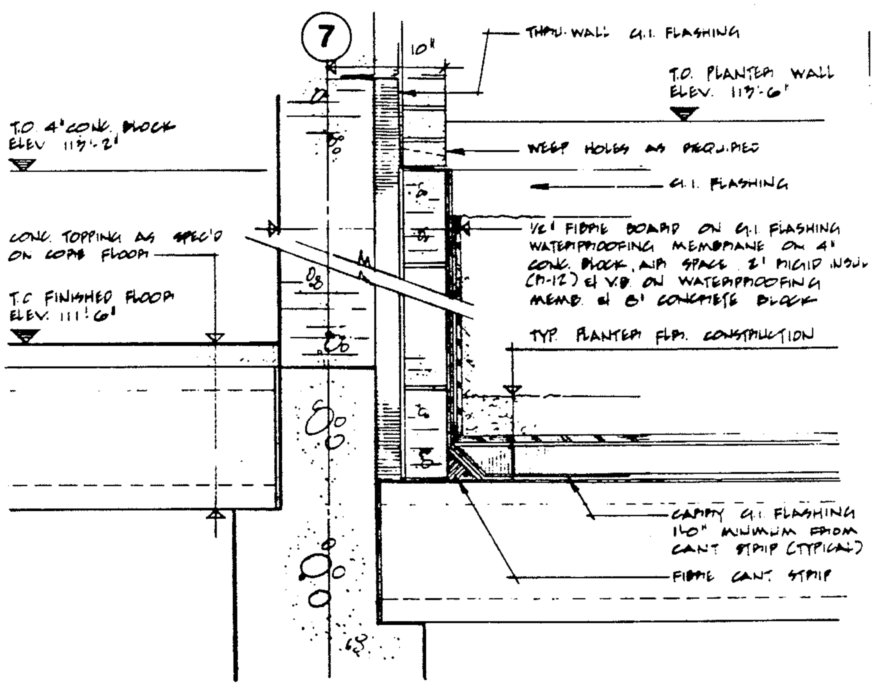
PLANT SPECIFICATION
(For Built-In Planters)

QUANTITY	BOTANICAL/COMMON NAME	SIZE/REMARKS
Trees and Shrubs		
22	Cornus alba siberica/ Siberian Dogwood	24" - 30" ht. Min. 5 major basal branches, well formed bushes. Container stock.
19	Prunus virginiana melanocarpa 'Shubert'/ Shubert Chokecherry	8' - 10' ht. 2" cal. Min. 10 major branches in well branched head of min. 4' dia. Over 5' ht.
82	Ribes alpinum/ Alpine Currant	15" - 18" ht. Min. 5 major basal branches, well branched overall. Container Stock.
60	Spiraea 'Snowwhite'/ Snowwhite Spriea	24" - 30" ht. Min. 5 major basal branches, well branched overall. Container stock.
78	Spiraea trilobata Threelobe Spirea	15" - 18" ht. Min. 5 major basal branches, well branched overall. Container stock.
11	Ulmus pumila/ Siberian Elm	5' ht. Well branched head. Min. 4' dia. B B. Max. 18" depth root ball.
Evergreens		
5	Picea pungens Colorado Spruce	2 - 10' ht. 2 - 8' ht. 1 - 6' ht. Well formed specimens. No broken leaders accepted. B & B. Max. 20" root ball depth.
6	Juniperus sabina 'Arcadia' Aracadia Juniper	18" dia.
2	Pinus mugho Mugho Pine	18" dia.

NOTE: Trees and evergreens 8' ht. and up, to be guy wired. 3 wires (9 guage flexible non-corrosive strand wire) per tree. Guy wire anchors to be well embedded timer deadman.

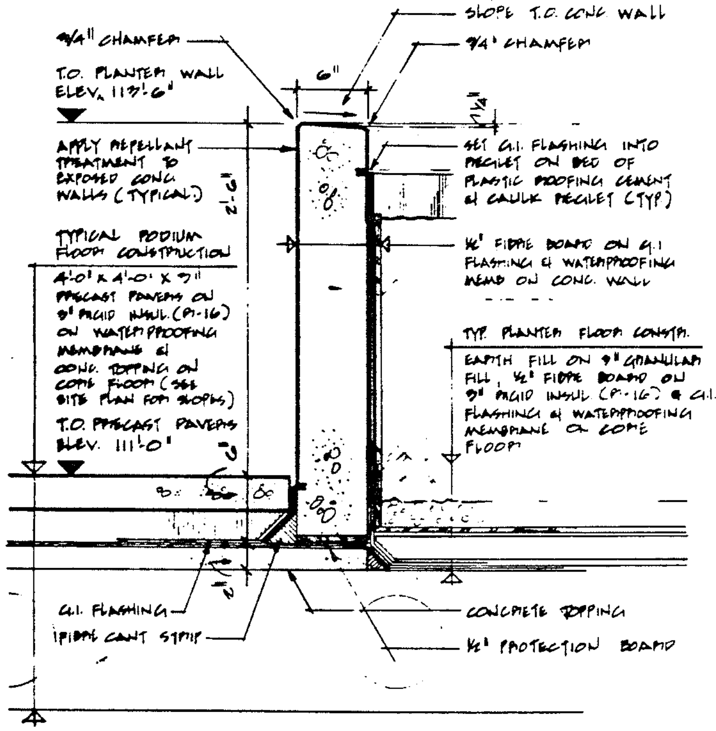


5 / B | 32 — BRICK DETAIL AT WALKWAY
1 1/2" = 1'-0"

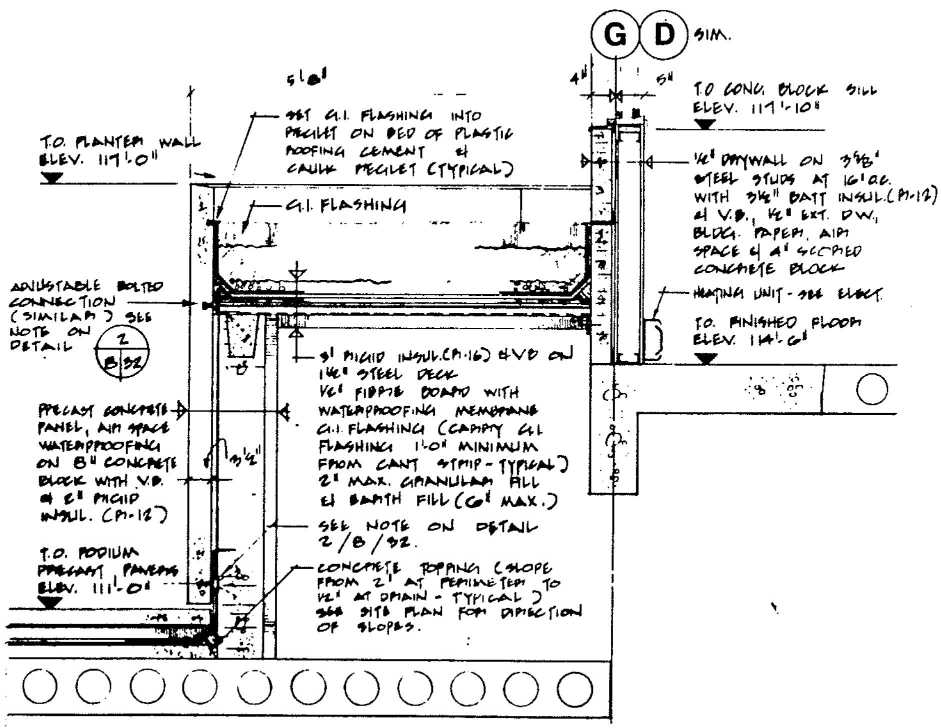


6 / B | 32 — BRICK DETAIL AT PLANTER
1 1/2" = 1'-0"

Colony Square Construction Details
Source: Smith Carter Partners

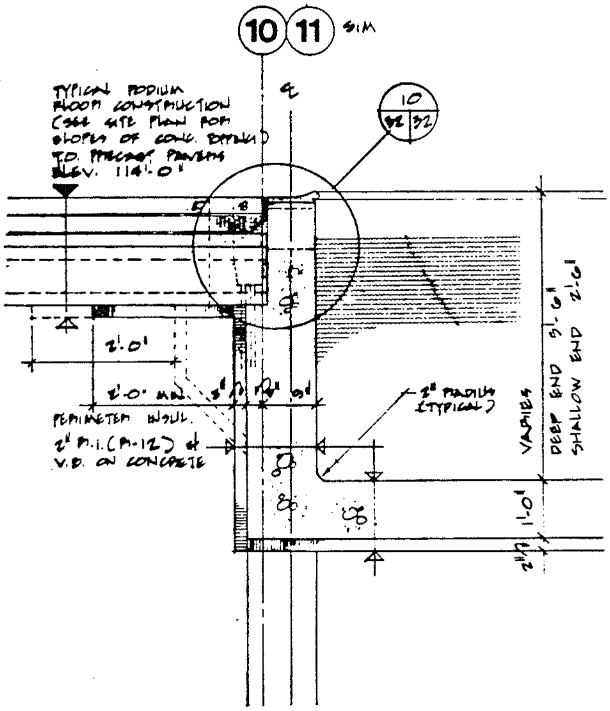


1 / B/32 SECTION THRU PLANTER
1½" = 1'-0"

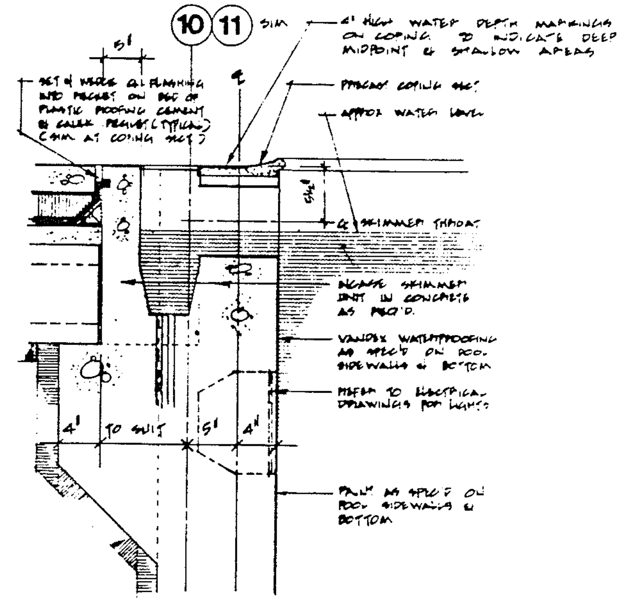


1 / B/32 PLANTER DETAIL
¾" = 1'-0"

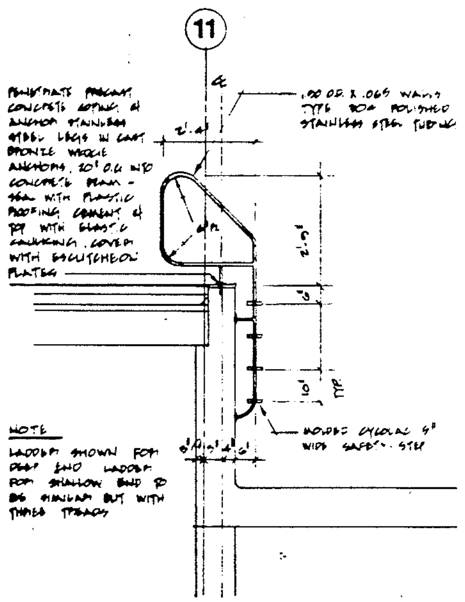
Planter Details
Source: Smith Carter Partners



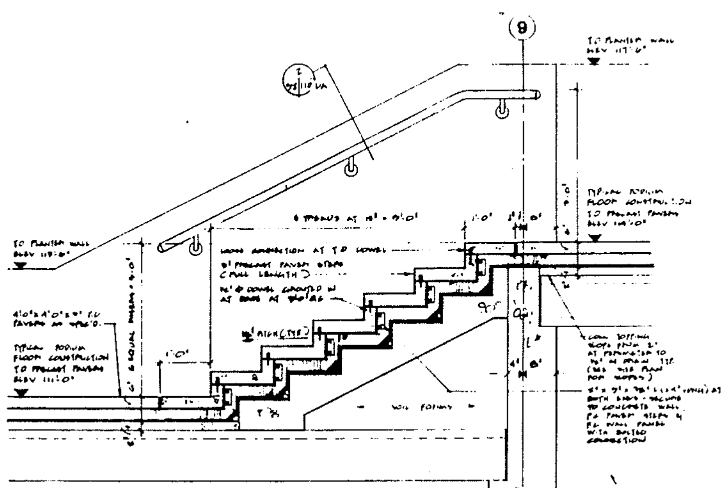
DETAIL AT SWIMMING POOL
3/4" = 1'-0"



TYPICAL COPING & SKIMMER DETAIL
1 1/2" = 1'-0"



SECTION AT LADDER
1/2" = 1'-0"



STAIR & PODIUM DETAIL AT PLANTER
1" = 1'-0"

Colony Square Construction Details
Source: Smith Carter Partners

APPENDIX D

LIST OF INTERVIEWS

APPENDIX D LIST OF INTERVIEWS

1.	Ron Bazarab	Architect De Roza Architects
2.	West Anderson	Architect Smith Carter and Associates
3.	Dave Duncan	Civic Properties Division City of Winnipeg
4.	Mr. Griffths	Campus Planning Department University of Manitoba
5.	Mrs. Fudge	Building Manager Colony Square
6.	Achim Jankowski	Landscape Architect Hilderman Feir Witty and Associates
7.	Jerry MacDonald	Architect MacDonald Cockburn and Associates
8.	Carl Nelson	Architect Department of Landscape Architecture University of Manitoba
9.	No. Ten Architectural Group	
10.	Joan Rankin	Parks Planner Parks and Recreation City of Winnipeg
11.	Ken Pugh	Landscape Architect Canada Mortgage and Housing Corporation
12.	Ed Lach	Structural Engineer Underwood McLellan Ltd.

APPENDIX E

STRUCTURAL LOADS AND PROCEDURES

APPENDIX E STRUCTURAL LOADS AND PROCEDURE

The following information on structural loads have been adapted from The National Building Code of Canada (1980) and its Supplements, issued by the Associate Committee on the National Building Code, National Research Council of Canada, Ottawa.

SUBSECTION 4.1.2. SPECIFIED LOADS AND EFFECTS

Loads

4.1.2.1.(1) Except as provided for in Article 4.1.2.2., the following specified loads, forces and effects shall be considered in the design of a *building* and its structural members and connections:

D—*dead loads* as provided for in Subsection 4.1.5.

L—*live load* due to intended use and *occupancy* (includes vertical loads due to cranes); snow, ice and rain; earth and hydrostatic pressure; horizontal components of static or inertia forces.

Q—wind or earthquake, whichever produces the more unfavourable effect.

T—contraction or expansion due to temperature changes, shrinkage, moisture changes, creep in component materials, movement due to differential settlement or combination thereof.

(Information on effects due to temperature changes can be found in the Commentary on Effects of Deformations in Building Components in NBC Supplement No. 4, "Commentaries on Part 4 1977.")

(2) Minimum specified values of these loads, as set forth in Subsections 4.1.5. to 4.1.10., shall be increased to account for dynamic effects where applicable.

Loads not listed

4.1.2.2.(1) Where a *building* or structural member can be expected to be subjected to loads, forces or other effects not listed in Article 4.1.2.1., such effects shall be taken into account in the design based on the most appropriate information available.

SUBSECTION 4.1.5. DEAD LOADS

4.1.5.1.(1) The specified *dead load* for a structural member consists of
(a) the weight of the member itself,
(b) the weight of all materials of construction incorporated into the *building* to be supported permanently by the member, including permanent *partitions,*
(c) the weight of permanent equipment, and
(d) forces due to prestressing.

(2) Except as provided in Sentence (3), in areas of a *building* where *partitions* other than permanent *partitions* are shown on the drawings, or where *partitions* might be added in the future, allowance shall be made for the weight of such *partitions*. This allowance shall be determined from the actual or anticipated weight of the *partitions* placed in any probable position, but shall be not less than 20 psf over the area of floor being considered. *Partition* loads used in design shall be shown on the drawings as provided in Clause 4.1.1.9.(2)(d).

(3) In cases where the *dead load* is counteractive, the load allowances as provided in Sentence (2) shall not be included in the design calculations.

SUBSECTION 4.1.6. LIVE LOADS DUE TO USE AND OCCUPANCY

4.1.6.1. The specified *live load* on an area of floor or roof depends on the intended use and *occupancy,* and shall not be less than the uniformly distributed load patterns in Article 4.1.6.3., the loads resulting from the intended use or the concentrated loads in Article 4.1.6.4., whichever produces the most critical effect. Loads due to use of floors and roofs

4.1.6.2.(1) Where the use of an area of floor is not provided for in Article 4.1.6.3., the specified *live loads* due to the use and *occupancy* of the area shall be determined from an analysis of the loads resulting from Uses not stipulated
(a) the weight of the probable assembly of persons,
(b) the weight of the probable accumulation of equipment and furnishings, and
(c) the weight of the probable storage of materials.

4.1.6.3.(1) The uniformly distributed load shall be not less than the values listed in Table 4.1.6.A., reduced as may be provided for in Sentences (4) or (5), applied Full and partial loading
(a) uniformly over the entire area, or
(b) on any portions of the area,
whichever produces the most critical effects in the members concerned.

(2) Where an area of floor or roof is intended for 2 or more *occupancies* at different times, the value to be used from Table 4.1.6.A. shall be the greatest value for any of the *occupancies* concerned. More than one occupancy

(3) When the *occupancy* of a *building* is changed, the *building* shall conform to the requirements of this Bylaw for the new *occupancy.* Change in occupancy

4.1.6.4. The specified load due to possible concentrations of load resulting from the use of an area of floor or roof shall not be less than that listed in Table 4.1.6.B. applied over an area of 2½ ft by 2½ ft located so as to cause maximum effects, except that for *occupancies* not listed in Table 4.1.6.B. the concentrations of load shall be determined in accordance with Article 4.1.6.2.

Table 4.1.6.B.

Forming Part of Article 4.1.6.4.

Area of Floor or Roof	Minimum Concentrated Load, lb	Minimum Concentrated Load, kN
Roof surfaces	300	1.3
Floors of classrooms	1,000	4.5
Floors of offices, manufacturing *buildings,* hospital wards and stages	2,000	9.0
Floors and areas used by passenger cars	2,500	11
Floors and areas used by vehicles not exceeding 8,000 lb gross weight	4,000	18
Floors and areas used by vehicles exceeding 8,000 but not exceeding 20,000 lb gross weight	8,000	36
Floors and areas used by vehicles exceeding 20,000 lb gross weight	12,000(1)	54(1)
Driveways and sidewalks over areaways and basements	12,000(1)	54(1)

Table 4.1.6.A.

Forming Part of Sentence 4.1.6.3.(1)

Use of Area of Floor or Roof	Minimum Specified Load, psf	Minimum Design Load, kN/m²
Assembly areas with fixed seats that have backs over at least 80 per cent of the assembly area and including Auditoria Churches Classrooms (also without fixed seats) Courtrooms Lecture halls *Theatres* and other areas with similar uses	50	2.4
Assembly areas other than those listed above, including Arenas Balconies Churches Dance floors Dining areas Foyers and entrance halls Grandstands, reviewing stands and bleachers Gymnasia Museums Promenades Rinks Stadia Stages *Theatres* and other areas with similar uses	100	4.8
Attics having limited accessibility so that there is no storage of equipment or material	10	0.5
Balconies, exterior and interior	100	4.8
Corridors, lobbies and aisles over 4 ft wide (except upper floor corridors of residential areas of apartments, hotels and motels)	100	4.8
Corridors, lobbies and aisles not over 4 ft in width and all upper floor corridors of residential areas only of apartments, hotels and motels	[1]	[1]
Equipment areas and service rooms including Generator rooms Mechanical equipment exclusive of elevators Machine rooms Pump rooms Transformer vaults Ventilating or air-conditioning equipment	75[2]	3.6[2]

Table 4.1.6.A. (Cont'd)

Use of Area of Floor or Roof	Minimum Specified Load, psf	Minimum Design Load, kN/m²
Exits and fire escapes	100	4.8
Factories	125[2]	6.0[2]
Garages for Passenger cars Unloaded buses and light trucks Loaded buses and trucks and all other trucking spaces	 50 125 250	 2.4 6.0 12.0
Kitchens (other than residential)	100	4.8
Libraries Stack rooms Reading and study rooms	 150 60	 7.2 2.9
Office areas in office *buildings* and other *buildings* (not including record storage and computer rooms) located in Basement and first floor Floors above first floor	 100 50	 4.8 2.4
Operating rooms and laboratories	75	3.6
Recreation areas that cannot be used for assembly purposes including Billiard rooms Bowling alleys Pool rooms	75	3.6
Residential areas Sleeping and living quarters in apartments, hotels, motels, boarding schools, colleges and hospitals	40	1.9
Retail and wholesale areas	100	4.8
Roofs (for roof snow loads see Article 4.1.7.1.)	20[3]	4.8[2]
Sidewalks and driveways over areaways and basements	250	2.4 [2]
Storage areas	100[2]	1.0[3]
Toilet areas	50	12.0
Underground slabs with earth cover	[2]	
Warehouses (see Storage areas)		

Notes to Table 4.1.6.A.:

[1] Corridors, lobbies and aisles shall be designed to carry not less than the specified load required for the *occupancies* they serve.

[2] Loads due to the intended use must be calculated and allowed for in the design.

[3] To cover occasional short term loads such as due to workmen. This load is not additive to loads due to snow, ice or rain.

COMMENTARY H

Snow Loads

VARIATIONS OF SNOW LOADS ON THE GROUND AND ON ROOFS

1. Snow loads on roofs vary according to geographical location (climate), site exposure, shape and type of roof, and of course from one winter to another.

2. Before the roof snow loads can be discussed, however, the ground loads must be considered, since they are the basis for the determination of the roof loads. Ground snow loads, forming part of the basic climatic information needed for building design in Canada, are dealt with in Chapter 1 of this Supplement.(1) There, the snow loads on the ground are given in the form of a table, "Design Data for Selected Locations in Canada."

DESIGN DATA FOR SELECTED LOCATIONS IN CANADA

Province and Location	Design Temperature: January 2½%, °C	January 1%, °C	July 2½% Dry, °C	July 2½% Wet, °C	Degree Days Below 18°C	15 Min. Rain., mm	One Day Rain., mm	Ann. Tot. Pcpn., mm	Gnd. Snow Load, kN/m²	Hourly Wind Pressures 1/10, kN/m²	1/30, kN/m²	1/100, kN/m²	Seismic Data Zone	Acceleration Ratio, A
Manitoba														
Beausejour	-33	-35	28	23	5 986	28	66	563	2.1	0.31	0.37	0.45	0	0
Boissevain	-32	-34	32	23	5 769	33	146	499	1.8	0.44	0.52	0.63	0	0
Brandon	-33	-35	31	22	5 965	36	141	488	1.8	0.37	0.45	0.54	0	0
Churchill	-39	-41	24	18	9 214	8	52	397	2.9	0.48	0.59	0.72	0	0
Dauphin	-33	-35	30	22	6 150	25	100	506	2.2	0.31	0.37	0.44	0	0
Flin Flon	-38	-40	27	20	6 764	13	77	458	2.3	0.42	0.52	0.65	0	0
Gimli	-34	-36	29	23	6 119	28	125	537	2.1	0.30	0.37	0.45	0	0
Island Lake	-36	-38	26	20	7 210	13	63	510	3.1	0.37	0.43	0.50	0	0
Lac du Bonnet	-34	-36	28	23	6 100	28	76	510	2.3	0.28	0.34	0.41	0	0
Lynn Lake	-40	-42	27	19	8 144	8	77	458	2.5	0.47	0.58	0.71	0	0
Morden	-31	-33	31	23	5 603	28	143	524	2.0	0.40	0.48	0.56	0	0
Neepawa	-32	-34	30	22	6 032	33	85	479	2.6	0.33	0.40	0.49	0	0
Pine Falls	-34	-36	28	23	6 242	25	67	574	2.3	0.29	0.35	0.43	0	0
Portage la Prairie	-31	-33	30	23	5 757	36	131	513	1.6	0.36	0.43	0.51	0	0
Rivers	-34	-36	30	22	6 050	33	139	484	1.8	0.36	0.43	0.51	0	0
St. Boniface	-33	-35	30	23	5 830	28	101	539	2.1	0.35	0.42	0.49	0	0
St. Vital	-33	-35	30	23	5 830	28	89	510	2.1	0.35	0.42	0.49	0	0
Sandilands	-32	-34	29	23	5 890	28	89	560	2.3	0.31	0.37	0.44	0	0
Selkirk	-33	-35	29	23	5 870	28	89	510	2.1	0.33	0.39	0.47	0	0
Split Lake	-38	-40	27	19	7 880	10	51	410	2.8	0.51	0.60	0.71	0	0
Steinbach	-33	-35	30	23	5 887	28	83	548	2.2	0.31	0.37	0.44	0	0
Swan River	-36	-38	29	22	6 442	20	85	510	2.0	0.30	0.35	0.42	0	0
The Pas	-36	-38	28	21	6 851	15	78	471	2.6	0.35	0.43	0.52	0	0
Thomson	-42	-45	26	19	7 930	10	51	430	2.6	0.49	0.58	0.68	0	0
Transcona	-33	-35	30	23	5 830	28	89	510	2.1	0.35	0.42	0.49	0	0
Virden	-33	-35	30	22	6 092	33	104	465	2.0	0.36	0.43	0.51	0	0
Whiteshell	-34	-36	28	23	6 100	28	76	510	2.3	0.28	0.34	0.41	0	0
Winnipeg	-33	-35	30	23	5 887	28	84	535	2.1	0.35	0.42	0.49	0	0

Effect of Wind on Snow Accumulation on Roofs

9. In perfectly calm weather falling snow would cover roofs and the ground with a uniform blanket of snow. If this calm continued, the snow cover would remain undisturbed and the prediction of roof loads would be relatively simple; the design snow load could be considered as a uniformly distributed load and equal to a suitable statistical maximum of the ground snow load.

13. Flat roofs with projections such as penthouses or parapet walls often experience triangular snow accumulations that reach the top of the projections on the buildings, but usually the magnitude of the load is less than on roofs situated below adjacent higher roofs.

16. In special cases roofs have been designed with reduced design loads for areas of the country with large snow loads by incorporating into the roofs snow melting systems which throughout the winter periodically clear them of snow. However, a decision to use such a system should be considered carefully, because with possible future energy shortages, adequate energy may not be available for melting snow.

Minimum Roof Load

23. For roofs with a slope of 30° or less, Article 4.1.7.1. of the National Building Code provides for a minimum roof load of 1 kN/m² where the calculated snow load is less than this amount.

DETERMINATION OF DESIGN SNOW LOADS ON ROOFS

Basic Snow Load Coefficients and Modifications to the Coefficients

29. The minimum design snow load on a roof area or any other area above ground which is subject to snow accumulation is obtained by multiplying the snow load on the ground, S_o, specified for the municipality or area considered by the snow load coefficient, C_s, applicable to the particular roof area considered

$$s = C_s S_o$$

where s = design snow load in kN/m²,
S_o = ground snow load in kN/m²,
C_s = snow load coefficient.

30. The basic snow load coefficient is 0.8, except that for roofs exposed to the wind, under certain conditions to be described, this value may be reduced to 0.6.

33. On multi-level roofs the areas on the lower roofs that are adjacent to the higher roofs are subjected to heavier snow loads due to drifting. The coefficients for the increased load on the lower level of multi-level roofs are provided in Figure H-5.

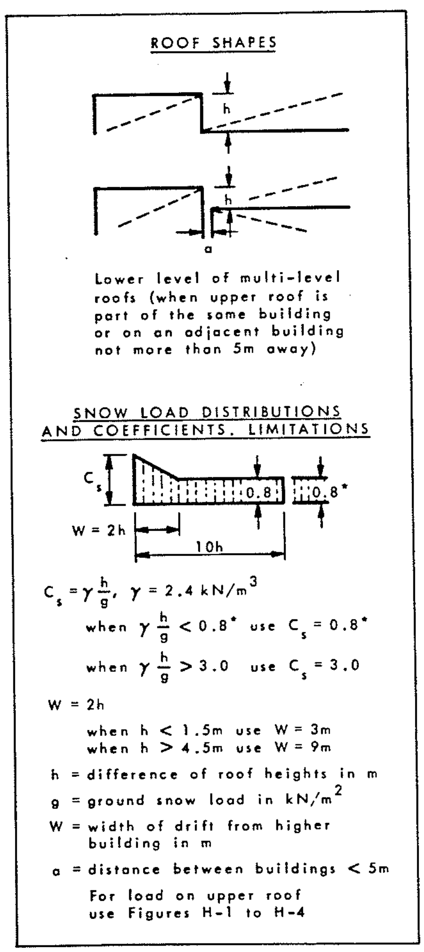


Figure H-5
Lower roofs of multi-level roofs

APPENDIX F

WEIGHTS OF MATERIALS

APPROXIMATE WEIGHTS OF MATERIALS

Soil, Etc.	lbs. per cu. ft.
Clay, damp	110
Clay, dry	63
Sand or gravel, loose & dry	90-105
Sand or gravel, wet	118-120
Topsoil, loose & dry	76
Topsoil, moist & packed	96

Stone	lbs. per cu. ft.
Granite	175
Limestone & Marble	165
Sandstone & Bluestone	147
Slate	175

Concrete	lbs. per cu. ft
With stone, reinforced	150
With stone, not reinforced	144
With Perlite	35-50
With Vermiculite	25-60

Fluids	lbs. per cu. ft.
Gasoline	75
Water at 4°C.	62.4
Water, ice	56

Metals	lbs. per cu. ft.
Aluminum, cast	165
Bronze, statuary	509
Iron, cast gray	450
Iron, wrought	485
Lead	710
Steel, rolled	490

Wood (12% MC)	lbs per cu. ft
Birch & Red Oak	44
Cedar, western red	23
Douglas Fir	34
Oak, white	47
Pine, southern	29-36
Redwood	28

Masonry (with mortar)	lbs. per sq. ft.
4" brick	35
4" stone or gravel	34
6" concrete block	50
8" stone, gravel, block	58
12" stone, gravel, block	90

From Site Design and Construction Detailing. By Theodore D, Walker PDA Publishers, West Lafayette. 1978.

Weight of Materials

BRICK AND BLOCK MASONRY		PSF
4" brickwork		40
4" concrete block, stone or gravel		34
4" concrete block, lightweight		22
4" concrete brick, stone or gravel		46
4" concrete brick, lightweight		33
6" concrete block, stone or gravel		50
6" concrete block, lightweight		31
8" concrete block, stone or gravel		55
8" concrete block, lightweight		35
12" concrete block, stone or gravel		85
12" concrete block, lightweight		55
CONCRETE		**PCF**
Plain	Cinder	108
	Expanded slag aggregate	100
	Expanded clay	90
	Slag	132
	Stone and cast stone	144
Reinforced	Cinder	111
	Slag	138
	Stone	150
FINISH MATERIALS		**PSF**
Acoustical tile unsupported per 1/2"		0.8
Building board, 1/2"		0.8
Cement finish, 1"		12
Fiberboard, 1/2"		0.75
Gypsum wallboard, 1/2"		2
Marble and setting bed		25-30
Plaster, 1/2"		4.5
Plaster on wood lath		8
Plaster suspended with lath		10
Plywood, 1/2"		1.5
Tile, glazed wall 3/8"		3
Tile, ceramic mosaic, 1/4"		2.5
Quarry tile, 1/2"		5.8
Quarry tile, 3/4"		8.6
Terrazzo 1", 2" in stone concrete		25
Vinyl asbestos tile, 1/8"		1.33
Hardwood flooring, 25/32"		4
Wood block flooring, 3" on mastic		15
FLOOR AND ROOF (CONCRETE)		**PSF**
Flexicore, 6" precast lightweight concrete		30
Flexicore, 6" precast stone concrete		40
Plank, cinder concrete, 2"		15
Plank, gypsum, 2"		12
Concrete, reinforced, 1"	Stone	12.5
	Slag	11.5
	Lightweight	6-10
Concrete, plain, 1"	Stone	12
	Slag	11
	Lightweight	3-9
FUELS AND LIQUIDS		**PCF**
Coal, piled anthracite		47-58
Coal, piled bituminous		40-54
Ice		57.2
Gasoline		75
Snow		8
Water, fresh		62.4
Water, sea		64
GLASS		**PSF**
Polished plate, 1/4"		3.28
Polished plate, 1/2"		6.56
Double strength, 1/8"		26 oz
Sheet A, B, 7/32"		45 oz
Sheet A, B, 1/4"		52 oz

Insulating glass 5/8" plate with airspace	3.25
1/4" wire glass	3.5
Glass block	18
INSULATION AND WATERPROOFING	**PSF**
Batt, blankets per 1" thickness	0.1-0.4
Corkboard per 1" thickness	0.58
Foamed board insulation per 1" thickness	2.6 oz
Five-ply membrane	5
Rigid insulation	0.75
LIGHTWEIGHT CONCRETE	**PSF**
Concrete, aerocrete	50-80
Concrete, cinder fill	60
Concrete, expanded clay	85-100
Concrete, expanded shale-sand	105-120
Concrete, perlite	35-50
Concrete, pumice	60-90
Concrete, vermiculite	25-60
METALS	**PCF**
Aluminum, cast	165
Brass, cast, rolled	534
Bronze, commercial	552
Bronze, statuary	509
Copper, cast or rolled	556
Gold, cast, solid	1205
Gold coin in bags	509
Iron, cast gray, pig	450
Iron, wrought	480
Lead	710
Nickel	565
Silver, cast, solid	656
Silver coin in bags	590
Tin	459
Stainless steel, rolled	492-510
Steel, rolled, cold drawn	490
Zinc, rolled, cast or sheet	449
MORTAR AND PLASTER	**PCF**
Mortar, masonry	116
Plaster, gypsum, sand	104-120
Plaster, gypsum, perlite, vermiculite	50-55
PARTITIONS	**PSF**
2 x 4 wood stud, GWB, two sides	8
4" metal stud, GWB, two sides	6
4" concrete block, lightweight, GWB	26
6" concrete block, lightweight, GWB	35
2" solid plaster	20
4" solid plaster	32
ROOFING MATERIALS	**PSF**
Built up	6.5
Concrete roof tile	9.5
Copper	1.5-2.5
Corrugated iron	2
Deck, steel without roofing or insulation	2.2-3.6
Fiberglass panels (2 1/2" corrugated)	5-8 oz
Galvanized iron	1.2-1.7
Lead, 1/8"	6-8
Plastic sandwich panel, 2 1/2" thick	2.6
Shingles, asphalt	1.7-2.8
Shingles, wood	2-3
Slate, 3/16" to 1/4"	7-9.5
Slate, 3/8" to 1/2"	14-18
Stainless steel	2.5
Tile, cement flat	13
Tile, cement ribbed	16
Tile, clay shingle type	8-16
Tile, clay flat with setting bed	15-20

Wood sheathing per inch	3
SOIL, SAND, AND GRAVEL	**PCF**
Ashes or cinder	40-50
Clay, damp and plastic	110
Clay, dry	63
Clay and gravel, dry	100
Earth, dry and loose	76
Earth, dry and packed	95
Earth, moist and loose	78
Earth, moist and packed	96
Earth, mud, packed	115
Sand or gravel, dry and loose	90-105
Sand or gravel, dry and packed	100-120
Sand or gravel, dry and wet	118-120
Silt, moist, loose	78
Silt, moist, packed	96
STONE (ASHLAR)	**PCF**
Granite, limestone, crystalline	165
Limestone, oolitic	135
Marble	173
Sandstone, bluestone	144
Slate	172
STONE VENEER	**PSF**
2" granite, 1/2" parging	30
4" granite, 1/2" parging	59
6" limestone facing, 1/2" parging	55
4" sandstone or bluestone, 1/2" parging	49
1" marble	13
1" slate	14
STRUCTURAL CLAY TILE	**PSF**
4" hollow	23
6" hollow	38
8" hollow	45
STRUCTURAL FACING TILE	**PSF**
2" facing tile	14
4" facing tile	24
6" facing tile	34
8" facing tile	44
SUSPENDED CEILINGS	**PSF**
Mineral fiber tile 3/4", 12" x 12"	1.2-1.57
Mineral fiberboard 5/8", 24" x 24"	1.4
Acoustic plaster on gypsum lath base	10-11
WOOD	**PCF**
Ash, commercial white	40.5
Birch, red oak, sweet and yellow	44
Cedar, northern white	22.2
Cedar, western red	24.2
Cypress, southern	33.5
Douglas fir (coast region)	32.7
Fir, commercial white; Idaho white pine	27
Hemlock	28-29
Maple, hard (black and sugar)	44.5
Oak, white and red	47.3
Pine, northern white sugar	25
Pine, southern yellow	37.3
Pine, ponderosa, spruce: eastern and sitka	28.6
Poplar, yellow	29.4
Redwood	26
Walnut, black	38

NOTE

To establish uniform practice among designers, it is desirable to present a list of materials generally used in building construction, together with their proper weights. Many building codes prescribe the minimum weights of only a few building materials. It should be noted that there is a difference of more than 25% in some cases.

From AIA Architectural Graphic Standards. By Ramsey/Sleeper. John Wiley & Sons, 7th edition. 1981.

WEIGHTS OF MATERIALS

MATERIAL	Unit Weight (pcf)
METALS, ALLOYS, ORES	
Aluminum	165
Brass	534
Bronze, 7.9-14% tin	509
Bronze, aluminum	481
Copper	556
Copper ore, pyrites	262
Gold	1205
Iron, cast, pig	450
Iron, wrought	485
Iron, spiegel-eisen	468
Iron, ferro-silicon	437
Iron ore, hematite	325
Iron ore, hematite in bank	160–180
Iron ore, hematite, loose	130–160
Irone ore, limonite	237
Iron ore, magnetite	315
Iron slag	172
Lead	710
Lead ore, galena	465
Magnesium	112
Manganese	475
Manganese ore.	259
Mercury	849
Monel	556
Nickel	565
Platinum	1330
Silver	656
Steel, rolled	490
Tin	459
Tin ore, cassiterite	418
Zinc	440
Zinc ore, blende	253
MASONRY	
Ashlar masonry	140–160
Brick masonry, soft	110
Brick masonry, common	125
Brick masonry, pressed	140
Clay tile masonry, average	60
Rubble masonry	130–155
Concrete, cinder, haydite	100–110
Concrete, slag	130
Concrete, stone	144
Concrete, stone, reinforced	150
SOLID FUELS	
Coal, anthracite, piled	47-58
Coal, bituminous, piled	40-54
Coke, piled	23-32
Charcoal, piled	10-14
Peat, piled	20-26
ICE AND SNOW	
Ice	56
Snow, dry, fresh fallen	8
Snow, dry, packed	12-25
Snow, wet	27-40

MATERIAL	Unit Weight (pcf)
TIMBER, AIR-DRY	
Birch	43
Cedar	22
Fir, Douglas, seasoned	34
Fir, Douglas, unseasoned	40
Fir, Douglas, wet	50
Fir, Douglas, glue laminated	34
Hemlock	30
Larch, tamarack	35
Larch, western	38
Maple	46
Oak, red	43
Oak, white	47
Pine, jack	30
Pine, ponderosa	32
Pine, red	28
Pine, white	26
Poplar	30
Spruce	28
For pressure treated timber add retention to weight of air-dry material.	
LIQUIDS	
Alcohol, pure	49
Gasoline	42
Oils	58
Water, fresh at 4°C (max. density)	62.5
Water, fresh at 100°C	60
Water, salt	64
EARTH, ETC. EXCAVATED	
Earth, wet	100
Earth, dry	75
Sand and gravel, wet	120
Sand and gravel, dry	105
VARIOUS BUILDING MATERIALS	
Cement, portland, loose	94
Cement, portland, set	183
Lime, gypsum, loose	53-64
Mortar, cement-lime, set	103
Quarry stone, piled	90–110
MISCELLANEOUS	
Asphaltum	81
Tar, bituminous	75
Glass, common	156
Glass, plate or crown	161
Glass, crystal	184
Paper	58
Grain, bulk, barley, corn	37
Grain, bulk, oats	26
Grain, bulk, rye, wheat	48
Fruit, bulk	38
Vegetables, bulk, potatoes, turnips	44

WEIGHTS OF MATERIALS

MATERIAL	Weight psf
CEILINGS	
Plaster board, per inch	5
Acoustic, and fire resistive ceiling tile per inch	2
Plaster, gypsum-sand, per inch	8
Plaster, gypsum-light aggregate, per inch	4
Plaster, cement sand, per inch	12
Metal lath	2
ROOFING	
Three-ply felt and gravel	5.5
Five-ply felt and gravel	6.5
Three-ply felt, no gravel	3
Five-ply felt, no gravel	4
Shingles, wood	2
Shingles, asbestos	3
Shingles, asphalt	2.5
Shingles, 1/4-inch slate	10
Shingles, tile	14
INSULATION, PER INCH	
Vermiculite, porous glass	2
Batts, rockwool, fibreglass	1
Fibreboard, rigid insulation	1.5
Cork board	1
Mineral fibre, sprayed	1
PARTITIONS	
Steel partitions	4
Solid 2" gypsum-sand plaster	20
Solid 2" gypsum-light agg. plaster	12
Metal studs, metal lath, 3/4" plaster both sides	18
Metal or wood studs, plaster board and 1/2" plaster both sides	18
Plaster 1/2"	4
Hollow clay tile 2 inch	13
3 inch	16
4 inch	18
5 inch	20
6 inch	25
Hollow slag concrete block 4 inch	24
6 inch	35
Hollow gypsum block 3 inch	10
4 inch	13
5 inch	15.5
6 inch	16.5
Solid gypsum block 2 inch	9.5
3 inch	13
MASONRY WALLS, PER 4 INCH OF THICKNESS	
Brick	40
Glass brick	20
Hollow concrete block	30
Hollow slag concrete block	24
Hollow cinder concrete block	20
Hollow haydite block	22
Stone, average	55
Bearing hollow clay tile	23

MATERIAL	Weight psf
FLOORING	
Hardwood, per inch	5
Sheathing, per inch	2.5
Plywood, fir, per inch	3.0
Wood block, treated, per inch	4
Concrete, finish or fill, per inch	12
Mastic base, per inch	12
Mortar base, per inch	10
Terrazzo, per inch	12.5
Tile, vinyl 1/8 inch	1.5
Tile, linoleum 3/16 inch	1
Tile, cork, per 1/16 inch	0.5
Tile, rubber or asphalt 3/16 inch	2
Tile, ceramic or quarry 3/4 inch	11
Carpeting	2
DECKS AND SLABS	
Steel roof deck 1½"—14 ga.	5
—16 ga.	4
—18 ga.	3
—20 ga.	2.5
—22 ga.	2
Steel cellular deck 1½"—12/12 ga.	11
14/14 ga.	8
16/16 ga.	6.5
18/18 ga.	5
20/20 ga.	3.5
Steel cellular deck 3" —12/12 ga.	12.5
14/14 ga.	9.5
16/16 ga.	7.5
18/18 ga.	6
20/20 ga.	4.5
Concrete, reinforced, per inch	12.5
Concrete, gypsum, per inch	5
Concrete, lightweight, per inch	5-10
MISCELLANEOUS	
Windows, glass, frame	8
Skylight, glass, frame	12
Corrugated asbestos 1/4 inch	3.5
Glass, plate, 1/4 inch	3.5
Glass, common	1.5
Plastic sheet 1/4 inch	1.5
Corrugated steel sheet, galv.—12-ga.	5.5
14-ga.	4
16-ga.	3
18-ga.	2.5
20-ga.	2
22-ga.	1.5
Wood Joists—16" ctrs. 2 x 12	3.5
2 x 10	3
2 x 8	2.5

From Handbook of Steel Construction, Canadian Institute of Steel Construction, Toronto. 1970.