HONG KONG, A CASE OF URBAN SETTLEMENT EXPANSION:
An Investigation of Implications of Waterborne and Hillside Development

By
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B. Arch., University of Minnesota (1974)

Submitted in Partial Fulfillment of the Requirements for the Degree of MASTER OF ARCHITECTURE IN ADVANCED STUDIES
At the MASSACHUSETTS INSTITUTE OF TECHNOLOGY June, 1978

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Chairman, Departmental Committee on Graduate Students
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HONG KONG, A CASE OF URBAN SETTLEMENT EXPANSION:
An Investigation of Implications of Waterborne and Hillside Development

By: Roderick C. Leung

Submitted to the Department of Architecture on May 12, 1978, in partial fulfillment of the requirements for the degree of Master of Architecture in Advanced Studies

The intention of this thesis is to examine the different possible approaches of development or construction over water and on the slopes. These ideas could be applied as a means to ease the problem of lacking buildable land in high density urban centers or simply to take advantages of the resourceful and stimulating environment that it could provided.

The organization of the thesis is in three parts. The first part outlined the conditions and needs of the settlement of Hong Kong as each settlement has its unique origin and path of development. The second part consists of a brief survey of the potential areas for waterborne and hillside developments. An alternative approach to the existing new town scheme is suggested. To further illustrate the potential of such approach, a light weight steel system for housing on the slope is presented. The last part of this thesis included some of the issues, concerns and a series of conceptual approaches for waterborne and hillside developments.

Thesis Advisor

Waclaw P. Zalewski,
Professor of Structures
PREFACE

In recent decades, cities around the globe, under the pressure of urbanization, face the demand of physical expansion. Primarily, this is due to actual population growth and the migration of rural settlement. For some already overcrowded, terrain restricted cities, which have been complicated by the demand due to the increasing personal income of their inhabitants, thus shortage of buildable land and unconscionable environment are evidenced. The physical environment system of an area at a point in time can be considered to consist of a set elements interrelated within an ecosystem. The environment as is perceived contains only those elements of image and idea derived from the physical environment through decision-making processes. The actual behavioral environment which elicits a behavioral response is a subset of the perceived environment.
With awareness of the potential richness of a place, my study presents a conceptual proposal of utilizing local available environmental resources and potential, under a certain assumed conditions for future development. In this case of my target city, Hong Kong, the uncertainties lay in the political and financial environs of the Colony.

The factors affecting human settlement, their forms of habitation, intercommunication and modes of living are many and complex. These can be varied from social, cultural and technological to economical contexts. Frequently, they are intertwined and difficult to be identified. Whether it is local or on a world scale, before a well balanced form of settlement becomes established, trials and errors may well play a part; and then this stabilized settlement pattern or form and its well being may be upset or even discontinued by an unmanaged external influence such as the transfer of ideas of an origin of different context.
The present settlement of Hong Kong was not seeded until the mid-nineteenth century. It consisted of small rural fishing villages sparcely scattered along the bays; and minor farming villages which were restricted by the hilly terrain. Briefly, there are two major factors that nucleus the settlement pattern of Hong Kong. They are the financial development and the population growth of the Colony. The development of Hong Kong into a commercial center began with the founding of the Hong Kong Island as a British Colony in 1842 as
a result of the so called First Opium War under the Convention of Chuengi, January 20, 1841. Before that time, the British found themselves without a station for their merchant fleet to use in order to trade with China. Later on, the Kowloon Peninsular was leased under a perpetual term. By the Convention of Peking on June 9, 1898, New Territories were leased for 99 years. The move was claimed to be directly against France and Russia for territorial reasons.

With the great advantage of her natural harbour, Hong Kong earned her livelihood predominantly as a entrepot, with only a minor disruption by the Japanese in the Second World War, until the United Nations imposed an embargo on trade with China in 1951 for her involvement in the Korean War. The growth in Hong Kong's entrepot trade was seriously disrupted as China was the most important market for re-exports. At about the same time, a large number of people fled from China as a result of the Civil War, and among these migrants were entrepreneurs with capital.

As a matter of survival, Hong Kong, with limited natural resources, had to seek and develop an alternative source of income. The logical and only alternative was found in the manufacturing sector, which took advantage of the presence of a flooded labor force, capital and, most of all, the growing demand for manufactured goods in the world market in the post-war
was found in the manufacturing sector, which took advantage of the presence of a flooded labor force, capital and, most of all, the growing demand for manufactured goods in the world market in the post-war period. By 1962, the domestic manufacturing industries were well established on a solid ground. The manufacturing sector has always been and still is the largest employer, accounting for over 40 percent of the number employed. There is evidence that a more rapid growth was experienced in the commercial and financial sectors in the early seventies than was experienced in the manufacturing sector. This seems to be a logical development as the success in the industrial trade accumulated a certain amount of recyclable capital, combined with an absence of exchange controls, made Hong Kong especially attractive for international financial activities. The role of Hong Kong as a leading financial center for the region increase as the author perceives it. On the other hand, the manufacturing sector will adjust itself to produce a higher quality products to meet the challenge of trade restriction as well the challenge from other developing nations. Looking backward, it appears that the economy of Hong Kong has been dynamic and flexible enough to adapt the new economic environment as she enjors a growth in
The population growth of Hong Kong was at a dramatized proportion since 1851 to the late 1960's due to the migration primarily from the mainland of China. Because of the compactness of Hong Kong, the population growth and her physical environment are intertwined. In just six years since her colonization, the population tripled to 23,900 persons and by 1859, there were over 85,000 residents. The dramatic increase of population could not be anticipated by the administration and, as there was no planned provision of accommodation for the newcomers, living conditions soon became exceedingly congested. By 1865, there were 125,000 persons settled in the Colony.

A report by Dr. Ayres, in the Hong Kong Government Gazette 1874, said that houses were found commonly occupied by three to eight families per room which were in a filthy state and were constructed without any regard for basic sanitary requirements. Up until this period, development was heavily concentrated along the western coast of the northern shore of Hong Kong Island. Because of the steep terrain, a series of reclamations had taken place to provide room for new urban growth. On the level site, houses were com-
Fig. 3 Aerial view of the development of Hong Kong Island, in 1935. Since 1850's, development was heavily concentrated along the west section of the northern shore of Hong Kong Island. Because of the steep terrain, a series of reclamation were taken places to provide room for urban growth.

monly built back-to-back, whilst on slope sites, buildings had a narrow lane along the face of the embankment seldom more than five feet wide. Tenement houses were constructed so that each floor was one undivided room. Each floor was usually leased to a separate tenant and then sublet to other families; severe overcrowding became a way of life. The drainage system was very elementary and water supply was not adequate; some families had to obtain their supply from public standpipes at a limited time of the day. The neglected and inadequate basic public health requirement led to a outbreak of the bubonic plague in 1894. An ordinance was passed intended to control the overcrowding condition; the standard measurement per living unit being 30 square feet of floor area and 400 cubic feet of space per occupant.
In 1898, the New Territories were leased from China. By 1921, the population jumped to 625,000 from 457,000 in 1911. Of the total, 123,000 resided in the rapidly developing Kowloon Peninsula where extensive reclamation had been carried out. Some proposals were forward in 1923 recommending to decentralize the population into new self contained communities and to reduce building density.

In 1947, after the Japanese occupation in WWll, the population reached 1.8 million. The housing problem became even worse as a consequence of the civil war in China. Thus, by 1950 the population was standing at 2.1 million as the houses were filled to capacity. People literally overflowed into the streets and erected overnight large squatter settlements on the urban periphery, on the roofs of buildings and in sheltered coastal embarkment on boats.
By 1951, the government started to establish 'approved' areas, in which squatters could build cottages made of fire resisting materials. 'Tolerated' areas were also created in which poorer families were allowed to erect wooden huts. The population of the Colony had increased by 30 percent to 3.13 millions in 1961, since 1956. Over 83 percent of the population lived in the main urban areas of Hong Kong, Kowloon and New Kowloon where the average density of some congested areas came to 963 persons per acre and over 500,000 households were inadequately housed.

Fig 5 By 1950, the population was standing at 2.1 millions as the houses were filled to capacity. People erected overnight large squatter settlements on urban periphery. 'Tolerated' areas were created in which poorer families were allowed to erect wooden huts.

In order to stimulate a greater participation by the private sector in housing construction, new building ordinance was introduced in 1956. As a result, the high intensity of development with high residential occupancy rates, imposed severe strains on the urban transportation system, created considerable problems in the
delivery of utility services and also added to the congestion of areas which were already deficient in open spaces and community facilities. It was consequent ly found necessary to control the runaway development. In 1966, new regulations, which were introduced in 1962, were adapted, reducing the plot ratio and site coverage. During the 'period of grace' between 1962 and 1966, there were large volume of private residential development, most of which was concentrated in the old inner suburbs. Thus, within the span of ten years, the urban form of Hong Kong underwent transformation as a result of which blocks of buildings of up to twenty stories replaced the earlier four to five story buildings. The 1962 zone regulations also began to shape the city form. In 1966, the population had increased to 3.7 million and nearly 60 percent were without adequate accomodations.

Fig 6. As a result of the new building ordinance, 1956, which was intenited to stimulate private sector in housing construc- tion, the high intenised development imposed severe strains on transportation and utility services, and also added to the areas which were already deficient in open spaces and commu- nity facilities, additional congestion.
Thus, there was an average of 1.29 households for each living quarter. In other words, over 182,000 households made up of 785,000 persons had to share accommodations with other families. Furthermore, there were still over 295,000 persons who lived in subdivided structures.

The census also indicated a shift of population from many of the older, congested central districts to areas of the developing New Territories. To a large degree, this outward shift is the result of the location of government-aided housing estates and industrial sites in such satellite towns as Tsuen Wan, Castle Peak and Shatin in order to release some pressure off the inner areas. The plain fact is that in addition to the population growth and immigration problem relating to housing, physical expansion is still a challenge to the government and the private sector of the Colony.

The 1971 census indicated the population of the Colony was at 3.9 million, of the total 3.5 million lived in the compact metropolitan areas of the harbor. Within 802,500 households occupied 617,900 living quarters.
RECENT ECONOMIC GROWTH AND ITS IMPACT ON PHYSICAL EXPANSION: NEW TOWN DEVELOPMENTS

Since the embargo by the United Nations on trade with China, rapid economic changes have led to Hong Kong's present position as a major center for industries, trades and finances. The presence of mass population, the arrival of established entrepreneurs from Shanghai, the growing purchasing power and consuming levels of international markets, provided the environment for domestic manufacturing industries, despite the fact that all raw materials have to be imported. The manufacturing sector has been and still is the largest employer, accounting for over 40 percent of the total employed.

Average annual rates of growth in the world trade were 5.3 percent from 1950-1958; 7.4 percent from 1958-1967 and 10.2 percent from 1967-1973. The postwar liberalization of trade up to the Dillion round of tariff reductions implemented in 1962 contributed to an average annual growth rate of 14.7 percent in the value of domestic export between 1961-1967. The Kennedy round which was implemented in 1968, stimulated an annual growth rate of 19.5 percent between 1967-1973, but about nine percent of the points were accounted for by price increases.
Most manufacturing industries, particularly clothing, are under tariff restrictions which are defined in terms of quantities and have so given manufacturers the incentive to produce higher quality products, partially to offset the high cost of speculation. Also Hong Kong industrialists have responded to the increasing competition from the developing countries in the region by continuing to modernize their operations and by moving into more sophisticated product lines. But there is indirect evidence that because of the more rapid growth experienced in the commercial and financial sectors in the early seventies, the relative importance of the manufacturing sector has been reduced. The economy of the Colony had developed large and diverse financial and commercial sectors during her early years because of her manufacturing and export sector which is a precondition of the present strong currency.

The statistics of M1 and M2 (see chart) which monitor the monetary volume, represents a summary of Hong Kong's economic progress. M1 reflects the domestic economy as a whole. M2 reflects the time and saving deposits, in other words, the accumulated cash for re-finance. The period from 1961 up to 1967-68 of the civil disturbances, both M1 and M2 grew smoothly, with M1 growing at an average annual rate of 12 percent and M2 at a faster rate of 16 percent. After 1968, the two series
expanded continuously strong, with \( M_1 \) at 18 percent and \( M_2 \) at 21 percent. It is possible that the strong growth of \( M_2 \), may reflect the rapid expansion of the financial sector and in particular Hong Kong's role as a financial entrepot. Another indication of Hong Kong's international financial activities is the bank's consolidated statement of liabilities and assets. During the 70's, the amount of the bank's liabilities increased from 2.2 billion to 66.3 billion with 21.1 billion outstanding.

As a result of the rapid increases in industries, trades and finances, activities in all sectors of the economy are stimulated along. The steady economic growth brought equally rapid increases in domestic income at all levels.
Consquently, spending on all consumer goods rises particularly those commodities which have been inadequate, mainly living space.

Hong Kong, as a fact, faces limited suitable land for development. Much of the land is hilly and the rest scattered and surrounded by water, of the total 404 square miles, only 12.4 percent or 50 square miles has been developed. With the available capital, the discontented environment of the living conditions is now being improved at the expense of the overall natural landscape. The limitations of the terrain and the demands of the expanding economy impose constraints on the natural environment of the settlement.
With the limitations of the terrain and the demands of the rapid expanding economy, it imposes constraints on the natural environment of the settlement.

Activities in public sector expenditure of such economic and social infrastructure as transportation, educational and medical facilities, housing estates, new towns for settlement and industrial developments were stepped up.

Over $4.2 billion transportation system is planned and is well under construction to relieve the congested areas and open up outlying areas through the 1990's. The phase one of the $1.7 billion twin-tube mass transit is expected to be completed in the early 1980's. Arterial expressways along the shorelines and looping around the foothills in Kowloon including a section of underground freeway beneath the airport are well under construction.
Tunnels are being built on Hong Kong Island and the Lion Rock on Kowloon. With the completed cross harbor tunnel, a direct north-south connection for the Colony is achieved. Bridges are approved or understudying to provide accesses to the islands of Aplichan, Lantau and Tsing yi. Most of all, another one is suggested over the eastern end of the harbor connecting Hong Kong to Kowloon. The Kowloon-Canton Railway line with a $1.0 billion improvement plan will be carried out in the next ten years.
In order to improve the service efficiency to all sectors and to release some of the pressure on the congested and chaotic urban areas, new towns on marginal and reclaimed land through the public and private development have been introduced. A new department known as the New Territories Development Department was established within the Public Works Department in 1973. It is responsible for planning and developing the new towns, in consultation with the New Territories Administration, the Housing Authority and other governmental departments. Public housing has been given high priority in the planning of the new towns, and private residential developments are being strongly encouraged.

Shatin, to the north of Kowloon Peninsula, includes a plan for 500,000 residents by 1985 in an area of 1,740 hectares. Tsuan Wan, a new town for 900,000 people by 1986 is well underway at the southwest of the New Territories. Tuen Mun, a new town for 480,000 at the western end of New Territories occupies an area of 540 hectares including an independent port. Master plan of transportation network, incorporated with the future development of the whole Colony, is already at the stage of construction. The physical expansion is at a race with time or rather lives under the shadow of the prosperity of her world trade. At such a fast pace, some of the developments indicate that the potential of the city development with its landscape has not been fully explored.
Fig 11 Shatin New Town Plan. Majority of the new town development will occupied on the reclaimed land.

Fig 12 Aerial photograph shows the natural landscape form of the Shatin New Town site. As can be seen on the photograph, part of the land had been reclaimed.
Fig 13 Tuen Mun New Town Plan. By means of reclamation, as of for Shatin, flat land is made available for new construction.

Fig 14 Aerial photograph shows the natural landscape form of the Tuen Mun New Town site.
PROPOSAL

ALTERNATIVE APPROACHES FOR NEW SETTLEMENT: WATERBORNE

Over three quarters of the surface of the earth is covered by water. Under the conditions of limited buildable land, or to a lesser extend, simply taking advantage of the resourceful and stimulating environment, the idea of waterborne development has been demonstrated by projects such as the Ponte Vecchion in Florence; Chateau de Chenonceau on the River Cher near Paris; Edgar J. Kaufmann House in Bear Run, Pennsylvania; Palace Pier in Brighton, England.

Fig 15 Aerial view of a water village in Mexico. A well established human settlement on water.

Fig 16 Ponte Vecchio, 13th century, over the Arno River in Florence. A mixed-use structure for commercial and residential activities.

Fig 17 Palace Pier, 1891-1899, in Brighton, England. A linear mall of shops and entertainment facilities extended 530 meters over the sea.
Even in the land-rich America of the nineteenth century, the cities were impatient with their natural water boundaries. Almost 60 percent of the old city Boston was under water, including the entire Back Bay District; the Chicago lakefront contains more than 2,000 acres of land that were once under the surface of Lake Michigan. More recently, Port Grimand, a French water-town was completed in 1972, in the Gulf of Saint Tropez on the Mediterranean coast of southern France.

The use of water frontier for urban development has also been applied through history. Venice was first settled as a refuge by mainlanders fleeing Atticas hordes in the fifth century. The Netherlands have begun reclaiming a large area of the delta areas of the River Rhine, Maas and Scheldt in the thirteenth century.
A scoreful of proposed projects and studies such as the Triton City, made up of a proto-type floating neighborhood community of 5,000 residents was suggested by the Triton Foundation under the direction of Buckminster Fuller; the Sea City for 33,000 inhabitants, floating off the coast of England, was proposed by the English architect Moggridge and Martin; the Urban Matrix proposed by Stanley Tigerman of Chicago; a residential bridge for Zurich was proposed by architect Hugo Wandeler; the Urban Expansion Plan for Helsinki was suggested by a group of Finnish architects and the Tokyo Plan proposed by Kenzo Tange Group, further illustrated the ideas and possibilities of utilizing the natural landscape. Basically, there are some common constraints and factors that might alter the planning and design of waterborne development. Some of these constraints and factors are included in Appendix B.
HILLSIDE

On the other hand, many metropolitan areas under physical expansion, either due to real population growth or economic expansion, face with the constraints of high slope ratio of its surrounding terrain. Cities such as Los Angeles, Caracas, Hong Kong, Honolulu Pittsbury and San Francisco are in these categories.

Traditionally, the security of the hilltop was chosen for its inaccessibility. Many fortified structures were positioned on these peaks, both for the self-security and the commanding view. Gradually, settlement sprang up around the peaks. The towns of Assissi, Sienna and Urbino of Italy; Monteferio, Setenil, Cuevas de Almanzora on Iberia Peninsula are some of the examples. Other settlement appeared on hill top or slope for the advantages of the external environment provided, such as

Fig 22 Citadel, Machu Picchu of Peru. Inca, a well established civilization in the 15th century. The settlement located on a high altitude.

Fig 23 Santorini, a hill-town on the island of Thera, in the Aegean Sea. With the advantages of self-security and the commanding view.
less exposure to the sun or the natural cooling effects of the unobstructed wind. Building or buildings which integrated with the natural terrain, can be illustrated by the Spanish Steps in Rome, Italy; the Acropolis in Athens, Greece; Djenaneel-Hasan Housing in Algeria; Tourist village in Torre de Mare, Italy; Halen Estate near Bern, Switzerland or the Scarborough College in Toronto, Canada.
AN ILLUSTRATIVE PLAN

In addition to the assumption that the population and economic growth will continue, in order to arrive a valid master plan for urban expansion, further study has to be conducted with respect to the following issues.

Climatic and Geological Elements
Soil Conditions (Slope and Waterbed)
Wind and Currents (Seasonal and Occasional)
Infrastructure Network
Circulation and Transportation (Public and Private)
Utility Services Water
Sewage
Electricity

Land Use
Desirable Pattern and Density
Open Space
Feasibility
Costs of Construction
Method of Finance

POTENTIAL SITES FOR ALTERNATIVE DEVELOPMENT
1 KUNG TONG, industrial district
2 protected open water for recreation
3 bridge
4 operable bridges
5 artificial island as break-water
6 operable channel (for water circulation)
7 ferries
* open space

ALTERNATIVE APPROACH AN ILLUSTRATION
A HYPOTHETICAL HOUSING PROPOSAL

EXISTING PUBLIC HOUSING

In 1952, a first attempt to release the severe shortage of housing in the Colony by the newly formed Hong Kong Settlers Housing Corporation to provide publicly financed cottages fell short. About the same time, the Hong Kong Housing Society, an independent voluntary agency, with government loan and land subsidies to provide public housing based on mass production technique was incorporated. After the 1953 disastrous fire in a squatter settlement, the government stepped up its participation and initiated an emergency program to build basic resettlement accommodation. By 1957, 120,000 persons were sheltered under the program. In the next 5 years, the population increased by 30 percent from 2.4 millions to 3.13 millions. There were nearly half-a million households or 2.2 million persons were living in inadequate conditions. To challenge the demand, a government low-cost housing scheme was introduced in 1961 and in the next five years nearly 70,000 persons were benefited by the new program. The success of it carried into the seventies and by 1975, over 650,000 persons were living in one of the estates under the management of Hong Kong Housing Authority which was established in 1973 under the Housing Ordinance 1973.
The intention of this housing program is to accelerate the housing ownership in the private sector. This program also enable the public sector to recovery the cash flow in a relative short period of time and can be cycled for other beneficial investment. This project will be incorporated with the New Town Development Plan on land designated for private residential use. The proposing housing project is initially financed and constructed by a public agent. The relative higher costs for infrastructure on slope site development could be offset by the high land value due to its location and environmental qualities, this program permits the qualified occupants to purchase the unit, air right and partial access to the site which is fully owned and managed by the co-operation found by the new owners.

UNIT AREA REQUIREMENTS

Three reports of different sources are presented here for comparation: the existing public housing unit sizes as in the Hong Kong Housing Authority Annual Report 1975-76; a table formulaed from the suggestions of three U.S. governmental agents (H.U.D.,U.D.C. and H.R.A.) prepared by Loren Ahles, Master Thesis 1977, Massachusetts Institute of Technology; and a study conducted by BIRG of Cheng Kung University, Taiwan.
Based on the substantial improving living standard of Hong Kong and the increasing purchase power of the residents, the last of the three reports by the BIRG, Cheng Kung University, is adapted as primary references. For simplification, the negligible cultural and living habits indifference is omitted. Further research and study are needed to determine the actual conditions for such program.

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Area in Square meters


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<td>8.10</td>
<td>8.10</td>
<td>8.10</td>
<td></td>
</tr>
<tr>
<td>Bedroom 2</td>
<td>7.29</td>
<td>7.29</td>
<td>7.29</td>
<td>7.29</td>
<td></td>
</tr>
<tr>
<td>Bedroom 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedroom 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bath</td>
<td>2.52</td>
<td>2.88</td>
<td>3.24</td>
<td>3.24</td>
<td>3.60</td>
</tr>
<tr>
<td>Closet/Storage</td>
<td>1.08</td>
<td>1.62</td>
<td>2.16</td>
<td>2.70</td>
<td>3.24</td>
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<tr>
<td>Gross Area</td>
<td>16.58</td>
<td>26.14</td>
<td>39.19</td>
<td>50.09</td>
<td>63.70</td>
</tr>
</tbody>
</table>

Area in square meters

Fig 27 A suggested area requirements for public housing units for Taipei, Taiwan conducted by BIRG of Cheng Kung University, Taiwan.
**DESIGN CONSIDERATIONS**

*To develop an approach which can be adjusted to the slope terrain.*
*To adapt a structural system of light weight components to reduce dead loads on the foundation.*
*To unify the construction process and details for a better efficiency.*
*To take in consideration of labor, transportation and material costs.*
*To provide the units with flexibility for adaptation and changes.*
*To utilize the interior and exterior spaces for daily activities.

*To provide direct access for the units to private and public outdoor courts and terraces.

*To provide identities for the units and the cluster neighborhood in order to achieve a visual sense of personality and individuality, and sense of place and orientation.

MODULAR DIMENSION / UNIT SIZE

<table>
<thead>
<tr>
<th>Modular Dimension (M)</th>
<th>Unit Size in Square Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>M²</td>
<td>3.9m</td>
</tr>
<tr>
<td>1.5M²</td>
<td>15.21</td>
</tr>
<tr>
<td>2M²</td>
<td>22.82</td>
</tr>
<tr>
<td>2.5M²</td>
<td>30.42</td>
</tr>
<tr>
<td>3M²</td>
<td>38.02</td>
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<td>4.5M²</td>
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</tr>
<tr>
<td>5.5M²</td>
<td>76.05</td>
</tr>
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<td></td>
<td>83.65</td>
</tr>
</tbody>
</table>

Unit Size in Square Meters
For slope OX, with slope ratio of about 1:2, due to its steepness, special consideration are necessary in order to minimize the possibility of the occurrence of structural failure (see Appendix B). The following section is a study of modulated housing on such a slope. The mean angle of inclination of OX, is $32.03^\circ$, thus the modular dimension being chosen for study is 4.2m.
UNIT CONFIGURATION

17.65 m²

26.46 m²
SITE ACCESS PLAN SCHEMATIC

SITE ACCESS SECTION SCHEMATIC

Key:
- Horizontal circulation
- Vertical circulation (mechanical means: vertical or inclined, could be integrated with multi-stories structure)
- Circulation on slope (pedestrian)
- Vehicle access (transportation & services)

Note:
The distance between M & N and the distance between the vehicle service roads are determined by the volume of users and the distance to the units being served.

NOTE:
This is based on the assumed preference of maximum vertical pedestrian movement with no mechanical assist to be up 3 stories or down 4 stories.

PO is 8 story rise or about 22 meters.
PARTIAL BUILDING PLAN AN ILLUSTRATION
STEEL CHANNEL BEAM 4.0M
STEEL JOIST intermediate beam 4.2M
STEEL CHANNEL as alternative to steel joist 4.2M
METAL DECK 2.1M/2.7M

STRUCTURAL COMPONENTS

PANEL DIMENSIONS (cm)

P opaque
Q translucent (fixed or projected)
R clear (fixed or projected)

EXTERIOR PANEL COMPONENTS
FRAMING VARIATIONS

BUNDLED COLUMN VARIATIONS
connections by welding

steel bearing plate
positioning device

10x10 cm steel column

8x8 cm L welded to column
20x8 cm E beam bolted to angle

column welded to base plate

cast-in foundation network on slope

earth

SECTION AT COLUMN
coping
caulk on both sides

built up roofing
roof insulation

coping
caulk on both sides

concrete floor on steel deck
shear wire transverse reinforcing

25 cm open web steel joist

20 x 8 cm C beam

caulk at joints

operable window (projected)

reinforced metal stub

clipped on exterior finish panel

1.5 cm gypsum wallboard

noise deadening board

metal furring channel

1.5 cm fire-rated gypsum board
built-up roofing

concrete floor on steel deck

25cm open web steel joist

fiber insulation (roof only)

20 x 8 cm beam

1.5 cm gypsum board

metal framing stub

fill with insulation when required

finish floor (carpet, wood or tile)

noise deadening board

metal furring channel

1.5 cm fire-rated gypsum board

SECTION AT INTERIOR BEAM
- coping with handrail above if required
- caulk on both sides
- cap flashing
- reinforced metal stub panel
- built-up roofing
- clipped on exterior finish
- fiber insulation as alternative to rigid insulation on top of concrete deck
- operable door
- rigid insulation
- wood decking, ceramic tile or cement topping on terrace
- noise deadening board
- shear wire transverse reinforcing
- fiber insulation as alternative

SECTION AT ROOF TERRACE
APPENDIX A

WATERBORNE DEVELOPMENTS

The behavior of water waves in open sea is one of the most intriguing and probably one of the least understood of nature's phenomena. While any kind of disturbance in water is likely to generate waves, there are three prime natural causes: earthquakes, tides, or winds. Waves manifest themselves by curved undulations of the water occurring at periodic intervals. Water disturbance is distributed to a considerable depth, as the depth of the water has an effect on the character of the wave. When the wave reaches shallow water where the water is equal to about one and one-quarter of its height, the wave will break.

*Fig 29* Orbital motion related to wave propagation and decreased in wave amplitude and orbital radius with decreasing water depth.
Size of wave: The size of a wave at a particular time for a location will depend upon the velocity of the wind, the duration of the wind and also the direction of the wind.

<table>
<thead>
<tr>
<th>Wind Velocity in knots</th>
<th>Length of fetch in feet</th>
<th>Distance in hours</th>
<th>Average of the highest length (feet)</th>
<th>Period when most energy is concentrated (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10</td>
<td>2.4</td>
<td>0.9</td>
<td>4</td>
</tr>
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<td>15</td>
<td>34</td>
<td>6</td>
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<td>20</td>
<td>75</td>
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<td>10</td>
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<td>25</td>
<td>160</td>
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<td>30</td>
<td>280</td>
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<td>40</td>
<td>710</td>
<td>42</td>
<td>28</td>
<td>57</td>
</tr>
<tr>
<td>50</td>
<td>1420</td>
<td>69</td>
<td>48</td>
<td>99</td>
</tr>
</tbody>
</table>

*Fig 30 Conditions in fully developed seas.*

Diffraction: The typical example of wave diffraction occurs in a harbor protected by breakwaters. The gap in the breakwater which serves as a circulation channel admits a certain amount of waves into the otherwise still water of the protected area.

*Fig 31 In the absence of defraction, sequence of waves passes an obstacle, the wave energy originally concentrated between b and c is spreaded between a and c.*
Refraction: Refraction simply means bending. A simple example is that of a set of regular waves approaching a straight shoreline at an angle. The inshore part of each wave is moving in shallower water, and consequently moves slower. The result is that the wave fronts tend to become parallel to the shoreline. The effect of refraction is the concentration of wave energy against the headland.

![Diagram of wave refraction](image)

**Fig 32** When approaching the shore, the friction of the bottom causes wave to slow down. Thus, it causes a straight wave front to bend until almost parallels the shoreline with the energy relatively concentrated at the headland.

Reflection: Nonbreaking waves acting on a vertical wall, cliff or steep beach do not lose their energy by the impact but are reflected. As a matter of principle, it is desirable to destroy the wave energy inside a protected area as soon as possible, and not to allow
it to be reflected back and forth. There are many method to minimize wave reflection. Breakwaters should be aligned in such a way that the reflection are not directed toward other installation. Slope can be designed for the wave to break.

![Diagram showing wave reflection and smooth bottom](image)

**Fig 33** Under an isolated condition, standing wave patterns may occurred in which the water particles move as indicated. It exerts relatively little force on the structure that reflects it. Virtually, any obstacle will reflect some part of the wave energy.

**FOUR CONCEPTUAL SOLUTIONS FOR WATERBORNE DEVELOPMENT:**

Conceptually, there are four ways of building on water:

**LAND FILLING** This is the basic method for building in the water, involving simply the displacement of water with other materials. This method is practical at shallow depth (0-20') when fill is readily available. But because fill is paid for by volume of filling, the cost rises directly as the depth of the water increases.
In the scheme as shown below, the great weights of the buildings are carried by casson to the firm underbottom. The sides of the island are armored with waves and current resisting materials.

POLDERING Dry land are made by putting up dikes to restrain the waters, and exposing the former sea bottom or lake bottom, as shown in the following diagram. The dikes themselves are built much like long strips of landfill, pumping system usually included as part of the concept to pump out any seepage along with rain water. Polders are generally more economical than landfill for reclaiming large areas because less material is used. So far, the deepest polder in the Netherlands, near Rotterdam is twenty one feet below sea level.

PILING This system has been used to support many water structures, from the wooden poles on which most of Venice rests to the gigantic steel or concrete structure that support offshore oil-drilling platforms. If they are intened to hold up any kind of permanent structure, they must be driven into firm bottom soil. Piling has two important advantages over the previous methods of land filing and poldering. Structure can be erected at greater practical depths and, instead of blocking normal water currents, they permit them to pass underneath. This could reduced the impact of destructive wave and current. The deepest known piling
installation is an oil platform in 300 meters of water in the North Sea.

FLOATING This concept of support on water has been applied in designing airports, oil rigs and housing projects. Floats, the most flexible form of building on water, can be moored at varying depths without increasing their cost and can be moved from one location to another. A floating structure can be built in shipyards or drydocks and tow to the building sites, using the sea itself as a highway. In most cases, water depth of 30 feet and above is sufficient to float an average load of 20 storeies above the water surface. As a rule, floating structures cost more than other methods of building on water.

Principles applicable to design of offshore foundation are basically similar to those used in design of foundation for land and waterfront structures. The design is frequently burdened, however, by certain factors characteristic of offshore construction; such as load on individual foundation units may be far greater than those encountered in land structure because of the large wind and wave forces and high overturning moments; soil data are difficult and costly to obtain; the form of foundation structures varies so widely from land practice that experience with conventional land construction is not always fully applicable.
Fig 34 FILLING Costs are directly proportional to the volume of material used; therefore it is more feasible to apply on relative shallow water (0'-20').

Fig 35 POLDERS Large area can be reclaimed by this method as compared to the amount of materials used for building the surrounding dikes.
piles allows currents to pass through, thus reducing the impact of the destructive waves. Piles can be of concrete or steel but measurement has to be taken due to electrolysis.

Fig 36 PILES: This can be used in deep water (over 100m.) and has an advantage of allowing currents to pass underneath.

network of anchors to stabilize the structure from drifting. Foundation can be of concrete or steel and also subject to electrolysis.

Fig 37 FLOATING: This can be used in deep water to any depth and the water provides mobility and serves as a means of highway for transportation of the structure itself.
HILLSIDE DEVELOPMENTS

Natural slopes are formed by and exist due to geologic processes. After the formation of natural slopes, they are under constant various forces which tend to eliminate or flatten the formed slope. In evaluating the stability of slopes, the force due to gravity is the prime consideration; whenever the total forces overcome the internal resistance, a landslide or land transformation occurs. Other influences besides gravity include the action of wind, water and ice; loads on the slope surface; seepage of underground water; vegetation chemical or temperature changes; occurrence of earthquakes and other environmental conditions. The slope, in accordance with its geometry and the properties of its component materials, provides resistance to the composite effect of the acting forces.

PHYSICAL PROPERTIES OF SUB-SOIL

The most apparent important physical characteristic pertaining to stability of material comprising a slope is its shear strength. However, the overall shear strength of the slope material is not the only element,
a specific potential failure surface within a soil or rock mass may alter the ultimate resistance of a slope to failure.

Cohesionless soils: These group consists of gravels, sands and silts or combinations thereof, which have no cohesion between the grains. The only source of shear strength is the friction between the grains. Fine-grained soil such as inorganic silts exhibit apparent cohesion due to normal forces caused by capillary moisture; these apparent shear strength disappears on complete saturation or complete drying. However the important property of cohesionless soil is the ability of a material to lose its frictional strength because of a reduction in normal pressure due to seepage forces. An extreme example is the liquefaction phenomenon which occurs in a loose, saturated cohesionless soil due to densification caused by vibration, shock, or simply dilation. The seepage pressure reduces the normal pressure between grains to zero, thus transforming the soil temporarily into a liquid condition. Soil of loose sand and saturated silt are considered to be unstable and capable of liquefaction and ultimate failure.
Saturated clays: These are clays which, when completely saturated and subjected to shear stresses with no change in water content, develop their shear strength independent of the applied external stress. For simplification, a constant shear strength equal to one half the maximum unconfined compression strength can be used for design. However, these soils are subject to lose in strength with time, a common phenomenon in plastic materials. Also there is the possibility that soil may crack due to drying and that the crack may latter fill with water, exerting a hydrostatic pressure on the sides of the crack. Also clays which once had shrinkage cracks that subsequently healed, may have hidden planes of weakness.

Partilly saturated clays and soil mixture: For clays which are partially saturated, and for all soil mixtures containing sufficient sand, gravel or silt so that the volume can change almost as fast as a load is applied, the soil may be considered to have a shear strength of a combination of friction and cohesion.
Under no external forces in the slope but the dead weight of the homogeneous soil, the shear strength can be illustrated graphically by a Mohr Failure Envelope (see diagrams). The nature of the envelope depends up the type of soil. In a report prepared by the National Academy of Science, three types of soil have been considered: cohesionless soils; saturated clays; and partially saturated clays and soil mixtures.

**Fig 38 Saturated Clay:** When completely saturated develop its shear strength independent of the applied external stress.

**Fig 39 Partially Saturated Clay and Soil Mixture:** These can be considered to have a shear strength of a combination of friction and cohesion.
EXTERNAL ENVIRONMENT

Surface of the earth is constantly in a state of change due to natural processes, new slopes are formed and they are subjected to the process of transformation. The slope can be categorized into level land (0-5%), slight slope (less than 25%) and steep slope (greater than 25%). The overall environment of the slight slope is similar to level land. On the other hand, steep slope is very much different. Especially on a steep slope, the exposure to the sun, the unprotected wind and runoff water are the major causes of the local environmental changes which affect the soil properties in the long run.

Light: Different plants require different minimum qualities and quantities of light for satisfactory growth. The amount of solar energy, that a slope receive, is made up of direct sunlight and diffused radiation from
the sky and the surrounding landscape. Therefore the orientation of the slope affects the growth of plants which can be used as a protection from surface erosion.

Wind: Plants on a slope could be affected by moderate wind. The orientation and the steepness of the slope has different wind exposure. The surrounding landscape form can be an element to be considered that disruption of the wind pattern might occur. Generally, wind is primary a structural and ventilating concerns, but at a high velocity it becomes a factor of consideration for habitation.

Surface Runoff: The third, and the most damaging, element that might affect the steep environment is the rainfall. Surface runoff occurs when the intensity of precipitation exceeds the infiltration capacity of the soil...
the excess water flows to drainage channels across the surface or within the very top particles of the soil surface. The steeper the slope the greater is the speed of runoff and the smaller the fraction of water that had time to filter into the soil. This runoff water could cause erosion, thus upsetting the stability of the slope. Obstructions, such as roughness or uneveness of the surface and a covering of vegetation will tend to increase the percentage of infiltration and thus reduce the surface runoff.

Subsurface drainage: Water that has penetrated the soil surface and percolated through the soil is distributed in various ways. A small fraction, which depends on the nature and contents of the soil, is retained, while the remainder is free water which moves through the soil under the gravitational force. Ultimately this reaches the water table where rate of water supply exceeds that of its further drainage. The depth of these saturated layer occurs and the material which these layer formed are critical to the stability of the slope as a weakening of the soil structure might occurs, which might lead to a sliding of the soil over the less permeable layers.
SLOPE INSTABILITIES, ITS TREATMENT AND PREVENTION

There are two main types of slope stability failure: slumping and erosion. Subsurface instability can lead to major destructive movement of slumping and surface instability is the major cause of erosion.

Fig42 Base failure in homogeneous material, slip circle is tangent to the firm base.

Fig43 Slope failure in non-homogeneous material, the instable soft clay layer acts as the sliding plane.
Slumping: This involves a circular movement of the entire slope which results in the top of the slope falling in level, and the toe of the bank rising or pushing forward. This type of failure usually occurs where the material has been weakened by an increase in water content.

Erosion: This stability failure involves the surface of the slope, where the surface material is eroded away by wind, rain or other surface water.

Treatment for Slumping: Most landslides result from adverse subsurface moisture conditions and inadequate strength of slope material. To reduce the possibility of landslide, several measures can be considered. Surface and subsurface drainage can be controlled by interceptor drainage trenches above the landslide area. Seepage process can be reduced by installation of horizontal borings through the landslide to the seepage zone. Soil strength can be increased by replacement of the sliding material with properly compacted fill. External retention by means of retaining walls piling, rock bolts or buttress of various materials.
Treatment of Surface Erosion: Erosion is caused by wind, ice and most of all flowing water. The magnitude of the destructive force depend on the gradient of the slope, quantity of flow and the shape and roughness of the slope surface. On the other hand, control of erosion can also be accomplished by increasing the resistance of the slope to erosion. The total flow can be reduced by ditch-and-dike interceptor channel at top of the slope to divert water away or to eliminate the concentration of runoff water at the undesired area. Resistance to erosive forces can be increased by providing a sealing surface by means of concreate, asphalt or plastic or the surface can be protected by vegetation, mulching or terracing which also reduced the speed and volume of the runoff water.

On a slope with an angle of inclination of \( \sigma \), the total weight \( W \), of the structure due to gravitation can be considered to consist of two components: the compressive force \( C \), acting perpendicular to the slope; and the lateral force \( L \), acting parallel to the slope. These two components are distributed through the foundation onto the soil.
At equilibrium, where soil conditions allow, the normal force \( N \), equals to \( C \); and the lateral resisting force \( R \), equals to \( L \).

Thus, \( N = C = W \cos \sigma \)

\( R = L = W \sin \sigma \)

Because of the surface and subsurface instability of the soil below the structure, weakening of local lateral resistance will lead to a concentration of the lateral load at other part of the foundation. If further deterioration of the soil is not prevented or controlled it will reach a point that the lateral resisting force \( R \), fails to retain the lateral load \( L \), and failure of the foundation will occur.

\( R < W \sin \sigma \)
Disregard the lateral load on a slope for the moment, as comparing the gravitational load $W$, with the normal load $N$,

$$N_s (W \cos \sigma) < W$$

$$L_s > L_b$$ \hspace{1cm} (Ratio of areas, the loads act on)

thus, $N/L_s << W/L_b$

therefore the gravitational load $W$, is a higher concentrated load than the normal load $N$, on the slope, if we could eliminate or reduce the lateral load $L$.

There are two approaches to increase the stability of the structure on a slope. One is the re-distribution of the compressive and lateral loads by means of a structure system to a location or depth where the soil conditions are stable. The other is the elimination or reduction of the lateral load by means of one of the schemes illustrated in the following section.
FOUR CONDITIONAL SOLUTIONS FOR HILLSIDE DEVELOPMENT:

Fig 46 Part of the lateral load of building A is being transferred to building B which has a good soil condition, by means of compressive components.

Fig 47 Part of the lateral load of building A is being transferred to building B, which has a good soil condition, by means of tensile components.

Fig 48 The lateral load of building A is being counter balanced with the lateral load of building B, which is at the opposite slope of a valley, by means of compressive components.
A study of the relationship between the ratio of the volume of structure at the base of the slope to volume of structure on the slope and the inclination of the slope under different soil conditions had been studied at the Massachusetts Institute of Technology and the following is a condensation of the study.

Fig 49 The lateral load of building A is being counterbalanced with the lateral load of building B, at the opposite side of a ridge, by means of tensile components.

Fig 50

$V_B$ = Volume of building at the base.

$V_s$ = Volume of building on the slope.

$c$ = Angle of inclination of the slope.

$\theta$ = A function of $R/N$ and is relative to the soil capacity on the slope.

$F_R$
Under the assumption that the vertical component of the force transmitted to the foundation under $V_B$ should be more than four times greater than the horizontal component resulting from the protection of the slippage of $V_S$,

$$\frac{V_B}{V_S} \geq (4 - \tan \sigma) \frac{\tan \beta}{\tan \beta + 1}$$

Thus, with $\tan$ and $\tan \beta$ known, $\frac{V_B}{V_S}$ can be calculated.

Generally, the elements that affect the lateral stability of the structure at A or B, are the condition of the slope, the mass of the structure and the foundation system being applied.

Thus $R \propto \mu \cdot M \cdot S$,

where $\mu =$ coefficient of shear strength

$M =$ mass of the structure

$S =$ performance of the foundation system
All diagrams and photographs were prepared by the author except those of the followings:

Ahles, Loren, Livability and Variformity: A Study of Concrete Component System for Housing, for Fig. 26.

B.I.R.G., Cheng Kung University, A Preliminary Study of Industrialized Housing for Taipei, Taiwan, for Fig. 25.

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