Low Cost Residential Development and Renewal in Taipei, Taiwan, China

by

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Dear Dean Anderson:

In partial fulfillment of the requirements for the degree of Master of Architecture, I hereby submit this thesis entitled "Low Cost Residential Development and Renewal in Taipei, Taiwan, China."

Respectfully,

Chiway Yieh Hsiung

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Abstract

The main objective of this thesis is to study methods and procedures for low-cost residential development in the city of Taipei, Taiwan, China. The first part of this thesis contains a brief description of the general conditions in Taiwan. Existing housing situations and government housing policies are, then, reviewed. Based on these facts,the second part of this thesis is devoted to formulate the methods and procedures for the low-cost residential development. The District of Tai-Tung is selected as a community to explain the specific details.

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I. Introduction:

Immediately after World War II, housing was not a problem in Taiwan due to the fact that many houses were evacuated by the repatriation of Japanese military personnel and civilians. Beginning from 1948, conditions on the Chinese Mainland took an adverse turn by the military force of the Chinese communists. At that time, people who were unwilling to live under the communist control flocked from all directions to Taiwan, thus rapidly enlarging the population of this island. In the period of 1948 and 1949, the population increased by about 900,000, not including the evacuated military personnel on active service. As a result, housing shortage became a serious problem, especially in the urban areas. At the same time, because of the combined effects of natural growth in population (3.3%), improvements in public hygiene, and the damages on houses caused by typhoons and earthquakes, housing problems worsened year by year.

The housing problems resulted in congested and deteriorated conditions in large cities, especially Taipei, the capital of the Republic of China. The City of Taipei was poorly planned, primarily due to inadequate planning staff. Planning work has always lagged behind actual expansion. In recent years, city planning has received more attention than before. Nevertheless,

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1. Housing in Taiwan, Public Works Bureau, Taiwan, 1965
2. Taiwan Restoration Twenty Years, 1965

chaotic circulation, overcrowded narrow streets, and no public facilities or utilities are still common scenes in the urban areas.

The critical conditions in Taipei as described above may be alleviated by low-cost housing development. The formulation of methods and procedures for such development in Taipei is the primary objective of this study.

II. General Conditions in Taiwan

To provide the background information about Taiwan the geographical information, ways of living, and the economic conditions are presented in this section.

II-1. Geographical Information

Taiwan is an island, situated in the southeast corner of Mainland China, with the Taiwan Strait in between. The total territorial area is approximately 36,000 square kilometers (14,000 square miles), of which only the western part is flat with plains and basins, while the central and eastern parts are mostly mountainous areas occupying more than two fifth of the entire island.

Taiwan is located in the subtropical zone. The summer season is very long, but the temperature is mild, with an average of 83°F in July, 59°F in January. The highest temperature never exceeds 100°F and the lowest 35°F. Rainfall is abundant, the mean annual precipitation is about 2,500 mm. Each year between May and October, Taiwan is frequently attacked by typhoons with wind velocities as high as 250 km (156 miles) per hour, and accompanied by heavy rainfalls. The typhoons usually result in severe property damages.

Taiwan, being near the center of the earthquake zone which extends from Japan to and through the Philippine archipelagoes, has frequent occurences of tectonic shocks that can go as high as the 6th grade. Suddenly occured earthquakes above the 4th grade often cause severe damages.

II-2. Ways of Living

China is an old country with more than 5,000 years of cultural history. Almost all customs and traditions are derived from Confucius' sayings and Buddhism; therefore, all Chinese emphasize morality and politeness. This shows in every aspect of their life, such as family structure, social relationships, training of children, literature, music, houses and food.

In recent years, since the invasion of Japan, the ways of living changed a great deal, especially in family structure. While Chinese households may still consist of three generations, larger family units no longer exist. The family is very closely united, and social life is somewhat confined to the family group. Visiting, talking, celebrating, are usually done at home. Main recreational activities outside the house are movies, plays and native opera. Athletics are not popular, although basketball and soccer have gained increasing popularity.

Buddhism and Confucian were the two major religions, but in the last decade many people became Catholics and Protestants.

Becuase of the fast growth ratio, the average family size is five persons. Therefore, more than half of the family income is spent on food, the other half is divided into general use, medicine, recreation, education and housing. As a result, it is not easy for any family at middle or low income level to build a decent house. What they are able to do is to attach simple shelters onto their original houses in order to solve the housing problem caused by increasing family size.

On the other side, people usually try their best to save money in order to buy modern appliances such as radio, record player, television, and refrigerator. It is not surprising to see a handsome phonograph or a television set in a simple shelter.

The diet of Chinese consists of rice, beans, fish, meat, fresh fruits and vegetables. The housewives have the habit of going to the food market everymorning, eventhough they have refrigerators. The reason is that Chinese like fresh food better than frozen food. The Chinese cooking is 'heavy',oily, and strong, and it takes time to prepare

II-3. Economic Conditions

The average income per capita in Taiwan was NT $ 1,505[1] (US $ 38) per annum in 1952, but it had jumped to NT $ 6,003 (US $ 150) in 1964. The annual growth ratio is about 10% in recent years(Table 1).

Table 1. Average Income per Capita[2]

Year	NT(Yuan)	US$
1952	1505	38
1960	4337	108
1961	4580	114
1962	4843	121
1963	5361	134
1964	6003	150

In general, the majority of Chinese are at the middle and low income level. The living standard of Chinese in Taiwan is the second highest Asia.

As indicated in Table 2, the food expense is more than half (52.1%), and the money could be spent on house is only 13%. If it is assumed that the average family has 5 persons and the per capita income is US $ 150 a years, the total family annual income would be US $ 750. The average family can therefore spend US $ 98 a year or US $ 8 a month on housing.

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1. NT $ is the symbol of Taiwan currency.
2. Taiwan Restoration Twenty Years, 1965.

Table 2. Average Distribution of Private [1]
Consumption Expenditure

Food, drink	Cloth	House, rent, fuel	Recre.	Health care	Transp. communi.	Hobby	Other
52.1	5.9	12.8	2.5	8.1	11.8	4.8	2.0

In order to give some idea about the family income of low-income level, it shquld be mentioned here that the average family income of low-income level is only US $ 445, and the average expenditure spent on housing is 33.9% of the total income. From these figures, one can see clearly that there is a big gap of family income between low-income level and average income. Also, the low-income level family has to spend a much greater percentage of its income on housing than the average family. Therefore, an attempt was made in this thesis to cut down the cost of housing in order to improve the living standard of the low-income level families.

1. Taiwan Restoration Twenty Years, 1965

III. Housing Problems in Urban Areas

As indicated elsewhere in this thesis, housing problems are critical especially in urban areas. A review of the present housing conditions and government actions on housing are presented in this section.

III-1. Review of Present Conditions

As statistical data on housing census are not yet available, the following analysis based on some existing studies serves to explain the present housing conditions.

1) Population growth: The population of Taiwan is 12,000,000, and the annual growth ratio is 3.14 per cent; therefore, each year population increases by 376,000 persons.[1] If the average family has 5 persons, the demand is 75,000 new houses each

The population growth ratio in urban areas' is higher than rural areas. Taking Taipei as an example, the average increase in population is 5% each year. In other words, the increase is more than 50,000 each year. It will require about 10,000 new houses to accommodate the increased population, if we assume that 5 persons need a house.

1. Taiwan Restoration Twenty Years, 1965

2) It is estimated that there is an annual increase of about 50,000 units in the housing need, caused by destruction of houses due to disasters, and the rehabilitation of the turn-down illegal housing.

3) Squatters: There is a large number of squatters located in urban areas. For instance, there are about 40,000 families of squatters in Taipei (1963 survey).

4) Many problems resulting from rapid urbanization involve inadequate housing, chaotic use of land, congested traffic, squatter shacks and slums, insufficient recreational spaces, inadequate systems of water supply and sewerage, poor sanitation, and inadequate community facilities.

5) Insufficient housing often result in the following conditions:

A. Illegal constructions appear everywhere they are poorly built and not up to the minimum standards of safety and sanitation.

B. Over-crowding in small houses becomes a common phenomenon.

III-2. Government Actions on Housing[1]

The National Government of the Republic of China started to work on housing problems from 1954 by the "National Housing Commission".

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1. Housing in Taiwan, Public Works Bureau, 1965

In 1956, the work of this commission was transferred to the Taiwan Provincial Government. The chief objectives are to relieve the scarcity of houses, to raise the stanard of living, and to improve social welfare. An important step towards these objectives is to build more and better houses to meet the demands of the people.

The measures adopted by the government are the following:

1) To encourage private investiment in building houses.

A. Supply land at reasonable prices for building purposes.

B. Offer long-term and low-interests loans for building new houses.

C. Assist in borrowing money from banks.

D. Exempt land tax and building tax on new houses for a certain period of time.

E. Construct essential public works for the building site.

F. Give technical assistance including provision of standard blueprints and cost estimation.

G. Help in procuring important construction materials.

2) To encourage social groups, factories, mining areas and other business enterprises to build houses for their emplyees; measures adopted are similar to those stated in the preceeding paragraph.

3) Government construct houses for lease, or sell to those prople who are poor or whose incomes are low.

4) The government extends loans for house repairing. The loan shall be used only for repairing those houses which still have a utility life of not less than 15 years, and the repairs will improve their safety or sanitation.

Government provides new house loan up to 80% of the total cost, and at the 15-year long-term basis with an interest rate of 6% per annum.

Government provides new house loan for low-income families at the 20-year long-term basis without any interest.[1]

Although government plays an active role in solving housing problems, what the govenment can do is, nevertheless, a small part, as shown by the following statistics:

From 1955 to 1964, within ten years, government provided 61,150[1] families with the loan for building their own houses, while the demand was more than 75,000 units each year (natural growth only). Thus, the percentage of government loan to demand was only 10% or less. Therefore, majority of the people had to find their own way of solving housing problems.

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1. Taiwan Restoration Twenty Years, 1965

IV. Low-Cost Residential Development for the City of Taipei

On the basis of the information presented above, specific measures of low-cost residential development for the city of Taipei were studied. The proposed measures are illustrated by using a particular district in Taipei as an example. The district selected for this purpose is the District of Tai-Tung, the location of this district in the city of Taipei is shown in Fig.1. In this thesis, the informations of the present housing conditions are obtained from the Report on Taipei Housing in Five Selected Areas. Based on these informations, the recommended solution which would improve the present housing condition is then formulated.

In this section the present housing conditions of the District are discussed first, the proposed measures of improving housing condition are presented latter.

IV-1. District of Tai-Tung

The reasons for choosing this district as an example site are the followings:

1).It is one of the rapidly growing areas in Taipei.

2).It is one of the areas known to be most crowded.

3).It is the area known having lower income than other parts of Taipei.

4) There are more illegal houses in this area.

5) It is one of the districts which are near a major business area and yet suitable for living.

6) It is one of the five selected areas for the governmental housing condition survey in 1963.

As shown in Fig. 2, one third of the district of Tai-Tung is scarcely populated (people grow rice on this land), while the other two thirds has a population of more than eighty-seven thousand. This district has no planning at all, most of the residents are land invaders. Consequently, roads are narrow and inconvenient. Fire engines cannot reach the heart of the squatter area, causing it to be constantly threatened by fire. Also, as the road system cannot reach the whole site, houses tend to crowd along the road for easy access. Since the population grows at an higher rate than the development of road system, the already urbanized area gets more heavily populated while the vacant land is left open.

This district is one of the fast growing areas in Taipei. The population was 44,046 in 1950, but ten years latter in 1960, it has jumped to 87,597. Average annual growth ratio in recent years is 7.i percent.
The density of Tai-Tung was 149 persons per hectare(61 person/acre) in 1950, while in 1960, it was 278 person/ha. (113 persons/acre).

IV-2. Housing Condition Survey

The only information on housing conditions in Tai-Tung is provided by the Housing Condition Survey conducted by the Provincial Public Works Bureau in 1963. This survey included 70,000 people in about 9,000 families in five of the areas known to be most crowded. It was conducted through five primary schools serving these areas and thus including only the families with children of primary school age.

The data may be subjected to a considerable margin of error because of the use of children as enumerators, since the data naturally did not include information about the young married couples, those people who live alone, and those families who have no children of primary school age.

Findings of the survey in this area are as follows:

1) Age Distribution:

The age distribution was as shown in Table 3.

Table 3. Age Distribution

Age	Person	Percentage
6-less	2,693	16.0%
7-12	4,511	26.7
13-18	2,827	16.8
19-24	1,187	7.0
25-up	5,648	33.5

2) Family size:

A. The average persons per family was 7.73.

B. There were 72.7% of family having 5-9 persons, 83%, 4-10 persons.

C. Families per unit: There were more than half (57%) of dwelling units with 2 or more families living together, 24.9% with 2 families, 19.3% with 3 or 4 families, and 12.8% with 5 families or more. The average number of families per unit was 2.6.

3). Floor area:

A. There are 22% of the families having floor areas of 20 square meters or less, 40% have 32 or less, 22.6% between 32 and 61 square meters, 23% between 61 and 91 square meters.

B. Those who live in overcrowded living spaces made up 23.7% of the total population.

C. In 1964, government set 5.2 square meters per person to be the minimum required floor area. According to this criteria, 42% of the families were living in substandard housings.

4) Income and Expenditure:

A. The range of family incomes are tabulated below:

Table 4. Family Income in Common Occupations

Occupation	Percent	Monthly income	Annual income
commercial	25%	US$47.0	US$565
Transportation	2.7	46.4	557
Mining	0.5	45.7	550
Govt. Education	19.9	39.5	475

Professional	8.1%	39.0	470
Industrial	14.0	33.7	405
Farmer, Fisher	2.8	28.8	346
Others	7.6	28.8	346
Common labor	16.5	26.9	323
Peddler	2.6	24.9	300
Average	100.0%	37.0	445

B. The average income on the national level was US$ 150 per capita in 1964, since in this area the average family size is 7.73, the averagefamily income would then be US$ 1,160. But in reality, it is only US$ 445. This indicates that the income of this area is very low.

C. The distribution of monthly family income and family expenditure are tabulated below.

Table. 5. Family Monthly Income and Expenditure

Monthly income	Percent of total family	Monthly expenditure
US$ 13-less	7.9	US$ 16.9
13-25	33.4	26.3
25-38	21.5	35.4
38-50	18.0	46.2
50-63	6.9	57.9
63-75	5.6	69.5
75-88	2.0	75.5
88-more	4.7	99.3
Average	100.0%	US$ 40.2

In this area, there are 77.7% of total families whose monthly expenditure are more than their monthly regular income. This means that they have to work over time or to find a second job in order to make the balance. The percentage of families with expenditure over regular earnings are shown in table 6.

Table 6. Percentage of Families in this Area with Expenditures over Regular Earnings

Income Level	% of Families in this Level	% of total Families
1000-less	100%	41.4%
1000-2000	75%	30.0%
2000-3000	50%	6.3%
3000-more	00%	0.0%
Total		77.7%

D. There are 26% of the dwellings in need of small repair, 25% need large repair, and 9% are unsage or beyond repair.

E. The average monthly cost of housing for repairing is NT $ 169 (US $ 4.24).

F. The ratio of monthly cost for house repairing to the average monthly expenditure is 10.5%.

5). Ownership and Rent

A. The ownership of house and land is 42%.

B. The number of house-rent families equals to 30.5% of total families. The average rent per family is NT $ 542.9 (US $ 13.6), the average rent per expenditure is 33.9%.

6). Conclusion

Comparing to the average figure, the family incomes in this area are very low. As a result, most families do not have enough money to spend on housing. They are forced to live in substandard dwellings which are often overcrowded as well. However, inspite of this general low income, housing problems must be solved in some way, and living conditions must be improved. The following sections will discuss the proposed measures for reaching these goals.

IV-3. Proposed Measures for Low Cost Residential Development

The specific measures for low-cost residential development in the District of Tai-Tung were formulated on the basis of the existing conditions as well as the expected development in the future.

1). The Community

Existing conditions of Tai Tung and the general approach for low-cost residential development are illustrated in Fig. 3 and Fig. 4. As shown in these figures, the layout will follow existing tendencies, but urban form will be redesigned.

A. Community concept

As indicated in Fig. 3, the basic concept is to divide the whole area into six neighborhoods, a recreational belt, and light industrial areas. Recreational belt will be located along the river, where one can enjoy broad,open views. Light industrial areas will be located near the railroad, as proximaty to railroad is essential for convenience in transportation. At the present, the railroad station is located at the east side of the track. Since the west side is much more heavily populated, it seems worthwhile to expand the station to the west side of the track.

B. Educational facilities

Because of the uneven distribution of existing primary schools, some children have to walk a long distance to the nearest school. In order to improve this condition, two new primary schools will be added, and one primary school will be relocated. The analysis diagrams are shown in Fig.3. As there are already a sufficient number of high schools and colleges, additional ones will not be provided.

C. Circulation

As illustrated in Fig. 4, the existing circulation condition is poor, chaotic and improperly distributed. People can not easily reach the vacant land. As a result, they tend to crowd around already heavily populated sections. The proposal is to develop circulation throughout the district to give the residents convenient access.

D. Commercial facilities

In this particualr site, existing commercial facilities are grouped into two strips, they are the extensions of the down town commercial areas. Since the whole site will be divided into six neighborhoods, the proposed commercial facilities will follow the existing trend, but it will be extended to the whole site. The analysis is shown in Fig. 4. In addition to the neighborhood shopping areas, a community center will be provided for the entire community.

E. Proposed land use plan

Based on the analysis above, the proposed land use plan was formulated. Land use depends primarily on the types of functions it is most suitable for, and need of the community. Existing conditions are to be retained as much as possible. The land use plan is shown in Fig. 5.

2). The Neighborhood

As mentioned before, in this area there are six neighborhoods, each with a population between 10,000 and 20,000. In each neighborhood there will be a primary school, a neighborhood center, a food market, and neighborhood shopping areas. A portion of the typical neighborhood is illustrated in Fig. 6.

Primary education is compulsory. Every child of primary school age, 6 to 12, must go to school. Seventeen percent of the total population is composed of children in this age group, totaling approximately 14,900. Therefore, each school will have 2500 students. This is definitely below the average figure of Taipei, 2850 students per school. The longest distance between school and home is around 400 meters, which is about 15 to 20 minutes of walking.

The neighborhood center will have a nursery station, admisistration office, paper and magazine reading room, television room, and a social hall. It is impossible to provide the athletic field in each neighborhood, thus the field and other facilities of the schools are also for the use of the neighborhood residents.

The food market is an important place, every housewife meets her friends here almost everyday. Therefore, the food market serves two main functions: it provides daily needs and also a place for social contact.

Concentrated neighborhood shopping sections provide daily needs other than fresh foods. Special shops, such as laundry, tailor shop, stationery, ice cream shops and magazine stands also will be found here. Corner shops will be located at various points. They will not have special structures, ordinary residential dwelling units can be used for this function.

The dwelling units are arranged in such a way that every family is within twenty meters of an open court, as shown in Fig. 11. In this open court, there is a playground for children. Outdoor furnitures are also placed there for the convenience of grand-parents and mothers. Adults can watch children play as well as socializing among themselves.

3). Dwelling Units

A. Basic requirement

Because this thesis deals with low income level families in China, the unit design has to meet a few requirements as stated below:

(1) The structure should have reinforcements in order to prevent suddenly occured failure due to earthquakes and Typhoons.

(2) The canopy is needed to protect openings, because of the abudant rainfall.

(3) The self-help and prefabrication methods should be considered as means of saving labor cost and material cost.

(4) Narrow lots reduce public utility costs as well as increase social contact.

(5) Expandability of unit should be considered for future family expansion and move-up situations.

(6) Expansion of structure should be accomplished with convenience and without any waste of material.

(7) The interior partitions should be at a minimum for saving building cost.

B. Unit Types

In this particular district, three types of housing units are provided for various individual needs. Dwelling unit A, as shown in Fig. 7, is provided for the majority of low income families. Dwelling unit B, as shown in Fig. 8, is provided for those who have the intention of either opening up stores themselves or renting out the units for such purpose. Unit B is usually located along shopping streets. Dwelling unit C, as shown in Fig. 9, is designed for higher income families and those who need more privacy. Another type of dwelling unit is the apartment building, suitable especially for young married couples.

C. Unit Size and Cost

Since the majority of families in this area are at low-income level, the following discussions will cover only dwelling unit A.

According to the housing survey, there were 72.2% of families with 5-9 persons. If unit A is provided for this group, the unit size can be obtained by taking government's minimum area per person (5.2 m^2) as the standard, and multiply that with the number of people in the family. Suppose most of the families have 5, 7, and 9 persons, the sizes would be 26, 36, and 47 square meters respectively.

The traditional steel reinforced brick house costs US $ 23 per square meter. There is no way of reducing the cost if the existing construction system is used. The proposed constructi... system (see Chaper V for detailed discussions) is bamboo reinforced concrete block. The cost of this system will be less than the traditional one[1]. It will be approximately US $ 20 per square meter. Thus, the cost of buildings will be US $ 520, 720, and 940 for houses with floor areas of 26, 36, and 47 square meters respecitively.

If a building is to be constructed in a good community,

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1. The average need of steel in a conventional house is 1600 kg. (from "Taiwan Restoration Twenty Years, 1965). The steel would cost about NT $ 8,000 (US $ 200). Since the average floor area of a conventional house is 60 M^2, 26.6 kg. of steel are required for each square meter of area. That amount of steel costs US $ 3.44. If 1/2" dia. steel bar is used for reinforcements, 87 ft. of steel bars are required. If bamboo is used instead of steel, then 30 meters of bamboo will be required if the diameter of bamboo is assumed to be 1 1/4" . And this amount of bamboo only costs 38 cents. Thus, one can conclude that the cost of bamboo reinforced concrete blocks is cheaper than steel reinforced ones. The bamboo reinforced concrete blocks are estimated to be around 20 dollars per square meter.

considerations should be given to the land cost, land cost, land improvement, public utilities, access, administration, etc.

In general, the land cost is about NT $ 350 per pin (US $ 2.6 per m^2). Since each lot is 40 to 50 square meters, the land cost will be US $ 104 and US $ 130, respectively.

The cost of public utilities and administration are the same, 10% of the structure cost, thus this cost should be added into the cost of the house.

If the interests of a building loan is 6% per annum, and the term is 15 years, the total interests for 15 years will be 40% of the building cost.

From an economic point of view, a person can only borrow money as much as his three years' salary. If it is beyond this limit, very possibly, one can never pay it back. Therfore, the minimum monthly salary could be derived from the total cost of building divided by 36 months.

The building costs of contractor-built houses that are owned by families of various income groups are as tabulated in Table 7. From this table, it can be seen that only 50% of the families could afford to buy a 36 m^2 house.

Table 7. Building Costs of Houses Built by Contractor

Item	Floor area per family: 26 M^2	36 M^2	47 M^2
Structure	US $ 520	US $ 720	US $ 940
Land	104	104	104
Utilities	52	72	94
Administration	52	72	94
Subtotal	728	968	1232
Interests	290	390	501
Total	1080	1358	1715
Min. salary/month	28	38	48
% of Families can afford	60%	50%	40%

The book "Taiwan Restoration 20 Years" states that average number of man-days required for a 60 square meters house is 207. A man-day in Taiwan is about NT $ 80 (US $ 2.0). Thus, the labor cost is NT $ 380 dollars per square meter (US $ 7 / M^2).

If the houses are constructed by the aided self-help method, (see Chapter V for further discussion), the labor cost which may be eliminated is given in Table 8.

Table 8. Labor Costs

Unit	Cost/M^2	Cost/Unit
26 M^2	US $ 7	US $ 180
36 M^2	7	250
47MM^2	7	330

The informations on the previous page indicates that a reduction of approximately 35% of the structure cost may be ahieved by emplying the self-help method of construction.

Table 9. Building Cost - Houses Built by Self Help

Item	Floor Area per Family (M^2) 26	36	47
Structure	360	470	610
Land	104	104	104
Utilities	52	72	94
Administration	34	47	61
Sub-total	530	693	869
Interests	210	277	346
Total	740	970	1215
Min. Salary/Month	21	27	34
% of Families can afford	90%	62%	55%

It is clearly indicated in Table 9 that 90% of the total families can afford to buy a 26 M^2 house, 62% can afford to buy a 36 M^2 house, and only 55% can afford to buy a 47 M^2 house. Therefore, for those families (8%) with extremely low incomes, such as US $ 13 or less per month, only a lot with public utilities can be provided. The reason for providing a lot for those who have extremely low incomes is to give every family an equal opportunity to grow, to move up to the house-owner level.

4). Evolution Process

As illustrated in Fig. 10, the process of stage construction for a typical low-cost dwelling unit has four phases. Since most of the families will not be able to build a house at one time, the building design will be made based on the self-help method of construction. The unit could start with a temporary shelter as shown in Phase I, where it is only one room without utility. When the owner's financial condition is improved, a permanent structure could be built in place of the temporary shelter, as shown in Phase II. In this phase, utilities could be brought inside the house. At the third phase, Phase III, the unit is expanded to the second floor. Finally, if owner wants to rent out the upper floors in order to get more income, he could build an outside stair directly connected to the upper floor to make it a separate unit. The process of stage construction for a typical low-cost dwelling unit is shown in Fig. 10.

5). Procedures for Development

In order to establish a workable procedure for changing the deteriorated housing area to a healthy housing area, the program is designed in such a way as to develop the district step by step, as illustrated in Fig. 12, rather than to demolish the whole site and then build a new community. It will take a long time to accomplish the development, but it involves less problems.

To begin the development, establishment of a team of planning staff must first be considered. This team could be organized either by the government or the said community. It should take full responsibility of designing the possible layout of the site and carrying out the development. Of course, designing of the layout can be simplified if the recommanded layout in this thesis is followed. Also, in this team, there should be a consulting engineer. The duty of this engineer is to give technical assistance to the families who will build their houses by self-help method.

After the planning team has been established, development of vacant land and new roads can be started. When this phase of development is completed, people who presently live in slum areas can be relocated to these new housing units. Because development strats from vacant land, many legal problems can be avoided. This newly developed section can then be used as a demonstration project to test the attraction and stimulation of interest concerning residents as well as investors, and the workability of the development procedures.

At the second phase, development could start at the sites from which inhabitants have been relocated. Also, carry out the development of light industrial areas, extention of railroad station to the site, and partial renewal of community centers.

The third phase includes the construction of new primary schools, as well as the developments of neighborhood centers and river front housing.

Recreational areas are to be completed in the last phase, the fourth phase. Any unfinished work concerning renewal of community centers and development of neighborhood centers must also be carried out.

V. Method of Construction for Low-Cost Housing

To implement the development of residential areas as discussed in the previous sections, it is necessary to adopt improved methods of construction for low-cost housing. The information obtained from a survey of the current methods of construction and the specific details of the proposed method are presented in this section.

V-1. Survey of Current Methods of Construction

Generally speaking, because of the low standard of living and the favorable climatic conditions, highly technical and expensive equipment of construction are not required for Taiwan.
Thus, from a realistic point of view, the prevailing construction materials and skills can be accepted.

Primary constructional materials most commonly used are cement, brick, concrete block, wood, steel reinforcing, glass, clay and bamboo. Reinforced concrete, reinforced bricks, and reinforced blocks are also commonly used because of their resistance to weathering and corrosion.

As for the constructional methods, hand labor constitutes the major element of building construction. Mechanized means are generally quite crude, because men power is abundant.

There are basically four different types of construction systems, as shown in Fig. 13, Fig. 14, Fig. 15, and Fig. 16. The numbers on the drawings indicate the construction sequence. The four systems are discussed briefly in the following paragraphs.

1). Combined Timber and Brick Structure System

In this system emplying timber and brick, as shown in Fig. 13, a low brick base wall is first constructed. Then, timber structure could be added onto this base wall. Panels between wood posts are bamboo and wood laths. On the surface of the laths is a layer of mud and straw mixture. The finishing material could be plaster (mainly for interior partitions), or stucco (exterior partitions).

2). Reinforced Brick Structure System

Reinforced brick structure system is illustrated in Fig. 14. This is a very commonly used structural system because of its permanency and ease of construction. Exterior walls are 8" thick layers of brick. Reinforced concrete columns are used. On top of the walls are continuous reinforced concrete tie beams. These beams prevent the differential settlements of the brick walls.

3). Reinforced Concrete Structure System

The reinforced concrete structure system shown in Fig. 15 is mostly used for public buildings. In this system, the frame is built first, then bricks or blocks are laid in place. The system is the strongest one, comparing to the other three systems. It is also the most expensive. Therefore, it is not common for building small houses.

4). Bamboo Structure System

Babmoo structure is a product of cheap materials and cheap labor. Therefore, bamboo structure is often seen in developing countries, but not in more advanced countries such as the United States. Relatively speaking, bamboo structure lacks permanency. It can last only 15 years or less, if bamboo is left exposed.

V-2. Proposed Method of Construction

Because of the gap between family income and housing cost, it is quite common that the cost of a new house of sound construction is higher than the buying power of the low and lower-middle classes. This section disusses the methods of construction that can reduce this house construction cost to bring it down to the level of low income families.

1). Methods of Reducing Construction Costs

In order to avoid the risk of developing a slum in the future, it is recommended to provide minimum living space for everyone rather than to cut down the floor area. Thus, the only way of reducing cost of housing is to cut down the construction cost. There are two ways of accomplishing the said purpose.

A. Cut down the labor cost

Use aided self--help method method to construct the house in order to save labor cost (usually labor cost is about 40% or more of the total construction cost).

B. Cut down the material cost

In general, the material cost can no longer be cut down. For permanency, reinforced construction systems must be used. Among

Among the different types of construction systems, reinforced block is the least expensive at the present.

According to the local prices, reinforcing steel is the only material with high cost. This situation makes it Possible to consider bamboo as the reinforcing material instead of steel. As there are abundant supplies of bamboo in Taiwan, the price of bamboo is relatively low.

2). Aided Self-Help Method

It is usually quite impossible for the low-income people to build a house at one time, because they do not have enough capital. Also, they do not have credit to borrow money. However, everyone has the desire to own a piece of property, whether it is large or small. In order to achieve this desire, these prople can buy a piece of land first, and then build their house gradually by contributing their own labor on the house. This is what one calls the "Self Help" construction method.

One dangerous result usually follows. It is highly probable that the area will be turned into a slum because of the inadequate planning, insufficient utility, and unhealthy environment.

Therefore, in this design, the proposed method is to divide the site into lots by an organization. The organization also takes full responsibility of controlling the plan and giving technical assistance to these prople who build houses on the site. In this way, predictability of the final environment can be assured. This is the reason why the method is called "Aided Self-Help".

Self-help is the oldest and the most widely used of all methods of shelter production. It provides in many circumstances a satisfactory answer, if not ideal, to housing needs all around the world. Aided self-help is an important transition from houses built by families without any outside help, those houses are usually inadequate, unhealthy and subjected to deterioration, to houses constructed by the building industry which is beyond the reach in cost for most families in Taiwan.

3). Bamboo Reinforced Concrete

The "Chinese Engineer's Handbook", published in 1944 at Shanghai, states that many concrete works with bamboo reinforcements were constructed. Bamboo was found to be an efficient reinforcing material.

A. Properties of bamboo

The properties of bamboo are as follows.

(1) The tensile strength of bamboo is from 1,465 to 3,042 kiligrams per square centimeter, (21,000 - 43,000 lb/in^2).

(2) The compressive strength is 540 kg/cm^2 (7,700 lb/in^2).

(3) The modulus of elasticity, E_b, is equal 80,000 to 467,000 kg/cm^2, averaging around 273,500 kg/cm^2.

(4) The modulus of elasticity of 3,000 psi reinforced concrete is E_c = 140,000 kg/cm^2.

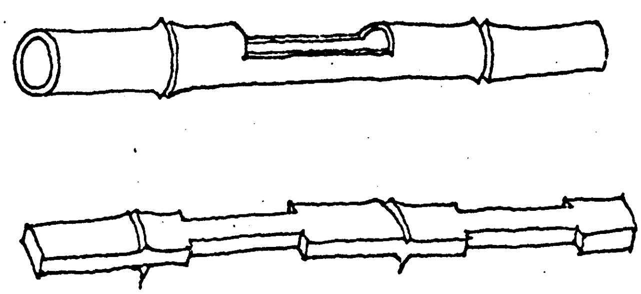
B. Bond between bamboo and concrete

The two major possible weaknesses to the bond stress for using bamboo as reinforcing material are surface smoothness and water absorption of bamboo.

(1) Surface smoothness

Bamboo is a very useful material. One of the reasons is its surface smoothness. It can be used to make furniture, build houses, decorate rooms and for many other things. However, this same property which makes bamboo desirable in other uses makes it quite undesirable for concrete reinforcing. Surface smoothness causes bamboo to slip when force is applied on the bamboo reinforced concrete. The bond stress is too small for resisting the applied forces. Therefore, bond between bamboo and concrete must be improved. There are two ways to improve bond.

(a). To cut part of bamboo between nodes for providing more contact surface between bamboo and the concrete to increase bond.



(b). To use 0.09 wire as tie around bamboo reinforcings to increase anchorage.

(2) Water absorbtion

During the period when concrete is poured and being cured, bamboo will absorb water from the concrete, and as a result the volume of bamboo will increase.

After setting, when concrete gets dry, concrete will absorb water from the bamboo and the volume of bamboo will decrease. As soon as bamboo reduces its size, the bond stress will largely be destroyed.

The effect on the bond stress in a bamboo reinforced concrete will mainly depend upon the volume change of bamboo. The volume change of the bamboo in turn depends on how much water it absorbed. Therefore, the water absorption test may be conducted to obtain the desired informations.

Discussions on the two tests carried out can be found in the back of this thesis. In conclusion, it can be stated that the water absorption of bamboo is quite high.

At the present time, no information is available concerning the maximum allowable change in the perimeter of bamboo for the purpose of minimizing the loss in bond stress. Nevertheless, it is desirable to waterproof the bamboo before using it as a concrete reinforcing material.

C. Bamboo tensile strength

Although there are some information concerning the strength of bamboo available in different sources, but there is appreciable difference between these figures (Tensile strength is between 8,400 to 49,700 psi, in H.E.Glenn 's book "Bamboo Reinforcement of Portland Cement Concrete Structures", while tensile strength is between 17,000-40,000 psi in the "Chinese Engineer's Handbook"). In order to get some idea about the tensile strength of bamboo, a test was made with Instron, the multi-purpose testing machine, in the Materials Laboratory of the Department of Civil Engineering at M.I.T.. The test is discussed in detail in the appendices of this thesis, and it seems to indicate that the tensile strenth of bamboo can be as high as 28,600 psi.

4). Proposed Construction System

As shown in Fig. 17, the use of reinforced concrete blocks and prefabricated bamboo reinforced concrete slabs are proposed systems for the construction of low-cost housing. The reasons are as the following.

A. Concrete block is the least expensive building material capable of carrying large loads.

B. Concrete block is the most common material, thus can be obtained easily without extra cost.

C. The size of concrete block is easy for one man to handle.

D. Bamboo is a low cost material and capable for using as concrete reinforcement.

E. Bamboo reinforced concrete slab needs no skilled labor to cast, if people have the help of technical assistants from the beginning.

F. The prefabricated bamboo reinforced concrete slab could use standard form, and needs no machine equipment.

G. These concrete units are easy to install, thus resulting in the saving of labor cost.

H. Expandability is provided by these concrete units.

In order to keep the prefabricated slabs acting as a whole, 5 centimeters of concrete toping should be added on top of the slab plank.

The roof could use the same prefabricated bamboo reinforced concrete slabs but without topping. In order to provide the expandability, build-up roofing will not be used. Instead, the light-weight asbestos sheet roofing will be built on the slab. In the future, the asbestos sheet could be removed without damaging other materials, the the added room could be built on.

VI. Summary

The main objective of this thesis is to study methods and procedures for low-cost residential development in the City of Taipei. In the particular site selected for dicussion and study, the family incomes are very low. Therefore, the low-cost of the construction is the main consideration. The low-cost of construction can be attained by using Aided Self-Help construction method and bamboo reinforced construction system. As for the whole community, an organization should be established to plan and control the development processes. The community should be properly zoned, with different sections of the area serving different functions. Community development should be accomplished step by step. Special attention should be given to road development and lot division. Ample roads must be provided to avoid the concentration of population around few areas. Lot division should be carefully studied so that there will be enough living space for each resident.

It is believed that with a proper combination of the above mentioned measures, the housing problems in Taiwan can be greatly alleviated.

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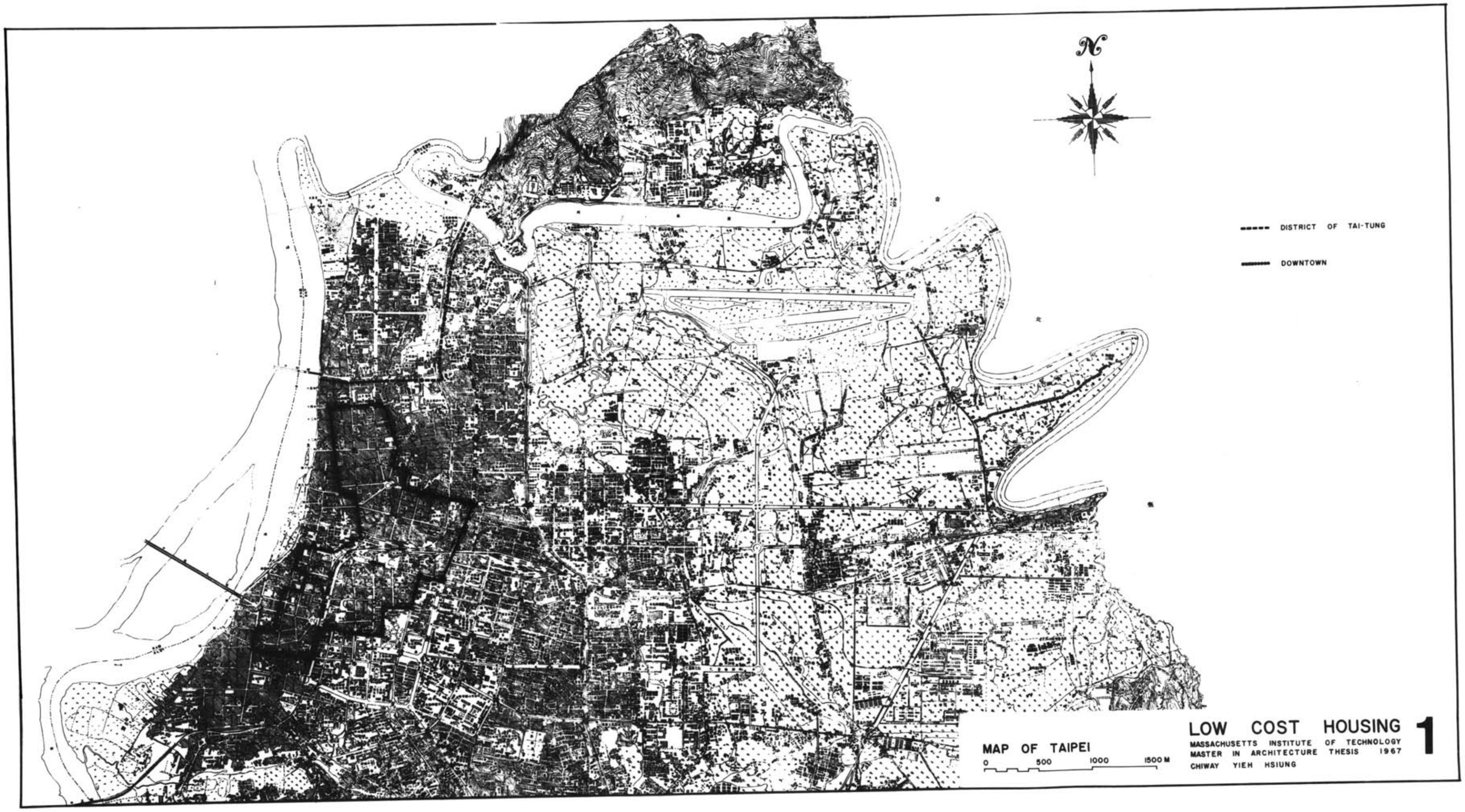

Fig. 1. Map of Taipei

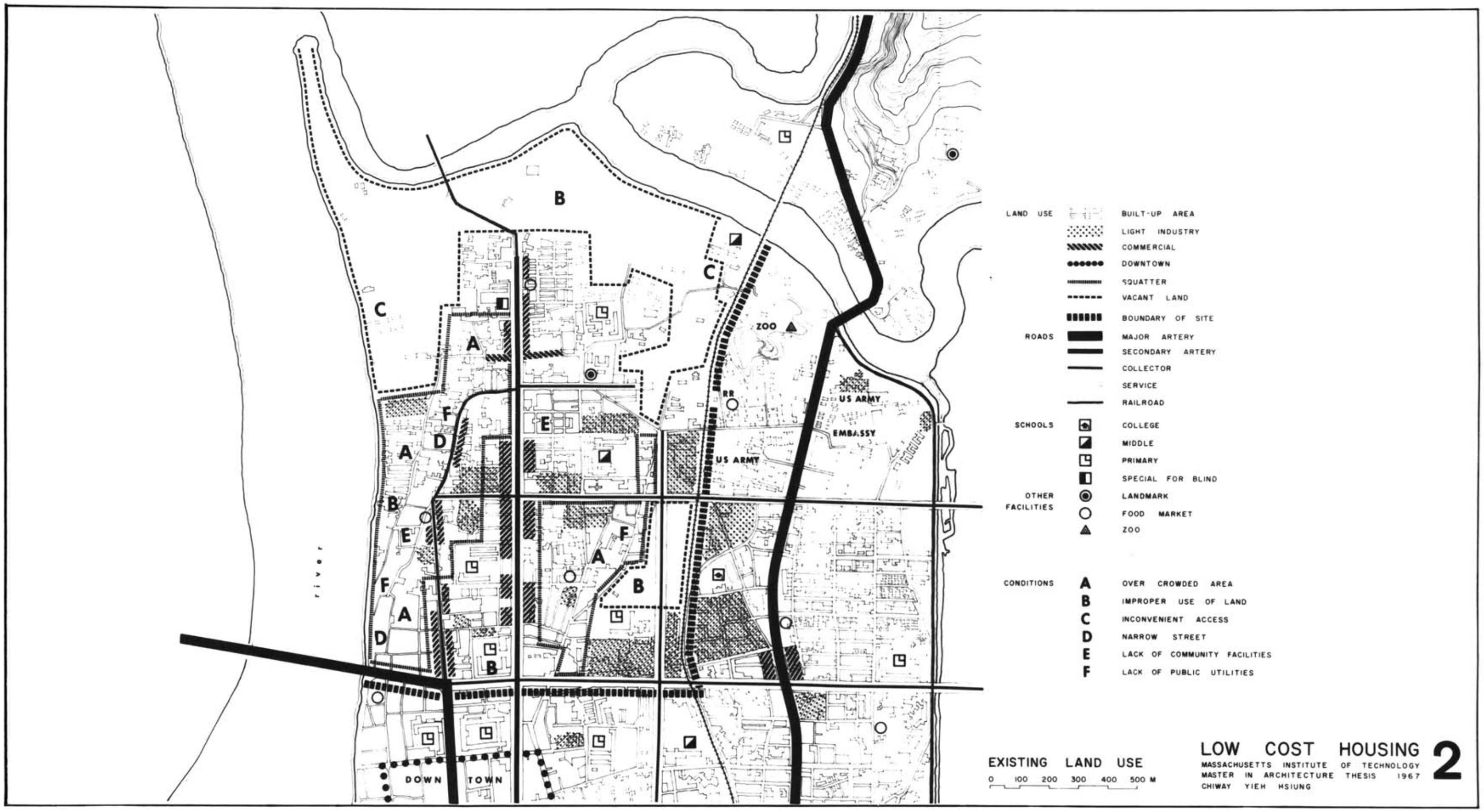

Fig. 2. Existing Land Use of District of Tai-Tung

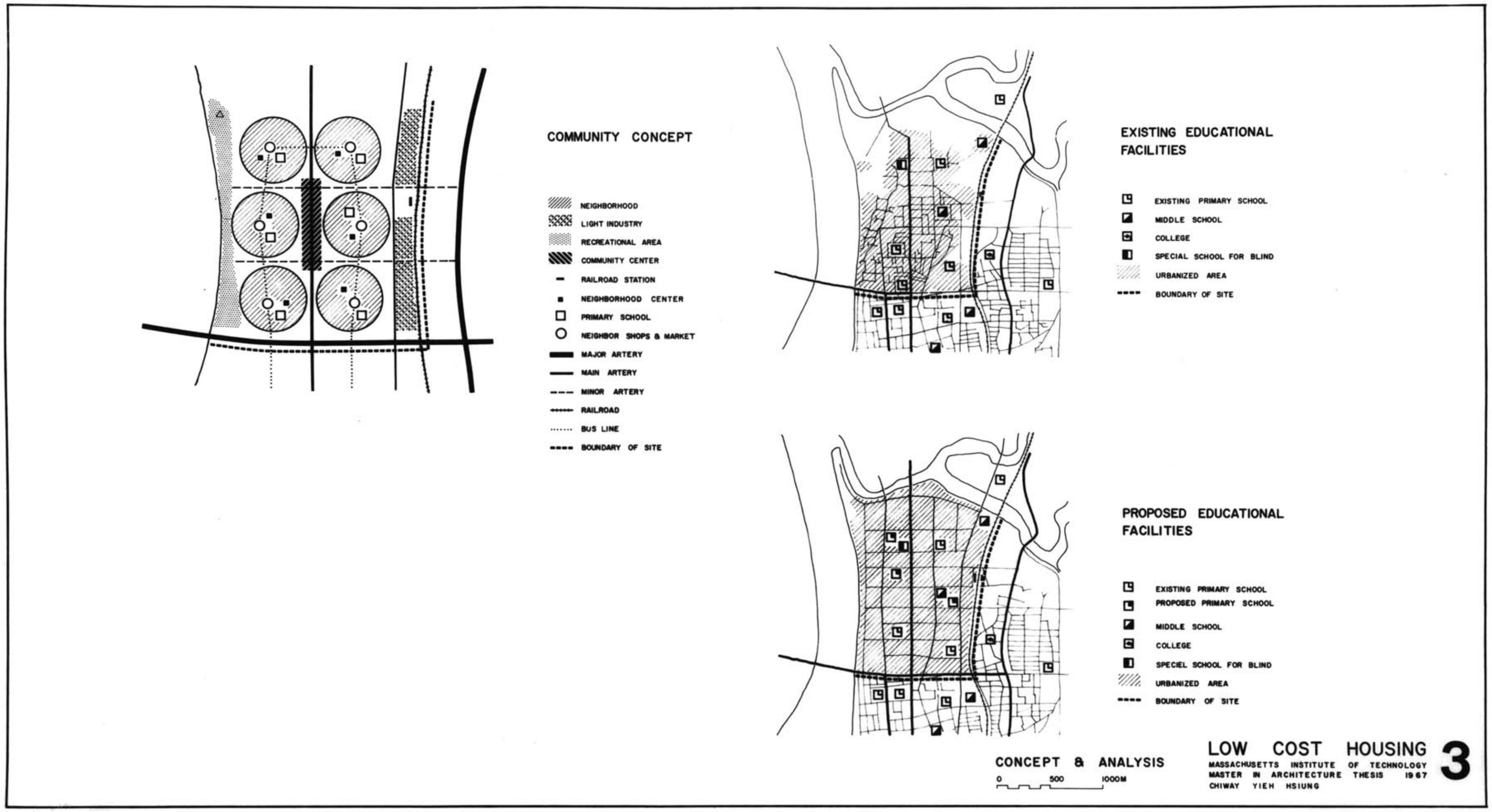

Fig. 3. Concept and Analysis

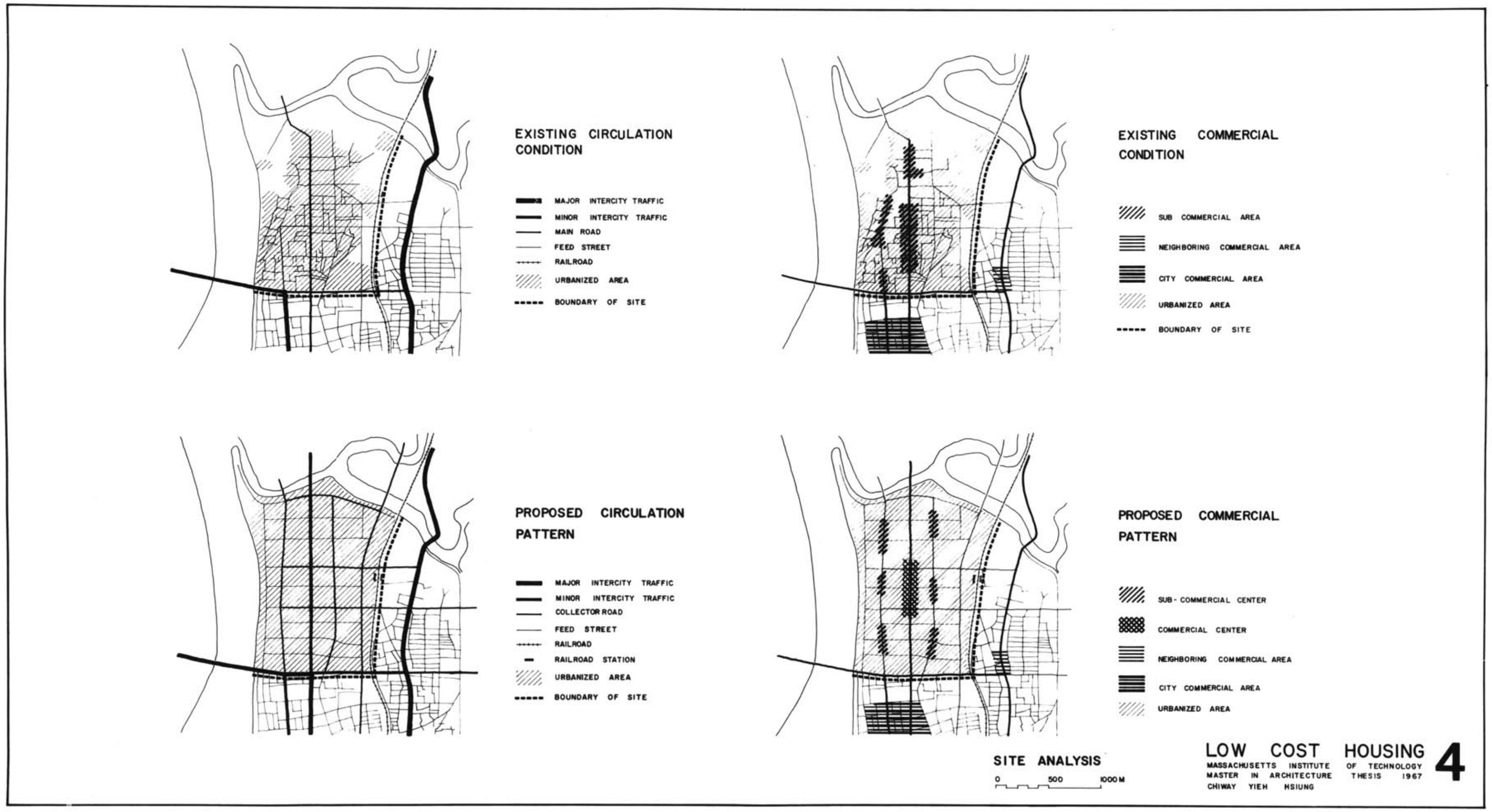

Fig. 4. Site Analysis

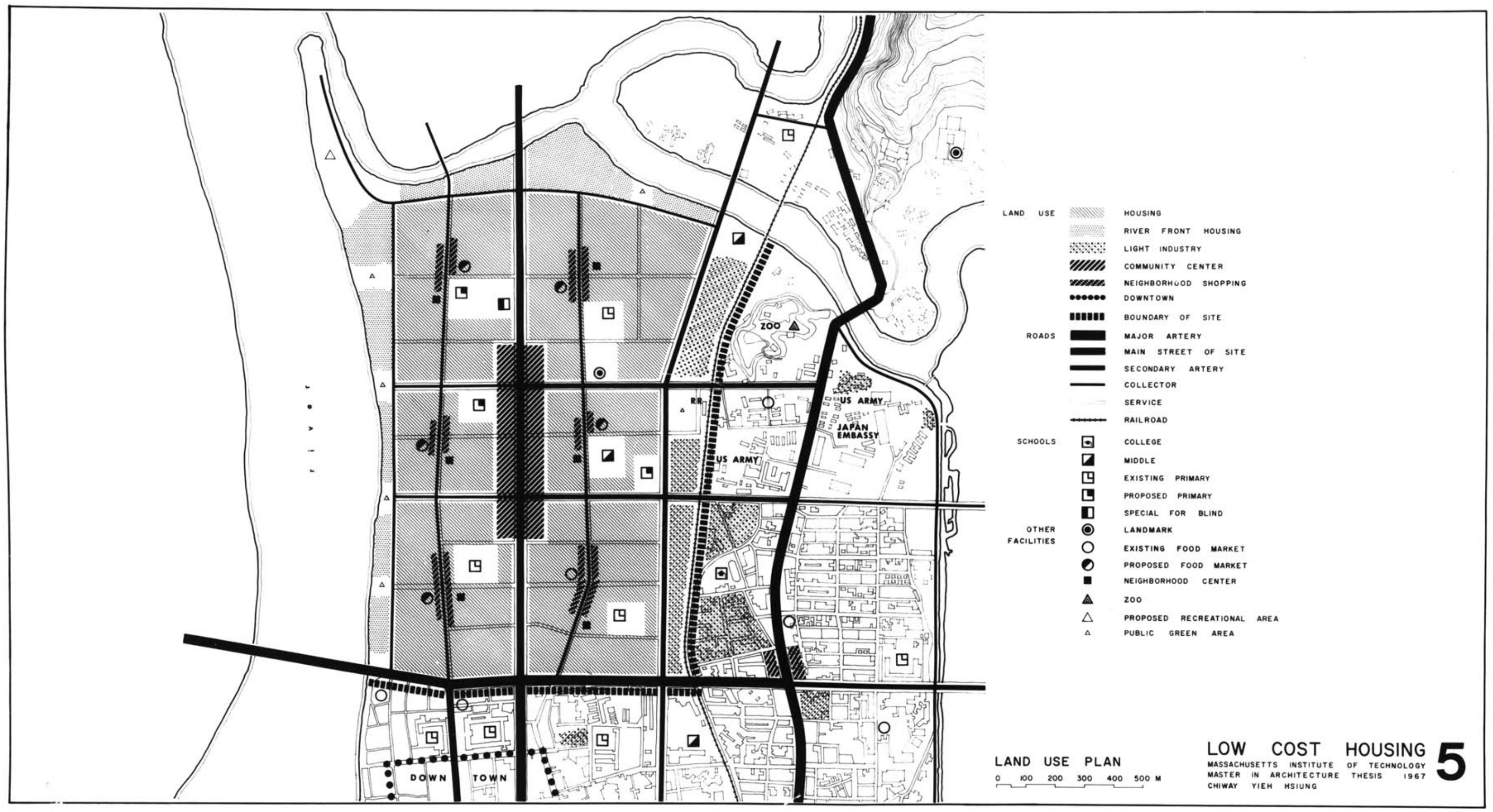

Fig. 5. Land Use Plan of District of Tai-Tung

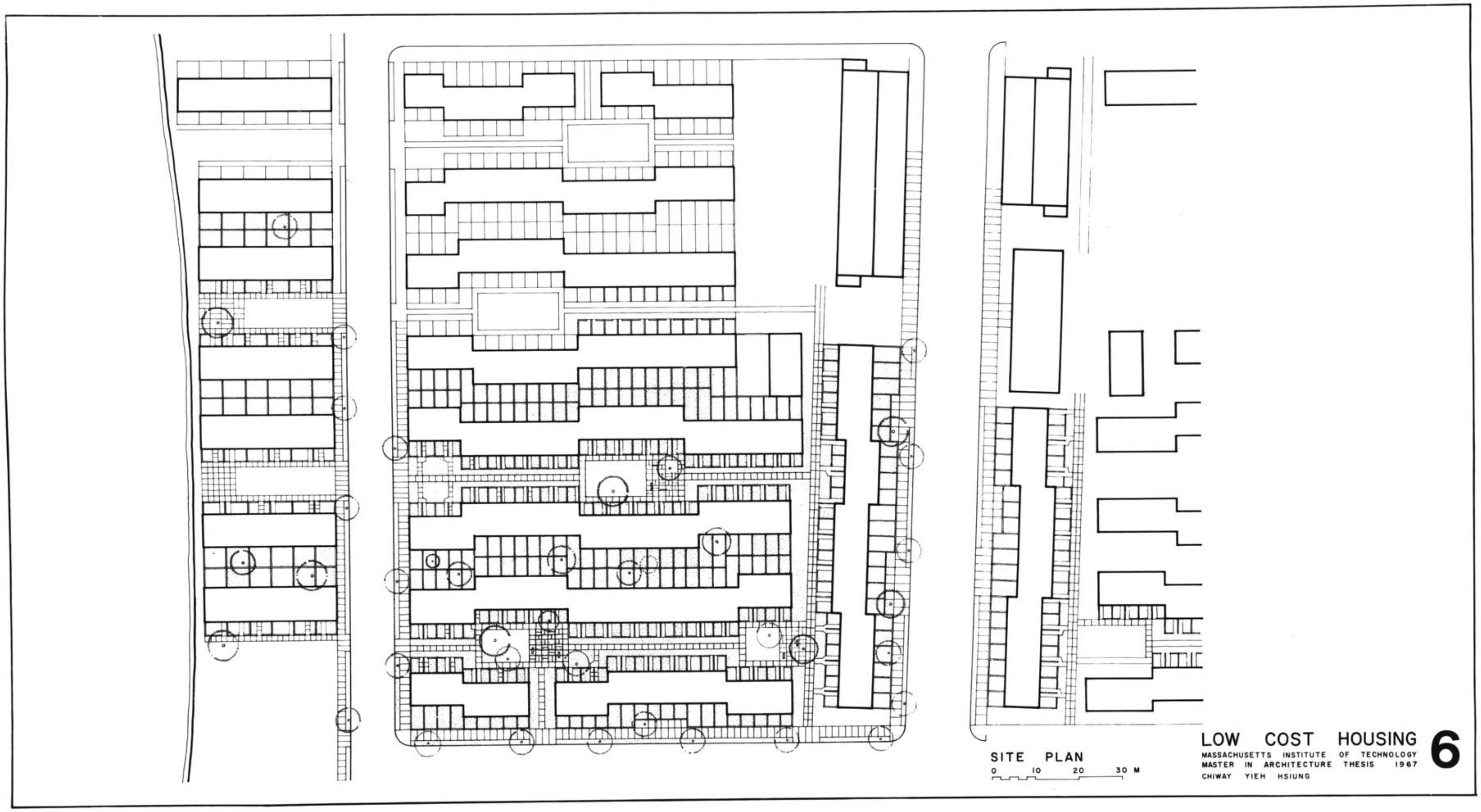

Fig. 6. Site Plan

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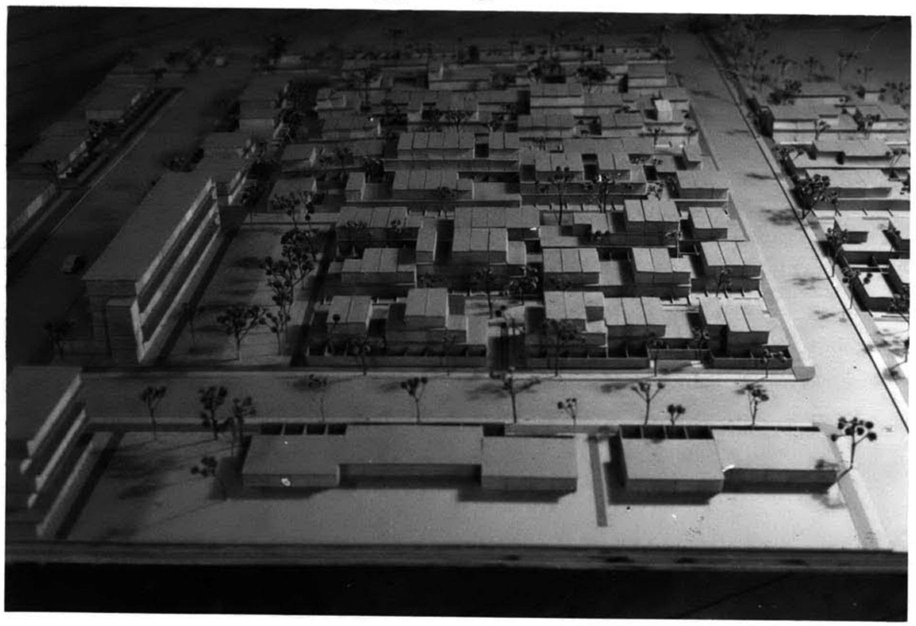

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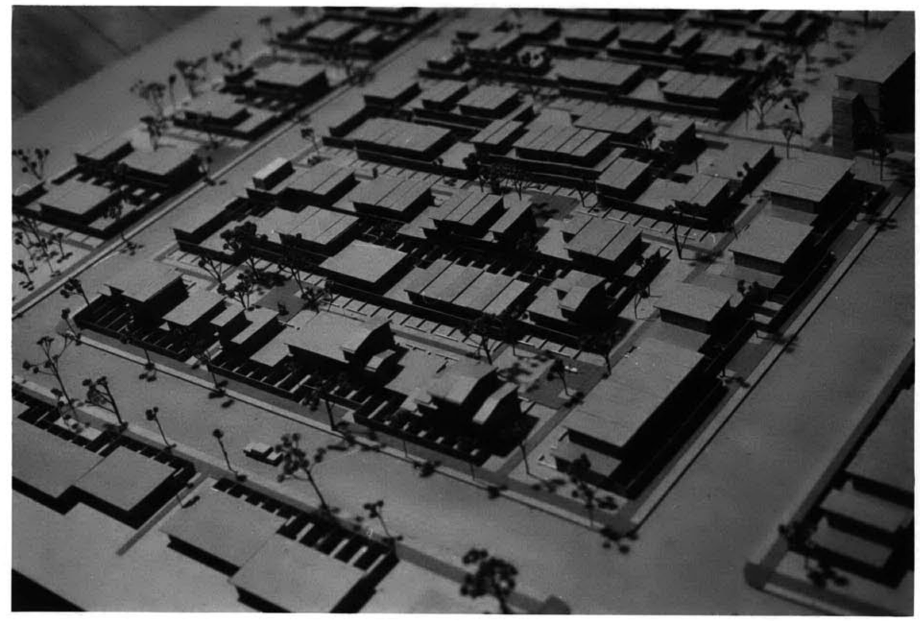


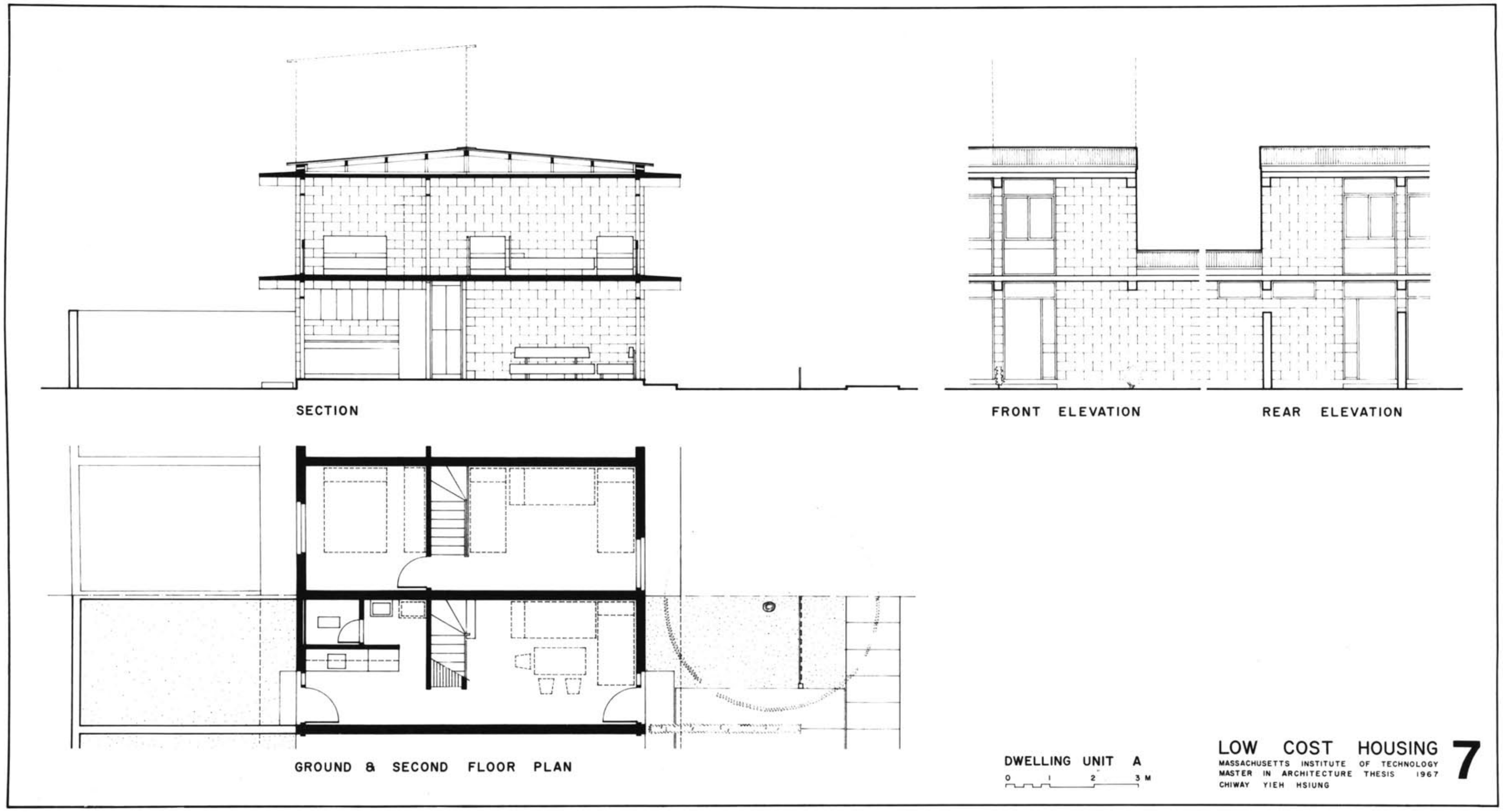


Fig. 7 Dwelling Unit A

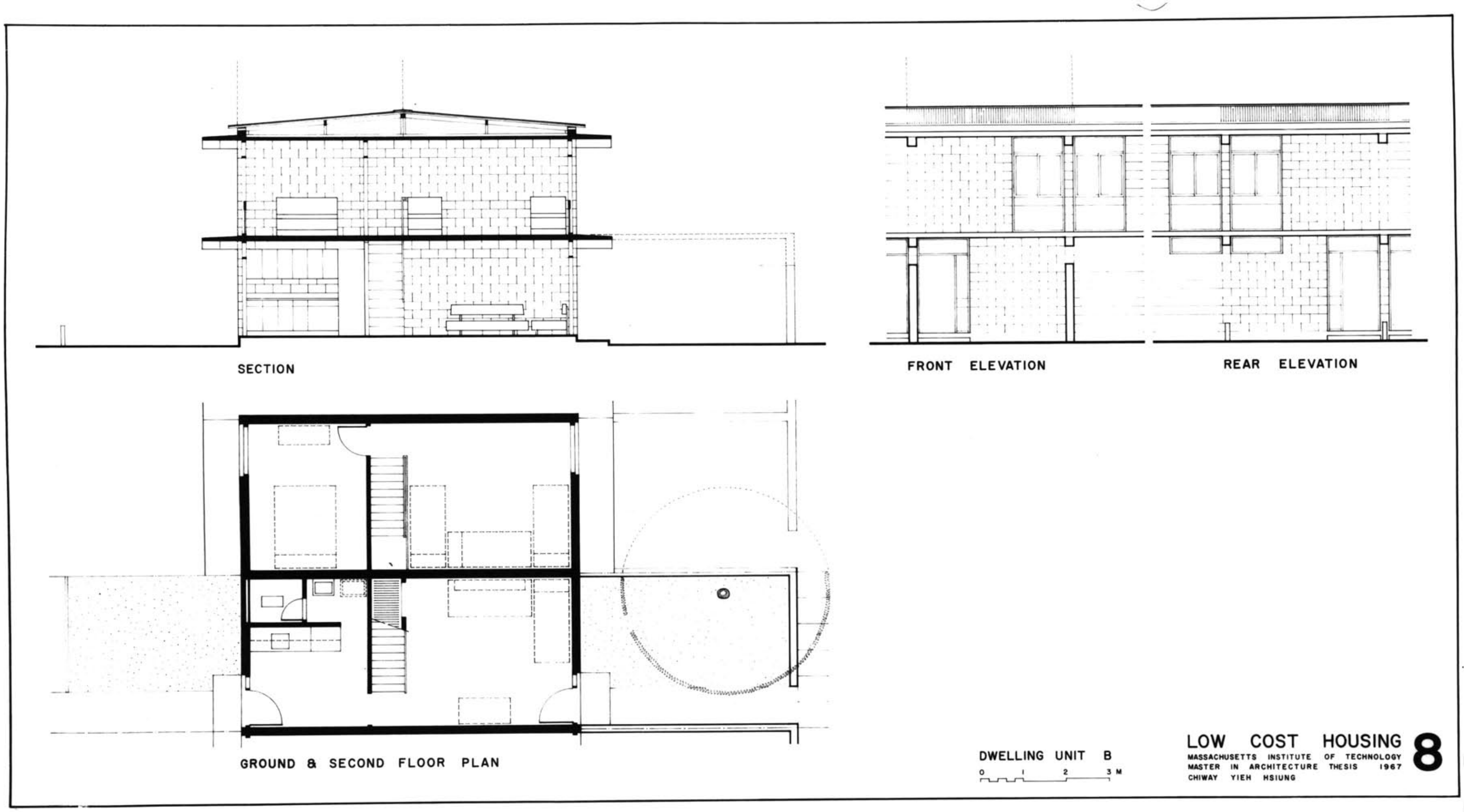


Fig. 8. Dwelling Unit B

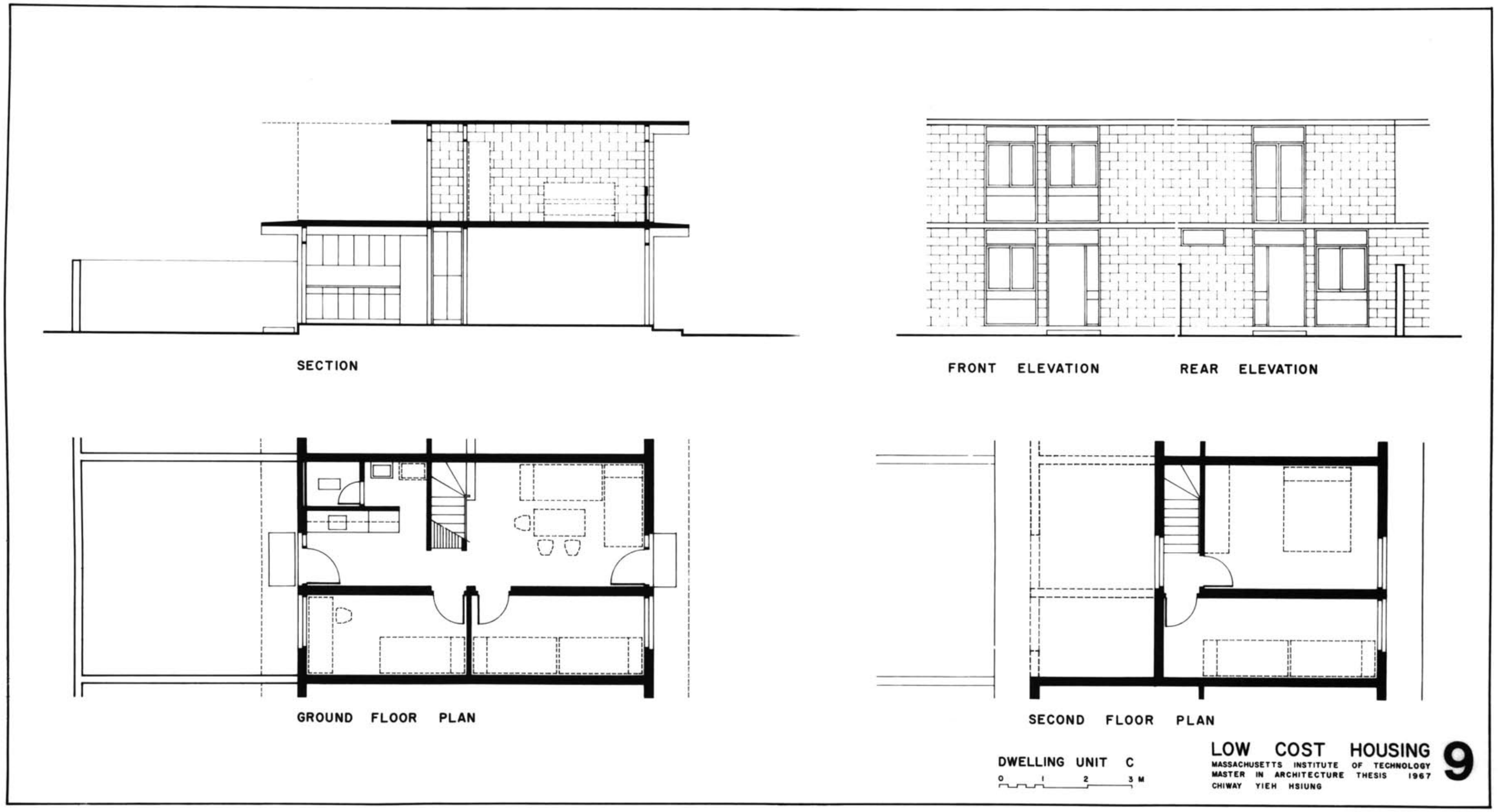


Fig. 9. Dwelling Unit C

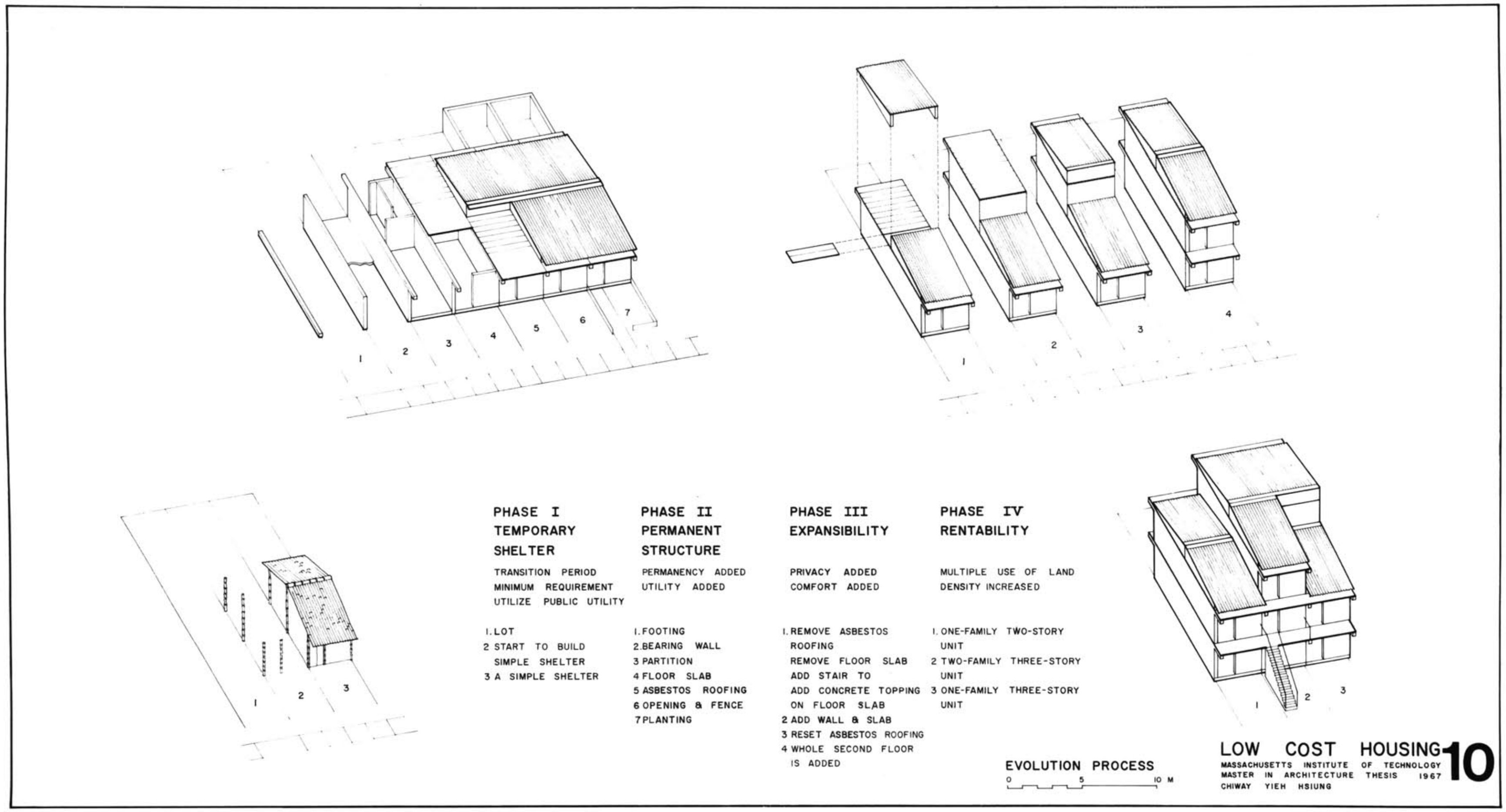


Fig. 10. Evolution Process

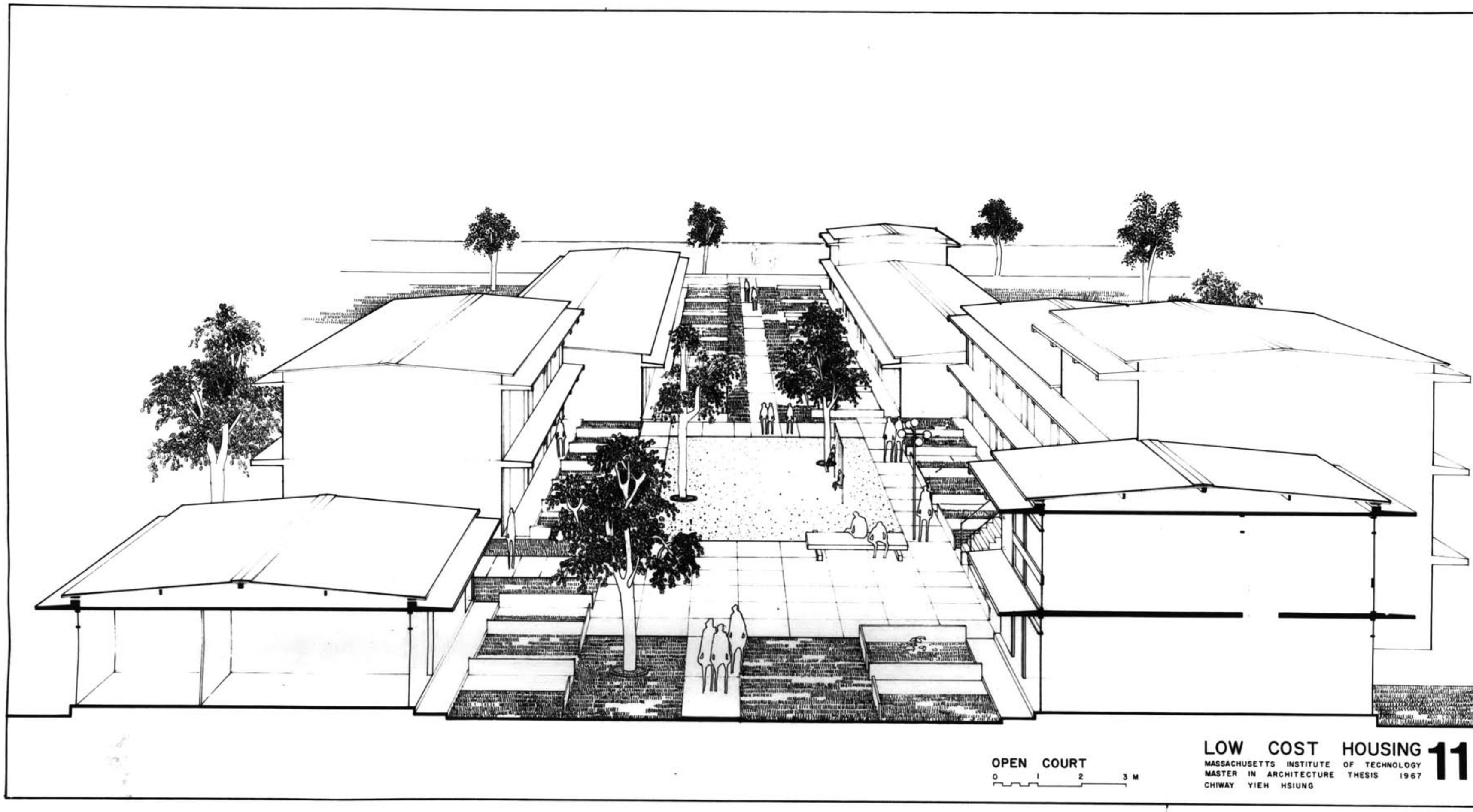


Fig. 11. Open Court

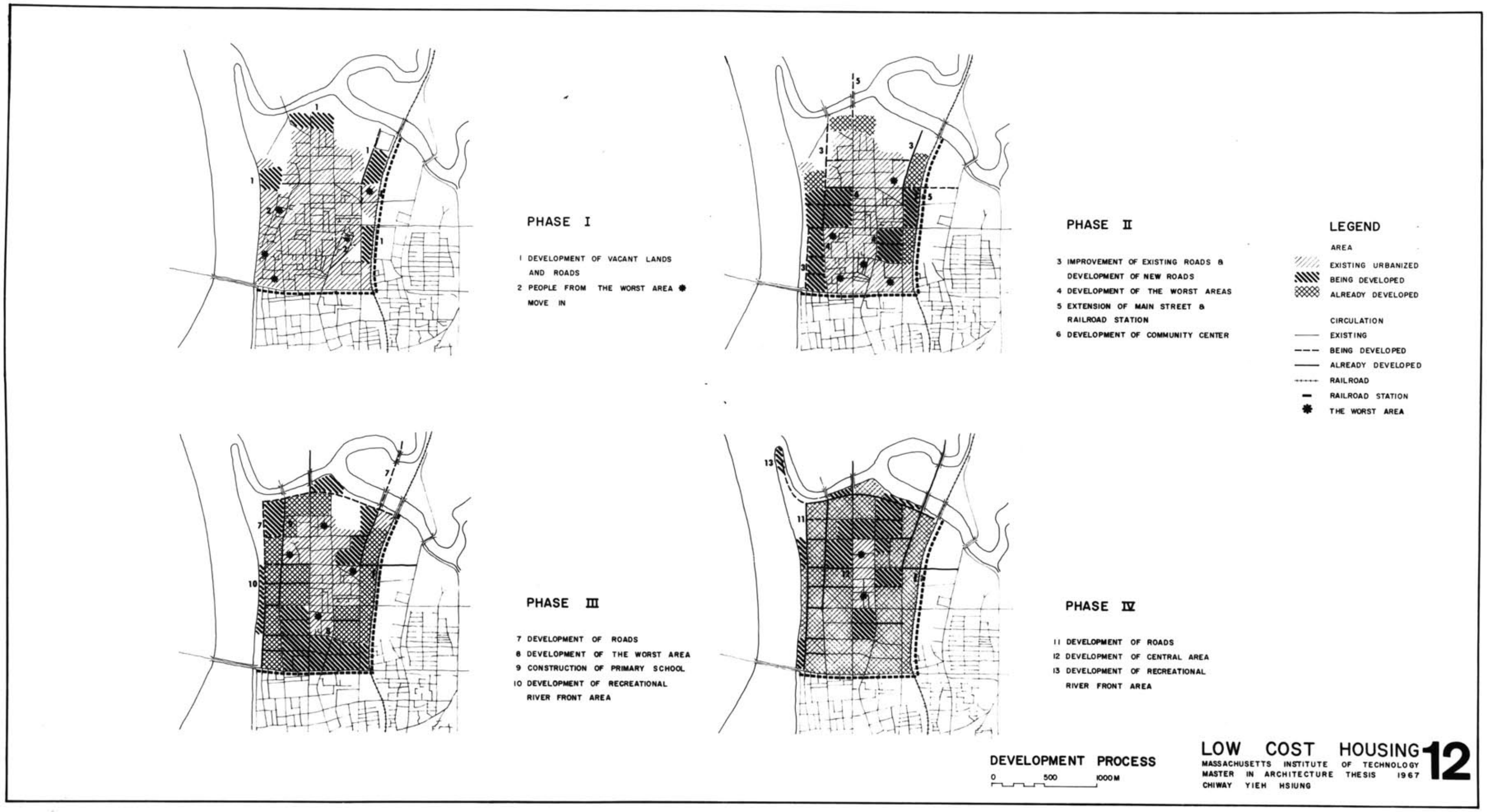


Fig. 12. Development Process

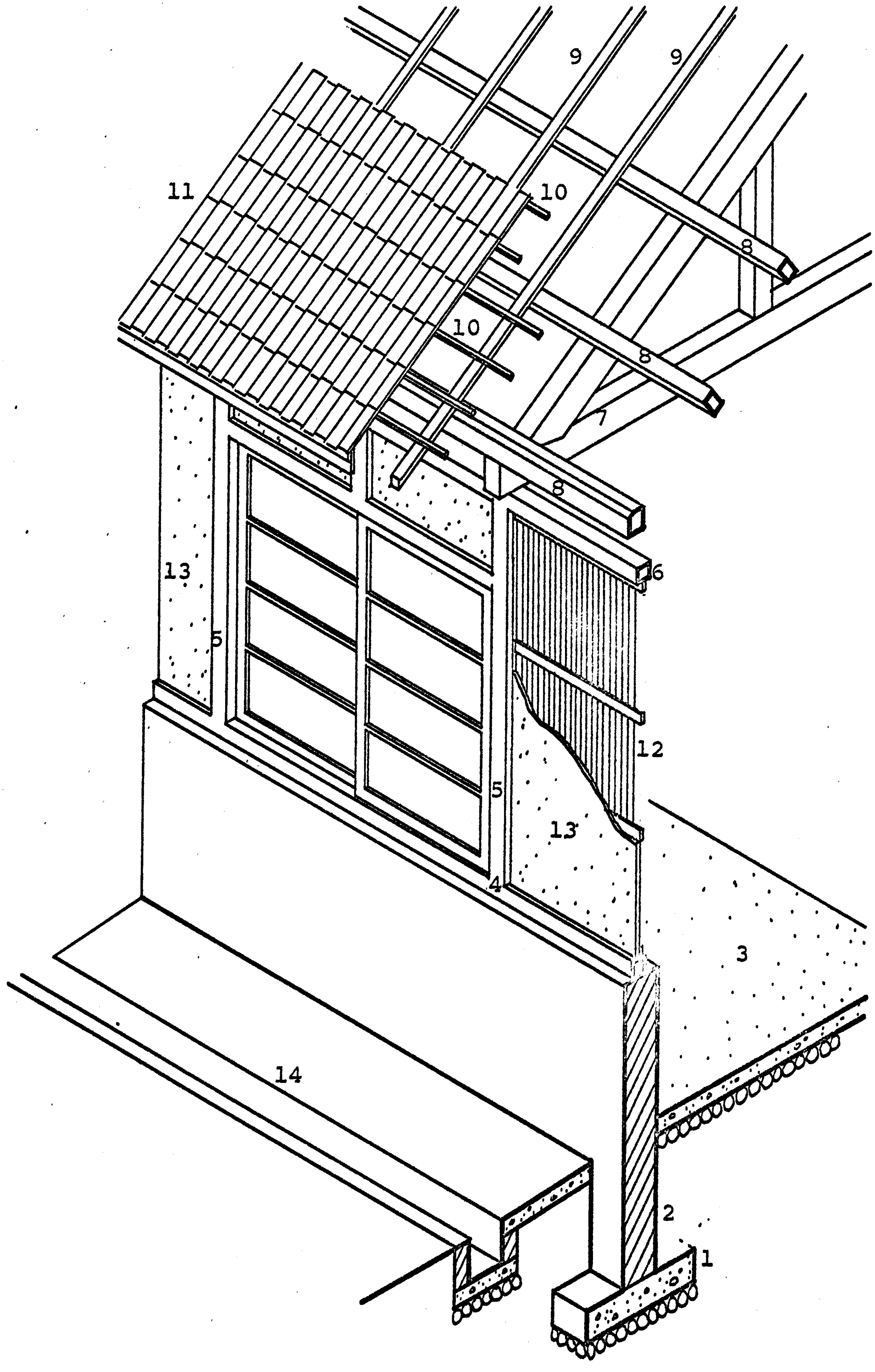


Fig. 13. CombinedTimber & Brick Structure System

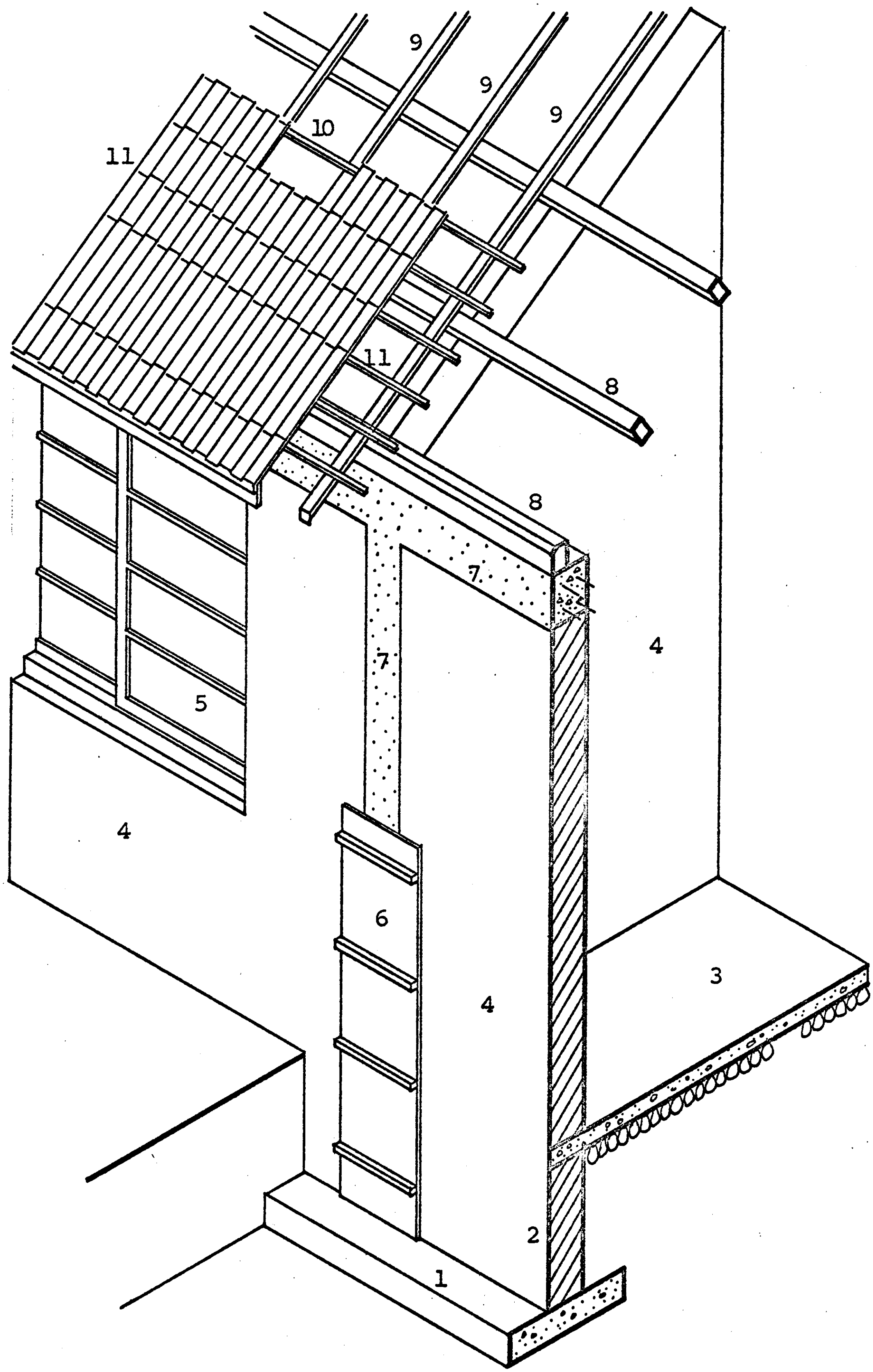


Fig. 14. Reinforced Brick Structure System

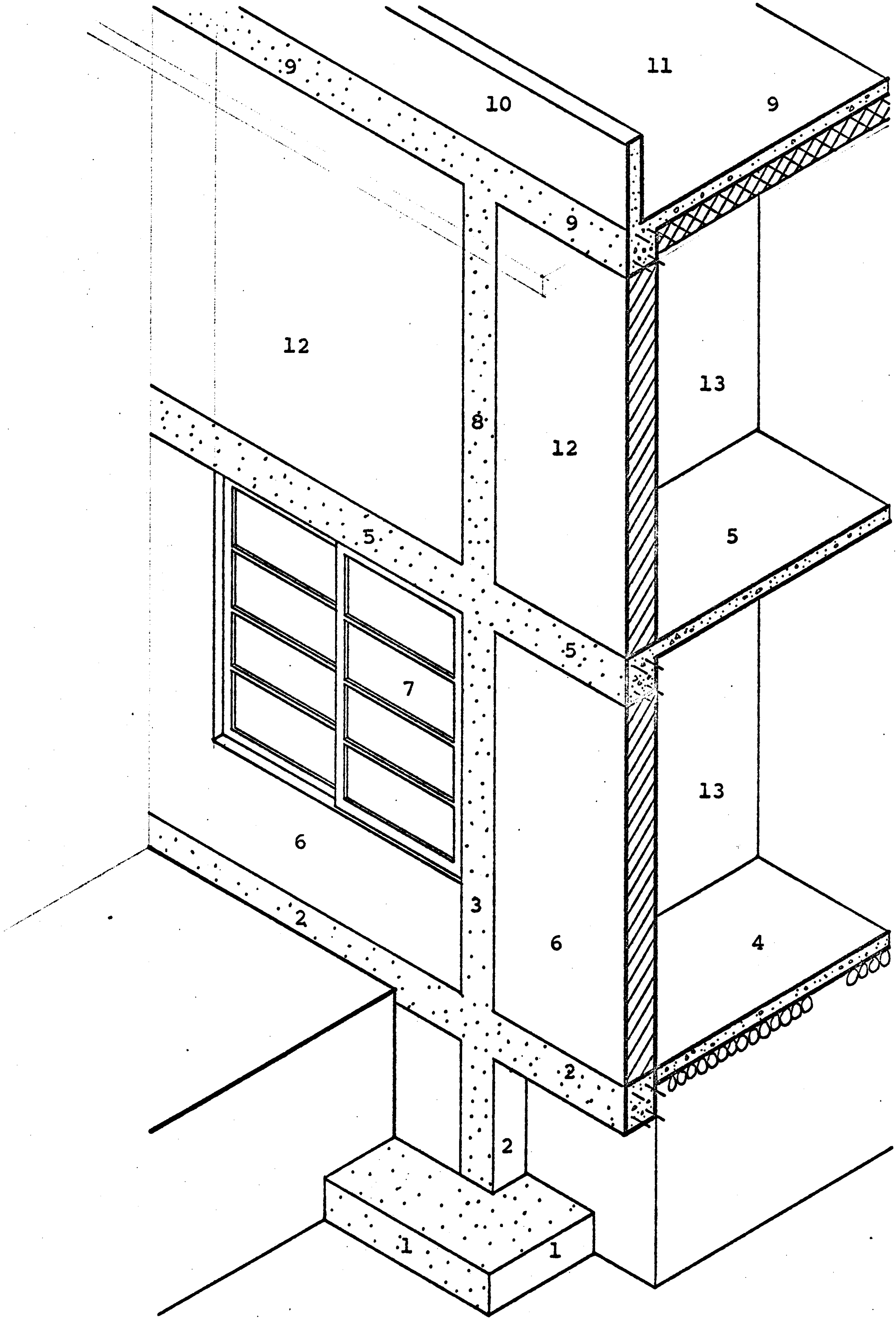


Fig. 15. Reinforced Concrete Structure System

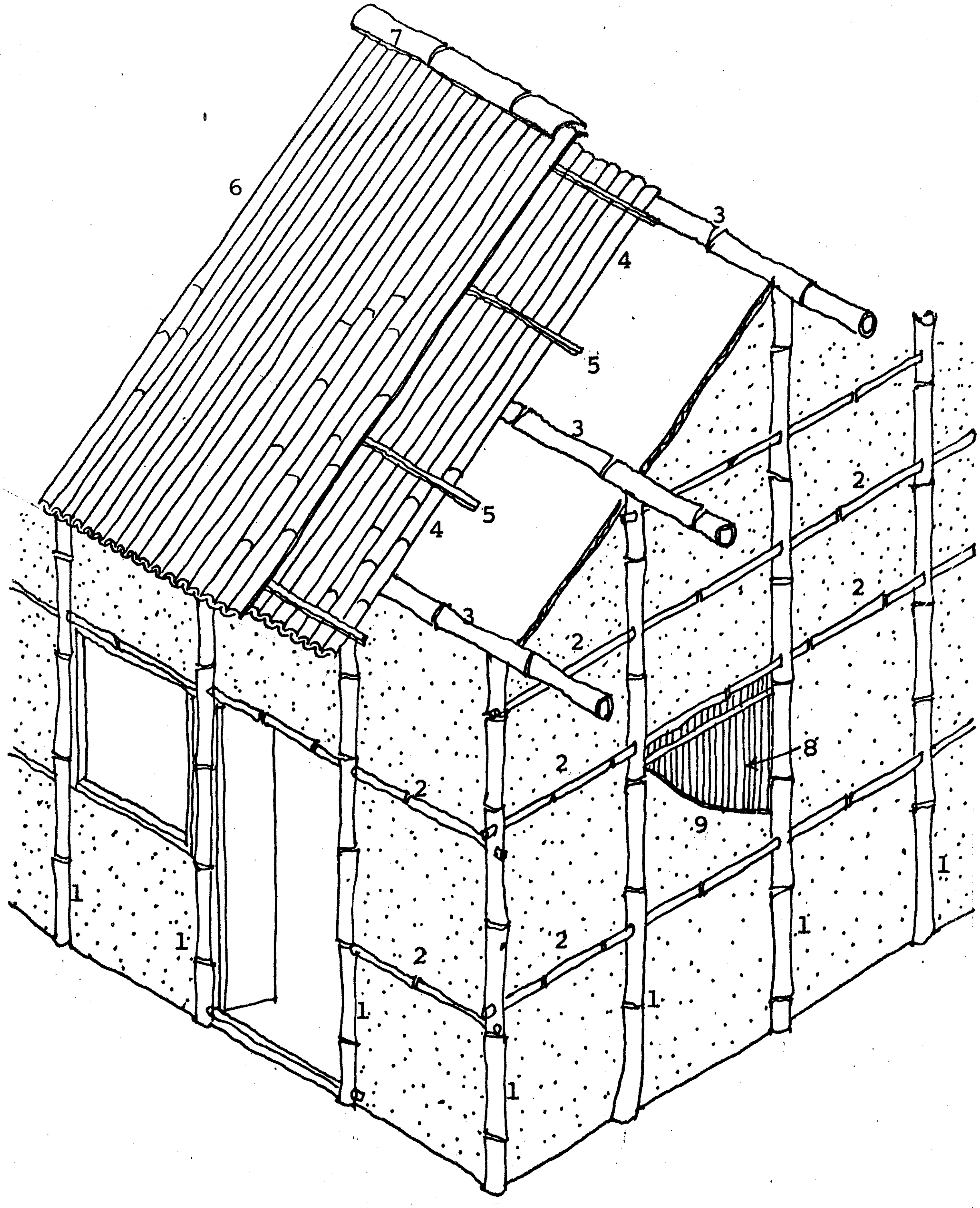


Fig.16 Bamboo Structure System

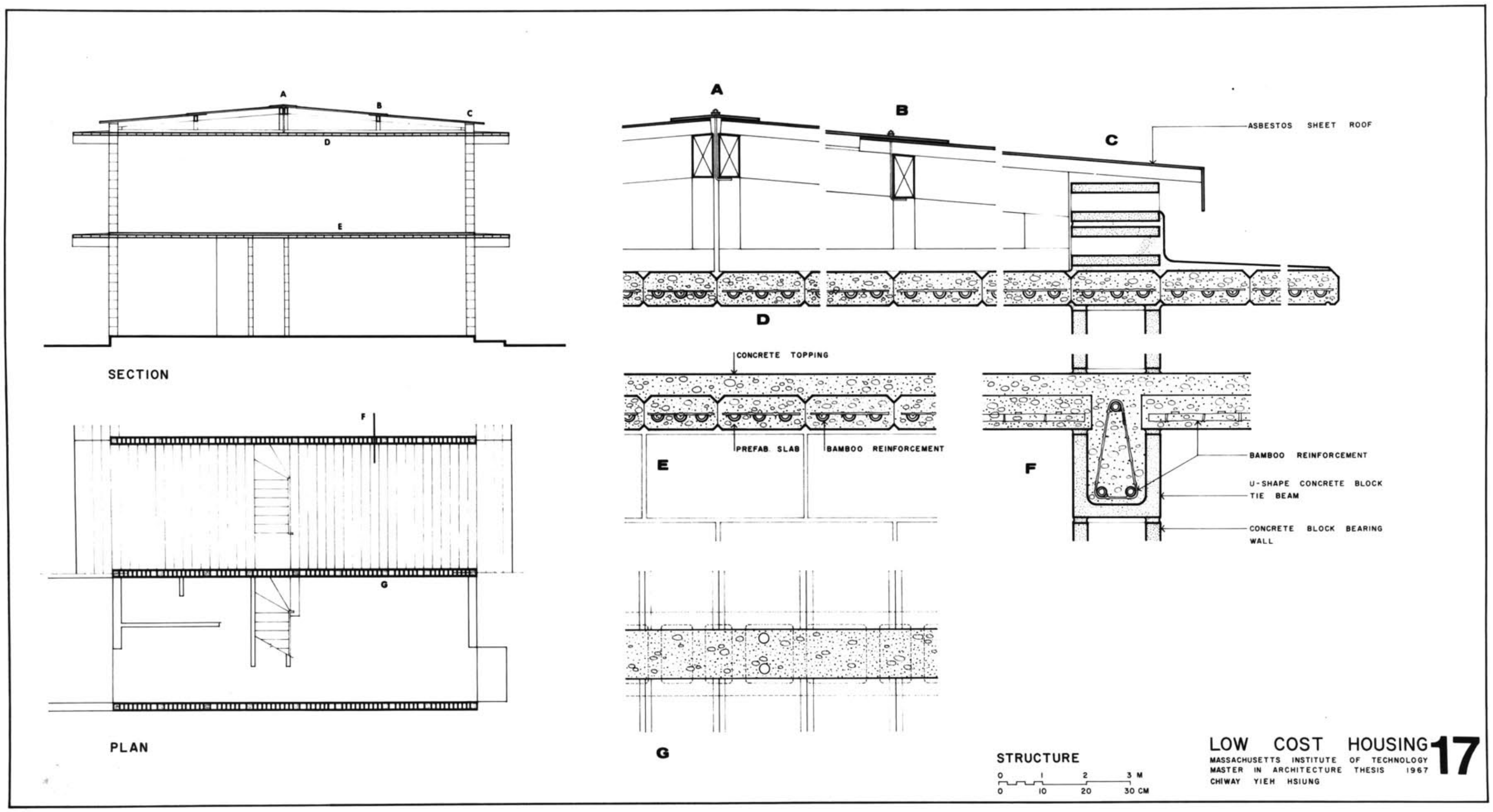


Fig. 17. Proposed Structure System

Appendix A. Bamboo Reinforced Concrete Beam Test

A. Object:

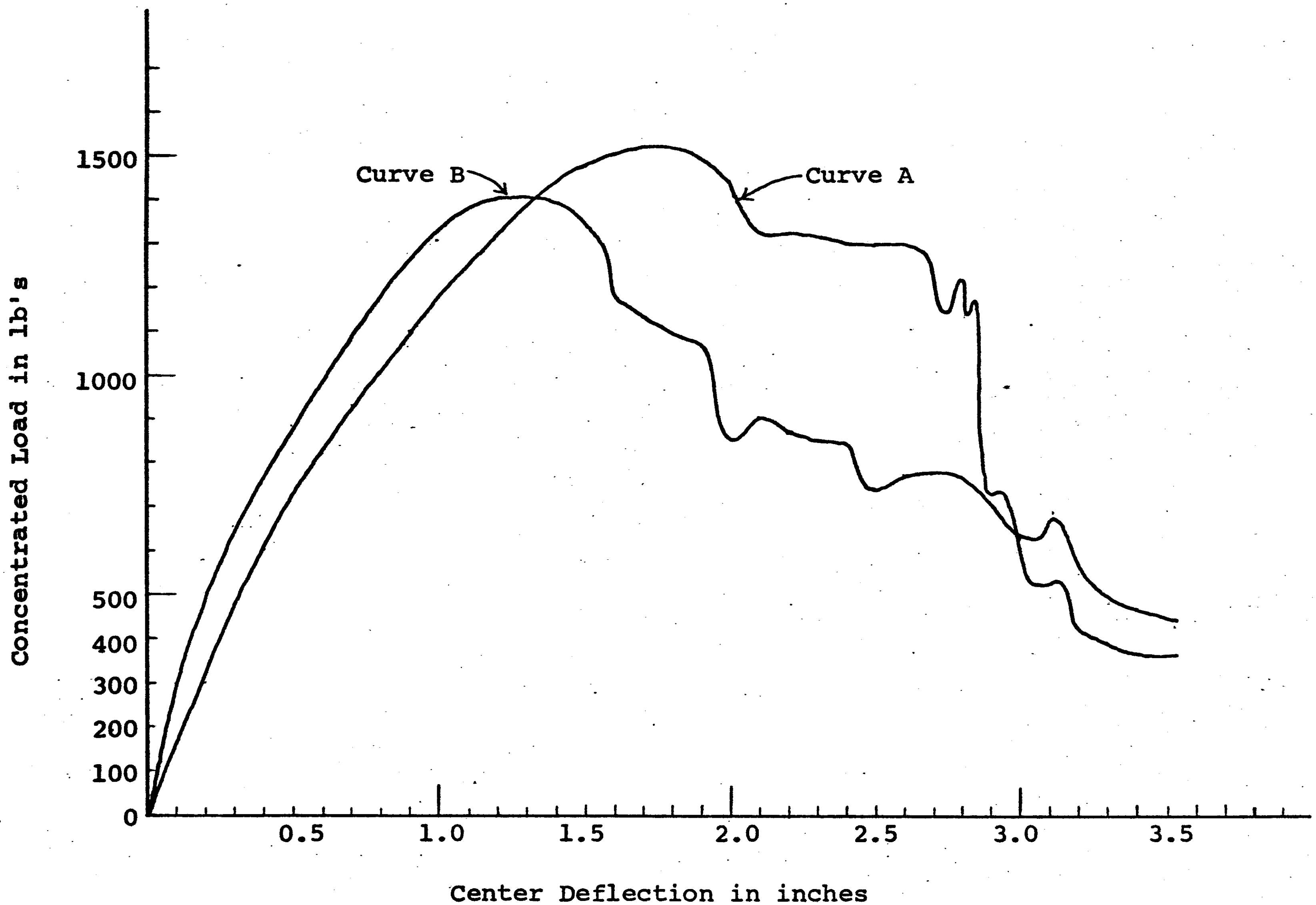
To investigate the behavior of bamboo reinforced beams under concentrated load.

B. Materials and equipments used:

Portland cement, sand, gravel, bamboo sticks, 1/16 inch diameter steel wires, motor oil, 1/2 inch plywood, deflection gage, and hand operated testing machine.

C. Procedures:

1) Two plywood forms were made. Each with a cross section of 3.15 in. x 7.9 in. (8 cm. x 20 cm.) and a length of 5 feet.
2) Bamboo reinforcing bars were cut and coated with motor oil for water proofing. Formworks were also coated with motor oil.
3) Bamboo reinforcing bars were placed into the forms. This was then followed by the mixing and pouring of 1:2:4 concrete.
4) Beams were covered with wet paper and permitted to stand for twenty three days.
5) At the end of setting period, beams were tested by an hand operated machine. Sharp wedge supports were used for support at both ends of the beam so that the beam was allowed to rotate freely. Concentrated load at the center was used to test the strength of the beams. Load


Curve B
Curve A
Concentrated Load in lb's
0
100
200
300
400
500
1000
1500
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Center Deflection in inches

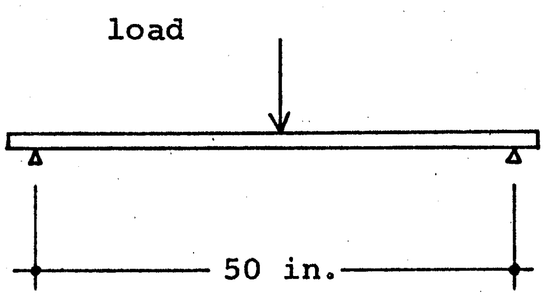
was gradually increased and corresponding deflections were recorded by reading off the deflection gauge.

6) Conditions of the beams at various stages of loading were photographed.

D. Computations and conclusions:

Loadings are plotted against corresponding deflections at the center in the graph on following page. Curve "A" is for the beam with cross section as shown in Fig.i , and curve "B" is for the other beam with the cross section as shown in Fig.ii .

Both beams started to crack at about 700 lb's of concentrated load. This corresponds to a maximium moment at the center of 730 ft-lb.



$M = PL/4$

$M = 700 \times 50 / (12 \times 4)$

$M = 730$ ft-lb

Or:

$M/\text{ft} = 730 / (7.9 \times 12)$

$= 1{,}111$ ft-lb/ ft

This is equivalent to the moment resulting from a uniformly distributed load of 92.6 lb/ft^2.

$wL^2/8 = M$ $1{,}111 = w\,(300 \times 0.0336)^2/8$ $w = 92.6$ lb/ft^2

Dead load of slab: $3.15 \times 120 / 12 = 31.5$ lb/ft^2

$92.6 - 31.5 = 61.1$ lb/ft^2

The liveload can be resisted is 61.1 lb/ft^2, which is about the usual design value.

From the graph, one can see that after the appearance of the first crack, the beams continued to increase their strength. Maximuim load was around 1,500 lbs. Even after testing, the bamboo reinforcing bars did not crack. Thus, a design based on 700 lbs of loading would be quite conservative. Also, crude equipments were used in mixing the concrete and in tesing the beam. With a little more skill, the strength of bamboo reinforced beams will propapably be much higher.

With the above facts in view, it seems that bamboo reinforced concrete can be an economical structural material for use in low cost housings.

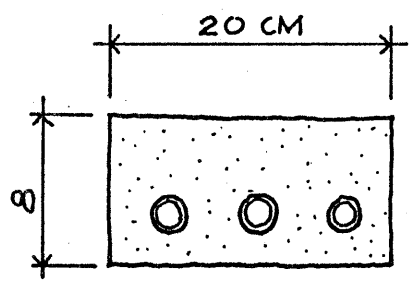


Fig. i. Beam Section A

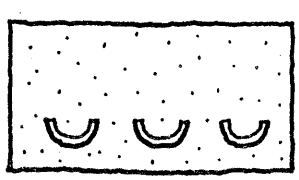


Fig. ii. Beam Section B

Appendice B. Bamboo Tensile Strength Test

A. Object:
To test the tensile strength of bamboo and its behavior under large loads.

B. Materials and equipments:
Bamboo and Instron (Multipurpose testing machine).

C. Procedures:
1) Two bamboo testing samples were prepared. Sample A, as shown in Fig vi, was cut between nodes. Sample B, as shown in Fig. vii, was cut with node in the center.

2) Samples were tested on the Instron, Both samples were tested to complete failure.

D. Data and Conclusion:
Resulting graphs are included on the next page. The area of Sample A was 0.0665 in^2. The highest load could be carried by this sample was 1900 lbs. This gives an ultimate strength of 28,600 psi. The area os fample B was 0.0885 in^2. The highest load resisted was 1660 lbs. This gives an ultimate strength of 18,8000 psi.

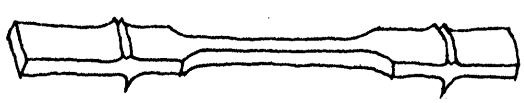


Fig. vi Sample A

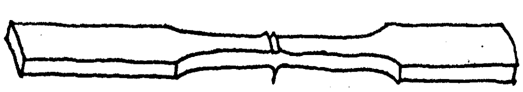


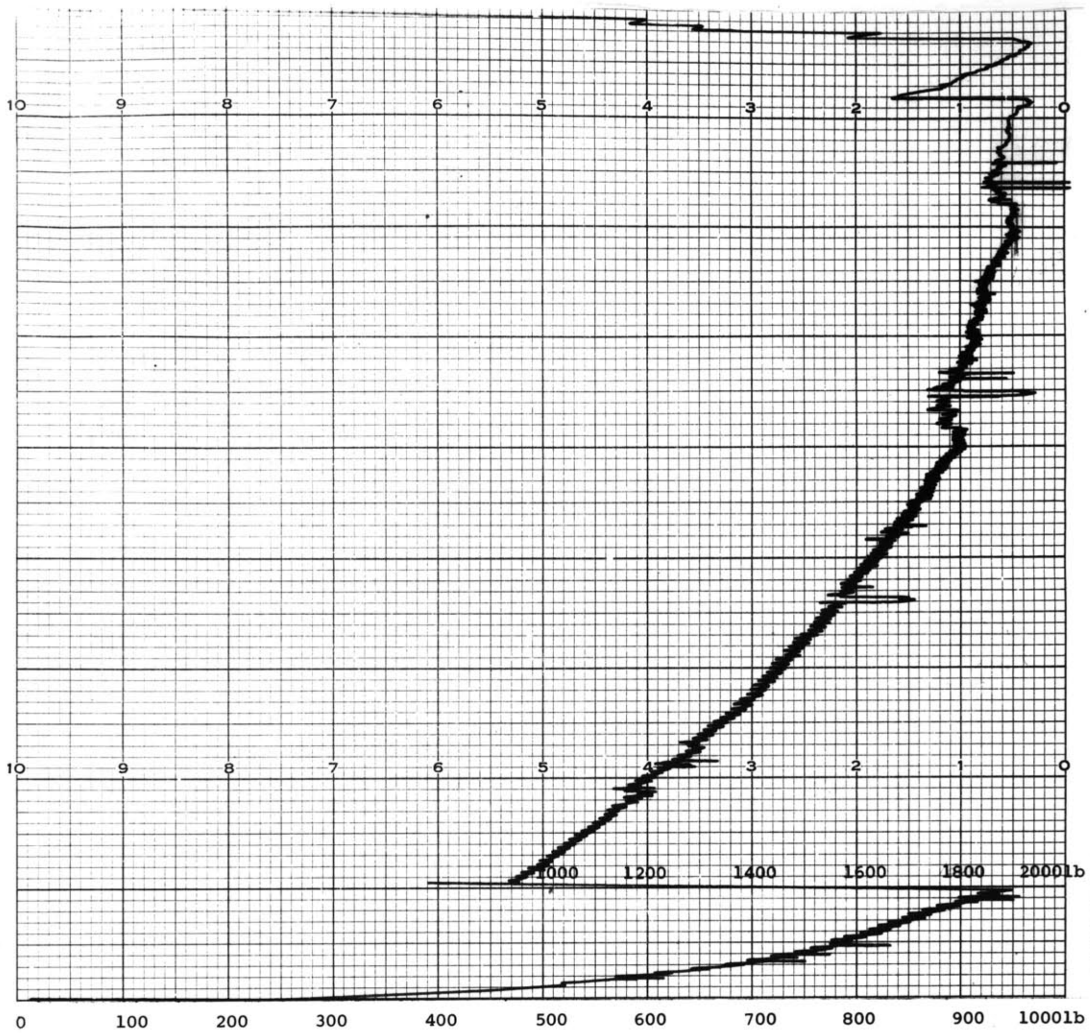
Fig. vii Sample B

In both cases, skin failed first, Then skin and inner part splited. Finally, the inner part failed.

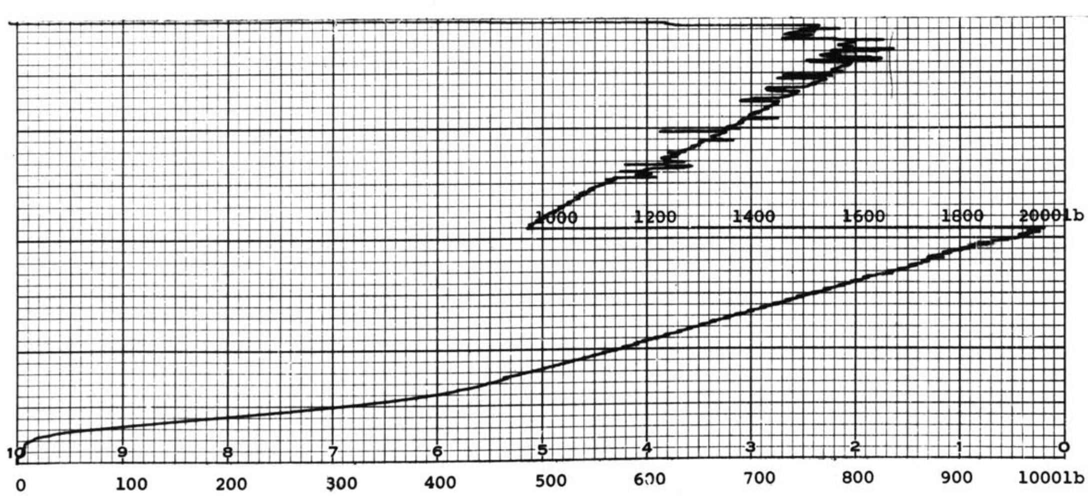
Another interesting fact was noticed. Bamboo with node began to fail at the nodal location,and its ultimate strength was 36% less than that of the sample without nodes.

In both tests, failure occurred at the cramped ends. Skin at the cramped places were damaged. As a result, bamboo sample slipped out of the cramps. One has good reason to believe that much higher loadings could be applied if more secure supports were used.

According the "Chinese Engineer's Handbook", bamboo has the largest tensile strength when it is 4 to 5 years old. As bamboo samples used in this test were cut from very small and young bamboo sticks, one can rest assured that the tensile strength of most bamboo sticks on the market will be greater than the values obtained in this experiment.



Tensile strength of bamboo without knots



Tensile strength of bamboo with knots

Appendice C. Water Absorption Test

A. Object :

To study the water absorption characteristics of bamboo.

B. Materials and equipments used:

Bamboo, measuring tape and scale.

C. Procedures:

Essentially, two tests were performed. One involves the change in weight and the other considers the change in dimensions.

1) Weight considerations

a. Two short samples of bamboo were prepared. They are as shown in Fig. iii, and Fig. iv. Sample A was unsplited and had nodes at both ends, while sample B was a splited piece.

b. Weigh both samples on the scale.

c. Immerse both samples in water for 24 hours.

d. Weigh both samples again.

2) Size considerations

a. Two samples were prepared. Sample C is the same as sample A. Sample D, as shown in Fig. v, did not have nodes at ends.

b. Measurements of the perimeters of both samples were taken.

c. Samples were emmersed in water for 24 hours.

d. Meaurements of the perimeters were again taken at the same points.

D. Conslussions:

In the first test, after emmersion in water, sample A and B increased weight by 12,2% and 26.8% respectively. In test two, sample C increased its perimeter by .86%, while sample B increased its perimeter by 1.78%.

In conclussion, it is clear that the water absorption of bamboo is quite large, but the change in perimeter is relatively small. Apparently most of the absorbed water filled the pore spaces of the bamboo plank. It is also obvious that closed bamboo segments with inner skin well prevented from coming into contact with water tend to sbsorb less water and thus do not expand as much as the open segments.

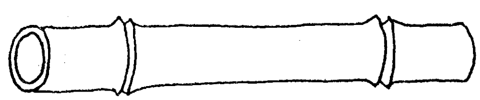


Fig. iii. Sample A & Sample C

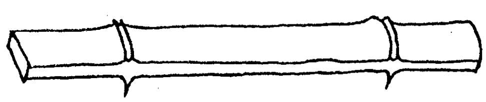


Fig. iv. Sample B

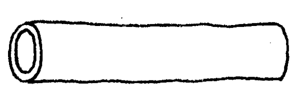


Fig. v. Sample D