A HOUSING SYSTEM:
STUDY OF MODULAR-BOX HOUSING UNITS
APPLIED TO PULL-UP SYSTEM.

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Submitted in Partial Fulfillment of
Requirements for The Degree of
MASTER OF ARCHITECTURE, ADVANCED STUDIES.

At the
MASSACHUSETTS INSTITUTE OF TECHNOLOGY


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Dean William Porter  
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Dear Dean Porter:

In partial fulfillment of requirements for the degree  
of Master of Architecture, Advanced Studies, I hereby  
submit this thesis entitled:

A HOUSING SYSTEM: STUDY OF MODULAR-BOX HOUSING UNITS  
APPLIED TO PULL-UP SYSTEM.

Respectfully,

Tong Hongladaromp.
ACKNOWLEDGEMENTS

The author gratefully acknowledge the following people who assisted in the development of this thesis:

Professor Waclaw P. Zalewski, Thesis Advisor.
Department of Architecture.

Professor Eduardo Catalano
Department of Architecture
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ABSTRACT

A HOUSING SYSTEM: STUDY OF MODULAR-BOX HOUSING UNITS APPLIED TO PULL-UP SYSTEM.

By Tong Hongladaromp

Submitted to The Department of Architecture on May 11, 1973 in partial fulfillment of requirements for the degree of Master of Architecture, Advanced Studies.

This thesis is intended to develop a housing system based on industrialized technology for high-rise configuration.

The written section provides a brief overview of housing in high-density urban situation, potential of industrialized housing systems, the constraints within which the design proposal is developed, and the advantages of the design proposal.

The design proposal demonstrates how to construct different components in factories into the box-units, how to construct those boxes on building site by using pull-up technique, how boxes composed into different forms of apartment units, and how the system forms into vary types of building.

Thesis Supervisor: Professor Waclaw Zalewski

Title: Professor of Structures, Department of Architecture.
INTRODUCTION

The demand of housing in high-density urban situation grows up quickly during this pass decade and is predicted to be the same way in the next decade. There are certain sources of this demand, one is the slowdown of nation economy, investors turn against the risk in commercial and industrial investment and looking toward housing development or real-estate bussiness, other sources are the return of U.S. people from abroad is increasing during this four or five years, the decrease in quality of existing housing in cities and towns, etc..

This demand turns the mobile-home and many other housing manufactures to take the important part in construction industry during this pass decade. But when taking the close look at this industry, one can see that most of the products emphasize on supplying low-density housing area, for example products of mobile-home and wood-boxes housing units. No real attempt working toward high-rise housing or application to housing in cities and towns area. The reason is that they have to confront to a lot of building regulation, transportation regulation, high cost of land, high cost of construction, etc., those are existing in project developments in towns or cities area. But we all realized that the real big market and demand is there. Therefore, this study is aiming toward the application of industrialized housing system in that area.
HOUSING IN HIGH-DENSITY URBAN SITUATION

To develop housing projects in high-density area, for instance in towns or cities, the most important thing that has to be carefully considered is the use of land. The cost of land is surely very high and one must make the maximum value out of it. Low-rise housing or low-income housing is nearly impossible in such configuration, the high-rise should be more considered for it responds to the efficient use of sites. It is a good idea if one can free the low-level of high-rise housing to be used for commercial area or recreation area which will increase the value of the project.

There are numbers of problems in development in cities or towns area which are indicated as follow;

Limitation of Transportation.

To supply building material to the construction sites in towns or cities, one has to confront transportation regulations which are different from one state to another. The maximum size of unit that can be transported on high-ways is 60'-0" long, 18'-0" high (from road-level), and 14'-0" wide, some states allow smaller size than this. The weight of units is also limited, usually not over 30 tons, and more emphasized in city area. In conventional construction which most of material supply comes in small sizes, this regulation is not as big problem as in modular-box construction.
Building Regulation

Building codes is always create a lot of problems in design development of projects in cities or towns, for example fire-regulation usually requires two hour fire-rating at out-side facades, corridors, and cover all structural members those do not have fire-proooving quality. It hardly leaves room for light-weight modular-box construction, which most of them are constructed of wood or metal. Another constraint according to building codes or other standards (for example F.H.A. or M.F.H.A. standard) is the standard sizes of each room, for example 12'-0" width required for major bedroom, 14'-0" width for living room. This gives the difficulty in design of modular-box systems, for those boxes can not be over 14'-0" or even less in width according to the transportation reguration.

Citizen Participation

Project developments in cities always confront to this problem and likely to be more everyday. Many of projects are blamed of distroying charactor of communities, increasing traffic, etc.. This indicates that to develop projects in such area requires good political contract, relationship with community organizations as well as good technology.

Construction Labour

Labour workers in this country are organized in form of
unions, especially in construction industry, and those unions contain a lot of influence over the construction especially in big cities. New technology or systems which provide decreasing number of labour workers are strongly opposed by unions. This is one of the answers why industrialized housing systems are not well developed in this country even though the U.S. is farther developed in technology than other countries. The unions always negotiate higher labour wages and make the labour-cost to be the major problem in construction, especially on-site labour cost.

Limitation of Site to Operate Construction.

Construction in cities or towns lacking of site to operate is always happen, for example minimum site to move or install cranes, store building material, etc. Many times one has to rent some area near by or use public traffic area for extra site to operate construction, which means extra more money has to be spent.

Difficulty to Operate Construction on High-level.

The cost of construction per square-foot always higher if it has to operate at higher level, for it is difficult to carry members or material by cranes to work on level over 100' (mostly because of wind or bad weather). Especially in conventional construction which a lot of activities such as concrete pouring or facade finish have to be done on high-level, those work is confronted
to the difficulty of operation and many of times have to delay. The rental cost of equipments to operate construction on level over 130' to 140' up is very high (There is about 50 to 60% increase of rental cost if one wants the cranes to work over 140' high and 30 tons load, for working capacity less than mentioned can be carry out by mobile-crane or hydraulic truck-crane.)

Financing of Construction Time.

The construction time is the important subject in development in cities or towns. Minimum construction time is always the objective of every project, for it means the minimum of financing interest, labour cost, equipment rental, and many other overhead cost.

Through these problems one can realizes that the technology alone cannot fulfill this situation, it surely requires strong administration, political contract, and assisting of many other people involved. This study is carried out the attempt of solving some problem mentioned.
DESIGN PROPOSAL

This system begins by factory process of constructing modular-boxes from different standard components. The standard dimensions of boxes are 14'-0" width, 9'-6" hight and four different lengths 20'-0", 24'-0", 28'-0", and 32'-0". Basic structure is steel frames with addition of light-weight concrete floor and gypsum or asbestos boards for fire-proothing. Interior partitions, closets, and cabinet works are wood construction. Bath-rooms and kitchens are installed, H.V.A.C. plumbing electrical, and most of final finish are done from factory stage. This provide maximum finishing work and minimum transport-ation weight to each box-unit.

On site-work, circulation cores with dimensions of 20'x 20', or 20'x 24', or 28'x 28' (depend on which type of building) are built by slip-form technique. Lifting-machines are installed on top of cores and hang down lifting-tendons and lifting-shoes to the ground-level. On ground-level, modular-boxes are stacked up four storey high (Each box is welded to the boxes near by.) in a steel truss frame forms a giantic beam called a package unit. After the first package unit is done with nescessary finish, it will be pull up along the circulation cores by lifting-machines on top of cores to the exact location on high-level, and the supports for the package are provided to support it to the the cores before lowdown the lifting-shoes.
Corridor and ceiling panels are installed after the first package is already supported, final works such as main utility, trimming, painting, etc. are done at the same time. Material supply for final finish on first package unit is carried out by using circulation cores. By the same time that activities take place at high-level, on ground floor the construction of second package unit begins. Then carry the same sequence until finish.

For better understanding in design proposal, the drawing section is provided in this study.
ADVANTAGES OF DESIGN PROPOSAL

Less On-site Labour.

Comparing to conventional system, the design provides less on-site labour approximately about 60 to 70%, for most of the work are finished from factories. In practicing the cost of on-site labour is 50 to 60% more than labour cost in factories, and on-site labour requires security insurance more. Overhead cost in case of delay or strike is less in factories than in open shop.

Less Construction Time.

As most of the work are done from factories and the standard is already provided for design, using the system surely save a lot of time in construction fields as well as in design development. The system provides minimumum high-level operation which sometimes causes delay of work as mentioned, that also means saving of construction time. Using this system, most of the work are operate on not more than four storey high level, it surely easier to work or weather-proof, even the work on final finish of package units at high level most of them are operate indoor, very few work is left outside.

Free Ground-level
This is the most advantage of the design proposal. The system provides free low-level space that can be used as commercial spaces, traffic or beautiful recreation area, parking facilities, etc. This configuration contributes services to communities on the sites and increasing the value of the projects.
DESIGN PROPOSAL:

DRAWING SECTION

COMPONENTS
PLAN.

END CONDITION FOR DUCT SPACES

ISOMETRIC

FLOOR COMPONENT
1" = 8'-0"

COMPONENT
3" X 3" CHANNEL
2" X 2" T-SECTION
1" X 1" L-SECTION
ALUMINUM.

2" X 2" L-SECTION
DIFFERENT END CONDITION.

PLAN.

2 HOUR FIRE-RATING GYPSUM-BOARD WITH FINAL-CEILING FINISH.

ISOMETRIC.

CEILING COMPONENT.
1" = 8'-0"
**PLAN.**

**CEILING COMPONENT**
- 1" x 3" L-SECTION
- 3" x 3" CHANNEL
- 2" x 3" CHANNEL
- 3' x 7'-6" DOOR

**FLOOR COMPONENT**

**ELEVATION.**

**CORRIDOR SIDE END-WALL.**

**G.B. FIRE-WALL**
- 1 1/2" RC. PANEL
- OUT-SIDE FINISH.

**HEATING RADIATOR**
- 1 1/2" RC. PANEL
- 3" x 3" CHANNEL
- 2" x 3" CHANNEL
- 3" x 3" CHANNEL
- 1" x 3" CHANNEL

**FLOOR COMPONENT.**

**OUTSIDE WALL.**
- 3'-0"
- 4'-0", 6'-0"
- 12'-0"
- 14'-0"
- 20'-0"
- UP TO 32'-0"

**PLAN.**

**STANDARD SIDE WALL WITH OUT-SIDE FINISH.**

**ELEVATION.**

**WALL COMPONENT**
- 1" = 8'-0"
BOARD WITH OUT-SIDE FINISH
CORRIDOR END-WALL
2 HOUR FIRE-RATING GYPSUM-BOARD WITH OUT-SIDE FINISH

3' × 7'-8" DOOR

3" × 3" CHANNEL
2 HOURS FIRE-WALL
1" × 3" L-SECTION

FINAL FINISH INSIDE

2" × 3" CHANNEL

3" × 3" CHANNEL

ISOMETRIC

1" = 4'-0"
BATH ROOM COMPONENT.

KITCHEN COMPONENT.

DOOR

CLOSET

INTERIOR PANEL

INTERIOR COMPONENT.

1" = 8'-0"
CONSTRUCTION OF COMPONENTS

CONSTRUCTION OF BOXES, Corridor and Ceiling Finish (On-Site)

1" = 8'-0"
<table>
<thead>
<tr>
<th>Box</th>
<th>Dimension in Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>20'-0&quot;  24'-0&quot;  28'-0&quot;  32'-0&quot;</td>
</tr>
<tr>
<td>B</td>
<td>20'-0&quot;  24'-0&quot;  28'-0&quot;</td>
</tr>
<tr>
<td>C</td>
<td>20'-0&quot;  24'-0&quot;</td>
</tr>
<tr>
<td>C1</td>
<td>20'-0&quot;</td>
</tr>
<tr>
<td>C2</td>
<td>20'-0&quot;</td>
</tr>
<tr>
<td>C3</td>
<td>24'-0&quot;</td>
</tr>
<tr>
<td>D</td>
<td>20'-0&quot;  24'-0&quot;  28'-0&quot;</td>
</tr>
<tr>
<td>E</td>
<td>24'-0&quot;</td>
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<tr>
<td>F</td>
<td>24'-0&quot;  28'-0&quot;</td>
</tr>
<tr>
<td>F1</td>
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<td>F3</td>
<td>24'-0&quot;</td>
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<tr>
<td>G</td>
<td>28'-0&quot;  32'-0&quot;</td>
</tr>
<tr>
<td>H</td>
<td>32'-0&quot;</td>
</tr>
<tr>
<td>J</td>
<td>20'-0&quot;</td>
</tr>
<tr>
<td>K</td>
<td>24'-0&quot;  28'-0&quot;</td>
</tr>
</tbody>
</table>
CONSTRUCTION SEQUENCE
1. **Construction Sequence**

- Circulation cores are built by slip-form technique, temporarily-bracings are placed among cores.
- Install lifting-machine on top of cores, place lifting-tendon & shoes.
- Start constructing 4-storey-high package unit, penhouse or machine rooms are built if required.
2.

- Lift the first package, remove temporarily bracings during the period of lifting and replace them after if necessary

CONSTRUCTION SEQUENCE
- Support the first package at high-level, low down lifting-shoes
- Start building the second package
- Start constructing corridors, install necessary utility, and start finishing ceilings and trimming on the first package.

Construction Sequence
- LIFT THE SECOND PACKAGE

CONSTRUCTION SEQUENCE

1" = 60'-0"
- CONTINUE THE SAME SEQUENCE

CONSTRUCTION SEQUENCE
6.

FINISH LIFTING-SEQUENCE, START BUILDING NECESSARY REQUIREMENT ON LOW-LEVEL

CONSTRUCTION SEQUENCE
CHARACTER AND DETAIL
ISOMETRIC OF PACKAGE UNITS
1" = 30'-0"
DETAIL OF STEEL TRUSS
FRAMED AROUND CORE
1" - 10' - 0"
DETAIL AFTER
FINISH WITH R.C. PANEL

1" = 10'-0"
TENDON INSULATION

CEILING

HEATER

1/2" THICK CONCRETE
FINISHING PANEL

MODULAR-BOX

METAL FLASHING

STEEL TRUSS MEMBER

FLOOR

BUILT-UP ROOF

FLASHING

DETAIL OF FINISHING BOXES WITH FRAME
1" = 3'-0"
CIRCULATION CORE
SUPPORTING BEAM SLIDED OUT FROM CORE 5"x8" CHANNEL
GUIDE RAIL 2"x1" CHANNEL
GUIDE WHEEL Ø 2"
5"x8" VERTICAL MEMBER
1½" CONCRETE PANEL
5"x8" CHANNEL
Ø 3" LIFTING-TENDON
10"x10" VERTICAL MEMBER

PLAN.

LIFTING-TENDON
10"x10" VERTICAL MEMBER
R.C. CIRCULATION CORE

GUIDE RAIL
GUIDE WHEEL
5"x8" CHANNEL
FINISHING PANEL
5"x6" CHANNEL
5"x8" CHANNEL

PANEL SLIDED FROM CORE TO SUPPORT PACKAGE UNITS
Ø 1/3" BOLT

ISOMETRIC

DETAIL AT CONER OF CORE
1" = 2'-0"
STEEL MEMBER OF WALL
FINAL INTERIOR FINISH
GYPSUM BOARD
LOW-MEMBER OF WALL
TOP MEMBER OF FLOOR
LIGHT-WEIGHT CONCRETE
METAL DECK FLOOR
T.SECTION 3" x 3"
BOTTOM MEMBER OF FLOOR
Ø 1" GUIDE PIN
FLOOR STRUCTURE FRAME
ELECTRIC PIPE
CEILING STEEL FRAME
1" x 1" ALUMINUM MEMBER

inside box

REINFORCEMENT
VERTICAL MEMBER
PIPE
GUIDE PIN
WELDED TO MAIN TRUSS
STEEL BOTTOM-CORD
5" x 8" L-SECTION
3" x 3" CHANNEL

bottom cord of main truss

FINAL FINISHING PANEL

SECTION
1" = 10"
FINAL FINISH AT CORRIDOR
GYPSUM BOARD
STEEL MEMBER OF WALL
METAL FLOOR DECK
FLOOR STEEL FRAME
METAL FLOOR DECK
2"x2" L-SECTION
STEEL MEMBER OF TRUSS
PIPING SPACE AT CORRIDOR

CEILING STEEL FRAME
CEILING PANEL, CORRIDOR
CEILING FINISH
MAIN TRUSS MEMBER
FIRE-COVERING

CORRIDOR PANEL

MAIN PIPING SPACE
BELOW 1ST. LEVEL
BOX WELDED TO MAIN TRUSS
5"x6" L-SECTION
5"x6" L-SECTION
2"x2" L-SECTION
3"x3" CHANNEL
MAIN TRUSS VERTICAL MEMBER

SECTION
1" = 10"

Sec
CORRIDOR

PLAN 20' × 24'

D. – DUCT SPACE
T. – TRASH SPACE
J. – JANITOR STORAGE
S. – STORAGE

PLAN 20' × 24'

STAIR-CORE
CIRCULATION CORE
1" = 10' - 0"
PLAN 20' x 20'

D. - DUCT SPACE
T. - TRASH SPACE
J. - JANITOR STORAGE

STAIR-CORE
CIRCULATION CORE
1" = 10' - 0"
PLAN 20'x 24'
ALTERNATIVE FOR TWO ELEVATORS

PLAN 20'x 24'
ALTERNATIVE FOR THREE ELEVATOR
ELEVATOR CORE
CIRCULATION CORE.
1" = 10'-0"
PLAN 20' x 20'

CIRCULATION CORE

ELEVATION CORE

1" = 10' - 0"

BOX

C OR R I D OR

ELE.

LOBBY

ELE.

BOX

C OR R I D OR

ELE.

LOBBY

ELE.

BOX

C OR R I D OR
PLAN 20' x 20'

ELEVATION CORE
CIRCULATION CORE
1" = 10'-0"
PACKAGE UNIT & BUILDING TYPES
E.S. - END SECTION
M.S. - MIDDLE SECTION
SI. - STAIR CORE
20' x 24'
S2. - STAIR CORE
20' x 20'
EI. - ELEVATOR CORE
20' x 20'
E2. - ELEVATOR CORE
20' x 20'

PACKAGE UNITS
1" = 60' - 0"
TWO-WAY COMPLEX

1" = 100' - 0"
TWO PACKAGE A.

PACKAGE A. AND B.

TWO PACKAGE B.

DOUBLE-LOAD CORRIDOR TOWERS
1" = 60'-0"
STRUCTURE FLOOR PLAN

TOWER TYPE

1" = 16' - 0"
ISOMETRIC

STRUCTURE FRAME
OF TOWER PACKAGE

1" = 30' - 0"

FLOOR PLAN

CENTER CORE TOWER

1" = 16'-0"
PACKAGE B., MIDDLE SECTION FIRST LEVEL

1" = 8'-0"
PACKAGE B., MIDDLE SECTION
FIRST LEVEL  1" = 8' - 0"
PACKAGE B., MIDDLE SECTION
SECOND LEVEL 1" = 8'–0"
PACKAGE B., MIDDLE SECTION
THIRD LEVEL  1" = 8'-0"
PACKAGE B, MIDDLE SECTION
THIRD LEVEL  1" = 8'-0"
PACKAGE B., MIDDLE SECTION
FOURTH LEVEL  1" = 8'-0"
TWO BEDROOM UNIT

PACKAGE B., END SECTION
FIRST LEVEL  1" = 8'-0"
TWO BEDROOM UNIT.

PACKAGE B., END SECTION
SECOND LEVEL  1" = 8'-0"
THREE BEDROOM UNIT

PACKAGE B., END SECTION
THIRD LEVEL  1" = 8' - 0"
THREE BEDROOM APARTMENT.

PACKAGE B., END SECTION
FOURTH LEVEL  1" = 8'-0"
PACKAGE A, MIDDLE SECTION

1" = 8'-0"
THIRD LEVEL

FOURTH LEVEL

PACKAGE A, MIDDLE SECTION

1" = 8'-0"
PACKAGE A., MIDDLE SECTION
FIRST LEVEL  1" = 8'-0"
PACKAGE A., MIDDLE SECTION
FIRST LEVEL 1" = 8'-0"
PACKAGE A., MIDDLE SECTION
THIRD LEVEL  1" = 8' - 0"
PACKAGE A., MIDDLE SECTION
FORTH LEVEL  1" = 8'-0"
PACKAGE A, MIDDLE SECTION
FOURTH LEVEL  1" = 8'-0"
PACKAGE UNIT A., END SECTION
FIRST LEVEL 1" = 8'-0"
PACKAGE A, END SECTION
SECOND LEVEL 1" = 8'-0"
PACKAGE A., END SECTION
SECOND LEVEL  1" = 8'-0"
PACKAGE A, END SECTION
THIRD LEVEL  1" = 8'-0"
PACKAGE A, END SECTION
THIRD LEVEL 1" = 8'-0"
PACKAGE A., END SECTION
FOURTH LEVEL  1" = 8'-0"
PACKAGE A., END SECTION
FOURTH LEVEL 1" = 8'-0"
BIBLIOGRAPHY


2, M.I.T., 1971 Department of Architecture Master's Class with Professor Eduardo Catalano, "Housing Systems; Seven Studies for Factory Produced Concrete and Steel Modular Units", Limited Published Master's Thesis, M.I.T.

3, M.I.T., Department of Architecture and Civil-Engineering, "Economic Study of Pull-up System" and "Guide to The Use of Pull-up System"

4, Daniel Quinn Mills, "Industrial Relation and Manpower in Construction".

5, Richard H. Clough, "Construction Contracting".

6, 1971, The Construction Engineering Research Laboratory (CERL) of U.S. Department of Army, "The Study on Potential of Industrialized Building for The Department of Army"
