MASS PRODUCED BUILDING SYSTEM FOR UNSKILLED LABOR

By:
Angelo Petrozzelli, Boston Architectural Center, Certificate of Architecture, 1966

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Thesis Supervisor

Chairman, Department Committee On Graduate Students

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Dean William Porter
School of Architecture and Planning
Massachusetts Institute of Technology
77 Massachusetts Avenue
Cambridge, Massachusetts

Dear Dean Porter:

In partial fulfillment of the requirements for the degree of Master in Architecture, I hereby submit this thesis entitled "Mass Produced Building System For Unskilled Labor".

Respectfully yours,

Angelo Petrozzelli

Enclosure
ABSTRACT

A Strategy For Developing A Mass Produced Building System For Unskilled Labor

by Angelo Petrozzelli

Submitted to the Department of Architecture on May 12, 1972 in partial fulfillment of the requirements for the Degree of Master of Architecture.

It should be noted that this thesis is a continuation of an earlier submission by the office of Imre and Anthony Halasz, Inc. and various other participants. This submission was part of the H.U.D. Operation Breakthrough Program RFP No. H-55-69.

The reason for selecting the development of a mass produced building system for unskilled labor is my reaction to presently available housing systems that by their size and complexity create a physical and human strait jacket ill suited to user participation in any stage of its development or existence. This thesis prepares the ground work for a building system sympathetic to this need and applicable in the immediate future at minimal cost.

It is the hope that this thesis will stimulate a research program to develop a full-scale model to test and improve the system.

The illustrations shown in the text deal with housing, but the system is not limited to this use. It seems to adapt well to other building types with similar clearance and span requirements.

Thesis Supervisor: John Steffian
Associate Professor of Architecture
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GOALS AND DESCRIPTION OF THE SYSTEM
A. BUILDING SYSTEM CONCEPT

1. GOALS AND DESCRIPTION OF THE SYSTEM
   
a. General

   The basic rationale underlying the concept of this proposed building system is that the system should not only fulfill the needs for shelter but also should become a source of employment, primarily for the unskilled of our society. The essential feature of this system is simplicity, based on the following objectives and solutions.

i. Participation by the unskilled or semi-skilled members of society, who would be able to erect, and maintain the system with minimal training and supervision.

ii. Minimal capital investment for production and construction so as to allow immediate application in any volume, anywhere and throughout the country.

iii. The use of available commercial products in order to minimize new building components. A few of the system components may be especially fabricated, but the parts will be standard. It is hoped that these components will be stocked in local outlets.
iv. Shop fabrications should be done with minimum investment on the part of the supplier. Fabrication of some of the components may be accomplished on the site at first in order to keep investment to a minimum.

v. The components shall be of a size and weight that can be handled manually by two people. This will result in modest spans and small components. Small component size will allow greater individual freedom for different assemblies and will allow the system to be adapted to a wide variety of needs.

vi. Simple mechanically fastened joints are intended for the entire system without using special equipment and skilled labor.

vii. A universal joint is proposed at all intersections of structural members.

viii. The system will expand or contract in every direction due to the use of the universal joint. Change and growth can occur without disruption of the finished spaces already occupied.

viii. The system will take advantage of readily available components from other systems that are practical and usable.
x. High standards of quality, low cost, easy adaptability to individual preferences, combined with the consumer's possible involvement in the production and marketing process, should assure his acceptance and identification with the housing product.

Following this logic the system consists of a series of independent structural frames with replaceable infill panels that constitute all finished surfaces. Prefabricated mechanical units will form an integral part of the system.

b. Architectural

The architectural character of the system.

i. Additivity

One of the chief dangers generated by prefabricated and preassembled industrial systems is that they often eliminate flexibility. This system, both in the relationships of its components to each other and in the components themselves, is based on the principle of additive flexibility. The resulting environment, be it an individual house or a complex settlement, can be molded and articulated according to specific needs and human desires rather than forced into an imposing preconceived industrial strait jacket.
11. Component Parts

The principle of additivity is maintained by the relatively small size of the basic floor and wall panels between the structural frames. Since the assembly of the components is designed for the utmost simplicity, the number of joints does not adversely influence cost. However, by virtue of modest spans, small components, and great individual freedom of different assemblies the system can adapt itself to a wide variety of needs. Old systems based on large component parts often offended our sense of human dignity by limiting additive modulation. The selection of the smallest component parts, readily available through the regular channels of the construction industry has its advantages not only in cost, easy handling, self-help, etc., but chiefly in that the small component parts enable the user to contribute to the form of his environment, exercise choice and initiative, and thus restore his pride in his place of living because he can adapt the system to his specific needs and requirements.
iii. **Diversity**

Since the system consists of relatively small components and a very large degree of additive flexibility, it can adapt itself to different housing densities, site conditions, and individual needs. Since the wall panels are designed for additive flexibility, they can adapt to different climatic conditions, as well as various zoning and building code requirements.

The main test of every contemporary system is its behaviors in terms of change and growth. The proposal allows change and growth on different levels. It can most easily **expand** in every direction by virtue of the universal joint.

It permits the **alteration** of the standards of housing units themselves, even in higher densities, by exchanging components without interfering with the rest of the units.

Since the proposal does not concern itself with a building as a product, but with an additive process it will **change itself** through field experience, demand, research and human ingenuity.
The ease of assembly implies the ease of
dismounting. Change and growth demands
addition as well as removal of parts in
relation to the whole, without disruption.

c. Structural
i. Low-rise Construction
The basic structure consists of a light
gauge metal frames and infill panels that
form all finished surfaces.
A prefabricated "universal" joint piece,
which is placed at every intersection be-
tween frame members, allows simple attach-
ment of column and beam units. No element
exceeds 150 pounds in weight. All frame
connections in the field are by high tensile
bolts. Details are such that while all the
frame parts will be prefabricated in a shop,
all assembly will be handled by unskilled
labor, without any hoisting equipment.
All panels, for floors, exterior and interior
walls and partitions, are of standard manufac-
ture and are set into the frames by simple
connections. The use of advanced fastening
deVICES is contemplated to assure easy, rapid
and safe assembly. Fairly large tolerances
are employed to avoid the need for exacting precision.
The frame structure is designed to withstand all vertical loading and the effects of wind or earthquake forces.

ii. High-rise Construction
The system is adaptable to any building height with the provision that it becomes a subsystem in a megastructure whenever it exceeds four stories. In such a case a basic concrete frame, consisting of columns, core walls and floor slabs at four-story intervals will be constructed. The structure serves as a four-hour fire barrier, both in vertical and horizontal planes, in addition to its load bearing function. The low-rise light gauge steel frames and infill panels will be plugged into the megastructure, with provisions for fire protection. While the megastructure will demand skilled labor, all the infill structure will be manufactured and assembled exactly as the low-rise units.

d. Interior Work
Prefabricated assemblies of stairs, cabinets,
partitions and closets are introduced into the system, at a wide variety of possible modular applications, allowing any pattern of growth and change.

e. Mechanical, Electrical

The general approach, here as well as in the structure, is based on the following premises:

i. Simple mechanical installation by unskilled labor.

ii. Individual control of the mechanical system in each dwelling and independence from occupants of other units.

iii. Possibility to change, remove or upgrade the mechanical installations.

A suggested outline specification has been developed for some housing units investigated. These are included in the Appendix.

f. Foundations

The system is designed to be supported at discrete points, the cases of the frames. As such, it is applicable to practically any soil condition. The flexibility of the steel frames and the tolerances between infill panels make the system relatively insensitive to minor differential settlements of the supports.
SYSTEM ADAPTABILITY
2. **SYSTEM ADAPTABILITY**

a. **Housing Types and Scope**

The proposed system will allow maximum freedom of choice and degree of self-participation at densities up to 15 units per acre. At these densities the capacity for growth and change can be employed to a very large extent. Simple family detached or attached homes can expand in all directions in small or large increments by the use of building components (stair, mechanical unit) and by use of columns, universal joints and panels. The limit of the proposal serving as a primary system is in the range of 40 dwelling units/acre. The accompanying illustration assumes the following restraints:

- 100% parking
- on-grade parking
- limited walking distance from car to units
- walk-up with maximum two flights of stairs
- emergency and service traffic only within the residential matrix
- no more than four stories (possible duplex on top)

Residential densities higher than 40 u/a will adapt the proposed components as infill or
secondary systems. These densities will change the rationale of parking relationships and circulation considerations in general.

The attached site application addresses itself to the upper limits of the system in terms of its residential densities as demonstrated in the general site matrix. This type of site utilization is a long neglected prototype for urban housing.

The well known later day prototypes in the lower and upper extremes of urban residential densities did not fulfill the aspirations and promises of their urbanistic conception. Not only did they stereotype their architectural presence but a non-compromising social segregation followed. The careful study and revitalization of middle density housing is most timely and necessary. The proposed system is best suited to such middle density applications while still effective in all other types of residential development.

b. Climatic Areas

No restriction.

Steel frame is designed to resist any specified horizontal and vertical load. Infill construction is such that any insulation value is attained by using an appropriate insulating blanket.
c. **Geology and Soils**
   The system is usable on soils with poor natural drainage and unstable soils, due to the relative flexibility of the structure which is capable of adjusting to differential settlements without excessive stress. All infill panels allow minor distortion without damage to them.

d. **Site Topography**
   At sloping sites footings with piers of adjustable length will allow the use of the system both in the same form as on flat sites as well as with the introduction of partial lower levels.

e. **Site Size**
   The system is adaptable to any site size.

f. **Site Situations**
   The basic concept of the system, its simplicity in the use of unskilled labor and finished light materials that are available anywhere, renders it applicable to any site situation and basically independent of local labor and material supplies. The presence of existing or removable structures does not restrict the applicability of the system.

g. **Changes**
   All components are removable or can be added on, as desired. Thus the standard of surface finishes,
cabinets, etc. can be improved at any time by simple exchange of panels. Expansion and rearrangement are handled similarly. In many cases the frame may be erected at the time of construction, to serve as porch or terrace, and later enclosed by snapping the finished panels into the frames.

h. Regional Applications

No restriction.
SYSTEM COMPONENTS
PLAN OF UNIVERSAL CONNECTOR: TYPE A
SECTION AT TYPICAL INTERIOR JOINT
PLAN OF TYPICAL INTERIOR JOINT

10'-12 GA. BEAM

6' COLUMN
PLAN OF EXTERIOR CORNER AT FOUNDATION
PLANS OF UNIVERSAL CANTILEVER CONNECTOR JOINT TYPE: B
ELEVATIONS OF UNIVERSAL CANTILEVER CONNECTOR: TYPE B
EXPANSION

MINIMUM UNIT

SELECTIVE EXPANSION

1 BEDROOM UNIT

SELECTIVE EXPANSION

VERTICAL
3 BEDROOM UNIT

SELECTIVE EXPANSION

3 BEDROOM UNIT

SELECTIVE EXPANSION

4 ADAPTED TO SLOPING SITE

STRUCTURAL ADAPTABILITY
Proposed system primary
Max. possibility for self-help
Adaptability and change and
growth for each Living Unit

Proposed System Primary
Establishes a Range of
possibilities for self-help,
Adaptability and change and
growth for each Living Unit

Proposed System subsystem of
'Structural Matrix. Limited
possibility for self-help
Adaptability and change and
growth for each Living Unit

SYSTEM APPLICATION DIAGRAM
This diagram is a generalized illustration of the relationship between cost and type of housing development. Housing is divided into three categories in terms of number of living units per acre. These categories and the implications of the proposed structural system for each category have already been discussed.

The solid-line curve in the diagram represents the relationship between construction cost and density of housing. The dashed-line curve represents the relationship between environmental cost and intensity of land use, i.e., the environmental factors, or costs, necessary to develop a socially and economically successful community. The underlying assumption is that the success of a housing development depends not only on the comforts provided by the living unit itself, but also on the services available to the community. These services range from utilities, open spaces, parks and recreation areas, schools, shopping centers, community centers, transportation networks, etc. to more abstract benefits which determine the quality of socio-economic life. Based on past experience with housing types and community development, it is assumed that the cost per living unit of these supporting services decreases as the intensity of land use, hence the sharing of facilities by larger numbers of living units, increases.
However, this relationship is not directly proportional. The diagram indicates that the benefits of increasing land use intensity grow in smaller increments as increasingly high densities are reached.

These considerations led to the selection of the 15-40 living units per acre density as the area of intensive study; (the shaded area in diagram). This type of housing was selected because it represents the low to medium range in terms of construction cost and promises better environmental benefits with increasing land use intensity.

The 15-40 living units per acre density was selected for intensive study because it appears to be more economical in terms of construction cost and of environmental cost, and also offers a desirable range of possibilities for self-help, adaptability, and change and growth for each living unit.

The proposed construction system may be used to develop a wide range of site plans at a density of 15-40 living units per acre. The "General Site Matrix" and the "Diagrammatic Layout of Housing Matrix" illustrates a possible application of this system.
POSSIBLE CENTRAL PEDESTRIAN ROUTE TO COMMUNITY FACILITIES

PARKING FEEDER ROAD

PEDESTRIAN OCCASIONAL SERVICE ACCESS

PLANTED SPACES BETWEEN BUILDINGS

THIS DIMENSION EXPANDS WITH INCREASE IN HOUSING UNITS

THIS DIMENSION IS DETERMINED BY OPTIMUM WALKING DISTANCE

THIS DIMENSION EXPANDS WITH INCREASE IN HOUSING UNITS

DIAGRAMMATIC LAYOUT OF HOUSING MATRIX
DIAGRAMATIC EXAMPLES OF HOUSING TYPES: 20'-0" MODULE UNITS
POSSIBLE FAMILY GROUPINGS
20' UNIT MATRIX
LEGEND

E  EFFICIENCY APARTMENT
1B  ONE BEDROOM APARTMENT
2B  TWO BEDROOM APARTMENT
3B  THREE BEDROOM APARTMENT
C  CLOSET

[SHADED AREAS INDICATE POTENTIAL PREFABRICATED COMPONENTS]
STRUCTURAL LAYOUT
E &1B FLOOR PLANS
2B & 3B FLOOR PLANS
SECTION 3 STORY
SECTION · 4 STORY
DIAGRAMATIC EXAMPLES OF HOUSING TYPES: 32'-0" MODULE UNITS
SPACE STANDARDS

It is suggested that another method of reducing costs in housing units is by examining present-day space standards. Significant savings in low-cost housing can be achieved by a reasonable reduction in these standards. The following plans are based on English space standards currently recommended as minimum standards.
POSSIBLE FAMILY GROUPINGS
32' UNIT MATRIX
STRUCTURAL LAYOUT
STRUCTURAL LAYOUT
E & 3B FLOOR PLANS
SECTION · 3 STORY
SECTION · 4STORY
DIAGRAMATIC EXAMPLES OF HOUSING

TYPES: TOWNHOUSE MODULE UNITS
APPENDIX 1

MECHANICAL SYSTEMS DEVELOPED FOR ILLUSTRATED HOUSE TYPES

HEATING
PLUMBING
ELECTRICAL
PLUMBING

The basic design of plumbing is in accordance with the "Recommended Minimum Requirements For Plumbing" (Hoover Report) as published by the United States Department of Commerce. Consequently, all sanitary piping is not only inexpensive, but, as can be observed by inspection of the drawings, also lends itself in its simplicity to installation by unskilled labor. In single family isolated units, and where there is no incentive towards inclusion of hot water, individual hot water heaters are installed in each unit. Hot water heaters may be gas or electric as dictated by fuel and energy costs at each specific location. Where rent inclusion of hot water is permitted in multiple occupancy units, further economies can be realized by providing one hot water heater per building in lieu of one hot water heater per dwelling unit. Piping materials can be ferrous, nonferrous metal, or synthetic as indicated at each location by availability, adaptability, acceptance, and cost.
HEATING AND VENTILATION

Heating of each apartment is accomplished by a warm air furnace located in each unit and discharging directly into a ceiling plenum. The plenum is fabricated under the general construction, thus avoiding sheet metal work. The system can utilize fossil fuel or electricity as a source of heat as dictated by economic analysis at each location. The system requires no skilled labor to assemble in the field. Technicians are required only during initial firing where fossil fuels are incorporated and not at all where electric heat is utilized. Each apartment will have its own thermostatic control. Interior bathrooms are exhausted through shafts constructed in the general construction and topped by wind-driven turbine exhausters. Interior stairways are also similarly ventilated by means of wind-driven turbines at the top of the staircase. Both avoid expensive wiring, fans, and maintenance. Accordingly, installation of the heating system consists primarily of setting a single factory assembled warm air heating unit in place. Sheet metal duct work is almost non-existent. The heating system lends itself readily to rent inclusion of hot water or to individual metering as may be desired. It also lends itself to future installation of mechanical cooling.
ELECTRICAL

All wiring conforms to the requirements of the National Electrical Code. Individual fuse boxes in each apartment permit convenient servicing of the system by each tenant as well as individual or master metering of electrical consumption. Cooking can be electric or gas. Branch wiring is inexpensive aluminum not metallic sheathed cable. Telephone system can be readily prewired in the construction.
TYPICAL FLOOR PLAN

HEATING

SCALE: 1/8" = 1'-0"
TYPICAL ONE BEDROOM

SECTION

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

TYPICAL TWO BEDROOM

SECTION

SCALE: 1/4" = 1'-0"
HOT WTR HTR

FURNACE

RANGE

4TH

3RD

2ND

1ST

GAS METER

GAS COIL

TYPICAL GAS PIPING TYPICAL GAS PIPING TYPICAL GAS PIPING

ALL GAS EQUIPMENT FURNACE ONLY PIPING

NO SCALE NO SCALE FURNACE &

HOT WTR HTR

NO SCALE
Typical Floor Plan

Plumbing

Scale: 1/8" = 1'-0"
BATH
KITCHEN
C.W. & H.W.

WEV
WEV
RISER

RISER
RISER
DIAGRAM

DIAGRAM
DIAGRAM

NO SCALE

LEGEND

--- SANITARY WASTE W
--- VENT PIPING V
--- COLD WATER C.W
--- HOT WATER H.W
VTR VENT THRU ROOF
H.B. HOSE BIBB
C.O. CLEANOUT
HWH HOT WATER HEATER
P.1 WATER CLOSET
P.2 LAVATORY
P.3 BATH TUB
P.4 KITCHEN SINK
A.C. AIR CHAMBER
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