RICE UNIVERSITY

A SYSTEM OF PREFABRICATED CONCRETE HOUSING FOR CHILE

by

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IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF

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Thesis Director's signature:

Houston, Texas

May 1969
To my Norma
and
our children
ACKNOWLEDGMENT

I express my gratitude to the prestigious Rice University for giving me the opportunity to study in this institution and for the Fellowship granted me.

I also appreciate the generosity of the Doctors Mr. and Mrs. Herman Suit, my sponsors.

In the first stage of my studies at Rice, I had an interesting and profitable experience with relation to aspects of housing and design referring to low-income families in Houston, under the direction of the Associate Director of the School of Architecture, Professor Jack Mitchell.

This thesis, which concerns the problem of housing in Chile, was made under the direction of Professor C. Newton and with the help of Professors H. S. Ransom and N. W. Krahl. It culminates a year of intense work and represents a valuable and meaningful study of actual problems.

I thank all the professors mentioned and all the people who directly or indirectly contributed to the fulfillment of my objectives.
ABSTRACT

A System of Prefabricated Concrete Housing for Chile

Sammy Liberman

The final objective of this thesis is to contribute to the solution of the habitational problem for families of meager means in Chile.

To bring about this objective, I propose the following:

1) A rational system of construction or execution of works that involves the participation of the government, the community, and the individual.

2) A design: a) that possesses flexibility, permitting a natural and step by step evolution of the dwelling as a function of economic resources and the progressive necessities of the inhabitant.
   b) that permits an effective control of functional, esthetic and stable aspects of a dwelling considered as a unit and as an entity within the urban frame.
c) that reconstitutes the potentialities of the dwelling to provide to its tenants an adequate environment where equilibrium and dignity can be found.

3) A prefabrication system whose fundamental components are composed of concrete.

The methodology for the verification of this approach includes the following:

1) A qualitative and quantitative appreciation of the existing situation of housing in Chile.

2) An analysis of the most common solutions and designs in use today in order to qualify their effectiveness and to be able to evaluate proposed solutions.

3) A structural design of the main components of the dwelling.

4) A proposal for a joint government - community venture for implementation of the project.

5) To make evident, with respect to flexibility, the efficacy in various circumstances seen from the following points of view:
a) From an urban scale.

b) From its constructional, functional and esthetic aspects.
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INTRODUCTION

In the first part of this thesis, corresponding to a process of analysis, I have done a study of housing that shows the different initiatives taking place as a result of the strong social pressure that has accrued through the years.

Posteriorly, I made a study of the habitability of several economic houses with the purpose of accumulating experience that can be used as criteria for design and evaluation of future housing projects. With the purpose of making this study, I present the experienes taking place in direct contact with the inhabitants by the Instituto de Vivienda de la Universidad de Chile (Institute of Housing of Chile's University) and Universidad Catolica de Chile (Chile's Catholic University).

I attempt to show the negative effects brought upon by inadequate living space and the need for improved housing, in terms of flexibility of design and quality of construction.

Finally, I shall propose a system of collaboration between the community, government and individual,
and an evolutionary method of construction with concrete which is adaptable to diverse topographical conditions. A complete description of the structural proposals is included.
HOUSING IN CHILE

DEFICIENCY

The first serious attempt that was made in Chile to document the housing problem was the National Housing Census taken in 1929. This revealed the existence of 931,359 acceptable dwellings (88%), and 129,716 which were not acceptable (12%). This included the Indian dwellings, the callampas, and conventillos. On the other hand, regarding the quality of construction and the state of preservation, 588,651 dwellings were acceptable (56%), and 462,424 were not acceptable (44%). These figures included the 129,716 dwellings already classified as not acceptable, and thus it can be assumed that the figure 462,424 represented the magnitude of the housing deficiency in Chile. To this number one must add the new dwellings which the natural growth of the population required. The most recent estimate raises to 514,000 the number of dwellings which are lacking (1964).

1 Facultad de Ciencias Economicas, La Economia de Chile en el periodo 1950-1963.
This figure of over half a million dwellings that ought to be built would turn out to be even larger if the criteria of quality and overcrowding were a little more strict.

With regard to the quality of construction, unfortunately, the occurrence of earthquakes has caused the number of inadequate dwellings to be increased. Fifty-eight thousand seven hundred (58,700) dwellings were destroyed in 1960, with the tragic loss of human life in many cases. In spite of the magnitude of the problem, the resources employed in the successive housing plans have only been able to keep up with the needs created by the natural growth of the population. The figure proposed for the years 1964/1970 has been 60,000 units annually. One fact that tends to aggravate the deficiency is the practice of making dwellings with very little floor space. Even though these dwellings solve the most urgent problems, they later become classified as inadequate because of overcrowding.
CAUSES

The high rate of habitational deficiency is, in general terms, similar in all Latin America due to the following reasons:

1) The High Rate of Population Growth

Between the census of 1952 and 1960, the population increased by 1,407,000 inhabitants or about 23.7%. That means a 2.5% average increase every year. Between the census of 1940 and 1952, the annual average was only 1.5%. These figures reveal an accelerated process of growth.

2) Migration from Rural to Urban Areas

We can see this constant process as stated in the estimate of the Institute of Economy in 1962:

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<th>Census</th>
<th>Urban</th>
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<td>1962</td>
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*The estimated population in 1962, according to The Economic Institute was 8,138,000 and an Urban population of 5,507,000.
Generalizing on the basis of this data, we can say that since the beginning of the century the rural population has increased by 75%. This demographic movement, which affects mainly the principal urban centers, is felt in the form of social and economic pressures. Fundamentally serious in these circumstances is the insufficient number of jobs and dwellings. The inadequate number of jobs is due both to the lack of knowledge and preparation of the individual in the most affected social strata and to the country's economic condition. These circumstances provoke a large number of unemployed individuals, who, consequently, have low and irregular incomes which lead them to poverty and progressive misery, accentuated by sub-standard dietary and health conditions.

For these social groups the pressing problem of finding a place to live can only be solved by:

a) Trying to get a location in old areas of the city, but these areas are usually densely populated and consequently they can only obtain one or two rooms in dwellings already occupied by other families.
b) Renting a few rooms in a "conventillo".

c) Building improvised dwellings on usurped lands in peripheral zones of the city, which progressively become enveloping rings and are incorporated into the city. This phenomena is similar in all Latin America. Those squatter settlements receive different names in every country: Callampa in Chile; Villa Miseria in Argentina, Favelas in Brazil, Barriadas in Ecuador and Peru, Barrios Paracaidistas in Mexico and Ranchos in Venezuela. Many times these squatter settlements develop on their existing hills of cities such as in the "Favelas" of Rio de Janeiro or in "Cerro Blanco" of Santiago or in Valparaiso.

3) Low Rate of Economic Development

This factor influences housing not only because of the country's low development of economic resources, but also because housing does not represent an effective return on a short term capital investment. Because of this, housing receives comparatively low resources from the government in the national development programs.  

2 Fernando Kusnetzoff K. Dimensiones de una Política Habitacional para el sexenio 1964-1970,
PLANS FOR DEVELOPMENT OF HOUSING

General View: The initial efforts to solve the housing problems in Chile have a long history. In order to permit the direct participation of the state in the solution of the housing problem, a special Department of Housing was created in the Ministry of labor in 1932. The results of this act were not effective.

A new step forward was made by the promulgation of Law No. 5950, which created the Population Dwelling Fund on October 10, 1936. Its inclinations originated a specific institution dedicated to encourage the economical dwelling. Its first article stated that there will be established a Popular Dwelling Fund under the Ministry of Labor, destined to promote the building of healthful and low priced houses with kitchens and gardens for work and domestic purposes, and to other ends assigned by this Law. Law No. 7600, which superseded the text of the former and was published in the "Diario Oficial" on October 20, 1943 had more economic

recourse to achieve its ends. According to its twenty-first article, the Popular Housing Fund could build houses to sell or rent to the workers, employees, and persons of little means, and could provide loans to provide funds with which landowners could build. Article 28 allowed loans with 3% interest and 1% amortization to workers, employees, and persons of little means who had land on which to build. On January 24, 1939 various provinces in the southern part of the country, especially Nuble and Concepcion, were rocked by a terrible earthquake which practically razed various cities and towns.

In order to repair the damage, by virtue of Law No. 6640, the Corporation of Reconstruction and Aid was born. Law No. 9113 of October 1, 1948 prolonged the life of this Corporation until December 31, 1958. Both of these laws were established with the purpose of repairing the destruction, especially in housing, caused by any catastrophe which might occur in Chile.

On July 25, 1953 Law No. 285 originated the Housing Corporation fusing the Housing Fund and the
Reconstruction Corporation. The Housing Corporation (CORVI) was charged with the urbanization, restructuring, remodeling and reconstruction of neighborhoods and sectors included in the Housing Plan and in the Regulation Plans explained by the Ministry of Public Works. It was also charged with the study and the encouragement of the construction of economic housing. 4

The Pereira Law on October 8, 1948, Law No. 9315 was ordered to be enacted. It had as its objective the stimulation of construction of economic housing by private individuals, free of established tax franchises. The main points of the law were:

a) that dwellings, constructed in accordance with determined prerequisites would be free from all taxes imposed on the land for ten years, excepting those which had to do with the payment for services such as paving or sewage. b) that societies constituted for the exclusive purpose of constructing economical housing would be granted certain tax exemptions. c) that economic dwellings be understood as those whose plans and specifications would 4 Ibid
be in accordance with the regulations, ordinances, and the specifications of the Housing Fund and which were approved by it, and whose cost of construction per square meter would not be more than a certain percentage of established salaries.  

The Habitational Plan of July, 1959 established the criteria of economic housing, with the purpose of encouraging its construction, as much with public investment as with private. The concept of "economic housing" embraces any dwelling which is built to conform to the dispositions which Law No. 2 specifies and that have a minimum of 35 square meters of floor space and a maximum of 140 square meters.** In some cases minimum housing of 25 square meters may be built, when the CORVI thinks it urgent.  

There are a series of stimulii for the dwellings which come under the Habitational Plan. When the floor space does not exceed 70 square meters, the house is free of all taxes for twenty-years; if it does not exceed 100 square meters and is more than 70, for 15 years; if it is more than 100 and less than 140 meters, for ten years.

5. Ibid
6. Ibid

**Conversion factors: page 64
Within the limits of financing, apart from the fiscal resources and the contribution of the "cajas de prevision", the Habitational Plan created the system of quotas of readjustable savings. They are readjustable annually in accordance with the wage and salary index and they give the right to the depositor to obtain a loan for the purpose of buying or acquiring a dwelling through the Corporation of Housing. In this manner it is hoped to stimulate private savings which have been reduced substantially during the years of inflationary crisis. Furthermore, the Habitational Plan contains provisions destined to increase the financial resources for the construction of housing through an investment induced from industry, business and agriculture. In addition to extending to agriculture the 5% tax on utilities destined to the CORVI, it permits the investors holding this amount to transform it into "savings quotas" with the condition that they invest them in houses which can be sold to employees or workers.
The establishment of the Private Savings and Loans Associations took place in 1960. These are private and regional institutions which receive savings deposits from individuals backed up by a central bank. Their objectives are similar to those of the CORVI.

The Law No. 326, April 6, 1960 established cooperatives of housing and self-construction. Those cooperatives ought to be formed with the approval of the office of the Ministerio de Economia, Fomento y Reconstruccion and its activities were to be supervised by the CORVI in everything that deals with acquisition, conveyance, and urbanization of lands.

**HOUSES FOR LOW INCOME PEOPLE IN CHILE**

In 1959 a plan was begun to relocate poor families in basic housing which they could acquire. This plan was continued in a similar form through the present government administration (1964-1969). It is being carried out in two steps: (1) Relocation of people and (2) Construction of permanent housing.

1) **Relocation of People**

Large numbers of people originally living in uncontrolled urban settlements characterized by their
crowded and miserable conditions are moved to extensive areas supplied with minimum facilities. Often provisions for water, sewage, and electricity are communal. Families are generally housed in two-room temporary structures which are already built on the property which they will acquire. These areas of temporary construction are located in the rear part of the property so that the permanent houses may be constructed with adequate space in the forward area, near the future street. Each temporary plot has a provisional cesspool and provisional boundaries. This process is terminated when street, foot-paths, and final connections for utilities have been provided.

2) Construction of Permanent Housing

Private builders are contracted to construct the permanent houses. Plans and all specifications are usually furnished by the government which also finances the works. The person who will occupy the house becomes the owner by paying a fixed low monthly sum.

A recent example of relocation was the "Operation Sitio" whose initial objective was the development
of 22 new neighborhoods which were allotted to 16 communes. This plan developed 10,743 definitive houses, 13 schools, 36 kindergartens, 18 social centers, 42 play yards for children, 114 commercial stores, 10 sport centers, 6 markets, and 11 churches.

The inclusion of community facilities means an advance in the process of relocation, since the plans were originally done with the sole purpose of providing housing (Poblacion San Gregorio, 1959). Thus the new situation demanded more specialized planning and a special department (Oficina de Equipamiento Comunitario) was established to study the problem with the aid of International funds. The Ford Foundation financed the initial collaboration of Rice and Harvard Universities. In addition, a group of architectural students at Rice University studied special problems related with Community buildings. Characteristic of "Operacion Sitio" was the use of prefabricated systems to develop the "permanent house." Public bids were held where builders proposed their prefabricated systems to provide two kinds of houses that
were designed by the architects of the housing Ministry. (See Fig. 1).

In the first stage of "Operacion Sitio", 3,414 houses of type A (37.8 sq meters in area) were constructed; and 831 houses to type B (50 sq meters). Type A has a similar design to the houses of type 651 (33.44 meters), and type 661 (34.68 meters), (See Fig. 2) which were built a few years ago in the "Poblacion San Gregorio". Due to the similarity in the design of these houses, it is important to study existing information concerning their habitability in order to evaluate whether a repetition of this design is justified.

San Gregorio's Housing - Social Aspects

"This study of the family and its housing considers only the 651 and the 661 type dwellings, which actually represent 85% of all the housing. The other 15% are collective blocks which were constructed later, and which not only conform to the necessity of getting the greatest amount of
FIG 1

House Type A.
Area 37.8 square meters

House Type B.
Area 50 square meters

FIG 2

TYPE 651
construction on high cost lands, but also give to San Gregorio an exterior appearance distinctly different from its interior reality." 7

"The programs of the 651 and 661 dwellings consist of two bedrooms, one bathroom and one communal area that includes a dining room and kitchen. The habitable area has a maximum capacity of five beds." 8

"Fig. 3 shows the square meters corresponding to the Groups of individuals when the area which they command is 33.77 m² (an average value resulting from the dwellings 651 and 661). One observes how the resulting curve penetrates the critical area (14 to 12 m² per person) and the pathologic area (10 to 8 m² per person) determined by the Group of Social Ethnology of Chombart de Lauwe." 9

"The average family obtained in the survey in San Gregorio (6 persons per family) would require a dwelling of 78 m² in order not to exceed the beginning of the critical area (Curve C), Fig. 3." 10

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8 Ibid, p. 65.
9 Ibid
10 Ibid
OVERCROWDING IN THE DWELLING

House Area 33.44 Type 651
House Area 34.68 Type 661
Area Average 33.77 m²

Critical Zone.
Pathological Zone.

 Curve C corresponds to m² per person in a house 78 m² for six persons that does not exceed the critical zone.
The research that was done by the Chombart de Lauwes, combined the skills of sociology and psychology. They collected measurable data on every conceivable aspect of the crowding in terms of the number of residents per dwelling unit. This index revealed very little and the Chombart de Lauwes then decided to use a new index to establish crowding—the number of square meters per person per unit. The results of this index were startling. When the space available was below eight to ten square meters per person, social and physical pathologies doubled! Illness, crime, and crowding were definitely linked. When the space available rose above fourteen square meters per person, the incidence of pathology of both types also increased, but not so sharply. The Chombart de Lauwes were at a loss to explain the latter figure except to say that families in the second category were usually upwardly mobile and tended to devote more attention to getting ahead than they did to their children. 11

OVERCROWDING IN THE DWELLING according to total number of individuals for type of family group and the $m^2$ corresponding Area 33.77m$^2$. 

FIG 4.

OVERCROWDING IN THE DWELLING
With respect to this variable behavior of parents toward their young children as a result of the effects of over-population, we can cite the laboratory experiments completed by John B. Calhoun, who demonstrated the abnormal maternal behavior in female rats exposed to the pressures of high population density.  

Fig. 4 shows the degree of over population of 100 dwellings according to the total number of people in each type of family group, with relation to the critical and pathologic rudiments which were mentioned before.

Returning to Fig. 3 and considering the critical zone as optimum, we obtain a deficit of 4,100 m², which is equivalent to the area of approximately 120 dwellings. That is to say that the individuals of these 100 families have at their disposal only half of the area that they really need in order not to exceed the critical zone.

Fig. 5 consists of a diagram which indicates the manner in which 100 families occupy their

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13 Ibid
14 Ibid
### WAYS OF OCCUPYING THE BEDROOM

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**FIG 5**
bedrooms. Each rectangle represents one family. Each continuous line drawn in it represents one bedroom which is used, and the number on the inside of each rectangle represents the number of beds which are used.

This diagram also expresses the structure of each family. The black and white dots located in each rectangle represent men and women respectively. The relative position of the dots to the 6 lines which arrange them horizontally express the degree or state of chronological development of the individuals. They have been classified as children under 5 years, children up to 12 years and adolescents (from 13 to 17) youths (from 18 to 24), parents (any age) and adults (over 24). The superimposing of both diagrams allows us to know who share the same bedroom according to their sex and stage of chronological development.15

San Gregorio's Housing - Technical Aspects

In San Gregorio more than 2,000 dwellings have been built through the system of self-construction. If we consider the success in this aspect and its 15. Ibid, p. 71.
mass production, this would be a good argument to prove the effective possibility of a self-construction method in Chile. A more evolutionary system, that of self-help and mutual-help, would produce, without a doubt, even better results particularly if they were to build of a really prefabricated system.

The most important task was to move more than 3,000 families living in slums. 3,904 lots of land were available at San Gregorio and the whole area was divided into two parts: one for some 3,000 families who were considered good prospects to build by self-help and the rest for families who would build by other means, i.e. by contract. 16

METHODS OF CONSTRUCTION

A reinforced concrete floor slab was poured on every lot, to act as a foundation. This was left to a contractor. Two main systems were used in the construction of houses:

1) System "Mosso", 1,500 units, solid wooden panels.

2) System "Marchetti", 300 units, wood block walls 4 inch thick.

Total housing units.........................3,904
Houses built by self-help...................2,050
Average area per lot......................2,600 sq.ft.
Average area per house....................370

Owner's labor:
  a) hours/worker/house "Mosso".. 205 hours
  b) hours/worker/sq.ft. "Mosso".. .6

  a) hours/worker/house "Marchetti" 205
  b) hours/worker/sq.ft. "Marchetti" .9

Percentages hours/worker per sq.ft. of construction:
  a) owner's labor ................. 40.4%
  b) labor paid..................... 59.6%

Costs:

  Average cost of the lot........US$ 760
  Average cost of a finished house 1,534 "Marchetti"

  Average cost of a finished house 1,457 "Mosso"

  TOTAL COST: "Marchetti": US $2,294
               "Mosso"   US $2,217

Figures 8 and 9 show the basic elements and construction of the Marchetti and Mosso Systems.
EXPERIMENTAL HOUSING

Study made by Institute of Housing Catholic University of Chile

FIG 8

Method: Wood Blocks

Proposed by Enrique Marchetti
Experimentation Housing
Study made by Institute of Housing
Catholic University of Chile

Method: Mossopanel (Also commercial trademark)
Proposed by Mosso, Industry of Wood, Inc.
GENERAL CONCLUSION

1. The number of houses built annually does not cover even a minimum amount of the deficit of 500,000 houses which are lacking or should be replaced. Additional programs must be begun to provide the necessary housing.

2. The economic development of Chile is proceeding at a comparatively low rate. We cannot expect new housing programs to be based on large investment of capital. New programs must consist of new and more rational construction technique which would permit an increase in the production of dwellings using present funds.

3. New dwellings should be built of effectively durable materials which are resistant to fire and earthquakes in order to protect the initial investment. With regard to construction systems and materials of insufficient quality "Operacion Sitio" has been called The Institutionalism of deterioration. 17

4. The old areas, Conventillos and squatter settlements (where the problems are the gravest) should be eliminated or reconstructed as soon as possible.

5. New building systems should be adaptable to various site conditions (flat as in Santiago, Antofagasta, Arica and steeply sloped as in Valparaiso).

6. A potentially successful aspect of the habitational plan is the reinforcement of the idea of the individual savings account. It is apparent that the plans of housing construction are most successful when they take into consideration the personal efforts of the individual.

7. Cooperatives of housing and self-help-construction have been legalized since the year 1960. Therefore, it is a procedure with which one can easily operate today without having to incur special authorization.

8. Present relocation plans are carried out in two stages. The first stage consists of a temporary dwelling and the second stage consists of a
permanent dwelling which is totally independent and separate from the temporary one. This system creates a loss of investment since the temporary dwelling is not used as an integral part of the ultimate development of the home.

9. In "Operacion Sitio" prefabrication has been established as a normal construction procedure. This promises an effective advance in the new manufacturing processes cited in conclusion #2.

10. Dwelling designs of the past ten years are inefficient in that they do not reflect the improvements in the new construction techniques with which they were built.

11. The current massive employment of the above dwelling designs over a period of ten years indicates the absence of a revision and evaluation policy. Such a policy must be established by the institutions charged with finding a solution for the housing problem in Chile.

12. With regard to the social aspects of San Gregorio's Housing, we see that the dwellings
(Figs. 3&4) were made from the point of view of minimum habitability (pathological zone-8 to 10$m^2$; critical zone-12 to 14$m^2$ established by Chombart de Lauwe, for a partial group of Frenchmen under special circumstances). Consequently, although it has the merit of functioning as a "cry of alarm" for the crowding housing conditions, this study does not really express the magnitude of the problem in Chile. "The degree to which peoples are sensorally involved with each other, and how they use time, determine not only to what point they are crowded, but the methods of relieving crowding as well. Puerto Ricans and Negros have a much higher involvement ratio than New Englanders and Americans of German or Scandinavian stock. Highly involved people apparently require higher densities than less involved people, and they may also require more protection and screening from outsiders. It is absolutely essential that we learn more about how to compute the maximum,
minimum, and optimum density of the different cultural enclaves that make up our cities.**'* It would be useful to establish different values of minimal habitability for the different groupings of Latin America. This would permit a more adequately realistic design.

13. With respect to Chile, as a point of departure, the rural origins of the individuals could be considered; this can be shown by their special way of handling the patio of the house. This is shown in Fig. 6 (ways of occupying the dwelling; daily inhabited zone), where we observe an ample use of the exterior space for diverse activities which are not exclusively the result of the small dimensions of the house; a more elaborate study of external space would aid us in our urban designs.

14. In Fig. 7 we can appreciate the aspects which will later relate to our proposition. In addition to inadequate space, this expresses:

18 Edward T. Hall, *op cit.*
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**Utilización del terreno**

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<td>CIERRO DE ANTEJARDÍN</td>
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**Fig. 6**

**Ways of occupying the dwelling**

120 dwellings

- Common Area
- Bedroom
- Exterior Shelter
- Exterior

A RAPOSO PLANIFICACION UCH
FIG. 7

UNCONTROLLED GROWTH OF DWELLING
a) In spite of unplanned growth, the individual possesses the initiative of enlarging his house.

b) Individuals possess the initiative to complete work by themselves which often does not correspond to their skills.

c) With the passing of time, they sometimes obtain certain economic means which permit them to augment the size of their houses.

15. In the negative aspect they indicate: The growth has taken place without any esthetic or functional consideration and without any control of the total stability of the dwelling, which can be dangerous for the inhabitant. With respect to San Gregorio, we lack statistics of the number of houses which were enlarged, the materials which were used, or the enlarged surface. In general, however, the tendency to enlarge dwelling dimensions is almost a national characteristic, that should be controlled to produce the best results for housing and for the urban environment.
16. The manner of occupying bedrooms and the number of beds shown jointly in Fig. 5 establish conclusions with respect to the bedroom furniture. Unfortunately, we have no detailed figures of the furniture and the general furnishings of the house, but from our observations in the "Poblaciones", we can say that it is necessary for basic furniture to be integrated with the design of the dwelling, in order to better the usefulness of the latter.

17. In Fig. 10 we see, in general terms, what the population distribution has been:

a) In many cases the housing locations lack a balance with working functions of the individual housed.

b) There is a tendency towards the creation of large residential units on low-cost lands. This is a concept that might work out well in theory, but in practice it means the immense accumulation of minimal housing in areas that often suffer from the lack of normal community facilities. This
b) inevitably results in an environment which is depressing for its occupants. In addition, the segregated ghetto-type characteristics psychologically reflect upon the economic level of its occupants. A positive experience in overcoming this location disaster has been accomplished in the Colon Oriente subdivision, which has traditionally been a sector with high standard of housing. (Fig. 10 location of CORVI housing in Santiago #29).

c) There is a tendency towards urban dispersion in the peripheral areas of the city. The necessary extension of all services annuls the attractiveness of the low land costs.

d) There is a lack of effective interest in remodeling the old sectors of the city.
LOCATION OF CORVI HOUSING IN SANTIAGO

Fig 10

UBICACION DE LAS VIVIENDAS CORVI EN SANTIAGO

LOCATION OF CORVI HOUSING IN SANTIAGO

Población CORVI

CIEN FAMILIAS

LIMITE DE SANTIAGO

INDUSTRIA

Fig 10
PROPOSITIONS
GENERAL

We have observed the fundamental problems which slow down the production of housing for low-income people and which produce unsatisfactory solutions concerning habitability, construction, and urban ubiquity. Ingenious individual architectural solutions are not enough to overcome these immense problems. There come into play complex problems of the general development of the country which elude the control of those who possess the maximum political and economic power to achieve solutions. These developmental problems, even in the cases of the most energetic action to solve them have their own cycle of existence, at the end of which one can appreciate positive results. This "life cycle" of the solutions greatly exceeds the life cycle of different generations of human beings. However, for these people reality establishes itself in the present. This individual reality presents itself solidly entwined with a process of a vicious cycle of the following factors: jobs, income, education, knowledge, food and housing. The
individual cannot break down one of these barriers which creates a descending spiral to poverty. In order to produce a break in this circle, it is necessary to actuate the strongest means within our grasp. One source of relatively untapped energy in our times is community action. I propose a system of modified self and mutual help in order to insure the success of this effort. It is essential to propose an evolutionary design system for housing in order to accommodate diverse individual economic circumstances. We must resolve the problem of the small house and at the same time establish functional, aesthetic and structural controls. A rational building system can best be achieved through prefabrication. I propose that the principal components be of reinforced concrete which will guarantee the least amount of maintenance for the prefabricated dwelling units.
SOCIAL ASPECTS

Self-Help Construction

The self-construction system has produced favorable results in various countries of the world. In Chile the utilization of the prospective dwelling occupant in the construction of his own house has proven successful. This self-help system can develop individual initiative and many times acts as an incentive to economic self-improvement.

Community Action

Community action which requires organized effort from small social groupings in a framework of self and mutual assistance, has been little utilized in Chile. The speed and efficiency possible within an organized group of persons working together in building a dwelling unit for one of its members is an effective device for lowering cost. This system may also serve to strengthen bonds of mutual friendship and cooperation among the participants and encourage the inter-action of individual to community.
Government Action

An effective and dynamic system of state action can achieve two important goals:

a) To form a partnership between the state and residential developers to promote requisite levels of housing. If this integration of purpose can be clearly recognized by the two parties, a substantial reduction in the ultimate sale price of each dwelling unit can be realized due in part to the benefits accruing to the producer as a result of an assured and predictable market. It could, indeed, become a cooperative venture between the state, the community and the individual.
JOINT ACTION OF GOVERNMENT, COMMUNITY AND INDIVIDUAL

Government Action

1) Organizing with industry.
2) Contracts with individuals who would be future owners.
3) Provision of lots in urbanized areas.
4) Regulation and controls for distribution of components.
5) Transportation of components to jobsite.
6) Renting of small machinery.
7) Technical supervision.

Community Action

1) Survey of applicants: Detailed questionnaire.
2) Analysis of questionnaires based on:
   a) Appraisal and investigation of the ability to pay the costs of the house establishing similar time and working schedules for construction.
   b) Priorities based on:
      (1) Need for housing.
      (2) Condition of existing dwelling
(3) Skills directly or indirectly related to building

(4) Physical condition and age of individual

(5) Degree of acceptance of the program

(6) Attitude towards the program

(7) Record of last experience in community improvement

3) Selection of eligible families

4) Meetings: The self-help housing society is established. Responsibilities are established and assigned.

5) Organization of working groups

6) Educating the individual and the working groups to use the construction system.

7) Undoubtedly, in the process of building houses the most convenient system will be the one of mass-construction. The savings that multiple production permits will be cumulative. For example working equipment such as concrete mixers, pick-up trucks, and miscellaneous tools can be utilized in a community fashion.

8) Administrative organization to maintain
communication between government and the individual and to insure continuity of this action program.
DESIGN ASPECTS

It has been my intention to propose a flexible system. If I set out to evaluate the concept of "flexibility" as established by William Caudill, we will have the following: 19

1) Expansibility (exterior growth) the system has been devised with special attention to this aspect.

2) Convertibility (interior change or growth) this aspect has also been considered in proposing houses that can evolve from the minimum area of the temporary house to the maximum area of permanent housing. In the different stages the spacing adapts itself to different functions.

3) Versatility (multi-function) this aspect is relatively simple housing and can be achieved in particular with the equipment used (furniture, folding doors, closets).

4) It is necessary to add the concept of adaptability. The system should be adaptable to different economic needs of the individual and to different topographic configuration of the site.

JUSTIFICATION OF THE MODULE

The use of a box 3.60m. x 3.60m. (12' x 12') and 2.40m. high (8') or half a module follows the consideration of cost and minimum spacing where different functions can be carried out (beds, closets).

This module is flexible because the main beams which fix the horizontal size of the unit are fabricated in a continuous form and can vary in length. Consequently, the effective module is the width of one concrete panel of 0.60m. or (0.30m.) but this factor can also be modified. It has been adapted because its multiples and sub-multiples 0.30, 0.15, 0.120, 0.90 coincide with other materials which can eventually be combined into the system (cement fiber, sheet rock, brick and tile).

This module must also be used in the main furniture of the house, in order to integrally resolve the space problem.
GENERAL DESCRIPTION OF THE SYSTEM

The system I propose consists of prefabricated concrete elements: foundation, columns, beams, panels, secondary beams and floor blocks. These elements are put together with concrete at the jobsite with the purpose of forming habitable modules which grouped together begin the house.

These modules can be grouped horizontally. This solution is practical for flat areas (Santiago, Antofagasta) or can be grouped vertically in small tracts of land or vertically at different levels in sites with a steep slope (Valparaiso).

The modules can be put together at different stages which allows individuals of little means to construct their house in successive stages.

I have adapted the D.Y.M. system which is presently being used in Chile for the wall panel system (placing concrete between plates). However, in designing the system, the beams and columns are calculated as a complete independent structure,
A SYSTEM OF PREFABRICATED CONCRETE HOUSING

FOR CHILE

Fig. A

Progressive development of the house

Solution for one floor dwelling

1st Stage Temporary House:

2-1/2 modules
36 sq. m. total area
32.5 sq. m. usable area

2nd Stage It is added 2-1/2 modules: Total 5 modules:

36 sq. m. + 36 sq. m. = 72 sq. m. total area
32.5 sq. m. + 32.5 sq. m. = 65 sq. m. usable area

3rd Stage It is added 1-1/2 modules: Total 6-1/2 modules

72 sq. m. + 22 sq. m. = 94 sq. m. Total area
65 sq. m. + 19.5 sq. m. = 84.5 sq. m. usable area

4th Stage It is added 1 module: Total 7-1/2 modules

94 sq. m. + 14 = 108 sq. m. Total area
84.5 + 13 = 97.5 sq. m. usable area

5th Stage It is added 2 modules: Total 9-1/2 modules

108 sq. m. + 28 sq. m. = 136 sq. m. Total area
97.5 sq. m. + 26 sq. m. = 123.5 sq. m. usable area
PROGRESSIVE DEVELOPMENT OF THE HOUSING

A SYSTEM OF PREFABRICATED CONCRETE HOUSING FOR CHILE
A SYSTEM OF PREFABRICATED CONCRETE HOUSING FOR CHILE
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A SYSTEM OF PREFABRICATED CONCRETE HOUSING FOR CHILE
PROPOSITION

TECHNICAL ASPECTS
A SYSTEM OF PREFABRICATED CONCRETE HOUSING
FOR CHILE

Fig. A

Progressive development of the house

Solution for one floor dwelling

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2-1/2 modules
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5th Stage It is added 2 modules: Total 9-1/2 modules
108 sq. m. + 28 sq. m. = 136 sq. m. Total area
97.5 sq. m. + 26 sq. m. = 123.5 sq. m. usable area
TECHNICAL ASPECTS

I propose a system of construction based on structural prefabricated components encased in concrete, made in factories, and transported to the work site for later assembly.

Component elements:

Columns

Dimensions

Cross-section: 0.15m. x 0.15m. (5-1/2 x 5-1/2)

Height: a) column of the second floor; height of height of panel 2.40m. (8')
+ height of beam 0.24m. (9'7/16)
+ 2 height of beam 0.48 (19'')

Characteristics

They are made of precast concrete.

The grading of aggregate is a function of the sand and gravel which is used. There will be needed a resistance to the compression of 400 to 450 kg/cm² (in a sample cube of 0.20m. x 0.20m.) during the twenty-eight days of normal setting. Melon type extra cement will be used (bag of 42'5 kg.) In general terms, we can say that this resistance will be achieved with the following proportions:
7 bags of cement/m$^3$  300 kg/m$^3$

113 litres of gravel/for bag of cement =
791 litres of residue/m$^3$

65 litres of sand/for bag of cement =
455 litres/sand/m$^3$

16 litres of water/for bag of cement =
112 litres/water/m$^3$

(Technology of cement/E. I. dM.)

The column molds will be of steel to avoid deformations, In its interior will be placed the reinforced steel bars with dimensions established by structural design.

Once placed in the mold, the concrete will be vibrated. Afterwards they will be submitted to a curing process in vapor chambers with temperatures between 40C. and 60C.

The vapor chambers will be hermetically sealed in order to permit an excess of pressure (with respect to normal atmospheric pressure) of 3 or 4 kg/cm$^2$, a procedure which considerably elevates the resistance of the concrete; thus making it possible to economize cement and permit a more frequent use of the molds.
Characteristics of the Design - connection to beams

At the height where the connection with the beams is made, the columns have a piece of steel "T" shaped on which the beams rest, steel bars begin at this point with the objective of later joining with the steel bars of the beams. As an alternate solution, I propose a column that is 2.40 high and which permits continuity of the concrete and the bars between the beams.

Lateral connection with the plaques

This is done by introducing concrete between column and panels.

Connection with the top columns

On the top surface of the pillar crop out eight connection rods which will be placed in the hole which the top pillar has in its base; this is later filled with concrete.

Beams

Dimensions

Rectangular section: interior 0.15mx 0.30m exterior 0.19mx0.30m
Length: Production being continuous in the mold, they can achieve any length. In order that there exist a correspondence with the wall panels, this length will be a multiple of the width of the panel: 0.60m (2'). Under normal circumstances, the length of the beams is 3.60m (12') = (1 module) and its half-way point 1.80m (6') = (1/2 module).

Characteristics

The prefabricated hollow beams of precast concrete are in reality the mold of the beam; in the interior of those hollow beams the steel reinforcing bars are placed which will be joined to the steel bars of the column, using sleeve nuts. The end of making hollow beams is double:

1) to use a lighter element

2) to make possible the joining of the steel bars before encasing them in concrete.

These hollow beams are also provided with perforations in back (in case of being supported over walls) which let the concrete go through and let the
steel bars situated between the panels be introduced on the inside of the beam also.

Panels

Dimensions
Height of panel = $2^{40} \text{m} (8')$
Width = $0.60 \text{m} (1 \text{ module}) (2''); 1/2 \text{ module} = 0.30 \text{m} (1')
Thickness = $0.15 (5-1/2'')$

Characteristics
The panels are, in essence, a sandwich made up of two external faces of extremely hard concrete; this concrete undergoes a vacuum treatment, and later a steam treatment. It has a high percentage of cement and a quantity of "puzzolana" dirt which improves the grading of aggregates. In the middle of the sandwich there is polyesterene insulating material which has a very light weight. 20 The two exterior faces are connected in four places besides the three central connections (in which the concrete goes through the polyesterene). The object of these

20 The procedure of making lightweight panels, placing expanded polyesterene between two sheets of mortar, is being used successfully by the D. Y. M. system to achieve high quality, economic housing.
connections is to unite the two exterior faces in order to reduce the bulging and vibration of the panels, and at the same time add to its compressive resistance. The four sides of the panel form channels where, during the process of construction of the walls, concrete is inserted; this concrete (considering the panel vertically), in reality forms a small column, which lets the whole wall function as a beam at the same time, by being united with the higher and lower beams. This constitutes an extraordinary advantage in resistance against high winds and earthquakes. The iron molds with which the panels are made permit smooth surfaces to be made which can be painted immediately after grinding. The edges of the panel, for greater precision are rectified with a special concrete grinding machine. When required by difficult working conditions, the prefabricated wall panel can be produced in smaller sections.

Secondary beams are supported with the overhanging
edges of the principal beams. Their object is to serve as a support for the concrete blocks which constitute the floor and the roof. The length of this beam is also about 3.6 meters.

Roof and floor blocks

These are blocks of vibrated mortar .6 meters (2') by .2 meters (8"). These are placed between the secondary beams, in order to prevent any lateral sliding; once it is in place the whole thing is covered with a coat of mortar which makes a homogeneous surface for floors or a flat gradient to the roof which is sufficient for draining water over a waterproof surface.

Foundation

The foundation is formed with a hollow, truncated cone of precast concrete. This element is first placed in the corresponding excavation and then the steel bars of the columns are inserted into the hollow part of the form which is later filled with concrete. The depth of the foundation can be increased by the progressive placing of truncated
cones one on top of the other.

**Interior Walls**

The interior walls can be made with the same panel that was used for the other walls, with a small beam which prevents cracks and breakage in case of earthquakes. In case they are walls, which change location when the dwelling grows, they should be made of wood, and should be attached to the secondary beams of the floor and ceiling.

**Sanitary Installations**

On the design, the bathroom and kitchen are placed close together in order to take advantage of common use of pipes. Standard sanitary equipment is used. All the drains are united in one big concrete pipe which carries away the waste to an inspection chamber which in turn empties into a sewer or a septic tank. The hot and cold water pipes and the gas pipes will be preassembled and will be placed on the outside of the walls allowing for repair and change (the electrical installation will be in iron pipes inserted into the joints of the panels; this gives complete
security and insures that the concrete walls will not be damaged when, for some reason, the wire must be changed.

The disadvantages of using traditional sanitary equipment in prefabrication are evident, but there exists no possibility of making completely prefabricated units at competitive prices.
MAIN BUILDING STAGES ON THE SITE

1. - Construction of storage and field office.
2. - Site clearing
3. - Surveying
4. - Excavations
5. - Placing of foundation cones
6. - Checking location of foundations.
7. - Placing the precast hollow beams on the foundations. (Reinforcement cage included in hollow beam).
8. - Fastening all necessary threaded connections between reinforcement.
9. - Checking vertical alignment of columns
10. - Placing the precast columns
11. - Placing steel bars in future joints of panels
12. - Pouring of concrete in hollow beam and foundation cones.
13. - Curing concrete
14. - Placing of wall panels, window panels, or door panels (steel bars between panels).
15. - Placing of scaffolding
16. - Placing of precast hollow beam on next floor
17. - Fastening all necessary threaded connections between reinforcement.

18. - Pouring and curing of concrete.

19. - Placing of secondary floor beams.

20. - Placing of concrete floor blocks.

21. - Placing of roof insulation.

22. - Placing roofing material—galvanized steel sheets.
A SYSTEM OF PREFABRICATED CONCRETE HOUSING FOR CHILE
1. Concrete panel
2. Connection between concrete faces
3. Connection working as a little beam
4. Steel bar of connection
5. Beam #2 (Precast form beam)
6. Beam #3 to be poured inside #2
7. Bars that link both beams
8. Channel imbedded in beams #2
9. Steel bar connection
10. Steel bars of the column
11. Temporary face
12. Steel bracket
13. Beam #1, floor support
14. Concrete block (forming the floor or the roof)
15. Column between wall panels
16. Foundation form
17. First floor column
18. Second floor column
ISOMETRIC OF BASIC MODULE
PLAN VIEW OF CONNECTION

BEAM SECTIONS

A SYSTEM OF PREFABRICATED CONCRETE HOUSING FOR CHILE
STRUCTURAL DESIGN
Design Data:
Assume concrete to have 3000 psi, compressive strength @ 23 days.
Reinforcing Steel to have 20,000 psi, allowable.
DESIGN BEAM I

Assume Dimensions Shown and design cross hatched section as simply supported rectangular beam.

LOADS

Beam weight = 150 lb/ft³ [0.5(0.25) + (0.17)(0.08)]
Beam = 50 (0.27) = 153 lb/ft²
Block = 35 (0.25) = 53.0
Concrete Floor = 170 (0.08)(0.777) = 23.6
Live load 40 (1.97) = 78.8
Residential = 10.0 lb/sq ft

design for \( w = 182.3 \) lb/sq ft.

REACTIONS

\[ R_L = R_R = \frac{W}{L} (185)(11.6) = 1075 \text{ lb} \]

MOMENT

\[ M = \frac{1}{8} wL^2 = \frac{1}{8} (182.3)(11.6)^2 = 3110 \text{ lb-ft} \]

Replaced \( d_m = \sqrt{\frac{3110(12)}{226(4)}} = 1.45 \text{ inch} \)

\( d_r = \frac{1075}{4 \times 60} = 4.48 \text{ inch} < 5 \text{ inches} \]

solution \( d = 5 \text{ inches} \) as shown

\( b = 4 \text{ inches} \) as shown

since \( v = \frac{1075}{4(5)} = 53.8 \text{ psi} \) allowable 60 psi (ACI code).

\( \times \)

STEEL REQUIRED

\[ A_s = \frac{M \times 12}{f_s J d} = \frac{3110(12)}{20,000(0.872)(5)} = 0.429 \text{ inch}^2 \]

Note: \( f_s = 20,000 \text{ psi} \) = Steel Tensile Stress allowable.
\( J = 0.872 \) (ACI Handbook pg 101)

using 2 bars, 0.22 inch² is required

Solution 2 - #5; those bars have \( A_s = 0.31 \text{ each} \) and \( S_o = 2 \text{ each} \)
Bond: for #5 bars, allowable 42 ksi ACI Handbook pg 101.

\[ S_o = \frac{42}{1.75} = 24.425 \text{ ksi} \]
DESIGN BEAM I (continued)

CHECK CRITICAL SHEAR SECTION ON OVERHANG:

Consider Length of Beam of 1'0".

\[ W = \frac{1}{2} (53.0 + 23.6 + 78.8) \]
\[ W = 77.7 \text{ pounds per foot} \]

Total Length = 78 lb.

Total Area = (2)(12) = 24 in²

\[ \sigma = \frac{W}{A} = \frac{78}{24} \approx 3.25 \text{ psi} < 60 \text{ psi} \]

DESIGN BEAM 2

NOTE: Beam 2 is to be used only as a forming beam for Beam 3. That is, Floor beams should not be placed on Beam 2 until Beam 3 has been poured and cured.

Weight of form, beam 2: \( \frac{60}{3} \text{ lb/ft} \)

\[ 150 \times \frac{60}{3} \left[0.08(12.5)(2)+2(0.17)(0.33)\right] = 46.8 \text{ pcf} \]

Weight of concrete to fill inside:

\[ 150 \times \frac{60}{3} \times 0.92(0.5) = 69.0 \text{ pcf} \]

\[ W = 115.8 \text{ pcf} \]

REACTIONS (FOR TOTAL BEAM 2):

Left = Right = \( \frac{1}{2} \times (116)(11.18) = 648 \text{ lb} \)

MOMENT (FOR TOTAL BEAM 2):

\[ M = \frac{1}{8} W L^2 = \frac{1}{8} (116)(11.18)^2 = 1810 \text{ lb-ft} \]

FOR HALF OF BEAM 2,

\[ R = \left(\frac{1}{2} \times 648\right) = 324 \text{ lb} \]

\[ M = \frac{1}{2} (1840) = 920 \text{ lb-ft} \]

Consider Each Bottom corner as an effective beam:
DESIGN BEAM 2

For Each Half of Beam 2, \( R = 324 \text{ lbs} \); \( M = 905 \text{ lbs} \).

- **depth req'd for shear** \( \approx \frac{324}{60} (3) = 1.8" \)
- **depth req'd for moment** \( \approx \sqrt{\frac{905 \times 12}{226 (3)}} = 4" \)

Considering only each bottom corner as acting alone as a beam 3' x 4'.

**Explanation:**

From A C I Code, pg. 318-53, and pg. 318-49:

\[ v = \frac{V}{6d} \]

\[ b = \text{width of beam} \]

\[ v = 60 \text{ psi} \text{ allowed for beams with no web reinforcement} \]

\[ d = \frac{V}{6v} \]

**NOTE** Web reinforcement is not required but will be included to serve a means of reinforcing the thin portions of the form as well as to tie the form to the concrete beam, to be poured inside.

Also,

From A C I Design Handbook, pg. 226:

\[ K = \frac{M}{6d^2} \]

\[ b = \text{width of beam} \]

\[ M = \text{Moment} \]

**Solution**

\[ d = 4" \text{ inches} \]

**BOTTOM As REQUIRED**

\[ A_s = \frac{M}{f_y A_d} = \frac{905(12)}{20,000(0.872)(3)} = 0.207 \text{ inch}^2 \]

Use 2 bars as shown. 2 bars have \( A_s = 0.22; \) \( \phi = 1.978 \text{ inch} \)

Check Bond:

From Handbook, pg. 101, Allowable

From A C I Code pg. 318-57,

<table>
<thead>
<tr>
<th>\text{To check Bond:}</th>
<th>\text{From Handbook, pg 101, Allowable}</th>
<th>\text{From A C I Code, pag 318-57}</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ u = \frac{V}{2000 f_y A_d} ]</td>
<td>[Recommended ( \phi = \frac{324}{500 (0.872) (3)} = 0.848 &lt; 1.178 \text{ psi} )]</td>
<td></td>
</tr>
</tbody>
</table>
CHECK CAPACITY OF THIN SHELL BOTTOM

Consider a section of Beam 2, one foot long and full of concrete and assume no reinforcement.

weight of concrete inside = 69 lb.

\[ w = \frac{69}{6} = 11.5 \text{ lb/in} \]

\[ q_{left} = q_{right} = \frac{1}{2}(11.5)(6) = 34.5 \text{ lb} \]

\[ v = \frac{4}{3}(11.5)(6)^2 = 51.8 \text{ lb/inch} \]

Check Shear:

\[ v = \frac{34.5}{12(1)} = 2.87 \text{ psi} < 60 \psi \]

\[ M_T = \frac{M_c}{I} = \frac{M}{3} \]

where \[ S = \frac{6t^2}{6} = \frac{12(1)^2}{6} = 2 \text{ in}^3 \]

\[ 6t = \sigma_c = \text{extreme fiber stress in tension} \]

ACI code pag 318-49 allow \[ \sigma_c = 88 \psi \]

USE #2 Stirrups spaced at 12" as shown.

STRUCTURAL STEEL CHANNEL AT ENDS OF BEAM

From Beam 2 Reactions (sh 3)

\[ P = 324 \text{ lb} \]

\[ R = 2P = 648 \text{ lb} \]

Moment:

\[ M = \frac{Rl}{4} = \frac{648(9)}{4} = 1460 \text{ lb-in} \]

Required \[ S = \frac{1460}{22000} = 0.0664 \]

use \[ I 3 \times 4.1 \]

piece of Steel T.

*Channel with both ends embedded in Beam 2.
DESIGN ST BRACKET (SUPPORT FOR BEAM 2)

From sht. 5, Channel Reaction,

\[ P = 648 \text{ lb} \]

Max. \( M = 648(4.5) = 2920 \text{ lb}\cdot\text{in} \)

Req'd. \( S = \frac{2920}{22800} = 0.132 \)

Use Piece of S T 3 B 6

Tension per anchor bolt:

\[ 37 = 2920/7 \]
\[ T = 486 \text{ lb} \]

USE 2 projecting 6'' Rods each face with threaded ends.

TRIAL DESIGN OF BEAM 3 (To support floor & wall on its level)

Loading: Convert all to equivalent uniform

Wall Load \( \approx \frac{1}{12} (6(312)) = 152 \)

Floor Beams = \( \frac{1}{12} [16(100)] = 873.0 \) (Req 2)

Beam Dead Load

Total \( w = 115.8 \text{ lb/ft} \)

From A C I code pg. (318 - 37)

Positive \( M = \frac{1}{8} (37) \cdot L^2 \)

\( (+) M = \frac{1}{8} (1140.6)(11.8)^2 = 11300 \text{ lb}\cdot\text{ft} \)

Negative \( M = \frac{1}{8} w L^2 \)

\( (-M) = \frac{1}{8} (1140.6)(11.8)^2 = 17700 \text{ lb}\cdot\text{ft} \)

Shear \( = 1.15 \frac{wL}{2} = 1.15 \frac{(1140.6)(11.8)}{2} = 7750 \text{ lb} \)

For shear, \( d \) req'd = \( \frac{7750}{6(224)} = 4.72 '' \)

For \( M \), \( d \) req'd = \( \sqrt{\frac{7750(12)}{224(16)}} = 12.5 '' \)

Note: Make Beam 3 = 6'' wide x 11 deep.
FRAME ANALYSIS

WIND LOADS:
Assume 30 psf. wind.
Consider wind acting on front elevation shown.

\[ P_1 = 30 \times (12.3) (4,42) \approx 1630 \text{ pounds (libras)} \]
\[ P_2 = 30 \times (12.3) (8.85) \approx 3220 \text{ pounds} \]

\[ 1 \text{ Kip} = 1000 \text{ libras} \]
For Wind,
\[ P_4 = 4.63 \text{ K} \]
\[ P_3 = 3.22 \text{ K} \]

EARTHQUAKE

For Frame B analysis, calculate \( P_1 \), \( P_2 \), and \( P_3 \) based on the Uniform Building Code Formula: \( F_p = Z C W_p \)
\( Z \) shall be taken as 1 (Zone 3)
\( W \) shall be taken as 0.2 for all parts of the building.
\( C = \text{constant for each part} \)

Find \( P_4 \):

WT. Roof Beams & 1" thick roof = 10 (1075 pounds) = 10750 lb \rightarrow 0.2 (10.7) = 2.14 Kips
WT. Main Beams = 115.8 lb (12) \rightarrow 432 lb \rightarrow 0.2 (4.28) = 0.86 g
WT. Columns = 150 lb/ft (3) \rightarrow 333 lb \rightarrow 0.2 (0.332) = 0.066 Kips
WT. Walls = 312 lb (6) (2.5) (4,45) \rightarrow 594 lb \rightarrow 0.2 (2.97) = 0.592 Kips

Total \( P_1 = 3.625 \text{ Kips} \)

Find \( P_2 \): By Inspection of loads for \( P_1 \)
Roof Beams = 2.14 Kips,
Main beams = 0.16 Kips,
columns = 2 (0.066) = 0.132 Kips;
walls = 2 (0.56) = 1.12 Kips.
Total \( P_2 = 2.14 + 0.16 + 0.132 + 1.12 = 4.65 \text{ Kips} \)

Find \( P_3 = P_1 + P_2 = 3.63 \text{ Kips} \)
Earthquake Loads > Wind Loads: Design Frame B for earthquake.
FRAME ANALYSIS (FRAME B - VERTICAL DEAD & LIVE LOADS)

MEMBER STIFFNESSES:

Assume that all columns are 6 inches, Square.

Assume all beams have the effective cross section of 6 inches wide X 11 inches deep.

Therefore,
For all beams,
Moment of inertia: \( I = \frac{b^3}{12} = \frac{6^3}{12} = 0.0324 \text{ ft}^4 \).
Span (\( L = 12.3 \text{ ft} \)).
Stiffness (rigidity): \( K = \frac{L}{L} = \frac{0.0324}{12.3} = 0.00266 \text{ ft}^3 \).
NOTE: Because of symmetry, use \( K_{\text{beam}} = \frac{4}{3} (0.00266) = 0.00833 \).
For all columns,
\[ I = \frac{b^3}{12}, \quad L = 8.5 \text{ ft}, \]
\[ K = \frac{I}{L} = \frac{0.0052}{8.5} = 0.00059. \]

Member Distribution Factors (For Analyzing half of frame because of symmetry.)

At Joints A, and C,
\[ \Sigma K = 0.00133 + 0.00059 = 0.00192 \]
Therefore
Distribution Factor from A to F = \( \Delta F_{AF} = \frac{K_{\text{beam}}}{\Sigma K} = \frac{0.00133}{0.00192} = 0.693 \)
Distribution Factor from A to B = \( \Delta F_{AB} = \frac{K_{\text{column}}}{\Sigma K} = \frac{0.00059}{0.00192} = 0.307 \)

Similarly \( \Delta F_{AC} = 0.693 \)
And \( \Delta F_{CE} = 0.307 \)

At Joints B and E:
\[ \Sigma K = 0.00133 + 0.00059 + 0.00059 = 0.00251 \]

Therefore,
\[ \Delta F_{BD} = \frac{0.00059}{0.00251} = 0.233 \]
\[ \Delta F_{BE} = 0.233 \]
\[ \Delta F_{ED} = \frac{0.00033}{0.00251} = 0.53 \]

FIXED END MOMENTS FOR BEAMS.

F.E.M. = \( \frac{4}{12} W' L^2 \)
For final design of beam, \( W' = 1141 \text{ lb/ft}, \quad L = 1.14 \text{ Kips/ft} \).
F.E.M. = \( \frac{4}{12} (1141)(12.3)^2 \)
F.E.M. = 14.4 Kip ft.
FRAME ANALYSIS

MOMENT DISTRIBUTION: FRAME B - VERTICAL DEAD & LIVE LOADS

\[ a x: (4.4+0.36) = 9.93; \quad \Sigma = 14\% \text{ check } -14\% + 14\% = 0 \]

\[ +5.23 \]
\[ -0.36 \]
\[ +1.17 \]
\[ -9.98 \]
\[ +4.4 \]
\[ -0.693 \]

\[ \begin{array}{c|c|c}
5.23 & 2.35 & 2.35 \\
0.36 & 0.28 & 0.28 \\
1.17 & 7.63 & 7.63 \\
9.98 & 14.4 & 14.4 \\
0.693 & 0.53 & 0.53 \\
\end{array} \]

CHECK MOMENT DISTRIBUTION:

At each joint, \( \Sigma M = 0 \)
At each level, \( \Sigma V_H = 0 \)

\[ +M_1 + M_3 = \frac{1}{8} w l^2 = 5.23 = \frac{1}{8} (1.14)(2.3)^2 - 5.23 \]
\[ +M_1 = +M_3 = (\pm) 16.27 K \]
\[ +M_2 = \frac{1}{8} (1.14)(4.23)^2 - 8.83 = 12.67 K \]
FRAME ANALYSIS

MOMENT DISTRIBUTION *: (FRAME B- Earthquake Loads)

This case of loading which involves sidesway, will
be analyzed by "cantilever moment distribution " as
presented by B. R. Cooke, in his discussion of,
Lateral Load Analysis of two Column Bents, by John E.

MEMBER STIFFNESSES

Since' loading is antisymmetrical, the beams will be assigned values
of $K' = \frac{3}{2}K$ and only half of the
frame moments will be analyzed.

For all beams,

\[
\begin{align*}
I &= 0.022A \frac{ft^3}{(\text{sheet 8})} \\
L &= 12.3 \frac{ft}{} \\
K &= \frac{I}{L} = 0.00266 \rightarrow K' = \frac{3}{2}(0.00266)
\end{align*}
\]

For all beams, $K' = 0.00399$

Furthermore, according to B.R. Cooke,
For all columns, $K' = \frac{1}{4}K$

From sheet 8, $K = 0.0059$ \rightarrow For columns, $K' = 0.00148$.

DISTRIBUTION FACTORS

At Joints A & C, $\Sigma K = 0.00414$
At Joint B, $\Sigma K = 0.00429$

Therefore

\[
\begin{align*}
DF_{CB} &= DF_{BA} = \frac{0.00215}{0.00429} = 0.048. \\
DF_{AD} &= DF_{AF} = \frac{0.00329}{0.00429} = 0.077. \\
DF_{BC} &= DF_{BA} = \frac{0.00215}{0.00429} = 0.035. \\
DF_{BE} &= \frac{0.00399}{0.00429} = 0.939
\end{align*}
\]

FIXED END MOMENTS

By B.R. Cook Method

\[
\begin{align*}
F.E.M_{CB} &= F.E.M_{BC} = \frac{1}{2} (363) \left( \frac{8.85}{2} \right) = 8.02 \text{kip-ft} \\
F.E.M_{BA} &= F.E.M_{AB} = \frac{1}{2} (363 + 425) \left( \frac{8.85}{2} \right) = 19.4 \text{kip-ft}
\end{align*}
\]

carry over factor

For this type of moment distribution, a carry over factor of (-) 1 is used instead of the usual (+) $\frac{1}{2}$.
FRAME ANALYSIS

MOMENT DISTRIBUTION BY CANTILEVER METHOD
FRAME B - EARTHQUAKE LOADS

\[
\begin{array}{c|c|c|c}
\text{Frame Number} & \text{Moment} & \text{Reaction} \\
\hline
\text{Frame B} & -8.60 & 0.88 \\
& -0.88 & -7.72 \\
\hline
\end{array}
\]

\[
\begin{array}{c|c|c|c|c|c}
\text{Frame Number} & \text{Moment} & \text{Reaction} \\
\hline
\text{Frame B} & +8.60 & -0.03 & +0.03 & -0.03 & +0.03 \\
& +7.38 & -0.03 & +0.03 & -0.03 & +0.03 \\
& +17.08 & -0.03 & +0.03 & -0.03 & +0.03 \\
& +17.68 & -0.03 & +0.03 & -0.03 & +0.03 \\
\hline
\end{array}
\]

CHECK:
AT EACH JOINT \( \sum M = 0 \)
AT EACH LEVEL \( \sum V = 0 \)
FRAME ANALYSIS

COMBINED LOADING: VERTICAL + HORIZONTAL LOADS
CONVERSION FACTORS
BETWEEN METRIC AND ENGLISH UNITS

METRIC UNITS TO ENGLISH UNITS

1 meter = 39.37 inches
1 square meter = 10.76 square feet
1 kilogram = 2.205 pounds
1 kilogram/meter = 0.6721 pound/foot
1 kilogram/square cm = 14.22 pounds/sq. inch
1 kilogram/square meter = 0.2049 pound/sq. foot
1 kilogram/cubic meter = 0.06243 pound/cu. foot

ENGLISH UNITS TO METRIC UNITS

1 inch = 0.02540 meter
1 square foot = 0.09290 square meters
1 pound = 0.4536 kilogram
1 pound/foot = 1.488 kilogram/ meter
1 pound/square inch = 0.07031 kilograms/square cm.
1 pound/square foot = 4.883 kilograms/square meter
1 pound/cubic foot = 16.02 kilograms/cubic meter.
BIBLIOGRAPHY

Abrams, Charles Man's Struggle for Shelter in an Urbanizing World.

Ahumada, Jorge En vez de la miseria.


Baltra, A. C. Crecimiento Economico de America Latina.


Earthquake Engineering Seminar Held at the University of Roorkee Ill., 1959.

Empresas Industriales "EL MELON" S.A. Tecnologia del cemento, 1968.


Heitmann, Luis Bravo *Instituto de la Vivienda. Facultad de Arquitectura, Universidad de Chile, Casas Experimentales CORVI*, 1965.

------------------------- Urbanizacion caos o progreso.

*Instituto de Economia Universidad de Chile La Economia de Chile periodo 1950-1963.*

-------------------------- La migracion interna en Chile 1940-1952. 1959.

-------------------------- La poblacion del gran Santiago, 1959.


Jung, Carl *Sobre cosas que se ven en el cielo.*


-------------------------- Un essai d'observation experimentale.

Meyerson and others *Housing, people and cities*. 1962.

Moore, Astolfo Tapia *Sociologia del Urbanismo: Algunas realidades Latino Americanas. Universidad Chile Instituto Vivienda Urbanismo y Planeacion.*

Ortega y Gasset, Jose *The Revolt of the Masses*.


----------*Report of the "ad hoc" group of experts housing and urban development*. 1962.

**Periodicals:**


Greep, Roy O. *"The Population Crisis is Here"*, *Urban Land*, November 1968.


Lewis, Oscar *"The Culture of Poverty"*, *Scientific American*, October 1966.


--------- "Renovacion Urbana", *Colegio Arquitectos*, Universidad de Chile, Santiago, 1968.

Raposo, Alfonso "La Familia Habitante y su Vivienda", *Planificacion No. 2*, December 1965, Seminario Universidad de Chile 1962.