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Industrialized Low Cost Housing in Missouri, A Case Study

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INDUSTRIALIZED LOW COST HOUSING IN MISSOURI

A CASE STUDY

by

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INTRODUCTION

Industrialized housing is defined as that type of living unit that is substantially completely built in a factory and shipped to the site and then erected on a pre-prepared foundation in one or two days. The unit may be similar in appearance and construction to conventional units, or may be drastically different in appearance and/or construction. The basic structural methods used are the box, panel, beam and column or the structural system.

There are many reasons why industrialized housing is capturing more of the market each year. One of the major reasons is cost. One study in Missouri indicates that 80% of the people cannot afford a new conventionally built home. As a result, over one-third of the new living units built are mobile homes which are at present the most economical type of factory-built unit. In general, the mobile home can be purchased at less than 1/2 the cost per sq. ft. of a conventionally built home.

At the present time industrialized housing that is similar in appearance and construction to conventional housing is selling for about 25% less than equivalent conventional housing. In addition, some industrialized builders are planning on using new materials, new joining techniques, modern architectural and engineering design and modern production techniques that promise an industrial revolution in the home industry.

There are many serious problems that must be overcome before the cost of new housing can be brought within the reach of most families. Some of these are restrictive building codes, seriously different interpretations of the same building code, multiplicity of building codes, restrictive and uneconomical zoning practices, fragmentation of the home building industry, inadequate financing, unfair and restrictive federal regulation, union discrimination, regressive tax policies, inadequate development of electrical and mechanical equipment and restrictive practices by public and private utilities (1) thru (12).

In spite of the multitude of difficulties, factories are being built and industrialized housing units are being produced at an increasing rate. Missouri is one of the states that is increasing its production of industrialized housing. There are over thirty firms in the state that are producing housing or parts therefor. The trend in Missouri is similar to that in other states. Most of the factories are located outside of the large urban areas. As a result, most of the installations are also outside of the large urban centers and housing costs are much less in these areas. It is ironic that the large cities with their supposedly progressive attitudes should be lagging behind in this new vital industry.

Progress is being made in overcoming the serious problems associated with industrialized housing. Twenty states have passed industrialized housing laws that waive local codes and attempt to obtain statewide regulation. Serious attempts are being made to bring the nationwide codes such as BOCA and the Uniform Building Code together into one code and remove some of the unfair and ultra-restrictive requirements on new types of construction. Several federal agencies are working on a nationwide code that would replace the local or statewide codes. Model zoning is being studied with the hope of producing more attractive and economical developments. Large corporations and financing institutions are becoming interested in housing and multimillion dollar factories are under development and construction. Some of the industrialized housing producers are being organized by several unions. As a result, the units produced are being installed by organized labor on the site with a minimum of interference. (13)

The purpose of this paper is to study one type of low-rise unit that is manufactured by the Home Building Corporation in Sedalia, Missouri. The design and construction is evaluated on the basis of an industrialized performance specification written at the University of Missouri-Columbia that was developed as part of the "Mizzou Housing Project-Application of Turn-Key Construction to Industrialized Urban Housing in Missouri". (6)

HBC UNITS

A pair of modules designed by Reyburn & Wright Architects and built by Home Building Corporation at their Sedalia, Missouri, factory have been studied. These modules have been placed in cities throughout the state and have been approved for both Farm Home Administration and Federal Housing Administration loans. They have received the BOCA seal signifying that they meet the requirements of the BOCA Basic Building Code, which is one of the accepted codes in the state of Missouri. Home Building Corporation has been picked as a winner in the Operation Breakthrough competition and will soon be placing similar houses in the St. Louis area. The house analyzed can generally be described as a frame structure composed of two modules, approximately 40 feet long and 12 feet wide. An additional three feet of width is provided in the finished house by panel inserts at the center of each end of the house and sections of roof and floor that complete the remainder of the extension. The exterior of the house is specified as 3/8 inch plywood with battens at 16 inches on center. The interior walls are covered with paneling or sheetrock. Floors are either carpeted or covered with vinyl sheet flooring. The windows have metal frames and slide to the side to open. Rooms included in the modules are a living room, kitchen-dining area, three bedrooms and a bath. There is also a utility room containing the furnace, hot water heater, a space for a clothes washer and a storage area. Another dominant feature of the house is the vaulted-type ceilings. All ceilings except those in the hall feature exposed, sloped, mahogany-trimmed beams. The hall is lighted by soffit lighting. The units are sold at the factory for about $10,000 each.

The Home Building Corporation is a well organized modular factory producing single-family houses and townhouses. The factory layout consists of a single production line for half house modules or two story townhouse units, fed by short production lines for the components of the house. At station one, the floor system is put together in sections about 12 feet wide by 34 to 45 feet long. These dimensions conform with the allowable highway transportation size for the state of Missouri. The floor sections are built on steel beams having wheels that follow a track to the end of the production line. The two halves of the house that are later to be mated travel in sequence on the production line, although they never touch until they are placed on the foundation. The entire flooring system including the vinyl covering for the kitchen and bathroom floors is placed before the module is rolled to the next position. At this next station and at each succeeding production station, completed components are brought onto the floor system and fastened into place. The entire process of production is sequenced so that the material flows onto the floor system in an orderly manner. An example of the efficiency and forethought in the operation is that the bathtub is placed before the bathroom walls are positioned. One panel of the wall in an adjacent hall is designed to allow removal if the bathtub should have to be replaced at a later date. Power nailers and saws greatly reduce the amount of labor involved in each house. Jigs are used to produce the wall sections and roof sections before they are placed on the floor system. Glue is used to secure joints in addition to nails whenever possible. This method increases the structural rigidity of the unit. Scaffolding for working on the roof is permanently connected to the ceiling of the factory to allow easy, safe access to the module roof and is also designed to swing out of the way to allow the house to pass to the next station. An important factor relating to the possible acceptance of modules from this factory is that all of the workers employed are union members. This helps avoid some of the union problems at the building site.

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It is the policy of the management not to keep completed units in stock. Therefore, before a house is started on this production line it is already sold. This is possible because production time for a particular house is very short, less than one week. The management hopes that production will be at three units a day on the Operation Breakthrough project. At the end of the production line the modules are loaded onto flatbed trucks for delivery to the foundation. The module is so complete when it leaves the factory that the street number is already affixed to the front door sill. When the module arrives at the foundation, a large crane lifts the half houses off of the flatbed and onto the foundation. The foundation is prepared by the purchaser of the modules, but must meet HBC standards. It takes only a half day for a crew of four men to set the house on the foundation and make it ready for utility hookup.

PERFORMANCE SPECIFICATIONS AND ANALYSIS

The objectives of performance specifications are twofold: to develop performance specifications which can be used state or area-wide with only minimal changes for local conditions and to develop true performance specifications which judge housing construction by its performance, in terms of structural or mechanical or electrical adequacy with a proper factor of safety rather than in terms of its methods, materials, allowable stresses, etc. Most performance specifications must be divided into low-rise (3 stories or less) or high-rise because of the differing requirements (fire protection, etc.). The Mizzou low-rise specification (6) covered the following items: architecture, site, foundation, structural (basically a factor of safety of 1.5 was specified), mechanical, utilities and landscaping.

The structural analysis of the unit can be divided into four parts. First the exterior loads acting on the unit are determined. Wind and snow loads can be estimated from maps developed from United States Weather Bureau records. Secondly, the dead load of the superstructure can be found by estimating the unit weight of all materials used and the quantity of each material used. Dead loads are recorded in a manner to allow estimation of the dead load at any critical location in the structure. The critical points for analysis are then selected. The most critical combinations of snow load plus wind load or a minimum live load as stated in the performance specifications plus the dead load are used to calculate stresses and deflections at the critical points.

The Mizzou performance specifications state that the structure shall possess the minimum fire requirements for classification type 4-A as described in the BOCA Basic Building Code/1970. The BOCA Code states that a type 4-A structure should have a fire resistance rating of 3/4 hour. Fire resistance ratings are found for components similar to those in the dwelling in Building Materials List-1969, Underwriters' Laboratories, Inc., and Uniform Building Code, Vol. 1, 1967 Edition.

Minimum Property Standards for One and Two Units and Minimal Property Standards for Multifamily Housing, both published by the U.S. Department of Housing and Urban Development and the Federal Housing Administration present the requirements for insulation properties and methods of heat loss calculation. The major criteria in the Mizzou specification is that the heat loss shall not exceed 50 Btuh per square foot of the total floor area to be heated to 70° F.

Minimum acoustical quality for floors and ceilings are specified as sound transmission class 48 and for walls and partitions are specified as sound transmission class 40. Sound transmission class ratings for typical housing components obtained by procedures contained in ASTM E90-66T can be used.

The performance specifications require a transmission rate of no greater than 1/2 perm for the ceiling and roof and a transmission rate of not greater than 1 perm for the walls.

For a structure to resist destructive elements, materials should be protected with chemical coatings, paints or other types of surface protection. Ventilation and avoiding contact with the ground are also important. The components used can be reviewed to see if they are protected by any of these methods.

RESULTS OF SUPERSTRUCTURE ANALYSIS

Eight critical areas of stress and deflection were analyzed to determine the maximum theoretical values. All eight parameters proved to be within the tolerances specified in the performance specifications. The specifications also called for analysis of the uplift force on the roof and the overturning force due to the design maximum wind load. The factor of safety against uplift was found to be 1.8 and the factor of safety against overturning was found to be 7.1.

The performance specifications require that the dwelling unit shall be classified as type 4-A. This type of dwelling unit is required to have a 3/4 hour fire resistance rating for all major components. All components proved to have a sufficient fire resistance rating.

The performance specifications require that the heat loss not exceed 50 Btuh per square foot of total floor area maintained at 70° F. Calculations show the heat loss for these modules to be only about 30 Btuh per square foot.

The minimum sound transmission class is specified to be 48 for floors and ceilings and 40 for walls and partitions in this dwelling. The STC rate for walls similar to those used in these modules was found to be 31. This fails to meet the performance specification. The impact noise rating was given as -18 db for floors of the type used in the module. This rating means that the floors are rated at -18 db below the FHA impact noise curve. The higher the INR, the better the impact isolation of the structure.

A maximum value of 1/2 perm vapor transmission rate is required for the ceiling and floor of the dwelling. The walls are required to have a permeance of less than 1. Aluminum foil backed drywall as used on this module has a permeance of .084 to .385. Both the ceiling and the walls pass the performance criteria. The plywood floors have a permeance rating of between 3.0 and 6.0 and therefore do not pass the performance specifications.

Precise values for parameters of durability, weatherability and appearance were not developed for this study. The conventional nature of the materials used in this dwelling suggests that they have been found to possess these attributes.

SUMMARY AND CONCLUSIONS

The case study met most of the performance specifications for the superstructure. The structural analysis shows all of the components to have factors of safety greater than the required 1.5. Fire protection and insulation properties specifications were also met by all the components checked. The acoustical quality was below the performance specification level, but was essentially the same as most low- to medium-priced frame houses. Vapor barriers were within specification except for the floor system. Durability, weatherability, and appearance were found to be equivalent to most conventional frame dwellings. The dwelling met almost all of the performance specifications with relatively large factors of safety.

The large factors of safety suggest that there are areas where costs could be cut and still have the dwelling achieve the level of performance required. Roof joists seemed to be the most over designed component in the superstructure. Their factor of safety for stress was well over 20 and the deflection was less than 1/200 of the allowable. The depth of the roof joists was required for insulation but better insulation material would allow a thinner section and possible material savings. The interior walls were structurally over-designed, but did not meet the required acoustical properties. New acoustical materials would allow redesign for the wall sections and provide possible cost savings.

Performance specifications such as the one used in this study encourage the use of new materials and methods to bring the factors of safety into proper relationship and allow areas of possible cost savings to be explored.

Although the units used in this study are produced by factory methods at significant savings in cost, they are produced by relatively crude methods as compared to the methods used on autos and other similar equipment. It appears that considerably greater cost savings, that can be passed on to the consumer, can be realized in the near future. In addition, new methods of structural design can be developed to reduce costs further. Perhaps one of the greatest potentials for cost reduction is in the area of mechanical and electrical installations. Very few items that are really new and fit the industrialized unit have been marketed on a large scale. In addition, the site preparation and utilities techniques need an in-depth study to industrialize this portion of the overall project. Perhaps statewide or other performance specifications should be written to overcome the restrictive and costs requirements of the utility organizations.

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