26 Apr 1972

# Suspended Modular Component System

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by

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## INTRODUCTION

The Department of Housing and Urban Development Program, "Operation Breakthrough," is challenging governmental innovation designed to stimulate the various segments of our society to explore ways as to how technology may be applied to provide mass produced housing (1, 2, 3, 4, 5, 6, 7). The objective of this program is to supply a sufficient number of homes at a reasonable cost to our rapidly growing population which will provide comfort, choice and mobility while concurrently upgrading the quality and habitability to the disadvantaged segment of society (1, 2, 8, 9, 10).

The solutions to many of the foregoing problems either directly or indirectly involve planning, design and construction on a massive scale. Building technology, traditional planning criteria and codes, construction practices and various other constraints such as labor and financing have limited the building potential in the United States in the past, since efforts have been segmented and uncoordinated. The present trend toward Systemization is most necessary due to limitations of funds and time. Systemization of the building process must be accompanied by innovations in technology.

It is the purpose of this paper to present such innovations by examining partial details of a study (11) which has resulted in a structural building system which will decrease both the cost and the time for construction by taking advantage of mass production techniques. To this end, the Suspended Modular Component System has been conceived following an extensive research of the various requirements, current building system proposals, and those areas of technology which have been neglected.

The Suspended Modular Component (SMC) System involves suspension of prefabricated modules or floor systems from a tower core and/or tower cores connected by cable to overhead truss. Since the modules involve only their individual structural integrity, they may be constructed of the material offering the greatest economy. The SMC System provides for minimal on-site construction and provides for more effective utilization of structural components.

## SUSPENDED MODULAR COMPONENT SYSTEM

The Suspended Modular Component System involves suspension of modules or other types of floor systems from overhead trusses supported by tower and/or several tower cores. The suspension system offers particular appeal because of the potential efficiency in the use of material and the possibility of minimizing and isolating foundations by spanning large distances. Since all loads are transferred to the supporting tower by tension members, there is no need to increase member sizes to accommodate the reduction in allowable stresses for buckling considerations. Steel, aluminum or wire rope can therefore be used to their maximum advantage. The drawing of steel into wire form increases the proportional limit to stresses on the order of 160,000 psi and the breaking stress to over 220,000 psi. The suspension system combined with mass produced modules embraces tremendous cost saving possibilities and saving in erection time. The SMC System lends itself to varying degrees of prefabrication: the module, panel systems, expandable utility cores and lift slab techniques.

The SMC System overcomes the inefficiency of the stacking or dependent system since all modules are supported independently of all other modules. (4) Since the modules involve only their individual structural integrity, they may be constructed using minimum materials. Therefore, each module may be constructed identically, which is a prime requirement for systemization. Modules may be constructed of the materials offering the greatest economy: wood, concrete, steel, or plastic.

The method with which the study is devoted, SMCS I, is indicated in Figures 1 and 2. This method was selected since it was considered to be the most economical approach. The modules are lifted floor by floor by utilizing the tower core as a lifting crane, supplemented, of course, by some additional lifting equipment removable upon the completion of the project. Figure 3 indicates the general approach which might be taken in the multiple tower core system.

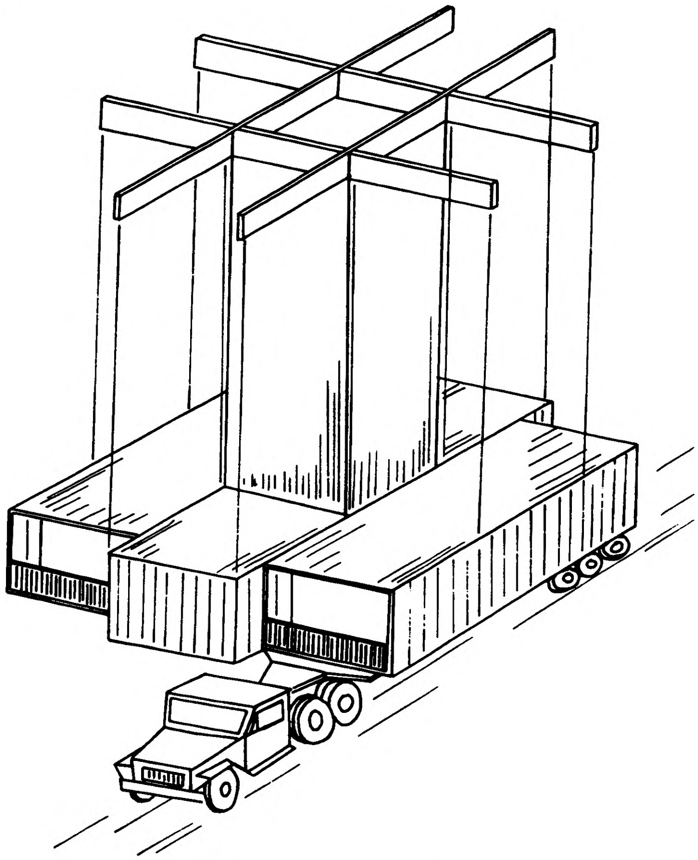

**Fig. 1. Single Tower Core - On Site Erection - SMCS I**

## STRUCTURAL SYSTEMS

The selection of the various structural alternatives presented in this section considers primarily structural performance and considers the various other requirements only to the extent that they are generally addressed. The proposed structures are several of many possible systems. It is the primary purpose of this discourse to analyze the structural behavior of the various systems under various loading conditions and to develop criteria by which the suspended structure can be better evaluated.

1. Single Core Tower

Suspension Span. The single core tower with cable supported cantilevers for suspending modules is indicated in Figure 4. The suspension system will be referred to as Structure 1, the tower core shall be referred to as Structure 2.

2. Four Core System

The structure presented in Figure 5 was devised to provide for better modular coordination and increase the number of com-

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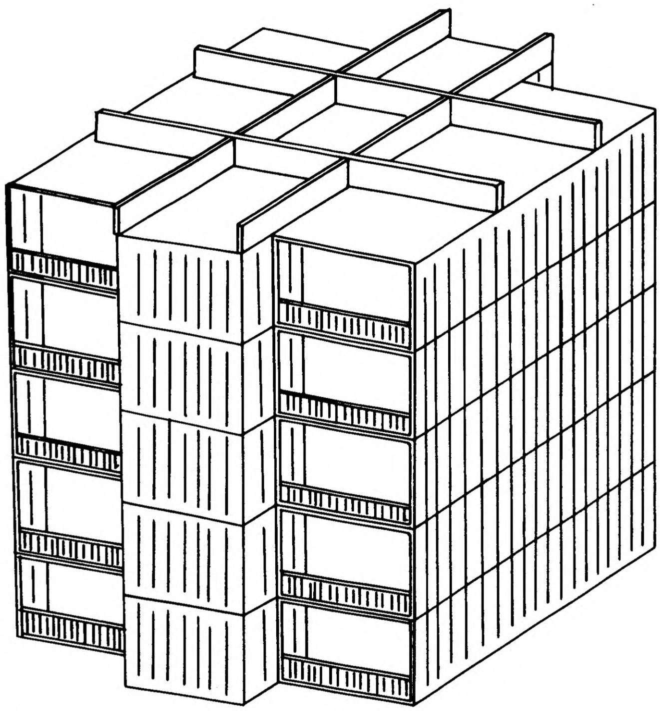

Fig. 2. Single Tower Core - Modules in Place - SMCS I

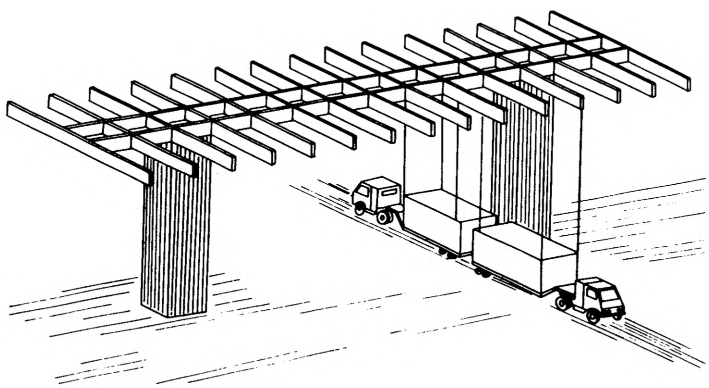

Fig. 3. Multiple Tower Cores - On Site Erection - SMCS II

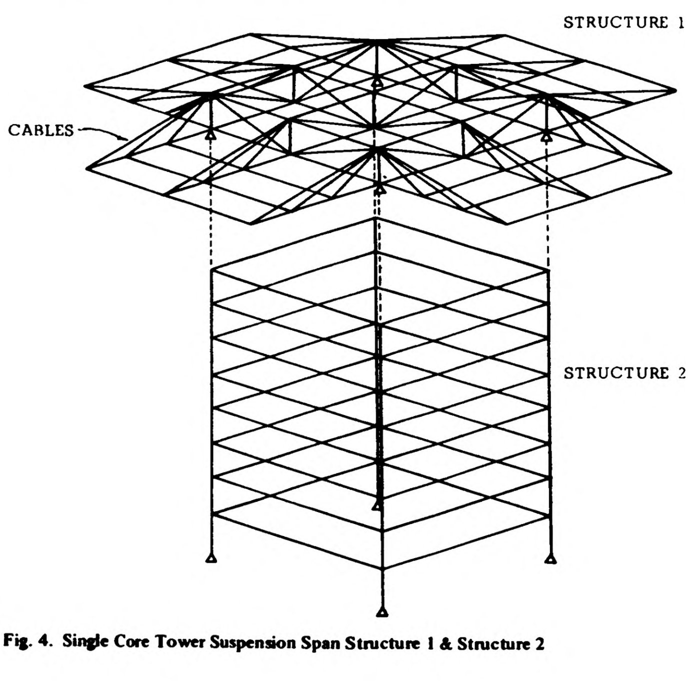


Fig. 4. Single Core Tower Suspension Span Structure 1 & Structure 2

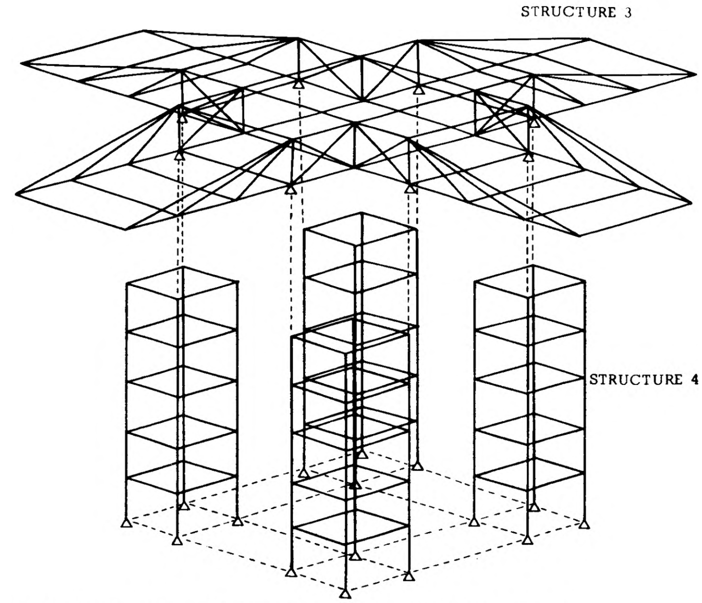


Fig. 5. Four Core Tower Suspension System Structure 3 & Structure 4

ponents in the tower core which could be prefabricated and erected at the site for possible savings in cost and erection time. The truss shall be referred to as Structure 3 and the tower shall be referred to as Structure 4. Some of the flexibility in floor plan possibilities is lost with these structures; however, this arrangement should increase the ability of the structure to support horizontal loads.

## ANALYSIS AND DESIGN PROCEDURES

The analysis and design procedures employed to evaluate the performance of the tower core and truss supporting systems are based upon standard elastic steel design criteria. The elastic stiffness matrix technique was utilized to analyze the structural systems. The American Institute of Steel Construction Specifications have been used as a guideline for the design requirements. Computer programs have been employed to develop data on the performance of the structures under various service loads.

## STANDARD CRITERIA

### 1. General

A primary goal of this study was to develop a standard design and planning criteria in terms of suspended modular component system structural requirements related to module dead weight and the capacity of the system relative to people.

Attainment of this goal represents a significant step toward systemization. The SMC System represents a structural system which is simple, flexible and adaptable to a variety of manufacturers' modular products. The system represents an identifiable method of overcoming technical constraints confining current manufacturers to building systems of several stories in height.

The criterion presented in this section has necessarily been limited to steel due to the range of considerations and variety of structural systems considered. The use of concrete in the tower structure should be developed to provide further flexibility in the use of materials and construction methods. Other structural configurations should be considered in order to provide further information for optimizing the SMC System. Nonetheless, the criteria provided herein demonstrate the technique that may be employed to integrate the low cost single story module into an efficient highrise structure.

## 2. Planning Criteria

Figures 6 and 7 represent charts for use in developing relationships between the capacity of Structures 1, 2 and 4 in terms of people, module dead and live loads, number of stories, the total weight of the structures, and the direct cost of the placing of the steel frame. These charts provide valuable planning criteria in a convenient form such that project scopes can be quickly determined based upon available funds, modular products available, and the number of people to be provided.

The capacity in terms of people was developed by dividing the number of square feet of floor area available by the average of the floor area requirements per person for FHA one, two and three bedroom apartments. The FHA requirements provide approximately 320 square feet per person. This unit person requirement could easily be revised, depending on the code dictating these requirements.

The weight of the structures was developed from summation of the member selections presented in detail elsewhere. (11) The member selections are proportional to the total dead and live load which can be supported relative to the number of stories involved. The member selections presented were only for 20 psf, 60 psf, 100 psf and 200 psf modules. Accuracy of these charts could be improved by additional designs for specific module dead loads.

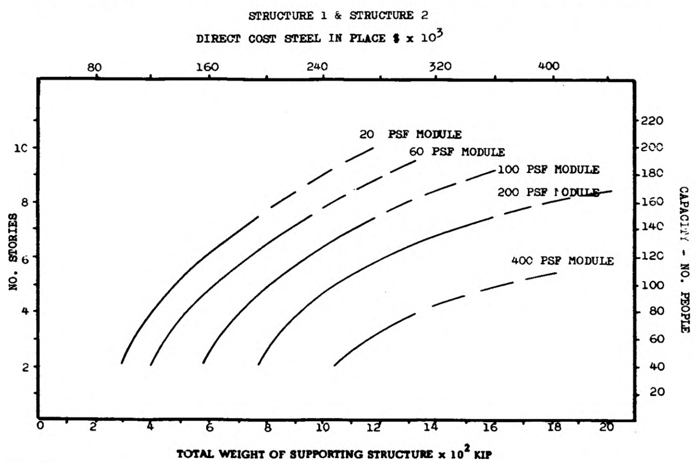


Fig. 6.

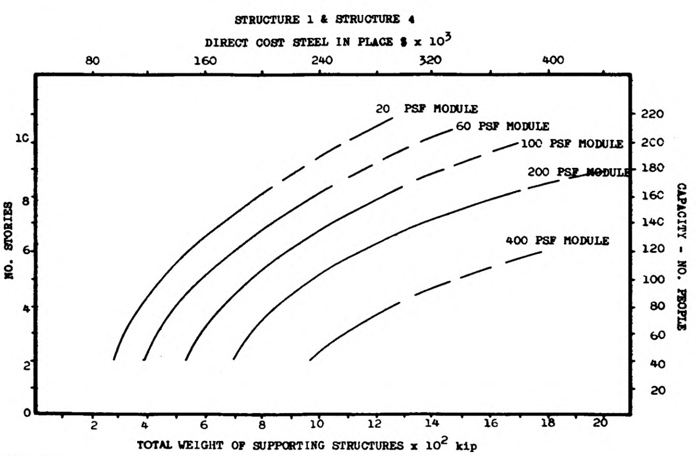


Fig. 7.

## 3. Design Criteria

Charts for use in the selection of members for each structure relative to the loads applied have also been developed. (11). These design charts represent the member group section modulus requires to support various live and dead loads, with the exceptions of the cable groups which are based upon cross-sectional areas.

## CONCLUSIONS

Preliminary standard criteria have been developed through computer programs for analysis and design. The stiffness matrix method of structural analysis has been employed to analyze the structural alternatives presented. The design of the structure is based upon standard American Institute of Steel specifications.

The results of the investigation are presented in the form of standard criteria which might be utilized in the planning of structures employing the SMC System.

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