The 9th International Symposium on Automation and Robotics in Construction June 3-5, 1992 Tokyo, Japan

A Construction System With Standard Connections

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ABSTRACT

Automation of construction, by means of robots, is not limited to any particular design. Yet, from the cost effectiveness stand point some designs are more suitable for automation than others, in particular when social- economic aspects are also taken into consideration. This paper describes the design features of a general purpose construction system, which can be easily automated and applicable in various environments. From the technical stand point the system comprises two types of elements namely, full size panels, i.e. walls and slabs, and linear connecting, or interfacing, members into which the panels are linked by means of standard mechanical connectors. Auxiliary components can be superimposed on this primary system, as required.

1. INTRODUCTION

The objectives of construction automation may differ in different environments, or different countries. In industrialized societies where construction labor is in short supply and costly, even custom houses could be built economically by robots. In less developed societies where low cost labor is in abundance, only mass production of housing will justify the investment in the equipment and its use in lieu of manual labor.

Robots can be designed and programmed to perform any specified task. Yet, maximum gains, from the view point of robots' manufacturers and society housing needs, will depend on the design which is adopted for automation. The interest of robot manufacturers is to increase production and sales of their products. The interests of home buyers and the construction industry are to reduce costs and increase productivity.

Generally speaking, every construction system which is based on the assembly of prefabricated components will be suitable for automation. On one hand, the plant, where building components are manufactured, is a controlled environment which can be fully automated. Then, the assembly of the individual components at the site, can also be handled by robots in accordance with a given program. Any set of components can be manufac-

tured at a plant. It is the method by which the elements are assembled which defines the construction system and its characteristic features.

Some of the most desirable features of a construction system, which utilizes prefabricated elements, are:

1. Flexibility in design.
2. Flexibility in the use of materials.
3. Built-in utility lines and fixtures.
4. Possible later additions, or upgrading.
5. Applicability to various environments.
6. Systemized assembly.

Flexibility of layout and use of materials allow the designer to provide for the individual owner's needs and preferences, and render some unique features to the appearance of a building.

The cost of the structure is generally on the order of 30%-50% of the cost of a completed house. Therefore, one should attempt to automate the installation of the utilities and finish work as well.

From the stand point of financing and changing needs of the buyer, it will be desirable to offer the possibility of upgrading a residence at a later date. A construction system which enables rapid addition of living spaces, with minimal disturbance to the tenants, will have a special appeal to people of low income, as well as to housing authorities and lending institutions.

A general purpose construction system should preferably be applicable in most common environments. Thus, no special arrangements and details will be required for different soils, seismic or weather conditions.

2. MATERIALS

Concrete and other cementitious products, such as blocks and bricks, are at the present time, and will remain so in the foreseeable future, the prime materials for the construction of buildings. The use of these materials is compatible with conservation of the environment (forests), hygiene, safety, long life and minimal maintenance. The raw material is available in infinite quantities, in almost every location on earth. Only small quantities of steel reinforcement are required in order to develop the necessary tensile strength in concrete members. Wood panels can also be used, independently or in combination with concrete.

3. PREFABRICATION

The prefab industry has been in existence for many years. Generally

speaking, this industry is more oriented to the production of building components, than to the making of completed products, or even only completed structures. Nevertheless, several specialized systems were developed, in different countries, for the construction of low cost housing projects. Thus far, the prefab industry has failed to develop high quality hardware for the connections of the components, which to this date are improvised with primitive means and techniques. As a result, the final products of prefabricated constructions often exhibit geometrical and structural defects, in the form of dislocations and cracks. These factors, coupled with the unattractive appearance of the improvised connections, are responsible for the public perception of prefab construction as being of low quality, in comparison with custom built buildings.

Prefab construction has the potential to surpass conventional construction in every aspect, cost, time and quality. Also, prefab construction offers the ideal approach to complete automation, by means of relatively simple robots.

The concept of modular construction was invented by the prefab industry, in order to facilitate the erection of complete structures with identical elements along lines of modular grids. With modern computerized fabrication technology, different size elements can be produced with common precision platforms, using limiters, as is illustrated in Fig.(1). What is required, in order to establish an industrial grade construction system, is to provide a suitable hardware and method by which prefabricated components are inter-connected at the construction site.

4. THE PREFAB SANDWICH PANEL SYSTEM

From the standpoint of engineering design the proposed systemized method of construction is based on the use of two types of elements namely, full size two dimensional panels and linear connecting, or interfacing, elements. As indicated above, the dimensions of the elements can vary. The linear interfacing elements provide the mechanism by which the structure is assembled. In addition, these auxiliary elements can also be used as stand alone columns or beams, when necessary. Standard connectors are installed in both the panels and the linear members, so that each panel is attached, on all four sides, to these auxiliary members. For stability and proper functioning only a few, typically 2-4, connectors per side are required, either for wall or for slab elements. The structural advantages of using only a finite number of point connections, as compared with line continuity, will be discussed in the sequel.

The general features of the connectors are illustrated by Fig.(2). The sketch shows a typical cross section of a joint, where two wall panels and one floor panel are interconnected. Identical detail will apply to the corner intersection of wall panels. As shown, the mechanical connectors are made of two parts, one of which is embedded in the panel and the other in the interfacing linear element. The locking mechanism con-

sists of threaded coupling, with or without a damping component.

The connectors are standard mechanical hardware, having identical external dimensions and locking mechanisms. The inner structure of the connectors can be adjusted in accordance with the required performance, such as dissipation of energy in oscillatory environment, resistance to shock impulse or accommodating temperature fluctuations.

In order to reduce both weight and cost the panels are given a sandwich like structure namely, top and bottom skins with only intermediate shear keys. For the same weight the stiffness of the sandwich will be higher as compared with that of a solid plate. Higher stiffness will result in smaller deflections and higher natural frequencies in service. Another advantage of the sandwich like structure is that various utility lines and bases for fixtures can be installed in the hidden space.

The versatility of this construction system is illustrated in Fig.(3). A CAD program can be used for the architectural design of the house. The output of the design program will be used by the production program to control the fabrication of the elements, positioning of the connectors and factory installed subsystems. In turn, the output of the production program will establish the assembly data base which will direct the automated assembly at the site.

The use of standard mechanical connectors facilitates clean and precision assembly of the components. Under these conditions the prefabricated panels can be transported to the site with various finishes, such as tiles and coverings, in addition to utility lines and various other subsystems. Thus, the field assembly can be reduced and simplified, conceivably reducing the time of construction from months to days.

5. ADVANTAGES AND DISADVANTAGES OF THE PROPOSED SYSTEM

Every construction system imposes some restrictions on the designer. However, from a practical stand point, the advantages of a technically perfected system will often outweigh some loss of freedom in the architectural design. After all, the most significant features of a building in service are the absence of leaks, cracks, distortions and deterioration. Generally speaking, these features can be attained through the use of an integrated, fully industrialized system. The substantial reduction in the time of construction adds another dimension, both to financing and to feasible volume of production. These advantages will, by far, offset the cost of transporting and lifting the large size and relatively heavy elements.

The idea of preplanning the future upgrading of a house, possibly even while in the design phase, may seem a bit odd, at least from a contemporary viewpoint. However, a construction system which allows for rapid expansion of an existing house could offer the only practical so-

lution to housing problems in many parts of the world.

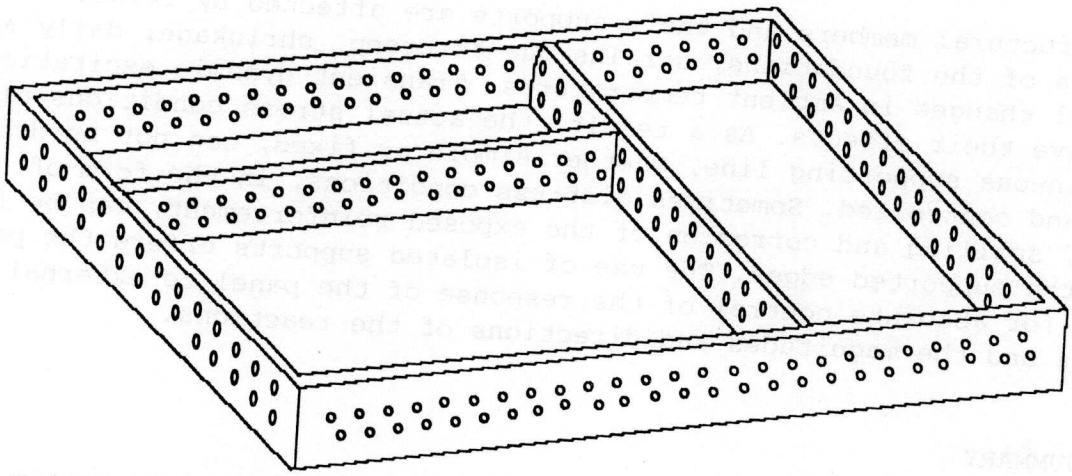
Structural members and their supports are affected by relative settlements of the foundations, strains due to creep, shrinkage, daily and seasonal changes in ambient temperatures. Transient dynamic excitations also have their effects. As a result, the actual stress conditions along a continuous supporting line, whether simple or fixed, can not be determined and controlled. Sometimes distress conditions, in the form of cracks, spalling and corrosion of the exposed reinforcement, can be found along the supported edges. The use of isolated supports offers the possibility for absolute control of the response of the panel to external effects and the magnitudes and directions of the reactions.

6. SUMMARY

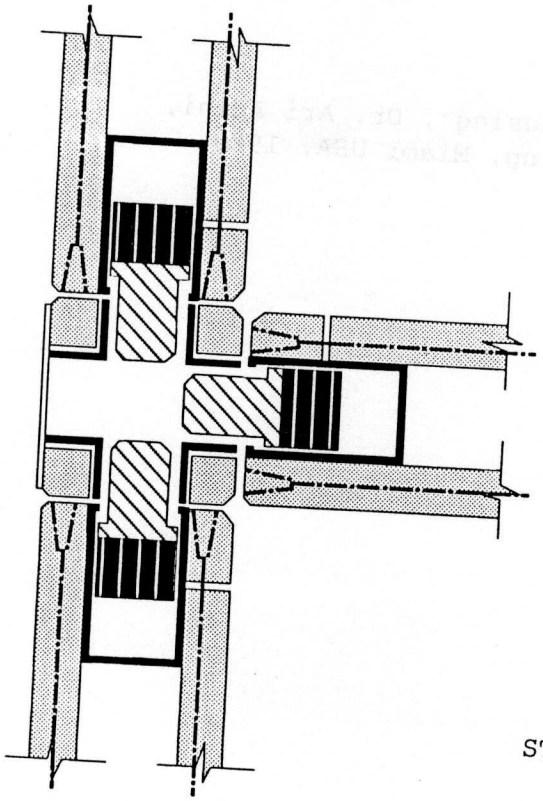
The design features of a new prefabricated construction system have been described. This system will enable full utilization of advanced technology in design, fabrication and erection at the site. Rapid assembly of high quality houses will have a profound effect on the development of new approaches to the solution of housing problems, both in industrialized and developing societies.

REFERENCES

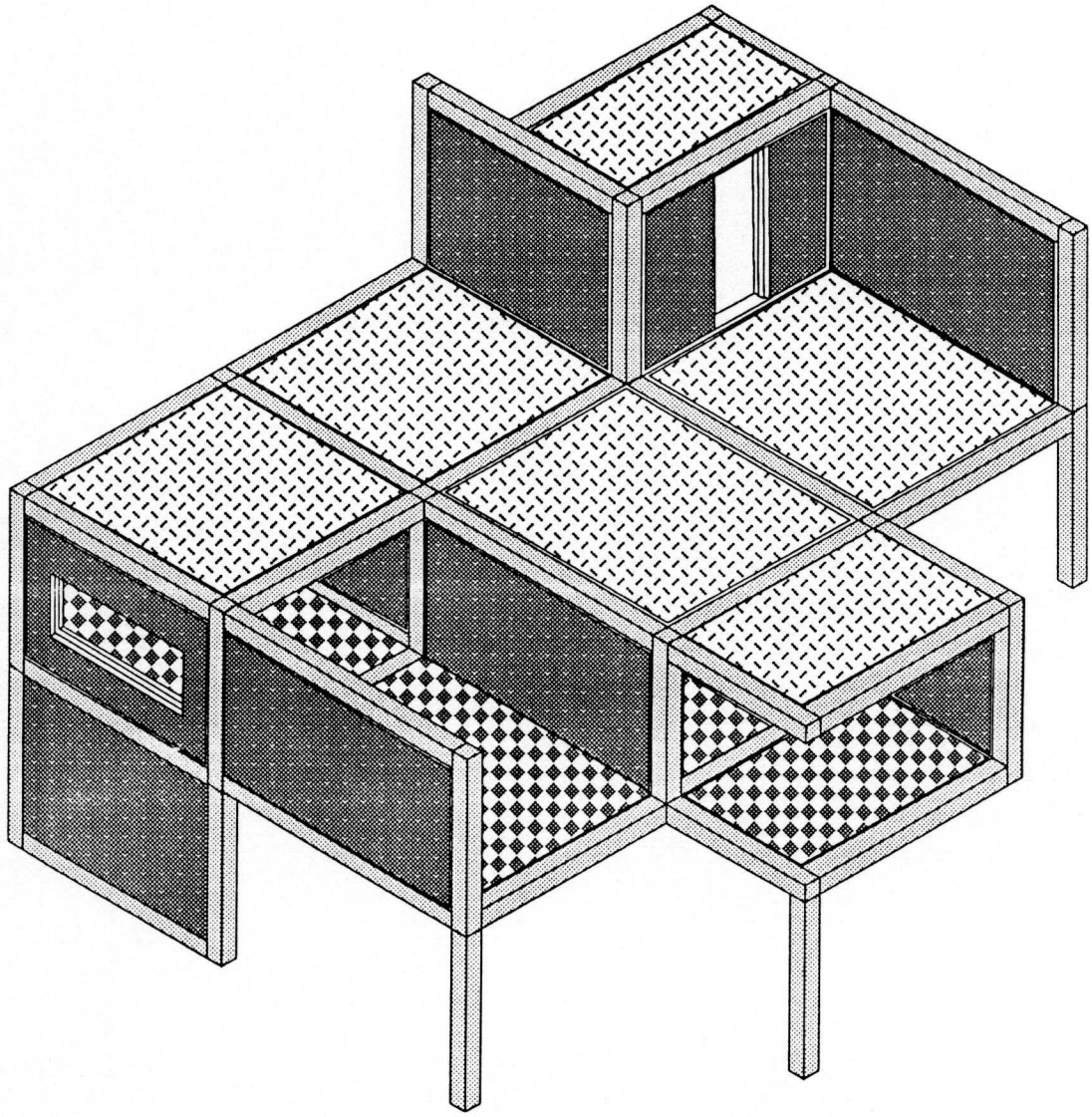
"The Expandable House & Low Cost Housing", Dr. Ari Adini, ASCE Conference on Affordable Housing, Miami USA, 1989



A COMMON FABRICATION PLATFORM
FIGURE 1



STANDARD CONNECTION
FIGURE 2



ASSEMBLY OF A BUILDING
FIGURE 3