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CONCRETE STRUCTURE CONSTRUCTION ON THE MOON

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This paper describes a precast prestressed concrete structure system on the Moon and erection methods for this system. The horizontal section of the structural module is hexagonal so that various layouts of the modules are possible by connecting the adjacent modules to each other. For erection of the modules, specially designed mobile cranes are used.

INTRODUCTION

A habitable structure in space must be designed to resist internal pressure. One current plan proposes that a large lunar structure can be constructed by connecting metallic modules. However, the plan restricts the size of each room so that the size of the module is not excessive. To illustrate, in a structure such as a dome providing large living space, if the dome is subjected to one internal atmospheric pressure it will develop very high membrane stresses that exceed the strength of existing material. Therefore, design of such a dome would be difficult.

This paper presents a new concept on module construction for spacious structures. The modules would be made with frames and detachable panels. This concept can be applied to any type of habitable structure in space, including concrete habitable structures on the Moon. The use of a standardized frame and panels permits easy assembly and the creation of large spaces. An artist's conception of a concrete structure lunar base is shown in Fig. 1.

PRIOR CONDITIONS

Certain conditions must exist prior to the feasibility of this system. (1) The technology to produce concrete from regolith must be established on the Moon; and (2) an Earth-to-Moon transportation system must be fully activated to provide the required materials (e.g., hydrogen) to the Moon from the Earth.

CONFIGURATION OF THE MODULE

Figures 2 and 3 show the shapes and sizes of the proposed modules. The net floor area of a module is approximately 15 sq m. The size of a module was determined according to the weight of the unit and the strength of the cables that are used for post-tensioning the modules together.

In order to pressurize the inner air of the module, a precast prestressed concrete structure is used. The frames are prestressed by post-tensioning at the lunar module manufacturing plant, and the joints of the modules are also post-tensioned on site.

COMBINATION OF MODULES

When several modules are combined and panels between contiguous modules are detached, a continuous large space can be created. A large number of modules of specific functions can

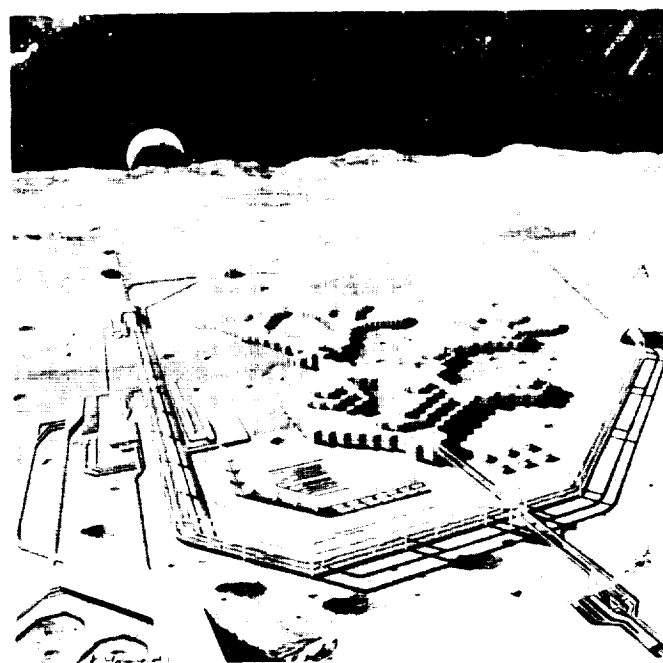


Fig. 1. Image of concrete structure lunar base.

be put together to form one large unit. The design must consider the architectural layout and usable area. One such layout of modules for habitation, research, and experiments is shown in Fig. 4. The entire structure is divided into three compartments: a habitation zone, a research zone, and a passage zone.

Since the size of the modules and the installation of equipment would be standardized, the structure could be easily modified in case the need for changes in layout arises in the future.

AN APPLICATION FOR A LARGE-SPACE STRUCTURE

Although the basic idea for space (room) expansion is to remove panels between contiguous modules, larger space could be ensured if more modules are added and if interior modules themselves are removed instead of panels between them (see

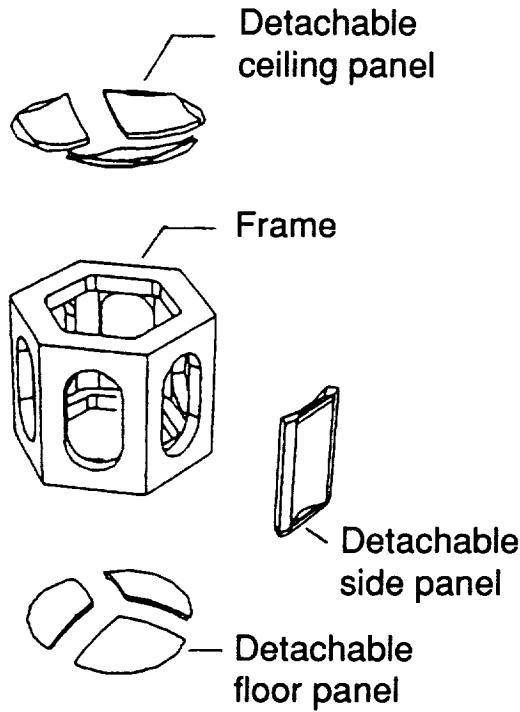


Fig. 2. Configuration of the module.

Fig. 5). Corresponding to requirements, pillars would be placed to bear tensile forces. As the weight of the accumulated modules constituting the roof increases, a large space without pillars could be created by balancing the weight of the modules against the internal air pressure. Of course, the roof structure should be designed to resist its own dead load and any live load, even if a loss of internal pressure should occur.

PRODUCTION PROCESS OF THE MODULES

Concrete production technology on the Moon is one of the necessary prior conditions. Figure 6 shows a flow chart that explains the production process. A module manufacturing plant needs a power plant, a cement plant, a prestressed material plant, and a water plant. At the module factory, concrete will be mixed and cast. After casting, the prestressing cables will be post-tensioned and the modules will be assembled. Finally, the internally pressurized modules will be shipped from the plant. The holes for inserting prestressed material are made by placing tubes in the mold before the concrete is cast. After the concrete hardens, the module is prestressed by the post-tensioning method.

Since the air pressure required for casting concrete does not have to be one atmospheric pressure, the air pressure in the plant could be relatively lower. Therefore, the module manufacturing plant can be a dome-like structure with a large space inside and the frame of the module can be integrated in the plant.

CONSTRUCTION PROCESS

Modules produced at the plant on the Moon are transported to the construction site. One module would weigh 30 tons on the Moon. Since the modules have to be plied between the plant and the construction site several times, and weak regolith stratum exists on the lunar surface, the use of self-propelled vehicles is inappropriate for module delivery. Therefore, a transportation

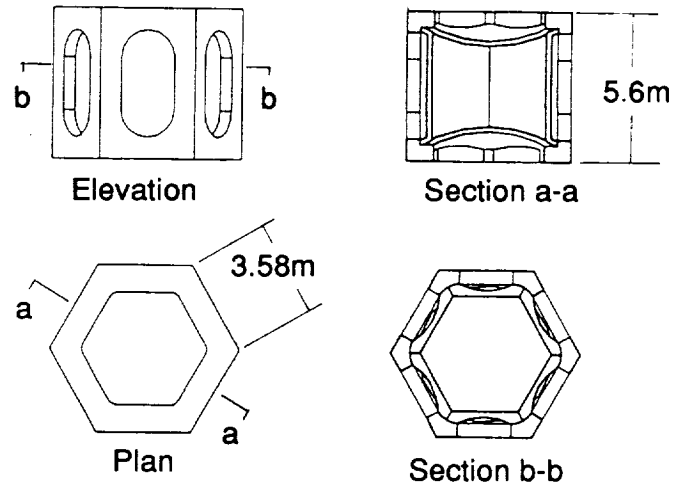


Fig. 3. Size of the module.

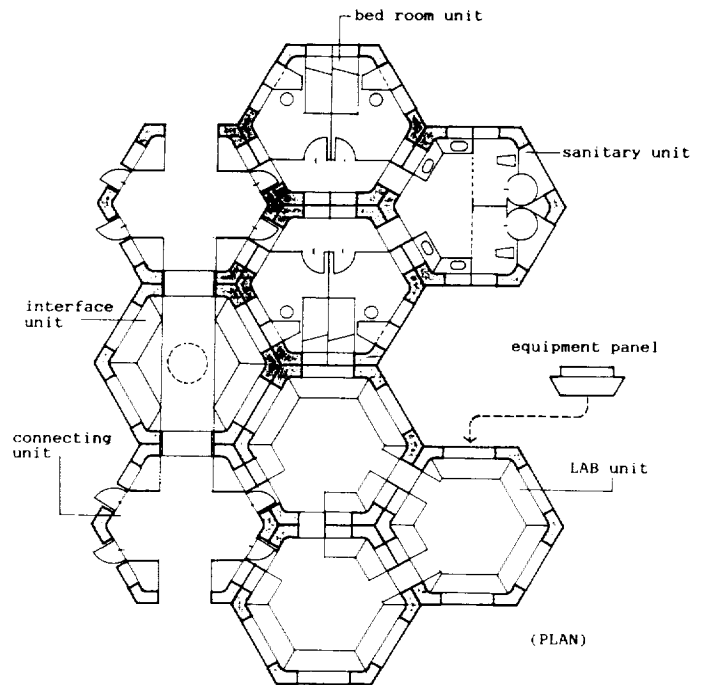


Fig. 4. An example of the module layout (equipped with habitation, research, and experiment facilities).

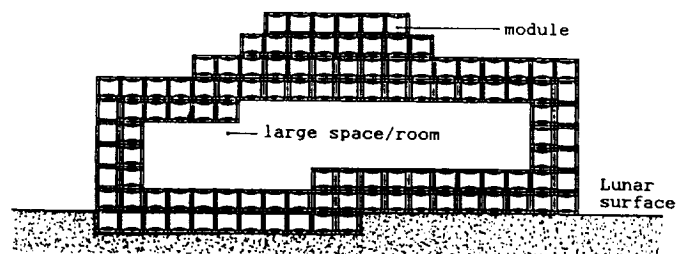


Fig. 5. Creation of large space/room by modules.

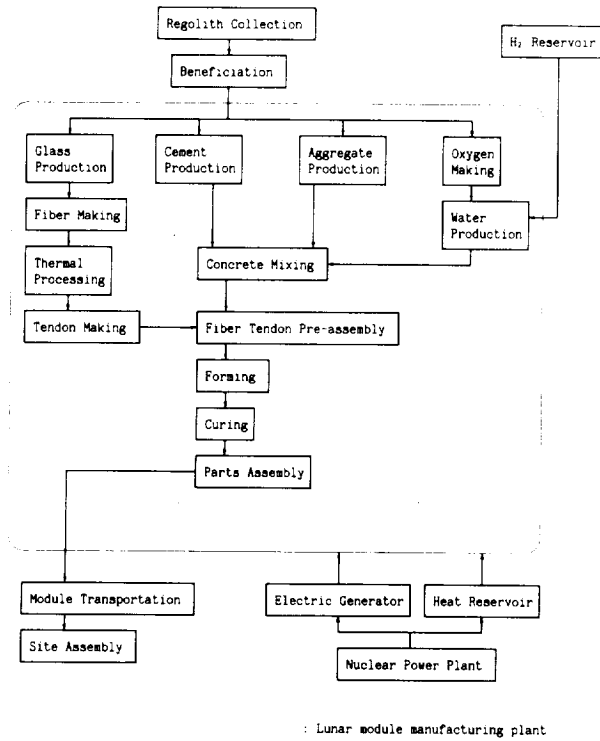


Fig. 6. The lunar module manufacturing plant and other necessary factories.

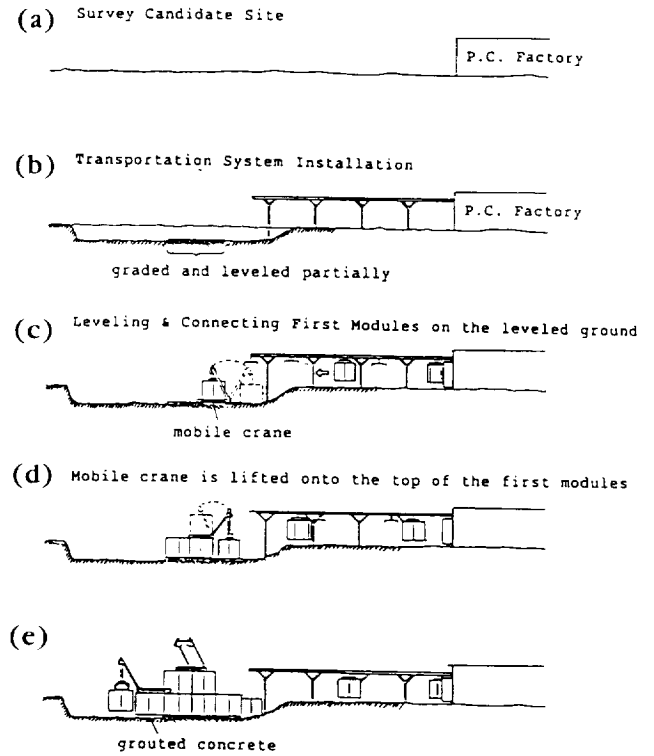


Fig. 7. Construction process.

system for delivery will be established to link the construction site with the plant. It is preferable that the construction site be as close as possible to the plant. In addition, the site should be on stable ground, which can be found by excavation of the thin regolith stratum.

The construction process is shown in Fig. 7. First of all, the transportation system is installed and the surface of the Moon where the first several modules are to be must be leveled (Figs. 7a,b). Second, the modules are transported to the leveled ground and a structure that consists of several modules is completed (Figs. 7c,d). By using the roof of the completed structure as the base, additional modules are placed one by one. At that time, additional modules to be placed are temporarily supported as a cantilever attached to previously placed modules and the gap between those additional modules and the ground is grouted with concrete (Figs. 7d,e). Therefore, the ground where the modules are placed need not be completely leveled. Prior to the grouting process, an inflatable stopper is placed under the module edge as an isolator.

OPERATION UNDER A PRESSURIZED ENVIRONMENT

Since the modules are pressurized before leaving the factory, a construction operator can work inside the module without wearing a spacesuit.

Figure 8 circumstantially explains how an additional module is installed. Horizontal cables on the top and bottom of the modules are tightened to support additional modules as a cantilever at-

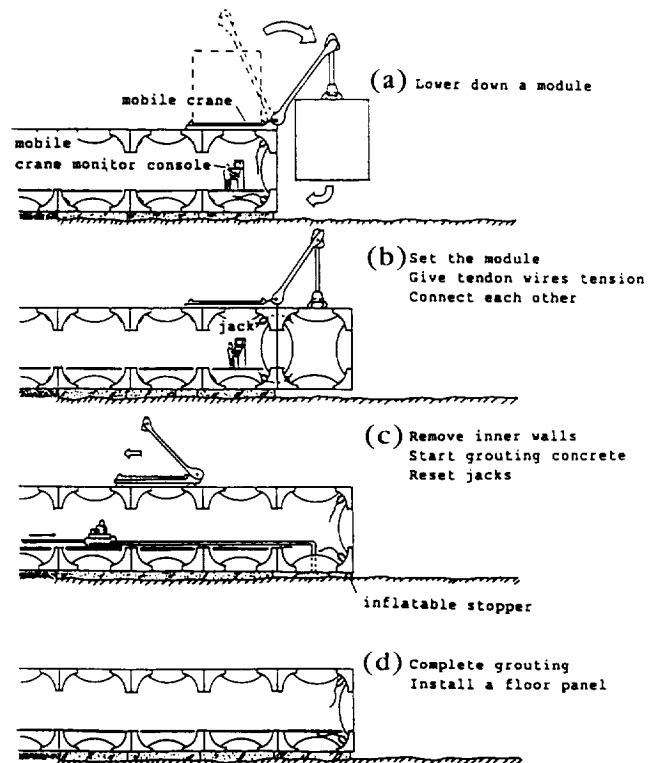


Fig. 8. Docking process under pressurized environment.

tached to the executed modules. Tightening of the cables can also be done under a pressurized environment if the dead end of the cable can be fixed by a specially designed latching system. Moreover, after removing the side panel between an additional module and an executed module, the operator can grout the gap between the additional module and the ground under a pressurized environment. The construction process will be efficiently and consistently performed under a pressurized environment.

CONCLUSION

The proposed lunar habitable structure has been examined in terms of architectural and structural design, manufacturing, and construction. The distinctive features of the structure are as follows:

1. The module consists of the frame and detachable panels. A contiguous large space will be gained by removing panels between two modules that are connected.

2. The configuration of the module is determined by the method of tightening parts with cables. Concrete is considered to be the most appropriate material for the module construction.

3. The method whereby a large number of modules is used to create a large space simplifies the architectural zoning decisions. In addition, the standardization of the interior parts of the module easily accommodates changes in the module and extension work in the future.

4. The frame of the module will be cast on site to simplify the construction process and to provide airtightness to the module.

5. Erection of the modules is carried out one after another using mobile cranes.

6. Connecting joints and grouting gaps can be performed under a pressurized environment.