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CONSTRUCTION OF THE 16 METER LARGE LUNAR TELESCOPE (LLT)

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Introduction

NASA is currently involved in studying the possibility of constructing a 16 meter telescope on the moon's surface that is capable of UV, visible and IR observations. This telescope will be scanning the skies looking for extraterrestrial life on planets that could not be seen using earth based telescopes.

Lunar based telescopes offer distinct advantages over earth and space telescopes. The moon's gravitational forces (Although only one sixth of earth's gravity) add stability to the telescope structure. In addition, the superstructure can be anchored in the moon's surface, thus eliminating a lot of vibrations and wobbling that is observed in space telescopes. Furthermore, the absence of any atmosphere on the moon eliminates any interference with the incoming light and thus provides a more clear picture than any earth based telescope. Furthermore, the long lunar nights (about 28 earth days) provide astronomers with longer viewing time than is possible using earth based or space telescopes.

There are many concerns that have to be addressed when designing a structure for a telescope of this magnitude. First, the large size of the primary structure that holds the primary mirror (16 meter diameter) results in excessive flexibility thus causing large deformations. Secondly, Due to the sensitive nature of the instruments used in the telescope, the total deflection between any two mirror clusters should be limited to one millimeter. Thirdly, there always are uncertainties when dealing with the stress-strain characteristics of the lunar soil. This makes it difficult to predict settlements that can be expected under the foundations. The fourth concern deals with the difficulty in construction and site preparation on the lunar surface. The fifth concern deals with packaging and transporting the telescope components to the moon.

Material Availability

Reinforced concrete was the first material considered. There are several advantages to using concrete on the moon. They include among others fire and heat protection for equipment housed inside the structure, protection from solar radiation, and low coefficient of thermal expansion (10×10^{-6} m/m/°C). Most research done on producing concrete on the moon describe two methods of production. The first, is the conventional method of mixing cement and aggregates with water in a sealed and pressurized environment to produce concrete that is similar to terrestrial concrete. The other method involves sintering compacted lunar regolith to form a glass like material which has strength characteristics similar to those of terrestrial concrete.

Although both methods of producing concrete on the moon described above are possible, the author feels that it is not feasible to utilize concrete at this stage because of the following reasons. The first method requ'res water to mix with the cement and aggregates, but water will be a precious commodity on the moon and will be used for drinking rather than mixing concrete. In addition, the mechanics of mixing concrete and the properties of the mixed concrete on the lunar surface are not well understood. Furthermore, concrete transporting, mixing and placing is labor intensive, something we normally try to avoid in lunar construction because of the limited labor resources. The method of sintering is time consuming if we use solar energy for heating.

There are several Aluminum alloys existing today that have a wide range of properties. The main advantage of Aluminum is that it is a light weight and strong material. Aluminum alloys have lower modulus of elasticity than steel. Welding is normally difficult in Aluminum alloys and produce weak joints around welds. The coefficient of thermal expansion of most Aluminum alloys is approximately 23×10^{-6} m/m/°C.

At this stage of telescope's development, the material used for the pedestal is not important because new and better materials will be developed by the time the telescope is ready to be built. Materials with high modulus of elasticity, low coefficient of thermal expansion and high tensile and compressive strengths should developed and used. For the model developed in this study an Aluminum-Manganese alloy was used because of its low CTE (9×10^{-6} m/m/°C).

Structural Design of the Telescope's Pedestal

The mass of the mirror clusters and their driving hardware are currently estimated at 30 Kg/m^2. The primary structure is basically a truss comprised of thin Graphite Epoxy tubes. The total mass of the primary structure including the mirrors was estimated to be 30,000 Kg. The motor turning the telescope about its vertical axis applies a torque of 1200 N.m to rotate the telescope. This torque will cause torsional stresses to develop in the pedestal that have to be taken into account in the design. Although theoretically the load from the primary structure should be concentric because we are using counterweights to balance the load, a minimum eccentricity of 3 meters was considered in the design. This should account for any accidents that might occur during construction.

The pedestal will house the motors that drive the pointing system and a Coude' mirror. Therefore, a tube structure was chosen for the pedestal to provide protection for the motors and mirror from lunar dust contamination and impact of micro-meteoroids.

The pedestal's structure was designed to support the primary structure with minimum lateral and vertical deflections. Several pedestal configurations were considered and analyzed to obtain the optimum structure.

Figs. 1 and 2 show the front and top views of the designed pedestal, respectively. It consists of three segments. Each segment is a tube four meters high and three meters in diameter. Eight vertical and two horizontal stiffeners are used for each segment to increase stiffness and reduce possibility of buckling. The circular horizontal stiffeners are 25 cm wide and 25 mm thick. While the vertical stiffeners are 3.95 meters high and have thicknesses that vary depending on the applied loads. The three segments can be either transported completely assembled or unassembled depending on volume limitations of the transporting vehicles. It is recommended that the three pedestal segments be attached using bolts or rivets and not welding to eliminate the possibility of creating weak joints normally caused by welding in Aluminum.

Design of Telescope's Foundations

Excavation on the lunar surface is a difficult and tedious operation. There is not enough traction for the excavating machinery to operate effectively. In addition, low gravity on the moon requires special anchoring procedures of the construction machinery. Furthermore, the subsurface conditions at the telescope's site are not well established. It is difficult to predict the density of the soil at a given depths at a given location. Preliminary studies show that the density of the soil tends to increase with depth. At depths exceeding 2 meters at some locations, the soil density was close to that of limestone rock which is extremely difficult to excavate. Therefore it is recommended that shallow foundations be used. Three different shallow foundation systems were considered and are presented here.

The first system, shown in Fig. 3, is called the Spudcan footing developed at the University of New Mexico. This footing will cause minimum soil disruption and will be placed using a vibration machine. The footing is filled with lunar regolith to give it stability. This footing requires minimum site preparation. However, the vibrating machine has to be transported to the moon thus increasing the weights to be transported. In addition, the vibration will cause dust scattering on the site which might cause dust contamination of sensitive instruments and construction machinery.

The second system, shown in Fig. 4, is a spread footing. This footing is efficient if the solid dense soil is no more that two meters below the surface. It consists of a thin walled Aluminum container that is filled with condensed lunar regolith for added stability and strength. The contact diameter of the footing is five meters. The spread footing system requires excavating the site to a depth where the solid soil id found, cleaning and grading the site so that it is flat.

The third system, shown schematically in Fig. 5, utilizes the Lunar Excursion Vehicle (LEV) as a base support for the telescope's pedestal. The LEV legs should have automatic leveling devices to correct for any settlements in the soil. Transportation experts indicate that LEVs are designed as expendable vehicles that will be discarded after their fifth mission. The pedestal will be attached to the LEV on its final trip to the lunar surface where it will land on the prepared site of the telescope. Several problems have to be addressed before considering this option feasible. A study should be conducted to investigate the strength and stiffness requirements that should be imposed on the LEV so that it can be used for this purpose. Furthermore, a damage assessment should be made to study the effects of landing on the different components of the LEV and the telescope's pedestal. Since the LEV is in its design stage, the findings of such a study should be communicated to the LEV designers to see if it is practical to design the vehicle for this particular application.

Summery

In this study the different materials that could be used to design the pedestal were identified and comparisons were made. The most appropriate material so far is an Aluminum alloy. The material that should be used should have low coefficient of thermal expansion, high modulus of elasticity and high compressive and tensile strengths. Two different pedestal designs have been presented. The first design is complete, while the second, the telescopic pedestal, is still under investigation. Preliminary studies of the telescopic pedestal show promising results and should be investigated further.

Due to variations in lunar soil conditions both vertically and horizontally, three foundation systems have been presented. The spudcan footing can be used in the case where dense soil is very deep (more than three meters). The spread footing is recommended where the dense soil is between one and three meters below the surface. Finally the LEV support requires a prepared site. The soil should be compacted and stabilized if necessary to reduce settlements.

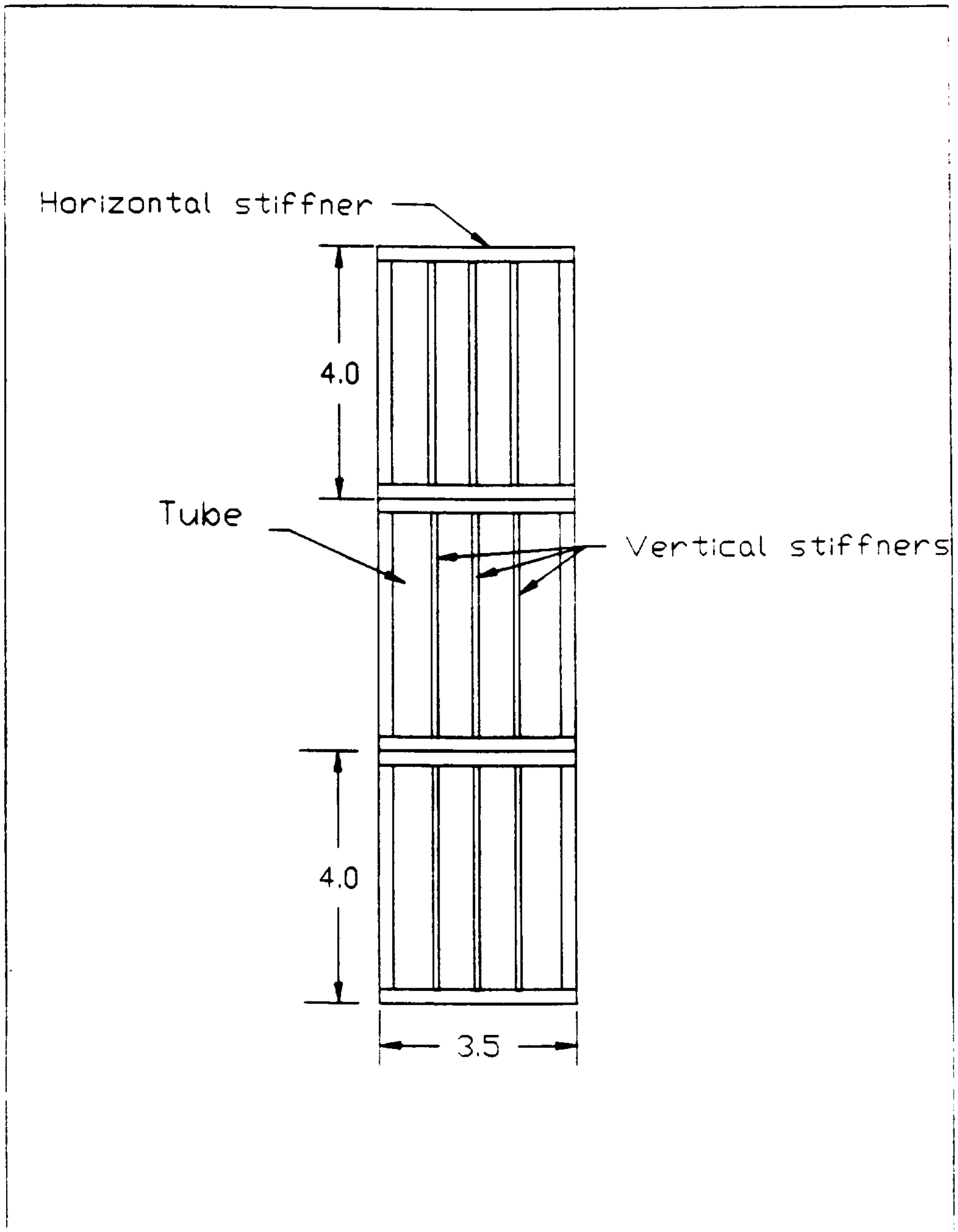

Fig. 1: Front View of pedestal

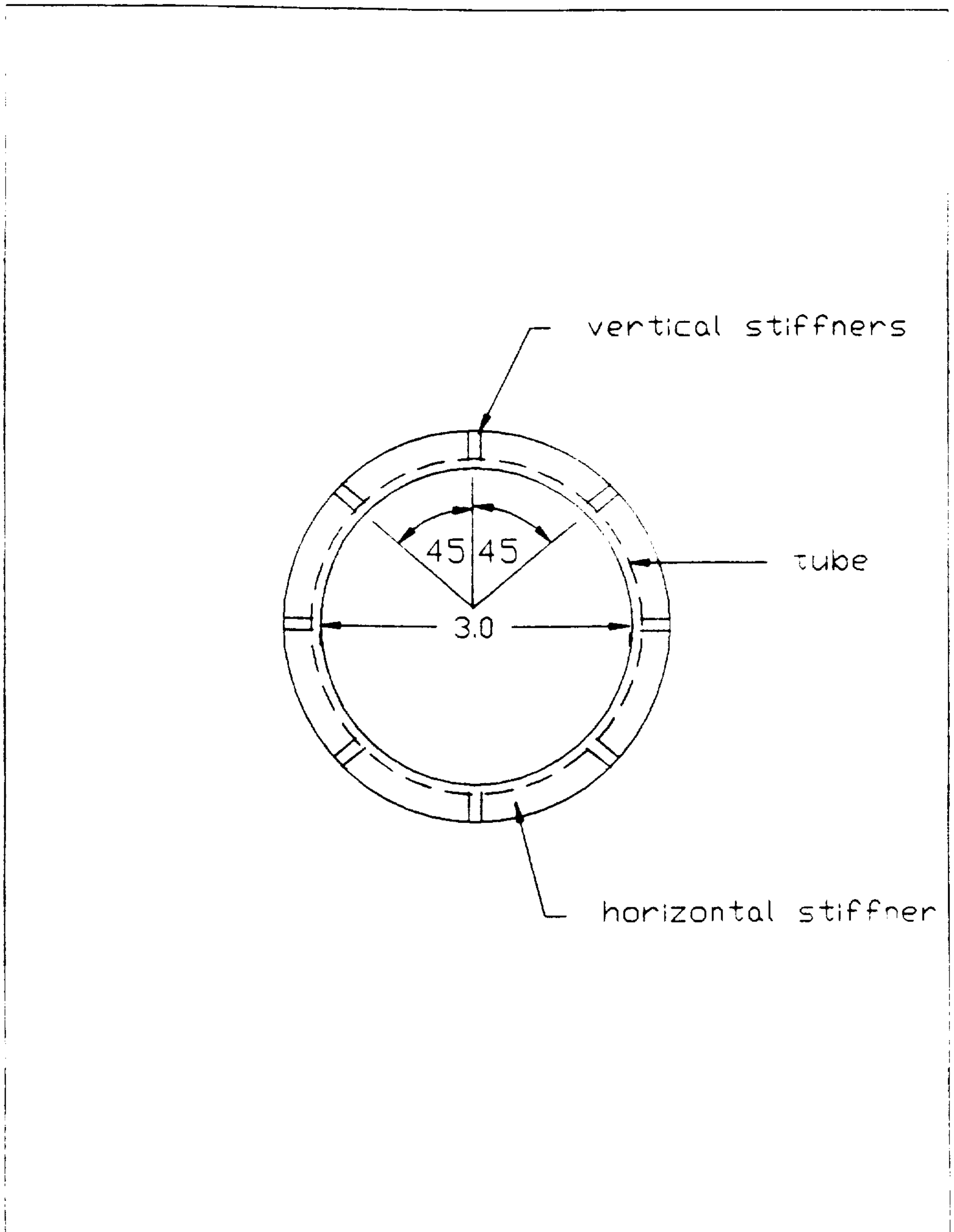

Fig. 2: Top View of Pedestal

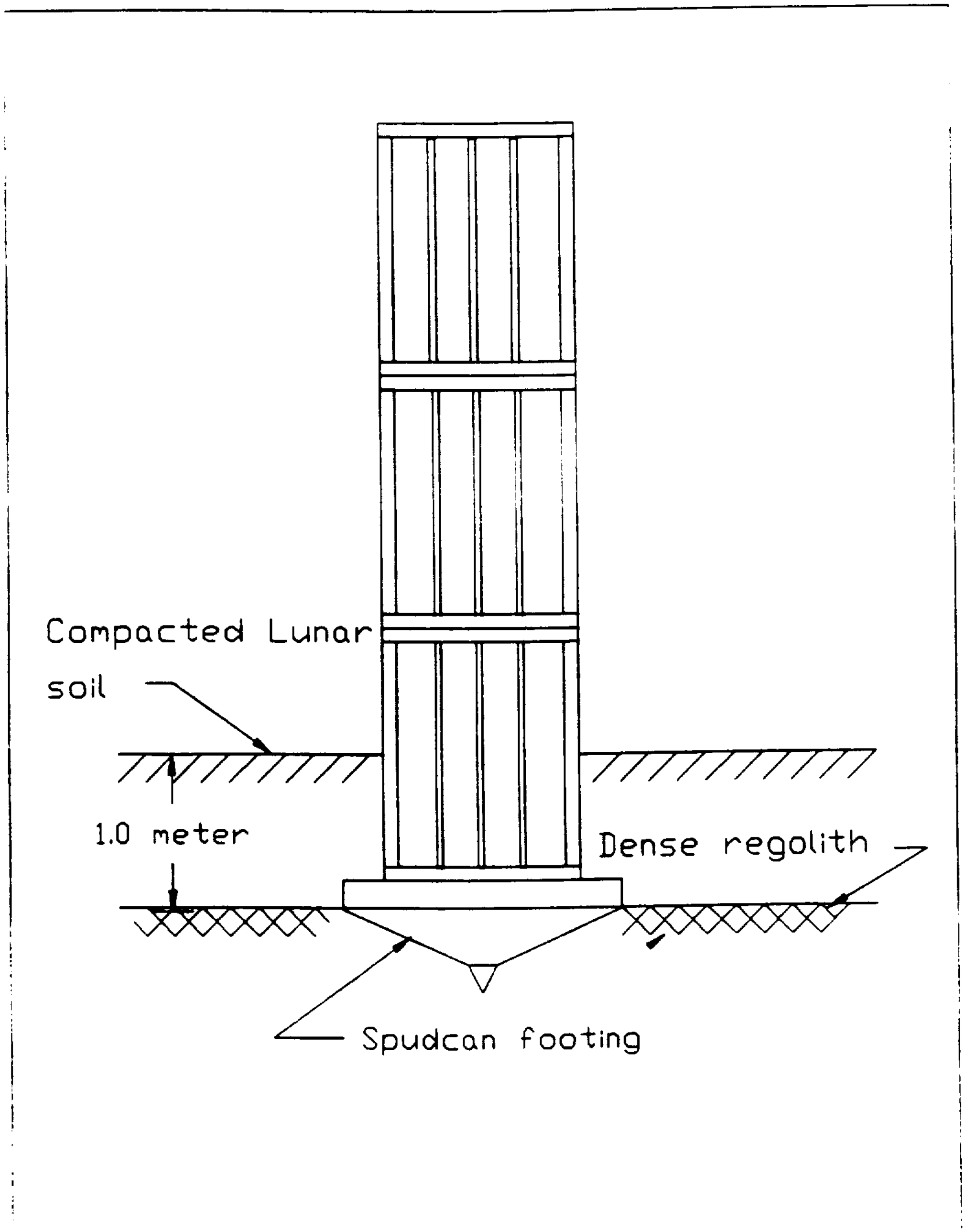

Fig. 3: Spucan Footing

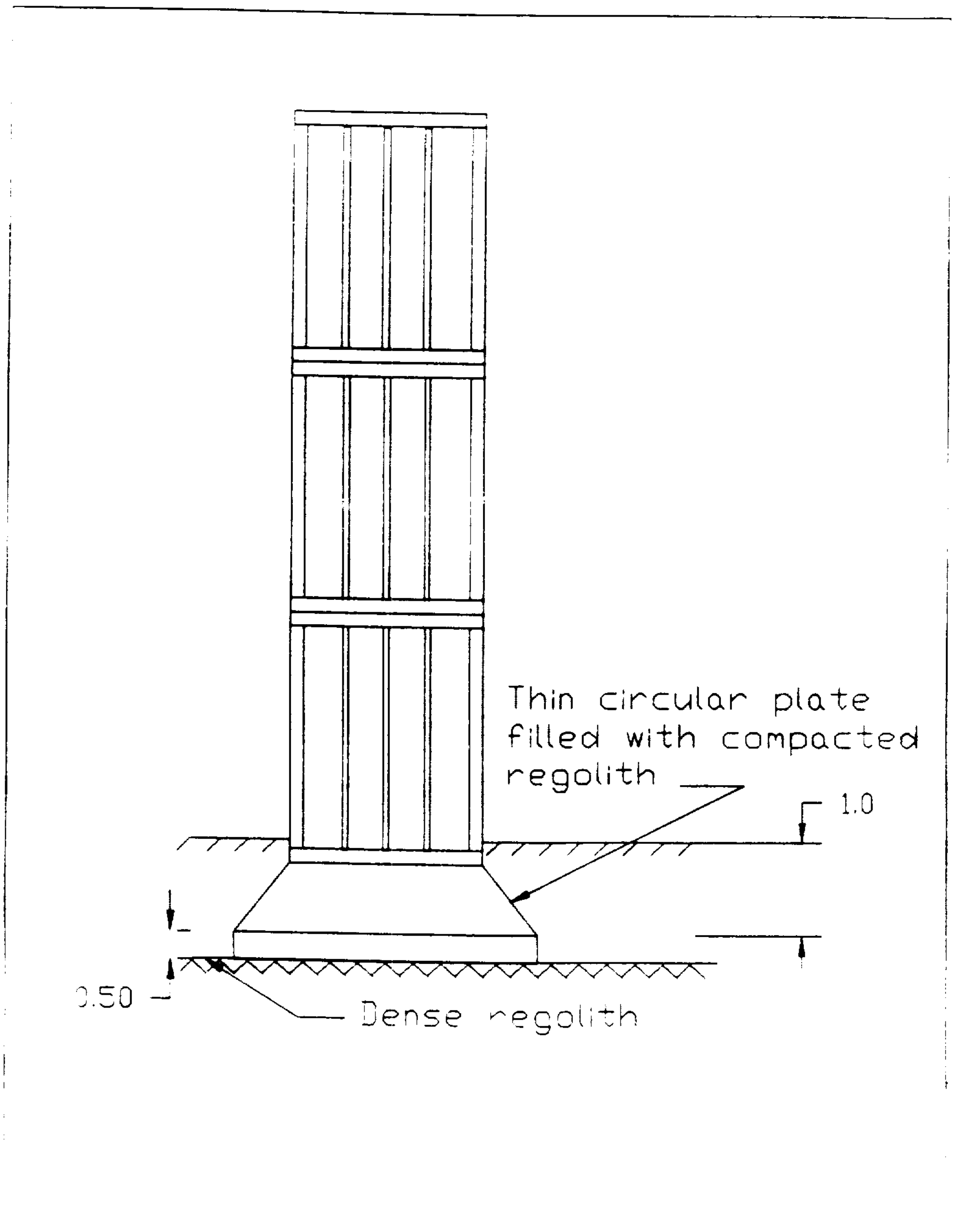

Fig. 4: Spread Footing

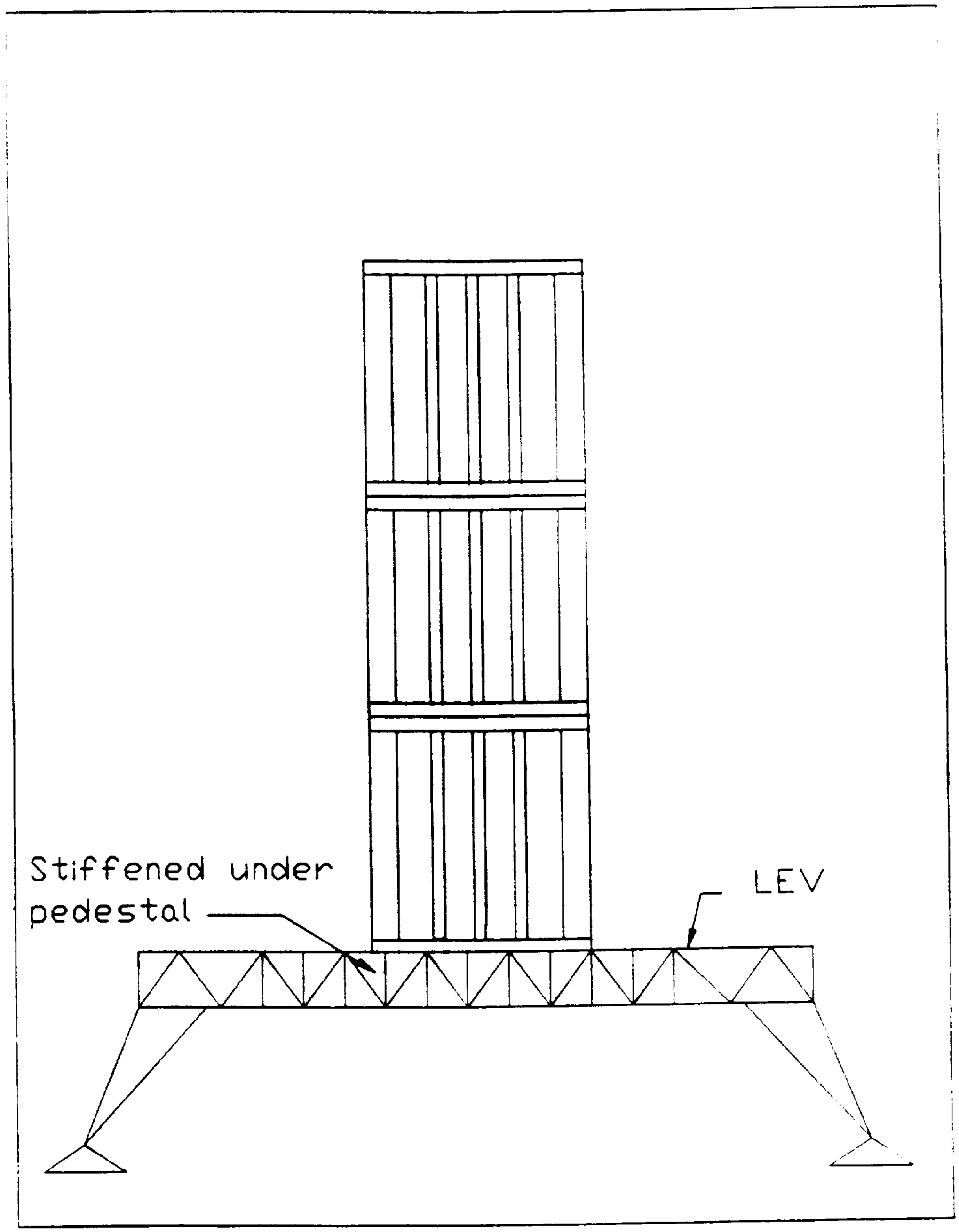

Fig. 5: LEV Support