ANALYSIS OF A CIRCULAR CONCRETE FLOATING FLOOR

A Project
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Department of Civil Engineering
Brigham Young University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by

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This project by Michael Anderson is accepted in its present form by the Department of Civil Engineering of Brigham Young University as satisfying the project requirement for the degree of Master of Science.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

Concrete has remained one of the foremost building materials throughout time, due to its ability to conform to any shape and yet provide tremendous strength after curing. This versatility allows the engineer an almost unlimited resource. The modern structural engineer is always searching for innovative, efficient building functions which provide protection from the elements (earthquake, weather, etc.) and serve the purpose of the structure. Airplane hangars are structures that could use innovative modifications to decrease door size in order to increase the strength of the building. A concrete floor designed as a turntable would provide access to all airplanes from one small common door much like a roundhouse in a train station.

The average airplane hangar contains three supporting walls for bearing and shear with the fourth being used as a large door to provide access to the planes. The door is unable to provide the shear needed for keeping the building from rotating during an earthquake or violent windstorm. The ideal building consists of four walls and a roof with evenly distributed shear and flexure throughout the building but in reality the door must be big enough to allow access to each plane without moving other planes individually. With a rotating concrete floor the size of the door is minimized to the height and width of the largest plane and access can be obtained at any given moment without disrupting plane positions (see fig. 1), thus maximizing the use of materials and building layout. Given enough materials anyone can build a structure but the engineer can maximize the building capacity with minimal materials.

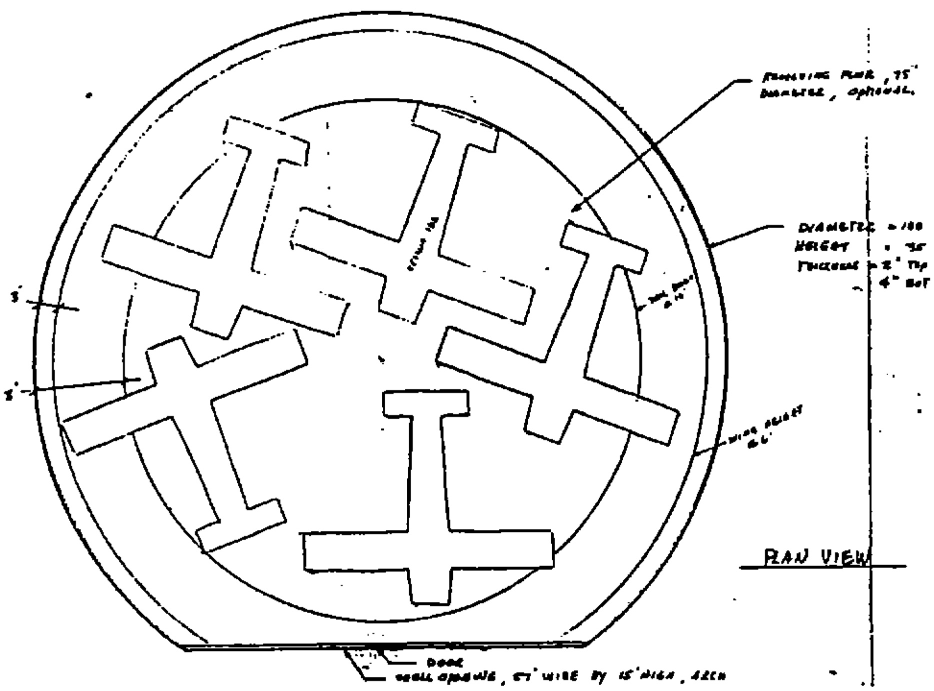


Fig. 1. Scaled 100 ft. diameter dome holding five Cessna 182 airplanes.

Floating concrete floors are not new; several have been patented. AirBarge makes Standard Air Caster which is a big rubber bladder ring that uses air pressure to raise a given slab or object allowing for rotation or movement. The purpose of this project was to demonstrate that an alternate system, without a bladder, could be built on site to accomplish the same result. I chose to use a concrete slab that would lift and rotate an uneven load on a cushion of air contained by a column of water (see fig. 2).

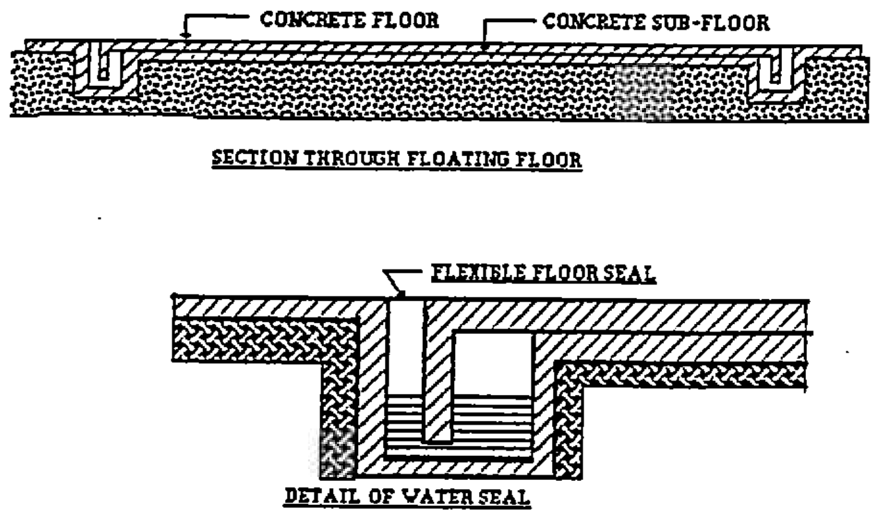


Fig. 2

CONSTRUCTION

The construction site of the model was the Structural Lab at Brigham Young University which had sufficient floor space to construct a fifteen foot diameter working model. The lab's ten ton overhead crane was available to assist in the concrete placing. The system had to be constructed in different stages to provide progression beginning with the bottom ring footing (see Fig. 3). After the footing was poured, the interior four-inch thick, thirty-inch high wall was poured (see Fig. 4) allowing us to fill the interior with 16 cubic yards of crushed rock (see Fig. 5).

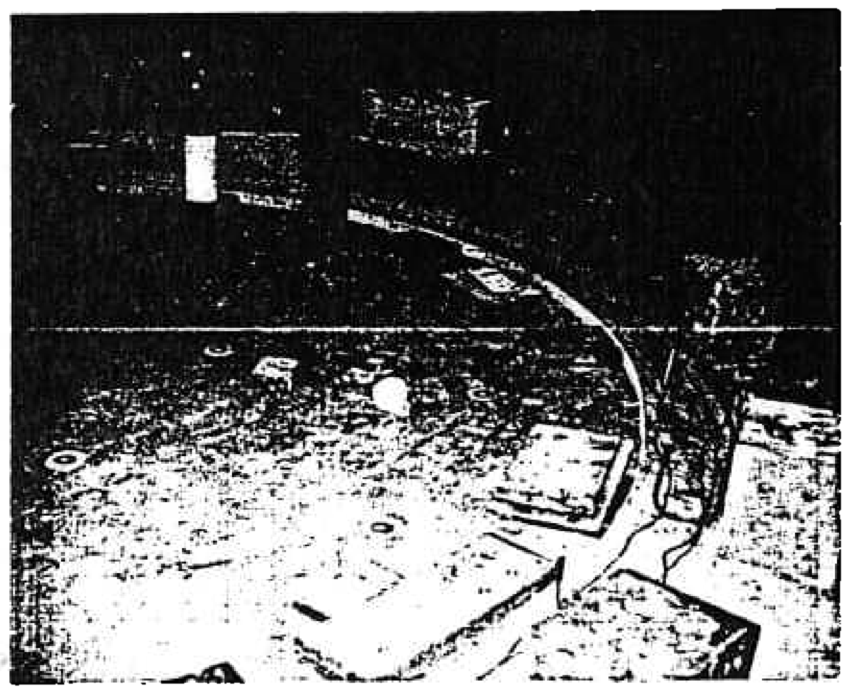


Fig. 3. Bottom ring footing.

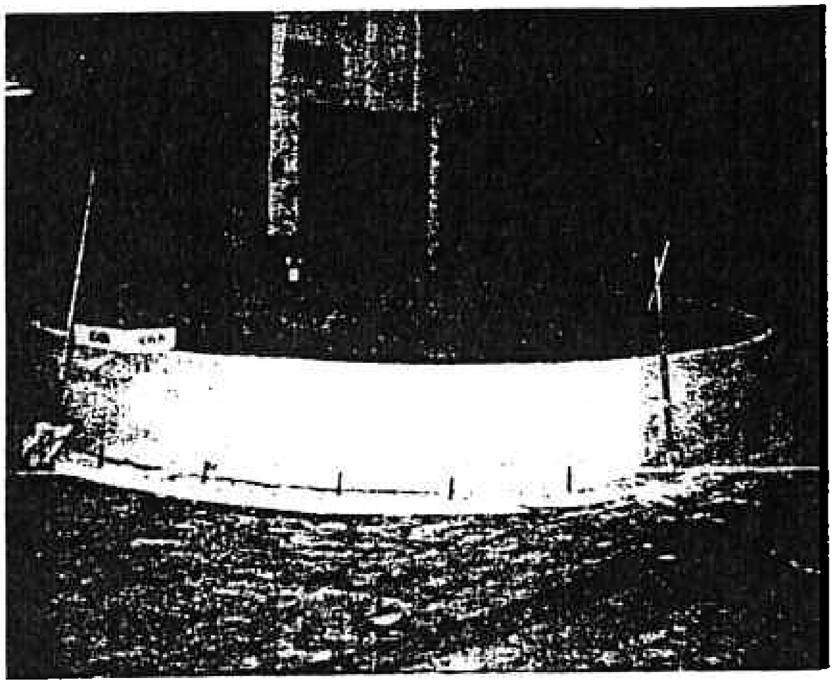


Fig. 4. Interior wall.

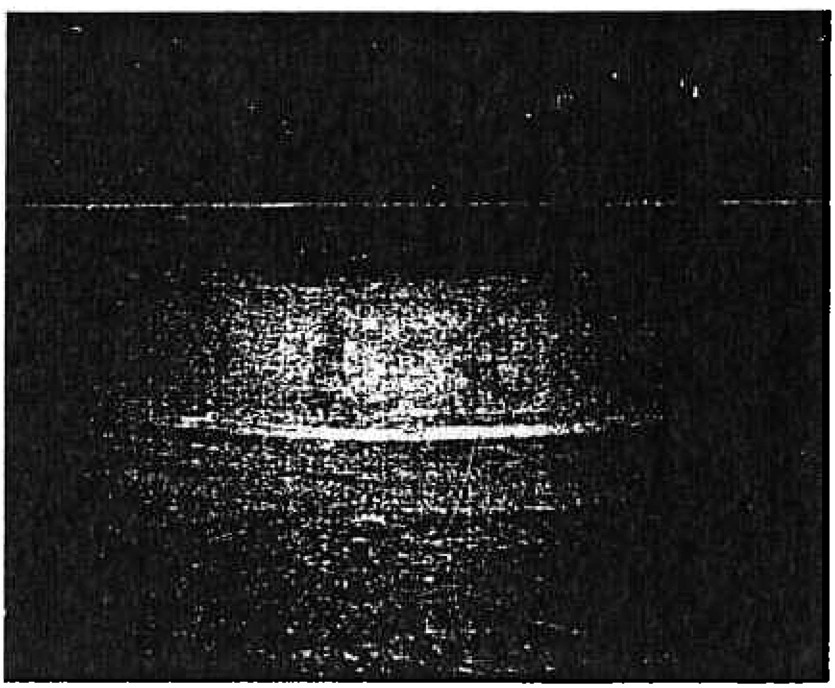


Fig. 5. Filled interior section.

After placing the rock in the interior of the model, with the help of the overhead crane we cast the six-inch floating floor separately (to the side), the four-inch sub-floor over the rock, and the three-and-a-half-inch outside perimeter wall at the same time (see fig.'s 6-12).

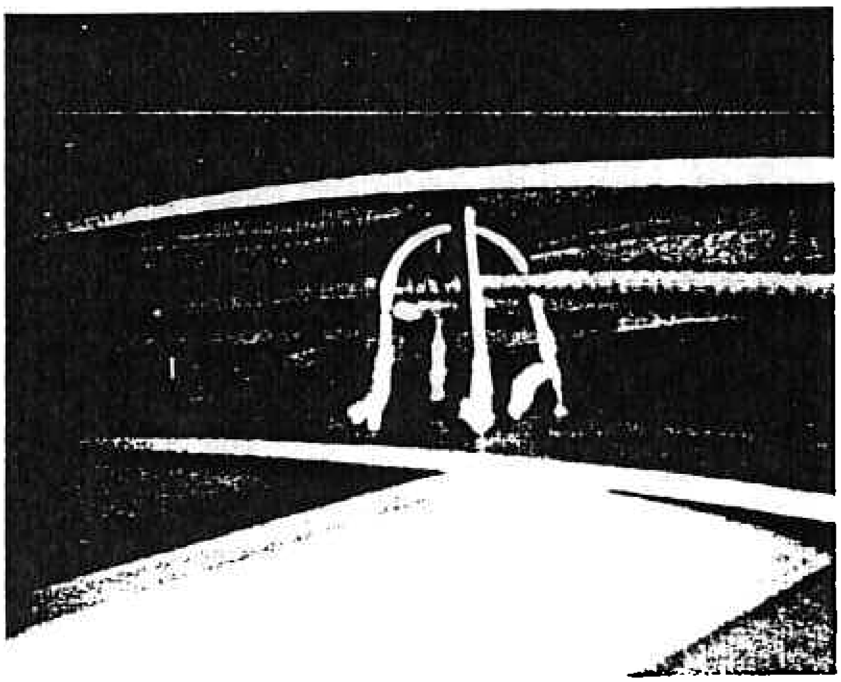


Fig. 6. Exterior wall reinforcing.

This would not have been possible on a full-scale floor because the slab for the floating floor would be too heavy to lift after curing and too risky. In reality, the sub-floor would have to be poured, a bond-breaker applied to the sub-floor, and the floating floor cast on top.

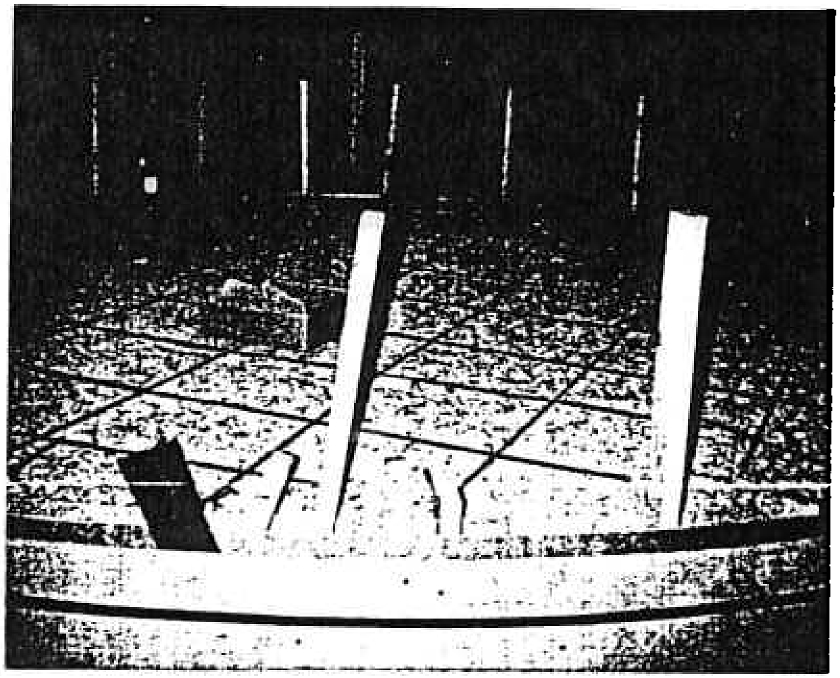


Fig. 7. Bottom slab reinforcing.

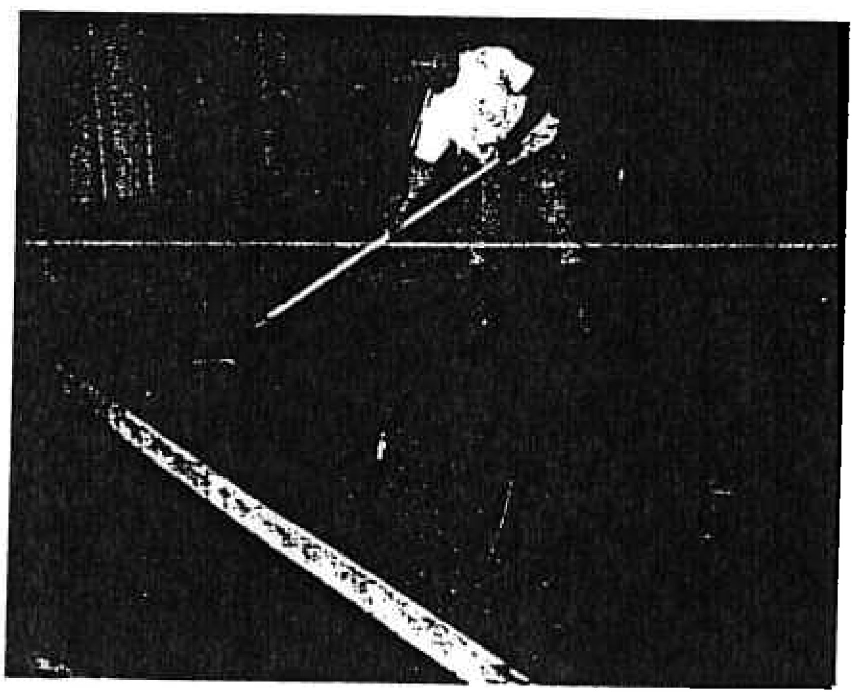


Fig. 8. Top slab being poured separately.

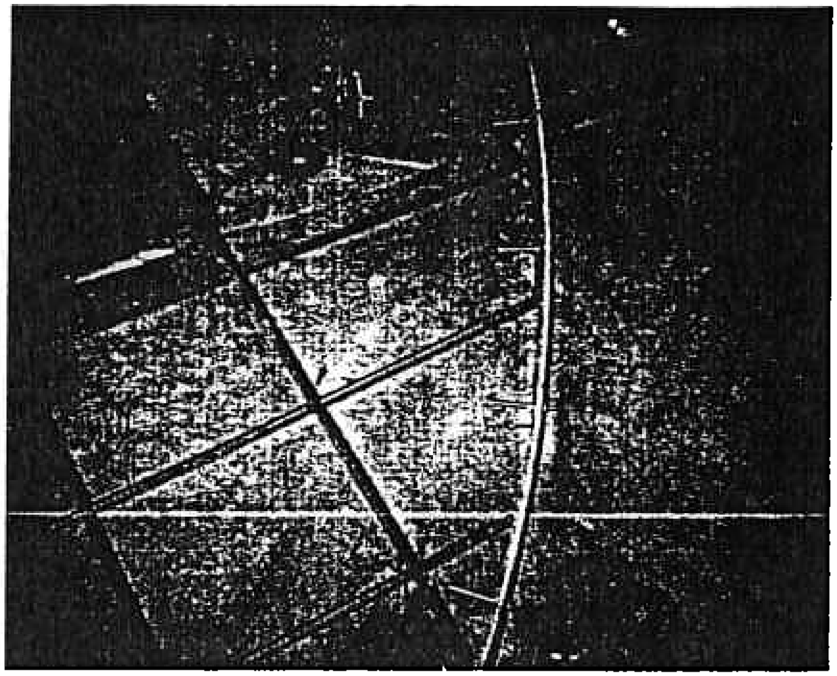


Fig. 9. Skirt anchor bolts and top slab reinforcing.

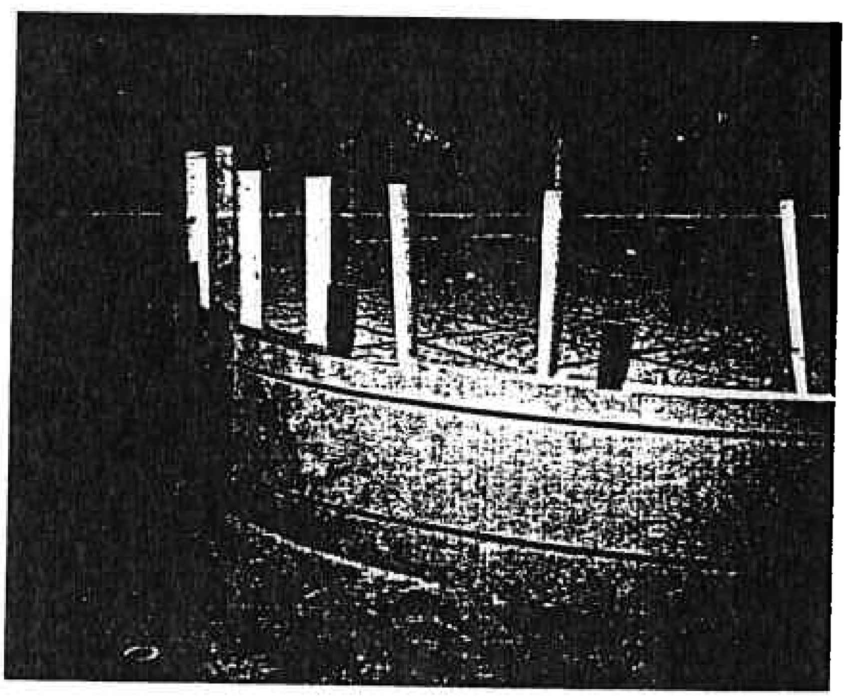


Fig. 10. Exterior wall and bottom slab forming.

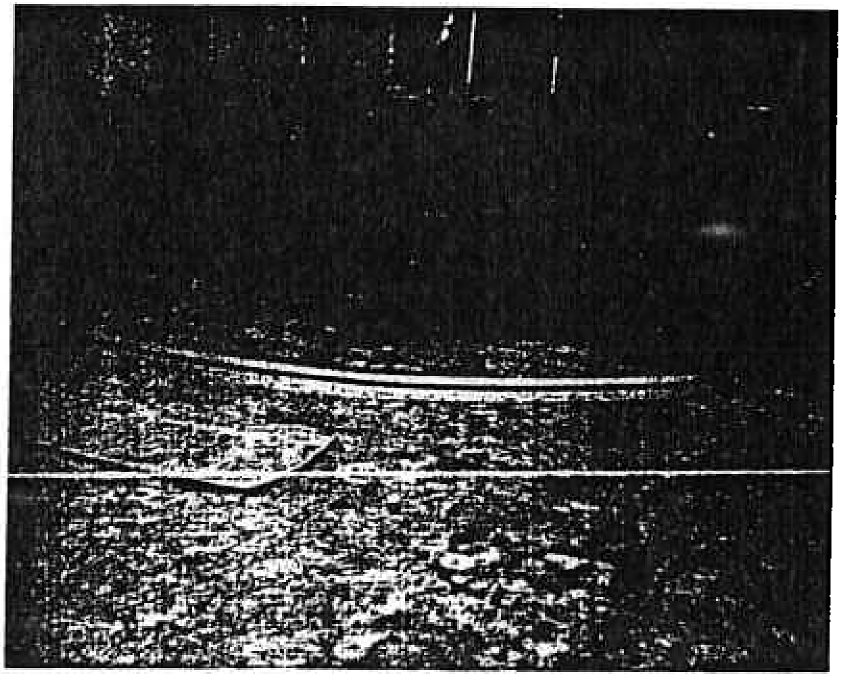


Fig. 11. Pouring of top slab.

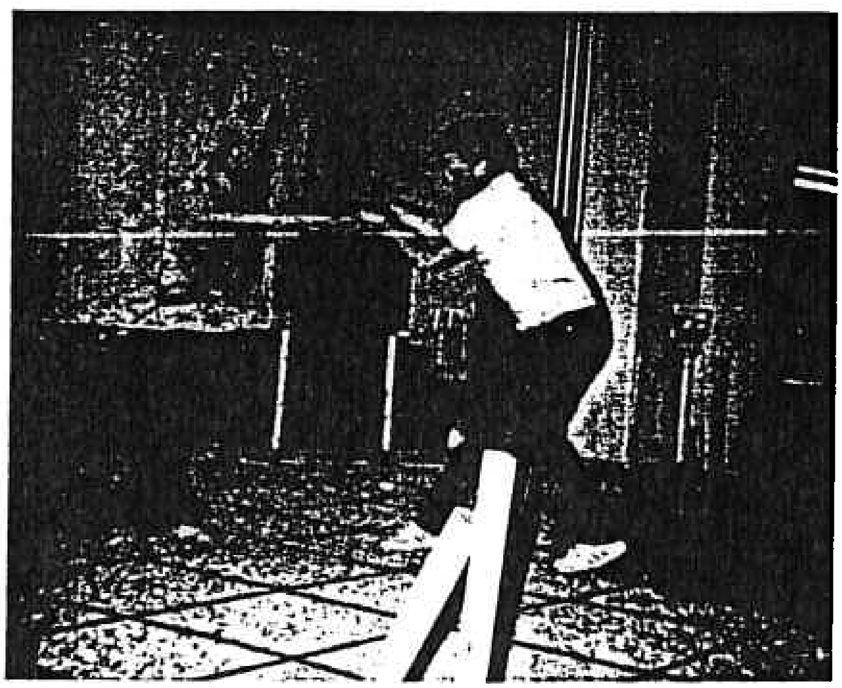


Fig. 12. Concrete pouring of bottom slab.

The six-inch floating floor was one foot bigger in diameter than the sub-floor allowing for space to attach a skirt which would contain the air. This slab was cast on the structural floor of the lab which contains small pockets for holding through rods used in various experiments, thus the lab floor was not perfectly smooth which created indentations on the underside of the floating slab. On an actual design the two slabs will be cast one on top of the other making a perfect match.

The original plan was to connect a concrete skirt to the floating slab but, after further thought we realized that almost any building material could be used, such as plastic, tin, etc. Therefore, due to the cost, of 20 gauge sheet metal were used to create the skirt that would contain the air pocket. The maximum length of sheet metal which we could get was eight feet requiring us to use five sheets around the perimeter with a silicone-sealed seam at each splicing of the sheet metal skirt. The method chosen to attach the sheet metal skirt were small bolts anchored in the concrete floating slab (see fig. 9). This seemed to work well in theory but in reality it could not provide the airtight seal which we needed. Therefore, three-quarters of the bolts were broken off and the rest were used to assemble and hold the sheet metal while banding material and heavy silicone provided the airtight seal around the perimeter of the floating slab. The overhead crane was used to pick up the slab and hold it while we attached the skirt (see fig. 13).

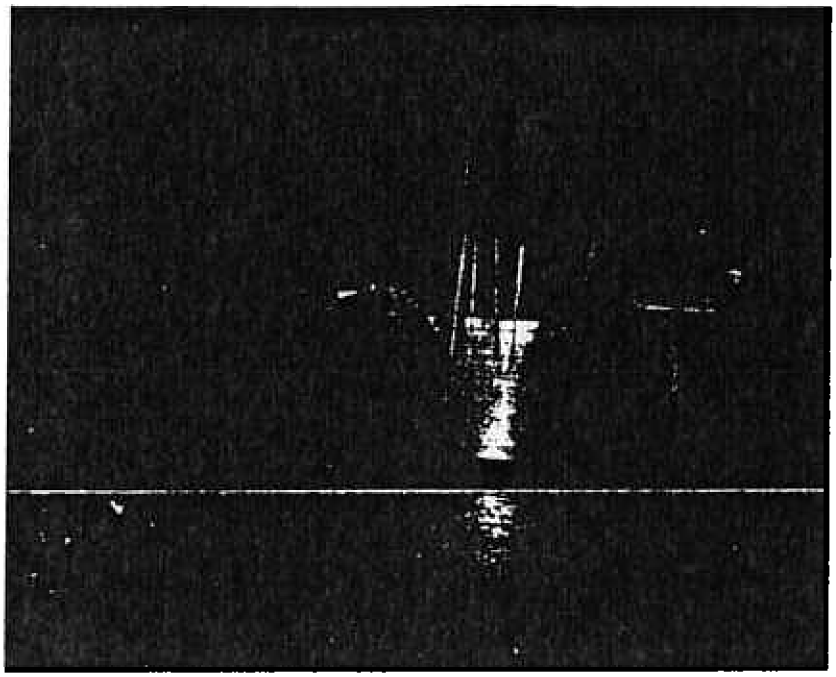


Fig. 13. Fastening skirt to top slab with the overhead crane suspending.

Due to the limited tensile strength of the banding material we were not able to provide the tension necessary for a complete airtight seal. Many different types of silicone were tried with only limited success due to the gaps created by the inadequate banding material. Thus, we used small pieces of wood driven between the banding material and the sheet metal to help seal the leaks. Eventually, a sufficient seal was achieved for the needs of this experiment.

To lift the floating slab from the sub-floor requires air cavities in which air pressure could be pumped to achieve the initial lift (see fig. 14). Thus, four metal cookie sheets with a long truck tire valve stem (for inflation) in one were evenly spaced around the slab and

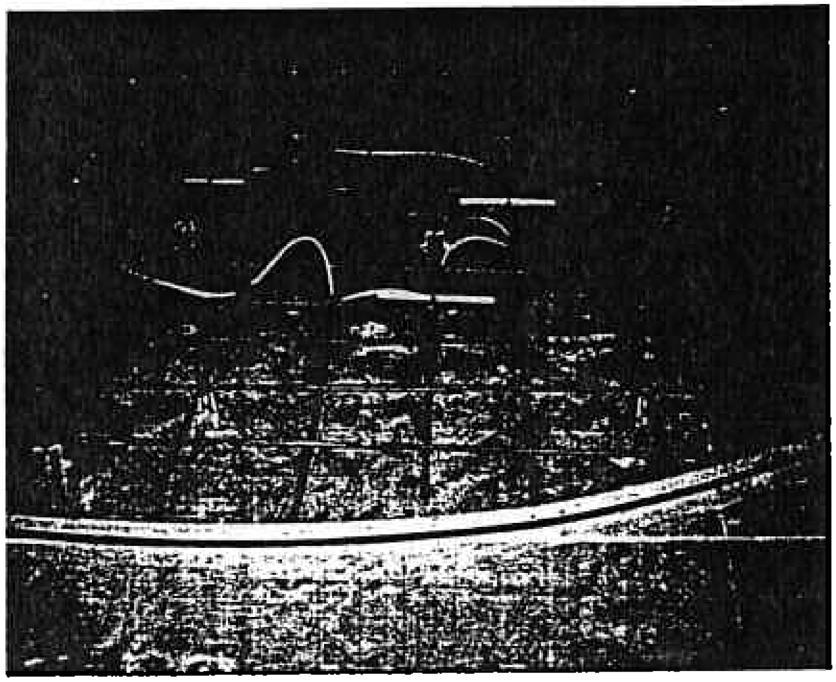


Fig. 14. Pressure chambers located in top slab.

connected in series with plastic tubing before the concrete was placed (see fig. 15). This would create a void for high pressure air (100 psi) to break loose the slab. Once the slab is broken loose the high air pressure is dissipated into a much larger area and thus becoming only a few psi which the floor floats on.

The final three-and-a-half-inch outside wall was cast with twelve vertical angles protruding from the top (see fig. 16-17). These angles were then fashioned into "L"-shaped legs with rollers on the bottom to ride on top of the floating slab as the air pressure lifts it (see fig. 18). As an uneven load is applied the slab will not be able to tilt due to the upward force of the air and the downward

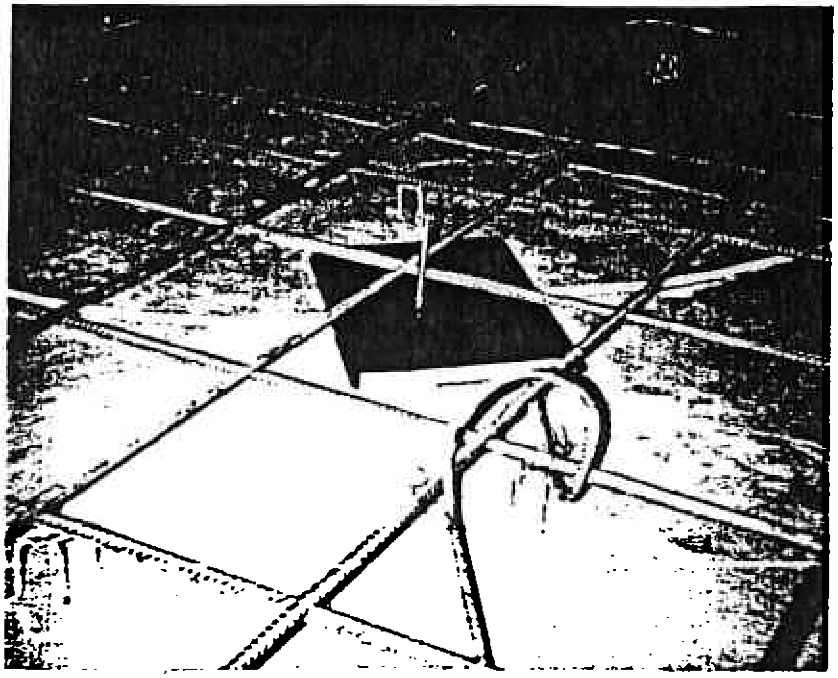


Fig. 15. Close-up of pressure chamber and valve stem.

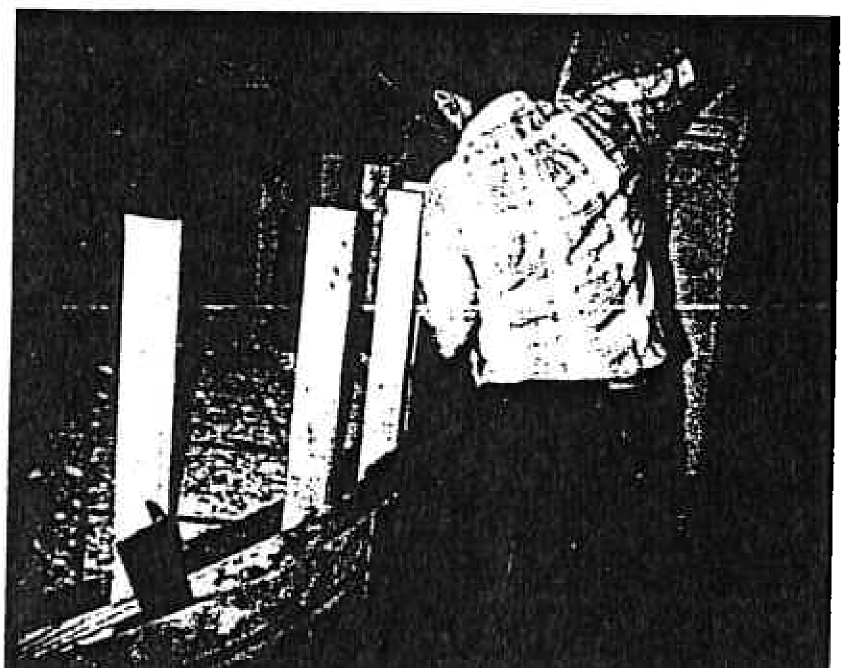


Fig. 16. Pouring of exterior walls and slab.

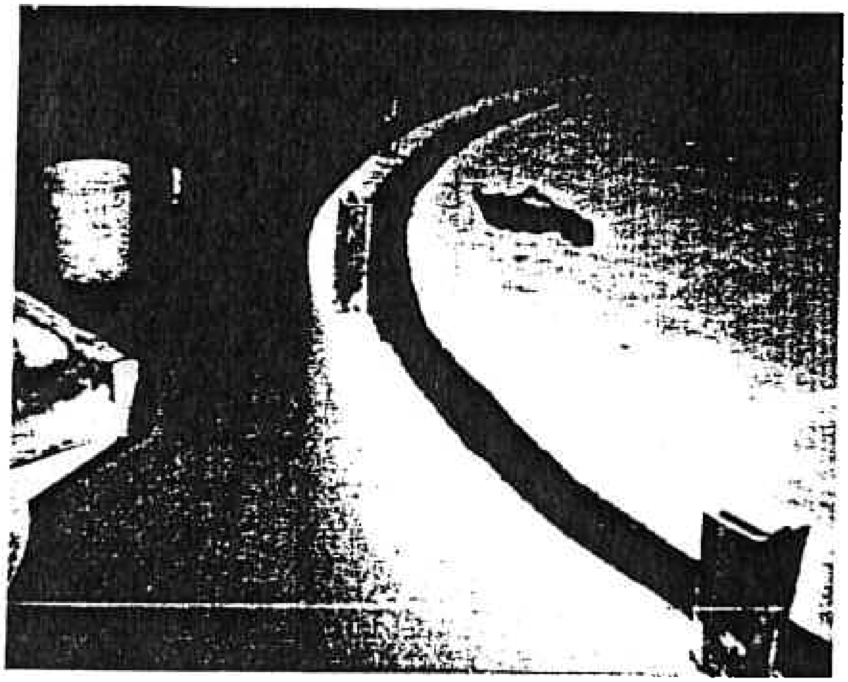


Fig. 17. Completed and heavily tarred walls and slab.

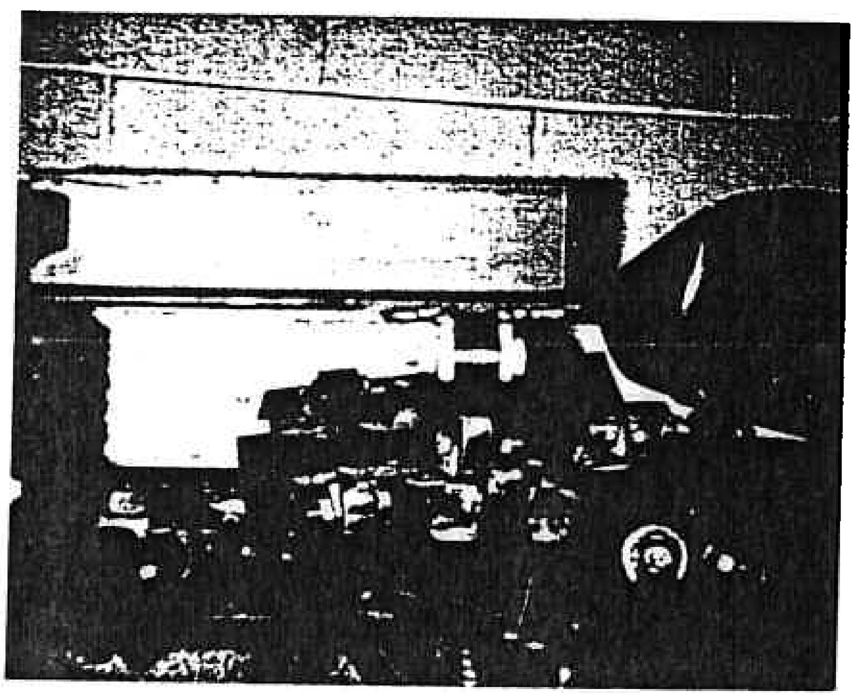


Fig. 18. Roller welded to L-shaped arm.

force of the "L"-shaped roller legs. The roller system consisted of twelve small ball bearing rollers scavenged rom a military auction.

The moat created between the two walls needed to be extensively tarred to keep the water from leaking out due to the poor quality of concrete forms used. This poor quality kept us from vibrating the concrete enough to consolidate and control porosity. Even after several layers of tar we still had some small leaks which we had to live with.

TESTING

The first test consisted of floating the weight of the slab itself, adjusting the water height, plugging air leaks, and miscellaneous other details. Once the L-shaped rollers were welded in place we could not remove the floating slab with the overhead crane without extensive rewelding and retrofitting. Therefore, several tests were completed before the rollers were welded in place.

The height of the water in the moat determines the total amount of air pressure which we can use, thus, dictating the total amount of weight the system can support. I chose a one-foot depth of water which translates into a two-foot differential water height on either side of the skirt. With the density of water at 62.4 pcf, a one-foot depth of water would yield 62.4 psf or .43 psi. Likewise, a two-foot depth would yield .86 psi. Using 1.0 psi as our upper limit times the square inches of area of the slab (25,434 sq in) gives a total lifting capacity of 25,434 lbs. The dead weight of the six-inch slab was approximately 13,083 lbs. leaving a 12,350 lbs. live load capacity. The flexural capacity of the six-inch slab was estimated at approximately 10,000 lbs. due to the steel reinforcing (#5 @ 12" O.C. both ways).

The first weights put on the completed model were various steel beams and columns lying around the structural lab. The slab lifted these loads with no visible deflection of the L-shaped rollers, therefore we attempted to rotate the slab manually which was done without any difficulty. A large commercial scale was used to weigh several lead weights (1000 lbs. total) which we used for testing the system. We placed the weight at three feet and then six feet from the center of the slab. Opposite the weight we placed a piece of angle iron with springs underneath the bar spanning between two L-shaped rollers. As the slab lifted, the springs would deflect opposite the load thus, with the spring constants, we could determine the amount of load on the L-shaped rollers and therefore size them. The spring constant was 250 lbs per inch found by putting them in a testing machine located in the structures lab. Combinations of five, ten, and twelve springs were all tried as my data shows (see Appendix).

The heaviest object that we could find was the lab forklift at approximately 8,000 lbs. which we set on the slab at the very edge near the rollers. This proved impossible to lift due to insufficient water height on the opposite side of the load which caused the air inside the skirt to escape. Therefore, the forklift was moved to the middle but was not centered providing an uneven loading which we required (see fig. 19-20). This time the slab was floated without incident bringing the water height in the moat to its maximum elevation.

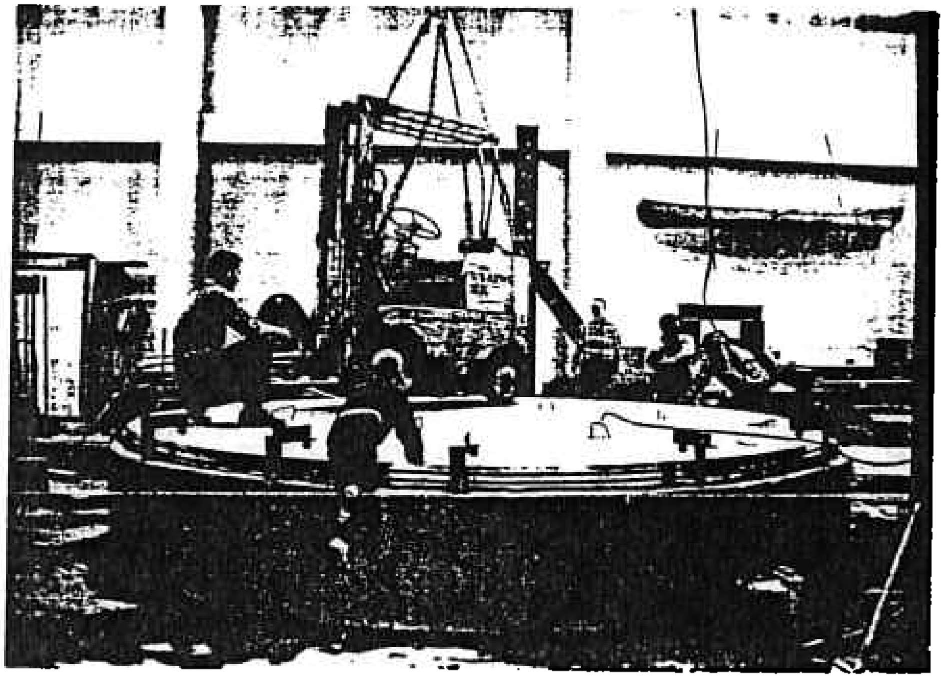


Fig. 19. Placing the 8,000 lb. forklift onto the slab.

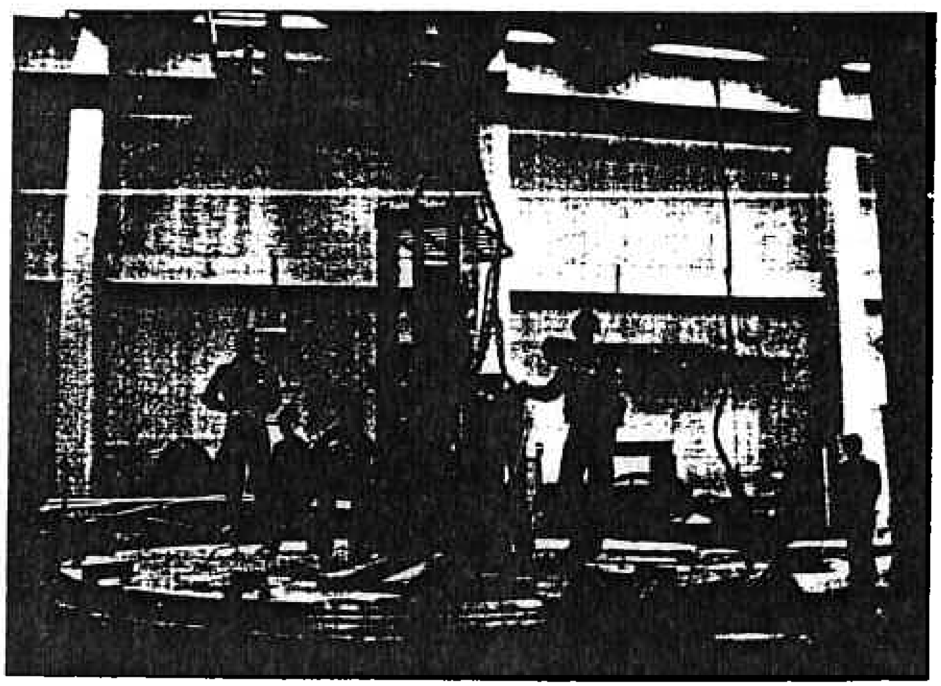


Fig. 20. Successful lifting of the forklift as an uneven load.

CONCLUSIONS

The purpose of this project was to determine whether a floating concrete floor could be built on site that could support and rotate an uneven load. This was accomplished and proven as the pictures and data show. The sizing of the L-shaped members through testing is an area which requires more testing with better equipment and controls. The data gives the average air pressure at 1.2 psi which is greater than what the water column was capable of supporting (.86 psi). Therefore, I would tend to fault the pressure gage which we used, due to the fact that it was not calibrated before testing began. The spring constant may have also been incorrect due to the lack of time to duplicate the spring constant calibration. Most of my time was spent building and modifying the project leaving little time for rigorous testing and evaluation. As the project was personally financed, funds were not available to test the slab and determine more accurately the actual force which the L-shaped members receive when any given uneven load is applied.

To the engineering community this system would be a great benefit to better utilize a given floor space while allowing for maximal structural strength and efficiency. The actual L-shaped roller would in reality be a member cast into the side of the outside wall there by eliminating all above grade obstructions (see fig. 21). This design is my

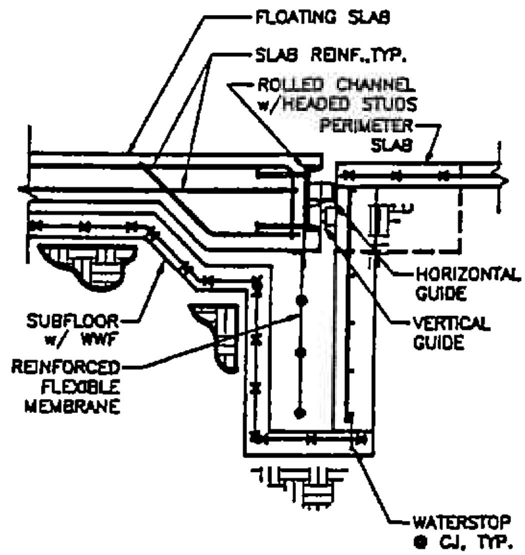


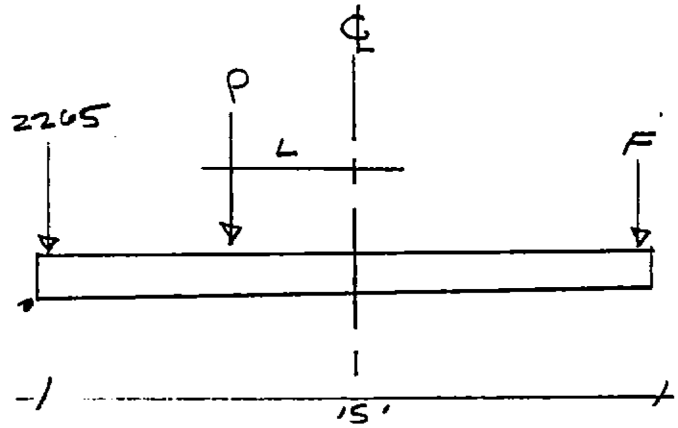
Fig. 21. Design revision 1 for hold down arms (L-shaped rollers).

idea of what would make the system the most efficient and buildable for the next generation of concrete rotating floors. The metal skirt could be replaced with an 80 mil thick continuous plastic sheet around the perimeter, with one butt splice to seal the ring. A much stronger banding material, like pre-stressing cable, could be used to seal the plastic skirt to the concrete slab much like my model, thereby eliminating the greatest source of air leaks.

All the aspects of the project except the sizing of the L-shaped members were proven to be acceptable: (1) an uneven load can be supported, (2) the slab can be rotated without much force input, and (3) the system was built on site without a patented bladder system.

Appendix

Calculations:



P = 1000 lbs

spring constant

k = 250 lb/in

@ 5 springs @ 1.2 psi: Δ = 2.5" L = 3'

@ 10 springs @ 1.25 psi: Δ = 1.25" L = 3'

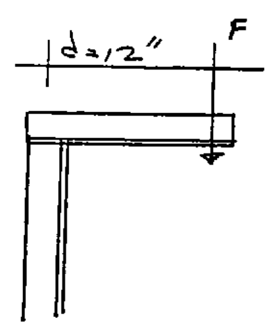
@ 12 springs @ 1.2 psi: Δ = 1 7/8" L = 6'

Slab = 13,100 lbs spring = 250 lb/in · 2.5" · 5 springs = 2265 #

$\circlearrowleft + \sum M_o = 0$

$-(1.2\,psi)(25{,}447\,in^2)(7.25) + 1000(4.25) + F(15) + 13{,}100(7.25) = 0$

F = 8144 lbs



M = F·d = 1 · 8144 = 8,144 lb-ft

M = S·F_b

$S = M/F_b = \frac{8144 \times 12}{36 \times .75}$

S = 3.62 in^3

we used L 2½ x 2½ x ¼"

S = .394 in^3

∴ N.G. The arms should have Bent But ours Didn't