Precast prestressed "Space Mountain" highlights Walt Disney World

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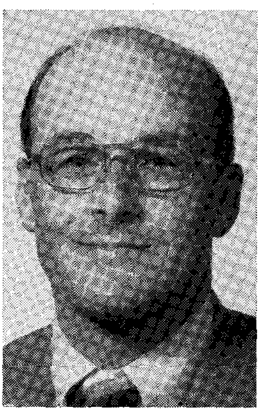

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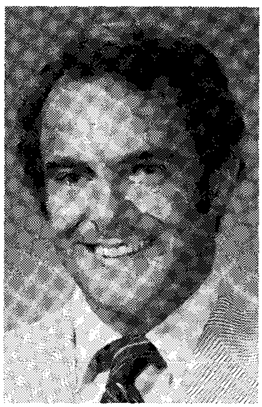

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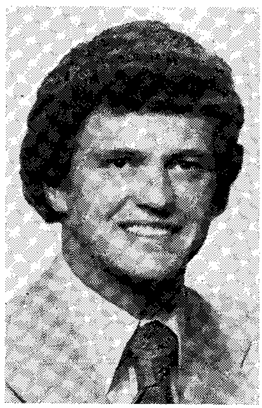

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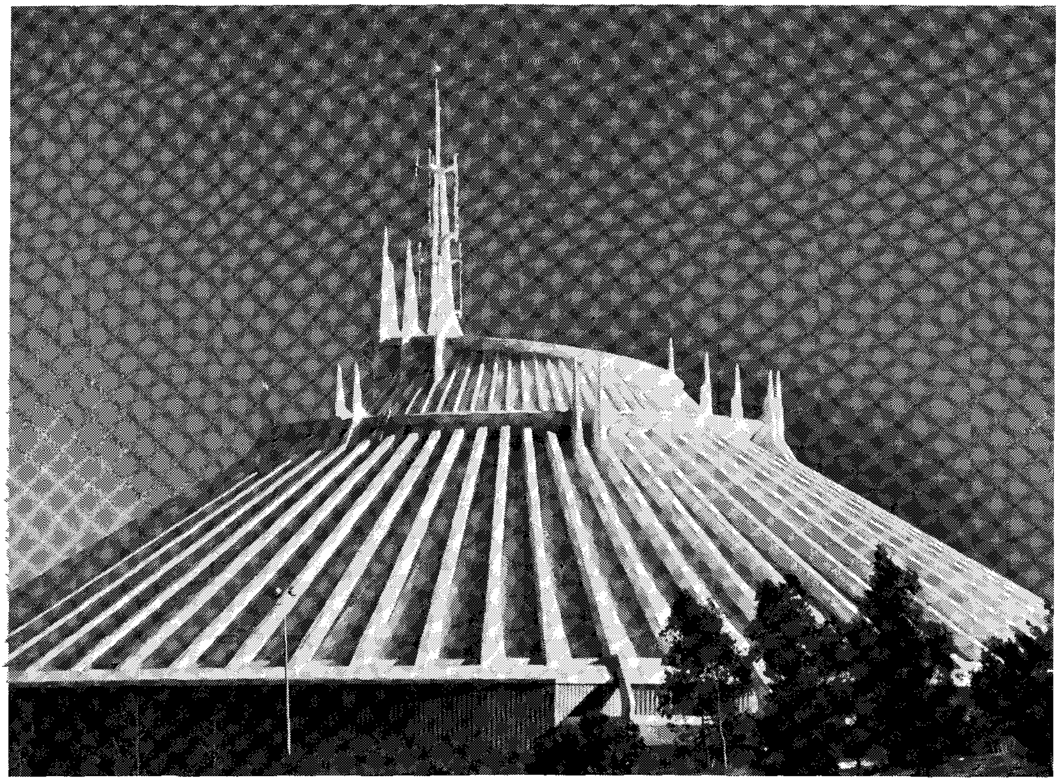
Describes the precast prestressed design/construction considerations that went into building Walt Disney World's monumental "Space Mountain" at Lake Buena Vista, Florida.



Space Mountain

Precast prestressed concrete was used effectively to build Walt Disney World's spectacular "Space Mountain" at Lake Buena Vista, Florida.

This mammoth structure, which is in the shape of an elevated truncated cone, reaches 183 ft high and has a 300-ft diameter.

Inside its sky-high, column-free arena, Space Mountain houses a series of space-age rides—combining the natural thrill of weightlessness and nonlinear motion with a brilliantly conceived illusion of space travel.

The facility was opened to the public in January 1975.

Conceptual Design

The size and function assigned to the structure as well as the general appearance and style of surrounding facilities in the park-like layout demanded a "futuristic" design concept that would yet be compatible with the adjoining structures.

WED Enterprises* suggested a truncated cone roof with external, radial ribs. The interior surface of the cone was to be used for image projections.

*The master planning, design, and engineering arm of Walt Disney Productions.

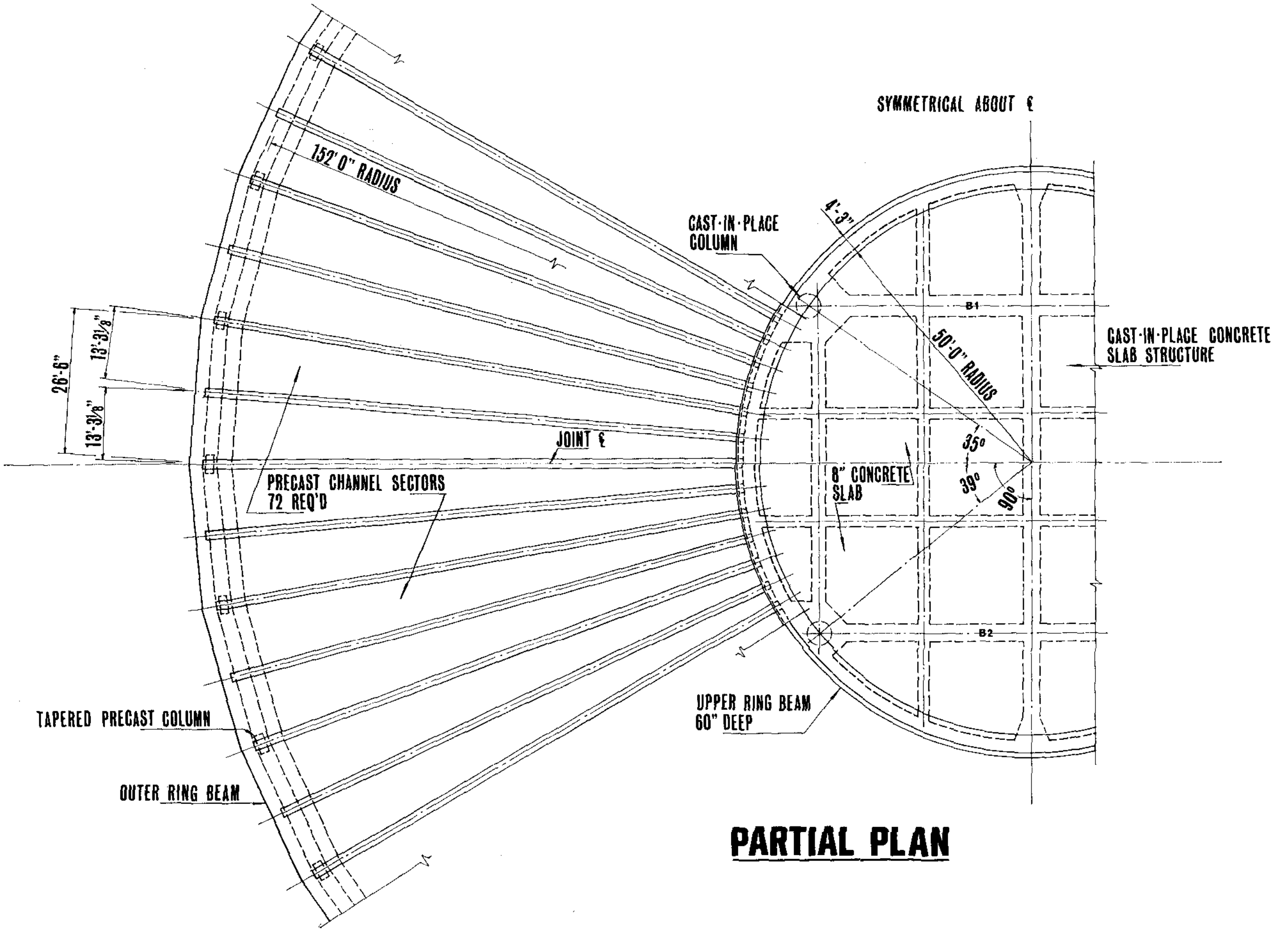


Fig. 1. Partial plan of structure.

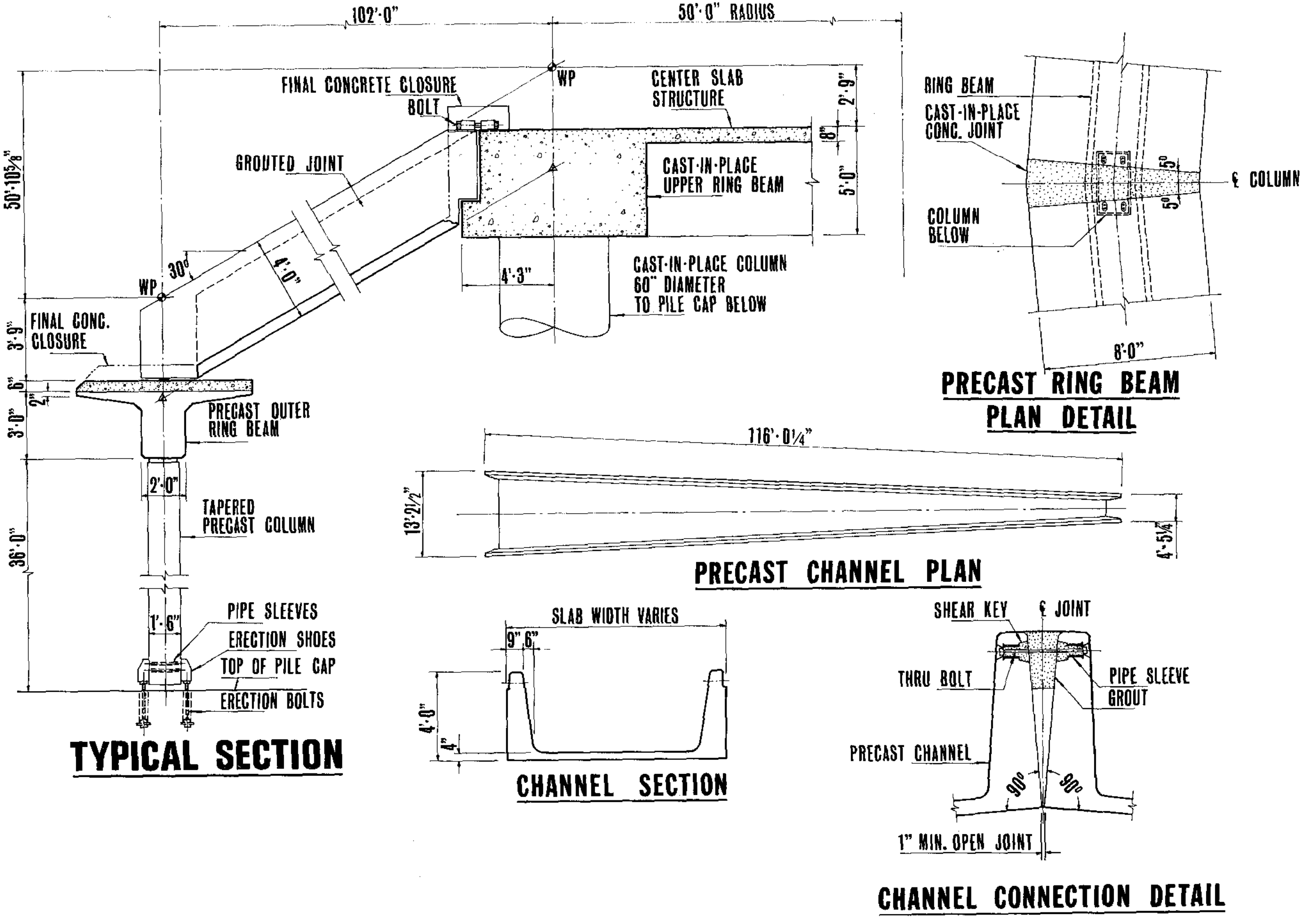


Fig. 2. Typical structural details.

However several consultants pointed out that such a concept was not only exceptionally difficult to realize but also structurally questionable, and a traditional "bubble" shaped dome should be considered.

Finally, the eventual structural engineer was consulted to render an opinion as to the feasibility of the "bubble" concept. This firm suggested an imaginative concept featuring the extensive use of precast and prestressed concrete components—allowing a structural configuration that is in close conformance with WED Enterprises' initial design.

The resulting structure features a cast-in-place, post-tensioned concrete "waffle" center slab, elevated on cast-in-place columns, precast concrete peripheral columns, precast/prestressed concrete outer ring beams, and precast/prestressed concrete pie-shaped, channel-type roof elements.

Structural Components

As was mentioned previously, the basic structure of Space Mountain is in the form of an elevated, truncated cone.

The conical roof surface, consisting of 72 tapered channel beams with stems extending upward, is supported by a center slab at its apex and a series of 36 ring beam segments at its lower perimeter. The ring beams, in turn, are supported by 36 precast columns.

The overall diameter of the structure is 300 ft at the perimeter and 100 ft at the center slab. The clear inside height is 35 ft at the perimeter and 100 ft at the center slab.

The following is a brief description of each individual structural component. See also Figs. 1 and 2 for a plan of the structure and details of the components.

Center slab

The center slab is supported by four 60-in. diameter columns which are located so as to provide a minimum amount of obstruction to ride structures inside the building. A beam grid spans between the columns and in turn supports the ledger ring which receives the roof channels.

The overall depth of the center slab is 60 in., with an integral 8-in. slab spanning between grid beams. The center slab structure contains 700 cu yds of concrete and was cast-in-place on scaffolding 96 ft off the ground.

The principal beams, B1, B2, and B3 (see Fig. 1), were post-tensioned in the field to balance the loads from the roof channel erection. The remaining beams and the ledger ring have only mild reinforcing steel.

To simplify the post-tensioning operations, an erection sequence for the roof elements was developed so as to provide a symmetrical load pattern for the center slab.

Roof channels

The 72 roof channels, approximately 116 ft long, span the 100-ft horizontal distance between the center slab and the ring beams. They weigh about 75 tons apiece and are inclined at 30 deg. to the horizontal.

The channels were cast in a self-stressing steel form, capable of reacting a 700-ton initial prestressing force. The formwork was manufactured to very close tolerances in accordance with the required closeness of fit in the final structure.

The upturned legs of the channel section are tapered for ease of form removal, and splay in plan to cover a 5-deg sector.

A 4-in. slab spans between the channel legs—11 ft clear at the ring beam and 2.2 ft at the center slab. They are 4 ft deep, with an overall width of 13 ft 2½ in. at the bottom.

One-half of the prestressing steel is located in the 4-in. slab, the remainder divided between the two channel legs and harped at the one-third points. To limit deflections to a minimum, the prestressing moment has been designed to accurately balance the dead load moment imposed by the channel weight.

Outer ring beam

The outer ring beam structure is a closed, circular multi-bay frame consisting of 36 piled foundations interconnected by grade beams, an equal number of precast concrete columns extending from the foundation and connected at the top by 36 precast and prestressed tee beams. All connections are rigid to react sidesway imposed by lateral loads.

The precast, simply reinforced columns are 35 ft 9½ in. long with a bottom cross section of 1 ft 6 in. x 4 ft 6 in. and a 1:48 taper on the longer axis. The columns were cast in forms already on hand from a previous project.

The precast and prestressed ring beams are of a tee configuration, 25 ft long with an 8-ft flange width and 3-ft overall depth. Stems are 2 ft wide at the base, flanges are 2 in. thick at the ends tapering up to 4½ in. at the stem.

Connections are facilitated by extending the column reinforcing steel a certain distance beyond the upper and lower end faces. The bottom extensions were placed in corrugated pipe "cans" cast into the pile caps, the columns positioned and levelled on a set of levelling bolts and the metal cans filled with concrete upon final alignment. The gap between column and pile cap was later filled with low shrinkage grout.

Similarly, the top column bar extensions were placed in pipe sleeves provided in the tee beam stems and consequently grouted in place. An in-situ concrete placement with mild reinforcing, providing a 6-in. topping to the tee beam flanges and joints between beams, produced a continuous ring beam structure. After erection of the roof channels, the final concrete closure is reinforced as a complete tension ring and diaphragm connection between precast columns.

Number and Dimensions of Precast Units (see also Figs. 1 & 2)

Channel Beams

72 precast, prestressed concrete channel beams, 4 ft deep and 116 ft ¼ in. long. Width varies from 13 ft 2½ in. at bottom to 4 ft 5¼ in. at top. Stems are 15 in. thick at base, tapering to 9 in. Slab thickness is 4 in.

Tee Beams

36 precast, prestressed concrete tee beams, 25 ft long with flange width of 8 ft. Base width of stem is 2 ft. Flange is 2 in. thick at ends tapering to 4½ in. at stem.

Columns

36 precast concrete columns, 35 ft 9½ in. high. Base cross section is 1 ft 6 in. x 4 ft 6 in., with a 1:48 taper on the longer axis.

Design Considerations

The design concept developed for Space Mountain, resulted in a visual appearance that is both excitingly futuristic yet very compatible with the surrounding structures and facilities. The extensive use of precast and pre-

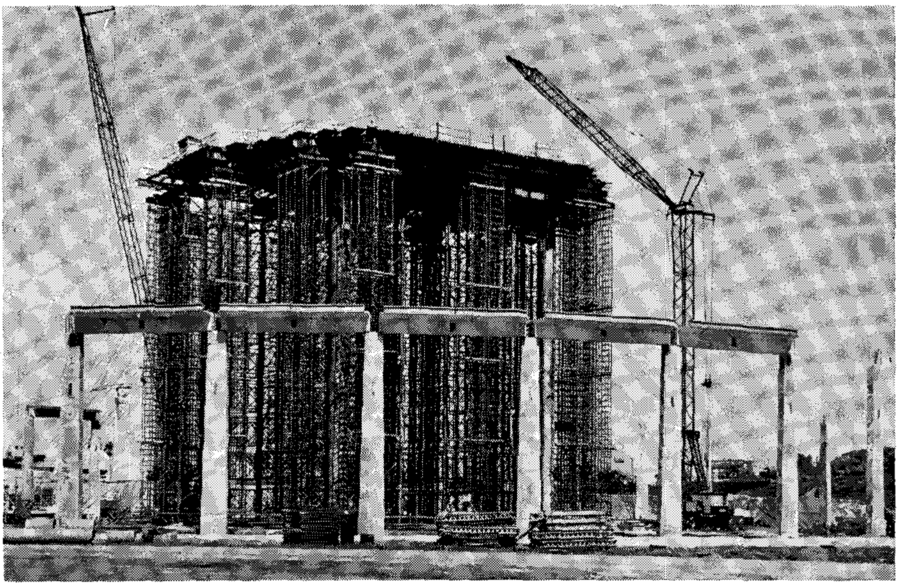
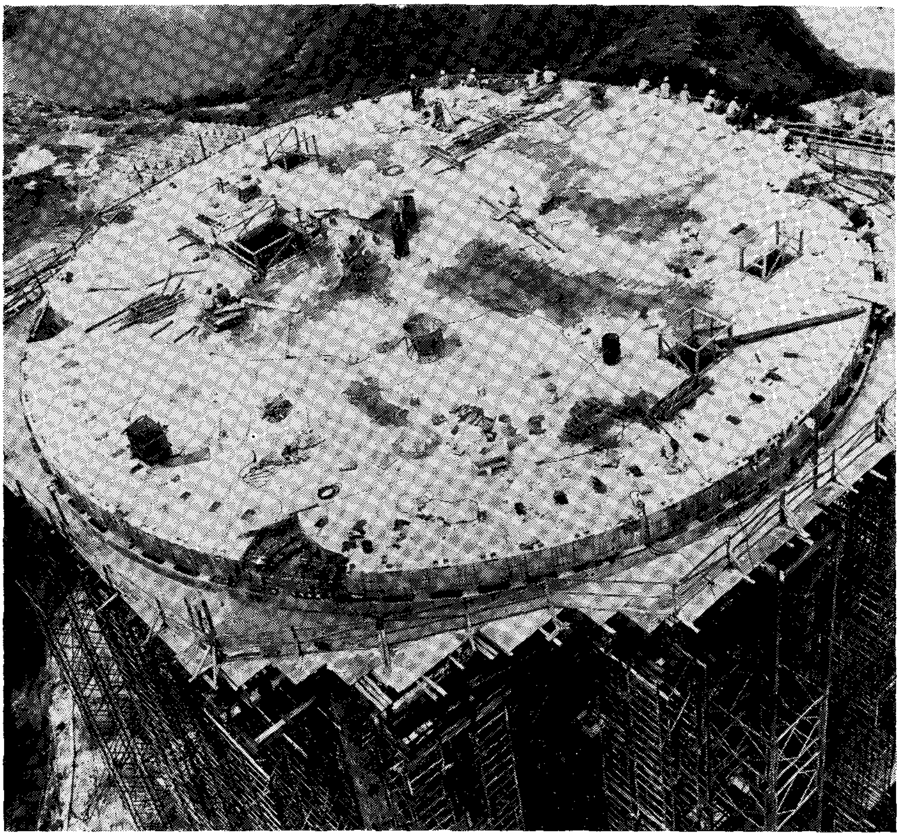


Fig. 3. Installation of precast peripheral columns and precast prestressed peripheral tee beams in outer ring. Center slab scaffolding and formwork is in background.

Fig. 4. Aerial view of center slab. Note recesses for post-tensioning anchors.



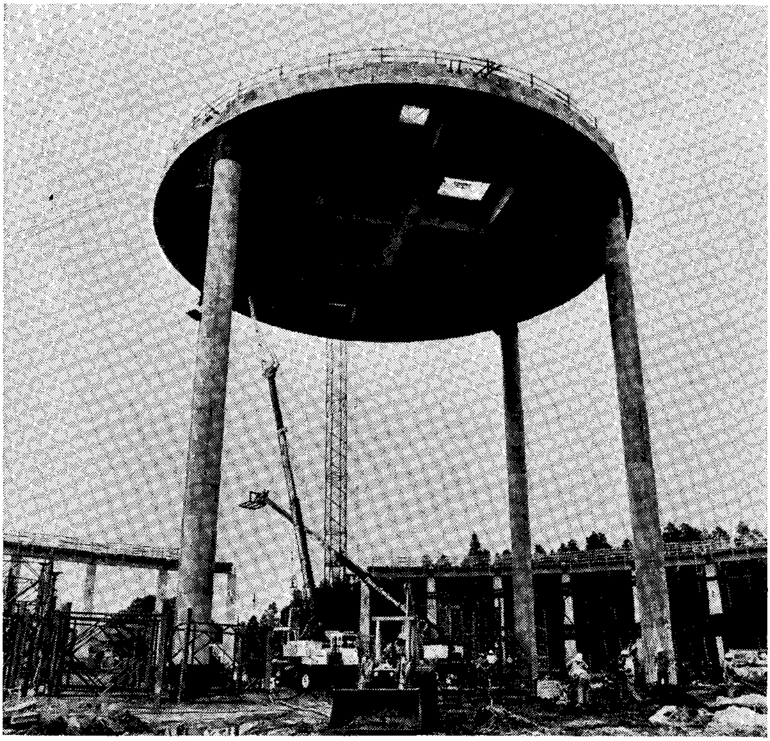
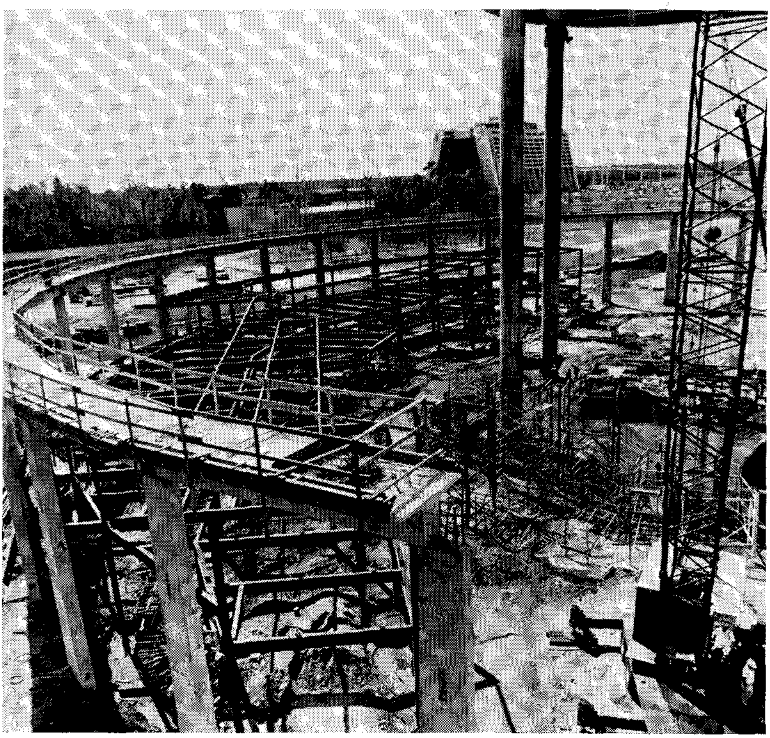


Fig. 5. Completed center slab structure temporarily guyed to outer ring foundation.

Fig. 6. Ring beam installation. Note that the ride structure is being erected simultaneously.



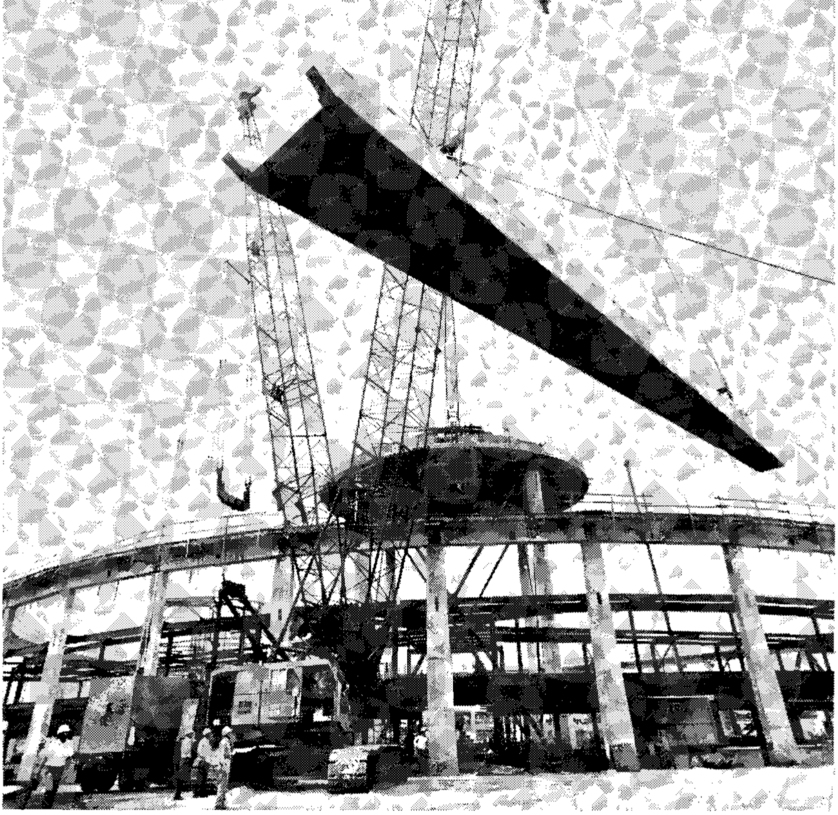
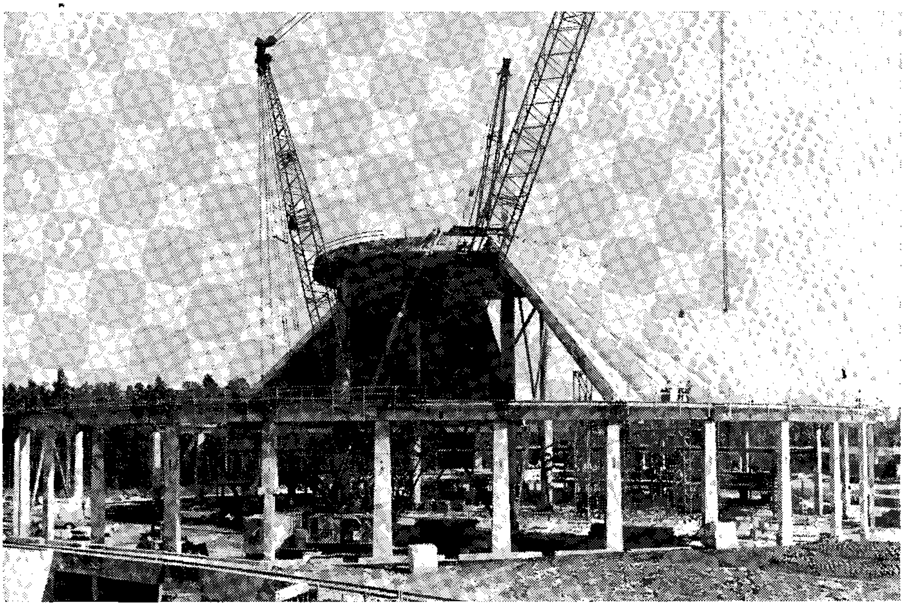


Fig. 7. Placement of first roof channel. The X-bracing of center columns now replaces the guying wires. The crane outside is the American Sky Horse. A special derrick on the center slab will pick up the top end when the channel is inside. The channels weighed about 75 tons apiece.

Fig. 8. Roof installation process about halfway complete.



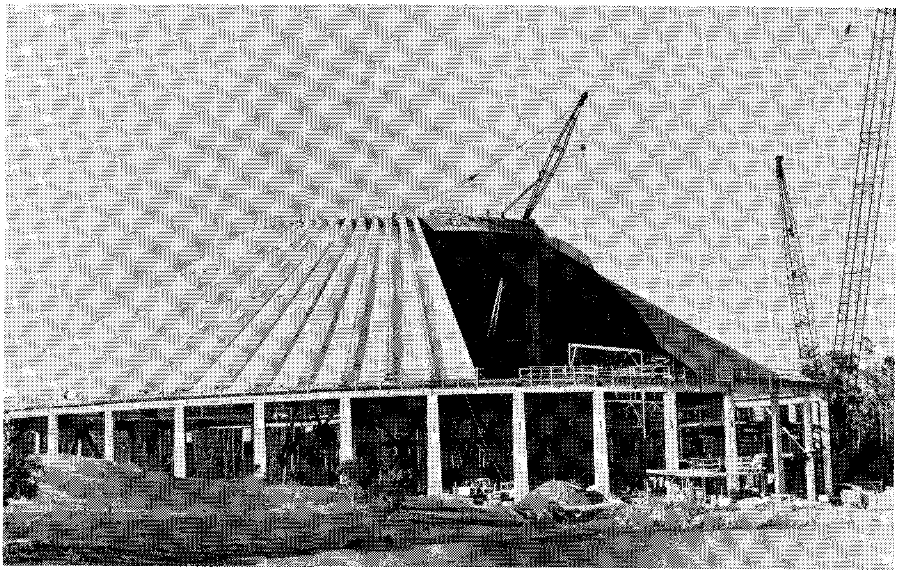
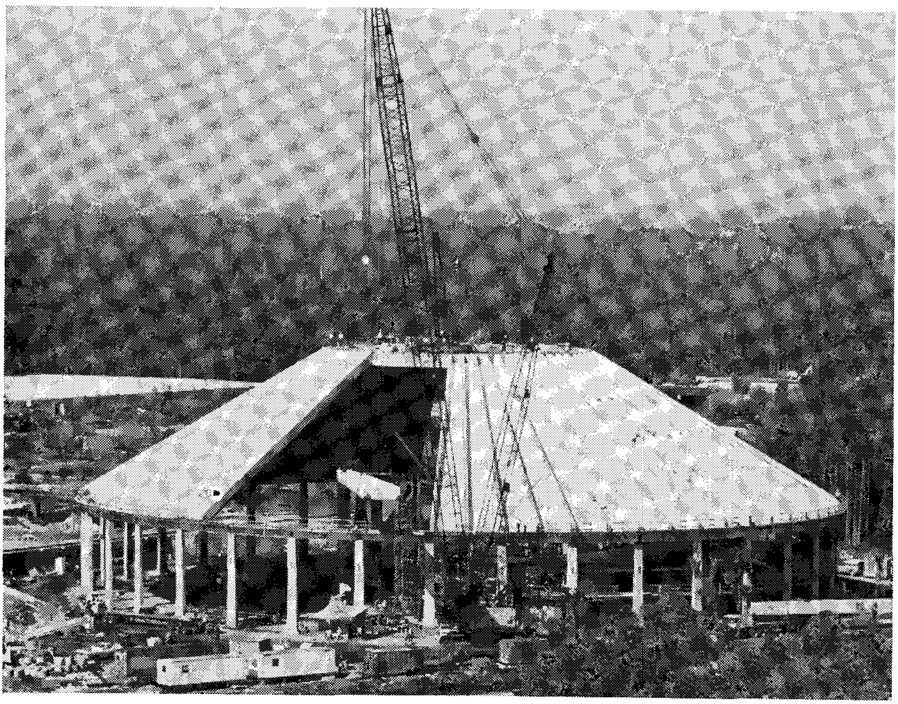


Fig. 9. Roof installation progress. The channel sections were placed symmetrically (see also Fig. 8).

Fig. 10. Roof installation nearing completion.



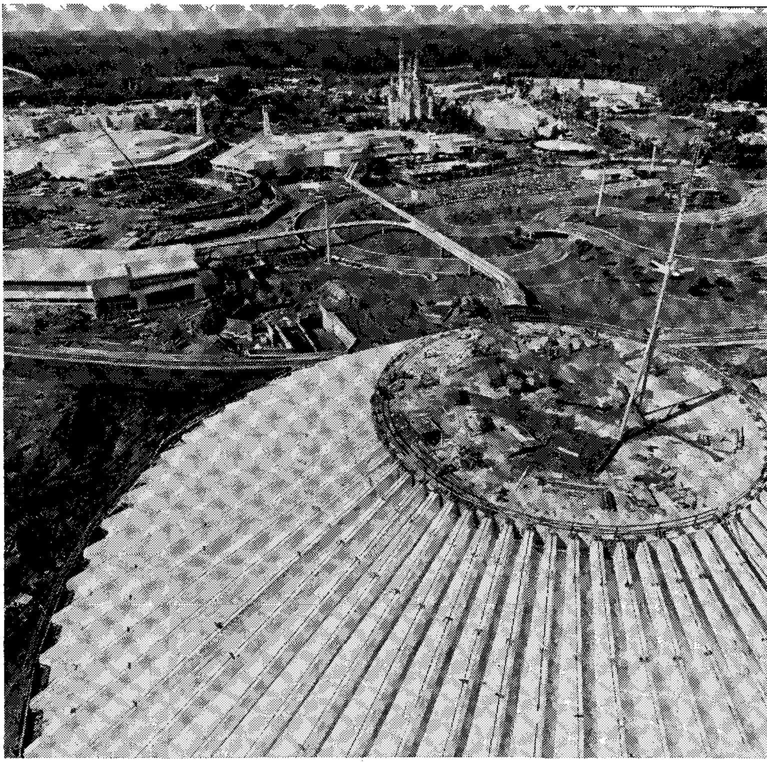
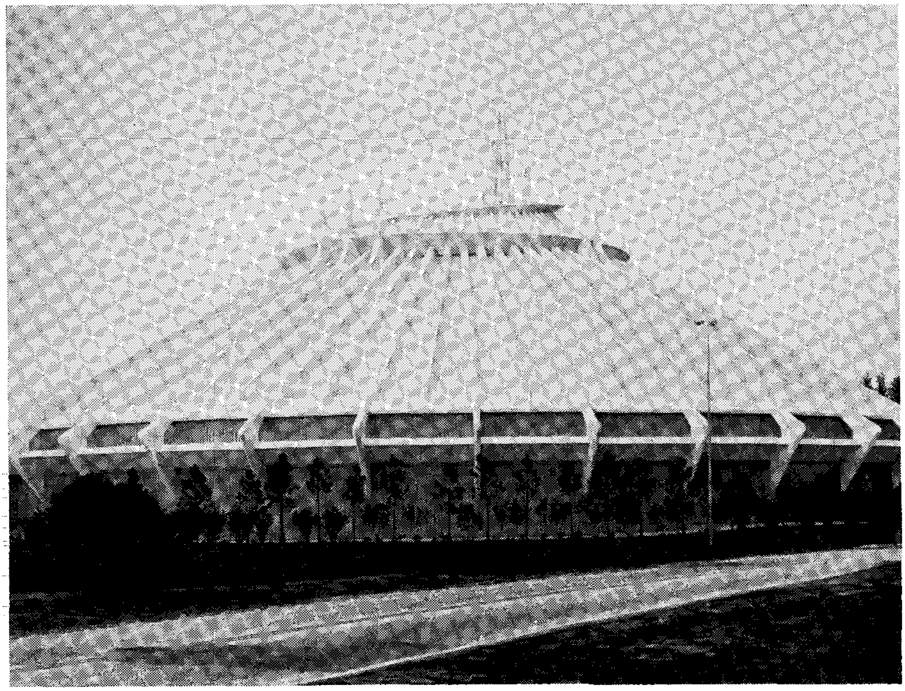


Fig. 11. Aerial view of completed roof structure.

Fig. 12. Completed structure.



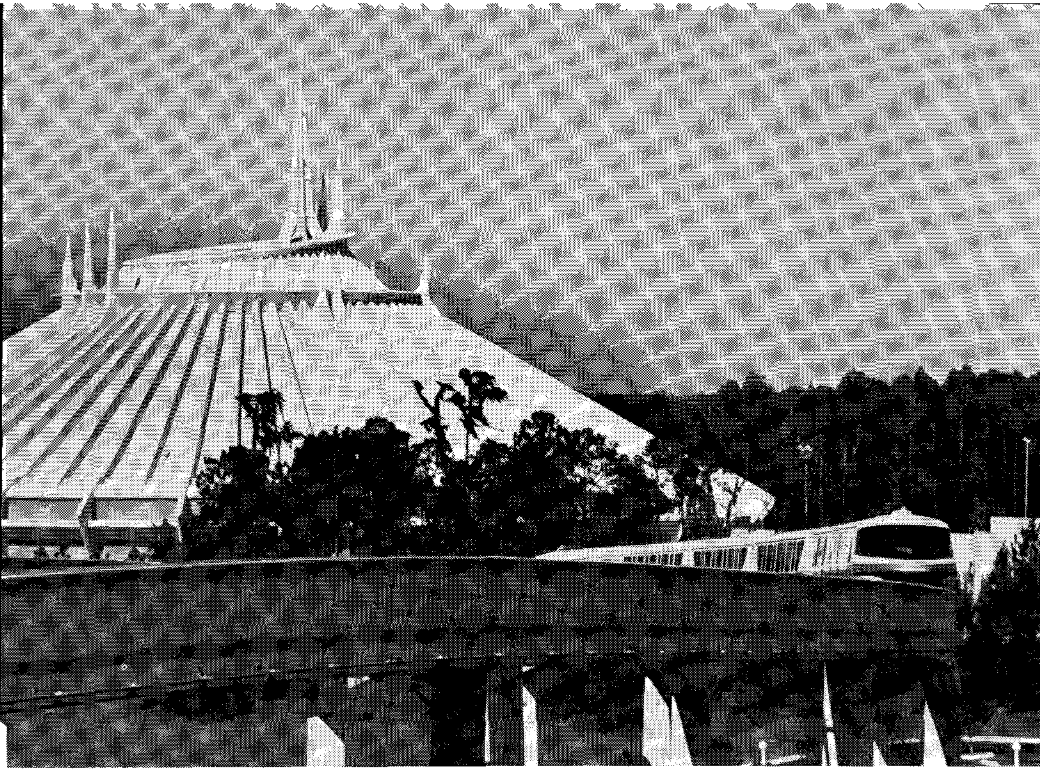
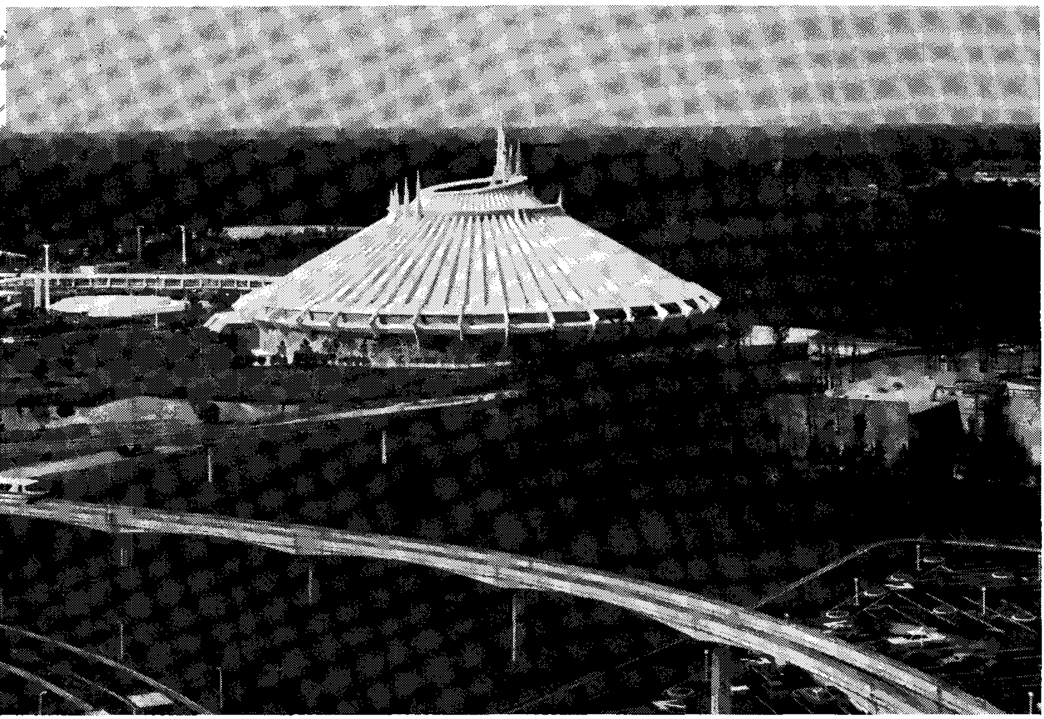


Fig. 13. Space Mountain majestically nestled.

Fig. 14. Panoramic shot of Space Mountain and environs.



stressed components accomplished two major objectives:

1. WED Enterprises' desire to create a conical roof configuration was realized after such a concept had previously been advised against by other consultants. The truncated cone roof surface, the interior of which is used for image-projection associated with the rides, was given a monolithic insulating/reflecting layer during channel beam production. The material, in sheet form, was installed in the form prior to concrete placement; thus the beams once removed from the form were complete with interior finish.

2. Because of a very tight construction schedule, a concept had to be devised that would facilitate erection of structural elements from the outside of the building while interior nonstructural activities could proceed concurrently without delay or obstruction. The roof system solution based on prefabrication of beam sections, eminently accomplished this objective, and the construction schedule was complied with.

The simplifications and innovations developed through the successful completion of the structural design are worthy of some mention:

The previously mentioned restrictions on inside activities required the roof elements to span from the outer ring to the center slab structure without intermediate shoring nor shell-type action. Normally in a shell, circumferential forces would be induced during superimposed loadings with compression within the shell and tension in the outer ring.

These forces were not introduced since the channels had sufficient strength to span radially without intermediate supports. Therefore, a channel connection detail was developed which would allow circumferential movement as the channel would deflect inward. The joint connection uses bolts as shear friction reinforcement in order to establish diaphragm action necessary for lateral resistance.

Construction

Figs. 3 through 14 show pictorially the various construction stages of Space Mountain.

The central slab, elevated on four cast-in-place columns, was concreted in situ and post-tensioned (see Figs. 3, 4, and 5). The center structure was temporarily guyed to the outer ring foundation.

At about the same time, the precast peripheral columns and precast prestressed peripheral tee beams were erected (see Figs. 3 and 6).

When this operation was complete, the 75-ton precast channel sections could be lifted into place (see Figs. 7 through 11).

At the precasting plant, lifting loops were cast into the channel slabs for handling and erection purposes. Ceiling material was also placed in the form prior to the start of concreting operations. Later on, this surface was painted before the members were hoisted into place.

All of the precast prestressed elements were manufactured near the building site.

Installation of the giant-sized units was done with an American Sky Horse crane. A specially-designed radial derrick that consisted of a crane boom hinged to a T-frame helped this operation. Wheels on the frame enabled it to run on a radius at the edge of the core slab. Powered by a three-drum hoist, the derrick tilted the roof pieces to their final 30-deg angle.

Figs. 12 through 14 show various configurations of the completed structure.

Since completion, the structure has performed well and, in general, has confirmed the philosophy of design.

Credits

Design (Conceptual/Architectural/Engineering): WED Enterprises, Glendale, California.

Prestressed Concrete Consultants: ABAM Engineers, Inc., Consulting Engineers, Tacoma, Washington.

Design (Structural): Wheeler and Gray, Consulting Engineers, Los Angeles, California.

Owner: Walt Disney World Co., Inc., Lake Buena Vista, Florida.

Precast Concrete and General Contractor: Buena Vista Construction Co., Lake Buena Vista, Florida.

Acknowledgment

The Prestressed Concrete Instiute wishes to express its appreciation to WED Enterprises for release of this technical information and for their he'p during the preparation of this paper.

Discussion of this paper is invited. Please forward your discussion to PCI Headquarters by February 1, 1976.