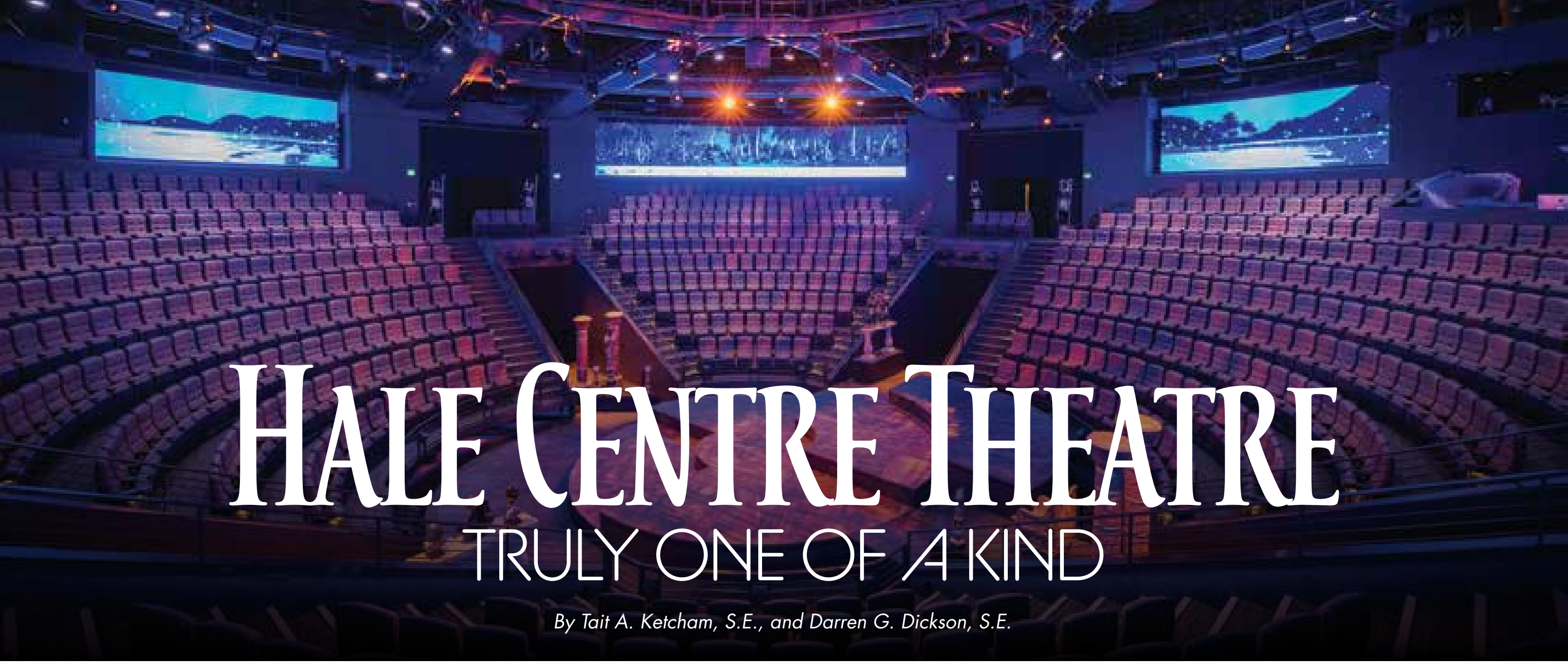


HALE CENTRE THEATRE

TRULY ONE OF A KIND

By Tait A. Ketcham, S.E., and Darren G. Dickson, S.E.

Hale Centre Theatre in Sandy, Utah, is a world-class theater experience that is truly one of a kind. It features a centrally located round stage with seating radiating concentrically outward, each row increasing in diameter. When patrons experience a show at Hale Centre Theatre's center stage, the viewing angle is 360-degrees.

The Theatre is approximately 130,000 square feet with two separate stages. The theater-in-the-round seats over 900 patrons and the smaller Jewel Box theater seats 460 people. The total construction cost of the building was $80 million, of which $20 million was allocated to the stage technology and overhead crane systems. What makes this theater unique is the stage and crane system technologies incorporated into the design. TAIT Towers from London, England, was the designer and installer of these systems. About Hale Centre Theatre, they have stated: "You will not be able to find a lift system or overhead crane system like this anywhere." These high-tech systems created several unique structural design challenges for the structural team.

The round revolving stage was designed to provide 20 feet of vertical travel. This required the overall stage structure to be at a height of 40 feet. The theater was designed to have the stage level 14 feet below grade. The level that supports and houses the round stage and ancillary equipment is known as the sub-pit, which extends an additional 40 feet below the pit level. The existing groundwater table was approximately at the elevation of the stage, compounding the challenges. Many options were vetted, and the resulting design was to permanently dewater 14 feet (to pit level) and design for hydrostatic and buoyancy pressures reaching over 40 feet at the bottom of the sub-pit. The resulting design hydrostatic uplift pressures exceeded 3000 psf. The structural design utilizes a 52-foot inside diameter, 18-inch-thick wall that acts as a compression ring to resist the water pressure forces. The walls are supported on a 36-inch-thick continuous mat footing underpinned with twenty-nine 16-inch round steel pipe piles extending over 70 feet below the mat footing.

Aerial view showing the subpit compression ring.

The overall building height is primarily driven by the requirements for the stage – clearances required over the stage, catwalks, and subsequent clear height required for the overhead crane systems or "bogies." These combined requirements resulted in a total structure height of just over 158 feet, with approximately 90 feet above exterior grade and 68 feet below grade. The perimeter walls of each theater are 18 inches thick, designed to meet the stringent sound transmission requirements as well as act as the primary lateral system for the building. Due to the quantity and thickness of the walls, the shear demand due to seismic loads is relatively low. The more significant design issue was adequately connecting these very tall and heavy walls to the diaphragm for out-of-plane loads. The tallest individual wall was 116 feet above the footing. One interesting fact is that, due to this height and thickness, the resulting concrete yield calculates to over 6.5 cubic yards of concrete per linear foot of wall.

The radiused suspended seating is also one of the most unique aspects of this project. To allow for two slip stages used to cover stage openings when the stage is lowered to the pit level, the seating was required to be suspended. These slip stages retract below the seating on opposing sides. The beams for seating matched the radius of the stage and had to span to sloping beams, creating large torsion effects. This resulting thrust was resolved with tube sections at strategic points along the radius beams extending up the seating and into the floor diaphragm at the top of the seating. Directly over the slip stage, at the bottom of the seating, it was required to maintain the typical 21-inch step between seating rows. As a result, a very shallow structure was required to still allow for the 16-inch-deep slip stage and associated clearances. The design utilizes cantilevered tubes in-plane with the deck that results in a structural depth of only 4 inches at this lowest row of seats.

One of the governing factors in the design was to have a column-free space within the viewing area of the theater. Also, the "Loading

Loading level framing supporting a suspended three-tiered catwalk below.

900-ton crane hoisting 6-foot-deep plate girders.

Level" above the stage and seats was to be used as a storage space for show sets, props, wardrobe, and other support spaces for the theater production. The resulting design has four main columns within the box of the theater that provide the majority of the load support for the floor and the roof above. This level is approximately 36 feet above the seating and designed with 125 psf storage loading. The design utilizes six-foot-deep, built-up plate girders. Four of the girders span 110 feet to two transfer plate girders spanning up to 107 feet. The weight of the transfer girders exceeds 700 plf. This level also supports all the catwalks that encircle the space above the stage and seating areas. The catwalks are suspended from this level using tube column hangers resulting in the column-free space desired in the viewing area.

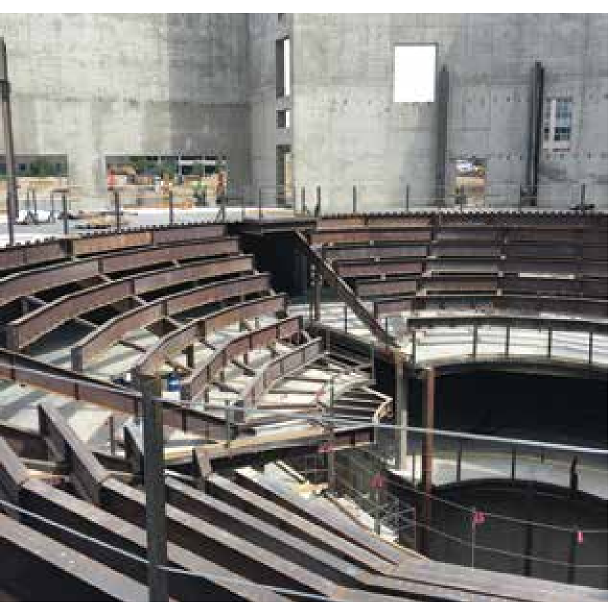
The clearance above the Loading Level was driven by the height required to support two 15,000-pound overhead cranes or "bogies" with 4,000-pound payloads and the associated hoisting requirements for each. One concern for the bogie support is that the hoisting requirements are exact, down to ⅛ inch. Keeping snow load deflections within this limit, while allowing precise calibration of the hoists, was not realistic within the same structural system. This also was not acceptable from a safety standpoint. The solution was to support the bogies from two trusses that are supported independently from the roof. The result is two steel wide flange trusses that span 138 feet and are independent of the roof. The trusses are braced laterally to the exterior walls via a series of struts and ties. The trusses have been designed to limit the maximum deflection of 1 inch while under full loading of the bogies in a dynamic loading condition.

In addition to design challenges, there were many construction challenges for the contractor, Utah-based Layton Construction. For example, constructing the sub-pit that extends approximately 54 feet into the groundwater. The contractor decided to install steel sheet piling in a circle, slightly larger than that required to construct the round sub-pit. The circular geometry was chosen over a square because it allowed for a compression ring to brace the sheet piling while excavating without adding horizontal tiebacks or internal bracing that would create future construction conflicts. Then a series of construction wells were constructed to draw the water down.

In addition to the depth into the ground, the height above grade was also a significant challenge to construct. With very thick and heavy walls that extend up to 116 feet above the footing, constructing these walls before any floor diaphragm being in place was a significant concern. Close collaboration between the contractor's construction approach and the wall design allowed the contractor to build and sequence the construction in a manner that met the project schedule.

An additional interesting construction challenge that required collaboration was the installation of the large plate girders. The concrete walls were required to be constructed for the full height of the structure, so a 900-ton crane was over 90% utilized to hoist the furthest girder into place, over 125 feet away from the crane set-up location and 90 feet over the wall. Due to the proximity of the crane outriggers to the basement wall, the wall was designed to accommodate the 450-kip outrigger reactions caused by the crane. The resulting outrigger pad consisted of 15- x 20-foot bearing mats of 12- x 12-inch wood timbers with an additional 10-inch x 8-inch x 15-foot solid steel bearing pad on top of the wood mat. The resulting bearing pressure was near 1400 psf.

From the outset, the owner's goal was to create a world-class venue that would attract theater-goers from all continents. The unique design issues from a structural perspective were challenging, but, in the end, add significantly to the overall experience of the venue. Hale Theatre's mission is to provide innovative, professional family theatre education that involves and elevates the community.▪



Suspended radius framing for seating with cantilevered tubes at bottom row to allow the slip stage to retract beneath the seats.

Independently supported "bogie" truss system.

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