ALADDIN HOTEL

A 38-story design-build steel structure features a staggered-truss frame

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WITH A BUILDING BOOM UNDERWAY IN LAS VEGAS, IT WAS ONLY A MATTER OF TIME BEFORE AN INNOVATIVE DEVELOPER TURNED TO THE DESIGN-BUILD APPROACH TO HELP ERECT A NEW HOTEL UNDER A SUPER FAST-TRACK SCHEDULE. The new Aladdin Hotel is a 2,600-room, 38-story tower replacing the old Aladdin Hotel, which was imploded in March 1998. In addition, the $1.2 billion mixed-use retail mall and casino utilized a staggered truss frame for the hotel tower portion of the project. The design, provided by structural engineering firm McNamara/Salvia, Inc., of Boston, was developed with the steel fabricator, AISC-member SMI-Owen Steel Company of Columbia, SC.

Staggered trusses were utilized to provide column-free space and precast plank provides the floor framing between the trusses. The lateral load resisting system is provided by two braced core structures and four separate bracing bents at the ends of the tower wings.

An unusual plan and vertical irregularity of the tower masses presented challenging engineering design problems. Extensive wind tunnel analysis along with complete three-dimensional seismic analysis was performed for the design.

The steel staggered truss structure was presented to the owner as an alternative to the traditional poured-in-place concrete tower usually constructed in Las Vegas. With overall system evaluations (including fire protection and finishes) providing definite cost savings and a significant reduction in total construction time, the staggered truss system was selected by the owner as the most economical solution for the new hotel structure.

Building Geometry of Loading

The hotel tower is composed of six retail, restaurant and office levels, and 33 levels of guestrooms. The upper five levels are special guestrooms and suite floors. The lower six levels are integrated into the surrounding low-rise complex made up of casinos, retail malls, back of house services and parking structures. The entire project surrounds the historic performing arts center. The site also allows for another 31-story hotel with separate theming from the Aladdin Hotel.

The unusual building geometry of the tower necessitated an extensive wind tunnel investigation for overall strength loads and for occupancy comfort. Extensive computer analysis of the tower for seismic effects was also required because of the irregular mass and stiffness distribution.

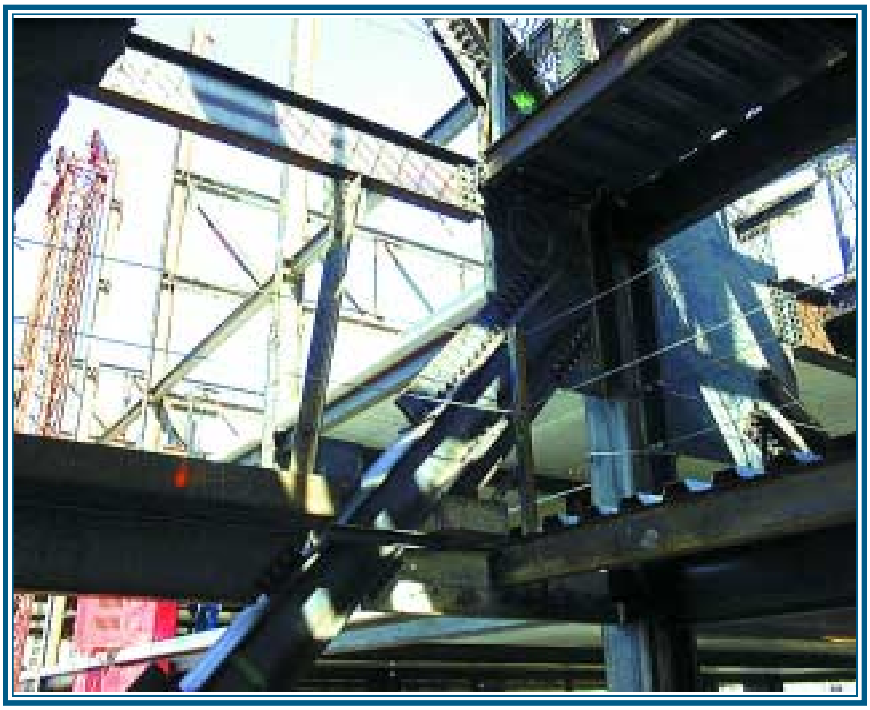
Building Foundations

Foundations for the tower were originally conceived to be spread footings and mats based on limited sub-surface investigations. After demolition of the old Aladdin Hotel, additional sub-surface investigations revealed the absence of the cemented soil layer found in much of the Las Vegas basin. Without the cemented soil layer the differential settlements between the high-rise and low-rise towers were found to be unacceptable and a caisson foundation system was selected. The caisson system was the first used in Las Vegas for a high rise building. Load tests were performed on caissons to determine the soil design parameters. All loads are carried on the caisson through skin friction to the surrounding soil.

Caissons range from 3' to 6' in diameter and are drilled to depths of 50' to 80'. Tie beams are used to connect all caissons. Soil structure interaction analysis was utilized for the lateral load design of the foundation caisson systems.

Tower Structure – Staggered Trusses

The staggered truss system, originally developed at MIT in the 1960s in conjunction with William LeMessurier, was utilized and the basic gravity system. Trusses are 9'-0" deep with a large corridor opening (9'-7") in the center panel. The 63'-4" span of the staggered trusses provided column free spaces under the tower footprint. Eight-inch precast planks span the typical 31'-4" and 22'-4" between trusses. Because of the very large "sail" area of the tower, the wind forces on the structure were large for a structure with a height of 400'. The need to eliminate shear walls in the lower levels also presented design problems for the lateral force resisting system.



Tower Structure – Lateral Load System

The staggered truss system with the wide corridor openings in the center panels was not stiff enough to resist the lateral loads. The arrangement of the trusses would also require moment frames in the long direction of the building. The conventional systems used for staggered truss buildings of 30 stories would not work for the 38-story tower.

A primary lateral force resisting system was designed to provide the necessary stiffness and strength to the entire structure. Each major elevator core was wrapped in bracing or moment frames to provide two central boxes. A braced frame at the end of each tower wing supplemented these boxes. Conceptually, these bents were located at the ends of each wing to control the overall torsional behavior of the tower. Changes of vertical planes in the lateral system were accommodated through a major diaphragm transfer at the sixth level to accommodate architectural planning requirements in the non-guest rooms.

Wind Tunnel Results

Viewing the plan layout of the tower, the shape resembles an airfoil, albeit a crude one. Wind tunnel studies were carried out at RWDI in Ontario, Canada, and the results proved to be very interesting. The overall gross forces specified by the UBC Code with the Clark County Department of Buildings' modification of the maximum wind velocity of 75 mph, closely matched those measured in the wind tunnel. The significant finding from the wind tunnel was that the center of force was located approximately 100' from the center of the stiffness resulting in large twisting forces on the structure. The end bents were able to resist these eccentricities and at the same time limit the rotational component of the floor acceleration to within acceptable levels for hotel occupancy structures. A total of 24 different loading conditions were generated by the wind tunnel engineers to envelop the wind effects on the tower.

Seismic Analysis – Zone 2B

Clark County Department of Buildings requires all structures in Las Vegas to be designed for UBC Zone 2B. This represents a peak ground acceleration of 0.2g. A complete spectrum analysis for the three-dimensional structure was performed. An interesting balance between the wind-governed design for the high tower and the seismic-governed low-tower resulted.

The structural analysis of the tower itself was an interesting study using several models to envelop the design values. Gravity analysis governed the simple span staggered trusses. However, for lateral loads, the diaphragm action of the plank and the subtle nature of the staggered trusses must be simulated. Couple this analysis complication with the 24 load combinations from the wind tunnel and eight seismic spectrum directions, a significant database for member design was generated. Further complicating the issue was the fact that all major seismic connections were designed for unreduced seismic forces much larger than those developed for the member design envelope (the 3Rw/8 effect). The plank floor system was analyzed utilizing finite element analysis to assure elastic behavior at seismic levels.

Design-Build Interaction

Throughout the development of the contract documents for submittal to the Clark County Department of Building, we worked very closely with SMI-Owen Steel Company engineers to develop a truly optimized design from a cost point of view.

Items such as truss geometry and member sizes, connections, lateral system geometry, and column splice locations; stiffeners

versus no stiffeners were all discussed jointly with SMI-Owen Steel Company to obtain the least cost structure. Speed of erection was paramount importance to SMI-Owen Steel Company, prompting their recommendation of a four-tier column splice arrangement. All moment frame columns were selected on the basis of connection and erection ease.

With this combined team effort and daily communication with the SMI-Owen Steel Company field team, the project is rising on Las Vegas Boulevard much faster than any other previous structure. Early opening in Las Vegas is an extremely valuable aspect of this structure.

CONCLUSION

The utilization of the steel staggered truss system on the Aladdin tower allowed the ultra-fast track project delivery to be executed. Significant owner initiated changes, late in the development of the total project, could be accommodated because of the steel structure. Many of the program-driven options would not have been possible with a traditional concrete system. Essential to the successful completion of this project was the close cooperation provided by the SMI-Owen Steel Company/McNamara/Salvia, Inc. design-build team and the project owner.

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