STEEL *on the* S·T·R·I·P

THE LAS VEGAS STRIP IS CONSTANTLY CHANGING. Its current incarnation is a land of luxury hotels, restaurants run by celebrity chefs, ultra-high-end shopping, a constantly rising minimum bet, and $17 martinis (don't get me started on this last one).

Back in March, I was standing in a suite on the 32nd floor of the Strip's newest resort-casino, the Palazzo, looking down at what would soon become an outrageously opulent pool deck. A chain of pools stretched from one end of the hotel tower to the other. (One-upsmanship is an art form out here; they *had* to make it better than the previous best pool deck in town.) The room I was in had two large flat-screen TVs—two more than I have at home—modern, dark-wood furniture, and lots of room to spread out. Oh, and it was framed in steel. And in this town, where resorts have traditionally relied on steel for the base structure and concrete for the hotel tower, this is a big deal.

Of course, as anyone who lives here will tell you, there's more to Vegas than just the Strip. The current housing bust aside, this place has been growing steadily for years, and it's been attracting some major construction projects as of late. Two such structures are the World Market Center, a multi-phased mammoth of a complex that will bring a world-class furniture showroom and convention space to the city, and the Frank Gehry-designed Lou Ruvo Brain Institute, which will serve as a national research center for the treatment of Alzheimer's, Parkinson's, and Huntington's diseases. Both are steel-framed structures. Las Vegas is also now home to multiple steel-framed parking garages, including garages at the Palazzo, the Cosmopolitan, and the soon-to-be-open Fontainebleau, and another that is given exclusive use to employees of the Venetian and Harrah's.

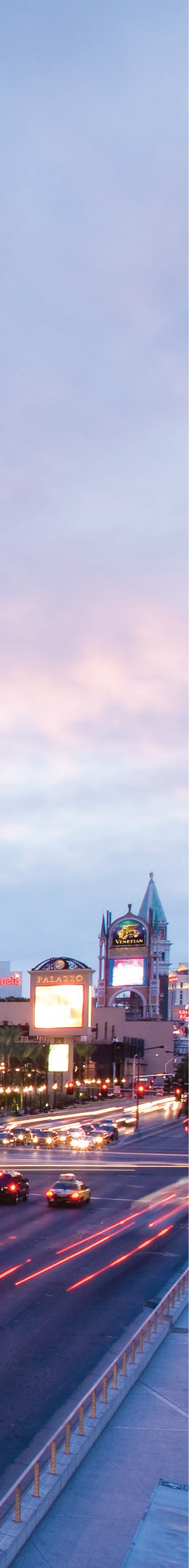
Besides material and location, one thing that all of these projects have in common—and really, this applies to Las Vegas in general—is the massive scale. This is a place where buildings that look a couple of blocks away are actually a mile down the road—where the Mirage hotel-casino really *is* a mirage. You know that hotel I was standing in, the one with the impressive pool deck? More than 70,000 tons of structural steel. And it's not even the biggest resort on the Strip.

The following pages provide more insight on the above projects and others, all of which illustrate that steel is definitely becoming stronger in Sin City.

- Geoff Weisenberger

Fitting In

BY BRIAN CAUDLE, P.E., AND PAULETTE RUDOLPH, P.E.



©Blake Marvin/HKS Inc.

The Palazzo overcomes spatial hurdles to become the latest high-class resort on the Las Vegas Strip—not to mention the world's largest LEED-certified building.

THE MANTRA OF "NEWER, BIGGER, SWANKIER" HAS BEEN REPEATED IN LAS VEGAS FOR QUITE SOME TIME NOW. And every year one or two hotel-casinos become the latest and greatest on the Strip.

The Palazzo Las Vegas has staked that claim for 2008. The new $1.9 billion, 50-story hotel, which opened earlier this year, is part of the Venetian Resort Hotel Casino complex and is connected to the Venetian by a high-end shopping mall and indoor canal. Located in the heart of the Las Vegas Strip, the 3,066-guest suite tower sits atop a 105,000-sq.-ft casino, 450,000 sq. ft of shopping, dining, and entertainment space, and a four-level, 4,330-car underground parking garage.

While mammoth hotel properties have become the norm on the Strip, each has something that makes it stand out from the rest. For the Palazzo, one of these "wow factors" is sustainability on a grand scale. At more than 7.5 million sq. ft and using 70,000-plus tons of structural steel, the Palazzo is the largest LEED-certified (Silver) building in the world—more than four times larger than any previously certified building.

The Palazzo's triangular-shaped site is bounded by Las Vegas Boulevard on the west, Sands Avenue to the northeast, and the Venetian on the south. The site imposed two significant limitations on the project—horizontal *and* vertical—that challenged the ingenuity of the design team. First, at only eight acres, the site was less than half the size of that required for a typical casino resort of this magnitude on the Las Vegas Strip. And second, close proximity to McCarran International Airport prompted the FAA to impose height restrictions on the Palazzo and the surrounding buildings.

Disappearing into the Wall

While the FAA height limitations made it necessary to minimize floor-to-floor heights in order to maximize the number of hotel room floors, high ceilings in the living area are characteristic of the Venetian's signature room quality. In order to maximize ceiling heights while maintaining minimum floor-to-floor heights, the goal was to have a beam-free floor within the room, with beams buried inside the demising walls between rooms—in other words, a beam-in-wall system.

The typical room plan includes a seating area by the windows, which is 1 ft lower than the sleeping area. The challenge was to minimize structural depth within the seating areas while incorporating the 1-ft step in structure. The additional challenge of obtaining the desired number of rooms across the tower's north-south width meant that the width of the beams buried within the demising wall was limited to 5 in.

Schematic design studies were implemented on various floor framing schemes for the rooms. Two cast-in-place concrete structural systems were studied. The first scheme was a flat-plate system. The only way to resolve forces across the 1-ft step within a concrete flat plate floor was to add columns within the demising walls at the step in the slab. But the tower sits above casino, retail, and garage space, where the number of columns needs to be minimized for aesthetic reasons and ease of operation. Studies showed it to be cost-prohibitive to employ additional columns at each 1-ft step and transfer the columns, supporting 47 floors, at the podium.

The second cast-in-place concrete scheme—a beam-and-slab system in which the beams would be buried in the demising walls—was discarded, because the beam within the demising walls would have been much wider than the 5-in. width limitation.

But using steel, keeping the members within the demising wall to a width of only 5 in. was possible. The beams chosen were standard steel W-sections with the bottom flanges trimmed to 5 in. A composite slab spans 15 ft 9 in. across the width of the room to the beams within the demising walls. This slab is 3 in. of deck and 4½ in. of concrete reinforced with mild steel to achieve the minimum fire rating and eliminate the need to fireproof the slab. Where the 1-ft step occurs along the length of the trimmed beam, a W12×14 was included on top of the beam and another framed between the beams at the step. By using a W12 section at the step, the low slab could be supported by the W12's bottom flange while the high slab is supported by the beam's top flange. The complete result is a clean, open, beam-free seating area with high ceilings. It's also a unique arrangement; while Las Vegas resorts typically consist of a concrete hotel tower and a steel base for the casino and entertainment portion, the Palazzo is the first major resort tower to use steel for the hotel portion.

Straight Down

While the Palazzo's hotel rooms are certainly luxurious, Vegas is all about being out and about, and theater entertainment has become a large part of the city's attraction. The Palazzo has two theaters, but the tight site led both of them to be located under the hotel tower footprint instead of adjacent to the tower. Seven tower columns are situated so that if extended down to the ground, they would be located in the middle of either the stage or the seating area of the theaters. Structural steel was instrumental in supporting the 47 levels of the tower above cantilevering over the theaters. A cast-in-place concrete solution would require massive concrete walls cantilevering off of the remaining columns extending to grade, and the width of these concrete walls would have taken valuable square footage out of the guest rooms. Steel trusses support the disappearing columns off of the columns that extend to grade, and steel braces were configured to avoid conflicts with the main guest corridor running the length of each wing of the tower.

Adjustable for the Future

During the podium's design and construction, the Venetian was still obtaining tenants for retail, restau-

©Walter P Moore

©Walter P Moore

Top: The Palazzo uses more than 70,000 tons of structural steel.

Bottom: W12 sections with flanges cut to a width of 5 in. provide a 12-in. step within each of the Palazzo's typical suites.

rant, and theater space. Many of these spaces had to be left as open areas to be fitted out to meet tenants' specific needs at a later date, and the structural steel frame allows for flexibility. Additional connections can be incorporated in the field to add floor framing while a cast-in-place concrete structure would require drilled and epoxy dowel connections and the introduction of formwork within a building that was already receiving finishes.

During the original design of the tower, the exact location of the balcony and theater seating was not yet known. The only two tower columns that were allowed to pass through the edge of the theater space were strategically chosen to support the future theater balcony, and the associated loads were considered in the original column design. Until the theater balcony was designed and built, these columns were temporarily braced back to the composite slab structure of the tower to minimize their unbraced length. Once the balcony was built, these braces were removed, allowing the space to take its final shape and fulfill its function.

Similarly, using steel allowed some of the restaurant and club tenants to incorporate mezzanines within their new spaces. Again, the new steel-framed floors were able to easily connect to the existing steel structure. However, unlike the theater, the additional floors within these spaces were not anticipated. Plates were used to strengthen columns and beams, without a significant impact on member depth.

Adaptive Columns

The structure was extended as close to the property line as possible in order to use every square foot of the site while maintaining the FAA height restrictions for the building. The perimeter walls were braced internally by four underground diaphragm slabs, since permanent tiebacks outside of the property line were not allowed by the local building department. This strategy to resist large lateral earth pressures by floor slabs eliminated the possibility of providing expansion joints for podium slabs with very large plan dimensions.

Small shrinkage, elastic shortening, creep, and thermal strains generally do not result in significant design challenges for small floor plates. However, for very large floor plates without expansion joints, these small strains can result in extensive movements. Walter P Moore studied all of these sources of movement in detail and focused on the relative movement between the foundation and the first elevated floor. Large relative movement generated significant internal forces in columns supporting the first elevated floor. The internal forces in column due to relative movement of two floors are directly proportional to its stiffness. Concrete columns were not considered due to their inherent large flexural stiffness; instead, steel was found to be the preferred material.

Walter P Moore explored further to make the column design even more economical. Instead of using a traditional approach of designing these columns for both axial load and moments due to relative movements, the possibility of designing them for only axial load was studied. It was concluded that when internal forces were developed due to compatibility for columns that are not part of the lateral load resisting system, and when lateral torsional buckling is not a design consideration, the compatibility moments can be ignored in column design. Using this concept, significant cost savings were achieved for more than 500 columns.

Elegance Despite Limits

The Palazzo's relatively small site and the FAA's height restrictions for the project's proximity to the airport certainly created constraints on the overall dimensions of the structure. But the design team met the challenges, and with the use of structural steel, was able to produce a world-class resort destination in a city of world-class resort destinations. MSC

Brian Caudle is a principal and managing director of the structural engineering services group and can be reached at BCaudle@walterpmoore.com. Paulette Rudolph is a senior associate and project manager and can be reached at PRudolph@walterpmoore.com. Both are with Walter P Moore's Austin office.

Owner
Las Vegas Sands Corporation

Architect
HKS, Inc., Dallas

Structural Engineer
Walter P Moore, Austin and Dallas

Construction Manager
Taylor International, Las Vegas

Steel Fabricator and Erector
Schuff International, Phoenix
(AISC Member)

Steel Detailer
BDS Steel Detailers, Tempe, Ariz.
(AISC Member)

Structural Software
ETABS, SAP2000

Detailing Software
Tekla Structures

Ample Parking

BY RON POLIVKA, PH.D., P.E.

While the Palazzo takes center stage, there's another, less-hyped addition to the Venetian complex whose importance, in terms of steel, is equally notable. The 1.4 million-sq.-ft Shared Parking Facility (SPF) is a 15-level, 4,244-space, steel-framed garage. Used exclusively for employees of Harrah's and the Venetian, it is one of the tallest and largest steel parking structures in North America, if not the world. Its overall dimensions are 600 ft × 160 ft, housing 1.34 million sq. ft of supported parking area using 9,000 tons of steel. Such a large garage is a natural outgrowth of the need for parking for casino employees—not surprising when you consider the enormous manpower it takes to run these facilities.

The facility is located on a very tight site, southwest of an access road that services the back side of both casinos. It is bound by the Las Vegas Monorail (LVM) easement to the north and west, and was built out to sit exactly atop these easements in order to maximize its size.

The decision to use steel instead of concrete was based on overall ease of erection, reduced construction time, and cost-competitiveness. The project's fabricator, Schuff Steel, developed an initial RAM structural model that was freely exchanged back and forth with DeSimone as the design progressed, ensuring that an efficient grid layout was being used, the specified member sizes were readily available, and the various connection details were properly worked out in order to minimize ensuing RFIs and facilitate efficient field construction. In addition, this process enabled larger steel sizes, which required longer lead times due to international procurement, to be identified early on. The balance of the steel required shorter lead times and was fabricated domestically by Schuff. At the conclusion of the design phase, DeSimone provided Schuff with the RAM model developed for design purposes, allowing Schuff to immediately cut weeks from the detailing phase of the project.

The project was designed according to the 2003 IBC, which was the governing code in Clark County at the time the building was permitted. Special moment resisting frames (SMRFs) using "slotted web" connections, designed by Seismic Structural Design Associates (SSDA), provide lateral resistance to wind and seismic forces in each of the two principal directions of the building. SSDA connections were chosen because they allow for the use of large W36 columns, which were needed to provide the necessary building stiffness; SMRF columns ranged from W36×260 to W36x650, and beam sizes ranged from W36x150 to W36x359.

To reduce cost and construction time, the design called for a 6-ft-thick foundation mat at the bottom floor of the structure, eliminating the need for an additional slab on grade. The top elevation of the mat followed the existing grade, which has a natural 2.5% slope from west to east. Moment frame columns were cast into the mat to provide fixity at the base, and this saved approximately 100 tons of steel on the project.

In addition, the large volume of foot traffic between the garage and the two casinos called for the construction of two, 175-ft long steel-framed pedestrian bridges that had to provide truck clearance on the below roadways while also staying beneath the elevated tracks of the LVM. MSC

Steel-framed pedestrian bridges carry staff to their respective hotels.

Ron Polivka is managing principal of DeSimone Consulting Engineers' San Francisco office.

Owner
The Venetian Casino Resort, LLC

Structural Engineer/Prime Consultant
DeSimone Consulting Engineers, Las Vegas

Parking Consultant/Architect
Carl Walker, Inc., Frisco, Texas

Steel Fabricator
Schuff Steel Company, Phoenix, Ariz. (AISC Member)