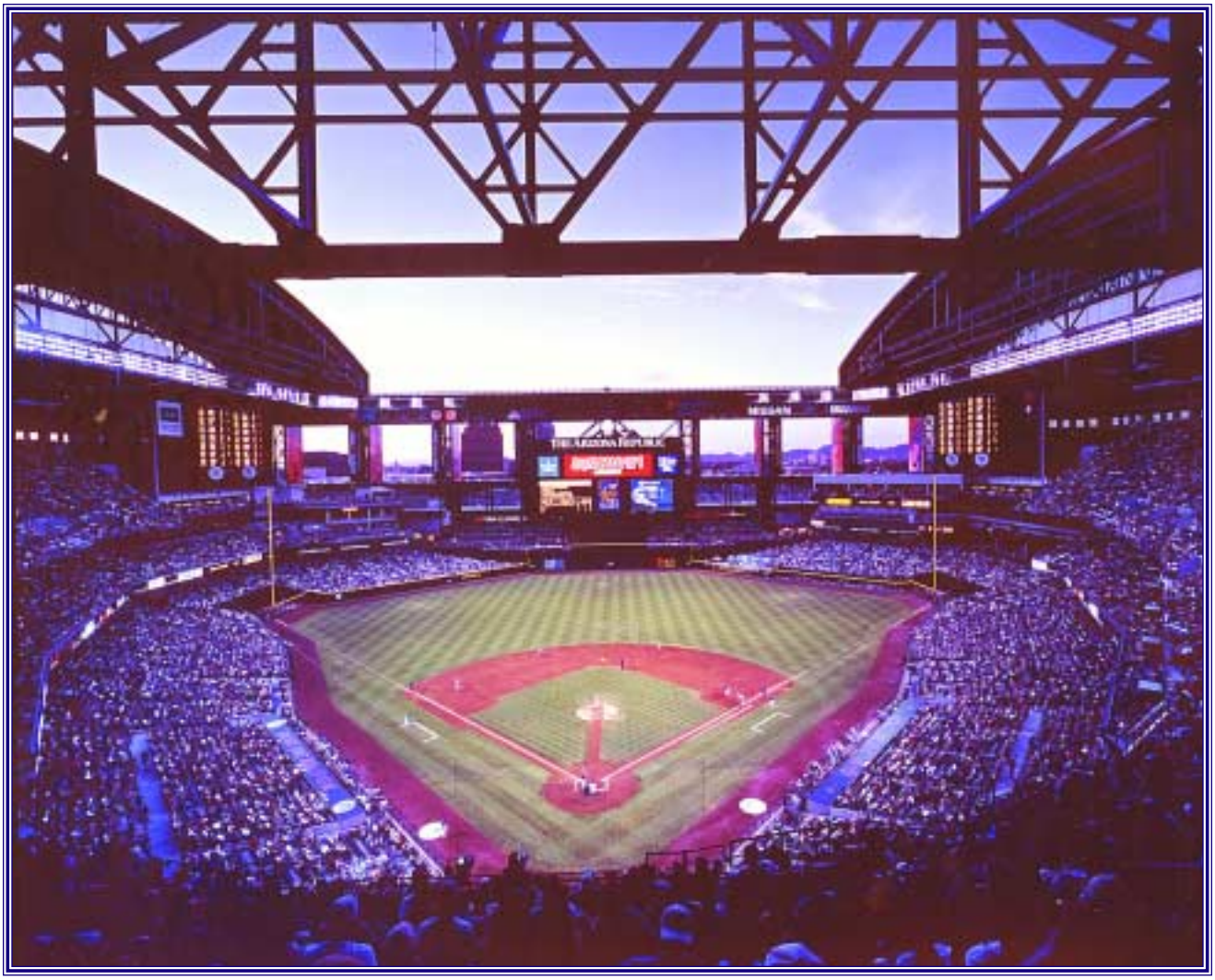


Arizona Diamondbacks Bank One Ballpark

Phoenix, Arizona

Kicking off a new trend in stadia design, the Bank One Ballpark, home of the Arizona Diamondbacks, features a moving roof. The 49,500-seat stadium, which rests on 24 acres of land in downtown Phoenix, has become both a tourist attraction and landmark for the city of Phoenix.

The owner's fundamental objective with Bank One Ballpark was to create a dynamic and unique home for the Arizona Diamondbacks baseball franchise. Not only did the stadium need to have its own special characteristics (including a swimming pool behind centerfield), but also it had to have natural grass and be air-condi-

tioned. In order to accomplish this, a stadium with a moving roof was designed and built.

The objective of the design team was to meet the requirements listed above and also to:

- Design a modern major league quality baseball stadium;
- Exceed the requirements for disabled access of the Arizona Disability Act Guidelines;
- Provide opportunities for revenue;
- Provide a facility that can be used for events other than baseball;
- Open for the 1998 baseball season;
- Incorporate the latest technology where appropriate.

Structural Considerations

A combination of steel and concrete was used to maximize the efficiency of the structure. While the overall frame was cast-in-place concrete supported on spread footings, the roof, roof support structure, cantilevered seating and exterior walls all were steel members.

In keeping with current stadia design trends, the Bank One Ballpark was designed to be reminiscent of an "old-time" ballpark. To capture the desired look, much of the steel—including the 40' cantilevered trusses—was left exposed. Additionally, the structure was designed to allow for large open concourses for fan comfort while also providing opportunities for revenue locations.

To satisfy the seemingly conflicting need for both natural grass and air conditioning, the structural engineering design team developed a moving roof stadium capable of closing during an event. However, the tight site prevented the design team from moving the roof completely off the stadium. This presented the design team with the challenge of combating "sunshadowing" on the natural grass playing field. This, in turn, created the design challenge of somehow reducing the height of the structure to compensate for the "sunshadowing." This was done by developing a telescoping and stacking structural system. This unique design is driven by a very economical and safe cable and winch drive system using gantry crane technology. The structural engineer of record worked very closely with the owner, architect, and construction manager to integrate the compressed design and construction schedule on the tight downtown site.

Unique Structural Features

To allow for maximum flexibility and sunlight control, each half of the roof can move independently. The roof is cable driven using gantry crane technology. Six telescoping panels are retracted in 4-1/2 minutes, revealing a 5.3-acre opening to the sky. Each panel is supported by the panel beneath it and moves on a steel wheel guide roller system. This piggyback arrangement reduces the structure height and allows the most sunlight to reach the natural grass field given the tight site limitations. A computer control system adjusts the roof opening similar to a camera aperture for the angle of the sun, allowing the maximum amount of light on the field and the least on the seats to reduce heat gain.

The moving panel system was also used as a construction aid, substantially reducing the need

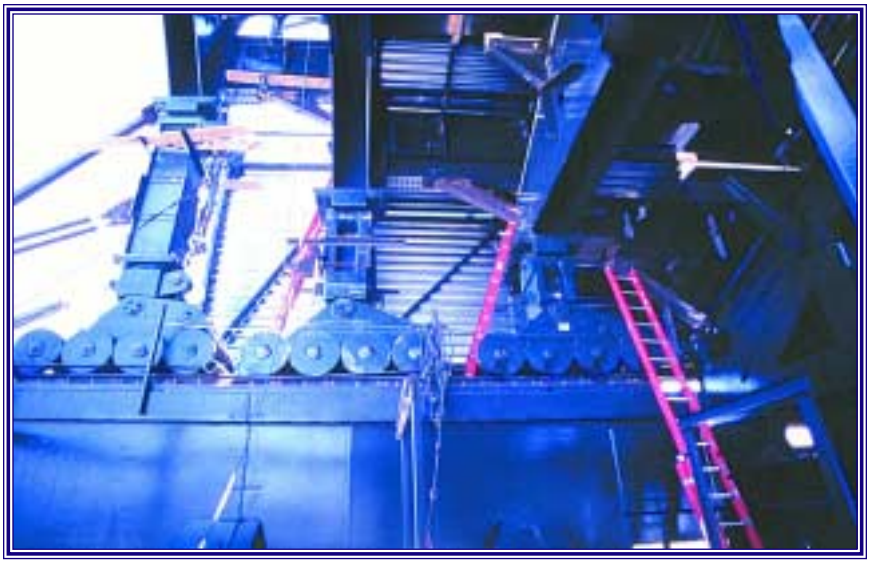
for shoring. Fixed panels were fabricated on the ground and lifted into place. The moving panels were then erected from this elevated "platform." The stadium bogie and rail systems were also used during construction to facilitate positioning and storing of panel sections. The six 800-ton panels are pulled by 4 miles of steel cable attached to two gearboxes and two 200-horsepower electric motors. To reduce the weight of the roof and its effect on the moving system, high strength steel (65 ksi) was used in the roof trusses. The low roof profile also reduced the size of the drive motors required to "drive" the roof into the wind.

Integrating the design and construction process was a huge challenge. The structural engineers spent the equivalent of 15 man-years on the design of the roof portion of the stadium. The compressed schedule was dictated by lack of funding to start design and construction until the baseball team was awarded to Phoenix and the inflexibility of the completion set for opening day. Design and design packaging decisions were dictated by the construction methods and construction schedule. To allow for safety and sequencing of concrete work, and, to eliminate the need to shore the overhead steel, the fixed steel roof trusses at the ends of the stadium were accelerated in design and erected before the concrete work was started. The stadium substructure (seating, concourses, etc.) was built after the roof sections were in place - this is the opposite of normal construction sequencing. Adding to the complexity was the tight site, bordered by streets on three sides and railroad tracks on the fourth.

As design started, it was determined an outfield wall would need to be constructed to support the roof and close the building for air conditioning. The roof's height would also need to be reduced as much as possible to compensate for "sunshad-

owing." The structural engineer reduced the height of the structure, compressing the roof to a total stacked height of 243' while achieving 200' clear above the playing field. Multiple loading analysis were performed on the loading conditions that change with the slightest movement in the roof. The number of load cases was magnified because of the desire to be able to position the roof at any location regardless of the weather conditions. The intense Phoenix summer heat added to the difficulty during construction by causing the steel trusses to expand and contract daily by several inches. The stadium roof successfully withstands thermal, wind and seismic forces; as well as the dynamic loads of the moving structure. Because the roof was designed to resist all of the required code loads at any position, opening the roof has become a game event.

Intricate computer modeling, well beyond the usual applied to building structure and accounting for temperature variation, moving loads, dynamic effects and changing geometries, became a vital tool throughout design and construction. The modeling included a nonlinear P-Delta buckling analysis linking the independent moving panels.



Jurors' Comments

"The use of a moving, long-span structure in a harsh environment is a significant achievement."

"A simple and elegant solution to a complex problem."

"An engineering marvel, considering the configuration and space requirements together with the design tolerances and environmental conditions."

Engineering Significance

The $350 million Bank One Ballpark opened on time and met the total goals and concepts of the client. Meeting the opening day completion date was a huge accomplishment given the schedule and the fact that this was the first of its kind. This was a result of the extraordinary efforts of the design and construction team. The engineering that was done at the ballpark has provided baseball fans with a modern venue to watch major league baseball games. It is a very "user-friendly" stadium, and the engineering played a very significant role in that fact. Concourses are easily accessible, seating is comfortable, and the structure itself is very safe and able to provide numerous amenities.

Bank One Ballpark not only accommodated the specific parameters of a moveable roof that allows for natural grass and air conditioning; it exceeded all anticipated possibilities. The 40,000+ baseball fans that flood the downtown streets 80 nights during the summer months have revitalized the nightlife of Phoenix. This "Economic Engine," as the ballpark has been referred to, is estimated to have an annual economic impact of over $300 million to the downtown Phoenix area.

The scope of the project is demonstrated by the magnitude of construction requirements.

- The 49,500-seat ballpark was designed and constructed in 36 months;
- 1,250,000-sq. ft.
- Structure height: 250';
- Field dimensions: 335' right field; 328' left field; 376' power alleys; 407' center field;
- 69 luxury boxes;
- 6 party boxes;
- 4,400 club level seats;
- 1,200 field level club seats;
- 18,000 tons of steel;
- 60,000 cubic yards concrete;
- 5.5 acre opening over the field;
- Roof Size: 376,000-sq. ft.;
- Roof Weight: 7,600 tons (40.5 psf);
- Roof opens or closes in 4½ minutes;
- The structural engineer of record logged approximately 69,000 total engineering hours on the ballpark, 30,000 of which were dedicated to the roof.

Project Team

Owner:
Maricopa County Stadium District, Phoenix

Structural Engineer:
Martin/Martin, Inc.
Wheat Ridge, CO

Architect:
Ellerbe Becket, Inc.
Phoenix

General Contractor (joint venture):
Perini McCarthy & Perini/Tutor-Saliba

Steel Fabricators:
Schuff Steel, Phoenix
Zimmerman Metals, Denver
Mountain State Steel, Lindon, UT

Steel Detailer:
Schuff Steel, Phoenix

Joist Manufacturer:
Vulcraft