PARKING by DESIGN

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Parking structures at Germany's Cologne/Bonn Airport show that careful planning and thoughtful design can result in economical and aesthetically-pleasing solutions.

The recent expansion of the Cologne/Bonn Airport in Germany is typical of airport projects around the world. No longer is the requirement for a simple expansion of a terminal facility but for a total solution combining airside facilities, passenger terminals, expanded parking capacity and integrated rail services.

As passenger traffic grew beyond the capacity of their existing terminals, Flughafen Köln/Bonn retained the Chicago architectural firm of Murphy/Jahn to create a comprehensive design solution for a new terminal structure. Murphy/Jahn's assignment included not only the terminal but also a station for the InterCity Express, a railway link to the neighboring cities, a steel roadway structure and two parking structures designed to accommodate a total of 10,300 vehicles.

On similar projects of this nature the parking structures are often treated as secondary structures with little consideration given to their optimal design, aesthetic appeal and cost effectiveness. Murphy/Jahn's Senior Vice President and Project Architect, Steven Cook, was determined to integrate the parking structures into the overall terminal project in a cost effective manner. Working under the direction of Principal Architect, Helmut Jahn, the project team invested the time necessary to evaluate alternatives for the functional layout of the parking, visual characteristics, various cladding options and structural systems.

The project was divided into two separate parking structures to allow the parking to optimize the space available on the site and provide alternative parking fees based on location. The first structure to be constructed, Parkhaus 2, needed to be configured in a wedge shape to fit within the pre-existing roadway system, which was subsequently demolished. The site for Parkhaus 3 allowed for a traditionally configured rectangular structure. Ninety-degree parking bays were determined to be optimum for both structures with a parking bay width of 16 m (52.5′). Parking bay widths in Europe are slightly smaller than their US equivalent (60′) due to the smaller dimensions of the average vehicle.

To facilitate the speed of entry and exit from the garages, external ramps were chosen. Spiral ramps were selected for Parkhaus 2 as a function of site geometry and to facilitate the flow of vehicles exiting the facility. External step ramps were utilized for Parkhaus 3. No parking was accommodated on any of the ramps.

Project:	**Parkhaus 2 and 3, Cologne/Bonn Airport, Bonn, Germany**		
Parkhaus 2	160,000 m^2 (1,721,600 ft2)	6 levels	5,800 spaces
Parkhaus 3	110,000 m^2 (1,183,600 ft2)	8 levels	4,500 spaces

Aesthetically, the owner's desire was that the garages blend architecturally with the surrounding structures and not disrupt the view across the airport landscape. A stainless steel mesh, similar to that used on conveyor belt systems, was selected as the exterior façade treatment for both garages. The fine stainless steel mesh allows ample natural light and air to pass through and easily meets the German requirement of 33% openness (U.S. codes typically require 50%). The choice of stainless steel was appropriate in recognition of having been first developed in this area of Germany and the availability of several suppliers in the immediate vicinity. To further enhance the aesthetic appeal and avoid fire protection and mechanical ventilation requirements, 10 m (33') wide light wells were designed into the structure at regular intervals. These courtyards, providing additional natural light and air, are not enclosed by the stainless steel mesh skin, but rather by an ivy covered wire trellis to create the effect of distinct, smaller structures integrated within the total structure.

In order to optimize the cost of the structure, Murphy/Jahn requested the structural engineer provide alternative design scenarios utilizing cast-in-place, composite, pre-cast and steel framed systems. This request, studied by the structural engineer, ultimately claimed that a cast-in-place concrete structure was the most cost effective structure.

To prove the engineer's assumption, the project acquisition process was altered from a traditional design-bid-build scenario to a modified design-build approach. A comprehensive functional specification was developed and provided to a number of experienced contractors. The functional specification detailed the desired parking layout, the exterior cladding, the glass and steel stair and elevator enclosures, the courtyard configurations and standard railing systems. Each proposer was free to select the structural system and type of construction material that would be utilized in the completed structure. Selection of the contractor would be based on a combination of the proposed cost and the effectiveness of the proposed solution to address the requirements of the functional specification.

Numerous proposals were received from interested design-build teams. These proposals reflected all of the potential structural systems except conventionally reinforced concrete decks on a cast-in-place frame, which was considered too expensive by all proposers. In evaluating the merits of each competing system, the owner and project architect determined that weight of the composite system required excessive foundation requirements. Precast was examined as an option, but the lack of quality control and uniformity between precast panels created tolerance problems for the deck surface. A proposal to top the deck surfaces with 3 mm (1") of asphalt was rejected as not providing adequate waterproofing for the deck system. The request for the steel frame system, a composite floor slab on a stay-in-place metal form coated with a high quality epoxy membrane, received the highest quality ratings.

Interestingly, the steel option was also the least expensive system proposed for the project. DSD-Hilgers Bausystem GmbH was selected as the contractor for the project, and Werner Sobek Ingenieure provided the structural design for the specialty steel items (façades, trellises, stair and elevator towers). The Parkhaus 2 structural frame consisted of five supported levels utilizing a 10 m (33') by 16 m (52.5') grid with filler beams at 5 m (16.5'). The structural frame consisted of welded columns similar to European wide flange beams HE300Ms, girders were HE550As and filler beams were European I beams IPEA 550s. STE 460 European Standard "Fe E460" steel similar to ASTM A572 grade 65 steel was utilized. A floor-to-floor height of 2.85 m (9.3') was obtained through the use of a deck system that positioned the top of the stay-in-place metal form at the top of the top flange of the beams. This system developed by Hoesch Siegerlandwerke GmbH supports the metal deck on steel bars welded perpendicular to the web of the beam on the top flange. The bottom flutes of the metal decking are 205 mm (8") deep and 185 mm wide (7.3") on 735 mm centers (29"). Pairs of the perpendicular steel bars support the deck by fitting into a small channel on either side of the upper edge of each flute. The deck does not extend over the beam but is fitted with a cap in both the flute area and across the interface of the beam and the deck to prevent concrete spillage through the deck. Reinforcing bars are placed in the bottoms of flutes and in the deck itself. Shear studs are then located on the upper flange of the beam, and an 80-mm (3.1") concrete cover is poured over the metal deck to form the parking deck surface. The deck is then cured and sealed with an epoxy membrane. Conduit for lighting and parking control systems was embedded in the slab and stubbed through the metal deck for future connections. The deck is powder coated by the manufacturer to protect against corrosion.

For both Parkhaus 2 and 3 the structural members were hot-dipped galvanized and then painted with a two-coat 'Eisenglimmer' paint system to provide long-term durability and an attractive metallic appearance. The steel columns were placed on concrete footings utilized for the foundation system.

In order to lower the elevation of the top deck, Parkhaus 2 has one level of parking below the natural grade. This level is still considered open, as a berm was created down to the level allowing

natural ventilation. For code purposes, this lowered first level is considered as the actual grade level of the structure.

The woven stainless steel mesh skin was attached from the top deck down to the first supported level where it is attached to the exterior beam with a series of springs designed to hold the mesh taut against the face of the structure. For Parkhaus 2, two circular ramps at opposite ends of the structure provide for the flow of traffic into and off of the parking decks.

The average cost per space for above ground, open-deck parking structures in Germany at the time of the completion of Parkhaus 2 ranged between 15,000DM and 20,000DM (1DM = $.47US or a range of $7,050 to $9,400). Parkhaus 2 was completed for a total cost of $12,500DM ($5,900) per space including the membrane and a complex parking control system that tracks the location of available spaces for patrons. The efficiency of the design resulted in an average space per vehicle of 27.3 m^2 (290 ft^2/space).

As a rectangular structure, Parkhaus 3 reflected a more simplified design. It consists of seven supported levels with the same floor-to-floor height of 2.85 m (9.3′) satisfying the parking demand for 4,500 cars. The total height of the structure does not exceed the high-rise limitation of 22 m (72′) for unprotected structures. Just as in Parkhaus 2, a light well was introduced to avoid the necessity for mechanical ventilation and fireproofing of the steel frame. Interestingly, code requirements in this area of Germany are more stringent with respect to deck dimensions that equivalent U.S. codes. Both Parkhaus 2 and 3 were restricted to a maximum deck width of 70 m (230′), while in the U.S. any point on an open deck must be within 200′ of an open side allowing deck widths up to 400′ when both opposite sides are open. The frame for Parkhaus 3 was built utilizing a 5 m (16.5′) by 16 m (52.5′) bay without filler beams. The same deck system utilized in Parkhaus 2 was used in Parkhaus 3. A large external stairway and elevator facility extend out from the stainless steel façade while external straight ramps provide for vehicle traffic between levels. The simpler design of Parkhaus 3 resulted in an average cost per space of only 9,000DM ($4,230/space) and a parking density of 24.6 m^2 per space (265 ft^2/space).

The contractor issued a five-year warranty for the structure to the owner. Construction proceeded rapidly aided by the fabricated steel frame and the simplicity of the deck system. Mr. Fernando Kochems of DSD-Hilgers commented that "steel construction allowed us to utilize long spans and fewer columns than a comparable concrete building. For users, this means comfortable driving and parking. The columns have a relative small diameter, and together with long spans and open surface, the whole building conveys a transparent and secure impression on the user. The prefabricated steel columns and beams allowed a shorter erection period."

Flughafen Köln/Bonn has been extremely pleased with both the aesthetic appeal and functionality of both Parkhaus 2 and Parkhaus 3.

Steven Cook commented that Parkhaus 2 "was the best construction experience I have ever had. The specification was functional, there was a good list of parts, the fabricated steel arrived ready to erect and the deck forming and pouring moved smoothly across the structure. I don't understand why more parking structures aren't built using steel frames. We'd sure look forward to doing another one."

Helmut Jahn concurred when he summarized the project noting "during the design process, several construction systems including cast-in-place concrete, pre-cast concrete, composite systems and steel were considered for the structural system. The car park was designed to accommodate all structural systems, and the bidders were asked to propose the most cost efficient construction. The result of the bidding process showed that steel in conjunction with composite floor decks provided the most cost effective structure. Furthermore, steel had the advantage of prefabrication, ease of erection and appropriate aesthetics."

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