Figure 5. To accommodate overhead clearance requirements at Ualena Street, shallower-depth precast concrete guideway segments are used. Photo: Parsons Corporation.

superstructure in this area, the post-tensioning was slightly modified from the typical spans and consisted of four tendons per web, typically with twenty 0.6-in.-diameter strands per tendon and additional continuity tendons over the piers. Access for future inspections and maintenance is provided by access hatches through the bottom slab of the boxes or from span-to-span through-access "doghouses."

Special Piers and Foundations

In the urban area of Honolulu, pier placement became more challenging. It was preferable for each pier to be centered directly under the guideway; however, the ground space was not always available, and offset columns or straddle bents were needed.

The offset columns are often referred to as C-bents and L-bents, with the difference being the placement of the foundation. For a C-bent, the foundation is centered under the guideway, while for an L-bent, the foundation is centered under the column. The permanent, offset loads of the guideway to the column create significant flexural demands. The most efficient means of resistance is to provide post-tensioning; however, this option is inherently nonductile, which is not desirable in a moderate- to high-seismic zone. In the C-bents, if the tendons were bonded, the strain deformations in the strand would occur over the crack widths within the hinge zone. To overcome this challenge, the vertical tendons in the column were unbonded and avoided participation with the ductile portion of the column. Thus, in the current detail, the deformation in the tendon is distributed over the height of the pier.

L-bents were used when there was limited access to place a pile cap, and the most extreme case on the project occurred over the Aolele Canal. The design was originally envisioned as a straddle bent, but construction access was extremely difficult at this location, so the design team developed an L-pier solution. The dimensions included an offset of 17 ft between the center of alignment and the column, a 7 × 9 ft oblong column, and a 12-ft-diameter drilled shaft (**Fig. 6**).

Because Oahu is a volcanic island, subsurface conditions along the AGS corridor are quite varied. Several types of soil encountered on this project present notable challenges:

- Coralline detritus and coralline reef rock: These soil layers consist of the fossil remains of coral reefs and related debris and marine deposits. The soils can be very porous and weakly cemented, and therefore are not considered for tip (bearing) resistance.
- Recent alluvium: Thick, layered, continuous beds of fine-grained marsh sediments. These medium- to very-loose sediments include organic material, shells, clays, and silts. Total layer thicknesses in some areas, such as near Kalihi Stream, exceeded the boring depths.
- Ko'olau basalt: The oldest geologic unit, it generally consists of lava flows with mantles of cobbles and boulders.

In areas toward the west end of the project, basalt elevations were relatively shallow, resulting in shaft lengths on the order of 20 ft. These dry, shallow drilled shafts were generally installed using standard auger equipment, and were either 7.2 or 9.8 ft in diameter. In contrast, in Kalihi Stream, the maximum 9.8-ft-diameter shaft is approximately 350 ft deep, which at the time was the deepest shaft of its kind ever drilled.

Conclusion

The HART AGS guideway is an example of efficient, repetitive, and economical construction that is ideal for elevated

AESTHETICS **COMMENTARY**

by Frederick Gottemoeller

"Improving aesthetics always adds cost!" How many times have you heard that one? Well, here's an example where improved aesthetics *reduced* cost. The segment cross section was optimized by the design-builder to reduce the guideway's cost, but the resulting changes also improved its appearance. The shallower angles on the webs and the more definitively rounded corners on the box give the guideway a sleeker and more streamlined shape, making the structure more transparent and thus a more welcome component of the communities through which it passes. Such "twofers" are available more often than most people imagine. They should be the goal of all engineering refinement.

There is sometimes a tendency to make decisions based on the optimization of one part of a structure, ignoring the costs that it might add to other aspects of the construction. Following widely accepted rules of thumb is one way to fall into this trap. For example, everybody knows that shorter spans are more economical, unless the additional piers cost more than the savings on the superstructure. For this project, the conventional wisdom was that the Ualena Street segment would be more economical as cast-in-place construction, but the design-builder recognized that this choice would impose costs elsewhere in the project due to the need to redeploy the construction gantry. Instead, they developed an innovative way to use segmental precast concrete construction on Ualena Street. As a result, the guideway looks the same throughout the length of the light-rail transit system, giving the whole project a visual continuity that makes it a welcome neighbor in all the varied communities it serves.