The substructure of the new Clays Ferry bridge consists of a spill-through abutment, 6 piers varying in height from 39' to 199', a stub abutment and two barrier walls, one at each end of the bridge. These are shown in Fig. 1. The substructure contains 9,822 C.Y. of concrete and 1,205,875 lbs. of reinforcement. All of the substructure is to rest on solid limestone rock. The piers were designed as frames, Piers 1 and 6 are one story frames, Piers 2 and 5 are two story frames and Piers 3 and 4, the largest piers, are three story frames. Pier 3, the largest pier, is 199' tall, this is one foot taller than the tallest pier on the present Clays Ferry bridge. Piers 3 and 4 are the same height from the top of the footing to the bridge seat, but the footing for Pier 3 is deeper because the rock elevation is much lower at this point. By making the two large piers similar, the design was simplified and the construction of the piers should be cheaper. As you can see in Fig. 1, clearance is not a factor, and high water is not very high on the main river piers. Pier 3, the tallest pier, contains 3378.2 C.Y. of concrete and 230(608 Lbs. of steel. Pier 4 contains less concrete, 2803 C.Y. but more steel, 603,051 Lbs.

Fig. 2 shows an elevation and an end elevation of Pier 3. This is an expansion pier and a three story frame. The footing is 50' x 30' x 29' deep. Because of the quantity of concrete in the footing, we have shown a permissible keyed construction joint in the footing. This will allow the first pour to be 12' thick and contain 667 C.Y. of concrete. The second pour, 17' thick will contain 944 C.Y. of concrete. The footing is plain concrete without any reinforcement. It may be erroneous to call this a footing, it is actually a distribution block, to distribute the column load from the column to the rock foundation. No bending is anticipated in the footing. To have bending, the rock would have to settle and this is very unlikely. The A.A.S.H.O. Specifications states that reinforcement is not required in a footing on rock if the distance from the column to the edge of the footing is less than 3/4 the footing depth. The size of the column at the top of the pier is 8'-6" by 9'-0". Three faces of each column are beveled and the fourth face is vertical. The vertical face is the inside face of each column. The batter of the top section is 5/16" per foot, the middle section 1/4" per foot and the lower section 5/16" per foot. The columns at the top of the footing are 12'-8 5/8" by 16'-5 1/4". All three of the struts are 12' deep but they vary in width. The widths of the struts are one foot less than the corresponding width of the column. There is a 6" x 6" notch in the corner of each column. This notch runs from the top of the pier to just above the ground. This gives a pedestal effect at the bottom of the visible portion of the pier. The width of the struts are in the same plane as the inside of this notch. The piers are divided into ten 17' sections with a construction joint at each section. At each construction joint, there is a 4" raised key. The raised portion of the key comprises 1/5 of the area of the section. There is a rustication groove at each construction joint in the column. This is a 3/4" groove and gives a neater appearance to the joint. The vertical reinforcement is lapped and the longest bars run through 2 sections. The maximum length of any bar will be slightly over 40'.

Because the actual center line of the columns is sloped due to one of the faces of the column being vertical and the others battered, the frames were analyzed as sloping and as vertical frames. We obtained almost identical results.
from the two methods if we added to the moments obtained from the vertical analyzes the moments calculated by multiplying the lever arm between the actual center line and the vertical lines by the axial load. This method is less cumbersome than the sloping frame analysis and was used in the remaining piers.

Fig. 3 is a section of Pier 3 just above the footing. This section is taken below the 6" notch. The stirrups are Number 6 bars spaced at 12" centers. Each of the stirrups is one continuous bar lapped 12" at one corner. A field inspection of the present Clays Ferry piers showed vertical cracks in the columns. We are using Number 6 bars instead of Number 5 to try and eliminate these cracks. The dowels and the vertical bars are shown in this section. They are both Number 11 bars. 126 Number 11 dowels will be used. The clear distance to the stirrups is 2½". This clearance is the same in all the piers except Pier 4 which will be mentioned later.

Fig. 4 is another section of Pier 3. This section is taken through the 6" x 6" notch. About the only difference in this section and the lower one is the shape of the stirrup to clear the 6" notch and the reduced number of vertical bars.

A section through the lower strut is shown in Fig. 5. This strut is the same in Pier 3 and Pier 4. The dimensions are 11'-2½" at the top, 11'-11½" at the bottom and 12' deep. Because of the large shear in the strut, 6 rows of Number 9 bars spaced at 6" were required. One stirrup runs completely around the section for 2 of the 6 bars. The other 4 bars are made up of a W shaped bar that is shown in the middle of the strut. In some instances, when the contractors have built a cage of steel and raised it into place, they have had trouble with the cage being sturdy enough to be lifted. With the one bar around the section and if tied together securely, the cage should be fairly strong. The moments, as well as the shear, are large in the strut, 26 Number 11 bars were required in the top and bottom of the strut.

The section shown in Fig. 6 is the bottom of the column of Pier 4. This is the fixed pier and the moments were rather large. The wind blowing on the pier at 60° controlled most of the design of this pier. The 60° wind gave large moments in two directions in the columns of the pier. A large number of bars were required as shown in Fig. 6. One problem encountered in this pier was getting enough vertical steel in the pier. To keep the required space between bars, we used Number 145 bars. These are 1¾" round bars. Two rows of steel are required in each longitudinal side of the columns and one row at each of the other faces. These bars are lapped front to back instead of side by side as they are in the other piers. This gives more clearance between bars at the lap. To keep from bending these large bars and to keep the stirrups tight against the vertical steel, the stirrups dimensions are smaller in alternate lifts. In one section, the clear distance to the stirrup will be 2½" and in the adjacent lift, the clear distance will be 2½" plus the diameter of the vertical bar or 4¼". In other words, instead of bending these large bars out to get them firm against the stirrup after they get past the lap, the dimensions of the stirrup were reduced to bring the stirrups in contact with the vertical bars.

Fig. 7 is the same pier but the section is taken through the 6" notch. About the only difference between this section and the lower section is the stirrup. One stirrup will be tied to the outside row of steel and the adjacent stirrup will be tied to the inside row of steel. The vertical bars are still lapped front to back as shown in this section. By placing alternate vertical bars further from the outside face of the column, the moment of inertia of the section was reduced slightly. The moments in these sections were not as large as in the sections where the steel was close to the outside face, so this did not affect the design.
FIG. 5
Symmetrical about B

2' berels (typ)

37 bars N6 equal spaced

28 bars N5 equal spaced both rows

24 bars N5 lap with N5 both rows

2½ clear

26 bars N4 lap with N5 both rows

7 bars N3 equal spaced

7 bars N3 lap with N5 equal spaced

6'9" typical

28 bars N5 equal spaced both rows

37 bars N5 equal spaced

Bridge

FIG. 7