In a pier just completed the length of piles varies from about 40 to 106 feet, and they were placed with centres 11 x 12 feet apart.

The pile is reinforced with longitudinal steel rods, four of them, each five-eighths of an inch square, being set in piles 16 inches square and from 35 to 40 feet long, and eight rods each one inch square in piles 20 inches square and from 90 to 100 feet long.

In order to facilitate driving, the piles are given a taper, beginning about ten feet from the point, tapering to ten inches square.

In setting the reinforcement, soft steel wire, one-quarter of an inch in diameter, is wound spirally around the rods, with spacing for the wire of about six inches.

It may be of interest to state that one of these piles 20 inches square and 100 feet long weighs about 20 tons.

In designing such a pier it is necessary to drive test piles of wood in advance, so as to determine bottom conditions. Borings are also made. In the plans, the length of each pile is specified. If it turns out to be too long when actually driven to refusal, the top of the pile is blasted off with dynamite, and if it turns out to be too short, it is built up by concrete to the proper level.

A question may arise in your minds as to the difficulty of handling without marring such a long and heavy pile. On the contrary, with a proper pile-driving rig it is marvelous to see how deftly and safely the pile, grasped at three or four points by wire ropes, is dragged and lifted along the wharf or sometimes from shore to barge, and thence hoisted into driving position.

As a long pile, frequently 90 to 100 feet in length, goes into the air, it is most interesting to note what elasticity it possesses, shown by its bending and flapping like a monster whip, but straightening out most perfectly when it is set in the pile-driving frame.

Another question may arise as to possibility of fracture in hard driving. Here is shown the most astonishing result. Local engineers who have made observations during the process of driving have repeatedly confessed to us their amazement that the pile can stand the powerful hammering it receives with almost perfectly satisfactory results. Generally speaking, not a crack, big or little, is visible.

The top of the pile, during the driving, is protected by a rope cushion and a wooden block about six inches thick, and usually the point is not protected at all. It might be supposed that the point, under such circumstances, would spread out or mushroom, but such is not the case, even in hard compacted sand or clay.

In sea-wall construction, however, where we first put in at base a loose rock fill and then drive such piles through the rock as supports for the deck or bulkhead wharf, a hole is made for the pile by driving a wooden "bull-dozer" ahead of it, and the point of the pile is often protected by a steel shoe.

Thus far we have driven piles only into good, firm holding ground, securing usually a penetration of about thirty to forty feet.

Much of our water-front is very soft mud, running frequently to a depth of 100 feet or more, before stiffness is found, and in such regions the concrete pile has not yet been used.

Sometimes the depth of the water at the outer end of our piers puts a limit on the length of piles practicable in such locations.

Results already obtained in handling piles up to 106 feet long and 20 inches square are encouraging us to try even larger piles in some contemplated work, and very likely before long piles 115 to 125 feet long and 2 feet square may be tried. Of course, such piles will necessitate specially built drivers.

Comparing such concrete piles with concrete cylinders, it must be acknowledged that the piles to the lay mind give a most satisfying sense of real strength and durability. You see them made, you can examine them, you know whether there are voids or not, you see them hauled and lifted into position and stand hammering of tremendous force, and you go away with a feeling that that particular thing will stay put for a long, long time. You have all the gratification that comes only from ocular demonstration.

One does not get the same consciousness of sureness from the cylinder type, especially where the concrete cylinder is supported under the mud by wooden piles, which is necessary in the absence of a sufficiently hard bottom to sustain the loads.

Let us turn now to the cylinder form of concrete supports.

They may be divided into two main types as used in the harbor of San Francisco.

The first type was introduced about fifteen years ago and has been entirely abandoned because of its deficiencies manifested by the lapse of time in many piers.

The composition of this type was as follows: Wooden piles, sometimes one, sometimes three close together, were driven to refusal, the tops coming up to near the wharf deck, then a wooden stave form of cylindrical shape was placed around them and driven into the bottom, no steel reinforcement being used, and then the concrete was poured in and allowed to set as best it might. Generally speaking, the mud was too deep to permit one to say that there was any bed-rock or hard bottom at all under this construction. Such cylinders were about three feet in diameter.

It will be seen that in reality this type could be best described as a wooden support, protected by concrete, because the wooden piles carried the load of the wharf and also sustained the concrete, the theory being merely to protect the wood from marine borers by the casing of concrete.

To be clear, I may add that these borers cannot live below the mud line, and, of course, it is well known that wood while covered by water or mud will last indefinitely.

The design of such cylinders, which almost uniformly proved failures, contemplated that the bottom of the concrete would extend about two feet below the mud line. The calculation was that this was sufficiently deep to guard against shifting or other removal of the mud, that might in consequence expose the wooden piles to the attacks of the voracious teredo.

This calculation proved futile. Modern vessels with their swift and powerful propellers, raised such a disturbance of the waters, that the mud was whipped or sucked away from the supporting wooden piles. The teredos thereupon honeycombed them full of holes in short order, and the concrete columns above them necessarily fell into the water. This was a common occurrence in piers so designed.

Such cylinders were all built without steel reinforcement, but the absence of the reinforcement was manifestly not the particular cause of failure in this instance, as the whole cylinder fell when the wooden supports were eaten off by the teredo.

Another serious mistake, with costly consequences, was made by pouring the wet concrete mixture into the cylinders without removing the water from the bottom of the form. The result invariably was that such wet mixture deposited in water never did set into true concrete