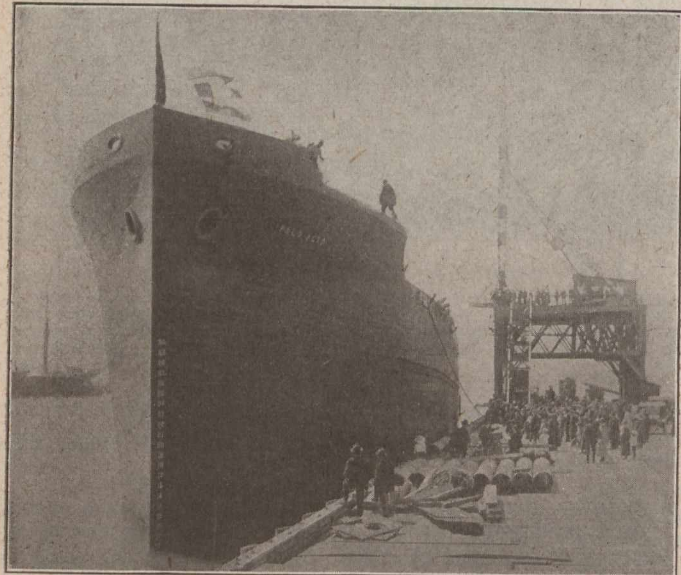
the present day. They have shown up many fallacies and have definitely shown that various by-laws have fallen very wide of their mark in the control of stresses, etc.

The fact was that if ships were to be made of reinforced concrete and were to comply with any of the existing by-laws and regulations, it would have been necessary for them to have shells at least 15 ins. thick, as compared with the 4 ins. finally adopted.

Tests of large reinforced concrete beams were started to make certain that no mistake was being made in using



REINFORCED CONCRETE SHIP, 7,500 TONS
U.S. government ship, "Palo-Alto."

the 4-in. shell. These first tests were made on: (a) Beams 4 ft. 4 ins. deep and 18 ft. 6 ins. long; (b) one beam 10 ft. deep and 22 ft. long; and (c) specimen ship frames of full-size cross-section and 20 ft. span. The frames were cut off at a point corresponding to the point of inflection, or 4 ft. 6 ins. above the top of the keel. The tests were made in the 10,000,000-lb. testing machine at the Bureau of Standards laboratory in Pittsburgh.

For the beams the load was applied at the centre of the span upon the upper flange. The beams were supported at each end on a steel plate girder. The beam 10 ft. deep was first loaded forty times with 640,000 lbs., which was four times as much as the maximum which the standards of the Joint Committee on Concrete and Reinforced Concrete would have allowed as its working load. The widest crack at the first application of this load was thirteen one-thousandths of an inch, and with forty repetitions of the load there was no appreciable increase in widths of cracks. The beam was then inverted and load was applied in the opposite direction, causing failure at 1,363,000 lbs., or nine times as much as the Joint Committee standards for reinforced concrete design would have allowed as a working load.

To about the middle of 1919, over 600 beams and ship frames were tested. These beams varied in depth from 18 ins. to 10 ft., and in lengths up to 20 ft. The tests involved over 20 items of interest, including bond, shear, etc. In regard to shear, a certain number of beams were made with webs reinforced against shear in various ways. In some, vertical stirrups alone were employed. In others, diagonal stirrups sloping upwards towards the supports were employed. In some others, diagonals in both directions, sloping both upward and downward towards the supports, crossing each other at an angle of about 90 degrees, were employed. And in still others, horizontal bars were also used.

The main tension and compression members of this series of beams were made strong in proportion to the webs, in order to ensure a failure by shear. The web thicknesses varied from 3 ins. to 8 ins., the main members projecting about 6 ins. on either side of the web.

In order to overcome the discrepancies which might result from the fact that the main members composed a rigid frame around the web, one series of beams without the webs was tested, and from the results obtained it was possible to deduce very closely the true shear value of the web.

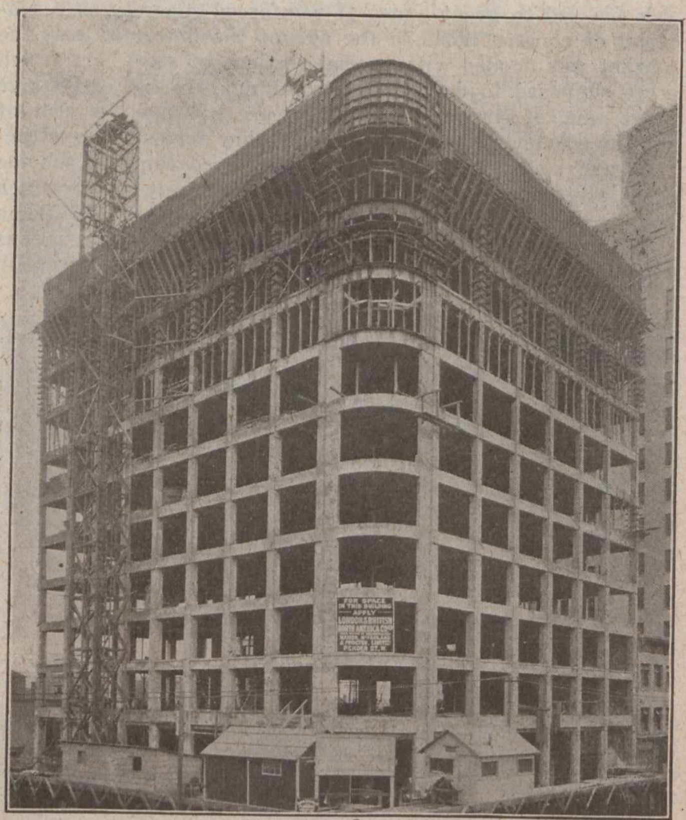
The failures were practically all shear failures as designed, and the diagonal cracks, no matter what the relation of depth to length, were inclined at an angle of about 45 degs.

The cracks in the specimens were very minute in width, so that it was necessary to paint them that they might show up properly in the accompanying photographs.

One of the accompanying photographs shows diagonal tension failure with small amount of web steel. Another shows beam with web reinforcement of sufficient amount to cause failure to the concrete by diagonal compression. Note the uniform spacing and the large number of cracks.

With the high percentages of web reinforcement, the diagonal cracks were finer and uniformly distributed over quite a wide area. With smaller percentages of web reinforcement, the cracks were fewer and further apart, and at the same time wider.

It was found that the shear carried was dependent upon two things: Firstly, the amount of shear reinforcement; and secondly, the diagonal compression strength of the concrete, values as high as 2,500 lbs. per sq. in. being



REINFORCED CONCRETE FRAME, BIRKS BLDG., VANCOUVER
Built in 1912. Cost 6.2 cents per cu. ft., in condition shown above. This photograph taken ten weeks after work started above level of ground floor. Area, 100 by 120 ft.

recorded at failure of a concrete having an ultimate strength in straight compression of about 4,000 lbs. per sq. in.

It can easily be seen that if all the shear is taken by the steel, the only limitations to the ultimate strength of the member are the amount of shear reinforcement and the diagonal compressive strength of the concrete in the web.

The arbitrary restrictions of the various by-laws, Ontario Railway and Municipal Board specifications, etc., limiting the shear stress under these conditions to such values as 100 or 120 lbs. per sq. in. on the concrete, are utter fallacy.

The tests carried out by the Emergency Fleet Corporation have distinctly shown that text book theories are largely at fault. Many people have the opinion that because something is in print in a text book, it must be absolutely