the top of the wall was held up. This surcharge of sand had been washed down against some of the form work from the slopes above and, of course, was heavily laden with water.

A few details, such as railings along the top, some sodding on the slopes, etc., remain to be completed.

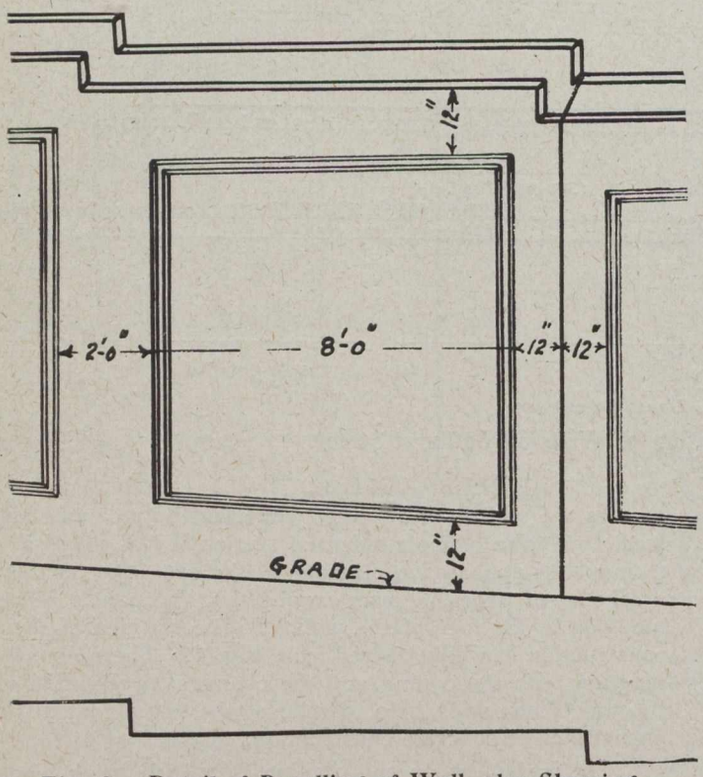

Fig. 6.—Detail of Panelling of Wall, also Showing Location of Expansion Joint.

The cost of the work will be approximately $260,000, and in view of the important bearing the street will have on the future of the city of Toronto the taxpayers' money could hardly have been better invested.

RAILWAY EARNINGS.

The following are the weekly railroad earnings for April:—

Canadian Pacific Railway.

	1916.	1915.	
April 7	$2,482,000	$1,766,000	+ $716,000
April 14	2,577,000	1,701,000	+ 876,000
April 21	2,343,000	1,623,000	+ 720,000
April 30	3,166,000	2,074,000	+ 1,092,000

Grand Trunk Railway.

April 7	$1,155,486	$1,008,320	+ $147,166
April 14	1,024,505	864,658	+ 159,847
April 21	1,059,661	869,772	+ 189,889
April 30	1,445,853	1,263,028	+ 182,825

Canadian Northern Railway.

April 7	$ 677,000	$ 457,000	+ $220,000
April 14	668,900	463,700	+ 205,200
April 21	634,000	442,300	+ 192,000
April 30	844,100	585,900	+ 258,200

The gross earnings for three transcontinental roads for the first four months of the calendar year show the following gains:—

Month:		
January	$14,724,216	+ $3,966,033
February	14,667,915	+ 3,237,879
March	17,344.243	+ 3,731.539
April	18,077,805	+ 4,959,127

DESIGN OF MASONRY AND CONCRETE ARCHES.*

By R. J. Williams, BS.C. (Eng.).

MOST masonry and concrete arches which have been erected in this country appear to fulfil the primary condition of strength and stability which every structure must satisfy. It is a rare occurrence for an arch to collapse, and this, perhaps, accounts for the fact that the theory of the arch is not better understood.

It is, however, doubtful if many existing arches have been designed with due regard to economy, and the cost may probably be much decreased, as explained in Table I., by a proper method of design. In view of the great number of bridges which will have to be rebuilt in different countries on the termination of the war, when money will be scarce, the design of arches ought to receive more attention from practical engineers than has hitherto been the case.

It is not proposed in this article to deal with the subject from the mathematical point of view, though most of the results have been obtained by mathematical calculations. Mathematicians too often leave problems at the stage when they begin to be of interest to the engineer, with the result that their investigations have not been of such service as they might otherwise have been. It has been considered preferable to give sufficient particulars to draw the necessary diagrams, so that the reader may verify the accuracy of the results obtained, and thus form an opinion as to the merits of the designs.

For reasons which will be stated later, the arches have been designed without backing or filling, and the effect of the horizontal pressure of the gravel on the extrados of the arch ring has not been taken into consideration. As the term "arch" is applied to both the arch proper and the complete structure (which includes the gravel), the arch proper will be called the "arch ring," wherever confusion would be likely to arise.

The stresses have been calculated on the usual assumption that the stress curve on a cross-section is a straight line, and the maximum stress is obtained from the formula:—

$$f = \frac{Q}{t}\left(1 + \frac{6s}{t}\right)$$

where f = maximum stress in lb. per square foot.
Q = normal thrust on a close section in lb.
t = thickness of arch ring in feet.
s = distance between the line of pressure and the centre line, in feet.

The line of pressure, to avoid tension in the arch ring, is supposed to lie entirely between the two middle third lines, but it is certain that the arch ring would not fail in tension at a section unless the maximum compressive stress on that section exceeds the safe compressive stress. The results of experiments on blocks of concrete asymmetrically loaded would be interesting.

The chief difficulty in the design of the arch is, probably, the determination of the position of the line of pressure. It must be a link polygon for the system of loads, but an infinite number of such polygons may be drawn by varying the polar distance, which represents the horizontal thrust, or by making the link polygons pass through different points in the cross-section at the crown. Hence the system of loads is not sufficient to determine the position of the line of pressure. If the arch

*"Surveyor," London, England.