With the spoil divided and placed well back from the trench, with excavation slopes of 1:1, and with drainage, there would appear to have been small possibility of slides; but even these precautions were not sufficient when the soft dark, waxy clay was encountered. This clay varied from a dark black to a pale gray color, depending upon the amount of drying it had received. When in its natural state it was very plastic and soft, but when air-dried it became extremely hard and showed great shrinkage. This stratum of soft clay occurred throughout long stretches of the trench and varied in thickness from 1 ft. to over 50 ft. In some places it occurred 5 or 6 ft. above invert grade, and in other places it occurred at the bottom of the excavation. In such places

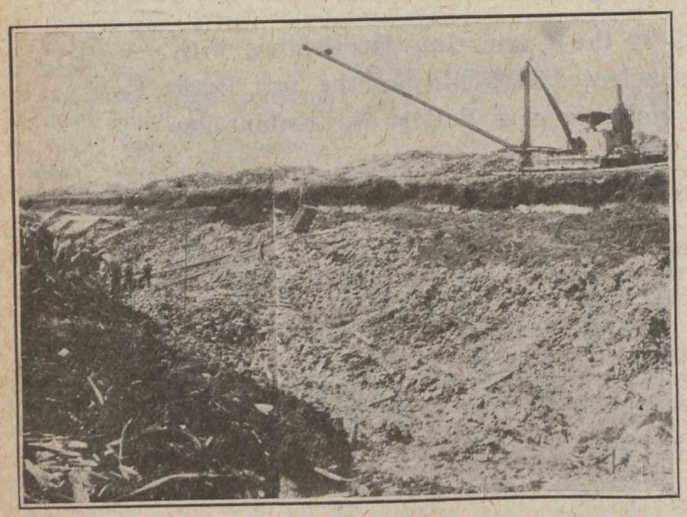

FIG. 5—TRAVELLING DERRICK REMOVING PORTION OF SLIDE ALONG CENTRE LINE

as the latter, heavy inverts and piling were used to carry the structure. The chemical analysis of this clay was as follows:—

Moisture and water of combination ..	15.10%	Chromic oxide	1.40%
Silica	34.75%	Calcium	5.30%
Iron oxide	15.20%	Magnesium	3.25%
Alumina	24.10%	Sulphates	2.90%

The accompanying table gives some bearing tests to show the difference between this soft clay and other materials encountered on the work.

Whenever this clay was encountered, movement of the trench walls took place. These movements varied from local sloughing, as shown by typical example in Fig. 2, to large slides, as shown by typical examples in Figs. 3 and 4. In the latter cases, the spoil bank appeared to settle vertically and to squeeze the material into the open trench. This had the effect of cracking the earth and allowing water to get into the mass. This water lubricated the earth and soon accumulated a head which tended to produce further motion. In addition, the water under a head forced its way into otherwise impermeable material and extended its lubrication. This combination of water pressure and lubrication kept the materials moving from time to time at various rates of speed, depending on the local conditions. As an example of the manner in which this clay transmitted vibration: The drag-line runner dropped a cubic yard of solid clay from a height of 10 ft. above the bottom of the trench, to the north of the structure, which was carried on piles (see Fig. 7). Standing on the opposite bank, 60 ft. away and 18 ft. above, one could feel the jar from the impact of the earth on the trench bottom.

The principal methods employed by the contractor to overcome these slides were:—

1. On the section of trench where the soft clay occurred near the bottom of the trench, and where the structure was carried on piles by use of special inverts, the sliding material was moved far back, an extra width of trench bottom was excavated (see Fig. 7) and the bank was sloped at a flat angle. This removal of the slide, as it were, meant the handling of large quantities of excavation, and later, of backfill.

2. Where firm material lay under the sliding materials, the method adopted was to flatten one slope and remove by the Class No. 24 drag-line such material as it could reach from the opposite side of the slide. This flat slope was allowed to drain and harden by air-drying. Then the final excavation along the centre line was made (as shown by Fig. 5) by means of a travelling derrick and hand labor. This method did not involve the handling of as much earth as did the first method, but it was only successful where the excavation was far ahead of the concrete work.

TABLE 1—BEARING TESTS ON VARIOUS MATERIALS, WINNIPEG AQUEDUCT

Area of pedestal, 36 sq. ins. Weight of pedestal, 121 lbs.

Under "Duration," read 17:16, "seventeen hours and sixteen minutes"; read 0:32, "thirty-two minutes"; etc.

Station	Foundation	Immediate (in feet) Under 3 Bags of Gravel	Immediate (in feet) Under 12 Bags of Gravel	Duration in hrs. and minutes Under 12 Bags of Gravel	Penetration in feet
4623+25	Dark gray clay* ...	.022	.082	17:16	.232
4637+80	Dark gray clay	.000	.013	1:18	.015
4677+50	*Soft dark clay .....*	*.006*	*.997*	*0:32*	*1.057†*
4679+80	*Soft dark clay .....*	*.234*	*.434*	*1:12*	*.966*
4769+25	Sandy clay	.031	.289	17:40	.457
4772+05	*Soft dark clay .....*	*.023*	*1.120‡*	.....	....
4800+00	Sandy clay	.015	.196‖	1:23	.324
4818+00	Bluish clay	.007	.059¶	1:48	.188
4831+50	*Soft dark clay .....*	*.022*	*.902*	*26:47*	*1.074*
4840+90	Blue clay with pebbles	.004	.382	18:32	0.459
4854+00	Blue clay with pebbles	.017	.077	28:35	0.100
4845+40	Blue clay with pebbles	.004	.116	4:40	0.181
5093+00	Yellow clay	.002	.011	17:35	0.036
5087+25	Heavy blue clay	.002	.009**	1:45	0.019
5078+00	Yellow and blue clay	.001	.028	8:32	0.050
5028+30	Grayish blue clay ...	.004	.032	19:53	0.052
5005+18	Blue clay with sand.	.003	.029	16:39	0.033

*Dark gray clay just under the muskeg; had a water-bearing sand stratum below the bottom of the invert.
†Resting on braces.
‡Platform and posts went down to braces before all bags were put on.
‖Water around base of post.
¶Trace of water around the post.
**Under 11 bags of gravel.

3. Pole-sheeting of the trench was used through a section of slide when the drag-lines were busy on other slides.

FIG. 6—SHEETING THROUGH SLIDE

This pole-sheeting and bracing is shown in Fig. 6. This was a slow method of work, as special overhead bracing was required to allow the steel forms to be moved along the trench. The overhead bracing used to hold the slides while the arch concrete was being poured, was not as heavy as the first bracing placed, as by drying out the material near the pole sheeting the pressures were reduced. This