survey parties, headed by the chief locating engineer of the company, Mr. H. K. Wicksteed, before the C.N.R. were certain that the standard set could be obtained. The construction work is finished now, and throughout the entire 1,016 miles between Montreal and Port Arthur, there is only ten miles where the gradients against east-bound traffic is 26 feet to the mile, or half of one per cent. That is located between Pembroke and North Bay. For the remaining 1,006 miles the line has been built to a standard which allows a rise of only 21 feet to the mile against trains moving towards the Atlantic and 26 feet to the mile against equipment moving in the opposite direction. The Sudbury-Port Arthur division is claimed to be one of the longest stretches of uniformly easy grades in the world, being comparable with that of the New York Central and the Michigan Southern between Schenectady and Toledo. But in the case of the Canadian Northern the way was through rough, unexplored territory, while the American lines traversed settled country, and run alongside the Mohawk River and Lakes Ontario and Erie for the entire distance. On the trunk line of the Canadian Northern between Toronto and Ottawa a high standard has likewise been adhered to. The maximum gradient in either direction is 26 feet to the mile.

THE ACTION OF WATER UNDER DAMS.

THE results of a study of the action of water under dams was undertaken by Mr. J. B. T. Colman at the University of Michigan, and presented in a paper before the American Society of Civil Engineers on September 15th. An attempt was made to investigate the relation existing between the height of water on the face of a dam, the length of the base of a dam measured perpendicular to the face, the distribution and upward pressure on the base of the structure, and the effect of sheet-piling placed at the heel and at the toe of the dam. In procuring complete data for the determination of the foregoing factors, a second field was entered: that of the relation existing between the elements just mentioned, the porosity and effective size of the sand grains, and the resulting movement of the water through the porous medium.

In the discussion accompanying the presentation of his results, the author points out that the principles governing the action of water under pressure in the sand forming the foundation of any structure, such as a weir or dam, may be compared with the action of water in a large number of small pipes. The upper ones would represent the sand layer adjacent to the weir floor, the second ones the next lower layer, and so on, until in a sand of relatively great depths the tubes representing the lower layers would have a length many times that of those in the first layer. These imaginary tubes extend from different points in the floor of the reservoir to points at various distances down stream from the toe of the weir.

Lines of Equal Pressure.—In taking up the discussion of the equal-pressure contours, dams without sheet-piling at the heel or toe are first considered. All lines of equal pressure start from the lower surface of the floor of the dam and extend in directions varying from nearly horizontal up stream to a similar position down stream from the structure. These lines naturally fall into three divisions: The first, or higher-pressure contours are relatively closer together, and, in carrying out the pipe analogy, would be comparable with entrance pressure. The difference in pressure between any two contours represents loss of head, and is comparable with entrance loss in pipes. The second division comprises the contours through the body of the sand. They are quite uniformly spaced, and are comparable with the loss of head in pipes due to friction. The third division is that of the lower-pressure contours, which are closer to one another and indicate a greater loss of head in the last portion. Thus it is seen that in any element of water which passes from above the dam to a position below the structure, there is, through entrance eddies in the first division, a comparatively great loss of head. After this, the flow lines become nearly parallel, and head is expended at a uniform rate until near the vicinity of exit from the sand particles. Here eddies again break up the flow lines and tend to resist the exit of the water from the sand.

Lines drawn on each diagram perpendicular to the pressure contours would indicate the paths followed by the particles of water from point to point, and show the distribution of flow. These lines would be much closer to one another just below the floor of the dam than at greater depths. This indicates that the flow is greatest near the floor and decreases with the depth.

By comparing the pressure diagrams for different lengths of floor, it is shown that the shorter floors give the greater entrance loss. It is also noticed that the flow lines in the shorter floor diagrams are concentrated near the floor more than in the longer ones. In this case there are but few lines, and a resulting small flow at greater depth.

Turning to the pressure diagrams of sheet-piling at the heel only, and comparing them with those of no piling, it is observed that the higher-pressure contours extend from the piling forward in nearly horizontal lines, and that the succeeding contours are moved forward, showing reduced pressure throughout the foundations. Short contours, back of the piling and extending from the piling to the floor, indicate a region of very small movement of water.

The greater number of flow lines follow down the face of the piling to its lower end. Here they turn down stream and rise to the surface at some distance beyond the floor of the dam. At the end of the piling they spread out fan-like through nearly a quadrant, a few turning vertically upward back of the piling. By far the greater number, however, approximate the shortest path from the bottom of the piling to a point a short distance beyond the floor. The piling increases the length of the flow lines, but exposes a greater depth of soil to the attack of the water. This, in turn, necessitates a less degree of concentration beyond the piling, and offers less resistance to the movement of the water.

To make the piling at the heel effective, it must be water-tight. It was found that a very small leakage through the piling destroyed its effect. To eliminate the increased upward pressure, resulting from the toe piling where used, the latter should be loosely driven, in order that the flow may escape.

The experiments demonstrate that the pressure decreases from point to point in the direction of the flow lines. It is also seen that the pressure decreases with the depth in front of the dam; but, beyond a certain point, which varies, if piling is used, the pressure reverses itself, being greater at a depth than nearer the floor of the dam. This lower pressure tends to continue in straight lines, and disappears only after travelling a relatively great distance.