Corrugated steel or iron pipes have been used extensively where lack of suitable materials or labor prevent the making of concrete pipes. These can be laid in places where it would not be suitable to lay concrete pipes. We have also used semi-circular reinforced concrete culverts cast in place with success. These cost about the same as the corrugated iron pipes. We seldom use pipe culverts of over 30-in. or 36-in. diameter. Above that we advocate reinforced concrete box culverts.

Careful Designing Necessary

All bridges should be designed by competent engineers. The design of ordinary steel bridges is so well standardized that there is very little difficulty in getting a suitable bridge after the loads that it may be called upon to carry have been decided upon. The fixing of the proper loading will require careful study, but in the end it must remain largely a matter of judgment. The tendency up to the present has been to increase the weight of loads carried on highways. Many bridges have been discarded recently owing to the fact that they were not heavy enough for present traffic. In western Canada, the heaviest likely load appears to be a large tractor. In Manitoba, we design our floor system for a tractor load of 18 tons, plus 30% impact, and our trusses for this tractor, or a load of 100 lb. per sq. ft., whichever produces the greater stress. The tendency appears towards lighter tractors, rather than towards heavy ones. Before these bridges are worn out, however, some of them may be called upon to support heavy truck loads, but it is doubtful if these will ever exceed 18 tons.

The design of the foundation is most important. The bearing power of different soils varies so greatly, and similar soils vary so greatly under different conditions, that careful examination must be made of the soil in order to properly design a foundation. It is a strange fact that there are probably less data on the variable factors in the behavior of soils than on most other materials of construction, and, therefore, the assumptions made in the design of foundations is largely a matter of experience and judgment.

The design of reinforced concrete structures is not so well standardized as the design of steel bridges, and structures should not be considered which have not been designed by a competent and experienced engineer.

Importance of Close Inspection

Proper construction is just as essential as proper design. Great care must be taken in the selection of the material. For steel bridges the material rolled by steel mills is so nearly standard that for ordinary bridges there need be no hesitation in accepting structural shapes. But in order to eliminate poor field riveting, enlarged rivet holes made by drifting in erection, and other faults which may produce stresses for which no provision has been made, all shop work should be carefully inspected before the material is shipped to the job.

In reinforced concrete work the inspection must be more rigid. The cement should be subjected to standard tests before it is used. The making of cement is a delicate process, and any one of several factors entering into its manufacture may cause a variation in the product. Especial care should be given in the selection of the aggregates; these must be well graded and absolutely clean. It is probable that more failures occur through the use of improper aggregates than from any other cause. The water used must be clean and just the right proportion used. Prof. Abrams has shown that the proportion of water to cement is one of the big factors affecting the strength of concrete. The amount of water used should be just enough to make a workable mix, and any greater proportion of water rapidly decreases the strength of the concrete. There is only a certain amount of water required to cause the setting up of the cement, and it is quite evident that any amount beyond this, when it has dried out, leaves voids in the concrete.

The inspection of the steel is also very important, not only to discover quality, but to ensure that the bending is done according to plans. It is a common idea that any sort of steel will do for concrete reinforcing, but such is not the case. This steel is designed to take its share of the stress fully as much as the steel in a steel bridge. It must occupy the exact space it is designed for, otherwise it is of no use in the structure. For this reason the bends shown in the plans must be strictly observed.

Care in Construction

It is also important to have experienced contractors for concrete work, and inspection of construction is just as impoortant as inspection of the material. This inspector must be a man who knows his business better than the contractor, and who has sufficient tact and judgment to get the work properly carried out without undue hardship to the contractor. It is a mistaken idea that any person will do for an inspector.

The form work is very important in concrete work, as it must be strongly built to withstand the pressure which will come upon it. It must also have a smooth surface, for every flaw in the forming shows up in the finished structure. Careful ramming of the concrete is necessary in order to make a dense concrete, to prevent voids forming next to the forms, and to ensure a close bond between the concrete and steel.

In these days of specializing, transportation is second in value only to production, and only within the last few years have most people realized the vital part that the road plays in our transportation system. At a time of shortage in the prime necessities of life, when the world teeters between enough and starvation, our market highway system is of greatest importance. The bridge is the important link in this system. Nominally, the bridge serves to carry water under a road or traffic over the stream. Actually, its possibilities are unlimited. Its existence may mean a supply of food to a starving being on another continent, or the difference between life and death to a sick one, or the difference between hope and despair to a toiler. Its appearance may be the cause of pleasant fancies, or it may be the cause of a feeling of repulsion. Let us, therefore, in our bridge work, do what we can to cause pleasant thoughts and create pleasant memories, and in this work, as in all our highway work, build well.

MONEY SPENT ON HARBORS SINCE CONFEDERATION

A RETURN recently tabled by Hon. A. L. Sifton in the House of Commons, sets forth the amount of money spent on the different harbors in Canada since Confederation, as follows:—

The Department of Marine and Fisheries, to December 31, 1919, had expended through harbor commissions the sums of $28,785,308 at Montreal and $10,809,807 at Quebec. Nothing was spent in this way at Vancouver.

The Department of Public Works spent the following amounts:—

Halifax, $75,569.64. Terminal facilities at Halifax were paid for by the Department of Railways and Canals.

St. John, $14,636,146.93.

Quebec, $12,060,263.92, including Louise Basin, two graving docks and St. Charles River works.

Montreal, $5,978,324.73.

Toronto, $6,014,259.76.

Port Arthur, $4,078,457.15.

Hamilton, $587,336.98.

Fort William, $8,790,408.65.

Victoria, $6,928,919.10.

Vancouver, $4,410,450.49.

The Intercolonial Railway expended the following sums at Halifax and St. John:—

Dredging at St. John, $28,584.05.

Wharves at St. John, $457,807.02.

Wharves at Halifax, $1,453,948.59.

Dredging and blasting rock at Halifax, $128,896.99.

Removing boulders, Halifax, $11,453.21.

Ocean terminal docks, Halifax, $6,799,235.71.

Total I.C.R. expenditures for both harbors since confederation, $8,879,927.57.