of construction may be used for practically the same spans as stated for the plain concrete arches.

Footings for piers, abutments, and wing walls may be required for the purpose of distributing the pressure caused by the weight of the completed bridge structure and its "loadings" over a sufficient area to keep the pressure per square foot within the amount that will be carried safely by the material composing the foundation. In some cases, where the wall is designed for a gravity section—that is, without reinforcement—no footings will be required. This occurs, for example, where the side walls rest upon rock for a foundation. If the wall is of the reinforced-concrete type, then footings are practically always required. The cause for many broken wing walls is the lack of suitable footings under them.

As a matter of practical convenience in construction, footings are very generally built to "true up" uneven places in the foundation, and they are built up to some convenient elevation upon which the walls or piers rest.

The width of the footing is determined from the load to be carried and the bearing power of the foundation material. Its depth is determined from its width and the load carried; and, if constructed of plain concrete or masonry, its depth should be equal to its projection from the pier or wall, or even greater. The depth of the footing required to carry a load may be reduced somewhat by the use of steel reinforcement placed near the bottom to strengthen the projecting portions of the footing.

Another consideration that must not be overlooked in the construction of the footings is their liability to be undermined. They may, however, be protected by "riprapping" or paving around them, or by "cut-off" walls across the stream to prevent erosion of the stream bed at the location in question.

In view of the practice of the past, there is great need for the consideration of the subject of abutments and wing walls.

In many cases abutments and wing walls have not been built at all, but the four corners of the bridge span have been set on cylindrical piers or posts with possibly only a few planks to hold the earth approach. The rapid destruction of the planks and consequent sinking in of the earth approach often make dangerous holes at the two ends of the bridge. This type of construction is defective in the fact that it does not protect, but subjects the bridge and also its approaches to a greater possibility of being washed away by high water and swift currents. The damage thus caused is often more than the amount required to build substantial abutments and wing walls.

The abutment serves a twofold purpose: First, it supports the end of the bridge span resting upon it; and, second, it acts as a retaining wall for the material composing the approach to the span. The wing walls, too, serve as retaining walls and as a protection to the banks or slopes of the approach to the bridge from erosion by the water currents.

The abutment must then be designed, first, to support its load after the bridge is in place, and, second, to act as a retaining wall to resist the overturning forces of the material back of it before the bridge span is placed in position.

The wing walls must be designed to act as retaining walls. It is not the purpose of this publication to give a technical treatment of the principles of design, and it may be sufficient to say that, as a general principle, the thickness at the bottom of a retaining wall should be at least 40 per cent. of its height. This thickness should be increased if the wall is surcharged—that is, where the filling back of it is higher than the wall.

Piers.—The discussion of the subject of piers falls properly under the question of economic design. Whether or not it is economical to construct piers depends upon the relative cost of the different spans, and also upon the size of the piers required. The area of the waterway and the liability of piers to destruction by ice jams, logs, or floods, and the kind of foundation available are important matters and any one of them may be a controlling factor in the design.

From two designs for a concrete bridge with a 40-foot span and a 20-foot roadway a difference of about $200 in the cost of the superstructure alone appears in favor of building two 20-foot spans, instead of one 40-foot span. From this amount the cost of the centre pier must be taken to determine which is the more economical plan. Estimating the cost of concrete at $8 a cubic yard, including forms, it is possible to use 25 cubic yards of concrete for the centre pier. This would limit its height to about 8 feet in order to make the cost of the two structures about the same.

ELECTRIC CRANES FOR STEEL MILL SERVICE.

By E. Friedlaender.*

The rapid and cheap handling of all kinds and sizes of material by means of electric cranes has greatly influenced the making of steel products and helped considerably to reduce cost. One man can produce only about 33,000 foot-pounds of work in ten hours, where by means of a crane the same man could perform easily ten times as much work in the fraction of one minute.

Electric cranes are not nearly so wasteful in power consumption as hydraulic cranes; power is used in direct proportion to load lifted; on hydraulic cranes, however, cylinders have always to be filled, regardless of whether the hook is handling full, light, or no load. Nevertheless, the large number of gears, shafts, bearings, ropes, etc., on electric cranes cause a great amount of frictional resistance, which should not be overlooked. Good lubricated cut gears have an efficiency of from 96 to 98%, but when dry worn and out of alignment as low as 92%. Each bearing causes a loss of from 1 to 7%, according to lubrication and alignment. Rope stiffness reduces efficiency from 1 to 3%, depending on the diameter of sheaves and drums.

The total mechanical efficiency of electric cranes hardly ever exceeds 65 to 75%, and, together with electrical losses in motors, controllers and conductors, brings overall efficiency down to 50 to 60%. It is, therefore, very important to use the least number of shafts, bearings and gears possible to reduce dead weight to a minimum, and, last, but not least, keep all frictional surfaces properly machined, aligned and well lubricated. This will not alone decrease power consumption, but at the same time reduces considerably the cost of maintenance and repairs of motors and controllers. The wrong application of brakes can also greatly increase power consumption on cranes and punish severely all mechanical and electrical parts. Motors should not work against friction of brakes, but be released from it on the first step of the controller. This is easily accomplished by the use of magnetic-actuated brakes, but is entirely dependent on the skill of operator with hand or foot brakes.

More important yet is the proper speed control of crane motors; their rapid starting, stopping and reversing by unskilled men is not only very wasteful in power, but also very hard on all machinery, especially electrical. The best

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