holidays. This cantilever arm was completed in over 25 per cent. less working time than was taken for the north cantilever arm, and over a month ahead of schedule time. With the completion of the south cantilever arm the bridge is in readiness for the floating in and hoisting into place of the suspended span. This span is 640 feet long, 88 feet wide, and weighs in the floating-in condition approximately 5,000 tons. The erection of this span has proceeded simultaneously with that of the south cantilever arm and it is expected that it will be placed in its final position in the bridge during the early part of September, 1916.

The work is being carried out under the supervision of the Board of Engineers, Quebec Bridge, composed of Messrs. C. N. Monsarrat (chairman and chief engineer), Ralph Modjeski and H. P. Borden.

The St. Lawrence Bridge Company is the contractor for the superstructure, George F. Porter being engineer of construction, W. B. Fortune superintendent, and S. P. Mitchell consulting engineer of erection.

FORMS FOR CONCRETE WORK.*

By R. A. Sherwin.

NUMEROUS cost-analysis diagrams prepared in our office from the actual costs of average reinforced concrete buildings of the industrial type, not taking into account the cost of any equipment, show that the labor on forms averages about one-third the labor cost, and the lumber about one-tenth of the total material cost, including sub-contracts. The total labor cost is usually about 35% of the cost of the building. The design and erection of forms is, therefore, the most important single item in concrete building construction and one upon which much thought and study can be well spent.

Economical forms must be designed as light and with as few sticks as possible to give the necessary strength and stiffness. You will note I say "Necessary," for this is the point to keep in mind. We must remember on the one hand that human lives and the cost of failure, both in money and reputation, are dependent upon the design, and, on the other, that forms are temporary structures loaded fully for a short time only. A low factor of safety is therefore allowable.

The main question, then, is one of strength with enough stiffness to prevent any appreciable sags in the finished concrete. Any slight deflection that might occur in the timbers themselves is taken care of in the camber always given horizontal members in erection.

The floor timbers should be designed for the full live and dead load, but any serious deflection will be caused only by the dead weight of the wet concrete. The full live and dead load can act together for only a short space of time. Therefore, I think that limiting the centering by small deflections and using full live and dead load is questionable practice. One place where deflection should be carefully guarded against is at the window-head. At this point a slight deflection will cause much trouble and expense in setting the sash.

The principal cause of settlement of form work is crushing of the soft spruce or pine lumber perpendicular to the grain in the girt over the post, and also in the adjustment of the wedges under the posts as the full load is applied. In this connection, Professor Johnson, on page 468 of his "Materials of Construction," says: "Since timber is very weak in crushing across the grain, as compared to crushing endwise, this is found to be one of the most common methods of failure in practice. It is common to rest a timber column on a sill of the same wood and to design the column for its maximum working load, paying no attention to the utter inability of the sill to carry this load without crushing. Many failures of timber structures are due to this cause alone." An average safe value to use in form design for this crushing stress, as determined by numerous tests, is 400 lb. per square inch for spruce. Considering this stress, a 4 by 4-in. spruce post under a 4-in. wide girt is good for 6,400 lb. The trouble due to wedges can be almost entirely eliminated by using large hardwood wedges. If the posts are cut square at the ends to give an even bearing and heavy wedges used to bring the posts to grade, no settlement will occur.

Posts are usually placed on a plank sill. When these sills are laid on the ground great care is needed in order to avoid settlement because of deflection in the plank when a hollow place comes under the post. This often occurs when sills are placed on frozen ground, and salamanders thaw out portions of the surface and cause soft places under the sills. When light sills are placed on a rough concrete floor, deflection is liable to occur unless care is taken to give the sills an even bearing. For these reasons I believe that limiting the floor timbers to small deflections and at the same time using high loads on the posts is not consistent, and surely not economical.

Design.—The first thing to be done in preparing a form design for a concrete structure is to make a careful analysis of the plans submitted by the engineer. This should be done as soon as the preliminary plans are available, for many details which seriously affect both the progress of the work and the cost of the forms may be brought to the engineer's attention and changes made for the benefit of the owner. These points are often overlooked by the engineer, who does not always look at the structure from the construction point of view. Chief among these points is that of story heights. It is desirable that these heights be kept uniform throughout the building so that the column forms can be re-used from story to story without either cutting off or splicing. Failing this, it is better to have the high stories at the bottom, as cutting off forms is much cheaper than splicing them.

Another important point is that of joints. I refer only to construction joints. These should be planned and the reinforcement detailed so that the forms can be erected in the simplest possible manner. These joints should, of course, come at a natural stop for a day's work and be located so that they will least affect the appearance of the finished structure. The position and detail of any expansion joints should be determined early, as they will affect the form design and probably require special study.

An example of a detail to be considered in connection with the question of joints is the important one of making the dowels for the column rods long enough so that the necessary lap will come above the point where the column forms will actually start. For example, it is not uncommon to find a wall beam, which comes above the slab, detailed so that it must be cast with the floor, but at the same time to find the lap for the column rods shown above the top of the slab instead of above the top of the wall beam, as it should be. It is economical to cast a curtain-wall beam, used sometimes in mushroom construction, as a later operation. The forms can be made and erected more cheaply. This can easily be arranged for by providing pipe sleeves through the column to take the

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* Abstract from paper presented at the convention of the American Concrete Institute, Chicago, February, 1916.