A DESCRIPTION OF THE ERECTION AND OPERATION OF SLIDING FORMS IN GRAIN ELEVATOR CONSTRUCTION.

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Introduction—Earlier types of elevators—Elevator construction—Sliding forms—Lifting mechanism—Reinforcement—Concrete plant—Scaffolding—Jacking—Concreting—Plumbing—Openings—Difficulties—Removal of forms—Cost—Conclusion.

Introduction.

The whole subject of Grain Elevator Construction is a fairly comprehensive one, and, to one who has had to do with it, extremely interesting; first, because an engineering firm of contractors usually does everything, including design, excavation, construction and installation of machinery; in fact it usually receives the first shipment of grain and runs it through all bins, spouts, scales, dryers, cleaners and belts to test all working equipment and, incidentally, to clean down remnants of concrete and construction debris; and, secondly, because the subject of the efficient handling of solid substances, which are almost liquid in their action in bulk, in such a way that it can be properly in and out weighed and easily transferred from any one place in the system to any other, is always interesting from an engineer's point of view. The terminal elevator system of Montreal is such, that grain can be freely shipped from one elevator to another and from either elevator to any of the fifteen ship berths, by starting a few motors and opening a few valves. In this paper, however, only one portion of elevator construction will be dealt with, which, up to the present, is a form of construction almost peculiar to grain elevators, and that is, the construction of bins or tanks by means of sliding forms.

Earlier Types of Elevators.

The earlier elevators had their bins built of cribbed timber, ten or twelve inches by three or two inches. In fact some very small elevators are still built in this manner. However, as timber became more expensive, and in view of the facts that it was eventually destroyed by dry rot and the danger of fire was great, this method of construction was abandoned. Steel bins were then tried, but they, on account of expense and structural

and other difficulties, were also more or less abandoned in favour of reinforced concrete. Bins built of reinforced concrete are permanent and fire proof, and, on account of the low conductivity of concrete, act almost as refrigerators. The walls, both exterior and interior, were at first built with movable forms, that is, one set erected and the concrete poured, a second set being then erected and the concrete poured, after which the first set was removed and erected on top of the second set and so on. This proved laborious, expensive and slow, and made walls that were not monolithic. Finally the sliding form was evolved and this method has proved satisfactory, giving a comparatively cheap wall with monolithic construction.

Elevator Construction.

As there are many varied forms of elevators, so there are many forms of construction and of sliding forms ; to make matters easier to understand and talk about the writer proposes dealing with a specific case and describing the details thereof. While different works of different engineering companies, and even of the same company, will differ considerably in details, the same general principles govern them all in this work.

The elevator, the construction of which will be described, is two hundred feet long by one hundred feet wide and consists of seventy-eight circular bins, each twelve feet in diameter and the consequent ninety-eight interspace bins with the addition of several " leg " walls for the elevating machinery, etc. A glance at Plate No. 1 will show how these circular bins and interspace bins look in plan.

The excavation having been completed, the foundations, basement and first (track) floor having been poured, there are on the top of the first floor columns, the bin girders and slab, which, for simplicity will be taken as a simple reinforced concrete slab two feet in thickness, on which the bin walls, ninety feet high, will be supported and on which the rather elaborate " sliding forms," which have been in preparation in the job saw mill while the work has been progressing to this stage, are assembled.

A true, levelled and planed platform had to be built on the ground and the various shapes of bin forms scribed thereon, full size, and the forms built accordingly. This particular work was made more difficult owing to the fact that there were a considerable number of different sized bins and none of the so-called circular ones were really circular, but had one diameter one foot longer than the other. Another reference to Plate No. 1 will show this

Sliding Forms.

The forms consist of four inches by two inches lagging, placed vertically and with the face, which is to be against the concrete, dressed. They are nailed to the "girts," with a space of one-sixteenth of an inch between each to allow for expansion when wet. There are two rows of these horizontal girts, one row placed six inches below the top of the lagging and the other placed six inches above the bottom. These girts are built of two, sometimes three, thicknesses of eight inches or ten inches by two inches timber cut out by power saw to the required arc and spiked together, forming a laminated member or waling. The lower inside girt is built a little smaller than the top one, so that the four feet lagging has a draft of three-sixteenths of an inch and when placed adjacent to the outer form, the bottom of the opening is three-eighths of an inch wider than the top. This is to allow for clearance when the forms are "sliding." The bin slab, having been laid out as to centres, etc., the circular bin forms or units are hoisted up by derrick and set very carefully and levelled in their appointed places. The interspace units are then brought up, placed and levelled. They are temporarily tied together with small pieces of wood, which are removed when the system is complete. This has to be very carefully done so that when completed, the spaces left for the concreting will be very accurate. The outside forms, which are in a straight line except at the corners, are then brought up and placed. A reference to Plate No. 2 will give a good idea of what these forms look like when so assembled. The posts, six inches by six inches or six inches by eight inches, four to each circular bin, in round numbers, are then fitted. These posts serve two purposes. They are "gained" into the girts and have the jacks fitted on them and they, accordingly, pull up the forms. They also form yokes, by means of wooden blocks and through bolts, in the case of the outside forms, and by means of angle irons, iron straps and pipes in the case of the interspace bin forms, and, while they allow one bin form to "slip" vertically to a limit of say eight inches with respect to its neighbours, they keep it, horizontally, in exactly the same relative position to those neighbours throughout the operations. These are further stiffened by ten inches by two inches timbers bolted at their tops, as shown in Plate No. 3. These with a few planks placed on them for walks, serve as a floor for storing the working reserve of reinforcing steel and jack rods which is called the "steel floor" of the forms. In all the bins, six-inch joists are placed resting on the top row of girts, and the

tops of them coming flush with the top of the lagging, a one-inch floor is placed, running out to the " concrete face " of the lagging, giving a floor, called the wheeling floor, extending over the whole building except the walls, the minimum thickness of which is seven inches and are to be concreted. In the floor of each bin, both circular and interspace, a manhole is cut, sufficiently big for a man to get through, and a wooden cover fitted.

Lifting Mechanism.

A jack is then fitted, by means of wooden jack blocks and bolts, to each post or yoke, with its axis in the centre of the wall ; as a rule there are four jacks to pull up each circular bin form, and the interespace bins are pulled up by steel rods connected to four inches by four inches blocks supported by the ten inches by two inches timbers of the " steel floor." These jacks are, of course, special ones and in general, they consist of a cast iron block, on which a small capstan works. An inch or inch and a quarter mild steel rod runs vertically through the jack and as the capstan is turned, it pulls up the post or yoke to which it is fitted. In some cases the rods are threaded and the jack is " screwed " up by means of this thread. In others a plain rod is used and the upward movement is obtained by special clamps embodied in the jack. On the job the writer has in mind, about forty thousand lineal feet of threaded jack rods were used. It is impossible to go further into the details of the " Mechanism " here, but to any one interested, a close study of Plates Nos. 2 and 3, will show how the work is done.

Reinforcement.

The jack rods are placed in the jacks, with their ends resting on the bin slab. These are alternately eight, twelve and sixteen feet in length, one-third of each, so that as the work rises and new rods have to be put in, the joints, which are always weak spots, will not come at the same level. The initial reinforcing, which consists of sufficient three-quarters inch round steel, placed vertically, to tie the horizontal steel to, and three-quarters inch by one-quarter inch hoop steel, placed horizontally, one-and-a-half inches from both faces and about six inches apart vertically, is then placed and operations are ready to start as far as the sliding forms are concerned.

Concrete Plant.

In the meantime, a concrete plant with a mixer and a hoist tower, one hundred and fifty feet high, has been made ready for operation at each end of the job, and a movable spout from

each placed, running down to points of economical distribution into a hopper, from which the two-wheeled concrete buggies are to be filled. The wheels of these buggies are two-and-a-half to three feet in diameter so that they easily cross over the seven-inches wall openings in the wheeling floor. For two days before concreting is started, water is played on the lagging to swell it up to maximum size, otherwise the joints would soon fill with concrete and when expansion took place, the result would be warping.

The concreting is now started by putting in two or three inches of rich, but very soupy grout, and on top of that six or eight inches of ordinary concrete, throughout all the walls. By the time this has been done, about three hours will have elapsed, and the time has come to " break set," that is, for the jacking gang to turn all the jacks a very little to ensure that the forms have been raised about a quarter of an inch from the bin slab. This is a very anxious time, for if done too soon, the grout and concrete will " slush " out at the bottom, and if too late, it will " freeze " to the forms and lift with them. Once away successfully, the jacking gang continues to raise the forms one quarter of an inch at a time and the concrete gang work to get the concrete up to the top of the lagging as rapidly as possible. As there were about one hundred cubic yards to every vertical foot of lift, this was no mean task.

Scaffolding.

As soon as the forms are well clear of the bin slab, gangs start placing a safety scaffold which is suspended from the form frame in every circular and interspace bin and around the outside of the building. All materials have to be in readiness and the work done quickly, for the concreting and jacking goes on apace, and if there is too much delay, the last part of the work has to be done by means of ladders. The interior scaffold consists of four bolt hangers in each bin, run through the bottom girt, with their bottom ends suspending two stringers which support the scaffolding, consisting of say eight to ten inches by two inches timbers. The details of the outside scaffolding need not be gone into here. These scaffolds serve several purposes. If a man falls through a man-hole, there is something for him to catch, and when the work gets eighty or ninety feet above the bin slab, this is a consideration. These platforms are also used by the workmen to wood float the walls from, as the work progresses, this being the only kind of rendering that is done. If any trouble such as " lifts " is encountered, they are rectified from

these scaffolds while the concrete is still green. Finally in every bin, there is a permanent steel ladder and these are placed as the work progresses, the bolts being hammered through the green concrete as soon as the form has passed the position of the bolt, and the ladders fastened to them forthwith.

Jacking.

Jacking is practically a continuous process, for if the forms be allowed to rest for more than an hour, they are likely to "freeze" to the concrete and all sorts of difficulties will follow. Accordingly, there is a day and night jacking gang and these work from seven to seven, with half an hour off at half time for food. There were roughly four hundred jacks on this job and that meant two jacking gangs of fifty men each. Each jack was numbered and each man of the gang had a corresponding number, that is, with a total of four hundred jacks and fifty men, each man had eight definite jacks to attend to. The men take up their positions at their first set of jacks and the foreman blows his whistle, when, they all take a half turn on their jacks. If everything is going well, he may continue to give them whistle signals enough to raise the forms an inch, if not, he may only have them take two half turns. He then gives another signal which moves them on to their next set of fifty jacks, where he gives exactly the same number of signals as at the last set and so on to the end of the house, when the process is started again. All this care is to keep the forms horizontal and level, one with another. This may sound obvious, but it is extraordinary how difficult it is to keep them anywhere near level, inspite of the greatest precautions, and it is no uncommon thing to go on the work in the morning and find the floor surface in a most alarmingly undulating position. This, of course, must be avoided for, if you have one of the circular forms sloped to one side, on which only three-sixteenths of an inch draft has been left, the bottom of the four feet lagging is dragging against the concrete. At more or less frequent intervals, a leveller has to come out at the midday half hour break and put an arbitrary level on the jack rods, which are about the only stationery things, by means of a hammer and cold chisel and to these the jacking foremen have to work until the forms are again level.

Concreting.

The concrete is distributed, as already indicated, by concrete hoppers and two-wheeled buggies. The idea is to keep the forms as nearly full as possible. In practice, when everything is in full swing and going well, the jacking gang go up and down the full length of the building several times, while

the concrete gang is going once, so that the latter gang usually have about eight vertical inches to fill up. The concrete is put in in a very slushy state and not rammed but simply "puddled" with a very thin spade to prevent voids against the face of the form and around the steel. It is surprising how quickly this concrete sets up, and the writer has known eight vertical feet to be completed in twenty-four hours, that is, the concrete that was poured at seven o'clock in the morning, was just being bared at seven o'clock at night and was supporting a load of four feet of green concrete. That is, of course, somewhat of a record, but the writer has known of ninety-five vertical feet of wall being completed in nineteen days or an average of five vertical feet every twenty-four hours. In the meantime the steel gang is also putting in the reinforcement and they judge the position of the horizontal steel by marks on the vertical.

Plumbing.

There are two difficulties to contend with, first to keep the building line straight, and second to keep the whole building plumb. When the load of concrete comes on the forms and they are jacked clear of the bin slab they will spread a little and, if there be any weak spot in the system, there will be a dangerous spreading there. Again, as the forms get higher and higher there is nothing to keep them travelling vertically and the tendency is for the whole system to drift to one end or one side. To obviate this, plumbing is started as soon as the forms leave the slab and done every twenty-four hours or oftener, if necessary. This is done by taking certain definite plumbing points at the corners and certain-points at intervals along the sides and ends. A six or seven-pound plumb-bob with a fine piano wire suspension is used and a careful record is kept. Any local weakness or a general tendency to drift is soon detected. The former is corrected by any local strengthening necessary and the latter by jacking higher at one end (or side), so that, actually, the forms are being raised at an angle to the vertical and this soon corrects any faults of "drifting." This sounds rather formidable, but in practice with reasonable care, any drift is absolutely unappreciable to the eye and is not sufficient to interfere with belts, etc., running inside.

Openings.

In some of the walls, holes have to be left for passenger lifts, belt conveyor gallery to run along an outside wall, anchorages, doors and other openings. To get these at the right level, and here it must be remembered that everything is

moving, steel bars are placed vertically in the concrete wall, long enough ahead to allow them to set before the level for the opening is reached. The proper level is then marked on these and a washer with a set screw is placed at that level. A box, the size of the opening, with holes bored for these rods, is then placed on the rods and rested on the washer. Another washer with set screw is placed on top and the box (or frame) is then set at the proper level, and when, in due course, the concrete reaches that height, it flows to every place but into the box, and when the time comes, after the concrete has set, the box is knocked out and the correct opening is left.

For elevations, the datum is carried up each mixer tower at even ten feet intervals, and the elevation marked thereon so that a glance at the tower will tell at what elevation the top of the lagging is. For any accurate setting an instrument is set on the nearest of these bench marks and the required setting made.

Difficulties.

Of course one has difficulties and the worst of these is the jack rods failing at a joint and buckling out of the comparatively green concrete at the bottom of the lagging. In one case, all four jacks on a circular bin failed at the same time and gave rather a bad time. With the system of "slip" joints, it was possible to continue for a few inches with all the rest of the system, but beyond that the work could not go without the "lame duck," and that meant the forms would "freeze" to the concrete and chaos. The work was sixty feet above the bin slab at the time and was dealt with as follows ;—the broken jack rods were hacksawed off and new ones placed with a six inches by twelve inches steel plate under each. These, of course, had to set for at least thirty-six hours before any pressure could be placed on them. Six inches by six inches timbers (four sets) were erected from the bin slab up to the bottom of the broken-down bin by men in bosuns chairs, a screw jack was placed under each and kept the whole system going for the requisite thirty-six hours, after which the new jack rods, around which the concrete had by now set sufficiently, were used. Then there are "lifts," when the green concrete insists on coming up with the forms and suddenly a great hole or crack appears at the bottom of the lagging as the forms rise. It is, however, impossible to go into further details.

Removal of Forms.

When the concrete in the walls was poured to the necessary height, the concreting was stopped and the jacking continued more or less at the usual rate so that when they were "jacked clear," the concrete was fairly well set up. Planking was then placed on top of the concrete walls to support the forms, which were then dismantled, except the floor system. When this was completed, the floors were lowered until they were flush with the top of the walls and these, supported by strap steel on the walls, made the form for the "Spouting floor slab." After the reinforcement had been laid and the spouting floor slab poured, this floor system was, in turn, dismantled by men in bosuns chairs, through the man-hole left in each bin for the ultimate purpose of spouting grain therein, and lowered through the bottom openings in the bins. Thus, the "sliding forms" are completely dismantled.

Cost.

While the description may make these sliding forms appear very cumbersome and expensive, several things must be borne in mind. First, they serve for pouring a great deal of concrete, say nine thousand cubic yards on an average job, and that greatly reduces the cost per unit, second, with a small saw mill, which is usually provided on work of this kind, and a good organization, the construction is not as formidable as it may sound and, third, the steel part such as jacks, are capable of being used on an indefinite number of jobs, and some of the heavier wooden parts, such as posts, jack blocks, etc., on two or three similar jobs. The writer does not know how costs work out now, but before the war, a very approximate cost of construction of an elevator including every thing from excavation to installation of machinery, was fifty cents or at pre-war rate of exchange, Re. 1/8/- per bushel of grain storage. This of course, was very approximate, and did not take into account the different costs of foundations, etc., but in general, it worked out fairly close to the actual cost.

Conclusion.

Calculations for the design of these forms have not been touched on in this paper. The concrete as poured is considered as a liquid substance, in this work it is nearly so, and the design as far as strength is concerned, is not difficult. The size of bins on different works vary from twelve feet in diameter up to forty feet, so that the design for any particular work must be peculiar to that work.

DISCUSSION.

MAJOR J. K. WYMAN said that the over-all cost of the elevator including machinery was one rupee eight annas a bushel at pre-war prices and rate of exchange. The system of sliding forms was not patented ; the only part that was possibly patented was the jack, of which there were three or four kinds. In Canada several large companies made a speciality of grain elevator construction, and a great deal of this work was done on the cost-plus-percentage basis, the rate before the war being 10 per cent. of the entire cost, which percentage included supervision, plant, estimating and design. Concrete was probably not economical in small way-side places and in Canadian way-side railway stations wooden elevators were used. The synchronising of jacking and form lifting required care, more particularly at the start, which was apt to be troublesome, but once started the maintenance of smooth running was not difficult, provided accidents to the plant did not occur. A jacking crew consisted of (approximately) 50 men headed by a foreman ; the work was unskilled except as regards the foreman, and it was necessary for an Engineer to take instrumental observations from time to time, by which the uniformity of level in the former could be checked. Owing to the great height of the structure fixed forms were impracticable. In recent years there had been serious explosions in elevators and other industrial plants caused by certain kind of dust, and unfortunately this affected reinforced concrete buildings as well as less strong materials but by the use of compressed air cleaning apparatus the difficulty should probably be largely overcome. This question of erosion on the concrete structure did not enter, because there was not much friction between the grain and the concrete face, the grain being put into a manhole at the top and falling vertically, and the bin being emptied from the centre of the bottom through a valve, consequently rubbing between concrete and grain was practically

A firm of contractors from Canada undertaking the
struction of elevators in India would be obliged to send ou
of men (probably 10 to 20) trained in the special work t
the local labour.

MR. C. A. H. TOWNSEND, Director of Agricu ıal,
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would become one on elevators generally, as it h henab
circumstances he wished to say a few words, as h locality.
thing of the working of the Lyallpur elevator. has not

worked by Messrs. Clements Robson and Co. So far the experiment was not unpromising ; but the elevator could not be fully tested till a large parcel, say 20,000 tons, of elevator wheat was placed in the London market. This, however, had hitherto been impossible owing to restrictions on export. It would, he hoped, be done as soon as those restrictions were removed. Last summer about 2,000 tons of wheat were passed through the elevator, it was principally purchased by Indian mills, and generally fetched a premium of four annas per maund over the best bazar wheat, so well was it cleaned and graded by the elevator manager at Lyallpur. They had been lucky in getting so good a man.

Karachi in good years exported over a million tons of wheat, so it was obvious that the whole question of elevators in the Punjab and Karachi merited careful consideration. He thought the best way to tackle the problem as a whole and not piecemeal, as had been done hitherto, would be for a Committee appointed by Government representative of all the various interests concerned visiting North America, England, and the North of India. They would deal with the question from the broadest aspect, and he thought the report of such a Committee should be very useful. A similar procedure had been, he understood, adopted by some of the Australian Governments when considering the introduction of elevators on a large scale : and it had, he believed, worked well.

There was, however, no doubt that a cheaper form of construction than that adopted at Lyallpur would have to be discovered if the erection of an elevator in any numbers was desired.

MR. A. S. MONTGOMERY hoped that the experience gained from the construction of the wheat elevator at Lyallpur would bring home to the Punjab Government the difficulties which had attended the construction of the Lyallpur elevator. The Public Works Department were asked to design the elevator and had consulted specialists in England and he thought a mistake was made in asking such a firm for the designs. The Director of Agriculture should have in the beginning stated his definite requirements, but it was doubtful if he really knew what was really wanted or how the system was to be worked. Government should then have gone to specialists in Canada or England for a design and not have paid anything till the elevator had been actually worked. This would have avoided the frequent changes that were found necessary late in the day.

RAI BAHADUR LALA GANGA RAM described the indigenous system of storing grain in underground pits as practised in the United Provinces. Major Wyman's figure of cost in terms of capacity worked out to one rupee eight annas a bushel, equal to very nearly two rupees a maund (1 maund = 82 pounds approximately). He asked what the Lyallpur elevator had cost in terms of capacity, (Mr. Townsend here stated that it had cost four rupees a maund approximately). He thought it might be possible to devise some cheap form of elevator and a cheap form of underground pits on the lines indicated in Major Wyman's paper that would prove of great use to farmers in the Punjab.

MR. F. T. BATES anticipated that in future elevators would be built at *mandis* (grain markets) as well as in towns, but progress was arrested for lack of knowledge on the subject, and Major Wyman's paper had given a start. But for the execution of reinforced concrete the quality of local labour would have to be improved. In spite of the cost of the Lyallpur wheat elevator it was structurally sound, and being the first of its kind in the Punjab he thought that it was most creditable to the Buildings and Roads Branch of the Public Works Department to have tackled the work and carried it to a successful conclusion. He desired, on behalf of the Congress, to thank Major Wyman for his very interesting paper on the subject,

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