ERRATA

Page	*Para*	*Line.*	*Read*	*For*
246	3	6	existed	exists
246	4	4	Jhajra	Kushalya
248	end of para 2.		insert (see Plate Nos. 2A and 2B)	
248	4	2	gabbing	grabbing
248	5	6	stretchss	stretches
251	1	7	delete 'on'	after 'kept
251	1	7	agitation	agitated
252	6	1	cemented	cement
254	2	2	36 ft.	36″
254	2	3	hand	band
254	5	3	shows	showed
255	4	4	insert 'using' in between 'when and fine'	
256	4	3	'a'	'the'
257	4	1	house	houses
259	4	6	proposed	propped
260	2	3	add 'of' after 'section'	
260	2	6	of	at
260	5	5	15000 ft.	1500 ft.
261	5	4	after 'design load' add 'is'	
263	7	2	into	to
264	3	14	insert '(Plate 10 A)' after 'Pins'	
264	3	15	omit 'so' after 'convenient'	
266	5	6	exagerated	exaggerated
267	3	4	after '12' and before 'initial' and mark ÷	
269	end of para		insert 'as shown on Plate No. 10 A'	
270	6	3	add 'of' after 'placing'	

PAPER No. 239.

CONSTRUCTION OF A CEMENT FACTORY IN PATIALA STATE

BY

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PART I—GENERAL

1. Introduction.

As is well known, the Punjab Cement Factory at Wah, a unit of the thirteen factories owned by the Associated Cement Companies, has for the past 16 years supplied all cement required by the Punjab Government for its many departments, and as the Punjab factory is situated at Wah, almost in the extreme north-west corner of the Punjab, the outlay on freight on cement used by Government departments situated in the south-east and south of the Punjab has been comparatively high ; whereas those Government departments situated nearer the factory have enjoyed cheaper freight rates on cement. The freight handicap to the Southern Punjab had long been realised, but pending a sufficient increase in the normal demand for cement from the market, the construction of a factory further down in the Punjab had to be deferred on commercial grounds. Recent years have seen a steady increase in the demand for cement from the markets and when this demand was sufficiently high to warrant the construction of another factory, negotiations were at once put in hand to this end.

2. Selection of Site.

It may be thought that the selection of a site for such a factory is a fairly straightforward matter, but

on the contrary a close examination of prospective sites invariably will go to show that perhaps one site in five carries commercial possibilities and of several such sites the various factors calling for serious comparison are legion.

Unfortunately, as is well known, in the flat lands of the Punjab, the occurrence of limestone deposits of sufficient quantity and of good quality are few and far between and it may be said that with the exception of the deposits in the districts around Dandot, no suitable deposit has been located between the very large reserves available in Wah reserved for that works, and the Patiala deposits available in the Malla Quarries from which the Surajpur factory draws its supplies, whilst, for economical reasons, it is convenient to construct a factory at some point where the proximity to coal supplies and the centre of gravity of the demand for cement coincide.

The existence of limestone on the Malla hill in Patiala State has been known for a considerable number of years and as early as 1915, its suitability for cement manufacture was reported upon by Mr. M. M. Goswami, Mining Engineer to Patiala State and later by the late Mr. Nicholson of the Punjab Irrigation Department who examined the deposit as far back as 1920.

Early in 1935 the deposit was examined in more detail by geologists acting on behalf of Messrs. F. E. Dinshaw Ltd., and later by the Geological Department of the A. C. C. Ltd., who carried out the real pioneer work in estimating the available reserves and proving by means of detailed analysis on some hundreds of samples taken over the whole range of the deposit, that the quality of the limestone and clays left nothing to be desired and could in combination produce a sound Portland cement. Having found the raw material reserves, it only remained to prove the economy of the project and if proven, to find a suitable factory site within His Highness's territory and sufficiently close to the raw materials.

This work was taken up by the Development Department of the A. C. C. Ltd., who carried out extensive

surveys and calculations before satisfying themselves that the project was a sound one and some of the alternatives considered are detailed in the following text.

The essential requirements for a cement factory in addition to the raw material deposits, are the existence of a railway line within reasonable and economical range of the site and the existence of a safe " all the year round " water supply for the process and for domestic use.

A reference to Plate No. 1 will show that the limestone deposit at Malla occurs at a distance of 7 miles from the nearest point of the N. W. Railway main line serving Kalka from Ambala, but access to the deposit is complicated by the intrusion of six river-beds which normally remain dry but which, in the monsoon period, flow in very heavy spate so that the immediate problem was to link up the deposit with the factory and railway system either by carrying a siding to the deposit and building a factory adjacent thereto or by arranging for the transportation of the raw material to a suitable factory site already situated in close proximity to the railway line.

Detailed surveys were carried out on three different sections starting from the limestone deposit and culminating on the main line which at this place moves round between Chandigarh and Kalka in almost a semicircle.

Estimates were made for the construction of a broad gauge siding from Chandigarh to the deposit, but were soon found to be prohibitive on account of the numerous bridges required involving the provision of expensive foundations to withstand flood water which by test, had been found to flow at a speed of 25 ft. per second.

The various other alternatives of providing a narrow gauge line for the transport of raw material, of grinding the raw material at the site of the quarry either in a wet or dry condition, the latter stage permitting of pneumatic transport by pipeline, were all examined in turn and

found to be uneconomical, and it was eventually decided to resort to the provision of an aerial ropeway as the most suitable means of communication over the broken country encountered.

Owing to the semicircular route of the railway line, the distance from the deposit to the three available sites for the cement factory was almost equidistant, so that the problem had been narrowed down to a selection of a site large enough upon which to build a factory, close to a reasonably good water supply and capable of being served by a siding from the existing main line.

Unfortunately, as many of you gentlemen who frequently travel to Simla, will be only too well aware of, the line from Chandigarh to Kalka rises in a gradient of 1 in 40, making it an impracticable proposition to take off a siding anywhere excepting from a few places where a level line existed, namely, the Station Yards at Chandigarh, the existing railway station at Surajpur or from a point just beyond Pinjore where the line bridges a Nalla, the bridge being level.

Any siding taken off from Chandigarh would of necessity have had to be of great length in order to reach territory within Patiala State and as the only territory available was close to the banks of the Jhajra river, doubts were felt as to the safety of such a factory during exceptionally high floods. The site beyond Pinjore proved, amongst other things, to be impracticable on account of the difficulty of obtaining water, whilst the N. W. Railway authorities were not very hopeful of permission being granted to take off a siding in such close proximity to a main line bridge.

This left the site at Surajpur station which perforce had to be decided upon, although the site was known to possess certain disadvantages. For one thing the area between the railway line and the hills was limited, the provision of a siding entailed heavy excavation, and the only available land had a natural gradient of from 1 : 15 to 1 : 30 across the factory section.

Negotiations were then continued with the Government of His Highness the Maharaja Dhiraj of Patiala and were successfully concluded on 24. 11. 1937.

A wet process cement plant incorporating the latest improvements and of the most modern design was ordered from Messrs. F. L. Smidth and Co., Ltd., Copenhagen who gave a very prompt delivery of this machinery and equipment.

3. Layout of the Factory.

The normal limitation set by the authorities for the construction of a goods siding in respect of the permissible gradient and the maximum radius of curvature of the line limited very considerably the placing of the centre line of the factory, but detailed examination of the standard layout soon showed that modifications to the layout to suit the existing slope of the hill side might very profitably be made use of.

Tentative drawings for the location of a factory on a hill slope were then made out and it was eventually decided to divide the factory into three different basic levels in order to minimise the amount of excavation or plinth work. The plan of the factory layout as eventually decided upon is shown on Plate No. 2.

In a cement factory the various departments are invariably interconnected by conveyors, the angle of slope of which has very definite limit and further, in devising any layout one of the foremost conditions to be fulfilled is the provision of adequate facilities for future extensions of the plant. The main feature in the standard layout of the modern cement factory lies in the provision of a central crane gantry supporting a high speed electrical grabbing crane for the handling of the raw meterials, coal and gypsum and the clinker obtained from the rotary kiln. This material is required to be transported to various bins or hoppers which form a buffer storage over various machines and these hoppers are usually inserted within the crane gantry in order to be within reach of the grab on the crane. The capacity of these hoppers is fixed by so many hours' run of the particular machine to be served and as the angle of repose of the material to

be stored fixes the slopes of the hopper sides, it follows that the height of the hopper is also fixed in relation to the level of the machine and the height of the crane gantry.

These factors, then, limit any desired modifications to layout, but it was found that by utilising the natural ground formation on the site, the level of the rotary kiln, the raw grinding mill and the cement grinding mill could be depressed in relation to the basic level of the crane gantry whilst the conveyors serving the Power House and rotary kiln with fuel could be taken from underground without in any way affecting the capacity of the hoppers whilst still allowing the broad gauge sidings to come into the factory on a permissible gradient starting from the fixed level at Surajpur Station.

This arrangement necessitated slightly larger conveyors, an increased distance from the centre line of the gantry to the centre line of the kiln and Power House in order to maintain the maximum angle of inclination of the belt conveyors, but not only enabled access by means of a broad gauge line to the stores and workshop on the North side of the crane gantry possible, with increased facilities for the unloading of coal into the gantry, but in addition gave a crane gantry of equivalent capacity to the normal one with a saving in height of the crane gantry supporting columns of 15·5 feet.

As the moments produced on these supporting columns by the gabbing crane are very considerable, this saving in height resulted in very great economy in the size of the columns.

The layout of the crushing plant and stone handling plant as well as of the various working tram lines in the limestone quarry presented a rather unusual problem as the limestone deposit consists of a belt of stone varying in thickness from 2 ft. to 60 ft., follows the contours of the hills, and stretchss for a distance of approximately two and three quarter of a mile through fairly dense forest land.

The level of the deposit varies from R.L.-1800 feet to R.L.-2520 feet and with the quantities to be handled, the

problem was to arrange for easy transport to the site of the crusher on tram lines as nearly level as possible.

Prospecting revealed that the major portion of the deposit, which can be divided into three main groups, occurred at R.L.-2280 and above and this point was, therefore, fixed as the basic level for the crushing plant and the ropeway terminal level was then arranged to suit.

Interspersed with the stone are pockets of clay and shales, as the strike line of the stone is now here consistent so that in certain cases it is only possible to work a quarry for a few months before clay is encountered necessitating cleaning out operations. For this reason it was thought advisable to develop as many separate quarries as possible so as to provide adequate day to day reserve quarries.

This was accomplished by carrying the tram-lines round the contours of the hill at two levels, R.L.-2280 and R.L.-2300 and at the same time by designing a double inlet hopper having one inlet placed at R.L.-2280 and one inlet at R.L.-2300, so that loading from both working level tracks could be accomplished. The hopper, which is rather unique, (shown in dotted lines in section on Plate No. 4 and) has a capacity of some 200 tons of limestone rock.

In due course the upper levels of limestone will have been worked away and it will then be necessary to instal a haulage way to recover the stone from the lower levels, this portion of the hill being very steep and difficult of access.

4. A Glimpse of the Process of Cement Manufacture.

Before turning to the question of the various types of structure involved, it may be of advantage briefly to describe the flow process in a cement factory so that the circumstances met with may be realised.

The first part of the working consists of quarrying the limestone and digging the clay containing the silica and alumina necessary to combine with the calcium carbonate in the limestone when burning cement clinker. The stone after being quarried is transported in 2 ft. gauge

tip tubs to a crushing plant where it is broken down to a size of one inch and under. About 375 tons of this stone and 95 tons of clay are used daily for the production of 300 tons of cement.

The stone is led away from the crusher by means of an inclined steel belt conveyor from whence it can be scraped off at different points into a storage space housing some 5,000 tons of crushed stone (see Plates No. 3 and 4). From the storage it is scraped by electrically driven scrape haulers to loading shoots for loading the ropeway buckets for onward transmission to the raw material grinding mill.

A stock of raw material of about 15,000 tons is stored in between two rows of columns comprising a crane gantry on which a high speed electric grabbing crane travels and takes the material to the desired points. This crane gantry not only stores the raw material, but is extended throughout the length of the factory to accommodate the cement clinker storage, the gypsum storage and the raw coal storage, raw coal from railway wagons being unloaded directly into the crane gantry.

The raw material grinding mill, is capable of grinding the product to a residue of 4% on a 170 sq. inch mesh sieve when driven by an 825 H. P. Motor and consists of a steel shell lined with special steel lining plates and divided into four different compartments. Each of these compartments is loaded with a charge of grinding media consisting of special steel balls varying from a diameter of 30 mm. to 90 mm. and of other grinding bodies known as Cylpebs made up of special steel cylinders approximately as long as their diameter which varies from 25 to 12½ mm.

The aggregate weight of this charge in such a mill amounts to 62 tons and the mill rotates at a speed of 21 revolutions per minute.

The electric crane deposits clay and broken limestone from the crane gantry storage into the respective hoppers above the mill and material is fed to the mill by means of rotating feed tables together with some 34% of water.

The resultant ground material, which is known in the industry as slurry, is thereafter transported by means of elevators to four containers usually known as slurry silos having a capacity of 330 dry tons and after correction by the Laboratory is allowed to flow by gravity to a larger basin of a capacity of some 1500 tons of dry meterial where it is kept on agitation by compressed air and a mechanical stirring device.

From the slurry basin the slurry is again elevated to a measuring device before it is passed in to the end of the rotary kiln at a known rate of tons per hour.

The rotary kiln in Surajpur has a normal capacity of 300 tons of clinker per day and consists of a steel shell lined with special firebricks which rotates at an average speed of 75 seconds per revolution and which runs on supporting rollers at an angle of 4%, the lower end naturally being the outlet end. The length of the shell is 390 feet with a maximum diameter of 9′—10½″.

The slurry is fed into the higher end of the kiln and by virtue of the rotation of the kiln and its inclination, slowly gravitates towards the outlet end ; the outlet end is equipped with a firing nozzle through which coal, previously pulverised in a grinding mill similar but smaller to the grinding mill for raw material, but in addition equipped with a drying chamber for removing the moisture in the coal as received, is forced through by a high pressure fan, which in turn supplies the primary air for combustion. The length and characteristic of the resultant flame are adjustable at will as well as the position of the burning nozzle. This pulverised coal flame produces a temperature in the material flowing down in the kiln of some 2800°F. over a limited length of the kiln technically known as the burning zone.

The resultant hot clinker passes out of exits in the kiln shell into cooling devices through which the fan for secondary air at the higher end of the kiln draws its supply of cold air.

The clinker, now cooled, passes on to an inclined bucket conveyor at the discharge end of which it is

weighed in an automatic weigher and from thence tipped out into the crane gantry storage.

The coal for use in burning in the rotary kiln is first of all deposited in a raw coal hopper within the crane gantry from whence it is extracted to a coal crusher and a screening plant. The coarse coal retained on a vibrating screen is by-passed to a system of elevators and conveyors for transport to the steam boiler plant whilst the finer coal which passes the screen is transported by means of a rubber belt conveyor to a reinforced concrete coal hopper having a capacity of some 55 tons situated above the rotating feed table to the coal grinding mill previously described.

The cement mill for grinding the finished clinker is a machine equal in size to the raw material grinding mill and almost identical in construction. The motive power required is the same, but the output of cement is only some 70% of that of the raw material grinding mill by virtue of the fact that the clinker has a much greater resistance to abrasion than the primary limestone and clay.

Adjacent to the reinforced cement concrete hopper for clinker is a second hopper for the reception of raw gypsum which is added to the mill together with the clinker at a rate of some 4% of the mill output. The addition of this gypsum enables the control of the setting time of the resultant cement.

The finished cement when leaving the cement grinding mill is discharged into an automatic weighing machine, tipped into a pneumatic worm conveyor and fed from there into a pneumatic conveying apparatus which pumps the cement as a fluid through a 5″ pipe-line over a distance of 450 ft. elevated to a height of some 65 ft. and is then discharged into containers known as cement silos each capable of storing 3,300 tons of cement for an indefinite period, the air in the cement being allowed to escape through special filters.

From the cement silos, cemented is extracted at the base by means of pneumatic worm conveyors, transported underground to an elevator which, in turn, deposits the

cement into a steel hopper which directly feeds the packing apparatus. The cement is then packed into jute bags, check-weighed, sealed and loaded into railway wagons.

This process involves the provision of a variety of structures including a Power Plant, comprising boilers and a 2600 K.W. Turbine, various types of hoppers, a crane gantry, silos and numerous special buildings, the construction and design of which are beyond the scope of this paper.

5. Constructional Plant.

All information was now available for estimating purposes and work was started on preliminary outline drawings which provided data for detailed estimates of each department. Estimates were completed within a month and submitted to the Directors of the Associated Cement Companies Limited for approval.

Immediately the construction had been decided upon, arrangements were made to provide an early supply of electricity in order to obtain power for pumping purposes and for driving the various necessary machine tools which fortunately had been ordered some 3 months previously and which were, therefore, available almost in the beginning of the construction.

The power unit chosen consisted of a 75 K.W. high speed Ruston Hornsby Diesel Engine generating 3 Phase, 50 Cycles current at 400/230 Volts.

A temporary workshop was quickly erected with brick panel walls and corrugated iron roof supported on light trusses. As a matter of interest, the cement mortar used in the construction of the temporary workshop wall was a mixture of 1 : 13, it being thought that this would facilitiate the demolition of the building when the permanent workshop structure had been completed.

In point of fact this temporary workshop building was in existence for almost 10 months and when the time came to demolish it, it was not found possible to break the wall down and keep the bricks intact ; on the

contrary the wall had to be smashed up in the manner of broken concrete.

The workshop tools in the first place consisted of a 36 ft. circular saw, and automatic wood planning machine a hand saw, 7″ centre lathe, 1½″ radial drill, 27 in. shaping machine, electrical grinding stone, a high speed pillar drill, oxy-acetylene and electrical welding plants.

For work in the field five Millar 8 c. ft. crude oil engine driven concrete mixers were used and proved eminently satisfactory whilst a 10 H.P. electrically driven Capstan having a haulage capacity of 3,000 lbs. and a rope speed of 105 ft. per minute was employed for hoisting concrete.

The bulk of this machinery was installed and power available by April, 1938, prior to which resort had to be made to the hand method of sawing timber for shuttering and, a water supply brought in by means of "Mussaks." The first staff houses and living accommodation for the Manager were constructed under such difficulties and by means of bricks imported from a brick kiln some 9 miles away and it is noteworthy that the first bungalow was completed ready for occupation in 6 weeks from the date of taking possession of the land.

In the meantime, a well had been sunk over existing bed springs on the bank of the Jhajra river and tests carried out shows this to have a capacity of some 350 gallons per minute.

PART II—CONSTRUCTIONAL DETAILS

1. Work Specifications

Approximately 56% of the construction work was carried out departmentally and the balance by contractor, and the Code of Practice adopted for general use was the Indian Railway Standard Code of Practice for Reinforced Concrete construction (as adopted in 1936) with the additional stipulation that not less than 0·4% distribution steel be used in reinforced concrete roof slabs exposed to the rays of the sun.

A figure of 0·3% had previously proved effective in ensuring a completely water proof slab when employing the aggregates available at the Punjab Cement Works but it was found in Sarajpur that the extremely fine sand, giving rise to much greater shrinkage in a concrete having lower early tensile strengths, culminated in shrinkage cracks. It was eventually found necessary to increase the ratio of distribution steel to concrete to a minimum of 0·5% and a limiting diameter of 5/16 in after which no further trouble was experienced and roofs so constructed have proved to be completely water-tight.

This ratio is admittedly a high one and, in many cases, approaches the normal percentage of main reinforcement in a slab but in practice it has seemed possible to make use of the heavy transverse reinforcement by altering the position of supports so as to enable the slab to be designed as a slab reinforced in two directions.

The fine sand available made it very necessary to employ the correct proportion of sand to coarse aggregate for various proportions of mix as there is less latitude available in this proportion when fine using sand than when using coarser sand but the resultant economy in yield and the reduction of the shrinkage problem to a minimum made the additional trouble well worth while.

Unfortunately the correct proportioning of sand to aggregate and the proving thereof involves some rather tedious laboratory work which not everyone is in a position to carry out and it might here be added that the laboratories of the Punjab and Bhupendra Cement Factories are, at all times, prepared to assist consumers in the carrying out of such tests according to adopted practice.

2. Earthquake Protection.

According to advice from the Seismological department of the Government of India, there were reasons to presume that the next earthquake of any magnitude to occur in India would be as likely to occur somewhere in the region of the Simla Hills as anywhere else. In other words the location of the Works was placed in zone I as regards earthquakes risks; it was, therefore, decided that, rather than spend large sums annually on earthquake insurance premium, the money could as well be spent in building all structures as earthquake resistant ones, it being calculated that the additional expenditure required over and above that for normal buildings would be more than offset by the saving on years of recurring premiums on earthquake insurance.

After discussions with the Consulting Engineers, Messrs. F.L. Smidth & Co., of Copenhagen, it was decided that it would be moderately safe to employ an all-round seismic co-efficient of 0·10 similar to that adopted in California, where earthquakes of great intensity have been very frequent and in this connection it may be mentioned that the Concrete Association of India have published a very interesting pamphlet on this subject entitled "Earthquakes."

As far as the factory buildings were concerned, the provision for earthquake stresses was a comparatively simple matter as the buildings by a very nature of their duties had either to be constructed in steel or reinforced concrete having inherent earthquake resistant features ; consequently it was only necessary to take into account the increased loads

arising from the use of the chosen co-efficient, when designing these structures. In certain instances, the loads produced were no greater than those encountered in catering for a wind pressure of 30 lbs. sq. ft. and it was not thought necessary to allow for combined earthquake and wind stresses occurring at the same time, but to design only against the maximum of the two loads.

Consideration of design against earthquake in regard to the housing scheme for housing the works employees was, however, a different matter as such questions as coolness in the interior of the buildings, speed of construction and ultimate appearance had also to be given due consideration.

Various methods were investigated and it was eventually decided to adopt a modified concrete frame structure with hollow brick panel walls, the plinth being partially reinforced and placed upon a foundation which had previously been smoothed off and treated with whitewash in order to allow a free movement, of the structure above foundation level.

The types of house, office and staff buildings decided upon were, in some cases, modified forms of buildings as previously used some years ago by the Bundi Cement Works in Rajputana.

The 9 in. hollow brick walls made with ordinary standard red brick were constructed in the bond shown on Plate No. 5 and hoop iron reinforcement introduced in every eighth course of brickwork, the hoop iron being carried through into the reinforced concrete corner pillars.

As a matter of interest, it may be pointed out that whilst this type of brick work affords the necessary strength and in addition provides an insulation space, it can be constructed at a costs of Rs. 25 8as. per 100 c. ft. as compared to Rs. 30, 8as. per 100 c. ft. for a 9″ solid brick wall.

The existence of the hollow space in the corners was utilized for the insertion of steel reinforcement for

the frame work and the concrete was poured round this steel work as soon as the masonry work had been carried out to some 2 feet in height. These reinforced pillars were introduced at all corners of the buildings and at all important cross wall junctions where stresses due to earthquake forces would be at a maximum. The lower end of the vertical reinforcement bars were laid in alongside the steel reinforcement in the plinth and the upper ends of these bars were bent to join the reinforcement in the reinforced concrete roof slabs. This method is illustrated in Plate No. 6

The mortar used in the panel walls for the housing scheme was a mixture of 1 cement 6 sand and it may be of interest to give an analysis of the cost of this type of construction compared to that when using lime mortar or a mixture of lime and cement mortar, the cost of cement being taken at present market rate and of lime at Rs. 30 per ton.

Cost of 9 in. solid wall in lime mortar 1: 2	=Rs. 30 per c. ft.
Cost of 9″ solid wall in 1 : 6 cement mortar	=Rs. 30-8as. per c.ft.

It should here be pointed out, however, that apart from any consideration of cost, speed on the construction of living accommodation for the large staff to be housed during the construction period was an essential consideration and by the use of sand and cement mortar the masonry walls were capable of being subjected to the rough usage encountered in placing shuttering for the roof slabs as soon as they had been carried to the proper level so that no time was wasted in having to allow the brick work to stand for a period to develop strength.

3. Standardisation of Form Work for Columns.

Where a large number of columns have to be constructed as in the case of this factory, it has been proved by experience that it rarely pays to design individual columns for different buildings on the lines of the smallest sections based on the pre-decided stresses in the steel and the concrete, as the cost of manufacture of the

different sizes of forms for the columns in itself amounts to a large proportion of the cost per c.ft. of the concrete poured.

An endeavour was made, therefore, to standardize on a maximum of four different column sections for the more normal columns serving to support concrete roofs or floors and to vary the steel reinforcement to suit the section of the column adopted.

As many as 140 columns were constructed in this manner by the use of four forms only, the forms being made of $1\frac{1}{2}$ in. timber very securely braced with stiffeners and tie bolts as shown on Plate No. 7.

The inside of the forms were lined with mild steel sheets of 28 gauge secured to the planking by ordinary nails and owing to the rigidity of the forms, it was possible to hoist these into position upto lengths of as much as 22 ft., the form work being proposed in the vertical position by means of four ordinary ballies.

Three sides of the form were closed whilst the fourth side was closed for the first 4 ft. only in the manner shown on the drawing. The remainder of the open side of the column was then closed in sections of 4 ft. as the concreting progressed. Alternate braces were extended so as to form a zig zag ladder to facilitate the passing up of concrete in ' tagaries.'

Columns of a cross section of 54″ by 20″ were constructed in this manner and one gang consisting of two carpenters, one mason, 16 mazdurs could easily complete the entire column upto 19 ft. in height in a working day of 9 hours.

Columns so completed at 6 o'clock in the evening were stripped at 6 o'clock the following morning, and the forms cleaned and re-erected on the next door footing and in this way one column per day per form was completed.

The finish given by the mild steel sheeting re-pays the initial outlay and at the same time protects the timber from early deterioration.

As a matter of interest the cost of form work per c. ft. of concrete in these cases worked out to 0·85 anna per c. ft. of concrete.

Stripping after the concrete is only 12 hours old was found to be quite feasible on columns down to a section 9″×9″ and as a matter of interest it may be pointed out that the strength and compression of a normal 1 : 5 concrete made of reasonably good and clean aggregate of 12 hours especially when poured during the time of the year when the shade temperature is between 90°F and 109°F will amount to as much as 1200 lbs. per sq. inch as tested in ordinary test cubes of 4 to 6 inches square section.

It is, therefore, reasonable to expect the strength of the concrete in the interior of a column of larger mass to develop considerably greater strength than this owing to the increased temperature within the mass arising from the heat of hydration of the cement.

Whilst on the subject of standardisation of form work, it might not be out of place to mention what is thought to be a rather unique method of concreting a beam and slab roof as employed on the extension of the Wah factory.

In this case, the design of crane gantry comprised, in addition, to the usual columns supporting the crane beam, a concrete slab lean-to supported on a portal frame built in conjunction with the main columns and the length of roof to be constructed amounted to some 15,000 ft. in a width of 21·5 ft.

This obviously called for a great quantity of shuttering if carried out in the usual way and it was decided to endeavour to devise a reliable method by which standard shuttering could be utilised over and over again.

The shuttering eventually adopted is shown on Plate No. 8.

It will be seen that the shuttering was made up of box sections, the depth being equivalent to the depth of the beams and the sides tapered to permit of easy

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release. The box sections were filled inside with cross stiffening planks and the whole lined with thin sheet iron and the result was a form which was perfectly rigid.

Small derricks were erected on the previously made column heads and the shuttering hoisted into position by block and tackle through the medium of supporting girders.

It will be seen that this form of shuttering provides the mould for both the beam and the slab and in practice four sets of shuttering only were used to complete the whole length of 1500 ft.

Reference has been made in the previous pages to the early stripping of form work for columns and it may be of interest to record the minimum time at which stripping was carried out in this construction work for normal slabs and beams.

As the majority of the concrete floors and slabs required in a cement factory are designed to carry a live load of 150 lbs. per sq. ft. the ratio of ordinary dead load to design load in the region of $^1/_4$ and it has been found that the only limit to the early stripping of the form work is the ability of the green concrete surface to withstand the barring tools used by the strippers.

With shuttering well oiled before pouring the concrete, the time limit was rarely extended beyond 48 hours for slabs and simple beams and only in the case of large span slabs designed for a normal live load of 60 lbs. per sq. ft. with a dead live load ratio of 0·8 was it deemed expedient to leave the shuttering in place for as long as four days, supports under the beams being allowed to remain for seven days.

4. Construction by Means of Sliding Forms.

Perhaps the most interesting part of the construction of the factory relates to the method adopted in constructing the four slurry silos, the 4-way composite elevator tower and the two cement silos, all of which were erected by the use of sliding forms and continuously poured concrete.

The use of sliding forms is not new, many of the larger contractors in Europe and various other parts of the world having used this form of construction for some years past ; but it is believed that this method was first adopted in India with the successful construction of six slurry silos carried out under the writer's supervision for the Punjab Cement Works where the remarkable short time of 62 hours construction period for one silo was attained as against a normal time of some $2\frac{1}{2}$ months with the older methods.

This method was repeated in the construction of similar silos for the Sind Cement Works at Rohri and the Kistna Cement Works at Bezwada and was again repeated in the case of the silos in the Surajpur factory under review.

The method is briefly described in the following :—

In completing the foundation concrete up to the portion above the usual cone in the silos where the parallel barrel walls begin, anchor bars (1) of 1″ mild steel round section are cast into the concrete at equal distances round the circumference. The distances apart, of course, vary according to the diameter of the silo to be constructed but as a general rule a spacing of about 8 ft. as a maximum is considered to be the best. These anchor bars are left projecting to a height of some 12 ft. where shuttering of the construction as shown on Plate No. 9 is used and preferably the lengths of these bars should be irregular.

Reference to the drawing of the shuttering shown on Plate No. 9 will show that this is made up in the usual manner for circular shuttering, *i. e.*, built up of laths of timber to form the correct radius and in addition to being equipped with the usual stiffening members is provided with two vertical timber hangers (2) from the outer and inner rings respectively ; these hangers culminate in a system of cross bars (3) at the top which are drilled to receive a jacking gear and guides.

The shuttering is tapered so as to have a dimension at the base of some 3/8″ greater than the thickness of the concrete wall and it has been found by experience

that a much better job is produced when the shuttering is lined with thin sheet iron.

The jacking gear consists of a 2″ hollow spindle (4) threaded with a ½″ pitch square thread outside and is equipped at its lower end with a loose clamping head, (5) equipped with hardened steel jaws. The top of the spindle is fitted with a 4-way handle (6) for ease in turning the screw which rotates within a nut (7) secured to the cross bars attached to the form work.

Having erected the form work in place round the previously projecting 1″ anchor bars, the jacking gear is threaded over the anchor bars and through the nut on the form work. The clamping jaws are then tightened securely to the anchor bars so that any rotation of the handle at the top of the spindle produces an inverse jacking action and the shuttering is thereby raised, its weight being transmitted through the jacking screws to the anchor bars.

The method is then to fill the forms with concrete and to turn each jack simultaneously at definite intervals of time and as the forms move upwards to maintain the level of concrete therein.

For convenience, a working platform (8) is constructed inside the silo, its weight being supported on the inner ring of forms and this platform, of course, follows the forms as the work proceeds.

Concrete is hoisted in buckets or drums in a tower constructed adjacent to the silo from the top of which it is shot down a shute on to the working platform from where it may be shovelled into 'tagaries' or small buckets and distributed equally round the work.

The main reinforcement has to be prepared previously into the correct radius and is hoisted up at a convenient place and placed in position as the concreting proceeds whilst the vertical reinforcement bars are added in any convenient lengths.

The two factors requiring the greatest supervision during the work are the maintenance of the forms in the correct vertical position and the speed of raising the

forms, which must bear a definite relationship to the initial setting time of the concrete in use.

The level of the forms is easily checked by constructing a small platform on the working platform to accommodate a dumpy level and before commencing the work, level marks are painted on the inside of the vertical hangers so that after the jacking operation, it is only necessary to swing the dumpy level round and to check up the level on each of these marks.

The level is liable to be disturbed when extending the anchor bars as on such an occasion, the clamping head for that particular bar has to be released and the load which it carries, is transferred to the adjacent bars. It will be realised that these anchor bars have eventually to continue right to the top of the work but it is, of course, inconvenient and would indeed be difficult to insert anchor bars of any great length. The original anchor bars are, therefore, drilled at their upper end to receive a steel pin and when it becomes necessary to extend them, the anchor bar extension, which has also been drilled in a similar way at either end, is placed within a small steel sleeve which, in turn, anchors both bars by means of the steel pins. As this work takes a few minutes to complete, it is convenient so to adjust the lengths of the anchor bars so that any required extension occurs in rotation and the changes are thus spread over larger intervals.

To commence the process, with the form work in place and correctly aligned, the forms are first filled with concrete to a height of 18″ and this concrete is allowed to harden after which the forms are raised so that the bottom of the form is level with the top of this 18″ wall. The forms are then treated with tallow on the steel facing and filled to the top with concrete, the progress of the work being carried out at approximately the same speed as will be attained throughout the construction, usually from 7″ to 12″ wall per hour according to the atmospheric conditions. Whilst filling the forms in the first case the jacking speed is maintained at about one quarter of the above so that as the concrete work proceeds faster than the shuttering is moved,

the concrete work eventually catches up on the movement and the forms become full to the brim.

At this stage jacking is then gradually accelerated to full speed and it is then essential that the concrete work follows the speed of the jacking so that the forms remain completely filled throughout the remainder of the work. If the level in the forms is allowed to fall a few inches below the top, there is a possibility of pieces of cement concrete adhering to the exposed form and setting in the air so that these hard pieces eventually become buried within the added concrete and offer resistance to the mass of wet concrete above them whenever the jacking operation takes place and this will invariably result in a nasty tear in the wall which does not become visible until the full length of the shuttering has been jacked past that particular point. In other words the keeping of the forms full of concrete maintains the cleanliness of the sliding surface. Cleanliness is the most important factor contributing to the success of the work and it is essential that all set concrete which may have been spilt or adheres to the reinforcement bars is removed from time to time before it is covered by wet concrete.

The form usually used in such construction has a depth of 4 ft. so that with a speed of concreting of say 8 inches per hour a period of 6 hours elapses before the green concrete appears below the lower part of the form work. By this time the final set of the cement should have taken place and the concrete has sufficient strength in compression to take the load distributed from the anchor bars, of the whole of the shuttering, working platform and concreting gang.

The following table shows the progressive compression strength of the concrete from 4 to 24 hours, as actually found in practice.

Nominal Mix 1 : 2 : 2 Slump 4″

Hours.	Compressive strength lbs. sq. in.
4	170
6	455
8	825
10	1030
12	1175
24	1950

It is essential to carry out setting time tests during the course of the work and these setting time tests should be carried out on the actual concrete mix employed and must also be done in the open so that the concrete being tested is maintained under exactly similar conditions to the concrete which is being poured into the forms. Having ascertained the setting time, the speed of jacking is adjusted to suit.

The relation between setting time and speed of sliding carries a simple explanation.

The action of jacking up the forms produces friction between the walls of the forms and the setting concrete and if this friction is not counteracted by an opposing force, the setting material will be disturbed, tend to rise with the forms and in this manner be torn apart. The speed of sliding, therefore, must be such that the mass of concrete present, in which the initial set has not yet taken place, is heavier, acting through gravity, than the upward thrust transmitted from the forms through friction. In other words, when jacking takes place, there must be no visible movement of the wet concrete, but the forms must rise freely leaving the concrete behind.

Although the area of form exposed to plastic concrete is directly proportional to the depth and, therefore, volume of plastic concrete within the forms, the total friction does not increase proportionately to the depth of concrete above the point of initial set as the friction generated per inch depth increases from zero at the top of the form to a maximum at the point of initial set.

Further, since the forms are tapered, the point at which the initial set takes place determines the thickness of the resulting wall and the forms become clear of the wall from there downwards. The accompanying Plate No. 10 illustrates this point very clearly, but the slope of the forms has been exagerated for ease of illustration.

It will be seen, therefore, that the quicker the setting time, the quicker must the forms be raised and as the setting time of the concrete decreases with increasing temperature, it follows that the work must necessarily

proceed faster during day light hours than during the night and faster during hot weather than cold.

The limit to the speed which can be used would appear to be the loading on the jack screws due to friction and with more than 15″ of plastic concrete above the point of initial set, the jacks become difficult to turn.

Generally speaking, it has been found safe to adjust the speed to the setting time to ensure that 12″ of plastic concrete is maintained above the point of initial set so that the speed in inches of lift per hour will be 12 intial setting time in hours.

As the setting time is also influenced by the water cement ratio, it is, of course, essential to keep this at a constant figure. This is set originally to give a suitable slump (about 4″) to enable the concrete to be poured and worked round the reinforcement.

The first silos were constructed in Wah during July, the hottest months of the year and the final ones during the more temperate autumn months, the maximum shade tempratures being 112°F. and 90°F. respectively. The initial setting time of the concrete in the former case was, at one time, only 36 minutes although the cement used gave a standard laboratory figure for initial set of 95 minutes when tested under standard conditions, the reason being that the aggregate and the steel test moulds had been lying in the sun and were extremely hot whilst the mixing water was also of a temperature of some 95°F. In addition, the vertical reinforcement already placed in position was also exposed to the sun's rays and the amount of heat conducted to the concrete mix in the comparatively thin wall section was considerable. It being found impossible to maintain the required speed of 20″ per hour owing to the difficulty in keeping pace with the ring reinforcement, resort had to be made to an increase in the water cement ratio.

It is necessary to rod the concrete very thoroughly as it is placed so as to ensure proper distribution and a uniform mass.

The method of constuction does give a truly monolithic product and the finish attained when using steel

lined forms, has the appearance of an egg shell and requires no further treatment. If the working platform is constructed over the full area of the diameter of the silo, the curing is automatic on the inside at least as the heat of setting of the concrete generates an appreciable amount of steam and as the concrete and not the shuttering is exposed to this hot and humid atmosphere within the silo. The outside is sprayed by means of a hose-pipe whilst the silo can safely be filled with water three to four days after completion.

The quantity of concrete required per minute to maintain a speed of 10″ per hour is much lower than would be thought at first sight. For instance, with a silo wall 12″ thickness as constructed in Surajpur, the concrete consumption is only 0·436 c. ft. per minute, so that it was found convenient to slide 2 silos at the same time and fed from the same hoisting tower, the total number of men used for the operation being as follows:—

On working platform :

Unloading buckets	=2 Khalasies.
Placing reinforcement	=8 boys, 8 mazdurs.
Transport and placing of concrete	=16 mazdurs, 4 masons.
Supervisor	=1
Watering	=2 mazdurs.
Clamping and unclamping jacks	=2 carpenters.

On Ground

Concrete Mixer	=10 Mazdurs.
Pushing Trolly	=2 ,,
Hoist driver	=1 ,,

This, of course, pales into insignificance when compared to a recent contract in London where as many as 55 grain silos were slid at one and the same time over a period of 9½ working days.

As time is money, the cost of construction by this method may be taken as some 65% only of the older and slower method and the system should prove ex-

tremely useful in the construction of high level water towers for which there is a sufficient demand throughout India especially by contractors who could use one set of forms and jacking gear over and over again.

Where openings are required in the finished structure, all that is necessary is to insert a light wooden frame tied to the reinforcement, the thickness being the thickness of the walls so that the sliding forms can pass over the frame.

It is also possible to cater for stair landings, beams or other required projections by inserting the reinforcement.

After the sliding forms have passed over this reinforcement, the surface is chipped away, to expose the top of the reinforcement rod and the rod is then bent out, whilst to facilitate the fastening of shuttering, at a later date, it is possible to arrange for bolt holes to be left by merely inserting pieces of pipe as shown on the plate.

In more recent years concrete chimneys have been constructed in this method and patents have been taken out whereby the forms are adjustable to wall thickness as the work proceeds and it then becomes possible to construct a taper shaft with a base wall thickness of say 14″ and only $4\frac{1}{2}$″ at the top.

PART III—IN CONCLUSION

1. Duration of Work.

The first staff arrived at site in the early part of December 1937, but it was not until practically the end of April 1938, that preliminary arrangements had been completed and the layout finally decided upon so as to enable the poper construction work to be taken in hand.

With the exception of the aerial ropeway for which certain parts fabricated in India were awaited, the factory was completed by the 14th of June 1939, when the opening ceremony was performed by His Highness The Maharaja-Dhiraj of Patiala.

Relations with labour in the trying conditions during the construction period were excellent and the only set back encountered was when large numbers of *mazdurs* suddenly started to desert on account of a rumour that the company were about to comit *'Bali'* by sacrificing seven *mazdurs* who were to be buried under the foundations to propitiate whatever diety was concerned, before putting the Diesel Engine into commission. Needless to say they were soon persuaded to return to work.

An idea of the magnitude of the work may be conveyed by quoting some statistics.

At the height of the work, the peak number of people employed on construction amounted to over 5,000 and in addition some 200 donkeys without which it seems difficult to carry out any extensive excavation or transport of material in this part of the world.

Apart from 58 lakhs c. ft. of excavation having been carried out, 7875 tons of cement were consumed involving the placing approximately 60,000 tons of concrete, 880 tons of reinforcement steel and 433 tons of sectional steel whilst the gross weight of machinery erected amounted to 3630 tons.

The remarkably quick speed of erection, the entire absence of any trouble and the excellent spirit which

prevailed throughout this large scheme was in no small measure due to the close co-operation and very real assistance rendered at all times to the management by His Highness The Maharaja of Patiala's Government.

The control of the programme of construction, selection of machinery, reponsibility for layout, and the ultimate decisions on the numerous problems which arise from time to time on a work of this nature were in the hands of the Development Department of the A.C.C. Ltd., which was at the same time responsible for the design and building of two other A.C.C. factories under construction elsewhere in India so that co-ordination between the three works and the Managing Agents was thus ensured.

The supervision of construction and design work was assisted by Mr. Frank Burgess, B. Sc. (Hons.), A.M.I.M.E., Chief Engineer, Bhupendra Cement Works, Mr. I.C. Holm, Civil Engineer, C and Polt. M. Ing. F., representing the consulting engineers Messrs. F.L. Smidth & Co., and Mr. S.R. Chadda, C.E. (Roorkee), Civil Engineer, Bhupendra Cement Works.

2. The Completed Plant.

An idea of the appearance of the completed plant can best be given by a reference to the accompanying photographs showing the different departments and special attention is drawn to the appearance of the boiler house building, the sides of which are covered by reinforced concrete louvres, cast in between the supporting columns. These louvres give a pleasing finish to the structure, allow plenty of light and ventilation and are cheap to construct costing some $5\frac{1}{2}$ annas per sq. ft. of covering only and at the same time act as side bracing to the long columns.

Plate No. 11 also shows an elevation of the north-east face of the factory and Plate No. 12 sections through the same.

3. The Product.

In conclusion it might not be out of place to comment upon the quality of the cement which, it has been

found possible to produce from the Bhupendra W
and the Government Test House at Alipore have al
submitted several official test certificates, an examp
which is given below :

"Test Certificate No. CT/PC/54, dated Alipore
August 31, 1939, issued to Messrs. The Asso
Cement Companies Ltd., Administration Departm
Bombay, with reference to letter No. DD/PE/1/212, d
the 8th August, 1939, from the Manager, Cement W
B. C. W. Surajpur (Patiala State) and in continuatio
this office Test Certificate No. CT/PC/54, dated th
August, 1939.

Register No. 289 P. C., dated 11-8-39.
Sample received on the 11-8-39

FINAL REPORT

BRITISH STANDARD TEST FOR PORTLAND CEMENT

Name and Brand of Cement "B. B. B." Brand Portland
Nature of Sample Labelled "Mark 1."

	Results obtained.	Standard
1. *Fineness of Grinding*	%	
Residue on B. S. Mesh No. 170 ...	3·87	Not more than
,, No. 72 ...	0·02	"
2. *Chemical Composition*	%	
Lime	63·56	
Soluble Silica	21·65	
Alumina	5·97	
Iron Oxide	2·88	
Magnesia	1·45	Not more than
Sulphur calculated as SO_3 ...	1·89	"
Loss on ignition	1·95	(in hot climates) Not more than
Insoluble residue	0·65	
	100·00	

found possible to produce from the Bhupendra W
and the Government Test House at Alipore have al
submitted several official test certificates, an examp
which is given below :

"Test Certificate No. CT/PC/54, dated Alipore
August 31, 1939, issued to Messrs. The Asso
Cement Companies Ltd., Administration Depart
Bombay, with reference to letter No. DD/PE/1/212, d
the 8th August, 1939, from the Manager, Cement W
B. C. W. Surajpur (Patiala State) and in continuatio
this office Test Certificate No. CT/PC/54, dated th
August, 1939.

Register No. 289 P. C., dated 11-8-39.
Sample received on the 11-8-39

FINAL REPORT

BRITISH STANDARD TEST FOR PORTLAND CEMEN

Name and Brand of Cement "B. B. B." Brand Portland
Nature of Sample Labelled "Mark 1."

	Results obtained.	Standard
1. *Fineness of Grinding*	%	
Residue on B. S. Mesh No. 170 ...	3·87	Not more th
,, No. 72 ...	0·02	"
2. *Chemical Composition*	%	
Lime	63·56	
Soluble Silica	21·65	
Alumina	5·97	
Iron Oxide	2·88	
Magnesia	1·45	Not more th
Sulphur calculated as SO_3 ...	1·89	"
Loss on ignition	1·95	" (in hot climates) Not more than
Insoluble residue	0·65	
	100·00	

	Result obtained	Standard 1931.
proportion of Lime to Silica and Alumina	2·64	Between 3·0 and 2·0
3. *Tensile Strength (cement and sand)* (average of 6 briquettes) lbs.	565	Not less than 300 lbs.
(,,) lbs.	682	,, 375 lbs.
4. *Setting Time* (*a*) for normal setting cement		
... ...	102 mins.	Not less than 30 mins.
... ...	2 hrs. 23 mins.	Not more than 10 hours.
(*b*) for quick setting cement		
... ...		Not less than 5 mins.
... ...		Not more than 30 mins.
5. *Soundness* ansion after boiling 3 hours in Chatelier Mould		
(*a*) Unærated cement ...	1 mm.	Not more than 10 m. m.
(*b*) Cement ærated for 7 days' test (a) having failed ...	...	,, 5 m. m.

Proportion of water used in gauging.

(*a*) Setting time pats ... ...21·7%
(*b*) Cement and sand briquettes ... ... 7·9%

Temperature during period of testing ...80°F–92°F

arks.

The sample complies with B. S. Specification 12-1931 for Portland Cement both physically and nically.

(Sd.) A. N. CHOUDHRI,
For Superintendent,
Government Test House.

These tests are, of course, based on the British dard Specification for the testing of Portland cement do not, therefore, include compression tests which ld give a better indication of the quality of cement

to the Engineer although it is of interest to no[te] advance information on the proposed revision [of] B. S. S. shows that in future compression tests [are] included although they remain optional.

Compression tests are, however, carried out [in] Works' laboratory as a matter of routine an[d] following table sets out the average results so far ob[tained] at 1, 3 and 7 days :

Cement ground during the week ending.	*Compression Tests as obtained in the W[orks] Laboratory for the cement made by the Bhupendra Cement Works.* *Lbs. per sq. inch.* 1 : 3 *cement* : *Standard sand.*	
	1 Day.	3 Days.
13-8-39	3934	6777
20-8-39	3537	6545
27-8-39	3405	6678
3-9-39	4231	7074
17-9-39	3967	6479
1-10-39	4066	6744
8-10-39	4066	5719
29-10-39	3008	6446

The chemical composition of the cement as [shown] the above Government Test House report is very [close] akin to that of the cement produced in the Punjab [Cement] Factory at Wah whilst the results of the physical [tests] as can be seen, are extremely gratifying. The [colour] pleasing, being a slightly greenish tinge, and [as] Government Engineers in the south-east of Punjab [may] in future be supplied with this cement at Government option, they will, no doubt, be interested to hear that the market is well pleased with the result [and] some 20,000 tons have already been put into use. It is the earnest consideration of the Company to maintain the quality of the product from their latest factory at Wah in keeping with the reputation already enjoyed by all the many other brands of A. C. C. cement.

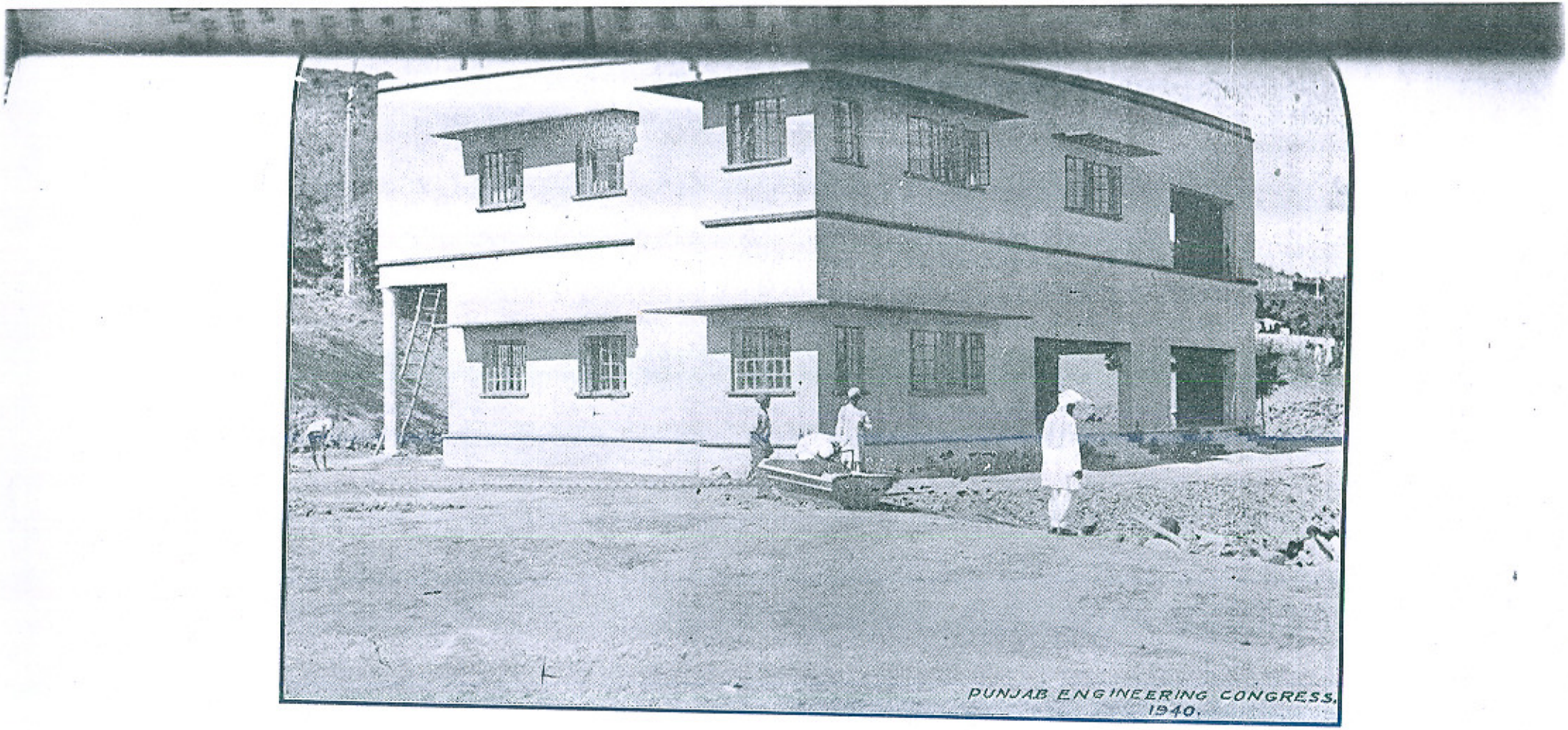


Photo No. 1—Manager's House "A" Type.

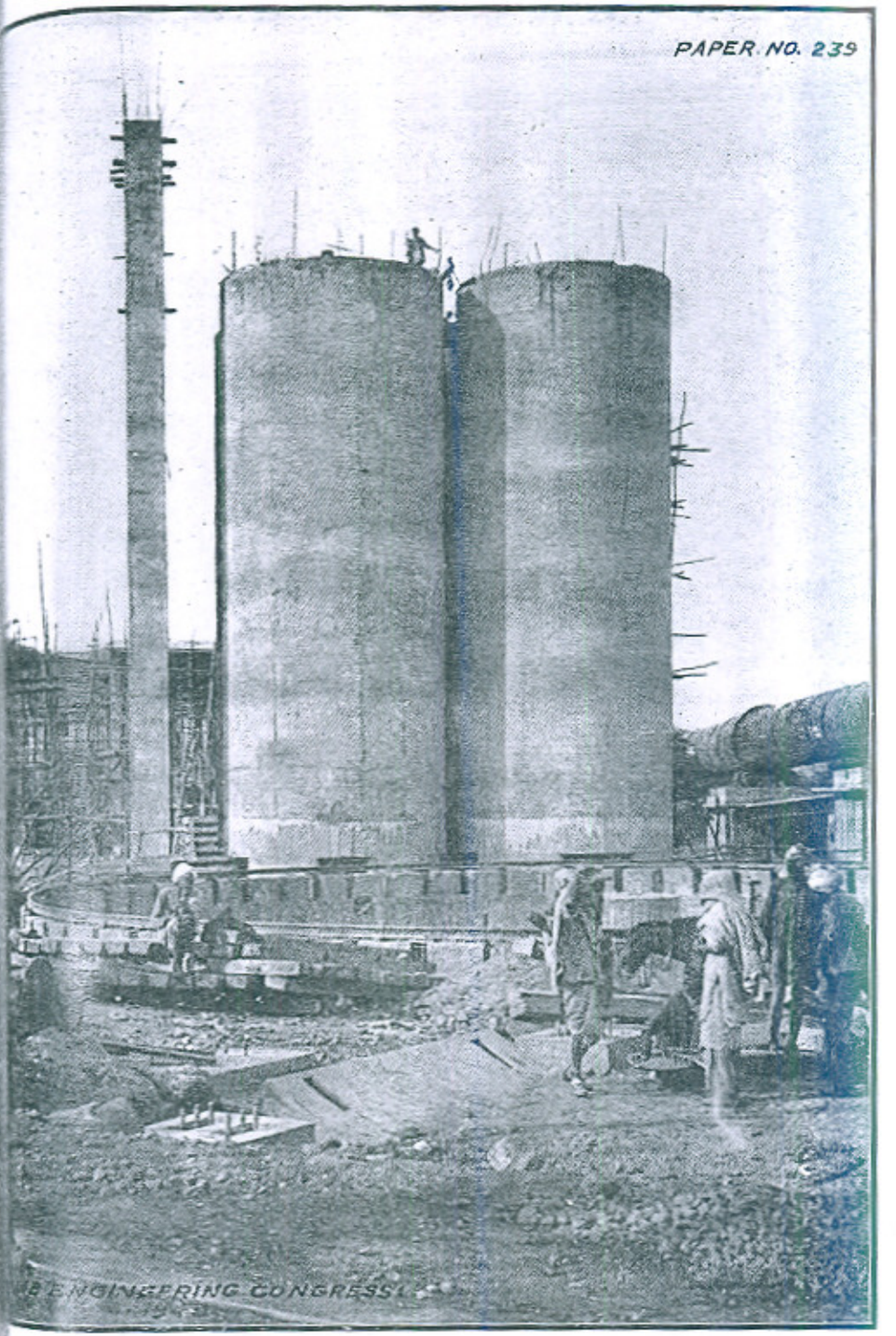
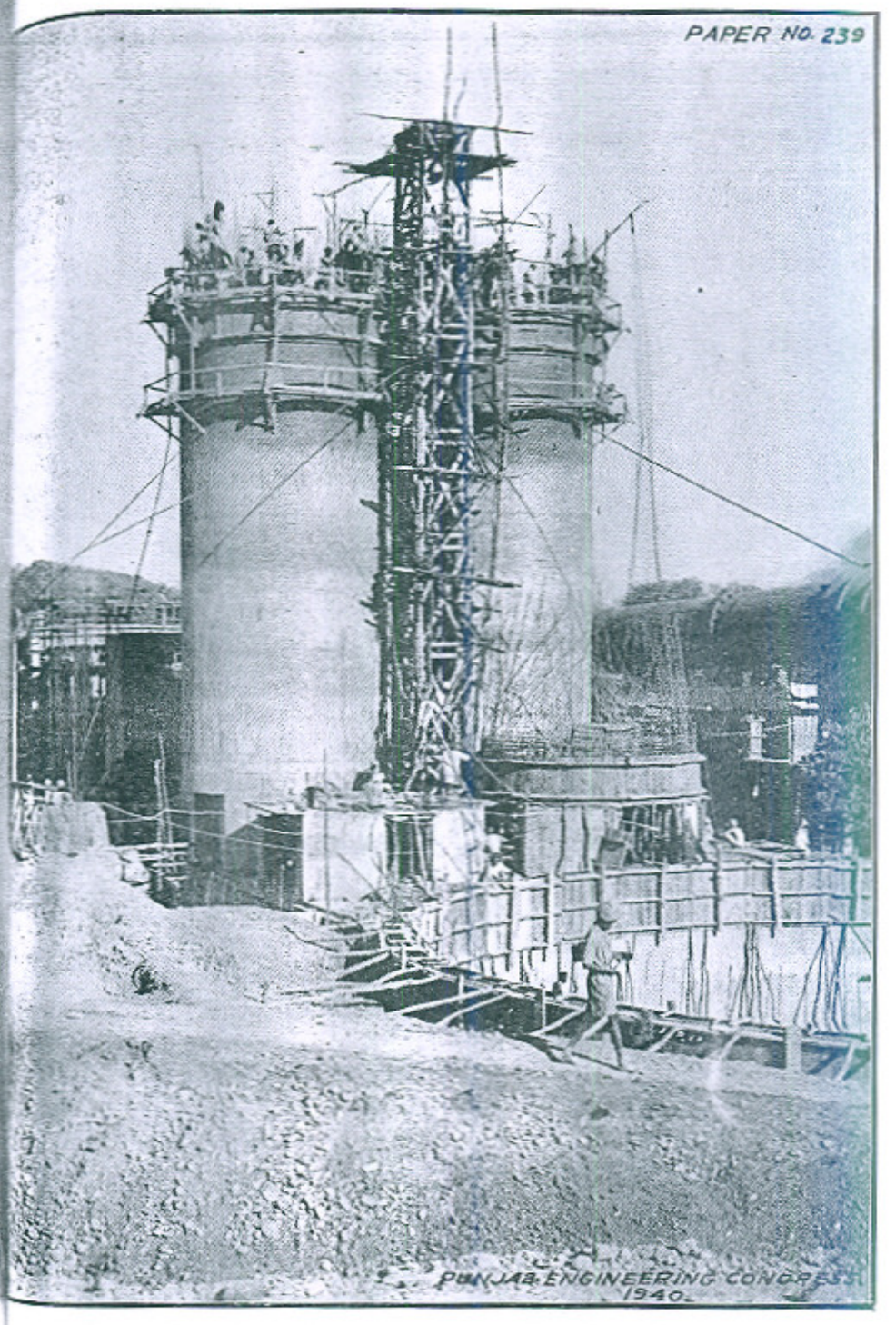


Photo No. 2—Slurry Silos and Elevator Tower after Removal of Sliding Forms.



oto No. 3—Slurry Silos under Construction by Sliding Forms.

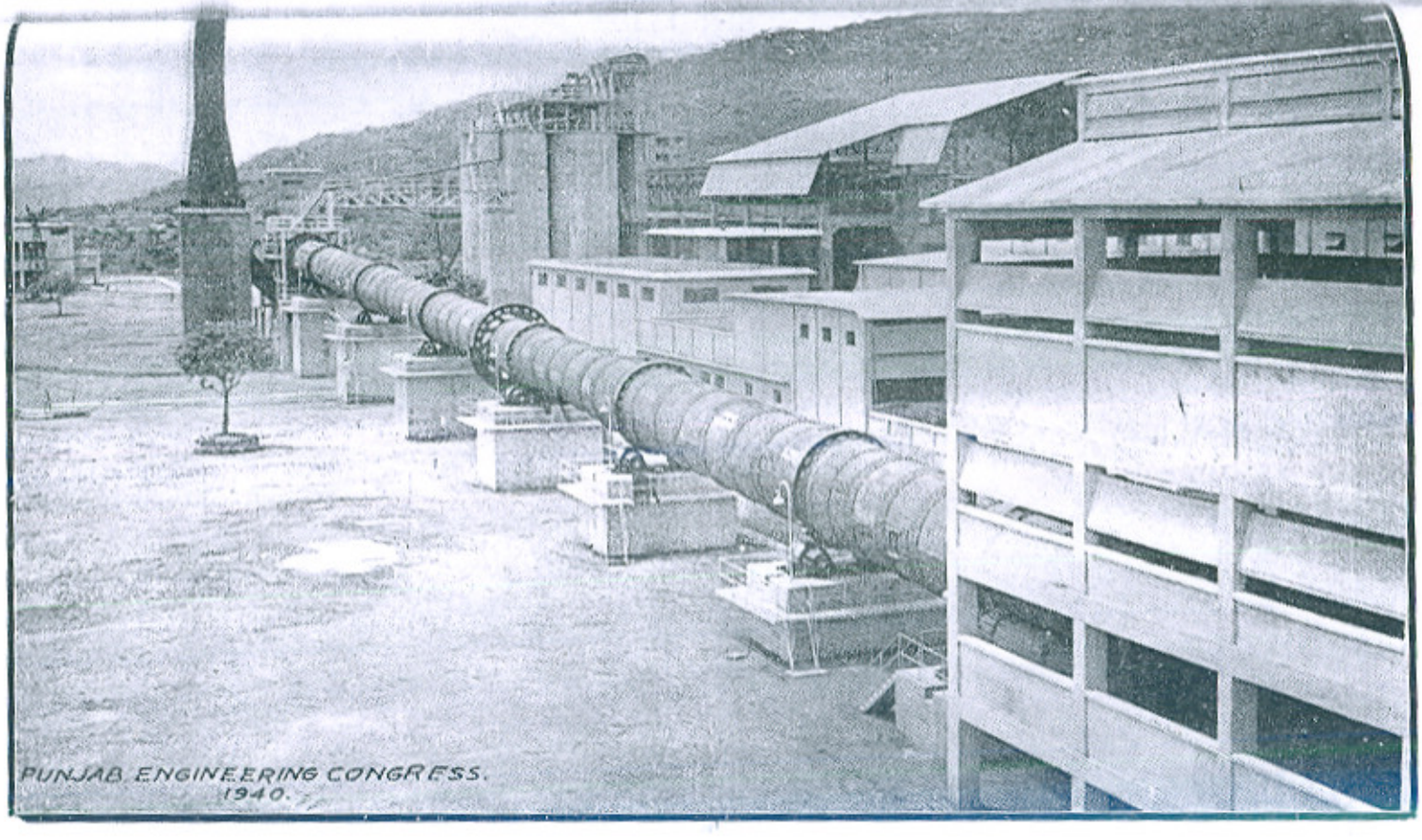


Photo No. 4—View of Completed Works.
The Rotary Kiln.

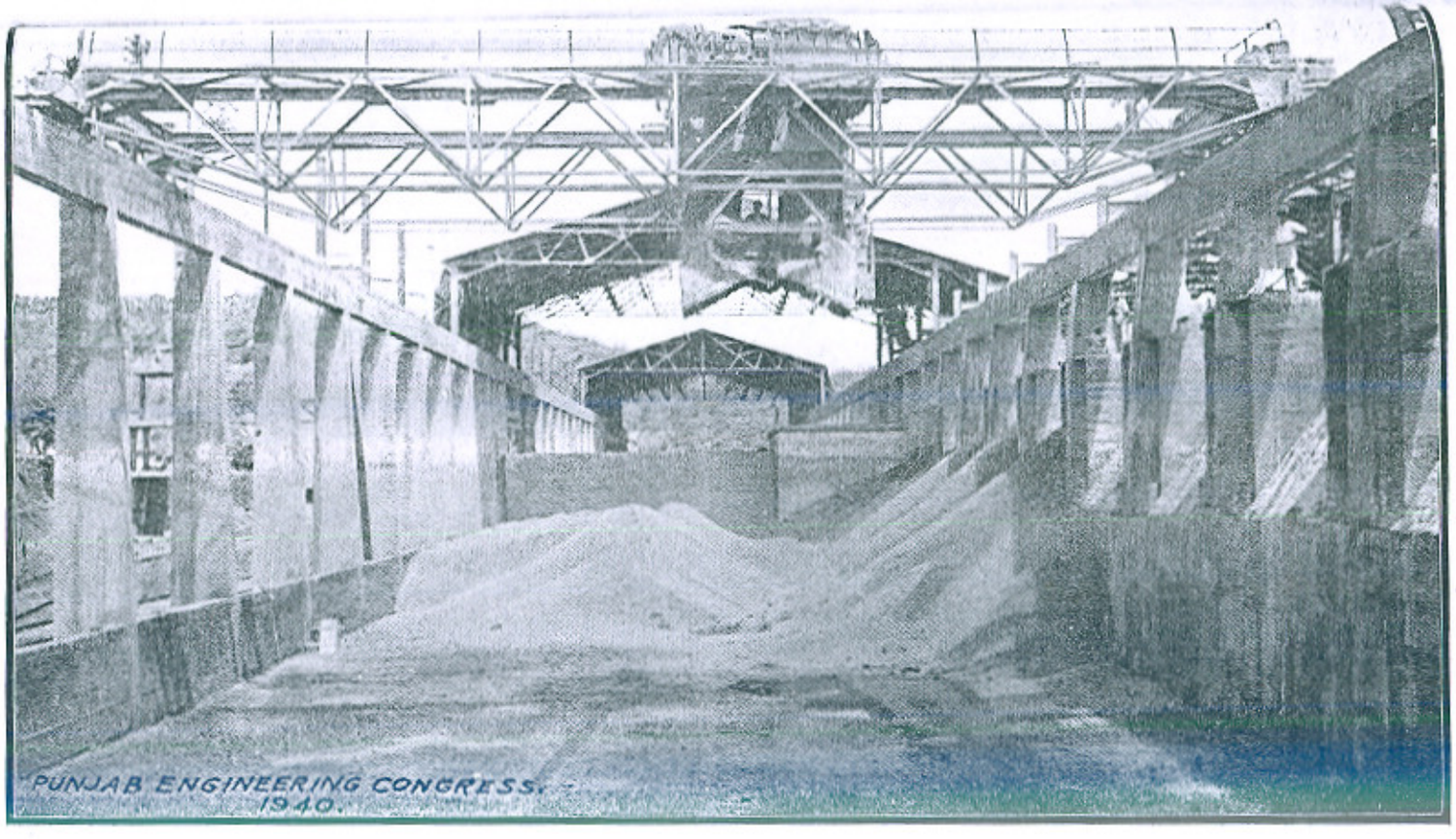


Photo No. 5—View of Completed Works.
Crane and Crane Gantry.

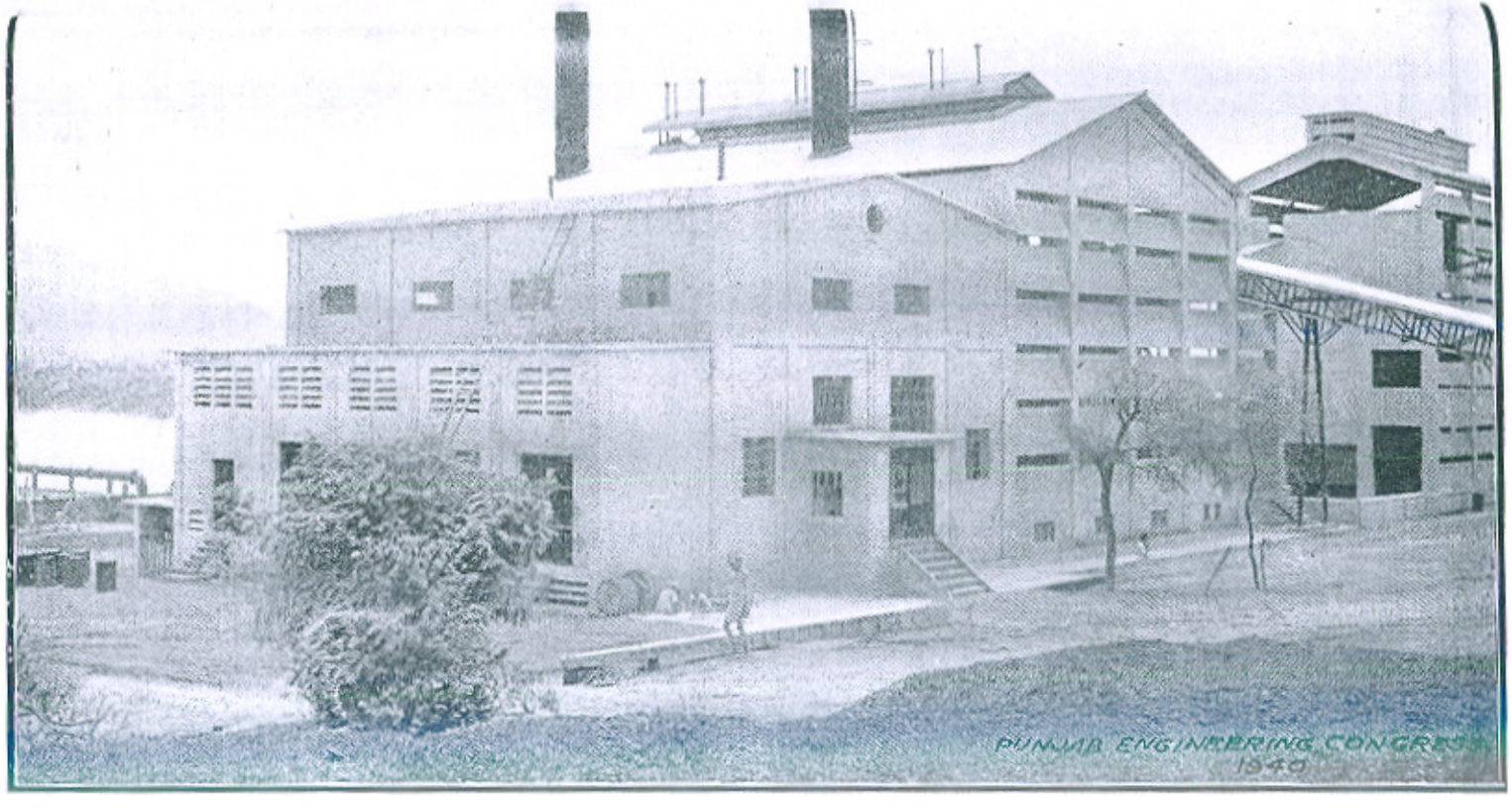


Photo No. 6—View of Completed Plant.
Turbine and Boiler House.