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IRON AND STEEL INDUSTRY

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(Contd. on Cover page 3)

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CONTENTS

Iron and Steel Industry

by

BHILAI STEEL PLANT, BHILAI

Abstract

The demand for iron and steel has been steadily growing with the increased tempo of industrialization of the country. To put the country on a self-generating economy, it is imperative to develop the iron and steel industry to the maximum. This calls for an effective utilization of modern techniques and scientific research. The Bhilai Steel Plant has made considerable headway in this direction. The plant has developed several scientific innovations to tackle problems arising in the field of production, construction, and maintenance. These innovations will go a long way in increasing productivity, reducing cost of steel, and in better utilization of indigenous raw materials and skill.

Some of the important innovations of the Bhilai Steel Plant are the development of a coke blend incorporating 10—20% inferior (unwashed) coal ; a sinter containing more fluxes which gives more iron at much lower coke rates ; utilization of the surplus gases from blast furnace and coke ovens as open-hearth fuel, thereby getting the lowest cost of fuel/ton of ingot steel for equivalent practice in other steel plants ; speedy repair of open hearth bottom (within 2 hours lasting for 100 heats as against the usual 5—6 hours lasting for only 25—30 heats). The plant has also adopted various modern techniques of construction and maintenance to suit its requirements.

In order to sustain the pace of industrialisation and to put the Nation on a self-generating economy, planning for increased steel production and assessment of future requirements on a long term basis is imperative.

At the time of formulation of the Third Plan, it was estimated that demand for steel in the country during this period will be of the order of 10.2 million tonnes. This formed the basis of expansion programmes of the three Public Sector steel plants. It has also been decided to set up a new steel plant at Bokaro by the end of the Third Plan with an initial capacity of 1.5 million tonnes to be expanded to 4.0 million tonnes by the end of Fourth Plan (1970-71).

A scientific study was made to assess the demand for steel in the country, so as to estimate the efforts needed to achieve the capacities in time. For this purpose the 'end use' method was used which is quite well-known and gives a reliable picture. The forecast is given in Table 1 in million tonnes.

Paper presented at Symposium on 'Science and the Nation during the Third Five Year Plan.'

Table 1

	1965-66	*1970-71*	*1975-76*	*By end of the century*
Steel ingots	11 4	19.0	29.0	110.0
Finished steel	8.6	14.21	21.92	—

The per capita consumption of steel in India is very low as compared to industrially advanced countries. In 1962, the per capita consumption of steel in U.S.A. was 420 kg., in U.K. 365 kg., in Japan 255 kg., and in India only 17 kg. Since per capita consumption of steel is a clear index of the degree of industrialisation and economic activity of a country, it is abvious that steel consumption will have to be increased manifold to narrow the gulf that separates her from viable, self-generating economy. The fulfilments and targets for Third Five Year Plan are given in Tables 2 and 3 respectively.

Table 2—Industrial Capacity and Output of Steel from 1960-61 to 1965-66

Products	*Unit*	*1960-61*		*1961-62*		*1962-63*		*1963-64*		*3rd plan Annual T.*		*1965-66 Likely A*	
		C	*O*	*C*	*O*	*C*	*O*	*C*	*O*	*C*	*O*	*C*	*O*
Ingot Steel	M.T.	6.0	3.3	6.0	4.27	6.0	5.39	6.0	7.54	10.2	9.2	9.2	7.8
Saleable S.	M.T.	4.5	2.4	4.5	2.9	4.5	4.0	4.5	4.4	7.5	6.8	6.5	5.8
Pig iron for sale	M.T.	1.1	1.1	1.1	.97	1.1	1.97	1.1	1.06	1.5	1.5	1.2	1.2
Alloy tool & Stainless steel (Finished).	Thousands tons.			—	—	—	—	—	—	200	200	50	50

C—Capacity *T*—Target *A*—Achievement *S*—Steel
O—Output *M. T*—Million tons

Table 3—Third Plan Targets and Achievements.

Products	*Unit*	*1960-61*	*1961-62*	*1962-63*	*1963-64*	*Target estimate*	*Likely achievements 1965-66*
Ingot Steel	M.T.	3.3	4.27	5.39	5.74	9.2	7.8
Saleable Steel	M.T.	2.4	2.9	4.0	4.3	6.8	5.8
Pig iron for sale	M.T.	1.1	0.97	1.06	1.5	1.5	1.2
Alloy tool stainless steel	00 ton	—	—	—	—	200	50.0

A glance at Tables 2 and 3 reveals that we have not been able to utilize the installed capacities fully. We have been lagging behind in the achievement of our targets for Third Plan, and as a result of delays in expansion programmes of the Public Sector steel plants and in the installation of the Bokaro Steel Plant, we may further lag behind even by the end of the Third Plan.

The emphasis throughout the Third Plan is on the development of basic industries like steel, machine building etc., which will make the economy self-sustaining. In recent years, we have felt the shortage of iron and steel specially in flat products, special steels, and pig iron for foundries.

In all directions there are large and growing demands which can be met in the field of basic industries only by judicious utilization of modern technologies and by putting science to the fullest service of the Nation. During the current plan the direction and management of Indian economy will call for improved methods and machinery for planning and execution, better statistical and economic intelligence, greater appreciation of Science and Technology, fuller knowledge of country's potential resources and generally for more systematic analysis and research. In every section of the Iron and Steel Industry, vital statistics must be collected, compiled and analysed, so as to make the best use of what has already been achieved by the steel plants in the field of technology or maintenance. We will summarize in the next few pages various scientific innovations made in the fields of production, construction and maintenance in Bhilai Steel Plant which may be of interest to Scientists and Engineers.

A mentionmay also be made of the problem of skilled and trained manpower to man the steel industry. Owing to rapid advances in Science and Technology and growing complexity of the Steel Industry, demand for higher skilled and trained man-power was enormous at the beginning of the Third Plan. We solved this problem to a certain extent by giving a scientific bias to our training programme.

A production target of 20 million tonnes of steel by the end of the Fourth Plan (1971) is now being considered as against the 18 million tonnes suggested earlier.

To make 18-20 million tonnes of steel we shall require 45 milllion tonnes of coking coal, 28 million tonnes of iron ore, and about 9 million tonnes of limestone, leaving aside other raw materials, human and transport problems. A tremendous effort and coordination of Scientists and Engineers is required to make this target a reality.

Scientific problems arising in day to day operations of a steel plant are sometimes beyond the scope of operational research within the Plant. In order to solve these problems, Bhilai has branched out in a new direction by fostering cooperation with scientific institutes like the I. I. T., Kharagpur, Bombay, etc. Lectures by senior officers and professors in the respective organisations are arranged where problems are discussed and views exchanged which prove beneficial to both. This also helps to train young student engineers in tackling practical problems and in a way forging their skills and theoretical background.

COKE MAKING

The problems faced by the country due to shortage of metallurgical coal of higher quality is well known. The method usually applied for reducing ash content of coking coal is washing; however, it was considered impractical and costly to meet the entire demand of our coke ovens by washed coal. From the economics of coke making at Bhilai it was felt essential to make partial use of unwashed coking coals in the blend.

A scientific investigation was conducted to find out the most suitable blend from the view point of coke quality for our blast furnaces, gas making for the steel plant, and cost. It was found possible to blend inferior coal to the extent of 10-20%, without much affecting the quality of coke. Suitable changes in coal preparation were done after a scientific study so as to find out the basic causes which help in making coke of the highest quality such as fineness of the crushed coal, coking periods, etc.

Possibility of utilising different grinding properties of various petrographic components of coal have been engaging our attention lately and we hope to start experimenting in this direction to find out the suitability of this method to utilize coals available nearby.

IRON MAKING

1. Trend of Blast Furnace Design

The general trend of installing bigger blast furnaces, specially in USSR and USA, was carefully studied here and it was found that our coke (+40 mm sizes) are quite suitable for operating big capacity blast furnaces. So a wise decision was taken to instal bigger blast furnaces of 1,719 M^3 useful volume which can produce about 2,000 ton/day of iron, thus bringing down the cost/ton.

2. Process intensification by scientific innovations to produce more iron at lower coke rates and lesser cost

(a) USE OF SUPER FLUXED SINTER IN OUR BLAST FURNACES :

Sinter is no longer regarded as simply an economical means of disposing of the wastes arising in mines and steel plants but rather as a better method of burden preparation with metallurgical advantages in increasing productivity of blast furnaces vis-a-vis reduction in coke rates. Super-fluxed sinter is in itself a fully prepared burden, the use of which results in considerable decrease in coke rate and increase in production.

In January, with 707 kgs. of sinter/ton of 1.54 basicity in the burden, we brought down coke consumption to 792 kgs./ton from 900 kgs./ton.

The importance of reduction of basic fluxing material in blast furnace burden was realized by us quite early and we started incorporating more and more fluxes (limestone, dolomite etc.) in our sinter. The use of this sinter together with a reduction in the proportion of raw iron ore in the blast furnace was an instant success. We could get more iron from same furnaces at much lower coke rates thereby attacking the following problems facing this country in one stroke :—

(*i*) Conservation of coking coals.

(*ii*) Filling the gap between demand and supply of pig iron for internal use.

(*iii*) Utilization of ore fines generated in mechanized mining of iron ore, which is unavoidable in large scale operations of iron ore mining.

The minimum 10% gain in production in our blast furnaces and lower coke rates which has come down by 10% can be attributed to this scientific innovation. We hope to increase our sinter production with more and more fluxes incorporated in it in our expansion plan.

The adverse Al_2O_3/SiO_2 ratio in Indian Heamatite iron ores has been one of the basic causes preventing Indian blast furnaces to produce low silicon Open Hearth-grade iron, which justified duplexing in some Indian plants and desiliconizing in Durgapur plant. In Bhilai, we have been able to produce basic iron consistently due to increased incorporation of super-fluxed sinter as blast furnace burden as also due to lower heat requirements in the hearth thereby avoiding absorption of silicon by the hot metal.

Coming to the utilization of the ore fines generated, which amount to 40% of the run of mine ore, the process of sintering offers very promising results for our blast furnaces. Experience at the Bhilai Sintering Plant has shown that Rajhara ore, though containing high alumina, can be successfully sintered. However, the same may not be easily possible for other plants due to adverse Al_2O_3/SiO_2 ratio in their fines and higher ash in coke breeze. The alternative may be to wash ore fines and beneficiate it before using it for sinter making. Though we have succeeded in producing good super-fluxed sinter, there is scope for further improvement in the way of beneficiation, possibly by simple method, and the ore fines may be made into gangue-free concentrates. In such a case, pelletising will be a better proposal. This we have in our mind. This is a challenging problem for our scientists and metallurgists.

The disadvantageous metallurgical features of our otherwise rich ore (high Al_2O_3/SiO_2 ratio) which causes operational difficulties were partially solved by conducting experiments using sinter of high MgO content. This has been quite encouraging in our blast furnace practice. The technology of production of fluxed sinter with high MgO content has been successfully mastered for the first time in India.

In addition to utilization of ore fines in our sintering plant and coke breeze which replaced the equal quantity of blast furnace coke, we have been able to utilize, after careful research under Indian condition, lot of other waste products like flue dust, raw dolomite (from our Refractory Material Plant), mill scale and limestone chips (from our limestone quarries), by proportioning the sinter charge to suit our demands. This has resulted in an overall economy of the plant.

(*b*) SCIENTIFIC INNOVATIONS IN IRON MAKING IN BLAST FURNACE :

Science has again contributed towards intensification of the reduction process in blast furnace by using techniques based on scientific theories, some of which have been adopted in our blast furnace and are briefly mentioned below :

(*i*) *High top pressure* : Blast furnace process of reduction of iron ore being a two component process, prepared and proportioned burden consisting of ferrous materials, fuel and fluxes descending downwards and ascending gases, the contact time of reducing gases and the reducible material, immediately assume importance. The adoption of high top pressure results in better contact due to more retention time and in better utilization of energy of the reducing gases. In addition to this it helps in reducing dust losses due to decrease in kinetic energy of the ascending gases.

(*ii*) *Humidification of hot blast* : Usually a blast furnace operator experiences difficulties due to variation in moisture content of the blast. This gave rise to secintific thinking to regulate the humidity of blast artificially by introduction of known quantity of steam. The idea was based on the fact that thermal condition of the hearth became better with known moisture content. Also the steam introduced at the tuyer level decomposes into H_2 and O_2 This being an endothermic reaction, favoured at high temperatures, corresponding increase in hot blast temperature is made to compensate for the heat losses. Thus the hot blast stoves are utilized to the maximum extent resulting in further coke economy and better control over thermal regime of the furnace.

(*iii*) *Injecting secondary fuels* : In order to cut down our coke rates further in blas furnaces with a view to promote the conservation of metallurgical coal, we are thinking in terms of compensating the heat load of the hearth in blast furnaces by injecting some secondary fuel at the tuyer level, like CTF 200, and liquid Naptha produced at our Bye-Product Plant, we have designed a scheme to inject these in our blast furnaces at the tuyer level. The scien tific reasoning behind this is that the injection of hydrocarbons at the tuyer level will increase the rate of heat input by burning of the hydrocarbons and will release hydrogen as an additional reducing agent without any addition of slag forming constituents.

SCIENTIFIC INNOVATIONS IN STEEL MAKING DEVELOPED AT BHILAI

I. Use of oxygen in basic Open Hearth :

Introduction of oxygen into the combustion air increases flame temperature, accelerating the rate of combustion without adding to the volume of waste gases and lowers refractory consumption. This scientific principle in combustion technique has been introduced in the basic Open Hearth practice at Bhilai Steel Works. The alternative use of oxygen by roof lancing into the steel bath is envisaged in the expansion. At present, bath lancing is practised in primary way through the peepholes of doors. The enhanced rate of oxidation of nonmetallics increases rate of productivity and raises bath temperature and indirectly helps to reduce specific consumption of fuel. The use of oxygen through roof lancing would be fully adopted on more scientific lines in our expansion plans.

II. Use of bye-products gases as Open Hearth fuel :

The Bhilai Steel Plant is unique in the sense that it buys most of the electrical power from outside (Korba Thermal Power Station), and as such the power and blowing station within the plant is run partly on high ash coal or on middlings and partly on excess gas available. This leaves a huge quantity of surplus blast furnace and coke oven gases. Ordinarily coke oven gas with its low emmisivity end blast furnace gas with its low calorific value are unattractive to be used in Open Hearth as a fuel. But we have scientifically modified the mixture of these two gases when using as Open Hearth fuel. The modification has been achieved by :

1. Carburating the flame with addition of liquid fuel thereby increasing its luminosity.

2. Cracking the coke oven gas in gas regenerators.

3. Enriching the air with oxygen (upto 25%) thereby intensifying the combustion process.

Thus due to scientific design and changed thermal regime, we have been successfully using these gases as Open Hearth fuel getting the lowest cost of fuel per ton of ingot steel for equivalent practice in India.

4. *Basic roof in Open Hearth* : The trend in Open Hearth operation now-a-days is to operate the furnaces on "heat input basis" which means that to get maximum tonnage in minimum heat time and to increase availability of the furnace as a whole, the quality of refractories used in vulnerable parts of the furnace must be such as to withstand high temperature. As such a change from silica roof to basic roof (chrome magnesite) had to be incorporated to get the desired results. This is one of the latest contribution of science towards steel making which has been incorporated as a routine feature in our Plant.

5. *New speedy bottom making in Open Hearth* :Reconditioning of worn out bottom of the Open Hearth furnace (due to formation of pits and accumulation of metal) is an intrinsic process involving downtime and unavoidable loss of production. Due to incorporation of basic roofs, cooling and heating of bricks during bottom repair causes spalling and low life. This problem was studied scientifically and it was decided to overcome this by : (*a*) Speedy repairs; and (*b*) longer life of bottom.

It is now posssible in Bhilai to repair the bottom in 2 hours which lasts for 100 heats instead of the usual practice of 5-6 hours which used to last for 25-30 heats. This has been possible due to research on novel bottom making mixture wherein the periclase formation of magnesite is intensified by addition of Cr_2O_3.

6. *Indianization of basic roof bricks* : We have experimentally used Indian manufacture chrome magnesite bricks on the roof of one furnace and prolonged the life (No. of heats before repair) by gunning with a refractory mix evolved after extensive research in our Plant.

7. *Teeming practice for rail heats* : As rails form a major portion of product mix from Bhilai, the yield of first class rails from ingots assumes highest importance. As against the standard practice, we developed and standardized the technology of semi-skilled steel making, teeming in wide end down moulds without hot top and successfully produced rail steel. By studying the metallography of dissected rail steel ingots and blooms, we have been able to achieve high yields. This was the guiding principle behind the story of Bhilai as the maximum producer of quality rails in the country.

8. *Continuous casting* : It is well known that in ingot making, soaking of ingots has an important bearing on the cost of finished or semi-finished steel. Advanced countries have already started continuous casting to produce semis (on small scale) to do away with the processes of teeming, stripping, soaking and blooming. We are contemplating the adoption of this technique in our

third expansion (3.25 million tonnes/year), so as to combine L. D. converters and continuous casting to save space, cost, man-power and to improve product quality.

Scientific application of evaporation cooling

Evaporation cooling of circulating water is a unique feature of our open hearth furnace. The open hearth furnace has an evaporation system for cooling gast ports: skew backs and reversing valves are water cooled.

The essence of evaporation cooling is the use of latent heat of evaporation for cooling the furnace parts located in the high temperature zone. For this reason, the quantity of water needed for cooling is sharply reduced. This allows use of chemically cleaned and de-aerated water required in evaporation cooling and increases the life of cooling devices.

Evaporation cooling of a liquid is defined as cooling of liquid through the combined effect of heat transfer and mass transfer processes that occur on the free surface of the liquid when it comes in direct contact with atmospheric air. Heat is then exchanged between the water and air by contact and by radiation and, in addition, surface evaporation of the water takes place at the expense of part of the heat of the liquid.

Evaporation cooling of the upper part of the furnace is based on natural circulation caused by difference in specific gravities of water fed to the cooled parts, and of steamwater mixture which is generated by them. The steam-water mixture passes through rising pipes to tank separators installed above the furnaces whereby change of speed and direction of travel, the steam-water mixture is separated into steam and water. The water is fed to the furnace parts to be cooled, while the steam is drawn off the consumers.

The steam so generated as a bye-product of evaporation cooling system is used for pre-heating the boiler feed water resulting in thermal efficiency of boilers and overall economy of the plant.

Role of Radioactive Isotopes in scientific studies in steel plant

The scope of the use of radio isotopes in Bhilai Steel Plant is quite vast.

1. With constant use at high temperature, the refractory bricks of the roof of open hearth furnaces are bound to wear off and these have to be replaced periodically. By placing radio isotopes at different depths of the refractory lining and following the activity from outside by means of radiometers, it is possible to tell exactly when the furnace needs repairs or change of lining. This avoids sudden breakdowns causing delays and hold up of production. A similar use of isotopes is made in hot metal mixer refractory lining also.

2. In the blast furnace, applying the same principle as in open hearth, we can place isotopes and follow the rate of wear of lining to determine the time of capital repairs.

In regular operation of blast furnace, isotopes can be used to study rate of descent of the charge by following the activity in slag and metal. This may also tell us whether there is any obstruction or hanging in the course of its travel through the furnace.

3. In sintering plant isotopes are used to indicate the levels of materials in inaccessible bins. Penetrating beams of radiation from highly radio active sourceses such as cobalt-60 are being used for this purpose.

4. At present, we are studying rate of diffusion in metallic phases in steel by the help of isotopes.

5. Rapid estimation of ash in coal and coke by radio isotopes is going on.

6. Detection of pipes in hot blooms by means of gamma radiation.

In future, we are thinking of using Co 60 for the detection of pipe in hot Rail Steel Blooms. The chart (Scintillation counter) clearly shows the presence of pipe and its location, etc. The basic operations are as follows: the gamma rays pass through the bloom and subject to the density of bloom, they produce different count rates which are recorded on a chart via a measuring instrument.

7. Radio isotopes may also be used at a later date to locate the segregation of sulphur and phosphorous in steel.

Roll pass design

In Bhilai, we are rolling as per ISI specifications for structural steel. These standards when compared to those of other countries are among the tightest. The troubles that might occur during the development of these sections could not be foreseen with the limited knowledge which we had in India.

The success which we had in producing these sections is due to the use of modern grapho-analytical method of roll pass design. This system was first mentioned recently in USSR and it is now widely adopted in our plant. This method is based on correlating calculations of dimensions of individual passes to the falling curve of temperature. It gives uniform distribution of load, longer life of rolls commensurate with high quality production.

The highlights of our rolling achievements are the following sections which have been rolled for the first time in India; (1) Crossing sleepers; (2) Beam 600×210mm; (3) H-Beam (Parrallel flange) 150×150mm; (4) Channel 400; (5) Crane rails.

In addition to these, we have supplied rails of 105 lbs and 90 lbs which are in great demand in the country at very high rate of production consistently.

Role of mixer type settling ladles in Foundry

In the 1 million ton plant, ingot moulds for steel melting shop were produced from coupla metal, the coupla using 70% cold pig iron (foundry grade) and 30% of iron and steel scrap. This practice of repetitive melting of cast iron results in loss of silicon effecting reduced graphatization of carbon; as such the ingot moulds produced from such a coupla metal has lower heat resisting properties. To improve upon this after expansion, we will use direct Hot metal from blast furnace through two mixer type settling ladles in foundry to cast ingot moulds for S.M.S. This scientific innovation will result in improved life (heats poured) of the ingot moulds as well as economy in fuel consumption, and will go a long way in reducing the cost of castings in foundry. The average service life of the direct cast moulds is 10 to 50% longer than that of coupla moulds. The direct cast moulds are found to be generally superior in structure and mechanical properties to the coupla iron moulds.

Science as a help to modern techniques of maintenance

In the field of preventive maintenance, much depends upon the prior investigations made and the defects are accordingly diagnosed. With the help of science, prior investigations of the diagnosis have become simpler. Normally a history report is maintained for each equipment where its behaviour during the course of running is periodically recorded. Any replacement of spare-parts is also noted and the reports of periodical inspections are briefly stated. For example, in the base of high dynamically loaded machines, it might be necessary to periodically inspect and record the vibrations on the bearing blocks. Prompt remedial measures are required to be undertaken if the vibrations are beyond permissible limits. Similarly, any rough and clinking noises near the moving parts might indicate a possible wear of some parts. In the case of blast furnace charging equipment the extent of wear of small bell may be assessed fairly accurately by the leakage of gas. The level of crane track may be periodically examined by the help of Theodolites.

Manufacture of spare-parts calls for a wide knowledge of science, engineering and metallurgy, since at every stage the basic priniciples of science and technology are required. Take for instance steel casting. It has to be decided in what pattern it should be made and what types of mould boxes would be required. The system of gating, risers and runners has also to be decided in advance to get a sound casting. The making of required composition of steel has to be carefully gone through. The pouring system of liquid steel in the moulds has to be settled and finally after settling, casting is to be annealed under proper thermal regimes to bring out best physical properties required for its usage. It might be necessary to test a casting radiographically where radioactive radiations are applied to discover the internal defects on the photographic plate. It may be possible to detect internal defects by ultrasonic waves or electronic meters, etc. All this requires application of science at every stage. After machining, it might be necessary to heat-treat the casting and that again requires knowledge of radiography and heat-treatment.

In the field of fabrication, extensive use of gas-cutting and pressure welding in an atmosphere of inert gas, argon, atomic hydrogen and carbon dioxide, has now been adopted.

Application of science in construction techniques

Judicious application of science has been done by construction organisation and few important items are briefly mentioned below :

1. *Modern Welding Techniques* : The latest of all the welding techniques is *Molten Bath Welding* which has been widely used in our expansion plan. Instead of conventional method of welding the reinforcement bars, molten bath welding was adopted for welding reinforcement bars for use in the structure of blast furnace. This has resulted in considerable saving in electrodes labour and four fold increase in productivity. In short the principle of bath welding is that of providing molten metal between the rod ends in such a way that the top of the deposited metal is in a molten condition throughout the process of welding. The molten metal is deposited by simple

welding. The butt ends of rods are fused together by heat supplied by the electrode deposited metal and a weld is formed. The steel bath provided around the ends of the rod to be welded prevents the molten metal from running off and gives a proper shape to the welded seam.

Bath welding can be used for welding of rods from 20 to 36 mm in diameter. More economy of steel can be achieved by using removable copper or ceramic baths for shaping the welds. In using the molten bath method of welding, the reinforced rods must be correctly joined.

In case a steel bath is used besides providing a proper shape to the welded joint, the bath itself can be welded to the rods to provide additional strength to the joint. When this method is employed, it is called *Bath-seam welding*. Rods of diameter 36 to 80 mm can be welded together by using bath seam welding. This method was used for welding of reinforcement rods of blast furnace stoves in the expansion plan.

The quality of welded joints may be checked by cutting out a welded joint and testing it. When cutting of a welded joint is not possible, the welding may be tested by isotopes. Bath welding and bath seam welding are quite easy to learn and can be mastered by any welder. It is recommended that wide use should be made of these techniques in the other projects also to effect economy and efficiency.

2. *Foundation laying*. Construction is an applied science and therefore its technology involves a thorough understanding of behaviour of soils under different conditions and strength of materials used. Prior to laying any foundations, detailed investigations regarding suitability of soils is necessary.

In Bhilai, most of the foundations are laid on firm murrum soil where black cotton soil or ordinary player soil was encountered. For important structures like chimneys, blast furnace, etc., the entire area was spread with sand to a depth of 300mm and R.C.C. foundations have been laid on this layer of sand.

In certain important structures, inflow of seepage water from the bottom of the foundation is not desirable. This is prevented by using a water-proofing memberance of either bituminous layer or a layer of tar felt over a coat of bituminous plant. To prevent reinforcement bars from adhering to bituminous coat, a layer of thin cement plaster is normally given over the bitumen coated tarfelt layer.

In all the foundations a bottom layer of lean concrete is laid over the excavated surface of soil. After this the reinforcement is placed.

The most important final check before concreting is the geodetic check, regarding the position of foundation and its levels. All the foundation bolts for small and heavy foundations are fixed in position prior to concreting.

Concreting of blast furnace No. 4(2000M^3 Vol. of concrete used) had to be completely mechanized for shortage of space. Temporary approaches were constructed over the foundation and continuous concreting done with tippers bringing concrete from batching plant. In laying concrete of such huge quantity, care is taken to avoid segregation by use of chutes. Vibrators are used to eliminate voids as far as possible. As in Bhilai we have to transport concrete from long distance, retarder like sulphited cellulose extract is used to retard the initial setting. If we need quick setting, calcium chloride is used for this purpose.

Utilization of Waste Blast Furnace Slag

It is well known that there is a tremendous shortage of cement in the country due to a high tempo of project activities. In our expansion plan of 2.5 million ton we have envisaged setting up a plant for utilization of waste B.F. slag for producing slag granules, which will be ultimately used for cement manufacture. This will go a long way in helping the nation in the production of much needed cement. The blast furnace slags of the Bhilai Steel Plant are of the basic type and meet the requirements for granulated slags used in cement production. The granulation of molten blast furnace slag is to be performed by the hydraulic chute technique which ensures high efficiency, adequate economy, operational reliability and high quality of production.

In addition, our slag processing plant will produce slag aggregates, mineral wool, and mineral wool mats with a synthetic resin binder. All these will go a long way in utilization of the blast furnace slag which is so far going waste. This is the first time in India that we are going to scientifically utilize the blast furnace slag on a large scale.

Steel Plant Construction

by

P. H. VAIDYANATHAN & DR. N. R. SRINIVASAN

Abstract

The paper gives an introduction to steel production during the Third Five Year Plan, with specific reference to the products and actual achievements. Mention is made of the details of production by the main producers, categories of production and the demand and consumption of steel, including the import of steel products.

The next aspect of the paper dealt with is the major achievements, developments and discovery of new techniques in the production of steel, in all its places, in the various advanced countries. This review focusses attention on the most outstanding developments in the fields of raw materials, their beneficiation and blending techniques, coal washing, production of sinter and pellets, increased productivity in blast furnace by the use of newer techniques, alternative methods to the blast furnace method of making molten iron, steel making processes such as the new pneumatic process, rolling and finishing steel, and the most recent development of continuous casting, vacuum degassing of steel, testing methods and allied phenomena.

The paper then deals with the application of the developments mentioned above in the Indian steel industry. This includes a few topics, such as beneficiation of raw materials, coal washing, sinter production, blast furnace productivity, LD steel making, hot strip rolling, cold rolling and a few others. Mention is made of the projected developments in the steel industry such as the expansions of the existing units and the installation of new units such as Bokaro, continuous casting and so on.

The final part of the paper deals with the specific topic of the application of Science to Engineering Construction, as applied to steel plants. Mention is made of the most recent developments in the design of structures, foundation engineering, concrete, structural steel construction and equipment installation. The application of science to heavy foundations, soil mechanics and soil testing, house building and the like is described. Finally the paper indicates the benefits resulting from the application of science in the attainment of economies in construction and better economy to the Nation.

Steel in Third Plan

In any expanding economy as in India, steel production forms the hard core for development of Industry. Though iron and steel industry can be said to have made a small beginning in the private sector from the turn of this century, it is only since independence, that the Government entered the field in a big way, bringing about rapid strides in its growth. Though the First Five Year Plan of India was agriculture-oriented, the Second and Third Plans placed emphasis

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on steel production. India produced in 1951, 1.5 million tonnes of saleable pig iron and 97,000 tonnes of finished steel, while importing 177,000 tonnes of steel products. The following table illustrates the production of finished steel in India at the beginning and the end of the Second Five Year Plan and in the subsequent years[1].

Table 1
Production of Iron & Steel (million tonnes)

Year	*Pig Iron*	*Finished Steel*
1956	1.87	1.336
1961	4.958	2.845
1962	5.726	3.779
1963 (7 mths.)	3.974	2.473

Three new 1 million ton steel plants were established during the Second Plan at Rourkela, Bhilai and Durgapur with the active support of West Germany, U.S.S.R. and U.K. respectively. The contribution of finished steel for 1956, 1961 and 1962 by the new Public Sector steel plants and those in the private industry[2] is indicated in Table 2.

The pattern of steel production[3] in India has changed with the setting up of the three state-owned plants, in order to meet the domestic demand for the categories required and is illustrated as at the beginning of the second and the third plans (Table 3).

Table 2—Unitwise Production—Finished Steel Tonnes

Unit	*1956*	*1961*	*1962*
Tata Iron & Steel Co.	516,789	875,588	949,500
Ind. Iron & Steel Co.	290,759	563,054	701,700
Mysore Iron & Steel Works	35,964	37,693	39,000
Rourkela	—	145,027	433,100
Bhilai	—	256,558	503,600
Durgapur	—	49,613	188,700
Secondary Producers	203,505	825,561	202,500

Table 3—Finished Steel Output

Category	*1955—56*		*1962—63*	
	Qty. (M. Tonnes)	*Per cent*	*Qty. (M. Tonnes)*	*Per cent*
Railway Materials	0.14	11.3	0.54	13.7
Structurals	0.21	17.0	0.70	17.8
Bars & Rods	0.45	36.3	1.41	35.8
Plates	0.06	4.8	0.31	7.9
Sheets	0.13	10.5	0.29	7.4
Galvanised Sheets	0.13	10.5	0.15	3.8
Tin Plates	0.07	5.6	0.09	2.3
Others	0.05	4.0	0.45	11.3
Total	1.24	100.0	3.94	100.0

The demand for steel in India has been steadily rising along with the increasing production, necessitating imports, despite the tight foreign exchange position. The imports for 1961 to 1963 were 1,046,809, 856,216 and 475,341 tonnes (7 months only) respectively. The projections for steel demand in India have recently been made by an American Steel Mission, M/s. Dastur & Co. and the National Council of Applied Economic Research, the estimates of the last being almost an average of the extremes suggested by the other two[4]. Accordingly, the demand and availability of finished steel in India were 6.2 and 4.15 million tonnes for 1961-62 (the beginning of the Third Plan) and 7.5 and 6.4 million tonnes in 1965-66 (the end of the Third Plan). A target of 17.5 million tonnes of ingot steel (12.5 million finished steel) has been fixed by the Steering Group in the Ministry of Steel, Mines & Heavy Engineering. The Third Plan targets are expected to be achieved by the current expansion of the three public sector plants and other units. However, according to the latest indications from the Advisory Council of Industries in New Delhi, it is understood that the targets in steel intended to be reached by the end of the Third Plan period are now sought to be achieved only by the end of the first year of the Fourth Plan[5]. It might not be out of place to indicate here the latest figures for crude steel production in a few advanced countries in order to appreciate in proper perspective the production in India[6].

1963 : U.S.A. 109.3 m.tons., U.S.S.R. 88.0, Japan & W. Germany 34.0 each.
U.K. 24.8, France 19.4, Italy 11.0

On the basis of 1962 steel output, HSL. occupied the 23rd place among the top 32 steel companies of the world which accounted for 41% of the world steel output. In the years to come, it is to be expected that the steel industry in India will move up the ladder[7].

Recent Developments

In the post-war era, significant developments have taken place in many leading steel producing countries, with greater production and reduced costs[8]. In the field of raw materials, emphasis is being focussed on beneficiation of iron ore by magnetic separation and other techniques and improving quality of fluxes used in iron making. In view of the fact that the resulting metallic concentrates are in the form of fine powders, they have naturally to be compacted by sintering, pelletising or other agglomeration processes[9]. The cardinal advantages of sintering lie in the utilisation of ore fines or concentrates and materials from the steel plant hitherto wasted, such as coke breeze, millscale and flue dust. The use of self fluxed sinter has been accepted as the current standard practice for blast furnace burden. It has been demonstrated that a sinter charge in blast furance can increase production, reduce coke rate, reduce overall costs and also give a better technological control in the furnaces. There is hardly any blast furance in Japan, Germany, U.K. or U.S.S.R. which does not use sinter. Recent developments have indicated that screened and sized sinter gives a better performance in blast furnace. It is herein that the technique of pelletisation has proved superior to sintering, though the adoption of this process on a large scale is difficult at all the steel plants[10]. The use of metallised ore-coke pellet and pre-reduced ore pellets has been indicated[11]. The more important advances in blast furnace production of iron are the use of sized raw materials including sinter or pellets, oxygen enriched and humidified blast, high top pressure working, fuel injection and so on. Recently a few processes such as the Ferdo, H iron processes have been developed, which produce molten iron by reduction in rotary furnaces with hydrogen or inferior fuels[12]. Though these processes by themselves are attractive, a stage may not be reached to replace the conventional blast furnace for some conceivable time.

Steel making has radically changed in recent times with the introduction of oxygen. According to a recent survey by the United Nations Economic Commission for Europe[13], there will be no new acid bessemer shops or bottom blown converters or any new open hearths shops. New shops will be equipped almost exclusively with oxygen converters of different types and electrical arc furnaces. Of the two types of rotating steel making vessels, only the Kaldo furnace is likely to find favour. If scrap is abundant, then cold-charged electrical furnaces are more economical ; with hot charge-based low phosphorus iron, classical LD appears to be the most attractive. It is quite possible that powdered lime and iron ore will be used with oxygen in O.L.P.and L.D. — A.C. processes. The basic oxygen furnace is becoming more popular in the United States[14]. The British Iron and Steel Research Association has developed a process known as F.O.S. (Fuel-Oxygen-Scrap) method for steel making[15]. Attention is simultaneously being paid to the recovery of sensible heat from oxygen converters and gas cleaning and fume arrestment in oxygen steel making process[16].

Vacuum degassing of steel has been a recent and remarkable development wherein several processes have been developed. R.H. process can reduce hydrogen by half and oxygen by threefourths in 20 minute cycle, with the use of argon[17]. The D. H. process can handle heats as large as 400 tonnes[18]. The Cero ingot mould degassing process will be used to degas blooming and forging ingots produced from open hearth and electrical furnace shops[19].

Continuous casting is a recent advance in steel shaping, which combines well with steel from electrical or oxygen steel furnaces giving regularly spaced modest deliveries. It is not well suited for large tonnage open hearth furnaces. There are 52 continuous casting installations in the world with 14 more under construction, primarily in the USSR, USA, Canada, Mexico, South America, Japan and Europe. In continuous casting, there is a saving in capital cost by elimination of ingot moulds, soaking pits and blooming-slabbing or billet mills. The cost of production is less and the yield very good[20]. It has been reported that the present capacity for continuous casting of 1.87 million tonnes in 1964 will be increased to 4.2 million tonnes in 1965 and to 22 million tonnes in 1967 in the USSR. Process for continuous casting of slabs of austinitic chromiumnickel steels has been developed in Austria[21]. Pressure pouring of stainless steel has been successfully done[22].

In steel finishing, significant changes have taken place recently. The production of thin tin, plastic coated pipes, plastic lined pipes, hollow structurals, cold finished bars and others have been developed[23]. Continuous galvanising and annealing have been incorporated in many plants. Automation of several steel making processes has revolutionised concepts and economy in the industry.

Application in India :

The Iron and Steel Industry in India has so far adopted the more recognised and conventional techniques in the making and shaping of steel. It is only in the last few years that attempts have been made to incorporate recent developments in new steel plants in the country. Though India is endowed with large reserves of iron ore, the availability of good quality coking coals is limited. Naturally India should apply such processes as will conserve the raw materials or use inferior kinds of raw materials. In the iron ore mining industry nearly 35 to 40% of the run-on-mine ore has been in the form of fines and has hitherto been discarded. The adoption of sintering will render the iron ore fines readily useful as also some waste products from the steel plants such as coke breeze, mill scale and flue dust. It was in TISCO that the first sintering plant was erected, where straight sinter was sought to be produced. In the 1 million ton steel plant of Bhilai, fluxed sinter is being produced and provision has been made for expansion of the sintering capacity. In the expansion of the Rourkela Steel Plant, a sintering plant with a capacity of 1.2 million tons per annum is under erection. Durgapur Steel Plant will also have a sintering plant in the expansion programme. Bokaro plant when set up, will have a sintering plant with a capacity of 4 million tonnes of stabilised self-fluxed sinter. Experiments have been conducted in the National Metallurgical Laboratory in the production of pellets from Indian iron ores. It has been recognised that pellets are superior to sinter in blast furnace production; however it will take some time before pellets are produced in quantity in India. In view of the high alumina contents of Indian iron ores, beneficiation is necessary. Recently a scheme has been formulated for a beneficiation plant at the Barsua iron ore mines. A similar scheme for Durgapur is understood to be ready.

Coal washing has come to stay in India and several washeries have been established under the aegis of the Government and washed coal produced is being blended with raw coal in coke production. The recent trend has been the incorporation of a certain percentage of coke breeze in coking as adopted in the steel plants. Further, attempts are being made to reduce the coke consumption in iron production.

In blast furnace technology, the applications of modern trends have been in the use of humidified blast, control of blast temperature and high top pressure. Experiments have been conducted on fuel injection in the blast furnace. In steel making, only the Rourkela Steel Plant has adopted the LD process and has three converters of 40 tonnes capacity each. In the expansion of Rourkela Steel Plant two 60 tonne converters will be added. The Bokaro project report envisages use of LD process in 200 tonne converters.

In steel shaping the first hot strip mill and a cold rolling mill have been established at the Rourkela Steel Plant. Extensions to these units as also an electric sheet mill and electrolytic tinning line have been proposed in the expansion programme. Bokaro will also have a 2,000 mm. hot strip mill, cold rolling mill and electrolytic tinning line. The Alloy Steels Plant at Durgapur will produce different alloy and tool steels. Some smaller alloy steel plants are in the private sector.

The first single-strand continuous casting machine will be installed at Mangalore to produce billets of silicon-manganese steel[24]. With further expansion of the iron and steel industry in India, it is possible that there may be applications of new processes or developments which will be aimed at utilising the available resources in India and reducing costs.

The National Metallurgical Laboratory is engaged on investigations relating to the applications of techniques in the metallurgical field. The Central Fuel Research Institute, Dhanbad has carried out experiments to conserve the coking coals in India. The Central Glass and Ceramics Research Institute is engaged in experiments to produce better refractories for the steel industry.

Science plays a dominant role in the field of construction of steel plants besides in the metallurgical aspect of ore steel industry. The construction of steel plants is a complicated task which calls for the deployment of diverse talents. Normally it takes about 5 years for a steel plant to be built on a virgin site. Even if a year is allowed for initial administrative processing, it may not be possible to complete the construction of a steel plant in less than four years. The investment on a new plant is of the order of Rs. 200 crores. An idea of the magnitude involved in steel plant construction may be gleaned from the following figures for a 1 million ton plant.

Works area	5 sq. Km. (Perimeter 14 Km)
Earth work	6,100,000 M^3
R.C.C.	870,000 M^3
Structurals	90,000 tons
Equipment	120,000 tons
Refractories	97,000 tons
Erection of Structures, Equipment and Machinery.	260,000 tons
Power Supply	80,000 KW average.
Make up water supply	60 cusecs.
Works railway	110 Km
Works roads	21 Km

It is common knowledge that some of the requisites for the establishment of a modern plant are :

(*i*) Proper location with respect to availability of raw materials, water supply and power supply;

(*ii*) accessibility to rail and pit heads;

(*iii*) good foundations for installation of heavy and complicated structures and equipments; and

(*iv*) availability of cheap construction materials both of good quality and adequate quantity.

Judged from recent experience which has shown the initial investment for a million ton steel plant to be Rs. 200 crores, the investment over the next 7 years on steel plant construction will be Rs. 2,400 crores to achieve the target of 17.5 million tonnes at the end of the Fourth Plan. It will be obvious that in such a large capital investment, correct techniques and due appreciation for economy in construction will save crores of rupees to the exchequer. Conventional and thumb rule usages and methods hitherto followed in the pre-war era, have to give place to rational and scientific principles For example, structural work which amounts to about 90,000 tons in a one million ton steel plant could easily be replaced for a great majority of the shop structures by either reinforced concrete or prestressed concrete elements. In countries like U. S. S. R. such an adoption has been in vogue for some time and this has saved considerable cost in the overall plant investment. In this country, the idea is just getting acceptance. In the construction of residential houses attached to a steel plant, economies are possible by the adoption of prefabricated concrete construction. Use of slag aggregates for concrete also makes for certain cheapness. All these and similar innovations in construction are the result of laboratory experiments and scientific approach to the problems involved.

Assuming that a proper site is selected on considerations of land available, water resources, raw material supplies, etc., utilisation of these in the most economical way requires a good deal of planning and forethought. Supply of water is an important factor in the working of a steel plant. It is estimated that about 50 cusecs of filtered water supply will be required all through the year for every million ton of steel production even assuming that there is re-circulation provision in the operation of the plant. To make available such a huge water supply with due filtration, and conforming to the quality specified for such usage, involves application of modern techniques in the design and construction of storage, treatment and distribution system. Even though there are standard practices to be followed in such cases, with a large variety of by-products coming out of the steel processing methods, it should be our endeavour to use such of the by-products as would prove adequate in substitution of conventional chemicals for water treatments, thereby effecting economies in the maintenance of the water supply system. It has been proved that such alternative applications are feasible, and in certain plants they have proved successful.

In the matter of sewage purification in a steel plant, with coke oven batteries discharging substances like cyanides, tar and other deleterious by-products into the disposal points, constant attention in rendering the final effluents has to be taken. Application of science in this regard has resulted in improvements in the existing methods.

Smoke and dust coming out of a steel plant have an injurious effect on the health of the population. Control of these by dust catchers and channellising heavy smoke through filter media to make them free from noxious elements, is another field where science helps to reduce the health hazards in an industrial area.

Foundations for the various structural and equipment erection, present much complications depending upon their locations. For facility of keeping movement of tracks within the plant more or less at the same level, considerable earth-work in levelling-up the yard involving varying depths of filling becomes necessary. Where hard surface is available within easy depth, the condition is ideal for foundations, but it is not usually the case in any area comprising more than about 30 sq. miles, required for a steel plant and ancilliaries of the size of one million ton capacity. Where open foundation may not be economical, pile foundation will have to be resorted to. In pile foundation itself quite a number of alternatives are available today, e.g. cast-in-nitu driven piles, precast driven piles, bored piles, vibri piles etc., all of which have got varying degrees of efficiency and utility for adoption. A steel plant foundation problem invariably is complex and comes under the classification of heavy foundations. For instance, the blast furnace foundation in the Rourkela Steel Plant recently constructed, involved 43,000 cu. m. of concrete in one pour at a depth of about 9 meters. This one block of concrete, measuring about 28 × 25 square metere will take an equipment load of about 12,000 tonnes, half of which will be steel structures and plant unit and the other half refractories. The assembly of the huge structure is a complicated problem in erection work, involving heavy lifting tackles, cranes, etc. Similarly, in the case of erection of steel melting shop or the cold hot rolling mills, heavy structural parts have to be handled both in fabrication and in erection. The working conditions in any plant cannot be considered ideal for conventional methods being followed in all cases nor have we the proper equipment to handle everything in a mechanised way.

Quite a number of improvisations have, therefore, to be adopted whether it is in the field of foundation engineering, or in erection techniques. For all these, adaptation of scientific knowledge and personal experience of individuals have a bearing on the final finished structure.

Soil Testing is an important scientific aid for determining the type of foundation to be provided. Soil Mechanics is a recent development and much has yet to be perfected in that field. Soil stabilisation, embankment consolidation, deep excavations for heavy foundations, etc., application of this science is constantly being made in the day to day progress of the work.

Likewise, in the matter of preparing concrete, the old concept of volumetric proportion of sand, aggregate and cement is no longer accepted in any major construction. Concrete today is a highly rational product which can be designed and produced to give specificed strength, by laboratory techniques. With such scientific aid, use of concrete in foundations which form nearly 80% of the civil engineering works,is a highly controlled and mechanised job in any steel plant construction aimed at speed and economy.

Again, in the matter of preservation of structural steel, and other surfaces requiring application of paints, continued developments and new processes are being tried.

Use of slag for road metal by due processing has of late become a regular feature in all the steel plants, thereby effecting some savings in the cost of road work. This has a direct bearing on the application of laboratory technique in selecting and processing out the proper type of slag for such usage.

Though an attempt has been made to indicate in general, as to how far in the construction of a steel plant, science has come to the aid of engineers in developing new ideas in economising cost of construction, it is not claimed that the instances indicated are exhaustive. It is only intended to highlight that in the continuing quest for knowledge and improvements in our practices, it is essential that we should always be guided by a scientific bent with patience and vigilence, to bring about economies in construction practices, resulting in ultimate benefits to the nation.

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Science News

Largest Steel Melting Furnace

A 14-ton capacity steel melting furnace, the largest yet to be made indigenously in India, will be manufactured in Calcutta by AEI Mfg. Co. to the order of Guest, Keen, Williams Ltd., one of the leading manufacturers in India of iron and steel products. Some of the components of the furnace, which cannot as yet be produced in the country will be imported from Britain.

(Brit. Inf. Ser. BF 583)

* * *

Stainless Steel

A new process for making stainless steel strip recently put into commission in Britain is claimed to be a notable advance in this field.

Because of the high surface finish produced by this process, polishing costs can be considerably reduced and this enables fabricating companies to cut production expenses and market finished articles at more competitive prices. It will produce stainless steel strip in varying thicknesses and in widths up to 12 in. at 150 ft. per minute.

Previously, the bright annealing of stainless steel was possible only in muffle type furnaces which have the inherent disadvantages of limited life, dependent on working temperature and the risk of marking the highly finished surface of the strip.

The new equipment removes these disabilities and has the additional advantages of higher maximum operating temperature and much reduced floor space in relation to output capacity.

(Brit. Inf. Ser. BF 185)

* * *

New Hydraulic Press

A new hydraulic press for the cold extrusion of steel and other metals has been developed by a British firm in co-operation with the British Production Engineering Research Association.

One of its principal features is an entirely new double-action motion which enables a wide variety of forward or backward extrusions, or a combination of both, to be performed without elaborate tooling arrangements or stripping devices.

The Association states that substantial savings in production would be achieved by firms machining various types of components if the exact volume of metal could be formed accurately to the shape of the finished component, thus eliminating completely the waste inherent in turning metal into swarf.

(Brit. Inf. Ser. BF 492)

* * *

Stoving Enamel.

A new, duel-purpose, stoving enamel has been developed by a Glasgow paint manufacturer.

The material, will make it unnecessary to re-stove slightly damaged finishes. Components can be touched-up and air-dried. The product is intended for use as a normal stoving enamel. But with the addition of a special accelerator, it can be used to touch up any article which has been damaged in the stoving process. After being touched up, the surface will air-dry to a finish comparable to a normal stoving finish without any colour difference.

(Brit Inf. Ser. BF 492)

* * *

Protecting Metal Surfaces

A strippable coating to protect highly polished metal surfaces from abrasions and corrosion during handling or while in transit has been developed by a British firm.

The material is a PVC plastisol supplied as a thixotropic liquid at spraying viscosity. It is sprayed on with a conventional air gun, and then fused in an oven where it foams to about twice its original thickness.

The coating, the manufacturers state, does not affect the metal surface of objects in any way, and can be easily stripped by hand. The colour selected for the foam can be used for identification.

(Brit. Inf. Ser. BF 492)

* * *

Immersion Heater Furnace

A new electric immersion heater furnace, developed in Britain, for use with pressure die-casting machines, has fully automatic temperature control and is claimed to be noiseless and fumeless in operation.

It is suitable for use with zinc and zinc alloys, including a special alloy containing about 95 per cent. zinc, 4 per cent aluminium and traces of magnesium, which is easily handled at around 400°C. The electric resistance heaters, suitably sheathed, are immersed in the molten metal, ensuring that all the generated heat is transferred to the metal charge.

The absence of a firing chamber around the molten metal bath allows the bath to be larger in relation to the overall size than it would be in a fuel-fired unit. Since the temperature of the bath never exceeds that of the metal, low temperature insulation can be used reducing heat losses to a minimum.

A wall-mounted cabinet houses all the electrical and control apparatus, including the temperature indicating control unit. The only additional item is a free-standing transformer.

The furnace is suitable for melting down the initial charge and can be used for bulk melting, hot chamber die-casting, scrap re-melting or ingotting.

(Brit. Inf. Ser. BF 523)

* * *

Automatic Spraying Machine

A spraying machine for the automatic decoration of metal or plastic bezels, such as are used on car facia panels, car accessories, electrical instruments, toys and clocks, is being manufactured by a British firm. The machine is easy to operate and requires, only one unskilled operator.

Spraying is performed upwards through a spray mask. Each article is placed face downwards in the mask and held in position by a clamp to ensure maximum contact with the mask. On pressing a foot pedal the spray gun follows the contour of the bezel applying a smooth even thickness of material. On completion of the spray cycle, the component is removed and the process repeated.

Results, it is claimed, are consistently better than those obtained by highly skilled operators using conventional methods.

(Brit. Inf. Ser. BF 290)

* * *

New system cuts Building time

A new British building system just announced holds the promise of a 20-storey block of flats completed in 25 weeks—or in a third of the time required by traditional methods, and at considerably less cost.

The system, said to be extremely flexible both in planning and execution, covers the full range of housing from a single "bed-sitter" to a six person flat. Its general principles are said to meet the need for rational planning of sites and buildings, standardisation of component parts, and mechanisation and planning of production techniques and erection programmes.

Under this system the site itself will become the focal point of structural component production in factories which are themselves standardised. They and their equipment can be rapidly set up and then dismantled for operation in another part of the country when the job is complete.

The casting of external concrete cladding blocks will vary from site to site, employing expendable moulds for small contracts and heavy permanent moulds for repeated use from one large contract to another. Each flat or group of flats to be built will consist of a number of repetitive types of unit with a planned sequence of operations, from casting to final position in the building, to a strict time-table.

(Brit. Inf. Ser. BF 105)

Planning for Cement

by

N. R. CHANDRAN

Abstract

The mid-term appraisal of the Third Five Year Plan has revealed that there is a big gap between the present demand and production of cement achieved so far. The estimates indicate a shortfall of 1 million ton or more which demands urgent Government action for correction. This article dissects the Indian Cement Industry and probes deep into its maladies revealing the deep rooted problems of heavy capital requirement, insufficient machinery-making capacity, small pockets of raw materials and paucity of foreign exchange.

A three-pronged attack is suggested to bridge the wide gap between production and demand. The installation of small scale plants at district level will transform the existing structure of the cement industry and is recommended as the most urgent course to eredicate the evils of concentration and to step up production. Manufacture of blended cements can increase production without material expansion of present factories. An incessant war has to be waged to prevent waste and ensure maximum utilization of cement.

To achieve cohesion and convergence of action in executing the plan in respect of cement, the formation of a purposeful Cement Planning Board is recommended. CSIR can give a helping hand to restore the balance and progress of the industry, if one of its National Laboratories marshals its resources and details a team of scientists and designers to grapple with the problem of cement industry.

The development of modern civilization depends to a large extent on the contribution made by cement as it is universally accepted as one of the essential materials of building construction. Together with steel, it is considered as an index of the economic development of a country as cement production and utilization reflect the industrial and social activity of a nation. As cement is considered as one of the key industries in India, the planning for cement has assumed the place of pride in planning of heavy industries in our Five Year Plans as well.

Planning and Targets

When India achieved independence, it emerged out of a long period of economic stagnation crippled against the background of colonial oppression and staggering pressure of population. India had a slender industrial base which called for planning on

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a national scale encompassing all aspects of economic and social life and efforts to mobilise resources to achieve technological and industrial progress with the utmost speed possible. The economic planning based on Five Year Plans created a spectacular growth in the cement industry as well which is borne out by the increased capacity and production achieved during the period. During the First Five Year Plan, the production of cement increased from 3.22 million metric tons in 1951 to 4.57 million metric tons in 1955. By the end ot the Second Five Year Plan the production of cement jumped to 7.80 million metric tons in 1960. A fresh capacity of 4.7 million tons is expected to be added during the Third Plan period i.e. between 1961—66. The capacity target of 15.24 million tons for the Third Plan was based on an assumed growth of demand at the rate of 10—12 per cent per annum. The targets set by the Planning Commission appear to be impressive at a glance, but a careful study of the cement production as compared against international standards, brings to focus the dismally low per capita consumption of cement in our country.

Per capita consumption (in kgs.) of cement during 1959 in a few selected countries

Federal Germany	420
U.S.A.	341
United Kingdom	224
India	16

The fixation of such low targets for per capita consumption of cement in the Third Five Year Plan can be attributed to the following reasons :—

(a) The population explosion in our country, which makes nonsense of the industrial growth and achievements of the Industry causing the dilution of the national gain to an imperceptibly low level.

(b) The limits of the resources of the country in matters of finance, power, transport, raw-materials, technical manpower and above all foreign exchange.

Short Falls and Planning

In spite of the absolute minimum targets fixed for the Third Five Year Plan, which itself stands to revision in the face of increasing demands by various sectors of economy, the mid-term appraisal of the Third Five Year Plan has revealed a wide gap between the targets and supply of cement. The demand for 1965—66 was estimated at 13.2 million tons corresponding to a capacity of 15.24 million tons. However, the production in 1965—66 is not expected to be more than 12 million tons indicating a shortfall of nearly a million tons in 1965—66. Against this background of shortfall in production and unfulfilled targets, the following questions are relevant :

To what extent is the Planning Commission responsible for the working out and implementation of the Plan ? What is its role in the attainment of the production targets and in creating conditions for the maximum production and utilisation of the existing resources ? Is there any central agency which has got the necessary machinery and resources to take up the great task of enforcing and ensuring the implementation of the Plan ?

A purposeful economic plan in a decentralized economy like ours should have two main objectives. First the plan should lay out the objectives and priorities for the period covered and work out the forecast for the coming years. Secondly, the Plan should be able to achieve convergence in action. The necessity of the first objective is amply evident by the acceleration of techhical progress and the growing complexity of economic interdependence. However this objective does not prophesy the future ; it shows what the future can be if everyone works on the basis of the same hypothesis of growth. Thus the second objective becomes relevant ; it necessarily leads to action. Coherent action is not automatically assured in a mixed society of public authority and private initiative such as ours. Private firms cannot be depended to carry out economic actions, exactly according to the requirements of the Plan and hence there should exist somewhere a body or an organisation to ensure that the Plan is implemented as envisaged in the forecast. The complexity and magnitude of such a task of the implementation of the Plan can be readily understood if we focus attention to a single subject as Cement Planning, which deals with problems of cement production, productivity and ultimate utilisation of the cement by the consumers.

Present approach

The present approach of the Government for attainment of the targets in cement as projected by the Planning Commission is to issue out industrial licences to private industrialists who propose to set up cement factories in the country. The Technical Development Department advises the Licensing Committee regarding raw materials, power and other resources and the licensees are completely relied on to fulfil the targets of production. This method is thoroughly undependable as the entrepreneurs have their own problems in the execution of the project and hence cannot live up to their commitments. While in some cases the licensees can be blamed for their inaction, there are genuine difficulties in case, of others to set up large scale cement factories which can be summarised as below :—

(a) DIFFICULTIES IN RAISING CAPITAL

Cement is a capital intensive industry. In India, the capital cost of construction of a new factory is about Rs. 150 per ton of annual capacity excluding power plant. Thus the capital cost of a new factory of capacity 1 lakh ton of cement per year (which is the average size of a factory in India) works out to be Rs. 150 lakhs. Thus the incidence of the abnormally high capital investment raises serious difficulties in the formation of cement enterprises and definitely precludes the small scale and medium scale industrialists in entering the field of cement production.

(b) DIFFICULTIES IN DESIGN AND FABRICATION OF CEMENT PLANTS IN INDIA

Due to the unfavourable foreign exchange situation in the country, the import of equipment and accessories for the cement factories have been banned by the Govt. and the needs of the industry have to be met by the indigenous manufacturers. The cement machinery-making capacity lies in the hands of five or six parties and their capacities are totally inadequate to meet the demands in the country. Machinery manufacturers are themselves handicapped as they are dependent on foreign firms for technical know-how and design, and elaborate workshop facilities are required for fabricating the heavy components of the conventional rotary kilns. Thus it can be seen that the cement making capacity of the country is indirectly dependent on the cement machinery making capacity and something radical has to be done to obviate the difficulties of the machinery manufacturers before we grapple with the problem of cement production.

(c) INADEQUATE RAW MATERIALS

The raw materials for making cement viz. limestone, gypsum and coal are all indigenously available, but the deposits are widely dispersed throughout the country. A large number of deposits of limestone are of low grade, and the extent of deposits in many states like Madras, Maharashrta, Punjab and Assam are not sufficient to warrant the establishment of conventional large size rotary kilns. The deposits of coal are also located only in selected areas which leads to transportation difficulties and high cost in reaching coal to cement factory sites. This obviously points to the dispersion in the location of the cement factories and a reduction in the capacity of the unit as well.

Methods to overcome cement shortage

The shortfall in production in cement in the Third Five Year Plan has now become a foregone conclusion and the capacities envisaged in the Fourth Five Year Plan will also fall miserably short of expectation unless the present approach and policy of the Government takes a more dynamic and purposeful attitude. The formation of the Cement Corporation of India in Public Sector (which has been announced by the Govt.) as an answer to the problem of the cement industry, can yield results only during the fourth plan, and there again, the problem of the industry like machinery manufacturing capacity, reliance on design and know-how on foreign countries and raw materail shortage will retard the progress in the building of of new conventional large scale cement factories.

However a detailed study of the technology of cement production and a review of the advances made by foreign countries in maximising production indicates the possibility of overcoming the shortfall in cement and achieving quick results which are desired within a span of one or two years if the following methods are adopted :—

(a) INCREASE EXISTING CAPACITY BY CONCENTRATING ON SMALL SCALE PRODUCTION OF CEMENT

Production of cement has so far been treated as a large scale industry and rotary kilns of capacity 300 tons per day or more are accepted as the standard units. The widespread belief that small scale units are uneconomical and the quality of product is unsatisfactory has been proved to be wrong and absolutely baseless, which can at best be attributed to the complete ignorance of the modern developments of small scale plants which are operating with remarkably high degree of efficiency in foreign countries. There are already more than 150 small scale cement plants (vertical kilns) now operating in Europe, Japan and Australia and their capacities vary from 60T/day to 200T/day. The modern small kilns are fully automatic (a factor which till now could not be successfully achieved in rotary kilns) and the quality of clinker is excellent. They run on even inferior fuels like coke and anthracite and the fuel efficiency is about 10 - 15% better than the rotary kilns. A small scale vertical kiln plant of 30T/Day capacity can be accommodated in a floor area 100′ x 100′ and the kiln and various machinery weigh not more than 100 tons. Fabrication of the plant can be done in any medium sized workshop in India and should not take more than 6 - 9 months. The capital cost is extremely low and a plant of 30T/day capacity does not need an investment of more than Rs. 20 lakhs. The cost of production of cement in small kilns is higher by about Rs. 5 - 10 per ton of cement compared with the giant rotary kilns which is more than nullified by the saving in packing and transportation costs which may be anything upto Rs. 20 per ton.

It is indeed a pity that in a vast country like ours, where cement is consumed in far flung places of the land which necessitates long haulages causing bottlenecks in transport and increased expenses, we do not think in terms of decentralisation of cement production based on the small pockets of raw materials which can be found in almost every state. In the pattern of development envisaged in the Plans, through democracy and widespread public participation, development along socialistic lines can be achieved only by promoting small scale industries. This will also check some of the undesirable tendencies which urbanisation and the growth of modern large scale industry cause by introducing new disparities in levels of income and opportunity. By placing small scale cement industry on the pattern of rural development, a revolutionary change can be brought about in the structure of cement industry in our country where the small plants meet the local demands and augment the production capacity of the giants to fulfill plan targets.

To implement the scheme of introduction of small scale vertical kiln plants at the district level, Government has to extend active assistance to the small entrepreneurs who do not enjoy the advantages in organisation and expertise in access to capital market and ability to obtain foreign collaboration. The answer is to set up a central design and development organisation capable of taking on the task of designing and fabricating and commissioning of these small plants in various parts of the country. The financial and promotional institutes like Industrial Finance Corporation, State Finance Corporation etc. can take appropriate fiscal measures to ensure that the necessary credit is available for meeting the capital expenses towards such projects. To promote growth of small scale plants, the State Governments can set up demonstration plants under State aegis. Madras Government has recently announced plans to set up vertical shaft kiln as a model plant for Madras State—a measure as commendable as it was long overdue.

(b) INCREASE PRODUCTION BY MANUFACTURING BLENDED CEMENTS

Apart from the increase in capacities of cement by setting up new units (small scale, or conventional size), it would be possible to bridge the big gap between the present level of production and demand by manufacturing different varieties of blended cements, which by virtue of their special properties could meet the specific demands of the construction engineer.

(*i*) *Masonary Cement.* Masonary cement is composed of Portland cement interground with carefully selected additives such as limestone and plasticizers in desired proportions. In this way an increase in output of cement production upto 10% can be achieved without increase of clinker output. Only extra grinding capacity will have to be installed in the existing cement factories and the increased production could be obtained without any large scale capital.

(*ii*) *Slag Cement.* Portland blast furnace slag cement is obtained by mixing Portland cement clinker and granulated blast furnace slag in suitable proportions and grinding the mixture together. Slag cement is extensively manufactured in U. S. A., France and other European countries and is eminently suited to Indian conditions because of its quick curing properties in tropical climates. With the setting up of the steel plants in the country, 4 million tons of slag is available for cement industry, but the tempo of development in this field till now has been unsatisfactory, which is borne out by the fact that the total production in 1963 was only140,000 tons, even though a capacity of nearly 1.2 million tons per annum was licensed for the manufacture of slag cement in the country. It is advisable for the new cement factories, particularly those near to the steel factories to plan additional cement grinding capacity for intergrinding slag with clinker especially in view of the fact that 20-50% of slag can be utilised to step up overall production of cement in the country. The planning of steel plants should also cater for the scheme for granulation of slag to make available as much granulated slag as possible for increased production of cement. The utilisation of its slag production in 1949 was about 71% in America and 51% in U.K. which definitely points out a way to us for increasing cement production, apart from its significance as utilisation of a waste material.

(*iii*) *Pozzolana Cement.* Pozzolana cement is composed of cement clinker interground with pozzolana between 15 to 35% by weight. There is a large quantity of fly ash which would be available from the industrial areas in Bihar and other places where a number of Thermal Power Stations are in operation. The use of fly ash and other pozzolana materials can substantially increase production of cement in our country. All this can be done with existing facilities or perhaps with the addition of some extra facilities in the operating plants, if proper emphasis is directed towards such schemes for increasing cement production without getting bogged down with the major problem of increasing clinker production.

(c) Prevention of Cement Wastage

(*i*) In the present situation when we are faced with cement shortage, and alternative methods of stepping up production which naturally take time for implementation, cannot be counted on to tide over the present scarcity, our attention should naturally be focussed on various methods of prevention of waste and maximum utility of the existing product. Prevention of waste itself can count for 10-15% increase in available cement and hence has to be studied from all aspects. The escape of cement dust along with exit gases from the kiln chimneys, during manufacture is a major source of waste. The collection of this dust can be done by installation of suitable precipitator equipment, which unfortunately exists only in very few factories in India. This aspects is a highly desirable feature and should be introduced in all Indian factories as a means of achieving more production, as well as for creating cleaner atmosphere and better working conditions in factories which will ultimately contribute to increase in productivity.

(*ii*) Losses occur due to inadequate storage facilities which are in a deplorable state in our country. Cement even though packed in gunny bags, is highly susceptible to moisture and exposure. Adequate number of cement warehouses will have to be constructed all over the country to prevent deterioration and wastage of cement in storage.

(*iii*) Another aspect which deserves our attention is that the use of cement should be restricted to building activities where full benefit is made of its cementing properties and only on applications where alternate materials cannot be used. It is common knowledge that large quantities of cement are used indiscriminately in wasteful proportions, in construction jobs, partly due to insufficient technical knowledge and partly due to neglect and misuse. Concerted effort should be directed on dissemination of technical information about techniques and uses of cement, a task which can be well handled by Research Laboratories, Public Works Departments and Private Cement Associations.

Transportation and Cement Planning

The concentration of the larger cement factories in selected areas has aggravated the problem of distribution, resulting in long haulages to reach cement to consumers. Loose cement cannot be profitably sent over large distances and hence the cost of packing borne by the industry is as high as Rs. 18 per ton contributing to about 25 per cent of the ex-factory price of cement which ultimately has to be borne by the users. Long haulages also create difficulties in ensuring that the cement reaches consumers in the right quantities according to their varying demand. The problem of distribution accentuates cement shortage by creating artificial scarcities and damages the economy further. Rationalising the movement of cement by eliminating all cross movement and ensuring that cement is moved regularly and over shorter regional heads in one direction only as far as possible, is in itself a gigantic task which is being tackled by the State Trading Corporation, and the Planning Commission. However it is difficult to understand why the transportation problem is being studied only in its narrow aspects without considering the cause of the malady itself viz. concentration of giant cement factories in far flung places; for which the only effective answer is to decentralise cement production by installation of smaller units covering all regions. By setting up small scale local units catering to the demands of the local area, cement can be distributed direct from the factory to consumers in silo set lorries. The advantages are obvious; yet they have escaped official attention.

Another method suggested for saving in packing charges and prevention of waste is to adopt "Split Location" basis. By this method it is proposed that cement grinding mills should be located in consuming centres and clinker from the existing factories brought over to these centres in open wagons, as clinker is immune to ravages of weather. This method was recently adopted in Singapore, where a huge cement crushing plant was built through joint investment by MITSVI & CO., JAPAN and a firm in Singapore. Clinker is brought all the way from Japan to Singapore where it is crushed and cement is distributed for local consumption.

Convergence of Action

The method suggested for over-coming the present crisis of cement shortage covers divergent areas viz. increase in capacities, increase in production by other methods and also the maximum utilisation and prevention of waste. It can be seen that this task is now handled piecemeal by an impressive list of organisations which covers the subject from its own limited perspective.The Indian Investment Centre is taking measures for inviting foreign capital and investments for supplementing the needs of Cement Industry. The National Productivity Council has made studies on the method of increasing productivity and production of cement. The Technical Development Department advises the Ministry in matters of licensing and raw materials. The S.T.C. is the sole authority to handle the internal distribution and sale of cement and rationalises movement of cement. Cement manufacturers have their Association like Cement Association of India to guide the industry and formulate its own plans. Again, there are a host of research organisations who are pursuing further studies in cement. The problem of cement industry in India today is not the problem of lack of awareness or technical know-how on the subject, as much as the problem of effectively co-ordinating and obtaining a convergence of action to meet the present crisis. We have failed to forge out an organisation, which is responsible for the implementation of the task as detailed by the Planning Commission and answerable to the Government for the shortfalls in execution of the plan targets when they occur. There is a crying need, for the creation of a Cement Planning Board which can approach the cement problem boldly and execute action to supplement the functions of the Planning Commission. It is too much to expect that this task can be taken care of by the Technical Development Department which do not have the necessary means or resources for initiating programmes of production, investment and marshalling of resources for each particular sector of activity. The role of the Cement Planning Board should be to assure the cohesion of the diverse agencies who are currently tackling the problems of cement and to trigger action so as to make the plan a reality.

C.S.I.R. and Cement Planning

The importance of research and development, covering the development of cement and concrete technology has long been recognised by the Council of Scientific & Industrial Research, and valuable contributions have been made by some of their laboratories in this field. Considerable work has been done by the Central Building Research Institute, Roorkee, on the manufacture and quality of the Portland blast furnace slag cement. Work on production of white cement from falspar was carried out by Regional Research Laboratory, Hyderabad, on a pilot plant of 300 Kg. per day capacity. Central Road Research Institute is currently engaged in the studies of different types of mortar and testing of cement. However viewing from the angle of national planning for cement, the work done so far by CSIR appears to be fragmentary and insignificant. C.S.I.R as a dynamic and competently administered research organisation can and should step into the present void of cement planning, so that it can do a great and valuable service to the promotion of cement industry in India at the persent period of crisis. Apart from indulging in basic research, covering properties of cement and field research pertaining to performance of concrete, CSIR should also concentrate on industrial design and manufacture of cement so that it can build up a competent design and engineering team capable of designing the various machinery, equipment and accessories for cement industry. This is a role which perhaps no other parallel research organisations in foreign countries have taken on their shoulders, but in India the lack of technical know-how and insufficient industrial design experience and paucity of foreign exchange impose additional burden on our laboratories. The introduction of small scale cement manufacture advocated in this paper will necessarily demand the assistance and help of an organisation for designing, building and commissioning the plants in the various states. CSIR may have to reorient its research programme in such a way as to make one National Laboratory, responsible for planning of cement so that it attains the stature and prestige required to make the Private Industry, Planning Commission and Government respect its views in cement plnnning and treat it as an effective organisation for the execution of the plan as well. If each one of the key industries in India is thus earmarked for separate National Laboratories, the Laboratories in turn can act as the store house of all technical information and know-how on that specific industry which makes it possible to render expert advice backed by the first hand knowledge and experience of the scientists, engineers and designers who are day to day working on that subject in the laboratory. The role of the Technical Development Department as the technical adviser to the industry—a role for which it is ill-equipped and under-staffed at present –caa then be taken over by the CSIR which can muster all the resources at its command to save the present plan and ensure success of future plans.

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