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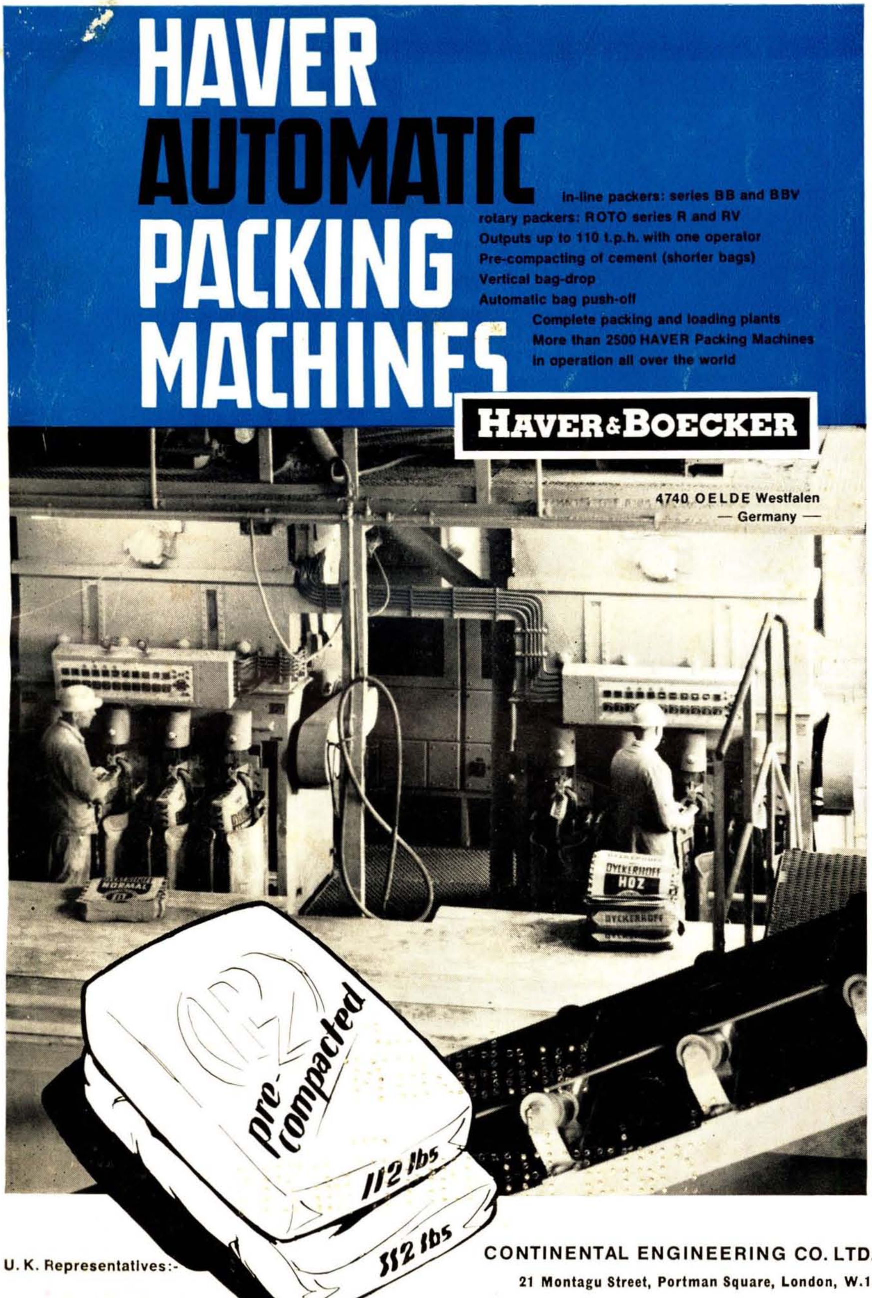

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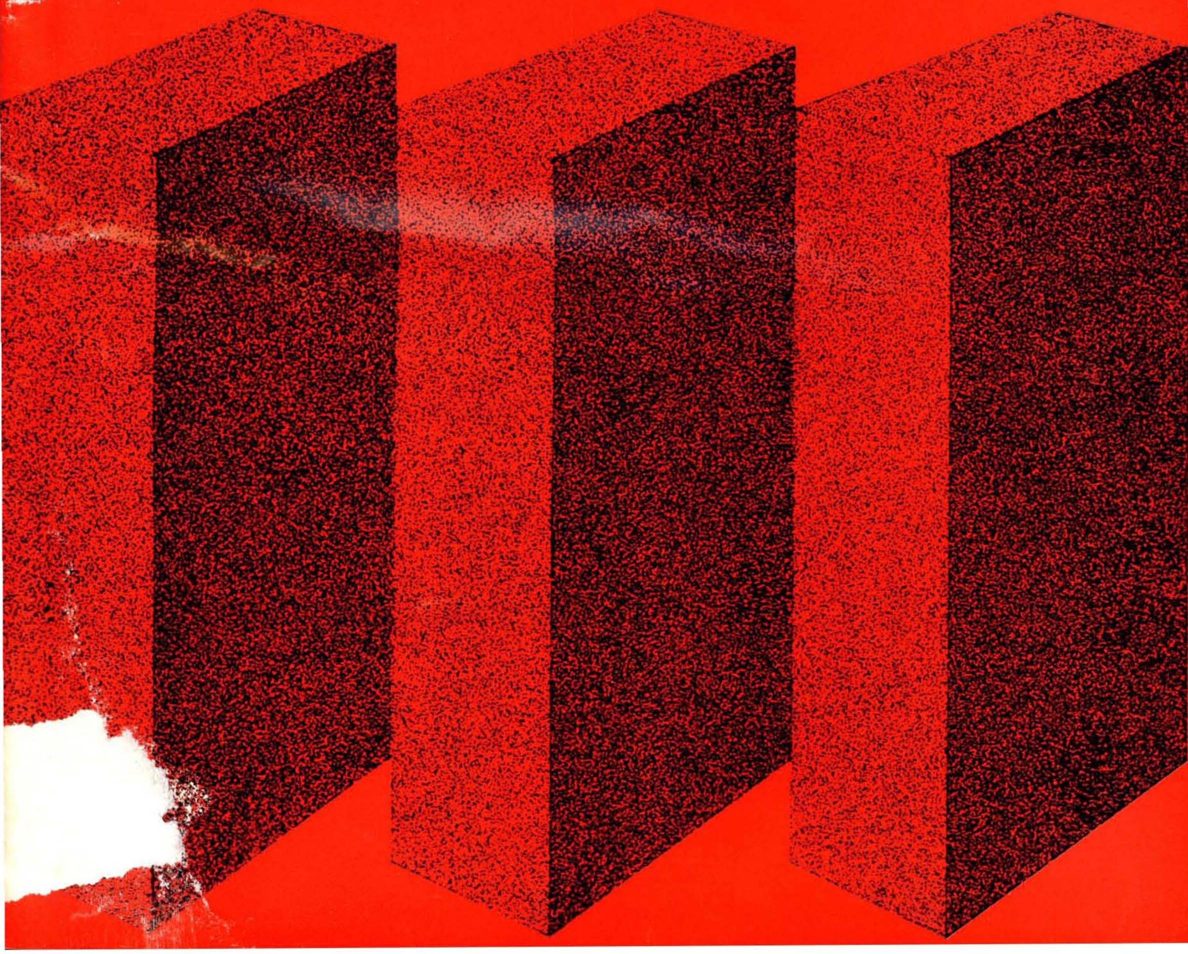

CEMENT AND LIME MANUFACTURE

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VOLUME XLII NUMBER 3 MAY, 1969

Determining the Proportions of Slag and Cement or Lime in a Mixture of these Materials

By DR. F. S. FULTON

DIRECTOR, PORTLAND CEMENT INSTITUTE, SOUTH AFRICA

IN SOUTH AFRICA, it is common practice on many construction sites to use blends of Portland cement and milled granulated blastfurnace slag for the manufacture of concrete. The hydraulic properties of the milled slag are relatively weak but, in a mixture of Portland cement and slag, the calcium hydroxide formed by the hydration of the cement appears to activate the slag. Provided the blending is adequate, the mixture on site of ordinary Portland cement and milled blastfurnace slag in equal proportions by weight produces a material having properties similar to those of Portland blastfurnace cement.

The blending is usually carried out on the site simultaneously with, and as part of, the concrete mixing operation. In practice one 94 lb. (43 kg.) sack of milled slag is substituted at the mixer for one 94 lb. (43 kg.) sack of Portland cement and no extension of the normal mixing time is necessary. On large works, the slag and the cement are generally supplied in bulk, and these materials are blended prior to feeding to the batching plant.

As a control measure, and more particularly as a check on the efficiency of the blending plant, it is necessaıy to be able to determine accurately the proportions of cement and milled slag in the mixture. A number of methods have been developed, involving X-ray diffraction,[3] D.T.A.,[4] or sulphide determinations.[5] The disadvantages of these methods are the expensive apparatus required, the need for skilled interpretation of the results, and a rather low degree of accuracy.

The principle involved in the method proposed in this article is that, if curing water is continuously available to a fresh cement paste, water is continuously absorbed by the hydrating cement. The amount of water is a direct measure of the reduction in volume of the paste system, and approximates to a linear function of the amount of "combined" or non-evaporable water contained therein. According to Powers and Brownyard,[1] $W_a = kW_n$, where W_a is the weight of water absorbed to a given hydration stage, W_n is the weight of "combined" or non-evaporable water at this stage of hydration, and k is a constant depending on the particular cement contained in the paste.

The author [2] has shown that this expression should more accurately be written $W_a = A + BW_n$, where A and B are constants for the particular cement.

In a blend of milled slag and Portland cement, the amount of "combined" water at any stage of hydration depends on the characteristics of both the slag and the cement and their proportions in the mix. Consequently, if the absorption rates of blends of milled slag and Portland cement made up in known proportions are established by test, then the amount of water absorbed in the same period by a blend of unknown proportions can be used to establish the quantities of slag and cement in it.

The method has been developed specifically for use with slag mixtures, but it is considered probable that it can be applied to blends of cement and other materials having pozzolanic properties. The main disadvantage is that in order to perform the test, samples of the Portland cement and slag used in the mixture must be available. This is of little consequence on a large project where continuous sampling from bulk silos presents no difficulty.

Apparatus

The only essential piece of apparatus, except for a balance, is the absorption burette shown on *Figs.* 1 and 2. The flask consists of a 500-c.c. Consol preserve jar provided with the usual glass cover plate, metal cap and rubber ring. The metal cap is drilled to receive a burette, the joint being made watertight with epoxy resin. The advantage of this type of apparatus is that the mass-produced Consol jars are so inexpensive that they can be discarded after use, while the cover plate and burette can be re-used any number of times.

It is convenient to use large samples of paste, say, up to about 400 c.c. Even with burettes graduated only to 0·1 ml., the amount of water absorbed can be accurately read to 0·1 mgm. per g. of cementitious material.

For the purposes of this test, a 6-ml. burette, graduated to 0·025 ml. is most suitable. For tests extending over periods exceeding twenty-four hours, a 20-ml. burette is preferable. It is important that the burette be thoroughly cleaned out, using a wad of cotton wool, after each test. If this is not done difficulties may be experienced in reading the meniscus.

Procedure

A quantity of 400 g. of binder is mixed with 160 g. of distilled water. Mixing is carried out by hand for a period of four minutes in a stainless-steel or enamel bowl. For accurate laboratory work, controlled humidity and temperature are desirable. The paste is then poured into the jar and consolidated by jolting to

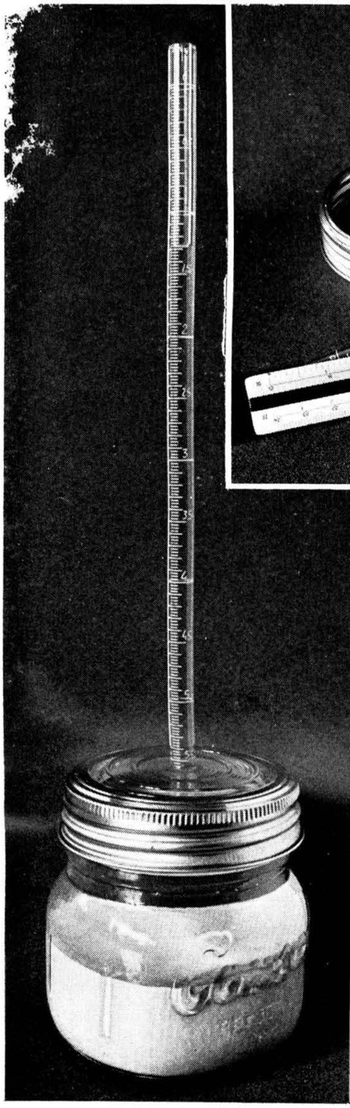

Fig. 1 (left).—Absorption Burette Assembled: Test in Progress.

Fig. 2 (above).—Components of Absorption Burette.

expel any air bubbles. Immediately thereafter, the jar is filled with tap water, using a small hand syringe in such a way as to prevent disturbance of the surface of the paste. The operation is completed by placing the whole apparatus in a tank or sink filled with water, and fitting tightly the burette cover, metal cap and rubber ring to the jar under water in such a way as to exclude all air. On removal from the tank, the metal cap is finally tightened and the burette is filled to about the 0·5-ml. mark. Unfortunately, the tightening as at present carried out requires two

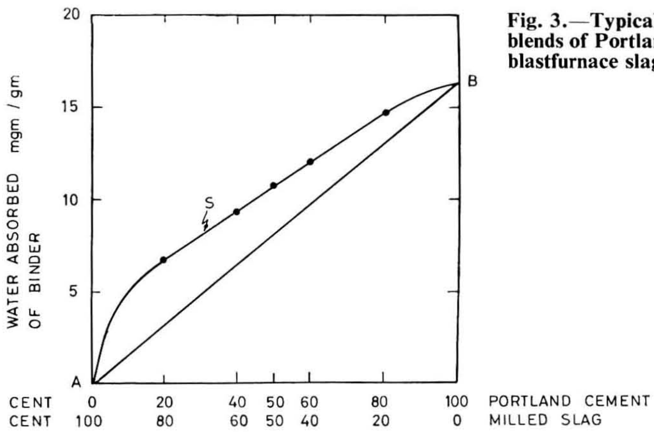

Fig. 3.—Typical absorption cur· blends of Portland cement and · blastfurnace slag.

operators. Finally a few drops of oil are placed on the water surface in the burette to prevent evaporation, and the apparatus is placed in a storage cupboard. For accurate laboratory work, controlled temperature conditions during storage are necessary.

The first reading of the burette is taken exactly two hours after commencement of mixing, and this is regarded as the zero reading for the test. The final reading for each sample is taken exactly twenty-one hours after the addition of the mixing water. Other periods of storage could well be chosen, but the 21-hour period proved suitable at the Portland Cement Institute laboratories. Five samples were prepared in an afternoon in such a way that the zero reading for the last sample was taken just before the laboratories closed at 5 p.m. This meant that the test ran overnight, and the results were available first thing next morning.

Results

The 21-hour absorptions of various blends of milled slag and one cement are shown by the curve ASB in *Fig.* 3, which is typical of the results obtained. The absorptions are simply calculated by dividing the drop in the burette meniscus by the weight of combined slag and cement in the paste, the results being expressed in mg. per g. of cementitious material.

It may be noted that with slag:cement proportions between 40:60 and 60:40, the absorption curve is for all practical purposes a straight line. In order to determine the proportions of a blend, therefore, it is only necessary to make up blends of the available materials in 40:60 and 60:40 proportions, and to compare their 21-hour absorptions with that of the unknown mixture. The proportions of the latter can then be obtained by direct interpolation. For more accurate determinations an increased number of samples and a closer grouping are desirable.

Table 1 shows the results obtained for blends of five normal cements and milled slags from two sources. In addition, as a control measure, corresponding blends were made up of the cements blended with an inert material, for example, marble dust crushed to the fineness of cement. Although the water absorptions deter-

..LE I—ACTUAL AND DETERMINED PROPORTIONS FOR BLENDS OF PORTLAND CEMENTS, MILLED SLAGS AND AN INERT MATERIAL

C... nt	Slag	Actual Proportions									
		55/45		52½/47½		50/50		47½/52½		45/55	
		W_a	Det. %	W_a	Det. %	W_a	Det. %	W_a	Det. %	W_a	Det. %
03	1	11·08	44·57	10·60	48·05	10·30	49·98	9·97	52·62	9·67	54·78
	2	11·27	44·76	10·82	47·87	10·53	49·81	10·10	52·76	9·80	54·81
	Inert	11·32	44·98	10·82	47·71	10·42	49·89	10·00	52·17	9·43	55·25
04	1	9·25	45·23	9·03	47·30	8·73	50·16	8·57	51·72	8·17	55·53
	2	9·55	44·75	9·18	48·20	9·03	49·62	8·77	52·14	8·43	55·28
	Inert	9·32	44·84	8·95	47·71	8·68	49·78	8·27	52·99	8·05	54·70
08	1	10·27	44·96	10·01	47·58	9·80	49·70	9·47	53·02	9·30	54·74
	2	11·90	45·47	11·67	47·37	11·40	49·60	11·07	52·36	10·70	55·39
	Inert	10·56	45·05	10·30	47·33	9·92	50·65	9·82	51·52	9·37	55·45
09	1	10·60	44·78	10·26	47·44	9·85	50·64	9·64	52·28	9·31	54·86
	2	11·16	45·03	10·86	47·62	10·60	49·86	10·32	52·28	9·98	55·21
	Inert	11·24	44·93	10·82	47·43	10·35	50·24	9·97	52·51	9·57	54·89
010	1	10·37	44·92	10·08	47·33	9·73	50·25	9·42	52·83	9·20	54·67
	2	11·08	45·43	10·92	46·98	10·58	50·27	10·42	51·82	10·04	55·50
	Inert	11·05	44·80	10·63	47·80	*	*	9·99	52·37	9·62	55·02

* Insufficient material

mined for the latter blends were corrected for the absorption of the marble dust with no additive, in practically all cases the results show values of W_a exceeding those obtained for the corresponding blends containing slag No. 1. This may point to some small reaction between the marble and the cement as postulated by a number of authorities.

Conclusions

(1) The test is extremely simple compared with present chemical or other methods.

(ii) The apparatus is simple and inexpensive, and the test can be confidently carried out by a practically unskilled laboratory technician.

(iii) The tests show that the error in the estimate of the proportions is usually less than 0·5 per cent.

(iv) The test is highly reproducible and obviates a number of undesirable variations inherent in other tests, namely, those due to the efficiency of the operator, compaction, use of aggregates, etc.

(v) The test can be carried out with fair accuracy in the field. Provided there is no large temperature change in the 40-minute interval between preparing the first and third specimens or in taking the corresponding burette readings, temperature control is not of much importance. If the specimens are stored together, any

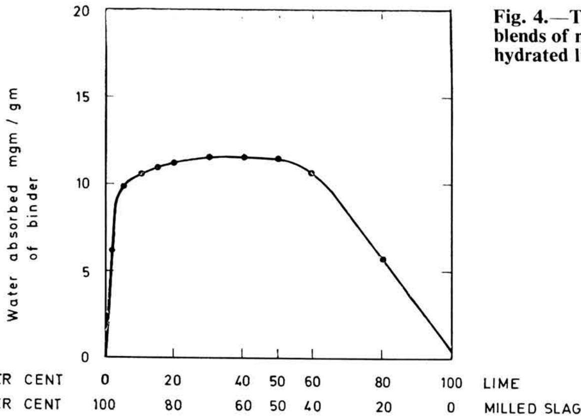

Fig. 4.—Typical absorption cu blends of milled blastfurnace s hydrated lime.

change in ambient temperature will affect all three in the same degree. Humidity is of no importance unless very large changes are experienced in the short period of mixing the three samples.

(vi) The test offers a means of modifying concrete mixes to suit changes in slag or cement characteristics within twenty-one hours after receipt on the site of these materials.

(vii) It appears that the contribution of the milled slag to water absorption, and consequently to the strength of the blend is negligible at least up to the age of twenty-one hours.

Hydrated Lime and Milled Slag Blends

In South Africa, blends of hydrated lime and milled granulated slag are frequently used for the stabilisation of road bases. The lime and the slag are generally supplied in bulk and are blended prior to spreading in a specially designed portable blender. The problem is again that of determining the exact proportions of the two materials in the blend.

TABLE II—ACTUAL AND DETERMINED PROPORTIONS OF BLENDS OF MILLED SLAGS AND HYDRATED LIME

Actual Lime Content % by weight	Slag 1		Slag 2	
	W_a	Det. %	W_a	Det. %
20	2·80	21·58	6·98	20·09
22·5	2·69	22·12	—	—
27	2·62	26·44	6·55	26·58
30	—	—	6·43	27·85
32	2·24	32·80	—	—
34	2·36	33·80	6·03	33·12
36	—	—	5·85	35·38
38	2·04	37·55	—	—
40	2·09	41·58	5·43	40·76
42	—	—	5·23	43·43

ne method already described in this article is entirely suitable for the purpose. ortunately the blend commonly used is 2 parts by weight of slag to 1 part by ght of lime. As can be seen from *Fig.* 4, the water absorption curves for blends approximately these proportions are rather flat, and a high degree of precision not possible. The difficulty is overcome by making up blends of slag and lime known proportions to "bracket" the unknown blend. These blends are intimately mixed with equal quantities by weight of hydrated lime. By this means it is possible to work in the range of lime contents characterised by the steep section of the absorption curve shown on *Fig.* 4. Re-conversion to the original blends is a matter of simple arithmetic.

The results of a limited series of tests are shown on *Table* II. The dilution of the original blends with lime introduced a degree of error which, having regard to the purposes of the blending, is nevertheless tolerable. It should, however, be pointed out that it is necessary to use a water: cementitious material ratio of 0·75 by weight in order to obtain a grout sufficiently fluid to permit easy compaction in the jars.

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Films on High-alumina Cement

LAFARGE ALUMINOUS CEMENT CO. LTD. have recently had made three films on the industrial uses of the high-alumina cements manufactured in the U.K. under the trade names of "Ciment Fondu" and "Secar". Each film is designed to be shown separately or in conjunction with the others.

One film, entitled "The Cement for Modern Industry", deals with general technical aspects and outlines the special properties of high-alumina cements and the manufacture and distribution of these materials.

Another film is entitled "Castable Refractories" and is concerned with the particular usefulness of "Ciment Fondu" and "Secar" in refractories, where high performance and ease of casting make for durable refractory linings.

The third film is entitled "Ciment Fondu Structural Concrete" and emphasises the contribution which "Ciment Fondu" has made to the construction industries by virtue of its extreme rapid-hardening properties, resistance to various aggressive chemicals, and high structural strength.

The films were produced by Chapman Raper & Associates Ltd. in association with Allardyce Palmer Ltd.

Cement Industry in the United Kingdom

Cement Production in 1968

ACCORDING TO statistics prepared by the Ministry of Public Building & Works, the total production of cement in the United Kingdom for the year 1968 was 17,659,000 tons, which is 327,000 tons more than in 1967. Home deliveries of cement amounted to 17,573,000 tons, which is 385,000 tons more than in 1967.

The tonnage of cement delivered by the Rugby Portland Cement Co. Ltd. Group in 1968 in the U.K. was 7·9% in excess of that for 1967. Deliveries at home and overseas together, for 1968, were 10·3% up on 1967.

Extensions at Widnes Works

Holst & Co. Ltd. have been awarded the contract to construct the extensions to the cement works at Widnes for The Associated Portland Cement Manufacturers Ltd. The contract includes bulk-loading silos, extensions to the mill house, a cement intake pit, a motor repair depot, extension to stores, cement packing complex, paving and railway sidings. The consulting engineers for the work are Oscar Faber & Partners, and completion is expected early in October.

Equipment at Pitstone

In connection with the extension of the Pitstone works of Tunnel Cement Ltd., the firm of Kent Instruments Ltd. of the George Kent Group has secured several orders for instrumentation, the orders being placed through the main contractors, F. L. Smidth & Co. Ltd., of Croydon. The Kent equipment, which will feed in signals to a computer installed to control a new dry-process kiln, includes 30 DI transmitters, five Multipoint Mk. 3 recorders, gas-analysis equipment, the new quick-response pump, and sampling system for the analysis of industrial flue gas. Seventy-five current transmitters are also being supplied by Evershed & Vignoles, which firm is also in the George Kent Group.

The plant will have a high electrical content, the equipment for which includes nineteen motors of up to 2,700 h.p. and fed at 3,300 volts and over 350 medium-voltage motors fed from eighteen control panels and controlled, in turn, from a computerised process controller. Some twelve miles of cable are required in this installation and, in view of the vital importance of safety, the earthing system will contain nearly 5 tons of copper. The contract for the cables and earthing installation has been awarded to the Shoolbred Electrical Co. Ltd., members of the Electrical Division of the Deritend Group of Companies.

The illustration on page 49 shows the new reinforced concrete chimney at the Pitstone works in the course of construction. The chimney is 108 m. (350 ft.) high and the special travelling formwork is shown being removed by helicopter on the completion of the structure. The shaft tapers from 8·5 m. (27 ft. 6 in.) at the base to 3·1 m. (10 ft.) at the top and was constructed by the slipform method using special formwork which was capable of being continuously varied in diameter to suit the taper of the chimney. The consulting engineers are Sir Frederick Snow & Partners and the main contractors are J. L. Kier Ltd.

Seventh in succession

Stein have seven tunnel kilns at Manuel Works near Linlithgow. They produce Firebrick, High Alumina and Basic Refractories. This is No. 7. It is one of the most modern and efficient kilns in the world and it typifies the planning and enterprise that

High purity in raw materials is an essential feature of Stein Quality. This is the modern Fireclay Treatment Plant. ▶

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Feeding this k n
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...c batching plant.
...rgely automatic
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in...

Production in the Stein mines is mechanised with tractor-shovels.

The packaging machine that wraps and seals an entire pallet of sacked monolithics in a tough polythene bag.

Similarly advanced manufacturing resources are employed for all the other Stein products.
In the expanding field of monolithics – refractory concretes, plastics, cements etc. – Stein have kept pace with demand by building a special plant at the Castlecary Works. Separate flow lines for each type of material prevent contamination of the product. Improved packaging techniques ensure that every consignment, large or small, reaches the customer in perfect condition.

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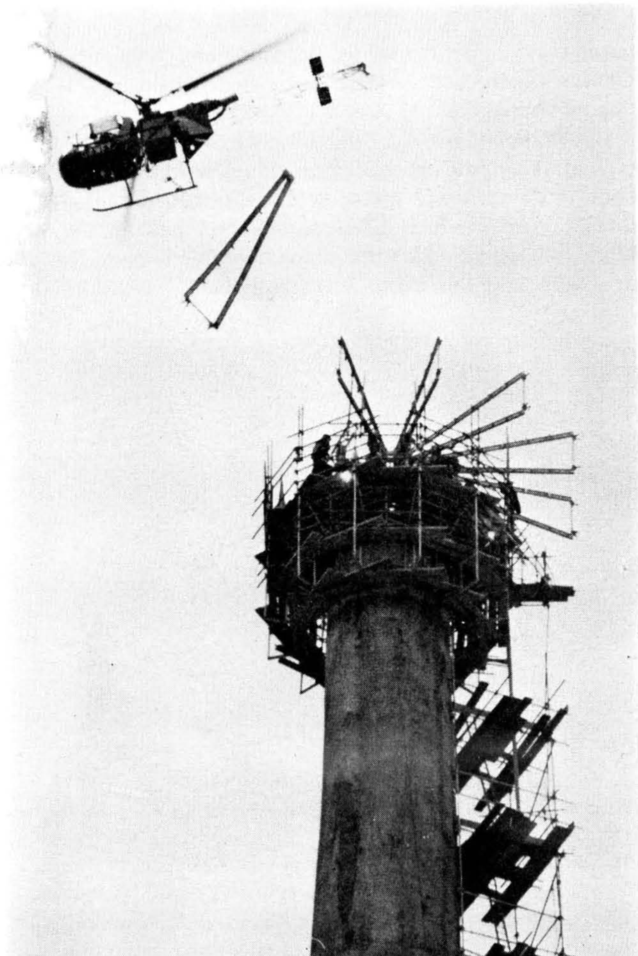
STEIN *Refractories*



Pitstone Works Extensions: Reinforced Concrete Chimney in course of Erection **(see page 48).**

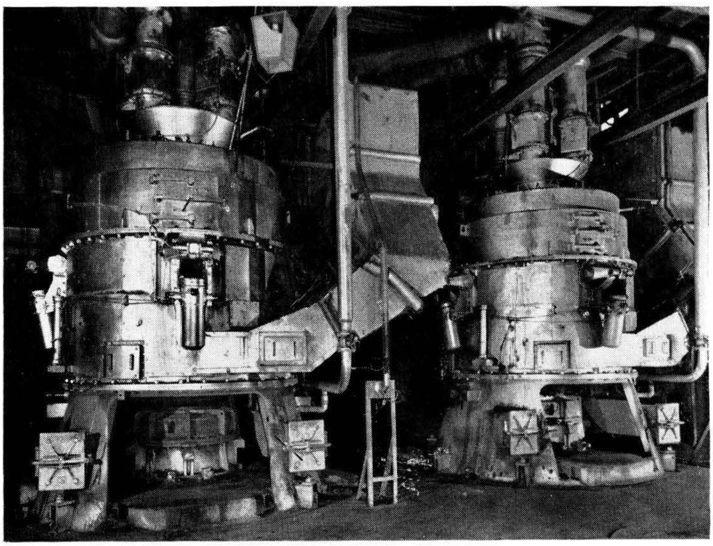
Cement From Billingham Works

All cement produced by I.C.I. at their Billingham works is now being sold and delivered by The Cement Marketing Company. This arrangement commenced on March 1, 1969, and orders are now dealt with through The Cement Marketing Company's office in Newcastle upon Tyne.

New Pulverised-fuel Mills

THE OUTPUT of the cement works of The Associated Portland Cement Manufact' Ltd., at Hope, Derbyshire, is being doubled and the new equipment includes tw coal mills for supplying pulverised fuel to the new kilns. The capacity of the kiln is 2,000 tons per day. The improved maintenance procedure devised for the ı which are of the 7E type made by Babcock & Wilcox Ltd., is expected to result a considerable reduction in the time that mills are normally out of commission.

Undertaking maintenance is avoided in the summer, when the demand for cement is at its peak. No stand-by plant for pulverising fuel is provided, and routine maintenance is kept to a minimum. Wear is greatest on the grinding



elements and, in the new mills, accessibility has been improved by providing for the easy removal of the upper part of the mill, the coal-chute above the mill, and part of the pulverised-fuel outlet. A pneumatic device automatically adjusts the pressure on the grinding elements to compensate for wear, an operation which, on the pulverised-fuel mills installed elsewhere is usually done manually, each loading point being adjusted in turn.

The new mills, which are similar to those shown in the accompanying illustration, will supply $12\frac{1}{2}$ tons of pulverised fuel an hour to each of the kilns. A supplementary pneumatic system will recover from the reject system coal which would otherwise escape grinding.

The air-flow through the mill will be induced by suction. By reducing the proportion of air-to-coal passing through the mill, the amount of cold air drawn into the kiln is reduced and economies in fuel consumption will be achieved.

National Standards for Portland Cement

On PAGES 52 to 59 is given the second of a series of tables giving the requirements of most of the national standard specifications for Portland cement. The first table in this series related to the chemical composition and was given in the number of this journal for March last. The table in the present number relates to the tensile, compressive and bending strengths. Some of the data are abstracted from "Cement Standards of the World 1968", but some of the information is in accordance with the requirements of later available Standards. Other revisions may have been effected since these tables were prepared for the press.

In later numbers of this journal it is intended to publish additional tables giving data relating to other physical properties of Portland cements.

The following abbreviations for the various types of Portland cement are used:

O—Ordinary

RH—Rapid hardening (or high early strength)

LH—Low heat

SR—Sulphate resistant

AE—Air entrained

Cement Industry Abroad

Singapore.—IHI (Ishikawajima-Harima Heavy Industries Co. Ltd.) recently received an order from Onoda Cement Co. Ltd., of Japan, for a clinker unloader of the 330 tons per hour level-luffing type equipped with a hopper and a 500 cu. m. (655 cu. yd.) bag-filter dust collector, for the Singapore Cement Manufacturing Co. Ltd. This plant will replace the present 160 tons per hour unloader and will be installed at Singapore Port. It will be used by Singapore Cement Manufacturing Co. Ltd. for unloading clinker which is transferred to the works for grinding.

Singapore Cement Manufacturing Co. Ltd. was jointly established by Mitsui & Co. Ltd., Horyu Co. Ltd., and Onoda Cement Co. Ltd. and operates a cement works having a capacity of 500 tons per day. Because of an unexpected increase in the local demand for cement, the Company is doubling the works and the purpose of the new unloader is to increase the clinker-unloading capacity.

India.—The works of The India Cements Ltd., at Sankarnager, Tirunelveli District, Madras State, are being extended and as a consequence the present productive capacity of 1,500 tonnes per day will be increased to 1,000,000 tonnes per annum. The new plant is being supplied by F. L. Smidth & Co., Denmark.
(*See also page 62.*)

TABLE II.—STRENGTH OF PORTLAND CEMENT. (*See page 51*)

UNITS.—Strengths are given in kilogrammes per square centimetre. To convert to Newtons per square millimetre multiply by ten (or, more exactly, multiply by 9·8). To convert to pounds per square inch divide by 0·07.

Country (Date of standard)	Type of Cement	Tensile Strength Age of specimen in days				Bending Strength Age of specimen in days			Compressive Strength Age of specimen in days				Remarks
		1	3	7	28	3	7	28	1	3	7	28	
Argentina O (1964; revised 1966) RH (1966)	O	—	—	—	—	—	35	55	—	—	170	300	RH only Bending at 1 day: 22 at 2 days: 40
	RH	—	—	—	—	50	65	75	100	270	400	500	Compressive at 2 days: 200
Australia (1963; amended 1964 & 1966)	O	—	—	—	—	—	—	—	—	193	281	387	7·07 cm. cubes
	LH	—	—	—	—	—	—	—	—	176	246	316	
	RH	—	—	—	—	—	—	—	—	281	387	527	
Austria (1963)	OI 275	—	—	—	—	—	30*	50	—	—	110*	275	Bending at 1 day: 30* (HS only) *optional
	OII 375	—	—	—	—	30*	40	60	—	150*	225	375	
	HS 475	—	—	—	—	50	60*	90	100*	300	360*	475	
Belgium (1959)	O	—	18	23	27	—	—	—	—	200	300	400	
	HS	—	23	27	30	—	—	—	—	300	400	500	7·07 cm. cubes
	RH	20	27	30	32	—	—	—	225	400	500	575	
Brazil (1967)	O	—	—	—	—	—	—	—	—	80	150	250	Cylinders: 5 cm. dia. × 10 cm.
	RH	—	—	—	—	—	—	—	110	220	310	—	

Britain O, RH, LH (1958; amended 1960 and 1962) SR (1966)	O/SR	—	—	—	—	—	—	—	—	155	239	—	Mortar cubes
	RH	21*	—	—	—	—	—	—	—	211	281	—	
	LH	—	—	—	—	—	—	—	—	77	141	281	
	O/SR	—	—	—	—	—	—	—	—	84	141	—	4 in. concrete cubes. The quantity of dry aggregate shall be determined by trial. The weight depends on the s.g. of the aggregate and shall be approximately 1950 g. for each cube. Mix cement/aggregate approx. 1:6. Water/cement ratio 0·60
	RH	—	—	—	—	—	—	—	—	120	176	—	
	LH	—	—	—	—	—	—	—	—	35	70	141	
Bulgaria (1956)	O 200	—	—	12	16	—	—	—	—	—	20	200	
	250			16	20						160	250	
	300			20	25						200	300	
	HS 400	—	20	25	30				—	200	280	400	7·07 cm. cubes
	500	—	25	30	35				—	260	380	500	
	600	—	27	32	38				—	300	450	600	
Canada (1961; revised 1963, 1964 and 1966)	O	—	14	19	25	—	—	—	—	84	148	246	2·75:1 mortar for compressive test. 2 in. cubes
	RH	19	26	—	—	—	—	—	120	211	—	—	
	SR	—	11	18	23	—	—	—	—	53	105	211	
Chile (1951)	O	—	20	25	30	—	—	—	—	200	250	350	7·07 cm. cubes
	HS	—	25	30	35	—	—	—	—	250	350	450	

TABLE II.—STRENGTH OF PORTLAND CEMENT. *(Continued)*

UNITS.—Strengths are given in kilogrammes per square centimetre. To convert to Newtons per square millimetre multiply by ten (or, more exactly, multiply by 9·8). To convert to pounds per square inch divide by 0·07.

Country (Date of standard)	Type of Cement	Tensile Strength Age of specimen in days				Bending Strength Age of specimen in days			Compressive Strength Age of specimen in days				Remarks
		1	3	7	28	3	7	28	1	3	7	28	
China (mainland) (1959)	200	—	—	12	18	—	—	—	—	—	100	200	7·07 cm. cubes
	250	—	—	12	18	—	—	—	—	—	140	250	
	300	—	—	15	22	—	—	—	—	—	180	300	
	400	—	15	19	23	—	—	—	—	160	260	400	
	500	—	19	23	27	—	—	—	—	220	350	500	
	600	—	21	27	32	—	—	—	—	260	420	600	
Cuba (1956)	O	—	11	19	25	—	—	—	—	84	148	246	2·75:1 mortar for compressive test 2 in. cubes
	MSR/MLH	—	9	18	23	—	—	—	—	70	127	246	
	RH	19	26	—	—	—	—	—	120	211	—	—	
	LH	—	—	12	21	—	—	—	—	—	56	141	
	SR	—	—	18	23	—	—	—	—	—	105	211	
Czechoslovakia O (1957) HS (1962) RH (1960)	O 250	—	—	17	25	—	—	—	—	—	180	250	7·07 cm. cubes
	O 350	—	—	23	30	—	—	—	—	—	250	350	
	O 450	—	25	28	33	—	—	—	—	275	375	450	
	O 550	—	28	32	35	—	—	—	—	340	430	550	
	HS 450	—	25	28	33	—	—	—	—	275	375	450	
	HS 500	—	28	32	35	—	—	—	—	300	400	500	
	RH 500	18	28	32	35	—	—	—	200	340	430	500	

Denmark O (1933) RH (1942)	O	—	—	20*	25*	—	—	—	—	—	320	400	Tensile and compressive at 28 days combined wet and dry storage: 30 and 450
	RH	—	20	20	25	—	—	—	—	300	320	400	Ditto 30 and 6399/450
Eire (1963)	O	—	—	—	—	30	40	—	—	150	225	—	RH only
	RH	—	—	—	—	40	—	—	100	220	—	—	Bending and compressive at 1 day: 20 and 100
Finland (1945)	O	—	—	—	—	30*	40	60	—	150*	225	350	All types.—Mortar = 2 (coarse): 1 (fine): 1 (cement) Bending strength at 1 day: 25 (RH only) Bending and compressive strengths at 90 days: 60 and 350 (LH only)
	RH	—	—	—	—	50	60*	70	100*	300	375*	450	
	LH	—	—	—	—	—	30*	50	—	—	125*	250	
France (1964)	O 1	—	—	—	—	—	35	50	—	—	160	250	
	O II	—	—	—	—	—	40	55	—	—	270	325	
	RH I	—	—	—	—	—	55	65	—	—	315	400	Bending and compressive at 2 days: 45 and 160
	RH II	—	—	—	—	—	60	70	—	—	355	500	Bending and compressive at 2 days: 40 and 200
Germany (East) (1968)	O	—	—	—	—	30	40	60	—	150	225	350	Bending strength at 1 day: 30 RH II only
	RH I	—	—	—	—	40	50	70	—	200	300	400	
	RH II	—	—	—	—	50	60	80	100	275	350	450	
Germany (West) (1969)	O I	—	—	—	—	—	—	—	—	—	175	375	≯ 550 at 28 days
	OII	—	—	—	—	—	—	—	—	100†	—	375	≯ 550 at 28 days
	HS I	—	—	—	—	—	—	—	—	100†	—	450	
	HS II	—	—	—	—	—	—	—	—	175†	—	450	† values at 2 days
	HS III	—	—	—	—	—	—	—	—	300†	—	550	
	SR/LH	—	—	—	—	—	—	—	—	—	100	275	≯ 450 at 28 days

TABLE II.—STRENGTH OF PORTLAND CEMENT (*Continued*)

UNITS.—Strengths are given in kilogrammes per square centimetre. To convert to Newtons per square millimetre multiply by ten (or, more exactly, multiply by 9·8). To convert to pounds per square inch divide by 0·07.

Country (Date of standard)	Type of Cement	Tensile Strength Age of specimen in days				Bending Strength Age of specimen in days			Compressive Strength Age of specimen in days				Remarks
		1	3	7	28	3	7	28	1	3	7	28	
Greece (1954)	O	—	—	18	25	—	—	—	—	—	180	275	Tensile and compressive at 28 days combined wet and dry storage: 30 and 350
	RH	—	25	—	30	—	—	—	—	250	—	400	Ditto 40 and 500 7·07 cm cubes
Hungary (1956)	400	—	—	20	26	—	—	—	—	—	280	400	7·07 cm cubes
	500	—	—	27	30	—	—	—	—	—	350	500	Tensile and compressive at 2 days: 20 and 200
	600	—	—	32	35	—	—	—	—	—	450	600	Ditto 25 and 250
India (1968)	O	—	25	25	—	—	—	—	—	160	240	—	Bending tests to RILEM/ CEMBUREAU methods and strengths optional
	RH	25	38	—	—	—	—	—	160	295	—	—	
	LH	—	—	—	—	—	—	—	—	100	160	370	7·07 cm. cubes
Indonesia (1965)	O	—	23	26	30	—	—	—	—	250	325	400	7·07 cm. cubes
	RH	—	26	30	34	—	—	—	—	325	400	475	
	LH	—	17	21	27	—	—	—	—	175	250	325	
Israel O (1962) HS (1964) SR (1965)	O	—	22	27	—	—	—	—	—	100	155	—	12 cm. cubes
	HS	—	27	32	—	—	—	—	—	140	190	280	RILEM/CEMBUREAU methods for bending and compressive if requested. Values to be agreed.
	SR	—	—	25	32	—	—	—	—	—	85	155	
Italy (1965)	O	—	—	27	34	—	—	—	—	—	450	600	Tolerance 5%
	HS	—	24	33	38	—	—	—	—	450	600	730	

Japan (1964)	O	—	—	—	—	15	25	40	—	55	110	220	2:1 mortar (all types). Bending strength at 1 day. 10 for RH.
	RH	—	—	—	—	25	40	60*	40	90	180	280*	
	LH	—	—	—	—	10	20	30	—	35	70	150	
Mexico (1967)	O I	—	11	20	25	—	—	—	—	85	150	250	2·75:1 mortar for compressive test. 5 cm. cubes
	SR/LH II	—	9	18	23	—	—	—	—	70	125	250	
	RH III	19	27	—	—	—	—	—	120	210	—	—	
	LH IV	—	—	12	21	—	—	—	—	—	55	140	
	SR V	—	—	18	23	—	—	—	—	—	105	210	
Netherlands (1953)	O (A)	—	—	—	—	22	33	44	—	90	150	250	Bending at 1 day: 25 for RH II
	RHI (B)	—	—	—	—	30	40	50*	—	125	225	325*	
	RH II (C)	—	—	—	—	40	50	55*	100	250	350	450*	
New Zealand O, RH (1964), LH (1962)	O	—	—	—	—	—	—	—	—	155	239	387	7·07 cm. cubes
	RH	—	—	—	—	—	—	—	—	239	352	492	
	LH	—	—	—	—	—	—	—	—	70	113	264	
Norway (1961) (1) Moist mortar	O	—	16	22	27	—	—	—	—	200	280	370*	7·07 cm. cubes
	RH	—	25	27	30	—	—	—	—	350	400	450*	
(2) Plastic mortar	O	—	—	—	—	40	50	60	—	175	250	350*	Compressive at 1 day: 150. RH only. RILEM/CEMBUREAU method
	RH	—	—	—	—	50	60	70	150	250	350	400*	
Pakistan (1962)	O	—	21*	—	—	—	—	—	—	155	239	—	7·07 cm. mortar cubes
	RH	21*	—	—	—	—	—	—	—	211	281	—	
									—	84	141	—	4 in. concrete cubes
									—	120	176	—	
Poland O I, O II (1960), RH (1964), HS I (1961), HS II (1967), SR/LH (1965)	O I	—	—	—	—	—	30	50	—	—	130	250	Bending at 1 day: 25 RH only
	O II	—	—	—	—	25	40	60	—	130	225	350	
	RH	—	—	—	—	45	—	65	100	200	—	400	
	HS I	—	—	—	—	40	55	70	—	180	280	450	
	HS II	—	—	—	—	50	60	80	—	250	400	550	
	SR/LH	—	—	—	—	—	30	50	—	—	130	250	

TABLE II.—STRENGTH OF PORTLAND CEMENT. *(Continued)*

UNITS.—Strengths are given in kilogrammes per square centimetre. To convert to Newtons per square millimetre multiply by ten (or, more exactly, multiply by 9·8). To convert to pounds per square inch divide by 0·07.

Country (Date of standard)	Type of Cement	Tensile Strength Age of specimen in days				Bending Strength Age of specimen in days			Compressive Strength Age of specimen in days				Remarks
		1	3	7	28	3	7	28	1	3	7	28	
Portugal (1956)	O	—	—	—	—	25	35	50	—	110	180	275	
Roumania O I, O II (1967) RH I, RH II (1961)	O I	—	20	25	28	160	250	375	—	200	280	400	Tensile and compressive: moist mortar. 7·07 cm. cubes
	O II	—	25	30	34	200	350	475	—	260	380	500	
	RH I	20	26	30	—	—	—	—	200	300	380	—	Bending: plastic mortar 40 × 40 × 160 mm. prisms
	RH II	22	28	32	—	—	—	—	250	340	400	—	
South Africa (1959)	O	—	—	—	—	—	18	28	—	155	239	—	
	RH	—	—	—	—	—	28	39	—	211	281	—	
Spain (1964)	O I/SR I	—	—	—	—	—	37	56	—	—	167	250	
	O II/SR II	—	—	—	—	33	45	64	—	179	250	350	
	O III	—	—	—	—	50	60	70	—	275	375	450	
Sweden (1960)	O	—	—	—	—	30	45	65	—	160	260*	420*	*Optional
	RH	—	—	—	—	60	65	—	160	340*	420*	—	Bending at 1 day: 30.
	LH	—	—	—	—	—	30	50	—	—	160	290*	Bending and compressive at 90 days; 60 and 420*
Taiwan (1962)	O	—	11	19	25	—	—	—	—	84	148	246	2 in. cubes.
	SR/LH	—	9	18	23	—	—	—	—	70	127	246	2·75:1 mortar
	RH	19	26	—	—	—	—	—	120	211	—	—	

Turkey (1959)	O	—	—	22	28	—	—	—	—	—	300	350	7·07 cm. cubes
	HS	—	23	27	30	—	—	—	—	300	400	500	
	RH	—	25	30	35	—	—	—	—	400	500	600	
Uruguay (1962)	O	—	—	—	—	—	—	—	—	—	150	—	Cylinders 5 cm. diam. × 10 long
	RH	—	—	—	—	—	—	—	110	—	310	—	
U.S.A. (A.S.T.M. 1967) I O, I A O/AE, II SR/LH, II SR/LH/AE, III RH, III A RH/AE, IV LH, V SR	O I	—	11	19	25	—	—	—	—	84	148	246*	
	SR/LH II	—	9	18	23	—	—	—	—	70	127	246*	
	RH III	19	26	—	—	—	—	—	120	211	—	—	Unless specified compressive tests shall govern.
	LH IV	—	—	12	21	—	—	—	—	—	56	141	
	SR V	—	—	18	21	—	—	—	—	—	105	211	2 in. cubes. 2·75:1 mortar.
	AE IA	—	—	—	—	—	—	—	—	63	105	197	Adoption of 40×40×160 prisms for bending and compressive
	SR/LH/AE II A	—	—	—	—	—	—	—	—	53	98	197	
	RH/AE III A	—	—	—	—	—	—	—	91	176	—	—	
U.S.S.R. (1962; amended 1967)	O I "300"	—	—	—	—	—	—	45	—	—	—	300	
	O II "400"	—	—	—	—	—	—	55	—	—	—	400	
	O III "500"	—	—	—	—	—	—	60	—	—	—	500	
	O IV "600"	—	—	—	—	—	—	65	—	—	—	600	
	RH	—	—	—	—	40	—	—	—	250	—	—	
	SR/LH "300"	—	—	—	—	—	—	45	—	—	—	300	
	"400"	—	—	—	—	—	—	55	—	—	—	400	
Venezuela (1960)	O	—	—	—	—	—	—	—	—	85	150	250	2 in. cubes. 2·75:1 mortar.
	SR/LH	—	—	—	—	—	—	—	—	70	125	250	Prisms 40×40×160, for bending and compressive
	RH	—	—	—	—	—	—	—	120	210	—	—	
Yugoslavia (1967)	O I	—	—	—	—	—	30	45	—	—	160	250	Tolerance 10%
	O II	—	—	—	—	—	40	55	—	—	250	350	
	RH	—	—	—	—	35	45	60	—	200	350	450	

Slurry-press Conveyors

IN CONNECTION with the extensions at the Dunstable works of The Associated Portland Cement Manufacturers Ltd., a system of seven press conveyors, used for the first time to hold the complete volume of cake from the press to provide a controlled rate of discharge, has been installed. The duty of the conveyors, which are installed directly below each of the cement slurry presses, is to receive slurry cake in slab form from each of the presses which are discharged in sequence. Each pressing operation and slab discharge takes 34½ minutes, and during this period each conveyor belt is stationary. The quantity of slurry cake discharged by each press is 15 tons, which corresponds to the holding capacity of one conveyor. This amount is then discharged by the conveyor in 7½ minutes. The discharge rate, therefore, of each conveyor is 120 tons per hour. Each cake slab is 4 ft. (1·2 m.) square and 2 in. (5 cm.) thick.

Each conveyor has a 60-in. (1·5 m.) flat belt and is 43 ft. (13·1 m.) long. A slight incline of the belt assists water shedding over the taildrum to fall onto the belt during the pressing operation, and also assists in washing down the belt when it is stationary. The drive-head comprises a 5 h.p. 1,500-r.p.m. foot-mounted motor connected to a double reduction worm-reduction box by means of a V-rope drive. The gear-box is connected to the head-shaft by a flexible coupling and spur-wheel and pinion. The speed of the head-shaft is 0·54 r.p.m. and results in a belt speed of 3 ft. (0·9 m.) per minute.

Because the slurry cakes are in slabs and are of a soft plastic nature, they have to be broken up so as to produce material of a size which is more suitable for handling by a belt-conveyor. This is done by a rotating picker shaft, which is mounted above the conveyor drive-drum and comprises a series of blades set around the circumference and along the length of a shaft mounted in ball-bearing plummer blocks, set parallel to and above the conveyor head-drum. The speed and distance between the blade and the top of the conveyor head-drum is determined by the rate of discharge required from the conveyor, and the nature of the material being handled. The picker shaft is driven by a 5-h.p. 1,500 r.p.m. foot-mounted motor through a V-rope drive and torque-arm gear-box to produce a shaft speed of 30 r.p.m.

The frame of the conveyor consists of channel stringers supporting a closely-pitched bed of mild steel flat idlers 4 in. (10 cm.) in diameter, above which are skirt plates to receive and retain the material on the belt. Because of the large quantity of material amounting to 15 tons, and the sizes of the slabs, the height of the skirt plates is 4 ft. 3 in. (1·2 m.) above the belt line and nominally the same distance between plates. Because of the soft plastic nature of the material, the cross-section of the skirt plates are specially designed to stop the material adhering to them by sloping the plates outwardly to give a distance between skirts of 4 ft. 3 in. (1·2 m.) at the top and 4 ft. 6 in. (1·3 m.) at the bottom. To ensure a clean discharge, the skirt plates are increased by 3 in. (7·5 cm.) in width between the tailend and the discharge end.

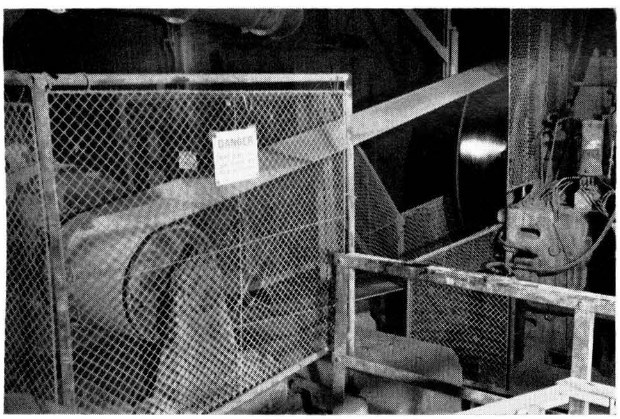
Because of the non-abrasive nature of the material and its softness, and in order to reduce skirt friction to a minimum, rubber seals were replaced by circular rods welded continuously to the bottom edge of the skirt plates, leaving a small clearance between the rods and the belt. To prevent water spilling over the edges of the belt, the edges are inclined on short continuous rubbing plates.

The tail-end unit is screw operated. The belt, which is 60 in. (1·5 m.) wide, is of three-ply ribbed-fabric construction with $\frac{1}{8}$ in. (3 mm.) top cover and $\frac{1}{16}$ in. (1·5 mm.) bottom cover and a vulcanised joint. The conveyor is provided with guards for couplings and V-rope drives, the skirt plates and tail-end units being protected by open-mesh guards.

The design, supply and installation of the press conveyors was undertaken by Richard Sutcliffe Ltd.

A Transmission Belt at Lime Works

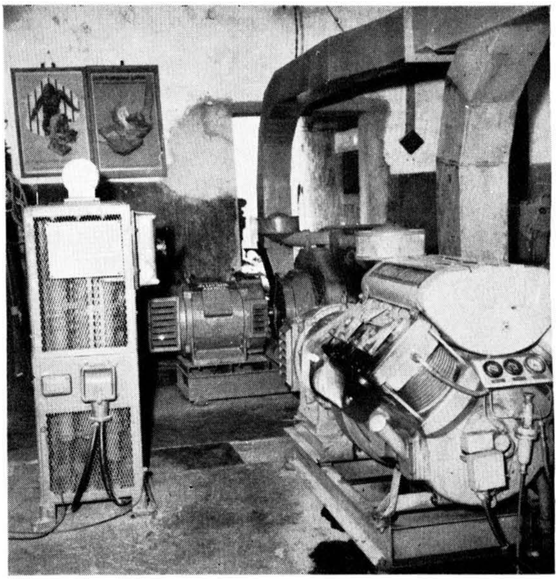
IT IS REPORTED that the drive-belt on a crusher at the Clitheroe works of the Horrocksford Lime Co. Ltd. has been in continuous operation since 1965. The belt is 20 in. (50 cm.) wide and is a T.B.A. whipcord flat transmission belt of



quality number RB.63. It is 48 ft. 6 in. (14·8 m.) long and was supplied by Turner Brothers Asbestos Co. Ltd. The Hadfield crusher to which it is attached runs at a normal load of 200 h.p. with peak loads up to 300 h.p. The accompanying illustration shows the belt in operation.

New Equipment at an Indian Limestone Quarry

INDIA CEMENTS LTD., which was established as a public company in 1949, had initially a daily output of 300 tons, and by 1956 the output had reached about 700 tons per day. By 1959 the plant had been doubled. In Madras State, the Company obtains about two-thirds of the requirements of limestone from contractors working deposits about five miles from the cement works. The bands of limestone run east-west on either side of the Sankarankoil Road for about three miles. This deposit, which is of igneous and metamorphic origin and contains intrusions of granite and quartz, is for the most part suitable for making cement. Occasional pockets of coarse calcite, fine-grained saccharoidal



marbles and of calciphyres occur. The balance of the Company's limestone requirements are obtained from its own quarry near the works, where there is a band of medium-grained saccharoidal calcite limestone and white marble extending for 1½ miles along the eastern foot of the Talaiyuthu Hill. The greater part of the deposit is impure and contains only narrow bands of high-grade calcite.

In the early 1960s, in order to satisfy the increased demands from India Cements Ltd., one of the contractors installed two "Atlas Copco AR3" stationary compressors. In view of the performance of these machines, India Cements Ltd. recently obtained two "Atlas Copco BT6" stationary two-stage single-acting air-cooled compressors. Each of these machines, one of which is shown in the accompanying illustration, has a capacity of 282 cu. ft. (9 cu. m.) per minute.

The compressors supply power to operate jack-hammers and rock-drills.

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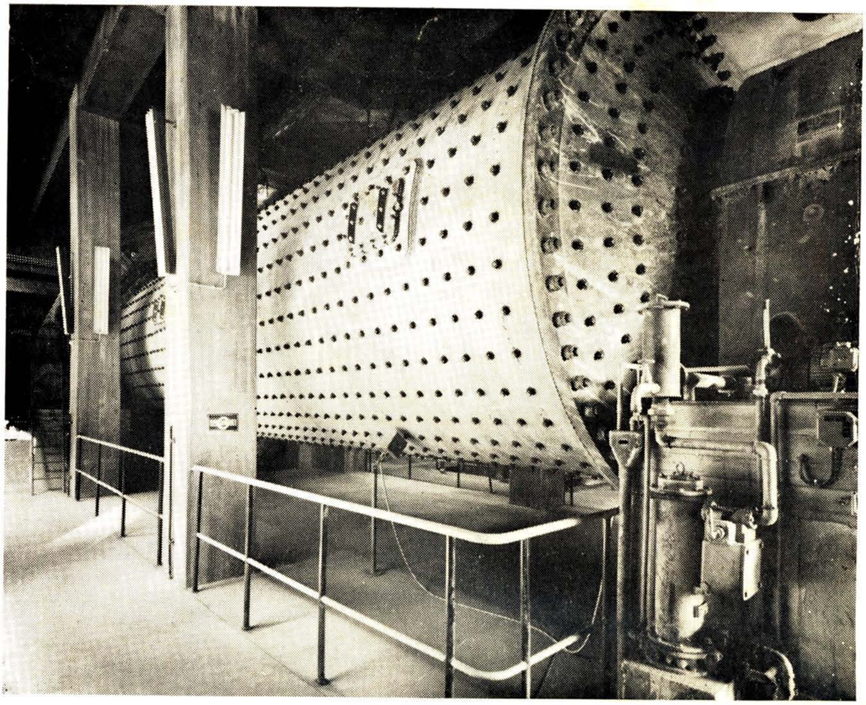

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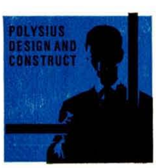
The illustration shows a closed circuit grinding mill, 4 metres diameter, 12 metres long, with twin pinion drive. This mill has an output of 80 tons/hour of cement at a fineness (Blaine) of 3000 cm²/g when grinding hard clinker from a rotary kiln.



POLYSIUS

POLYSIUS
4723 Neubeckum
(Germany)
Telephone (0 2525) 711
Telex 08 92 1581

POLYSIUS LTD.
The Brackens,
Ascot, Berks. (England)
Telephone: Winkfield Row 2011
Telex: 84 102

POLYSIUS S.A.F.L., Paris

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