



सत्यमेव जयते

# REPORT

OF THE

TECHNICAL COMMITTEE ON CEMENT

*AUGUST 1958*

GOVERNMENT OF INDIA



MINISTRY OF COMMERCE AND INDUSTRY

NEW DELHI

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## CHAPTER I

### INTRODUCTORY

The Government of India, taking cognizance of the acute shortage of cement in the country and the fact that the domestic demand was far in excess of indigenous production—necessitating, therefore, economy in the use of cement and increasing its availability by all possible manners—appointed a Committee consisting of the following *vide* Resolution No. Cem-18 (174)/56, dated 23rd March 1957.

1. Shri K. C. Sood, Chief Design Engineer (Civil) Central Standards Office for Railways, Ministry of Railways, Baroda House, New Delhi—Chairman.
2. Shri V. N. Pai, Messrs Associated Cement Cos. Ltd., Kistna (Guntur),—Member.
3. Shri S. L. Soni, M/s Shree Digvijai Cement Co. Ltd., Sikka (Saurashtra)—Member.
4. Shri N. C. Roy, M/s Orissa Cement Ltd., Rajgangpur (Orissa)—Member.
5. Shri Dwarka Prasad, Chief Engineer, M/s Rohtas Industries Ltd. Dalmianagar (Bihar)—Member.
6. Shri V. M. Rao, B.E., M.Sc. (MIT), C/o V. Ramakrishna & Sons, 38, Mount Road, Cathedral P.O., Madras-6—Member.
7. Sardar Sarup Singh, Director, National Buildings Organisation, Ministry of Works, Housing and Supply, Government of India, New Delhi—Member.
8. Shri M. S. Bhatia, Superintending Surveyor of Works, (Central Zone), C. P. W. D., New Delhi—Member.
9. Shri P. C. Hazra, Superintending Geologist, Geological Survey of India, Calcutta—Member.
10. Prof. G. S. Ramaswamy, Central Building Research Institute, Roorkee—Member.
11. Shri George Oommen, Director (Dam), Central Water and Power Commission, New Delhi—Member.
12. Shri C. B. Patel, Housing Adviser to the Government of India, Ministry of W. H. & S., New Delhi—Member.
13. Dr. R. R. Hattiangadi, Hony. Technical Adviser (Cement) to Government of India, C/o Messrs Associated Cement Cos. Ltd., Bombay—Member.
14. Dr. S.P. Varma, Development Officer (Mineral Industries), Ministry of Commerce and Industry, New Delhi—Member-Secretary.

Sardar Robinder Singh, Joint Director (Materials), represented the National Building Organisation vice Sardar Sarup Singh, Director, National Building Organisation, retired. Mr. M. S. Bhatia has since taken over as Housing Adviser to the Government of India, and Mr. K. C. Sood as Director, Research Designs and Standardisation Organisation, Ministry of Railways. Mr. V. Kandaswamy has taken over as Superintending Engineer in place of Mr. M. S. Bhatia and Mr. S. K. Chopra represented the Central Building Research Institute in some meeting in place of Prof. G. S. Ramaswamy.

2. The Terms of Reference of the Committee were to—

- (i) investigate and report the availability of materials of pozzolanic nature in various parts of the country, particularly the ones found close to either the cement-producing centres or where cement is to be consumed in bulk, *i.e.*, dams, etc.
- (ii) examine the feasibility of admixing such pozzolanic materials available in the country as do not adversely affect the properties of the ultimate mix vis-a-vis Portland Cement for specified jobs; the percentage of the pozzolanic mix as well as the stage at which the mixing should be effected;
- (iii) suggest suitable specifications of the pozzolan cement and suitable marking on the pozzolan cement bags;
- (iv) investigate the nature of blast furnace slags that would be available from the existing steel factories as well as the newly-projected plants with reference to their suitability for manufacturing Blast Furnace Slag Portland Cement in accordance with the Indian Standards Specification No. IS. 455-1953.
- (v) examine the feasibility of using lower grade gypsum (80—85%) as a retarder and use of other retarders to conserve gypsum.
- (vi) examine the prospects of manufacturing high alumina cement by fusing together limestone and bauxite.
- (vii) investigate and report on such other matters as the committee may think fit regarding the economy in the use of cement.

3. The Committee was expected to submit its report in about three months' time after its inception. Subsequently, the life of the Committee was extended from time to time and finally up to 31st August 1958.

4. The Committee held the following meetings—

- 1st meeting of the Technical Committee—20th May 1957.
- 2nd meeting of the Technical Committee—16th September 1957.
- Meeting of the Pozzolan Sub-committee—17th October 1957.
- Meeting of the Slag Sub-Committee—18th October 1957.
- 3rd meeting of the Technical Committee—12th February 1958.

5. The Committee endeavoured to collect all possible information on the subject as was available with the manufacturers and consumers of cement, such as C.P.W.D., Central Building Research Institute, Geological Survey of India.

State Public Works Departments, National Buildings Organisation and certain leading construction companies as well as the existing and newly projected iron and steel factories. The type of information collected by the Committee from various sources is indicated in the proformae given in Appendix I.

6. The Committee in its first meeting held on 20th May 1957 appointed two sub-committees, one on pozzolans and the other on Blast Furnace Slag Cement. The Sub-Committee on Pozzolan and Pozzolanic Cements consisted of:

- (i) Dr. R. R. Hattiangadi.
- (ii) Shri N. C. Roy.
- (iii) S. Rabinder Singh.

In the second meeting of the committee held on 16th September 1957, the Pozzolan Sub-Committee was reconstituted to include a representative of National Building Organisation, S. Rabinder Singh and three other members, Shri M. S. Bhatia, Prof. G. S. Ramaswamy and Dr. S. P. Varma.

#### *Acknowledgement*

The Committee is indebted to Shri Manubhai Shah, Minister (Industry), Government of India, Shri N. Subrahmanyam and Dr. A. Nagaraja Rao, Joint Secretaries to the Government of India, Ministry of Commerce and Industry, and Dr. G. P. Kane, Senior Industrial Adviser (Chemicals), Development Wing, Ministry of Commerce and Industry, for their valuable guidance.

Thanks of the Committee are also due to all the individuals, organizations, both private and public, for the valuable information given by them and assistance accorded to the Committee in its working, particularly, Shri P. B. Nag, Under Secretary, Ministry of Commerce and Industry; Dr. A. Lahiri of Fuel Research Institute; Sarvashri N. K. Koomar; K. S. Raghupati of Ministry of Steel, Mines and Fuel, K. Vyasulu of Planning Commission; Principal Engineering Officer, Tripura; Chief Engineer, General and Irrigation, Trivandrum; and also the Mysore Iron and Steel Works; Durgapur Steel Project; Jaipur Udyog Ltd; Digvijai Cement Co. Ltd., U. P. Government Cement Factory, Churk; Rohtas Industries, Dalmianagar; Associated Cement Companies; Andhra Cement Co. Ltd., Dalmia Cement (Bharat) Ltd.; Orissa Cement Ltd.; Ashoka Cement Ltd.; Hindustan Construction Co. Ltd.; Kalyanpur Lime and Cement Works Ltd.; Sone Valley Portland Cement Ltd.; Dalmia Dadri Cement Ltd.; and the Public Works Departments of the Governments of Bombay, Assam, Rajasthan, Orissa, Himachal Pradesh, U. P., Punjab, Andhra Pradesh, Mysore, Madhya Pradesh and Madras.

## CHAPTER II

### PRESENT POSITION OF THE CEMENT INDUSTRY, ITS PROGRAMME OF DEVELOPMENT, ACTUAL PRODUCTION AND ESTIMATED DEMAND

The Cement Industry of India had a humble beginning and the first attempt to manufacture portland cement was made early in the present century, when in 1904 a small factory was established in Madras using sea-shells as a source of lime. The venture was short-lived but a decade or so later the industry revived and three factories were set up one each at Porbandar, Katni and Lakheri and by 1918 the three factories were producing approximately 80,000 to 90,000 tons of cement per annum. During the years of postwar-I boom, seven more factories were established by 1924, and by 1930 the production of the industry had risen to 5,64,000 tons. The development of the industry in recent years *i.e.*, 1948-57 was phenomenal and ten more factories came into production, one each at Sevalia, Kottayam, Tirunelvely, Rajgangpur, Swai Madhopur, Sikka, Sindri, Churk, Dalmianagar and Bagalkot.

2. The production of cement during the last ten years has been as follows:—

Year	No. of units	Production in tons
1947	18	14,47,000
1948	18	15,52,907
1949	21	21,02,425
1950	21	26,12,910
1951	22	31,95,442
1952	22	35,37,056
1953	24	37,80,327
1954	25	43,97,440
1955	27	44,95,920
1956	28	49,28,660
1957	28	55,98,000
1958	29	32,40,281(Jan.-June.)

3. There are, at present, 29 cement factories having an installed capacity of over 6·8 million tons per annum working in the country with both dry and wet processes. It is estimated that a capital of Rs. 30—40 crores is invested in the industry which gives employment to more than 30,000 people. The capacity target for the cement industry under the Second Five Year Plan is 16 million tons per annum. Some 50 schemes had been approved by the Government of India, 24 by way of substantial expansion of the existing factories involving an additional capacity of nearly 3·6 million tons per annum, and 26 new factories

with a total installed capacity of 4.7 million tons per annum. It was expected that when the various schemes were implemented, the capacity of the industry would increase to over 15 million tons a year as follows—

Year					Installed capacity in tons
1958	..	..	..	..	9,321,700
1959	..	..	..	..	12,438,700
1960	..	..	..	..	14,131,700
1961	..	..	..	..	15,301,700

4. A statement showing State-wise distribution of the existing factories and the ones that are expected to come up, is given in Appendix II. As explained later in this report, however, there has been a considerable slackening of demand and with a corresponding diminution in the rate of development of the cement industry.

#### 5. Demand—

The Planning Commission had, in their programme of Industrial Development during the First Plan, estimated the demand for cement at about 3.3 million tons by 1955-56 exclusive of the requirements for multipurpose schemes and road construction. The total demand was estimated at 4.5 million tons by 1955-56. However, subsequent developments appeared to show at one time that these estimates were on the conservative side and the demand for cement was substantially higher, as was evident from the actual production as well as the estimates of requirements of the various States and projects received by the Ministry of Commerce and Industry. In fact, the present annual demand for cement based on such estimates was expected to be of the order of 9—10 million tons per annum. This belief was further reinforced by the evidence of the Indian Institute of Public Opinion which estimated the growth of housing during 1954-61 to be 10.9 per cent per annum. On this basis, the demand by 1960/1961 was estimated to be 15.5 million tons for which a capacity of 16 million tons was considered necessary. Furthermore, these estimates also looked realistic considering that the per capita annual consumption of cement in India was extremely low, being 33 lbs. as against 594 in United States, 649 lbs. in Germany and 847 lbs. in Switzerland. The per capita annual consumption of cement in some countries is given below :—

					Lbs.
Austria	..	..	..	..	499.4
B. L. E. U.	..	..	..	..	688.6
Denmark	..	..	..	..	486.2
France	..	..	..	..	451
Germany	..	..	..	..	649
Greece	..	..	..	..	160.6
Iceland	..	..	..	..	869
Italy	..	..	..	..	420.2

					Lbs.
Norway	..	..	..	..	613.8
Netherlands	..	..	..	..	440
Portugal	..	..	..	..	156.2
Sweden	..	..	..	..	660
Switzerland	..	..	..	..	847
Turkey	..	..	..	..	121
U. K.	..	..	..	..	444.4
Ireland	..	..	..	..	453.2
India	..	..	..	..	33

6. Having regard to the foregoing, it was felt that the rate of growth of the cement industry as measured by the capacities brought into being for the production of Portland cement was not sufficiently vigorous to catch up with the demand. Therefore, a Technical Committee on Cement was appointed by the Government, and one of its essential objectives was to look into ways and means of producing additional but different kinds of cementing materials in the country which, while not being appreciably inferior to Portland cement, could be made available to consumers expeditiously. Possibilities in this direction were the manufacture of the various kinds of pozzolanic cements, blast furnace slag cement, etc. Concurrently with the deliberations of the Technical Committee, however, there began a slackening in the demand of cement, mainly on account of the difficulty of obtaining enough foreign exchange which held up a number of important projects. Internal financial difficulties were also an important contributory factor. Meanwhile, the installed capacity of the industry rose to about 6.8 million tons per annum and it appeared that by the end of 1959 the additional capacity undertaken by the various manufacturers would raise the capacity to about 8 million tons. The combined effect of all these factors, led to a considerably easy position regarding supply of cement. This easy supply position of cement has naturally reduced the urgency of producing blended cements like pozzolanic, masonry, blast furnace, etc. In the opinion of the Committee, however, the present easy supply position is regarded as a temporary phase and the Committee feels that as soon as the foreign exchange crisis is over and the internal finance is also improved, the tempo of industrialization would revive in such a manner as would place a far greater demand on the cement industry than hitherto. Nevertheless, the present situation appears to offer a good opportunity to the Government and the cement industry to reorientate the programme of future development of the cement industry in the light of the observations made by the Committee and its recommendations in connection with manufacture of slag and pozzolan cements in the country. There is no longer an immediate need to economize in the consumption of cement and finding of such new applications and uses of cement manufactured in the country as would maintain an adequate offtake of cement, ensuring at the same time a rational reversal of the policy whenever demand increases once again due to the revived programme of industrialization and construction of multipurpose projects, has become rather problematic. It is hoped that both the Government and the industry would continue to foster the growth of the cement industry notwithstanding the temporary respite that appears to have set in.



7. It was recognised throughout the deliberations of the Committee that one of the 'sine qua nons' of producing pozzolanic and other types of cement was that these would be governed by a specification. Otherwise, under the guise of 'pozzolanic cement', a spate of adulterated products would be thrown in the market to the distress of the consumer. Therefore, the Indian Standards Institute was apprised of the Committee's deliberations and was requested to take in hand early the finalization of a specification for pozzolanic cement in regard to which it appeared the ISI had already done a certain amount of work. It is understood that the ISI has done a considerable amount of work on this since.

8. There has, of late, been a noticeable shift in favour of larger cement kilns and a number of rotary kilns giving a daily production of 700 tons have been installed in preference to smaller kilns of 250—300 ton daily capacity. There are, however, many areas in the country where availability of the main raw material, viz., limestone, is limited and which would not lend to setting up of large factories. Many of such areas are deficit in cement and several schemes are afoot for establishing cement factories with a production capacity of 60 to 175 tons per day. The recent advances in the Continuous Shaft Kiln Process have made it possible to manufacture cement by the Shaft Kiln Process economically depending upon the location of the plant and other local factors.

## CHAPTER III

### POZZOLANS AND POZZOLANIC CEMENTS

#### 1. Pozzolans—

The term 'Pozzolana' was first applied to rocks of organic origin occurring in the neighbourhood of Pozzuli in Italy and has since been extended to include not only volcanic tuffs and trass but also diatomaceous earths and other highly siliceous rocks and artificial products like burnt clays, shales, fly-ash etc. The pozzolanas may be described as siliceous, aluminous or ferroginous materials which though not cementitious in themselves contain constituents which at ordinary temperatures will combine with lime in presence of water to form compounds which have low solubility and possess cementitious properties. In a typical pozzolanic reaction, the reactants are lime and active silica derived from the pozzolana and the principal reaction product is a hydrous calcium silicate. Calcium Hydroxide is liberated during the hydration of Portland cement. This compound contributes hardly anything to the strength and water-tightness of mortars and concretes on account of the ease with which it can be leached out with water. But on the addition of a pozzolana to the mix, calcium hydroxide combines with the siliceous constituent of the pozzolana forming a compound of low solubility. This interaction results in controlling the detrimental effects of calcium hydroxide on the properties of mortars and concretes and simultaneously produces some desirable properties in concretes.

Generally, silica is present in pozzolana to the extent of more than 50 per cent; although pozzolanas with 40 per cent silica are also reported to have satisfactory pozzolanic activity. Alumina, iron oxide, calcium oxide and alkalis may be present in pozzolanas in amounts upto 30, 20, 10 and 10 per cent respectively. Since it is not possible to judge the pozzolanic activity of a substance from its chemical composition alone, several other methods are known to have been developed for this purpose.

Pozzolanas may be classified into two groups:

- (1) Natural Pozzolanas.
- (2) Artificial Pozzolanas.

Natural pozzolanas may be further sub-divided depending on the nature in which silica exists into:

- (a) those derived from volcanic rocks, such as volcanic ashes, pumice or pumice-stones, obsidian etc.;
- (b) those derived from rocks or earth in which the silica constituent contains *opal*. Examples are Ciatomites, cherts, shales, clays containing substantial quantities of opaline silica.

The group of artificial pozzolanas includes the waste products of industrial processes, e.g., coal or fly-ash, surkhi, etc. Generally speaking, natural pozzolanas improve their activity substantially when calcined. In a number of cases,

on the other hand, the pozzolanic activity is destroyed while heating to high temperatures. Consequently, the effect of calcination on any natural pozzolanas is a matter of detailed investigation.

Pozzolanas may be used as additions or replacements and these terms refer to the manner in which pozzolanas are employed. In the case of "additions", small quantities of pozzolanas in fine state are added to the concrete at the time of mixing. These amounts are insufficient to affect strength and weather resistance of concrete materially but sufficient to improve workability, prevent segregation, etc. On the other hand, the object of 'replacement' is to improve the properties of concrete and as large amounts of pozzolanas are used in this case, an additional advantage is the saving in cement in an equivalent amount of portland cement. A considerable amount of work has been done in the field of utilization of pozzolanic materials. The Bureau of Reclamation, Denver, U.S.A., has carried out extensive work on the effect of calcination on natural pozzolanas. In India also, work on effective calcination of clays has been done in South India, at Hirakud and at Bhakra Dam. The Committee had an occasion to review the work and also to consult the authorities who had conducted these investigations.

## 2. Portland Pozzolana Cement—

Portland pozzolana cement is made by blending Portland cement with a natural or artificial pozzolana and thoroughly inter-grinding the mixture to the fineness of cement.

There are possibilities of manufacturing Portland-pozzolana cement in India by making use of the following pozzolanas:

- (1) Brick Jhama (Surkhi)
- (2) Coal ash or fly ash.
- (3) Calcined shale.
- (4) Crush-conglomerate.

The advantages of the above pozzolana cement are:

- (a) Improved workability and less segregation and bleeding;
- (b) increased durability in sulphate waters;
- (c) increased water-tightness and reduced tendency of lime to separate;
- (d) somewhat high tensile strength, low heat of hydration and less cracking in mass concrete ;
- (e) prevention of damage by alkali aggregate reaction ;
- (f) saving in the cost of cement.

Some disadvantages, on the other hand, are :

- (a) Some loss of early compressive strength although it is regained at a later stage ;
- (b) less resistance to corrosion, weathering and alternate freezing and thawing although it is claimed that this can be counteracted by using air-entraining agents ; and
- (c) slightly greater expansion on wetting and contraction on drying.

### 3. Fly Ash—

The present production of coal in India is 40 million tons per annum which will be stepped up to 60 million tons by the end of the Second Plan period. The country has to rely increasingly on extensive deposits of inferior coals. A large quantity of high ash byproduct fuel is available in the form of middlings and rejects. The disposal or utilization of coal-ash presents a serious problem.

When pulverised coal is burnt in steam-raising unit the ash which is finely divided containing some amount of combustible matter is recovered from the flue gases by precipitators. Depending upon the chemical composition, the amount of free carbon, the degree of fineness and the specific gravity, a number of applications of fly-ash has been suggested. Fly-ash can be used as a raw material for cement manufacture as well as an addition to cements or to mortars and concretes. But the cost of handling ash is often not in keeping with its cheapness and the amount of water needed for the slurry is also considerable and leads to higher fuel consumption. Its application can be economical if the fly-ash producing units are located close to cement factories.

Some fly-ash with some low carbon content can prove to be very good pozzolanas and as such replace Portland cement in concrete to a considerable extent. Its use as a Pozzolana material is due to its high specific surface and suitable shape of the particles. In the construction of largest fly-ash concrete dam, viz., Hungry Horse Dam of Montana of U.S.A., 135,000 tons of fly-ash (of carbon-content less than 10%) were used to produce 3,100,000 cubic yards of concrete, in the proportion :

32% of fly-ash and 68% portland cement for the interior and 24% fly-ash and 76% portland cement for the rest.

Cinder, on the other hand, has been used in large quantities for making Cinder concrete masonry blocks. In India, there appears to be a potential market of the boiler and furnace waste materials. Analysis of coal-ash shows that it is a fairly-high percentage of carbon which under proper treatment may be reduced to 3 to 4 percent. It is found to contain a comparatively high percentage of silica and alumina and less of fluxes which indicates its refractory nature. The Committee is of the view that the coal ashes available from thermal power stations and other undertakings throwing away coal ashes as waste products should be analysed and their application in the manufacture of cement or as pozzolana material systematically determined. It is only after compilation of authentic data that any positive recommendation can be made on such general a matter as utilization of ashes.

### 4. Availability of Pozzolanas—

The Central Building Research Institute and Geological Survey of India have compiled detailed information and data regarding the availability of natural pozzolanas in India. These are given in Appendix II(e).

A considerable amount of work on manufacture of pozzolana or pozzolanic cements has been done in India by a number of cement factories, notably Orissa Cements Ltd., Digvijai Cement Co. Ltd., Sikka; Sone Valley Portland Cement Ltd., Japla; Jaipur Udyog, Ltd. Swai Madhopur; U.P. Government Cement Factory, Churk; Rohtas Industries, Dalmianagar and some factories

belonging to the ACC group. The work done at the Rajgangpur factory is rather extensive and certain broad conclusions regarding manufacture of pozzolanic materials have been arrived at by the utilisation of crush-conglomerate. This material is highly siliceous and easy to grind. It has the following composition :

							per cent
SiO <sub>2</sub>	..	..	..	..	..	..	87.0
TiO <sub>2</sub>	..	..	..	..	..	..	0.4
Al <sub>2</sub> O <sub>3</sub>	..	..	..	..	..	..	6.4
Fe <sub>2</sub> O <sub>3</sub>	..	..	..	..	..	..	1.6
CaO	..	..	..	..	..	..	0.4
MgO	..	..	..	..	..	..	0.6
Loss	..	..	..	..	..	..	1.5
							<hr/> 97.9
I. R.	..	..	..	..	..	..	96.6
Soluble SiO <sub>2</sub>	..	..	..	..	..	..	2.5

Various percentages of additions have been tried and the properties like residue on 170 mesh sieve, expansion, setting time, tensile strength and heat of hydration determined.

The sample of pozzolan cement has been tested also at the Government Test House, Alipore, Calcutta. The findings are more or less conclusive. At another cement factory, viz., Swai Madhopur, investigations have been carried out by mixing cement with Surkhi and Jhama in various proportions. The properties tested were residue on 170 mesh sieve, soundness, tensile strength and compressive strength. The analysis of Brick Jhama utilised is as follows:

*Analysis of Materials—*

Particulars				Brick Jhama	Portland cement
CaO	..	..	..	10.25	62.8
SiO <sub>2</sub>	..	..	..	68	19.52
Al <sub>2</sub> O <sub>3</sub>	}	..	..	18.45	6.7
& Fe <sub>2</sub> O <sub>3</sub>					2.8
MgO	..	..	..	1.7	3.15
SO <sub>3</sub>	..	..	..	..	1.85
Loss	..	..	..	1.58	2.0
Insoluble	..	..	..	..	0.52
				<hr/> 99.98	99.34

The conclusion reached is that 70 parts of cement and 30 parts of over-burnt Jhama-surkhi yield the best results. However, the storing property of Jha a cement has not been determined.

##### 5. Possibilities of manufacture—

In view of the fact that a wide range of pozzolanic materials are available throughout the country and not all of them are likely to be suitable for admixture with cement, the Committee feels that there is need to regulate not only the quality of Portland cement marketed to the consumers but also to bring the distribution of pozzolana cement under the Cement Control Order. It is, therefore, imperative that a specification for pozzolana cement is formulated with a view to guide its manufacture and ensuring the interests of the consumers. The Committee took up the matter with I.S.I. and a draft specification as prepared by them is given in Appendix IV. In his draft specification, the limiting percentage of pozzolana has been kept at 25% although a much larger percentage of pozzolana such as fly ash has been made effective use of in some countries.

The next consideration in regard to the manufacture of portland pozzolana cement is the range of field of application in construction. Pozzolana cement unlike blast furnace slag cement is not a general purpose cement, because its compressive strength at the early age is low though the ultimate strength may be the same. It should also be noted that for the development of ultimate strength, presence of moisture is essential. The Committee contacted the Public Works Departments of the various State Governments and from the replies received it is evident that in spite of the above handicap there is a tremendous scope of utilisation of materials of pozzolanic nature. The Committee is of the view that the application of pozzolana cement might be usefully divided into two categories :

- (1) Construction work in which its use has been well established e.g. Mass Masonry construction of dams, marine works, etc.
- (2) Construction jobs in which it can be and has been used, e.g., Tunnel lining, foundations, piers and abutments of bridges etc., water conducting structures like aqueducts, brick work for walls, etc.

Further work is, however, required to be done before its usefulness for reinforced concrete or prestressed concrete can be established.

From the above it will be seen that while pozzolana cement is preferred in certain types of jobs because of the technical advantages of pozzolana cement over normal portland cement, it may not be suitable for other jobs because of its lower strength at early stages.

The immediate possibility of application of pozzolana cement lies in the construction of massive structures like dams as is being done at Bhakrè Dam in Punjab and at a number of dams in South India. The Committee, therefore, feels that whenever a new dam is planned, the availability of pozzolanic materials, either natural or synthetic, near the dam site or the cement factory from where cement will be drawn for the construction of the dam should be investigated. It could then be decided as to whether the pozzolana material should be mixed with cement at the dam site itself or at the cement factory,

Further the committee is of the opinion that its use should be extended to other types of construction given under item 2 mentioned above keeping in view the properties of pozzolana cement.

Another important factor which has a bearing on this subject is the availability of limestone in India. Although good limestone in fair abundance is available in India, it occurs in certain pockets which are distant from coal fields and consumer markets. Since ordinarily the future development of the cement industry is likely to be confined to areas where limestone is available and as it would impose a heavy strain on the existing transport system, the Committee is of the view that the use of Pozzolana cement is particularly important as thereby the existing limestone reserves can be made to last longer. Nevertheless, it feels that unless the use of pozzolana cement can be extended to the general field of construction it would not be advisable to establish a regular capacity for its manufacture.

The Committee also suggests that caution would be necessary before a decision is taken to set up regular manufacture of pozzolana cement. Trend of production and demand may be studied for some time more, particularly in view of the likelihood that the supply position may improve with the completion of schemes already under implementation, while in the matter of offtake the consuming industries may not be able to make a corresponding progress in view of the difficult foreign exchange position and certain other reasons. The initial reluctance of the consumer to take a new substitute may also have to be reckoned with, necessitating steps to lower the prices of pozzolana cement.

## CHAPTER IV

### BLAST FURNACE SLAG CEMENT

In Iron and Steel plants, blast furnace slag is an essential by-product. This material which was considered a waste by-product some years ago has now come to be regarded as an important industrial byproduct and it is being utilized in many ways. In India, however, it is still a waste material and its disposal presents a serious problem.

In a number of jobs like construction of highways, railway tracks and for soil treatment in agriculture the blast furnace slag can be used directly. It is also used for making concrete and concrete products after crushing and grading. Other applications are : manufacture of slag wool, slag cement and commercial glassware. However, its use in cement manufacture deserves special consideration both on account of its abundant availability and also restricted availability of limestone in certain areas.

It is estimated that from 2 tons iron-ore, half a ton of slag is produced and for ores which are not rich in iron, the output of slag may be as much as one ton for every ton of pig iron produced.

2. The iron and steel industry in India is undergoing a phenomenal development programme and by the end of the Second Plan period, a capacity of six million tons per annum would have been established. The total availability of slag would at that time be nearly 3 million tons per annum.

3. It is essential that the slag emerging from the blast furnace be granulated. The molten slag crystallizes on cooling and formation of crystals depends largely on the rate of cooling as the minerals start forming as soon as cooling starts and the process is fairly complete when the molten mass solidifies. It is very important that the material should be in the glassy forms and no mineral should have crystallised out in order that the slag may be suitable and have hydraulic properties. Slag can be granulated in a number of ways. The three methods generally employed are—

(i) 'Pit'

(ii) 'Jet' and

(iii) 'Dry Granulation' processes.

4. In the 'Pit' process, molten slag is run into a pit of water. In the 'Jet' process, as the stream of molten slag flows out, it is disintegrated by a high pressure water-jet or water and air-jets. In the dry process, on the other hand, the stream of molten slag is broken into relatively small particles by the impact of a mechanical granulating device. The slag thus obtained is a granular product containing glass and has grains of different sizes. The most important characteristic of granulated slag is that it has latent hydraulic properties which are very much enhanced in the presence of activators. The hydraulicity of slag



is ascribed to the presence of glass in the slag or in other words, there is a relationship between the glassy state and reactivity of slag. In general, a granulated slag of the following range of composition has adequate hydraulic properties—

						General composition of slag per cent
Calcium Oxide	..	..	..	..	..	35—45
Silica	..	..	..	..	..	27—32
Alumina	..	..	..	..	..	24—31
Iron Oxide	..	..	..	..	..	0—1
Magnesium Oxide	..	..	..	..	..	0—8
Manganese Oxide	..	..	..	..	..	0—2
Sulphur	..	..	..	..	..	0—2

5. The granulated slag may be used in the manufacture of cement in two years : (i) it may be used as a raw material, as it contains a high percentage of lime. It would thus replace clay or shale and limestone required per ton of cement produced would be substantially less. The fuel consumption would also be less than when only limestone and clay are used. This method of utilising granulated slag is popular in the Continent of Europe; and (ii) granulated slag is added to portland cement clinker and then inter-ground with gypsum for regulating its setting time. In other words, this method aims at replacing a part of portland cement, with finely ground granulated slag and adjusting the content of gypsum accordingly.

6. Distinction can be made in the three types of slag cements *viz.* (a) Portland slag cement (b) Slag portland cement and (c) Slag sulphate cement, depending upon the principal component in each case.

7. A considerable amount of work has been done by the Central Building Research Institute, Roorkee, in this field. They obtained sample of slag from the Tata Iron and Steel Co. Ltd., interground them with portland cement clinker and carried out a number of tests on the Portland blast furnace slag cement. The conclusions reached are—

- (i) the slags investigated are suitable for making portland blast furnace slag cement ;
- (ii) although the slag is comparatively harder to grind than the portland cement clinker, the grinding of two materials together or separately does not affect strength of concretes substantially ;
- (iii) Portland blast furnace slag cements have advantages like lower heat of hydration and increased resistance to attack of sulphate water ;

8. The optimum gypsum content has to be determined in each case before starting the manufacture of Portland blast furnace cement conforming to ISI Specification No. 455-1953 on Blast Furnace Slag Cements.

9. A capacity of nearly two million tons per annum has been licensed under the Industries (Development & Regulation) Act for manufacturing portland blast furnace slag cement based on the slags available from the newly projected steel plants as well as the existing iron and steel factories. It is, however, understood that only Messrs. A.C.C. have so far made definite arrangements with Messrs. Tata Iron & Steel Co. for procurement of slag for their Chaibasa cement plant. The various schemes for producing Portland slag cements are :—

Name of Firm	Location	Capacity tons p.a.	Source of slag
Mysore Iron & Steel Works	Bhadravati	18,000	Mysore Iron & Steel Works.
A.C.C. .. ..	Chaibasa	2,40,000	TISCO Jamshedpur.
A.C.C. .. ..	Drug	1,70,000	Bhilai Steel Works.
Orissa Cements	Rajgangpur	7,30,000	Rourkela Steel Works.
Durgapur Cements	Durgapur	2,40,000	Durgapur Steel Works.
Birla Brothers Ltd.	Durgapur	2,30,000	Do.
A.C.C. .. ..	Sindri	1,70,000	Do.
		19,98,000	

10. In the case of Bhilai Steel Project, when all the three blast furnaces are put into operation, the output of slag would be in the neighbourhood of 7 to 8 lac tons per annum by 1960. The slag would be granulated and would have the following approximate chemical compositions :—

Constituents	When producing	
	O.H.Iron %	Foundry Iron %
Silica .. ..	31.6	31.8
Alumina .. ..	21.7	22.0
Lime .. ..	33.8	36.8
Magnesia .. ..	8.8	6.3
Calcium Sulphide .. ..	1.9	1.9
Ferrous Oxide .. ..	0.9	0.3
Manganese dioxide .. ..	1.3	0.9
Total .. ..	100.0	100.0
Basicity of slag .. ..	1.3	1.2

11. Similar information in regard to other newly projected steel plants, *i.e.*, Rourkela and Durgapur, is not yet available but the slags are likely to be granulated and available within such limits of chemical composition as would make them suitable for cement manufacture. The following is the availability and chemical compositions of slags at Mysore Iron & Steel Works, Bhadravati, Indian Iron & Steel Co. and Tata Iron & Steel Co.

		Mysore I & S Works.	TISCO	IISCO
(i) Total slag available.	Present	33,000 tons p.a.	5,80,000	2,40,000
	Future	No expansion	9,00,000	7,20,000
(ii) Granulated or not	Slag from electric furnace only (80 tons per day would be granulated).		Granulation plant being set up capacity 150,000 tons.	Experiments in progress to decide whether the slag should be granulated.
(iii) Chemical Composition (%)	SiO <sub>2</sub>	30-35	30-31	28.5
	Al <sub>2</sub> O <sub>3</sub>	25-30	25-28	29.5
	CaO	30-35	36.5-38.2	36.2
	MgO	NA	3.2-3.3	3.0
	Mn	NA		0.5
	Fe	NA		0.9
	S	NA		1.0
(iv) Price per ton	Not given.			Rs. 6/7 per ton for unprocessed slag.

Messrs. Sone Valley Portland Cement have also conducted a number of experiments with the mixture of blast furnace slag and clinker in their laboratory and have studied the physical properties of the mixture, *i.e.*, setting time, tensile strength, expansion and compressive strength. The results obtained are as follows :—

Mixture	Setting Time		Tensile strength		Expansion	Compressive strength			
	Initial mts.	final mts.	1.3 lbs/sq inches			1.3 lbs/Sq. in.	3 days	7 days	
			3 days	7 days					
30% slag .. 66% clinker 4% gypsum	..	..	52	101	434	530	0.75	2300	3700
25% slag 71% clinker 4% gypsum	..	..	62	120	495	550	1.0	2500	3750

12. Similarly, Messrs. Kalyanpur Cement Works, Banjari, have experimented with slag obtained from Messrs. Tata Iron & Steel Co., Jamshedpur M/B161MofC&I-3(a)

and Messrs. Indian Iron & Steel Co. Kulti. The analysis of slags and physical properties of cements as found by them is as follows:—

Analysis of slag cements prepared by mixing 20, 15 and 10% slag with portland cement clinker and 4% gypsum.

		I			II			III
		I. I. & S. Co. Ltd.			T. I. & S. Co. Ltd.			Portland Cement with 4% gypsum
		20%	15%	10%	20%	15%	10%	
Loss on ignition	..	0.69	1.22	1.67	1.00	1.40	1.38	1.46
Silica SiO <sub>2</sub>	..	19.94	20.44	20.74	22.36	21.54	21.12	20.66
Insol. Residue	..	2.84	1.84	1.50	0.36	0.32	0.28	0.14
Alumina (Al <sub>2</sub> O <sub>3</sub> )	..	8.64	7.68	6.96	8.28	7.86	7.45	5.11
Iron (Fe <sub>2</sub> O <sub>3</sub> )	..	3.82	3.62	3.56	3.36	3.26	3.35	3.77
Calcium (CaO)	..	57.86	58.98	59.96	58.46	59.73	60.73	62.84
Magnesia (MgO)	..	3.60	3.66	3.68	3.72	3.82	3.73	3.82
Sulphur Trioxide (SO <sub>3</sub> )	..	2.05	1.83	1.80	1.85	1.80	1.78	1.85
Total	..	99.44	99.27	99.87	99.41	99.73	99.43	99.65

#### PHYSICAL PROPERTIES OF I, II and III.

		I			II			III			
		Water %	20%	15%	10%	Water %	20%	15%	10%	Water	10%
Setting time (mts.)	21				21				21		
Initial	..	225	185	190	155	165	175			210	
Final	..	290	230	240	230	235	225			290	
Residue on 170° mesh BSS	..	3.7	2.1	3.0	2.7	2.4	4.5			2.0	
Expansion in mm. by LECHATLIER'S APPARATUS	125	1.0	1.0	1.0	19.5	1.0	1.0	1.0	19.5	1.0	
Tensile strength in lbs sq. inch.	3 days	7.5	498	513	526	7.5	510	515	525	7.5	580
3 Parts sand plus 1 part cement		7 days		570	582	592		522	580	597	

After the various schemes relating to the manufacture of portland blast furnace slag cement referred to above are implemented, a capacity of over 1 million tons of slag cement would have been established in the country. However, as the availability of slag is rather large its full utilisation for manufacture of cement cannot be foreseen in the near future. It is recommended that

apart from the utilisation of slag in the manufacture of cement it should be used for roads, slag wool and other insulation products, concrete and concrete products and the like even though such applications would not also consume the entire quantity of slag likely to be available in the country. It would also be advisable for the new cement factories, particularly the ones close to iron and steel factories, to plan additional capacity of, say, 50% or so, in the cement mills. Such additional capacity can be utilised for intergrinding slag with cement clinker. It is estimated that slag cement factories would cost nearly 40—60% less than ordinary portland cement factories for a given capacity. It is also observed that the cement storage capacity in some cement factories is limited. The present practice is to store clinker instead and to grind it by utilising the spare cement mill capacity whenever necessary. The additional cement mill capacity as suggested would, therefore, be necessary so as to accommodate the manufacture of blended cements whenever necessary, as also to take care of periodical surges in the offtake of cement from an individual factory.

CHAPTER V  
HIGH ALUMINA CEMENTS, MASONRY CEMENTS, UTILISATION  
OF LOW GRADE GYPSUM, ADOPTION ON  
METRIC SYSTEM, ETC.

The Committee finds that cement industry is already using gypsum of 80—85% purity in the manufacture of cement and that gypsum of higher grade is being used for manufacturing fertilisers. The problem is not of an immediate significance and may, therefore, be deferred. The committee recommends, however, that the Central Building Research Institute may, if necessary, carry out investigations on the use of other materials in place of gypsum, as retarders in view of overall short supply of gypsum of good quality.

2. The Committee feels that high alumina cement may also be excluded from the present study and the question of making this type of cement should be taken up entirely as a different proposition for it is not expected to solve the problem of shortage of cement in any manner. As high alumina cement is reported to disintegrate at 25°C or 80°F in a climate as obtaining in this country, the Committee does not recommend its use as a masonry cement. Its use for all intents and purposes appears to be confined as a refractory cement only.

3. In regard to the economy of cement in its actual use, the Committee is of the view that as another Experts' Committee on "Economy in the use of cement in Building Construction" appointed by the Government of India has already submitted its report to the Government, it may not deal with the matter of economising cement as is commonly understood by the Civil or Construction Engineer. It should rather confine itself to suggesting ways and means of increasing the availability of cement and various cementing materials directly akin to Portland Cement. The Committee, therefore, takes note of the report of the Experts' Committee on "Economy in the use of cement in Building Construction".

4. *Masonry Cement*—Masonry cements, patent mortar cements and various other combinations of portland and natural cements, of hydraulic limes with variously hydrated limes, ground shales, or other forms of finely divided argillaceous materials have appeared in the markets in many parts of the world during the past 25 years to provide substitutes for mixtures of portland cement and lime. The masonry cements are largely proprietary mixtures and their formulations are never disclosed by the manufacturers. ASTM Specification C 91/55T contains requirements for time of setting, soundness, compressive strength, straining and water retention of masonry cements. The specification places no limits regarding the chemical compositions of masonry cement and consequently there is a wide variation in the constituents of the various brands. The physical properties of mortars made from these seems also vary over a wide range.

It is reported that in United States there was a chaotic condition which developed as a result of a number of such cements in the market, while that should not in any way deter us from developing a suitable masonry cement of common use, it is necessary to ensure that a confusion does not arise. In a number of cement factories in India there is considerable rejection of low quality limestone or dolomite which can be used successfully for the manufacture of masonry cement. Nevertheless, the Committee is of the view that slag and pozzolan cement should be developed first and the masonry cement should come next. In the meantime, the Central Building Research Institute may be approached to explore the possibility of experimental production and testing of masonry cements based on low grade limestones and rejects as are available in the country.

The Committee has examined also the feasibility of utilizing the surplus milling capacity in some cement factories, and requirements of power and foreign exchange for setting up additional cement mill capacity with a view to establishing manufacture of masonry cements. It is observed that only in a few cement factories there is some surplus milling capacity and in some cases the milling capacity is inadequate even for the existing production of clinker. The manufacture of masonry cement, therefore, does not seem to hold out any prospects in the immediate future in India and it should be tackled as a long term problem requiring detailed examination.

5. The Committee recognizes the need to give an incentive to the consumers of slag and pozzolan cement when their production commences in the country by way of making these cements cheaper than ordinary portland cements. The cost of production of such cements is expected to be somewhat lower and to that extent the benefit should be passed on the consumers. A suggestion was made to the Committee that pozzolan slag cements should be exempted from levy of excise duty or the duty should be levied only on the portland cement constituent of slag on pozzolan cements. This is a matter for the Government to decide but the Committee would recommend that a price concession in the case of pozzolan slag cements would pave the way for their quick development in the country.

6. The Committee examined also the matter of adoption of metric system by the Cement Industry, as requested by the Secretary, Standing Metric Committee. The industry buys pits consumption coal, power, gunnies, engineering stores and materials, and there would be no difficulty in following the metric system once it is adopted by the Suppliers and Manufacturers of such stores. As regards packing of cement, the Committee was advised that according to the current practice, 1 cwt. gross cement is packed in each bag. This could be taken as 50 kgm. net on the metric scale and would not involve any major change in the packing plant. The only change that would be required to be made is in the marking of weight in metric system on the cement bags.

## CHAPTER VI

### SUMMARY

1. (a) Even though rapid and substantial progress has been made by the Indian cement industry during the last decade, the *per capita* consumption of cement is yet too small in comparison with the consumption in other advanced countries. There is a considerable scope for further expansion of Portland Cement Industry and for the development of Pozzolanic and Blast Furnace Slag Cements. [Cf. Chapter II, para. 5, pp. 9-10]

(b) Pozzolanic materials, both natural and artificial, are reported to be available in various parts of the country. These are given in Appendix II(a). However, their activity and suitability as pozzolanas should be thoroughly investigated. [Cf. Chapter III, para. 4, pp. 19-20]

2. (a) Before the use of pozzolanic materials is to be advocated, it will be necessary to finalise Indian Standard Specification for such materials. The work is already in hand with the Indian Standards Institution. [Cf. Chapter III, para. 5, pp. 20-23]

(b) Preliminary work so far done in the country shows that the admixing of Pozzolanic materials available in the country with Portland Cement is feasible for specified jobs. [Cf. Chapter III, para. 1, pp. 14-16]

(c) Use of Pozzolanas in the construction of river dams should be promoted to a more extensive scale. The proposition, *viz.*, use of pozzolanas, should be invariably examined before sanctioning of the project so that effective economy could be ensured in the use of cement. [Cf. Chapter III, para. 5, pp. 20-23]

(d) Mixing of Pozzolanas with cement can be done either at the dam site or at such cement factories as are located close to the dam projects as well as in areas which are deficient in the production of portland cement but are close to the source of pozzolanas. [Cf. Chapter III, para 5, pp. 20-23]

(e) Manufacture of pozzolanic cements for general application is not considered advisable in view of the present somewhat easy availability of portland cement, but the industry should be enabled readily to take up such manufacture, should a contingency arise. To this end further investigations and steps as necessary may not be postponed. Furthermore, unless the use of pozzolanic cements can be extended to the general field of construction, it would not be advisable to establish a regular capacity for its manufacture. [Cf. Chapter III, para. 5, pp. 20-23]

(f) It appears necessary to make available portland slag cements at a concessional price with a view to offering incentive to the consumer who is otherwise likely to continue to use portland cement. [Cf. Chapter V, para 5, pp. 34-35]

3. The formulation of specifications for pozzolanic cements and their packing has already been taken up by the I.S.I. [Cf. Chapter III, para 5, pp. 20-23]



4. (a) Suitability of Blast Furnace Slag for manufacture of portland cement seems to have been established in the case of slags available from Mysore Iron and Steel Works and Tata Iron and Steel Cos. A number of schemes are already under implementation for utilising blast furnace slag. These schemes should be speedily implemented. Full utilisation of the available quantity of slag is not foreseen at present. [Cf. Chapter IV, paras. 11 and 12, pp. 28—31]

(b) The new iron and steel plants that are being established in the country should provide for facilities for granulating slag so that slag can be utilised by the cement industry. [Cf. Chapter IV, para 12, pp. 29—31]

5. The Cement Industry is already using lower grade gypsum of 80—85 per cent purity. The Central Building Research Institute should, however, investigate into the possibilities of using other retarders in place of gypsum. [Cf. Chapter V, para. 1, p. 32]

6. Manufacture of High Alumina Cement which is a refractory cement is not likely to retrieve the shortage of Portland Cement in the country. [Cf. Chapter V, para. 2, p. 32]

7. The Central Building Research Institute may be approached to explore the possibility of experimental production of masonry cements based on low grade limestones and rejects available in the country. [Cf. Chapter V, para. 4, pp. 33-34]

8. No practical difficulty is envisaged in the adoption of the Metric system by the Cement Industry. [Cf. Chapter V, para. 6, p. 35]

## CHAPTER VII

GOVERNMENT RESOLUTION ON THE FINDINGS OF THE COMMITTEE  
(Published in Part I, Section I of the Gazette of India, dated the 11th July 1959)

GOVERNMENT OF INDIA

MINISTRY OF COMMERCE AND INDUSTRY

New Delhi, dated 30th June 1959, 9 Asadha, 1881

### RESOLUTION

By their Resolution No. Cem-18(174)/56, dated the 23rd March, 1957, the Government of India, faced as they then were with the problem of acute shortage of cement in the country, appointed a Committee under the Chairmanship of Shri K. C. Sood, Director, Research and Designs Organisation, Ministry of Railways, consisting of both official and non-official members, to suggest ways and means for effecting economy in the use of cement and to increase its availability.

2. The Committee submitted its Report in August, 1958. The main recommendations of the Committee are summarised below:—

(A) The Committee observed at the outset that although the position in regard to availability of cement had changed considerably from that of acute shortage to that of easy supply, this is only a temporary phase and that with the general rise in the tempo of developmental activities, demand for cement is certain to revive. The per capita consumption of cement is very low in this country as compared to its consumption in other countries. There is, therefore, scope for further expansion of portland cement industry and for the development of pozzolanic and blast furnace slag cement.

(B) *Pozzolanic Cement*—

- (i) There is a wide range of both natural and artificial pozzolanic materials available in the country, but their activity and suitability as pozzolanas needs to be investigated.
- (ii) Before the pozzolanic materials are admixed with Portland Cement, it would be necessary to fix Indian Standard Specifications for such materials.
- (iii) Pozzolanic cement is not a general purpose cement, but its use in Mass Masonry construction of dams, Marine works etc. has been well established both in India and abroad. In addition, it can be beneficially used for certain specific jobs like Tunnel Lining and Foundations, piers and abutments of bridges etc.

- (iv) Use of pozzolanas in the construction of dams should be made on a more extensive scale. The possibility of such use should invariably be examined before any new project is sanctioned.
- (v) Mixing of pozzolanas may be done either at the site of the dam or at cement factories located close to the site, as well as in areas which are deficient in the production of portland cement but are close to the source of pozzolanas.
- (vi) Unless the use of pozzolanic cement can be extended to the field of general construction, it would not be advisable to establish any regular capacity for its manufacture. Also in view of the present easy availability of cement, some caution would be necessary before any decision is taken to establish capacity for its manufacture. But the industry should be in a position to take up such manufacture, should a contingency arise, and investigations and steps necessary for this end, should not be postponed.

(C) *Blast Furnace Slag Cement--*

- (i) Suitability of Blast furnace slag for manufacture of portland cement seems to have been established in the case of slag available from the Mysore Iron and Steel Works and Tata Iron and Steel Companies. The schemes which are at present under implementation for utilisation of this slag in the manufacture of cement may be speedily executed.
- (ii) The possibility of the use of slag for manufacture of cement has also been kept in view while planning the lay-out of the three steel plants in the public sector. A granulation plant has already been designed in the case of Bhilai Steel Project.
- (iii) The new cement factories, specially those near Iron and Steel Plants should provide for 50 per cent additional milling capacity, so as to take to manufacture of blended portland slag cement, whenever necessary.
- (iv) Not all the available slag can be utilised for manufacture of cement and its use in the manufacture of slag wool, insulation products, construction of roads etc., should be investigated and encouraged.

(D) *Alumina Cement—*

Alumina Cement disintegrates at temperature of 25°C or 80°F and considering the climatic conditions in the country, it is not advisable to use it as a Masonry cement.

(E) *Masonry Cement—*

The Central Building Research Institute should explore the possibilities of experimental production of masonry cement based on low grade limestone and rejects in the country.

(F) *Gypsum used in the manufacture of Cement—*

In view of the overall short supply of good quality gypsum, the Central Building Research Institute should investigate the possibilities of using other materials as retarders in place of gypsum used in the manufacture of cement.

3. The other recommendations of the Committee are:—

- (A) No practical difficulty is envisaged in the adoption of metric system by the cement industry.
- (B) To overcome the initial reluctance of the consumers to buy portland pozzolana or portland slag cement, it would be necessary to fix concessional price for these types of cement.
- (C) To ensure equitable distribution, it would be necessary to bring pozzolana cement under the purview of the Cement Control Order.

4. The Government of India generally accept in principle the recommendations made by the Committee in Para. 2 above and recommend that Ministries/Organisations concerned may take steps to implement them and conduct further investigations on the lines suggested by the Committee. As regards the recommendations of the Committee in paragraph 3, the Government of India observe as follows :—

(i) *Recommendation in Sub-para. 3 (A)*—

Steps are being taken for introducing metric system in the cement industry.

(ii) *Recommendation in Sub-para. 3(B) & (C)*—

These recommendations can be considered only after some capacities for regular production of pozzolana and slag cement have been established.

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#### ORDER

Ordered that a copy of this Resolution be communicated to all concerned and that it be published in the Gazette of India.

(Sd.) S. RANGANATHAN

*Secretary to the Government of India*

## APPENDIX I

### SCHEDULE I (for Cement Factories only)

1. Name of the factory.
2. Installed capacity—
  - (a) Raw mill capacity— . . . . tons per day.
  - (b) Kiln capacity— . . . . tons clinker per day.
  - (c) Cement mill capacity— . . . . tons cement per day.Please state if the above are working to their rated capacity or whether the average output is lower than rated capacity. In the case of latter, please give what is the actual average output.
  - (ii) Do you have any additional cement mills lying unutilised or uninstalled? If so, the type of cement mills and the total capacity available may be furnished.
3. Please give any information on puzzolanic materials that you may have collected, i.e., its availability in your area, the nature of the material and its puzzolanic activity as well as the total availability.
4. Have you done any work in your laboratory or factory on admixing of such puzzolanic materials available near your factory or elsewhere, with portland cement, and studied setting and other properties of the resulting cement. If so, please give briefly the details of the work done and results obtained. Also state if you have examined storing property (deterioration of quality with time) of such a mix vis-a-vis ordinary portland cement. If so, please give data.
5. *Gypsum*—What grade of gypsum in your opinion is most suitable for portland cement. Have you tried gypsum of 80—85 per cent purity and with what result? Have you carried out any experiment in connection with replacement of gypsum by any other retarding material? If so, please give details.
6. What would be the additional requirements of power, packing, conveying and storage facilities for 20—30 per cent extra grinding and handling of blended cement?
7. If you do not have any spare mill capacity and facilities for packing, conveying, storage, etc., to cope with your current production plus 20—30 per cent additional production (by way of blended or replaced cements). Please state if it is possible for you to arrange for these and what will be the requirements of foreign exchange.
8. Are you in a position to market portland cement and neat puzzolanic materials (i.e., without mixing it with cement) separately or would you rather market portland cement and puzzolanic cements.

9. What in your opinion, what would be the ex-factory price of puzzolanic cements, i.e., portland cement blended with 20/25 per cent of puzzolanic materials.
10. Any other information not covered by the above which in your opinion would be useful.

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**SCHEDULE II (For consumers of cement only)**

1. Do you have any information on the materials of puzzolanic activity available in the country and about their puzzolanic nature and total quantity available? If so, please furnish a list of places where such materials are understood to be available.
2. Please indicate any work that you might have yourself done or be aware of to have been done in India or elsewhere in connection with the use of materials of puzzolanic activity in the cement mix with a view to increasing the effective use and production of local building materials. If so, please furnish a brief note.
3. What is your considered opinion on the use of masonry cements which are specially formulated and interground mixtures of portland cement clinker lime-stone, gypsum and air-entraining agents. Some cements are very popular in other countries and have been found to have excellent plasticity and water retention properties. They make mortar which places well, sets and hardens rapidly above or under water and produces high strength mortar joints.

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**SCHEDULE III (For Iron and Steel factories only)**

1. How much blast furnace slag is at present available with you and what quantity would be available after your expansion programme has been implemented, and when?
2. State whether the slag would be granulated or not.
3. What is the chemical composition and mineralogical state of the slag? Also indicate if you have determined its grindability.
4. Approximate price per ton at which you might be in a position to supply granulated slag.

**APPENDIX II**

*Statement showing the existing Cement Factories, and Approved Schemes of New Units and Expansions*

Serial No.	Name of firm	Location	Existing Units			New Units			Remarks
			Existing capacity	Approved Expansion capacity if any	Total capacity	Capacity approved	Expansion approved	Total capacity	
			(Tons per annum)						
1	2	3	4	5	6	7	8	9	10

**ANDHRA PRADESH**

1	Andhra Cement Co. Ltd., Madras (V. Rama Krishna).	Rama Vijayawada	198,000	..	198,000	..	..	..	
2	K.C.P. Madras (V. Rama Krishna) .. ..	Macherla ..	100,000	150,000	250,000	..	..	..	
3	Associated Cement Cos. Ltd., Bombay (A.C.C.)	Kistna ..	255,000	..	255,000	..	..	..	
4	The Associated Cement Co., Ltd., Bombay (A.C.C.)	Manoherial ..	..	..	..	165,000	165,000	330,000	
5	Panyam Cements & Mineral Industries Ltd., Kurnool (Independent).	Panyam ..	..	..	..	62,700	..	62,700	
6	The Associated Cement Cos. Ltd., Bombay (A.C.C.)	Yerraguntla	..	..	..	165,000	..	165,000	
7	Andhra Cement Co. Ltd., Madras (V. Rama Krishna).	Nadikudi ..	..	..	..	198,000	..	198,000	

APPENDIX II—*contd.*

1	2	3	4	5	6	7	8	9	10
<b>ANDHRAPRADESH—<i>contd.</i></b>									
8	India Cements Ltd., Madras (Narayanawami)	Vizianagram	..	..	..	200,000	..	200,000	
9	Rayalseema Development Cor. Ltd., Madras (Independent).	Kamlapuram	..	..	..	126,000	..	126,000	
			553,000	150,000	703,000	916,700	165,000	1,081,700	
<b>ASSAM</b>									
10	Assam Cements Ltd., Shillong .. ..	Umtyngar ..	..	..	..	66,000	66,000	132,000	
<b>BIHAR</b>									
11	The Associated Cement Cos., Ltd., Bombay (A. C.C.).	Chaibasa ..	200,000	100,000 170,000 (Slag)	470,000	..	..	..	
12	Rohtas Industries, Dalmianagar (Sahu Jain) ..	Dalmianagar	330,000	247,500	577,500	..	..	..	
13	Ashoka Cement Ltd., Dalmianagar (Sahu Jain)	Do.	280,000	..	280,000	..	..	..	
14	Kalyanpur Lime & Cement Wks. Calcutta (Independent).	Banjari ..	144,000	99,000	243,000	..	..	..	
✓15	Sone Valley Portland Cement Co. Ltd., Calcutta (Sahu Jain).	Japla ..	250,000	231,000	481,000	..	..	..	



16	The Associated Cement Cos. Ltd., Bombay (A.C.C.)	Sindri	200,000*	100,000	300,000	..	..	..	*From sludge of the Sindri Fertilizer Works.
17	The Associated Cement Cos. Ltd., Bombay (A.C.C.)	Khalari	100,000	..	100,000	..	..	..	
18	Bihar Lime Stones & Mineral Co. Ltd., Calcutta (Independent).	Demu	..	..	..	100,000	..	100,000	
			1,504,000	947,500	2,451,500	100,000	..	100,000	

BOMBAY

19	Shree Digvijay Cement Co. Ltd., Bombay (Soman).	Sikka	430,000	200,000	630,000	..	..	..	*White and cold cement.
20	The Associated Cement Cos. Ltd., Bombay (A.C.C.)	Dwarka	220,000	115,000	335,000	..	..	..	
21	The Associated Cement Cos. Ltd., Bombay (A.C.C.)	Porbander	42,000	123,000 25,000*	190,000	..	..	..	
22	The Associated Cement Cos. Ltd., Bombay (A.C.C.)	Sevalia	200,000	..	200,000	..	..	..	
23	Saurashtra Cement & Chemicals Industries Ltd., Porbander (Independent).	Porbander	..	..	..	200,000	..	200,000	
24	The Associated Cement Cos., Ltd., Bombay (A.C.C.)	Veraval	..	..	..	165,000	..	165,000	
			892,000	463,000	1,355,000	365,000		365,000	

KERALA

25	Travancore Cements Ltd., Kottayam (Independent).	Kottayam	50,000	5,000	55,000	..	..	..
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APPENDIX II—contd.

1	2	3	4	5	6	7	8	9	10
<b>MADHYA PRADESH</b>									
✓ 26	Associated Cement Cos. Ltd., Bombay (A.C.C.)	Kymore ..	350,000	213,000	563,000	..	..	..	
✓ 27	The Associated Cement Cos. Ltd., Bombay (A.C.C.)	Banmore ..	60,000	..	60,000	..	..	..	
28	The Associated Cement Cos. Ltd., Bombay (A.C.C.)	Drug ..	..	..	..	165,000	85,000	250,000	
29	Birla Jute Mfg. Co., Calcutta (Virias) ..	Satna ..	..	..	..	330,000	..	330,000	
30	Shri Sanwalram More, Bombay (Independent)	Neemuch ..	..	..	..	150,000	..	150,000	
31	Shri L. Rammohan Rao, Naidadavol (Independent).	Drug ..	..	..	..	200,000	..	200,000	
			410,000	213,000	623,000	845,000	85,000	930,000	
<b>MADRAS</b>									
32	Dalmia Cement (Bharat) Ltd., Calcutta (J. Dalmia).	Dalmiapuram	247,000	165,000	412,000	..	..	..	
33	India Cements Ltd., Madras (Narayanawami)	Talaiyuthu ..	215,000	250,000	465,000	..	..	..	
34	Associated Cement Cos. Ltd., Bombay (A.C.C.)	Madhukarai	280,000	..	280,000	..	..	..	
35	V. Ramakrishna & Sons, Madras (V. Ramakrishna).	Thirubottiyur	..	..	..	16,500*	..	16,500	*White and coloured.
36	Madras Cements Ltd., Rajapalayam (Ramaswami Raja).	Ramanathapuram	..	..	..	198,000	..	198,000	
			742,000	415,000	1,157,000	214,500	..	214,500	

**MYSORE**

37	Mysore Iron & Steel Works, Bhadravati (Mysore Govt.),	Bhadravati	80,000	18,000	98,000	..	..	..
38	Bagalkot Cement Co. Ltd., Bombay (Tendulkar)	Bagalkot ..	100,000	100,000 (1st stage) 100,000 (2nd stage)	300,000	..	..	..
39	Associated Cement Cos. Ltd., Bombay (A.C.C.)	Shahabad ..	350,000	100,000	480,000	..	..	..
40	Mysore Cements Ltd., Bangalore (Sarangapani Mudaliar).	Obalapura ..	..	..	..	200,000	..	200,000
			580,000	318,000	878,000	200,000	..	200,000

**ORISSA**

41	Orissa Cement Ltd., Calcutta (J. Dalmia) ..	Rajgangpur	365,000	365,000	730,000	..	..	..
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**PONDICHERRY**

42	K.C.P. Ltd., Madras (V Ramakrishna) ..	Pondicherry	..	..	..	200,000	..	200,000
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**PUNJAB**

43	Associated Cement Cos. Ltd., Bombay (A.C.C.)	Surajpur ..	400,000	..	400,000	..	..	..
44	Dalmia Dandri Cement Co. Ltd., Delhi (R. K. Dalmin).	Dalmia-Dadri	235,000	..	235,000	..	..	..
			635,000	..	635,000	..	..	..

APPENDIX II—*contd.*

1	2	3	4	5	6	7	8	9	10
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RAJASTHAN

45	Associated Cement Co. Ltd., Bombay (A.C.C.)	Lakheri ..	360,000	165,000	525,000	..	..	..	
46	Jaipur Udyog Ltd., N. Delhi (Sahu Jain) ..	Sawaimadho- pur	581,000	245,000	806,000	..	..	..	
47	Associated Cement Cos. Ltd., Bombay (A.C.C.)	Abu-Road	..	..	..	165,000	..	165,000	
48	J. K. Commercial Corpn., Kanpur (Independent)	Nim-ki-Thana	..	..	..	156,000	..	156,000	
			921,000	410,000	1,331,000	321,000	..	321,000	

UTTAR PRADESH

49	U. P. Govt. Cement Factory, Churk (U.P. Govt.)	Churk ..	200,000	231,000	431,000	..	..	..	
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WEST BENGAL

50	Birla Bros. Ltd., Calcutta (Birlas) .. ..	Durgapur	..	..	..	330,000	..	330,000 (Slag)	
51	Durgapur Cement Ltd., Calcutta (Independent)	Durgapur	..	..	..	240,000	..	240,000	Portland and slag cement.

	...	..	..	570,000	..	570,000
GRAND TOTAL ..	6,832,000	3,517,500	10,349,500	3,798,200	316,000	4,114,200

Total cement capacity sanctioned (Total of Columns 6 and 9) = 14,463,700 tons

\*Provisionally approved schemes :-

(1) Associated Cement Cos, Bombay ..	..	Drug (M. P.)	165,000 tons p.a.
(2) Birla Bros. Ltd., Calcutta ..	..	Satna (M.P.)	330,000 tons p.a.
(3) Rajpur Cement Works, Bombay ..	..	Rajpur (Bombay)	240,000 tons p.a.
(4) M/s. Veraval Oilcake Co., Veraval (Saurashtra)			49,500 tons p.a.

TOTAL .. .. 784,500 tons p.a. 784,500 tons

GRAND TOTAL 15,248,200 tons

15.2482 Million tons (As on 1-9-1958).

## APPENDIX II (a)

### NATURAL POZZOLANAS IN INDIA

#### *Shale:*

Shale occurs widely in the Vindhyan, Kurnool, Gondwanas, Jurassic of Cutch and tertiary formations of Assam. It appears that no information on its production is available.

Some localities where Vindhyan shale occurs, however, are given below—

(i) Newar ( $24^{\circ} 35' : 82^{\circ} 5'$ )

(ii) Patandh ( $24^{\circ} 33' : 83^{\circ} 05'$ )

(iii) Markundi area ( $24^{\circ} 36' : 86^{\circ} 6'$ ) and west of Agori ( $24^{\circ} 33' : 83^{\circ} 00'$ )

Good exposures of shales also occur along the Son Valley in the following localities :—

(i) Brechi ( $24^{\circ} 32' : 82^{\circ} 47'$ )

(ii) Banjoro

(iii) Bijaegart ( $24^{\circ} 34' : 83^{\circ} 13'$ )

Shales belonging to the Kurnool formation are known to occur in the Kandari and Palnad tract, good outcrops of shale are found to occur near about the town of Nandyal. (Geology of India & Burma—M. S. Krishnan).

In the Vindhya Pradesh Vindhyan Shales occur; mention of some of the localities is made hereunder—

(i) Near Bankola village, Maihar State.

(ii) Near Badampur village, Maihar.

Shales occurring within the Gondwanas are found to occur in the coal fields of Raniganj, Jharia, Bokaro, Karanpura, Ramgarh etc. Some of the localities where shale occurs are mentioned below—

Talchi State:

(i) Gopalprasad, Talchir State.

(ii) South of Tehernpur, Talchi State.

(iii) Near Lurhaga village, Distt. Hazaribagh, Bihar.

#### *Volcanic Tuff or Ash :*

It seems that no information with regard to the production of volcanic tuff is available. Details regarding its occurrence are given below—

(i) Singhbhum District, Bihar—

There is a zone of tuffs between the lava and the banded hematite-quartzite of Noamandi east ridge.

(ii) These are also well developed around Gua; in the bank of the Karo river; east of Gua there is a good exposure of tuff,

- (iii) About  $\frac{1}{2}$  mile west of Jamda station also in the stream to the S.W. outcrops of tuffs occur.
- (iv) Within an area defined roughly by the villages Somera ( $22^{\circ} 35'$ ); — ( $85^{\circ} : 28^{\circ}$ ) Lota Pahar ( $22^{\circ} 57' : 85^{\circ} 34'$ ) volcanic tuffs occur.
- (v) In the west of Porahat some excellent coarse tuffs are associated with the phyllite to the south of the main volcanic flows.
- (vi) North of Sirijang ( $22^{\circ} 32' : 85^{\circ} 12'$ ) a tuff occurs with some epidiorite which contain abundant ejected fragments.
- (vii) Occurrences of tuffs are also noted at Pahardia ( $22^{\circ} 30' : 85^{\circ} 11'$ ), in the stream course SE of Nawatoli ( $22^{\circ} 34' : 85^{\circ} 11'$ ) a good occurrence is recorded.
- (viii) Metamorphosed tuff occurs N.W. of Kotia ( $22^{\circ} 43' : 85^{\circ} 16'$ ) and also Losodtole ( $22^{\circ} 40' : 85^{\circ} 09'$ ).

*Orissa :*

*Athmallik State:*

A peculiar occurrence of white clay is reported on the bank of the Mahanadi near Khumbi ( $22^{\circ} 53' ; 84^{\circ} 18'$ ). The material is extremely light and consists of small flakes and particles of glassy silica.

*Bombay :*

Baroda—There is an occurrence of clay reported from near Kelkach about three miles east of Uni Rly. Station. This appears to consist of fine sandy material, and possibly a volcanic tuff.

Near Chaibasa also there are some occurrences of volcanic tuff, the localities of which are given below—

- (i) South of vill. Katiguta ( $22^{\circ} 33' 50'' : 85^{\circ} 50' 26''$ )
- (ii) N.W. of the vill. Doosorasai ( $22^{\circ} 33' 6'' : 85^{\circ} 50' 30''$ )
- (iii) West of milestone No. 2 on the Chaibasa—Seraikella Road.

*Diatomaceous Earth deposits in India.*

The following are the known localities of diatomaceous earth occurrences in India—

1. Andaman and Nicobar Islands (Ritchies Archipelago presence of radiolaraca and sponge spicules) reported by Messrs. Tipper & Gee.
2. Aleppy coast-dried mud—Travancore State.
3. Karewas, Galmarg-clays collected near Galmarg from sides nala.
4. Santhal Parganas—silicified earth from Santhal Parganas and Birbhum District.

5. Guntur District, Madras village Timmapalan of Vinkunda Taluq, Guntur District (locality to be kept confidential).
6. Substitute for Tripoli, found near Narainpur—Tatawara Railway Station on B. B. & C.I. Railway. Silicon sand capping —Tarohum Hornstone Breccia.

*T. Occurrences and reserves of pozzolanic materials in India—*

The information which we have, has been incorporated in the consolidated statement entitled "List of the occurrences of possible natural pozzolanic materials in India". It is not implied in this presentation, that all of the possible materials listed will, ultimately, be found suitable. The list is intended merely to guide the future work on pozzolanic materials in India.

Regarding the total quantity of pozzolanic materials available in each area, field-work for obtaining this information can be undertaken *only after laboratory tests have confirmed the existence of certain types of pozzolanic materials in any particular area*. No information is available on the reserves of possible pozzolanic materials in India, except for the deposit being utilised for this purpose, on the Bhakra Dam Project.

*II. Research on Pozzolanic materials in India and elsewhere—*

This can be divided into two categories—

- (i) Research on behaviour of pozzolans in concrete and in mortar;
- (ii) Research on the petrographic identity of pozzolanic materials.

With regard to (i), so far is known to us, only the Research Stations attached to the various river-valley projects, or to the State and Central Governmental Organisations, have gathered some valuable information on pozzolanic materials, in particular, the Hirakud Research Station and the Bhakra Research Station. On the Bhakra Dam Project, calcined Dagshai shales and siltstones are serving as the source material for pozzolans which are being used on this project since May, 1957.

In the U.S.A., the Bureau of Reclamation, the Portland Cement Association, the American Concrete Institute and the Waterways Experiment Station of the U.S. Army Corps of Engineers, are some of the organisations which have been actively pursuing the research of pozzolans in concretes and mortars. The results of their work are available in a large number of publications put-out by these Organisations. It is well-known that in the U.S.A., portland-pozzolan cements have been used in the construction of several large engineering works. I think information on the nature of pozzolanic materials used in the construction of engineering works in the U.S.A. would be of interest to the Committee on the Economy in use of Cement.

We have given below in Table I, a list of some of the pozzolanic materials used in certain engineering works in the U.S.A., along with the petrographic identity of the pozzolans. Further information on the use of pozzolanic materials in these engineering structures may perhaps be available from the organisations responsible for their construction.



TABLE I

Petrographic classification of pozzolan	Active ingredients in the pozzolan	Engineering structures in which pozzolans have been used
1	2	3
(1) Opaline shale and chert	Opal & Beidellite (a clay mineral)	Golden gate and San Francisco's Bay Bridges; highway pavements, California; San Jacinto Tunnel, near San Jacinto, California; Davis Dam, Nevada-Arizona.
(2) Oil-impregnated shale	Beidellite (a clay mineral).	Big Creek Dam No. 7, Fresno County, California.
(3) Siliceous shale	.. Beidellite	.. Experimental highway pavements, Kansas.
(4) Pumicite	.. Rhyolite glass	.. Friant Dam; Pardee Dam; Canal structures, California; Altus Dam in Oklahoma.
(5) Altered tuff	.. Clinoptilote (a mineral of the zeolite group) and beidellite.	Los Angeles Aqueduct, California.
(6) Argillaceous silt	.. Illite and montmorillonite type clay.	Bonneville Dam, Washington-Oregon.
(7) Diatomite	.. Opal	.. East Bay Sewage project, Oakland, California.

In regard to similar work on the nature of pozzolanic materials in India, one of our officers (V. S. Krishnaswamy) has done some research on the petrography of natural pozzolanic materials available in the Hirakud Dam Project area. This work was conducted by him during 1953-54, when he was attached to the Bureau of Reclamation, as an "in-service" trainee under the Point Four Programme. A preliminary report on this work can be had from the Geological Survey of India. An abstract of the results of the work done is given below—

#### HIRAKUD DAM PROJECT

“Three types of pozzolanic materials were examined, using petrographic, thermal and X-ray methods.

(i) Talabira fire-clay from the Hingir-Rampur Coalfield, Orissa.

(ii) Talchir shale from Gap IV, Left Dyke, Hirakud Dam.

(iii) Cuddapah Shales from the right abutment of Hirakud Dam.

The mineralogic composition of the Talabira clay, with 50 per cent Mullite, 45 per cent Tridymite, 3 per cent Quartz and less than 5 per cent glass, indicates that the material has already been calcined by an as yet unknown natural agency. This information explained the anomalous behaviour of the calcined and uncalcined Talabira clay which was used as a pozzolan in mortars and concrete fabricated in the Hirakud Research Station laboratory. It was recommended that the possible long-term expansion of the concrete due to the reactive siliceous material present in the clay (viz. Tridymite and glass), has to be verified, before the naturally occurring pozzolan can be recommended for use in concrete, without calcination. The Talchir shale had a significant percentage of Beidellite, and hence, was expected to behave as a good pozzolan, after calcination at the proper temperature. Further, this shale exhibited the tendency to form a light, vesicular, but tough mass on calcination at 1600°—2000°F, thereby indicating its potential value as a source of light-weight aggregate for concrete. Further experimental work on a large scale, using a pilot calcination plant, as well as field work for locating adequate reserves of acceptable shale material, was recommended, before accepting the Talchir shale as a source of light-weight aggregate for concrete.

The Cuddapah shales showed a good percentage of Illite and Hydromica, in certain proportions, as well as a small percentage of Kaolinite. The variety of shale having a high percentage of Illite, was indicated to possess better pozzolanic properties upon calcination, than those with a high percentage of Hydromica."

### BHAKRA DAM PROJECT

The petrographic identity of the Dagshai shales now being used as a pozzolan on the Bhakra Dam Project, has been studied in the Bureau of Reclamation Laboratories; extensive laboratory tests, using this material in concrete cylinders, have been conducted in the Research Station at Bhakra.

Apart from the piece of research work done by V. S. Krishnaswamy, Geological Survey of India, probably very little information has been collected on the nature of other, possible pozzolanic materials in the country.

In the statement given below in Table II, the probable nature of prospective pozzolanic materials in India have been described. This statement should not be taken as being conclusive, either in regard to the identity or the activity of pozzolanic ingredients. Many of the natural pozzolans listed in the statement, may owe their activity to more than one ingredient, about which no information is available at the present time. It should also be stressed here that the description of the active pozzolanic ingredients in any prospective material is, in itself, no indication of the quality of the pozzolan, in as much as the proportion of the active ingredient or ingredients, may vary within wide limits. We do not as yet have any information on the relative percentages of active and inactive ingredients in the possible pozzolanic materials listed in Table II. Furthermore, the fineness and particle-size distribution of the material strongly influence pozzolanic activity of all types of pozzolans. All of these aspects have to be studied in the field and in the laboratory, before a definite opinion can be given on the occurrence and utility of pozzolanic materials in India.

Even if adequate reserves of pozzolanic materials of acceptable quality are proved to be available in any particular part of the country, the costs of quarrying, handling, processing and transporting them to the consumer centres, will have to be carefully weighed, before taking a decision on the actual use of the pozzolan as a measure of economy in the consumption of cement.

TABLE II

Tentative Identity of the essential active ingredients in some of the possible natural pozzolanic materials in India.

Acti- vity Type	Principal active ingredient	Possible natural pozzolanic material in India having the active ingredient (more than one active ingredient may be present)
1	Volcanic glass	(1) Acid volcanic rocks from Pir Panjal area. (2) Rhyolites of Pavagad and Panchmahals in Bombay. (3) Rhyolites and volcanic ash from Girnar and Rampur in Saurashtra. (4) Tuff deposits in Malani, Jalor and Jodhpur areas. (5) Volcanic ash and pumicite beds from Barren and Narcondam Islands. (6) Some deposits of Bentonite in Jammu, if they are derived from alteration of ash beds. (7) Tuffs in the Iron ore series and the Dunjori and Dalma Volcanics in Bihar.
2	Opal	(1) Radiolarian beds of Andamans. (2) Diatomaceous earths A. & N. Islands.
3	Clay Minerals: Kaolinite Montmorillonite Illite Mixed clays with vermiculite Palygorskite Hydromica(?)	(1) Cuddapah shales. (2) Vindhyan shales. (3) Dagshal shales. (4) Siwalik shales and clays. (5) Other Tertiary shales (?) and clays (!) (6) Gondwan shales. (7) Ceramic and fireclay beds in the coalfields of Bihar, Orissa and elsewhere. (8) Fuller's earth and Bentonite deposits in J. & K. State and in Rajasthan. (9) Marls in U.P. (10) Soil material suitable for 'Surkhi' manufacture. (11) Daling phyllites (?) (12) Some varieties of Archaean phyllites as at Rihand (?)

NOTE—Some of the shales may also have active ingredients of Type 2.

TABLE II—*contd.*

1	2	3
4	Zeolites (certain varieties like clinoptilolite).	(1) Some of the altered ash and tuff beds mentioned under activity type I may also have zeolitic minerals. (2) Some of the deeply-altered zeolitic traps in the Deccan basalts.
5	Hydrous aluminium oxides.	(1) Lithomarge deposits in Ranchi Plateau. (2) Some of the low-grade Bauxite deposits. (3) Lithomarge and ochers occurring near Katni and other areas.

NOTE—This group of materials may also have active ingredients of type 2 and 3.

NOTE—The statement presented in Table II above does not claim to be an exhaustive one. An attempt has been made to indicate the lines of future research on prospective pozzolanic materials in India.

*Occurrences of possible natural pozzolanic materials in India*

Pozzolans are siliceous materials, which, though not cementitious in themselves, contain constituents which at ordinary temperatures will combine with lime in the presence of water to form compounds which have a low solubility and possess cementing properties.

In this note, industrial products like blast furnace slag, fly ash etc., which would satisfy the definition of a pozzolan, have not been considered. A list of possible natural pozzolanic materials in the country is given below, with the known occurrences grouped under five regions, viz., Northern, Eastern, Central, Western and Southern Regions. This list includes all of the naturally occurring pozzolanic materials which can be used either in the raw state (*e.g.*, Pumicites) or after necessary processing (*e.g.*, Calcined shales and clays).

It is not implied, however, that all the materials listed will, ultimately, be found suitable for use as pozzolans. At present time, very little information is available on the reserves or quality of these occurrences of possible pozzolanic materials, with the exception of the Tertiary shale deposit which is being used as a source of pozzolan on the Bhakra Dam Project and the Gondwana fireclay deposit which was, at one time, considered for use on the Hirakud Dam Project.

It is suggested that as a first step in the research on prospective pozzolanic materials in the country, a number of samples should be collected, after a preliminary field survey, preferably by geologists. These samples will have to be tested in the laboratory for petrographic properties, chemical and mineralogical composition as well as for strength and various other relevant properties when used in concrete cylinders and mortar bars. Based on this information, adequate

field work will have to be undertaken subsequently, in areas having proved pozzolanic materials, in order to establish the uniformity and reserves of materials of acceptable quality.

It is to be remembered that in the case of many occurrences of pozzolanic materials, like volcanic rocks and shales, the cost of quarrying, handling, grinding, calcination and transportation will require consideration in a comprehensive study of the economics of utilising particular raw materials, even though these may be of acceptable quality for the intended use as an admixture to cement. It is, therefore, obvious that a considerable amount of work has to be done, before any firm opinion can be given regarding the utility of the raw materials for pozzolans, which have been listed below; *the list is intended merely to guide the future search for pozzolanic materials in the country.*

*A list of occurrences of possible Pozzolanic materials in India*

The available information re: probable sources of pozzolanic materials, is as follows, arranged State-wise.

Name of States	No. given in the map	Serial No. State-wise	Description
1	2	3	4
<b>Northern Region</b>			
J. & K.	1	1	Deposits of Fuller's earth in Jammu.
	2	2	Acid volcanic rocks from Fir Panjal area.
	3	3	Tertiary and younger clay and shale beds in Jammu area.
U.P.	4	4	Deposits of Bentonite in J. & K. State.
	5	1	Gondwana and Tertiary shales near Singrauli coal-field in Mirzapur Dist.
Punjab & H.P.	6	2	Phyllites in the Rihand Dam area.
	7	1	Tertiary and younger shales in Punjab and Himachal Pradesh.
Rajasthan	8	1	Fuller's earth and Bentonite deposits of Rajasthan (in Bikaner area).
	9	2	Eocene shales and clays of the Jaisalmer and Palena areas.
	10	3	Tuff deposits in Malani, Jalor and Jodhpur areas.
<b>Eastern Region</b>			
Bengal, Bihar & Orissa.	11	1	Clay and shale beds in the Gondwanas in Bihar, Bengal and in the Orissa coal-fields.
	11-A	2	Glassy flows in Rajmahal Treps.
	12	3	Lithomarge deposits in the Ranchi plateau.
	12-A	4	Tuffs in the iron ore series (?) and Dhanjori and Dalma volcanics in Bihar and Orissa.

1	2	3	4
	13	5	Cuddapah shales in Orissa.
	13-A	6	Phyllites from Gangpur series. (Investigated for Hirakud Dam Project).
Assam (including NEFA)	14	1	Gondwana shales in the Himalayan foothills.
Andaman & Nicobar Is.	15	1	Diatomaceous earth in Andaman & Nicobar Is. (Ritchies Archipelago).
	16	2	Eocene and Miocene shales and clays in Nicobar and in the Middle and North Andaman Is.
	17	3	Radiolarian cherty beds in South and Middle Andaman Is.
	18	4	Volcanic ash and Pumicite from Barren and Narkondam Islands.
Central Region			
M.P.	19	1	Vindhyan shales.
	20	2	The lithomarge and others occurring below the Bauxite in Katni and other localities.
	21	3	Bijawar Phyllites.
	22	4	Tuff and ash beds—Inter-trappean formations in the Deccan basalts.
Western Region			
Bombay	23	1	Tertiary and Jurassic clays and shales, from Saurashtra and Cutch.
	24	2	Rhyolites and volcanic ash beds of Girnar, Ranpur and Osham hills in Kathiawar.
	25	3	Rhyolites of Pavagad and Panchmahals in Bombay.
	26	4	Clay deposits in Baroda in Bombay State of suspected volcanic origin (?)
Southern Region			
Madras, Andhra, Kerala & Mysore.	27	1	Clay beds over the Neyveli lignite seam in South Arcot district.
	28	2	Warkalli clay beds in Kerala.
	29	3	Cuddapah shales.
	30	4	Gondawana shales.

In addition to the general information on possible pozzolanic materials in India, given in the foregoing list, specific information on the location or geographical co-ordinates of the occurrences of particular types of pozzolanic materials is available from the published and unpublished reports of the Geological Survey of India. This information has been collected and is presented below under three groups, viz., Volcanic rocks, Shales and Miscellaneous formations. It is stressed here that the information given below does not purport to be exhaustive.

## I. VOLCANIC ROCKS

(a) *Rhyolite*—It occurs in the following areas—

(a) (i) Malani, (ii) Jalor and (iii) Jodhpur in Rajasthan.

(b) Girnar hills ( $21^{\circ} 31' : 70^{\circ} 30'$ ) and Osham hill ( $21^{\circ} 38' : 70^{\circ} 19'$ ) in Kathiawar.

(c) Pavagad ( $22^{\circ} 28' 30'' : 73^{\circ} 32'$ ), Panch Mahal district, Bombay Presidency.

(b) *Tuff and ash beds*—Brief details regarding the occurrence of volcanic tuffs and ash are arranged State-wise—

*Bihar: Singhbhum district*—

(i) A zone of tuffs occurs between the Lava and the banded-haematite-quartzite of Noamundi east ridge.

(ii) Similar tuffs are well-developed around Gua and in the bank of the Karo river.

(iii) About  $\frac{1}{2}$  mile west of Jamda station and in the stream to the south-west outcrops of tuffs are found.

(iv) Occurrences of tuffs within the area roughly defined by the villages of Somera ( $22^{\circ} 35' : 85^{\circ} 28'$ ), Lotapahar ( $22^{\circ} 37' : 85^{\circ} 34'$ ), Ututua ( $22^{\circ} 35' : 85^{\circ} 86'$ ) and Kaira ( $22^{\circ} 32' : 85^{\circ} 31'$ ).

(v) West of Porahat some excellent coarse tuffs are associated with phyllites.

(vi) North of Sirijang ( $22^{\circ} 32' : 85^{\circ} 12'$ ) tuffs occur with epidorites (Tuffs contain abundant ejected fragments).

(vii) Occurrences of tuffs at Pahardia ( $22^{\circ} 30' : 85^{\circ} 11'$ ).

(viii) Exceptionally good examples of tuffs are found about 1 mile north of Nawatoli ( $22^{\circ} 34' : 85^{\circ} 11'$ ), and S.E. of Jantai ( $22^{\circ} 44' : 85^{\circ} 16'$ ).

(ix) Metamorphosed tuff occurs north-west of Kotia ( $22^{\circ} 43' : 85^{\circ} 16'$ ) and also at Losodtole ( $22^{\circ} 40' : 85^{\circ} 09'$ ).

(x) Near Chaibasa there are some occurrences of volcanic tuffs, e.g.,

(1) South of the village Katiguta ( $22^{\circ} 33' 50'' : 85^{\circ} 50' 26''$ ).

(2) N.W. of the village Dooborasai ( $22^{\circ} 33' 6'' : 85^{\circ} 50' 3''$ ).

(3) West of the mile-stone No. 2 on the Chaibasa—Saraikela Road.

*Bombay-Baroda*—

The deposit of clay reported from near Kelkach about 3 miles east of Uni Railway Station. This appears to consist of fine sandy material, and may possibly be a volcanic tuff.

*Orissa-Athmallik State*—

A peculiar occurrence of white clay is reported from the bank of the Mahanadi near Khumbi ( $20^{\circ} 53' : 84^{\circ} 18'$ ). The material is extremely light and consists of small flakes and particles of glassy silica.

## II. SHALES

Shales occur widely in the Vindhyan, Kurnools, Gondwanas, Jurassic of Cutch and also in the Tertiary formations of Assam.

Some of the localities where Vindhyan shale occurs are—

- (i) Newar .. .. . (24° 35' : 82° 5')
- (ii) Patandh .. .. . (24° 33' : 83° 05')
- (iii) Markundi area (24° 36' : 86° 06') and west of Agori (24° 33' : 83° 00').

Good exposures of shales also occur in the Son Valley at the following localities—

- (i) Brechi .. .. . (24° 32' : 82° 47')
- (ii) Banjoro .. .. . (24° 41' : 84° 00')
- (iii) Bijaegart .. .. . (24° 34' : 83° 13')

Shales belonging to the Kurnool formation are known to occur in the Kandari and Palnad tracts; good outcrops of shale are found to occur around the town of Nandyal. In the Vindhya Pradesh, Vindhyan shales occur at the following places—

- (i) near Bankola village, Maihar State.
- (ii) near Badampur village, Maihar State.

Shale belonging to the Gondwanas are found to occur widely in the coal-fields of Raniganj, Jharia, Karanpura, Ramgarh, Rajmahal, Palamau, Talchir, Tatapani, Jhilmili, Korba, Mohpani, Kanhan-valley, PENCH valley, and Godavari valley coal-fields.

## III. MISCELLANEOUS FORMATIONS

(a) *Fuller's Earth*—

*Rajasthan*—The deposits of fuller's earth are found, overlying the Barmer sandstone which is assigned to Cretaceous, at the following localities—

- (i) Kapurdi (25° 54' : 71° 21')
- (ii) Rohli (25° 58' : 71° 23')
- (iii) Joranada (26° 11' : 71° 15')
- (iv) Dip-ki-Dhani.

*M.P.*—It is found in the Lower Vindhyan rocks of Katni, Jubbulpore District.

*Kashmir*—A seven-foot bed of fuller's earth occurs in the Salkhala series of Budil, Rajaori District (Jammu Province).



(b) *Diatomaceous Earth*—

The following are the known localities of diatomaceous earth occurrences found in India—

- (i) Andaman and Nicobar Islands— (Ritchies Archipelago).
- (ii) Aleppy coast (dried mud), Travancore State.
- (iii) Silicified earth from Santhal Parganas and Birbhum district.
- (iv) Guntur District, Madras—Small deposits near village Timmapalam of Vinkunda Taluq, Guntur District.
- (v) Substitute for tripoli, found near Narainpur—Tatawara Railway Station on BB&CI Rly. and Silica sand capping Tirohan hornstone breccia.

## APPENDIX III

### 2. CYANIDE SLUDGE AS A POZZOLAN:

K. Narasimulu,  
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#### SYNOPSIS

Cyanide sludge is an industrial by-product at the Hyderabad Gold Mines. Several hundred tons of this material, which exists in the form of a very fine powder, is being deposited every day. At the suggestion of Dr. K. L. Rao a preliminary examination of this material has been carried out to see whether the same could be utilised as a pozzolanic admixture. It has been observed that this material could be advantageously utilised as a pozzolanic admixture after a preliminary heat treatment.

2.1. *Introduction*—Search for indigenous pozzolanic materials is being made in order to meet the heavy demand of construction materials with a view to combating the shortages in the supply of cement and also to effect economy in the cost of construction. In the previous reports of these laboratories, the usefulness of coal ash as a pozzolanic admixture has been pointed out. Another indigenous material of this nature which forms the basis of the present study is a bye-product from the Hyderabad Gold Mines. About three hundred tons of this earthy material, that has been crushed to a very fine powder during the process of extraction of gold, is deposited as a bye-product every day. The availability of this material in the form of such fine powder could be advantageously made use of if the same could be utilised as a pozzolanic admixture. As such a few preliminary investigations have been carried out to know the nature of this material and to see if it exhibits any pozzolanic properties.

2. 2. *Properties of cyanide sludge*—

2. 2-1. *Physical Properties*—By appearance cyanide sludge is a greyish earthy material. About 95 per cent of this material passes through 100 mesh and about 70 per cent passes through 200 mesh. The material has a specific gravity of 2.7 and a fineness of 3,000 sq. cm/gm.

2.2-2. *Chemical Properties*—An idea of the chemical composition of the material can be had from a knowledge of the origin of the same. The material under study is a bye-product from an industry for the extraction of gold from underground ores by the cyanide extraction process. Gold occurs in quantities large enough to pay for extraction in many quartz veins or lodes in rock formation. The gold disseminated in quartz is also accompanied by brown oxides of iron in the upper portion of the deposits and by sulphides of iron in the deep-seated portions. The origin therefore suggests that this material is mainly rocky or earthy matter and it is accompanied by some compounds of iron. The chemical composition of this material (Table 2.1) shows that the predominant constituent of this material is silica which accounts for about 57

per cent of the material. Besides, this, the other significant constituents are alumina, iron oxide and calcium oxide. During the process of extraction of gold the material becomes associated with alkali owing to the addition of alkali cyanides. These latter salts are thoroughly recovered from the sludge before it is thrown out. Ultimately the quantity of this constituent in the by-product is negligible as is indicated by the water soluble salt content of the sludge which is only .28 per cent. Thus the percentage of constituents of the material under study is similar to some of the natural soils or clays used for surkhi manufacture. Therefore, it was thought that the same could be utilised advantageously after a proper heat treatment of the same.

2.3. *Heat treatment of the cyanide sludge*—Heat treatment of natural pozzolans is an important aspect for the development of reactivity. While in the case of some pozzolans such as volcanic ash and coal ash etc., the process of heat treatment has taken place due to geologic changes and due to burning of coal respectively and these materials are available in a state ready for use as pozzolanic additives, heating is an essential pre-treatment necessary for developing reactivity in the case of other natural pozzolans such as clays, shales, etc. As is apparent, from its origin, cyanide sludge comes under the latter category of natural pozzolans and hence, heat treatment is essential for developing pozzolanic activity of the same. It is also evidenced by the low values of compressive strength obtained by using the raw material as an admixture that it has no pozzolanic characteristics. Hence it was decided to test the material for pozzolanic activity after heat treatment.

It has been observed that each of the natural pozzolans requires heat treatment over a critical range of temperature for obtaining optimum reactivity. Heating at lower temperature than this critical range is not likely to stimulate completely this reactivity while heating at a higher temperature than this is likely to destroy the activity. Thus for fixing up a range of temperature of heat treatment for optimum activity, the material was burnt at 600°C., 900°C. and 1,000°C. and its pozzolanic activity estimated at each of these stages by the lime reactivity test.

2.4. *Test for pozzolanic activity*—Pozzolanic reactivity of cyanide sludge was evaluated according to the lime reactivity test, the procedure adopted being similar to the one developed by U.S. Bureau of Reclamation. Pure calcium hydroxide, cyanide sludge and Indian standard sand were mixed in proportions of 1 : 2 : 9. The water content was adjusted to give a flow of 10° to 115 per cent. This mortar was cast into 1½" × 3" cylinders. These cylinders were cured in humid chamber for 24 hours. Later these cylinders were sealed in the moulds and cured at a temperature of 135°F. — 2 to 7 days. After this period, the cylinders were sealed to room temperature and tested for compressive strength. These values are given in Table 2.2.

2.5. *Conclusions*—From the above tests it is observed that :

1. The chemical composition of cyanide sludge is within limits of a pozzolan.
2. Cyanide sludge requires pre-heat treatment before it can be used as a pozzolanic additive.
3. After a proper heat treatment cyanide sludge can be used as pozzolan with advantages over other pozzolans such as 'surkhi' etc.

Further experiments to study the effects of the addition of cyanide sludge as a pozzolanic additive to cement mortars and concretes are in progress.

TABLE 2·1

*Chemical composition of cyanide sludge*

Sl. No.	Constituents	Percentage.
1	Loss of ignition .. .. .	7·36
2	Insoluble residue .. .. .	1·48
3	Silica .. .. .	56·69
4	Aluminium Oxide .. .. .	16·80
5	Iron Oxide .. .. .	10·91
6	Calcium Oxide .. .. .	8·87
7	Magnesium Oxide .. .. .	0·53
8	Total water solubles .. .. .	0·28
9	Soluble silica .. .. .	0·59

TABLE 2·2

*Physical characteristics of cyanide sludge and its pozzolanic activity*

Sl. No.	Temperature of calcination.	Sp. gravity.	Sp. surface* sq.cm/gm.	Compressive strength† psi.
1.	Raw sample .. .. .	2·70	3,000	30·6
2.	600°C. .. .. .	2·62	2,544	110·5
3.	900°C. .. .. .	2·59	2,319	268·6
4.	1,000°C. .. .. .	2·56	2,505	544·0

\*Specific surface estimated according to Blane's method.

†Values of compressive strength of lime reactivity test of specimens cured at elevated temperature for 7 days.

## APPENDIX IV

### DRAFT INDIAN STANDARD SPECIFICATION FOR PORTLAND-POZZOLANA CEMENT (TENTATIVE)

#### 1. *Scope*—

1.1. This specification covers the manufacture and physical and chemical requirements of a type of blended hydraulic cement in which a part of the portland cement is substituted by a pozzolanic material. It is intended for general use wherever ordinary portland cement is used, as also for use in mass concrete in place of low heat portland cement.

#### 2. *Definition*—

2.1. *Portland-Pozzolana Cement*—Portland-Pozzolana cement shall be an intimately interground mixture of portland cement clinker and pozzolana, or an intimate and uniform blend of portland cement and fine pozzolana. The pozzolanic constituent shall not exceed 25 per cent by weight of the portland-pozzolana cement and shall conform to the pozzolanic activity test prescribed in Appendix 'C' of this Specification.

2.2. *Portland Cement Clinker*—The material obtained by intimately mixing together calcareous and argillaceous with or without silica, alumina or other iron oxide bearing materials and burning them at a clinkering temperature.

2.3. *Pozzolana*—Pozzolana shall be a silicious or silicious and aluminous material which in itself possesses little or no cementitious value but will in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds with cementitious properties.

Pozzolana that is to be blended with finished portland cement to produce portland-pozzolana cement shall conform to the physical requirements prescribed in table below:—

*Physical Requirements of Pozzolana*—Specific surface (sq. cm. per g as determined according to Appendix B of I.S. 455-1953) should not be less than 3,200.

Pozzolanic activity test, vide Appendix C.

Pozzolanic strength—min. psi 600.

Pozzolanas that may be employed in the manufacture of portland-pozzolana cement include such natural materials as some of the diatomaceous earths, opaline cherts and shales, tuffs, and volcanic ashes or pumicites; various materials processed by calcination such as those just named and some of the more common clays and shales of the kaolinite and montmorillonite types, and such artificial materials as precipitated silica and some of the fly ashes.

No material other than gypsum or water or both are added and not more than one per cent of such proprietary air-entraining reagents as Vinsol Resin, Darex, etc. which have proved not to be harmful.

### 3. Tests—

3.1. The sample or samples of cement taken as described in clause 7 shall be tested in the manner described in the relevant appendices for the following characteristics:—

- (a) Chemical Composition (Appendix A)
- (b) Fineness
- (c) Soundness
- (d) Setting time
- (e) Pozzolanic activity test for pozzolana only (Appendix C)
- (f) Compressive strength (Appendix B).

### 4. Chemical Requirements—

4.1. Portland cement clinker used in the manufacture of portland-pozzolana cement shall comply in all respects with the chemical requirements specified for the ordinary portland cement in I.S. 269-1951 and the purchaser shall have the right, if he so desires, to take the samples of the clinker used in the manufacture of cement.

4.2. Portland-Pozzolana cement shall comply with the following chemical requirements:—

Magnesia (Mgo) Max. per cent	..	5.0
Sulphuric anhydride Max. per cent	..	2.75
Loss on ignition Max. per cent	..	4.0

### 5. Physical Requirements—

5.1. The temperature range within which physical tests may be carried out should, as far as possible, be between 27.5°C and 32.5°C.

5.2-1. *Consistency of Standard Cement Paste*—The quantity of water required to produce a paste of standard consistency, to be used for the determination of soundness and setting time, shall be obtained by the method described in Appendix B of I.S. 269-1951.

5.2. *Consistency of Standard Plastic Mortar*—The quantity of water required to produce a mortar (of 1 cement : 3 Standard sand) of standard plastic consistency, to be used for determination of compressive strength, shall be obtained by the method described in Appendix B.

5.3. *Fineness*—When tested by any one of the first two methods described in Appendix B of Indian Standard Specification of Portland-Blast Furnace Slag Cement (Tentative) I.S. 455-1953, the Portland-Pozzolana cement shall comply with the following requirements—

*Method I*—After sieving, the residue by weight on I.S. Sieve 9 shall not exceed 10 per cent.

*Method II*—Specific surface (sq. cm. per g) by Air Permeability Method shall not be less than 3,000.

#### 5.4. Soundness—

5.4-1. When tested by the method described in Appendix D of I.S. 269-1951, un aerated portland-pozzolana cement shall not have an expansion of more than 10 mm.

5.4-2. In the event of the cement failing to comply with the above requirements, a further test shall be made in the manner described in Appendix B of I.S. 269-1951 from another portion of the same sample, after aeration, by being spread out to a depth of 3 in. (or 76 mm.) at a relative humidity 50 to 80 per cent. for a total period of 7 days when the expansion shall not be more than 5 mm.

5.5. *Setting time*—The setting time of the Portland-Pozzolana cement when tested by the method described in Appendix E of I.S. 269-1951 shall be as follows—

<i>Initial setting time</i>	..	..	Not less than 1/2 hr.
<i>Final setting time</i>	..	..	Not more than 10 hrs.

#### 5.6. Pozzolanic Activity Test—

5.6-1. The pozzolana that is to be blended with finished portland cement shall have a specific surface (sq. cm. per g. as determined by Appendix B of I.S. 455-1953) not less than 3,200, and when tested for pozzolanic activity in the manner described in Appendix C, shall give a compressive strength of not less than 600 lbs./sq. inch. Pozzolana intended for use in the pozzolanic activity test shall also conform to the above fineness test.

The fineness requirement does not apply to the pozzolanic material that is or will be interground with portland cement clinker in the production of pozzolanic cement, but pozzolanic activity test shall apply.

5.7-1. The average compressive strength of not less than three mortar cubes of standard plastic consistency as determined according to Appendix B and prepared in the manner described in Appendix G of I.S. 269 and stored and tested in the manner described in Appendix G of I.S. 269-1951 shall be as follows—

7 days	..	..	..	..	2,000 lbs./sq. inch.
14 days	..	..	..	..	3,000 lbs./sq. inch.

#### 6. Storage—

6.1. The cement shall be stored in such a manner as to permit of easy access for proper inspection and in a suitable weather-tight building to protect the cement from dampness and to minimise warehouse deterioration.

#### 7. Sampling—

7.1. *Samples for Testing and by Whom to be Taken*—A sample or samples for testing may be taken by the purchaser or his representative, or by any person appointed to superintend the Works for the purpose of which the cement is required, or by the latter's representative.

#### 7.2. Procedure for sampling—

7.2-1. *Sampling Small Quantities*—Each sample for testing shall consist of a mixture of approximately equal portions selected from at least 12 different positions in the heap or heaps when the cement is loose, or from not less than 12

different bags, or other packages, when the cement is not loose; or where there is a lesser number than 12 different bags or other packages, then from each bag, or package. Every care shall be taken in the selection to obtain a fair average sample. The final sample shall weigh at least 10 lb. (or 4.54 kg). The sample thus collected should be stored in an air-tight container for being forwarded to an approved laboratory.

7.2-2. *Sampling Large Quantities*—From large quantities sampling may be done by any of the methods described in 7.2-2-1 and 7.2-2-2. In each case, the samples collected by small increments shall be rapidly mixed in a place free from draught, and thereafter stored in air-tight containers of 15 lb. capacity. In case of dispute, at least two such containers shall be filled, one sent to an approved laboratory and the other kept as a reference sample by the vendor.

7.2-2-1. *From Conveyor Delivering to Bulk Storage or Discharge from Bulk Storage*—One sample of not less than 5 lb. shall be taken from each 1,000 bags or 50 tons, or parts thereof, passing over the conveyor, or from discharge openings of bulk storage, by taking small samples at regular intervals, either by scoops or automatic samplers.

7.2-2-2. *From Bulk Storage by Means of Proper Sampling Tubes*—When the method described in 7.2-2-1 cannot be applied, and when the depth of cement to be sampled does not exceed 10 ft. samples may be obtained by proper tubes inserted vertically to the full depth of the cement. Samples so taken shall be obtained from points well distributed over the area of storage.

7.2-2-3. In all other cases, samples shall be taken from each 50 bags or portion thereof in the lot, and combined to form test samples. In the case of samples from trucks where the cement is being trucked from one mill, it is permissible to combine the samples from several trucks to form a test sample representing not more than 1,000 bags. When bulk shipments are samples, representative samples shall be taken from well-distributed points.

7.3. *Facilities for Sampling and Identifying*—The manufacturer or supplier shall afford every facility, and provide all labour and materials, for taking and packing the samples for testing the cement and for subsequently identifying the cement sampled.

#### 8. *Manufacturer's Certificate*—

8.1. The manufacturer shall satisfy himself that the cement conforms to the requirements of this Indian Standard, and, if required, shall furnish a certificate to this effect to the purchaser or his representative.

#### 9. *Non-compliance with Tests*—

9.1. Any cement which does not comply with any of the tests and analyses specified above, or which has not been stored in the manner provided in 6, may be rejected as not complying with this standard.

#### 10. *Independent testing*—

10.1. If the purchaser or his representative requires independent tests, the samples shall be taken before or immediately after delivery at the option of the purchaser or his representative, and the tests shall be carried out in accordance with this standard on the written instructions of the purchaser or his representative.



10.2. *Cost of Testing*—The manufacturer shall supply, free of charge, the cement required for testing. Unless otherwise specified in the enquiry and order, the cost of the tests shall be borne as follows—

- (a) by the manufacturer in the event of the results showing that the cement does not comply with this Indian Standard, and
- (b) by the purchaser in the event of the results showing that the cement complies with this Indian Standard.

10.3. After a representative sample is drawn, tests on the sample should be carried out as expeditiously as possible.

#### 11. *Delivery*—

11.1. The cement shall be packed in bags\* (gunny, multiply paper or cloth) bearing the manufacturer's name or registered mark and the gross weight of each bag shall be 1/20th of a ton (or 112 lb.) or 1/24th of a ton (or 93·1/3 lb.), depending on the size of the bag used.

11.2. Supplies of cement in bulk may be made by arrangement between the purchaser and the supplier (manufacturer or stockist).

### APPENDIX A

(Clause 4·1)

#### METHODS OF CHEMICAL ANALYSIS OF POZZOLANA-PORTLAND CEMENT

Method of Analysis is the same as given in the Methods of Analysis of Portland Cement, Indian Standard Specification for Ordinary, Rapid Hardening and Low Heat Portland Cement (Tentative) I.S. 269-1951, Appendix A (Clause 4) except as follows—

(1) *Magnesium Oxide*—Weigh out a quantity of the ignited sample equivalent to 0·5 g of the moisture-free sample, calculated as follows—

$$0·5 (100·00 - \text{Percentage loss on ignition})$$

$$\text{Weight of ignited sample, g} = \frac{\quad}{100}$$

The ignited material from the loss on ignition determination may be used for the sample.

Thoroughly mix the sample with 4 to 6 g of  $\text{Na}_2\text{CO}_3$  by grinding in an agate mortar. Place a thin layer of  $\text{Na}_2\text{CO}_3$  on the bottom of a platinum crucible of 20— to 30— ml capacity, add the cement— $\text{Na}_2\text{CO}_3$  mixture and cover the mixture with a thin layer of  $\text{Na}_2\text{CO}_3$ . Place the covered crucible over a moderately low flame and increase the flame gradually to a maximum (approximately 1,100 C) and maintain this temperature until the mass is quiescent (about 45

\*The weight of a gunny bag to hold 1/20th of a ton is about 18 to 20 oz and the weight of a 6-ply paper bag to hold 1/20th of a ton is approximately 14 oz. To hold 1/24th of a ton, the weight of bag is usually about 15 to 17 oz. in the case of gunnies and about 11 to 12 oz. for 6-ply paper bags.

min). Remove the burner, lay aside the cover of the crucible, grasp the crucible with the tongs, and slowly rotate the crucible so that the molten contents spread over the sides and solidify as a thin shell on the interior. Set the crucible and cover aside to cool.

Rinse off the outside of the crucible and place the crucible on its side in a 300-ml casserole about one-third full of water. Warm the casserole and stir until the cake in the crucible disintegrates and can be removed easily. By means of a glass rod, lift the crucible out of the liquid, rinsing it thoroughly with water. Rinse the cover and crucible with HCL (1:3); then add the rinse to the casserole. Very slowly and cautiously add 20 ml of HCl (sp gr 1.19) to the covered casserole. Remove the cover and rinse. If any gritty particles are present, the fusion is incomplete and the test must be repeated, using a new sample.

Beginning with the instructions in section 4.1—

“Evaporate the solution to dryness on a steam bath”, remove silica, the ammonium hydroxide group and calcium in accordance with sections 4.1, 4.2, 4.4, 4.5, 5.1 and 8.1 respectively.

Determine MgO in accordance with either section 9.1 or 9.2.

(2) Sulphur Trioxide—Section 10 except that the shell be moisture-free and need not be completely decomposed.

(3) Loss on Ignition—Section 3.

## APPENDIX B

(Clause 5.2-2)

Determination of consistency of standard plastic mortar.

### 1. Scope—

1.1. This method of test covers the procedure for determining the quantity of water required to produce a plastic mortar of standard consistency. The quantity thus determined is to be used for preparing specimens for compressive strength test by vibration.

### 2. Apparatus—

2.1. The Vicat Apparatus, described in Appendix B, Clause 2.1 of I.S. 269-1951, shall be used, the plunger G, 10mm, in diameter, being substituted for the needle shown in position, and loaded with an additional load of 2 Kg, making with the plunger weighing 300 gm., a total load of 2,300 gm.

### 3. Procedure—

3.1. The standard consistency of plastic mortar is defined as that consistency which will permit the loaded Vicat plunger as described above to penetrate to a point  $30 \pm 1$  mm. into the 40 mm. deep Vicat mould, when the cement-mortar is tested as described below.

3.2. Prepare a mortar with 1 part Pozzolana cement, 3 parts standard sand, both by weight, mix dry with a trowel for one minute, and then add a weighed quantity of water, taking care that the time of gauging is not less

than 3 minutes nor more than 5 minutes. Fill the Vicat mould with the mortar, the mould resting on a non-porous plate. After completing filling the mould smooth off the surface of the mortar, making it level with the top of the mould. The mould may be slightly shaken to expel the air.

3.2-1. Clean appliances shall be used for gauging, and the temperature of cement and water and that of the test room, at the time when the above operations are being performed, shall be from  $30^{\circ}\text{W} \pm 2.5^{\circ}\text{W}$ .

3.2-2. In filling the mould, the operator's hands and the blade of the gauging trowel shall alone be used. The trowel shall weigh about  $7\frac{1}{2}$  oz. (or 213 g. approx.).

3.3. Place the test block in the mould, together with the non-porous resting plate, under the rod bearing the plunger; lower the loaded plunger gently to touch the surface of the test block, and quickly release, allowing it to sink into the mortar.

3.4. Prepare trial mortars with varying percentages of water and test as described above until the amount of water necessary for making up the standard consistency as defined in 3.1 is found. Express the amount of water as a percentage by weight of the dry cement.

## APPENDIX C

(Clause 2.3)

### 1. Scope—

1.1. This method of test covers the procedure for determining the activity of the pozzolanic constituent with Hydrated lime.

### 1.2. Standard Materials—

1.2-1. *Hydrated lime*—The hydrated lime shall conform to the requirements for normal finishing Hydrated lime and in addition conform to the following additional requirements—

- (a) The calcium compounds present in the lime, and calculated as CaO shall not be less than 93 per cent by weight of the ignited sample.
- (b) The loss on ignition, after correction of  $\text{CO}_2$ , shall be between 21 and 25 per cent by weight.
- (c) The expansion in the Le Chatelier soundness test shall not exceed 2 mm.
- (d) The residue on I.S. Sieve 9 (89 Micron) shall not exceed 2 per cent.

1.2-2. *Standard sand*—This shall be standard Ennore Sand.

### 2. Preparation of Test specimens—

2.1. *Proportioning and mixing*—The mortar shall contain one part hydrated lime, two parts oven-dry pozzolanic material, and nine parts of standard sand by weight. The amount of water for preparing a mortar of standard plastic consistence shall be determined in accordance with Appendix B.

2.1-1. Clean appliances shall be used for mixing and the temperature of the water and that of the test room at the time when the above operations are being performed shall be from  $30.0 \pm 2.5^{\circ}\text{C}$ .

2.1-2. Place on a non-porous plate a mixture of hydrated lime, pozzolana and standard sand in the proportion of 1 : 2 : 9 by weight. Mix it dry with a trowel for one minute and then with water until the mixture is of uniform colour. The quantity of water to be used shall be as determined in accordance with Appendix B. The time of mixture shall in any event be not less than 3 minutes and should the time taken to obtain a uniform colour exceed 4 minutes, the mixture shall be rejected and the operation repeated with a fresh quantity of cement, sand and water.

2.1-3. The material for each cube shall be mixed separately and the quantities shall be as follows—

Hydrated lime	..	..	..	90 g
Pozzolana	..	..	..	180 g
Standard Sand	..	..	..	810 g
Water	..	as required by method in Appendix B.		

## 2.2. Moulding Specimens—

2.2-1. In assembling the moulds ready for use, cover the joints between the halves of the mould with a thin film of petroleum jelly and apply a similar coating of petroleum jelly between the contact surfaces of the bottom of the mould and its base plate in order to ensure that no water escapes during vibration. Treat the interior faces of the mould with a thin coating of mould oil.

2.2-2. Place the assembled mould on the table of the vibration machine and firmly hold in position by means of a suitable clamp. Securely attach a hopper of suitable size and shape at the top of the mould to facilitate filling and this hopper shall not be removed until completion of the vibration period.

2.2-3. Immediately after mixing the mortar in accordance with 2.1 above, place the entire quantity of the mortar in the hopper of the cube mould and compact by vibration.

2.2-4. The period of vibration shall be 2 minutes at the specified speed of  $12,000 \pm 400$  vibrations per minute.

2.3. *Curing specimens*—Keep the specimen cubes, in the moulds, first at  $30.0 \pm 2.5^\circ\text{C}$  for 24 hours, and then at  $55^\circ \pm 2.5^\circ\text{C}$  for six days until 4 hours before the time of testing, then cool the specimens to  $30.0 \pm 2.5^\circ\text{C}$ .

## 3. Testing—

3.1. At the age of 7 days the cubes shall be tested on their sides without any packing between the cube and the steel plattens on the testing machine. One of the plattens shall be carried on a ball and shall be self-adjusting, and the load shall be steadily and uniformly applied, starting from zero at a rate of 100 to 500 lb./sq. inch per minute.

## 4. Calculations—

4.1. Calculate the compressive strength from the crushing load and the average area over which the load is applied. Express the result in lb./sq. inch to the nearest 10.

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