REVIEW OF ESTIMATES OF PREDICTIONS OF ATMOSPHERIC ENVIRONMENTAL QUALITY AT TAJ MAHAL AND AGRA MONUMENTS

Contributions from Different Sources in Summer and Winter

Expert Committee on Atmospheric Environmental Quality

and Preservation of Taj Mahal and Agra Monuments

The Committee has reviewed the observations and assessments on estimated predictions contained in Reports and Statements of NEERI with regard to Mathura Refinery, the Industries at Agra and Ferozabad on the Atmospheric Environmental Quality at Taj Mahal and is attaching herewith its appreciation of the NEERI estimates. These have not been included in its Report on the above subject completed on 30 April 1995.

(B.B.Sundaresan)	(S.C.Sharma)
(Jagat Pati Joshi)	(K.K.Baksi)
(R.Anandakumar)	(S.Varadarajan)

New Delhi

30 April 1995

Review of observations and estimated predictions contained in Reports and Statements of NEERI with regard to Mathura Refinery, the Industries at Agra or Ferozabad on the atmospheric environmental quality at Taj Mahal.

General

The Committee had decided to gather information from a variety of sources on

State of Monuments and changes in them during the last 50 years.

Ambient air quality at the Taj Trapezium Zone and especially in the vicinity of monuments in different seasons over the past 10 to 15 years including long term average as well as short term variations.

Quantitative estimates of all forms of energy available and utilised by different consumers such as households, commercial establishments, transport, hospitals, offices, hotels, restaurants, shops, small, medium and large industries and infrastructure.

Technologies adopted or available in many countries to ensure safe and clean operations while meeting social, industrial and commercial needs in a competitive economic system.

Plans of major consumers and producers of energy in the short term of 18 months and medium-term of five years to contribute to requirements of rapidly attaining and maintaining high ambient air quality on the short term and effect further improvements.

The Committee had studied carefully the Report of NEERI on "Air Pollution Studies to Redefine Taj Trapezium Co-ordinates" submitted to Ministry of Environment and Forests. The Committee has also collected information from a number of sources. Information has been obtained on coke/coal supplies from Ministry of Coal and on Petroleum products from Ministry of Petroleum and Natural Gas. A Report entitled "Air Pollution by Industries in Taj Trapezium Zone (TTZ): status-problems-solutions" prepared by a Committee formed by UP Government under the Chairmanship of the Commissioner of Agra was received from the Chief Secretary of UP State Government.

The Committee requested NEERI on 15 March 1995 to provide any information available on state of Monuments and Marble in Trapezium and on similar monuments in India and abroad on deterioration and discolouration attributable to pollution and information collected by NEERI on various energy materials usage over a period in TTZ as well as on the air quality indicators in major cities, heritage locations in the world. A copy of the fax sent to NEERI is enclosed as Annexure I. Dr.A.L.Aggarwal, Dr.Mrs.R.Thakre and Shri S.M.Tahmne met the Committee at Delhi on 19 March 1995 and were kind enough to loan a copy of a Report on air quality in 20 megacities. A copy of a Technical Note Summary (Annexure II) was also provided to the Committee by NEERI Scientists. They agreed to send further information requested on 15 March 1995. Professor P.Khanna could not be present at the meeting on 19 March 1995.

The Committee has an opportunity to study a Report submitted by NEERI to Indian Oil Corporation Ltd. (IOCL) on April 1994 on "Rapid Environmental Impact Assessment for Proposed Matching Secondary Processing Factories of Mathura Refinery - Uttar Pradesh:" The Committee has also studied the following Reports submitted by NEERI to the Hon'ble Supreme Court.

Summary Inspection Report dated October 16-18, 1993

Sulphur Dioxide Emission Control Measures at Mathura Refinery

Technical Report dated March 7, 1994

Issues Associated with Fuel Suppy Alternatives for Industries in Agra-Mathura Region

Inspection Report dated April 5, 1994

Inspection of Air Pollution Control Device in Taj Trapezium.

On the information sought by the Committee from NEERI on 15 March 1995 (Annexure I); Professor P.Khanna and

Dr.A.L.Aggarwal met the Committee at Delhi on 24 April 1995 and handed over a document (Annexure III). The main statement is in 5 pages of text and eight figures. The Committee could not have any further opportunities to meet Professor P.Khanna or Dr.A.L.Aggarwal. In response to request for clarifications sent to NEERI during 26 to 27 April 1995, in the absence of Professor P.Khanna at Nagpur, Dr.A.L.Aggarwal had sent faxes. The faxes exchanged are placed in Annexure IV.

The Committee records below its appreciation of the estimates of prediction of atmospheric air quality at Taj Mahal in different Reports of NEERI from estimates of emissions from Mathura Refinery, Ferozabad Industries and Agra Industries.

IMPACT-OF-EMISSIONS-FROM-MATHURA-REFINERY-(MR)-ON-AIR-QUALITY AT-TAJ-MAHAL.

The following is quoted from NEERI's report (July 1993) recorded at page V-82 of the said report:

"The impact distances from MR are calculated separately as this is the single largest industry outside the Mathura Growth Centre. The impact distances for critical winter season at 10 microgram/m^3 level are only upto 13 km from MR because of higher stack heights of MR units. The maximum distance for 5 microgram/m^3

is about 34 km but still it does not penetrate the boundaries of Agra city as the distance between MR and Agra is 40 km........."

On page 2 of the Technical Note Summary provided by NEERI to the Committee (Annexure II) on 19.3.1995, it is stated,

"Predicted GLCs (24 hr.avg.) under impact of MR point source for winter as well as summer reflect that the impact zone of 10 microgram/m^3 rise in background extends upto the distance of 13 kms. Another range of maximum impact zone for 5 microgram/m^3 over the background ambient air level have been extrapolated in this study. The impact zone of 5 microgram/m^3 extends even upto 34 kms. These predictions being most conservative the actual concentrations are not expected to exceed 5 microgram/m^3 value. Hence, MR may occassionally cause maximum rise of 5 microgram/m^3 at Bharatpur. Exposure of Agra monuments will be still lower than 5 microgram/m^3 under the scenario of normal MR emissions because MR is at 40 kms from Agra city. However, any abnormal MR operating conditions demands immediate shut down of the refining process."

However, it is seen from Table 3 at page 17 of "Summary Inspection Report (Oct. 16-18, 1993) on Sulphur dioxide (SO_2) emission control measures at Mathura Refinery" submitted to the Hon'ble Supreme Court that the contribution of SO_2 emissions from Mathura Refinery at Taj Mahal is 30 percent (5.9 microgram/m^3) during winter season under normal condition.

The statements made in NEERI report (July 1993) and in their Technical Note Summary (Annexure II) are inconsistent with what has been indicated in Table 13 of "Summary Inspection Report (Oct. 16-18, 1993) on SO_2 emission control measures at Mathura Refinery" submitted to the Hon'ble Supreme Court.

It is seen from the Report of the Expert Committee on environmental impact of Mathura Refinery of 1977 that the contribution from the refinery to the long-term concentration of SO_2 at Agra would be of the order of one to two microgram per m^3 at Taj Mahal, Agra (page 25 of the report). NEERI Nagpur have prepared Rapid Environmental Impact Assessment (EIA) for proposed Matching Secondary Processing Facilities at Mathura Refinery (April 1994) and have indicated in Table 3.1.7 at page 261 of the report that the predicted seasonal long-term concentration of SO_2 due to Mathura Refinery during critical winter season is 1.5 microgram/m^3. The air diffusion models used in 1977 and 1994 are not the same but the predicted long-term concentration tally in their order of magnitude.

It may be noted that the above predicted SO_2 concentration values are in no way near to the values indicated either in Table 3 at page 17 of "Summary Inspection Report (October 16-18, 1993)" submitted to the Hon'ble Supreme Court or in Table-2 of NEERI reply of 24 April 1995 (Annexure III).

SHORT-TERM (24-Hr) SO_2 CONCENTRATIONS AT TAJ MAHAL

Table-2 of NEERI's reply circulated in the meeting of the Expert Committee on 24 April 1995 gives the maximum short-term (24 hr.) predicted GLC of SO_2 at Taj Mahal (as the concentration predictions have been made under worst meteorological conditions and highest observed peak emissions). These should tally with short-term

(24 hr.) SO_2 peak concentrations recorded as Taj Mahal which are much higher than predicted 18.9 microgram/m^3 during winter season and 26.4 microgram/m^3 during summer. Hence the predictions made by NEERI are difficult to comprehend.

<u>IMPACT OF SO_2 EMISSIONS FROM FEROZABAD ON AIR QUALITY AT TAJ MAHAL</u>

1. It is seen from Table-2 of NEERI's reply circulated in the meeting of Expert Committee held on 24 April 1995 that the contribution of SO_2 (predicted concentrations) at Taj Mahal from Ferozabad industries is 34 percent during summer season. Apparently this high percentage of SO_2 contribution from Ferozabad has resulted due to presumption of NEERI that 24 percent time winds are from Firozabad industrial area towards Agra (Taj Mahal) during summer season. It is not a correct presumption as the analysis of long-term wind data for Agra does not support such a high percentage of frequency of occurence viz. 24 percent time of easterly wind during summer season/or even 14 percent time during winter season. The Wind Rose diagram for Agra presented on pages II-4 and II-5 of NEERI report (July 1993) have percentage of wind from east to west as 5 and 6 respectively which is in agreement with the analysis of the long-term wind data.

Report (July 1993) of NEERI does not show that wind data was generated by NEERI at Ferozabad.

2. The contribution of SO_2 from Ferozabad industries at Taj Mahal during winter season has been reported as NIL, (Ref: Table 2 of the reply circulated by NEERI in the Meeting of Expert Committee on 24 April 1995) where it has been presumed by NEERI that 14 percent time winds are from Ferozabad industrial area towards Agra during winter season. NIL contribution of SO_2 from Ferozabad industrial area when winds have been presumed to blow 14 percent time from that area towards Agra appears rather inconsistent.

The clarification given by NEERI in their fax message dated 27.4.1995 received on 30.4.1995 regarding wind direction analysis for Ferozabad indicating 14% and 24% in winter and summer months instead of 5% and 6% respectively (refer pages II-4 and II-5 of NEERI report (July 1993)) is not tenable.

3. In order to check/verify the predicted concentration of pollutants due to air emissions from Ferozabad side towards Agra, a rational methodology would be to establish a network of air quality monitoring stations at relatively virgin locations between Ferozabad and Agra as has been done between Mathura Refinery (MR) and Agra.

The estimate of amounts of coal/coke usage by Ferozabad Glass and other industries is given in Table 4.6. (Page IV-20) of NEERI Report of July 1993. A copy is attached as Annexure V. The actual consumption of fuel is 743 MT per day. Assuming that all 1415 units work, instead of only 615 units, the estimate of fuel is revised to 1873 MPTD. In the NEERI Technical Report dated March 7 1994 to the Hon'ble Supreme Court in Table 3, the total coal/coke fuel is given as 1873 MPTD and no reference is made to the actual consumption of 743 MTPD. The emission values are estimated on the basis of the higher fighre of 1873 MPTD. Presumably the higher estimate was used in the Technical Report of March 7, 1994 to calculate the maximum amount of alternative fuels such as NG, LPG and propane required.

IMPACT OF AGRA INDUSTRIES

In the NEERI Report of July 1993 estimates of coke/coal usage by Agra Industries in Tables 4.3 (page IV-7) in normal operation is stated as 328 MTPD of which 26 Foundries account for 208 MTPD. In projection of usage contained in page IV-10, it is assumed that all 283 Industries Units including 131 Foundries would be working and the coal/coke consumption would be 1247 MTPD, of which 131 Foundries account for consumption of 1048 MTPD. The emissions from Agra industries are estimated on the basis of coal/coke consumption of 1247 MTPD in 1993 and 1258 MTPD in year 2001 due to small increase in Rubber Processing and Lime Processing Industries, taking total number of units to increase to 283 in year 2001 from the number of 305 in 1993 (Annexure-VI).

The DIC of Agra has reported the actual consumption of coal/coke in 1994 to be 129 MTPD, NEERI, it appears has assumed the consumption of coal/coke in each Foundry in Agra to be 8 MT per day. This assumption is not based on any survey of consumption by Units or supplies by Coal India Ltd. It has been estimated 26 Foundries working in 1993 would use 208 MTPD. If all 131 foundries are working, the total consumption would increase to 1048 MTPD. In such estimate, it is also assumed that all the 131 Foundries have the largest diameter size cupola furnaces. There are in reality, four different diameter sizes and the consumption of fuel and pig iron and production of cast steel vary accordingly.

In the NEERI Technical Report dated March 7, 1994 submitted to the Hon'ble Supreme Court (Table 3) the total coke/coal consumption by Agra Industries is estimated as 1247 MTPD, presumably to determine maximum quantities of alternative gaseous fuels that would be needed in year 2001.

The present Expert Committee of the Ministry of Environment & Forests has in its Report submitted on 30 April 1995 presented information collected from a variety of sources on coal/coke usage and supplies, including Commissioner of Agra, Coal India Ltd and Industries. Efficient design for energy conservation would lead to a coke to cast steel production of 1:6. *Liquid Petroleum Fuel* usage is reported to be 60 to 80 litres per tonne of steel produced in European Foundries.

ADDITIONAL EXPERT ADVICE

In view of the differences in the estimates of contributions of MR and Ferozabad Industries to the SO_2 concentrations at Taj Mahal in winter and summer in the different Reports of NEERI, the Expert

Committee sought expert advice from two well known Scientists, Professor B.Padmanabha Murthy of Jawaharlal Nehru University, School of Environmental Sciences and Professor P.K.Das, former Director General of IMD, Honorary Professor at IIT, Delhi and Expert Consultant of UNEP, Nairobi. Their assessments are attached as Annexures VII and VIII.

The expert advice/comments received from Prof.B.Padmanabhamurty and Prof.P.K.Das are as follows:

Table 1 & 2 results as indicated in NEERI's reply dated 24.4.1995 (Annexure III) are summarised below:

Season	Winds from Ferozabad	SO_2 Concn. at Taj	Winds from Mathura	Concn. Taj
Winter	14%	0 ug/m^3	7%	5 ug/m^3
Summer	24%	9 ug/m^3	11%	1 ug/m^3

The following comments are offered on the above Table:

The wind data showing winds from Ferozabad as 24% during summer is questionable as winds are normally from

Westerly/Northwesterly direction in Agra-Mathura-Ferozabad region most of the time during summer season and occurrence of 24 percent wind from east where Ferozabad lies is rare.

In summer, when unstable conditions prevail, most of the time, with low stacks in Ferozabad, even with easterly winds the ground level concentrations (glc) of pollutants decrease exponentially to low values beyond 5 km. Hence the concentration of 34% of glc at Agra from Ferozabad in summer is questionable.

Further the distance between Ferozabad and Agra is two-thirds the distance between Mathura and Agra. Hence during winter season if with 7% winds from Mathura the glc is 5 ug/m^3, the glc with 14% of winds and with higher emissions from Ferozabad which is at two-thirds distance cannot be zero at Taj.

Higher frequencies of winds have to yield high glc. It is noted that 14% of winds in winter from Ferozabad yield 0 ug/m^3 glc at Taj and 24% yield 9 ug/m^3 during summer at Taj. But from Mathura when 7% of winds in winter yield 5 ug/m^3, 11% in summer is only producing 1% ug/m^3 which is contrary to the former result. On this account too the data is questionable.

Table 2 of NEERI s report dated 24.4.1995 (Annexure III) gives predicted maximum glc and refers to worst meteorological conditions and highest observed stack emissions. Hence these must be peak values - 18.9 ug/m^3 in winter and 26.4 ug/m^3 in summer - which are to be compared with peak values in 1993 (Fig. 3 of NEERI's report dated 24.4.1995) i.e. greater than 100 ug/m³ (90th percentile values). As these do not tally, the predictions are unreliable.

It has been quoted by NEERI at page 2 under the Heading SOURCE SPECIFIC CONTRIBUTIONS OF SO_2 AT TAJ MAHAL" that,

"the major contributions to air pollution in Agra region is from point sources. It varies between 75 to 80 percent in summer and winter season, respectively".

The following comments have been offered on the above:-

From point sources, in summer high GlCs occur at short distances. In winter, high concentrations occur over longer distances away from stack and the cumulative effect of a number of stacks will be large. Agra being far away either from Mathura or Ferozabad, is expected to record higher Glc's during winter (particularly during nights most of the time.) Therefore, the variation of 75-80% in summer and winter seasons respectively is not a realistic one.

General Comments by Prof.B.Padmanabhamurty

TABLE 2 of NEERI's report dated 24.4.1995 shows that individual contributions from various sources is algebraically added to obtain total concentration at Taj. Predicted glc's in winter and summer in the Table are given as 18.9 and 26.4 ug/m^3 respectively.

It is noted from pages V-20 and V-30 of NEERI report (July 1993) that the cumulative impact of point, area and line sources for Agra city at the Taj Mahal is 13.9 ug/m^3 during winter season and 16.4 ug/m^3 during summer season respectively.

Either the model may be underpredicting with multiple sources or the algebraic addition of individual contributions may be improper. Model details and input data are not made available in the Report hence it is not possible to confirm either.

General Observations

Estimates of Coal/Coke Consumption by Industries in Agra

In the NEERI Report of July 1993 on Air Pollution Studies to Redefine Taj Trapezium Co-ordinates, certain assumptions on extent of coal/coke consumption by Agra Industries were made (Annexure VI). The figures were apparently based on information provided by DIC, Agra. The data from DIC were used by NEERI in their Report for all categories of industries (Ferro Alloys, Chemical, Rubber Sole, Refractory bricks, Engineering, Line processing) with the exception of Ferrous Casting (Foundries). In the case of Foundries alone (Table 4.3 in Page IV-7 of July 1993 NEERI Report) reproduced in Annexure VI, the estimate of consumption of coke/coal in normal operation of 26 units is given as 208 MTPD. The Committee notes in a letter dated 19

August 1994 from Dr.A.L.Aggarwal addressed to the Chairman of Agra Iron Foundries Association (AIFA) (Annexure IX) it appears that NEERI had arrived at the estimate of consumption of coke by a Foundry, not from the information provided by DIC, Agra but from studies carried out by NEERI in 1988-89 on cycles of cupola operation in Haryana/Punjab for evolving engineering designs of flue gas treatment of emissions. NEERI had also adopted for the July 1993 Report for TTZ, the highest of the average values of emissions of SO_2 from their studies in 1988-89. The coke consumption for each Foundry Unit was assumed to be 8 MTPD, which would allow steel production of 32 MTPD. In their Report of July 1993 on TTZ, NEERI had not included any explanation for the assumption leading to an estimate of consumption by 26 Foundries as 208 MPTD (Annexure VI). In projection of estimates of future, NEERI also assumed that all 131 Foundry Units would consume each 8 MPTA, giving a total of 1048 MTPD.

The actual consumptions by Agra Industries is given as 28,500 MTPA of hard coke (mainly by Foundries) and 21,600 MPTA of steam coal in the Report of the Commissioner of Agra, on Air Pollution by Industries in TTZ: Status-Problems-Solutions issued in August 1994. Relevant extracts of the Report are given in Annexure X. The total coke/coal per year by Industries is estimated at 50,100 Tonnes. On the basis of 360 and 250 days of working, the daily consumption would be 140 and 200 MTPD. NEERI had assumed consumption of coal/coke to be 328 MPTD in 1993 under normal operation by 120 out of 283 industries and had projected estimate of 1247 MPTD if all 283 units worked simultaneously. Emissions were estimated on the basis of 1247

MPTD consumption of coal/coke during 8 hours in a day (Annexure V). The Report of Commissioner of Agra cites a figure of 129 MTPD (Annexure X).

NEERI assumptions of the highest potential consumptions may be appropriate for the evaluation of the maximum possible emissions and their effect on air quality in TTZ and for the objective to redefine TTZ Coordinates of their Report of July 1993. The same figures were used by NEERI in the Technical Report dated March 7, 1994 (relevant extracts in Annexure XI) on "Issues Associated with Fuel Supply Alternatives for Industries in Agra-Mathura Region", leading to the recommendation of shifting of small scale industries outside TTZ to a new industrial site and provision of natural gas to the industries. NEERI had not examined possibilities of newer improved energy efficient technologies, by modifications of existing cupola furnaces and the use of relatively safe solid or liquid fuels, instead of gaseous hydrocarbons. NEERI had not examined the costs and time in shifting to new sites and the technology or equipment for the use of natural gas by small industries. NEERI had not made reference to the current status of foundries in Haryana/Punjab and the extent of their influence on air quality in the areas in which they are operating. All foundries in India, situated in urban areas, have to meet nationally accepted legal standards for emissions and it is not clear, if these can be achieved economically by use of Indian coke with an ash content of 30 per cent, without several modifications.

The real limitations in Foundry operation are the technologies and practices in utilisation of liquid steel. In Agra, the melted material is released in small amounts into containers with long handles carried by labour force and transferred to moulds. This is a slow process. A 3 or 4 tonne batch of melted steel may require considerable time and floor space for transfer to moulds. In modern foundries, steel plants, the melted steel is released mechanically and allowed to flow rapidly in channels to moulds and human labour force is not involved in transport of hot liquid metal in small batches. There is also a limitation of demand for cast products and capacity utilisation is dependent on availability of hard coke, demand and costs in a competitive system for supply in India and for export. The legal standards for emissions for such industrial units in all locations in the country are uniform and have to be complied with by appropriate choice of design, fuel, raw materials, mode of operation and inclusion of efficient emission treatment systems.

Coke with an ash content of 8 per cent in most countries is the most commonly used fuel and design of cupolas incorporates divided input of air at two levels for greater efficiency of combustion, including conversion of carbon monoxide to carbon dioxide and further dust removal, transfer of heat energy of output gaseous emission to incoming air through heat exchangers. Petroleum fuel oils or gas when used, reduce ash. Slag Lime addition with coke leads fixation of some sulphur and in larger plants, gypsum is obtained as a by product and may be added to cement. About half of the sulphur in coke or fuel is released as sulphur dioxide, the rest being incorporated partly in the steel and partly into the lime slag. SPM and SO_2 in emissions are reduced by cyclone separator and by wet alkali scrubbing. Many foundries in Developed Countries operating within urban areas have adopted efficient technologies to meet emission standards and yet remain commercially viable. Electric arc furnaces are clearly able to ensure clean technologies, if there is reliable power supply and the high quality products, justify the capital costs.

Through technological change and efficient operations, there are possibilities of reducing coal/coke consumption or even their replacement and this could be an alternative to shifting of small industries and use of natural gas. The cost and economics of these two alternatives have to be examined through demonstration plants. In the case of TTZ, it would be also desirable to obtain substantial improvement of ambient air quality within a period of one to two years. About 110 Foundry Units in Agra have sent identical letters to the Committee (Annexure XII) expressing willingness to adopt new technology, including divided cupola. Since the maximum short term incremental increases in air pollution occur at night times, especially in winter in TTZ, night operations of Foundries and other industries using coke/coal have to be strictly restricted. Staggering of working days among industrial units, and avoidance of simultaneous functioning of all, could also lead to lower levels of air pollution in ambient air and lessening of frequency of short term high concentrations of these.

In addition to the above, reduction of coal and high sulphur diesel usage in TTZ and especially the neighbourhood of Taj Mahal through replacement of these by electrical power, as also use of LPG and low sulphur diesel will lead to reduction of SPM and SO_2

levels. Overall reduction on automobile traffic close to the Taj Mahal and Monuments will lead to overall reduction of sulphur and nitrogen oxides.

Estimates of coal/coke consumption at Ferozabad

Information on the actual amounts of coal consumption was obtained by NEERI from DIC. Assuming all 1432 units would be working simultaneously, instead of only 615 units, the total fuel predicted usage was estimated by NEERI as 1873 MTPD. This was used to estimate potential total SO_2 emissions in the Report of July 1993. The same estimates were again used in the NEERI Technical Report of March 7, 1994 submitted to the Hon'ble Supreme Court. In this Report, the actual consumption figure of 743 MTPD was not mentioned and the basis of estimated consumption of 1873 MPTD was not specifically outlined. Availability of technology for use of natural gas in replacement of coal in glass industry, especially in pit and tank furnaces has not been examined. The constraints in making any valid estimate of the contribution of Ferozabad Industries to the levels of undesirable components in air in Taj Mahal in summer and winter, in the absence of air quality monitoring stations has been mentioned already. Reference has also been made to the problems of the assumptions made by NEERI in their document dated April 24, 1995 (Annexure III) and in the fax message received from NEERI on 30 April 1995 (Annexure IV).

<u>Estimates of contributions of SO_2 from Mathura Refinery to the air quality at Taj Mahal</u>

The estimates given by NEERI in different Reports and documents as already stated vary considerably although these are dependent largely on data collected from NEERI measurements during January-July 1993 and earlier as well as monitoring stations maintained by others including CPCB and UPSPCB. Further air quality measurements were made by NEERI in 1994 in an area of radius 10 km from MR and these are included in the NEERI Report of April 1994 on Rapid Environmental Impact Assessment for Proposed Matching Secondary Processing Facilities of Mathura Refinery, UP, sponsored by IOCL. Relevant extracts from this Report are given in Annexure XIII.

It is noted that the estimates of maximum short term (24 hr.) contributions of MR to the SO_2 levels at Taj Mahal as furnished by NEERI in their July 1993 and April 1994 Reports are in agreement and these are also reported in the NEERI Technical Note Summary given to the Committee on 19 March 1994 (Annexure II). However the estimates given in the NEERI Report of 16-18 October 1993 and the Documents given to the Committee on 24 April 1995 are different from the other three Reports mentioned above. It appears NEERI, in the Report submitted to the Supreme Court on 16-18 October 1993 and in the document given to this Committee on 24 April 1995 have used the value of the estimated short term concentration of SO_2 in the numerator and the long term seasonal average observed total concentration of SO_2 at Taj Mahal in the denominator to arrive at the percentage contribution of MR at Taj Mahal. This is not acceptable in any estimation of percentages. Long Term average figures for a season of several months or of a month or of a whole year have to be used in both numerator and denominator. For any short term contributions as percentages, estimated short term contributions under worst meteorological conditions and actual observed high short term totals at Taj Mahal have to be used. This has not been the method adopted by NEERI in their Reports of 16-18 October 1993 and their document of 24 April 1995. No satisfactory clarifications have been provided by NEERI in the faxes received on 27 and 30 April 1995 (Annexure IV).

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ANNEXURE I

K.K. BAKSI
ADDITIONAL SECRETARY

तार :
Telegram : PARYAVARAN,
NEW DELHI
दूरभाष :
Telephone : /Fax: 4362281
टेलेक्स (द्विभाषीय) :
Telex : (bi-lingual) : W-66186 DOE IN
Fax : 4360678

भारत सरकार
पर्यावरण एवं वन मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT & FORESTS
पर्यावरण भवन, सी. जी. ओ. कॉम्प्लेक्स
PARYAVARAN BHAWAN, C.G.O. COMPLEX
लोदी रोड, नई दिल्ली-110003
LODHI ROAD, NEW DELHI-110003.

DO No.Q-17012/21/93-CPW

15th March, 1995.

Dear Prof. Khanna,

As you know, a Committee has been set up under the directions of the Supreme Court of India to look into various matters concerned with air pollution in the Agra-Mathura region. You would kindly recall that I have addressed you in this connection recently.

We are obliged to you for kindly finding time to meet the members of the above mentioned Committee chaired by Dr. S. Varadarajan at 9.30 am on Sunday, the 19th March, 1995. The venue of the meeting will the Indian National Science Academy (INSA), Bahadurshah Zafar Marg, New Delhi-110 002. I am enclosing herewith a note which indicates the matters on which the Committee would like to hear your views, along with any other information you may like to bring out which could be useful for the work of the Committee.

With regards,

Yours sincerely,

(K.K. Baksi)
15/3/95

Prof. P. Khanna,
Director,
National Environmental Engineering
Research Institute,
Nagpur.

State of Monuments and Marble in Trapezium

It has been stated that the white marble has been damaged by pollution and the Taj Mahal has acquired a yellow colour. Information from Observatories and studies carried out by NEERI, during different periods in the last 15 years on the state of monuments, especially marble may be kindly provided. It would be useful to have any information regarding similar monuments at Delhi, Rajasthan centres as well as on other Heritage Centres in the world on deterioration and discolouration attributable to pollution, especially sulphur or nitrogen oxide, for example, in Rome, Athens, London, Paris especially during the period before 1970, when pollution levels were high.

Energy Levels in Trapezium

Air Quality has been related to the use of fuels such as coal, coke, firewood, individual petroleum products. Information on the total quantity of each of these yearwise during the past 15 years, utilised especially commercially sold would be valuable if these have been collected by NEERI. These could include bulk supplies made to Railways, Air Force, Army, Industries, large inhouse power plants of hotels as well as those sold through retail outlets. Trends in these in total may be related to air quality.

Electrical power availability and availability of uninterrupted supply would obviate the need to generate power through small and medium size generators in houses, shops, establishments, small and medium industries, hotels, restaurants. Information available if any from NEERI regarding designed and unanticipated interruptions in power supply during the last 5 to 10 years as well as on the estimates of approximate number of various sizes of power generators may kindly be provided. Any information on the future availability of electrical power supply to meet demands in the Trapezium Area could also be made available.

Similarly, any estimates of changes/increases in the motorised vehicles operating in the area over the past ten years and of future ten years would be of particular interest. These represent expansion in infrastructure of transport, commerce, trade, tourism.

Clean Fuels

It has been recommended that the Mathura Refinery should establish Hydrocracker improved Klaus Process Technology and use of piped Bombay High Natural Gas to reduce the quantum of sulphur dioxide released. These may take some substantial time to achieve as they require, technology selection, project formulation, investments, economic returns justification implementation, commissioning reliable continuous operation. Similarly supplies of natural gas, sulphur and lead free fuels to Industries, Transport vehicles, electrical power generation in the form of gas or liquid may take time, if these are dependent on the Refinery Improvement listed above. Any interim solutions to reduce pollution in the Trapezium Area outlined by NEERI could be mentioned.

NEERI may kindly provide information available on the levels of air quality indications in major centres cities, heritage locations during the last 20 years and especially changes which have been brought about through adoption of various measures to meet stringent standards especially in Western Europe, Japan, Western USA. Information on these achievements would form the basis for future actions on India generally and especially in the Taj Trapezium. It is noted that Refineries, Power Generation Stations, Fertilizer and Chemical Industries are often in close vicinity of human dense habitations and yet have been able to achieve good air quality. Automobiles are also supplied with low sulphur fuels. Information on technologies and standards would be valuable.

Human Health

Air pollution is said to be injurious to human health. The consideration of human health in densely populated Indian cities has to be highlighted while considering the effects of air pollution on heritage monuments. Information on the relationship between major air pollutants and human health and the standards by W.H.O. and others, which have to be achieved, if available, will be very useful.

Technical Note Summary

SO_2 Concentrations at Taj Mahal under Impact of Point Sources Includimg MR Emissions

Short term concentrations at Agra varies from 47 to 65 ug/m^3 (for one ton per hour emissions) while long term seasonal concentrations varied from o.6 to 1.0 ug/m^3 (1 ton per hour) as per the results of IMD study on dispersal of pollutants from the refinery using meteorological data collected at the Mathura observatory (Expert Committee Report on Environmental Impact of Mathura Refinery, 1977 page no. 79)

NEERI Predictions for Pollution Profile at Taj Mahal, Agra :

Two scenario's for industrial emissions viz. worst case, when all the industries are operating and normal case when only 26 foundries (20 % of 131) along with all other type industrial units are operating, have been generated for prediction purpose. Industries normally operated for 8 hrs duration in one shift.

" Predicted GLCs at different sensitive receptors : Taj Mahal, Etmad-ud-daula, Agra fort and Sikandara are 49, 30, 21 and 2.9 ug/m^3 under worst conditions and decline to 11,10,9.3 and 3 ug/m^3 at the same sites repectively under normal conditions. The isometric and isopleth projections of SO_2 : 24 hrs avg. concentrations for Agra city under worst case before source control implementation and under two normal cases : before and after implementation of source mitigation scheme for winter as well as summer seasons are developed. These concentrations at Taj Mahal do not include contribution due to MR refinery. (Page V-11 to 20)

In comparison to winter season the summer season GLCs at sensitive receptors : Taj Mahal, Etmad-ud-daula, Agra Fort, and Sikandara were in general, lower under extreme emission conditions as well as normal industrial operation schedule. As far as 8 hrs concentrations are concerned (for one shift among three), day time schedule result in much lower GLCs than night hours.

Predicted GLCs (24 hr avg.) under impact of MR point source for winter as well as summer reflect that the impact zone of 10 ug/m^3 rise in background extends upto the the diistance of 13 Kms. Another range of maximum impact zone for 5 ug/m^3 over the background ambient air level have been extrapolated in this study. The impact zone of 5 ug/m^3 extends even upto 34 Kms. These predictions being most conservative the actual concentrations are not expected to exceed 5 ug/m^3 value. Hence, MR may occassionly cause maximum rise of 5 ug/m^3 at Bharatpur. Exposure of Agra monuments will be still lower than 5 ug/m^3 under the scenario of normal MR emissions because MR is at 40 Kms from Agra city. However, any abnormal MR operating conditions demands immediate shut down of the refining process.

The actual monitored long term annual ambient air quality concentrations (trends) at Taj Mahal vary between 6 to 30 ug/m^3. Only 10 percent observations in a year may exceed 30 ug/m^3.

In order to clearly quantify the fractional contribution of MR vis-a-vis other point sources within APPZ towards over all (total) SO_2 (recorded ambient air SO_2 levels), tracer studies have been recommended.

Taj Mahal Degradation Studies

Regarding impact on Taj Mahal (marble degradation) no study on marble of Taj Mahal is reported highlighting the exact marble erosion rate at Taj Mahal. In such circumstances, the bibliography on such studies on world monuments was first perpared and it was summarised in the report also. (NEERI report, 1993 page III-12).

Marble erosion rates for ambient concentrations and climatic conditions using material damage model were calculated & reported in one publication (results summarised in table enclosed for reference).

Taj marble degradation studies through simulated marble exposure experiment have been also earlier recommended to evolve the criteria of marble degradation (erosion) rate and SO_2 level through exposure budget-response relation studies.

Public Health Concerns

As regards health effect component, no secondary data was collected because issue and scope of the study was different and total span avaliable for the study was only six months including data analysis / modelling / report preparation. However, earlier epedemiological studies were carried out at Bombay can be cited as a case from a prospective survey on 4129 subjects in 3 urban (high, medium & low according to SO_2 levels) areas and urban and rural communities.(Bombay Air Pollution - Health Study, 1984 page no. 15 & 35)

"The effects are seen at SO_2 levels between 40-60 ug/m^3 as yearly mean and SPM levels around 250 ug/m^3 and NO_2 around 15-20 ug/m^3 are probably due to added enhancement by factors of housing, econnomic factors, cooking fuel and nutrition. Thus, there seemed to be highly significant trend for health morbidities in the urban communities to fluctuate with SO_2 levels."

Fuel Emission Inventory

- NEERI study primarily concentrated on the current gross emission scenario collecting primary data in Agra and growth rate of different source emissions were worked out based on limited secondary data available on the regional growth rates.

- Data on electricity supply failure (frequency and duration) was not collected during this study. However, the observations reflected that during failure hours primarily in the evening peak load period more than 75% of commercial units were operating DG sets.

For current emissions during 1992 - 93, where ever data was not avaliable field observations (primary data) were collated to evaluate spatial & temporal variations of emission activities viz. for vehicle counts-manual roadside observations, for domestic emissions house to house surveys in different socio-economic categories of population groups.

As regards similar information available on studies carried out in other cities viz. correlation between the rise in ambient air concentration versus source emission growth, is concerned - case studies for three Indian urban centres, (report available in three volumes) for Bombay/ Delhi /Calcutta are attached for general reference. Report on **20 Megacities of The World** (Earthwatch Series) is also available for reference.

National Environmental Engineering Research Institute
Nehru Marg, Nagpur-440 020

Pollution in Agra Region

MEF Committee under the Chairmanship of Dr. S. Vardarajan

NEERI scientists attended the meeting conducted by the chairman Dr. S. Vardarajan on 19th March and discuss at length with the chairman and the other committee members on the aforementioned subject. Specific information on the issues raised during the discussion was provided based on the studies carried out by NEERI for MEF in 1993 on Redefining Taj Trapezium. The point-wise information on issues raised in this meeting is provided here as desired by MEF vide letter no. Q-17012/21/93-CPW dated April 6, 1995. The response is based on the notes taken in the meeting by NEERI scientists in absence of the minutes of the meeting on 19th March, 1995.

A. Status on Ambient Air Quality at Taj Mahal (Agra) :

- The air quality data for Agra is provided in **Fig. 1-3**. The data for three Indian as well as other important world cities is also annexed in **Figs. 1 through 8**.

- Regarding published literature on the effect of air pollution on marble and public health, the comprehensive information in 800 pages bibliography compiled by NEERI on pollution effects on world monuments was shared with the committee in the meeting on March 19, 1995. Three published documents related to monuments at California Building, San Diego & Cave Hill Louisville cemetery of USA and Victoria Memorial of India are appended herewith.

B. Source specific contributions to SO_2 at Taj Mahal

- Pending detailed analysis through tracer gas study proposed by NEERI in October 1993, the predicted assessment of percentage contributions from different sources within Taj Trapezium is summarised in **Tables 1 & 2**. The surface wind profile analysis reflected that for 14 and 24 percent time winds are from Firozabad industrial zone, whereas from Mathura Refinery direction these percentages are 7 and 11 in winter and summer seasons respectively.

- The report submitted in July 1993 by NEERI on Taj Trapezium study to MEF was based on data collection for six months. The study was not extended by MEF that could have enabled further investigations. The modelling exercise undertaken during this six month long study brings forth the following :

  - The major contribution to air pollution in Agra region is from point sources. It varies between 75 to 80% in summer and winter seasons, respectively. The contributions from automobile activity and domestic fuel combustion are comparatively lower in the vicinity of Taj Mahal **(Table 1)**

  - The contributions from Firozabad industries during summer is 34% **(Table 2)**. The strategy for reduction in the impacted area was delineated in the report submitted to the MEF in July 1993.

  - Contribution to SO_2 at Taj Mahal from the Mathura Refinery is about 26% **(Table 2)** in winter.

C. Selection of Appropriate Pollution Control Strategy

Various options on process technology and/or fuel shift were considered before reports on the topic were submitted to the Hon'ble Supreme Court. The copies of these reports are available with the Committee. The situation analysis is as follows :

- The Hydrocracker Unit (HCU) is a cleaner technology option as on one hand it reduces the sulfur content of the product (which are consumed in the region, viz. diesel, kerosene), and on the other excess sulfur present in the Industrial Fuel Oil (IFO) is recovered upto 95% through Claus process or 99% by using the biotechnology route. HCU has been accepted by the Ministry of Petroleum and Naural Gas in its ten points Programme on March 2, 1995. The commissioning of HCU shall reduce pollution and improve the refinery economics.

- The option of import of low sulfur IFO needs techno-availability analysis. The ultimate solution is in the use of Natural Gas (NG).

- The improvement in the quality of products after the commissioning of HCU will be substantial, viz. reduction in diesel 'S' from 1 to 0.5%, and the distribution of these products in the Agra-Mathura region shall effect reduction of SO_2 emission load in the region.

- Sulfhur content in IFO could be brought down from the level of 0.7 % wt to about 0.4% wt by, processing 50:50 Low Sulfur Heavy Stock (LSHS) mix of crude at the refinery. Further reduction in sulphur content of IFO to a level of 0.20-0.30% wt could be possible if crude mix is changed to 60:40 LSHS : low sulphur crude from Nigeria/Bombay High.

- In the event of reliable electric power made available in Agra region, the use of diesel generating sets shall be drastically reduced as more than 70% of the commercial units were found using diesel sets during the MEF study period due to frequent power cuts.

- NEERI has designed air pollution control technology packages for all major small/medium scale industrial sectors after considering differnt options. The packages include the cost of fabrication for typical emission characteristics. The generic design packages were submitted to the local industrial association, State authorities, and the Hon'ble SC in September & October, 1993 for possible implementation to enable around 80% reduction in the polluting industries.

Table 1

Predicted Concentration of SO_2 at Taj Mahal
From Major Soruces in Agra Region

Average : 24 Hrly **Unit : ug/m^3**

Season	**Agra Region**		
	Point Sources	**Non-Point Sources**	
		Area	**Line**
Winter	11.2	1.5	1.2
% contribution at Taj Mahal	(80)	(11)	(9)
Summer	12.3	3.0	1.1
'% Contribution at Taj Mahal	(75)	(18)	(7)

Source : NEERI Report on Taj Trapezium Study, July 1993

Table 2

Predicted Concentration of SO_2 at Taj Mahal From Major Soruces in Taj Trapezium

Average : 24 Hrly **Unit : ug/m³**

Season	Predicted SO_2 Concentrations (ug/m³)/Percentage contribution					
	Point	Agra Area	Line	Mathura* Refinery	Firozabad Glass Ind.	Total Concen.
Winter	11.2	1.5	1.2	5.0	Nil	18.9
% contribution at Taj Mahal	(59.0)	(8.0)	(7.0)	(26.0)	(Nil)	(100)
Summer	12.3	3.0	1.1	1.0	9.0	26.4
% contribution at Taj Mahal	(47)	(11)	(4)	(4)	(34)	(100)

* The prediction of SO_2 concentration at Taj Mahal are for worst meteorological conditions and highest observed stack emissions.

Source : NEERI Report on Taj Trapezium Study, July 1993

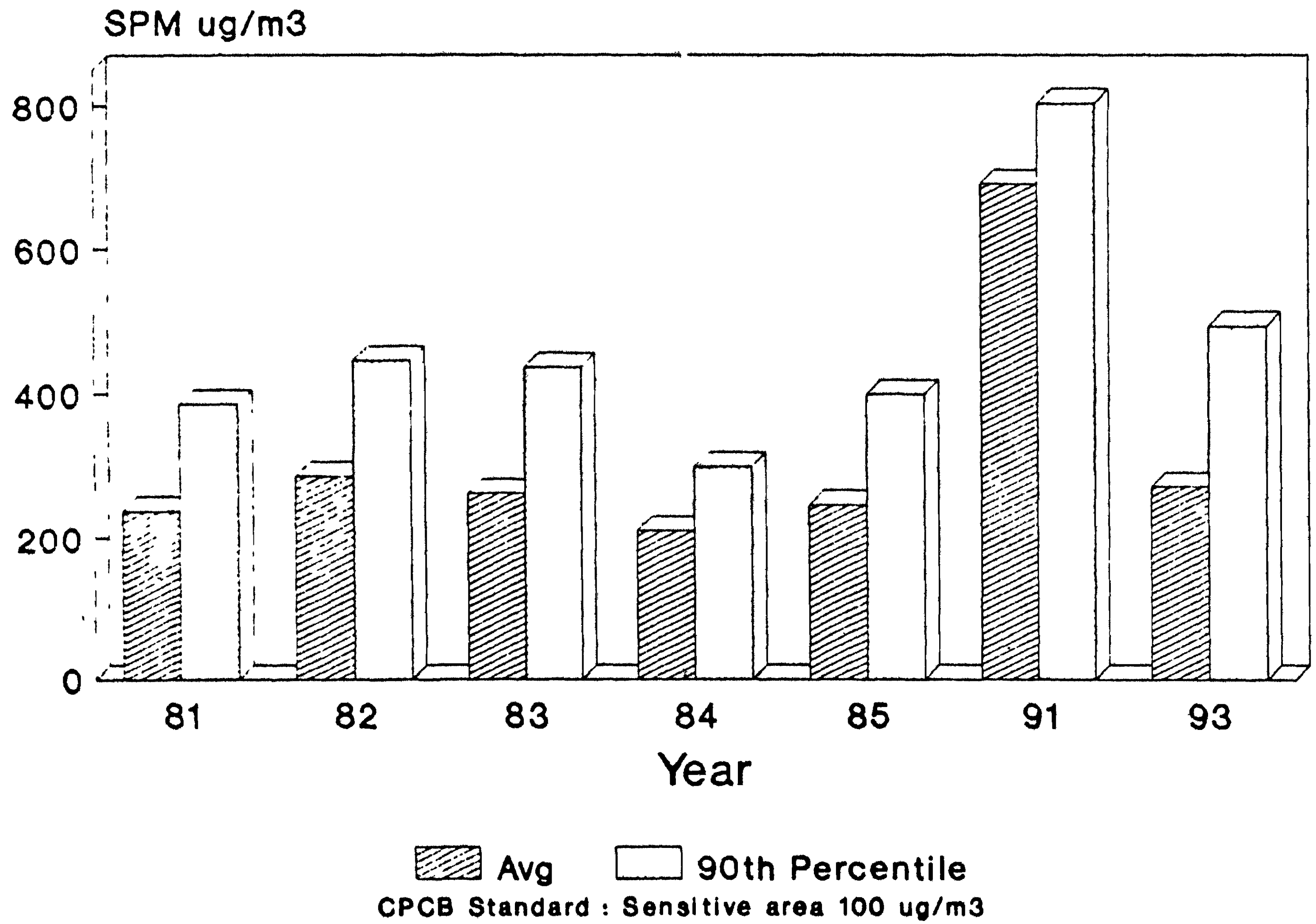
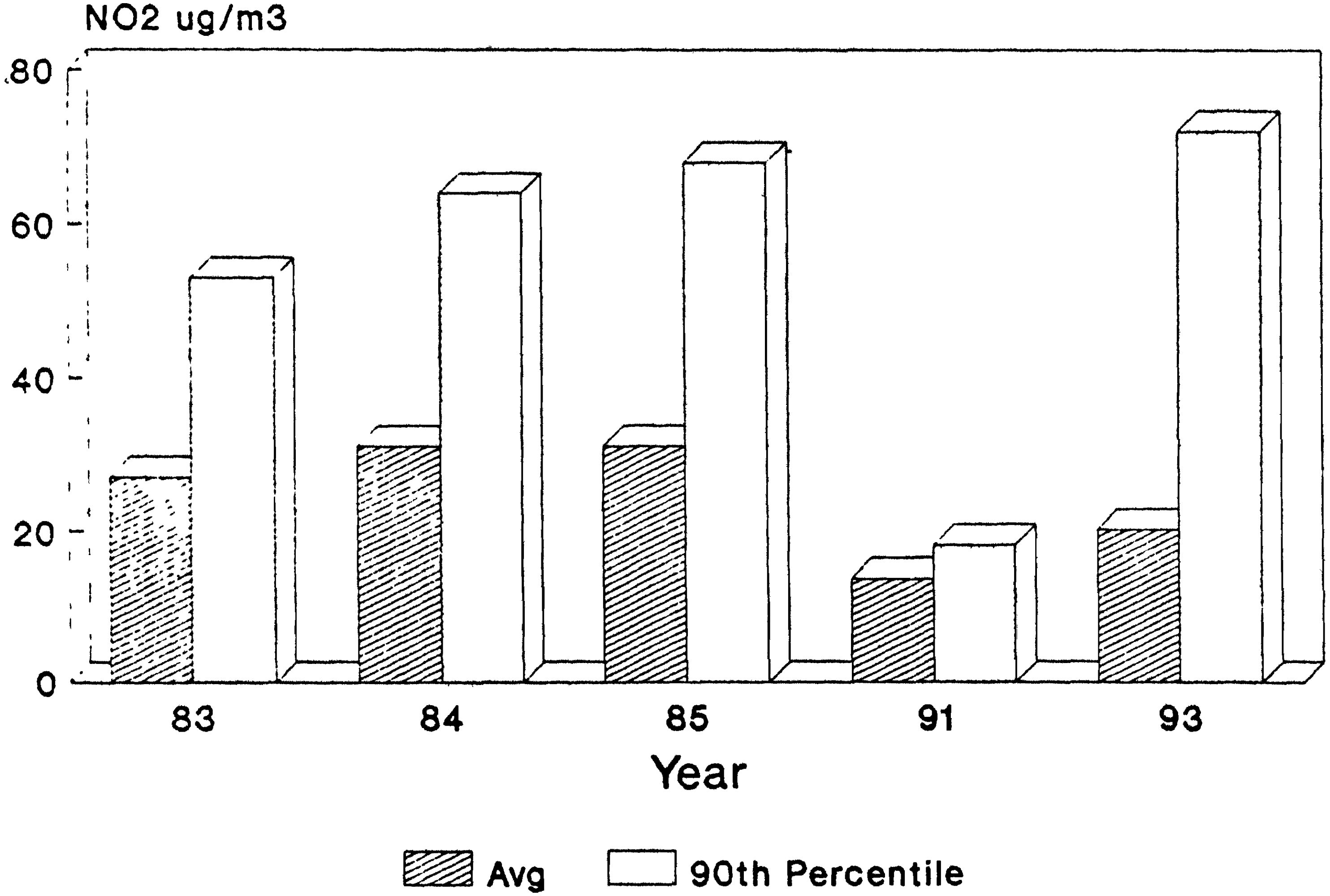


FIG.1 SPM TRENDS : TAJ MAHAL 1981-93



CPCB Standard : Sensitive area 15 ug/m3

Fig. 2 NO2 TRENDS TAJ MAHAL 1981-1993

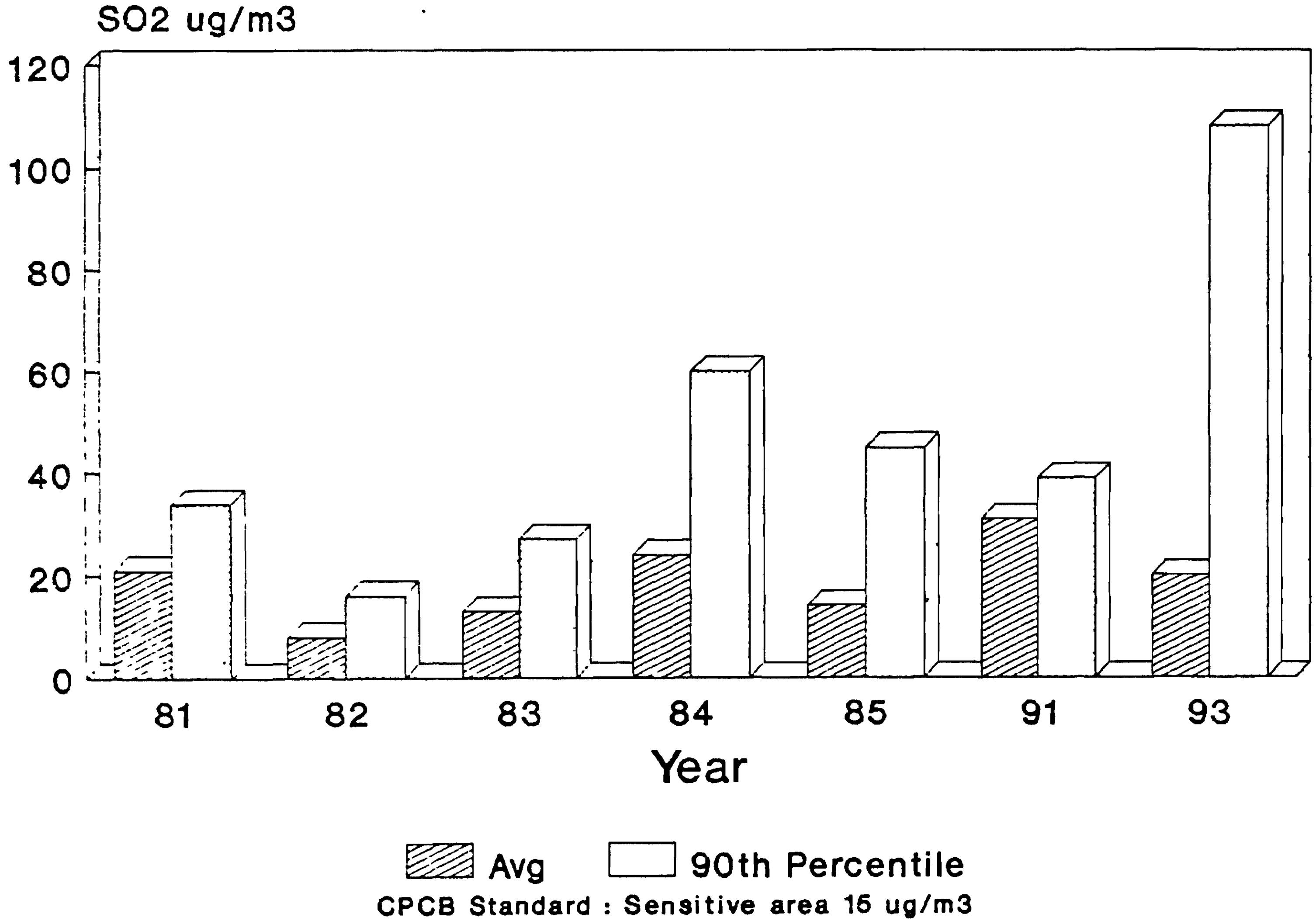
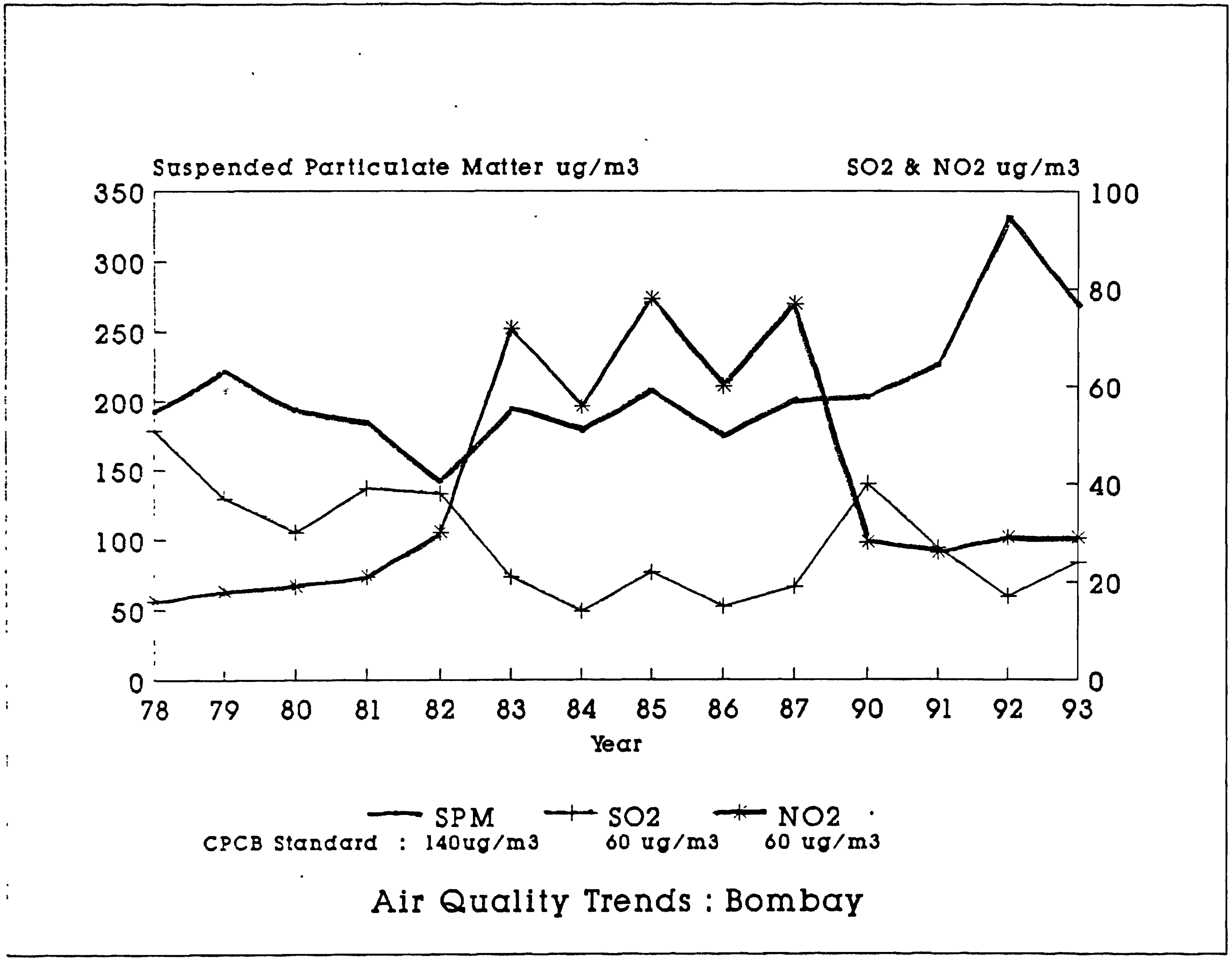
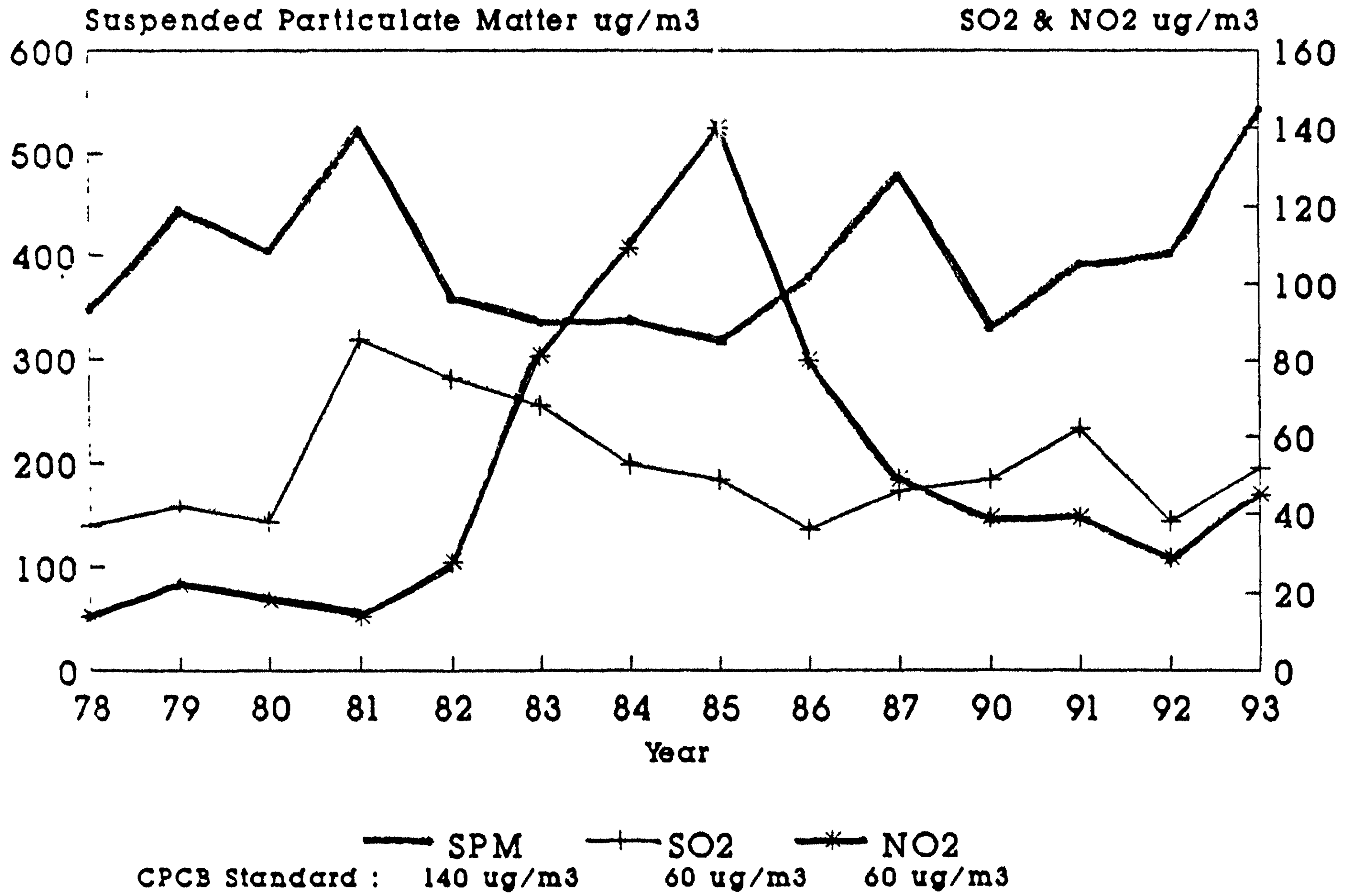


Fig. 3 : SO2 TRENDS TAJ MAHAL 1981-1993

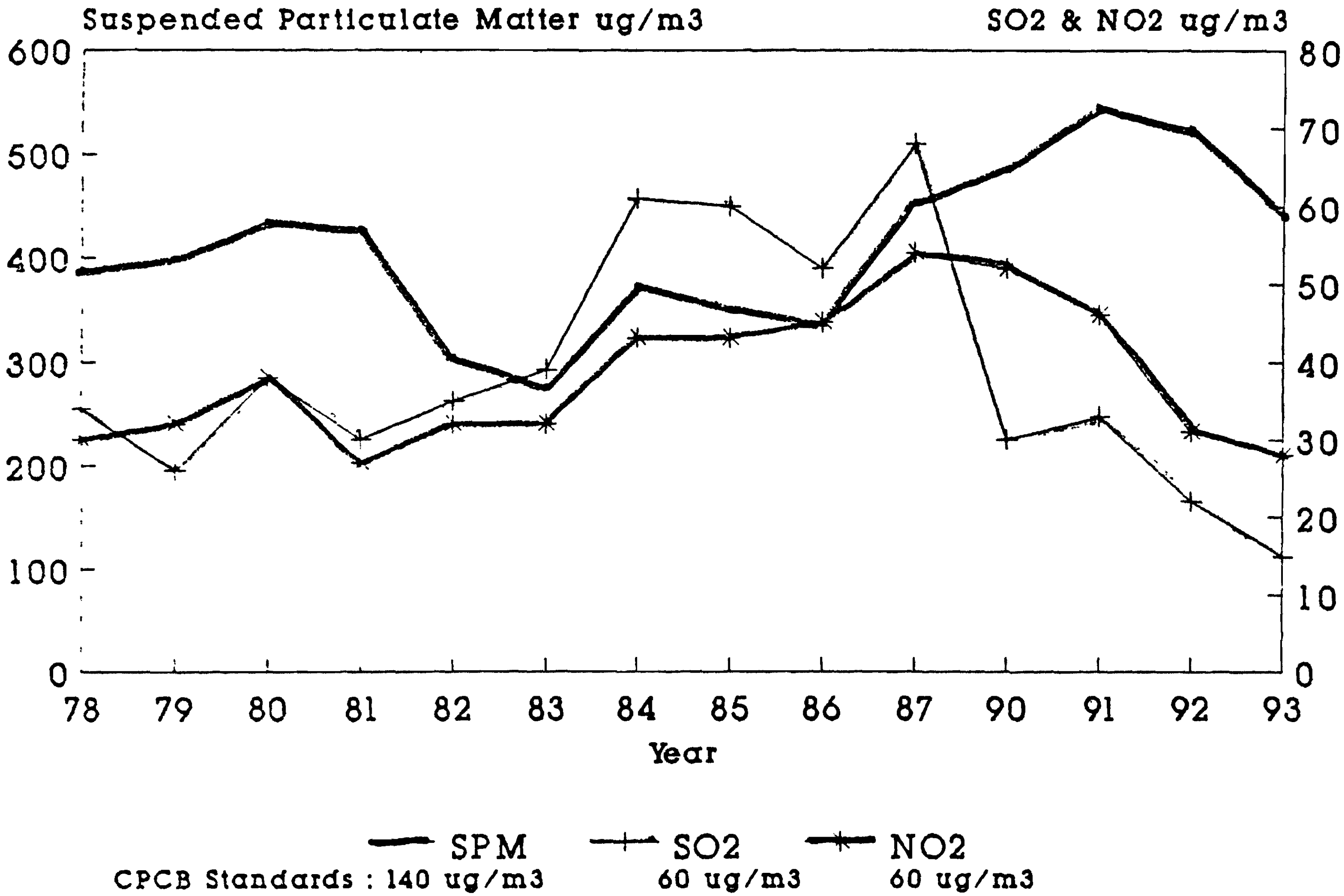


Suspended Particulate Matter ug/m3
SO2 & NO2 ug/m3
350
300
250
200
150
100
50
0
100
80
60
40
20
0
78 79 80 81 82 83 84 85 86 87 90 91 92 93
Year
SPM
SO2
NO2
CPCB Standard : 140ug/m3 60 ug/m3 60 ug/m3
Air Quality Trends : Bombay

Fig. 4



Air Quality Trends : Calcutta



Air Quality Trends : Delhi

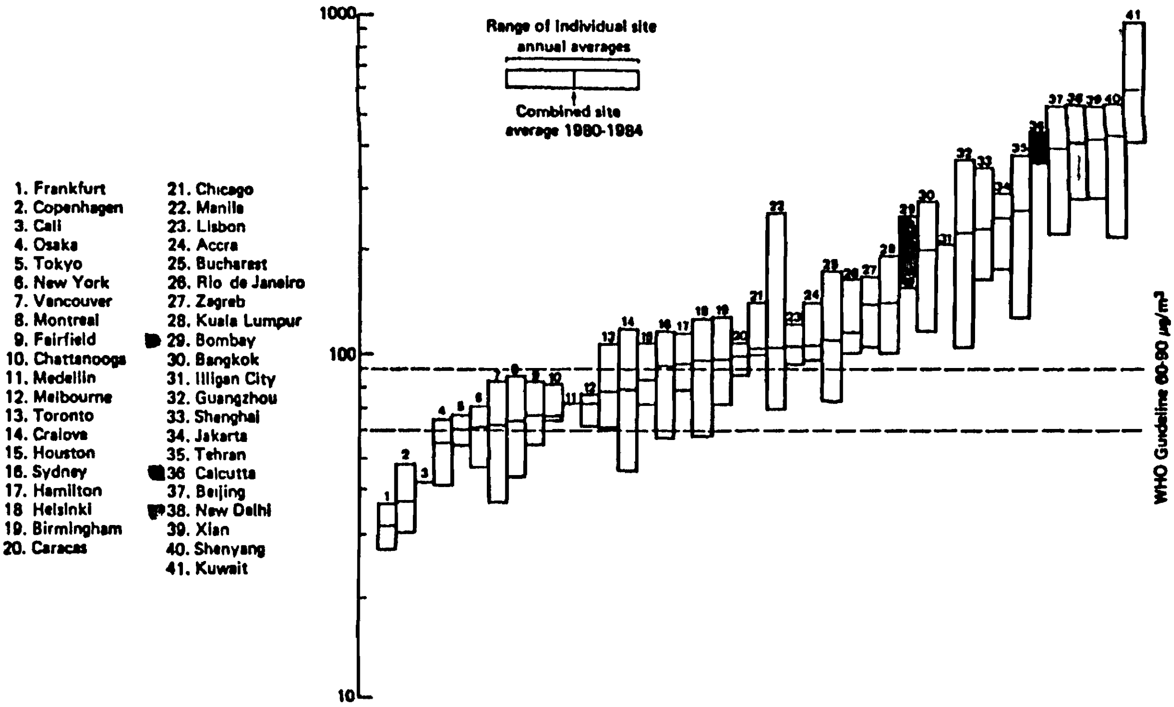


Fig 7 Summary of the annual SPM averages in GEMS/Air cities, 1980-84

Source : UNEP/WHO Document, 1988

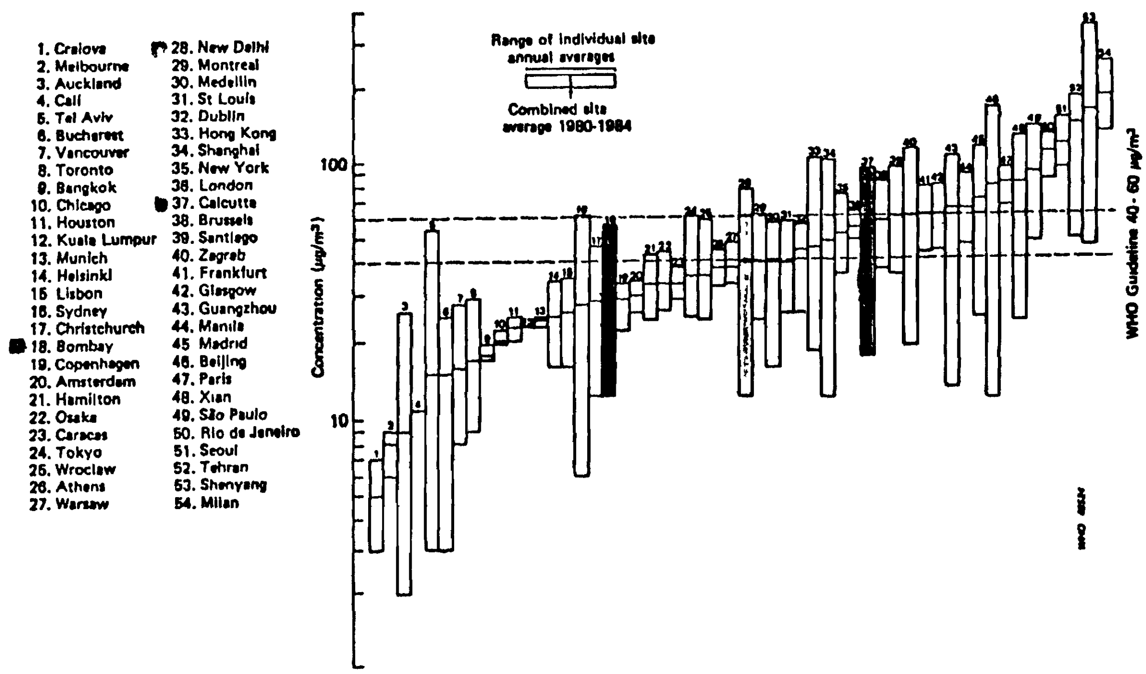


Fig 8 Summary of the annual SO2 averages in GEMS/Air cities, 1980-84

Source : UNEP/WHO Document, 1988

COLLOQUE INTERNATIONAL
INTERNATIONAL SYMPOSIUM

8585

ALTERATION
ET PROTECTION
DES MONUMENTS
EN PIERRE

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DETERIORATION
AND PROTECTION
OF STONE MONUMENTS

K.L. GAURI

Conservation of the California Building, San Diego, U.S.A. A case history

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PARIS, du 5 au 9 JUIN 1978
PARIS, JUNE 5th — 9th 1978

2585

CONSERVATION OF THE CALIFORNIA BUILDING, SAN DIEGO, U.S.A. A CASE HISTORY

K.L. Gauri
Department of Geology
University of Louisville
Louisville, KY 40208

ABSTRACT

Cast stone ornamentation and stuccoed surfaces of California Building, erected in 1915, had deteriorated due to weathering. Increment of water absorption, reduction of mechanical strength, and cyclical hydration of efflorescences had accelerated decay. Connecting iron bars had oxidized. Consequently, cast stone had fragmented in places; these areas needed to be patched. Heavy ornamentation that was safety hazard had to be replaced by light weight replicas of artificial stone.

Quantitative specification, developed from laboratory experiments, consisted of cleaning efflorescences (reduction of Na^{2+} to 0.02 percent of stone) and consolidating the cast stone with epoxy impregnation (among others, enhance compressive strength by 50%). Specification for artificial stone made from polymeric cement and inorganic aggregate related to bond and mechanical strength, water absorption, flammability, and linear expansion; these were determined using ASTM standards. These properties of the fabricated stone were similar to that of the cast stone.

Since its completion in early 1975, the building appears to be in a good state of preservation.

INTRODUCTION

The California Building was built in 1915 as part of an exhibition to celebrate the opening of the Panama Canal. This building was constructed in the Spanish Colonial Architecture to express the unique cultural heritage of California.

The major element of the building is the central dome which is flanked by four vaults and a bell tower; the last is located on the east side of the building, has ten stories, and is nearly 200 feet high. The building has an elaborate molded ornamentation in cast stone which is anchored to the inner reinforced concrete frame. The ornamentation of the main entrance of the building and the upper three stories of the tower as well as the plain stuccoed front of the lower seven levels of the tower are the subject of conservation discussed in this paper.

The cast stone was manufactured from quartzose aggregate of fine granules and coarse sand; lime-cement was probably used as the bonding medium. The physical properties of this cast stone are similar to that of a highly porous, poorly sorted, coarse-grained sandstone. Therefore, the behavior of the cast stone to weathering is similar to the behavior of natural, highly porous, sandstone with calcitic cement. The effects of weathering are perceptible even in deeper regions of cast stone. This is unlike concrete in which the weathering effects are surficial but the concrete, in surface region, is more severely damaged.

The weathering has produced several visible features (Plate 1-3) such as:

1. Reduction of surface relief. This is due to the dissolution of the calcitic cement. The grains of sand, thus having become unbonded, have gradually separated from the ornamentation.
2. Formation of efflorescences. The efflorescences, visible as white encrustations, were identified by x-ray diffraction as being gypsum and other complex salts as calcium and sodium as sulfates and chlorides. They were formed as a result of: a. chemical weathering of

the calcareous cement in the cast stone, b. as a probable inclusion of gypsum in the cast stone at the time of its fabrication, c. as deposits from oceanic sprays, and d. as reaction products of all these salts. The efflorescences are the major cause of the accelerated decay of the cast stone.

3. Oxidation of iron bars in structural concrete to which the ornamentation is attached. Due to this, both the concrete and the cast stone had ruptured in certain areas.

The effects of weathering not physically expressed but responsible for above visible effects are:

1. Reduction of abrasive index
2. Reduction of the mechanical strength of the weathered cast stone, and
3. Increment of the rate of water absorption and the total absorption of water by the cast stone.

The object of the preservative treatment was to recover these properties so that the stone became, at least partially, regenerated.

Further, as a result of weathering, some fragments from various portions of the building had fallen off. Also, poorly supported members of ornamentation which were considered to be unsafe due to the earthquake activity of the region had to be dismantled. The added function of the conservation treatment therefore was to design comparable materials for patching and for production of replicas. To achieve this and other function of the preservative treatment given in the preceding paragraph, the properties of the cast stone were determined. The samples for this purpose consisted of cores drilled from the various areas of the building and fragments that had fallen off naturally. The peeling of the cast stone was associated with the accum olation of the efflorescences behind the stone surface. These peelings were used to identify the mineralogical composition of the efflorescences. All these studies, performed on highly weathered and sound portions of the cast stone provided quantitative data. This data was used as the basis for specifications for treatment of the California Building.

CLEANING: The facade had some street dirt and soot but the main problem was the occurrence of efflorescences. These, in certain areas of the building, formed patchy surface encrustations. On the inside of the upper three stories of the tower, the heaved layers of the cast stone were directly due to the cyclical hydration of these efflorescences.

The efflorescences, as determined by x-ray diffraction, consisted mainly of gypsum ($CaSO_4 \cdot 2H_2O$), glauber salt ($Na_2SO_4 \cdot 10H_2O$) Sodium Sulfate (Na_2SO_4) and other complex salts such as $Na_2\,Ca(SO_4)_2$. The atomic absorption spectrophotometry was used for quantitative determination of ionic composition (Table 1).

TABLE 1

Ionic Composition (% weight of dry sample)
Samples with designation W are from the weathered portion.

Sample	Na^+	Ca^{2+}	SO_4^{2-}
1	0.046	9.58×10^{-4}	6.036×10^{-3}
1W	0.022	0.0174	0.0603
2	0.0465	0.00117	0.00804
2W	0.0296	0.0772	0.2181
3	0.0203	0.00525	0.00525
3W	0.0171	0.1256	0.3004
4W	0.0192	0.0395	0.185
6	0.0418	0.0032	0.0133
6W	0.049	0.0097	0.354
7	0.00073	7.575×10^{-3}	0.0179
7W	0.0053	3.43×10^{-3}	0.011
Peelings with Efflorescence from Inside Tower			
1	5.21	0.032	6.42
2	0.741	0.03	2.04

The data obtained for each element was expressed as a percent weight of the total sample. This permitted comparison of the quantities of efflorescences present in different areas of the building as well as a means for developing specification. For instance, in the upper three levels of the tower which are open, the quantity of Na^{2+} in the efflorescences in protected areas was found to be as high as 20%. In other areas where the cores had been drilled, the quantity of Na^{2+} varied from 0.02 to 0.05%. As the minimum quantity of Na^{2+} found in the cast stone was of the order of 0.02% and this cast stone was not damaged, it was therefore specified that after cleaning, the cast stone shall not have more than 0.02% of Na^{2+}. It was also later discovered that the British Standards recommend that best bricks are those in which the content of Na^{2+} is less than 0.02%.

The efflorescences were reduced to above specified quantities by the following procedures:

The stone surface was brushed where efflorescence was apparent by its white color. The stone surface was then washed with combination of water and rounded silica sand at such pressures which did not damage the stone. This, in addition to removing some efflorescence, also cleaned the stone of other dirt. Where the efflorescences were not reduced to specified quantity by means of above procedure, the stone surface was repeatedly treated with steam at high pressure followed immediately by washing with cold water. After washing, acetone was dripped down the surface to remove the water.

The cleaning of the facade of efflorescence to the specified level was a major undertaking. The authorities reportedly seriously adhered to the compliance of this specification by the contractor.

The use of Na^{2+} is a specification for cleaning needs further discussion. Na_2SO_4 is probably the most deleterious, though not most common, salt in stone weathering. The quantity of Na_2SO_4 which may be within safe limits can be determined by crystallizing known quantity of Na_2SO_4 in the stone pore space and hydrolysing it at 20°C when the maximum tensile stress is generated. The equivalent safe Na^{2+} quantity may be chosen as the basis of specification.

More often, $CaSO_4$ and Na_2SO_4 and complex salts thereof co-exist as in the case of this cast stone. For such cases it is advisable that SO_4^{2-}, rather than Na^{2+}, should form the basis for specification.

<u>CONSOLIDATION</u>: Besides providing additional cementation, well designed consolidation treatments must also improve the following properties:

1. <u>Compressive Strength</u>. The compressive strength reflects the overall mechanical behavior of stone. The improvement of compressive strength, obtained here by added cementation, automatically improves the tensile strength as well as the abrasive index. As a result, the stone does not easily lose grains and chances of failure due to crystallization of florescences are also reduced.

The compressive strength of the weathered cast stone is of the order of 140 kg/cm^2. It is assumed that the unweathered cast stone had a compressive strength of some 210 kg/cm^2. In laboratory experiments, it was determined that the compressive strength of the weathered cast stone could be improved to nearly 350 kg/cm^2. To achieve this, the specimen -- 7.6 cm. long, 3.8 cm. diameter core -- was immersed in 15% epoxy (Bisphenol A epoxy) solution in acetone for 20 min.; diethylene triamine was the curing agent. After this, the specimen was immediately transferred into 25% epoxy solution in

10 min. Similar treatment, also applied by brushing the surface of experimental area of the facade with above solutions for corresponding time periods, permitted the cast stone to become impregnated to a depth of over one-inch. Table 2 shows the relative compressive strength of corresponding treated and untreated cores. On this basis, the following specification was recommended for adoption.

TABLE 2

Compressive Strength (kg/cm^2) of cores. The abbreviations u and t indicate untreated and treated specimens.

Sample	Compressive Strength
1Au	231
1At	562
1Bu	273
1Bt	382
2Au (Chip missing)	99
2At	241
2Bu	166
2Bt	425
8Au	295
8At	398
8Bu	155
8Bt	388

The cast stone shall be impregnated to an average depth of one inch and compressive strength of the treated cast stone shall increase at least 50% as that of the untreated cast stone.

In actual treatment of the California Building, it was determined that 15% epoxy solution became too viscous during application due to the rapid evaporation of the solvent. Therefore, the cast stone was treated with successive 10% and 20% epoxy solutions, rather than 15% and 25% as had been determined as best method in laboratory experiments. The cores obtained from the treated building showed that the required specification had been met.

2. Water Absorption. The deterioration of the cast stone is directly related to the movement of the water through the pore space. The cast stone, especially the weathered portion, is highly water absorbant (Table 3).

TABLE 3

Water Absorption

Given as percent weight of untreated dry sample.
W indicates specimens from weathered portion of stone.

Sample	Water Absorption
1	2.34
1W	10.04
2	4.87
2W	12.62
3	4.88
3W	7.63
4W	7.75
6	3.25
6W	5.59
7	5.18
7W	7.52
9	11.99
9W	12.64

It was a ... function of the consolidation treatment to reduce the total water absorption as well as to retard the rate of water movement into the ... .

The treatment described above, in several weathered specimens, reduced the water absorption from nearly 12% to 1.5%. This water absorption was determined for untreated specimens and for those treated specimens the surface of which had been abraded to remove the epoxy coating. These specimens were dried at +100°C for one hour, cooled in a dessicator, and then immersed in water for 48 hours. For the rate of movement of water, similarly treated specimens were brought in contact with water in such a way that the surface of treatment of a specimen was placed normal to the water surface. The movement of water was observed on a cut plane surface, which was normal both to the surface of impregnation as well as the surface in contact with water. It was found that the water did not at all rise into the region near the impregnated surface even after 48 hours of contact with water. On the basis of this, empirically, the following specifications were recommended.

The weathered cast stone shall not have more than 5% water absorption. In the first 24 hours of contact with water, the water shall not rise into the ... region of the impregnated stone.

3. Permeability. The above specification dealing with water movement into the stone could have been easily met by placing a thick coating of polymer on the stone surface. Such coatings, in addition to being aesthetically unacceptable, also hinder the breathing of the stone. In order that the moisture should continue to exit at the surface, the permeability of the stone must be largely maintained. The above treated cores were tested

[illegible] in a well constructed permeability cell. A large number of permeability determinations permitted the design of the following specifications.

The sample taken from the treated building shall have at least 90% permeability of samples taken before treatment from corresponding areas of the California Building.

SURFACE PROTECTION: The major constituents of the cast stone, i.e., the quartzose aggregate, is chemically resistant but the original calcareous cement is attacked by the atmospheric gases. It was not given as a specification, but was recommended that the consolidated facade, after the removal of surface epoxy by abrasion, should be coated with solution of a fluorocarbon (Fluoropolymer-B by DuPont) in a solvent consisting of cellosolve acetate and methyl-ethyl-ketone. In laboratory experiments on marble with above fluorocarbon treatment, the reactivity of the specimens to CO_2 and SO_2 had been considerably reduced. The fluoropolymer-B does not absorb the ambient ultra-violet radiation. Unlike epoxy, therefore, it is not degraded due to exposure to sunlight.

The entire consolidated facade was coated by the above recommended fluorocarbon. The permeability specification was also met after the fluorocarbon treatment.

MATERIALS FOR PATCHING AND REPLICAS: Another major aspect of the treatment design of the California Building was the replacement of heavy cast stone ornamental objects such as lanterns and vases with lighter shells made from synthetic polymers. Also, those areas from where the pieces of stone had fallen off were to be patched. In the design of a synthetic composite material to prepare replacement moldings and patching compounds, it was deemed crucial that certain physical properties of these media were similar to the properties of the existing cast stone. Such properties were compressive strength, water absorption, permeability, linear expansion, flammability, and color retention. The author had developed some materials for the above stated purpose.

These materials consisted of:

A. Inorganic graded aggregate of fuzed quartz and natural sands of grain size and color comparable to the grains of the original stone. Whereas the fuzed quartz helped reduce the coefficient of thermal expansion, the graded particles helped to modify these and other physical properties such as color, water absorption, permeability, etc. Limestone and marble grains were also used when such were the parent stones of the buildings.

B. Organic polymers for cementation. These polymers, used individually, were:

1. Fluoropolymer-B and an acrylic prepolymer
2. Fluoropolymer-B and methyl-methacrylate (MMA)
3. Bisphenol-A epoxy

The first cement hardened as a result of evaporation of the solvent, while the second and third polymers hardened by reaction with the curing agent. As a result, the first cementing medium needed longer times (several days) for hardening and produced lesser strength (e.g. Unaxial Compressive Strength of Ca 200 kg/cm^2).

The polymerization of MMA could be achieved only at high temperature (appx. 100°C), therefore the product no. 2 could be used for replacement structures for which an enclosed higher temperature environment could be provided. The product no. 3 was very easy to produce but had the inherent difficulty of discoloration due to absorption of ambient ultra violet radi-ation.

In practice, therefore, the patching material and replicas were made from inorganic aggregate and fluoropolymer-acrylic cement mixed in selected proportions. In case of replicas, fiberglass backing was also used. The following specifications were adopted. These properties (Table 4) were determined by methods given by American Society of Testing Materials (ASTM).

TABLE 4

Properties of the compound
for patching and replication.

Properties	ASTM Method	Values
Compressive Strength	C170-50	> 200 kg/cm^2
Modulus of Rupture	C99-52	> 50 kg/cm^2
Water Absorption	C97-47	< 4%
Permeability	C577-68	± 5 centidarcy
Color Retention	G25-70	1000 hrs. exposure; no color change.
Coefficient of Thermal Expansion	E228	$< 2.2 \times 10^{-6}$/C°
Burning Characteristics	E162-67	4-10 (Flame index)

Another testing procedure thought to be useful was the bond strength of the composite to the parent stone. This procedure was not included in the specifications, but in several experiments it had been determined that the bond strength of the above composite with the parent stone was more than the tensile strength of the composite.

In early 1975 the conservation treatment of the front of the California Building had been completed. This project, after due testing of specified properties and the aesthetic appearance, had then been approved by the City of San Diego.

CONCLUSIONS

The author of this paper was responsible for above specifications and the design of the treatment. In the period between the acceptance of the treatment design and the actual completion of the project several administrative and logistic changes had occurred in the execution of the project. The preceeding presentation, as a consequence, is based primarily on the author's notes and his conversations with an official of the contractor who was, during operations, in constant communication with the author. The preservation treatment was completed in early 1975. The author last visited the building in Summer 1976: the photograph of Plates 4&5 were taken at that time. The building appeared to be in a good state of preservation.

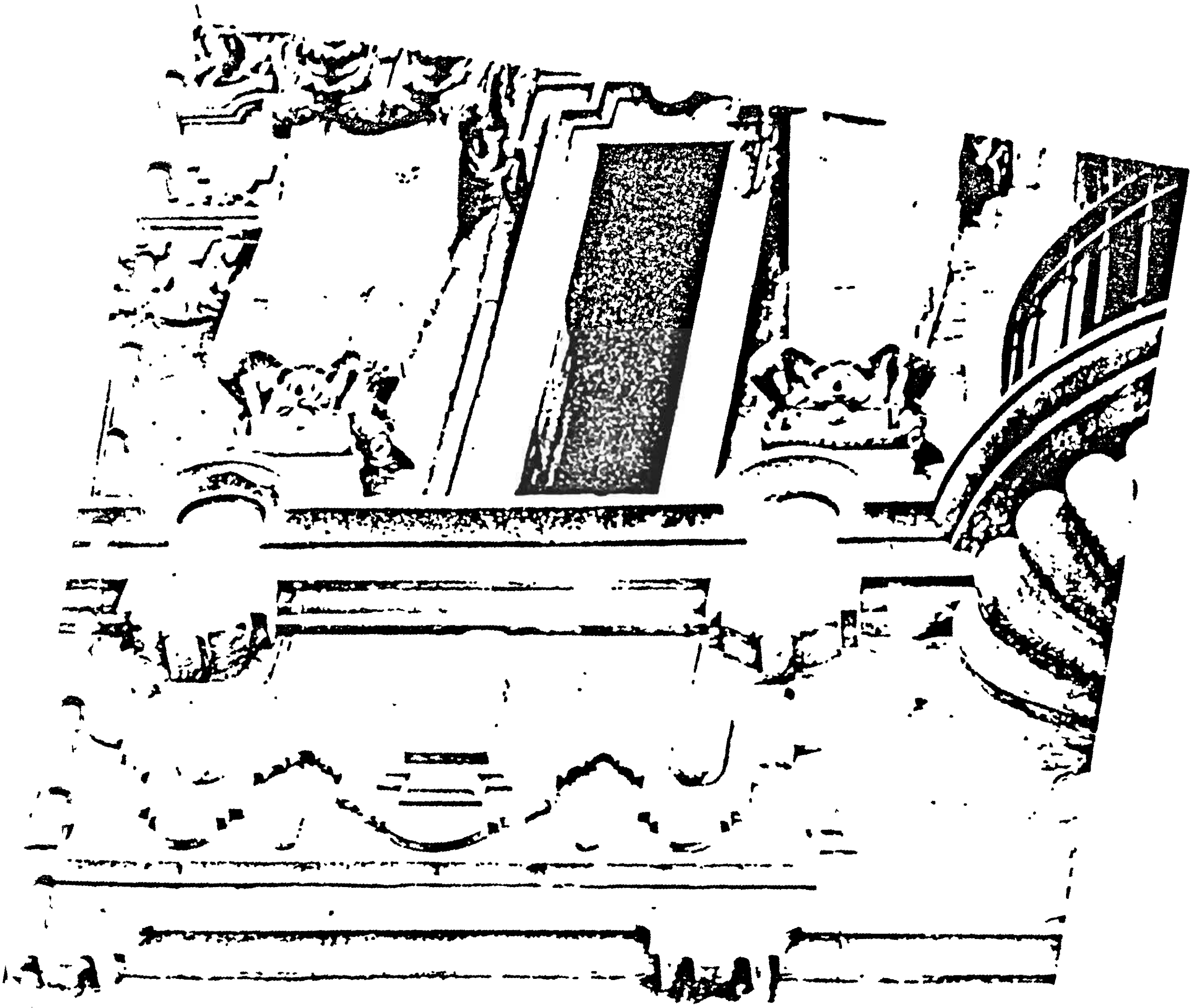
ACKNOWLEDGEMENTS

I would like to thank the citv of San Diego for the Plates 1-3.

Description of Plates

Plates 1-3. The facade of the California Building before treatment. Note the efflorescences and oxidized iron pins in Plate 1, fragmented portions and heaved surfaces in Plate 2 and the efflorescences, fragmented and cracked surfaces in Plate 3.

Plates 4&5. The facade of the California Building after treatment.



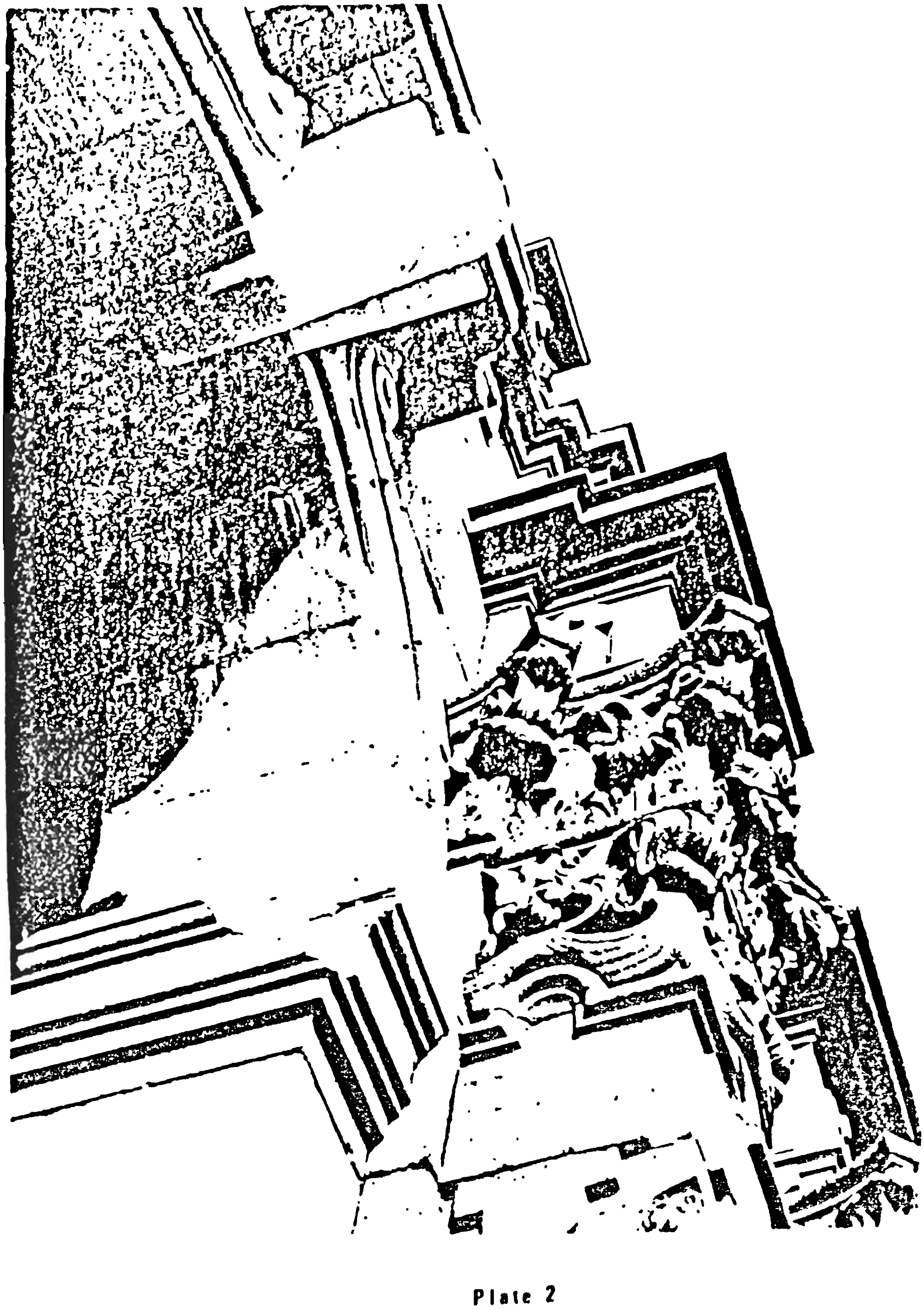


Plate 2

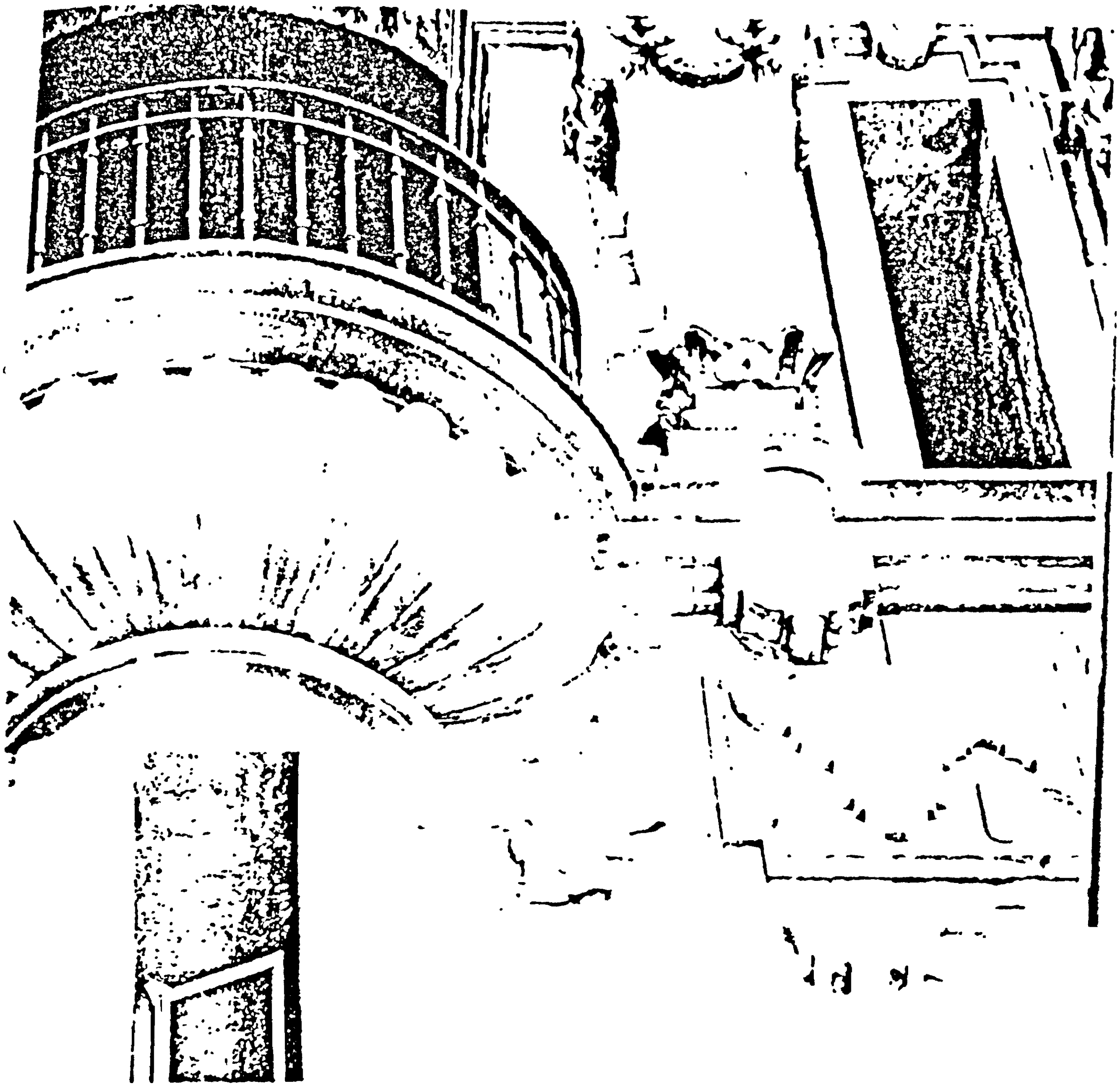
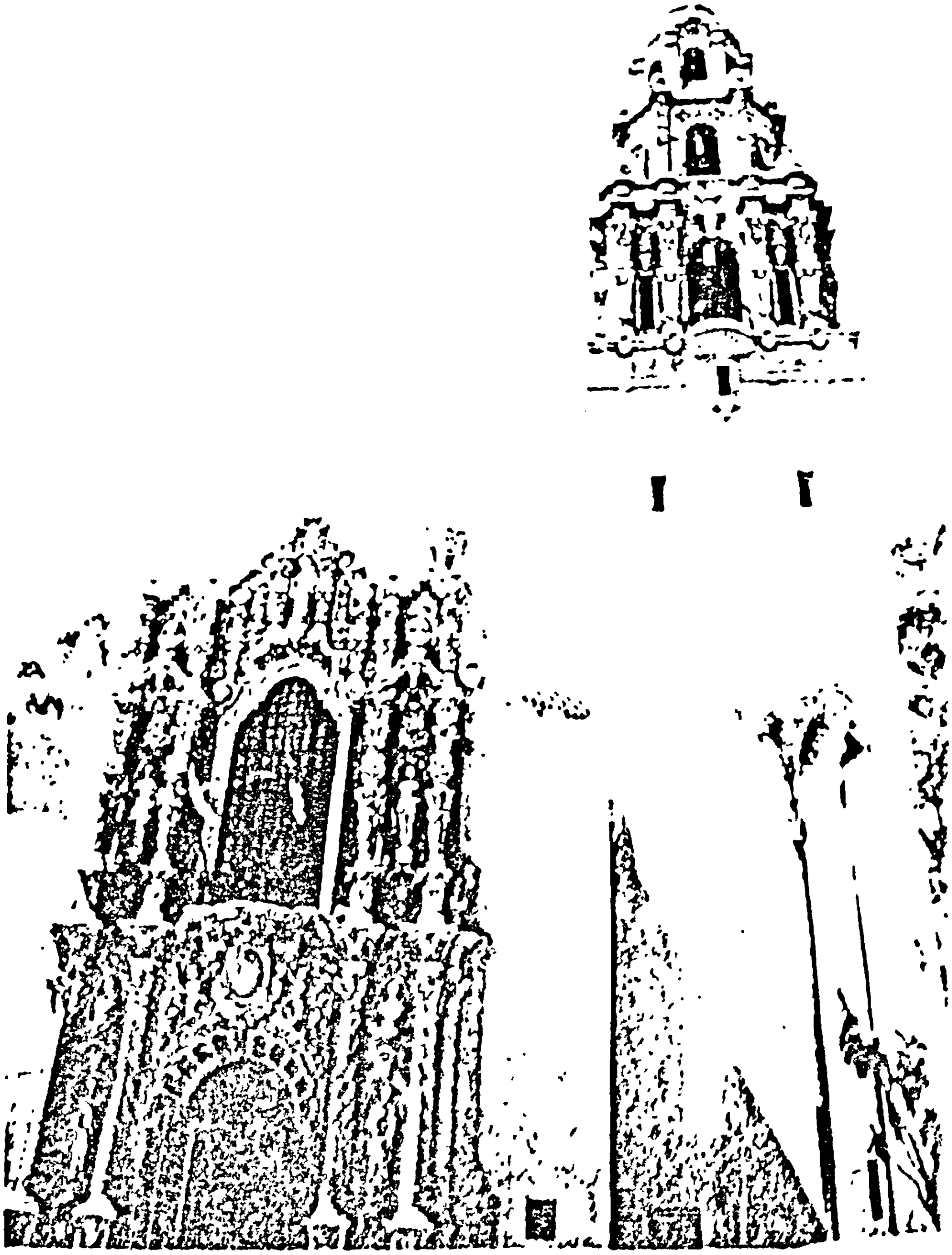


Plate 3

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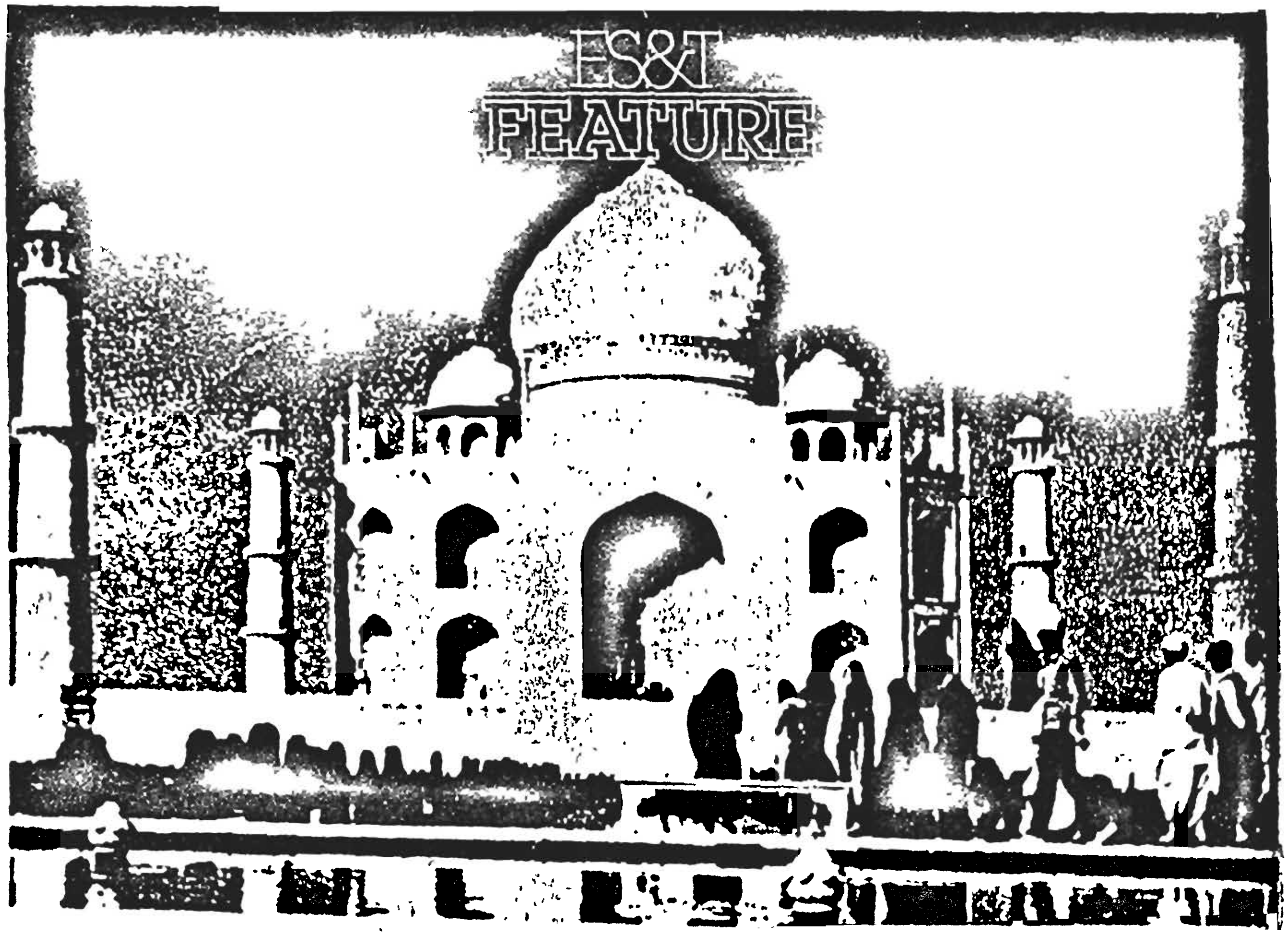

Pollutant effects on stone monuments

The outcome can be predicted with reasonable certainty

K. Lal Gauri
G. C. Holdren, Jr.
*University of Louisville
Louisville, Ky. 40292*

An oil refinery is being built nearly 30 km upwind from the Taj Mahal in Agra, India. This refinery is expected to emit 25–30 tons of sulfur dioxide daily, which is likely to travel towards the Taj Mahal from October to March due to the prevailing northwesterly winds (*1*). Such SO_2 emissions are expected to corrode the marble at the Taj Mahal in the same fashion that air pollution has contributed to the corrosion of marble at the nearly 70-year-old Field Museum of Natural History in Chicago.

Feature articles in ES&T have by-lines, represent the views of the authors, and are edited by the Washington staff. If you are interested in contributing an article, contact the managing editor.

In December 1978, the senior (first) author of this paper collected a few marble samples at the Taj Mahal to compare their condition with the marbles exposed at the Field Museum of Natural History in Chicago and the Erechtheion at the Acropolis in Athens. Knowledge of the mechanisms of marble decay enables the conclusion that the marble at the Taj Mahal—in the wake of the effluents of industrial combustion expected to pervade the environment of Agra—shall meet the same fate as the monuments of antiquity in industrial Europe and North America.

Of constituents produced by the combustion of fossil fuels, NO_x and SO_2 are the most potent for stone decay. During periods of dryness, they accumulate as particulate matter on stone surfaces and are activated by subsequent wetness. Dissolved in precipitation, they descend as acid solutions. In the eastern U.S., the acidity of precipitation has achieved a regional pH value below four (*2*). In the Los Angeles Basin, similar pH values exist due to acid nitrates (*3*).

Emissions rising from stationary sources are commonly deposited at considerable distances from their sources. The pollutants generated in the Ohio Valley (*4*), for instance, have significantly contributed to the acidity of precipitation in the northeastern U.S., just as Scandanavian precipitation has become contaminated with the emission effluents of Western Europe in the wake of prevailing westerly winds (*5*).

Precipitation in equilibrium with atmospheric CO_2, the natural cause of acidity, has a pH of 5.65. The weak carbonic acid (H_2CO_3) that forms by the dissolution of CO_2 in water has been, until recently, the major cause of marble decay. NO_x and SO_2 emissions, however, have increased the acidity of precipitation. The black crusts and crumbling stone on marble structures in industrialized regions are composed of calcium sulfate, nitrates, and organic particles. Some representative reactions of these emissions with the marble's calcite ($CaCO_3$)

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Figure 1A. The black crust, made of gypsum and soot, occurs in areas protected from rain. A portion of the crust is exfoliated at the site of the braids, obliterating details of the sculpture (Field Museum of Natural History, Chicago)

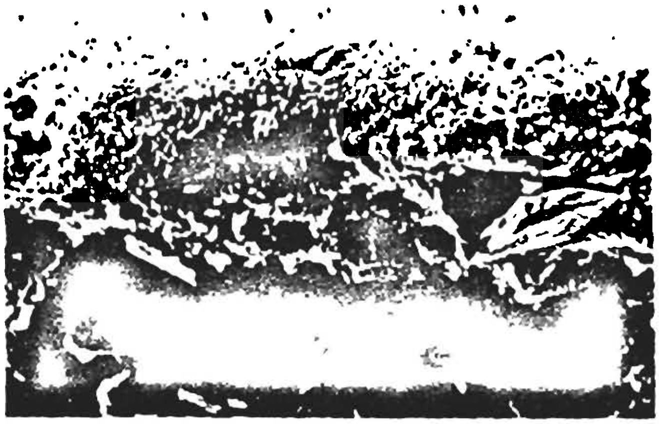

Figure 1B. The top one-fourth of this scanning electron micrograph shows the surface of the crust; beneath this is the entire thickness of the crust, followed by the calcite grains of marble, which is unaltered but has gypsum in the intergranular space

Figure 1C. An enlargement of the lower right corner of 1B shows the intercalated gypsum in continuity with the crust

may be written as follows:

$$CaCO_3 \xrightarrow[H_2O]{SO_2} CaSO_3 \cdot 1/2H_2O + CO_2$$
$$CaSO_3 \cdot 2H_2O + CO_2 \xrightarrow[H_2O]{O_2} CaSO_4 \cdot 2H_2O \quad (1)$$

$$CaCO_3 + SO_4^{2-} + 2H^+ + H_2O \rightarrow CaSO_4 \cdot 2H_2O + CO_2 \quad (2)$$

$$CaCO_3 + 2NO_3^- + 2H^+ \rightarrow Ca(NO_3)_2 + CO_2 + H_2O \quad (3)$$

Some of the gypsum ($CaSO_4 \cdot 2H_2O$) in solution is able to penetrate into the intergranular space (our methods of study—x-ray diffraction, and SEM and petrographic microscopy—have not enabled us to resolve $Ca(NO_3)_2$ as yet) while the rest is either washed away or deposited in the form of a crust on the marble surface (Figure 1). Such crusts are commonly found on stone underneath cornices and domes where the marble is protected from the direct impact of rain. Continued weathering behind these crusts causes them to fall off in layers, seriously damaging the structures (Figure 2).

In unprotected areas of buildings (those washed by rain), crusts are unable to form. However, acidic solutions freely migrate around the grains. The dissolution of calcite results in the grain-by-grain dissociation of marble. It may seem paradoxical, but marble in sheltered regions suffers more serious damage than marble in unprotected regions (Figure 2).

In crusted marble, the thickness of the zone of weathering—the region including the surface crust as well as the depth to which the gypsum has intercalated the intergranular space—varies with different marbles. This is controlled by the porosity characteristics of the marbles. Georgia marble is highly massive and contains bands of fine-grained minerals—probably clay minerals formed by the weathering of phlogopite, which occurs profusely in this marble. The zone of weathering of crusted Georgia marble is nearly 0.5 mm thick. A carrara-type marble, however, used in the construction of certain belt courses at the Field Museum, is more porous and lacks the secondary fine-grain minerals in the interstices. This permits a freer circulation of chemically active solutions through the pore space. As a result, the zone of weathering in this marble is much thicker, approaching a thickness of nearly 4 mm.

In unprotected, naturally cleaned surfaces, the zone of weathering lacks a definite identity. However, the enlarged space between calcite grains is clearly visible (Figure 3). Here, in fact, the thin zone of weathering is the region with enlarged intergranular space. X-ray diffraction and optical observations do not reveal any gypsum, but its presence has been confirmed by atomic absorption spectrophotometric analysis (Table 1). To obtain correlations between different samples, the ionic composition data, generated as mg/L of water-soluble species, is converted to weight percent of dry stone. This table reveals the trend of a

Figure 2. The angel under the dome is seriously damaged due to exfoliation of the crust; the angel outside the dome is in much better condition because of surface reduction of the marble caused by grain-by-grain dissociation of calcite (Cave Hill Cemetery, Louisville)

decreasing quantity of Ca^{2+}, NO_3^-, and SO_4^{2-} from crusted marble to naturally cleaned marble specimens.

The black crust on the marble surface at Field Museum contains as much as 13.6% Ca^{2+} and 20.4% SO_4^{2-}; however, the black soot on certain protected surfaces at the Taj Mahal (Table 2) contains only 0.6% Ca^{2+} and indeterminably small traces of SO_4^{2-}. X-ray diffraction reveals that gypsum and soot are the major constituents of the crust at the Field Museum while soot and quartz (SiO_2) are the main constituents of the black coating at the Taj Mahal.

The encrustation and marble specimens from the Taj Mahal for this study weighed a fraction of a gram. Although the general conclusions derived from them in terms of absence of SO_4^{2-} are correct, the following explanations for the distribution of other constituents are only speculative.

The ionic components of Specimens 1–3 (Table 2) seem to come from environmental dust, although some Ca^{2+} may be due to CO_2 reaction on marble. Data on Specimen 4, which has only trace quantities of these elements, lend credence to this supposition. This specimen is a clean marble chip devoid of any adhered environmental dust.

The moral is that the Taj Mahal, presently in a healthy state, will be affected by SO_2 emissions, over an extended period of time, in the same fashion as the Field Museum has been during its nearly 70 years of exposure. It is noteworthy that Chicago achieves 1.4 ppm SO_2 levels (*6*) while the air in Louisville, the site of the monuments in Figure 2, seldom exceeds 0.5 ppm SO_2. Although it is difficult to project the future levels of SO_2 in Agra, it may be assumed that the effects on the historic structure, envisaged to last for posterity, will be considerable.

Air pollution affects marble in more ways than those described above. The increased ionic concentration in marble, produced by direct deposition and by reactivity of calcite with chemically active gases, enhances decay. In regards to the Taj Mahal, this has twofold significance. Firstly, the anchoring iron bars, which have already fragmented the marble in various places (Figure 4), will, by accelerated rusting, cause further damage to the stone. Secondly, efflorescences in the sandstone used in construction around the Taj Mahal have already caused peeling of the surface layers of sandstone (Figure 5), and this will become more activated. These points are discussed in the following sections.

Rusting of iron bars. Iron bars and dowels, respectively, were used to attach marble blocks to the structural framework and to fasten adjacent blocks to each other. The bars near the surface have rusted, producing hydrous iron oxides. The increased volume attending change of iron into hydrous oxides has mechanically disrupted the stone (Figure 4). This fragmented stone has been artfully replaced with dutchmen (a term used in architectural jargon for artificially replaced stone in masonry structure).

The following equations give the chemical reactions (*6*) that iron undergoes due to SO_2 pollution:

$$4Fe + 4H_2SO_4 + 2O_2 \rightarrow 4FeSO_4 + 4H_2O \quad (4)$$

$$4FeSO_4 + O_2 + 6H_2O \rightarrow 4FeO \cdot OH + 4H_2SO_4 \quad (5)$$

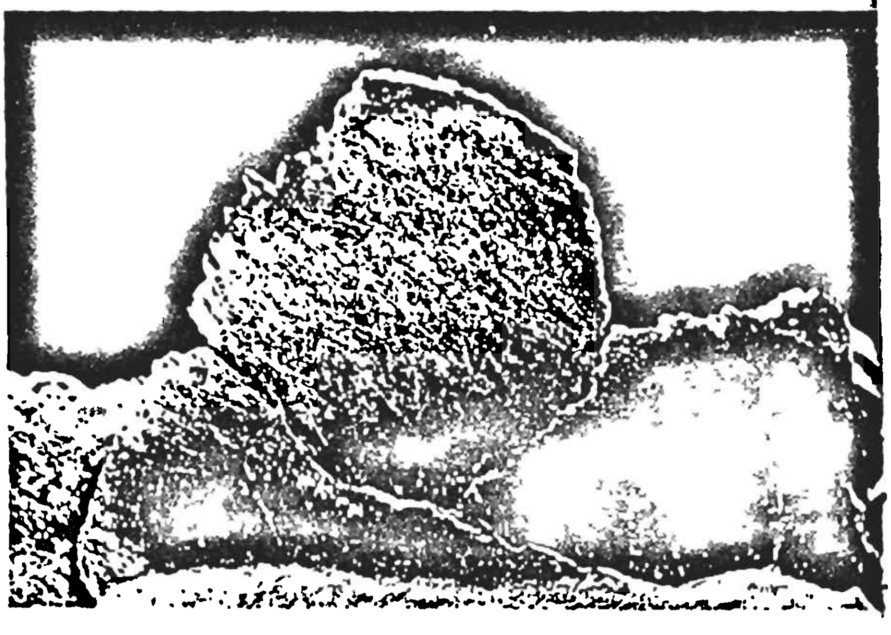

Figure 3. Individual grains in this specimen of weathered Georgia marble have been dissociated due to enlargement of the intergranular space (Cave Hill Cemetery)

although no soluble iron was detected ... samples made for this study (Ta- ... an... 3), these equations suggest ... reactions will continue to change the iron into hydrous oxides. It may ... be projected that the enhanced ... terioration of iron bars and contin- ... d replacement of fragmented marble ... ll eventually convert the entire fa- ... de of the Taj Mahal into a mosaic of ... tchmen

Efflorescences Efflorescences on ... sandstone surfaces around the Taj ... ahal consist of whitish, patchy encrustations of gypsum (Figure 5), which was deposited contemporaneously with the formation of the sandstone. Initially, the gypsum was uniformly dispersed in the sandstone, but centuries of wetting followed by evaporation of water at the surface has concentrated these salts at the surface and in the subsurface regions.

The efflorescences, being water-soluble, repeatedly dissolve and recrystallize in the alternating episodes of wetness and dryness of the stone. Thermodynamics suggest that enormous pressures are generated in such processes. For instance, gypsum crystallizing from a 10X supersaturated solution at 50 °C generates a pressure of 334 atmospheres (*7*). While such supersaturation conditions do not exist in the pore space of sandstone, the repeated crystallization over long periods of time has resulted in failure of the stone and creation of hollow patches.

Table 3 shows the ionic composition of sandstone specimens with visible whitish efflorescence. Although x-ray diffraction analysis reveals only the

TABLE 1

Ionic composition of weathered marble at the Field Museum of Natural History, Chicago (concentrations of water soluble species, wt % of dry sample)

Specimen [a]	Na^+	K^+	Mg^{2+}	Ca^{2+}	NO_3^-	SO_4^{2-}
1	0.144	0.213	0.062	13.6	0.264	20.39
2	0.035	0.005	0.010	0.825	0.073	1.20
3	0.159	0.018	0.0[illegible]	1.05	0.075	0.24
4	0.160	0.092	0.020	12.6	0.260	0.46
5	0.123	0.015	0.031	1.72	0.031	0.46
6	0.032	0.003	0.001	0.464	0.006	0.096
7	0.206	0.022	0.033	2.74	0.043	3.04
8	0.010	0.001	0.003	0.188	0.033	0.074

[a] 1–3—From a cornice drip made of carrara marble; (1) scraping from black crusted protected surface, (2) scraping from partially protected brown surface, (3) scraping from unprotected surface.
4–6—From a cornice drip made of Georgia marble: (4) scraping from black crusted protected surface, (5) scraping from partially protected brown surface, (6) scraping from unprotected surface.
7—Scraping from partially protected area under the portico at ground level.
8—Scraping from unprotected surface at ground level.

TABLE 2

Ionic composition of samples from the Taj Mahal (concentrations of water-soluble species, wt % of dry sample)

Specimen [a]	Na^+	K^+	Mg^{2+}	Ca^{2+}	NO_3^-	SO_4^{2-}
1	0.07	0.18	0.14	1.80	LDL [b]	LDL
2	2.33	2.33	1.00	14.00	2.67	LDL
3	0.20	0.53	0.42	4.68	LDL	LDL
4	0.30	0.04	—	0.63	LDL	LDL

1—Soot on marble surface but not directly in contact with marble.
2—Soot in contact with marble.
3—Sooty marble surface
4—Chip fragmented from marble along a fracture.
Concentration lower than detection limit.

TABLE 3

Ionic composition of efflorescences on sandstone structures around the Taj Mahal (concentrations of water-soluble species, wt % of dry sample)

[a]	Na^+	K^+	Mg^{2+}	Ca^{2+}	NO_3^-	SO_4^{2-}
1	1.26	0.75	0.002	0.21	0.22	0.51
2	0.07	0.07	0.025	0.78	0.28	0.30

1—Efflorescence from sandstone inside courtyard.
2—Efflorescence from sandstone outside courtyard.

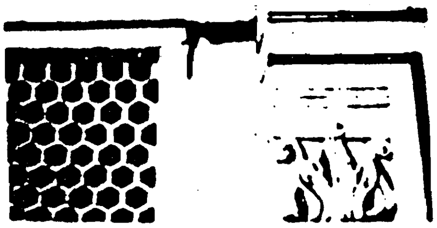

Figure 4. The iron pin visible in the central portion of the figure has rusted and caused a fragment of marble to dislodge. Note that the carvings around this area are in excellent condition due to the absence of SO_2 in the atmosphere (Taj Mahal, Agra)

Figure 5. Effluorescences in the sandstone are visible here as white patches. The frontal portion is more severely weathered because of more frequent episodes of wetting and drying, causing repeated crystallization of the gypsum (Taj Mahal)

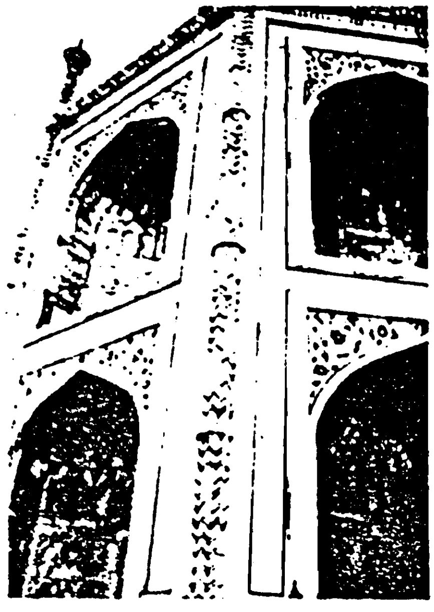

Figure 6. The surface of the marble under the arches is brownish due to the deposition of soot, firmly embedded in the surface layer. Chemically, the marble is otherwise in excellent condition (Taj Mahal)

presence of gypsum (besides the mineral composition of the sandstone), atomic absorption data suggest that some complex sodium salts may also be present. The large quantity of NO_3^- in these specimens may be of cultural origin. The emission of particulate matter from refinery emissions will make these potentially hazardous salts even more dangerous by facilitating their migration and their consequent accumulation near the stone surfaces.

Existing technology lacks proven methods for preserving stone structures containing gypsum in the zone of weathering (*8*). Because gypsum commonly accumulates on sculpture heads, some works are defaced during gypsum removal. At the International Meeting on the Restoration of the Erechtheion (*9*), methods were suggested to convert gypsum, in situ, to $CaCO_3$ by reaction with CO_2 in an autoclave at high pressure and temperature. It was also proposed that the gypsum be transformed to $BaSO_4$ by reaction with $Ba(OH)_2$. Polymeric treatments were discussed, but the degree of development of these methods does not promise complete success and therefore further research is essential. Following decisions at this meeting, the caryatids have now been moved from the Acropolis into a museum.

Cleaning the Taj Mahal is a relatively simple matter. The brownish discolorations under arches at the Taj (Figure 6) are presumably only environmental dust adhering with recrystallized calcite formed by CO_2 reaction with marble; these encrustations should be mechanically removed. Fine abrasives should be used to polish the marble surface. Such an operation should, in addition to removing dirt, give a polish to the marble, increasing its water repellency. The cleaned marble surfaces then should be washed regularly with water to prevent crusting. After cleaning, the marble may be given a surface treatment with polymeric materials, which act as semipermeable membranes (they do not absorb atmospheric gases) and are resistant to UV radiation (*10*). Calcite grains mixed in such polymers may be forced into cracks caused by the expansion of iron attachments to inhibit the movement of water into the stone.

The sandstone structures, however, need optimal removal of efflorescences and consolidation to improve strength and water-repellency (*11*).

In closing, now is the time to consider the consequences of allowing industrial pollutants in the vicinity of such architectural treasures as the Taj Mahal. The extra cost of relocation of pollution control devices may well be justified in cases, such as these, when a discouraging outcome can be predicted with reasonable certainty.

Acknowledgment

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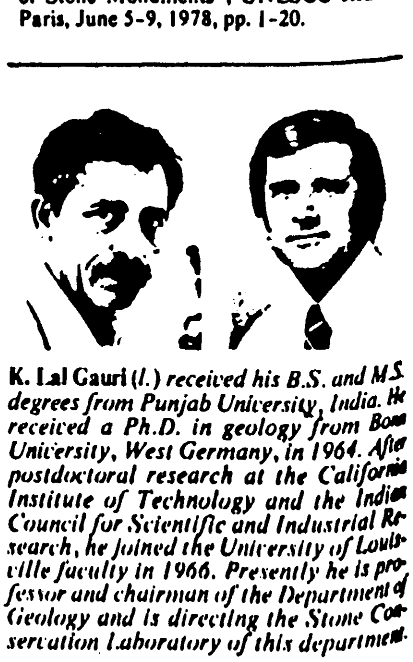
References

(1) Watts, G. *News & Cine, India*, 1979, Feb 9, 12.
(2) Likens, G. E. *Chem. Eng. News* 1976, *54*(48), 29.
(3) Liljestrand, H. M.; Morgan, J. J. *Environ. Sci. Technol.* 1978, *12*, 1271-73.
(4) Galvin, P. J.; Smason, P. J.; Coffey, P. E.; Romano, D. *Environ. Sci. Technol.* 1978, *12*, 580-84.
(5) Dovland, H.; Jaranger, E.; Semb, A. In "Impact of Acid Precipitation on Forest and Freshwater Ecosystems in Norway", F. H. Braekke, Ed.; SNSF project: NISK, 1432 Aas-NLH, Norway, 1976, 111 pp.
(6) Kucera, V. *Ambio* 1976, *5*, 243-48.
(7) Winkler, E. M.; Singer, P. C. *Geol. Soc. Am. Bull.* *83*, 3509-13.
(8) Yocom, J. E. *J. Air Pollut. Control Assoc.* 1979, *29*, 333-38.
(9) "Report of the International Meeting on the Restoration of the Erechtheion"; Greek Ministry of Culture and Sciences and UNESCO Athens, Greece, Aug. 8-10, 1977, 46 pp.
(10) Gauri, K. L. *Sci. Am.* 1978, *June*, 126-36.
(11) Gauri, K. L. In "Proc. International Symposium on Deterioration and Protection of Stone Monuments"; UNESCO RILEM Paris, June 5-9, 1978, pp. 1-20.



K. Lal Gauri (*l.*) *received his B.S. and M.S. degrees from Punjab University, India. He received a Ph.D. in geology from Bonn University, West Germany, in 1964. After postdoctoral research at the California Institute of Technology and the Indian Council for Scientific and Industrial Research, he joined the University of Louisville faculty in 1966. Presently he is professor and chairman of the Department of Geology and is directing the Stone Conservation Laboratory of this department.*

G. C. Holdren, Jr., (*r.*) *received a B.S. in chemistry at the University of Nebraska in 1971 and an M.S. (1974) and Ph.D. (1977) in water chemistry at the University of Wisconsin. He currently has a joint appointment as assistant research professor in the Water Resources Laboratory and assistant professor of chemical and environmental engineering at the University of Louisville.*

A STUDY ON MINERALOGY AND MICROSTRUCTURE OF BUILDING MATERIAL COMPONENTS OF VICTORIA MEMORIAL MONUMENT CALCUTTA.

1. INTRODUCTION :

A project on 'Air-quality studies and protection of Monument Victoria Memorial Hall, Calcutta (Project No.C-189)' has been undertaken by NEERI, Nagpur. A request from Zonal Laboratory, NEERI, Calcutta, was made to the Director, CGCRI, Calcutta, to extend the facilities regarding equipment and scientists available in CGCRI, for completion of a part of the above mentioned project. Director, CGCRI, agreed to extend facilities regarding testing of samples and interpretation of results by the scientists who will be considered as participating scientists (Vide letter No. CZL/VM/90/650 dated November 02, 1990).

The above project has a definite aim and objective - the effect of air-quality around Victoria Memorial Monument on the deterioration of the monument. In view of the above objective, the work assigned to CGCRI dealt with the study of microstructure and mineralogy of rocks and cementing stones which comprise the principal building material components of Victoria Memorial Monument.

2. SCOPE OF WORK :

The work assigned to CGCRI has the following scope of work :

1. Physical examination of rocks in situ.

2. Sampling from rocks/stones of the monument.
3. Study of rocks samples under optical microscope.
4. Study of porosity and pore size distribution of the samples.
5. Study of mineral phases present in the samples by XRD method.
6. Morphological study of the samples by SEM analysis.

3. PHYSICAL EXAMINATION :

The outside wall of the monument is made entirely of white marbles which are joined with mortars. These marbles have been subjected to weathering for eighty years. Inside the monument, the walls of the main hall and other rooms are made with light brown sand-stones. All the staircases inside the monument are built with sand-stone. The lower portion of the outside wall of the domes and arches, upto the height of one metre from the floor of the balcony are also made with sand-stone which has been exposed to weathering. Physical examination of these marbles, mortars and sand-stones revealed that some alterations had taken place locally. The alterations/ deterioration in the stones of the monument are classified as follows :

Marble :

a) Black patches or patina.
b) Yellow or cream coloured patches.
c) Green patches or patina - where copper plates were retained within the structure.

Sand-stone :

a) White patches or white patina.

b) Black patches or black patina.

c) Exfoliation with/without light brown ferruginous incrustations.

d) Efflorescence in places on the surface.

Mortar :

a) Green patches or patina - where copper plates were retained within the structure.

b) Mortars used in between two marble blocks have eroded away in parts where it is exposed to weathering.

4. SAMPLING :

To obtain proper precise information about the mineralogy and microstructure of the rock samples, suitable and representative specimens of proper size (i.e. 4" x 3" x 1" or 3" x 2" x 1") should be collected and labelled properly [A Text Book of Geology - P.K. Mukherjee, The World Press (Pvt.) Ltd., Calcutta (1980)].

However, it is difficult to collect representative samples of proper size from the stones/rocks with which the whole structure of the building was made without causing damage to the building structure. Most of the samples were collected from unprotected areas of the monument i.e. areas subjected to weathering. Sampling could not be done from inaccessible portions of the building. Samples were collected in the following ways:

1. Chips of marble taken from the weak portion where cracks have been developed.
2. Marble dust scrapped by wire-brush from marble surface.
3. Black patina taken by scalpel from marble.
4. Thin layers of samples taken from the exfoliated zone of sandstone.
5. Sandstone with white efflorescence taken by scalpel.
6. Sandstone with black patina taken by scalpel.
7. Chips taken after breaking the marble block actually used in maintenance work.
8. Samples of mortar taken from loose joints in between marble blocks, where much erosion had taken place.

5. PETROGRAPHIC AND MINERALOGICAL ANALYSIS (UNDER OPTICAL MICROSCOPE)

Marbles :

Marble is commonly a light coloured metamorphic rock in which calcite is the chief constituent and dolomite is frequently associated with it. Its texture is generally massive and granular.

Marble chips collected along cracks and joints occurring on the surface blocks were examined under a polarising microscope. Marble chips essentially consist of calcite, as a major mineral and muscovite and quartz as minor minerals. Most of the calcite grains are irregular having variable grain sizes. In places large angular or irregular grains of calcite occur within the groundmass of fine calcite grains. Remarkable textural variations within the marble samples rarely occur, except in coarseness and fineness Typical mosaic textures of marble, with more or less equant grains of calcite were found in a few samples, viz., virgin samples of Makrana marble. Prismatic and irregular flakes of muscovite of variable sizes and a few small grains of quartz occur as inclusions within calcite grains. Scrapping samples in the form of powder collected from different places, viz., black patina, white patina etc. were also examined under the optical microscope. Scrappings from black patina zone contain angular grains of small calcite and brownish/greenish rounded material clustered together. These materials may be organic materials deposited over the surface of marble. Minute black carbonaceous material were seen scattered within the powder samples. The occurrence of gypsum in marble chips and scrappings were not detected in petrographic study. The photomicrographs of marble samples were shown in figures 1 to 6.

Mortar :

Mortars from the joints of marble blocks have become loose in most of the places. These were collected for petrographic analysis.

Mortars essentially consists of small angular to irregular calcite grains and a few small angular quartz grains bonded with fine calcareous materials (probably lime or CaO). These mortars contain rounded pores of different sizes which in places are filled with small gypsum grains (Fig. 7 & 8). The occurrence of gypsum is also confirmed by x-ray analysis (sample No. 3, 24 etc.). Mortars collected near black patina zone contain fine black particles probably of carbonaceous materials. Overall texture of mortars are shown in figures 9 & 10. Quantitative estimation of gypsum in mortar was carried out with the help of micrometer scale under polarising microscope. The results show approximately 2% gypsum in the studied samples.

Sandstone :

Standstone is a sedimentary rock in which quartz is much the commonest mineral with occasional presence of felspar (usually Kaolinised) and fragments of other minerals. It has low to medium specific gravity and different shades of colour.

Sandstone occurring at different place has become exfoliated at the surface in most weathered places. Formation of white and black patina over the surface of sandstone blocks were also seen in places and samples were taken from these areas.

Exfoliated samples of sandstone essentially consist of rounded to sub-rounded grains of quartz cemented with siliceous clayey material (Fig. 12). Minute brownish ferrugious material also occur along with clayey materials (Fig. 11). Minute rounded greenish materials occurring in clustered form occurs in patches over quartz grains. These may be secondary deposition of organic masses. Sandstones contains minute pores. The occurrence of gypsum within sandstone was not detected.

6. PORE SIZE DISTRIBUTION :

Samples of marble, sandstone and mortar collected from the monument were tested in Autoscan Mercury Instrusion Porosimeter (Model 60 k) made by Quantachrome of USA.

Mercury is forced to intrude into the open pores of the samples by applying pressure for which high pressure is required to intrude into the lower size of pores. The radius is inversely proportional to the pressure applied which follows

Washburn equation :

$$P = \pm 2\gamma \cos \phi / r$$

where P = Pressure

γ = Surface tension of mercury

ϕ = Contact angle

r = Radius of pore

Results :

Marble : No open pores were found in the samples of marble i.e. apparent porosity in nearly zero.

Sandstone: Some variations in the distribution of pores are found in different samples of sandstones. Samples showing much erosion with exfoliation show A.P. 23.19%. In this samples 50% of the total open pores were below 0.40 microns whereas sandstone with white patina, but not with exfoliation showed A.P. 10.18%. In this sample 50% of the total open pore were below 0.55 microns. The sandstone in other place showing A.P. 7.91% have 50% of the total open pores below 0.17 microns. This sandstone showed less weathering.

Mortar: Generally mortars (Mkd. 2 & 24) showed A.P. within the range of 10-12% except the sample with green patina which showed 18.6% A.P. and larger pore radius also(Fig.14,15,16) Higher apparent porosity and pore size might be the cause of high penetration of green copper sulphate solution into this particular mortar which was used in the structure where copper plate was put inside the structure during construction of the building.

Salient features based on the observations through optical microscope and pore size distribution.

1. Marbles were generally hard and compact with no porosity. These were essentially composed of calcite grains of different sizes with minor presence of muscovite and quartz occurring as inclusions within marble. The occurrence of gypsum was not detected within marbles. Deposition of organic masses over the surface of marbles were very frequently observed. Deposition of carbon particles was very less in quantity.

2. Sandstones were essentially composed of quartz with silicous and clayey cementing material. Sandstones were very prone to weathering and exfoliation. It showed a wide range of porosity 7-23% which was responsible for exfoliation due to weathering. Deposition of organic mass was also seen over the surface of sandstone.

3. Mortars consisted of small grains of calciate in major amount and quartz in lesser amount cemented with calcareous cement. Mortars showed porosity in the range of 10-12% though higher porosity was also observed in places. Within the pores of mortars deposition of gypsum was observed in places.

7. X-RAY DIFFRACTION STUDY :

X-ray difractometer is an essential tool for mineralogical studies. In addition to petrographic analysis XRD analysis have been done as confirmative test for identification of mineral phases present in the rock samples.

The analysis has been carried out in Philips XRD generator (Model No. PW 1734). XRD tube was run at 40 KV 20 mA using CuKα radiation with the help of nickel filter.

Difractometer run off all the ground samples (-325 mesh) were taken under the above condition at 2° per minute (chart drive). dÅ value of each peak has been taken from the standard chart. Therefore all the diffraction peaks were analysed by finger print method with the help of J C P D S card index.

8. RESULTS & DISCUSSIONS :

It is evident from Table I that in marble calcite occurs as the major mineral. Quartz, dolomite, mica, gypsum and opaque minerals have been identified as minor minerals. Among these minor minerals gypsum and opaque minerals are not the constitutional minerals of marble. Minor constitutional minerals have also been identified by petrographic analysis. In case of sandstone constitutional minerals are quartz and clay. Mortar contains calcite as major mineral and quartz, gypsum as minor mineral. The deposition of gypsum in the pores of mortar is seen in photomicrographs taken after petrographic analysis :

TABLE - I

(Mineral phases present in the Sample)

Type of Samples	Nos. of Samples	Sample Marked	Mineral Phases Major	Minor
Marble	9	3	Calcite	Gypsum, Dolomite, Quartz
		4	Calcite	Quartz, Dolomite
		6	Calcite	Quartz
		14	Calcite	Gypsum, Quartz
		18	Calcite	Unidentified opaque mineral
		22	Calcite	Mica, Quartz, Beryl, Opaque mineral
		23	Calcite	Dolomite, Opaque mineral
		26	Calcite	Gypsum, Quartz, Dolomite, Beryl
		27	Calcite	Dolomite
Sandstone	3	10	Quartz	Kaolinite, Gypsum, Calcite
		12(a)	Quartz	Kaolinite, Gypsum, Calcite
		16	Quartz	Kaolinite
Mortar	3	2	Calcite	Unidentified opaque mineral
		13	Calcite	Quartz, Gypsum

8. S E M ANALYSIS :

Morphological examination by Scanning Electron Microscope (S E M) was carried out, because SEM with appropriate coating techniques and sample preparation allows for high magnification of material structure (10,000 times). Morphological study by SEM is helpful for identification of mineral phases present within the samples.

The present samples were analysed with Scanning Electron Microscope (Hitachi S-415A) coupled with IB-2 Ion Coater. Sample preparations were made with gold coating on the surface of the samples. SEM micrographs of marble chips show large crystals of calcite with cleavage layers (seen just like staircase (Fig. 17, 18). No occurrence of gypsum within the intergranular spaces of calcite was observed. Photograph of marble powder obtained by scrapping the outer surface of the marble blocks of the building did not show the occurrence of gypsum.

S E M photographs of sanstone revealed large irregular pores with granular quartz grains (Fig. 19, 20).

9. CONCLUSIONS :

Based on the part of job assigned to CG&CRI, the following conclusion is drawn :

1. Physical observations revealed that mortars in between marble slabs have loosened and eroded away in most of the places which was subjected to weathering. Wide gaps (upto 5 mm) prevail in some places due to erosion of mortars.

2. The copper plates within the structure where exposed to weathering results in green patina or patches over the surface of white marble and its jointing mortars. The anchoring iron bars have accelerated rusting, forming reddish brown patches over sandstone and marble in places where water seepage had taken place.

3. Deterioration of sandstone is localized, and identified as exfoliation, incrustation and efflorescence. Of these, the exfoliation was much observed over the surface of the sandstone which came in contact with rain water, or where chances of water seepage was much more.

4. Deterioration of marble blocks are much less. However, black patina is very common in places, specially below the domes and arches where blasts of rain water directly fall on it. Examination of marble dust obtained by scrapping black patina over marble blocks revealed the presence of black particles, may be of carbon particles, and subrounded greenish clustered mass may be of organic origin. Green patina was observed locally and it was formed due to formation of copper sulphate. Microscopic observations of marble did not show any alteration of calcite grains and occurrence of gypsum within it.

5. Physical examination of mortars at joints in between marble blocks showed much erosion of mortars in most of the places. These mortars showed high porosity (10-20%) determined with the help of mercury porosimeter. Optical microscopic study and SEM analysis revealed the presence of gypsum within the pores of the mortar. Quantitative estimation of gypsum within mortars showed the occurrence of 2% gypsum (Approx.) in the studied samples.

10. RECOMMENDATIONS :

Deterioration of building materials is an unavoidable process. Like cement and concrete, stone also deteriorates as a function of time. This is termed "natural deterioration". Rapid industrialization, however, can accentuate the deteriorative process. Though no industry is present around the monument, auto exhaust fumes is a major source of SO_2 in the atmosphere. Its oxidation to sulphate state, followed by its deposition as sulphate minerals is a well known phenomenon.

In the case of Victoria Memorial Monument, the building appears to be affected by both these forms of deteriation. Sea breeze from the Bay of Bengal from SW direction is the principal source of natural deterioration. The salt (halite or NaCl) contained in the breeze has caused slight pitting on the surface of marble blocks. Nevertheless, the redeeming feature of this type of erosion caused by rain water and wind, is an extremely slow process,and can extend to hundreds of years to manifest any form of major deterioration.

Chemical attack on the other hand can be much more severe and can deteriorate a structure within a very short span of time. The appearance of different coloured patinas, though localized, and the disjointing of marble-mortar interfaces is a positive indication of deterioration due to chemical agents.

Following site inspection by a team of Scientists comprising of CGCRI and NEERI, the following recommendations are made. It may be mentioned here that this team has been assisted by Prof. S.L. Sarkar of University of Sherbrook, Canada. Prof. Sarkar was then visiting CGCRI under a TOKTEN Programme on building materials.

Though Victoria Memorial Monument is still in healthy state, immediate protection of the monument from environmental pollution and weathering is mandatory to prevent further deterioration.

Recommendation may be classified into two categories :

(I) Immediate protection

(II) Long term protection

(I) IMMEDIATE PROTECTION :

a) MORTAR REPAIR

i) Immediate filling of the joints in between the marble blocks is needed.

ii) Thorough cleaning of joints to remove all loose mortar or debris by scraping, followed by water jetting.

iii) Infilling of the joints by conventional mortars should be avoided, because its porosity is high enough to make room for the deposition of deteriorative minerals within it, and its mismatching co-efficient of thermal expansion with marble.

Infilling of joints by low viscosity latex modified white portland cement with marble dust additives (-100 mesh) is strongly recommended. It should be pressure injected in slurry form . by means of syringes. This type of filling material has an advantage due to its less formation of shrinkage cracks, low water absorption and high elastic absorption properties.

Surface finishing of joints is much needed, because yellow colouration from the latex may appear after a few years. This may be done by hand pressing of lime and marble dust mixture in paste form.

It is further recommended that the latex (30-40% of total composition) should be tested at CG&CRI before application. Stone masons employed to do this delicate repair job should be thoroughly skilled.

b) SANDSTONE REPAIR

Deterioration of sandstone is localized and noted as exfoliation, incrustation and efflorescence.

The recommended mode of repairing job should be carried out by thorough cleaning with the help of water jet, preferably with hot water. The use of soap solution must be avoided.

Further detailed investigation should be carried out on the drainage pattern on the roof, because localised efflorescence is associated with improper drainage which leads to seepage inside the structure.

c) MARBLE REPAIR

Deteriorations of marble blocks are generally identified as formation of different coloured patches or patina on the outersurface of the block.

Green patina occurs where copper plates are used within the structure, resulting in the formation of copper sulphate solution which shows green colouration.

Green patina should be removed by light abrasion. It is strongly recommended that no chemical, specially acidic media should be used. After removal of the patina projective layer may be given at the joints or gaps where copper plates exist.

The black patina over the surface of marble block may be removed also by light abrasion followed by washing with water jet.

II. LONG TERM PROTECTION :

As a long-term preventive measure, the development of a green belt around the structure for reducing air pollution may be created.

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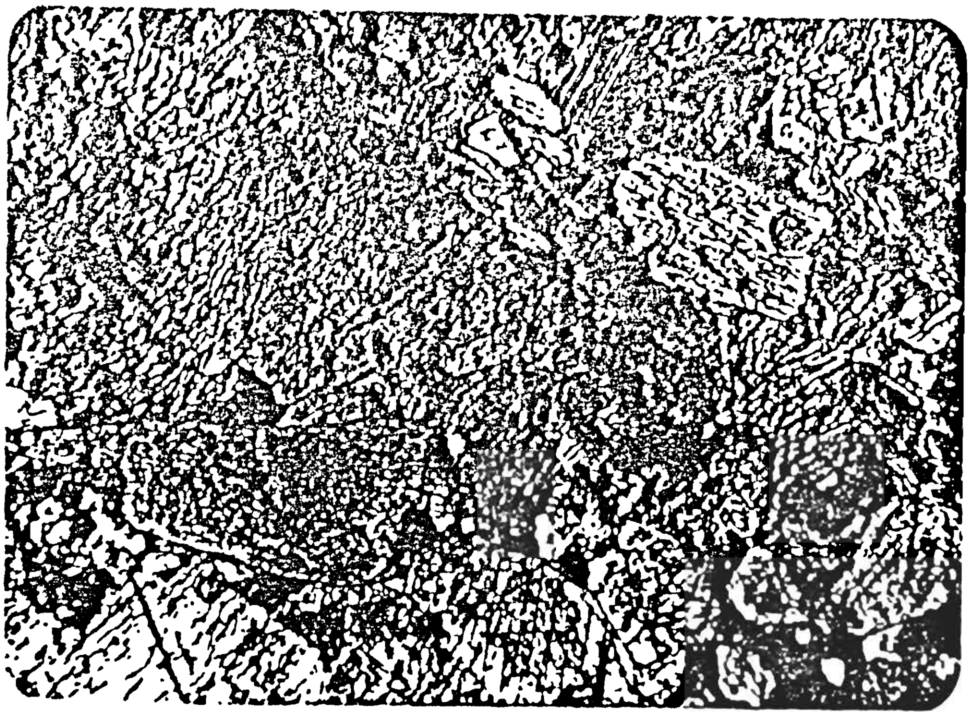
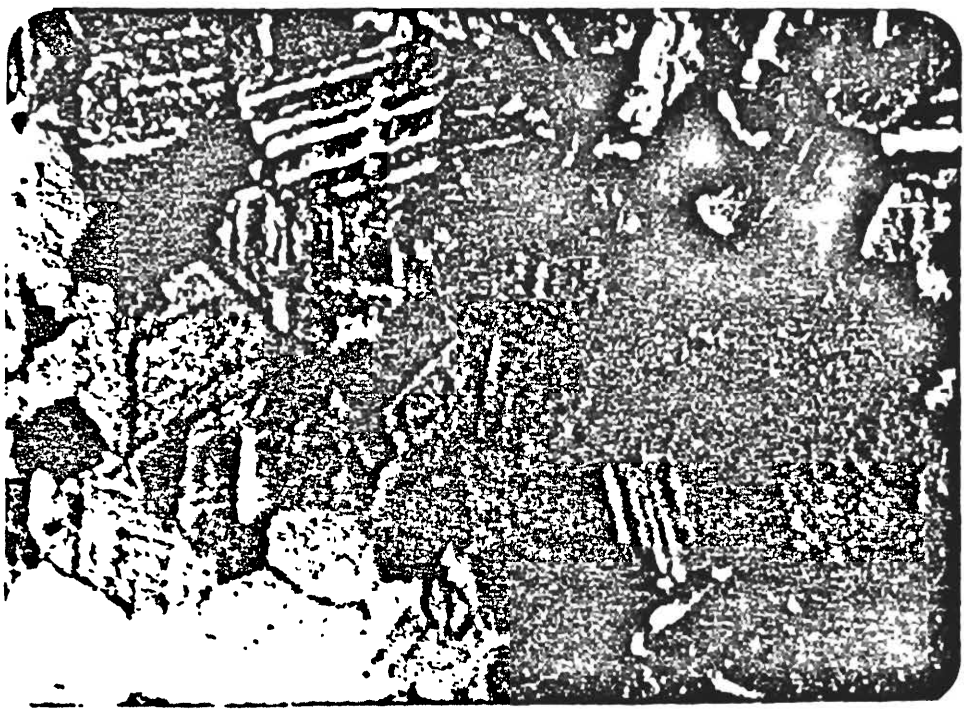


Fig. 1 Inclusions of muscovite flakes within marble. Crossnicol x25

Fig. 2 Inclusions of quartz within marble. Crossnicol x 25

Fig. 3 Inclusions of muscovite within marble.
Crossnicol x 25



--Fig. 4 Mosaic toxture shown by calcite grains
in marblo Crossnicol x 25

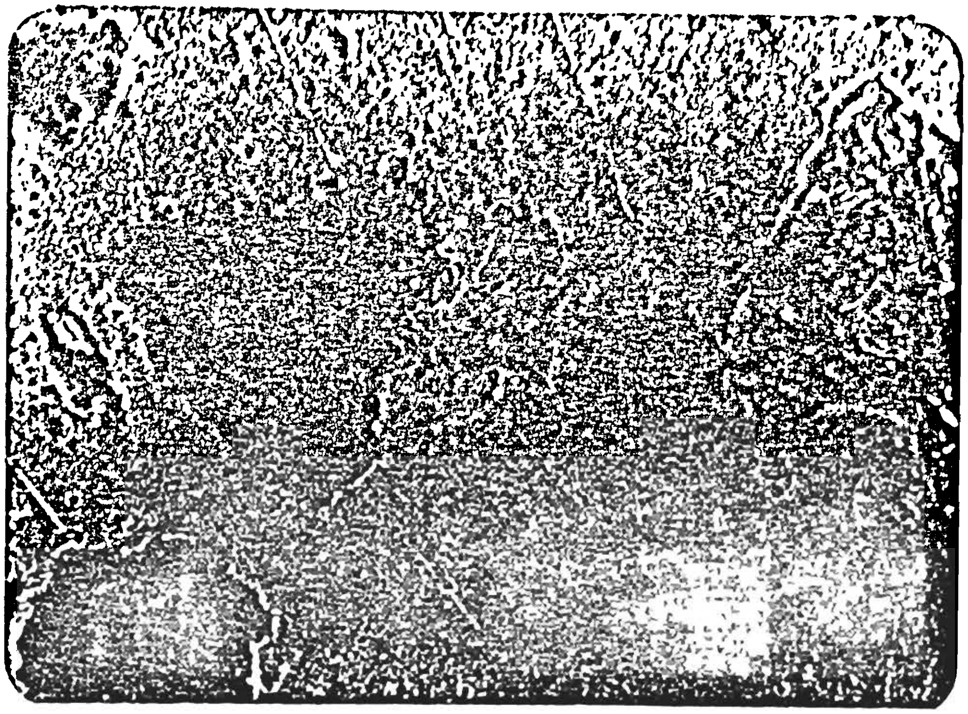


Fig. 5 Brownish/Greenish black rounded clustered material associated with calcite grains within marble dust. Plane Pol x 160

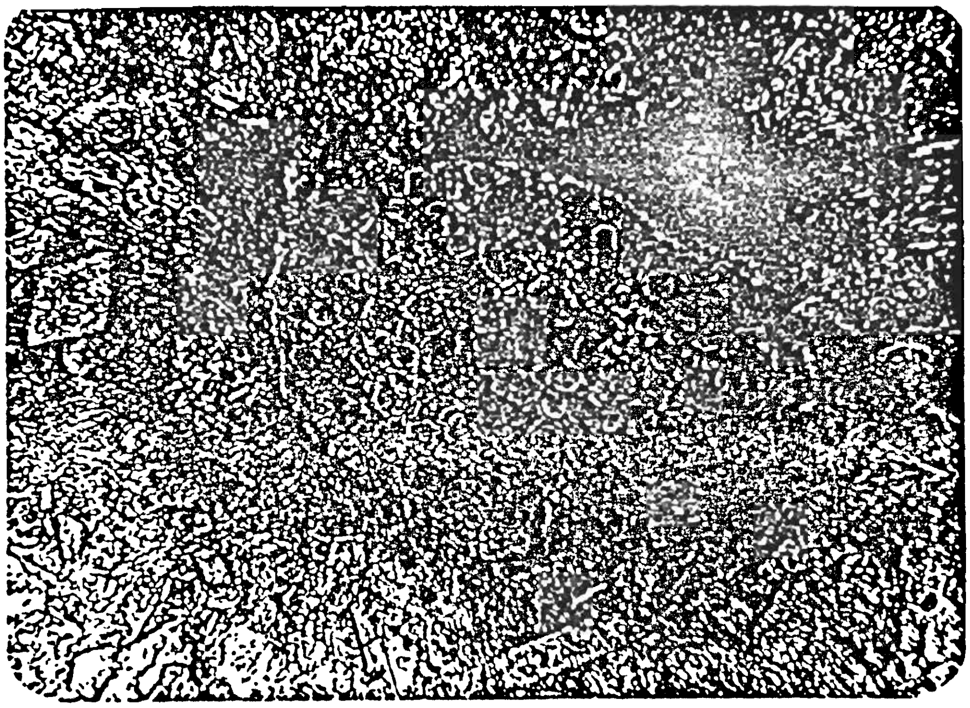


Fig. 6 Occurrence of clustered gypsum grains within pores of mortar. Plane Pol x 160

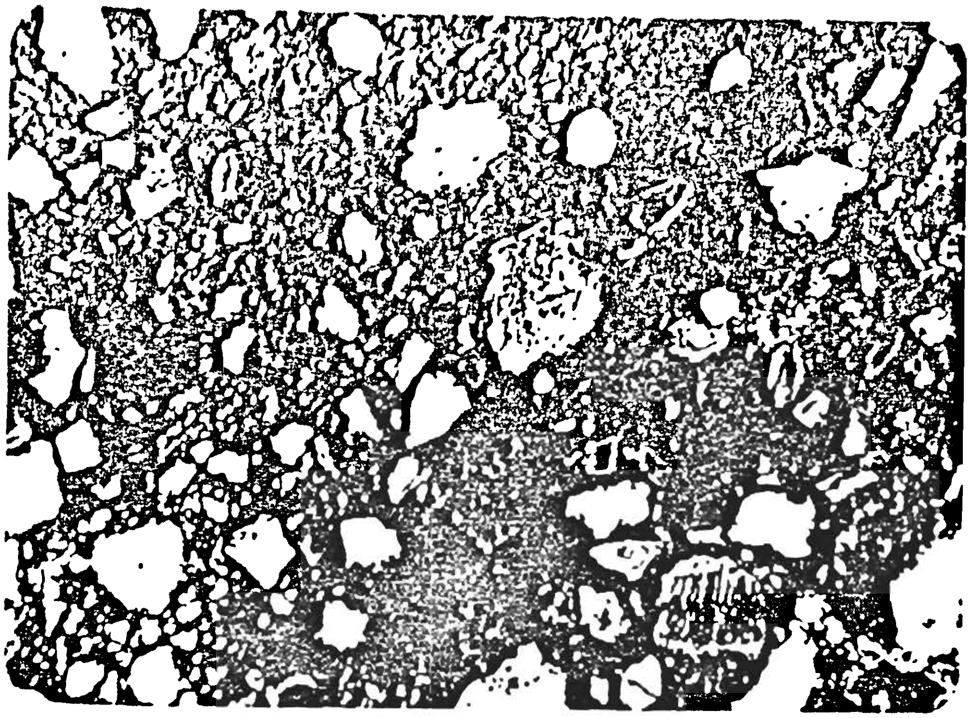


Fig. 7 Occurrence of quartz, Calcite and felspar grains within mortar Cross nicolx25

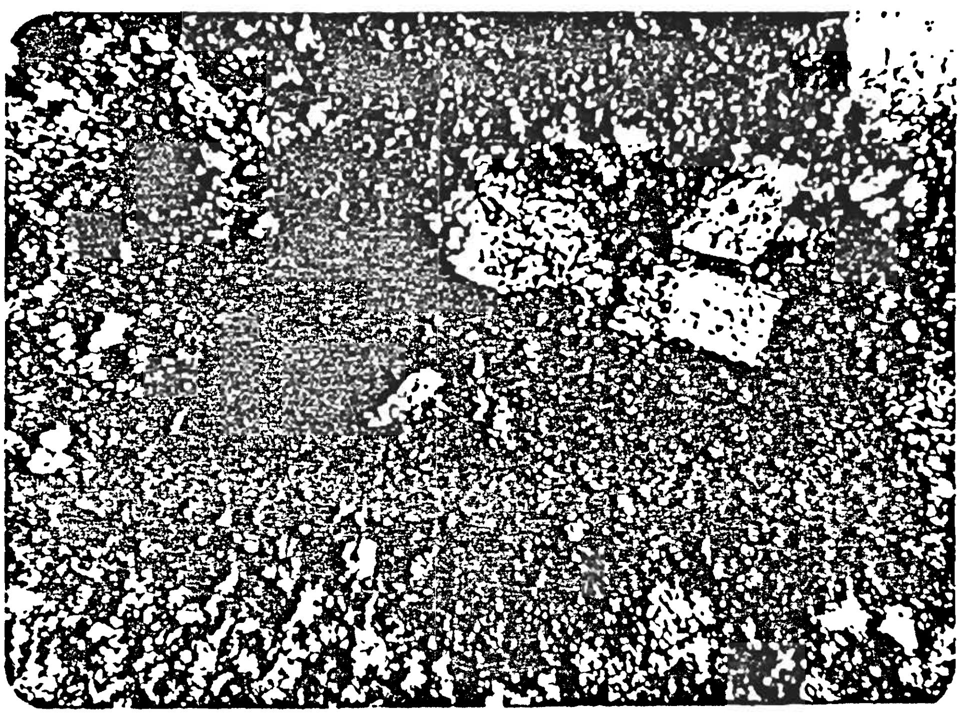


Fig. 8 Brown patch of ferruginous material within mortar Cross nicol x 160

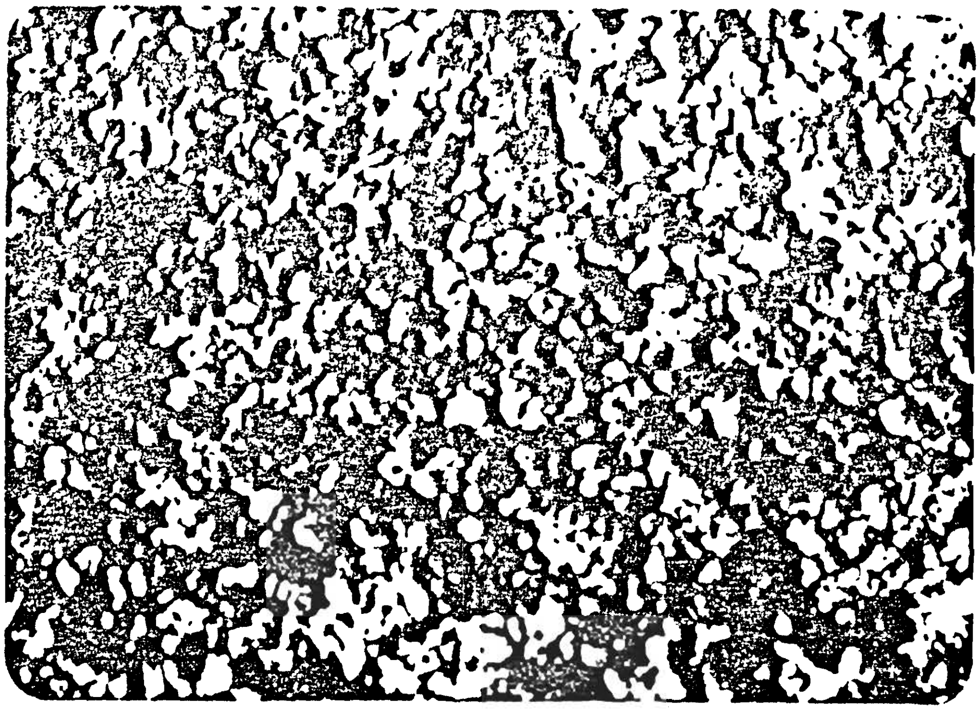


Fig. 9 Equigranular texture of sandstone with quartz and cementing material. Plane Pol x 25

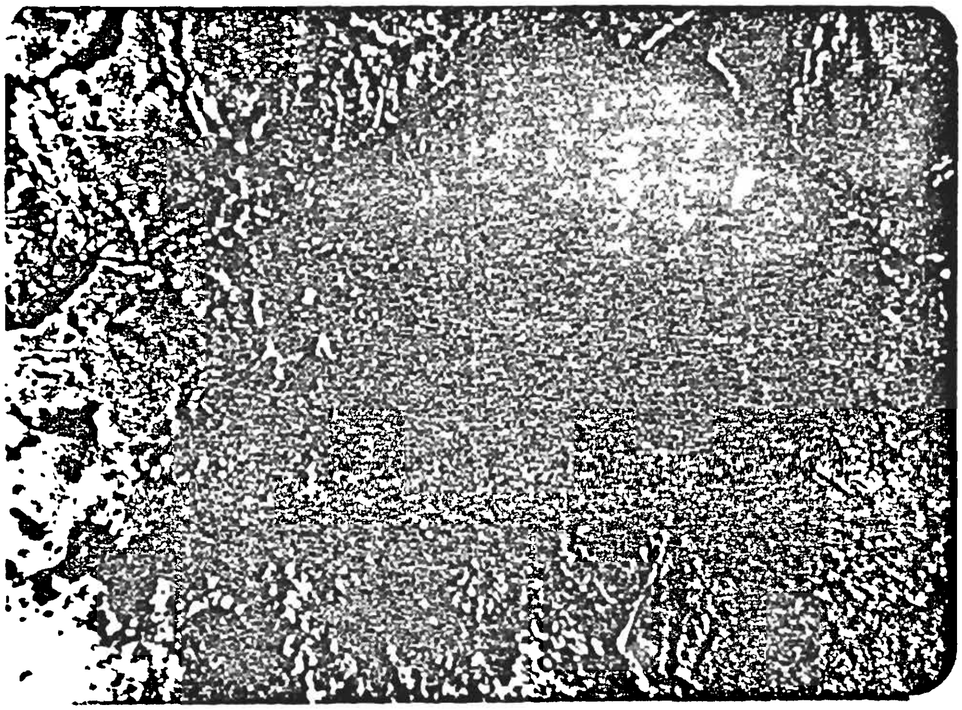


Fig. 10 Occurrence of brown ferruginous clay within cementing material of Sandstone. Plane Pol x250

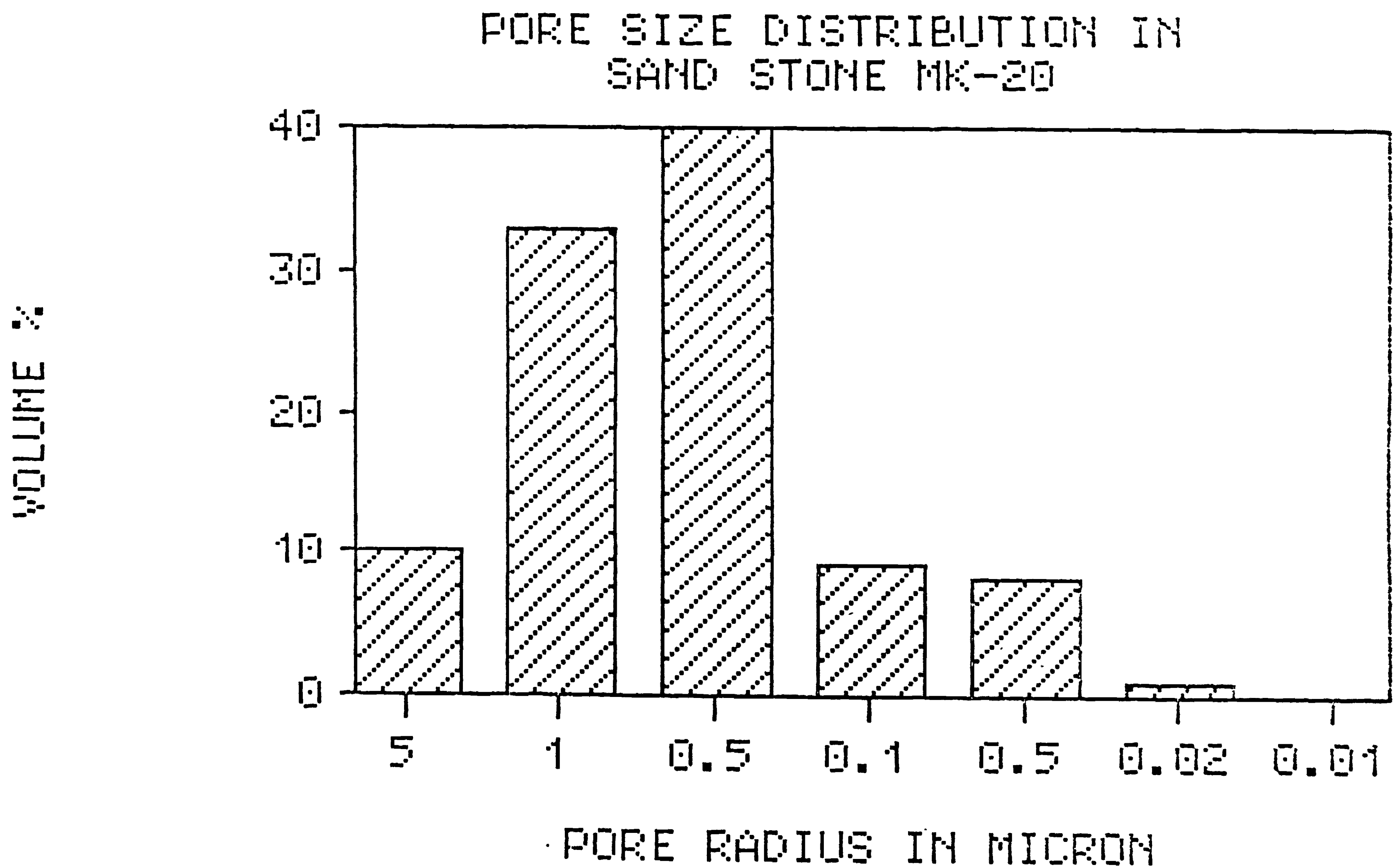
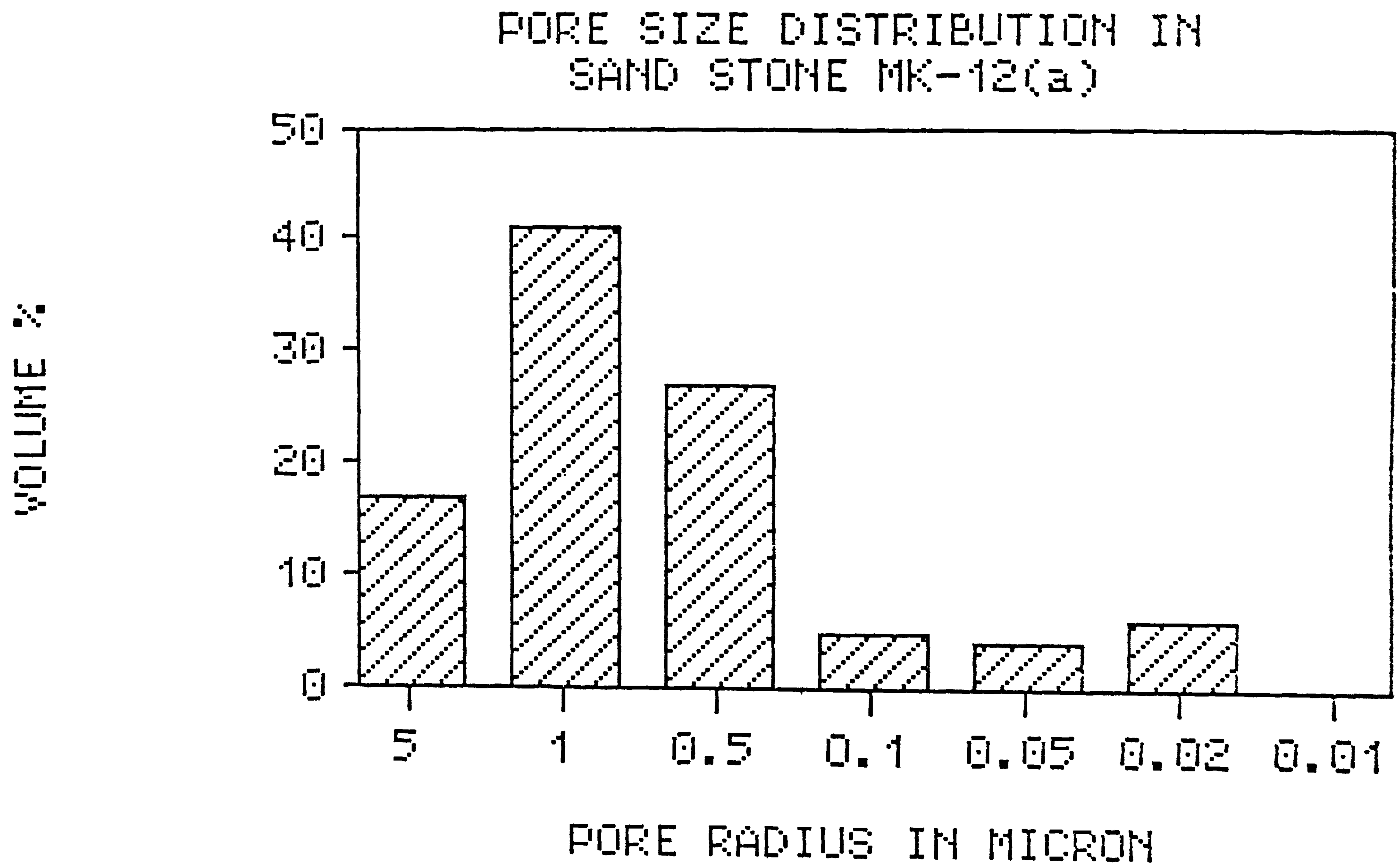

PORE SIZE DISTRIBUTION IN
SAND STONE MK-20
40
30
20
10
0
VOLUME %
5
1
0.5
0.1
0.5
0.02
0.01
PORE RADIUS IN MICRON

Fig. 11



PORE SIZE DISTRIBUTION IN
SAND STONE MK-12(a)
VOLUME %
50
40
30
20
10
0
5
1
0.5
0.1
0.05
0.02
0.01
PORE RADIUS IN MICRON

Fig. 12

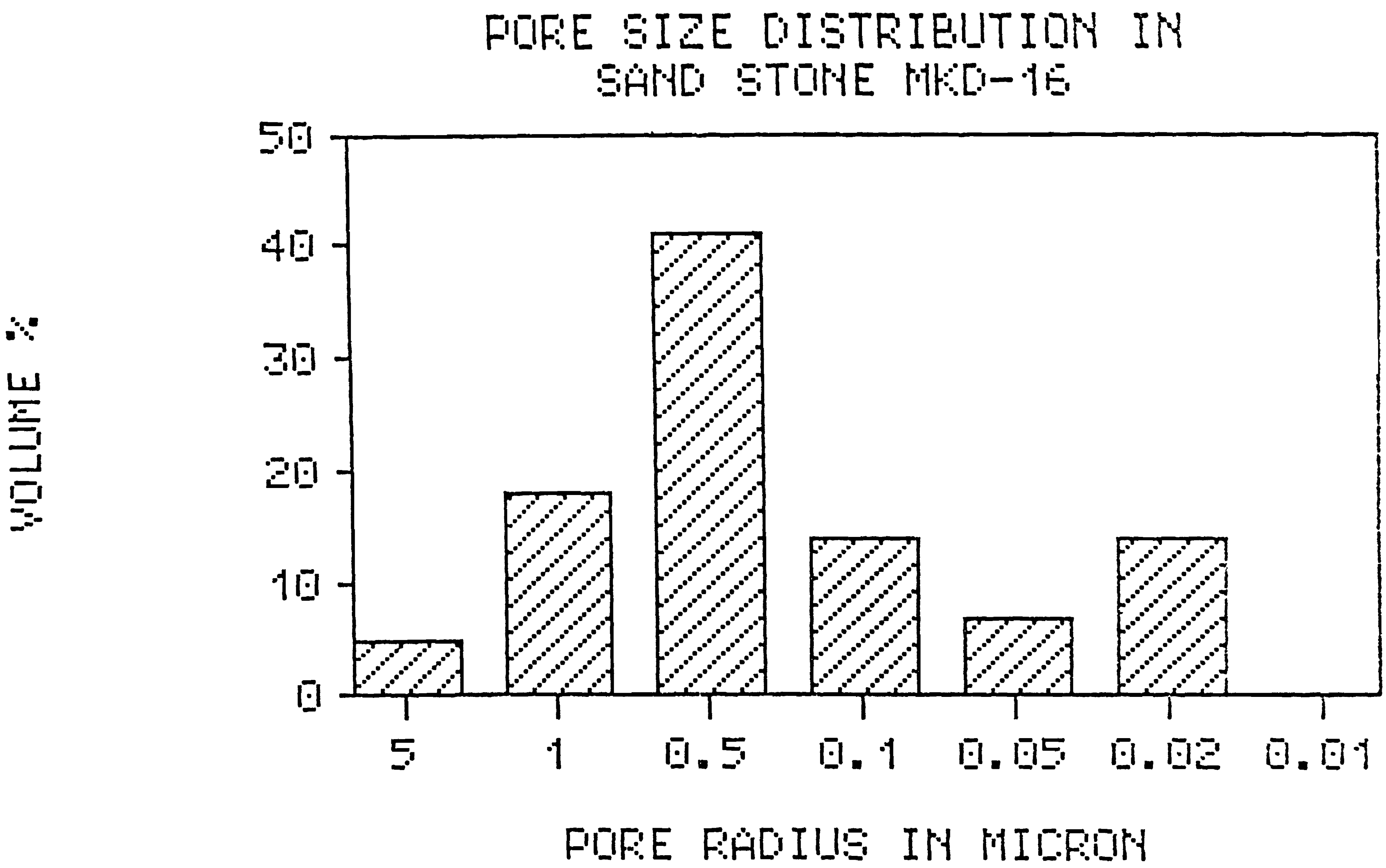

PORE SIZE DISTRIBUTION IN
SAND STONE MKD-16
VOLUME %
50
40
30
20
10
0
5
1
0.5
0.1
0.05
0.02
0.01
PORE RADIUS IN MICRON

Fig. 13

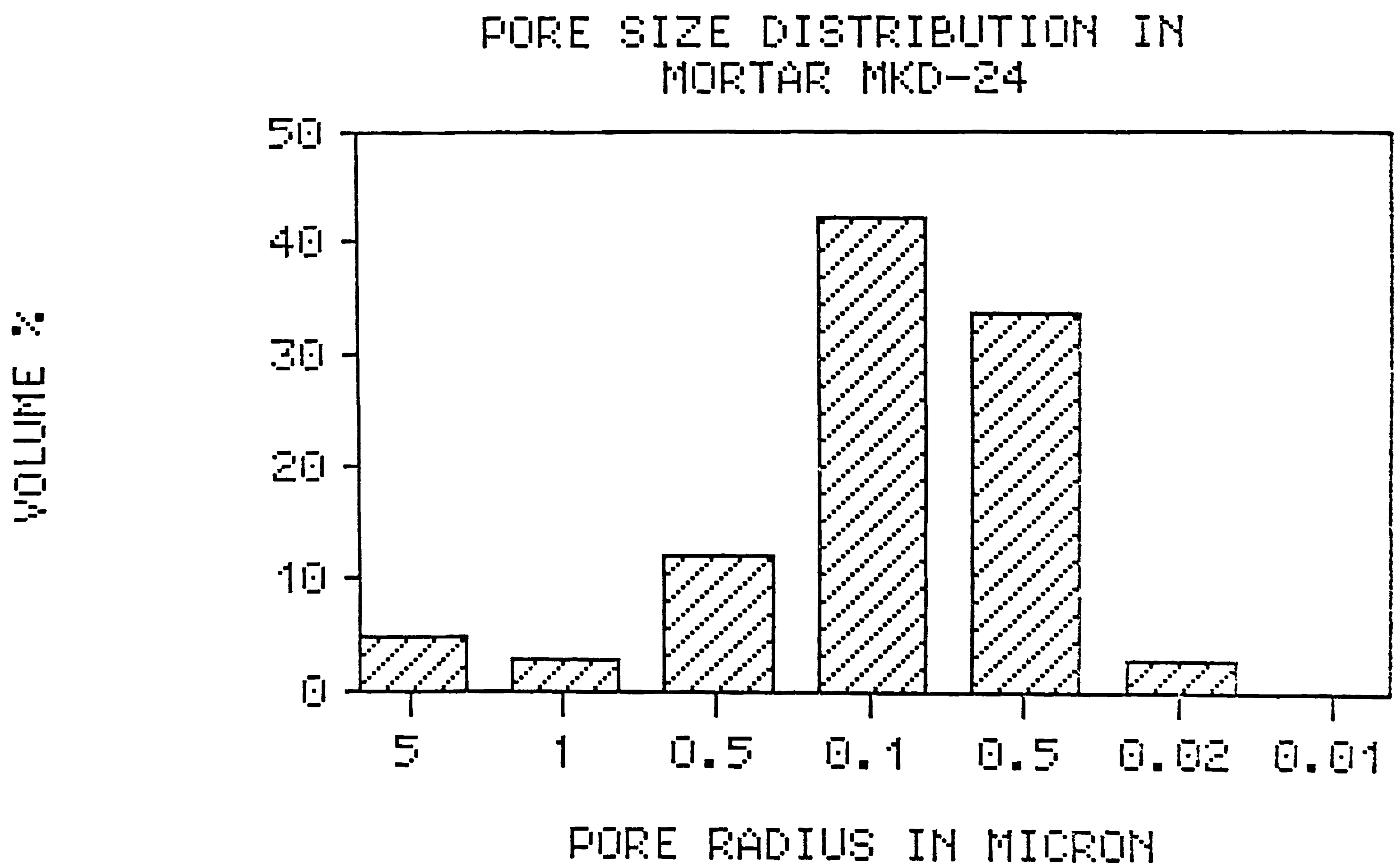

PORE SIZE DISTRIBUTION IN
MORTAR MKD-24
VOLUME %
50
40
30
20
10
0
5
1
0.5
0.1
0.5
0.02
0.01
PORE RADIUS IN MICRON

Fig. 14

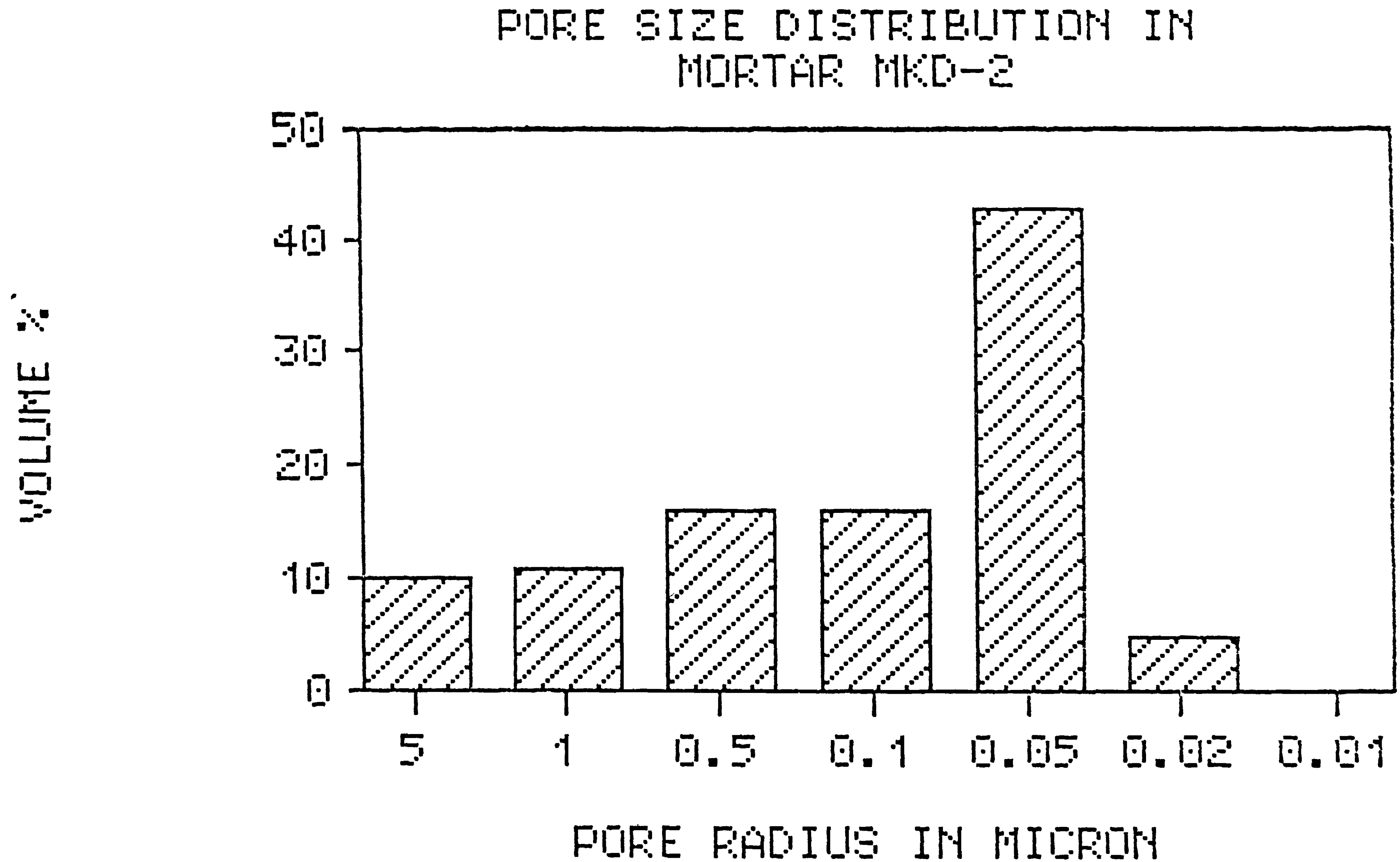

PORE SIZE DISTRIBUTION IN
MORTAR MKD-2
50
40
30
20
10
0
VOLUME %
5
1
0.5
0.1
0.05
0.02
0.01
PORE RADIUS IN MICRON

Fig. 15

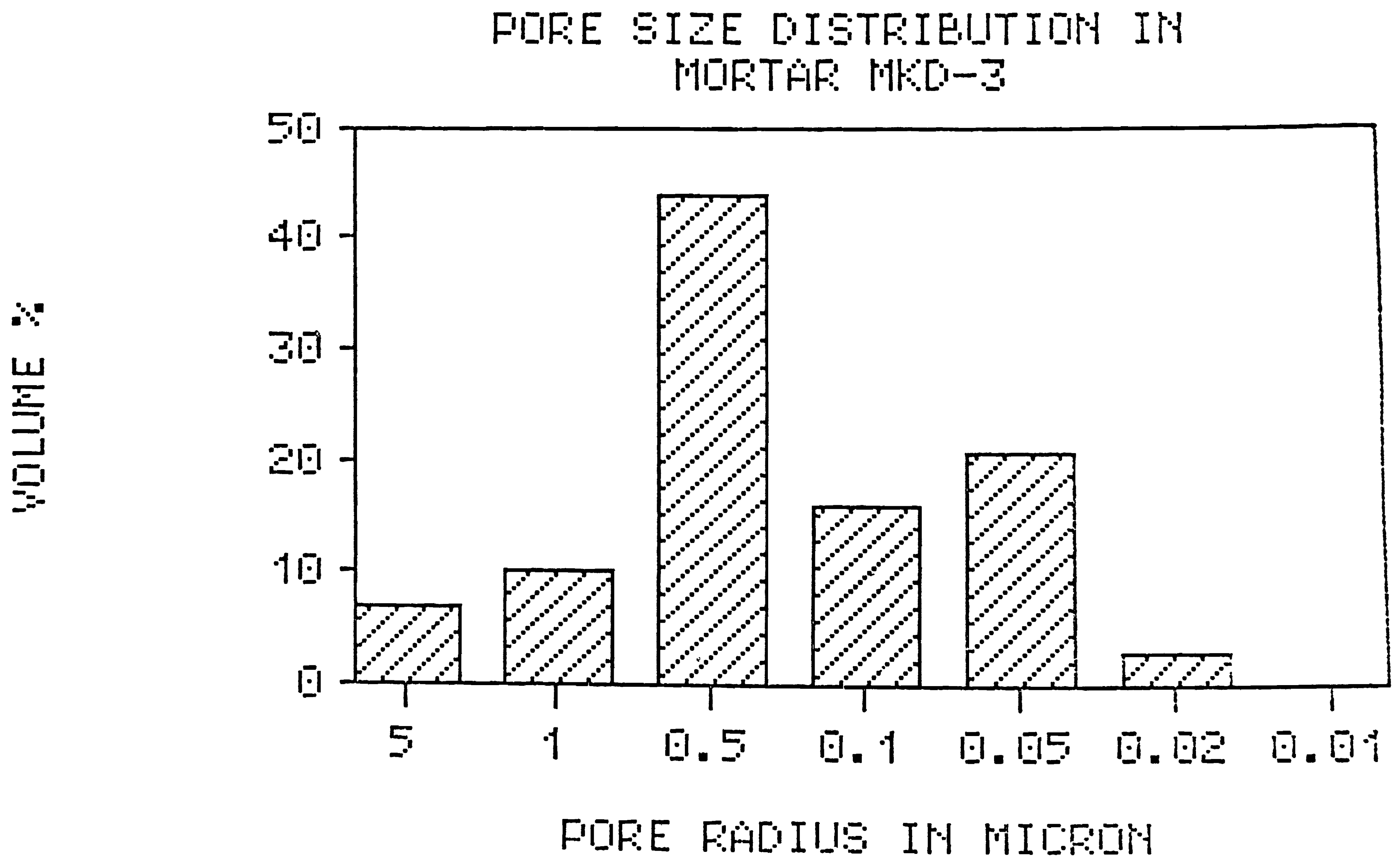

PORE SIZE DISTRIBUTION IN
MORTAR MKD-3
VOLUME %
50
40
30
20
10
0
5
1
0.5
0.1
0.05
0.02
0.01
PORE RADIUS IN MICRON

Fig. 16

Fig. 17 SEM photograph of marble showing cleavages of Calcite grains. (x 1300)

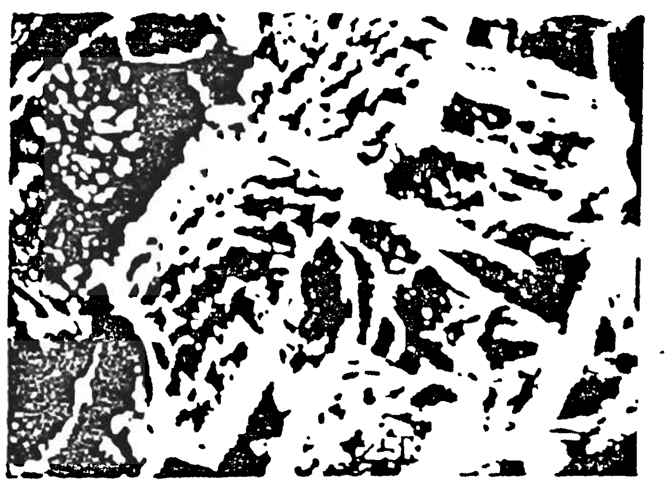


Fig. 18 SEM photograph of marble showing erosion of Calcite grains (x2500)

Fig. 19 SEM photograph of sandstone showing quartz grains and pores. (x2000)

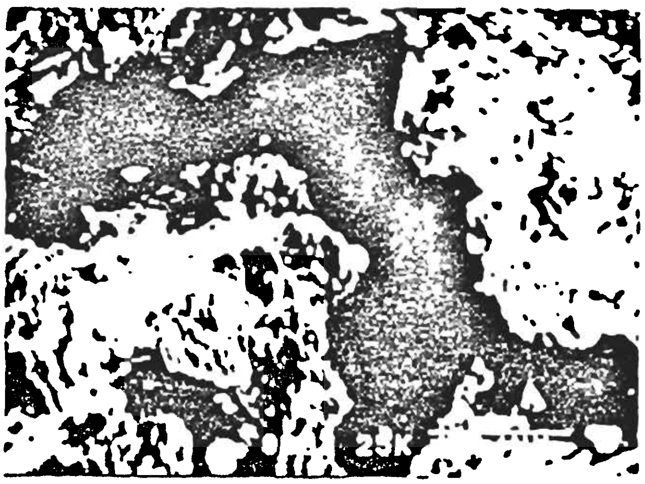


Fig. 20 SEM photograph of sandstone showing magnified pore. (x6000)

Fig. 21 SEM photograph of mortar showing occurrence of gypsum within pore (x1500)

Fig. 22 SEM photograph of mortar showing flower like crystal of gypsum (x 5000)

4.2 MONUMENT DAMAGE ESTIMATION

4.2.1 Physico-Chemical Factors

All the building material minerals in general, get affected by carbon dioxide dissolved in water. Calcite mineral, shows the maximum reactivity unlike the silicate minerals reacting at a lower rate and also the weathering products are also different. The end result is in terms of decomposition of stones. Weathering due to SO_2 present in the atmosphere is the major cause of decay of stones. These react with carbonates forming comparatively high soluble $CaSO_4$ (gypsum) crystals which causing blistering, scaling and loss of cohesion of the stone surfaces. In rain washed areas gypsum does not accumulate on stone surface due to washing off process exposing to the fresh surfaces. In sheltered areas, where the rain does not reach gypsum is likely to remain to form a hard dirty crust. These sulphate deposits or crust tend to be harmful rather than protective. It leads to spontaneous blistering and scaling of the surface.

Other common effect is discolorations produced by efflorescence which are water soluble salts that crystallise on the surface of the stone due to evaporation. During the salt crystallisation the pressure is exerted against the porewalls causing disruption of stone in the form of extensive spalling (P-16).

In the case of VM marble the deterioration occurs in two modes. In first mode weathering takes place where the marble is sheltered under domes and cornices and protected from direct impact of rain. Here a crust is formed which after many years exfoliates due to mechanical stresses. In case of marble exposed to rain, gradual reduction occurs because the reaction products are washed away by rainfall and fresh marble is exposed to renewed reaction. The crusts are formed primarily due to SO_2 but the cumulative effect of all pollutants shall be more damaging. It is also observed that trace metals present in fly ash and SPM e.g. Mn, Fe and V act as catalysts for oxidation of SO_2 and in turn enhance degradation of calcite to gypsum.

For estimation of damage of building material of VM, the models formulated and validated under controlled exposure experiments were used for predicting the stone errosion taking into considerations the local conditions of pollution levels, climate and physico-chemical characteristics of stones used in VM construction.

4.2.1.1 Damage Estimations for VM Marble

The literature available on the models on cause and effect relationship for a building materials (stone) and ambient pollution exposure conditions is very limited. One well documented model was evolved for the physical damage as a damage function for a white marble stone exposed to polluted atmosphere (major pollutants SO NO_2 etc.) with varied controled conditions of relative humidity by Haynie, Spence and Upham (1976).

In this model loss-in-weight is a parameter used for assessing the magnitude of damage caused by the pollutants. It is assumed that water soluble reaction products are constantly removed from the surface of exposed specimens due to maintenance/cleaning or rain washout and primarily account for the loss-in- weight. Each loss-in-weight value is converted to an equivalent thickness of calcium carbonate and expressed as an erosion rate-loss in thickness units per year (µm/yr). The assessment methodology employed in this model provides a tool for obtaining estimates of monthly or even annual material losses attributable to the mean pollution exposition.

The erosion rate of marble and stone are (building material at VM) have been evaluated using this model developed by Haynie et.al taking the mean atmospheric conditions for SO_2, NO_2 and RH for the year 1990 for the whole Calcutta city.

The monthly average of SO_2 concentrations at Calcutta exceeded 80 $\mu g/m^3$ in winter (Oct, Dec and Jan). NO_2 concentrations were higher in winter as compared to the other seasons. However, monthly mean NO_2 concentrations did not exceed 120 $\mu g/m^3$ mark. The average RH was higher than 60% in every month throughout the year. The maximum RH was 84% in rainy season as observed from Climatological tables of IMD. The loss in depth due to surface erosion was estimated between 0.12 to 0.28 µm/month. The rate was more than 0.2 µm/month except for Jan, Feb, Mar and Apr. However, the erosion rate per year was obtained as 2.66 µm, when average of SO_2 and NO_2 concentrations were 48.94 and 39.27 $\mu g/m^3$ respectively.

The marble erosion rate was 2.54 µg/year when calculated on the basis of annual average values of SO_2 and NO_2 obtained from air quality monitoring data around VM.

The empirical function (model) used above is a linear function model and have included all the important attributes as air pollutants, relative humidity and the damage due to erosion on white marble. Predictions show that this marble will erode upto 1 mm in about 320 years when exposed to 30 µg/m^3 SO_2 and NO_2 as per CPCB standard applicable for sensitive area and 80% relative humidity. However, as the monument is having age of hundreds of years and pollution is only one factor causing surface damage, the overall damage shall be higher than the predictions made based this on model considering air pollution and climate.

4.2.1.2 Damage Function for Sandstone and Limestone

Another model for the weathering effect of dry deposition of SO_2 on rain sheltered sandstone and limestone as well as on weight loss of unsheltered sandstone and limestone exposed for one year exposition of atmospheric pollution have been established by Luckat (1981) through relationships developed based on field exposure studies.

The seasonal averages of SO_2 monitored at VM were used to estimate the dry deposition of SO_2 (mg SO_2/m^2/day) and for the SO_2 uptake as well as percent weight loss of sandstone and limestone. The results indicate that the SO_2 uptake (mg SO_2/m^2/d) for both the stones were maximum in winter followed by monsoon and summer. The percent loss in weight was also higher in winter than in monsoon and summer. The annual average results indicate that SO_2 uptake was 14.11 and 5.75 mg SO_2/m^2/day by sandstone and limestone respectively. While the percent loss in weight was 0.83% and 1.07% respectively for sandstone and limestone. These results are summarised in the Table 4.5.

No.Q-17012/21/93-CPW 26th April, 1995

Fax No.230673

The Director,
NEERI
NAGPUR-440020

ATTENTION: DR. A.L. AGGARWAL.

In continuation of the telephonic talk which Dr. Varadarajan , Dr. B.B. Sundaresan and Dr. Sharma (IMD) had with Dr. Aggarwal regarding issues raised in the two reports prepared by NEERI. One dated July, 1993 (Air Pollution Studies to redefine Taj Trapezium Coordinate) and the second report dated April, 1994(REIA for proposed matching secondary processing facilities at Mathura Refinery).

The clarifications provided by NEERI under Table-2 refer to maximum short-term (24 hr.) concentrations expected at Taj Mahal under worst meteorological conditions and highest observed stack emissions. When long-term concentrations are predicted it will be very much on the lower side than short-term predicted values. These predicted values do not appear to be tallying with the observed vaues in different

(Contd...p/2)

locations between Mathura Refinery and Taj Mahal. It indicates that the values do not tally with the observed values in the field. On the other hand there is considerable variations between the two.

The surface wind profile in TTZ is reported to be 14 and 24% of the time winds are from Ferozabad Industrial Zone. The percentages are 7 and 11 in winter and summer seasons respectively from Mathura Refinery. Reference from Table-II-4 to II-7 in 1993 report the wind roses reveal an entirely different picture.

Clarifications is also needed on the various models used and assumptions made for different predictions.

Kindly confirm. An immediate response is requested.

Yours faithfully,

(R. ANANDAKUMAR)
Additional Director

N... ..NAL ENVIRONMENTAL ENGINEERING
RESEARCH INSTITUTE
राष्ट्रीय पर्यावरण अभियांत्रिकी अनुसन्धान संस्थान
Nehru Marg, Nagpur - 440 020
(INDIA)

Telex : 07 .. 7233 NERI IN
Gram : NEERI

Phone 226071 to 75
FAX 91(712) 230673
91(712) 222725

Date 27/4/95

From,

Dr. A.L. Aggarwal
Deputy Director
NEERI, Nagpur

To Mr. Anandakumar
MEF, Delhi

Fax : 4362281

Sub : Information on queries raised vide MEF fax message dated 26th April 1995 received here on 27th April 1995

Attn : Mr. R. Anandakum.., Additional Director, MEF, Delhi

The requisite information on the queries raised in the aforementioned fax message ... are as under :

A. Air Quality Models : (Taj Trapezium)

Following Air Quality models formed the basis for predictions :

- PTPLS PTMAX models were first applied for typical stacks of major industries (including MR..) to screen at the first instance the maximum GLC as a function of distance and stability condition and to plan & device appropriate receptors grid system in the impact zone of sources/area
- MPTER & AIDL (ALSM-NEERI version) based models formed the basis for computing detailed concentration from industrial centres and area & line sources respectively, after conducting the hourly frequency analysis of wind profile and evolving diurnal variations of meteorological data inputs at source as well as receptor. For area sources, AIDL (ALSM-NEERI version) model was used because of our experience on predictions for such sources

Contd...

Total No. of pages including this page : ...

- ❑ Box Model formed the basis for assimilative capacity [illegible] of major industrial zones within TTZ

B. Information on Assumption for Model Applications

Mathura Refinery

For impact zones of Mathura Refinery, 24 hrs & 8 hrs average [illegible] were made for the whole distance between MR & Taj. But first wind frequency analysis was carried to determine predominant wind direction as well as percentage [illegible]

For stability class determination also hourly [illegible] estimated. For mixing height patterns, NPL had carried out studies and ground level temperature profile was evolved through ballon studies carried out by University of Roorkee

Firozabad Industrial Zone

Predictions were carried out upto 32 kms. Stack height was taken between 10-15 m because of low height emissions for all the point sources. Prediction were made for 8 hours typical periods in a day for diurnal variation as as well as 24 hrs. Hourly frequency analysis as explained above was also carried out to evolve meteorological data inputs. Normal operation as well as the scenario when all the industries are working were considered for predictions.

Agra Region

For area sources (domestic and line) AUSM model was used and for point sources [illegible] model. Other meteorological analysis carried out are same as detailed earlier.

C. Information on Wind Direction Analysis

Mathura Refinery and Firozabad

- ❑ North-West at Mathura was considered as prominent direction for impact zone predictions from Mathura Refinery because of significantly elevated sources and specific coordinates

- ❑ East + 45° sector was considered as predominant direction for impact zone predictions from Firozabad industrial zone because the sources are of low height and quite scattered

- ❑ Because of high percentage of calm conditions, the concept of assimilative capacity was introduced in the study

D. Model Validation before Application for Predictions

It is well documented that models need validation for correct predictions and this is most essential [illegible] conditions. The choice of model also requires harmonization to obtain acceptable prediction results. In fact CPCB has appointed a committee on the subject and the draft submitted by Dr. A. L. Aggarwal is attached for reference.

Keeping this background in mind NEERI proposes [illegible] study [illegible] emission. This study shall also validate the models applied in Mathura Agra region.

This is for kind perusal of the committee

Yours faithfully

(A. L. Aggarwal)

NOTE

HARMONIZATION IN AIR POLLUTION MODELLING IN INDIA

Dr. A.L. Aggarwal

The GOAL of Development of this group should be to agree on a flexible, easy-to use model framework which is modular, well-documented, and capable of meeting both the near-term and the long term air quality modeling needs of industry as well as regulators of India.

The model ideally should be a multi-layer, multi species non steady-state (puff) dispersion model which can simulate the effects of time and space varying meteorological conditions on pollutant transport, chemical transformation and plume depletion. At present many versatile configuration of algorithms are under use in many western countries for near-source effects such as building downwash, transitional plume rise, subgrid scale terrain interactions as well as processes important on larger scales such as pollutant removal (wet scavenging and dry deposition), chemical transformation, overwater transport and even coastal interaction effects (viz: CAL PUFF MODEL of USA). Such algorithms can accommodate arbitrarily varying emissions from point sources and gridded or discrete area sources and these models also contains special sampling algorithms which allow a continuous plume to be represented in the near-field of a stack in a cost-effective manner. It is also now possible to contain options to treat the physical processes at different levels of details depending on the model application. For example, simple screening analyses can be conducted by-passing most of the technical algorithms (e.g., wet and dry removal processes, transformation, etc.) and executing the model in a "Plume-like" mode using spatially-constant meteorological data which is exactly the need for hormonization at the national level.

The ultimate modeling system required to be followed is presented as a flow diagram containing following four major components.

A hydrostatic wind field model which simulates mesoscale airflow resulting from differential surface heating and terrain effects.

A meteorological model which includes options for one or two diagnostic wind field modules and a micro-meteorological model for overland and overwater boundary layers.

A non steady state Gaussian puff model containing modules for complex terrain effects, overwater transport, coastal interaction effects, building downwash, wet and dry removal, and chemical transformation.

Besides above three components POSTPROCESSORS are also required for the time averaging, statistical analysis, and graphical display of the model's results.

In view of long-term requirements of modelling needs of the country as highlighted above, there is immediate need for a simplified version for application under current limitations of data availability base. However, the limitations and features thereof to be used for such data gaps pertaining to any one or more of the following features should be understood and highlighted.

- ☆ Spatial and temporal variability in the wind and other meteorological fields
- ☆ In the case of tall stack dispersion the basis of parameterization of turbulence in the boundary layer
- ☆ Coastal effects, such as the growth of Thermal Internal Boundary Layer (TIBL) and coastal fumigation
- ☆ Assumptions for wind structures in prominent low wind speed and calm wind conditions
- ☆ Assumptions on plume rise, including multiple source plume rise enhancement, partial plume penetration into elevated stable layers, vertical wind shear, neutral breakup plume rise, and touchdown plume rise, all of which are potentially important for assessing tall stack units viz. power plant impacts
- ☆ In the case of line source emissions, the ability to treat variations in emissions and buoyancy along the length of the line
- ☆ Module assumptions for assessing dry deposition based on a comprehensive resistance model
- ☆ Wet deposition and chemical transportation of SO_2, $SO_4^=$, NO_x, HNO_3, and NO_3
- ☆ Necessary assumptions for complex terrain effects based on past experience, if any, on complex terrain modeling
- ☆ Formulation changes (corrections factors) for building downwash in both the near-wake cavity region and far-wake region

The chosen modeling system should also address the following meteorological features:

- ☆ Model capability for sea-breeze circulations, including the return flow aloft, and flows in complex terrain such as slope-valley winds and terrain channeling
- ☆ Model assumption for turbulence fields, includes separate formulations for overwater boundary layer as well as the overland boundary layer model
- ☆ Diagnostic wind model parameterizing complex terrain effects such as slope flows, kinematic terrain effects and terrain blocking

The entire system should highlight the limitations for a user-oriented interactive module which allows the default constants and pollution menu, automatic data checking, and easy display of modeling results.

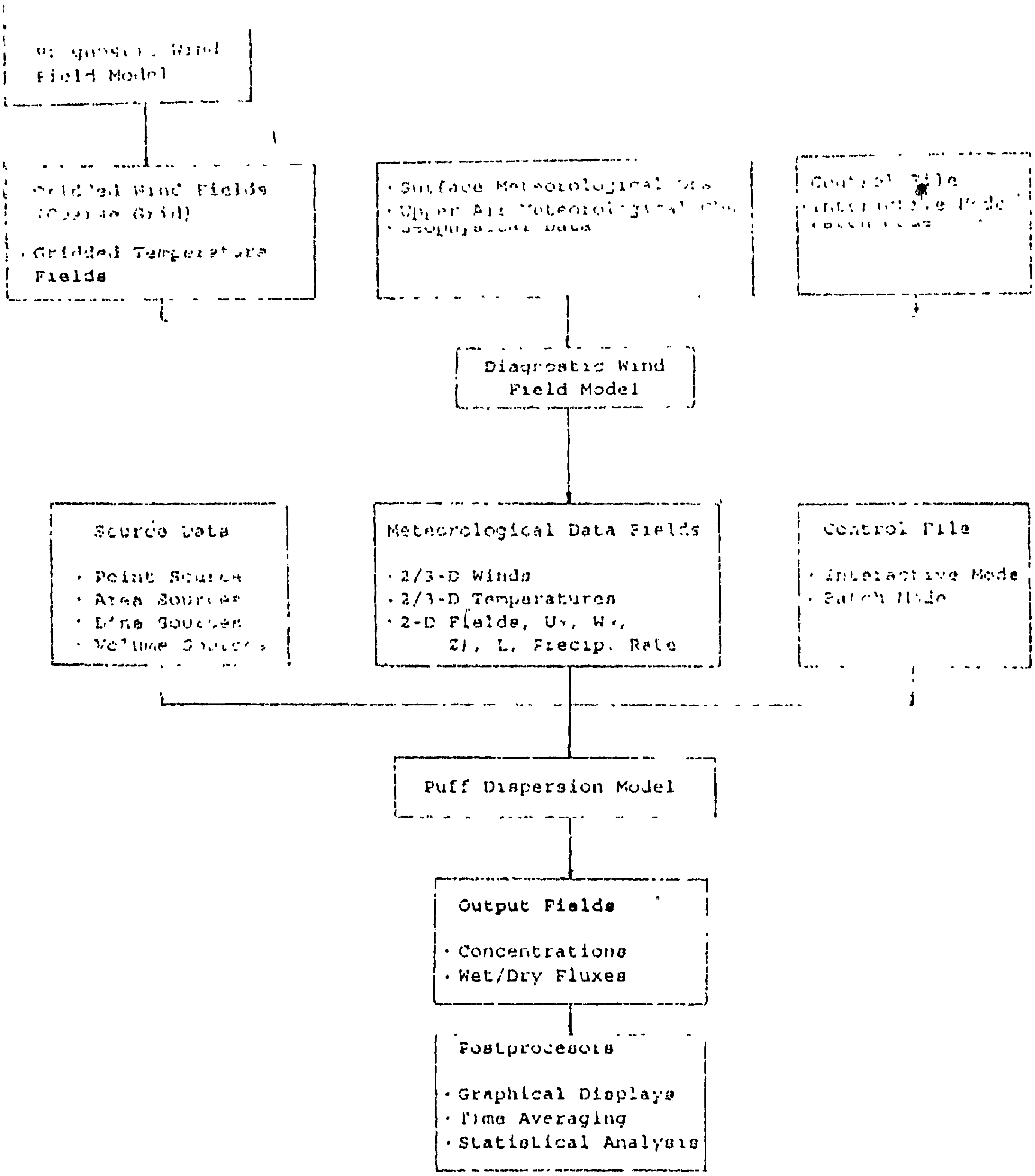


Fig. Ultimate Modeling System Requirement of India
(Flow Diagram)

तार :
Telegram : PARYAVARAN,
NEW DELHI
दूरभाष :
Telephone :
टेलेक्स :
Telex : W-66185 DOE IN
FAX : 4360678

भारत सरकार
पर्यावरण एवं वन मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT & FORESTS
पर्यावरण भवन, सी. जी ओ. काम्प्लेक्स
PARYAVARAN BHAWAN. C.G.O. COMPLEX
लोदी रोड, नई दिल्ली-110003
LODI ROAD. NEW DELHI-110003

April 27, 1995.

The Director
NEERI
Nagpur-440020.

Attn. : Dr. A.L. Aggarwal

Ref. : Your fax message dated 27th April, 1995.

The information contained in the above referred fax message was examined and following are our observations.

The wind rose diagrams for Agra presented at pp. II-IV and II-V of NEERI report show that 5 percent and 6 percent of the time wind flows from east to west i.e. Firozabad to Agra during winter and summer months respectively. July 1993 report of NEERI does not show that wind data was generated at Firozabad. The basis to take surface wind profile as 14 and 24 percent of the time from Firozabad industrial zone towards Agra as reported in your report circulated to the Expert Committee on 24-4-1995 is not provided.

The maximum short term (24 hrs.) predicted GLC of SO2 at Taj Mahal has been indicated at 18.9 Mg/m3 during winter season and 26.4 mg/m3 during summer season as per Table-2 of the report circulated by NEERI in the meeting of the Expert Committee on 24-4.1995. Our query that predicted values do not tally with monitored values at Taj Mahal where recorded Short Term (24 - hrs.) ambient concentrations of So2 have been observed much higher than the predicted values in Table-2 has not been answered.

Yours faithfully,

R. Anandkumar

(R. Anandkumar)
Addl. Director

NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE
राष्ट्रीय पर्यावरण अभियांत्रिकी अनुसन्धान संस्थान
Nehru Marg, Nagpur - 440 020
(INDIA)

Telex : 0715-7233 NERI IN
Gram : NEERI

Phone : 226071 to 75
FAX : 91(712) 230673
91(712) 222725

Date : 27/4/95

From : Dr. A.L. Aggarwal
Deputy Director
NEERI, Nagpur

: Mr. Anandakumar
MEF, Delhi

Fax : 4362281

Sub: Information on queries raised vide MEF fax message dated 27th April 1995

Attn : Mr. R. Anandakumar, Additional Director MEF, Delhi

The answers to the queries readdressed in the aforementioned fax received on 28th morning are as under :

Information provided on wind direction analysis reflect that East ± 45° (SE to NE sector) is prominant direction from Firozabad industrial area towards Taj Mahal because of scattered nature of industrial units. As Agra wind profile was used for Firozabad in the absence of long term wind pattern data availability at Firozabad, the percentage calculation reflects 14% and 24% in winter and summer months respectively (page II-4 & 5).

ii. Refer item B of NEERI fax dated 27th April 1995 regarding "Information on Assumptions for Model Applications", wherein it is indicated that hourly wind profile was analysed for each season separately before predicting ground level concentrations (GLC) in Agra zone. Hence, the given values are seasonal averages and not the annual mean (long term). Predicted and observed concentrations comparison in such a regional studies cannot be based on one spot reading. Predicted GLC at different locations in Agra city fluctuated both ways when compared to monitored values during the field study period of 1993 Taj report. The comparison analysis between predicted and monitored values was also documented in July 1993 report (Section 5.5 : Validation of GLC Predictions).

This is for kind perusal of the committee

Yours faithfully

A.L. Aggarwal

(A.L. Aggarwal)

Air Pollution Studies To Redefine Taj Trapezium Coordinates

Sponsor

Ministry of Environment & Forests

New Delhi

National Environmental Engineering Research Institute

Nagpur - 440 020

CREDITS

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Dr. P.Khanna

PROJECT LEADERS

Dr. A.L. Aggarwal
Dr. (Mrs.)R. Thakre

TEAM MEMBERS

Dr. S.K. Gadkari
Mr. S.D. Joshi
Dr. D.G. Gajghate
Mr. R.K. Gupta
Ms. P.S. Rao
Mr. A.G. Gavane
Mr. S.K. Goyal
Mr. R. Sivacoumar
Mr. S.M. Tahmne
Mr. C.P. Gajrani
Mr. A.D. Bhanarkar
Mr. D.S. Tajne
Ms. Vaishali Ramteke
Mrs. V.A. Deshpande
Mr. Roy Johnson
Mr. A.H. Khan
Dr. R.A. Sohony
Ms. Arti Vaidya
Dr. (Ms.) S. Sakalkar
Ms. S.D. Deshmukh
Ms. Vidhi Verma
Mrs. Vasudha Deo
Dr. Animesh Kumar
Mr. A.K. Jain
Dr. V.I. Pandit
Mr. K.M. Phadke
Mr. C.S.G.Rao
Mr. N.S. Manthapurwar

SECRETARIAL ASSISTANCE

Mr. R.G. Verma
Mr. A.N. Mishra
Ms. N.V. Gupta
Mr. D.G. Deshpande
Mr. A. Rashid
Mr. S. Pazare
Mr. S. Shadangule
Mr. R.M. Deshpande

TABLE 4.6

GLASS INDUSTRY EMISSIONS : FIROZABAD REGION

Industry	Number of Units	Fuel Consumption (MTPD)	Emission rate (Kg/hr)				
			SPM	SO_2	NOx	CO	HC
ACTUAL WORKING							
Glass Ware	24	193	80	107	12	362	80
Glass Bangle	66	153	64	85	6	287	64
Block glass	10	36	15	20	2	67	15
Glass Bead	8	150	62	83	9	281	62
Potteries & Ceramics	7	46	19	25	3	85	19
Muffle Furnace	500	165	137	183	21	619	137
Total	615	743	377	503	53	1701	377
ALL UNITS WORKING							
Glass Ware	57	458	191	254	29	859	191
Glass Bangle	157	364	152	202	23	683	152
Block Glass	35	125	52	69	8	234	52
Glass Bead	18	337	141	187	21	632	141
Potteries & Ceramics	33	215	90	119	13	403	90
Muffle Furnace	1132	374	311	414	47	1401	311
Total	1432	1873	937	1245	141	4212	937

Contd....

Industry	Number of Units	Fuel Consumption (MTPD)	Emission rate (Kg/hr)				
			SPM	SO_2	NOx	CO	HC
001							
lass Ware	73	587	245	325	37	1100	245
lass Bangle	177	411	171	228	26	770	171
lock Glass	42	154	64	85	10	288	64
lass Bead	26	487	203	270	30	914	203
otteries & eramics	43	280	117	155	18	525	117
ffle Furnace	1246	609	341	454	51	1535	341
ital	1601	3533	1141	1517	172	5132	1141

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INDUSTRIAL EMISSIONS AGRA REGION

Industry	Industries		Fuel Consumption (MTPD)	Emission rate (Kg/hr)				
	Total	In normal operation		SPM	SO_2	NOx	CO	HC
UNITS UNDER NORMAL OPERATION : 1993								
Ferrous casting (Foundries)	131	26	208	749	122	16	13998	-
Ferro Alloys (Pit Furnace)	34	20	20	72	12	1.5	1346	-
Chemical	34	28	42	53	70	8	236	53
Rubber sole	30	15	3	4	5	1	17	4
Refractory bricks	16	8	16	18	11	1.6	3.4	1
Engineering	20	15	13	16	22	2.4	73	16
Lime processing	18	8	26	33	43	.5	146	33
Total	283	120	328	945	285	56	15819	107

Contd...

Industry	Industries		Fuel Consumption (MTPD)	Emission rate (Kg/hr.)				
	Total	In normal operation		SPM	SO_2	NOx	CO	HC
ALL UNITS WORKING SIMULTANEOUSLY : 1993								
Ferrous casting (Foundries)	131	-	1048	3773	616	79	70530	-
Ferro Alloys (Pit Furnace)	34	-	34	122	20	3	2288	-
Chemical	34	-	51	64	85	10	287	64
Rubber processing	30	-	6	8	10	1	34	8
Refractory bricks	16	-	32	36	21	3	7	2
Engineering	20	-	17	22	29	3	98	22
Lime processing	18	-	59	73	97	11	329	73
Total	283	-	1247	4098	878	110	73573	169

Contd....

Industry	Total Numbers	Fuel Consumption (MTPD)	Emission rate*(Kg/hr)				
			SPM	SO_2	NOx	CO	HC
Year : 2001							
Ferrous casting	131	1048	3773	616	79	70530	-
Pit Furnace	34	34	122	20	3	2288	-
Chemical	34	51.5	64	85	10	287	64
Engineering	20	17.4	22	29	3	98	22
Refractories	16	32	36	21	3	7	2
Lime processing	20	65	81	108	12	366	81
Rubber processing	50	10	13	17	2	57	13
Total	305	1258	4111	896	112	73633	182

COMMENTS ON NEERI'S REPORT ON POLLUTION IN AGRA CIRCULATED BY PROF.P.KHANNA, DIRECTOR, NEERI ON 24.4.95 TO EXPERT COMMITTEE

PROF.B. PADMANABHA MURTHY

POINT.1

TABLE 1 & 2 Results are summarised below:

	Winds from Ferozabad	Concn. at Taj	Winds from Mathura	Concn. at Taj
Winter	14%	0 $\mu g/m^3$	7 %	5 $\mu g/m^3$
Summer	24%	9 $\mu g/m^3$	11%	1 $\mu g/m^3$

a. In summer winds are Westerly/ Northwesterly hence occurence of 24% from east where Ferozabad lies are rare hence the data is questionable.

b. Further Ferozabad is two-thirds the distance from Mathura to Agra, in the east. Hence with 7% winds from Mathura if the glc is 5 $\mu g/m^3$ the glc with 14% of winds at two-thirds distance and higher emissions cannot be zero at Taj.

c. Higher frequencies of winds have to yield higher glc. Accordingly, from Ferozabad 14% of winds in winter yield 0 $\mu g/m^3$ glc and 24% yield 9 $\mu g/m^3$. But from Mathura when 7% of winds in winter yield 5 $\mu g/m^3$ 11% in summer is only producing 1$\mu g/m^3$ which is contradictory to the former result. On this account too the data is questionable.

POINT.2

TABLE 2 Contribution of 34 % of glc at Agra from Ferozabad in Summer is questionable on two accounts:

a. Winds are normally from Westerly/ Northwesterly at Ferozabad most of the time in Summer

b. In summer, when unstable conditions prevail, most of the time, with low stacks in Ferozabad, even with easterly winds glc's (24 hr. SO_2) decrease exponentially to low values beyond 5 kms.

POINT.3

TABLE 2 Individual contributions from various sources is algebraically added to obtain total concentration at Taj. Predicted glc's in winter and summer in the Table are given as 18.9 and 26.4 ug/m³ respectively.

The cumulative impact on p.V-20-V-30 in the Report on Air Pollution Studies to redefine TTZ give for winter and summer as 13.9 and 16.4 µg/m³ respectively.

Either the model may be underpredicting with multiple sources on the algebraic addition of individual contributions may be improper. Model details and input data is not made available in the Report hence not possible to confirm either.

POINT.4

TABLE 2 gives predicted maximum glc and refers to worst meteorological conditions and highest observed stack emissions . Hence there must be peak values - 18.9 in winter and 26.4 µg/m³ in Summer - which are to be compared with peak value in 1993 (Fig.3 in the circulated note) i.e greater than 100 µg/m³ (90th percentile). As they do not tally, the predictions are unreliable.

POINT.5

CIRCULATED NOTES P.2 LINE 8: "Major contributions to air pollution in Agra region is from point sources. It varies between 75 to 80% in summer and winter seasons".

From point sources, in summer high glc's occur at short distances. With different stack heights, the distnce of maximum glc differs. In winter, high concentrations occur over longer distances away from stack and the cumultive effect of a number of stacks will be large. Agra, being farther either from Mathura or Ferozabad, is expected to record higher glc's during winter. (particularly nights most of the time). Therefore, the variation of 75-80% in summer and winter is not a realistic figure.

COMMENTS ON AIR POLLUTION STUDIES TO REDEFINE TTZ COORDINATES

Page I-2 Line 3-4: TTZ is based on 16 directions of wind but not on 12 as reported.

Page II-19 Line 7-9: Ventrical temperature profiles at one site cannot be deemed as average over the city nor several profiles can be averaged into one over a city. Vertical temperature profile depend upon the radiative properties of the underlying surface, wind profile and urban heat island. For example, at Taj there may be ground based inversions while in Agra city there may be slightly unstable layer at ground and an elevated inversion.

Fig.214: Shows elevated inversion but not ground based inversion. Rural areas near Taj, may have ground based inversion.

Figs.2.13,2.14,2.15

2.13 & 2.14 show superadiabatic on convective layer upto 100 m. while Fig.2.15 shows stable conditions with either F or E stability in the morning/ evening which is inconsistent.

Page III-55: SO_2 roses at Taj show that winds from NW/N contribute maximum while from SE/E contribution is low. Thus contribution from Ferozabad is low

V-24 Assimilative Capacity

Maximum Mixing heights occur at 1400 Hrs.and minimum in the early mornings at 0000 Hrs. Maximum Mixing heights at Delhi are 1320 m, 3130m, 1900 m and 2546 m in January, April,July, and October. Compared to these, those presented in the report are too low.

In winter maximum glc of 40 $\mu g/m^3$ at 1900-2000 Hrs. is reported and attributed to low mixing heights which does not occur at that time. This high concentration is mainly due to increased anthropogenic activity - domestic cooking, vehicular traffic and formation of ground level inversions and low/ calm winds leading to stagnation conditions but not due to low mixing heights.

Assuming same mixing heights/ ventilation coefficient/pollution potential over the entire Agra area and evaluating mean glc in different grids based on emissions that grid is over simplication of the problem. After all the boxes over the grids are not air tight compartments. Instead attempts to evolve an emission schedule to the industries would be useful.

Subject : Air Pollution Studies to redefine the boundaries of the Taj Trapezium: NEERI Report of July 1993.

The report cited above seeks to revise the boundaries of the Taj Trapezium from the earlier one drawn up by an Expert Group in 1979. The new boundaries are based on model projections of the scenario that might develop in future. The report considers only the pollution released by the industrial complexes at Agra, Mathura and Bharatpur. In this context, the following comments and suggestions are offered for consideration.

2. Model deficiencies and uncertainties.

The projections are based on a Gaussian plume model. Computer programmes for this purpose have been imported from abroad. The models assume the following general expression for the spread of pollution from a source of strength Q (g/sec)

$$C(x,y,z) = \left(Q/2\pi\sigma_y\sigma_z U \right) \exp\left[-(y-y_0)^2/2\sigma_y^2 - (z-c)^2/2\sigma_z^2 \right] \qquad (1)$$

where x_0, y_0 are the location coordinates of the source, C is the concentration and σ_y, σ_z are the standard deviations in the horizontal and vertical directions. Modifications are introduced to the above general expression for different source configurations, that is, for a continuous point, line or area.

The report does not specify the exact expression that was used for different sources but it is relevant to point out the uncertainties that are inherent in the Gaussian plume model. The main assumptions of the model are: (i) the mass of the effluent is constant. This can be seen by integrating (1). (ii) the spread or diffusion in orthogonal directions is assumed to be independent of each other and (iii) the standard deviations depend on on a number of meteorological factors, along with travel time and the nature of the terrain. In view of these assumptions, it is suggested that sensitivity tests be conducted to determine the range of model uncertainties.

To illustrate this let us consider the following example. The short term lateral spread is often given by an empirical expression of the form

$$\sigma_y = 0.017\, \sigma_\theta\, (x)^{0.87} \qquad (2)$$

where σ_θ is the standard deviation of the azimuthal wind. If an error of 20% , say, is made in determining the standard deviation then because equation (1) contains a term σ_y^2 the overall error in computing the concentration (C) will be considerably more. Sensitivity tests of this nature will improve our confidence in the model outputs cited in the NEERI report.

3. Uncertainties in wind direction

Uncertainties caused by fluctuations in wind direction are to some extent reflected in table 2 of the Suammary of the NEERI Report under consideration. Hourly wind directions were probably not considered for predicting SO_2 concentrations from the Firozabad Glass Industries. A ' zero' value for winter appears questionable, if it is based on only two wind observations per day. There is no mention of a diurnal variation in wind direction at this station. The same table states that ~~The same table states~~ that the pollution (SO_2) predictions for Mathura were for the worst meteorological conditions and highest stack emissions. A clarification of what was meant by the 'worst meteorological condition)' would be helpful. The figures in the table suggest that they are short term concentrations for 24 hours. It would be better to consider long term concentrations based on a wider data sample.

3. Addition of pollution concentrations from different sources.

Table 2 shows the cumulative concentration obtained by adding the individaual contributions from different sources, i.e., from Agra, Mathura and Bharatpur. This is not strictly correct, because the pollution from one source may interact with the pollution from another source. It should be treated as a non linear problem. Moreover, the wind direction from all the three sources need not be identical at any given time. There could be the possibility on effluents from one source interacting with those from another source to off-set each other.

4. Inversions

There is a critical value of the strength of an Inversion in temperature which is modt effective in trapping pollutants. In general terms, the effective temperature inversions should satisfy the following criteria: (i) the lapse rate of potential temperature should exceed 0.005 $^{o}C/m$ and (ii) the difference in potential temperature between the top and the base of an inversion layer should be greater than $2^{o}C$. It is not clear from the NEERI report whether these criteria were followed. On page II-19 an abnormally high value of the lapse rate ($28.6^{o}C$ / 100 m) has been cited, but there is no mention of the depth of this inversion layer.

5. Pasquill- Gifford classification

The standard deviations in the azimuthal and vertical directions are related to meteorological variables by following a classification due to Pasquill and Gifford. But, there are other classifications that are also in use. In this context, we may mention the scheme of Golder (D.Golder, 1972, Relations among the stability parameters in the surface layer,

From Over

Boundary Layer Meteorology, 3,57-58.) Would it not be worthwhile to conduct a few sensitivity tests on this aspect ?

Summary and Recommendations.

The following suggestions are offered:

(i) In view of the importance of the Taj Mahal for our nation any steps towards redction in the boundaries of the Taj Trapezium should be taken with great caution.

(ii) A more critical analysis of model uncertainties is desirable to determine the noise level in the different model outputs cited in the NEERI report.

(iii)Experiments may be made with different classifications to determine the relation between the horizontal and vertical standard deviations and meteorological parameters.

(iv) If possible a better data sample, especially on wind direction, should be used.

(v) The non. linear aspects of the problem should be examined in greater detail. It is not correct to add up the individual sources to get the sum of the the concentrations.

P.K.Das

(P.K.Das)

A- 59, Kailash Colony,
New Delhi 110 048.

टेलेक्स/Telex : 0715-7233
तार : नीरी/Gram : NEERI

फोन/Phone : 226071 to 226075
फैक्स/FAX : 91 (712) 230673
91 (712) 222725

राष्ट्रीय पर्यावरण अभियांत्रिकी अनुसंधान संस्थान
NATIONAL ENVIRONMENTAL ENGINEERING RESEARCH INSTITUTE

पत्र व्यवहार निदेशक के पते पर किया जाए उनके नाम से नहीं ।
communications to be addressed to Director and not by name

नेहरू मार्ग, नागपुर-440 020
Nehru Marg, NAGPUR-440 020
(India)

सं/No. APC/121-A/94/506

दिनांक/Date 19/08/94

Mr. Raman
Chairman, AIFA
Agra Iron Foundry Association
Agra

Sub: Clarifications for NEERI Reports

Dear Sir,

Kindly refer your letter No. AIFA/94-95/156 dated 1/08/94 addressed to Dr. P. Khanna, Director NEERI. The clarifications for the queries on NEERI reports raised by you are as follows :

* In the referred NEERI's studies the range of SO_2 emission rate observed in the actual field monitoring were :

Emission rate (kg/MT of coke)	NEERI Reports	
	1981-82	1988-89
Range	0.9 - 3.96	3.3 - 6.42
Avg.	1.8	4.7

In the year 1988-89, extensive studies for whole cycles of cupola operation in other states (Haryana/Punjab) were carried out for evolving engineering designs of flue gas treatment of cupola furnace emissions. Such studies in other places were essential because the SO_2 emission rates vary in a wide range being guided by source of coke supplies and its 'S' content.

* For Taj Trapezium report of 1993, higher amongst the two average values of emission factor was taken. It is a normal procedure in all such studies which are primarily meant to project the impacts of different air pollution management options in a region. In such studies maximum emission rates are taken to deliniate appropriate ultimate long term air resource management strategy applicable for whole region.

The variations in total emissions in these two (above reffered) studies were due to difference in data on following :

- No. of units working/day
- Working hours/day
- change in total coke consumption

Contd...

The information on number of foundry units, their working schedule etc. for 1993 report has been taken from DIC records (Ref. enclosed copy of concerned page of DIC report)

* Under the Supreme Court directives the objective of analysis carried out by NEERI was quite different because the requirement here was to find out alternate cleaner fuel option. As there are total 131 foundries, in Agra region, all the units were considered operating on a particular day to calculate the maximum fuel requirement of all the foundry units of Agra in order to obtain equivalent cleaner (other) fuel requirement vis-a-vis change in pollution load in the region.

I hope this shall clarify the matter raised by you in many previous letters.

With regards,

Yours sincerely,

AL Aggarwal

(A.L. Aggarwal)

AIR POLLUTION BY INDUSTRIES IN TAJ TRAPEZIUM ZONE (TTZ)

STATUS * PROBLEMS * SOLUTIONS

Report of the committee formed by U P Govt. vide order No 970/18-13-51/Bha/94 dated 30-5-94 under chairmanship of Commissioner Agra Division

a

Annexure - 2

Photocopy of page iv-30 of NEERI'S July 93 report.

TABLE 4.9

INDUSTRIAL FUEL CONSUMPTION : TTZ

Town/ City	Industries Type	Number	Fuel Consumption (MTPD)
Agra	Foundry	131	1048
	Pit Furnaces	34	34
	Rubber Sole	30	6
	Chemical	34	52
	Refractory Bricks	16	32
	Engineering	20	17
	Lime Processing	18	58
Firozabad	Glass	267	1264
	Muffle Furnaces	1132	374
	Pottery	33	215
Mathura	Foundry	8	64
	Oil Refinery	1	NA
Bharatpur	Oil Boilers	29	18
	Rolling Mil.	1	4
	Pottery	1	37
	Dairy	1	46
Faran	Foundry	4	32
Vrindavan	Foundry	3	24
Kumner	Oil Boiler	1	1
Rupbas	Lime kilns	2	10
Bayana	Lime kilns	2	10
	Oil Boiler	1	1
Hathras	Cotton Mill	1	8
	Oil Boiler	1	1
Mursar	Glass	50	22
Jalesar	Brass	530	17

8. WRIT PETITION IN SUPREME COURT.

In 1984 Mr.M.C Mehta filed a writ petition before Supreme Cour against GOI,MR . U.P.Govt. and other govt. agencies.department with a prayer that they be directed to take suitable measure including shifting of MR to save TAJ from threat of air pollutic caused by MR hearing started in 1993.

The Supreme Court directed UPPCB to file status of pollution i TTZ. UPPCB asked 511 units in TTZ thru Newspaper advertisement t submit their fuel consumption etc.A total of 212 units did nc reply. the Hon'ble Supreme Court ordered closure of these units As of now only 30 units in Agra & 67 units in Firozabad remai closed others have installed APCS and Hon'ble Supreme Court ha ordered their reopening

The Hon'ble Supreme Court on 15-2-94 directed NEERI(Nationa Environmental Engineering Research Institute - Nagpur) to examin use of SAFE FUELS like propane etc as alternative to currentl used fuels (Coke,Coal etc.) by foundries and other industries i TTZ.The report by NEERI to Supreme Court was devastating as i went beyond what Hon'ble Supreme Court had asked and conclude shifting of small scale industries from TTZ. The conclusions drawn were seemingly based on wrong and inflated data relating to use of COKE/COAL specially in Agra as given below

CITY	NO OF INDUSTRIES		COKE/COAL USED-PER DAY		
	As per NEERI	As per DIC	As per NEERI report of Feb.94	ACTUAL reported by	
				DIC	UNITS
Agra	292	305	1247 MT	129MT	92 MT
Firozabad	1432	1787	1873 MT	700MT	N A

The Hon'ble Supreme Court guided by this report asked industries in Agra to give information relating to shifting vide their order of 11-4-94.

Sensing that such step would kill the small industries and will play havoc with the life of 305 enterprenuers,57800 workers and their families peacefull demonstrations were held at TAJ on 27 & 28 April by enterprenuers and workers respectively Thoughtfully Hon'ble Supreme Court took cognizance thru 'News Paper" reports and directed GOI - ministry of environment to undertake a new study on "Air Pollution" in TTZ by any agency from India/Aborad.

7 NEERI REPORTS: (July 1993 and Feb. 94)

7.1 The objective of the NEERI'S July 1993 report was-:

1. Redefining the Taj Trapezium.

2. Delineating an Air Environment Management Plan(AEMP)

This is a lengthy report of some 310 pages. The trapezium has been redifined but the changes are marginal. As far as AEMP is concerned it has reiterated the fundamentals of any air quality management plan. These are

1. Mitigation at source through technology upgradation.

2. Pollution attenuation through Green Belts.

Following basic issues which should have been tackled by NEERI remain unanswered.

1. Are the Taj and other monuments in the area being damaged at a rate faster than those in non-polluted areas?

   The NEERI report does not address this issue. The Archeological Survey of India thinks not.

2. If the Taj is really in danger, what are the specific pollutants responsible?

   The NEERI report provides a general description, mostly citing literature.

3. Once the specific pollutants are identified, which specific sources are contributing and in what proporation?

   NEERI has not made any attempt in this direction and has not recommended the most cost-effective solution to reduce ambient air pollutants concentration within acceptable limits.

On the other hand some vital inacuracies have crept in like highly inflated coal/ coke consumption figures particulary in the ca e of Agra

NEERI'S February 1994 report:-

This report is submitted by NEERI to Supreme Court in response to their directive of 15th Feb. 94 and in this report it has given highly inflated figures of coke/coal consumption(10-12 times - annexure-3) and recommended shifting of small industry from TTZ (annexure - 4).

w ver Hon'ble Supreme Court has disregarded these reports and rected that another study be undertaken to study pollution in

11. PROBLEMS OF INDUSTRY IN ACHIEVING POLLUTION STANDARDS

The details of various industries in TTZ and air pollution control systems installed by them in Agra and Firozabad are given below:-

UNITS REGESTERED WITH INDUSTRIES DEPT.

A. AGRA

(i) No. of units- 305 (Foundries -167,Chemical,Plastic,Rubber Tannery,Engineering and others -138)

(ii) Coal Consumption - 28500 tpa Hard Coke (mainly Foundries) 21600 tpa Steam Coal

B. FIROZABAD

(i) No. of units - 393 (Glass-334,Ceramic-31,Chemical-28)

(ii) Coal Consumption - About 210000 tpa mainly Steam Coal (annual capacity 700000 MT)

(iii)Unorganised sector units - 1394 (mainly pakai bhattis of Glass)

APCS INSTALLATION STATUS

S.NO.	DETAILS	AGRA	FIROZABAD
1	No. of Industries (As per records of UPPCB)	293	217
2	No. of whom closure ordered issued by Supreme Court	88	152
3	No. which are open	205	62
4	No of units where APCS installed	260	146
5	No. where monitring completed and standards achieved	186	107
6	No. where APCS installed but standards not achieved	4	3
7	No. where monitring is to be done	4	21
8	No. of units closed and no progress in APCS installation	30	67

Technical Report

Issues Associated with Fuel Supply Alternatives for Industries in Agra-Mathura Region

The Hon ble Supreme Court
New Delhi

National Environmental Engineering Research Institute
Nagpur 440 020

March 7, 1994

Table 4 (A)

Projected Emissions from Combustion of different Fuels in Agra-Mathura Region

Town/city	Industries: Type	Industries: Number	Coal/Coke: Consumption (MTPD)	Coal/Coke Estimated Emissions, MT/day: SPM	SO_2	NO_x	CO	HC	Natural Gas: Consumption (SCMD)	Natural Gas Estimated Emissions, MT/day: SPM	SO_2	NO_x	CO	HC
Agra	Foundry	131	1,048	273.0	9.9	7.9	1.05	0.52	3,45,930	27.72	0.003	0.67	0.09	0.02
	Pit Furnaces	34	34	8.8	0.3	0.25	0.03	0.02	11,223	0.9	-	0.31	-	-
	Rubber Sole	30	6	1.6	0.06	0.05	-	-	1,980	0.162	-	-	-	-
	Chemical	34	52	13.5	0.5	0.39	0.05	0.03	17,165	1.37	0.0002	0.04	-	-
	Refractory Brick	16	32	8.3	0.3	0.24	0.03	0.02	10,562	0.85	-	0.02	-	-
	Engineering	20	17	4.4	0.2	0.13	0.02	0.01	5,612	0.45	-	-	-	-
	Lime Processing	18	58	15.1	0.5	0.44	0.06	0.03	19,145	1.53	0.0002	0.04	-	-
Firozabad	Glass	267	1,284	333.8	12.2	9.63	1.23	0.6	4,23,833	33.84	0.0040	0.81	0.11	0.02
	Muffle Furnace	1,132	374	97.2	3.6	2.8	0.37	0.2	1,23,453	9.90	0.0013	0.23	0.04	-
	Pottery	33	215	55.9	2.1	1.61	0.21	0.1	70,970	5.67	0.0007	0.14	0.02	-
Mathura	Foundry	8	64	16.6	0.6	0.43	0.06	0.03	21,123	1.69	0.0002	0.04	-	-
	Total	1,723	3,184	828.2	30.26	23.92	3.46	1.56	10,51,001	84.08	0.0097	2.2	0.25	0.04

Contd...

2.4 Safety Requirements

2.4.1 NG : The use of NG involves the defining of No Gas **Zone** for safe distribution. The new sites in Agra and Firozabad industries being identified by the Government of Uttar Pradesh shall minimise this hazard as the industrial estates shall be suitably designed for NG distribution.

The new industrial sites should preferably be out of the Taj Trapezium. The incentives for industries to shift to new industrial estates need to be established to ensure speedy implementation.

2.4.2 LPG : The supply of LPG would primarily be from MR. Safe handling and proper distribution system is essential for its supply, requiring open industrial areas to avoid hazards to nearby residential zones.

2.4.3 Propane : The use of propane involves special storage facility, and suitable distribution and handling systems. New open industrial estates are desirable to minimise safety hazards.

The safety requirements bring out that all the three fuel alternatives require open spaces highlighting the need for new industrial estates outside the Taj Trapezium where the existing industries in Agra-Mathura region could shift.

3.0 Summary

The various issues raised in this report pertaining to the fuel supply alternatives to the industries in Agra-Firozabad region and the Mathura Refinery, can be summarized as:

- Need for relocation of industries
- Availability of cleaner fuel (present and future)
- Environmental benefits from alternate fuels
- Safety considerations

DeAggarwal

The recommendations are summarized hereunder:

- Shifting of small-scale polluting industries outside the Taj Trapezium on industrial estate sites to be identified by the Government of Uttar Pradesh;

- Provision of natural gas to the industries in Agra-Mathura region and Mathura Refinery

LIST OF FOUNDRIES WHO HAVE VOLUNTERED TO CHANGE TO DIVIDED BLAST CUPOLA

1. THE NATIONAL IRON FOUNDRY
2. RAJ PATTERN MAKERS & FOUNDERS
3. RAGHAV ENGINEERING CO.
4. SHYAM STEEL
5. KAMAL ENGG. WORKS
6. MITTAL IRON FOUNDERS & ENGINEERS
7. SATYA DEEP UDYOG
8. S.A.IRON FOUNDRY
9. ESBE STEELS & CASTINGS
10. MANIK CHAND GARG & CO.
11. MEHRA CASTING WORKS
12. MAHARISHI DAYANAND IRON FORNDRY
13. SHREE RAM ENGINEERING WORKS
14. SHIVAM INDUSTRIES
15. EXPERT FOUNDERS & ENGINEERS
16. RAJ IRON FOUNDRY UNIT-I
17. ASSOCIATED INDUSTRIAL CORPN.
18. GULAB RAI CHHOTEY LAL
19. A.B.AUTO WORKS PVT. LTD.
20. AMI STEEL PVT. LTD
21. S.G.INDUSTRIES UNIT-I
22. CHINAR FOUNDRY
23. KANSAL IRON FOUNDRY
24. AJANTA INDUSTRIES
25. ACCURATE FERRO CASTINGS
26. K.J.INDUSTRIES
27. JAGDISH INDUSTRIAL CORPORATION
28. NARESH IRON FOUNDRY
29. INDIA CASTING COMPANY
30. HIMALAYA INDUSTRIES

32. SINGHAL INDUSTRIES

33. METAL CAST (INDIA)

34. INDIAN IRON FOUNDRY

35. SURAJ FOUNDRY

36. MITTAL INDUSTRIES

37. MAHENDRA IRON FOUNDRY

38. RAJ IRON FOUNDRY UNIT-II

39. S.G.INDUSTRIES UNIT-II

40. SHYAM METAL WORKS

41. DEVI SAHAI GOPAL DAS

42. SHREE MAHAVIR ENGG. WORKS

43. SURESH IRON FOUNDRY & ENGG. WORKS

44. STANDARD STEEL IRON FOUNDRY

45. RANDHIR SINGH KHUB CHAND IRON FOUNDRY

46. S.K.IRON FOUNDRY & ENGG. WORKS UNIT-I

47. S.K.IRON FOUNDRY & ENGG. WORKS.UNIT-II

48. VINAY IRON FOUNDRY

49. BANSAL CASTING CO.

50. DONERIA PRIVATE LTD.

51. GOPAL IRON FOUNDRY

52. MAHAVIR IRON FOUNDRY I

53. PARAS FOUNDRY

54. MAHAVIR IRON FOUNDRY II

55. OSWAL IRON FOUNDRY

56. JAIN FDY. & ENGG. WORKS

57. CASTWEL FOUNDRY

58. METAFAB ENGG. ASSOCIATES

59. GANGA ENGINEERS

60. GOYAL METAL INDUSTRIES

61. MODERN INDUSTRIES

62. MUDGAL IRON FOUNDRY

63. SRIRAM METAL INDUSTRIES

64. KAJECO INDUSTRIES-I

65. KAJECO INDUSTRIES-II

66. AGRA LOH UDYOG

67. B.C. IRON FOUNDRY

68. BAJRANG IRON FOUNDRY

69. AGARWAL TIN MFG.CO. ENGG.WORKS

70. MAHAJAN ISPAT

71. V.K.ENTERPRISES

72. RAVI AGRICULTURE INDUSTRIES

73. KAUSHAL FOUNDERS & ENGINEERS

74. R.R.IRON FOUNDRY

75. SARAD INDUSTRIES

76. MAHARAJA AGARSEN IRON FOUNDRY

77. BOMBAY ENGG. & MOULDING WORKS

78. SHRI BHAGWAN IRON FOUNDRY

79. RELIABLE INDUSTRIES

80. SHINING ENGINEERING WORKS(FOUNDRY)

81. PAROLIA ENGG. WORKS

82. SHANTI VRAT & SONS PVT. LTD

83. SHRI RAM IRON FOUNDRY & ENGG. WORKS

84. KAMAL ENGG. WORKS UNIT-II

85. BHARAT IRON & STEEL FOUNDRY

86. GOLDEL INDUSTRIAL CORPORATION

87. S.K.IRON FOUNDRY & ENGG. CO.

88. CHHAVAN ENGG. WORKS

89. GULAB CHAND CHHOTEY LAL

90. KHANDELWAL INDUSTRIAL ENTERPRISES

91. MOTILAL AGARWAL & CO.

TAJ TRAPEZIUM UDYOG SANGHARSH SAMITI
C-48, FOUNDRY NAGAR
AGRA-282006

FAX MESSAGE

011-4362281

28th April'95

Dear Mr.Varadarajan,

In continuation of my letter dated 23.04.95 I give below the list of foundries who have also volunteered to install divided blast cupola, kindly add these to earlier list.

1. S.B.Iron Foundry
2. G.T.Iron Foundry
3. Techno Industries
4. Shree Durga Bhagwati Industries & Iron Foundry
5. Shree Durga Laxmi Iron Foundry
6. Vijay Iron Foundry
7. United Industries
8. Brij Iron Industries
9. India Iron Foundry
10. G.C.Industries
11. Kalyan Steel Products P.Ltd.
12. N.K.Iron Industries
13. Shri Mahavir Glass & Silicate Works
14. Goyal Iron & Steel Works (India)
15. Goyal Iron & Steel Works
16. Ess Jay Steel Pvt.Ltd
17. Anil Metal Ind. (Foundry Dvn.)
18. Amar Enterprises
19. The Arhariya Iron Foundry

Out of 131 cupola foundries some have ceased operation, the balance letters are also expected in next few days.

Kind regards,

Sincerely yours,

(S.M.KHANDELWAL)

Dr.S.Varadarajan,
C/o Ministry of Environment & Forests,
C.G.O. Complex, Lodhi Road,
NEW DELHI-110003

Bajrang
IRON FOUNDRY (BIF)®

MANUFACTURERS & EXPORTERS OF :
C. I. PIPES AND FITTINGS, MANHOLE COVERS,
DIESEL ENGINE SPARES, C. I. CASTINGS, CENTRIFUGAL WATER PUMPS ETC.

PHONES
OFFICE :
344225
344215
RESI
381045
261213
65585
GRAM :
BAJRANG

B-4, FOUNDRY NAGAR, HATHRAS ROAD,
P. O. NARAICH, AGRA-282 006

Ref. No.

Date 22-04-1995

Dr. S. Vardarajan,
Chairman,
VARDARAJAN COMMITTEE,
Ministry of Enviornment & Forest,
NEW DELHI

Dear Sir,

We would like to submit the following steps already taken by us for reducing Emission and also Fuel (Hard Coke) consumption in foundries of Agra.

We are keen that still better technology be employed to reduce Hard Coke consumptions.

We have already installed Air Pollution Control System (APCS), due to our continuous endeavours for employing better available Techonology to reduce Pollution & Hard Coke consumptions.

In the process of our continuous efforts in this direction we have decided to install Divided Blast Cupola, with appropriate modifications to our existing Air Pollution Control System (APCS) and accordingly, SPM & SO2 level of emissions will further be reduced, resulting in further cleaning the Enviornment.

In this endeavour, our Association, namely; Agra Iron Founders' Association, 88 North Vijay Nagar Colony, Agra is in constant look-out for more positive actions to further cleaner enviornment and has recently entered into a 'MEMORANDUM OF UNDERSTANDINGS(MoU) with USAID that will made available all sorts of helps, in furthering the cause of still better enviornment.

The cost of such a unit is about Rs.5/6 lacs. The foundries in Agra region are very small and with all the problems confronting it for the last two years, due to stagnancy and their financial position is in a bad shape.

We would therefore request that a subsidy of 70-80% be given to the units for improving their melting system.

Cont'd.....p/2

Bajrang
IRON FOUNDRY

MANUFACTURERS & EXPORTERS OF :
C. I. PIPES AND FITTINGS, MANHOLE COVERS,
DIESEL ENGINE SPARES, C. I. CASTINGS, CENTRIFUGAL WATER PUMPS ETC.

PHONES
OFFICE : 344225 344215
RESI 381045 261213 65585
GRAM BAJRANG

B-4, FOUNDRY NAGAR, HATHRAS ROAD,
P. O. NARAICH, AGRA-282 006

Ref. No.

Date ....

We would stress that if better quality of Hard Coke, having high shatter index and low ash percentage, is made available to Agra region, it will certainly help reducing the levels of pollutants.

Yet, in our commitment to adopt for any methods that help keeping this enviornment more worth living, we are open for that.

Thanking you,

Yours faithfully,
For BAJRANG IRON FOUNDRY

Ashok Kumar Goyal

PARTNER

S. Vardarajan,
...an, VARDARAJAN COMMITTEE,
...ry of Environment & Forest,
...i.

D... Sir,

We would like to submit the following steps already taken u... for reducing Emission and also Fuel(Hard-coke) consumption foundries of Agra.

We are keen that still better technology be employed to reduce Hard-coke consumptions

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Yet, in our commitment to adopt for any methods that help keeping the environment more worth living, we are open for that.

Yours faithfully,

For The National Iron Foundry

21.4.95 Partner

Project Personnel

Dr. S.N. Kaul
Dr. S.K. Titus
Dr. (Mrs.) R. Sarkar
Dr. (Mrs.) A.S. Gadkari
Dr. (Mrs.) R.A. Thakre
Dr. M.Z. Hasan
Dr. B.Z. Alone
Dr. A. Ghosh
Mr. K.M. Phadke
Mr. S.D. Joshi
Mr. C.P. Gajrani
Mr. A.G. Gavane
Dr. (Ms). Sandhya Sakalkar
Ms. Vidhi Verma
Mr. J.K. Bhattacharyya
Mr. P.M. Patni
Mr. P.K. Mishra
Mrs. Manjusha Sargaokar
Mr. C.V. Deshpande
[illegible]

Mr. C.S.G. Rao
Dr Anunesh Kumar
Dr. N.S. Manthapurwar
Mr. S.M. Tamhane
Dr. D.G. Gajghate
Ms. Padma Rao
Mr. S.K. Goyal
Mr. R. Shivacumar
Mr. A.D. Bhanarkar
Mr. A.K. Jain
Mr. D.S. Tajne
Ms. B. Ramteke
Mr. R.A. Sohony
Mr. K. Vinodan
Mr. S.L. Lutade
Mrs. V.C. Shah
Mr. K.B. Meshram
Dr. (Mrs). Shantha Narayan
Mr. P.A. Deshpande
Dr. P.R. Chaudhari

Secretarial Assistance

Mr. A. Rashid
Mr. A.N. Mishra
Mr. M.M. Jambhulkar

Mr. R.G. Verma
Mr. M.P. Kasture
Mr. N.K. Tiwari

Project Leaders

Dr. V.I. Pandit
Mr. Piyush Mehta

Project Coordinators

Dr. A.L. Aggarwal
Dr. S.K. Gadkari

Project Guide

Dr. P. Khanna

Rapid Environmental Impact Assessment for Proposed Matching Secondary Processing Facilites of Mathura Refinery : U.P.

Sponsor

Indian Oil Corporation Limited

National Environmental Engineering Research Institute
Nehru Marg, Nagpur - 440 020

April 1994

Table 3.1.6

Predicted Short Term Maximum (24 Hrly. Avg.) GLCs at Certain Receptors

(Based on Actual Hourly Meteorological Data for 578 Hours During Winter 9

Recepter Direction 0° = North	Distance	Case-1 7.5 MMTPA existing ops.	Case 2 8.5 MMTPA existing ops.	Case-3 7.5 MMTPA +PRU/CRU	Case-4 7.5 MMTPA +PRU/CRU +MSPF	Case 5 8.5 MMTPA +PRU/CRU +MSPF
SE, 135°	1 km	23.6	26.2	24.6	24.9	25.9
	2 km	12.4	13.6	13.0	14.1	14.6
	4 km	13.3	14.4	14.4	10.3	10.8
	6 km	10.7	11.7	11.7	8.7	9.1
	8 km	8.5	9.4	9.8	7.2	7.3
	10 km	8.8	9.3	10.2	7.0	7.1
Farah, 133° (-300 m.off SE)	8.5 km	10.1	11.2	11.5	7.8	7.8
Keetham 133.5° (-600 m.off SE)	23 km	8.1	8.8	9.4	7.7	7.9
Taj Mahal, 123°	47 km	6.6	7.3	7.6	5.9	6.2
Bharatpur, 233°	29 km	6.6	7.0	7.6	6.3	6.5

Note : The above 24 hr. maximum GLCs at different receptors generally occur at different days depending on meteorological conditions prevailing on that 24 hr. period (day).

Table 3.1.7

Predicted Long Term (Seasonal) GLCs at Certain Receptors

(Based on Actual Hourly Meteorological Data for 578 Hours During Winter '94)

Receptor Direction 0° = North	Distance	Case-1 7.5 MMTPA existing ops.	Case-2 8.5 MMTPA existing ops.	Case-3 7.5 MMTPA +PRU/CRU	Case-4 7.5 MMTPA +PRU/CRU +MSPF	Case-5 8.5 MMTPA +PRU/CRU +MSPF
SE, 135°	1 km	4.9	5.4	5.2	2.1	2.2
	2 km	4.3	4.7	4.6	2.1	2.2
	4 km	3.2	3.5	3.5	2.3	2.4
	6 km	2.7	2.9	3.0	2.3	2.3
	8 km	2.5	2.7	2.8	2.0	2.1
	10 km	2.3	2.5	2.6	1.9	1.9
Farah, 133° (300 m.off SE)	8.5 km	2.7	3.0	3.2	2.2	2.2
Keetham 133.5° (600 m.off SE)	23 km	1.7	1.8	2.0	1.6	1.6
Taj Mahal, 123°	47 km	1.5	1.6	1.7	1.4	1.4
Bharatpur, 233°	29 km	1.1	1.1	1.2	1.1	1.1