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14848

1985

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

DEVELOPMENT PROGRAMME IN CHINA.

RESEARCH AND DEVELOPMENT ON FLY ASH UTILIZATION.

REF.: DP/CPR/81/026/11-54/32.1.K

FINAL REPORT

FROM

EXPERT ON MISSION

TO

THE PEOPLE'S REPUPLIC OF CHINA

SHANGHAI RESEARCH INSTITUTE OF BUILDING SCIENCES.

DECEMBER 2 TO 21, 1984

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INTRODUCTION

Along with the recent development of new industry in the People's Republic of China discharge of industrial wastes such as fly ash, slag and condensed silica fume has increased rapidly and caused a great threat and concern to the environment in many areas. By environmental control and collection of these siliceous byproducts, the material represents valuable resources both from an energy point of view and from the point of view of providing new resources for building materials to the construction industry.

Shanghai is the largest industrial city in China with a population of approx. 15 million people. Due to an increasing number of thermal power plants its capacity for fly ash discharge was raised from 0,54 million tons in 1979 to 0,82 million tons in 1980. Up to 1990 it is forecasted that the annual capacity for fly ash discharge will be up to 3 million tons. In addition, large quantities of slag and condensed silica fume from the steel and ferro-silicon alloying industry, respectively, are also being discharged at an increasing rate.

Shanghai is situated on the coastal plain with no natural resources of building materials, so every year huge quantities of materials have to be transported in from other provinces. At the same time there is a great need to speed up the construction of both residential and business buildings as well as industrial structures and basic infrastructure facilities. Therefore, research and development programs in order to utilize the industrial waste products have got a high priority from both national and local governmental authorities.

The present research program which was started in 1982, is conducted by the Shanghai Municipal Capital Construction Commission and carried out by the Shanghai Research Institute of Building Sciences (SRIBS). Approx. 100 people are involved in the project, and the Institute has already developed a high

level of technical and scientific skill and know-how. Although the present research program is limited in time and economy, continued research in this area is of vital importance not only to SRIBS and to the City of Shanghai, but for the creation of a national center for utilization of industrial wastes.

The utilization of fly ash, slag and condensed silica fume is not only interesting as a simple replacement for conventional portland cement. Fly ash can also be used as raw material for production of high quality light-weight aggregate. Extensive research over recent years has shown that condensed silica fume also is a valuable resource for production of cementitious materials with completely new, high-quality properties of great importance for special construction procedures and for development of products with completely new properties. Thus, within a short period of time the price of silica fume on the international marked has become significantly higher than that of portland cement.

The People's Republic of China is one of the very few countries with large quantities of condensed silica fume potentially available. Of an international production capacity for silica fume of approx. 1,3 million tons per year, it is assumed that 0,15-0,20 million tons is potentially available in China. However, at the time being less than 200 tons is being collected on an annual basis.

Since Norway is one of the largest producers of ferro-silicon products in the world, Norway does also produce large quantities of condensed silica fume (approx. 0,2 million tons per year). Since strict environmental control was introduced in Norway approx. 10 years ago large quantities of silica fume became available, and extensive research on the utilization of this material was started. The first experiences on the utilization of this material was published from The Norwegian Institute of Technology already in 1952.

This research has not only been of vital importance to the Norwegian construction industry, but also to the development of new and highly specialized applications of concrete. In particular the recent development on new high-strength and durable materials for offshore concrete platforms and facilities for the extensive oil and gas explorations along the Norwegian continental shelf has been very interesting. Also along the Chinese continental shelf a new and promising development on oil and gas explorations is now taking place. Hence, a cooperation between The People's Republic of China and Norway in this area is natural.

It is the extensive Norwegian experiences on the collection, utilization and highly spezialized applications of condensed silica fume which was the background for the invitation of the present author to assist at the on-going research program at SRIBS.

THE ASSIGNMENT

The mission was primarily to present a series of lectures and discuss the on-going research activities at SRIBS. Visits to a ferro-silicon alloying plant and a university was also included in the program.

Lecturing program

A list of four main topics with keywords had been suggested as a basis for the lecturing program. Upon my arrival to Shanghai, however, a more detailed program was suggested. During my visit a program on 7 main topics including 34,5 hours of lecturing was presented.

(1) "Collection, storage and transport applications of silica fume".

The lecture was presented on Tuesday 11. Dec. from 8.30 to 11.30.

The lecture covered the technical background for production of silica fume, facilities for collection, storage and transportation. Chemical and physical properties and quality control of the material. Possible effects on human health.

The lecture was partly repeated in the afternoon for the technical staff of Shanghai Ferroalloy Works during a visit arranged to this plant.

The People's Republic of China has approx. 15 major ferroalloying plants producing condensed silica fume, of which only Shanghai Ferroalloy Works is collecting some of the material, approx. 500 kg per day from a small furnace.

(2) "Properties of silica fume concrete - Part 1 "

The lecture was presented on Wednesday 12. Dec. from 8.30 to 11.30 and from 13.30 to 16.00.

The lecture covered general effects of silica fume on concrete properties, with emphasize on relationships between microstructure, density and properties.

(3) "Properties of silica fume concrete - Part 2 "

The lecture was presented on Thursday 13. Dec. from 8.30 to 11.30 and from 13.30 to 16.30.

The lecture included effect of silica fume on fresh concrete properties and strength development, bond strength, high strength concrete, abrasion resistance and durability. Combination of silica fume and fly ash was also covered.

(4) " International trends in cement and concrete technology"

The lecture was presented on Friday 14 Dec. from 8.30 to 11.30 and from 13.30 to 14.30.

The lecture included an overall view of recent developments on cements and admixtures, processing of aggregates, quality assurance and quality controll, curing technology and fracture mechanics and matematical modelling of properties. Durability and prediction of service life as well as maintenance and repair were also covered.

(5) "Applied techniques of silica fume concrete and its technical and economical analysis - Part 1 "

The lecture was presented on Saturday 15 Dec. from 8.30 to 11.30.

The lecture was mainly concentrated on shotcreting and underwater concreting techniques. In both of these areas the use of condensed silica fume has prooved to be extreemly efficient both technically and economically.

(6) "Testing techniques for chemical deterioration of concrete"

The lectures was presented on Saturday 15 Dec. from 13.30 to 15.30.

The lecture covered recent trends and development on the testing of concrete in chemically aggressive environments.

(7) "Applied techniques of silica fume concrete and its technical and economical analysis - Part 2 "

The lecture was presented on Monday 17 Dec. from 8.30 to 11.30.

The lecture covered a variety of practical applications of silica fume concrete and experiences from case histories.

(8) "Offshore concrete platform construction in Norway"

The lecture was presented on Monday 17 Dec. from 13.30 to 15.00.

The lecture summarized the experiences from the extensive Norwegian construction programs on offshore concrete platforms built for the North Sea during the period 1970 to 1984.

(9) "Reinforced and prestressed concrete in marine environments - Part 1 "

The lecture was presented on Tuesday 18 Dec. from 8.30 to 11.30 and from 13.30 to 15.00.

The lecture covered various deteriorating processes in marine environments (electrochemical corrosion, chemical and physical deterioration).

(10) " Reinforced and prestressed concrete in marine environments - Part 2 "

The lecture was presented on Wednesday 19 Dec. from 8.30 to 10.15.

The lecture covered preventive measures, field surveying techniques and experiences on maintenance and long-time performance for concrete structures in marine environments.

In addition to staff members from SRIBS the audience included people from industry, universities, research organizations and governmental authorities. The attention of the participants was very high, and a number of questions and discussions made the lectures more fruitful. The simultaneous translation provided by people from the technical staff of SRIBS worked very efficiently.

As background information SRIBS had received a number of reports and papers ahead of my visit. During the visit a number of further reports were given, and copies of all slides (more than 400) and overheads (more than 200) were made. In addition, all lectures were tape recorded.

Current research program

An introduction to the current research program on fly ash utilization at SRIBS was given already the first day of my visit Monday, 10 Dec. Various problems and aspects of the project was discussed more or less continuously during the whole visit. Laboratory facilities and testing procedures were also discussed and experiences exchanged. In our discussions emphasis was given to

- Collection, storage and handling of silica fume.
- Quality control of silica fume properties.
- Applications and production of various types of silica fume concrete.

- Technology related to a more extensive use of organic admixtures.

During the discussions and meetings with the staff the wish was expressed for a future cooperation between SRIBS, Norwegian industry and The Norwegian Institute of Technology.

Shanghai Ferroalloy Works

The visit took place during the afternoon and evening of Tuesday, 11 Dec. The plant which was built in 1958, had 23 furnaces and produced more than 20 various alloying products. A rapid expansion had taken place over recent years from a total of 70.000 tons in 1977 to 140.000 tons in 1984. The plant had approx. 4.500 employees.

The main production for 1984 included:

- 50.000 tons FeMn
- 40.000 " FeCr
- 30.000 " 75 % FeSi
- 2.000 " Si-metal

Inspection of 1 furnace for Si-metal (2700 KVA) and 2 furnaces for CaSi (each 2700 KVA) was made. Bag dust collectors were installed in 1981 (7 silos with 60 bags in each silo). A total of 500 kg/day of dust was collected. These small furnaces will be replaced in the near future.

A furnace of 20.000 KVA was also inspected. This furnace produced 45 tons/day of 75% FeSi with a consumption of 8100 - 8200 KWh/ton. All the silica fume was discharged into the atmosphere, a collection of which would have given approx. 8 tons/day.

An increasing rate of steel production in the Shanghai area is expected from 5 mill tons/yr in 1984 to 10 mill tons/yr in 1990. Hence, the need for more ferroalloying products will also increase. 14 new ferroalloying plants will be built in the near future. At a dinner with Messrs. Lieu, C.P., Tian Changyin and members of the technical staff of the Shanghai Ferroalloy Works a wish for a future cooperation with Norwegian ferroalloying industry was expressed.

Tongji University

The visit took place during the afternoon of Monday, Dec. 17. The university which was founded in 1907, was a specialized university for civil engineering. It had approx. 7.000 regular students in 15 different departments.

Department of Building Materials had a staff of 150 people and offered study programs in the five following areas:

- Cement technology
- Concret technology
- Polymers
- Testing techniques
- Building materials chemistry

A meeting was arranged with Professors Huang Yiun-yuan and Chen Zhiyuan of the Building Materials Department. Current teaching and research programs were discussed, and a wish for a future cooperation between Tongji University and The Norwegian Institute of Technology was expressed. A visit to the laboratories was also arranged.

Two of the current research programs were discussed in more detail:

- Effect of condensed silica fume on the bond strength of concrete.

- Effect of condensed silica fume on the abrasion resistance of high strength concrete.

On both of these topics research activities are also going on at The Norwegian Institute of Technology.

RECOMMENDATIONS

On the basis of my staying with Shanghai Research Institute of Building Sciences (SRIBS) which included visits to Shanghai Ferroalloy Works and Tongji University, the following recommendations can be given:

(1) Both from an energy, natural resource and environmental point of view the current research program at SRIBS on the utilization of industrial by-products is highly important. In this area the Institute has already developed a high level of technical and scientific skill and know-how. However, the current research program is limited in time and economy. It is of vital importance, therefore, not only to SRIBS and to the City of Shanghai but to the whole of the People's Republic of China to continue this kind of research in order to create a national technological center in this area. Further funding for such research should be provided.

(2) The country has a great potential for production of condensed silica fume, and great efforts should be made to start up collection and utilization of this highly valuable raw material as soon as possible.

(3) A cooperation between Shanghai Ferroalloy Works and Norwegian ferroalloying industry should be arranged. Attention should be given to:

- Closing or semi-closing of furnaces

- Utilization of heat from the smoke

- Collection technology for condensed silica fume and full environmental control

- Compaction, handling and transportation technology for condensed silica fume

(4) A cooperation between SRIBS and Norwegian industry on the utilization of condensed silica fume should be arranged This should include:

- Quality control of condensed silica fume

- Technology related to organic admixtures for concrete

- Production of silica concrete with special properties

- Technology related to special concrete construction techniques (shotcreting, underwater concreting etc.)

- Technology related to utilization of condensed silica fume in refractory materials and polymers

(5) The cooperation between SRIBS and The Norwegian Institute of Technology should be continued. Such a cooperation should include visiting researchers comming to The Norwegian Institute of Technology for a shorter or longer period, also including possible Ph.D-programs. A researcher from SRIBS is coming for a 6 months period already during the spring of 1985.

(6) A cooperation between To[illegible] University and The Norwegian Institute of Technology should also be arranged. This should include students coming for a Ph.D-program. Several Chinese students are already carrying out their Ph.D-programs at The Norwegian Institute of Technology.

ACKNOWLEDGEMENT

The present author would express his gratefulness to Mr. Jiang Dian cheng, Director of the Shanghai Municipal Capital Construction Commission, and Dr. Wang Pu, Director of SRIBS and his staff, Messrs. Shen Dan-Shen and Gu Zhang Zhao, for the warm welcome, the well organized visit and the great hospitality. Gratefulness is also expressed to Messrs. Lieu C.P. and Tian Changyin of Shanghai Ferroalloy Works and Professors Huang Yiun-yuan and Chen Zhiyuan of Tongji University for their hospitality. Mr. A.W. Sissingh of UNDP took well care of me upon my arrival to Beijing. My staying in the People's Republic of China was very pleasent, giving me a lot of nice memories and many good personal friends.

Trondheim 22 March 1985

Odd E. Gjørv