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RESEARCH AND DEVELOPMENT FOR FLY-ASH UTILIZATION - PHASE II

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CHINA

Technical report: The possibility of using fly ash in concrete mixes

Prepared for the Government of China
by the United Nations Industrial Development Organization,
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ABSTRACT

The report analyses the existing practices as well as new methods of making concrete with the specific aim of increasing the rate of use of fly ash in building construction. In this connection, the expert went to Shanghai Research Institute of Building Science, assisted the local research teams and presented the state-of-the-art of new applications and technologies in concrete production. The report mainly shows that the R and D capabilities available at the Institute are of a satisfactory level and that there is a possibility of increasing the use of fly ash in high-strength and lightweight concrete.

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INTRODUCTION

The technical intent of the visit was simply to share technology. In the opinion of the expert, a visit such as this should have two purposes: first, to make people aware of the latest technology; and second, to recognize the situation as it exists and try to help improve upon it. Learning how to cope with everyday problems is just as important as the development of a new product. From his prior dealings with people from the Institute, the expert felt that they were in a position to serve both purposes. It was with these ends in mind that he embarked on the visit.

I. LECTURES AND DISCUSSIONS

A. Background

Most of the lectures and discussions took place at the Shanghai Research Institute of Building Science. In attendance were predominantly material research engineers, although some field engineers were also present. Other discussions took place at the Huangpu river bridge project, at the R.M.C. Branch of Shanghai Building Engineering Material Company and at the Zhejiang Province 1st Construction Engineering Company in Hangzhou.

B. Subjects discussed

1. High strength concrete

At present 80 MPa has been successfully achieved in three cities in China, while 100 MPa has only been achieved in the laboratory of the Institute. It appears that the use of high-strength concrete is currently very limited and, in some cases, it has been the secondary effect of producing high early strength concrete (e.g. pre-cast). Of greatest interest were materials, slump loss, temperature control and placement techniques. The expert believes that the types of chemical admixtures used have a lot to do with the rate of slump loss, temperature control and pumpability. Admixtures and their materials will be discussed later in this report. The total concept of the proportioning of cementitious materials and aggregates is fully understood, although nuances produced by optimizing aggregate gradations or admixture dosages have not yet been evaluated. At present, the extent of what can be achieved is limited by the compulsory use of certain materials, viz. slag cement, class F fly ash and lignin water reducers.

2. Fly ash

All the fly ash currently used would be generally classified under ASTM (American Society of Testing and Materials) C-618 as Class F. This ash could have a fineness of 12 per cent to 34 per cent. Twenty seven per cent of the 5,000,000 m^3 of concrete produced in Shanghai in 1989 contained fly ash (about 45 kg/m^3). One of the factors limiting its use is that most of the cement used contains slag. Fly ash is normally used in high strength concrete up to 50 MPa. One of the research projects to be discussed later is the discriminatory collection of the finer particles of ash. Most of the fly ash is currently used in soil stabilization. In this regard, China is far ahead of the United States of America.

3. Chemical admixtures

(a) Air Entraining Agents

In as much as Shanghai experiences few freeze thaw cycles, little concrete is air entrained to enhance durability. More commonly, small amounts are used to enhance workability and pumpability.

(b) Water reducers

These materials are primarily lignosulfonates. They are basically waste products and therefore can be used very inexpensively. They afford excellent water reduction but have other attributes that can negatively affect the performance of the concrete: they will entrain air, which will adversely affect the compressive strength. This is especially important in the production of high-strength concrete. Lignosulfonates also inhibit bleeding and increase

the rate of slump loss. Both of these problems are accentuated when concrete temperatures are high, a common occurrence in Shanghai. One of the suggestions made by the expert was that they consider evaluating a non-lignin-based water reducer produced by one of the major admixture manufacturers, Master Builders or W. R. Grace. The selected use of an alkanolamine-type admixture in certain situations can eliminate many of the problems currently being experienced. These types of water reducers have been found to be much more flexible in terms of dosages and to have a synergistic effect when used in conjunction with superplasticizers. Currently, 80 per cent of the concrete produced in Shanghai contains a water reducer.

(c) Retarders

These materials are typically simple sugar-based materials and are adequate. They would be classified as an ASTM C-494 type B admixture. They are generally used for retardation during hot weather. The expert suggested that they be tested at higher than normal dosages to determine their effect on controlling temperature rise. This would be especially beneficial in mass concrete.

(d) Superplasticizers

Eighty per cent are naphthalene condensates and the other 20 per cent, lignosulfonates. Naphthalenes are widely used and have been found to be good strength producers. They can be sensitive to variations in cement and fly-ash chemistries. The expert suggested evaluating a melamine condensate. This might also help in their slump-loss problem. Contrary to many places in the world, in Shanghai, all the superplasticizer is added at the concrete factory. This complicates the problem. (The point in the batching sequence at which the admixtures are introduced was also discussed. A slight delay, allowing the cement to be wetted, can significantly enhance compressive strength as well as the set control.)

4. Lightweight concrete

Although there was significant interest in this material, the only plant able to produce lightweight aggregate has been shut down because of high operating costs. The production of lightweight aggregates is very energy intensive. The aggregate that was produced used fly ash as the base material. There was a great deal of interest in Aardelite, a low energy production system invented by a Dutch company and currently being evaluated in the United States of America. Inasmuch as he has personally had experience with this system, the expert suggested that this might be more appropriate for their circumstances. An inexpensive lightweight aggregate could be effectively used in the 10-20-storey residences common in China.

5. Quality control and standards

There would appear to be three governing bodies who establish construction policies and building codes: (a) national; (b) provincial; and (c) local or municipal. As in other parts of the world, involvement depends on the magnitude of the project. British standards are generally used to regulate the quality of materials. Engineering and quality-control functions are frequently performed by the Institute. The Institute may also act as a consultant or advisor. Through its research facility, the Institute develops and promotes innovative materials and designs. From the expert's observations, the Institute seems to be well respected for its technical ability. The testing procedures on the job as well as in the factories seemed to be first rate. The degree of testing is again related to the magnitude of the project.

6. Concrete production

As would be expected, the mechanics of producing concrete are the same as anywhere else. Because of labour constraints and logistical problems related to delivery, about 60 per cent of the concrete supplied to a project is produced on the job site. Although some newer factories are foreign built (mostly in the Federal Republic of Germany), most are older, less sophisticated, facilities. The expert was requested to send more information on any American or other foreign-made concrete plants. Problems related to production or delivery are similar to anywhere else: material consistency, moisture control, temperature control, slump loss etc. A more pressing and, indeed, now a universal problem, is the disposal of concrete returned from a project or left in the truck at the end of the day. Today, many places are considering this material hazardous waste and strictly regulating its disposal. There was much discussion as to how this problem was being handled in the United States of America. For the most part, the concrete is being disposed of in one of the following manners: (a) it is used to precast some kind of usable element, such as curbs or blocks; (b) it is allowed to harden and then dumped into a land fill; (c) it is put through a wash plant where the aggregate is separated from the slurry. The aggregate or slurry may be recycled; or (d) a special chemical retarding system is used to "regenerate" the concrete and allow it to be reused without any loss in quality. The last of these options was of great interest and the expert will send information regarding these systems.

7. Cement

Eighty per cent of the cement used contains slag. Generally, two grades are used, 425 and 525. These contain 35 per cent and 15 per cent of slag, respectively. There are 12 mills that supply the Shanghai area. Although the quality is similar, some variations exist between sources. Slag cement can be an excellent material but it does have its limitations. Early strength is lower and the use of fly ash is limited.

8. Concrete repair

Concrete structures in China are reaching the age when rehabilitating is becoming necessary. Repair and rehabilitation is a fairly new endeavour and there is a lot of interest in products and methods. Much discussion centred around cement-based patching materials and methods, both structural and non-structural. The expert will forward information regarding other types of bonding and repair materials, such as epoxies and resins. Much time was also spent discussing various ways of testing bond strength. The expert will send copies of test methods used in the United States of America. A modified flexural test was discussed as a research project.

9. Pumping

At present, a small percentage of the concrete is placed by pump but the popularity of this method is obviously growing. Modifications in mix designs, slump and slump loss were discussed. There was also much interest in the pumping equipment.

10. Costs

There was a general interest in material and construction costs. The expert gave them all the material costs and the variation in costs that exists across the United States of America. The influence of transport and labour costs was also discussed.

11. Other items discussed

(a) Fast setting, high early strength and non-hydraulic cements

These are all relatively new types of cements. They are not affected by temperature, high or low, and develop the equivalent of 28-day-strengths in 4 to 24 hours. etc.

(b) Plastic aggregate

The General Electric Company has developed a process for making aggregates from recycled plastic.

(c) Retarders used to "regenerate" concrete

These were a subject of great interest.

(d) Synergized concrete

Producing special effects by combining two or more admixtures of different types.

II. RESEARCH

A. General

Various concrete mixes were made in the laboratory of the Institute. The effect was measured of "super fine" fly ash (fly ash selectively collected) on water demand, slump and compressive strength. It appears that the finer particles of fly ash are more reactive and act as a "macro" silica. This was also compared to micro silica and in both cases a superplasticizer was used. Test results have not yet been reported.

B. Areas requiring further research

It was agreed that further research would be required in the following areas:

(a) Super fine fly ash in high strength concrete;

(b) Micro silica is currently used in a dry uncompacted form. This means that the material is very difficult to handle and transport. Work should be done on combining it with either cement, fly ash, or water. This would not only solve the handling problem but it would also allow a more even distribution throughout the concrete and subsequent higher strengths;

(c) Epoxy and resin-based repair materials should be investigated. Tests should also be conducted to measure the bonding capabilities of such materials. Some methods were discussed and copies of other methods will be sent by the expert;

(d) Evaluate new, non-lignin-based admixtures at various dosages as well as in combination. Strength, rate of strength gain, water reduction slump, temperature rise, rate of slump loss, shrinkage and setting times should be evaluated.

III. CONCLUSIONS

In general, the expert was very impressed with the work being done by the Institute. The staff are obviously very competent. There are many areas where improvements can be made but, in many instances, the materials or methods currently being used are used for other than pure technical reasons, such as availability, cost, usage of waste products or available labour. These factors cannot be ignored and, in many cases, may preclude the development of higher strength concrete or some other innovation.

The expert felt more productive discussing the "as is" situation than talking about products and procedures commonly used in the United States of America. He believes in the importance of continuing to look to the future and he fully endorses continuing visits of other experts who share new technologies. In his particular case, he feels that his visit should have begun in the field and ended with lecturing. This would have given him a better understanding of the situation, which, in turn, would have allowed him to make his lectures more relevant.

Considering the influence and respect that the Institute has, both locally and nationally, he would endorse all efforts on their part to maintain and further develop international relationships. He also believes that the Fly Ash Workshop being sponsored by them in September 1990 is an excellent way of bringing technology to China and for the rest of the world to recognize the level of technical talent that exists there.