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Availability and management of fly ash in India

V.M. Malhotra

The writer has made several visits to India during the past six years. These were associated with:

- (i) organising, international conferences and symposia on supplementary cementing materials and sustainability
- (ii) participating in CANMET/CIDA/CII-sponsored seminars
- (iii) participating in a number of very large seminars organised by Ambuja Cements Ltd.

During these visits, discussions were held with numerous people belonging to cement producers, ready-mixed concrete producers, construction companies and government agencies including National Thermal Power Corporation (NTPC). The following paragraphs are a brief summary of the observations made during the above visits.

- (i) Considerable progress has been made in India as to the awareness about the use of fly ash in concrete, and the benefits of the high-volume fly ash (HVFA) concrete technology. Unfortunately, the central and state agencies are still living in the past, and under the cloak of public safety, refuse to acknowledge the new facts and advances in supplementary cementing materials, and in general, prohibit their use in concrete. The Central Public Works Department (CPWD) has made moves in updating their specifications but they have a long way to go. This is rather unfortunate.

By an Analyst

I am thankful to the *Editor* for sending the write-up of Dr V. M. Malhotra for my perusal and comments. In the recent past I had contributed a *Point of View* feature on the topic, "Can HVFAC technology be adopted for site-mixed concrete?". Possibly, this might have prompted the *Editor* to approach me again.

At the outset, I would like to compliment Dr V M Malhotra and his team from CANMET, Canada, for their painstaking endeavour in the promotion of sustainable construction through the increased use of fly ash concrete in general and high-volume fly ash (HVFA) concrete in particular. I am sure the civil engineering fraternity in the country will join me in applauding the special promotional efforts of Dr Malhotra and his team in India.

Similar to many like-minded persons in India, I also happen to be an advocate of sustainable construction and strongly believe that the construction industry in India needs to follow the principles of sustainability in all its activities. There exists a vast potential to utilise agro-industrial waste fruitfully in Indian construction and fly ash happens to be one such major material.

Dr Malhotra has made a number of worthwhile suggestions and the genuineness and sincerity of his approach are beyond doubt. However, I am afraid that some of his suggestions are not pragmatic as these are not in tune with the ground realities in India. I would therefore like to comment on some of the views expressed by Dr Malhotra.

In India, there has certainly been an increase in the awareness about the fact that fly ash is not a polluting

(ii) The problem of fly ash availability and use in India starts with the coal-burning power stations producing fly ash. These utilities refuse to acknowledge that they are the source of the problem, and that they have to make substantial efforts to find a solution. Giving fly ash free to anybody who wants it is a cop out, and not a solution. It creates even more problems because of its potential misuse by small contractors and masons. It is recommended strongly that the utilities burning coal for power generation should adopt the following strategy to resolve the above issues.

- Develop a database on an on-going basis on the characterisation of the fly ash from their plants.
- Develop a collection system so that fly ash is collected from all the fields and combined. The final product is then taken to a simple air classifying plant (These plants cost less than US \$ 4.5 million or Rs 198 million) where the very coarse particles are removed. This percentage need not exceed 10 per cent. The final beneficiated product is then stored in a silo for sale to the cement and concrete industry. The fly ash must not be given free. A nominal price of US \$10/t (Rs 440/t) should suffice. For a thermal plant producing one million tonnes of fly ash as a by-product, this would generate a revenue of US \$ 10 million (Rs 440 million/t) annually to offset the cost of a simple air classifier and other associated costs. Just as the cement companies guarantee their product and provide chemical and physical properties of their product, the utility producing power, should provide similar guarantee of its product. This will enhance the image of fly ash as a value-added material and increase its use in concrete. If a utility producing power lacks the expertise or the will in undertaking the marketing of the fly ash, this can be contracted out to a subsidiary company or a broker as is the case in Canada and the U.S.A.
- The present practice of giving away finer fly ash from the selected field free to the users must stop. This renders 60 to 65 percent of the remaining fly ash from field one unsatisfactory for use in concrete. What is India going to do with 60 million tonnes of material annually, that has been rendered useless by the above approach?
- Some utilities in the state of Maharashtra (may be elsewhere also) are giving fly ash from selected fields to small companies which, in turn, bag the material and sell it to

industrial waste, but a resource material useful for various construction applications, including cement and concrete. The utilisation of fly ash in India has increased substantially in recent years. However, there exists a vast difference in the estimates of utilisation. For example, while the annual fly ash utilisation in the country, according to Vimal Kumar and Mukesh Mathur, has increased from 1 million tonne in 1994 to 41 million tonnes in 2004-05, Dr A K Mallick estimates that only 14 million tonnes of the total 100 million tonnes get utilised²³. One can estimate the volume of fly ash used in cement and concrete with some degree of reliability; however, the estimates vary widely in non-cement/concrete areas. This could be the reason for the wide disparity between the two estimates.

There seems to be an agreement amongst different experts that fly ash needs to be considered as a "resource", and hence it just can't be "disposed" off but should be "utilised" fruitfully. A number of experts have deliberated on different ways of effectively utilising fly ash and available literature indicates that besides cement and concrete, large volumes of fly ash can be productively utilised in building components such as bricks and blocks, roads and embankments, hydraulic structures, reclamation of low-lying areas, mine fills, agriculture, manufacture of zeolites, simultaneous manufacture of alumina and cement clinker — to mention a few.

It needs to be emphasised here that any meaningful utilisation of fly ash ought to be financially viable. The sustainability approach also encompasses sound economic framework. However, on many occasions, in our concern to narrow down the gap between the production and utilisation of waste products, the financial viability aspects take a back seat. Therefore, one needs to ensure that any technology of fly ash utilisation should be viable both technically and economically.

One more aspect that is important, as far as the utilisation of large volumes of fly ash is concerned, is the location-specific economy. A study by Chand and Rao of the spatial distribution of coal-fired power plants indicates that while nearly 50 percent of this capacity lies near the pitheads, 30 percent is close to the cities and only around 25 percent lies in the vicinity of the cement clusters⁴. This study seems to be based on the data of late 1990s and there is reportedly some degree of overlap in the capacities of each of the three categories. In the absence of any similar study done recently, it may not be widely of the mark to assume that no substantial difference has occurred in the percentage-wise spatial distribution in capacities of the thermal power plants and that the current distribution would be more or less similar.

Any techno-economic strategy for the effective utilisation of fly ash therefore needs to take into consideration the above-mentioned spatial distribution of the thermal power plants in India. Transportation of fly ash over long distances is a costly proposition, and if it were to be practised, would defeat the very concept of sustainable construction. I am sure that Dr Malhotra would appreciate these facts.

The cement industry seems to have realised the potential of fly ash as a resource as could be seen from the increased share of fly ash-based blended cement in the total cement

small contractors and house builders at prices ranging from US \$ 30 to 40 per tonne (Rs 1300 to 1700/t). The bags containing fly ash are somewhat like the cement bags. This is a recipe for a potential disaster and misuse by uninformed and uneducated small purchasers. This kind of marketing is most undesirable from a safety point of view, and is not encouraged. Furthermore, this creates the same kind of problem as mentioned earlier, that is, rendering the bulk of fly ash unusable for concrete.

- Both coarse and fine aggregate for making concrete are becoming scarce, and many cities and towns worldwide including India, do not allow the quarrying of sand or stone. This problem will become very acute in the near future. To overcome current and future shortages of these concrete-making materials, electrical utilities that are located within 100 km of large cities and towns, should set up fly ash light weight aggregate plants. These small plants can be set up at a cost of less than US \$10 million (approximately Rs 440 million) and the coarse lightweight aggregate so produced will then be sold to the construction industry at a subsidised cost. These aggregates, in addition to being lightweight, are not subject to alkali-aggregate reactions. This is a bonus. There is a plant in the U.K. producing such aggregates.
- A number of countries have no or very limited access to fly ash; some examples are France, Italy and Iran. Serious consideration should be given to exporting large volumes of fly ash to Middle-Eastern, South-East Asian and several European countries. But the export product must be a guaranteed product like cement. Processed fly ash, as mentioned earlier, will be a good candidate. In such situations, quality control will be very important. For example, in one instance, a construction company in the Middle East imported good quality fly ash from South Africa, about 10,000 miles away (16,000 km) for a large project.
- At present, India imports about 15,000 tonnes of silica fume primarily from Norway. This is basically a silica dust from ferro-silicon plants, but is much finer than fly ash, (with an average particle size of 0.1 micron) at a price in the order of US\$800/t (approximately Rs 35,000/t). This material is highly pozzolanic, and is used in small quantities for making so called

produced in recent years. The recent statistics of Cement Manufacturers' Association indicate that the share of Portland pozzolana cement (PPC) has dramatically jumped from 26.17 to 44.36 percent during 2000-01 to 2003-04 — an increase of almost 70 percent within a span of just four years⁵! Along with the increasing the share of fly ash-based blended cement, the industry has simultaneously attempted to increase the level fly ash absorption in PPC, from an average of less than 15 percent in the late 1990s to the current level of approximately 20-25 percent or even more. Even if a conservative average value of 20 percent fly ash absorption in PPC were considered for the year 2003-04, the total fly ash utilised by the cement industry would be of the order of 10.42 million tonnes (for the PPC production of 52.12 million tonnes). Dr Malhotra would agree that this is indeed a creditable achievement. In fact, the current scenario is such that on many occasions adequate quantity of fly ash is just not available to the cement plants, which are then constrained to reduce the fly ash percentage in the PPC.

Dr. Malhotra suggests that fly ash should not be given free; it should be charged nominally (say Rs 440/t) after beneficiation, either by the power plant or by a third agency. Obviously, this suggestion seems to be based on similar practice in the USA, Canada, and other advanced countries. However, I am afraid that this model may not be suitable to India, at least at the current juncture. This is mainly because of two factors. Firstly, the percentage of fly ash utilisation in India is presently quite low and any increase in the cost of fly ash may prove to be counter-productive, in that there is a danger of the consumption of fly ash getting reduced. Secondly, modernization and mechanisation of the construction industry in India is limited to urban centres and big projects. In the western world, the penetration of ready-mixed concrete (RMC) industry is high and widespread and this has augured well for large-scale utilisation of fly ash in these countries. In contrast, the RMC industry in India is only a decade old and is mainly urban-centric. Presently, the industry is able to consume less than 5 percent of the total cement produced in the country. More than 90 percent of the cement produced in India is used in constructions, which predominantly adopt labour-intensive techniques. For such constructions, fly ash based blended cement is the best option today. Thus, in my opinion, the responsibility of large-scale utilisation of fly ash in concrete construction in India falls basically on the shoulders of the cement industry.

The cement industry in India, therefore, needs to be encouraged to replace more and more OPC with PPC on the one hand and increase the level of fly ash absorption in PPC, on the other. Possibly, the government could provide some incentives in terms of tax concessions or other similar benefits to those companies, which utilise more fly ash than the average consumption level of the industry.

The maximum percentage of fly ash in cement, as permitted by the BIS, is 35 percent. There exists a scope to increase this level to 50 percent or even more. It is interesting to note that Dr Malhotra and his colleagues have already investigated the strength and durability properties of concrete made with the so-called high-volume fly ash (HVFA) cement produced from

high-strength/high-performance concrete. The total worldwide availability of this material is about 1.5 million tonnes. Beneficiated fly ashes with particle size approaching 1 to 3 microns can be used instead of silica fume to produce the above types of concretes, though some modifications to mixture proportions will have to be made. There is a considerable potential for this kind of material in India and in overseas countries. High-performance blended cements can be produced using this material. Such cements have been, and are being produced in Canada. The oversize material during the processing of fly ash can be fed back with the pulverised coal to the furnaces. Currently, there is a company in Texas, U.S.A. that is successfully marketing such a product. I understand that similar products are available in some European countries.

- During my recent visits to India and participating in lecture tours across the country, I found that there was no significant research being done in the use of fly ash in India, and whatever is being done is of poor quality. This is sad indeed! India produces about 100 million tonnes of fly ash annually at present. The projections based on energy needs of India show that this amount will increase to about 200 million tonnes by year 2015, as coal will remain to be the major source of energy in India and elsewhere in the world in the foreseeable future. Notwithstanding, the other energy sources such as hydro, nuclear, wind and solar, the consensus is that at least till 2025, coal burning power stations will provide more than 50 percent of India's energy needs. This, in turn, translates into huge supplies of fly ash in the years to come. Assuming a current utilisation rate of about 20 percent in various applications including cement and concrete, this means that more than 80 million tonnes of fly ash is being ponded or disposed of in landfills. This amount may increase to about 150 million tonnes annually in the near future, and in a ten year time frame will be more than one billion tonnes of fly ash in ponds or landfills. This is, in addition to what is already there. Can any country, India to say the least, afford this? The answer is categorically no. It is imperative that the country should undertake major research initiatives in research and development for the use of fly ash. To achieve this, the coal-based electrical utilities (not the central government) should fund a broad-based

a cement plant and the results are indeed encouraging⁶. They state, "Concrete made with the HVFA blended cement has excellent mechanical properties and durability characteristics, and its performance is similar to the HVFA concrete when fly ash is added as a separate ingredient at a concrete batch plant". Khadilkar and others have also investigated HVFA blended cement recently and found that the mechanical properties and durability of concrete made with HVFA blended cement are in fact superior to that of HVFA concrete produced by adding fly ash separately⁷. Thus, HVFA blended cement is a promising option for the typical Indian conditions. Trust, Dr Mallhotra would be in agreement with this.

As mentioned earlier, the spatial distribution of power plants indicates that nearly 30 percent of them are located near big cities. Fortunately, a number of automated ready-mixed concrete plants have also been set up, mainly in the metropolitan and other big cities. These plants can certainly use fly ash, if adequately processed variety is available at a reasonable cost. In fact, most of these plants have already started using fly ash in their concretes and this trend is likely to get strengthened further.

Dr Mallhotra has strongly objected to the practice of giving fly ash from selected fields to small companies (typically from Maharashtra), which are bagging and selling fly ash at much higher prices. Besides the RMC plants, such fly ash is also being sold to small contractors who are using it as a part replacement of cement. In a typical site-mixed concrete set-up, having very little control on batching and mixing of ingredients, and on the water-binder ratio and general quality of work, one can imagine the quality of concrete that would be produced. Quite rightly, Dr Mallhotra warns, " This is a recipe for a potential disaster and misuse by uninformed and uneducated small purchasers". I entirely agree with him. For a majority of site-mixed concrete, fly ash based blended cement is the best option.

The manufacture of bricks and blocks has a potential to consume a large volume of fly ash. Possibly, the brick and block industry can singularly cater to the maximum utilisation of fly ash. Dr Mallhotra has not commented on this, perhaps through an oversight. It is estimated that the current brick production in India is of the order of around 100 billion bricks per annum. Bhanumathidas and Kalidas report that as of 2001, over 700 FaL-G (fly ash, lime, gypsum) brick plants, producing more than one billion bricks annually have been set up in the country during the last decade⁸. The data of fly ash bricks/blocks produced from non-FaL-G technology are not readily available. However, one can safely assume that the utilisation of fly ash in such technologies may not be very high. Thus, as compared to the potential, the production of fly ash based bricks is meager. This has happened in spite of the concessions offered by the government and the notifications of the Ministry of Environment and Forest, prohibiting the production of clay bricks in the vicinity of thermal power plants. Here again, the economics is possibly not favouring the adoption of fly ash based bricks. One needs to look into the techno-economic feasibility of setting up fly ash-based brick plants in a holistic manner.

As regards aggregates, it is true that this natural ingredient in concrete is becoming scarce, especially in urban areas, and that good quality of aggregates need to be transported from

research facility for the use of fly ash in concrete and other building materials. Apart from R&D activities, the proposed research institute be mandated to carry out major transfer of technology activities including training of sub-professionals and construction workers. The writer is aware of the fact that there is a central Fly Ash Mission promoting the use of fly ash in India. Though the mission is doing a satisfactory job, its funding is perhaps too limited and the scope too narrow to make a major impact.

- About six years ago, during the writer's earlier visits to India, the writer had advocated the potential of India to make considerable sums of money through the route of carbon trading under the Kyoto protocol. This fell on deaf ears in India. All is not lost yet, and India should pursue aggressively this route. There is a small company in Visakhapatnam that has been successful in registering one project with World Bank for carbon credits. Large infrastructure projects are well positioned to use HVFA concrete technology and register these projects for carbon credit benefits. Some such projects include HVFA concrete pavements all over the country and HVFA concrete for canal linings.

Concluding remarks

Fly ash is a resource and not a waste product. Major initiatives are needed in India to use this in large volumes in construction especially housing and infrastructure projects, and to pursue technologies mentioned in this report to make it a value added product for export and use in India. India should aggressively identify projects that can be registered with World Bank for carbon credits.

Giving away fly ash free from selected fields from a coal burning power station is a very poor way of handling and utilising fly ash, and is counterproductive. This practice must be avoided.



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longer distances, thus increasing the cost. Besides urban areas in the country, aggregates — especially of the coarse variety — are scarce in the whole Gangetic belt of India. To overcome this problem, Dr Malhotra suggests that electrical utilities that are located within the 100 km radius of large cities and towns should set up lightweight fly ash aggregate plants. The suggestion is certainly welcome. However, one needs to work out the techno-economic feasibility of setting up such plants. I understand that the fly ash lightweight aggregates produced by the cold process are not suitable for structural applications. For such applications, structural-grade lightweight fly ash aggregates produced from an energy-intensive process would be needed. This would increase the cost of such aggregates — may be even higher than the cost of natural aggregates hauled from longer distances. Possibly, this may be main hurdle in the commercialisation of the lightweight fly ash aggregates.

Thus, there is an urgent need to develop cost-effective (read cheaper than conventional) technologies for the manufacture of bricks and aggregates from fly ash. It is here that some worthwhile R&D is needed. Dr Malhotra's suggestion of setting up a broad-based research facility funded by the coal-based electrical utilities is welcome. I feel our educational institutions, mainly the IITs, can also play a crucial role in this.

Conclusion

To conclude, it needs to be emphasised that meaningful utilisation of fly ash ought to be financially viable. Further, any technology of effective fly ash utilisation needs to take into consideration the spatial distribution of thermal power plants. Transportation of fly ash over long distances is a costly affair and would defeat the very principles of sustainable construction. For the typical Indian conditions involving predominant use of site-mixed concrete, high volume fly ash blended cement possesses better potential in view of the superior properties of concrete made from such cement on the one hand, and the possible higher level of fly ash utilisation, on the other.

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