A REVIEW: PROMISING APPLICATIONS FOR UTILIZATION OF FLY ASH

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ABSTRACT

Fly ash can be utilized as a resources material in numerous innovative applications. The study attempts to identify promising applications that can significantly contribute in maximizing the utilization of fly ash. Based on the synthesis of relevant literature the study identified promising applications and categorized them into two groups: (i) key application groups for sustaining the existing growth in utilization (ii) key application groups for further increasing the utilization of fly ash. The findings of the study are expected to assist in formulation of strategy for sustaining and improving fly ash utilization.

Keywords - Fly Ash, Strategic Management of Technology, Technology Management, Waste Management, Waste Utilization.

I. INTRODUCTION

Fly ash is a by-product of coal based thermal power plants. Huge quantity of fly ash generated at coal based thermal power plants if not managed appropriately pollutes air, water and soil. On the positive side, fly ash is also a useful resource material [1]. Many R&D Labs / institutions have developed technologies for gainful utilization of fly ash [2]. Continuous progress in research and development has enabled fly ash to be utilized in numerous innovative products. Various authors [3,4,5,6,7,8,9] have reviewed possible utilization of fly ash. Fly ash can be innovatively utilized as a resources material for concrete [3,5], cement [3,5,7], light weight aggregate/concrete [5,7], brick [3,5,6], tile [3,5] block [3,5,6], road construction [3,5,6,7], agriculture [3,5,7,8,9], floriculture [9], adsorbents for cleaning of flue gas [7], water and wastewater treatment [3,7], waste stabilization and treatment [6,8], for construction of ash dykes [3], construction of dams [3], recovery of valuable metals [4,8], reclamation [6,9], mine backfill [7], zeolites [6,8] blackboard chalks [6], ceramic filters [6], wood substitute [5], embankment [5], production of mullite [8], glass [8], composite materials [8], landfills [9], etc.

Some of the above applications are successfully commercialized as a result a large quantity of fly ash is utilized every year. According to Central Electricity Authority (CEA) in financial year 2012-13 about 163.56 Million Tons (MT) of fly ash was generated, out of which about 100.37 MT was utilized [10]. Such high utilization is desired and is required to be sustained. As there are many innovative applications of fly ash there is an opportunity to further increase the utilization. This is even more desirable as a considerable quantity of fly ash

still remains unutilized. Accordingly, there is a need to sustain and improve the commercialization of innovative applications of fly ash utilizations.

II. OBJECTIVE AND METHODOLOGY

There is a long list of applications. However no single application holds the potential to ensure 100% utilization of fly ash, thus a judicious mix of a number of applications is needed [2] for sustaining and improving the utilization of fly ash. It indicates a need for careful selection of applications. Attempting to promote all applications is not a good choice. This is because commercialization of an innovation usually takes long time and substantial resources. Thus attempting to commercialize an unavailable application is likely to lead to wastage of time and resources. Contrasting this, if a viable and meritorious application is not commercialized, it is a waste of opportunity. Further the utilization potential offered by innovative applications varies with applications, thus selection of a high volume promising application may lead to a huge utilization and wrongfully rejection of it may lead to a huge loss of opportunity. This necessitates a well considered selection of promising applications in order to solve the problem of fly ash. Accordingly the objective of the study is to review relevant literature and identify promising applications that can significantly contribute in maximizing the utilization of fly ash. Depending on the need of the situation, identification of promising applications can be done from various perspectives. Accordingly to include relevant vital viewpoints the literature review is done based on the following five perspectives:

1) Review the applications from the perspective of Fly Ash Mission (FAM) thrust area.
2) Review the applications from the perspective of Fly Ash Unit (FAU) thrust area.
3) Review the applications from the perspective of the actual utilization.
4) Review the applications from the perspective of the predicted future utilization.
5) Review the applications from the perspective of latent potential as identified in CEA's report.

To meet the objective suitable literature were collected from published reports, research papers and web pages of relevant authorities. The review was undertaken and the findings of the literature review are presented in next section.

III.FINDINGS

The need for judicious mix of applications for focused effort was recognized long back and it was one of the objectives for the launch of FAM [1]. It is a Mission Mode Project commissioned by Government of India in 1994 to promote safe disposal and gainful utilisation of fly ash by undertaking technology demonstration project towards confidence building in fly ash utilisation technologies [1]. FAM was a joint activity of Department of Science & Technology (DST), Ministry of Power (MOP) and Ministry of Environment & Forests (MOEF) [11] with Technology Information, Forecasting and Assessment Council (TIFAC) as the implementing agency and DST as the nodal agency [12]. For focused efforts through technology demonstration projects, FAM identified ten thrust areas; that is a list of key applications as well as activities. The ten thrust areas of fly ash utilization are:

- Roads & Embankments

- Building components
- Hydraulic Structures
- Agriculture Related Studies & Applications
- Underground Minefills
- Ash ponds & dams
- Reclamation of Ash Ponds
- Characterisation of fly ash
- Handling & Transportation of fly ash
- Research & Development for facilitation of further work/utilization

Source: [1].

After the approved period of FAM i.e. 31st March 2002 it was named as "Fly Ash Utilization Programme" (FAUP) and thereafter since May 2007 it is providing new focus and thrust under FAU, DST [11]. The latest nine trust areas of FAU as mentioned in DST web page are:

- Cement & concrete
- Building Materials (other than cement & concrete)
- Hydro Power & Water Resources
- Geotechnical applications
- Agriculture
- Mining Sector
- Value added applications
- Handling & Transportation
- Design & Management of Ash Ponds

Source: [13].

Due to the efforts of various government and private agencies, utilization of fly ash has increased from 1 MT in year 1994 [11] to 100.37 MT in year 2012-13 [10]. Out of 100.37 MT of fly ash utilized about 41.33 MT was contributed by cement Sector while agriculture applications contributed only 2.5 MT [10]. Thus contribution in terms of quantum of fly ash utilization varies significantly with application. Accordingly an attempt is made to identify key applications from the perspective of actual utilization. Data from CEA is utilized for this purpose. CEA, on behalf of MOP monitors and publishes data on fly ash generation and utilization including modes of utilization. According to CEA, based on the information collected from 138 thermal power stations which were in operation as on 31st March 2012, in the financial year 2012-13 about 482 MT of coal was consumed for general for electricity and 163.56 MT of fly ash was generated, out of which 100.37 MT was utilized [10]. The major modes in which fly ash were utilized during financial year 2012-13 along with the utilized quantity in each mode are shown in pie diagrams (Figure 1). The maximum utilization of fly ash to the extent of 41.18% of total fly ash utilized was contributed by cement sector. The second largest, 11.78% of total fly ash utilized was in reclamation of low lying area, followed by 10.89% in ash dyke raising, 10.30% in mine filling, 9.94% in making bricks & tiles, 6.00 % in roads & embankments, 2.49% in agriculture, 1.03% in concrete and 6.39% in

various other applications. Based on the actual utilization, the top 5 applications are: (i) cement, (ii) reclamation of low lying area, (iii) ash dyke raising, (iv) mine filling, (v) bricks & tiles.

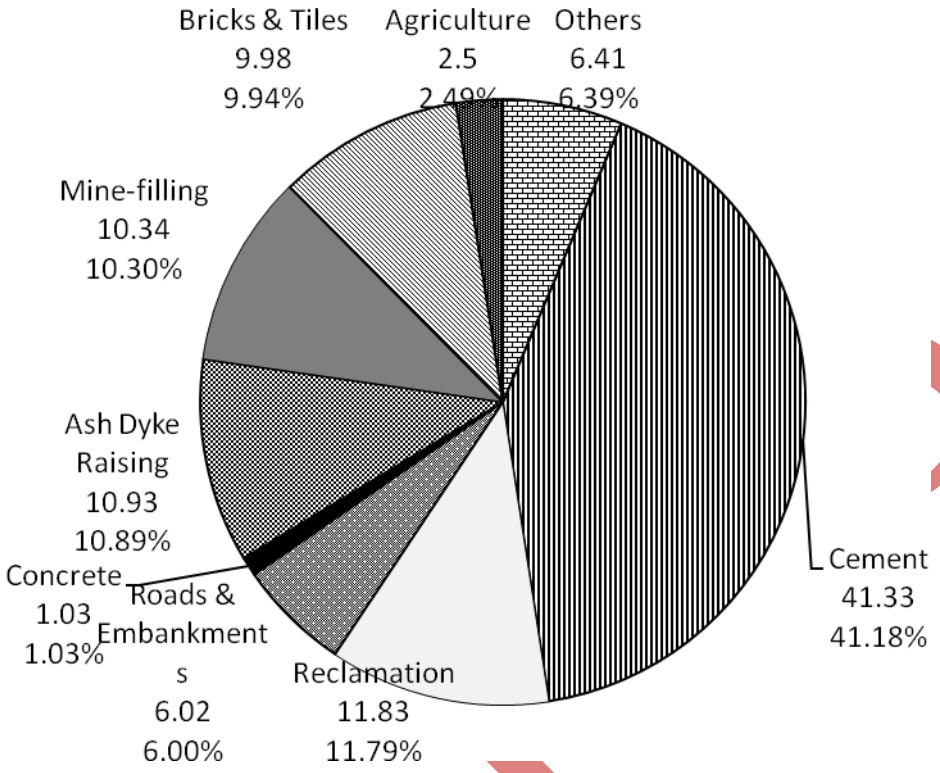

Fig. 1 Modes of fly ash utilization during financial year 2012-13

Source: [10]

Actual utilization describes the quantity of fly ash utilized in the selected applications in recent past. However the quantity of utilization in these applications may change in future. Accordingly an attempt is made to identify key applications based on the quantity of utilization in future. Loya and Rawani predicted quantum of fly ash utilization to be contributed by key applications in coming future. Based on the annual time series data they identified pattern of growth using regression analysis and predicted the quantity of fly ash to be utilized in select applications in coming future. The prediction for financial year 2020-21 is shown in pie diagrams (Figure 2) illustrating the major modes of utilization along with the predicted utilization quantity in each mode. The maximum utilization of fly ash to the extent of 44.19% of total fly ash predicted to be utilized in financial year 2020-21, is predicted to be utilized in cement & concrete sector. The second largest, 15.25% of total fly ash to be utilized in financial year 2020-21 is predicted to be utilized in roads, embankments & ash-dyke-raising, followed by 12.49% in reclamation of low lying areas & land filling, 8.84% in mine filling, 7.61% in bricks, blocks & tiles, 2.47% in agriculture and 9.14% in others. The category 'others' consisting a mix of applications each contributing small quantum of utilization in past, however in future some of them might contribute significantly thus an investigation on its compositions might reveal some promising applications [14]. Based on the future potential, the top 5 application groups are: (i) cement & concrete, (ii) roads, embankments & ash-dyke-raising, (iii) reclamation of low lying areas & land filling, (iv) mine filling, (v) bricks, blocks & tiles.

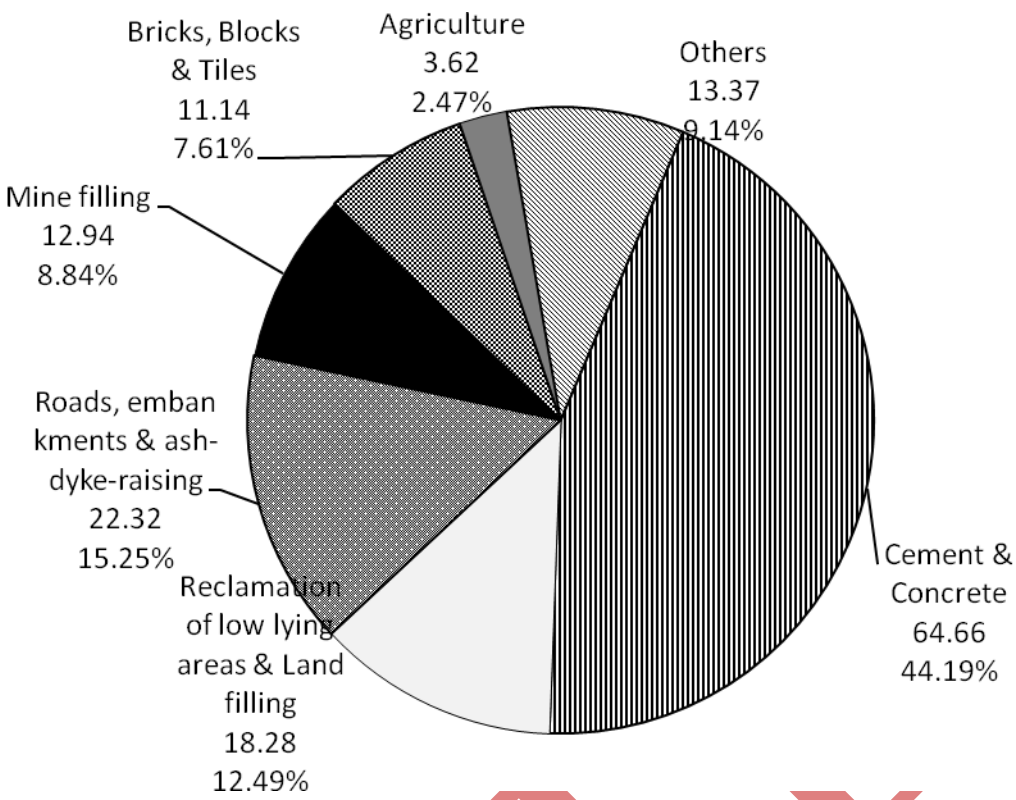

Fig. 1 Forecast of modes of fly ash utilization during financial year 2020-21

Source: [14].

The prediction of future potential is based extrapolation of trend line using regression model; that requires a past trend; and that assumes that the past trend would continue. Hence this forecast will not be able to identify the potential application that has no past trends, even though it may have a bright future. Also if there are any underutilized applications, this forecast will not be able to identify its latent potential. That is because when road blocks of underutilized application are identified and they are planned to be removed, the latent potential is expected to be actualized, in that case the utilization quantity is expected to form a new upward trend line. Thus it requires a change in the in trend line however the above forecast is based on assumption of continuity of trend line, hence it cannot recognize the latent potential of underutilized application. CEA reports identifies applications that have large potential of fly ash utilization however their potential are yet to be actualized, thus they need to be explored for increasing overall ash utilization in the country [10,15,16]. The applications that have been identified to have large potentials but yet to be actualized are: mine filling [10,15,16], bricks, tiles etc. [10,15,16], and roads & embankments [10].

IV. RESULTS AND CONCLUSION

Based on the synthesis of the findings; the promising applications of fly ash that can significantly contribute in maximizing its utilization are identified as shown in Table 1.

Table 1 Promising applications of fly ash from various perspectives.

Application	FAM Thrust Area	FAU Thrust Area	Top 5 Actual Utilization (Ranks)	Top 5 Prospective Utilization[$] (Ranks)	CEA Under-utilized potential
Cement & Concrete	✔ [#]	✔	1	1	-
Reclamation & Land filling	✔	✔ [*]	2	3	-
Roads, embankments & Ash-dyke	✔	✔ [*]	3	2	✔
Mine filling	✔	✔	4	4	✔
Bricks, Blocks & Tiles	✔ [#]	✔ [@]	5	5	✔
Agriculture	✔	✔	-	-	-
Value added Application	-	✔	-	-	-
Hydraulic Structures	✔	✔ [^]	-	-	-

[#] FAM thrust area: Building Components
[*] FAU thrust area: Geotechnical applications
[@] FAU thrust area: Building Materials (other than cement & concrete)
[^] FAU thrust area: Hydro Power & Water Resources
[$] Future potential if the existing trend continues

The identified promising applications were categorized into two groups: key applications to sustain the existing growth in utilization, and key applications to further increase the utilization of fly ash.

4.1 Key applications to sustain the existing growth in utilization: The utilization of fly ash has been increasing in past; to sustain this growth trend; three key application groups identified are: (i) cement & concrete (ii) roads, embankments & ash dyke raising; (iii) reclamation & land filling. The application groups are arranged in order of decreasing importance.

4.2 Key applications to further increase the utilization: Further increase in utilization of fly ash in the country; that is to achieve utilization trend higher than the existing trend line; might be realized by achieving the follow two points. First, the growing trend of select applications listed in section 4.1 (identified as key applications to sustain the existing growth in utilization) must be retained. Second, in addition to the first, underutilized large potential applications should be explored. The three key underutilized application groups identified are: (i) mine filling, (ii) bricks, blocks & tiles (iii) roads, embankments & ash dyke raising. There is no order of importance for the identified groups.

Actualizing the latent potential of underutilized application groups can assist in achieving additional utilization. However doing so may require an investigation on why these applications remained underutilized, what are the key barriers to adoption/commercialization, and, what changes should be done in strategy and action to overcome the identified barriers. These are important areas of investigations and may serve as agenda for future research. Further, this study only analysed existing applications those are found in literature and have some past records. Analysing utilization potential of new applications without any past records require a different methodology, and may be done in future research. The findings of the study are expected to assist in formulation of strategy for sustaining and improving fly ash utilization.

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