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Critical factors for the successful usage of fly ash in roads & bridges and embankments: Analyzing indian perspective

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ABSTRACT

Fly ash has been recognized as hazardous material causing air, soil and water pollution. Fly ash a 'waste by-product' of electricity generation from power plants (coal-based thermal) has an estimated annual production of approximately two hundred million tons. In-spite of many problems associated (like land requirement for disposal, toxicity to groundwater, handling issues etc.); we have started treating fly ash as a resource material. Present research addresses usage of fly ash in roads & bridges and embankments. In the present study, an attempt has been made to recognize and analyze comprehensively key elements and sub-elements of program implementation of fly ash usage and further to segregate Critical factors (CFs) of usage of fly ash in roads & bridges and embankments. Eight relevant CFs have been recognized for usage of fly ash in roads & bridges; and ten CFs for the usage of fly ash in embankments. Thereafter, Interpretive Structural Modeling (ISM) approach has been applied on these CFs and two models of driver CFs, linkage CFs and driven CFs have been obtained. Appropriate discussions along-with MICMAC analysis in the light of important elements and sub-elements have helped to present managerial implications useful for stakeholders.

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1. Introduction

Fly ash is produced in huge quantities by waste incineration processes and assumed as a hazardous material. The disposal and handling of fly ash is a major concern due to presence of the high concentration of easily leachable chlorides, heavy metals and toxic compounds (Kinnarinen et al., 2013). India has more than 120 thermal power stations, which use coal as the input, responsible for an annual production of more than 163 Mt of fly ash, which is likely to rise with passage of time (Mukherjee and Vesmawala, 2013). With the 'electricity demand increase', more power stations (coal-based thermal) may be required to be installed and commissioned, or there may be some increase in their existing capacity (Muneer et al., 2005). Fly ash has been one of the major issues in electricity generation, as India is expected to remain more dependent upon coal-based thermal power stations for coming decades (Dwivedi and Jain, 2014). Domestic coal, which is available and is used as raw material for these thermal power stations, has been identified with ash content ranging from 30% to 50% making this problem complex (Pandian, 2013). As estimated, generation of fly ash in India is likely to be around 900 Mt by 2031–32 (Singh and Gupta, 2014).

Till a decade back, fly ash was identified, considered and recognized as a 'polluting industrial waste' towards making hazards to environment; and disposed off in ash ponds raising a high requirement of land (Ahmad et al., 2014). At present, about 100,000 acres of land is concealed under the ponds containing ash. Haphazard fly ash disposal may be treated as a luxury as land being a scant resource (Kumar et al., 2005a). Energy and materials recovery from waste may be achieved by adopting suitable treatment processes (Smol et al., 2015).

Extensive efforts towards technologies' development have been

List of acronyms and abbreviations: AASHTO, American association of state highway and transportation officials; ACI, American concrete institute; ASTM, American society for testing and materials; CFs, Critical factors; CSFs, Critical success factors; FAUP, Fly ash utilization program; IRM, Initial reachability matrix; FRM, Final reachability matrix; ISM, Interpretive structural modeling; MICMAC, Matrices d'impacts croises-multiplication appliqué a un classement analysis; MT, Million tons; SSIM, Structural self-Interaction matrix; y, Years

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made for encouraging constructive use and environmentally safe 'fly ash management' of under 'Fly Ash Mission' of Government of India (GOI) since 1994 resulting into over 73Mt of fly ash utilization in 2010–11 (Singh, 2013). Shifting the category of fly ash from 'hazardous industrial waste' to 'waste material' has been recognized during the year 2000; and further, from 'waste material' to 'useful commodity' during the year 2009 (FAU, 2012).

1.1. Background and need recognition

Coal based thermal electricity generation has the major share in 'Indian electricity capacity'; however, quality of coal available in country is of low grade having up to 40% ash content as compared to 10–15% ash content in coal imported (CEA, 2014) resulting into large quantity of ash generated forming air and water pollutant. Few problems related to fly ash have been toxicity because of the heavy metal leaching to groundwater; disposal of fly ash and land area required; and causing air, soil and water pollution and disrupting ecological cycles (Monnet et al., 2015). To address these problems in order to deal with concerned economic, environmental and social issues; review of literature review has been made towards identifying related articles. Summary of important contributions has been presented as under.

The improving economic, environmental and social indicators of sustainable development have been drawing awareness to the construction industry, which is increasingly emerging sector globally, and very dynamic industry in developing countries and developed both (Ortiz et al., 2009). No natural resources constitute reserves that are limitless; however, for construction industry, sustainable and maintainability improvement primarily aims to save environment by using new methods, alternative materials and recycling as large amounts of solid waste are incorporated in civil engineering construction areas (Gencel et al., 2012). So far, by-products (along with fly ash) of the materials and energy sector, disposed of as waste, have been used to produce various useful products (Danthurebandara et al., 2015). Ash application in roads pavement and embankments is as a substitute for cement and/or sand (Smol et al., 2015). The generation of fly ash in India has increased from 68.88 Mt in 1996–97 to 163.56 Mt in 2012–13, of which only 100.37 Mt was utilized. India has attained a significant increase in its use from 9.63% in 1996–97 to 61.37% in 2012–13. However, approximately 40% of the fly ash is still unutilized. Therefore, there exist a huge scope and an essential requirement to increase the quantum of fly ash use in each and every sector. Especially, there is a broad scope for roads & bridges and embankments as the current utilization in these sectors are comparatively little (Yao et al., 2015).

It has been realized that management aspect of fly ash usage program implementation needs to be researched in Indian context; and for this, methodology of Interpretive Structural Modeling (ISM) and MICMAC techniques has been adopted. To carry out this research, it was necessary to have clarity in terms of important elements of program implementation as suggested by Saxena et al. (1992a, 1992b) helpful towards scenario building. One day workshop was organized in the month of April, 2014 (details have been discussed in Section 2) and sub-elements were sorted and finalized as tabulated and presented in Table 1.

1.2. Objectives of the paper

In present work, Critical Factors (CFs) for the effective use of fly ash in roads & bridges and embankments have been identified and analyzed. Following are the major objective of this paper:

- To identify various CFs of fly ash utilization from Indian viewpoint.
- To find the contextual relationships among identified CFs.
- To suggest a hierarchy structural models of CFs in utilizing the

Table 1
Key elements and key sub-elements of fly-ash usage in roads & bridges and embankments.

S. No.	Key elements	Key sub-elements
1.	Needs	• Skilled and trained human resource • Policy formulation • Adequate fly ash supply of required standard • Transport facilities • Technology
2.	Objectives	• To address problem of pollution, and environmental degradation caused by fly ash • To reduce land requirement for fly ash disposal • To assess the amount of fly ash that will be utilized in future • To identify technologies for appropriate fly ash usage • To achieve economic viability of fly ash usage
3.	Objective measures	• Amount of usage of fly ash in roads & bridges and embankments • Reduction in amount of fly ash in air, water and land • Reduction of land used for disposal of fly ash • Economic measures
4.	Alterables	• Availability of funds • Technological issues/competencies • Transport bottlenecks • Government regulations and compliance • Change management • Availability of skilled human resource • Quality of fly ash
5.	Major constraints	• Shortage of funds • Absence of suitable technologies soft/hard • Shortage of expertize • Absence of suitable laws/compliance
6.	Activities	• Training and development programs to overcome • Technology development and commercialization • Technology acquisition • Developing appropriate user friendly transport facilities
7.	Activities measures	• Numbers of training program held • Shortfall in funds to target
8.	Actors	• Government • Fly ash based industry • Academics • Technology agents • Thermal power plants • Financing agencies • Bureau of Indian Standard • International agencies • Consultants
9.	Community affected	• Thermal power plants • All living beings & society • Transporters • Fly ash based industries
10.	Critical factors of fly ash usage in roads & bridges	• Government support • Training, education & promotion • Material availability • Standard developed • Material properties • Socio-economic wealth • Environment acceptability • Technologies innovation
11.	Critical factors of fly ash usage in embankments	• Government support • Bulk utilization • Economic viability • Reduce soil liability • Conserve natural resources • Training, education and promotion • Standard developed • Ease in management

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