# Sustainable Utilization of Fly Ash in Smart Cities

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*Abstract* **The development of smart cities should promote the infrastructure which relies on concrete having an appreciable amount of fly ash, a coal combustion by-product of thermal power plants obtained by burning lignite and pulverized coal. This is a big step towards environmental conservation. In 1914, the use of fly ash as a pozzolanic ingredient was discovered but the earliest notable study of its use was conducted in 1937. The Pantheon in Rome or the aqueduct of Roman structures used volcanic ash or pozzolana which has similar properties to fly ash as pozzolan in their concrete mixture. Concrete has been a parameter of "civilization and urbanization" for ages. Since the invention of concrete in the 19th century, humanity has used concrete for domestic purposes as a building material, so it is found nearly everywhere in the world. Environmentalists across the globe criticize the concrete industry for contributing to the heat effect and increased water runoff during storms, leading to soil erosion and flooding. However, the main complaint in the construction process is the humongous amount of emission of CO2 in it. As the world struggles to come to terms with the changing reality brought on by globalization, urbanization, climate change, and global economic restructuring, the smart city concept continues to gain attraction. To create sustainable and economical smart cities', aware communities and governments across the world are experimenting with structures of concrete that can be sustainable enough not to cause any pollution or at least minimize the effect of it. The focus of the government of India for the development of major ports across the country by inviting investors through the route of public-private partnership (PPP) is to promote the usage of fly ash in it for a futuristic sustainable infrastructure. New smart buildings at major ports are encouraging from the point of view of utilization and shipping logistics of fly ash. The efforts of the government of India in ensuring cleaner air and unpolluted water and sustainable impact on the environment, fly ash utilization was taken on a war footing with the target of 100% utilization and it has borne fruit now as it has reached approximately 86 in a time-bound manner in the country is highly appreciable. The houses made up of fly ash concrete in smart cities will provide affordability and sustainability. Here is a discussion on fly ash sustainability and affordability in the development of smart cities.**

**Keywords— fly ash, sustainability, smart cities, concrete.**

## I. INTRODUCTION

To make modern cities more liveable, economically vibrant, and environmentally sustainable, the Government of India has launched Smart Cities Mission with an aim to improve the core infrastructure and services of these futuristiccities. In the last six years, the government has brought a turning point in the character of basic infrastructure in majorselected cities in general and a change in the mindset of citizens to get prepared with an upgraded attitude towards cleanliness and environmentally sustainable life. More than 20 percent of the urban population in India lives in these selected hundred future smart cities which would be further centers of attraction for the migration of rural to urban or urban-to-urban nature.

The Smart City Mission targets for the implementation of approximately 6,000 projects with an investment of more than rupees two lakh crores within five years. Building smart cities is not the business of individual cities or some selected private sectors, governments are supposed to be playing an enabler for the capacity building, upgradation, and innovativeinfrastructural solutions.

For the cement industry and building products production factories, fly ash is used as resource material. As part of theconstruction materials used in road and flyover embankments, the use of fly ash saves the earth and helps reduce the degradation of good agricultural lands which are filled otherwise to dump the fly ash.

The ingredients of the concrete mix have altered over a periodof time and the use of cement in it to make a composite building material has been debated for

ages. The performance characteristics of concrete change with the diversified forces acting on the concrete which may be gradual or intense like the gravity from the top, the soil crowded from the bottom, lateral loads, or others like erosion, abrasion, or chemical attack.

Concrete, the main component of any infrastructure, has four constituents: cement, water, sand, and aggregate in whose environmental impact is mainly connected to cement [1]. It has 80% of the environmental impact and it contributes 10% of an average concrete mix production-wise [2]. The main concern is how we balance the pros and cons of this particular technology in creating the future for ourselves.

China and India are leading the pack of developing countries with a huge focus on urbanization leading to the production of approximately 3.6 billion tonnes of global production of cement which makes the global concrete business the third top consumer of industrial energy [3]. This oldest form of industry is also the second biggest industrial carbon dioxide emitter of the globe. The disadvantages of the use of concrete in infrastructure are thatthe tensile strength of concrete is relatively less than other binding materials [4]. The second thing is that the weight of concrete is higher than its strength. We should emphasize environmentally friendly concrete to reduce its weight and increase its strength.

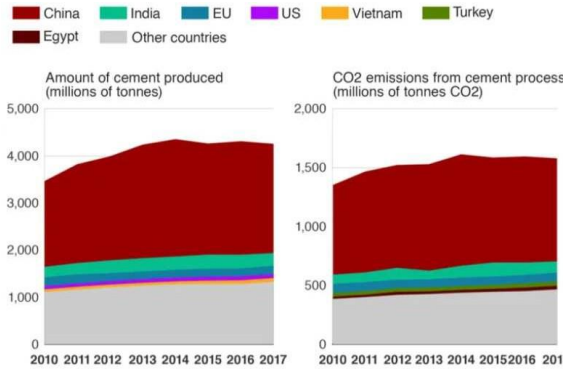
One of the alternatives is the massive use of fly ash in concrete. The very small particles of fly ash make the concretehighly dense and reduce its permeability which leads to higher strength in the building material. Thermal cracking is also prevented due to the low heat of hydration generated by fly ash concrete. The fly ash concrete is sulfate-attack and acid resistant. In 2018, the global market for Fly Ash utilization was valued at approximately four billion US Dollars which is expected to scale up to approximately seven billion US dollarsby 2026, at a compound annual growth rate, compound annual growth rate (CAGR) of 6.6%.

## II.DISCUSSION

### *A. Raison d'etre*

Jeremy Gregory, Executive Director, of Concrete Sustainability Hub, Massachusetts Institute of Technology (MIT) opined that limestone, cement's primary ingredient, needs to be heated to an extremely high temperature toproduce cement. This process is the main reason for environmental degradation as 1 kilogram of cement produces approximately 1 kilogram of carbon dioxide. But the other major concerns are the energy consumed during the process to get to the necessary high temperatures. Making clinker contributes up to 60% of carbon dioxide emissions in cement production due to a chemical reaction. One third of emissionsare due to burning of fossil fuels to heat kiln and one-tenth comes from fuels used for mining and transportation.

### *B. Global perspective*




Source: PBL Netherlands Environmental Assessment Agency

Fig. 1.: Amount of Carbon Dioxide vs Cement

Figure 1 shows the amount of cement produced and CO2produced during cement production. The cities of developingcountries are already struggling with the challenges of urbanization, pollution, and catastrophic natural events. Thereis a hidden need to address the challenges of the emission of carbon dioxide, costs, and societal impacts over their lifetimeby designing and making the new smart city infrastructure made up of fly ash concrete to ensure more sustainability andresilience.

### *C. Preparedness of the Indian Market*

A good eco-friendly option of cement in concrete is the use of fly ash as a resource building material in building smart cities. Decades back, India started using fly ash in concrete, bricks, building materials, roads, bridges, highways, and embankments on a mission mode has paid fruit now and we witness a cultural change in the new avatar of clean and green construction promoted by the current government which helped the waste being considered the best

now. Globally, natural resources have faced the challenge of extinction mainly because of rapid urbanization. Fly ash is a waste produced in power plants. It is a common practice to dump unutilized fly ash in the open area. If we start utilization of flyash at a mass level, this waste will be converted into wealth.

Earlier the power plants used to landfill the adjacent areas and vast fields with fly ash and bottom ash produced as a by-product. These unscientific acts of coal ash storage created problems of pollution by leaching and started contaminating the groundwater. To prevent this common practice, theGovernment of India has made it mandatory for thermal power plants for 100 % utilization of fly ash in the next 3-5 years. Consumption of this waste has been an issue for our government. Increasing its utilization in the smart city's infrastructure will reduce the cost and prevents air pollution and soil pollution on disposal.

While talking about a hundred proposed smart cities across India, Prime Minister shared his vision of "Digital India", "Cities in the past was built on riverbanks. They are now builtalong highways. But in the future, they will be built based onthe availability of optical fiber networks and next-generation infrastructure."

It must be emphasized that the development of smart citiesis very much concerned with the selection of materials. To accomplish the aspirations of millions of people in the countryand to maintain environmental sustainability, a balance mustbe maintained between environment and development. It is relevant to note that there is an inter-linkage between waste production, poverty, and environmental degradation. To eradicate poverty, infrastructure development with suitable means is the most important requirement, which cannot be ignored at any cost but at the same time, the protection of theenvironment can also not be ignored as the very survival of allbeings on the earth is possible because of it.

As per the Central Energy Authority (CEA) report, total fly ash generation is expected to increase by 25-30% but at thesame time, requirements of fly ash for cement would increasefour times. up to 151 MT. Still, 128 MT of fly ash will remainunutilized, which will require 2300 hectares of land for ash pond creation with a water requirement of approximately 1.3 billion cubic meters[5].

The projects such as Smart Cities Mission, which plan tojoin the important economies everywhere in India, have beenprojected as the solution to many environment-related problems. Such projects are expected to increase the usage of fly ash as construction materials. As per the recent data of the Central Energy Authority (CEA), if the current trends in the utilization of fly ash were to continue, overall, the consumption of fly ash will raise to 310 MT by 2030.

Globally the number of cities is growing rapidly. Today more than one-half of the global population lives in urban areas but by 2030, approximately 60% of them would need smarter cities with a potential requirement of 1.3 trillion US dollars ofinvestment to build them. So, the market is projected to growat a compounded annual growth rate of 19.4%.

## III.IMPACT OF THE USE OF FLY ASH IN SMART CITIES

Since our government is planning the development of smart cities at a faster rate, we can increase the use of fly ashin construction and try to get the solution to environment-related problems in one go. The quality of urban life can be improved by reducing the cost of living, smarter services and amenities management, modern mobility, sustainable housing, and a smarter economy is the need of the hour. The main aim isto solve the challenges of economic, social, and ecological nature through technological innovations in futuristic cities. One of the major focuses for the sustainable infrastructures of proposed smart cities would be the use of fly ash in environment-friendly cement production and concrete mix.

Fly ash can also be used in the manufacturing of bricks having high strength and excellent finish for load-bearing walls. To save construction time and cost in binding mortar and plaster, an excellent finish provided by the fine particle of fly ash-enabled cement would be a boon. Lightweight eco-friendly fly ash aggregate has almost half of the weight of conventional aggregates. This lighter aggregate makes lighter concrete which helps in bringing down the weight of the structure. Its high strength with low density in structural concrete is great for usage in bridges, roads, and other infrastructure of cities.

*A. Quantum of the Fly Ash Availability and Utilisation*

Source: CEA

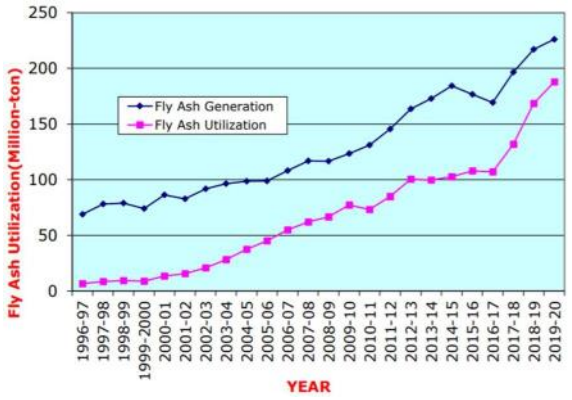



Fig. 2: Generation vs Utilisation of Fly Ash

Figure 2 is showing the increasing utilization in India above. The advancement in the applications of fly ash in various areas is expected to offer new opportunities for market growth. For example, manufacturing prefabricated building panels using fly ash is an upcoming trend, mainly in India, where commercial production of prefabricated building panels is still underdeveloped.

*B. Diversified Usage of Fly Ash*

Source: CEA

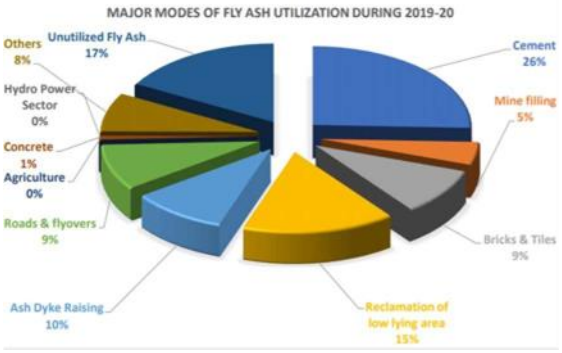



Fig. 3: Diversified Modes of Utilisation of Fly Ash in India

In 2019-20, the cement sector had the maximum utilization offly ash at 26% however 15 % of fly ash was used in the reclamation of low-lying areas but still, 17 % remained as unutilized as shown in the above pie [5].

The fly ash market is segmented by class, application, end-user, and region. On the basis of class, the market of fly ash issegmented into class C and class F. By application, it includes Portland cement concrete (PCC), bricks and blocks, asbestos sheets, structural fills, soil, and road base stabilization amongothers. Likewise, to increase the utilization of fly ash in India, smart cities can use fly ash in construction, transportation, and cement additives. Other uses can include the agricultural andmining sector as proposed across foreign countries in North America, Europe, and APAC countries.

Complete life-cycle analysis of the modified infrastructure material determines the true performance. The high production burden of building materials with better energy efficiency anddurability can have a low environmental impact. Rodrigues (2020) studied a methodology to evaluate the eco-toxicological potential of raw materials and cement-based construction materials. Use of 25 to 100 % fly ash instead of100 % cement reduces carbon emission by up to 80 %.

In 2019, the world's first 'green' road was constructed onmajor high-volume traffic leading to Sydney Airport, with concrete made from fly ash and co-products from the steel industry. At the same time, researchers from the Indian Institute of Technology Hyderabad have found a new technology that can convert Fly Ash into waterproofing material. The new technology can modify Fly Ash into superhydrophobic Fly Ash particles, a waterproofing material, by using this binding ability of stearic acid.

The strong growth in the Asia Pacific region in the fly ashmarket is due to government support in emerging countries like India and China and their continuous efforts to develop the infrastructure. The green building index (GBI) launched in 2009 by the Malaysian government encouraged the construction of buildings using green technology [4].

## IV. CONCLUSION

1. Globally cities are growing rapidly and today more thanhalf of the world's population lives in cities. By 2030, approximately 60% of them would need smarter cities with apotential requirement of 1.3 trillion US dollars of investmentto build them. So, the market is projected to grow at a compounded annual growth rate of 19.4%.
2. It is our government's efforts to reduce dependency on traditional cement that have encouraged the increased use of fly ash in the infrastructure and it also reduced the problem of

waste disposal to some extent. As the fly ash generation in India during 2019-20 reached 226 million tonnes due to the combustion of 680 million tonnes of Coal / Lignite, its utilizationhas increased from 9.6% in 1996-97 to the highest level of 83% in 2019-20.

3. Use of smart technology and eco-friendly materials is expected to solve economic, social, and environmental issues in cities. We need to make our infrastructure future-ready for sustainability and make it smart and resilient to face the challenges of rapid urbanization and environment conservation.
4. Smart cities facing one of the greatest challenges is sustainability and its cost. Smart city infrastructure requires alarge capital investment.
5. If we increase the application of fly ash in smart cities, it will solve two problems at the same time; one to consumption of fly ash, and second to decrease the cost of the construction.

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