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Utilization of industrial wastes for co-processing in cement production reducing environmental impacts

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ABSTRACT

Rapid industrialization in the State of Gujarat is increasing the tremendous amount of industrial wastes for disposal. Secured landfill (TSDF) is a safe and economical disposal method which requires very fewer efforts to generators. In another side, the cement industry is an intensive consumer of natural material resources, energy and also has great potential for pollution besides greenhouse gas emission. Proper utilization of industrial wastes as an alternative fuel and raw materials can decrease the environmental impacts lowering the consumption of natural materials and energy considerably. Further, utilization of wastes as AFR seems more economical to the generator as the cost of disposal at TSDF is almost zero and also for cement plant as it reduces costs towards mineral mined materials consumption and energy requirements.

Keywords— *Waste, Co-processing, Utilization, Cement, TSDF*

1. INTRODUCTION

Gujarat is among the highly industrialized state of India. Due to tremendous growth in the industrial sector, there is a generation of industrial solid wastes increased manifolds. Indiscriminate disposal of such industrial wastes poses serious environmental problems due to its hazardous in nature. The hazardous wastes from various chemical industries, Dyes and Dyes intermediates, Organic chemical manufacturing, metal treatment units etc. are high in volume and may create a great concern to the environment. Therefore, there is a need for the scientific disposal of industrial wastes in a more suitable cost-effective and environmentally sustainable way.

1.1 Industrial hazardous waste

As per inventory 2016-17 published by the Central Pollution Control Board, New Delhi, Gujarat State is having 11,200 numbers of hazardous waste generating industries, which are authorized to generate about 1449035 MT of hazardous waste and contributes about 40% of the total generation in the Country. The State has 09 common treatment, storage and disposal facilities for the treatment and disposal of hazardous wastes. As reported by Gujarat PCB, about 8, 50,393 MT of land-fillable (that is. direct landfill and landfill after treatment) hazardous waste have been disposed of during the year 2016-17. It shows disposal of land fillable waste may create havoc in near future due to the nearly exhaustible capacity of existing TSDF, shortage of new TSDF development in under threat of local conflict, unavailability of land pockets near industrial areas and other financial issues. Therefore, it was felt the need to attempt to find out more suitable technology for utilization of wastes into Eco-friendly and useful materials than simply disposal.

1.2 Cement industry

Cement is the main ingredient of the concrete which is one of the key construction materials in use today. Concrete is the most consumed material on earth, second only to water, with three tons per year used for every person. Mainly two types of cement that are being used that is Ordinary Portland cement and Portland cement. A supplementary cementation material when used in conjunction with Portland cement, contributes to the properties of hardened concrete through hydraulic and pozzolanic activity or both.

Cement industry itself is a very high intensive industry in terms of natural raw materials and energy. Further, a large volume of production of cement and ancillary activities associated with its production leads to emission of many harmful polluting gases and also carbon dioxide “greenhouse gas” in the atmosphere, which threats to climate change and global warming.

Hence, the researchers are currently focused on industrial waste material having to cement properties, which can be added as partial replacement of cement which reduces cement production then reducing associated impacts on environment and sustainability.

2. CRITICAL LITERATURE REVIEW

I.Sowmya1, A.Roopa (2013)[1]: The study stated that Quarry dust, a byproduct from the crushing process during quarrying activities and fly ash is an artificial pozzolanic material, having cementitious properties. Incorporation of quarry dust into the self-compacting Concrete mix as partial replacement material to natural sand resulted in higher compressive strength and optimization of sand replacement is 40%. Optimization of the addition of fly ash in total powder content is 30%.

Chetali Shrivastava (2015)[2]: Pozzolana that is commonly used in concrete includes fly ash, silica fume and variety of natural pozzolanas such as calcined clay and volcanic ash. Fly ash has been used in concrete at levels ranging from 10% to 30% by mass of the cementations material component. Site mix P.P.C concrete gives better strength for higher grade concrete up to 30% of fly ash replacement by cement and 10% of fly ash replacement for low-grade concrete.

J. Viguri1, A. Andre ÂS (2001)[3]: Selected metal hydroxide cakes from the `on-site' wastewater treatment of nickel and chromium electroplating activities and the anodizing of aluminium materials were treated with Portland cement and mixed with clay, offering possibilities of solidification/ stabilization prior to landfilling, and utilization in ceramic products. The environmental impact assessment based on criteria of eco-toxicity of acidic leachate leads to the conclusion that waste/cement ratios in the range of 3/1 to 1/ 2, and waste/clay between 1% and 3% are able to fulfil Spanish eco-toxicity limits. Introduction of metal hydroxides cakes in the manufacture of ceramic products is an immobilization strategy of these wastes providing a non-eco-toxic material and leachate, which can be controlled in low concentrations of pollutants in water.

Nafeth A. Abdelhadi (1995)[4]: Huge amounts of Phosphogypsum (PG) are produced as by-products of the phosphoric acid manufacture process. Heated PG showed an imperfect setting time, consistency and compressive strength over colder PG. The addition of 10% pozzolana showed a negative impact because of its large mixing ratio. Experimental results recommend the use of raw PG without treatment (heating) in cement production. This will eliminate a serious environmental source of pollution; besides, it will decrease the cost of cement production.

3. METHODOLOGY

There are a number of types and grades of cement and the different tests are done conforming to certain codes practised. The tests also depend on the use of cement for a particular type of work. India follows the codes formed by the BIS body.

Some of the codes that the cement should conform to are as follows

(a) IS 269: 1989– Specification for ordinary Portland cement, 33 grade.
(b) IS 8112: 1989– Specification for ordinary Portland cement, 43 grade.
(c) IS 12269: 1987– Specification for ordinary Portland cement, 53 grade.
(d) IS 455: 1989– Specification for Portland slag cement.
(e) IS 1489 (Part 1): 1991– Specification for Portland Pozzolana cement: Fly ash based.
(f) IS 1489 (Part 2): 1991– Specification for Portland-Pozzolana cement: Calcinied clay based.
(g) IS 3466:1988– Specification for masonry cement.

Properties of cement mainly divided into physical properties and chemical properties as summarized in table 1. Considering the major focused area on more eco-friendly and cost-effective disposal of wastes than conventional TSDF, the following main important quality test was chosen.

Table 1: Properties of cement

Physical Properties	Chemical Properties
Fitness	Loss of Ignition
Soundness	Sulphur Trioxide
Consistency	Free lime
Strength	Alumina
Settling time	Magnesia
Heat of hydration	Chloride etc.
Density	
Specific gravity	

3.1 Compressive test

The compressive strength of concrete is a measure of the concrete's ability to resist loads which tend to compress it. The compressive strength of concrete can be calculated by the failure load divided with the cross-sectional area resisting the load and reported in pounds per square inch in Mega Pascal (MPa) in SI units. If it is a normal concrete cured in normal water then it will take about 28 days to achieve 90% of its strength but you go for steam curing or hot water curing, the concrete will attain the strength early depending on the temperature at which it has been cured.

3.2 Loss on Ignition test

It consists of strongly heating of a sample of the material at a specified temperature, allowing volatile substances to escape, until its mass ceases to change. Loss on Drying (LOD). It may refer to the loss of any volatile matter from the sample.

4. EXPERIMENTAL PROCEDURE FLOW

Different industrial solid wastes collected from selected industrial plants gathered information on source industry, products and waste characterization collected from the generator and identified the concerned main contaminant. Laboratory tests that is Compressive strength and Loss of Ignition were carried out for selected industrial wastes including the following standard. Results were further analyzed in terms of Cement quality after mixing industrial wastes as supplementary Cementitious materials.

Following industrial wastes have been selected in the experiment as a substitute for naturally occurring materials:

(a) Chemical Gypsums from Common Spent Acid Treatment and Disposal facilities (type-1) and a Dye and Dye intermediate industry (type-3) categorised as hazardous waste have been selected as a substitute to mineral Gypsum as it plays a major role in retardant and strength of the cement.
(b) ETP sludge from physicochemical treatment of effluent from metal finishing industry (type-2) as a substitute of gypsum and iron oxide, it impacts colour, hardness and strength to the cement.
(c) Marble waste (type-4) is selected as a substitute of silica-sand; it impacts strength to the cement.

Table 2: Experimental samples

Type of mixer	Cement/ Waste ratio
Type-11	Clinker -97% , Ind. Gypsum-3%
Type-12	Clinker -95% , Ind. Gypsum -5%
Type-13	Clinker -72% , Ind. Gypsum-3% , Fly Ash-25%
Type-14	Clinker -70% , Ind. Gypsum-5%, Fly Ash-25%

Type-21	Clinker -97%, ETP sludge- 3%
Type-22	Clinker -95% , ETP sludge -5%
Type-23	Clinker -72%, ETP sludge -3% , Fly Ash-25%
Type-24	Clinker -70% , ETP sludge -5%, Fly Ash-25%
Type-31	Clinker -97% , Ind. Gypsum-3%
Type-32	Clinker -95% , Ind. Gypsum-5%
Type-33	Clinker -72% , Ind. Gypsum-3% , Fly Ash-25%
Type-34	Clinker -70% , Ind. Gypsum -5% , Fly Ash-25%
Type-41	Clinker -95%, Marble Sludge -2%, Ind. Gypsum-3%
Type-42	Clinker -90% Marble Sludge -5%, Ind. Gypsum -5%

5. RESULTS AND DISCUSSION

Experiments were carried out for the different proportion of wastes with cement clinker and after curing in days as 1d, 3d, 7d and 28 days. Results are mentioned in the figure 1 to 3.

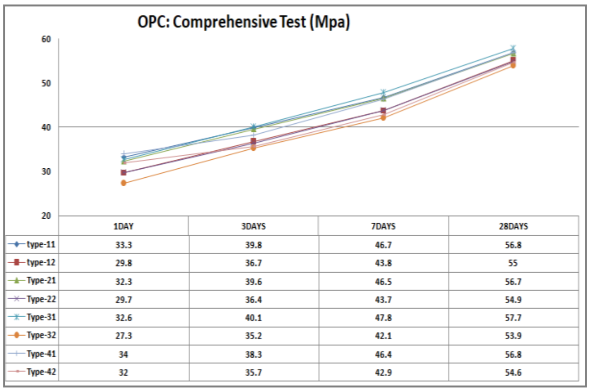

Fig. 1: Sample compared with OPC grade

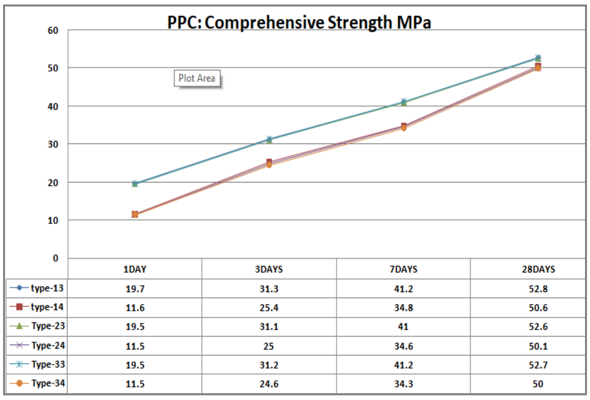

Fig. 2: Sample compared with PPC grade

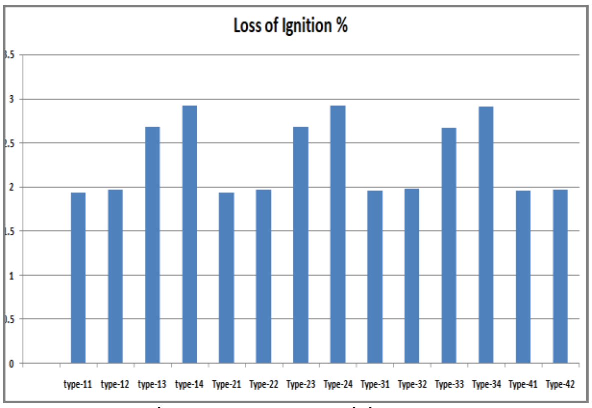

Fig. 3: Loss on Ignition test

Results of mixing of various wastes with cement clinker as shown in graphs 1 to 3 show the following main output:

(a) With the mixing of Gypsum, earlier comprehensive strength shows reduction than mixer without gypsum which later on increases at the desired level.

(b) Mixers were made by replacing 5% cement with marble powder shows good result in -terms of compressive strength.

(c) With maximum 05 percentages mixing of chemical gypsum or ETP sludge there is an increase of comprehensive strength. As expected, the strength increases as the curing time of concrete increases.

In all three cases, the comprehensive strength and Loss of Ignition percentages show results allowable as per the Indian standards IS 12269: 2013 and IS 1489 (Part 1): 1991 for OPC and PPC cement respectively.

The laboratory and operational trial indicated that locally available industrial wastes into proper percentages that is Gypsum waste by 5%, Marble waste by 5-10% and ETP sludge by 5 % does not deteriorate the comprehensive strength and Loss ignition properties of OPC/ PPC cement quality. However, the other important tests to ensure the quality of the cement may be carried out for the prefixed ratio of waste to the clinker before plant scale operation.

6. COST-BENEFIT ANALYSIS

Desktop analysis has been done with the help of various data from respective industries and cement plant and also with the help of past experience to get a clear picture about cost-benefit aspect. Major players associated with the projects are:

(a) Waste source Industry,
(b) Landfill (TSDF) site operators and
(c) Cement industry.

6.1 Economical aspects related to waste generator

Waste generators normally send their hazardous waste to "Treatment, Storage and Disposal Facilities" (TSDFs) to dispose of the waste. A generator is responsible for the hazardous waste it generates. Their liability doesn't end when the containers leave their premises. Hazardous waste generators continue to be responsible for their hazardous wastes as well as any costs associated with future releases of that waste. If there ever is an incident in the future involving the release of hazardous wastes that have been land-filled or otherwise land-disposed, everyone who has ever put waste into that landfill is a responsible party and is responsible for cleanup costs as TSDF are not always sufficient to cover the entire cost of cleanup and remediation after an incident. The following table shows the disposal of industrial wastes cost to generator includes following main aspects:

Table 3: Generator- cost associated with the disposal of industrial wastes

In plant waste storage and handling facility	Membership of TSDF	Regular Waste disposal charges to TSDF
Transportation of Wastes to TSDF	Manpower and supervision	Analytical charges to TSDF
The hidden cost of remediation in case of failure of landfill or accidental release of wastes into the environment		Regulatory supervision and permission cost

In case of illegal dumping of wastes, where a responsible party can or cannot be identified or may have another reason, the portion of the cleanup and remediation cost is reallocated to the other identical industries. This is why it is important for generators to carefully consider their waste handling and disposal options. Options like land filling are often initially less expensive than reuse or utilization, but they have a higher degree of future liability.

6.2 Economical aspects related to cement industry

A study done by the Tariff Commission gives an element-wise break-up of the overall weighted average cost of all the selected units for the year 2008-09, which provides the actual cost of production of the three varieties of cement. It can be seen that the cost of raw material and power account for 50% or above of the total cost of sales including interest for all the three varieties of cement. Similarly, transport expenses account for 20% or above of the total cost for all the varieties.
Following table show cost associated with cement grinding unit while handling industrial wastes:

Table 4: Cement grinding plant- cost associated for use of alternate raw materials

Cost of limestone/ other mineral raw materials	Cost of Alternate raw materials	Capital investment and infrastructure O and M
Transportation of raw materials	Blended Cement Selling infrastructure	Manpower and Supervision
Regulatory permission and supervision cost	Quality testing for raw materials and product	Cost of APCM operation

The cost of production of cement is a major factor that determines the prices of cement. The cost is directly related to the geographical location of cement plant and the location of raw materials. Further, in case of use of supplementary cementitious materials like industrial wastes such as chemical gypsum, ETP sludge and Marble waste, the Cement plant does not require major Capital infrastructures. Only some changes in the drying of wastes to remove moisture content and grinding to get proper particle sizes are required at once. In operation cost, there is no additional requirement or cost associated with alternative raw materials.

Following table shows Cost associated for use of alternate raw materials at cement grinding plant includes the following main aspects:

According to a research report published by lobby group Confederation of Indian Industry and consulting firm AT Kerney, India has a scarcity of gypsum resources, which does not bode well for the cement industry.

In India, gypsum reserves are found in Rajasthan, Gujarat, Jammu and Kashmir, Himachal Pradesh, Tamil Nadu and Uttar Pradesh. However, about 90 per cent of the total Indian production of gypsum comes from western and north-western Rajasthan. The report said that at present, usable gypsum reserves in India amount to 140-150Mt of which around 125Mt is available to the industry. These numbers are for Rajasthan and Gujarat, as reserves in other states are unusable. The available supply will be enough to support the cement industry for the next seven to eight years, beyond which the sector will need to rely on imports, the report added.

6.3 Economical aspects related to industrial waste landfill site- TSDF

Sitting of TSDF in India especially in Gujarat is always remains in controversy and publically conflict. The costs of a TSDF (secured landfill site for industrial wastes) are dependent on several factors. Costs are divided into two categories, namely capital expenditure and operating expenditure.

(a) Capital expenditure: Investment in plant and machinery that is depreciated over time.

(b) Operating expenditure: Operation and maintenance costs involved in daily activities.

Table 5: TSDF Operator

Capital and operational cost	
Preoperative investments	Closure and Liability
Capital Cost Land	Manpower costs
Plant and machinery	Maintenance
Analytical laboratory and Other infrastructure	Community engagement
Statutory compliance	Monitoring
Revenue	
Disposal Fees	Transport charges
Membership fee	Analytical services

In the above table, the cost associated with the TSDF operator is highlighted. In addition to the above, an important aspect for TSDFs is to sufficient provision for any liabilities from environmental accidents as well as the safe management of the landfill post capping, over typically a 30-year period.

6.4 Benefits to cement grinding unit

In case of use of industrial chemical gypsum over mineral gypsum, there is clear cut benefit of at least 50% reduction of gypsum cost as mineral gypsum rate at present ranges to 1200-2200 rupees per ton compared to almost free of cost industrial gypsum. Further, mineral gypsum availability is now predicted for one to two decade only for cement industry. These ways alternate industrial chemical gypsum seems very promising considering less material cost, continued availability and future security as industrial development is increasing very rapidly.

Transportation costs represent a significant portion of the overall costs of gypsum. In this case, due to the easy availability of industrial gypsum within 50 KM radius compares to 500 to 1000 km distance of suppliers of natural gypsum that is location of limestone mines at Saurashtra Coastal area or Rajasthan, the industrial wastes seems very cheaper. Further, as vehicular emission is directly related to the distance travelled, there may be decreased in vehicular emission and environmental impacts with a decrease in transportation distances. Here, the quality of road network, average road speeds for transport vehicles and other factors are not considered.

6.5 Benefits to waste generator industrial units

Normally the cost associated with the transportation of waste increase with distances. Here, in our study based on locally available industrial wastes to cement grinding unit, the distance between generators to cement plant compare to distance generator to TSDF is almost one-tenth that is about 30 km to about 400 km respectively. Further, there is no TSDF membership charge and nil cost associated with the disposal of the tonnage of industrial wastes. Thus, there is almost free of cost to the generator if they offer wastes to co-processing.

The economic analysis demonstrates that utilising industrial chemical gypsum/ ETP sludge within the cement manufacturing industry makes economic sense.

7. ENVIRONMENTAL IMPACT OF BENEFIT ANALYSIS

There are many Environmental Issues associated with the sourcing of gypsum through conventional methods, that is. mined and synthetic gypsum, and through recycling, has environmental impacts. Conventional gypsum is sourced through mining, either open cast or underground mining or synthetic generation. This method of gypsum production is a key contributor to physical resource depletion, global warming potential resulting from energy use, eco-toxicity, photochemical oxidation and acidification. The principal environmental impacts of mined gypsum arise from resource depletion and energy use in production.

The environmental impacts of industrial gypsum are principally attributed to the collection of waste from disperse locations and the associated environmental impacts of road transportation only e.g. emissions of carbon dioxide, nitrous oxides, and particulates only. There are no further impacts associated with its post utilization or future liability. It clearly shows that the co-processing in cement plants will have less adverse Environmental impact on the surrounding environment.

8. CONCLUSION

The experimental study concluded that locally available industrial wastes show very promising characteristics for Alternate Cementious materials in place of natural mined raw materials. There is no adverse effect on cement quality if wastes are added into clinker in a controlled manner. Further location of cement grinding unit near to industrial area shows considerable reduction in transportation cost and economically for cement plant. Substituting a portion of clinker with industrial waste gypsum reduces operational manufacturing costs, as no material cost of wastes. Industrial chemical gypsum, ETP waste etc. also do not require capital investments in manufacturing capacity.

Co-processing industrial waste has multifold environmental and financial benefits to waste generator as saving on waste transportation and disposal cost. For TSDF operators, there are savings on cost on developing, operating and monitoring TSDF, reduces land required for TSDF as wastes are diverted to utilization leaving no residues for disposal and developed TSDF may be utilized for more needy wastes having no reuse/ utilization potential. Thus, Co-processing of industrial solid wastes as alternative raw materials in co-processing is a Win-Win situation for Waste generator, Cement Plant and also TSDF operator.

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