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GUIDELINES FOR UTILIZATION AND DISPOSAL OF FLY ASH

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GUIDELINES FOR UTILIZATION AND DISPOSAL OF FLY ASH

Solid Wastes Sectional Committee, CDC 54

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Indian Standard
GUIDELINES FOR UTILIZATION AND DISPOSAL OF FLY ASH

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 21 April 1982, after the draft finalized by the Solid Wastes Sectional Committee had been approved by the Chemical Division Council.

0.2 Fly ash is a finely divided residue resulting from the combustion of ground or powdered coal and transported by the flue gases of boilers fired by pulverized coal. It is available in large quantities in the country as a waste product from a number of thermal power stations and industrial plants using pulverised coal as fuel for the boilers. At present there are more than 40 thermal power plants in the country producing over 5 million tonnes of fly ash per annum. The ash content of the coal used at most of these plants range from 17 to 45 percent. Since low ash, high grade, coal is reserved for metallurgical industries, railways, etc., the thermal power plants have to utilize high ash, low grade, coal and by-product fuel from coal washeries. It has been estimated that the average ash content of coal which will be available for thermal power plants in the coming years may range between 35 and 45 percent. Due to this factor, and increased industrialization, the present level of production of fly ash is expected to double in the next 10 years.

0.3 The use of fly ash as a pozzolana and a fine aggregate and also for other allied purposes is well established in a number of countries abroad, but it has come in vogue in India only recently. Some recent investigations of Indian fly ashes have proved their suitability for various uses. Indigenous fly ashes for partial replacement of cement, as an admixture for concrete and as a fine aggregate for mortar and concrete (*see* IS: 3812-1981*) have already been successfully tried out and greater attention is now being paid to fully exploit the potentialities of fly ash as construction material.

0.4 Disposal of fly ash is a problem being faced by most of the thermal power plants where it is being produced. This material, however, may be utilized in a number of ways, some of which have been mentioned above. If proper means and methods are not adopted for utilization and disposal of fly ash the problem will increase in magnitude, due to its increased production, over the next few years.

*Specification for fly ash for use as pozzolana and admixture.

0.5 This standard has been formulated with the assistance of Central Building Research Institute (CBRI), Roorkee and Central Road Research Institute (CRRI), New Delhi.

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1. SCOPE

1.1 This standard lays down guidelines for utilization and disposal of fly ash.

2. Fly ash may be collected from the flue gases, in thermal power plants, by mechanical collectors, electrostatic precipitators or a combination of both. It may be removed by 'wet system' or 'dry system' of ash removal. The 'wet system' involves mixing the fly ash with water and sluicing it to a settling tank or dumping areas. The 'dry system' involves removal of the fly ash in dry form either directly by screw feeders discharging into transport vehicles from the hoppers or by means of pneumatic conveying system for further disposal. The dry fly ash may also be stored in storage silos at the plant.

3. UTILIZATION AND DISPOSAL

3.1 Fly ash is a suitable raw material for a variety of products and may be utilized without further processing also provided it meets the requirements of the standards for such uses, if available. It may be utilized for the production of:

a) Portland pozzolana cement (using fly ash as pozzolana),

b) Cement-fly ash concrete and ready-mixed fly ash concrete,

c) Precast fly ash concrete building units,

d) Sintered fly ash light weight aggregate and concrete,

e) Lime-fly ash cellular concrete,

f) Cement/lime/silicate bonded and clay-fly ash building bricks,

g) Portland cement clinker,

h) Oil-well cement and masonry cement,

j) For road and airfield pavement construction using:

   1) lime-fly ash concrete,
   2) lean cement-fly ash concrete,
   3) cement-fly ash concrete,
   4) lime-fly ash soil stabilization, and
   5) lime-fly ash bound macadam.

k) As fill material in embankment construction,

m) As filler material in bituminous concrete, and

n) Insulating and semi-insulating bricks.

3.1.1 It may also be utilized for reclamation of low lying waste land, filling of mines and as a partial replacement of cement in mortars, structural concrete and mass concretes at construction sites.

3.2 Portland Pozzolana Cement (using Fly Ash as Pozzolana)

3.2.1 Portland pozzolana cement (using fly ash as pozzolana) may be manufactured either by intergrinding Portland cement clinker, fly ash and gypsum or by intimately and uniformly blending Portland cement and fly ash (*see* IS : 1489-1976*).

3.2.2 The intergrinding method does not involve any major addition to the plant and equipment already available at a cement factory. The blending process requires installation of a suitable blender or homogenizer. In India, Portland-pozzolana cement (using fly ash as pozzolana) is being produced over the past few years by the intergrinding process.

3.2.3 Most of indigenous fly ash possess good pozzolanic activity and are suitable for use in the manufacture of Portland pozzolana cement (using fly ash as pozzolana). The Portland pozzolana cement (using fly ash as pozzolana) having its strength at par with that of ordinary Portland cement at 7 days and conforming to the other requirements of IS : 1489-1976* may be used in place of ordinary Portland cement in construction works.

3.3 Cement-Fly Ash Concrete and Ready Mixed Fly Ash Concrete

3.3.1 Portland cement concrete in which a part of the cement has been replaced by fly ash is termed 'fly ash concrete'. When prepared and supplied to consumers in a plastic, unhardened, ready-for-use state, it is called 'ready mixed fly ash concrete'.

The process of producing ready mixed fly ash concrete mainly consists of two operations as follows:

a) Proportioning of fly ash concrete mix.

b) Batching and mixing of different ingredients.

3.3.2 The fly concrete mix is specially proportioned in order to attain required 28 day compressive strength optimally, equal to that of the corresponding mix of plain cement concrete. A number of methods of proportioning fly ash concrete mix are now available to achieve equal 28 day compressive strength. Any of these methods may be followed. One such

*Specification for Portland-pozzolana cement (*second revision*).

method is given in IRC : 68-1976 'Tentative guidelines for cement fly ash concrete for rigid pavement construction, issued by the Indian Road Congress, New Delhi. The quality of ready mixed fly ash concrete depends upon the quality of its ingredients, their proportions and thoroughness with which these are combined. The mixing of different ingredients may be done either at a central mixing plant or during transit in a truck mixer.

3.3.3 Ready mixed fly ash concrete has advantages such as better quality control and reduction in wastage, labour and supervision. As compared to plain cement ready mixed concrete, it is cheaper and there is a direct saving of cement upto 20 percent.

3.4 Precast Fly Ash Concrete Building Units

3.4.1 The use of fly ash in the production of various types of precast building units such as concrete building blocks (solid or hollow), RCC transmission poles, columns, beams, hollow core slabs and door and window frames, has been made in India in a limited way by different organizations. These precast concrete units were water cured. It was observed that breakage of these units during handling at the time of removal from the casting yard and subsequent stacking for water curing was more. The higher breakage in the fly ash concrete units could be, obviously, due to their having lower strength at one or two days when the units were removed. Fly ash concrete with 20 percent less cement, by mass, than the corresponding plain cement concrete can be so proportioned as to attain equal one-day compressive strength. With equal one-day strength precast fly ash concrete units can be lifted and handled in the same manner as the corresponding plain cement concrete units.

3.4.2 Large number of precast hollow concrete building blocks, flooring and roofing units, such as cored units channel units and cellular units produced using fly ash concrete having 20 percent less cement, by mass than the corresponding plain cement than concrete have been found to have comparable strength and other structural properties.

3.5 Sintered Fly Ash Lightweight Aggregate and Concrete

3.5.1 Fly ash contains a large proportion of minute spherical glassy particles. When heated at 1 100°-1 200°C these glassy spheroids soften and cohere to form a vitrified structure. The process of causing this cohesion is termed 'sintering' and the sintered agglomerates are called sintered fly ash lightweight aggregate (SFALA).

The manufacture of SFALA mainly involves the following two operations:

a) Pelletization or nodulisation of fly ash, and
b) Sintering of fly ash pellets or nodules at 1 100°-1 200°C.

*Specification for Portland-pozzolana cement (*second revision*).

3.5.2 The pelletization of fly ash may be done by feeding fly ash into a tilted rotating pan under a fine spray of water. The rotary motion of the pan causes the material to cascade and with this pellets are formed which are strong enough to withstand subsequent handling.

3.5.3 Normally, fly ash contains sufficient amount of unburnt carbon to provide for the fuel required for sintering. If it does not, then, extra fuel in the form of powdered coal or coke is required. Similarly, if fly ash particles do not cohere to form pellets, additives such as shale and clay are added. Additives, if any, are thoroughly mixed in fly ash before pelletization.

3.5.4 The sintering of the pellets may be done either in vertical shaft kiln or on a moving grate sintering strand. The use of rotary kiln has been tried on an experimental basis. A stationary grate sinter pot is also reported to have been successfully used. The production of SFALA from some of the Indian fly ashes has been successsfully carried out on a pilot plant moving grate sintering strand.

3.5.5 The SFALA is spherical, porous, hard and brownish grey in colour. Its bulk density ranges between 619 to 721 kg/m^3. It is suitable for use in the production of structural lightweight concrete and precast lightweight concrete building units used as load bearing and non-load bearing elements. Due to higher strength to mass ratio, lower thermal conductivity, nailability, sawability and greater resistance to fire, SFALA concrete is suitable for use in the construction of high-rise buildings. Its use speeds up construction and lowers haulage and handling costs by reduction in mass of building components. The reduction of dead loads also brings about savings in costs towards foundations and steel.

3.6 Lime-Fly Ash Cellular Concrete

3.6.1 To produce lime-fly ash cellular concrete, quick lime (calcium oxide content 70 percent minimum, magnesium oxide content 3 percent maximum) fly ash (specific surface, 3 000 cm^2/g; unburnt carbon content, 5 percent maximum) and gypsum ($CaSO_4 \cdot 2H_2O$ content, 80 percent minimum) are taken in certain proportions and wet mixed in a high speed mixer to form a thin homogenous slurry. A small amount of aluminium powder (fineness : residue on 75 μm IS sieve one percent maximum) is then added and mixed into the slurry. Hvdrogen gas liberated by aluminium and lime reaction aerates the slurry which is poured into steel moulds to 2/3rd depth and left undisturbed to set. The setting takes place in 4-5 hours. The stiffened material is cut into blocks of desired sizes which are subsequently autoclaved at a steam pressure of 11-12 kg/cm^2. After taking out from the autoclave the blocks are allowed to cool and are stacked for use.

3.6.2 The properties of lime-fly ash cellular concrete are similar to the cellular concrete produced using cement and ground sand. It is lightweight, has good thermal insulation and fire resistance properties and stability under conditions of varying temperature and humidity. It can be produced with dry bulk density of 700 kg/m^3 or higher and the units produced are suitable for load bearing walls in buildings of 2 to 3 storeys and partition walls in multistoreyed buildings. Its use speeds up construction, lowers haulage and handling costs and brings about savings in costs of foundations and steel by reducing dead weight.

3.6.3 The production of cellular concrete using lime and fly ash in place of cement and ground sand costs comparatively less, as it eliminates the use of cement which is costlier than lime and saves the cost of grinding sand.

3.7 Fly Ash Building Bricks

3.7.1 Good quality building bricks may be produced from fly ash using sodium silicate, cement or lime as binder (with or without accelerator). The mixture of fly ash, binder and coarse fillers such as bottom ash, cinder and sand in suitable proportions may be moulded into bricks under pressure. Except for sodium silicate, the other binders have to be mixed in dry state, followed by addition of water with/without accelerator. The sodium silicate bonded fly ash bricks are burnt at 1 060 to 1 150°C, but lime bonded fly ash bricks are autoclaved under saturated steam while the cement-bonded fly ash bricks are cured under water at ambient temperature to obtain the desired strength and are air-dried before use.

3.7.2 The process of manufacturing clay-fly ash building bricks is similar to that of production of normal clay bricks except that a certain amount of fly ash is mixed in the clay before moulding bricks. The actual content of fly ash added varies according to the plasticity of clay and may range from 30 to 70 percent by volume, as the clay changes from moderately plastic to highly plastic. Fly ash acts as a good opening material and effectively eliminates drying cracks in the bricks produced from black cotton clays. The unburnt carbon present in fly ash provides extra fuel for burning during firing The rate of fire travel during burning of clay-fly ash bricks in the brick kiln is also enhanced. Consequently, overall fuel consumption is reduced and production per season increased. The fly ash building bricks may be used in place of common burnt clay bricks for all types of brick masonry.

3.8 Portland Cement Clinker

3.8.1 Fly ash compares well with clay as a source of silicon dioxide and aluminium oxide. It may be used in place of clay in the raw meal for producing portland cement clinker by the semidry process. Small pellets or nodules (diameter 12·5 mm or less) of the raw meal consisting of an intimate mixture of the required quantity of ground limestone and fly ash may be prepared in a tilted pan pelletizer under a fine spray of water. Any other type of nodulizer may also be used for nodulizing the raw meal.

The nodules are fed into the rotary kiln and burnt at 1 350°C to produce portland cement clinker, which on cooling is ground with 4 percent gypsum by mass, to obtain portland cement.

3.8.2 The production of cement clinker at 1 350°C, instead of about 1 450°C normally employed, brings about a substantial saving in fuel consumption. In addition, it has been found that the use of fly ash in place of clay in the raw meal enables production of cement clinker with magnesium oxide content of 6 percent without causing unsoundness in the final cement. Thereby, it also helps in the utilization of magnesium limestone of marginally higher magnesium oxide content, which at present, is not used by the cement industry.

3.9 Oil Well Cement

3.9.1 Oil well cement is used for cementing the steel casings of oil wells to the rock formation. The cement slurry is pumped down through the steel casing to points located in the annulus around the casing, in the open hole below or in permeable formation around. For satisfactory performance under conditions of high temperature and pressure, which in deep wells may be as high as 350°C and 1 400 kg/cm^2 respectively or even more, it is essential that the cement slurry has ample fluid time to enable proper placement before setting and then harden fairly rapidily to give sufficient strength to support the casing and resist corrosive conditions of sulphur bearing gases or water containing dissolved salts.

3.9.2 Cement produced by intergrinding fly ash, Portland cement clinker, gypsum and certain admixtures in suitable proportions has been found to conform to the requirements of an oil well cement. It may be commercially produced at cement works which are located within economic distance of thermal power stations in India. Such a fly ash based cement is reported to have been successfully used in cementing oil wells in some countries.

3.10 Masonry Cements

3.10.1 Masonry cement is mainly intended for use in place of ordinary Portland cement in masonry mortars. It imparts, to the masonry mortars, much desired properties of high workability, plasticity and water retentivity. While it is widely used in some countries, it is yet to become popular in India.

3.10.2 It has been shown that masonry cement conforming to the standard requirements can be produced by intergrinding 2 parts of fly ash, 2 parts of hydrated lime and 1 part of Portland cement clinker or 5 parts of fly ash, 3 parts of Portland cement clinker and 5 parts of granulated blast furnace slag with suitable quantity of gypsum and an air entraining admixture. The production of these masonry cements and their utilization in the building industry will ease pressure on the demand of Portland cement.

3.11 Fly Ash Utilization in Road and Airfield Pavement Construction

NOTE — The techniques on fly ash utilisation described in **3.11.1** to **3.11.5** have been approved by the Central Assessment Committee of the Ministry of Shipping and Transport, Government of India for large scale adoption in pavement construction.

3.11.1 *Lime-Fly Ash Concrete*

3.11.1.1 Lime-fly ash concrete possesses significant flexural rigidity and thus offers superior load dispersion property in pavements as compared to conventional granular material, such as water bound macadam. Investigation have shown that when lime conforming to IS : 712-1973* and fly ash to IS : 3812-1981† is used for making lime-fly ash concrete of mix proportion 1 lime, 2 fly ash, 3 sand and 6 coarse aggregate has an equivalancy factor of 1·5 in relation to water bound macadam and, therefore, permits a reduction of 33 percent in the thickness of the layer replaced. In view of better load dispersion characteristics of lime fly ash concrete such bases or sub-bases are particularly suitable in areas having heavy rain-fall, poor drainage or weak subgrade for longer life and improved servicebility of the pavement.

3.11.1.2 In urban areas, foot paths are a necessity for safe movement of the pedestrian traffic. Investigations have shown that the lime-fly ash concrete of mix proportion as given in **3.11.1.1** can be successfully used for making precast lime-fly ash concrete blocks for foot paths. These precast blocks, however, require a top bonded layer 10 mm thick of cement-sand mortar (mix 1:3 and w/c 0·55 by mass) in view of low resistance to abrasion of lime-fly ash concrete. The suitable size of blocks is 30 cm × 30 cm × 10 cm. Instead of making precast blocks, lime-fly ash concrete can be rolled *in situ*. As in the case of precast blocks, in this case also the top mortar layer is to be laid simultaneously.

3.11.1.3 Lime-fly ash concrete can also be used for making building bricks and hollow blocks.

NOTE — The Indian Roads Congress has published IRC-60-1976 'Tentative guidelines for the use of lime-fly ash concrete as pavement base or sub-base'.

3.11.2 *Lean Cement-Fly Ash Concrete* — Lean cement concrete tends to segregate, bleed, has low plasticity and cohessiveness when green. The addition of flv ash improves upon such shortcomings of lean concretes. In lean cement concrete, the cement content is already low, so partial replacement of cement by fly ash is not advisable. Studies have shown that the benefits of fly ash addition can be maximized in the case of lean concretes by resorting to partial replacement of fine aggregate by fly ash which permits

*Specification for building limes (*second revision*).

†Specification for fly ash or use as pozzolana and admixture.

use of larger quantities of fly ash. Such partial replacement of fine aggregate by fly ash also makes available additional quantity of binder material in the mix due to pozzolanic reaction between the lime released as a result of cement hydration and the fly ash, leading eventually to increased strength for the resultant concrete. Investigations have shown about 100-175 percent increase in compressive strength of cement-fly ash concrete in which 50 percent of fine aggregate is replaced by fly ash over plain mixes (without fly ash) of equivalent proportions. Such concrete would be cheaper than plain concrete Suitably designed mixes can be used as base or sub-base course in road and air-field pavement construction in place of conventional water bound macadam. It can also be used in building foundations particularly where water table is high.

NOTE — The Indian Roads Congress has published IRC-74-1979 Tentative guidelines for use of lean cement concrete and lean cement-fly ash concrete as pavement base in sub-base course.

3.11.3 *Cement-Fly Ash Concrete* — The laboratory, semi-field and full scale field experiments have shown that 15-20 percent cement by mass can be replaced by fly ash conforming to IS : 3812-1981* thereby effecting 10-15 percent saving in the initial cost of construction besides releasing cement for other works.

NOTE — The Indian Roads Congress has issued IRC: 68-1976 Tentative guidelines on cement-fly ash concrete for rigid pavement construction.

3.11.4 *Lime-Fly Ash Soil Stabilisation* — Soil when stabilized with lime and fly ash can be used economically as sub-base both for roads and runways in place of granular materials such as oversized stone metal or water bound macadam. When lime conforming to IS : 712-1973† and fly ash to IS : 3812-1981* is used for soil stabilization results in increase of CBR value of the order of 50-100 percent. The mix proportions found to be generally satisfactory are 3 parts lime, 12 parts fly ash and 85 parts soil.

NOTE — CRRI in collaboration with CBRI has published an exhaustive report on lime-fly ash stabilized soil for roads and buildings.

3.11.5 *Lime-Fly Ash Bound Macadam* — In conventional water bound macadam, non-plastic or low-plasticity materials like morrum with or without screenings are used as filler for the stone metal. When such water bound macadam is used in the upper layers of a road pavement, thin bituminous surfacings like surface dressing or premix (open graded) thereon, permits penetration of water into it. The filler being material having no binding property, the water bound macadam gets markedly softened upon being wetted. As a result, pot holes form under traffic, which are enlarged by subsequent traffic. On the other hand, fillers made of a mixture of lime, fly ash and sand/morrum/soil in suitable proportion are known to improve the

*Specification for fly ash for use as pozzolana and admixture.

†Specification for building limes (*second revision*).

situation as these have cementitious properties and do not soften in presence of water. The usual proportion for the filler mix is 1 lime: 2 fly ash : 9 sand/morrum/soil by mass. Studies have shown that load bearing capacity of such macadam will be superior to that of conventional water bound macadam. It is expected that water bound macadam course constructed with lime-fly ash-sand as filler would have longer life and would contribute to better serviceability of the road.

3.12 Fly Ash as Fill Material in Embankment Construction — Studies have shown the suitability of fly ash as a fill material for the construction of embankments. The properties to be kept in view are grain size, density, shear strength, compaction characteristics and permeability. The fly ash has to be compacted at optimum moisture which is normally in the range of 15-30 percent. Because of its low density the material is suitable for locations where clayey soils get consolidated under overburden material. The permeability of compacted fly ash is low ($0{\cdot}05 \times 10^{-7}$ to 8×10^{-7} m/s) so in cases where the water table is very high or surface water likely to percolate down the embankment it is advisable to provide for drainage a layer of coarse material 300-450 mm thick below the fly ash.

3.13 Fly Ash as Filler Material in Bituminous Concrete — Bituminous concrete paving mixtures are usually designed with a small percentage of fine material like cement or lime dust mostly passing through 75 μm IS sieve. Fly ash compares well with conventional materials in respect of fineness. When fly ash is used as a filler due to the presence of unburnt carbon the amount of bitumin required is a little more, but because of low cost of fly ash the resultant mix may be somewhat cheaper or at par.

3.14 Insulating and Semi-Insulating Bricks — Good quality semi-insulating bricks may be produced from fly ash using china clay, saw dust and molasses or spent lye as binder. The mixture of fly ash and other constituents in suitable proportions are soaked for about a week and moulded into bricks under slight pressure. The bricks are air-dried and burnt in kilns at 1 100° to 1 150°C. These bricks, having porosity of 55-63 percent and cold crushing strength of 14-18 kg/cm^2 may be used for back face insulation of furnaces and other similar equipment. Insulating bricks may also be produced using the same procedure, after reducing the iron-oxide content of fly ash by suitable processing.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of subsrance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg. m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

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