THE PROSPECTS FOR UTILIZATION OF COAL ASH IN ROAD CONSTRUCTION IN VIETNAM

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abstract : Economic growth has now in Vietnam inevitably led to increasing demands for electric powder for agriculture, industry and human life. But to produce electric powder it is necessary to combust a huge amount of coal powder in many thermo-electric plants, which have been being used in the Nothern of Vietnam. Coal ash consists mostly of fused ash particles with some unburned granules of coal - the result of combustion of powdered coal in modern boilers. In the past 15 years, this waste product has become increasingly expensive to dispose of and become a resource breeding the environmental pollution problem. The report presents some investigation results of coal ash in Vietnam and the prospects of its utilization in road construction.

1. INTRODUCTION

The coal ash and fly ash problem developed when the rapid growth in the use of powdered coal in power plants encountered the increasingly restrictive regulations against discharge of smoke, particularly in densely populated areas.The magnitude of the problem may be seen when it is realised that for each ton of powdered coal burned from 72 to 130 kg of fly ash are produced. Using the new cyclone burners which utilise crushed instead of powdered coal, as little as 18 to 30 Kg of fly ash are obtained per ton of fuel used [Edward A.Abdun-nur, 1961]. With this type of burner, the ash that would otherwise go up the stack as fly ash, is recovered as molten slag, which then presents a problem of disposal in itself, so that in one way or another the ash from the coal presents a disposal problem. The restrictions against the discharge of fly ash through smokestacks led to the development of collecting systems of various types and efficiencies.At first, it was simple to dispose of the relatively small amounts collected, by dumping in nearby locations, but before long, such available sites grew scarcer and more distant while the quantities of fly ash being produced and collected increased at a phenomenal rate. This has been the experience not only in the United States and Canada, but also in other industrial nations utilising powdered coal, such as Australia, England, France, Germany, Japan and Sweden. As the quantities of fly ash and coal ash being produced increase, the disposal problem becomes more difficult and costly. The cheapest form of disposal is dumping near the source. Conveniently available dumping areas are therefore fast becoming scarce, and the longer hauls needed to reach available locations increase the disposal coal appreciably.

The seriousness of the disposal problem has resulted in concentrated efforts to find uses for fly ash and coal ash. The efforts to find outlets for this waste product of power production have resulted in developing many uses [Edward A.Abdun-nur, 1961] . Among the best-known uses are :

- Filler in rubber.
- Filler for paint and putty.
- Repairing top rot in power poles.
- As insulation.
- Raw material for glass.
- Raw material for bricks.
- Miscellaneous types of building blocks.
- Rostone block.
- Cementing material for miscellaneous aggregates.
- Filter layer under pavements.
- Soil stabilization.
- Filer for bituminous concrete and products.
- Lighweigh aggregate.
- Cement manufacture.
- Concrete pavements and pipes, etc.

The earliest work on record conducted to find uses for fly ash was carried out by the Cleveland Electric Illuminating Company and the Destroit Edison Company, and was reported in 1932.

In Vietnam, this waste product - Coal ash - was estimated about over12,000,000 tons and the annual discharged now from thermo-electric plants about 800,000 to 1,000,000 tons. Therefore, the study on utilization of coal ash in road construction in Vietnam is one of the important studies, which is not only solving the construction material for Civil Engineering, but also contributing to reduce the harmful impact of coal ash to environment.

2. PROPERTIES OF COAL ASH IN VIETNAM

2.1 Terms Relating to Coal Ash

- Pulverized fuel ash (PFA) may be described as the solid fine material carried out in the flue gases of power- station boilers that are fired with pulverized coal. The ash itself is a fine powder, which is why, in the technical literature, it is also referred to as ***fly ash*** [CAO'Flaherty, 1986]. Fly ash is a waste product which accounts for more than three-quaters of the residue obtained from burning pulverized coal in generation of electricity. The finer component of the ash, which is a light brown to dark grey colour, depending upon the mount of unburnt coal present, is removed from the flue gases with the aid of mechanical and electrical precipitators, and initially collected in hoppers

- The courser component of the residual ash is not carried over with the flue gases in the course of the burning process, but instead falls to the bottom of the furnace; this material is called *furnace-bottom ash* or ***bottom ash***.
- If hopper ash is deliberately passed through a mixer-conveyor plant so that a measured amount of water can be added to it prior to stockpiling, it is described as conditioned-PFA. At some power stations the PFA is mixed to a slurry and

transported hydraulically to storage ponds or lagoons; this material is known as ***Lagoon coal ash***.

2.2 Physic-mechanical properties of coal ash in Vietnam

According to ASTM, depending on the type of coal, fly ash are classified into two classes. They are the following low calcium ashes and high calcium ashes:

- Low calcium ashes are derived from bituminous and antracite coal and are referred to as class F fly ash.
- High calcium areas are derived from lignitic and sub-bituminous coals and are referred to as class C fly ash.

The fineness, chemical composition, and physical properties of fly ash vary depending on the source of coal, method of burning, combustion equipment, variation in load on the boilers, and methods of collection. Fig. 1 shows the particle-size compositions of various fly ashes and lagoon coal ashes from some of the major power stations in Vietnam. Particle size is important from two aspects. Firstly, from a stabilization viewpoint, fly ash is very vulnerable material. Secondly, analysis of the different size-fractions indicates that the chemically-reactive, non-combustible materials, i.e. silica, alumina, tend to be concentrated in the finer fraction of the fly ash.

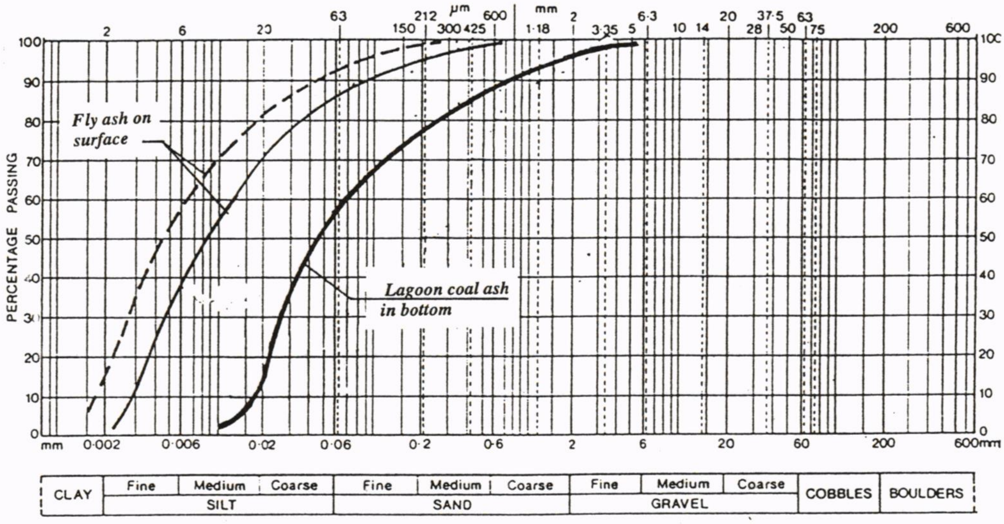

Figure 1 . The particle size analysis of coal ash in Vietnam

The investigation results in the Highway Laboratory of the RITST on the physic-mechanical properties of coal ash discharged from the Phalai power plant are given in Tab.1.

Table 1. The physic-mechanical properties of coal ash of the Phalai power plant

State of sample	*Max. Dried Density (g/cm^3)*	Optimal Water Content (%)	Compre. Strength (MPa)	CBR (%)	Wet Density (g/cm^3)	Water Cont. (%)	Angle of Shearing (φ^0)	Cohesion (KN/cm^2)
Dried	1.18 1.25*	28.00 23.80*	0.12	29.4	1.16	26.10	$18^0 30$	0.012
Saturated	-	-	-	1	1.19	30.20	$13^0 15$	0.005

(*) test proceeded in the modified mould.

2.3 Chemical Composition Analysis of Coal Ash

Many chemical composition analysis of fly ashes in Vietnam are found in the literature [SGI,IBST, 1996] most of which fall within the following ranges in Tab. 2.

Table 2. Chemical composition analysis of fly ashes

Samples of Coal ash	Content (%)						
	SiO_2	*Al_2O_3*	*Fe_2O_3*	*CaO*	*MgO*	*SO_3*	LOI
No. 1	44.47	15.57	9.60	1.96	0.50	3.50	24.38
No. 2	54.16	25.10	8.00	1.54	0.80	7.00	9.79

The Fe_2O_3, Al_2O_3 and SiO_2 tend to concentrate in the finer particles, while the Carbon predominate in the coarser grain size. The colour varies from light to dark grey, and in some cases is brownish. Generally, the darker the colour, the higher the Carbon content. Fly ash, as collected, is usually basis in reaction. The coarser particles give an acid reaction, while the material passing the No.400 sieve has a high pH.

Long ago, it was observed that some siliceous materials when mixed with lime produced cementing compounds possessed hydraulic properties. Such a material was a consolidated volcanic ash found near Pozzuli (Italy). As a result, the term Pozzolana has evolved the modern term " Pozzolan ". A variety of tests have been proposed for determining the pozzolanic activity of a material. Pozzolans are classified as natural pozzolans and artificial pozzolans. Natural pozzolans are materials that are found in nature which possess pozzolanic properties, or which can be converted easily into pozzolans by processing. Artificial pozzolans are those derived from industrial waste products. The most important artificial pozzolan is fly ash. In many ways, it is produced under conditions simulating very closely the natural conditions under which the volcanic ashes of Pozzuli were produced. Pozzolans combined or interground with Portland cement have definite advantages in concrete, among which are :

- Reduced water demand, in case of fly ash.
- Improved workability.
- Reduced segregation.

- Reduced bleeding.
- Lower heat of hydration and resulting decreased volume change.
- Reduced drying skringkage.
- Increased extensibility and plastic flow at early ages.
- Improved formed surface finishes.
- Increased ultimate compressive strength.
- Increased ultimate tensile strength.
- Reduced permeability and leaching.
- Improved sulphate resistance.
- Reduced cost, etc.

Fly ashes are pozzolans, i.e. in the presence of lime and water a reaction takes place which results in the formation of hydrous calcium aluminates and silicates, which are similar to the reaction products of hydrated cement. Thus fly ashes which contain significant quantities of water-soluble lime (CaO and MgO) and calcium sulphate can become involved in pozzolanic reactions, and thus are said to have self-hardening capability.

The quantity of unburnt carbon present in a fly ash, that is determined as loss on ignition (LOI), depends upon the efficiency with which the fly ash is burned in the furnace. This carbon exists in the fly ash as irregular, porous, coke-like particles. A high carbon content increases the moisture content requirement of any mixture in which the fly ash is used. It also results in lower dry densities, reduces the proportion of reactive surface area available to enter into pozzolanic reactions, and physically limits the contacts of cementitious materials. Hence it is generally accepted that the fly ashes with high carbon contents tend to be poorer-quality construction materials.

3. STUDY RESULTS ON UTILIZATION POSSIBILITIES OF COAL ASH AS A ROAD - MAKING MATERIAL IN ROAD CONSTRUCTION

Road-making materials can be classified either by the type of material, e.g. cement, bitumen, aggregate, etc. or by the pavement layer in which they are to be used, e.g. pavement, base, sub-base and subgrade. In the second example, which is more appropriate to alternative materials, it is necessary, before discussing the demand for, and specification of, road-making materials, to consider the methods currently in use for the vast majority of road construction project [PT,Sherwood, 1985]. A road structure is made up a number of layer (pavement layer) which are shown in Fig. 2. Two main types of construction are used

- flexible, in which the top layer are bituminous-bound (Fig. 2a),
- rigid, where the top layer is high-quality concrete (Fig. 2b)

In a layer road pavement structure of the type considered here, the quality, in terms of durability and bearing capacity, of each of the pavement layers increases from bottom upwards, i.e. the specification requirements for any given layer are always higher than those of the layer immediately beneath it. This means that the same material could be used for the construction of a particular layer and all the underlying layers; in principle, the whole road structure could be constructed from the materials used the top layer. Full-depth asphalt construction goes some ways to achieving this aim. However, building in layers generally means that costs are reduced and a very wide range of construction materials can be used. These materials range from material that occurs free on site for the construction of the bottom layer, to high-cost materials of high strength and skid resistance for the construction of the surface layer. This means that the scope for finding alternative materials as replacements for naturally-occurring materials decreases as the specification requirements for respective layer increases. Bulk fill is therefore the biggest possibility outlet for wastes, while very few such materials can be used in the surface layers.

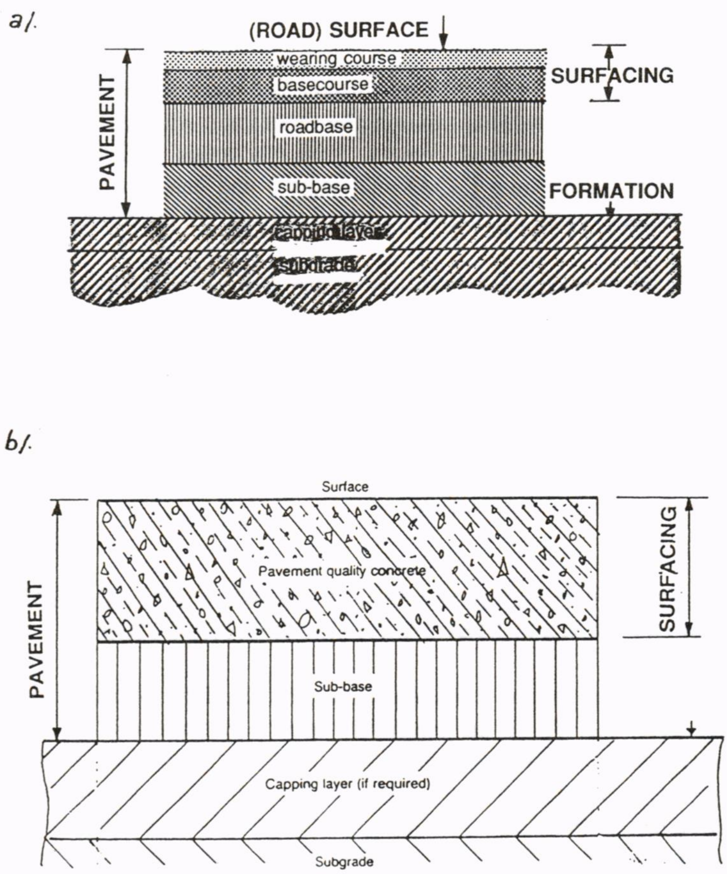

Figure 2.Typical flexible and rigid pavement construction layers

Three main aspects of utilization possibility of coal ash in road construction in Vietnam have been studied as follows :

- Utilization of Lagoon Coal Ash as a filling material, especially for subgrade on soft soil areas.
- Utilization of fly ash as an additive in stabilized mixtures by lime/cement for base and sub-base.
- Utilization of fly ash as an additive in concrete pavement.

3.1 Utilization Possibility of Coal Ash as a Filling Material

From an environmental viewpoint, it is perhaps fortunate that most Lagoon coal ash waste accumulations are located in relatively rural parts of Vietnam. From a road-making viewpoint, however, it has meant that little research has been carried out to determine its possibility as an engineering material, since its usage would be relatively low anyway, due to the high cost of transport to points of highway construction.

Experience to date would suggest that Lagoon coal ash waste is best used as a bulk fill material. The investigation result for Lagoon coal ash, which is shown in Tab.1, shows that it will be utilised well as a bulk-fill material for subgrade in dry condition only and is low bearing capacity in saturated condition. Therefore, Lagoon coal ash will be able to use as a good road-filling material if it was applied by appreciate technical solutions and treated by lime or cement.

The most important property of the subgrade is relation to road pavement design is whether or not it will provide uniform support for the pavement. The quality of subgrade is now usually presented by some parameters such as California Bearing Ratio Value (CBR), Unconfined Compressive Strength, Shear Strength and disintegration under saturated condition ,etc. Therefore, to be becoming as a filling material for subgrade, Lagoon coal ash has to meet all requirements of subgrade.

Laboratory Testing Program for the Lagoon coal ashes stabilised lime and cement, which is carried out by the RITST, was proceeded with 3 and 5 % of lime and cement in the mixtures.

The moisture-density relation test was carried out by compacting a prepared air-dried lagoon coal ash samples mixed with 3 and 5 % of lime according to the AASHTO T 180-90 and its result is shown in Tab.3

Table3. The compaction testing results of Lagoon coal ash stabilised lime

Lagoon coal ash stabilized with	Max. Dry Density (g/cm^3)	Optimal Water Content (%)
3 % of lime	1.26	26.60
5 % of lime	1.29	24.30

The unconfined compressive strength of the stabilized lagoon coal ash vary over a wide range. Results obtained are considerably influenced by such factors as the amount, type and quality of the stabilising additive, the method and length of curing of the test specimens, and state of the specimens before testing. The Laboratory Testing Results on the unconfined compressive strength of the stabilized lagoon coal ash are shown in chart in Fig. 3

The subgrade plays an important role in the design of the road structure as its bearing capacity decided the thickness of the road structure above it. The bearing capacity of the subgrade is most frequently measured in terms of the California Bearing Ratio (CBR). In this test, Laboratory compacted specimens are evaluated to give a numerical value related to the support the subgrade will give for pavement, i.e. in pavement design. Specimens were kept in dried state and immersed in water for four days before testing. The testing results, which were carried out by the RITST, are expressed by chart in Fig. 4.

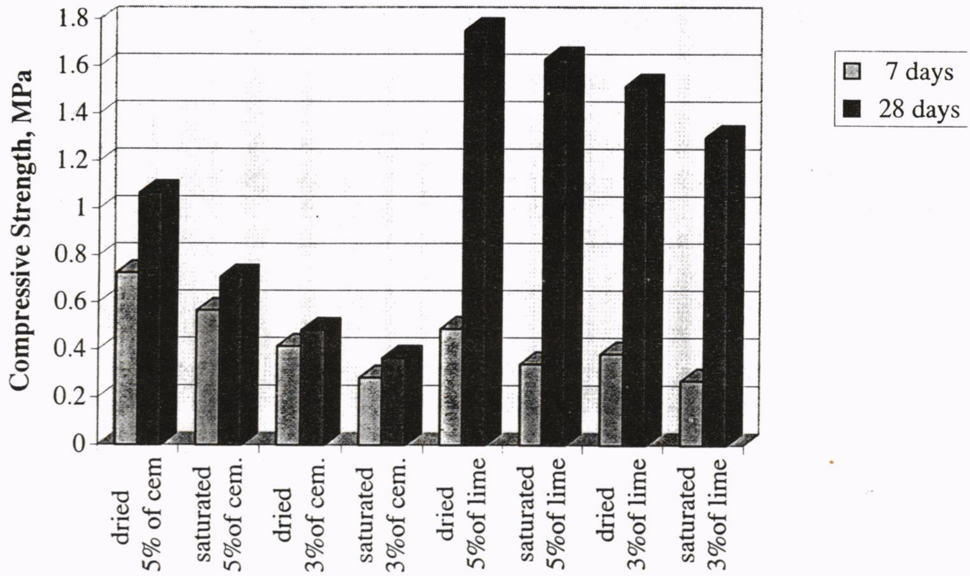

Figure 3.Chart expressed unconfined compressive strength of stabilized lagoon coal ash

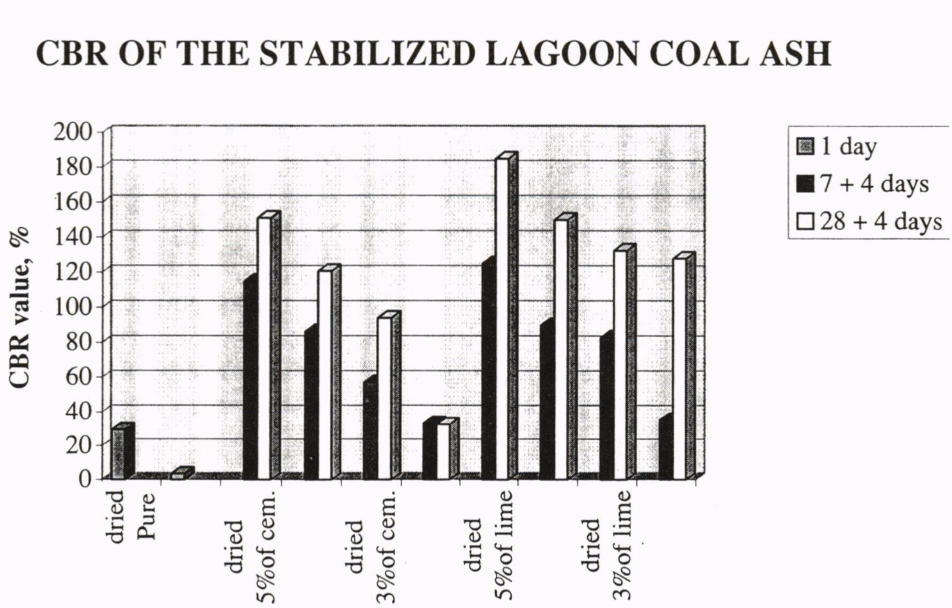

Figure 4 . Chart expressed CBR Value of the stabilized lagoon coal ash

The direct shear tests carried out by the RITST according to the Vietnamese Testing Standard 353/ QDKT 4 and their results obtained from Laboratory are shown in Tab. 4

Table 4. The shear resistance values of the stabilized lagoon coal ash

Lagoon coal ash stabilized with	Curing Time (days)	State of specimens	Angle φ	Cohesion c (KN / m^2)
3 % of lime	7	dried	24°59	35.0
	7	saturated	26°23	20.0
	14	dried	25°46	34.0
	14	saturated	27°01	23.0
	28	dried	26°44	69.0
	28	saturated	25°33	59.0
	60	dried	23°56	73.0
	60	saturated	24°42	62.0
5 % of lime	7	dried	26°19	35.0
	7	saturated	26°51	22.0
	14	dried	28°21	43.0
	14	saturated	27°35	29.0
	28	dried	21°56	104.0
	28	saturated	22°03	60.0
	60	dried	32°00	134.0
	60	saturated	22°03	87.0

Disintegrate Test is used to evaluate the stabilization of the studied lagoon coal ash specimens in water. Cylindrical specimens 50 mm diameter and 50 mm high were used in testing. They were immersed in water and observed in curing-days. Result of the observation of the specimen stability is shown in Tab. 5.

Table 5. Result of the disintegrate test

Lagoon coal ash stabilized with	Stability of the specimens in water			
	after 1 day	after 3 days	after 7 days	after 90 days
pure	*disintegrated*	*disintegrated*	*disintegrated*	*disintegrated*
3 % of lime	*disintegrated*	*disintegrated*	*stable*	*stable*
5 % of lime	*disintegrated*	*stable*	*stable*	*stable*
3 % of cement	*disintegrated*	*stable*	*stable*	*stable*
5 % of cement	*stable*	*stable*	*stable*	*stable*

Due to the existed properties of the pure lagoon coal ash and good ones of the stabilized lagoon coal ash, considerable research has been carried out by the RITST in an effort to find utilization potential of them in road construction. Fig. 5 shows two main possibilities to use them as the subgrade-filling materials in road construction in Vietnam.

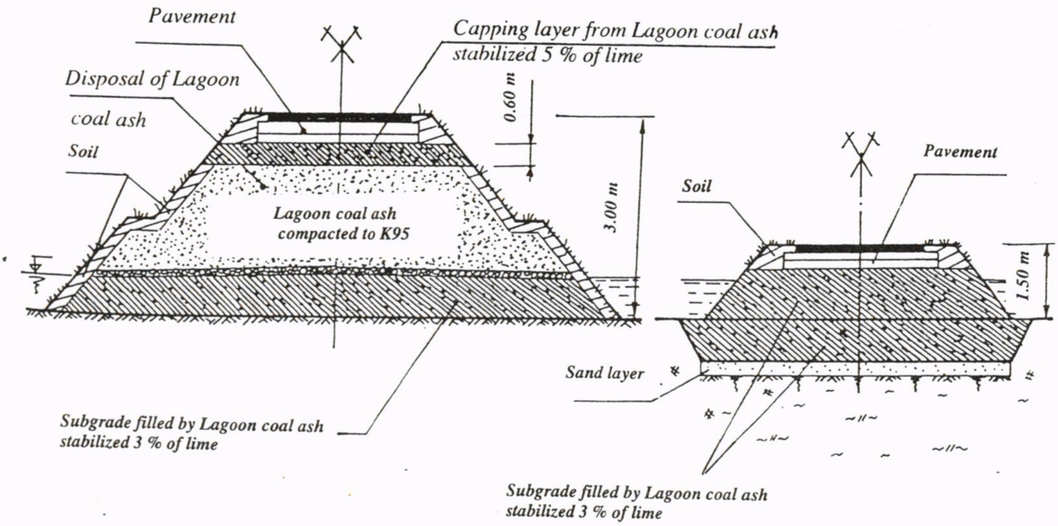

Figure 5 . Two main possibilities of utilization of lagoon coal ash in road construction

3.2 Utilization possibility of fly ash in roadbase

The road base is the main structural layer which provides the major part of the strength and load distributing properties of the pavement. It must resist permanent deformation and fatigue cracking from repeated loading.

Laboratory Testing Program for the mixtures of roadbase, which are applied for the (fine sand + fly ash) stabilized cement and the crushed stone stabilized (cement + fly ash) .

The usual test, which determine the percentages of individual particle sizes present in fine and crushed stone, is the standard method of test by wet sieving used for coarse material.

A great amount of different samples of the (sand + fly ash) stabilized cement and crushed stone stabilized (cement + fly ash) were tested to find out the most optimal gradation. The local materials were used during the investigation such as cement of Hoang Thach PC-30, fine black sand of Red river, crushed lime stone of Phuly Rc≥ 80 MPa, with dry fly ash from the Phalai power plant.

For testing of unconfined compressive strength, according to the Vietnamese Testing Standard 353/QDKT 4, the cylindrical specimens of the mixture (sand + fly ash) stabilized cement which are 50 mm diameter and 50 mm high, and the cylindrical specimens of the crushed stone stabilized (cement + fly ash) which are 100 mm diameter and 100 mm high, were used to test in Laboratory of the RITST. All the stabilized specimens compacted to 95 % of the max. dry density, and prepared by static compaction method. After that, they were in the dry and saturated state of age 7,14 and 28 days. In the course of the compaction test, the load is applied at a predetermined, uniform rate of increase of deformation in the cylindrical tested specimen of 3 mm per minute. The test results of unconfined compressive strength of these mixtures used fly ash are shown in Fig. 6 and Fig. 7.

The Laboratory Testing Results showed that the mixture of sand with a high additive of fly ash stabilized cement has many advantages over alternative materials for use in roadbase. In view of this, the properties of this mixture (sand + fly ash) stabilized cement are evaluated very well and showed that the pozzolanic property of fly ash will allow some of cement may be replaced by fly ash to reduce cement content in it, and in the long-term strength is increased strongly.

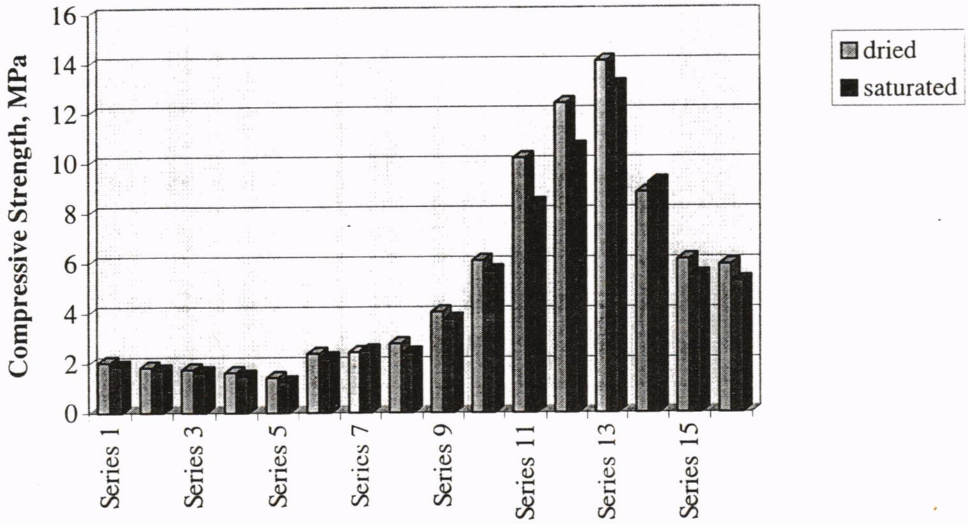

Figure 6 . Compressive strength of the mixture (sand + fly ash) stabilized cement

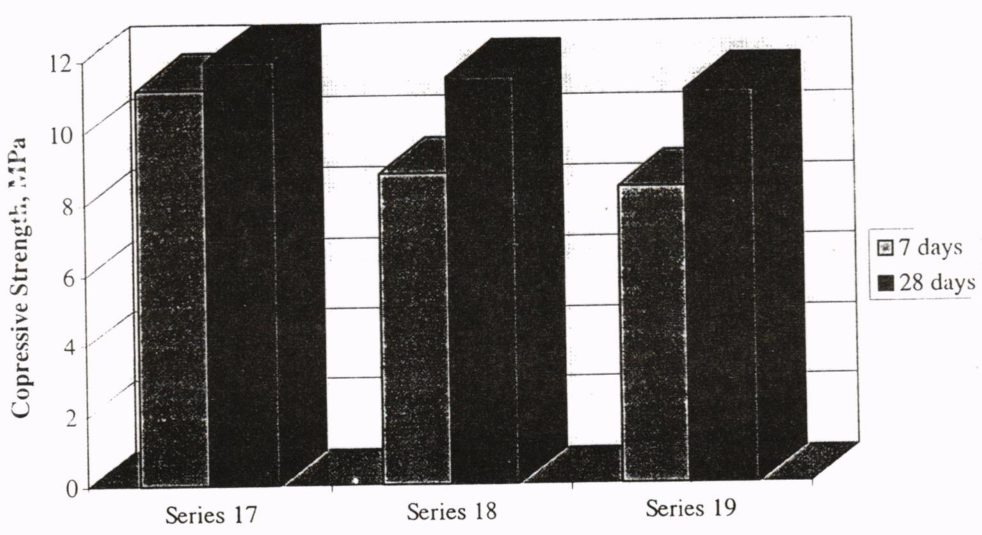

Figure 7 . Compressive strength of the crushed stone stabilized (cement + fly ash)

3.3 Utilization Possibility of fly ash in the concrete pavements

Fly ash has been used successfully in the concrete industry of the world for many years now. The technical aspects regarding the application rate, setting time, strength development, durability, and method of test have been well established. Although, the research on fly ash from the power plants in Vietnam has been studied in first time by Prof. Nguyen Xuan Man (RITST) since 1978, then Dr. Vu Luu (RITST) since 1991. However, utilization of fly ash in concrete pavements in Vietnam is one of the new matters still nowadays.

Many research works showed that the optimum amount of fly ash to use, in mixes adjusted to obtain cement reduction, depends on so many factors that for large projects it is best to determine the proportions by actual tests using the proposed cement and aggregate. Fly ash in this manner in the past have been from about 20 % by weight or absolute volume of the original cement in the mix, to as much as 50 %. In Laboratory Testing Program on utilization of fly ash in concrete pavements at the RITST, type F fly ash was used and cement of Hoang Thach PC-30 was replaced 30 % by fly ash of the Phalai power plant.

The laboratory testing results on compressive strength and tensile strength of the studied concrete (cement + fly ash) specimens, which were carried by the RITST, are expressed by chart in Fig. 8 and Fig.9.

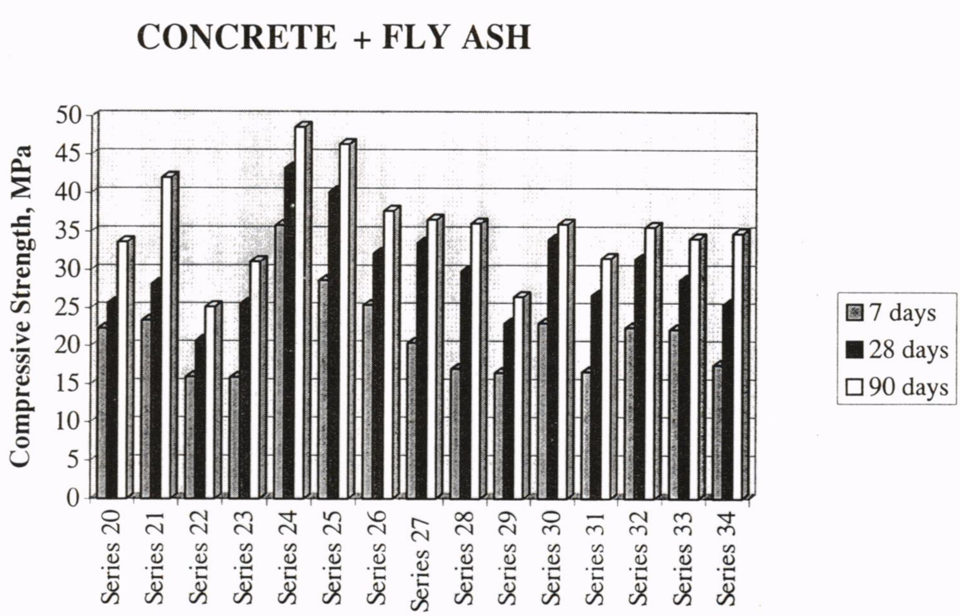

Figure 8 . Chart expressed the compressive strength of the fly ash-concrete

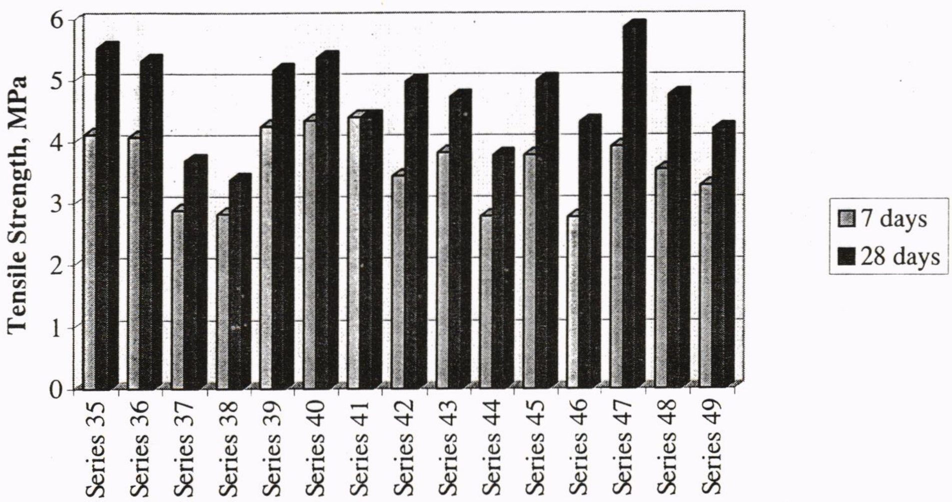

Figure 9 . Chart expressed the tensile strength of the fly ash-concrete

4. CONCLUSIONS AND DISCUSSIONS

4.1 Conclusions on Utilization Possibilities of Coal ash from Study Result

On the basis of the study results obtained mainly from Laboratory, the Authors of this study found in general as follows:

- Lagoon coal ash is a valuable bulk fill material and if this waste stabilized 3 to 5 % of lime / or cement will be suitable as a capping or sub-base layer material.
- Although it may have self-hardening properties, fly ash used alone is not suitable as a sub-base or roadbase-making material. Mixing sand with up to 40 % of fly ash, then stabilized cement is a high quality material for roadbase.
- In concrete mixes with the optimum amount of fly ash to use adjusted to obtain cement reduction. This cement reduction is considered about 20 to 30 %.

Tab. 6 summarises the conclusions that can draw with regard to the materials considered

Table 6. Summary of utilization possibility of coal ash in road construction

Waste products from the power plants	*Subgrade*	*Capping layer and sub-base*	*Roadbase*	*Concrete pavements*
Lagoon coal ash pure	Good /Low*	None	None	None
Lagoon coal ash stabilized 3 to 5 % of lime / or cement	High	High	None	None
Mixing sand with fly ash	High	Low	None	None
Mixing sand with fly ash stabilized cement	High	High	High	None
Fly ash as an additive	High	High	High	High

(*) in saturated state

4.2 Proposals on Utilization of Coal Ash in Road Construction in Vietnam

The Vietnam road network, which is an important part of the Vietnam infrastructure, is still nowadays very poor and backward. The total length of Vietnamese highway network is 106,048 Km with the following kind of road :

- National road ....11,353 Km
- Provincial road..14,499 Km
- Distric road..24,629 Km
- Village road..46,910 Km
- Urban road..3,211 Km
- Special road...5,451 Km

On this highway network, the RITST would propose to apply in future some typical types of pavement used partly coal ash in their structure, which are shown in Fig. 10

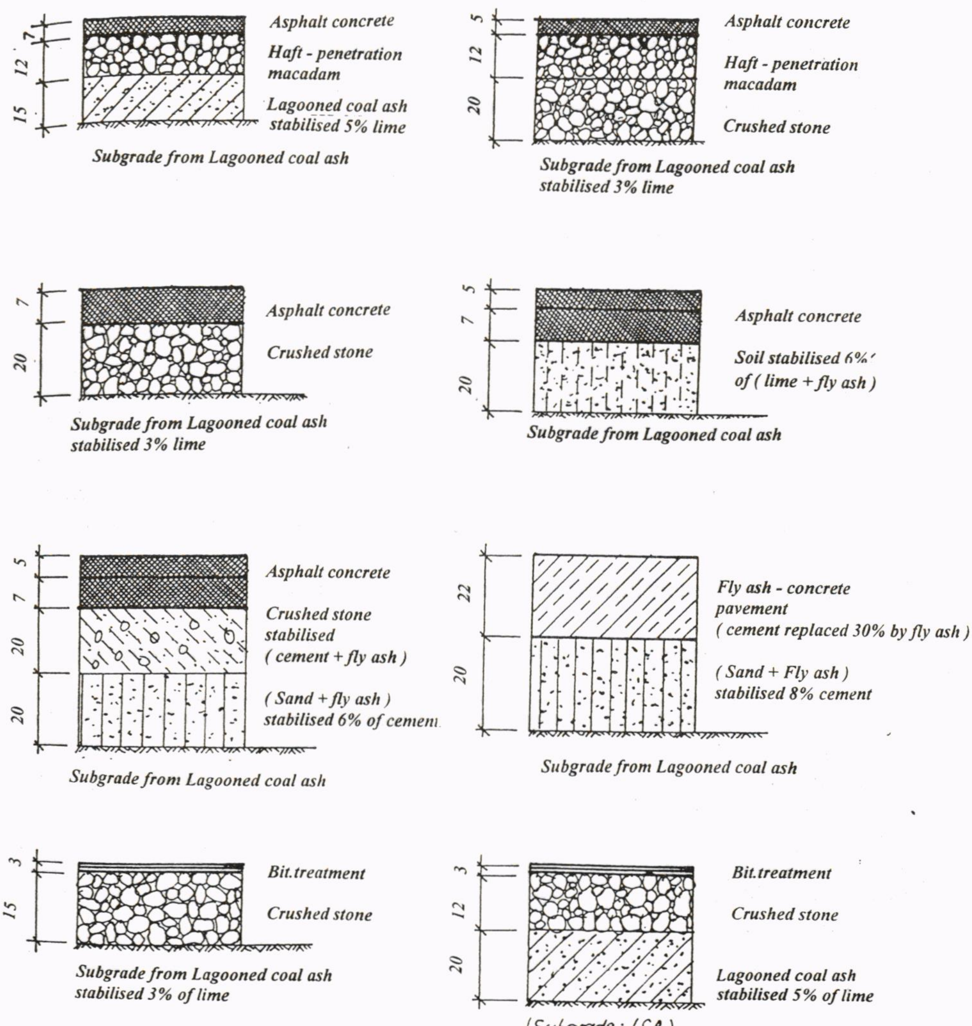

Figure 10 . Typical pavement structures using coal ash proposed in Vietnam

4.3 Discussions

The study results have shown that there are many environmental benefits to be gained by using coal ash in road construction. However, if coal ash to be so much as considered a potential substitutes, positive steps need to be taken to encourage their use. Possible methods by which this can be done are considered as follows:

- Guidance on the use of coal ash.
- Changing attitudes to the use of coal ash
- Administrative measures to increase the use of coal ash.
- Nomination of the use of coal ash in road construction and civil engineering by the policies and controls on supply and its use.
- Imposition of a Tax on the use of naturally-occurring materials
- Imposition of a Tax on the disposal of coal ash to landfill and dumping
- Imposition of requirement that all projects on road construction or rehabilitation in the areas of some provinces, which are built near the power plants, should incorporate a proportion of coal ash.

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