IMPROVEMENT OF SOFT SOIL BY USING FLY ASH AND BOTTOM ASH

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ABSTRACT

The studies conducted is focused on stabilization of soil situated in Pekan area which are chosen to be the investigation areas. The uses of fly ash and bottom ash in soil stabilization are intended to improve the physical properties of soil structural engineering. The amount of fly ash and bottom ash tried were 5%, 10%, 15%, 20%, and 25% by weight. Each testing was conducted five times to get the average value. The specimens were determined by using the laboratory testing such as particle size analysis, atterberg limits, standard proctor test, falling head permeability test, and unconfined compression test. According to AASHTO, the soil is classified by referred to the passing sieve No. 10, No. 40, and No. 200 which are 75.54%, 66.43% and 55.76% respectively. The average moisture content of plastic limit for the control soil is 36.71%. When cone penetration is 20mm, the moisture content of the soil is 38.5% for liquid limit. From this data, the plasticity index of the soil is 1.79%. From the graph compaction curve of control soil, it shows that the maximum dry density is 17.22 kN/m^3 and the optimum moisture content is 13.0%. The control soil has the lowest averages of the permeability coefficient which is 2.12 x 10^{-4} cm/s. The value of unconfined compressive strength, q_u is 1.132 x 10^{-10} kN/m^2. From Mohr's circle, the cohesion value that obtained is 0.566 x 10^{-10} kN/m^2. The consistency of control soil can categorize as very soft clay where the q_u value are in range 0 kN/m^2 to 24 kN/m^2. By comparing the liquid limit, plastic index and optimum water content for both fly ash and bottom ash, the additional of 25% bottom ash gave the lowest values than others percentages which mean that the soil were have the highest of maximum dry density. By comparing the values of unconfined compressive strength for both fly ash and bottom ash, the additional of 25% bottom ash give the highest value of compressive strength which is 1.465 x 10^{-10} kN/m2 and 0.732 x 10^{-10} kN/m2 for the cohesion value than others percentages.

ABSTRAK

Kajian yang dijalankan tertumpu kepada penstabilan tanah yang terletak di kawasan Pekan yang dipilih untuk menjadi kawasan siasatan. Penggunaan abu terbang dan abu dasar dalam penstabilan tanah adalah bertujuan untuk meningkatkan sifat-sifat struktur fizikal kejuruteraan tanah. Jumlah abu terbang dan abu dasar yang digunakan adalah 5%, 10%, 15%, 20%, dan 25% mengikut berat. Ujian dilakukan sebanyak lima kali untuk mendapatkan nilai purata. Spesimen yang telah ditentukan akan menjalani ujian makmal seperti analisis saiz zarah, had Atterberg, pemadatan Proctor Piawai, ujian kebolehtelapan, dan ujian mampatan tidak terkurung. Menurut AASHTO, tanah dikelaskan dengan merujuk kepada ayak No. 10, No 40, dan No. 200 yang masing-masing bernilai 75.54%, 66.43% dan 55.76%. Purata kandungan lembapan had plastik bagi tanah kawalan adalah 36,71%. Apabila kon penembusan adalah 20mm, kandungan lembapan tanah adalah 38.5% bagi had cecair. Daripada data ini, indeks keplastikan tanah adalah 1.79%. Daripada graf lengkung pemadatan tanah kawalan, ia menunjukkan bahawa ketumpatan kering maksimum adalah 17.22 kN/m^3 dan kandungan lembapan optimum ialah 13.0%. Tanah kawalan mempunyai purata pekali kebolehtelapan terendah iaitu 2.12×10^{-4} cm/s. Nilai kekuatan mampatan tak terkurung, qu adalah 1.132×10^{-10} kN/m^2. Daripada bulatan Mohr, nilai ricih yang diperolehi adalah 0.566×10^{-10} kN/m^2. Tanah kawalan boleh dikategorikan sebagai tanah liat yang sangat lembut di mana nilai qu berada dalam 0 kN/m^2 hingga 24 kN/m^2. Dengan membandingkan had cecair, indeks plastik dan kandungan lembapan optimum untuk kedua-dua abu terbang dan abu dasar, tambahan 25% abu dasar masing-masing memberikan nilai terendah berbanding peratusan yang lain. Ini bermakna tanah tersebut mempunyai ketumpatan kering paling maksimum. Dengan membandingkan nilai kekuatan mampatan tak terkurung untuk kedua-dua abu terbang dan abu dasar, tambahan 25% abu dasar memberi nilai kekuatan mampatan tertinggi iaitu 1.465×10^{-10} kN/m^2 dan 0.732×10^{-10} kN/m^2 untuk nilai ricihan berbanding peratusan yang lain.

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LIST OF ABBREVIATIONS

AASHTO	=	American Association of State Highway and Transportation Officials
kPa	=	Kilopascal
SiO_2	=	Silica dioxide
CaO	=	Calcium Oxide
ASTM	=	American Society for Testing and Materials
Si	=	Silicon
Al	=	Aluminum
Fe	=	Iron
Ca	=	Calcium
Na	=	Natrium
Mg	=	Magnesium
USCS	=	Unified Soil Classification System
LL	=	Liquid limit
PL	=	Plastic limit
PI	=	Plastic index
BS	=	British standard
g	=	Gram
mm	=	Millimeter
in	=	Inch
kg	=	Kilogram
cm	=	Centimeter
m/s	=	Meter per second
µm	=	Micrometer
kN/m^3	=	Kilo Newton per meter cube
cm^2	=	Centimeter square
cm/s	=	Centimeter per second
s	=	Second

mm^2	=	Millimeter square
kN	=	Kilo Newton
kN/mm^2	=	Kilo Newton per millimeter square
kN/m^2	=	Kilo Newton per meter square
c	=	Cohesion
q_u	=	Compressive strength

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CHAPTER 1

INTRODUCTION

1.1 Research background

Soil is the base of any structures as building will stand firm on it. Normally, a base must be strong, can resist failure and able to support huge load of a structure. This is why, before any constructions work can be done, analysis and study must be applied to the soil in order to know the status of the soil. The soil will give problems and difficulties to engineers as soil can present in many types, properties and strength. The variety of the soil is the factors that cause some soil to undergo excessive settlement, collapse, and have distinct lack of strength. Different types of soil could produce different soil characteristics as it is due to their nature of their pore fluids and their mineralogy of their fabric.

Soil stabilization has become one of the useful solutions to treat the soil in such areas to achieve the required engineering properties and specification. Soil stabilization can be defined as the modification of the characteristics of soil in order to enhance the engineering performance of the soil, for example improve the density of soil, mixing the soil with additives to change the chemical and physical properties such as stiffness, compressibility, permeability, and workability.

This study presents the determination of basic properties and effectiveness of soft soil in Pekan, Pahang. The research were conducted several of contents of fly ash and bottom ash mixed with soft soil as a samples. The samples set up by mixing soil samples with several of fly ash and bottom ash at optimum water content. The amount of fly ash and bottom ash tried were 5%, 10%, 15%, 20%, and 25% by weight.

1.2 Problem statement

Structures are meant to stand firm for many years to come and more importantly, could provide great strength to support loads within the structure. The unstable properties of soft soil are believed to be the major circumstances for any structure to be built on it. The major challenge of problems with soft soil are the stability of the soil and settlement.

Foundation settlements are the most emergence problems happened in building constructions. Many commercial and residential buildings have become distressed due to settlement. This problem is often caused by weak or improperly compacted soils. All buildings which are built on soft soil are compatible to be constructed with weak foundation and having a high risk for structure failure.

The high compressibility properties of soft soil are one of the major factor that could lead to high settlement. This is happened from the fact that soft soil are finer in particles and being too cohesive with the presence of water. High settlement are so dangerous as it could affects the movement of whole structure and would ended up with structure failures and cracks.

Soft soil have the lower value of permeability where water are hard to get through it particles and this is the reason why soft soil have a high moisture content. The presence of water could have made the soil become more unstable. Water could be the main agent that make the soil become unstable especially with the high ability of the soft soil to trap huge amount water within its particles. The soil particles have high tendency to bond closely with one another that make soft soil become easily compressed when undergoing compaction activity. By the weak conditions of the soil, the stiffness of the soil could easily be affected and this have made the soil become weak in strength. Strength of soil are the most vital part of any soil properties. Soil with weak strength could not sustain massive and high load on it. It becomes more dangerous when structures are built on the soft soil without having proper design and analysis to the soil. The structures are more subjected to fail rather than safe to be used. The development of any construction works in this type of soil perhaps the most challenging of all.

1.3 Objectives of study

The main objectives of this study are :

1. To investigate the engineering properties of Pekan soil.
2. To determine the effectiveness of soil stabilized by using fly ash and bottom ash.
3. To determine the optimum content of stabilizer those give the maximum strength.

1.4 Scope of study

The scopes of this research were focused on stabilization of soft soil situated in Pekan area. The soil samples were collected from Jalan Kuantan, Pekan while fly ash and bottom ash were obtained from Pahang Malaysian Rock Products. Sdn Bhd., Panching. The site investigation and analysis data were done to get engineering properties and strength for original soft soil as well as soil that added with fly ash and bottom ash.

The study focused on the fly ash and bottom ash to be used in soil stabilization of soft soil. There are three types of specimens were prepared which is soil as control specimen, soil added with fly ash and soil added with bottom ash. This specimens were added with different propotion of fly ash and bottom ash which is 5%, 10%, 15%, 20%, and 25%. Each testing were conducted five times to get the average value. The specimens were determined by using the laboratory testing such as particle size analysis, atterberg limits, standard proctor test and falling head permeability test, and unconfined compression test. The test result and analyzing were followed the AASHTO or Malaysian specification and supported by computer.

1.5 Significant of study

Soft soil can be categorized as problematic soil. The low strength and high compressibility characteristics the soil had, are the major reasons why a careful design analysis could be taken for any structure built on it. Due to these problems, soil investigation on the basic properties and shear strength of the soil must be carried out.

This study presents the determination of basic properties and shear strength of soft soil in Pekan, Pahang. Any construction works which have been constructed in soft soil area are believed to face more problems compared to other types of soils. Soft soil is believed to experience more failure through its characteristics due to weak compressibility and problematic. Some of the significant problems happened to soft soil are its failure to supports huge loads as a foundation and its nature of high settlement.

Consequently, soil improvement is a very important study in geotechnical engineering. Without this step, failures will occur which will cause losses of life, money and effort. Hence, before any construction, site investigations should be carried out to evaluate the kind of soil improvement in the site. Soil improvement can be done either by soil stabilization or soil consolidation. The results data of the basic soil properties and shear strength could also allow a quick and economic alternative in order to design for construction on soft soil.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Most area in Malaysia have soft clay soil as the major soil distribution percentage. This is happened from the fact that Malaysia has many parts of coastal areas and also rivers that located in many state in Peninsular Malaysia. The construction of building, roads, bridge and harbors on soft clays are facing the higher risk for settlement and stability problem. This has become main geotechnical problem in soft clay engineering (Brand & Brenner, 1981) stated that soft is defined as clay that has the shear strength less than 25kPa. Soft clay cause many problem to geotechnical engineers since it is highly compressible, high liquid limit and high plasticity.

2.2 Definition

2.2.1 Soil Stabilization

Stabilization is the process of blending and mixing materials with a soil to improve certain properties of the soil. The process may include the blending of soils to achieve a desired gradation or the mixing of commercially available additives that may alter the gradation, texture or plasticity, or act as a binder for cementation of the soil (Erdem O.T et al., 2011). According to Armstrong (1961), soil stabilization has been introduced during World War II to strengthen the weak soil so that it could bear with heavy military five machines.

2.2.2 Additive Stabilization

Additive is manufactured commercial products when added to the soil in the proper quantities which can improve some engineering characteristics of the soil such as strength, texture, workability, and plasticity. Additive stabilization is achieved by the addition of proper percentages such as cement, lime, fly ash and bottom ash, bitumen, or combinations of these materials to the soil. The selection of type and determination of the percentage of additive to be used is dependent upon the soil classification and the degree of improvement in soil quality desired. Smaller amounts of additives are required when it is simply to modify soil properties such as gradation, workability, and plasticity. Larger quantities of additive are used when it is to improve the strength and durability significantly. After the additive has been mixed with the soil, spreading and compaction are achieved by conventional means (McCarthy, 2005).

2.2.3 Fly Ash

Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants. This material is solidified while suspended in the exhaust gases and is collected from the exhaust two gases by electrostatic precipitators. Since the particles solidify while suspended in the exhaust gases, fly ash particles are generally spherical in shape (Ferguson, 1993). Depending upon the source and makeup of the coal being burned, the component of fly ash vary considerable, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal bearing rock strata. Fly ash produced from coal power stations is usually disposed of in landfills. But, nowdays fly ash can be reused in construction sector. The reuse of fly ash as an engineering material primarily stems from its pozzolanic nature, spherical shape, and relative uniformity. Fly ash recycling, in descending frequency, includes usage in Portland cement and grout, embankments and structural fills and road subbase.

2.2.3.1 Physical Characteristics

The physical, geotechnical and chemical parameters to characterize fly ash are the same as those for natural soils, e.g., specific gravity, grain size, atterberg limits, compaction characteristics, permeability coefficient, shear strength parameters and consolidation parameters. The properties of ash are a function of several variables such as coal source, degree of pulverization, design of boiler unit, loading and firingconditions, handling and storage methods. A change in any of the above factors can result in detectable changes in the properties of the ash produced (Parisaramahiti, 2007). The procedures for determination of these parameters are also similar to those for soils.

Specific gravity	1.90-2.55
Plasticity	Non Plastic
Proctor compaction - Maximum dry density (gm/cc)	0.90-1.60
Optimum moisture content (%)	38.0-18.0
Angle of internal friction (O)	30^0-40^0
Cohesion (kg/cm ^{2})	Negligible
Compression index	0.05-0.4
Permeability (CM/SEC)	10^5-10^3
Particle size distribution	
Clay size fraction (%)	1-10
Silt size fraction (%)	8-85
Sand size fraction (%)	7-90
Gravel size fraction (%)	0-10
Coefficient of uniformity	3.1-10.7

Figure 2.1 : Engineering properties of fly ash (Parisaramahiti, 2007)

2.2.3.2 Fly Ash Classification

This classification reflects the broad subdivision of US coals in bituminous and higher rank coal of the eastern states and the lower rank western coals with associated high calcium contents. Although widely used (Sloss et al., 1996, Smith, 2005), the ASTM classification may not be directly applicable to or adequately reflect the variability found in Australian fly ashes both with respect to chemistry and mineralogy. In Australia, three grades of fly ash are recognised (SAA, 1998) as shown in Table 2.1.

Table 2.1 : Classification of fly ash according to Austalian standard (SAA, 1998)

Grade	Fineness (% minimum mass passing a 45um sieve)	Loss on ignition (%maximum)	Moisture content (%maximum)	SO3 content (% maximum)
Fine	75	4.0	1.0	3.0
Medium	65	5.0	1.0	3.0
Coarse	55	6.0	1.0	3.0

Due to the variability of fly ash, doubts have been raised as to the suitability of the current classification schemes which may be overly simplistic and fail to take into account other important characteristics such as mineralogy (vide discussion in Sloss et al., 1996). Also, many of the current classifications have been developed for the use of fly ash in concrete and cement and thus may not be applicable for other end uses. A need has been identified for an overall rating system which would be useful for all potential end-users of fly ash (Sloss et al., 1996).

2.2.4 Bottom Ash

Bottom ash refers to the coal ash byproduct, formed in pulverized coal furnaces, which are too large to be carried in the flue gases and therefore fall to the bottom of the furnace into a dry bottom ash hopper. Bottom ash is produced in power generation as a by-product from the burning of coal. It is usually treated as a waste product which, in many instances, is required to be disposed of in the same manner as municipal wastes (Kayabali and Bulus, 1999). As the bottom ash is removed from the hopper, it is then passed through a grinder for size reduction, and resembles coarse sand in size and shape. The major components of the bottom ash material are silicon (Si), aluminum (Al), iron (Fe) and calcium (Ca). Bottom ash is well-graded granular and highly compactable materials. The physical, chemical and engineering properties, in particular, are important parameters affecting the behavior of bottom ash in various engineering applications.

2.2.4.1 Physical Characteristics

Bottom ashes colour was dark black similar to coal. They have angular particles with a very porous surface texture. Bottom ash particles range in size from a fine gravel to a fine sand with very low percentages of silt-clay sized particles. The ash is usually a well-graded material, although variations in particle size distribution may be encountered in ash samples taken from the same power plant at different times. Dry bottom ash is gray to black in colour, angular, irregular shape and has a porous structure and rough surface texture while wet bottom ash is composed of hard and angular to sub-angular particles with a shiny black colour and a smooth surface texture much like crushed glass. According to Huang (1990), majority portion of bottom ash formed in a dry condition and gray in colour with an irregular shape.

2.2.5 Clay

According to Whitlow (2001) clay is define as soils particles having sizes below 2μm which can be determine at site by its feel that is slightly abrasive but not gritty and clay also feel greasy. Clays are flake shape microscopic particles of mica clay minerals and other minerals (Helwany, 2007). Clay is a common type of cohesive soil (Liu & Evett, 2005) which has small particle that cannot be separated by sieve analysis into size categorizes because there no practical sieve can be made with the so small opening. Clay is said as a submicroscopic mineral particle size of soil which has the fine texture when clay present in dominant proportions compare with silt and sand the soil is described as having a fine or heavy texture. Fine textured soils are plastic and sticky when wet but hard and massive when dry. According to Tan et al., (2005) the heavy texture used because they are very heavy and difficult to flow.

According to Singer & Munns (2006), clay is said to be surface active which means that much happen on their surface. Clay minerals cohere to each other and adhere to longer mineral particles. Their surface absorbs and holds water, organic compounds, plant nutrients ion and toxic ions.

2.3 Clay Formation

Clay formation and translocation are processes that differentiate soils from rocks. (Singer & Munns, 2006), started that feldspar, mica, amphibole and pyroxene minerals are transformed into clays through process of hydrolysis, hydration and oxidation. As an example, in bitite mica, FE_{2+} can oxidize, K_{+} leaves the structure to maintain electrical neutrality and the structure is weakened. Next, soluble Ca_{2+}, Mg_{2+}, and Na_{+} in the soil solution replace the remaining biotite K_{+} to form vermiculite or montrimorillonite. All this may take place without any movement of mineral. Mica and other aluminosilicates can slowly dissolve into individual silica molecules and Al, Mg, K and Fe ions can recombine to form clay in the same location, where they recombine to form clay.

According to Brand & Brenner (1981) usually clay minerals are the product of rock weathering. The type and the amounts of clay minerals formed are affecting by climate, parent material, drainage pattern (topography) and vegetation. The most important affect is by the climate.

Young sediments such as soft clay must undergone little diagenese when it became to isostatic uplift or marine regression, whereas the sediments which are covered by big overburden, consolidate and dehydrate and make the particles become cemented. Further increase in temperature and pressure would lead to metamorphism, a process where the clay minerals are destroyed and new minerals such as mica and feldspar are formed. Tectonic pressure or volcanic activity can bring the metamorphism material back to the surface where the first diagenese occur and by the weathering of the exposed rock, the formation of clay minerals start a new (Brand & Brenner, 1981).

2.4 Mineral of Clay Fraction

Singer & Munns (2006) stated that clay minerals in Table 2.2 have some common properties and important difference that are:

a. Clay minerals tend to form microscopic to submicroscopic crystal with large surface area. They are colloidal particle which are in range of 1ηm to 1μm in diameter.

b. Clays are platy or flaky microcrystal, reflecting their layered crystal structure. The shape and size explain clays slipperiness and plasticity when wet and tendency of clay particles to stack and stick together to coat larger particles and to line pores. Plasticity describes the ability of clay to be molded into forms that remain their shape.

c. All clays absorb or lose water on their surface when the water content changes. Some clay allows water into interlayer of their molecule structure. When water is absorbed, clays expand as the water leaves the space.

Table 2.2: Typical Range of Index Properties of some Common Clay Minerals (Shroff & Shah, 2003)

Clay Mineral	**Liquid Limit Range**	**PI range**
Kaolinite	40 – 60	10 – 25
Illite	80 – 120	50 – 70
Sodium Montrimollite	700	650
Other montrimollite	300 – 650	200 – 250
Granular soils	20 or less	0

2.5 Sampling

Sampling can refer to the taking of soil or rock from bored holes (Liu & Evett, 2005). Besides that, Brand & Brenner (1981) state that samplings are the samples are used for soils identification and determination of soil properties and it is required for almost every investigation. Depending of type of soils, the choice of the sampler type and sampling techniques can be obtained and it necessary for obtaining undisturbed samples.