An overview of traditional and non traditional stabilizer for soft soil

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Abstract. Soft soil always deal with high compressibility, high water content, low shear strength and low permeability. All these challenges lead to soil failure such as excessive settlement, failure of sub structure which is lead to superstructure damage and many others failure. Hence, soil stabilization is one of the option in ground improvement technique by adding other stabilization agent either natural basis or chemical basis. This paper critically reviewed about advantages and disadvantages of chemical stabilizer namely traditional and non traditional. Also closely reviewed on polymer and lignosulfonate as soil stabilization agent in various type of soil. Reviewed and analysing of some references revealed that using non traditional stabilizer have more advantages than traditional stabilizer in term of engineering properties as well as chemical composition. Polymer and lignosulfonate also have their on specialties in order to corporate with various type of soil.

1. Introduction
Geotechnical engineer having a great challenge to construct on the soft ground area (Mohamad et al 2016). Many engineers tried to avoid soft ground as their construction site. But unfortunately in the rapid world development, utilization of the soft ground can not being avoid anymore. In 2010, Department of Quaternary Geological Map of Malaysia reported that soft ground in Malaysia usually located in the large area of coastal plain of west coast and east coast of Peninsular Malaysia and East Malaysia. Malaysia experience a quaternary sediment of soft soil which is consider as organic or peat soil and alluvial deposits (Kaniraj and Joseph, 2006).

Soft soil is existing all over the world, refer as any soil which is susceptible to failure or cause excessive settlement when superstructure is built over it (Mathew and Sasikumar, 2017). Also recognize with its high water content, high compressibility, low shear strength (Ayaldeen and Kitazume 2017; Said and Talib 2009; Vishwanath, Pramond and Ramesh 2014) and low permeability (Huat et al 1995; Huat et al 2005). These behaviour always lead to the major failure such as failure of foundation and differential settlement. Due to the listed behaviour it is obviously shows that soft soil always need an essential improvement before construction.

Today, improvement of the ground comes in various method. There are an excavations or replacement method, densification & compaction (mechanical modification), hydraulic modification, admixture stabilization (soil stabilization by adding other material), reinforcement method, electrical modification method, thermal modification method and etc (Raju 2009; Leung and Raju 2015; Mathew and Sasikumar 2017). But, the research and development on improving the soft ground still continues and growth. It drives experts in geotechnical field to work hard in order to find the most suitable method
to improve the soft ground. In this paper, author will discuss on admixture stabilization or soil stabilization method and focus on chemical stabilization which is using traditional and non traditional stabilizer for soft soil.

This paper is to compare the advantages and disadvantages between traditional and non traditional soil stabilization agent for soft soil and critically review on the polymer and lignosulfonates of non traditional soil stabilization stabilizer.

2. Review on Soft Soil Stabilization

Soil stabilization means alteration of the soil properties to improve the engineering performance (Fajobi, Ige and Adeleye 2012; Lim et al 2014). Thus, it can achieve predetermined performance especially in construction aspects (Latifi et al 2016a; Norazam et al 2017). Alteration of the soil properties means even a single part of soil particles had been altered its also called alteration. Ta’negonbadi and Noorazad 2017, said that the economical and lasting method to achieve the desire geotechnical properties is soil stabilization. In result, soil stabilization is the most choose method to stabilized the soft soil.

Latifi et al 2016a reported that in order to improve the physical and engineering properties of soil many researchers used various underlaying mechanism of soil stabilization such as mechanical, chemical, biology and electrical. This method is used in order to improve the engineering properties of a soil (Latifi et al 2016b). In this study, chemical stabilization will be investigate. To improve the physical and mechanical properties for a soil, chemical stabilization is widely used, low-cost and effectively technique (Saadeldin and Siddiqua, 2013). Chemical stabilization using chemical based stabilizer can be divided into two categories which is traditional and non traditional stabilizer.

2.1 Traditional Stabilizer

Traditional stabilizer is widely used as additive for strengthen the week soil. Cement was a greatest invention for construction materials. Since that, building a house, skyscrapers and other civil engineering project comes easily and faster. In the beginning of soil stabilization history, cement was first used as stabilization agent in 20th century (Azzam 2014). Yet, lime is the oldest stabilizing agent used in the world (Qingquan, Qing and Zhijing, 2004). Other binder also used as stabilization agent such as fly ash, gypsum, slag, alum, bituminous materials, kiln dust and stone dust (Naeni and Ghorbanalizadeh 2010; Marto, Latifi and Eisazadeh 2014; Mirzababaei, Arulnajah and Ouston 2017; Borthakur and Singh 2014 ). Amongst the traditional stabilization agent, lime, fly ash and cement is the most popular and widely used (Al-Jabban et al 2016; Yong and Ouhadi 2007; Talib and Noriyuki 2017).

Traditional stabilizer can gives much advantages for soft soil stabilization. Tingle and Santoni 2003 said that cement and lime gives effective result in stabilizing the low plasticity clay under wet condition test. Other then that, traditional stabilizer can neutralized the acidity and improve the strength for the various types of soil especially soft soil (Huat et al 2005). Cement stabilized soils were found to be a reliable engineering alternative to satisfy the entire requirements of sustainable infrastructure (Saeddelin and Siddiqua 2013). However, traditional stabilizer not only stabilized several types of soil, almost each of problematic soil can be stabilized like marine clay and peat soil (Al-Bared and Marto 2017; Rahman et al 2016; Bothakur and Singh 2014; Viswanath et al 2014; Yong and Ouhadi 2007). In fact, Kazemian et al 2015 said, the void ratio and secondary compression of treated fibrous peat was decrease. All these advantages shows that traditional stabilizer can altered the soil properties and strengthen the weak soil. Besides, traditional stabilizer is commonly available at market (Rahman et al 2016).

Unfortunately, the negative impact to the environment or issue on occupational health safety are reported (Indraratna, Athukorala and Vinod, 2013). Environment negative impact related to CO2 emission. According to Alyeldeen and Kitazumi 2017 one tone of CO2 is release with every production of cement. Cement industry could contribute as much as 8% of total emissions (Andrew, 2017). Dealing with traditional stabilizer usually needed relatively lengthy curing time and in a large amount (Yang and Yang 2009; Naeni and Ghorbanalizadeh, 2010). Lengthy curing time was due to the slow pozzolanic reaction which is normally complete in 28 days (Teja, Suresh and Uday, 2015). These two factor (time
and quantity of materials) will directly effect to the cost of the construction. Traditional stabilizer also could cause a very brittle behaviour in the soil and will be effect by seismic activities (Chen and Tan, 2012). This will lead to unstable foundation and structure failure. Other issue is the traditional stabilizer could increase pH value and effect to ground water and decrease soil fertility (Vinod, Indraratna and Mahamud 2010; Biggs and Mahony 2004; Indraratna et al 2013; Nalbantoglu and Tuncer 2001; Hamer 2012). If these two effect continuously happen, later we will lack of ground water source as well as food source (due to the decreasing of soil fertility). Decrease of soil fertility was related to reduction of ability of soil to retain water and nutrients.

2.2 Non traditional Stabilizer
Recently non traditional stabilizer become more preferable by geotechnic expert and researcher. Some of them are used as structure maintenance or structure treatment (Buzzi, Fityus and Sloan 2010; Issa and Debs, 2007). Non traditional stabilizer is one of the chemical formulated stabilizer which is slightly different from traditional stabilizer. These stabilizer is widely used in many field especially in construction. Modification of the traditional stabilizer also called as non traditional stabilizer (Qingquan et al 2004). It can be simpliﬁed that non traditional stabilizer as the chemical formulated based or modiﬁcation of traditional stabilizer. These stabilizer can classiﬁed by its dominant chemical basic (Qingquan et al 2004). In spite of, some researcher had their own understanding about non traditional types or classiﬁcation. Non traditional additives consist of various combination such as enzymes, liquid polymer, resin, acids, silicate, ions and lignin derivatives (Kassim, Hamir and Kok 2005; Hafez, Sidek and Noor 2008; Eisazadeh 2010; Horpibulsuk et al 2010; Eisazadeh et al 2011). Marto et al 2014, also agreed with these categories. Tingle and Santoni (2003), summarized that non traditional can be classiﬁed as salt, acids, enzymes, lignosulfonates, petroleum emulsion, polymer and tree resin. But, in the beginning of the non traditional history, Scholen (1992) categories of classiﬁed the non traditional stabilizer into 5 which is; electrolytes, enzyme, mineral pitches, clay ﬁller and acrylic polymer.

Even though non traditional stabilizer having disadvantages, but the advantages is more dominant and it makes research and study on these types of stabilizer growth and expand. Tingle and Santoni 2003 said that non traditional stabilizer sometimes is no longer commercially available or have altered their formulas or changed trade names. He also reported that lack of information for some stabilizer which is it becomes secretive of the company who invent it. Non traditional stabilizing compound usually having a proprietary chemical composition which means it is difﬁcult to predict the performance of the chemical in practice (Latifi et al 2016b).

Non traditional stabilizer comes with advantages that overcome traditional stabilizer disadvantages. They gives strong reason on choosing non traditional stabilizer as agent for soil stabilization. It can shorten in time for curing process (Mirzababei et al 2017; Tingle et al 2003) which is related to the cost. Besides, it become more ductile than brittle character (Ayeldeen and Kitazume 2017; Hamidi et al 2017; Ta’negonbadi et al 2017). When the treated soil become more ductile it lead to higher strength for the weak soil (Tingle et al 2003; Ayeldeen et al 2017; Fajobi et al 2012; Latifi et al 2016; Norazam et al 2016; Ta’negonbadi and Noorzad 2017; Azzam 2014; Qingquan et al 2004, Naini and Ghorbanalizadeh 2010; Marto et al 2014; Mirzababei et al 2010; Indraratna et al 2013; Eisazadeh 2010; Buzzi ans Sloan 2010 and Issa and Debs 2007). According to Indraratna et al 2013 and Tingle and Santoni 2007, they summarized that non traditional stabilizer less harm to the natural eco-system. Minimizing soil and water erosion also one of non traditional stabilize advantages (Genis, Vulfson and Ben-Asher 2013). So that it can increase the soil fertility.

2.3 Polymer
Polymer is one of types of non traditional stabilizer. Polymer means by its large or long hydrocarbon chain of molecule which is composed of repeated subunit. Combining monomers into a covalently bonded chain or network is called polymerization process. In soil stabilization polymerization means combining the polymer stabilizer with soil particle through its reaction. This process will altered the soil particle properties hence makes the soil having more strength and better result for engineering
properties. Studied and research about polymer as soil stabilization had been done since a century before. Application of these polymer in civil engineering not only as soil stabilizer, but mostly the purposed is to enhance and strengthen the particle or as maintenance.

Soil stabilization using polymer had been studied by many expert and geotechnical researcher such as Ayeldeen and Kitazume 2017; Ajayi-Mayebi et al 2010; Naeini and Ghorbanalizadeh 2010; Norazam et al 2016; Latifi et al 2016a; Liu et al 2011; Mirzababei et al 2017; Marto et al 2014 and others. In various types of polymer such as epoxy, polyvinyl alcohol, STW, envirotac, xanthan gum and many more. Polymer used as soil stabiliser usually in powder or liquid form. These form of material also gives different result to soil stabilization.

Stabilization of clay (either high plasticity or low plasticity) using polymer have been studied from the beginning of the polymer as soil stabilization. Hence there plenty of data and reliable result on this type of soil. However the study for this type of soil still going on and growth. But there is lack of study of polymer as soil stabilizer in peat soil. For an example, combination epoxy resin as soil stabilizer with soil like clay (either CH or CL) and sand are recently studied by Ajayi-Mayebi et al 2010; Anagnostopoulos 2015; Naeini and Ghorbanalizadeh 2010 and Hamidi and Marandi 2017. But, there is lack of data for epoxy as soil stabilizer in peat soil. However studied about other polymer incorporate with peat soil such as envirotac, xanthan gum, calcium based (SH-85) and silicate had been carried out by Norazam et al 2016; Latifi et al 2016a; Hassan 2015; Hamer et al 2009 and Hamer 2012.

The main point is polymer can give almost same result like stabilization using traditional stabilizer such as cement as shown in Table 1 (Verma 2013) but the amount of usage is totally different. 40% of cement content gave the same strength for 4% of polymer content, which is 10.4 MPa. Same as cement content of 20% and 30% compared to polymer content of 2% and 3% which gave strength in range 8.2 to 8.6 MPa. Hence, the usage of polymer content can reduce the cement usage. In Table 2 comparison between cement content and polymer and cement content obviously show the increasing of the UCS strength between 50% to 90%.

### Table 1: Comparison between cement and polymer strength (Verma 2013)

| Variation in cement content | Variation in polymer content |
|-----------------------------|------------------------------|
| Unconfined Compression Strength (MPa) | 20% | 30% | 40% | 2% | 3% | 4% |
| 5.1 | 8.2 | 9.7 | 4.9 | 7.8 | 9.56 |
| 8.5 | 8.8 | 10.4 | 8.2 | 8.6 | 10.35 |

### Table 2: Comparison between cement and combination polymer and cement (Hamidi and Marandi 2017)

| Variation in cement content | Variation in polymer and cement content |
|-----------------------------|----------------------------------------|
| Unconfined Compression Strength (MPa) | 5% | 10% | 20% | ER+5% | ER+10% | ER+20% |
| 0.2 | 0.5 | 1.3 | 2.2 | 2.9 | 2.6 |
2.4 Lignosulfonates
Lignosulfonates also on of the non traditional stabilizer for soil stabilization. Produce from wood pulping production. It is widely used in many field especially cement production. Studied using lignosulfonates as soil stabilizer had been carried out by researcher like Xu et al 2018; Ta’negonbadi and Noorzad 2017; Alazigha et al 2018; Vinod et al 2012 and Tingle and Santoni 2003. These researcher studied the effective of lignosulfonate to high and low plasticity clay. Tingle and Santoni 2003, reported that lignosulfonate 5% gives highest UCS result for CL. Lingnosulfonate also gives a good resistance to wet and dry more than untreated and increase the stiffness and without leading to brittle behaviour (Ta’negonbadi and Noorzad 2017). Microstructure analysis studied by Alazigha et al 2018 proof that lignosulfonate chemically and physically can bind the soil particle to get stronger soil as shown in Figure 1. SEM micrographs for untreated soil shows that there numerous small pores. Expansive soil that treated with 2% of Lignosulfonates shows that the numerous pores can be reduced to small number of pores. It proven that the LS can reduce the numbers of small pores in expensive soil although the LS content only 2%.

Figure 1. SEM micrographs of (a) untreated (LS = 0%); and (b) treated (LS = 2%) expansive soil (Alazigha et al 2018).

3. Conclusion Summary
It can be conclude that both method had their own advantages and disadvantages. But non traditional method seems to have more advantages rather than traditional stabilizer in term of environmental issue till the engineering properties of the soil. Non traditional stabilizer can be either modification of traditional stabilizer or chemical formulated stabilizer that comes from various source. Non traditional itself can classified into several type of stabilizer. Every researcher have their own ideas and opinion on how to classified the non traditional stabilizer. However, the basic things that they agreed is, classification of these non traditional stabilizer is based on their dominant chemical basic. Table 3 listed the advantages of non traditional and traditional stabilizer.

Polymer is the most highlighted stabilizer in non traditional stabilization. Some of them have been commercialize and successful in treating the weak or soft soil. It is proof that polymer can gives the best result either the polymer alone or combining with other stabilizer such as cement and lime. The dosage of polymer seems in a small amount rather than traditional stabilizer. Lignosulfonate also gives significant result on treated soil but not much as polymer. Ability of treated soil with lignosulfonate to work in wet condition makes this stabilizer seems to be having potential to work on the soil with high moisture content. However further study and research must be carry out in order to ensure the ability of these non traditional stabilizer as alternative or primary soil stabilization agent. Also can gives reliable data to other researcher.
Table 3: Advantages of non traditional and traditional stabilizer.

| Non Traditional                                                                 | Traditional                                                                 |
|--------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Chemical formulated or modification of traditional stabilizer                   | Cement and lime gives effective result in stabilizing the low plasticity clay under wet condition test |
| Shorten in time for curing process                                             | Neutralized the acidity                                                    |
| More ductile than brittle character                                            | The void ratio and secondary compression of treated fibrous peat was decrease |
| Less harm to the natural eco-system                                            | Commonly available at market                                                |
| Minimizing soil and water erosion                                              | Almost each of problematic soil can be stabilized like marine clay and peat soil |
| Higher strength for the weak soil                                              |                                                                            |

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