Recent Study on the Behaviour of CFG Pile, DM (Deep Mixing) Column and Stone Columns Ground Improvement Technology

[1]Prof N. B. Umravia [2] Manthan Parmar [3]Shreyas V. Patil [4]Pathan Yasirarfatkhan V [5]Modhiya Aman
[1]Professor [2,3,4,5]UG Student
[1]Department of Applied Mechanics
[1,2,3,4,5]Government Engineering College, Dahod, Gujarat, India

Abstract

In recent years, in ground improvement technique, such as deep mixing (DM) column, Stone Colum (SC), vibro-concrete columns, geosynthetic-reinforced embedded stone columns and CFG Pile, have been more and more used to support superstructures and embankments when they are constructed on expansive soil. Now a day's new improved technology has emerged, along with different concrete columns, Pile, and composite foundations. New technologies have been combined with other ordinary technologies. It is give a better result, work effective and economical solutions. Thought, the composite columns / CFG pile with the composite technologies can be presented difficulty geotechnical problems in design and construction. This paper summary different types of ground improvement technologies and their application, installation and function addresses design issues, and reviews recent research and development related to the CFG piles to improve soft foundations, including failure modes, load transfer mechanisms, bearing capacity, settlement, consolidation, and stability. Several theoretical solutions have been proposed for the rate of consolidation of column-reinforced soft foundations. Different failure modes should be evaluated for the stability of column-supported embankments. Limit equilibrium methods based on shear failure overestimate the factors of safety of embankments on rigid or semi-rigid columns in soft soil. CFG pile, DM, and Stone Column are with the proposed on the principle of optimal design under a flexible load.
Keyword- Soft Soils, CFG (Cement Fly Ash Gravel) Pile, DMC Deep Mixing Column, Stress Distribution

I. INTRODUCTION

In geotechnical engineering, the recent methods of ground improvement techniques are used for stabilization of soil like as vibro -Compaction, vacuum consolidation, preloading of soil, Soil stabilization by heating, Ground freezing, vibro-replacement stone columns, mechanically stabilized earth structures, Soil nailing. Nowadays industries adopted few new technologies like CFG pile, Encased stone column with geosynthetics, DM (deep mixing) piles have been used for deep soft soil to improvement, increasing surrounding soil bearing capacity, reduction total and differential settlement, densify loose deposits such as loose and problematical expansive soil, minimize liquefaction and collapse potential. These technics are various but principal of load transfer is a vertical sub-structural element, installed in situ by ground improvement techniques (replacement, displacement, or mixture with chemical agents), that transmits the load from a super structure or earth structure to underlying or surrounding geo-media through compression, shear, bending or rotation. These technics are mostly used to improve soft soils. This paper will discuss only these three technologies used to improve soft foundations, which include soft clay, silt, clayey or silty soil and peat. Different types of technique have been used, which have different construction techniques, materials and rigidity. Composite approaches have been developed to utilize the advantages of individual components of the columns technique. In case of CFG pile and Stone Column Technique have also been combined with other technologies, such as geosynthetic reinforcement, pre-fabricated vertical drains, and so on, to improve their performance. And stability. .

In china and India, ordinary Stone Column, Encased stone column, Cement–fly ash–gravel (CFG), Energy CFG pile, sand compaction piles (column), Deep Mixed (DM) columns, grouted column and vibro-concrete columns (VCCs) have been commonly used in practice. In the UAS rammed aggregate piers are commonly used for column Technology. In additional new types of technology have been introduced an internationally. Recent years Researchers have worked on the Geosynthetics- Encased columns or CFG pile with Composite foundation and controlled modulus.

II. SOIL CONDITION

The Soft soil ground is extensively distributed in India especially along the coastal area, where most of industrial revolution areas are located on soft marine clayey deposit. In inner India, poor soil can be expansive soil, fluvial soil, marsh soil, lacustrine deposits, and collapsible soils. Besides, there are large areas of reclaimed land and still there will be more than 1000 km2 land to be reclaimed in the near future. As shown in fig. 1. In general, Soft soils undergo sudden changes in volume and collapse when their moisture contents increase with or without loading; this occurs as soon as their saturation degree reaches above 50% and full saturation may not be required for them to collapse (Abbeche et al., 2010). Almost all naturally occurring collapsible soil deposits are either debris flow deposits or wind deposits (loess). Cementation consists of dried clay and other chemical precipitates that may have been added after deposition. Wetting under load weakens the cementation, reduces the soil suction and causes desiccation or collapse (Houston et al., 2001). The amount of collapse or settlement is usually a function of different parameters, including soil particles, permeability, and degree of saturation, initial void ratio, over consolidation ratio (OCR) and thickness of the collapsible layer. Collapsing soils of the loessial type are reported to exist in several parts of the world, such as the USA, Central and South America, China, Africa, Russia, India and the Middle East (Murthy, 2010). In practice, when working with collapsible soils geotechnical engineers are faced with several considerable challenges.

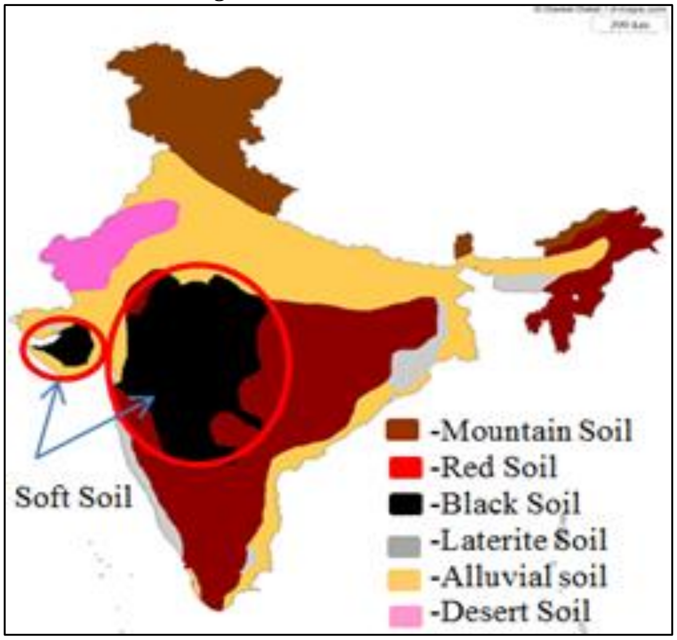

Fig. 1: Indian Map Soil Condition

A. *Types of Columns Technology*

Instead of India, China has constructed many highways and high-speed railways in the past ten years. In china new high speed railway line and highways have to be constructed on problematic soils and the treatment of such soils is expected to cost a considerable amount of money over the total budget. Zheng et al (2009). Ground treatment methods for buildings mainly include over excavation and replacement, dynamic compaction, vibro-compaction, vibro-replacement, preloading, vacuum preloading, sand or gravel columns, cement-flyash-gravel (CFG) columns, rammed-cemented-soil columns, rammed-soil columns, lime columns, lime-soil compaction columns, grouting, solution injection, deep mixing, jet grouting, and lime-soil columns. Among these methods, ten or more ground treatment methods have been adopted in the construction of highways and regular/high speed railways in China. In India these all are technology used for embankment construction, coastal area for industrial extension on soft/ Problematic soil. Normally these all techniques are similarly conventional column- type reinforcement element; they can be classified in to three categories based on the installation method, types of material used, mode of failure (rigidity behaviours). Table -1 shows column technology classified as per installation, material, and mode of failure. In this paper, the classification of the columns based on the material or rigidity will be adopted and major discussion on CFG pile, SC, and DM as following.

Method	*Types*	*Technology Examples*
Installation	*Replacement,*	*Sand Column (SC)*
	displacement,	*Sand compaction pile (SCP), Stone Column*
	Mixture,	*DMC, Ground Column, CFG*
	Combination	*Rammed Aggregate Pier*
Material	*Granular*	*SC, SCP, rammed Aggregate piers*
	Chemical Stabilization	*DM columns, grouted columns*
	Concrete	*Concrete columns, cement–fly ash–gravel (CFG) columns*
	Composite	*Geosynthetic-encased soil columns, stiffened DM columns, composite spun piles*
Rigidity (Mode of Failure)	*Flexible*	*Sand compaction piles, stone columns, rammed aggregate piers*
	Semi- Rigid	*DM columns, grouted columns, composite columns*
	Rigid	*Concrete columns*

Table 1: Classification of Column Technology

III. INSTALLATION, APPLICATION AND PERFORMANCE

A. Installation Methods

The Various approaches have been used to install column technology as mention in table no 1. They are classified in four categories: (a) replacement, (b) displacement (c) Mixture and (d) Combination

1) Replacement

The Replacement category includes sand columns and stone columns (SC), which comprise granular materials. These reinforcement elements can provide vertical drainage thus accelerating the consolidation of soft soil. However, they typically have relatively low bearing capacity, shear strength, and no bonding and tensile strength. Replacement is to remove the in situ soil and backfill the hole with better material. The removal of the in situ soil can be accomplished by water jetting or drilling. The replacement method has little to no effect on the surrounding soil. As a result, these reinforcement elements usually have bulging failure due to relatively low lateral support in the upper part of columns. For short floating columns, they may be punched into the underlying soft soil. Embankments over soft soil treated with sand columns or stone columns often experience large settlement. This type of reinforcement elements is typically less expensive.

2) Displacement

The displacement category includes lime columns, jet grouted columns and deep mixed (DM) columns, and, which are formed through chemical reactions between reagent and soil. In situ Technology subdivided in two methods: Deep Mixing Method (DMM) and Dry Jet Mixing Method. This technology are installed by soil mixing have high bonding strength, compressive resistance capacity and relative high shear strength of soil Replacement is to remove the in situ soil and backfill the hole with better material. The removal of the in situ soil can be accomplished by water jetting or drilling. The replacement method has little to no effect on the surrounding soil. This type of reinforcement elements is more expensive than that in the replacement category.

3) Mixture

The Mixture includes plain concrete piles, CFG Pile, concrete pipe piles, steel pipe piles, and so on. They have much higher shear strength, compressive strength, and bond strength. For reinforced concrete and steel piles, they can also have high bending and tensile capacity to resist lateral and uplift forces. However, they are often the most expensive.

4) Combination

A combined method, such as partial replacement and displacement, involves the process of removing the in situ soil partially and then displacing the surrounding soil during the installation of the column. Instead of replacement and/or displacement, columns can also be formed by mixing a chemical agent with the in situ soil using mechanical (deep mixing) or hydraulic (grouting) means. Granular and concrete columns are mostly installed by a replacement and/or displacement method, whereas chemically stabilized soil columns are mostly installed by mixing.

Various installation methods have various effects on the surrounding soil. These effect are also depend on the types of soil, length of pile optimize, groundwater table. In case of the displacement and replacement and mixing have limited effect to zero effect on surrounding soil.

B. Application

These all techniques have been used for improve the soft soil behaviors such as application; these techniques are provide (a) To provide support of super structures including loading wall, Embankment, (b) Lateral Support (c) Stability of slopes (d) To protection against Containment of water and pollution. In soft soil require to increase load carrying capacity, minimize settlement of soil enhance contain water, pollutant movement.

The CFG pile technology is widely applicable for treatment of foundation of High-rise building, high speed railway embankment, high volume payment design, such as piles with cement, fly ash, sand, gravel and required amount of water preliminary constructed by long spring pile drilling machine.

The deep mixing DM column technique has been dividing in two methods dry method (powder) and Wet Method (slurries) of soil which has binders to form panels or columns of improved soil in the ground.

C. Performance

All these techniques after installation are functions as reinforcement, load bearing, drainage and containment. The Stone column and CFG pile techniques are function as pile because it is often work as load- bearing elements and carry heavy load from superstructure easily transmit in to a deep soil layer. CFG pile function is also referred to as pile effect rather than DM column and Stone column. This pile effect increasing bearing capacities and reduces the settlement of soft soil. These techniques can serve as reinforcement to soft soils are the matrix. In composite foundation, SC /or DM and soil deformed together and surrounding soil are distribute under vertical applied load and increase shear resistance against sliding. Stone column can function as drainage path to soft soil and DM/ or CFG pile can increase in excess pore water pressure reduction process. Hung at al., [2009]; zheng et al., [2011]. Han and Ye (2001) found that the acceleration of consolidation of SC reinforced foundations is attributed to the drainage of the columns and the reduction of the vertical stresses on soft soils. The acceleration of consolidation of the composite foundation by low-permeability columns is mainly attributed to the reduction of the vertical stresses on soft soils.

IV. CONSTRUCTION METHOD

A. Stone Column

Stone columns are constructed by experienced contractors using high-tech heavy equipment. The construction uses an excavator with a vibrating probe to feed stone into the ground, forming a vertical column of stone. Some stone column rigs feed stone into the ground through the vibrating probe, exiting at the bottom, and other rigs require the stone to be fed in from the ground surface down the vertical hole in the ground. Both types use a vibrating probe that densifies the surrounding soils to help feed the stone into the ground.

B. CFG Pile

The process of CFG pile composite structure construction has described below

1) One Test pile is constructed as per mix design and tested for bearing capacity of single pile under differential vertical loading condition.
2) A wide range of piles could construct, after passing vertical bearing capacity of single pile test.
3) Putting lines: Locate the line and location of the pile
4) Pile position: Locate the piles position by total station
5) Adjust the vertical spiral drill pipe: To ensure long screw pile vertical
6) Pore-forming: Form the hole to the design elevation
7) Pumping concrete: Remove the hollow long spiral drilling machine to a suitable location, and pump concrete from the top of the drill to the design elevation.
8) Clean up the soil between piles: Keep the soil between piles (SbPs) clean to ensure the strength of pile.
9) Chiseling pile head: In order to guarantee the strength of pile concrete, the upper virtual pile should be chiseled.
10) The cushion layer paving: To ensure that the load of embankment and vehicle will be shared by pile and soil, then adjust the sharing ratio of pile and soil load to improve the stability of embankment.

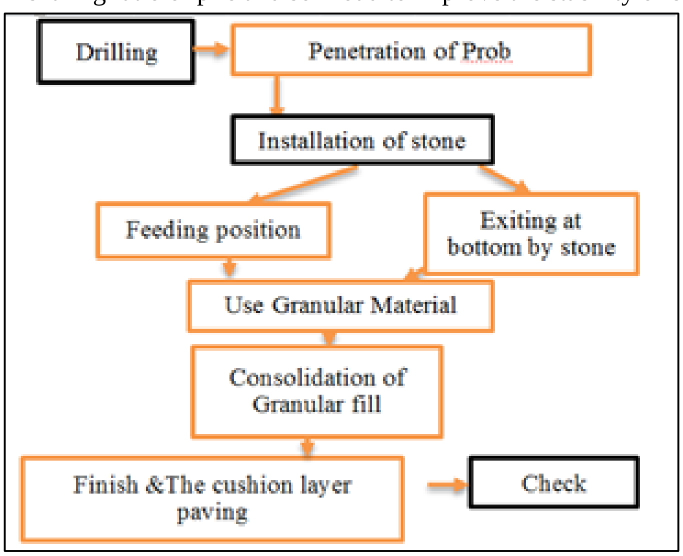

Fig. 2: Technical flow chart of Stone Column

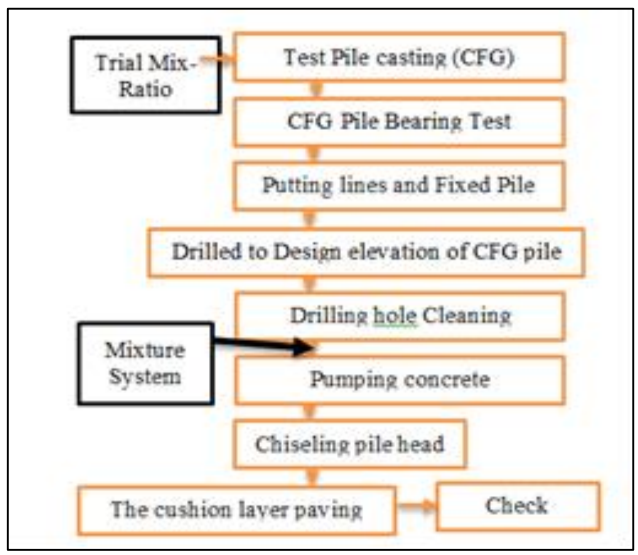

Fig. 3: Technical flow chart of CFG pile

C. DM (Deep Mixing) Column

In DMCs, the chemical agents, which are either slurry (wet mixing) or powder (dry mixing), are mixed into the soft ground to form columns of soil binders. For this purpose, a rotary mixing auger is drilled to the treatment depth. The drill's rotation direction is then reversed and retrieved whilst binders are pumped through the auger drill bit and the soil and binders are mixed (Bruce, 2001).

1) Stress Distribution under Axial Load

The DM, SC and CFG pile have been used to carry vertical load and transmit to deep soil strata as well as also increasing shearing strength of soft foundation for embankment or coagulated slope stability. There are much difficult to evaluate the stress concentration and distribution in column technology many factors have been affected such as length of pile, soft soil condition, water table end bearing, boundary condition and Modulus of fill material. In recent studies are mention that no stress concentration on column it means that vertical stress in column technology and surrounding soil have similarly. Figure 3 (a) and 3(d) mention that there are the same behaviors of vertical stress under the vertical load, hence stone column worked as flexible column and RCC pile work as rigid pile. Therefore lateral displacement of column under the vertical flexible load. In the field /or laboratory are test on a single stone column. The load is applied the column surface. Thus, for isolated columns, ar is a usually 100 %. It is more efficient to increase the loaded area.

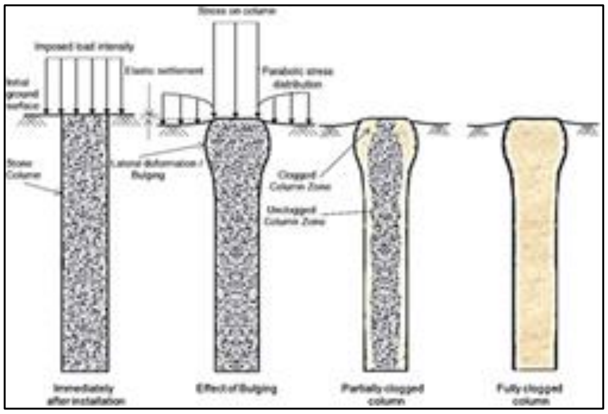

Fig. 4: Vertical stress distribution of SC

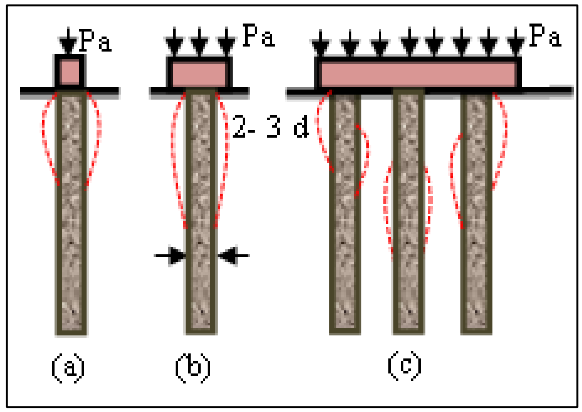

Fig. 5: Column Deformation for Different conspectus

In column technology column are transfer load easily. If the load on the single pile is greater than area ratio of column than the failure of column are under different configuration as explain in figure 4. Hence figure 4-(a), 4-(b), and 4-(c) are bulging types of failure mode generated respectively various load e.g. concentrate load, ULD load on top, of isolated column, and unformed load on group of the columns. The failure modes have explained as dotted line failure bulb should be twice to three times diameters of column. CFG pile can performed as semi rigid pile and CFG pile working on the simple principal as composite foundation. This configuration stress on the top of CFG pile is higher than stress at the surface of soil between piles under Vertical load. Therefore CFG pile can easily transfer load to deep seated soil.

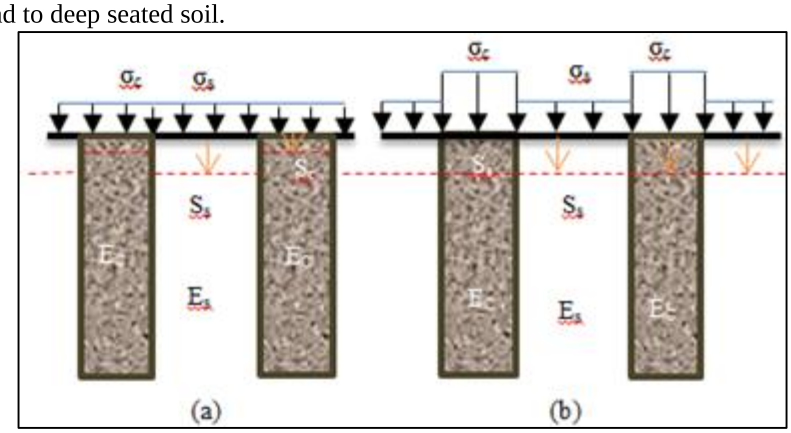

Fig. 5: Equal strain plotted against equal stress: (a) Rigid loading; (b) Flexible loading

The soil improvement techniques are DM, Stone Column, and CFG pile are effect under an equal stress (rigid load) condition; it means that pile and surrounding soft soil carry the same stress as a results have differential settlements between soft soils and pile 5(a). Application of it like as pile supported embankment has been concede a stress concentration ratio greater than 1.0. Therefore, a pile supported embankment has condition between equal stress and equal strain 5(b) for the equal settlement of pile and soft soil.

$$n = \frac{\sigma_c}{\sigma_s} = \frac{\text{stress in column}}{\text{stress in soil}} \qquad (1)$$

Whereas analysis in geotechnical engineering for pile and column technology the stress concentration ratio is play significant role. The concentration ratio is ‘n’ can assess from equation -1. CFG pile is more rigid column technology compare to DM and SC.

V. Conclusion

CFG pile is a rigid pile with a large modulus; CFG piles are larger than that of Deep Mixing column and Stone column technique. Therefore, pavement deformation, differential settlement and deformation of roadbed should be reduced. Rigid piles carried majority of the embankment load. The combination of the rigid piles and the reinforced concrete slab significantly reduced the stresses applied onto the soft soils. The above study indicates that when piles of higher rigidity are adopted, its settlement and differential settlement relatively decrease and the post-construction settlement is easy to control. It can be seen from the numeric computing results of the three schemes that within the code requirements of roadbed, an optimal scheme can be selected after considering the cost, time and difficulty of construction.

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