



Nigerian Institution of Highway & Transportation Engineers (NIHTE)

(A Division of the Nigerian Society of Engineers)

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January - April, 2025

Vol. 9

10th Edition

Think, Transform & Transcend

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The No. 1
Highway &
Transportation
Engineering
Development
Journal

INAUGURATION Ceremony

of

ENGR.
FRANCIS ORIAKHI
FNSE, FNIHTE, KSM

as the

6th

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CHAIRMAN**

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Dr. Samuel Ogbuku
Managing Director,
Niger Delta Development Commission (NDCC)

GUEST LECTURER: Engr. Sylvester Ijigbi FNSE, FNIHTE

Lecture
Topic:

EMERGING TRENDS AND
TECHNOLOGIES TO DRIVE NIGERIA'S
TRANSPORTATION SECTOR.

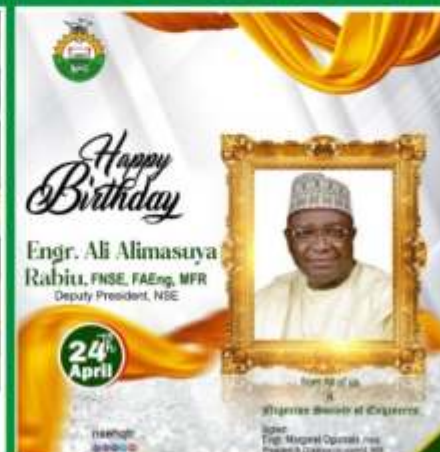
2:00 pm
Prompt

Tuesday, 25th
February 2025

NSE Main Auditorium,
Central Business
District Abuja



Hon. Minister of State for Works visits NSE President to strengthen engineering collaboration.



ISSN 2360-6826

OUR VISION

- ! To transform the nation's highway & transport sector that is centered on road safety, compliance, intervention, monitoring, assets management, reform, financing and capacity building for the nation's highway and transportation professionals.

OUR MISSION

- ! To think, transform and transcend the nation's highway & transport practice to that of global best practices.
To provide forum for members and partners of the highway & transport industry that foster education, innovation, research, fellowship, promoting a safe, sustainable and efficient highway & transport system.
To bring radical changes into the highway & transport practice in design, construction, maintenance, sustainability and management of highway & transport infrastructures.
To engage highway and transportation stakeholders.
To hold research, conference, seminar, technical publication, workshops, lectures in line with global best practices.
To provide professional leadership while developing and sharing knowledge, capacity building and technology acquisition.
To develop the nation's highway design and construction standards.
To net-work and engage with highway industry leaders from different countries of the world.
To have unparalleled professional and business development opportunities around the globe.

Core Values

Education and Innovation.
Diversity, Inclusiveness and Ethics.
Quality life
Fellowship.

Goals

Increase visibility.
Maintain membership and extend market diversity.
Promote education.
Educating highway & transport decision makers.

Aims & Scope

As an academic journal, the *Journal of the Nigerian Institution of Highway and Transportation Engineers (NIHTE)*, provides a platform for the exchange and discussion of novel and creative ideas, on theoretical and experimental research in the field of Highway and Transportation. This journal publishes high-quality peer-reviewed papers on engineering, planning, management, and information technology for highway transportation. The journal is committed to rapid peer review and publication.

The scope of the *Journal of the Nigerian Institution of Highway and Transportation Engineers*, includes: -

- Road engineering, railway engineering, environmental engineering, ITS and traffic engineering and bridge and tunnel engineering
- Automotive engineering, design, manufacture, and operation of vehicles
- Air transportation, maritime transportation, road transportation, and railway transportation
- Analysis, operation, optimization, and planning of highway and transportation systems and networks
- Travel behaviour, information technology, traffic control, and traffic flow theory
- Economics, health, safety, security, environmental and management of highway and transportation
- Multi-modal highway, transportation and logistics research
- Intelligent highway and transport systems
- Materials science,

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A NOTE FROM THE LEAD EDITOR'S PEN

Happy New Year and welcome to the First Quarter Edition of the NIHTE Journal, 2025.

I must first of all, credence immensely to our National Chairman, Engr. Sir Francis Oriakhi, FNSE, FNIHTE, KSM, for his full contribution and his Inauguration that took place on 25th February, 2025.

The NIHTE quarterly Journal includes the latest practical and theoretical achievements and in-depth features as well as news and product roundups. We invite articles, papers, adverts, goodwill messages, etc. from members and non-members.

The New Year is a time for looking back and for looking forward. Some people had resolutions to break bad habits, create new ones or maintain existing ones. The Editorial Team of NIHTE Journal also has a resolution it intends to keep: - to continue to deliver on our promises. On behalf of the whole Editorial Team, we wish you, your family and friends the very best for the New Year!

In this issue of Journal, we shall be seeing the NSE President, Engr. Margaret Aina Oguntala, FNSE, and NIHTE Chairman, Engr. Sir Francis Oriakhi, FNSE, FNIHTE, New Year Messages respectively and showcasing history that was made cum power transition during NIHTE Inauguration. Engr. Hassan H. Saidu, FNSE, FNIHTE, handed over to Engr. Francis Oriakhi Saidu, FNSE, FNIHTE, as the 6th National Chairman of NIHTE on 25th February, 2025, while, Engr. Ekwulo E. O., MNSE, MNIHTE,

took over from Engr. Olovie Charles Emem, FNSE, FNIHTE, as the 5th Chapter Chairman of NIHTE, Port Harcourt Chapter, on 27th February, 2025 respectively. The events were all colourfull with mammoth crowds.

Furthermore, various Technical Papers, as written by various Authors were published here.

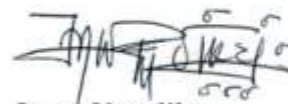
Our Editorial Office will continue to offer services with tremendous professionalism and dedication. Our Journal occupies a unique space in information dissemination and research. With quality, rigorously peer-reviewed manuscripts, we will bring it to a place of international prominence. We invite articles, papers, adverts, goodwill messages, etc. from members and non-members.

Once more, wish all of us the best, Happy New Year and thanks for your support.

We wish to stay connected during this time, so please, find time to email us at: - nihe.nse2013@gmail.com or japavisca@yahoo.com

Or call 08032630023, 08023549515, 07038064059, 08065668058, 08066898981, for submissions.

Welcome again to NIHTE quarterly Journal.



Jones Nwadike
Lead Editor

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NIHTE – the Nigerian Institution of Highway and Transportation Engineers – is a non-profit, non-partisan institution representing highway and transportation in the Nigerian Society of Engineers (NSE), in Nigeria. It represents all highway and transportation modes, including air, highways, public transportation, active transportation, rail, and water. Its primary goal is to foster the development, operation, and maintenance of an integrated national highway and transportation systems.

NIHTE works to educate the public and key decision-makers about the critical role that highway and transportation play in securing a good quality of life and sound economy for our nation. NIHTE supposed to serves as a liaison between national, state and local government departments of highway and transportation and the Federal government and is supposed to be an international leader in setting technical standards for all phases of highway and transportation systems development. Standards are supposed to be issued for design, construction of highways and bridges, materials, and many other technical areas.

Construction workers are often at risk of exposure to many infectious diseases, such as coccidioidomycosis, histoplasmosis, hypersensitivity pneumonitis, disseminated histoplasmosis, dengue, asbestos-related illnesses, silicosis, legionellosis, tuberculosis, blood-borne pathogens, and COVID-19. Due to severe working conditions and possible accidents, construction fields are high-risk zones by nature. It is very important to recognize and control the preventable health and safety hazards within these environments. The need for identification and prevention of these diseases is urgent, according to NIHTE. We can be nimble and quick in illustrating to those who are exposed to theses hazards, how to spot them and, hopefully, eradicate them, with help from health workers.



Dear Esteemed Colleagues,

WELCOME TO 2025!

Accept my sincere felicitations to you on the successful cross-over to the New Year. It is the Lord's doing and we rejoice in its marvel. To God be the glory.

Exactly a year ago, we commenced the journey of our administration, with me as the 34th President of the Nigerian Society of Engineers. Together, we set out on the course of Rebirthing NSE for the Growth, Empowerment and Advancement of Engineering in Nigeria.

Here's to an impactful and inspiring 2025!

Happy New Year!

CHAIRMAN'S NEW YEAR MESSAGE



Engr. Francis Oriakhi

FNSE, FNIHTE, FNICE, KSM
National Chairman (NIHTE)

AS I ASSUME OFFICE (01/01/2025 TO 31/12/2026) AS THE 6TH NATIONAL CHAIRMAN OF THE INSTITUTION OF HIGHWAY AND TRANSPORTATION ENGINEERS (NIHTE) - A DIVISION OF THE NIGERIAN SOCIETY OF ENGINEERS (NSE).

I wish all members of the Institution of Highway and Transportation Engineers across all the chapters in Nigeria and our stakeholders - ministries, agencies, parastatals, companies, firms and institutions etc. (among which are the Federal Ministry of Works (FMW), Federal Roads Maintenance Agency (FERMA), Nigerian Building & Road Research Institute (NBRRI), Niger Delta Development Commission (NDDC) and Rural Access and Agricultural Marketing Project (RAAMP), a happy new and eventful 2025.

As we commence the journey for the next 2 years of a new EXCO led by me, I use this opportunity to appreciate the immediate past National Chairman Engr. Saïdu Hassan, FNSE, FNIHTE, and all our past National Chairmen - Engr. Isa Emobabo, FNSE, FNIHTE, Engr. G.O Anaduaka, FNSE, FNIHTE, Engr. Dayo Oluyemi, FNSE, FNIHTE and Engr. George Nsonwu, FNSE, FNIHTE for their selfless service and contributions to the institution's founding, nurturing and growth over these years. They have brought the institution to this present enviable height it has attained today.

A lot of achievements and grounds have been covered by the institution over years of its existence, I am convinced that there is much room for improvement going forward. In the same vein, it is our sincere wish that the legislative and executive arms of our government look favorably at all our road reforms proposals/bills and other various positive suggestions and papers on our road/transportation improvement and maintenance before them.

Let us all join hands to make the Nigerian Institution of highway and Transportation Engineers achieve our primary objective of turning round the practice and delivery of the profession in Nigeria to global best practice standard in the next few years.

Long Live the Nigerian Institution of Highway and Transportation Engineers (NIHTE)

Long Live Nigeria

Sincerely,

Engr. Francis Oriakhi, FNSE, FNIHTE, KSM.

National Chairman - Nigerian Institution of Highway and Transportation Engineers (NIHTE)



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CRITICAL THINKING IN ENGINEERING LEADERSHIP: A KEY PANACEA TO ACHIEVE GROWTH

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Abstract

This study explains the restrictions impeding the actualization of robust practical engineering education goals, pivotal for fostering innovation engineering leadership. It scrutinizes the efficacy and impact of assets and service it delivers (the product), alongside the exploitation prospects during operational phases (the process). A comprehensive interpretation of 'critical thinking engineering leadership' is employed, encompassing the orchestration of engineering teams and technical staff through the entire project life-cycle - from conception, design, execution to operationalization – culminating in corporate triumph. The discourse posits that critical thinking engineering leadership is instrumental in advancing practical engineering education targets aligned with critical thinking leadership paradigms. Nonetheless, these targets must be explicitly articulated within the engineering education reform agenda, bolstering processes, products and services to meet an array of stipulations, adhering to budgetary constraints, scheduled timeliness and managing risks judiciously, thereby paving the path for sustainable development.

Keywords: Critical thinking, Critical thinking engineering leadership, engineering education, development.

INTRODUCTION

This paper reports the findings of in the study that are currently inhibiting the achievement of stronger practical engineering education objectives. Despite the wide recognition that critical thinking leadership attributes are needed in engineering graduates, there still remains a lack of clarity on the definition of 'critical thinking engineering leadership'. This is the reason the study adopted a very broad definition of 'critical thinking engineering leadership' that embrace leading a group of engineers and critical thinking personnel in all stages of project life, from creating, designing, implementing and operation, towards business success in organization. Critical thinking Engineering Leadership is a style of leadership based upon the concept of working co-operatively to develop critical thinking and intuitive ideas (Mumford M. D. et al, 2002). Why is creativity important to engineering and engineering education? The value that creativity and innovation offer lies in their ability to facilitate the development of novel and effective critical thinking technological solutions to problems stimulated by change (David H Cropley,

2015). Those who employ Critical thinking Engineering Leaders tend to do so by creating conditions which promote creativity and innovation. Creating such conditions, which are sometimes called "supportive contributions" (Mainemelis Charalampos, et al, 2015), are described as psychological, material, and/or social supports (operations) that trigger, enable and sustain critical thinking in others (Mainemelis Charalampos, et al, 2015). The term Critical thinking Engineering Leadership is commonly used in organizational studies and was first referenced in 1957 (Selznick P., 1984). In recent years, there has been a significant increase in research surrounding critical thinking and innovation leadership (Dinh J. E. et al, 2014) and the term has also been used increasingly among engineering practitioners (Nikravan L., 2012) and in the public sphere (Chernin Peter, 2002). Researchers and engineering practitioners have suggested that Critical thinking Engineering Leadership is more important in the current political and economic climate than ever before (Sternberg R. J., 2007). It has also been

suggested that critical thinking engineering leaders display behaviours that may contradict traditional management styles (Hunter S. T. et al, 2011).

To address this issue, the paper explores the impact / performance of the asset and the service it delivers (the product), and the opportunities during operation (the process). Engineering students must learn how to merge the physical, life and information sciences at the nano-, meso-, micro- and macro- scales; embrace professional ethics and social responsibility, be critical thinking and critical thinking and write and communicate well. Our students should be prepared to live and work as global citizens, understand how engineers contribute to society. They must develop a basic understanding of business processes; be adept at product development and high-quality manufacturing; and know how to conceive, design, implement and operate complex engineering systems of appropriate complexity. They must increasingly do this within a framework of sustainable development, and be prepared to live and work as global citizens. That is a tall order ... perhaps even an impossible order (Rethinking Engineering Education: The CDIO Approach). Engineering leadership development programs have become increasingly popular as there is a recognized demand for engineers who are well-rounded and possess leadership attributes (M. Klassen et al, 2016).

The paper concludes that critical thinking engineering leadership has the potential to promote practical engineering education objectives of organization. However, the objectives should be clearly identified in the reform of engineering education and also support processes, products and services to a set of requirements, within budget, and to a schedule with acceptable levels of risk in the new way for sustainable development. Critical thinking engineering leadership is a growing field of research with a lack of clarity and limited synchronicity. Education institutions and industry organizations looking to design or revamp critical thinking engineering leadership programs can also use this definition to provide guidance on the vision and goals of their programs.

Critical thinking engineering leaders develops mechanisms for effective conflict resolution, encouragement of interaction and information exchange among group members, and fostering cooperation in performing collective tasks (Shin et al, 2007 and Vera et al, 2004).

Taken together, critical thinking engineering leaders may facilitate the establishment of a strong work

group critical thinking identity by developing group capability to effectively use its members' diverse expertise, while also searching for new and better ways of completing group work.

Aims / Objectives of the Study

The aims / objectives are: -

- to have a group of engineers and critical thinking personnel that leads in all stages of project life, from creating, designing, implementing and operation, towards business success in organization, to eliminate poor leadership in engineering education (governance).
- to eliminate corruption.
- to eliminate unemployment & low education.
- to stop insecurity.
- to improve critical thinking in engineering education & reduce high cost of living and eliminate poverty.
- to make local people have say in determining governance composition.
- to have a group of engineers and critical thinking personnel that leads in all stages of project life, from creating, designing, implementing and operation (cdio), towards business success in organization / institution.
- to ensure that local content will have control over engineering education reform.
- to change the education system.

Statement of the Problems

- Bad government policies (Governance),
- Weak and unsuitable institutions & Shortage of critical thinking leaders,
- Competition with foreign education & Shortage of skills,
- Poor management & Political instability,
- Inadequate schools (Ill equipped) & Inadequate communication facilities,
- Lack of standard market & Inadequate skilled man-power,
- Lack of qualified manufacturing engineers & insufficient capital,
- High degree of foreign dependence,
- Lack of heavy-duty machinery manufacturing labour,
- Low purchasing power of populace & inadequate power supply, etc.
- Curriculum & ICT deficiency
- Inadequate Engineering Infrastructure
- Lack of Experienced Faculty
- High Cost of Engineering Literature
- Quality of Entrants & Quality of Graduates

- Students' Enrollment Processes
- Admission Requirements

Significance / Justification of the Study

- the role of critical thinking in engineering education in creating (conceiving), designing, initiating and operating (even in trade, manufacture, commerce and agriculture) cannot be swept under the carpet, for effective engineering leadership, because it embraces leading a group of engineers and critical thinking personnel in all stages of project life towards business success in institution / organization,
- population agglomeration,
- urbanization, modernization, commercialization, industrialization.
- movement of people and goods from one place to another,
- the role of critical thinking in engineering education as a key panacea for achieving the engineering leadership in the provision of job opportunities, technological cum infrastructural development, funding of education and research, training cum skilled manpower development and invariably improve the standard of living and general well-being of the people cannot be over emphasized.

Scope and Limitations of the Work

This work evaluates critical thinking in engineering education in critical thinking engineering leadership. The work is focused on critical thinking engineering leadership in organizations. In the competencies study, the work focuses on the transversal critical thinking engineering leadership competencies that engineers should have at graduation cycle (Bachelor) degrees. The wide scope of this work does not allow us to analyze the effect of all possible independent variables.

Research Methodology and Organization of the Study

The study adopts conjectural method of research that examined and discussed relevant issues of interest in the history of critical thinking engineering leadership as a viable tool for engineering education reform. Thus, the paper reviews existing literature on critical thinking engineering leadership. Because of the nature of the study (macro), the writer relies on published documents in the area of critical thinking engineering leadership using commissioned studies, non-commissioned studies and published works from various sources. Some of these secondary sources are narrow in perspective and scope, but they serve as useful materials for researchers wanting to embark on a macro-study.

The study is organized in six (6) sections, apart from

the introduction, aims and objectives, scope and limitations of the study, statement of the problem, justification / justification of the study and research methodology and organization of study. These are: - summary of definitions found in literature, review of literature, critical thinking engineering leadership mainstream, characteristics of successful critical thinking engineering leadership, conclusion and references.

Research Hypotheses

To aid the completion of the study, the following research hypotheses were formulated by the researchers.

H0: there is no positive effect of critical thinking engineering leadership in effective functioning of the engineering education.

H1: there is a positive effect of critical thinking engineering leadership in effective functioning of the engineering education.

SUMMARY OF DEFINITIONS FOUND IN LITERATURE

What is Critical thinking?

- critical thinking is a phenomenon whereby something new and somehow valuable is formed.
- the created item may be intangible, such as an idea, a scientific theory, a musical composition, or a joke or a physical object, such as an invention, a printed literary work or a painting.

What is Creativity?

Is Creativity a mysterious gift? A unique talent? A trait? An ability? An attitude? Is it innate, or can it be learned and taught? Does it develop spontaneously? Or is it always present in some individuals? Clearly, some people are more critical thinking than others. Is this due to the way they think? How they see the world? Or how they react to it? Are certain thought processes, attitudes or beliefs associated with critical thinking production? If so, perhaps anyone can learn to be more critical thinking (Larry G. Richards and Robyn Paul).

Creativity is a phenomenon whereby something new and somehow valuable is formed. The created item may be intangible, such as an idea, a scientific theory, a musical composition, or a joke or a physical object, such as an invention, a printed literary work, or a painting (Creativity – wikipedia.html).

What is Leadership?

Leadership is organizing and directing the efforts of a group. In a broad sense, leadership is creating (developing) and organizing (engaging) others in a common vision, clearly planning and organizing resources, developing and maintaining trust, sharing

perspectives, inspiring creativity, heightening motivation, and being sensitive to competing needs. Leadership is the art and science of influencing others toward accomplishing common goals and does not necessarily require a formal role or position within a group (Robyn Paul, 2018).

What is Engineering Leadership?

Engineering Leadership is the ability to lead a group of engineers and technical personnel responsible for creating, designing, developing, implementing, and evaluating products, systems, or services.

Critical Thinking Engineering Leader

The idea of critical thinking engineering leadership started with James McGregor Burns approximately three decades ago (Burns, 1978). The critical thinking engineering leader has been characterized as one who articulates a positive vision of the future that can be shared with subordinates and among peers, pays high attention to diversity and intellectually stimulates subordinates to perform beyond what they think is possible for them (Bass et al, 1990).

What is Critical Thinking Engineering Leadership?

Critical Thinking Engineering Leadership is the process of creating (envisioning), designing, initiating (developing), and organizing (supporting) new products and services to a set of requirements, within budget and to a schedule with acceptable levels of risk to support the strategic objectives of an organization." Note: This paper focused on engineering management, but the tone is very much towards teaching engineering management to "engage critical thinking engineering leadership towards business success" therefore the definition was included.

Numerous researchers have used the term Critical thinking Engineering Leadership since it was first used as a concept in the 1950s. The meanings may differ across research contexts (Mainemelis Charalampos RonitKark et al, 2015).

More views on the definition and scope of Critical thinking Engineering Leadership include: -Leading others toward the attainment of a critical thinking outcome (Mainemelis Charalampos RonitKark et al, 2015). - Deliberately engaging one's imagination to define and guide a group toward a novel goal-a direction that is new for the group (Puccio G., et al, 2011). - An imaginative and thought-through response to opportunities and to challenging issues that inhibit learning at all levels. It is about seeing, thinking and doing things differently in order to improve the life chances of all students. Critical thinking leaders also provide the conditions, environment and opportunities for others to be critical thinking (Stoll

L., et al, 2009). A critical thinking engineering leader induces others to focus the process and process education on meeting their challenges. They become consultants or facilitators in the process of solving the challenge rather than giving orders or doing the work themselves. Having transferred ownership, they then help others to achieve their own goals. These Critical thinking Engineering Leadership education hardly fit with the traditional management style that most organizations employ, but they can be learned (Mumford M. D., et al, 2002).

What is critical thinking in engineering education?

Critical thinking in engineering education is the process of creating (envisioning), designing, initiating (developing), and organizing (supporting) new products and services to a set of requirements, within budget and to a schedule with acceptable levels of risk to support the strategic objectives of an organization.

Why is Critical Thinking in Education important?

It helps to improve decision making;

It stimulates curiosity and the skills (Reasoning, evaluating, problem solving, decision making & analyzing) are necessary for success in many fields;

It enhances problem-solving ability and it refines research skills;

It polishes creativity and critical thinkers are less likely to just go along with the crowd;

It prepares students to educate themselves for the rest of their lives;

Critical thinking is not bounded by traditional concepts, rules or practices and often challenges the status quo.

Divergent thinking explore many possible solutions, often, leading to unexpected connections and insight.

Benefits of Critical Thinking include: -

Self-directed, learning, self-expression, personal integrity, personal growth and well-being, etc.

Advantages of developing Critical Thinking skills include: -

Lifetime skill, key to career success, broad range of cognitive learning, improves relationship, enhances creativity, etc.

The most challenge in Engineering Education

Among all the challenges, I think the most challenging thing is about engineering education. Even up till today, the best University in the world will face the same challenge, because everything we teach our students are the things in the past 200 years. The things we taught them – machine will do better. So, we have to think, what is the best way? What are the contents to teach our students in the future? We

have to teach the students to win the machines. The machines will never be able to win man, this is my belief, because the machines only have the chips, humans have the heart. So, I think we have to change from now the engineering education system. In the future, it is not about competition of knowledge, it is a competition of critical thinking and creativity, it is a competition of imagination, it is a competition of learning and it is a competition of independent critical thinking. If we think like a machine, the problem will continue.

In the past 20 years, we made people like machines. In the next 20 years, machine will look like people. So, in the future, it is not knowledge-driven, manufacturing-driven, it is wisdom-driven. In the future, it is critical thinking and creativity-driven. So, this is what we think the institution (world) should be focusing on.

LITERATURE REVIEW

A review of the literature related to these programs show that they aim to provide professional education such as creativity, communication, innovation, execution, personal drive and teamwork (Robyn Paul et al, 2015). National engineering bodies have also recognized this need to educate engineers in critical thinking engineering leadership. In the report entitled "The Engineer of 2020", critical thinking leadership was one of the key attributes mentioned (National Academy of Engineering, 2005, p. 53).

Conceive-Design-Implement-Operate (CDIO), critical thinking educational framework for engineering, also addresses the need for critical thinking engineering leadership in their most recent syllabus update (E. F. Crawley et al, 2014, p. 69).

The Canadian book, *Fundamental Competencies for the 21st Century Engineers*, has also recognized this need, and has added critical thinking leadership as an essential competency for engineers in their most recent edition (A. B. Dunwoody et al, 2018).

The attribute of leadership has also been included in the new student outcomes for ABET (Accreditation Board for Engineering and Technology), which has become effective in the 2019 - 2020 accreditation cycle (replacing the "a-k" outcomes). Students must be able to "function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives" (ABET, 2017, p. 40).

Interest is growing in the influence of critical thinking engineering leadership on creativity and innovation. Critical thinking engineering leaders raise the performance expectations of their followers (Bass, 1995) and seek to transform followers' personal values and self-concepts and move them to higher level of

needs and aspirations" (Jung, 2001).

There are several possible mechanisms through which critical thinking engineering leadership may enhance employee individual creativity. For example, critical thinking engineering leaders encourage followers to challenge the status quo and experiment with new and different approaches to their work (i.e., intellectual stimulation; Bass et al., 2003). First, critical thinking engineering leaders challenge followers thoughts and imaginations, recognize their critical thinking values, beliefs, and mind-set, develop individual employees and work teams' capabilities, provide resources and support and give them discretion to act, and energize followers to work harder toward achieving higher targets (Bass, 1985), all of which could help develop followers' self-views of being critical thinking. Critical thinking engineering leaders also create new learning opportunities for followers to grow, give followers discretion to act, and show appreciation and support of followers individual consideration (Bass et al., 2003).

Critical thinking engineering leaders develops mechanisms for effective conflict resolution, encouragement of interaction and information exchange among group members, and fostering cooperation in performing collective tasks (Shin et al, 2007 and Vera et al, 2004).

Taken together, critical thinking engineering leaders may facilitate the establishment of a strong work group critical thinking identity by developing group capability to effectively use its members' diverse expertise, while also searching for new and better ways of completing group work.

Critical thinking engineering leaders encourage followers to challenge the status quo and to solve problems by trying out new approaches. Furthermore, they appreciate followers' ideas even if they are different from the traditional way of thinking (Sharma et al., 2012 and Çekmecelioğlu et al, 2016). They frequently emphasize the value of novel ideas and thus followers feel comfortable in proposing new alternatives or even taking risks (Shin et al, 2003 and Çekmecelioğlu et al, 2016).

(Rowold et al, 2007), critical thinking engineering leadership has been studied extensively; several studies have reported that the critical thinking engineering leadership style has been associated with numerous variables, such as organizational learning (Mirkamali et al, 2011); employee effectiveness (Srithongrun, 2011); critical thinking flexibility (Sharma et al, 2012); communication competency (Çetin et al, 2012); leadership effectiveness (Zhang et al., 2012); and employees' job satisfaction (Munir et al, 2012).

Only very few empirical studies have focused on the relationship between critical thinking engineering

leadership and crisis management, such as Hasan et al, 2017, who examined the association between leadership styles and crisis management in the Ministry of Planning in Erbil, Iraq; the findings reveal that critical thinking engineering leaders can predict crisis management.

CRITICAL THINKING ENGINEERING LEADERSHIP MAINSTREAM

Competencies

According to Stoll and Temperley, 2009, 69–74, critical thinking engineering leaders foster conditions that can help to inspire creativity in others. These conditions include: -stimulating a sense of urgency if necessary, exposing colleagues to new thinking and experiences, providing time and space to facilitate the practicalities; - setting high expectations, promoting individual and collaborative critical thinking and design, using failure as a learning opportunity, relinquishing control and the modelling of creativity and risk-taking (Stoll L., et al, 2009). - Ball, 2015, suggests that the five (5) core competencies for Critical thinking Engineering Leadership are: -acting with passion and purpose, - applying an explorative mindset, -envisioning a better future, -orchestrating critical thinking teams, and - driving breakthrough change (Ball Rajiv, 2017).

Sohmen's, 2015, research argues that good critical thinking leaders consistently develop the following characteristics in themselves: -leadership styles and perceptions, - understanding of different cultures, - individual and team motivations, - interpersonal education, - levels of creativity, - ability to manage change, -communication styles, -listening ability, - decision-making education, and- personal ethics (Sohmen V., 2015).

Conceptualizations

Three different complementary conceptualizations have been suggested which reflect the different contexts in which Critical thinking Engineering Leadership can be applied: -facilitating creativity - directing ancritical thinking vision, and - integrating diverse critical thinking contributions (Mainemelis Charalampos et al, 2015).

Critical thinking Engineering Leadership may be enacted differently depending on the context.

Facilitating

In the context of facilitating, those who employ Critical thinking Engineering Leadership will support employees or individuals as primary creators, influencing their critical thinking contributions and shaping each stage of the critical thinking process. In the context of facilitating, critical thinking leaders lead in a way that increases employees' likelihood of generating new ideas (Mumford M. D., et al, 2002).

As facilitators, critical thinking leaders foster others' creativity and may take individuals through a process that helps them generate new ideas, such as brainstorming (Rickards T., et al, 2000 and Basadur M., 2004). In the context of facilitating, those who employ Critical thinking Engineering Leadership are involved in the entire critical thinking process and shape a supportive climate for creativity (Mumford M. D., et al, 2002).

Directing

In the context of directing, those who employ Critical thinking Engineering Leadership are the primary creators and their vision is enacted through contribution and collaboration from others (Mumford M. D., et al, 2002). Mumford, Scott, Gadis and Strange (2002) suggest that, in directing, a leader is integral to the production of critical thinking concept, while others support its implementation. The degree to which others contribute critical thinking may depend upon the situation. This can be compared to an orchestra conductor, who provides a vision and direction for musicians who bring their own individual contributions (Basadur M., 2004). A strong directive critical thinking leader may inspire, elicit, and integrate high-quality contributions from his or her collaborators (Mumford M. D., et al, 2002).



The Nigerian Society of Engineers

REQUEST FOR CLASSIFIED ADVERTS FOR THE NIGERIA ENGINEER MAGAZINE

In our bid to fulfil one of the terms of reference of the Editorial Board which is to generate funds and make The Nigeria Engineer magazine self-financing, we seek the dissemination of e-mail to all corporate members to notify them of the committee's request for classified Adverts for the next edition of the Magazine. The size of the advert should be 4.123 by 3.924 inches and will cost Fifty Thousand (50,000.00) only per advert.

Evidence of payment and advert should be forwarded to editorialcommittee@nse.org.ng

All adverts should reach the committee latest 10th September-December, 2022, this is to enable the committee complete the production of the magazine by the 15th of September-December.

Thank you and regards

Engr. Dr. Felicia Agubata, FNSE
Chairman, Editorial Board Committee

Integrating

In the context of integrating, there is a focus on the critical thinking leader's ability to integrate or synthesize his or her novel ideas with various critical thinking ideas from other individuals (Mumford M. D., et al, 2002). Compared to directing and facilitating contexts, there is a greater balance between the ratio of leader to follower critical thinking contributions and supportive contributions in the integrating context. Each individual can receive credit for their distinct contribution, and successful leadership in this context depends on the leader's ability to synthesize others' critical thinking inputs. Film directors are an example of leaders working in an integrating context, providing guidance to create a feature film that includes critical thinking contributions from numerous people: screenwriters, actors, special effects technicians, costume designers, etc. (Simonton, D. K., 2002).

As societies rapidly advance, and populations grow to unprecedented levels, engineering leaders are faced with solving increasingly complex problems of a magnitude not previously seen. Solving these problems will require more than just the critical thinking and critical thinking abilities that have traditionally been taught in engineering education programs. Rather, engineering leaders of the future will be required to possess key non-technical attributes which enable them to also understand and navigate social, political, economic, cultural, environmental, and ethical aspects of the critical thinking projects on which they are working (ASME, "2008). Engineering educators must meet the challenge of providing their students with professional attributes and essential critical thinking education to create the engineering leaders and innovators of tomorrow (D. J. Bayles et al, 2010).

CHARACTERISTICS OF SUCCESSFUL CRITICAL THINKING IN ENGINEERING LEADERS

Characteristics of success that Critical thinking Engineering Leaders share, including independence, generosity, purposefulness, and optimism.

Critical thinking Engineering Leadership is not industry specific, nor is it one-size-fits all. It is the individual act of a leader in the context of perpetual beta, and therefore path-dependent. In contrast to analytical forms of leadership, where the act of problem-solving culminates in one truth, Critical thinking Engineering Leadership presupposes that the drive for a solution to a problem or challenge can have several outcomes and is to a significant degree shaped by the leader.

Although Critical thinking Engineering Leadership is not exclusive to entrepreneurs, Critical thinking Engineering Leaders display many elements of

entrepreneurial behavior. These are: -

- Critical thinking Engineering Leaders empower their organizations by nurturing and cherishing the ideas of others.

- Critical thinking Engineering Leaders live in perpetual beta, they are never satisfied with the first solution. Critical thinking Engineering Leaders create urgency and shared inevitability to work towards a better future, for all, thereby inspiring others to act. They dare to be bold in new areas, not limited by present logic or institutions, embracing fears rather than avoiding them.

- Critical thinking Engineering Leaders think globally, strategically and towards the large impact. They understand how to mitigate risks, with a head in the clouds and feet firmly on the ground. They are able to master execution in uncharted territory with imperfect information and limited control. They maintain focus towards longer-term social impact, while being resourceful in capturing opportunities as these arise and overcoming challenges to keep the enterprise afloat. They are good stewards of natural and manmade resources.

- Casting and conducting of Critical thinking Teams, Cultivating Courage, and Optimistic Experiment.

- Critical thinking Engineering Leaders are able to master execution in uncharted territory.

- Critical thinking Engineering Leaders think big visionary, logically and globally, strategically and towards large impact with social passion and generous purpose. They have social awareness and holistic connectedness. They exhibit mindful self-awareness, being connected to what is happening in the here and now, demonstrate compassion for others, and exude a humble, open attitude. They are able to translate an appealing market opportunity into an enterprise concept that is critical thinking against incumbent business models. They can integrate large societal impact with attractive economic returns.

Critical thinking Engineering Leaders are able to attract team members who raise the calibre and diversity of the collective. They are capable of designing critical thinking processes that enable learning and improvement resulting in an accelerating rate of improvement, working toward a tipping point where change becomes unstoppable. Successful critical thinking engineering leaders pay meticulous attention to the smallest of details. For a successful critical thinking engineering leaders, communication means the ability to not only understand technical complexities, but the ability to succinctly and effectively translate technical jargon into layman's terms without patronizing others.

Any project, no matter how big or small, will face problems. Successful critical thinking engineering leaders must be able to effectively address these as they arise. Technology and methodologies are

constantly changing. Staying up to date with the latest developments puts Critical thinking Engineering Leaders ahead of the field.

They know what key values are important in one's life and act authentically upon them. They are transparent and honest, with congruence between intentions, words, presence, and actions. They build an organizational culture that nurtures and cherishes the ideas of others, removes barriers and structures incentives to reinforce the change that is being sought. They provide the story, experiences, and motivations that empower the organization toward a common goal. They orchestrate the ecosystem of partners in the public, private and social sector to bring systemic change.

Barriers

A number of key messages emerged from the work as barriers to future innovation in critical thinking in engineering education, these are: -

- Corruption: Inclusive of bribery, kick-back, embezzlement, theft, fraud, extortion, blackmail, favouritism, nepotism, improper political contributions, abuse of discretion), which is a major challenge at every stage of critical thinking in engineering education procurement cycle. The first step in tackling corruption is to increase transparency.
- Lack adequate reasoning, evaluating, problem solving, decision making & analyzing.
- Lack of funding.
- Lack of listening, explanation, flexibility, fairness, objectivity, research, observation, interference, communication.
- Lack of clarity and technical guidance
- Difficulty in quantifying benefits
- Insufficient data
- Limited understanding.

Recommendations

1. All Stakeholders must work co-operatively to re-establish the Engineering project team structure through:
 - a. The Federal Government to provide a matching grant to State Governments for the setting up of an Institutionalized Certification Board for craftsmen and technicians.
 - b. The State, Local Government and the Private Sector to work out a programme for re-establishing trade centres, workshops, and skill acquisition outlets, where craftsmen and technicians would be trained and retrained before they are certified to practice in the industry.
 - c. All institutions for the training of Technologists to be up-graded and re-accredited.
 - d. A Very Strong Accreditation Board for engineering

and technology to be set up immediately. The board shall now carry out accreditation of all courses in the Engineering Faculties of Universities and Schools of Technology.

The Federal Government and the Organized Private Sector to provide Adequate Funding for the sustenance of the institution.

2. A state of Emergency to be declared by the Federal, State and Local Governments on the issue of TEACHER QUALITY IMPROVEMENT at all levels of Primary, Secondary and Tertiary Education

3. For Science and Technology Education, the relevant agencies must:

Review/Reinforce the 6:3:3:4 or 9:3:4 system of education so as to ensure that primary mathematics, primary science, primary technology are handled by Qualified and Experienced Teachers for the purpose of laying a Very Sound Foundation at the early stages. Same should apply to the Secondary Schools.

4. Each University and its Engineering Faculty should be allowed to Determine and Husband entry requirements into their institution. The concept of centralized examination should be abolished.

5. Courses on Entrepreneurship, Project Management, Leadership, Strategic Planning, Environmental Studies, Ethics, Sustainable Engineering, Economics and Management, should form part of Degree programmes in engineering faculties.

6. University Governance in partnership with the Organized Private Sector should begin exploration into the concept of Near Campus Industrial-Estates (NCIE), which should serve as the engineering equivalent of the Teaching Hospital (i.e. the NCIE should be to Science/Engineering Education, what the teaching hospital is, to Medical Education).

The engineering faculties of the universities must begin to tailor their R & D efforts, in close collaboration with the industry towards the needs of the societies within the environment in which they are found.

7. The universities should Develop Local/Overseas Exchange and Linkage Programmes for academic, technical and students of the institution.

8. Universities should embark upon a sustained program of Producing Intellectuals and Academics. This requires appropriate Incentives, Mentoring and Training Programmes to motivate and retain young budding intellectuals and researchers in Nigerian Universities.

This is very essential for the Sustenance of Engineering Education Agenda.

9. The principles and practice of University Autonomy should oblige every University to renew and recreate itself by fashioning its market niche within the National University System and Global Market Place. Tenure and salary structure of each

University must be framed in such a way as to facilitate the Institution's Capacity to seek for the best within the industry.

10. Accreditation of University Curriculum Programmes shall now be taken up by relevant accreditation bodies.

The need to Decentralize NUC should also be pursued.

11. University teachers and workshop assistants should be encouraged and sponsored to spend short periods and sabbatical leave in the industry as a way of sharpening their technical skills.

12. Undergraduate Engineering students should be made to spend One Year of GUIDED MENTORING in the industry before their graduation.

13. There should be A Mandatory Periodic Evaluation and Review of Engineering Curricula, say every five years, by Teams comprising both Academics and Practicing Engineers.

14. A special emergency to be declared by the Federal, State and Local Governments which will allow a 3 year programme to Replace and Upgrade the Engineering Infrastructure in all the engineering and science institutions in Nigeria. This will also include special equipment for skills acquisition in the workshop.

15. The SIWES programmes in each university needs to be restructured to ensure better Faculty and Employer involvement in the execution and supervision. Engineering Faculties should have strong and pro-active industrial placement units.

16. Prominence should be given to the provision of Research Grants for students and lecturers. Attendance and participation in seminars and conferences must be made mandatory for all Lecturers.

17. All current bills on local content initiatives in oil and gas must be passed into law. New bills in other areas of Engineering such as PIB, NRF, FRA, NTC, NRA AND Ports and Harbour Bills among others, to be pursued by the engineering family as a way of ensuring that all members of the engineering family would have Fulfilling and Engaging Employment After Graduation. This will ensure sustainable and continuing Professional Development throughout one's career.

18. There is need to restructure and reposition COREN so as to deliver on the vision for which it was set up.

19. COREN currently functions as an appendage of the Ministry of Works, whereas it is supposed to be an Independent, Regulatory Body.

The Way Forward to Critical Thinking in Engineering Education for sustainability;

- ✓ All stakeholders must work dedicatedly to recreate the Engineering Project Team Structure,
- ✓ A massive and deliberate programme for retaining of Science, Engineering, Technology Teachers and Workshop Instructors and their certification

thereafter to be embarked upon.

- ✓ An Institutional/Legal Framework for the Retraining and Certification of our craftsmen and technicians must be pursued vigorously.
- ✓ All institutions for training engineering technologists must be Refurbished and Up-graded
- ✓ Special Training Modules, Kits, Soft-wares etc, for skills acquisition to be incorporated in all our Training Institutions
- ✓ All stakeholders to work co-operatively and to ensure that a statutory body for accreditation of engineering and technology institutions is implemented.
- ✓ All stakeholders to Re-engineer and Reposition COREN (agency for registration of Engineers and Technologists) as a Properly Funded, Powerful and Independent Institution.
- ✓ A careful review of the curriculum of our Undergraduate Engineering Schools to bring it to a form in which we can produce engineers, who on graduation can fit into the techno-economic manpower needs of the country in terms of direct relevance and practical problem solving ability.
- ✓ All mechanisms for local content initiatives in all spheres of engineering to be adopted and implemented. This will ensure that the Engineering Family is provided an opportunity for Continuous Professional Development.
- ✓ All stakeholders to work co-operatively and to ensure that a statutory body for accreditation of Engineering and Technology institutions is implemented.
- ✓ All stakeholders to work co-operatively to Process and Pass New Legislations in support of these Reforms.

CONCLUSION

The paper concludes that critical thinking in engineering education has the potential to promote practical engineering leadership objectives of institution / organization. However, the objectives should be clearly identified in the reform of engineering education and also support processes, products and services to a set of requirements, within budget, and to a schedule with acceptable levels of risk in the new way for sustainable development. Critical thinking engineering leadership is a growing field of research with a lack of clarity and limited synchronicity. This proposed definition provides a foundation for a clear understanding of the what, the how, who and the why of critical thinking engineering leadership. Education institutions and industry organizations looking to design or revamp critical thinking engineering leadership programs can also use this definition to provide guidance on the vision and goals of their programs. Engineering and students must be able to "function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment,

establish goals, plan tasks, and meet objectives" (ABET, 2017, p. 40).

Critical thinking engineering leaders develops mechanisms for effective conflict resolution, encouragement of interaction and information exchange among group members, and fostering cooperation in performing collective tasks (Shin et al, 2007 and Vera et al, 2004). Taken together, critical thinking engineering leaders may facilitate the establishment of a strong work group critical thinking identity by developing group capability to effectively use its members' diverse expertise, while also searching for new and better ways of completing group work.

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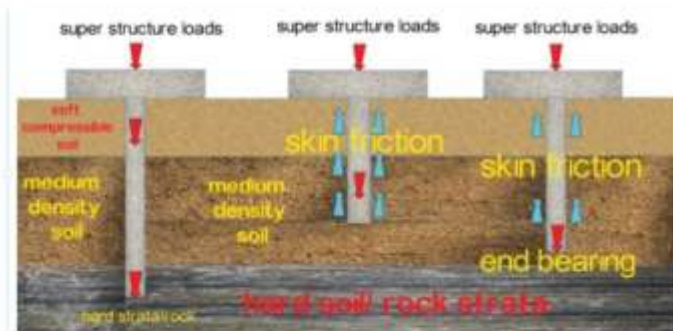


Figure 1-1 End bearing pile

Friction or cohesion piles

This type of pile is used when a suitable strata for negotiating the loads are available at a very deeper area and taking piles to that depth is not economically feasible. Friction piles utilize the shear stresses/skin friction along the surface of the pile. The load transfer is done through the frictional resistance between the pile surface and the surrounding soil. The total surface area of the pile is involved in the load transfer process. Greater the embedded length more is the load carrying capacity of the pile. Load carrying capacity of pile is directly proportional to its length. Carrying capacity is derived mainly from the adhesion or friction of the soil in contact with the shaft of the pile (see fig 1.2).

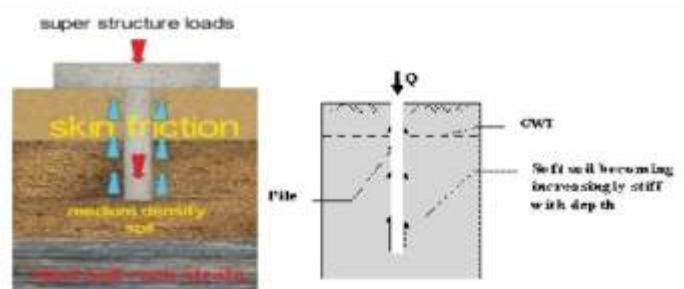


Figure 1-2 Friction or cohesion pile

Cohesion piles

These piles transmit most of their load to the soil through skin friction. This process of driving such piles close to each other in groups greatly reduces the porosity and compressibility of the soil within and around the groups. Therefore piles of this category are sometimes called compaction piles. During the process of driving the pile into the ground, the soil becomes moulded and, as a result loses some of its strength. Therefore the pile is not able to transfer the exact amount of load which it is intended to immediately after it has been driven. Usually, the soil regains some of its strength three to five months after it has been driven.

Friction piles

These piles also transfer their load to the ground through skin friction. The process of driving such piles does not compact the soil appreciably. These types of pile foundations are commonly known as floating pile foundations.

Combination of friction piles and cohesion piles

An extension of the end bearing pile when the bearing stratum is not hard, such as a firm clay. The pile is driven far enough into the lower material to develop adequate frictional resistance. A farther variation of the end bearing pile is piles with enlarged bearing areas. This is achieved by forcing a bulb of concrete into the soft stratum immediately above the firm layer to give an enlarged base. A similar effect is produced with bored piles by forming a large cone or bell at the bottom with a special reaming tool. Bored piles which are provided with a bell have a high tensile strength and can be used as tension piles (see fig. 1-3). In this case the piles can be terminated in a medium or stiff clay rather than resting on a hard strata. These types of piles are preferred and considered economical hence it is the most commonly used type of pile foundation.

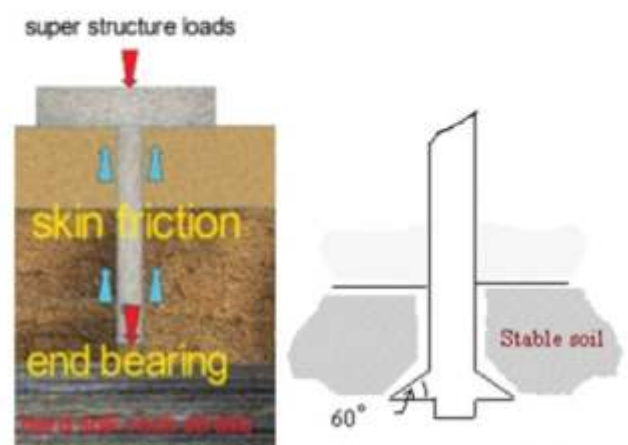


Figure 1-3 under-reamed base enlargement to a bore-and-cast-in-situ pile



The Nigerian Society of Engineers

Announces

CONFERMENT OF FELLOWSHIP

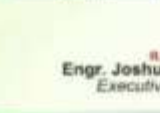
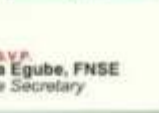
DATE: March 12, 2025

TIME: 4:30pm

VENUE: Abuja Chamber of Commerce and Industry, KM 8,
Umaru Musa Yar'Adua Road, Federal Capital Territory, Abuja

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A GUIDE TO PILE FOUNDATION DESIGN

A SYNTHESIS OF HIGHWAY PRACTICE

Part 1

(Extracted from Authors' Book)

By

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Of the making of many books there is no end. To stop learning is to stop growing.

Abstract

As the urbanization increases worldwide, the available land for building is becoming scarier and scarier, and the cost of land is becoming higher and higher, constructions are proposed even on refilled areas, which may be of natural fill or engineering fill. Thus, the popularity of tall structure are increasing day by day to withstand the load of these structures, proper stiff foundation is to be used such as pile foundation, which includes the study of static analysis of pile foundation. The first problem facing the designer of a foundation is to determine whether or not the site conditions are such that piles must be used. Piles are used where upper soil strata are compressible or weak; where footings cannot transmit inclined, horizontal, or uplift forces; where scour is likely to occur; where future excavation may be adjacent to the structure; and where expansive or collapsible soils extend for a considerable depth. Piles may be classified by material type or by method of placement. The choice of pile type is influenced by subsurface conditions, location and topography of the site and structural and geometric characteristics of the structure to be supported. The designer of a deep foundation must possess a variety of skills, much experience and considerable knowledge

of engineering sciences. At the driving site, the engineer needs to know whether a pile can be driven with a given hammer; if so, what is the set in the final blows, what is the maximum stress in the pile and should a hard or soft cushion be used? To answer these questions, a rational analysis may be useful. In Nigeria, building in certain areas, especially those with swampy, soft or unstable soil comes with a unique set of challenges. One of the most reliable solutions to these challenges is the piling foundation. Whether you are planning a high-rise building in Lagos, a waterfront property in Port Harcourt or building on a site with weak soil, understanding piling foundation is crucial. This paper breaks down everything you need to know about piling foundations, what it is, when it's used, the process involved and what you should expect in terms of cost, time and technical requirements.

Introduction

As the urbanization increases worldwide, the available land for building is becoming scarier and scarier, and the cost of land is becoming higher and higher. Thus the popularity of tall structure are increasing day by day to withstand the load of these structures proper stiff foundation is to be used such as pile foundation which



includes the study of static analysis of pile foundation. Foundation is that part of structure which transmits the load of the structure to the ground. It is the supporting part of the structure. It acts a connecting link between the structure and ground. Pile foundations are the part of a structure used to carry and transfer the load of the structure to the bearing ground located at some depth below ground surface. The main components of the foundation are the pile cap and the piles. Piles are long and slender members which transfer the load to deeper soil or rock of high bearing capacity avoiding shallow soil of low bearing capacity. The main types of materials used for piles are Wood, steel and concrete. Piles made from these materials are driven, drilled or jacked into the ground and connected to pile caps. Depending upon type of soil, pile material and load transmitting characteristic piles are classified accordingly. In the following chapter we learn about, classifications, functions and pros and cons of piles.

A piling foundation is a deep foundation system that transfers the load of a building to stronger soil or rock deep underground.

This is done using long, strong columns called piles, which are driven or drilled deep into the earth. These piles bypass weak surface soils and anchor the building into firmer ground or rock layers far below. Foundation is a substructure which is always in contact with soil to transfer super imposed load safely to the soil, so that the soil should not fail in shear as well as soil should not fail in excessive settlement and a footing is the bottom most portion of the foundation which is always contact with soil to transfer super imposed load safely to the soil.

There are many different types of piles (At least 100 have been described in the engineering literature) and they can be classified in different ways. Classification on the basis of material divides piles into timber, steel, and concrete. These materials are sometimes combined to form composite piles. Timber and steel piles are always prefabricated; concrete piles can be precast of reinforced or pre-stressed concrete, or cast in situ. Casting in situ is usually done under the protection of a casing, which can be removed to be re-used or, can be left in the ground as an integral part of the pile. Occasionally, in firm and stable ground, piles can be cast without any casing. Structural behavior of piles is greatly affected by the method of their placement into the ground. When classified on this basis, piles can be divided into displacement piles and bored (non-displacement) piles. Displacement piles are placed in the ground by operations such as driving, jacking, or vibration. In all cases, the pile displaces the surrounding soil and causes some increase in lateral ground stress, along with possible densification of the soil. The degree to which the effects of displacement are felt depends on the geometry of the cross section of the pile, as well as on the method of pile placement. Thus, a closed-end pipe or a full-section square pile causes much larger lateral-stress

increase than an open-ended pipe or a steel H-pile. (The latter two are examples of low-displacement piles.). In loose, cohesion-less deposits, driven piles may cause considerably more soil densification than vibrated or jacked piles and the degree of densification will, to a certain extent, depend also on the type of hammer used, as well as on the magnitude and frequency of driving strokes.

Non-displacement piles are driven prefabricated, or cast in a hole created by removing an equal volume of soil from the ground. This is usually done by operations such as augering (drilling, rotary boring) or grabbing (percussion boring), often under protection of a casing, or drilling mud, or both, which are used to prevent soil cave-in and large scale disturbance. In very dense, cohesion-less strata, jetting with water can be used, at least part of the way, to remove an equivalent volume of soil and to ease driving to the desired depth. Piles so formed would be classified as partially or fully non-displaced. Their placement causes little or no change in lateral ground stress, and consequently, such piles develop less shaft friction than displacement piles of the same size and shape.

The choice of appropriate pile type in any given circumstance is influenced mainly by subsurface conditions, location and topography of the site, and structural and geometrical characteristics of the proposed superstructure. Subsurface soil and water conditions usually represent the most significant factors. For example, if the bearing stratum is hard rock covered by boulders or disintegrated rock, it is essential to select a pile type that can penetrate to the desired elevation. The presence of thin strata of hard rock or of loose boulders, coarse gravel, or simply landfill containing debris of old, buildings also poses special problems of penetration that can preclude the use of several pile types and give special advantage to others. Loose cohesion-less soils develop much greater shaft-bearing capacities if driven, high-displacement piles are used. The displacement effect can be enhanced by the use of tapered shafts; however, the potential increase in shaft capacities is undesirable if negative friction is to be feared. High-displacement piles may also be undesirable in stiffer cohesive soils because they can cause excessive soil heaving. The presence of groundwater and its flow condition can be a deciding factor in whether or not to use casing for open-ended, cast-in-situ concrete piles. Sometimes, as in the case of artesian pressures in water, uncased piles should be excluded from consideration. Location and topography of the site may sometimes play an important role in selection of pile type. In congested urban locations, driven piles may be undesirable because of noise or the potential damage caused by vibrations, soil densification, or ground heave. Prefabricated piles may be undesirable if storage space is not available. In remote, rural areas, characteristics of access roads (bridge capacity and headroom) may restrict the use of certain kinds of pile construction equipment and thus

eliminate certain pile types. Local availability of a certain material, such as timber or steel, may often have a decisive effect on the economy of a certain pile type. An offshore or in-river location sometimes dictates the use of prefabricated as opposed to cast-in-situ piles. Steep terrain may make the use of certain pile-driving equipment more costly or even impossible. Structural and general characteristics of the proposed superstructure may also sometimes make certain pile types less desirable. For example, heavy structures with large reactions require high-capacity piles rather than timber and small-diameter cast-in-situ piles. For small, isolated structures the cost of bringing the pile construction equipment to the site can be significant; thus, pile types that can be placed by light, locally available equipment are advantageous. Although one pile type may emerge as the only logical choice for a given set of conditions, more often several different types may meet all of the requirements for a particular structure. In such cases the final choice is made on the basis of a cost analysis that should assess the over-all cost of alternatives, including uncertainties in execution, time delays, and cost of load testing programs, as well as differences in the cost of pile caps and other elements of the structure that may differ among alternatives.

A deep foundation, such as a pile, is a structural member that transmits loads from the superstructure to bedrock or a stronger layer of soil. Pile is a type of foundation that can be made of steel, concrete, or timber. In terms of cost, piles foundation costs are higher than shallow foundations. Despite its cost, piles are often necessary for structural safety purposes.

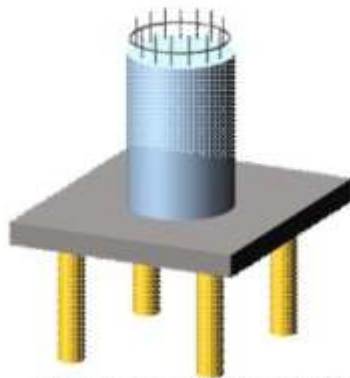


Figure 1: Pile foundation

Pile design involves selecting and sizing piles to safely and efficiently transfer structural loads to deeper, more competent soil or rock layers. It's a crucial part of foundation engineering, particularly when shallow foundations are unsuitable due to weak topsoil or when dealing with lateral forces or high water tables. The design process considers soil conditions, structural loads, and pile material to ensure the foundation's stability and performance.

Limit State Design

In pile foundation design, the limit state approach involves ensuring the structure can withstand loads

without failure or excessive settlement. This is achieved by considering two main types of limit states: Ultimate Limit States (ULS), which relate to structural collapse, and Serviceability Limit States (SLS), which concern functionality and often excessive settlement.

Ultimate Limit States (ULS)

Definition

ULS are conditions beyond which the structure can no longer support the intended loads and may lead to collapse.

Example:

A pile foundation failing in compression, bending, or shear, or a failure in the ground due to bearing resistance.

Design Approach

In ULS design, factors of safety are applied to the ultimate resistance of the pile (pile capacity) to ensure it exceeds the factored design loads.

Serviceability Limit States (SLS)

Definition: SLS are conditions that impair the functionality of the structure, but not its structural integrity.

Example: Excessive settlement, which can damage the structure or its components.

Design Approach: SLS design aims to maintain acceptable levels of settlement, often by specifying a maximum permissible settlement and designing the foundation to achieve this target.

Key Considerations in Limit State Design of Pile Foundations

Load Combinations

Design loads are combined to determine the most critical load scenarios.

Soil Properties

Soil parameters are used to calculate the pile's resistance and settlement.

Material Properties

Properties of the pile material (e.g., concrete strength) are considered for structural design.

Pile Type and Installation

The type of pile (E.g., end-bearing or friction pile) and its installation method can affect its performance.

Uncertainties

Uncertainties in soil properties and load predictions are addressed through safety factors and probability-based approaches.

In summary, limit state design in pile foundation design ensures that the structure is safe and functional under

various load conditions by considering both the potential for failure (ULS) and the acceptable level of functionality (SLS).

Key Aspects of Pile Design

Purpose:

To transfer structural loads from the superstructure to a deeper, more reliable bearing stratum, often avoiding shallow, weak soil layers.

Pile Types

Piles can be made of various materials like wood, steel, or concrete and are installed using methods like driving, drilling, or jacking. Soil investigation plays a significant role in the selection of pile type and estimation of the necessary length of the pile. Estimating the length of pile requires good technical judgment on the geotechnical site data. It can be classified depending on the load-transfer mechanism from the structure to the soil: -

- (a) end-bearing piles,
- (b) friction piles, and
- (c) compaction piles.

The ultimate load capacity of end-bearing pile depends on the load-bearing capacity of the underlying material at the tip of the pile. The necessary length of this type of pile can easily be estimated by determining the location of bedrock or a strong layer of soil as long as it is at a reasonable depth. For instances where a hard stratum is present rather than bedrock, the length of the pile can be extended for a few more meters into the soil layer, as shown in Figure 2b.

Friction piles

Friction piles (Figure 2c) are used when the bedrock layer or hard stratum doesn't exist or located at unreasonable depth. In that case, the use of end-bearing piles become very long and uneconomical. The ultimate load capacity of friction piles is derived from the skin friction developed along the length of the pile and the surrounding soil. Length of friction piles is relative to the shear strength of soil, applied load, and pile size.

Compaction piles

Compaction piles are a type of piles which are driven through granular soils to achieve proper compaction of soil near the ground surface. Length of compaction piles depends mainly on the relative density before and after the compaction, and the required depth of compaction. Compaction piles are generally shorter than the other types of piles.

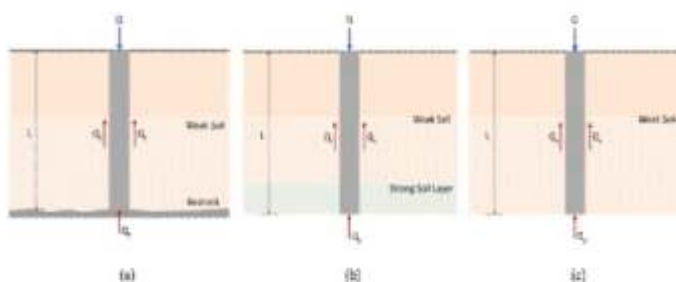


Figure 2: (a) and (b) End-bearing piles, (c) Friction Piles

Design Considerations

Soil Properties: Soil density, type, and bearing capacity significantly impact pile length and capacity. If the upper soil layers are too weak or highly compressible to support the loads transmitted by the superstructure, piles are used to transfer these loads into a stronger layer of soil or onto a bedrock. Piles that transmit loads into a bedrock are called end-bearing piles. This type of pile solely relies on the load-bearing capacity of the underlying material at the tip of the pile. On the other hand, when bedrock is too deep, piles can transmit the loads through the surrounding soil gradually by friction. This type of pile is called a friction pile.

Swelling or shrinking of soils may add a considerable amount of pressure to the foundation. It occurs on expansive or collapsible soils due to the increase or decrease in moisture content. It may also cause more damage for shallow foundations; in this case, piles can be used to extend the foundation beyond the active zone or where the swelling and shrinking might occur. Soil erosion at the ground surface may cause the loss of bearing capacity of the soil. This may severely damage structures with shallow foundations.

Load Requirements: The structure's weight and any lateral or uplift forces need to be considered. Piles are a more suitable foundation for structures subjected to horizontal forces. Piles can resist horizontal actions through bending while being able to transmit vertical forces from the superstructure. This is a typical situation for designing earth-retaining structures and tall structures subjected to high wind or seismic forces. Uplift forces are developed as a result of hydrostatic pressures, seismic activity, overturning moments, or any forces that may cause the foundation to be extracted from the ground. It is common on structures such as transmission towers, offshore platforms, and basements. In this situation, pile foundation is considered to resist these uplift forces.

Pile Material: The material's strength and durability in the soil environment are important.

Installation Method: The method used to install the piles (driving, drilling, etc.) can affect their behavior and capacity.

Design Methodology

Capacity Calculations: Various methods are used to determine the ultimate load-carrying capacity of a single pile, often considering end-bearing and skin friction.

Group Action: When piles are used in groups, their interaction and the overall group capacity need to be analyzed.

Settlement: Pile foundation settlements need to be assessed and controlled to ensure the structure's stability.

Lateral Resistance: The ability of piles to resist lateral loads, such as those from wind or seismic forces, is also a key design consideration.

Construction

Pile installation requires careful planning and execution to ensure the piles are properly installed and that the surrounding soil is not disturbed excessively.

Serviceability

Piles must be designed to withstand the loads imposed by the structure and to maintain their integrity over time, considering factors like corrosion and settlement.

In essence, pile design involves a comprehensive analysis of the site conditions, structural requirements, and construction methods to create a safe and reliable foundation system.

As discussed earlier, pre-foundation design data, such as pile type, length, and size, are pre-determined based on geotechnical report data. Some of the critical parameters which are necessary for further piles foundation design and analysis are the soil types, unit weight, shear strength, modulus of subgrade reaction, and groundwater data. Recent developments in structural engineering include structural design software which aims to enhance our skills as structural engineers and produce safe designs, especially with complex structures. There is various FEA software that we can use to model our structures and generate reactions, shear forces, and bending moments of the supports from the superstructure. The resulting data shall be then used for foundation design and analysis. Foundation design software for piles requires various input to perform design checks. It includes geometry data, soil profiles, material properties for concrete and steel reinforcements, reinforcement layouts, design parameters specified by the design codes, and the reaction data exported from the structural analysis software.

Historical

Pile foundations have been used as load carrying and load transferring systems for many years. In the early days of civilization [2], from the communication, defence or strategic point of view villages and towns were situated near to rivers and lakes. It was therefore important to strengthen the bearing ground with some form of piling. Timber piles were driven in to the ground by hand or holes were dug and filled with sand and stones.

In 1740 ChristoffoerPolhem invented pile driving equipment which resembled to days pile driving mechanism. Steel piles have been used since 1800 and concrete piles since about 1900. The industrial revolution brought about important changes to pile driving system through the invention of steam and diesel driven machines. More recently, the growing need for housing

and construction has forced authorities and development agencies to exploit lands with poor soil characteristics. This has led to the development and improved piles and pile driving systems. Today there are many advanced techniques of pile installation.

In Britain, a Roman bridge spanned the Tyne at Core bridges, about 20 miles west of Newcastle on Tyne, using piles to support the construction. The piles used in this were block oak and were 3mts in length. Amsterdam was founded about 1000 years ago, was built almost entirely on pile foundations of 15-20 meters of length. The Romans capped their piles with a mixture of stone rubble and concrete. Creasy (An Encyclopedia of Civil Engineering 1861) says that in Holland piling and capping by planking was still in use, with rough stones rammed between the planks.

Necessity of Pile Foundation

The pile foundation is necessary to resist the uplift forces created due to water table rise or any other cause. Uplift forces are more common in the construction of transmission towers and off-shore platforms. These structures will need pile foundations: -

- When the strata just below the ground surface is highly compressible and very weak to support the load.
- When the plan of structure is irregular to its outline and load distribution. It would cause non-uniform settlement.
- When horizontal forces in addition to vertical loads are to be resisted.
- When soil layer immediately below the structure are When structure is subjected to uplift, overturning moments subjected to scour.
- Where expansive soils, such as black cotton soil exist, which swells or shrink due to change in water content.
- In areas where settlement issues are common due to soil liquefaction or water table issues, pile foundation is a better choice.
- Pile foundation is necessary for areas where the structure surrounding has chances for soil erosion. This might not be resisted by the shallow foundations.
- Pile foundation is needed near deep drainage and canal lines.

Literature Review

Tomlinson Michael John and Murthy V. N. S. (1994) gives a good idea for the understanding of the behavior of pile under load. Murthy also gives a good sense of understanding for the failure of the single pile for specific type of soil and method of analysis for the pile group.

Varghese P.C. carried out the design of pile cap considering the case study of raja garden flyover which is situated in Delhi. The designing of the pile cap was done using the bending theory and truss analogy method. Various load combinations including seismic,

longitudinal and transverse loads were considered. Reinforcement details for each method were included. The load combinations considered for design of pile cap were the total vertical load, total longitudinal moment and total transverse moment. Load on pile cap had been calculated considering the maximum effects from normal case, seismic longitudinal case and seismic transverse case. In this paper the analysis was done by the bending theory and truss analogy method for the different pile caps under the flyover and maximum area of steel calculated by either of the method was provided. Gupta S. C. in this study, work carried out by S. C. Gupta was on the analysis method for calculating the bending moment of piles and results of it were supported by finite element analysis on computers. Most of the methods available for analysis of piles are given in standard books and Indian codes, are for single pile. The behavior of pile under combined axial and lateral loads is not defined in codes and in general literature. Most of the design engineers are designing piles based on length of fixity charts as given in IS 2911 Part 1. Further the work also includes the drawbacks for the moment calculation on the pile as per I.S. code and other formulas from which the code has suggested the method. To prove this drawback true, a pile group model was prepared with the help of finite element and STAAD Pro software. The general theory for the calculating the length of fixity suggested by code was the main concern for this study. The method for moment calculation on the single pile was suggested by the author and possible checks for the analysis were also included. The piles designed by the suggested method were not only economical but also safer. To prove this statement a case study on a real bridge design was considered, which were earlier designed based on the length of fixity calculation as per IS: 2911 and were crossed checked by the recommended method. This study concludes that the recommended method by not only economies the design by more than 30 percent in terms of flexural reinforcement but also reduces the overall length of the pile.

Ramamurtham S. gives a good example of the design for three pile group i.e. used for the triangular shape pile cap.

Tridibesh Indu had carried out the analysis work for different types of pile caps having different number of piles under it. Principles for the analysis were suggested and an illustration for a 4 pile rectangular cap under biaxially eccentric column load had been done, this principle was utilized for a few types of caps in respect of the application and scope of truss method. The paper includes the method to analysis for three pile group, hexagonal pile group and rectangular pile group. This paper was prepared and presented as the information on the application of the truss method for the design of the pile caps is scarce. The paper concludes that the approach provides conceptually elegant solutions for triangle, hexagonal and rectangular pile group, but then beam method should continue to be used as a safe general procedure

Stamante M. and Ganeselli L. (1982): - The design analysis according to the unified method indicate that the maximum load (sustained load plus drag load) is well within acceptable limits for the pile structural strength and that the expected settlement of the piled foundations will be smaller than the assigned limit of 25mm. Therefore, the performed tests prove that the project piles can be constructed to bearing in the glacial till and do not need to be taken onto or into the bedrock.

Fellelius H. and Ochoa M. (2009): Design for a large refinery expansion was undertaken at a site reclaimed from a lake 40 years ago. The natural soil consist of sand deposited on normally consolidated, compressible post glacial lacustrine clay followed by silty-clay till on limestone bedrock found at about 25m to 30m depth below existing grade. The site will be raised an additional 1.5m, which will cause long term settlement. Some of the new units are 30m to 70m in height and will be supported on piles several thousand in all. In anticipating negative skin friction to develop, the initial design called for subtracting the drag load from the allowable load determined from the pile capacity. Initial design also expected the piles to be constructed to bed rock. However a review of the design made clear that a drag load is a problem for the axial structural strength of a pile and should not be subtracted from an allowable load based on bearing capacity. Moreover analysis of the results of full scale static and dynamic loading tests demonstrated that it was not necessary to reach bedrock, but the pile would develop adequate capacity in the clay with till and they would not experience excessive down drag due to settling clay. The final revised design resulted in a saving of close to 25 million dollars and considerable construction time. The piles selected for the foundation were 457mm (18") diameter bored piles installed to about 1.5m into the glacial till. The paper presents site conditions, test results, and the design principles employed.

IS: 2911 The load carrying capacity calculation formula for single pile for different soil conditions are taken from Code gives the useful information for the design consideration for the bored pile, driven pile and pile cap for the pile group. Spacing, behavior of the pile in the pile group and reinforcement specifications for the pile group are used as per recommended by the code. The lateral resistance of the single pile is calculated using the code method. Bearing capacity is taken from the code.

Bowles J.E. [2] had a new concept based on the shifting rate of piles, and the settlement rate of the surrounding soils has been suggested for the study of negative skin friction. Negative skin friction occurs when the settlement rate of the surrounding soils is greater than that of the piles. Some relative equations have been established to define the negative friction zone of piles. Negative skin friction is dependent on the time factor and the degree of consolidation of the soil mass and can be negligible when the soil mass is nearly completely consolidated.

Arora K. R. gives a good idea about the classification of the different types of piles. General theories for the analysis of the single pile and brief knowledge of the pile group are also taken from this reference.

From the literatures referred, the following things are taken: -

A complete analysis of single pile for its load bearing capacity, is considered with different types of soils with different consistency, different density having different angle of internal friction and layers of sand and clay is carried out which also includes different pile parameters such as diameter, length and type of installation of it. The analysis is done with the IS 2911: 1979 code provisions.

The analysis method solved in the literature gives dimensions of the individual pile as per the soil data and given load.

Nine cases were solved in it for the evaluation of the bearing capacity of the individual pile considering different pile cap shapes i.e. triangular, square and rectangular for different types of the soil condition i.e. sand, present. The results are tabulated in table in the literature.

Pile cap with pile group analysis of different shapes mainly triangular, square and rectangular consisting of the different number of shapes is done.

The analysis for the pile group gives the ultimate bearing capacity of pile group by group action and by individual action, number of piles as per the soil condition and given load.

To get the idea of load carrying capacity of the pile group, in the literature different number of piles in a group were considered with pile having shape circular and square varying in the size from 0.15 m to 0.40 m in cohesion and cohesion less with different types of soil conditions. The variations of about 9 cases for single pile and pile group capacity were solved in it.

As given in the literature design of the different pile cap geometry having circular shape of piles under it is prepared showing the reinforcement details, considering the different type of loads i.e. vertical load acting on the pile cap.

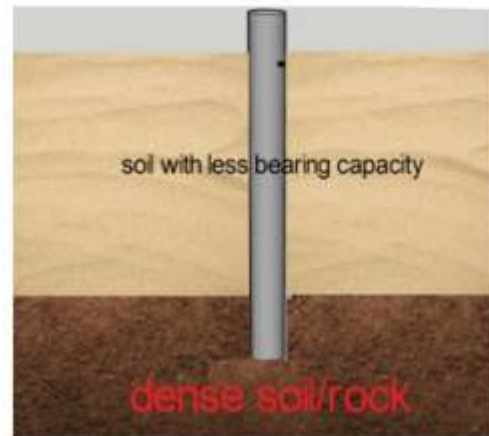
To know the most economical pile group for some given constant load conditions, 9 different cases were taken in the reference, considering the variation in number of piles in a group, shape of pile and soil conditions.

Choice of Pile Foundation

Pile foundations are preferred in areas with weak or compressible soil, where surface conditions cannot support the required structural loads.

- When the groundwater table is very high, other types of open foundations require huge dewatering. This is done by the well point or deep bore well method. It turns out to be quite expensive and not feasible.
- When heavy and non-uniform distribution of loads from the superstructure which causes unequal settlements in open foundations.

- The low soil bearing capacity makes the design of shallow foundations very conservative. Site



Function of piles

As with other types of foundations, the purpose of a pile foundations is: -

to transmit a foundation load to a solid ground to resist vertical, lateral and uplift load. A structure can be founded on piles if the soil immediately beneath its base does not have adequate bearing capacity. If the results of site investigation show that the shallow soil is unstable and weak or if the magnitude of the estimated settlement is not acceptable a pile foundation may become considered. Further, a cost estimate may indicate that a pile foundation may be cheaper than any other compared ground improvement costs. In the cases of heavy constructions, it is likely that the bearing capacity of the shallow soil will not be satisfactory, and the construction should be built on pile foundations. Piles can also be used in normal ground conditions to resist horizontal loads. Piles are a convenient method of foundation for works over water, such as jetties or bridge piers.

Classification of piles

Classification of pile with respect to load transmission and functional behavior: -

- End bearing piles (Point bearing piles)
- Friction piles (Cohesion piles)
- Combination of friction and cohesion piles
- Batter pile**
- Anchor pile**
- Sheet pile**

NIEEE PRESIDENTIAL HANDOVER CEREMONY



The Presidential Handover Ceremony of the Nigerian Institute of Electrical and Electronic Engineers (NIEEE) was successfully held at the NIEEE National Secretariat on Tuesday, 30th December 2025. The ceremony marked the formal transition of leadership between the 21st President of NIEEE, Engr. Felix O. Olu, FNIEEE, and the 22nd President, Engr. Felix Adegboye, FNIEEE. Although traditionally a brief and modest event, the handover ceremony was significantly enhanced on this occasion to allow distinguished personalities, senior members of the Institute, and key stakeholders to witness the historic transition. In attendance were eminent Fellows and leaders of the engineering profession, including the Past President of NIEEE, Engr. John Funso-Adebayo, FNIEEE; Past President of NIEEE and current President of CIEEN, Engr. Kings Adeyemi, FNIEEE, accompanied by his wife; and the Pioneer Immediate Past Executive Secretary (IPES) of NIEEE and Registrar of CIEEN, Engr. Isibor Simeon, FNIEEE. Also present were Engr. Atinuke Wuraola Owolabi, FNIEEE; the Incoming Vice President of the ICTE Section and Chairman of the 22nd Presidential Investiture Planning Committee, as well as a Member of the Board of Fellows (BoF), Engr. Adetunji Obakeye, FNIEEE. Other dignitaries included the Deputy Chairman of the Abuja Chapter, Engr. Lydia Oluwaniran, FNIEEE; Past Chairman of Abuja Chapter, Engr. Josiah Ahueyi, FNIEEE; and the Immediate Past Chairman (IPC) of Abuja Chapter, Engr. Ayila A. Cletus, FNIEEE. The ceremony was further attended by other members of NIEEE, the Institute's Legal Advisers, External Auditors, representatives of the print media, and other service providers to the Institute. The handover proceedings were presided over by the Executive Secretary of NIEEE, Engr. Kazeem Lawal, FNIEEE.* Following the opening prayer, the outgoing President, Engr. Felix O. Olu, FNIEEE, delivered his remarks and valedictory address, during which he highlighted key achievements

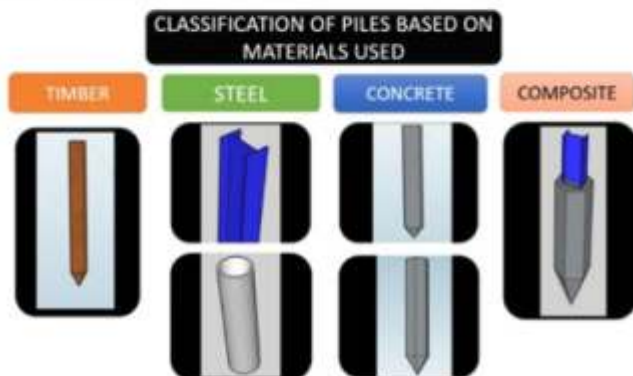
recorded over his 32-month tenure. He also offered strategic guidance and advice to the incoming President, identifying critical areas for improvement, growth, and expansion of the Institute. Subsequently, the Oath of Office was administered to the Incoming President. The Presidential Medallion, symbolizing the authority and leadership of the Institute, was thereafter formally handed over to the 22nd President of NIEEE, Engr. Felix Adegboye, FNIEEE, signifying the successful completion of the leadership transition.

In his acceptance speech, the 22nd President expressed deep gratitude to the entire membership for the confidence reposed in him and pledged to lead the Institute with vision, inclusiveness, innovation, and unwavering commitment to excellence. He emphasized that his administration would focus on consolidating existing achievements while reimagining the future of NIEEE. "With deep humility and a strong sense of duty, I accept the responsibility to serve as the 22nd President of the Nigerian Institute of Electrical and Electronic Engineers. I am grateful for the trust the entire membership has placed in me. The next two years will be dedicated not only to consolidating our gains but to reimagining the future of NIEEE—one that is nationally influential, globally relevant, professionally respected, and strategically aligned with emerging technologies and societal needs."

Following the acceptance speech, goodwill messages were delivered by the Past President, Engr. John Funso-Adebayo, FNIEEE; Engr. Kings Adeyemi, FNIEEE; Engr. Atinuke Wuraola Owolabi, FNIEEE; and the Representative of the Abuja Chapter Chairman, Engr. Lydia Oluwaniran, FNIEEE. The speakers commended the outgoing President for his service and achievements, while encouraging and charging the incoming President with the responsibilities of leadership ahead. The ceremony concluded with a vote of thanks delivered by *the Executive Secretary,* after which a group photographs were taken. Members of the Institute rejoiced with the 22nd President and congratulated him on the successful and seamless transition of leadership.

Classification of pile with respect to type of material

Timber
Concrete
Steel
Composite piles



Classification of piles based on material used

Timber piles

Used from earliest record time and still used for permanent works in regions where timber is plentiful. Timber is most suitable for long cohesion piling and piling beneath embankments. The timber should be in a good condition and should not have been attacked by insects. For timber piles of length less than 14 meters, the diameter of the tip should be greater than 150 mm. If the length is greater than 18 meters a tip with a diameter of 125 mm is acceptable. It is essential that the timber is driven in the right direction and should not be driven into firm ground. As this can easily damage the pile. Keeping the timber below the ground water level will protect the timber against decay and putrefaction. To protect and strengthen the tip of the pile, timber piles can be provided with toe cover. Pressure creosoting is the usual method of protecting timber piles.

Advantages of timber piles

- Timber piles are available in varied sizes and is cheaper than any other type of piles.
- It is easy to install and can be cut into any size as per the requirements.
- Timber piles is more reliable in marine works.
- Timber piles doesn't decay even when submerged in water for a prolonged time.

Disadvantages of timber piles

- It is difficult to get straight and long timber piles.
- Timber piles may not pass through all strata. It is difficult to drive piles in hard and dense strata.
- Timber piles can be used only as friction piles and not as end bearing piles. Splicing of a timber pile is difficult.
- As a prevention against possible decay timber piles has to be treated with preservatives.

Concrete pile

Pre-cast concrete Piles or Pre-fabricated concrete piles: Usually of square (see fig 1-4 b), triangle, circle or octagonal section, they are produced in short length in one metre intervals between 3 and 13 meters. They are pre-cast so that they can be easily connected together in order to reach to the required length (fig 1-4 a). This will not decrease the design load capacity. Reinforcement is necessary within the pile to help withstand both handling and driving stresses.

DIFFERENT TYPES OF CONCRETE PILES



Pre stressed concrete piles are also used and are becoming more popular than the ordinary pre cast as less reinforcement is required.

Different type of concrete pile: -

- Precast concrete pile
- Pre-stressed concrete pile
- Cast-in-situ
- Composite pile

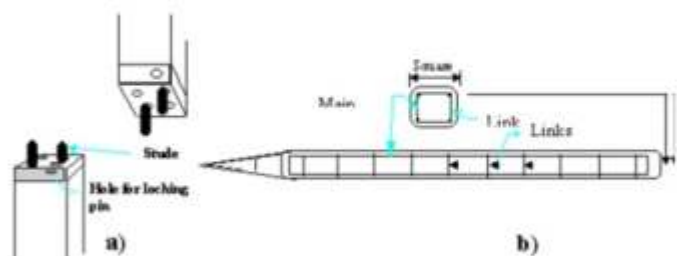


Figure 1-4 a) concrete pile connecting detail. b) square pre-cast concrete pile.

Pre-cast Concrete Pile

Precast pile uses conventional RCC. Piles are casted in a fabrication yard and conveyed to the location for erection. Precast pile are either square or round. The rectangle or square shaped piles are casted in a horizontal fabrication bed and round pile is casted vertically. Precast piles are designed to take care of the loads/stresses developing while lifting, conveying and driving.

The Hercules type of pile joint (Figure 1-5) is easily and accurately cast into the pile and is quickly and safely joined on site. They are made to accurate dimensional tolerances from high grade steels.



Figure 1-5 Hercules type of pile joint

Pre-stressed Concrete Pile

Pre-stressed concrete pile is preferred when the sizes of the precast piles go beyond a certain limit. Pre-stressing can optimize the pile size drastically making it very easy to lift, convey and erect. Pre-stressing is done by stretching the tendons and pouring concrete keeping the tendons in a stretched position. Once the concrete develops full strength the tendons are released. The

released tendons in the process of regaining its shape induces compressive stresses in the member.

Pre-stressing convert the pile into a high load carrying member which can resisting the stresses due to the impact loads generated on driving, the uplift forces and the combined moments. These piles can be used for an optimum design depth of 25-35 mtrs.

Cast-In-Situ Concrete Piles

Cast in situ piles are constructed by drilling a bore hole to the required level and filling it with Reinforced cement concrete. The bore hole can be formed by excavating ground with the help of a rotary drilling equipment or hydraulic rigs. Casings are driven into the bores locations before drilling. The casing will be removed gradually during concreting process or sometimes left in the bore as a permanent casing



Advantages of Cast-in-Situ Concrete Piles

Cast in situ piles are very flexible and the process of execution is easier compared to driven piles and other type of piles.

The reinforcement cages are light weight and easy to handle. The rebar cages are fabricated with the help of simple and conventional tools.

No chances of breakage during installation stage.

If there is some issue with the pile that prompts the customer to abandon, additional substitution piles can be done.

Disadvantages of Cast-in-situ Concrete Piles

- Installation requires careful supervision and quality control. Because once a pile gets abandoned executing a replacement pile is expensive and time consuming.
- Cast in situ piles generate a lot of pile muck (Mix of bentonite and soil). The pile muck has to be removed and disposed as per environmental policy. The pile head chipping also generates lot of concrete waste which has to be disposed.
- Requires space for movement of Rigs, cranes, stocking of materials and bentonite tank.
- Under water flow can collapse the piles.
- Concrete quality cannot be visualized. Hence health assessment tests like pile integrity test are to be conducted to confirm the pile integrity.

Composite Piles

A composite pile is made up of two or more sections of different materials or different pile types. The top portion shall be casted using concrete and the other portions shall be of steel or timber. These type of piles



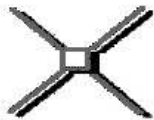
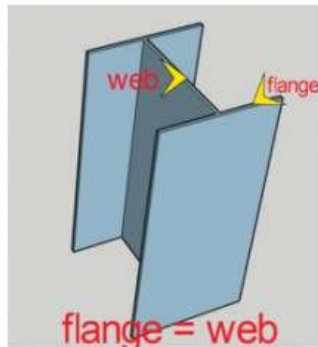
Driven and cast in place Concrete piles

Two of the main types used in the UK are: - West's shell pile: Pre cast, reinforced concrete tubes, about 1 m long, are threaded on to a steel mandrel and driven into the ground after a concrete shoe has been placed at the front of the shells. Once the shells have been driven to specified depth the mandrel is withdrawn and reinforced concrete inserted in the core. Diameters vary from 325 to 600 mm.

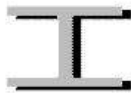
Franki Pile: - A steel tube is erected vertically over the place where the pile is to be driven, and about a metre depth of gravel is placed at the end of the tube. A drop hammer, 1500 to 4000 kg mass, compacts the aggregate into a solid plug which then penetrates the soil and takes the steel tube down with it. When the required depth has been achieved the tube is raised slightly and the aggregate broken out. Dry concrete is now added and hammered until a bulb is formed. Reinforcement is placed in position and more dry concrete is placed and rammed until the pile top comes up to ground level.

Steel piles

Steel piles: (figure 1.4) steel/ Iron piles are suitable for handling and driving in long lengths. Their relatively small cross-sectional area combined with their high strength makes penetration easier in firm soil. They can be easily cut off or joined by welding. If the pile is driven into a soil with low pH value, then there is a risk of corrosion, but risk of corrosion is not as great as one might think. Although tar coating or cathodic protection can be employed in permanent works. It is common to allow for an amount of corrosion in design by simply overdimensioning the cross-sectional area of the steel pile. In this way the corrosion process can be prolonged up to 50 years. Normally the speed of corrosion is 0.2-0.5 mm/year and, in design, this value can be taken as 1 mm/year.



a) X- cross-section



b) H – cross-section



c) steel pipe

Figure 1-6 Steel piles cross-sections

Advantages of steel piles

Steel piles are very easy to install. Due to their less cross sectional area it can penetrate through any type of soil layer with minimal soil displacement.

Splicing of steel piles are easy and it can go to any depth compared to other type of piles.

The penetrating properties of steel piles helps to go deep and hence can carry more loads than other pile types.

Disadvantages of steel piles

Steel piles are corrosion prone and has to be coated with anti-corrosive coatings before driving.

While encountered with a hard strata the H sections tends to deform or sometimes the verticality of pile is lost while driving.

The steel piles are very expensive.

Composite piles

Combination of different materials in the same of pile. As indicated earlier, part of a timber pile which is installed above ground water could be vulnerable to insect attack and decay. To avoid this, concrete or steel pile is used above the ground water level, whilst wood pile is installed under the ground water level (see figure 1.7).

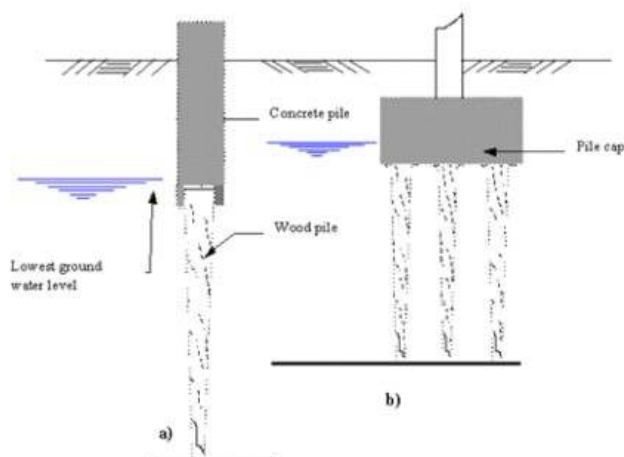


Figure 1-7 Protecting timber piles from decay:

- a) by pre-cast concrete upper section above water level.
b) by extending pile cap below water level

Classification of pile with respect to effect on the soil or construction methods

A simplified division into: -

- **Driven or displacement method**
- **Bored or replacement method**

Driven or displacement piles

Driven piles are considered to be displacement piles. In the process of driving the pile into the ground, soil is moved radially as the pile shaft enters the ground. There may also be a component of movement of the soil in the vertical direction. Displacement piles are basically designed to be installed without removal of soil. Special equipment are used to drive the piles and displace soil laterally. Depending on situations these types of piles are preferred over bored piles.

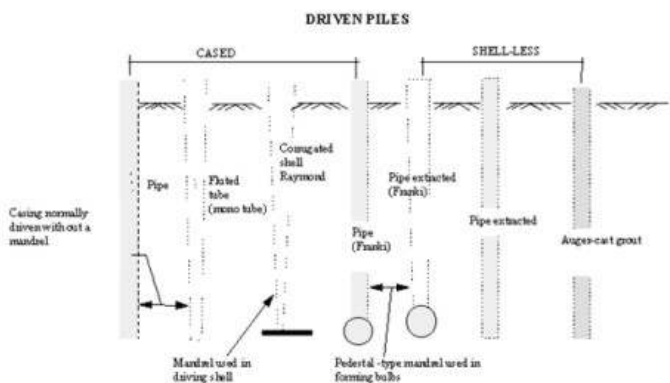


Figure 1-8 driven piles

Bored or replacement piles

Bored piles (Replacement piles) are generally considered to be non-displacement piles a void is formed by boring or excavation before piles is produced. Piles can be produced by casting concrete in the void. Some soils such as stiff clays are particularly amenable to the formation of piles in this way, since the bore-hole walls do not require temporary support except close to the ground surface. In unstable ground, such as gravel the ground requires temporary support from casing or bentonite slurry. Alternatively the casing may be permanent, but driven into a hole which is bored as casing is advanced. A different technique, which is still essentially non-displacement, is to intrude, a grout or a concrete from an auger which is rotated into the granular soil, and hence produced a grouted column of soil. There are three non-displacement methods: bored cast-in-place piles, particularly pre-formed piles and grout or concrete intruded piles.

The following are replacement piles: -

- Augered
- Cable percussion drilling
- Large-diameter under-reamed
- Types incorporating pre cast concrete units
- Drilled-in tubes
- Mini piles

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INAUGURATION OF ENGR. SIR FRANCIS ORIAKHI, FNSE, FNIHTE, KSM, AS THE 6TH CHAIRMAN OF NIHTE AND SWEARING IN OF EXCO MEMBERS



6TH ENGR. FYNE CHIMA OGOLO, FNSE, FNIHTE, MVHTE DISTINGUISHED ANNUAL LECTURE IN PICTURES



Potential of Blended Calcined Clay in Rutting Pavement Failure Reduction on Nigerian Roads due to Heavy Axles

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ABSTRACT

The potential of blended calcined clay as stabilizer to weak Ota-Idiroko road subgrade material (S) in reducing rutting failure under heavy axle configurations and at different pavement layer thickness combinations had been evaluated with this study. In order to determine Optimum Subgrade Lime Blend [OSLB] (blend with least Plasticity Index value), subgrade was initially modified with calcium carbide waste (CCW) by weight (0, 4, 8, 12, 16 and 20%) through Atterberg limit test. The blend of S+8%CCW with least PI (8.7%) was consequently used to activate the pozzolanic tendency of calcined clay (CC) by weight (3, 6, 9, 12, 15, and 18%). The blends were subjected to California bearing ratio (CBR), Elasticity modulus (E) and Density tests. Parameters from these tests were deployed to simulate the Horizontal Tensile Strain at the Bottom of Asphaltic Cover under the application of Truck 2 and Truck 7 Axles for each blend from where Number of Load Repetitions to Rutting Failure (Nr) and Damage Factor due to Rutting Failure (Dr) were determined using ANSYS Finite Element Software. The stabilized blends were modeled to have a uniform thickness of 1000 mm and an overlying layers of three different pavement layer thickness combinations of Subbase (150 mm, 200 mm, 250 mm), Base (150 mm, 200 mm, 250 mm) and Asphaltic Cover (40 mm, 60 mm, 100 mm) to represent Pavement layer thickness variations 1 to 3 respectively. Results showed that stabilization of weak subgrade with all blends of 8%CCW-CC effectively reduced Vertical Compressive Strain on top of Subgrade, Damage factor due to Rutting failure and increased the Number of Load Repetitions to Rutting failure under the applications of Truck 2 and Truck 7 Axles with the blends of OSLB+9%CC exhibiting best performance which was majorly a function of its high Elasticity modulus value (184.271MPa).

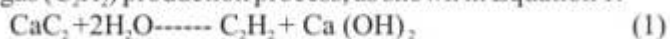
Keywords: Subgrade, Rutting failure, Damage factor, Calcined Clay

1.0 INTRODUCTION

Prominent highway researchers and engineers (Abiola *et al.*, 2010; Oduola, 2010; Osadebe *et al.*, 2013; Quadri *et al.*, 2019) in Nigeria through their various research findings substantiated the presence of weak subgrade soils in the nooks and crannies of the country as major factor responsible for premature pavement failures being experienced in the country (Oduola, 2010; Tijani *et al.*, 2017).

Stabilization technique was recommended by most of these stakeholders as one of the major ways of improving the properties of the weak or expansive soils to ensure longevity of these roads (Alabiet *et al.*, 2015; Alhassan and Alhaji, 2017; Babafemi *et al.*, 2017; Okafor and Ebge, 2016; Salahudeen *et al.*, 2014; Quadri *et al.*, 2019). A number of materials such as Fly ash, Rice Husk ash, cement, lime, cement dust, steel slag etc had been used by various researchers (Oduola, 2010; Sabat and Pati, 2014; Roy, 2014) to improve properties of weak or expansive soils and they had been found to be effective.

Calcium carbide residue (CCR), otherwise known as calcium carbide waste (CCW), is another form of industrial waste which is a by-product obtained from the acetylene gas (C_2H_2) production process, as shown in Equation 1.



Acetylene (C_2H_2) gas is widely used for welding in industry, while the by-product is often discarded as waste in landfills and thus poses a threat to the environment. However, in Nigeria CCR is highly abundant as an average of 750 tons of the waste is generated daily by panel beaters; translating to about 273,750 tons on an annual basis

(Chukwudebeluet *et al.*, 2013). CCR is mainly composed of calcium hydroxide with a mass fraction of above 92% and is highly alkaline with a pH > 12 (Sun *et al.*, 2015). It has been found that mixing CCR with certain pozzolans, which have high silicon dioxide (SiO_2) or aluminum oxide (Al_2O_3) content, could yield pozzolanic reactions, resulting in final products that are similar to those obtained from the cement hydration process (Wang *et al.*, 2013).

Quite a good number of highway researchers had worked on performance of stabilized weak subgrade in flexible pavement using finite element methods. Khabiri (2010) studied effect of stabilized subbase containing waste construction materials on reduction of pavement rutting depth and concluded that increase in lime percent between 2 to 6 percent led to extraordinary decrease in compressive strain on subgrade soil of pavement. Use of waste materials up to 20% caused a large decrease in compressive strain and it led to decrease in rutting depth. Use of waste material construction materials and its stabilization with lime to an average of 20% resulted in reduction of rutting depth or increase in asphalt pavement lifetime.

Gupta and Kumar (2014) worked on comparative structural analysis of flexible pavements using finite element method. They concluded that KENLAYER could be used to predict the performance of flexible pavement more easily and efficiently since it is more user-friendly. They added that subgrade modulus was the key element controlling the excess vertical surface deflection on flexible pavement with base course and surface layer modulus having minor effects on the excess vertical deflection in flexible pavement.

Oufet *et al.* (2016) evaluated stabilized pavement sections

using finite element modeling. They concluded that the vertical displacement and total stress increased with increase in load pressure. The significant reduction in vertical displacement and total stress occurred after stabilizing 20 and 30 cm of subgrade layer. The presence of 10 and 15 cm base layer led to significant reduction in the vertical displacement and total stress. Stabilization of subgrade provided a significant improvement in pavement section performance in the case of no base layer more than the case of the presence of base layer. Improvement in subgrade properties; young's modulus, density, cohesion and internal friction angle led to enhancement of the pavement section performance.

Saing (2017) worked on vertical deformation of lime treated base (LTB) model of laterite soil using numerical analysis. He concluded that lime stabilization on the laterite soil reached a maximum condition of 10% with 28 days curing time. At this maximum condition, the vertical deformation decreased three times less than the soil without stabilization. Lime treated base (LTB) layer met the maximum vertical deformation requirement of L/240 on lime addition of 7 and 10% based on the results of numerical analysis (Plaxis 2D) on the laterite soil with lime stabilization deformation model.

Tapase and Ranadive (2018) researched on predicting performance of flexible pavement using finite element method and observed that the value of tensile strain at the bottom of base course increased by 215.33% and 254.48% by an overloading in standard axle load by 2 times and 2.5 times respectively. A noticeable increase of around 252.95% and 336.40% was observed due to overloading of the standard axle load by 2 times and 2.5 times respectively. Based on their analysis, pavement started deteriorating earlier as the overloaded vehicles were consuming the designed life of the pavement, hence the conclusion that pavement should be designed considering the uncontrollable overloading of the vehicles instead of relying on the standard or legal limits.

However, rather than employing the conventional cement stabilizer for road material, locally sourced waste materials (CCW and clay) were employed because of their affinity to undergo hydration reaction in the presence of water when in finely divided form. This will in turn reduce menace of greenhouse gas emission characterized or associated with cement production and also, reduce menace CCW constitutes to the environment. This study evaluated the potential of blend of CCW and CC as stabilizer to the weak Ota-Idiroko road subgrade material in reducing rutting failure under heavy axle configurations and at different pavement layer thickness combinations using finite element software; ANSYS.

2.0 MATERIALS AND METHODS

The weak subgrade soil was sourced at a section (Latitude 6° 40' 53.082° N and Longitude 3° 9' 11.172° E) along Ota-Idiroko road while CCW and natural clay were both sourced from Automobile workshop in Ota and Owode-Ketu respectively in Ogun State, Nigeria. The CCW was air-dried, ground to fineness and sieved through 4.25µm aperture while the natural clay was air dried, calcined at a temperature of 700°C for 2 hours in the Kiln before being ground to fineness and sieved through 4.25µm aperture. The subgrade soil was subjected to Particle size distribution and Atterberg's limits according to BS 1377 (1990) in order that it can be classified according to American Association of Highway and Transportation

Officials (AASHTO) Classification and Unified Soil Classification System (USCS). The materials were also subjected to X-ray Fluorescence (XRF) test to determine their oxide contents. Subgrade soil was consequently modified with CCW in varying proportions by weight of soil (0, 4, 8, 12, 16 and 20%) to determine the Optimum Subgrade Lime Blend (OSLB), that is, the blend with the least PI value since the major essence of lime addition to expensive soil is to reduce its swell potential and PI as reported in FMW Highway Manual Part 1 (2013). The blend of S+8%CCW exhibited least PI value (8.7%), hence, OSLB. OSLB was blended by weight with CC to activate its pozzolanic tendency in the following percentage replacements (3, 6, 9, 12, 15 and 18%). The blends were cured for 7 days, soaked for 24 hours before subjecting them California bearing ratio (CBR) test according to BS 1377 (1990). These blends in cylindrical form (120 mm x 100 mm) were produced and moistly cured for 7 days and were subjected to compression test according to BS 1377 (1990) in order to determine their densities and elasticity modulus (E). A 7 day Traffic count was conducted for 2 hours (between 6.00am and 6.00pm) on Ota-Idiroko road at different strategic locations (Honda Bus Stop, Bells University Main Gate and A.U.D Primary School) along the road owing to their proximity to Industrial Estates in both Ota and Agbara which attract heavy axle vehicles. This was done in order to evaluate the Equivalent Single Axle Load (ESAL) using Equation 2 and characterizes the various axles on the road; most especially the most frequent heavy axle and the heaviest heavy axle on the road for stabilized weak subgrade performance. The blends of OSLB-CC were simulated using ANSYS Finite element based software in order to evaluate their resistances to Rutting failure (Nr) when subjected to Truck 2 axle (most frequent heavy axle) and Truck 7 axle (heaviest axle) employing some parameters as captured in Tables 1 to 2 with Tyre Pavement Contact Area of 225 mm x 155 mm and Tyre Contact Pressure of 600 kPa. Pavement model dimensions of 13, 800 mm x 3600 mm (Truck 2) and 23, 000 mm x 3600 mm (Truck 7) were adopted owing to variations in lengths of Truck 2 axle and Truck 7 axle. The Rutting failure and Damage factor due to Rutting were evaluated using equations 4 and 5 respectively according Asphalt Institute (AI). The load equivalency factor and Axle load per vehicle category were evaluated using Equations 5 and 6.

Equivalent Single Axle Load Calculation according to Huang (2004),

$$ESAL = (ADT)_0 (T) (T_r) (G) (D) (L) (365) (Y) \quad (2)$$

T = 0.033 (% of trucks on the ADT)

ADT = 104, 257

D = 0.5 (Directional distribution factor)

Y = 1

L = 0.9 (Lane distribution factor) according to AASHTO (1986)

T_r = 0.21 (Truck factor)

G = 0.5 {1 + (1 + 0.04)¹} at 4% growth rate = 1.02

$$\text{Modulus of Rupture} = M_R = 17.6 \times CBR^{0.64} \text{ (N/mm}^2\text{)} \quad (3)$$

$$N_r = 1.3654 E_c^{-4.477} 10^{-9} \quad (4)$$

E_c = Compressive Strain on Top of Subgrade

$$D = \sum \frac{N_i}{N} \quad (5)$$

N_i = Actual Number of Load Repetitions or ESAL

N = Number of Load Repetitions to failure

Table 1: Flexible Model Input Data for Simulation

Pavement layer	Thickness of pavement layer (mm)			Density (kg/m ³) (7 Days)	Elasticity Modulus (MPa)	Soaked CBR (%) (7 Days)	Poisson ratio
	Pavement Variation 1	Pavement Variation 2	Pavement Variation 3				
Wearing Course (AC)	40	60	100	2330	3450	-	0.35
Base Course	150	200	250	2100	290.73	80	0.3
Subbase	150	200	250	2000	155.19	30	0.4
Subgrade, S (0%)		1000		1856.6	37.54	0	0.45
S + 8% CCW (OSLB)		1000		1856.6	96.754	100.1	0.45
OSLB+3%CC		1000		1803.5	103.883	74.7	0.45
OSLB+6%CC		1000		1824.7	129.854	71.3	0.45
OSLB+9%CC		1000		1856.6	184.271	94.8	0.45
OSLB+12%CC		1000		1909.6	134.453	100.8	0.45
OSLB+15%CC		1000		1856.6	162.859	94.5	0.45
OSLB+18%CC		1000		1909.6	183.506	101.9	0.45

Note: Equation 3 was used to determine values adopted as elasticity modulus values of subbase and base in Table 1.

Table 2 (a – b): Axle Load Calculation

Category of vehicle	Code	Total axle load Distribution (tonnes)	Axle load (kg)	Axle load (kN)
Truck 2 Axle	1 - 2	18	18000	176.58
Truck 7 Axle	1 - 2.2.2 - 2.2.2	51	51000	500.31

Category of vehicle	Axle load (kN)	Load Per Axle (kN)						
		Axle 1	Axle 2	Axle 3	Axle 4	Axle 5	Axle 6	Axle 7
Truck 2 Axle	176.58	58.823	117.76	-	-	-	-	-
Truck 7 Axle	500.31	58.823	73.581	73.581	73.581	73.581	73.581	73.581

- 1 – Single wheel single axle
 2 – Double wheel single axle
 2.2.2 – Double wheel triple axle

$$\text{Load Equivalency factor (LEF)} = \left(\frac{\text{Axle load}}{\text{Standard ESAL}} \right)^4 \quad (6)$$

$$\text{Axle Load (per vehicle category)} = (\sqrt[4]{\text{LEF}}) \times \text{standard ESAL} \quad (7)$$

Standard ESAL = 18, 000 lb (80 kN)

3.0 RESULTS AND DISCUSSION

3.1 Physical and Chemical Properties

The natural subgrade was classified as A-7-5 (fair to poor subgrade) and ML or OL (inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity) soil according to AASHTO and Unified Soil Classification System respectively owing to its liquid limit of 46%, plasticity index of 14.8% and percentage passing sieve no. 200 of 64.21%. The sum of Al₂O₃ and SiO₂ for oven dried subgrade soil as observed in Table 3 is 78.43%. This is attributed to a very high content of clay minerals present in the subgrade soil (Mousavi and Karamvand, 2017). Calcined clay (CC) was found to be pozzolanic in nature and belongs to Class F according to ASTM: C618-08 standard owing to the aggregation of the three main oxides (SiO₂ + Al₂O₃ + Fe₂O₃) which was found to be 85.2%. Inspecting Table 3, CCW contains 93.74% mass fraction of clinker or quick lime (CaO) which makes it a potent binding material/binder with tendency to undergoing hydration reaction when mixed with water just as in the case of cement.

Table 3: Physical and Chemical Properties

Parameters	Subgrade	Calcium Carbide Waste	Calcined Clay
Liquid limit (%)	46	-	-
Plasticity Index (%)	14.8	-	-
Percentage Passing Sieve No. 200 (%)	64.21	2.975	-
AASHTO Classification	A-7-5	-	-
USCS Classification	ML or OL	-	-
Colour	Reddish-Brown	White	Darkish brown
SiO ₂	49.57	0.83	58.86
Al ₂ O ₃	28.86	0.71	16.23
Fe ₂ O ₃	15.58	0.20	10.11
CaO	0.53	93.74	3.25
Loss on Ignition (LOI)	3.10	0.96	2.20

3.2 Traffic Characteristics of Ota-Idiroko Road and Equivalent Single Axle Load Estimation

The total traffic volume recorded on Ota-Idiroko road was found to be 729, 800 with an Average Daily Traffic (ADT) of 104, 257. Out of the total traffic volume of 729, 800 vehicles, 24, 110 were heavy axle vehicles (from Truck 2 axle to Truck 7 axle) which accounted for 3.304% of the total traffic volume. A total of 386, 014 passenger cars, 220, 446 motorcycles and 99, 230 tricycles were also recorded and accounted for 52.89%, 30.210% and 13.596% of the total traffic volume respectively as shown in Table 4. An Equivalent Single Axle Load (ESAL) of 121, 044 was recorded on the road.

Table 4: Summary of Traffic Data Characteristics of Ota-Idiroko road

Type of vehicle	Honda Bus Stop, Ota		Bells University gate, Ota		N.U.D Primary School, Atan-Ota		Total	
	Idiroko bound	Ota bound	Idiroko bound	Ota bound	Idiroko bound	Ota bound	Idiroko bound	Ota bound
Heavy vehicles	5001	4452	4609	4143	2967	2938	12577	11533
Passenger cars	66802	73070	64400	68730	51564	61448	182766	203248
Tricycles	21139	21805	23074	21013	66093	6106	50306	48924
Motorcycles	42352	52045	42967	46979	18305	17798	103624	116822
Total							349273	380527

Total Traffic Volume on both directions = 729800

Average Daily Traffic (ADT) = 104257

Number of Heavy Vehicles = 24110

Overall Percentage of Heavy Vehicles = 3.304%

Overall Percentage of Passenger cars = 52.89%

Overall Percentage of Motorcycles = 30.21%

Overall Percentage of Tricycles = 13.596%

3.3 Rutting Failure and Damage Factor due to Rutting Analyses of Stabilized Subgrade due to Truck 2 Axle

Table 5 shows the compressive strain results of the blends at different pavement thickness combinations (pavement variations 1 to 3) when subjected to Truck 2 axle load. It was observed that stabilization of weak subgrade with different variations of 8%CCW-CC reduced its vertical compressive strain on top of subgrade from 2.64E-04 to 8.52E-05 for pavement variation 1, 2.04E-04 to 5.85E-05 for pavement variation 2 and 1.60E-04 to 3.24E-05 for pavement variation 3 with optimum reduction at OSLB+9%CC for the three pavement layer thickness variations.

Table 6 shows the Number of repetitions to rutting failure (Nr) and Damage factor due to rutting (Dr) results of the stabilized weak subgrade blends where it showed that stabilization of weak subgrade with varying proportions of 8%CCW-CC increased Number of repetitions to rutting failure from 1.42E+07 to 2.26E+09 for pavement variation 1, 4.55E+07 to 1.22E+10 for pavement variation 2, and 1.36E+08 to 1.71E+10 for pavement variation 3 with optimum increment at OSLB+9% for all the three pavement layer thickness variations. Stabilization with these blends also reduced the Damage factor due to rutting failure from 8.50E-03 to 5.35E-05 for pavement

variation 1, 2.66E-03 to 9.92E-06 for pavement variation 2, and 8.93E-04 to 7.07E-07 for pavement variation 3 with optimum reduction at OSLB+9%CC for all the pavement layer thickness variations. Plates 1 to 3 show the pictorial views of vertical compressive strains on top of subgrade for pavement layer thickness variations 1 to 3.

The improvement due to reduction in tensile strain and increment in number of load repetitions to fatigue failure of all blends could be adduced to cementitious compounds (Calcium Aluminate Hydrate; CAH and Calcium Silicate Hydrate; CSH) formed as a result of hydration when CCW rich in CaO (93.74%) reacted with silica in subgrade (49.57%), silica in CC (58.86%), alumina in subgrade (28.86%) and alumina in CC (16.23%) in the presence of water as captured in Table 1. This is in agreement with the position of Wijeyesekera *et al.* (2016), Horpibulsuk, (2012), Boriana, (2006), Peethamparnet *et al.* (2008), Solanki and Zaman, (2012) that when a cementitious additives are mixed or blended with expansive soils with loose grains, the intergranular spaces or voids would be filled or covered with hydration reaction products, that is, CAH and CSH. However, the improvement in the simulated flexible pavement performance as a result of stabilization could be likened to works of Khabiri (2010), Gupta and Kumar (2014), Oufet *et al.* (2016), Saing (2017) and Tapase and Ranadive (2018).

Table 5: Simulated Results of Compressive Strain on Top of the Subgrade under the application of Truck 2 Axle

Blend	Pavement Variation 1	Pavement Variation 2	Pavement Variation 3
Subgrade (S) 0%	2.64E-04	2.04E-04	1.60E-04
S + 8% CCW (OSLB)	1.26E-04	8.26E-05	5.14E-05
OSLB+3%CC	1.21E-04	7.96E-05	4.91E-05
OSLB+6%CC	1.06E-04	7.11E-05	4.21E-05
OSLB+9%CC	8.52E-05	5.85E-05	3.24E-05
OSLB+12%CC	1.04E-04	7.00E-05	4.12E-05
OSLB+15%CC	9.24E-05	6.29E-05	3.57E-05
OSLB+18%CC	8.54E-05	5.87E-05	3.26E-05

Table 6: Rutting and Damage Factor Analyses for Truck 2 Axle

Blend	Compressive strain (Ec)	No. of repetitions to failure (Nr)	Damage factor D = $\frac{1}{Nr^{0.25}}$
Pavement Variation 1			
Subgrade	2.64E-04	1.42E+07	1.21E+05
S + 8% CCW (OSLB)	1.26E-04	3.88E+08	1.21E+05
OSLB+3%CC	1.21E-04	4.67E+08	1.21E+05
OSLB+6%CC	1.06E-04	8.39E+08	1.21E+05
OSLB+9%CC	8.52E-05	2.26E+09	1.21E+05
OSLB+12%CC	1.04E-04	9.16E+08	1.21E+05
OSLB+15%CC	9.24E-05	1.57E+09	1.21E+05
OSLB+18%CC	8.54E-05	2.23E+09	1.21E+05
Pavement Variation 2			
Subgrade	2.04E-04	4.55E+07	1.21E+05
S + 8% CCW (OSLB)	8.26E-05	2.59E+09	1.21E+05
OSLB+3%CC	7.96E-05	3.06E+09	1.21E+05
OSLB+6%CC	7.11E-05	5.09E+09	1.21E+05
OSLB+9%CC	5.85E-05	1.22E+10	1.21E+05
OSLB+12%CC	7.00E-05	5.45E+09	1.21E+05
OSLB+15%CC	6.29E-05	8.82E+09	1.21E+05
OSLB+18%CC	5.87E-05	1.20E+10	1.21E+05
Pavement Variation 3			
Subgrade	1.60E-04	1.36E+08	1.21E+05
S + 8% CCW (OSLB)	5.14E-05	2.17E+10	1.21E+05
OSLB+3%CC	4.91E-05	2.66E+10	1.21E+05
OSLB+6%CC	4.21E-05	5.29E+10	1.21E+05
OSLB+9%CC	3.24E-05	1.71E+11	1.21E+05
OSLB+12%CC	4.12E-05	5.86E+10	1.21E+05
OSLB+15%CC	3.57E-05	1.11E+11	1.21E+05
OSLB+18%CC	3.26E-05	1.68E+11	1.21E+05

3.4 Rutting Failure and Damage Factor due to Rutting Analyses of Stabilized Subgrade due to Truck 7 Axle

Table 7 shows the vertical compressive strain results of the blends at different pavement thickness combinations (pavement variations 1 to 3) when subjected to Truck 2 axle load. It was observed that stabilization of weak subgrade with different variations of 8%CCW-CC reduced its vertical compressive strain on top of subgrade from 1.37E-03 to 1.61E-04 for pavement variation 1, 1.12E-03 to 1.31E-04 for pavement variation 2 and 8.73E-04 to 9.63E-05 for pavement variation 3 with optimum reduction observed at OSLB+9%CC for the three pavement layer thickness variations. Plates 4 to 6 show the pictorial views of vertical compressive strains on top of subgrade for pavement layer thickness variations 1 to 3.

Table 8 shows the Number of repetitions to rutting failure (Nr) and Damage factor due to rutting (Dr) results of the stabilized weak subgrade blends where it revealed that stabilization of weak subgrade with varying percentages of 8%CCW-CC increased Number of repetitions to rutting failure from 8.95E+03 to 1.30E+08 for pavement variation 1, 2.26E+04 to 3.33E+08 for pavement variation 2, and 6.76E+04 to 1.31E+09 for pavement variation 3 with optimum increment observed at OSLB+9%CC for all the three pavement layer thickness variations. Stabilization with these blends also led to reduction in Damage factor due to rutting from 1.35E+01 to 9.31E-04 for pavement variation 1, 5.37E+00 to 3.64E-04 for pavement variation 2, and 1.79E+00 to 9.24E-05 for pavement variation 3 with optimum reduction observed at OSLB+9%CC and OSLB+18%CC for all the pavement layer thickness variations.

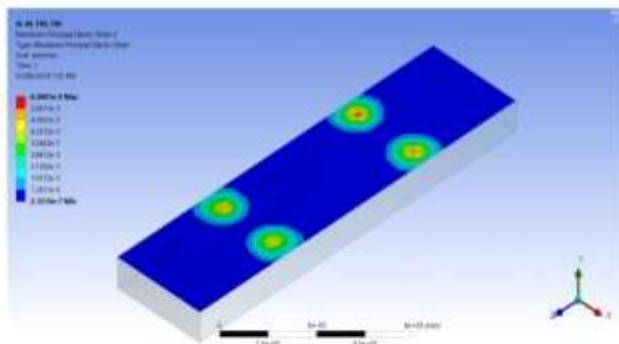


Plate 1: Mapping of Compressive Strain on top of Subgrade for Pavement Variation 1 under Truck 2 Axle Load

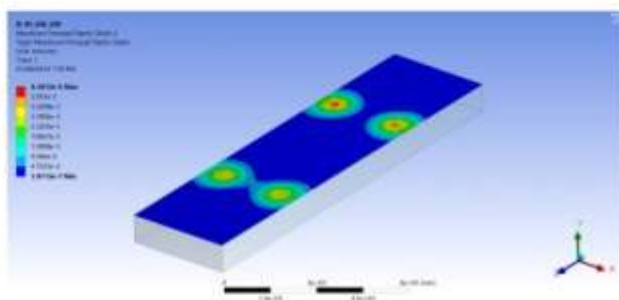


Plate 2: Mapping of Compressive Strain on top of Subgrade for Pavement Variation 2 under Truck 2 Axle Load

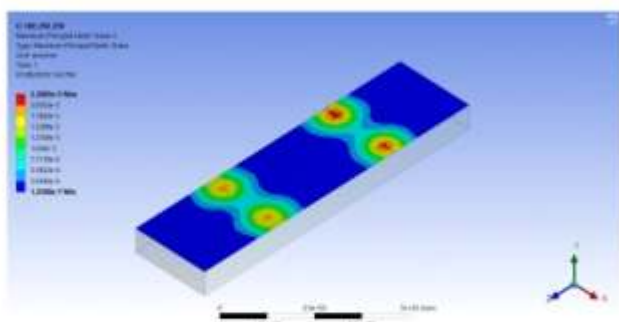


Plate 3: Mapping of Compressive Strain on top of Subgrade for Pavement Variation 3 under Truck 2 Axle Load

The improvement as a result of reduction in tensile strain, damage factor due to fatigue failure and increment in number of repetitions to fatigue failure of all blends could be adduced to cementitious compounds (Calcium Aluminate Hydrate; CAH and Calcium Silicate Hydrate; CSH) formed as a result of hydration when CCW rich in CaO (93.74%) reacted with silica in subgrade (49.57%), silica in CC (58.86%), alumina in subgrade (28.86%) and alumina in CC (16.23%) in the presence of water as captured in Table 1. This is in agreement with the position of Wijeyesekera *et al.* (2016), Horpibulsuk, (2012), Borian, (2006), Peethamparam *et al.* (2008), Solanki and Zaman, (2012) that when a cementitious additives are mixed or blended with expansive soils with loose grains, the intergranular spaces or voids would be filled or covered with hydration reaction products, that is, CAH and CSH. However, the enhancement in the simulated flexible pavement performance as a result of stabilization could be likened to works of Khabiri (2010), Gupta and Kumar (2014), Oufet *et al.* (2016), Saing (2017) and Tapase and Ranadive (2018).

Table 7: Simulated Results of Compressive Strain on Top of the Subgrade under the application of Truck 7 Axle

Blend	Pavement Variation 1	Pavement Variation 2	Pavement Variation 3
Subgrade (S) 0%	1.37E-03	1.12E-03	8.73E-04
S + 8% CCW (OSLB)	2.66E-04	2.07E-04	1.47E-04
OSLB+3%CC	2.52E-04	1.97E-04	1.40E-04
OSLB+6%CC	2.12E-04	1.68E-04	1.21E-04
OSLB+9%CC	1.61E-04	1.31E-04	9.63E-05
OSLB+12%CC	2.07E-04	1.65E-04	1.20E-04
OSLB+15%CC	1.78E-04	1.43E-04	1.05E-04
OSLB+18%CC	1.62E-04	1.31E-04	9.67E-05

Table 8: Rutting and Damage Factor Analyses for Truck 7 Axle

Blend	Compressive strain (Ec)	No. of repetitions to failure (Nr)	Damage factor D = $\frac{1}{Nr}$
Pavement Variation 1			
Subgrade	1.37E-03	8.95E+03	1.35E+01
S + 8% CCW (OSLB)	2.66E-04	1.39E+07	8.74E-03
OSLB+3%CC	2.52E-04	1.78E+07	6.82E-03
OSLB+6%CC	2.12E-04	3.78E+07	3.20E-03
OSLB+9%CC	1.61E-04	1.30E+08	9.31E-04
OSLB+12%CC	2.07E-04	4.21E+07	2.87E-03
OSLB+15%CC	1.78E-04	8.31E+07	1.46E-03
OSLB+18%CC	1.62E-04	1.28E+08	9.47E-04
Pavement Variation 2			
Subgrade	1.12E-03	2.26E+04	5.37E+00
S + 8% CCW (OSLB)	2.07E-04	4.25E+07	2.85E-03
OSLB+3%CC	1.97E-04	5.35E+07	2.26E-03
OSLB+6%CC	1.68E-04	1.07E+08	1.13E-03
OSLB+9%CC	1.31E-04	3.33E+08	3.64E-04
OSLB+12%CC	1.65E-04	1.17E+08	1.04E-03
OSLB+15%CC	1.43E-04	2.20E+08	5.50E-04
OSLB+18%CC	1.31E-04	3.27E+08	3.70E-04
Pavement Variation 3			
Subgrade	8.73E-04	6.76E+04	1.79E+00
S + 8% CCW (OSLB)	1.47E-04	1.95E+08	6.21E-04
OSLB+3%CC	1.40E-04	2.46E+08	4.93E-04
OSLB+6%CC	1.21E-04	4.66E+08	2.59E-04
OSLB+9%CC	9.63E-05	1.31E+09	9.24E-05
OSLB+12%CC	1.20E-04	4.96E+08	2.44E-04
OSLB+15%CC	1.05E-04	8.92E+08	1.36E-04
OSLB+18%CC	9.67E-05	1.28E+09	9.43E-05

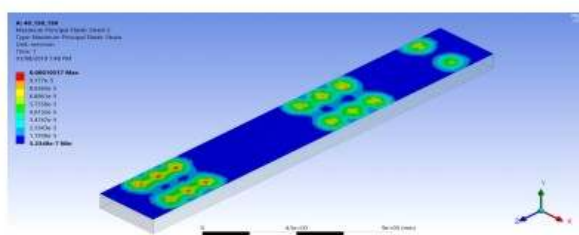


Figure 4: Mapping of Compressive Strain on top of Subgrade under Truck 7 Axle Load for Pavement Variation 1

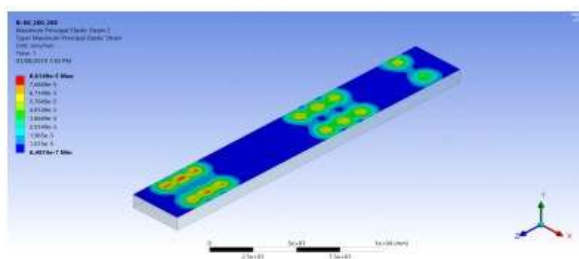


Figure 5: Mapping of Compressive Strain on top of Subgrade under Truck 7 Axle Load for Pavement Variation 2

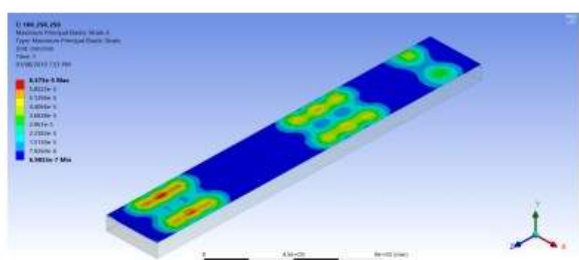


Figure 6: Mapping of Compressive Strain on top of Subgrade under Truck 7 Axle Load for Pavement Variation 3

4.0 CONCLUSION

Subgrade soil was classified as A-7-5 and ML or OL soil according to AASHTO and USCS. Generally, it was observed that Vertical Compressive Strain on top of Subgrade and Damage factor due to Rutting failure reduced with increase in Pavement Layer Thickness Variation (from 150 mm, 150 mm, 40 mm; pavement variation 1 to 250 mm, 250 mm, 100 mm; pavement variation 3) and the Number of Repetitions to Fatigue failure increased with increase in Pavement Layer Thickness Variation for both Truck 2 and Truck 7 axles with the blends of OSLB+9%CC exhibiting the best performance. The performance of all blends could be as a function of their Elasticity modulus results because an improvement in Elasticity modulus of weak subgrade was observed from 37.54 to 184.271MPa with optimum at OSLB+9%CC blend. Generally, the enhancement in the performance of the modeled pavement as a result of stabilization of weak subgrade with varying proportions of 8%CCW-CC could be adduced to its improved properties such as Elasticity modulus, CBR and Density which is agreement with observation of Oufet *et al.* (2016) where improvement in subgrade properties such as young's modulus, density, cohesion and internal friction angle was responsible for enhancement of the pavement section performance. When the performances of the stabilized blends under Truck 2 axle were compared to Truck 7 axle, reduction in Vertical Compressive Strain on top of Subgrade, Damage factor due to Rutting failure and improvement in Number of Load Repetitions to Rutting failure for all blends were prominent in Truck 2 axle owing to its less weight to Truck 7 axle.

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