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E- Mail: info@enrichedpublication.com
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Aims and Scope

Journal of Civil Engineering and Technology Research intended to bring together the information in different areas of civil engineering around the world. The aim of this journal is to combine theory and practice in civil engineering and thus advancement of civil engineering sciences. It will provide a platform for academicians, researches and engineers to share their experience and solution to problems in different areas of civil engineering.

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The impacts of plastic pollution on public health in Nigeria

Samuel IC Dibia, Kelachi T Wala, Uloma Onwuzurike, Benjamin Anabaraonye and Chukwudi P Arinze

ABSTRACT

Plastic, one of the most preferred materials in today's industrial world is posing serious threat to environment and consumer's health in many direct and indirect ways. Exposure to harmful chemicals during manufacturing, leaching in the stored food items while using plastic packages or chewing of plastic tethers and toys by children are linked with severe adverse health outcomes such as cancers, birth defects, impaired immunity, endocrine disruption, developmental and reproductive effects, among others. Plastic pollution is one of the glitches at the epicenter of the challenges plaguing the universe status quo with more than estimated eighty million tons of plastic related wastes being released into the sea annually. This study identified the impacts of plastic pollution on public health in Nigeria. It further identified the need for plastic pollution education across various communities, cities and institutions in Nigeria. The study also recommended the innovative tools of poetry, music and educational blogs among others for use in plastic pollution education for sustainable development in Nigeria. It concluded with the clarion call for more intensive research on the impacts of plastic pollution on public health in Nigeria.

Keywords: climate change, education, plastic pollution, public health, sustainable development

Introduction

Plastic pollution has remained one of the glitches at the epicenter of the challenges plaguing the universe status quo with more than estimated eighty million tons of plastic related wastes being released into the sea annually (Awuchi & Awuchi, 2019) [4]. Plastic pollution is one of several man-made environmental threats including ocean warming, overharvesting, ocean acidification, eutrophication, deoxygenation, shipping and underwater noise, invasive species, habitat destruction and fragmentation, as well as other forms of chemical pollution. Economic development and people's changing patterns of consumption and production have led to a drastic increase in plastic wastes all over the world (Chow et al 2017) [8]. Plastic pollution combines with other threats to marine life to form a precarious cocktail. The effects of plastic on marine ecosystems should not be considered in isolation. Ingested plastic can move right up the marine food chain – and is now found in human diets, too. When marine animals ingest plastics, field and laboratory studies have demonstrated that those plastics – and their associated chemical pollutants – can pass further up the marine food chain. Plastic pollution is everywhere in the global ocean, and levels have grown exponentially. The United Nations (UN) called it a 'planetary crisis' (MacLeod, Arp, Tekman, & Jahnke, 2021) [23], while Daltry, Merone, and Tait (2021) [21] referred to it as 'plastic

pandemic'. From the poles to the remotest islands, from the surface of the sea to the deepest ocean trench, the marine plastic pollution problem has grown exponentially, plastic pollution is now ubiquitous and is projected to increase even if current corporate and government commitments are met (Borrelle et al., 2020) [7]. Global and systemic actions are needed urgently in response (Elhacham, Ben-Uri, Grozovski, Bar-On, & Milo, 2020) [11]. The staggering figures of the impact of plastic pollution to life are frightening. As at 2018, about 380 million tonnes of plastic is produced worldwide per year. From the 1950s up to 2018, more than 7.8 billion tons of plastics have been produced globally. An estimated 12 per cent has been incinerated and 9 percent recycled (The Economist, 2018). Between 1996 and 2014, more than 23,400,000 tons of plastics were imported into Nigeria's technological sector, yet, less than 12% of the ensuing garbage was recycled. There is a need for sustainable management of this significant waste and resource category, given the threats this volume poses to local and global habitats and human health (Ugochukwu et al., 2018) [39].

In some regions there have been substantial efforts to lessen plastic pollution by promoting plastic recycling and reducing consumption of plastic (Walker, Tony and Xanthos, 2018) [41]. Many researchers suggest that by 2050 there may be more plastic wastes than fish in the world oceans by weight (Sutter, 2016) [35]. Globally, there have been a consistent and persistent increase in the production of plastic over the past fifty years, from 2 million metric tons in 1950 to 381 million metric tons in 2015, and is estimated to increase by 100% in 2020 (J and K Envis Hub, 2018) [19]. The total global production of plastics from its inception to 2018 is estimated at 8,300 million metric tons (Royer et al, 2018). Globally, plastic waste constitutes more than 60% of the total global municipal solid waste of which 22% were recovered and 78% disposed of (Ogwo et al., 2013; Ayo et al., 2018) [25]. An estimated 367 million tonnes of plastic were produced in 2020 with the production rate of about 12 tonnes of plastic waste produced per second (Sogbanmu, 2022) [33]. Over 280 million tons of plastics are produced annually and approximately 75% of the demand comes from four major sectors: packaging, construction, automotive and electrical or electronics. (Thevenon and Oliver, 2014) [38]. Plastic is a generic term used for polymeric materials that may contain other substances (additives) to improve efficiency, reduce cost and produce desired color (Hahladakis, 2018; Van et al., 2020) [15, 40]. The polymers used to make plastic materials are diverse, consisting of seven types of polymer resins (Bashir, 2013) [6]. These include Polyethylene Terephthalate (PETE), High Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Low Density Polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS) and others (which includes many polymer types, such as Polycarbonate (PC), Acrylic and Nylon) (Seaman, 2020) [30].

Methodology

This paper examined “the impacts of plastic pollution on public health in Nigeria” through existing literature review. The main purpose of this research work was to survey theoretical backgrounds and previous studies on the subject matter. It also examined the current progress on how to mitigate the public health impacts of plastic pollution in Nigeria.

Understanding plastic pollution

Plastic, one of the most preferred materials in today's industrial world is posing serious threat to environment and consumer's health in many direct and indirect ways. Exposure to harmful chemicals during manufacturing, leaching in the stored food items while using plastic packages or chewing of plastic tethers and toys by children are linked with severe adverse health outcomes such as cancers, birth defects, impaired immunity, endocrine disruption, developmental and reproductive effects, among others (Rustagi, Pradhan & Singh, 2011) [29]. Plastic pollution is the buildup of plastic particles, such as plastic bottles, plastic bags, and much more, in the global environment that adversely affects wildlife habitat, wildlife, and humans (Laura, 2018) [21]. Based on size plastics pollutants are categorized into macro-, meso-, or micro debris (Hammer et al., 2012) [17]. Plastics are durable and inexpensive, and consequently plastic production levels by humans are high (Hester and Harrison, 2011) [18]. Nevertheless, the chemical structure of some plastics makes them resistant to various natural degradation processes and therefore they degrade slowly (Le Guern, 2018) [22]. These two factors have together led to a very high incidence of plastic pollution in the world. Plastic pollution is destroying wildlife, damaging ecosystems, clogging drainage systems, and harming fisheries and tourism. Solving the plastic pollution problem is part of solving the climate change problem ravaging the world. Solutions for plastic waste and plastic substitutes will need to come through innovations. New skills, knowledge and education can help create enduring solutions to plastic pollution and develop systems whereby communities can turn waste into wealth, a concept that helps to view waste management of all types as a resource rather than a refuse (Sosale et al., 2021) [34].

The need for plastic pollution education in Nigeria

Plastic pollution education is a veritable approach to tackle the growing plastic pollution pandemic. Designing educational programmes at all levels of education promises to bring forward an in-depth understanding of the problems, equips people with the tools and strategies to manage the plastic pollution crises that are ravaging our planet. Urgent action is needed to curb plastic waste that pollutes the land, flows into rivers, and ends up in ocean (Sosale, Shepardson, Aedo & Jha, 2021) [34]. Education and skills can drive innovative solutions. First, education is important for changing human behaviour. Well designed educational programmes and innovative educational toolkits for plastic waste management can instill good environmental habits and behaviours and ultimately impart change to

parents and communities (Anabaraonye, Nji, Hope, 2018) [1, 3]. Second, education can equip young people with skills that can help them develop innovative climate solutions. Tertiary education is critical for such solutions. Training on climate change aspects and university-industry linkages can stimulate innovation, build education pathways between the technical environment, climate jobs and tertiary education, and expand opportunities. Third, education can promote innovation to expand solutions and equip people with skills to build with environmentally friendly, energy efficient, and climate resilient materials and renewable options. Such curriculum content that is focused on climate change adaptation and mitigation can also change behaviours and foster knowledge that can lead to climate action (Anabaraonye, Okafor, Hope, 2018) [1, 3]. Fourth and finally, through climate change research and development in higher education, the education sector can build knowledge and skills for adaptation, mitigation, and for articulating appropriate policy responses to address the transition to a fully decarbonized economy. More so, the education sector can impart solutions for collective action around innovation, including the scaling up of investments in all forms of capital.

The public health implications of plastic pollution in Nigeria

While once considered inert, untreated monomers and other harmful substances can be found within plastics. Some plastics may be chemically harmful, either directly toxic themselves or because they absorb and carry other pollutants (Rochman et al., 2013) [26]. Chemical effects include damage to the heart, nervous system, reproductive system and potential cancers (Sharma & Chatterjee, 2017) [32]. Monomers and other substances in plastics can mimic the effects of Oestrogen in living organisms. Pesticides and organic toxins are found on plastic particles at harmful concentrations – 100 times more than found in sediments and a million times more than in seawater (Rochman et al., 2013) [26]. Seafood, alcohol and plastic-bottled water are the greatest sources of micro-plastic ingestion in humans (Cox et al., 2019) [9]. While the investigation of the toxic effects of micro-plastics in food webs is complex and ongoing (Seltenrich, 2015) [31], evidence suggests that ingestion of these micro-plastics in humans may be associated with infertility, obesity and suspected endocrine dysfunction including oestrogen mimicking, which in women has been associated with breast cancer. While difficulty lies in separating the comparative exposure from pollution and food webs and exposure via food packaging (Seltenrich, 2015) [31], it could be argued that this separation is a moot point should significant human health effects begin to unfold. Human health risks from plastics stem from their component monomers such as bisphenol A (BPA), additives such as plasticizers, or a combination of the two (Halden, 2010) [16]. While there is very limited information about the long-term human health effects of plastics, research has demonstrated high levels of (BPA) in women and young infants (Rolland et al., 2020) [27] and this may cause alterations in neurological white matter in children (Ellahi & Rashid, 2017) [12]. These findings require more long-term research. BPA is both a plastic monomer component and an additive to

many varieties of plastic. Ingestion is the commonest route of exposure via plastic packaging, particularly re-usable plastic packaging where repeated washing and storage results in polymer breakdown. Studies have determined that around 95% of humans have detectable serum and urinary levels of BPA. The overall health risks of BPA are still under debate and are by no means fully comprehended; it is currently classified as an oestrogen mimic and endocrine disruptor in that it is known to bind to oestrogen receptors.

Animal studies have noted the effects of BPA to include: increased postnatal growth, early sexual maturation (in females), sex hormone imbalances in both males and females, decreased fertility in males, prostatic hyperplasia, alterations in immune system function, hyperactivity and more. Replacement phenols for BPA may be just as harmful to human health and research into alternative safe materials is required (Moon, 2019) [24]. The healthcare system in Nigeria utilizes an abundance of plastics owing to their inexpensive production and single-use sterile nature (Halden, 2010) [16]. Medical devices such as those used in dialysis, blood transfusion and extra-corporeal membrane oxygenation (ECMO) contain phthalates. These compounds can also be ingested from food contaminated from plastic packaging. Despite being rapidly metabolized, health concerns associated with phthalates include endocrine disruption and malformations of the male reproductive system in animals. Human studies have also drawn an association between serum phthalate levels, increased waist circumference and insulin resistance (Halden, 2010) [16]. The human health risks of phthalates remain under some scientific debate; however, there is evidence from longitudinal birth cohort studies in animals that peri-natal phthalate exposure can impair brain development and there is emerging evidence that phthalate exposure increases the risk of learning and attention deficits in children (Engel et al., 2021) [13]. While the risks and impacts of plastic-related toxin exposure need further investigation, more extensive and integrated safe recycling and disposal of plastics must increase significantly on a global scale to prevent potential harms. Additional to chemical effects, plastics disrupt ocean ecosystems with an indirect effect on human health. For instance, alongside climate-change-related ocean warming, plastic pollution is having a direct effect on coral reefs. Corals feed on zooplankton and similar small species, thereby ingesting micro-plastics. Coral reefs are essential coastal structures, not only functioning as vital components of food webs and ecosystems but also providing natural physical barriers to storms and cyclones. This the impacts of greenhouse gas emissions and other anthropogenic effects on the oceans; 87% worldwide of coral reefs have some level of degradation (Jones et al., 2018) [20]. Plastic-related health damage to coral reefs contributes to their declining health in an already increasingly hostile environment.

Recommendations

1. Inclusion of plastic pollution education in Nigeria's educational curricula at all levels is pertinent in entrenching the right attitudes to plastic pollution mitigation. There is dire need to educate the populace on the 5 "R" strategies of plastic waste management in Nigeria.

2. Plastic pollution prevention is partially addressed by the slogan: reduce, refuse, reuse, repurpose and recycle. This focuses on what individuals can do to divert pollution from the environment. Other sources of micro-plastics such as cosmetic beads and clothing also have relatively straightforward solutions but require legislative change as well as consumer information. The more complex issue of our societies' reliance on plastic needs discussion, policy development and decisions about production, use and waste management (Daltry et al., 2021) [10].

3. Long-term planning towards effective plastic waste management in major industries and infrastructure in Nigeria is greatly needed. We need to work hard to prevent new contamination of plastic pollution. Targeting the causes of plastic pollution before it happens is far more effective than cleaning it up afterwards (Tekman, Walther, Peter, Gutow, & Bergmann, 2022) [36].

4. Similar to the climate crisis, this issue of plastic pollution affects the entire planet. Plastic pollution levels are continuously increasing, and global collaborations and systemic solutions will succeed in response. Encouragingly, public attention is now focused on the issue, and calls are growing for decisive international action to turn the tide before plastic pollution overwhelms the resilience of a critical number of marine species and ecosystems (Walther, 2015) [42].

5. A far more important approach is simply to prevent plastic waste entering the environment in the first place, which also implies a major reduction in primary plastic production. Such an approach would have additional benefits including reduced resource use and pollution from manufacturing, transportation and disposal of plastic waste.

6. Poetry, music and educational blogs are recommended as veritable tools which can be used to educate individuals, communities and institutions across Nigeria on climate change issues as well as plastic pollution mitigation for sustainable development (Anabaraonye, Nji & Hope, 2018) [1, 3].

7. The Nigerian Government should provide sufficient funds to passionate and capable youths to enable them appreciate and maximize the green entrepreneurial opportunities in plastic waste recycling thereby helping to eradicate plastic pollution in Nigeria (Anabaraonye, Nwobu, Nwagbo, Ewa & Okonkwo, 2022) [2].

8. More efforts have to be put towards increasing people's awareness about bio-based and biodegradable products, their properties, their use, and the environmental and human health impacts (Filho, Barbir, Abubakar, et al. 2022) [14].

Conclusion

Plastic pollution education is an urgent task which needs to be undertaken by passionate individuals, educationists and professionals across various communities, cities and institutions in Nigeria. Furthermore, there is a great need for more intensive research to further identify the public health impacts of plastic pollution and ways to mitigate to achieve sustainable development in Nigeria.

References

1. Anabaraonye B, Okafor CJ, Hope J. Educating Farmers in Rural Areas on Climate Change Adaptation for Sustainability in Nigeria. Springer Nature Switzerland AG 2018. W. Leal Filho (ed.), Handbook of Climate Change Resilience; c2018. https://doi.org/10.1007/978- 3-319-71025-9_184-1 3.

2. Anabaraonye B, Nwobu EA, Nwagbo SN, Ewa BO, Okonkwo UC. Green Entrepreneurial opportunities in the plastic recycling industry for sustainable development in Nigeria. International Journal of Research in Civil Engineering and Technology. 2022;3(1):20-25.

3. Anabaraonye B, Nji AI, Hope J. Poetry as a valuable tool for climate change education for global sustainability. International Journal of Scientific & Engineering Research. 2018;9(9):81-85. ISSN 22295518.

4. Awuchi CG, Awuchi CG. Impacts of plastic pollution on the sustainability of seafood value chain and human health. International Journal of Advanced Academic Research. 2019;5(11):46-138.

5. Ayo AW, Olukunle OJ, Adelabu DJ. Development of a Waste Plastic Shredding Machine. Int. J Waste Resour. 2017;7:281. doi: 10.4172/22525211.1000281

6. Bashir NH. Plastic problem in Africa, Jpn. J Vet. Res. 2013;61:01-11.

7. Borrelle SB, Ringma J, Law KL, Monnahan CC, Lebreton L, McGivern A, et al. Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. Science. 2020;369(6510):1515-1518.

8. Chow CF, So WMW, Cheung TY, Yeung SK D. Plastic Waste Problem and Education for Plastic Waste Management. In: Kong S., Wong T., Yang M., Chow C., Tse K. (eds) Emerging Practices in Scholarship of Learning and Teaching in a Digital Era. Springer, Singapore; c2017. https://doi.org/10.1007/978-981-103344-5_8

9. Cox KD, Covernton GA, Davies HL, Dower JF, Juanes F, Dudas SE. Human consumption of microplastics. Environ Sci Technol. 2019;53(12):7068-74.

10. Daltry A, Merone L, Tait P. Plastic pollution: why is it a public health problem? Australian and New Zealand Journal of Public Health. 2021;45(6):535-537. doi: 10.1111/1753-6405.13149

11. Elhacham E, Ben-Uri L, Grozovski J, Bar-On YM, Milo R. Global human-made mass exceeds all living biomass. Nature. 2020;588(7838):442-444.

12. Ellahi M, Rashid MU. The toxic effects BPA on fetuses, infants, and children. In: Erkekoglu P, KocerGumusel B, editors. Bisphenol A Exposure and Health Risks. 1st ed. London (UK): Intech Open;

c2017. p. 143-154.

13. Engel SM, Patisaul HB, Brody C, Hauser R, Zota AR, Bennet DH, et al. Neurotoxicity of ortho-phthalates: Recommendations for critical policy reforms to protect brain development in children. Am J Public Health. 2021;111(4):687-95.

14. Filho WL, Barbir J, Abubakar IR, Pac A, Stasiskiene Z, Hornbogen M, et al. Consumer attitudes and concerns with bioplastics use: An international study. PLoS ONE. 2022;17(4):e0266918. https://doi.org/10.1371/journal. pone.0266918

15. Hahladakis JN, Velis CA, Weber R, Lacovidou E, Purnell P. An overview of chemical additives present in plastics: migration, release, fate and environmental impact during their use, disposal and recycling, J Hazard. Mater. 2018;344:179-199.

16. Halden RU. Plastics and health risks. Annu Rev Public Health. 2010;31:179-194.

17. Hammer J, Kraak MH, Parsons JR. Plastics in the marine environment: the dark side of a modern gift. Reviews of Environmental Contamination and Toxicology. 2012;220:1–44. doi:10.1007/978-1-46143414-6_1.

18. Hester, Ronald E, Harrison RM. Marine Pollution and Human Health. Royal Society of Chemistry, 2011, pp. 84–85. ISBN 184973240X

19. Envis J, Hub K. Beat Plastic pollution, If you can't refuse it, reuse it. Environmental Day Special. Department of Ecology, Environment and Remote Sensing, 2018, 5(2). ISSN 2455 – 8575, India.

20. Jones KR, Klein CJ, Halpern BS, Venter O, Grantham H, Kuempel CD, et al. The location and protection status of earth's diminishing marine wilderness. Curr Biol. 2018;28(15):2506-12.e3.

21. Laura P. We Depend on Plastic. Now We're Drowning in It, 2018. NationalGeographic.com.

22. Le Guern, Claire. When The Mermaids Cry: The Great Plastic Tide. Coastal Care; c2018.

23. MacLeod M, Arp HPH, Tekman MB, Jahnke A. The global threat from plastic pollution. Science. 2021;373(6550):61-65.

24. Moon MK. Concern about the safety of bisphenol A substitutes. Diabetes Metab J. 2019;43(1):46-48.

25. Ogwo PA, Obasi LO, Okoroigwe DS, Dibia NO. From Plastic Bag Wastes to Wealth: A Case Study of Abia State University, Nigeria. Journal of Environmental Management and Safety. 2013;4(1):35-39.

26. Rochman CM, Browne MA, Halpern BS, Hentschel BT, Hoh E, Karapanagioti HK, et al. Classify plastic waste as hazardous. Nature. 2013;494(7436):169-71.

27. Rolland M, Lyon-Caen S, Sakhi AK, Pin I, Sabaredzovic A, Thomsen C, et al. Exposure to phenols during pregnancy and the first year of life in a new type of couple-child cohort relying on repeated urine biospecimens. Environ Int. 2020;139:105678.

28. Royer SJ, Ferron S, Wilson ST, Karl DM. Production of methane and ethylene from plastic in the environment. PLoS ONE. 2018;13(8):e0200574. https://doi.org/10.1371/journal.pone.0200574

29. Rustagi N, Pradhan SK, Singh R. Public health impact of plastics: An overview. Indian Journal of Occupational and Environmental Medicine. 2011;15(3):100-103. DOI: 10.4103/0019-5278.93198

30. Seaman G. Plastic by number, Earth Easy, 2020. Accessed October 4th 2020. Available online at https://learn.eartheasy.com/articles/plastics-by-thenumbers/

31. Seltenrich N. New link in the food chain? Marine plastic pollution and seafood safety. Environ Health Perspect. 2015;123(2):A34-41.

32. Sharma S, Chatterjee S. Microplastic pollution, a threat to marine ecosystem and human health: A short review. Environ Sci Pollut Res Int. 2017;24(27):21530-47.

33. Sogbanmu TO. Plastic Pollution in Nigeria is Poorly Studied but Enough is Known to Urge Action, 2022. Accessed on September 11, 2022. Available at https://theconversation.com/amp/plastic-pollution-innigeria-is-poorly-studied-but-enough-is-known-urgeaction/

34. Sosale S, Shepardson K, Aedo C, Jha A. Tackling plastic pollution and climate change through education. Worldbank Blogs, 2021. https://blogs.worldbank.org

35. Sutter, John D. How to stop the sixth mass extinction. CNN, 2016.

36. Tekman MB, Walther BA, Peter C, Gutow L, Bergmann M. Impacts of plastic pollution in the oceans on marine species, biodiversity and ecosystems; c2022. 1-221. WWF Germany, 10.5281/zenodo.5898684 Berlin. DOI:

37. The Economist. The known unknowns of plastic pollution. The Economist; c2018.

38. Thevenon F, Oliver J. Plastic Pollution. Submerge. International Union for Conservation of Nature(IUCN) Global marine and Polar Programme (GMPP); c2014.

39. Ugochukwu SC, Ogbuagu GO, Okechukwu FE. An appraisal of the sources, quantities and prices of imported building materials in Nigeria. Int. J Adv Res. 2018;2(9):871-89. Available http://www.journalijar.com/from: uploads/877_IJAR4061.pdf

40. Van Dormalen, Bushmaker T, Morris DH, Holbrook MG, Gamble A, Williamson BN, et al. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1, N. Engl. J Med. 2020;382(16):15641567.

41. Walker, Tony R, Xanthos D. A call for Canada to move toward the zero plastic waste by reducing & recycling single-use plastics. The Resources, Conservation & Recycling. 2018;133:99-100. doi:10.1016/j.resconrec.2018.2.014.

42. Walther B. Nation engulfed by plastic tsunami, in Taipei Times; c2015. p. 8.

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Summary report for research entitled with causes and remedial measures of traffic accident in federal roads

Kefale Adefris

ABSTRACT

Despite having low road network density and vehicle ownership, Ethiopia has a relatively high accident records. Data obtained from Federal Transport Minister shows the vehicle ownership in Ethiopia is 1 vehicle per 145 populations; however on average 14 people per day died in Ethiopian roads due to traffic accident. Ethiopia losses 3.155 billion ETB from subsequent resource damage within 8 years (2008 to 2016) due to traffic accident, which constructs more than 158km asphalt road. This study is carried out to identify the main causes of traffic accidents in federal roads and to recommend possible countermeasures. To achieve the objective of the research both primary and secondary data were used. The secondary data was obtained by collecting the three year traffic accident record starting from 2015/16 – 2017 /18 which occurs within the selected road section. Using non random sampling AsellaBekoji, Adama-Metehara, Sebeta- Tulubolo, Combolcha-Dessie, Modjo-Ziway, Alemgena- Lemen, Dejen-Debremarkos and Bure- Dembecha road were selected as sample population. To identify the black spot the Flamish government formula and accident frequency method were used. The results of accident rate and accident severity index shows that, the traffic accident is very sever; the accident severity index of up to 55 and accident rate of 3.5 Mvkm (million vehicle kilometer) was obtained. Based on analysis, the main causes of traffic accident are; over speeding, not giving priority for pedestrian, not giving priority for vehicle, following too close, lack of traffic sign, poor pedestrian behavior and incompetency of the driver. Human factors, particularly driver behavior accounts up to 82% of the total accident. High number of accident occurred during good weather condition (87%), on good asphalt (95%) and with vehicles which have no defect (84%). Overturning collision and collision with pedestrian were the leading types of collision, they results up to 43 and 45% of the total accident respectively. Generally common problems were identified within black spot location. Installing rumble strips to control over speeding, providing traffic hazard light to prevent run off accident, installing traffic sign to providing information for driver and pedestrian, creating awareness, making road safety policy and enforcement, improving sight distance and modernizing accident data recording system is recommended based on observed problems.

Keywords: Road traffic accident, black spot, accident cause, mitigation measure

Introduction

Road traffic accidents are those accidents that occur on a way or Street open to public traffic, result in one or more persons being killed or injured, and at least one moving vehicle was involved"(economic commission for Europe, 2013). It includes collision between vehicles, vehicles and animals, vehicles and pedestrians or vehicles and stuck obstacle (Safe Carguide, 2004 sited by Girmay Giday, 2014) [17].

With the rapid increase in the population, advancement in industry, development and expansion of modes of transport and movement, traffic accident is increasing from time to time. Given the fact that more cars are driven on the streets of the developed countries than the undeveloped, one may easily assume that the number of people killed per car would be higher in developed nations (Tesfalem Hailu, 2010) [33]. However, compared to high income countries, per vehicle fatality rate is significantly higher in low and middle income countries. Despite having low road network density and vehicle ownership, Ethiopia has a relatively high accident record, over 5118 people being dead annually (Federal Police report, 2018). Data obtained from Federal Transport Minister Show's number of vehicle in Ethiopia reaches 831265 in 2017, whereas the total number of population was estimated at 106,399,924, which bring 1 vehicle per 128 populations (too small vehicle owner ship compared to developed nation).In Ethiopia, road traffic accident has been one of the top ten causes of death. For example, in 2013, the number of people killed by road traffic accident was equivalent to those who died due to malarial (which is 9th cause of death) throughout the country (The Centers for Disease Control and Prevention, 2013). Among the most prominent factors, human factor of which drivers' errors takes the lion's share of the blame. Fikadu, 2015 [12] argued that most safety studies have been based upon a person approach and stress the role of human error in the production of 75-90% of accidents.

Road traffic deaths and injuries has therefore been the key public health and development challenges of the country and will continue to adversely affect the livelihood of community and the economy of the country unless effective measures are taken to control the problem.

Method

Method Source of Data

Data for the research were collected using both primary and secondary sources. The primary data were obtained from questioner, interview and field survey, whereas, the secondary data were collected from:

1. Traffic Police office of the study road
2. Ethiopian Road Authority/ERA
3. Federal Police Commission and Transport Minister

To obtain detail information the three year traffic accident data from 2015/16 – 2017/18 were collected from each Wereda found in the study roads.

Population of the Study and Sample population

Population of the study for this research includes Federal asphalt road sections which have high traffic accident records. These road sections were selected based on the traffic crash data record. Using the Ethiopian road authority road network classification first accident per km length is determined. Next

roads having extreme value of accident per km length is selected. Based on the accident per km length, surface condition, traffic volume, road length and other criteria the sample populations are selected.

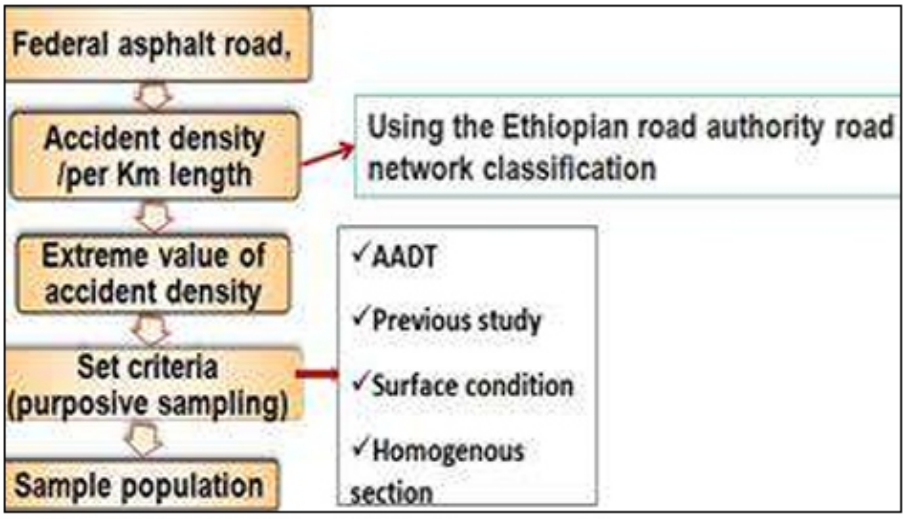

Fig 1: Sample selection procedure

Using the above procedure, Modjo-Ziway, Adama Metehara, Sebeta-Tulubolo, Combolcha-Dessie, AsellaBekoji, Alemgena-Lemen, Dejen - Debre markos, and Bure - Dembeca roads are selected as sample population. Hence, the nature of traffic accident in urban and rural area are different, the study focus road segments which are out of the urban area.

Method of Analysis

After all necessary data are collected from the site visit, from the interview and secondary data, the research proceeds to analyze the collected data. The questioner and interview were done to strength the secondary data obtained from traffic office and to obtain information for identification of black spot. The selection of method of black spot identification is based on available data. For this research the Flamish government formula, which is stated below and crash frequency method is used to identify black spot location. Flemish government formula First, site where in the last three years three or more accidents have occurred is selected. Then, a site is considered to be dangerous when its priority value (P), calculated using the following formula, equals 15 or more:

$P = X + 3*Y + 5*Z$, where

X = total number of light injuries

Y = total number of serious injuries

Z = total number of deadly injuries

Result and Discussion

Accident Rate

Accident rate is the best indicator of traffic accidents. It is defined as number of crashes that occur at a given site during a certain time period in relation to exposure (million vehicle miles of travel). Accident rate relates traffic accident with different parameters such as AADT, length of the road, and exposure. It is obtained by dividing annual accident (row 6) for annual exposure [(row 2*row3*365) or row 4*365] and multiply with one million. Doing so, a maximum of 3.5 and a minimum of 1 accident rate were obtained.

Table 1: Accident rate for the study roads

Road name								
Asella - Parameter Bekoji		Sebeta-Tulu Bolo	Adama-Metehara	Combo Icha-Dessie	Modj o-Alemg Ziway	ena-Lemen	Deje n-Markos	Bure-Dembeca
Average AADT	1523	4921	5121	3084	4895	6247	1607	1578
Length (mile)	30	30.5	48.5	14	51	23	55	50
exposure	45690	150090.5	243247.5	43176	249645	143681	88385	78916.67
Annual expo.	16676850	54783033	88785338	15759240	91120425	52443565	32260525	28804583
Accident/ yrs	55	39	135	46	211	36	71	64
Accident rate	3.5	1	2	3	1	1	2.2	2.3

Based on obtained result, a vehicle has a 3.5 in a million chance of being involved in an accident for every mile traveled on Asella-Bekoji road segment.

The total number of accident registered with in the study period: The total number accidents registered during the study period 2015/16 to 2017/18 in the study roads were shown in the table below.

Table 2: Total number of accident registered with in the study period

Road name	Adama - Metehara	Asella-Bekoji	Sebeta-Tulu Bolo	Combolcha-Dessie	Modjo-Ziway	Alemgena -Lemen	Dejen-Markos	Bure-Dembeca
Total accident	396	165	117	138	631	106	213	190

The above mentioned figure indicates the number of accidents, that means the number of people dead or injured were too much. Single accident causes some people to be dead, some to be injured. The total number accidents registered in the whole road during the study period 2015/16 to 2017/18 were 1956 accidents within 302 mile road segment. When we say the number of death injury, serious injury and slight injury it doesn't mean the number of people dead or injured, but it is to mean number of accident that results death or injury accidents. The chart below indicates the total number of accident and the number of people injured due to this accident for each road.

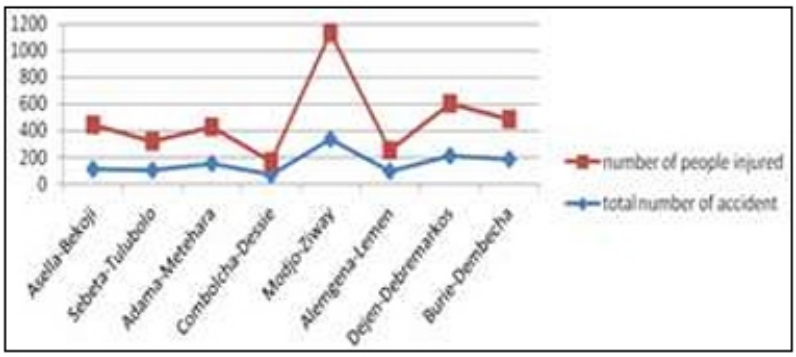

Fig 2: Showing Total number of accident and people injured

In all study roads number of people injured are greater than total number of accident; that means at least 2 peoples were injured from single accident. Severity Index: measures the seriousness of an accident. It is defined as the number of persons killed per 100 accidents. It is obtained by dividing number of people died for the total number of accident and multiplies by 100.

Accident severity index for the study road: Accident

Table 3: Severity of accident in the study road

Year	Accident severity index							
	Asella-Bekoji	Adama-Metehara	Sebeta- Tulu bolo	Combolcha-Dessie	Modjo-Ziway	Alemgena-Lemen	Dejen-Markos	Bure-Dembeca
2015/16	58	30	52	21	55	63	33	49
2016/17	51	32	48	21	53	55	32	51
2017/18	52	22	63	43	50	47	41	44
average	54	28	55	27	53	55	35	48

The above table implies how sever the traffic accident in the study road. In average 54 people in Asella – Bekoji road, 28 people in Adama - Metehara road, 55 people in Sebeta-Tulu bolo road, 27 people in Combolcha-Dessie road, 53 people in Modjo-Ziway, 55 people in Alemgena-Lemen road, 35 people in Dejen-Markos road and 48 people in BureDembeca road died from 100 accidents. When we see in the Whole country, in average from 100 accidents only 12 people were died, this implies the severity of traffic accident in the above road is very high. When we observe the proportion of accident for death injury, serious injury and slight injury; in all study roads the percentage of death injury is greater than serious and slight injury. See chart below.

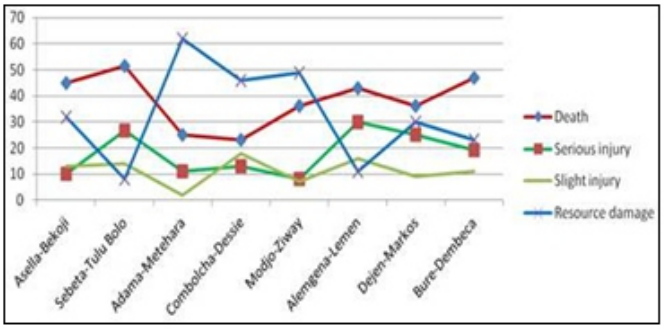

Fig 3: The proportion of accident with respect to death, serious injury, slight injury and resource damage

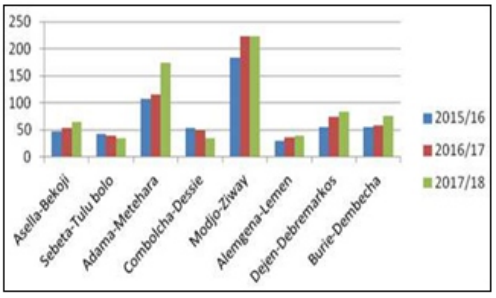

Fig 4: Trends of traffic accident in the study road

Fig 5: Intervention made at Sebeta – Tulu Bolo road (traffic hazard light).

The accident severity index and the proportion of accident implies severity of accident in rural area is very high than urban area, hence this study is focused on road segments out of the urban area. Different studies done in Addis Ababa indicate that the percentage of accident for death injury is very small

compared to slight and serious injuries, unlike the study roads. Majority of the accident happen in urban area results resource damage. The result of data analysis shows, this difference is observed as result of the following facts.

Due to low enforcement and absence of speed controlling mechanism, over speeding and not wearing seatbelt is common problem in all study roads (roads out of the urban area). An increase in average speed is directly related both to the occurrence of an accident and to the severity of the accident. Wearing seatbelt has a high potential for accident severity reduction. The results of the research done in 11 countries show that; the average effectiveness of Seatbelt at preventing fatal injuries was 47.1% (Road safety observatory 2019).

Trends of Traffic Accident in the Study Roads

Except Sebeta Tulu Bolo and Combolch Dessie roads the trend of traffic accident shows increasing. In Sebeta Tulu Bolo and Combolch Dessie roads there is a slight decrement in number of accident.

When we see the trends of traffic accident in Sebeta -Tulu Bolo and Combolcha- Dessie road, there is a slight decrement in the number of accident. As it was observed in data collection there was some intervention made by Sebeta – Tulu Bolo road traffic police at identified black spots, after intervention the number accident is decreasing to some extent.

Hazard location after long tangent at Sebeta-Tulu Bolo Traffic hazard light is very effective if it is implemented in the location where run off accident is occur frequently. To see the effectiveness of a treatment or traffic hazard light in Sebeta – Tulu Bolo road Accident modification factor was calculated.

Accident modification factor (AMF) = number of accident after treatment divided by number of accident before treatment

AMF= 35/42 AMF= 0.83

From this it is possible to calculate percentage of reduction in the number of accident. Percentage of reduction in the number of accident is obtained by multiplying number of accident before treatment by one minus accident modification factor.

Percentage of reduction = (1-AMF)*100

(1-.83) =17%

There are 7 black spots in which run off accident are dominated in Sebeta –Tulo Bolo road. 17% reduction of accident is obtained by applying traffic hazard light at three black spots; if traffic hazard light was installed in all (7) black spots, it reduces the total accident by 40% using cress cross calculation. The trends of traffic accident in Sebeta Tulu Bolo road tell us treating black spot has high potential for traffic accident reduction.

For the case of Combolcha – Dessie road, even if, it is not comfortable for vehicle occupant the construction of speed breaker reduces traffic accident significantly. There is a number of speed breaker

constructed on this road, however there is different problems on the constructed speed breaker.

Observed problem on Combolcha – Dessie road speed breaker

1. Vehicle occupant discomfort

2.Damage to vehicle

3.Excessive delay (a well-designed speed breaker is recommended to reduce speed up to 25 km/hr),

4.fuel consumption due to acceleration and deceleration

A speed breaker is effective if it is constructed by keeping standards and with proper signage; otherwise it may be the causes of accident. As per the road accident report, 2014 in India a total of 4726 lives were lost due to crashes at speed breakers on National Highways. The Indian road congress (IRC) recommends speed breaker having a dimension of width meter, height 0.1 meter and radius of 17 meter. It is better to study the impacts of speed breaker provision for traffic accident

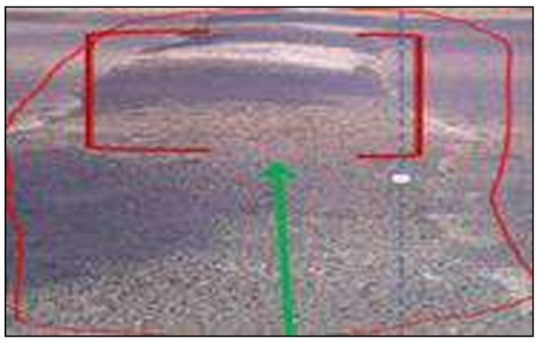

Fig 6: Unsuitable speed breaker on Combolcha – Dessie road

There should also a proper signage before and after speed breaker to indicate the presence of speed breaker.

Accidents and Contributory Factors

The main identified contributing factors of traffic accidents are human factor (driver and pedestrian), vehicle factor, and road and weather factor. Among the above listed contributing factors, human factor particularly driver behavior cause majority of the accident. (See figure below). By nature traffic accidents occur as a result of combination of factor, even if driver is the main factor, they are other factors which contribute for the occurrence of accident and aggravate the effect of accident.

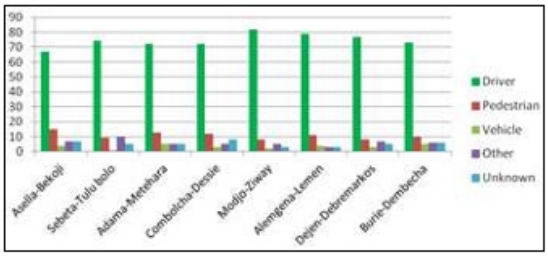

Fig 7: Indicates contributing factor for traffic accident

As the secondary data and reviewed literature indicates, the main contributing factors of traffic accidents are human factor (driver and pedestrian), vehicle factor, and road and weather factor. When we say 67% of the total accidents in Asella - Bekoji road were contributed by driver, it doesn't mean driver were the sole causes of this accident, but they are other factors which contribute for the occurrence of accident and aggravate the effect of accident. By nature traffic accidents occur as a result of combination of factor.

Driver Characteristics

The main problem that makes drivers to be the leading causes of accidents is;

1. Over speeding which contributes up to 40%
2. Not giving priority for pedestrian

Pedestrian behavior was the second contributing factor for the occurrence of traffic accident next to driver behavior. Not giving priority for vehicle was one of the main causes for pedestrian related traffic accident. Vehicle factor causes insignificant amount of the total accidents.

Fig 8: Traffic accident due to driver problem

Age of Drivers Vs Numbers of Accidents

The road traffic accidents caused by the driver also depends on the driver's age and their efforts. Several studies have showed that the age of drivers have a greater impact over the occurrence of road traffic accident/RTA. This is due to the fact that, the age of drivers affects their;

1. Driving behavior,
2. Concentration and
3. Sense of responsibility

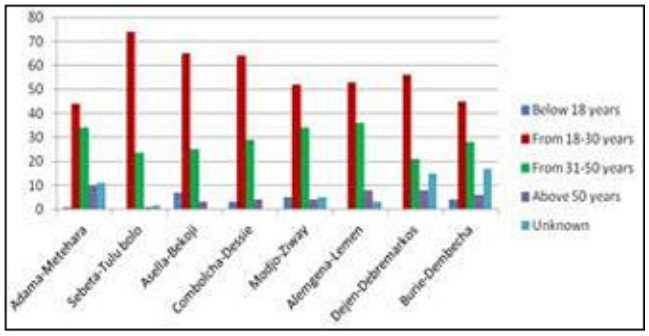

Fig 9: Traffic accident in relation to driver age

The driver age classification is based on Ethiopian federal police commission driver age classification. Most of the time accidents are caused by the driver in the age range of 18- 30 years. Drivers found in the age between 18 and 30 in the Sebeta - Tulubolo road are 3 times more frequently involved in road traffic accident than drivers aged 31 to 50. Overconfidence, risk taking behavior, lack of experience, drunk driving, and others behaviors can place young drivers in more hazardous situations than other drivers. This age group is most active in the economy of the country.

Road characteristics and weather condition

High number of accident is registered during good weather condition, on good asphalt and dry road condition for all study roads.

Table 4: Shows traffic accident in relation to road characteristics and weather condition

Road name	Accident on Good asphalt in %	Accident on dry road in %	Accident on Good weather in %
Asella-Bekoji	80	89	76
Sebeta-Tulu Bolo	87.3	87.3	77
Adama- Metehara	94	97	87
Combolcha- Dessie	79	85	78
Modjo-Ziway	95	96	70
Alemgena- Lemen	90	86	77
Dejen-Debre Markos	95	98	95
Bure-Dembeca	86	98	98

Why high accidents happen on good asphalt?

Most of the study roads are designed and constructed to achieve high level of service (riding quality), without implementing road safety action (speed limit, wearing seatbelt) and traffic calming measures. The road without speed controls and traffic calming measures, invites the driver to choose more than design speed, in distress asphalt the road limit operating speed. As a result roads with high levels of pavement roughness and distress will contribute low accident, regardless of riding quality and vehicle damage.

Fig 10: Sample photo of traffic accident on good asphalt collected during field survey

Vehicle factor

Vehicle type and number of traffic accident

To identify types of vehicle causing high number of accident, accident data were collected together with the types of vehicle. To simply the analysis, using the ERA vehicle classification the vehicles are classified under 8 groups. These are; Car, Land Rover, Small Bus, Large Bus, Small Truck, Medium Truck, Heavy Truck and Truck Trailer. All types of vehicle are categorized under these groups. Since the vehicle exposure or AADT by vehicle type affects the types of vehicle causing high number of accident the analysis considers the types of vehicle causing high number of accident together with their exposure in each study roads.

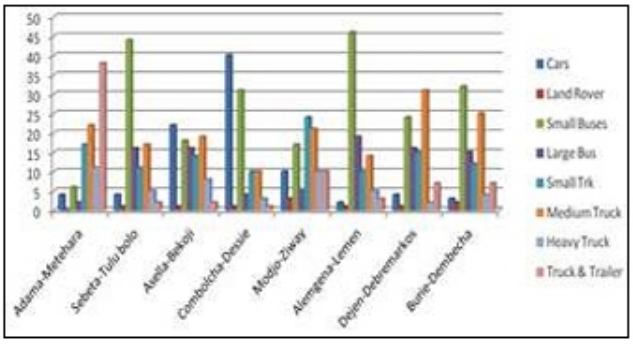

Fig 11: Percentage of traffic accident by Vehicle type causing the accident

The above chart shows types of vehicle causing high number of accident for each study roads separately. Regardless of their exposure from the chart small bus and medium truck causes high percentage of the total accident.

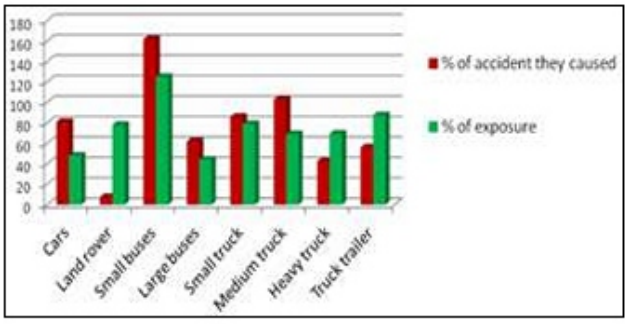

Fig 12: Vehicle exposure and traffic accident they causes

From the above chart the red color indicates percentage of accident caused by each vehicle types, and the green color indicates vehicle exposure in each road. Small bus, medium truck, large bus and small truck cause high percentage of accidents. Hence the percentage of accident they caused is greater than their exposure. Fatigue, driving long distance without rest alcohol, following too close incompetence of the drive are the main causes for truck accident. From small bus vehicle having 12 passenger seats is the main causes of accident. Over speeding and in appropriate overtaking are the main reasons for accident happening with this types of vehicle. Therefore Small bus, medium truck, large bus and small truck are the focus area for police maker.

Vehicle service year and traffic accident

When service life of the vehicles is increased, the reliability of them to travel longer distance gets less and less. Therefore, the accidents it can result will be increase. The part of the vehicle depreciates from time to time, and reduces its speed and other important conditions. However the result of data analysis shows that vehicles having service year of 2 -5 years causes high number of accidents.

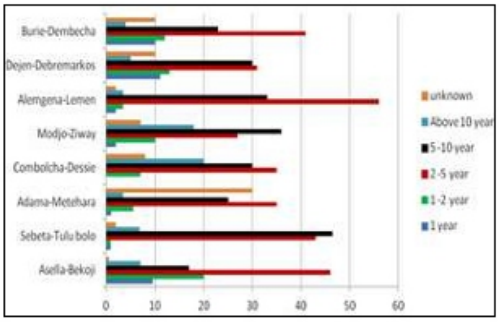

Fig 13: Vehicle service year and traffic accident

Vehicles having a service life between two – five years cause high percentage of accident. Secondly vehicle having a service life of five – ten cause high accident.

Vehicle defect and traffic accident

The largest share of accident in the study roads are caused by vehicles which have no defect. Defected vehicles caused the smallest share of total accident

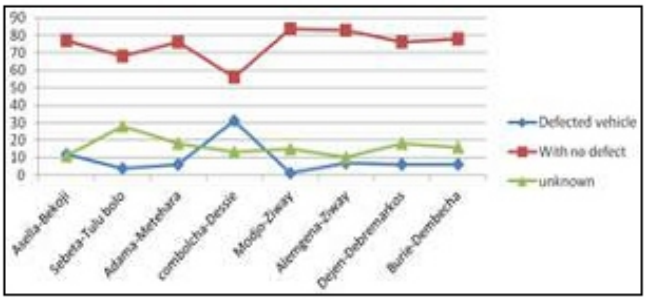

Fig 14: Vehicle defect and traffic accident

Vehicle service year and vehicle defect analysis result indicates vehicle problem causes very small amount of accident. In general vehicle is not the main causes of accident compared to other factors. But it not to mean defect vehicles cannot cause accident; in single accident there are a multiple factors that aggravate the effects of the accident, even if they are not the main factors.

Types of Vehicle Collisions and Traffic Accident

The main types of collision identified are; in front collision, front and back collision, front and side collision, side to side collision, overturning collision, collision with pedestrians and collision with

animal.

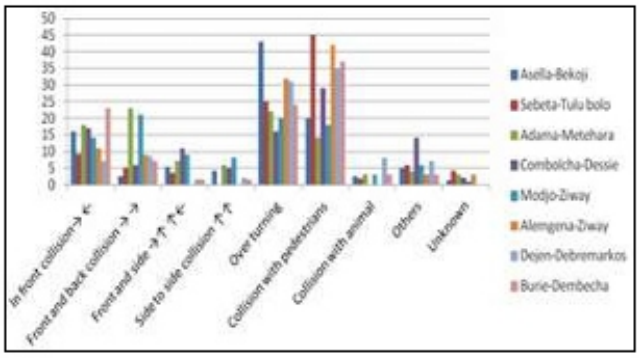

Fig 15: Types of vehicle collisions and traffic accident

Over turning collision, collision with pedestrian and in front collision is the main types of collision causing high number of accident. They are different factors for overturning collision, vehicle pedestrian collision and in front collision.

Overturning collision

Severity of the accident in the study road was very high; this is mainly due to over speeding. Speed is the governing factor for overturning of vehicle. As it is observed from secondary data, and interview conducted for traffic police, over speeding is the main problem of traffic accident. This is why overturning collision is become dominant types of collision

Fig 16: Hazard location after long tangent in Asella- Bekoji in which over turning accident is dominated

Collision with pedestrian

Not giving priority for pedestrian and vehicle were the root causes for pedestrian Collision, especially in school and religious area. The effect of pedestrian collision depends on operating speed. For example changing operating speed from 50 km/hr to 60 km/hr increases the probability of pedestrian collision death by 30%. Similarly increasing the operating speed beyond 80km/hr increases the probability pedestrian collision death by 100% (European commission for road safety).

Head on collision

In appropriate overtaking and absence of center line are the main causes for head on collision. Most of the roads in rural area are not maintained regularly, especially road marking. In the absence of road center line it is difficult for driver to keep their lane, as a result the uses the opposite lane. Center line rumble strip is effective for head on collision. Summarized Causes of Traffic Accident in Black spot Area and Number of Accident They Cause in Percent The following are the causes of accident identified by traffic police together with the number of accidents they cause. The data shows most of the causes are due to driver fault.

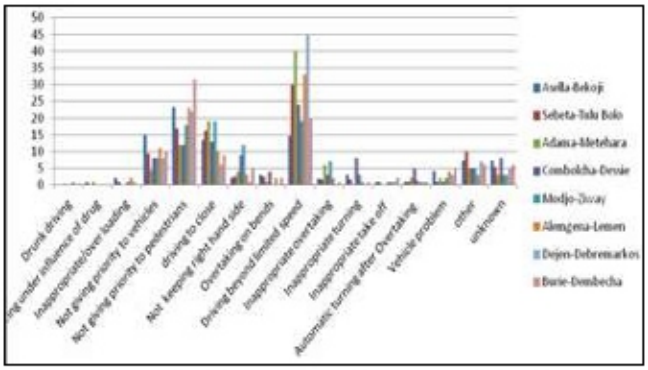

Fig 17: Causes of traffic accident and percentage of accident they causes

Conclusion and recommendation

Conclusion

The situation of roads traffic accident at the national level is very serious both in terms of severity and frequency of occurrence. Speed controlling and wearing of seatbelt are critical to reduce the Severity and rate of the accident. From results of data analysis the main causes of accident are;

1. Over speeding,
2. Not giving priority for pedestrian,
3. Not giving priority for vehicle,
4. Driving too close,
5. Not keeping right side,
6. Poor pedestrian and driver behavior

However, the above factors are not the sole causes of traffic accident; by nature traffic accident results from a combination of factors. For example if speed is the main causes of accident, the road side environment, lane width (road geometry), road surface, road infrastructure, vehicle condition, weather condition and etc aggravates the effects of accidents. In general traffic accident has no single cause. Speed is one of the governing factors that make the driver to be the leading causes of accident. Physical speed controlling measure is effective to reduce vehicle speed, which plays a vital role in accident severity reduction. Majority of the accidents are registered on good asphalt, during good weather condition and on good (dry) road condition. Absence of safety actions implementation and traffic calming measures are the main causes for accidents happen on good asphalt.

Among different types of collision, overturning collision and vehicle pedestrian collision are occurring frequently; together they account more than 50% of the total accidents. Absence of lane marking, speed limit post, pedestrian facilities, warning sign, and sigh distance problem with difficult road side environment, were the common problems identified within the black spot. Providing traffic hazard light at black spot location were effective measures to reduce run off and lane departure accident at minimum cost.

In genera in this research, adequate accident data together with their location and traffic data were collected to achieve the stated objectives. However, this data was not obtained simply; it was very tedious and time taking. The data recording system was not comfortable to extract data needed for the research. Recording accident data with soft copy was not cultured in most of the traffic police. In addition to this since Traffic Police Officers had many tasks and were usually out of their offices, it was difficult to get them.

Recommendation

The policy maker should have to work hard on road safety action implementation such as speed limits, pedestrian safety and speed control measures. Construct rumble strips, traffic hazard light and speed breaker at identified black spots. Shoulder rumble strips have reduced run-off road type crashes by 20 to 72 percent with benefit cost ratio of 5:1 to 20:1 Source Washington State Department of Transportation. Traffic calming measures, such as traffic sign, play a very important role in changing driver behavior over time and using them is useful for pedestrian protection. Maintenance of road marking and traffic sign continuously is significant. It is better to use modern technology that help at least to reduce the accident levels due to over speeding, such as speed measuring instrument (speed radar), and alcoholic test throughout the country. Providing separated pedestrian way and assigning traffic police (student traffic police) especially in school and religious area may be appropriate for those study roads. Creating awareness for pedestrian through social media (TV and radio), providing traffic safety education programs in all schools or adding traffic accident course on a curriculum (so that road safety for children

and teenagers can be achieved through educational programs) reduce this problem. Creating different association such as, ERA driver association etc and providing safety training through established association to improve driver's capacity the traffic police should have to modernize the accident data recording system. Poor recording system of accident data and lack of modern technology used to control the traffic flow should be improved. The traffic accident data should be recorded with exact location, if possible with their GPS coordinates, this simplifies black spot identification. The government should update road safety policy on speed limits and pedestrian priority. Traffic police have to practice consistent and well-oriented enforcement with respect of all road users. Visible enforcement against few risky drivers would mean educating others who see what is happening, from breaking the same laws. Finally Ethiopian road authority/ERA should implement the proposed mitigation measures on the identified black spot. Roads that are registering accidents repeatedly or black spots might have some sort of design problems. For example sight distance, narrow shoulders, narrow bridges, lack of accurate pedestrian walking-ways, difficult road side environments (side slope and back slope) etc. are some of problems observed in the study roads. Therefore, roads with design problems should be corrected through reengineering works.

References

1. Abdulla AL Hammoudi. Causes and Strategies to Reduce Road Traffic Accidents in Abu Dhabi; c2014.

2. Atsbeha Gebremeskel. Addis Ababa Road Traffic Accident Study and Possible Engineering Solutions: Case Study of Akaki Kaliti Sub City Roads; c2014.

3. Belachew Melese. Statistical Analysis of Road Traffic Car Accident in Dire Dawa Administrative City, Eastern Ethiopia; c2015.

4. Berhanu G. Effects of Road Safety and Traffic Factors in Ethiopia; c2000.

5. Staines BW, et al. Deer and Road Traffic Accidents: A Review of Mitigation Measures Centers for Disease Control and Prevention, (2013), Strategies to Prevent Obesity and Other Chronic Diseases; c2004.

6. Dawit Oluma. Road Traffic Accident and Safety Evaluation Case of Addis Ababa Bole Sub City; c2016.

7. Economic Commission for Africa /ECA Traffic Accident in Ethiopia; c2009.

8. Eduardo A Vasconcellos. Traffic Accident Risks in Developing Countries; c2005.

9. Elservier. Traffic Safety Assessment and Development of Predictive Models for Accidents on Rural Roads in Egypt; c2004.

10. Fanueal Samson. Analysis of Traffic Accident in Addis Ababa: Traffic Simulation; c2006.

11. Fesseha Hailu, Silesh Teshager. Road Traffic Accident: The Neglected Health Problem in Amhara

National Regional State, Ethiopia; c2014.

12. Fikadu Mekasha. Road Traffic Accident: Causes and Control Mechanisms: in Addis Ababa City; c2015.

13. Fred Mannering. Analysis of the Effect of Speed Limit Increases on Accident-Injury Severities; c2013.

14. Fred Wegman. Fewer Crashes and Fewer Casualties by Safer Roads; c2003.

15. Simon Washingtonb, et al. Characteristics of Police- Reported Road Traffic Crashes in Ethiopia over a Six Year Period; c2013.

16. Getu Segni. Causes of Road Traffic Accidents and Possible Counter Measures on Addis AbabaSHashemene Roads; c2007.

17. Girmay Giday. Spatio Temporal Assessment of Road Traffic Accident in Mekelle City Greg Chen (2009), Road Traffic Safety in African Countries Status, Trend, Contributing Factors, Counter Measures and Challenges; c2014.

18. Hailegnaw Getaneh. Web based Road Traffic Accident Reporting System for Ethiopia; c2010.

19. Khanna SK, Justo CEG. Highway Engineering, Nem Chand and BROS; c1986.

20. Kassu Jilcha. Road Accidents and Road Safety from Addis Ababa to Hawassa; c2009.

21. Lavalette. Road Safety Statistics: What is behind the figures?; c2017.

22. Lagarde, et al. journals Road Traffic Injury is an Escalating Burden in Africa and Deserves Proportionate Research Efforts; c2007.

23. Leidschendam. Traffic legislation and safety in Europe concerning the moped and the A1 category (125 cc) motorcycle; c2004.

24. Marta Agujetas, Fredu Nega, Frank Van. Roadside Planting in Ethiopia: Turning a Problem into an Opportunity; c2016.

25. Mossa Endris Ahmed. The Causes of Road Traffic Accidents in Bahir Dar City, Ethiopia; c2015.

26. Mohammed Abdul-Kadir. Training lay People as first Responders to Reduce Road Traffic Mortalities and Morbidities in Ethiopia: Challenges, Barriers and Feasible Solutions; c2015.

27. Notifier Engineered Systems Company (Nesco), 2002 manual Ogden, K. W (1996), Safer Roads – A Guide to Road Safety Engineering

28. Rune Elvic, Truls Vaa. the Handbook of Road Safety Measures; c2004.

29. RW Cuerden, MJ Edward, Pittman MB. Effect of vehicle defects in road accidents; c2011.

30. Sandra Vieira Gomes. Low-cost engineering measures for casualty reduction; c2000.

31. The Institution of Engineers Mitigation of Road Accidents; c2005.

32. Transportation Research Improving Road Safety in Developing Countries Board; c2006.

33. Tesfalem Hailu. Causes and socio-economic impacts of road traffic accidents in Addis Ababa; c2010.

34. Thomas R. Introduction to Trdaffic: A manual for Data Collection and Analysis; c2001.

35. TRL Report Socio-economic Aspects of Road Accidents in Developing Countries; c1997.

36. Eckersley W. Khat, Driver Impairment and Road Traffic Injuries: a View from Ethiopia; c2010.

37. Williams S. Road accidents are Africa's third biggest killer, African Business; c2003.

38. World health Organization (WHO) World Report on

39. Road Traffic Injury Prevention; c2004.

40. World health Organization (WHO), Global status report on road safety: Time for action; c2009.

41. World health Organization (WHO), Global Status Report on Road Safety; c2013.

42. Yared Debebe. Road Traffic Accidents and Human Security in Addis Ababa; c2012.

43. Yayeh Addis. The Extent, Variation and Causes of Road Traffic Accidents in Bahir dar; c2003.

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Renewable energy infrastructure projects as a veritable tool for enhancing climate resilience in Nigeria

Benjamin Anabaraonye, Charles C Anukwonke and Somkenechi S Unachukwu

ABSTRACT

The use of renewable energy and a lesser reliance on fossil fuels in Nigeria which is in line with the United Nations Paris Agreement will help to reduce the excessive emission of green house gases which is a major cause of global warming and climate change. Excessive emission of greenhouse gases has been discovered to affect the health of individuals, communities and institutions in Nigeria adversely. This study identified that the use of renewable energy which is one of the climate change mitigation strategies will help to enhance good health and well being, increase environmental sustainability and also boost sustainable economic growth in Nigeria. It further identified solar energy as the most promising of the renewable energy sources in view of its apparent limitless potential. This study further highlighted case studies of some renewable energy infrastructure projects in Nigeria. It concluded with the call for more intensive research on the use of renewable energy infrastructure projects as a veritable tool for enhancing climate resilience in Nigeria.

Keywords: Climate resilience, infrastructure projects, renewable energy, sustainable development

Introduction

Renewable energy is defined by the National Renewable Energy and Energy Efficiency Policy (NREEEP) as energy derived from energy sources whose use does not lead to the depletion of the earth's resources (NREEEP, 2015). Renewable energy sources have drawn more attention in recent years, and the Federal Government of Nigeria's (FGN) electrical strategy is beginning to emphasize them. As a result, the NERC and the REA both played crucial roles in the establishment of policy and regulatory mechanisms meant to encourage investment in renewable energy industry in Nigeria (Esan et al., 2021) [19]. The renewable energy infrastructure projects which will help to decrease the nation’s reliance on fossil fuels is also a mitigation strategy for which will enhance climate resilience in Nigeria. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as statistical variations that persist for an extended period, typically decades or longer. Similarly, they define adaptation as the "adjustment in natural or human systems to a new or changing environment. Adaptation to climate change refers to natural or human systems adjusting to actual stimuli or their effects that reduce harm or exploit beneficial opportunities. Various types of adaptation can be famed, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC, 2001) [24]. Climate mitigation is any action adopted to reduce the long-term risk and hazards of climate variations to human life, property and society. The Intergovernmental Panel on Climate Change (IPCC)

described mitigation as: "An anthropogenic intervention to suppress the causes or enhance the sinks of greenhouse gases "(IPCC 2001; GGW, 2018) [24]. Climate resilience is the capacity of a socio-ecological system to absorb pressures and maintain function in the face of external stresses resulting from climate change (Folke et al., 2010; Moench, 2014; Shamsuddin, 2020) [21, 26, 30]. It also includes the ability and capacity of an ecosystem to adapt, reorganize, and evolve into more desirable configurations that improve the system's sustainability, leaving it better prepared for future climate impacts (Carpenter et al., 2001; Folke, 2006) [15, 20]. In order to provide sustainable energy in Nigeria at competitive pricing, the Climate Investor One (CIO) program receives additional funding from the Nigeria Renewable Energy Programme (NREP) (EC, 2020). CIO is a blending finance facility with an overall budget of €115.1 million and an EU commitment of €10.1 million in 2020. It is intended to offer whole-of-life financing for renewable energy infrastructure in developing nations like Nigeria. The Nigeria Renewable Energy Programme (NREP), which focuses on centralized energy solutions, including off-grid programs, is anticipated to: Provide Nigerians with access to inexpensive, sustainable energy; develop, fund, and build an additional 150+ MW of capacity; Identify and address market weaknesses related to finance for investments in renewable energy technology in developing markets; help cut down on greenhouse gas (GHG) emissions while leveraging significant direct private sector investment into emerging markets like Nigeria. The development of technology able to use various sources of energy is primarily responsible for the explosive expansion of the renewable energy sector in Nigeria (Obasoyo, 2022) [27]. The shift to renewable energy is now seen as a support, rather than a replacement, for the more conventional source of income (oil) in Nigeria. The emphasis on renewable energy sources has increased in the Nigerian government's electrical strategy. To encourage investment in renewable energy, policy and regulatory tools have been established. The primary law establishing the sector's legal and regulatory framework is the Electric Power Sector Reform Act of 2005 (EPSRA). The Nigerian Electricity Regulatory Commission (NERC) was founded by the EPSRA as the industry's regulator and is given authority to issue rules, regulations, and policies (Obasoyo, 2022) [27]. The Nigerian government launched the Solar Power Naija Project in 2020 with the intention of supplying 5 million off-grid villages with solar-powered connections. According to estimates, the initiative will affect 25 million homes and generate 250,000 jobs. The Nigerian government started work on the project in Jigawa State in April 2021, with an estimated cost of US$620 million. The Central Bank of Nigeria has also established a solar intervention fund that offers loan providers of renewable energy projects low-interest loans (5% interest) of up to 500 million naira. The US-EXIM Bank granted Nigeria a $1.5 billion loan to expand the country's solar power infrastructure in ten distinct areas, according to Adam Cortese, CEO of SUN Africa LLC in the United States. (Elumoye, 2022) [18]

Additionally, it creates the Rural Electrification Agency (REA), which is in charge of establishing isolated mini-grid systems, extending the main grid, and encouraging the production of electricity from

renewable sources. To ensure more equal regional access to electricity, the REA, which manages the Rural Electrification Fund (REF), is in charge of promoting, supporting, and putting rural electrification plans into action. The United States Agency for International Development (USAID) and Power Africa's Renewable Energy and Energy Efficiency Project (REEEP) in Nigeria, which provided renewable energy to 261,938 Nigerians through 16,600 connections and decreased carbon emissions, are two projects that have been aimed at developing the renewable energy industry in Nigeria (Obasoyo, 2022) [27]. The Nigerian Federal Ministry of Power also invited qualified bidders to submit a tender in 2020 for the construction of different off-grid solar infrastructure projects and other energy infrastructure around the nation. One of the solar sectors with the fastest growth rates worldwide is the Nigerian solar energy subsector (Adegbite, 2021) [1]. With a mean generating capacity factor of 27%, the daily solar energy density is approximately 12.6 MJ/m2/day in the southern region and 25.2 MJ/m2/day in the far north, near to the Sahara (Ohunakin et al., 2014; Anon, 2015) [28, 7]. Ilorin and Maiduguri's capacity factors estimates of the production effectiveness of energy systems are calculated to be 25.85% and 28.67%, respectively, for these selected sites within the nation (Adewuyi et al., 2020) [3]. In order to distribute electricity utilizing solar-powered plants, the Nigerian Electrification Programme (NEP) was introduced in 2019. For the project's implementation, the federal government, working through the Rural Electrification Agency (REA), obtained funds from the World Bank, African Development Bank, Africa Growing Together Fund, and European Union. With this investment, at least 90 million Nigerians and business owners will have access to affordable renewable energy (Obasoyo, 2022) [27]. Michaelmas Chambers (2021) [25] claims that there are several types of renewable energy infrastructure. In terms of hydropower energy production, Nigeria has some noteworthy hydropower infrastructure in Niger State at Kainji, Jebba, and Shiroro. According to data for the northern and central parts of Nigeria, which are rich in solar energy, the estimated generation potential for solar PV is roughly 43,000 MW (Africa-EU Energy Partnership, 2015), of which only a very small portion has yet to be used. Compared to other VREs, solar energy research and development (R&D) activities have received more attention in Nigeria because to its comparatively simple technology and adequate capacity factor (Giwa et al., 2017) [22]. In 2017, the federal government spent over $20 billion on new solar projects, and Kaduna state has been chosen as the location for a private company's 30 MW solar farm project (Ayemba, 2017; Bulbulia, 2018) [11, 12]. A pilot wind farm is being built at Katsina, and there is some potential for producing wind energy in the country's north and along its coast (Oyedepo et al., 2012; Brimmo et al., 2017) [29, 14].

A total of $150 million worth of solar equipment was imported in 2019. An estimated $2 billion of Nigeria's $9 billion yearly market for solar home systems and mini-grids goes toward solar home systems. Significant financial resources have been devoted to the development and expansion of solar energy solutions in Nigeria through the Rural Electrification Agency (REA) and private non-profit

organizations including Shell-backed AllOn, IFC, and The Rockefeller Foundation. In remote regions, REA will have installed over 6,000 solar residential systems and seven mini-grids by 2020 (Adegbite, 2021) [1].

In 2019, AllOn Hub offered off-grid energy entrepreneurs a $3.5 million grant as part of a partnership with The Rockefeller Foundation to help them scale their firms at the ideation, growth, and market entry stages. The same year, through the Nigeria Off-Grid Energy Challenge, both organizations gave $50,000 in angel stage funding to Nigerian off-grid energy companies so they could reach communities without access to current power grids. This was done in collaboration with the U.S. African Development Foundation (USADF) (Adegbite, 2021) [1] Despite these noteworthy advancements, the solar energy industry is still in its infancy, with a total installed capacity of just 28MW. One key obstacle facing renewable energy technology is the hefty upfront cost. An enormous increase in renewable energy (particularly solar and wind) projects has been seen in many nations as a result of this worldwide paradigm shift and different legislative actions by governments to encourage their development and finance. Even for a nation like Nigeria, where renewable energy has always been a part of the energy mix (approximately 12.5% of its on-grid energy comes from hydropower), the present trend offers a chance to promote and draw in sustainable investment to its energy industry. (Esan et al., 2021) [19] to boost its perpetual abundance. Generally, this paper aimed to examine the "the use of renewable energy infrastructure projects as a veritable tool for enhancing climate resilience in Nigeria". This paper examined current progress with the use of renewable energy infrastructure projects which is a climate change mitigation strategy in Nigeria through existing literature review.

Methodology

Data used for this study is derived from published works, including academic journal articles, conference papers, textbooks and internet materials. The researchers gathered a lot of materials for the research but summarized the characteristics of the papers that centered more on "the use of renewable energy infrastructure projects as a veritable tool for enhancing climate resilience in Nigeria". This enabled the researchers to generate the synthesis of various researchers' views on the subject matter.

Results and Discussion

Just about 59.3% of Nigerians have access to electricity which is not stable and most are forced to resort to rely on alternate sources of energy which are unclean and have deleterious climatic effects. Similarly, only about 28.2% of the population primarily rely on clean energy and technologies for cooking. This however is not surprising as 62.6% of Nigerians were recorded as living below the poverty line and for this subset of the population, the primary concern would be survival and food security rather than the choice of technology for cooking due to cost (Ajator, Anabaraonye & Ewa, 2020) [5]. Nigeria wants to

cut its greenhouse gas (GHG) emissions by at least 47% by 2030, subject to certain conditions. The nation's nationally determined contributions (NDCs) under the Paris Agreement include the following goals: achieving zero gas flaring by 2030; reducing fugitive emissions from oil and gas production by 60% by 2031; and ensuring that 30% of on-grid electricity and 13 gigawatts of off-grid energy are derived from renewable sources.It is estimated that the NDCs will cost USD 177 billion to implement. In order to meet the anticipated rise in global demand, Nigeria is now attempting to introduce a carbon price and plans to develop its essential mineral reserves. (EITI, 2021). Recognizing the consequences and adverse impact of climate change on Nigeria, the country joined the global community to adopt treaties developed to tackle climate change. Nigeria became a Party to the UNFCCC in 1992 and ratified the Convention in 1994, it also became a Party to the Kyoto Protocol in 2004. Nigeria ratified the Paris Agreement (PA) in March 2017, which was approved by the UNFCCC on the 16th May 2017 and entered into force on 15th June 2017 (Manso & Behmiri, 2013) In June 2017, the Federal Government of Nigeria and the United Nations Development Program (UNDP) flagged off a $218 million renewable energy project. This project was aimed at reducing greenhouse gas emissions by meeting the energy targets set in the NDC (Ajator, Anabaraonye & Ewa, 2020) [5].

How renewable energy infrastructure projects can achieve sustainable development in Nigeria

In Nigeria, the limitless potentials of the renewable energy sources are yet to be fully utilized and maximized (Adewuyi et al., 2019) [2]. There is no question that Nigeria has a lot of untapped renewable energy potential that has appeared to be constrained throughout time by a number of factors. To stimulate the continuous growth of renewables into the economy's energy mix, the public sector, industry players, investors, and other stakeholders are, however, quickly developing frameworks and programs, as was previously indicated (Esan, et al., 2021) [19]. The establishment of the necessary energy framework required to power Nigeria's renewable energy infrastructure projects depends on the availability of investment funding. However, even though the necessary financial assistance may not always be accessible or may be subject to prohibitive conditions when it is available, specific steps can be taken at the nongovernmental and governmental levels to promote energy sustainability in Nigeria and other sub-Saharan African countries (Anabaraonye et al., 2021) [6]. Setting up a profit/benefit-oriented investment environment with beneficial regulations and legal paperwork that will support environmental sustainability while pursuing energy sustainability, such as alternatives in green entrepreneurship, is one way to attain this renewable energy efficiency (Anabaraonye et al., 2021) [6]. With minimal negative financial and socio-political repercussions, these circumstances will entice investors in both domestic and international alternative energy sources. Domestic consumers will be encouraged to participate in any way they can because current laws and policies will safeguard their rights and interests on a national and personal level (Adewuyi et al., 2019) [2]. Increased investment in hydropower technology is planned in terms of returns on investment, operation and maintenance, scale

economies, and other factors, hydropower continues to be among the most dependable energy sources. Therefore, increasing investment in hydroelectric power plants can greatly aid in achieving environmental and energy sustainability. Utilizing the available energy resources to their fullest potential is known as energy resource management. These energy carriers are frequently ignored, allowed to waste, and become a nuisance to the environment. Renewable energy sources in Nigeria have potential wastes that should be utilized. The ability to produce effective renewable energy will be lacking until this is accomplished in Nigeria.

Diverse energy resource management strategies, such as the implementation of effective waste-to-energy models for the disposal of agricultural wastes and some non-toxic/organic biological wastes from household and industrial wastes, are honorable initiatives with promise for renewable energy. Through the installation of a 100 kVA refuse-derived fuel (RDF) gasification power plant on their main campus, the University of Nigeria, Nsukka has led this initiative (Anon, 2019) [8]. Therefore, energy conservation focuses on maximizing the benefits from the energy output that is now accessible by reducing waste and making smart use of energy that has been sent (Askari et al., 2015) [10]. Ajator, Anabaraonye & Ewa (2020) [5] identified the solar energy as the most promising of the renewable energy sources in view of its apparent limitless potential. They further identified the health and economic benefits of the use of solar energy across various communities and institutions for sustainable development in Nigeria (Ajator, Anabaraonye & Ewa, 2020) [5]. As a deliberate strategy to hasten the adoption of renewable energy, there is a need. to increase investor incentives for promoting renewable energy. Although Nigeria's current regulatory framework for renewable energy is commendable, additional leadership enablers need to be fixed in order to improve process flow and policy execution across the many operators in the renewable energy infrastructure (Ajator, Anabaraonye & Ewa, 2020) [5]. To build Nigeria's renewable energy sector, the country's policy framework, which consists of legal, fiscal, and regulatory instruments, must be perfectly aligned with both domestic and foreign investment requirements. Meeting the goals of the Paris Agreement will need a fundamental shift toward renewable energy sources like solar and wind (UNFCCC, 2019) [31]. The Paris Agreement is a global climate change agreement that was ratified by 196 Parties at COP 21 in Paris six years ago. Its objectives are to keep climate change and the accompanying global warming below 1.50C compared to pre-industrial levels. As a result, the Paris Agreement is a turning point in the complex process of addressing climate change because it was the first to provide a legally enforceable commitment for all signatory countries to mainstream efforts to fight climate change and prepare for its hazards.

Recommendations

The Nigerian government should

A) Undertake risk assessment and risk reduction measures to increase resilience of the renewable energy infrastructure projects in Nigeria.

B) Develop and diversify secure energy backup systems to ensure both civil society and security forces have access to emergency energy supply through the renewable energy technology.

C) Encourage and fund further research projects to enable researchers and scientists to fully explore the use of the renewable energy infrastructure projects as a veritable tool to enhance climate resilience in Nigeria.

D) Individuals, Communities and Institutions in Nigeria should be well educated using innovative tools such as poetry, music, educational blog, social media, etc. on the use of renewable energy infrastructure projects to enhance climate resilience in Nigeria.

Conclusion

The Paris Agreement is a significant milestone for Nigeria's efforts to mitigate the effects of climate change and a step toward achieving its de-carbonization targets, which look at ways to reduce GHG emissions and advance the goal of achieving net-zero GHG emissions through various strategies like carbon crediting (Anukwonke and Abazu, 2020) [9] including the renewable energy infrastructure projects. Furthermore, The Nigerian Government should provide financial frameworks aimed at stimulating the expansion of the renewable energy electricity market. Considering the risk element involved in financing renewable energy infrastructure projects, Nigerian government investments should enhance rates of return and develop new policies in order to attract more investors into the renewable energy industry to enhance climate resilience in Nigeria.

References

1. Adegbite T. Where's Nigeria Headed with Renewable Energy?; c2021. https://www.thisdaylive.com/index.php/2021/11/14/wh eres-nigeria-headed-with-renewable-energy/

2. Adewuyi OB, Lotfy ME, Akinloye BO, Howlader HOR, Senjyu T, Narayanan K. Security-constrained optimal utility-scale solar PV investment planning for weak grids: Short reviews and techno-economic analysis. Appl. Energy. 2019;245:16-30. http://dx.doi.org/10.1016/j.apenergy.2019.04.008, http://www.sciencedirect.com/science/article/pii/S0306 261919306336.

3. Adewuyi OB, Kiptoo MK, Afolayan AF, Amara T, Alawode OI, Senyu T. Challenges and prospects of Nigeria's sustainable energy transition with lessons from other countries experiences Energy Reports. 2020;6:993-1009

4. Africa-EU Energy Partnership. Nigeria Renewable Energy Potential. European Union and the

African Union; c2015.

5. Ajator C, Anabaraonye B, Ewa B. The Health Benefits in Use of Solar Energy for Sustainable Development in Nigeria. EC Emergency Medicine and Critical Care. 2020;4(2):01-06.

6. Anabaraonye B, Ewa BO, Anukwonke CC, Eni M, Anthony PC. The Role of Green Entrepreneurship and Opportunities in Agripreneurship for Sustainable Economic Growth in Nigeria. Covenant Journal of Entrepreneurship, 2021, 5(1). ISSN: p.2682-5295

7. Anon. Today in Energy: Electric Generator Capacity Factors Vary Widely Across the World. U.S. Energy Information Administration (EIA); c2015. https://www.eia.gov/todayinenergy/detail.php?id=2283 2.

8. Anon. UNN Becomes the first Nigerian university to generate its own electricity using organic waste, 2019. https://witnesta.com/2019/03/20/unnbecomes-the-firstnigerian-university-to-generate-its-ownelectricityusing-organic-waste.html.

9. Anukwonke CC, Abazu CI. Green Business through Carbon Credit. In Climate Change Alleviation for Sustainable Progression: Floristic Prospective and Arboreal Avenues as a Viable Sequestration Tool. Science Publishers CRC Press Taylor and Francis Boca Raton, USA; c2020. ISBN: 9780367618872

10. Askari IB, Sadegh MO, Ameri M. Energy management and economics of a trigeneration system considering the effect of solar PV, solar collector and fuel price. Energy Sustain. Dev. 2015;26:43–55., http://www.sciencedirect.com/science/article/pii/S0973 082615000265

11. Ayemba D. Natural Nigeria Invests US $ 20 bn in 20 New Solar Power Projects. Construction Review Online; c2017. https://constructionreviewonline.com/2017/12/nigeriainvests-us-20bn-20-new-solar-projects/

12. Bulbulia T. DLO Energy resources invests in 30 MW solar plant in Nigeria; c2018.

13. http://www.engineeringnews.co.za/article/dlo-energy resources-investsin-30-mw-solar-plant-in-nigeria-201812-10/rep_id:4136.

14. Brimmo AT, Sodiq A, Sofela S, Kolo I. Sustainable energy development in Nigeria: Wind, hydropower, geothermal and nuclear (vol. 1). Renew. Sustain. Energy Rev. 2017;74:474–490. http://dx.doi.org/10.1016/j.rser.2016.11.162, http://www.sciencedirect.com/science/article/pii/S1364 032116309169.

15. Carpenter S, Walker B, Anderies JM, Abel N. From Metaphor to Measurement: Resilience of What to What? Ecosystems. 2001;4(8):765-781. https://doi.org/10.1007/s10021-001-0045-9

16. EC. European Commission, Europa external investment plans and projects including renewable energy programme. Facts Sheet in Gazette; c2020. https://ec.europa.eu/eu-external-investmentplan/projects/nigeria-renewable-energy-programmenrep_enit

17. EITI. Nigeria, Pathways to energy transition Using EITI data and dialogue. Overview of how the EITI can support Nigeria implications in addressing the economic of the energy transition; c2021.

https://eiti.org/documents/nigeria-pathways-energy transition

18. Elumoye D. Nigeria Secures 1.5 Billion from US to Boost Solar Power Infrastructure; c2022. https://www.thisdaylive.com/index.php/2022/08/05/nig eria-secures-1-5bn-loan-from-us-to-boost-solar-powerinfrastructure/

19. Esan W, Akinola J, Onakoya D, Monnou G. Renewable Energy in Nigeria: law, regulation, trends and opportunities, International Bar Association; Reference Update; c2021.

20. Folke C. Resilience: The emergence of a for social–ecological Environmental systems Change. analyses. Global 2006;16(3):253–267. https://doi.org/10.1016/j.gloenvcha.2006.04.002

21. Folke C, Carpenter SR, Walker B, Scheffer M, Chapin T, Rockström J. Resilience Thinking: Integrating Resilience, Adaptability and Transformability. Ecology and Society, 2010, https://doi.org/10.24926/ijps.v7i2.3386 12 15(4).

22. Giwa A, Alabi A, Yusuf A, Olukan T. A comprehensive review on biomass and solar energy for sustainable energy generation in Nigeria. Renew. Sustain. Energy Rev. 2017;69:620–641. http://dx.doi.org/10.1016/j.rser.2016.11.160, http://www.sciencedirect.com/science/article/pii/S1364032116309108.

23. Global Greenhouse Warming. Climate mitigation and adaptation, 2018. http://www.global-greenhousewarming.com/climate-mitigation-and-adaptation.html

24. IPCC. Climate change 2001: the scientific basis. Contribution of working group 1 to the third assessment report of the intergovernmental panel on climate change. Published by the press syndicate of the University of Cambridge, The Pitt Building, Trumping Street, Cambridge, United Kingdom. First published, 2001.https://ipcc.ch/ipccreports/tar/wg1/pdf/WGI_TAR _full_report.pdf

25. Michaelmas Chambers. Renewable Energy Deployment in Nigeria, 2021. https://www.michaelmaschambers.com/insightpage.php?i=20&a=renewable-energy-deployment-innigeria

26. Moench M. Experiences applying the climate resilience framework: linking theory with practice. Development in Practice. 2014;24(4):447-464.

27. Obasoyo O. Nigeria: Regulating Renewable Energy in Nigeria; c2022. https://www.mondaq.com/nigeria/renewables/1175982/ regulating-renewable-energy-in-nigeria.

28. Ohunakin OS, Adaramola MS, Oyewola OM, Fagbenle RO. Solar energy applications and development in Nigeria: Drivers and barriers. Renew. Sustain. Energy Rev. 2014;32:294-301. http://dx.doi.org/10.1016/j.rser.2014.01.

29. Oyedepo SO. On energy for sustainable development in Nigeria. Renew. 2012;16(5):2583-2598, Sustain. Energy http://www.sciencedirect.com/science/article/pii/ S1364032112001037.

30. Shamsuddin S. Resilience resistance: The challenges and implications of urban resilience implementation. Cities. 2020;103:102763. https://doi.org/10.1016/j.cities.2020.102763

31. UNFCCC. For every dollar invested in climate-resilient infrastructure six dollars are saved, Secretary-General says in message for disaster risk reduction day. United Nations; c2019. https://www.un.org/press/en/2019/sgsm19807.doc.htm#

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Stabilization of soil using geotextile

Himanshu Vimal, Nandini Kaushik and Devesh Jaysawal

A B S T R A C T

Engineering projects frequently use soil stabilization to boost soil strength and save building costs. Due to their many advantages over traditional stabilization methods, geotextiles, a type of geosynthetic material, have gained prominence during the past ten years. Geotextiles are permeable, flat sheets constructed of polypropylene or polyester resin with yarns that have been knitted, needle-punched, woven, thermally or chemically bonded, or combined all of these techniques. They can be created using materials that are readily available in the area, are inexpensive, and are easy to install. They are a great solution for big-scale construction projects like paving because they don't need highly skilled workers and their quality can be readily managed. Through a partial interaction between the soil and the geotextile material, the process of improving the soil with geotextile increases its stiffness and load-carrying ability. This enables the pavement system to have a lower overall thickness while extending its lifespan and lowering maintenance expenses. An important benefit of using geotextiles for soil stabilization is that it eliminates the requirement for expensive earth resources to be extracted from rented pits. Instead, the first earth elements found on the construction site can be used to pave roads, cutting down on construction expenses and the project's impact on the environment. Geotextiles are also good at keeping base layers and subgrade particles from blending together. When there isn't a geotextile at the subgrade/base course interface, the subgrade contaminates the aggregate. Particles, which reduces the overall durability of the pavement system. When subjected to dynamic loadings, geotextile-reinforced soils outperform conventional soil, making them suitable for use in pavements for roads and airports. Using geotextiles for soil stabilization is a cost-effective and sustainable construction. It offers several benefits over traditional soil stabilization methods and can aid in reducing construction costs, increasing service life, and minimizing the environmental impact of construction projects.

Keywords: Geotechnical test, geotextile, woven fibre, non-woven fibres, stabilization of soil

Introduction

Soil stabilization is a crucial aspect of civil engineering projects to ensure the longevity and safety of infrastructure. Geotextiles have emerged as a popular and effective solution for soil stabilization in recent years. In this journal entry, we will explore the concept of soil stabilization using geotextiles, their benefits, and their effectiveness in ensuring the stability of the soil.

What are Geotextiles?

Geotextiles are flat, permeable sheets constructed of polyester or polypropylene resin with yarns that have been knitted, needle-punched, woven, thermally or chemically bonded, or bonded with a thermal

agent. They belong to a class of geosynthetic materials that are frequently employed in civil engineering projects to stabilize the soil. In comparison to conventional stabilization methods, geotextiles offer a variety of benefits, including simplicity of installation, lower cost, and enhanced performance.

Benefits of Geotextiles for Soil Stabilization

Geotextiles have many advantages to stabilizing soil. First, because geotextiles may be laid with local resources, less expensive earth materials need to be carried to the construction site. This lowers expenses while simultaneously lowering the project's negative environmental impact. Second, the intermixing of base layers and subgrade particles, which can reduce the overall strength of the pavement system, can be effectively avoided by using geotextiles. Third, it has been shown that geotextiles can make the soil more rigid and capable of holding more weight, reducing the pavement system's overall thickness while extending its lifespan and lowering maintenance costs.

Effectiveness of Geotextiles for Soil Stabilization

Several research have been done to determine how effective geotextiles are at stabilizing soil. According to these investigations, geotextiles are quite successful at enhancing the soil's strength and stability. It has been demonstrated that geotextile-reinforced soils perform better than conventional soils under dynamic loadings, making them perfect for usage in pavements for roads and airports. The process of enhancing the subgrade soil's load-bearing capacity and engineering qualities to support structures and pavements is known as soil stabilization. This study investigated the use of geotextile as reinforcement to stabilize two soil samples (lateritic and clay). Particle size analysis, the Atterberg Limit test, moisture content, specific gravity, the compaction test, and the California Bearing Ratio test are all performed as part of geotechnical testing.

Woven-Fabric Geotextile

Commonly found geotextiles are of the woven type and are manufactured by adopting techniques similar to weaving usual clothing textiles. This type has the characteristic appearance of two sets of parallel threads or yarns. The yarn numbing along the length is called the warp and the one perpendicular is called the weft.

Fig 1: Woven Geotextile

Non-Woven Geotextile

Non-woven geotextiles are manufactured from either continuous filament yarn or short staple fiber. The bonding of fibers is done using thermal, chemical or techniques or a combination of techniques.

Fig 2: Non-Woven Geotextile

Table 1: Difference between the woven and non-woven geotextiles

Geotextiles	
Woven	**Non-Woven**
Separation	Separation
Reinforcement	Filtration
High Load Capacity	Drainage
Plastic Like	Felt-Like
Referred To by Tensile Strength	Referred To by Weight
Impermeable	Permeable

Literature Review

Geotextiles are frequently used to stabilize soil and boost the effectiveness of paving systems. They ensure that the overall strength of the pavement system is not compromised and protect base layers from contamination by subgrade particles. Geotextile-reinforced soils outperform conventional soil under dynamic loading situations, and they are robust, non-biodegradable, and extend the pavement's overall service life, according to D.A. Ogundare (2018) (1).

According to A.K. Choudhary, K.S. Gill, and J.N. Jha (2011) (2), adding more layers of reinforcement to geotextiles lowers their expansion ratio and raises their California Bearing Ratio (CBR) value. They discovered that geogrid is more effective in strengthening soils than jute geotextile.

According to Kaku et al. (2007) (3), geotextiles are also helpful in landscaping to control weeds and preserve soil conditions for plant growth. In 1987, R. M. Koerner of Drexel University in Philadelphia (4) distinguished between areal fill for stabilization and linear embankments for containment dikes or barriers. Both instances offer a wide range of potential applications and are currently the subject of intensive activity. According to Jon A. Epps, Ph.D. and Wayne A. Dunlap, Ph.D. (1970) (5), soil compaction is a practical and affordable strategy for stabilization. Additionally, chemically stabilized soils need to be properly compacted.

According to Ankit Singh Negi et al. (6), lime works well as a soil stabilizer for highly dynamic soils that frequently expand and contract. Using lime strengthens the soil's ability to carry loads, lessens the soil's tendency to shrink under wet conditions, lowers the plasticity index, raises the CBR value, and improves compression resistance over time. Within a few hours, the stabilization process gets started. Anil Pandey et al.'s (7) investigation into cement-based soil stabilization. The researchers came to the conclusion that soil cement is a desirable base or sub-base material because it offers strength and durability. It is also a great substitute material for affordable construction. In a study on bituminous soil stabilization, Sabbani Venkatesh (8) discovered that cationic bituminous emulsion is useful for enhancing subgrade soil strength. Rathan Raj R et al. (9), who studied the impacts of solid waste such as rice husk ash on the variance of different index values, shear strength, CBR value, and compaction characteristics of clay soil, examined the stabilization of soil with rice husk ash. The outcomes demonstrated that clay soil can be strengthened and have its qualities enhanced by rice husk ash. It is significant to note that these conclusions about geotextiles and soil stabilization have been independently investigated and reported; therefore, care should be made to ensure that the appropriate methods and materials are employed for each individual application.

Objectives

Sub-grade, sub-base, and course strength can be altered using the technique of soil stabilization to boost their bearing capacity by utilizing inexpensive, locally accessible soils and building materials, this strategy can also assist reduce the cost of building roads.

The process of stabilizing soil helps to improve some unfavorable characteristics of soils including excessive swelling or shrinking, high flexibility, and difficulties compacting. It reduces compressibility and minimizes settlements by facilitating compaction and boosting loadbearing capacity.

In addition, soil stabilization can enhance the soil's permeability properties, enabling better drainage and lowering the chance of water-related damage. before beginning any project, it is crucial to do a careful analysis of the soil's features and attributes.

Deciding on a soil stabilization strategy may include carrying out laboratory experiments to ascertain the strength and compressibility of the soil as well as field testing to evaluate the behavior of the soil under load.

Research -methodology

The mode of operation of a geotextile in any application is defined by six discrete functions:

1. Filtration
2. Drainage
3. Reinforcement
4. Cushion
5. Waterproofing
6. Separation

The flexible material geotextile is frequently used in the construction of roads for a number of purposes, including separation, filtration, strengthening, and sealing. One of its main uses is to function as a separator and stop the mixing of two adjacent soils. For instance, the drainage and strength characteristics of the aggregate material can be maintained by sandwiching geotextile between fine sub-grade soil and aggregates of the base course.

By permitting liquid flow while preventing soil loss across its plane, geotextile also contributes significantly to filtration. This is made feasible by the geotextile's porosity and permeability characteristics, which provide sufficient liquid movement without jeopardizing the stability of the soil system.

Another benefit of geotextile is its capacity to strengthen the soil, much like steel does system. Finally, geotextile can also be employed as a sealant. To form a waterproofing membrane, a non-woven geotextile layer can be impregnated and placed between the old and new asphalt layers. This contributes to decreasing the vertical flow of water into the pavement structure, hence increasing pavement longevity and lowering maintenance costs.

Table 2: Type of geotextiles

Function	Type of geotextiles recommended
Drainage	Non-woven (light or medium wt.)
Separation	Non-woven (Heavy wt.) Woven
Reinforcement	Non-Woven (Heavy wt.) Woven
Cushion	Non-Woven (Light wt.) Woven
Filter	Non-Woven Woven

Test

Moisture content

The natural water content also called the natural moisture content is the ratio of the weight of water to the weight of the solids in a given mass of soil. This ratio is usually expressed as a percentage. To sight a few, natural moisture content is used in determining the bearing capacity and settlement. The natural moisture content will give an idea of the state of the soil in the field.

W = [(W2-W3)/(W3-W1)] * 100

Specific gravity

Table 3: Test Results

Particulars	Sample A	Sample B
Liquid Limit (%)	36.10	43.60
Plastic Limit (%)	19.40	29.30
Plasticity Index (%)	15.10	14.30
Moisture Content (%)	18.10	19.20
Optimum Moisture Content (O.M.C) (%)	14.50	12.00
Max. Dry Density(g\cm^3)	1.29	1.35
Specific Gravity	2.72	2.60

Specific gravity (*GS*) is a property of the mineral or rock material forming soil grains. It is defined as

$$G_S = \frac{Mass\ of\ soil}{Mass\ of\ water\ displaced\ by\ soil} = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$

[The range of G_S for common soils is 2.64 to 2.72]

Compaction

The dry unit weight (γ_d) is calculated as follows:

$$\gamma_d = \frac{W - W_m}{(1 + w) * v}$$

Where:
W = the weight of the mold and the soil mass (kg)
Wm = the weight of the mold (kg)
w = the water content of the soil (%)
V = the volume of the mold (m3, typically 0.033m3)

The derived dry unit weight along with the corresponding water contents are plotted in a diagram along with the zerovoids curve, a line showing the dry unit weight correlationThe derived dry unit weight along with the corresponding water contents are plotted in a diagram along with the zerovoids curve, a line showing the dry unit weight correlation with the water content assuming that the soil is 100% saturated. No matter how much energy is provided to the sample, it is impossible to compact it beyond this curve. The zero-void curve is calculated as follows:

$$\gamma_d = \frac{G_s * \gamma_w}{1 + W * G_s}$$

Where
GS = the specific gravity of soil particles (typically, GS~2.70)
γ_w = the saturated unit weight of the soil (KN/m3)
Typical curves derived from the Standard and Modified Proctor tests, as well as the zero air voids curve.

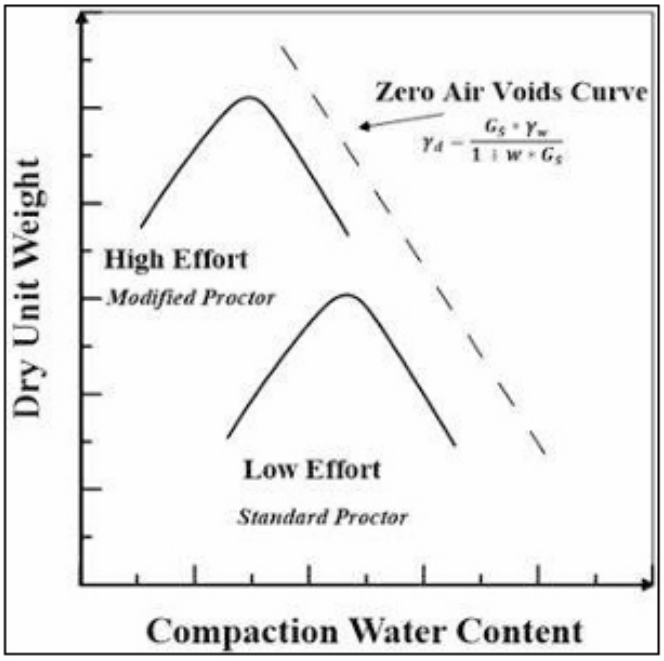


Fig 3: Dry unit wt. vs Water content

Atterberg limits

Testing of Atterberg limits is performed only on the soil fraction passing through a No. 40 sieve, according to ASTM D4318-00 (ASTM, 2003). Therefore, mixtures of cohesive clayey soil and fine rubber particles (< 0.425 mm size) have been studied and results showed that as the percentage of tire rubber increased, the clay content decreased and consequently Atterberg limits also decreased. In particular, the liquid limit stayed unchanged until levels of waste tire reached 30%, and then it started to decrease; the plastic limit stayed about the same up to 10% waste tire inclusion levels, started to decrease

at levels of 20% and then stayed the same. The plasticity index was found to stay the same for rubber chips up to 10% inclusion levels, while according to N. Oikonomou and S. Mavridou this was found to slightly decrease as the percentage of rubber increased to 10%.

CBR Test

The California Bearing Ratio or CBR test is performed in construction materials laboratories to evaluate the strength of soil subgrades and base course materials. Those who design and engineer highways, airport runways and taxiways, parking lots, and other pavements rely on CBR test values when selecting pavement and base thicknesses.

Where, PT = Corrected test load corresponding to the chosen penetration from the load penetration curve. PS = Standard load for the same penetration.

Table 4: CBR Experiment

Sample	Without Non-Woven		CBR (%)	With Non-Woven		CBR (%)
	2.5 mm	5 mm		2.5 mm	5 mm	
A	3.5	3.9	3.8	14.1	14.9	15.0
B	5.8	6.6	6.9	20.2	17.2	21.0

Fig 4: Soil Sample

Tensile strength

• Wide width tensile test

Samples of a particular size must be prepared in order to test geotextile specimens. Samples that are 200mm wide and 100mm long in both the warp and weft directions are needed for this purpose. For evaluating these samples, the machine strain rate should be 103% per minute. It is crucial to highlight that the choice of wide-width samples was made since geotextiles, particularly nonwoven ones, frequently acquire high Poisson's ratio values when put through testing on a narrow strip. Therefore, it is essential to use larger samples during the testing process in order to achieve reliable and representative results. The specimens should be mounted centrally once they have been processed to guarantee

consistent and accurate testing. By adhering to these recommendations, It is feasible to gather trustworthy and pertinent information about the toughness and longevity of geotextiles, which can then be used to create and put into practise efficient pavement separation systems.

Tensile strength measure as Tgeotextile = Fb/ W (kN/m)

Fb = Observed breaking force (kN), and

W = Specimen width (m)

Narrow strip tensile strength

Narrow strip sample size 75 mm x 25 or 50 mm, strain rate 300 mm/min, tensile strength appears to be less than wide width tensile strength, not recommended as design value

Grab tensile strength

To ascertain the efficacy of geotextiles, particularly in separator applications in pavement, a construction survivability test is required. With an initial clearance of 75 mm and a loading rate of 300mm/min, the specimen is tested using 25 mm narrow width grips. Nonwoven the test because it depends on the interaction of the filaments in the geotextile. The geotextile's tensile strength is measured in KN. However, because the sample is only partially clamped, the stress does not spread across the sample's entire width. The grab tensile strength is needed to design geotextiles for separation. The two lower stones are stretched laterally when pressure is applied to the higher stone, which releases tension in the geotextile. Similar to the grab tensile strength test, this tension exists. These tests can be used to decide whether a geotextile's strength and durability are suitable for situations involving pavement separation. To maintain the integrity of the pavement system, it is crucial to make that the geotextiles can sustain the anticipated loads and stresses.

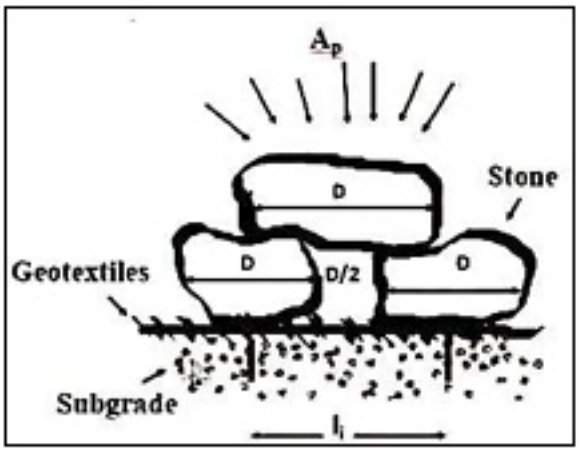
D= Diameter of stone
l_i= Initial length = D/2 + D/2+D/2
l_f= final length = D+2 (D/2)

Without any stone breakage or slippage, maximum strain in geotextile can be expressed as,

$$\varepsilon = \frac{l_f - l_i}{l_i} X100 = \frac{[D + 2\frac{D}{2}] - [\frac{D}{2} + \frac{D}{2} + \frac{D}{2}]}{\frac{3D}{2}} = \frac{1}{3} = 33\%$$

$$T_{reqd} = A_P\,(Dv)^2\,\varepsilon$$

T_{reqd} = required grab tensile strength reqd
A_p = Applied pressure
D= Maximum void diameter = $0.33D_a$



D_a= Average stone diameter

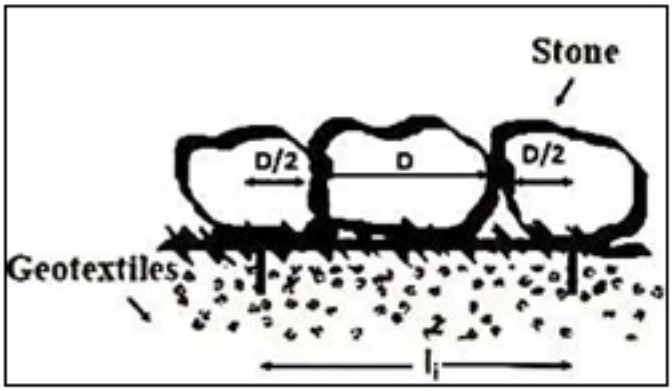


Table 5: MPU & GTP results

Particular	Non-Woven Geotextile
Mass Per unit (g\m^2)	205
Grab Tensile Strength	705

Conclusion

There are various crucial processes in the manufacturing process that must be followed to guarantee that the finished products comply with the appropriate standards and laws. These actions entail locating the product, choosing the right materials for it in accordance with the design guidelines and legal requirements, and monitoring the product's quality as it is being produced. Additionally, it is crucial to guarantee that the items fit the requirements for the use for which they are designed. To ensure that the items are flawless and satisfy the criteria, testing and inspection are required. In order to make sure that a product will work effectively and meet the requirements for a certain use, it is also critical to evaluate its appropriateness for that purpose. This evaluation entails evaluating the product's manufacturing process, materials, and design to make sure it is suitable for the intended application. Manufacturers can make sure that their products satisfy the essential quality requirements and are appropriate for their

intended usage by taking these actions and doing thorough assessments. Design engineers must have a good understanding of the necessary specifications in order to choose the best geotextile material for a project. Without this knowledge, it may be difficult to choose the ideal geotextile for the project's unique requirements. Conducting testing on the material through an impartial laboratory is one technique to confirm that the chosen geotextile material complies with the required criteria. The data sheets that manufacturers often supply. These sheets may not provide the degree of detail required to ascertain whether a specific geotextile material is suitable for a given project, but they do include minimum average roll values (MARV) for quality control. It is crucial to take samples of the material from the project site and send them to a lab for testing in order to reduce the environmental impact of utilising geotextiles in building projects. The strength, permeability, and durability of the geotextile may all be learned through this testing, which can assist confirm that the material is suitable for the demands of the particular project. Design engineers can choose the right materials for a project by thoroughly evaluating and analysing geotextile materials. This helps to ensure that the project is finished successfully while minimising its environmental impact.

Table 6: Advantages with or without geotextiles in road and highways

GEOTEXTILES IN ROAD AND HIGHWAYS	WITHOUT GEOTEXTILES	WITH GEOTEXTILES
REDUCED POTHOLES	✓	✓
CAN CONSTRUCT ON SOFT SOIL	✗	✓
QUICK INSTALLATION	✗	✓
BETTER LOAD-BEARING CAPACITY	✗	✓
COST EFFECTIVE	✗	✓
INCREASED LIFESPAN	✗	✓

Reference

1. Das Braja M, Khing Kim H, Shin Eun C. Stabilization of Weak Clay with Strong Sand and Geogrid at SanClay Interface. Transportation Research Board, 1611, National Research Council, National Research Council, Washington, DC; c1998.

2. Giroud JP, Norway L. Geotextile-Reinforced Unpaved Road Design, Proc. ASCE Journal Geotechnical Engineering. 1981;107(GT9):1233-54.

3. Maxwell S. Geosynthetics in stabilizing soft subgrade with breaker run. Wisconsin Highway Research Program, Final Report. 2005;0092-45-15:88.

4. Parkash EV, Kumar EV. Use of lime and saw dust ash in soil stabilization. International Journal of Innovative Research in Science, Engineering and Technology. 2017;6(2):1682-1689.

5. Ampadu SIK. A Laboratory Investigation into the Effect of Water Content on the CBR of a Subgrade Soil. Softbank E-Book Centre, Tehran; c2007.

6. Denton MJ, Daniels PN. Textile terms and definitions, 11th edition. (The Textile Institute, Manchester, U.K); c2007.

7. Olaniyan OS, Akolade AS. Reinforcement of Subgrade soils with the use of Geogrids. International journal of Science and Research. 2014;6(3):2579-2584.

8. BS 1377. Methods of Testing Soils for Civil Engineering Purposes. British Standards Institute, London; c2000.

9. Koerner RM. Designing with geosynthetics. 5th edition (Prenctice – Hall, Rotterdam, The Netherlands). 2005.

10. Prasad SK. Index properties of soil. S. J College of Engineering, Mysore; c2014.

11. Haliburton TA, Fowler J, Langan JP. Design and Construction of a Fabric Reinforced Test Section at Pinto Pass, Mobile, Alabama, Trans. Res. Rec. 1980, 79. Washington, DC.

12. Koerner RM. Soft Soil Stabilization for Wilmington Harbor South Dredge Material Disposal Area, Report to USAE Waterways Experiment Station, Vicksburg, MS; c1986 Jun, 28.

13. Lawson CR. Geosynthetics for Soil Reinforcement, Notes for a Short Course, Ascam Institute of Technology, Bangkok; c1982.

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Study on liquefaction of soil using cyclic load mechanism and pore pressure dissipation

Nandini Kaushik, Himanshu Vimal and Devesh Jaysawal

ABSTRACT

This report provides basic knowledge about the liquefaction of soil during a strong earthquake. The prediction of liquefaction and resulting displacements is a major concern for earth structures located in regions of moderate to high seismicity. The effect of these parameters was studied using excess pore pressure, lateral movement, and settlement time histories. Seismic disturbances can cause a sudden decrease in soil volume, creating pore spaces that become filled with water. This build-up of pore water pressure in the soil can be dangerous, as it can lead to a loss of shear strength in the soil. When the pore water pressure becomes equal to the total stresses in the soil, the soil can no longer resist the forces acting on it. As a result, the foundation on the soil may experience a large settlement, which can cause significant damage to buildings and other structures. In addition, the upward flow of water mixed with soil particles under turbulent conditions can cause further damage. It is important to understand the potential effects of seismic disturbances on soil and to take appropriate measures to mitigate the risks. This may involve designing foundations that are able to withstand the effects of earthquakes or implementing measures to reduce the build-up of pore water pressure in the soil. By taking proactive steps to protect against seismic disturbances, it is possible to minimize the risks and ensure the safety of structures built on or near potentially unstable soil.

Keywords: Pore pressure dissipation, cyclic mobility, cyclic lateral spreading mechanism, densification rule, cyclic id

Introduction

One of the main reasons for the damage of soil structures due to earthquakes in saturated conditions is liquefaction. The simplest way of modeling liquefaction which is still used in practice is done by means of total stress analysis. Liquefaction can be assessed from total or effective stress analysis. Effective stress analyses have been available for more than 25 years and are more fundamental. Triggering of liquefaction as well as post-liquefaction stability and resulting displacements can be considered in a single-time domain analysis. Most of the Northern part of India is coming under seismic zone IV or V. The failure behavior is broadly divided into two categories; flow liquefaction and cyclic mobility. Flow liquefaction leads to huge instabilities and deformations which are driven by cyclic shear stresses. On the other hand, cyclic mobility is another phenomenon that causes large deformations known as lateral spreading, but in comparison flow liquefaction deformation produced by cyclic mobility is driven by both cyclic and static shear stresses. Under earthquake and dynamic loading, the liquefaction phenomenon is common in loose saturated sands. In saturated sands, a longer drainage path and a lack of time between load increments contribute to the generation of excess pore pressure. When seismic

disturbances take place there is a sudden decrease in the volume of soil, this builds pore water pressure in the soil. A condition comes when this pore water pressure becomes equal to the total stresses, as a result of which soil loses of all its shear strength and a large settlement of foundation with vertical upward flow of water mixed with soil particles under turbulent conditions takes place.

Literature Review

A definition given by Sladen et al. (1985) states that "Liquefaction is a phenomenon wherein a mass of soil loses a large percentage of its shear resistance, when subjected to monotonic, cyclic, or shocking loading, and flows in a manner resembling a liquid until the shear stresses acting on the mass are as low as the reduced shear resistance".

When dense saturated sands are subjected to static loading they have the tendency to progressively soften in undrained cyclic shear achieving limiting strains which is known as cyclic mobility (Castro 1975; Castro and Poulos 1979).

(Seed 1979) defines that Cyclic mobility should not be confused with liquefaction. Both can be distinguished from the very fact that liquefied soil displays no appreciable increase in shear resistance regardless of the magnitude of deformation.

Ahmed-W. ELGAMAL1 And Zhaohui YANG2 directed a study about the liquefaction of soil during an earthquake using excess pore pressure drop, sharp acceleration spikes and associated regain of shear strength and stiffness in the liquefied soil.

N. Y. ELWakkad1, KH. M. Heiza2and M. Elmahroky the objective of this paper is to determine the behavior of structural elements to cyclic loads are summarized. The latest put forward by Robertson and Fear (1996); Cyclic Softening – Large deformations occurring during a cyclic load test to increase in pore water pressure that would tend to dilute in undrained, monotonic shear. According to Selig and Chang (1981) and Robertson (1994). cyclic load may produce a reversal in the shear stress direction when the initial shear stress is low i.e, the stress path passes through a condition that is known as a state of zero shear stress.

Robertson (1994) termed this, "cyclic liquefaction". It involves some deformation occurring while static shear stresses exceed the shear resistance of the soil (when the state of zero effective stress is approached). However, the deformations stop after cyclic loading ends as the tendency to expand quickly results in strain hardening. As defined by the National Research Councils Committee on Earthquake Engineering (1985), soil liquefaction is defined as this phenomenon in which there is a loss of shearing resistance or the development of excessive strains as a result of transient or repeated disturbance of saturated cohesionless soils. During cyclic mobility, the driving static shear stress is less than the residual shear resistance and deformations get accumulated only during cyclic loading. However, in layman‟s language, a soil failure resulting from cyclic mobility is referred to as

liquefaction.

Objectives

The objective of the present research is to develop deterministic, probabilistic, and reliability-based models to evaluate the liquefaction potential of soil using liquefaction modeling, cyclic load test and cyclic load spreading mechanism, and densification rule also. The scopes of the research are as follows:

1. To determine liquefaction modeling of soil under monotonic or cyclic loading for loose soil to compact under shear loading.
2. To study about Cyclic load test that describes the constitutive model.
3. To study about cyclic lateral spreading mechanism considered to ground deformation resulting from soil liquefaction in earthquakes.
4. To determine pore pressure dissipation and densification rule.

Research methodology

Liquefaction modeling

Liquefaction is defined as the loss of shear strength of soil under monotonic or cyclic loading, arising from a tendency for loose soil to compact under shear loading. The term "liquefaction" was originally coined by Mogami and Kubo (1953). Dilation plays an important role in the liquefaction process. As soil densifies under repeated shear cycles, grain rearrangement may be inhibited. Soil grains may then be forced to move up against adjacent soil particles, causing dilation to occur, the effective stress to increase and the pore pressure to decrease. Thus densification is a self-limiting process.

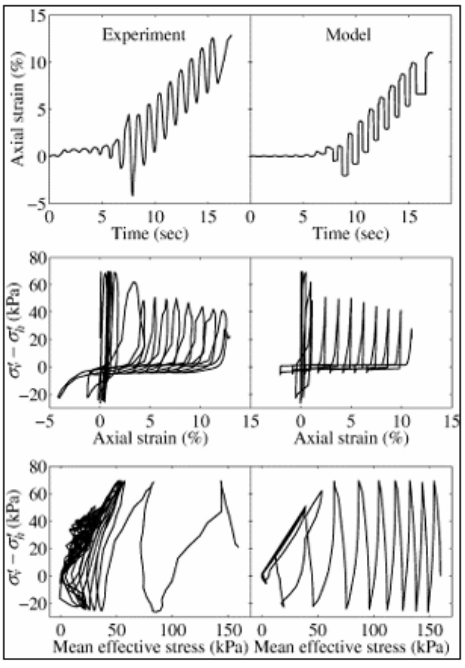

Fig 1: Mean effective stress

$$\frac{\Delta \varepsilon vd}{\gamma} = c1 \exp\left[-c2 \frac{\Delta \varepsilon vd}{\gamma}\right]$$

Where ΔƐvd is the increment of volume decrease, ϒ is the cyclic shear strain, and c1 and c2 are constants dependent on the volumetric strain behavior of sand. These constants are derived from the relative density, Dr as:

$$c_1 = 7600(Dr)^{-2.5}$$

$$c_2 = \frac{0.4}{c1}$$

This definition is available in FLAC, as a built-in model that incorporates into the standard Mohr-Coulomb plasticity model.

Cyclic ID

A site amplification computer code (CYCLIC CODE) describes the constitutive model that is currently available for execution using commonly available Internet browsers such as Internet Explorer or Netscape Navigator. In the level ground case, liquefaction is quickly reached in all but the deepest part of the stratum, and the high level of excess pore pressure remains throughout the shaking phase. This important buildup of excess pore pressure results in: I) loss of effective confining stress and shear strength, ii) degradation of shear stiffness, and iii) quick decrease and eventually the disappearance of lateral acceleration amplitude near the surface of the ground. It is also been observed that in the level ground case with uniform cycles of excitation, acceleration spikes are symmetric, with negligible permanent lateral deformation. In the inclined stratum case, the soil is subjected to the same symmetric cyclic base excitation superposed on a static locked-in shear stress (due to the 4 degrees inclined selfweight component of the ground). The presence of this static driving force results in the accumulation of significant permanent lateral deformation (lateral spreading) in the down-slope direction and in a pattern of asymmetric acceleration spikes. Although excess pore pressure initially builds up much like the level ground case, post-liquefaction behavior is completely different. The p-q diagram shows strong soil dilatancy as the stress path travels along the failure (or phase-transformation) line during liquefaction. This pattern of cyclic mobility results in 1) an instantaneous increase of confining stress and shear strength, 2) corresponding pore pressure drops, 3) associated regain in shear stiffness, and 4) the appearance of asymmetric downslope acceleration spikes (a direct consequence of this stiff dilative shear stress-strain response) at the ground surface. Thus, the above dilative mechanism may prevent an otherwise excessive amount of lateral spreading from accumulating.

Cyclic Lateral Spreading Mechanism

Restricting the consideration to ground deformations resulting from soil liquefaction in earthquakes, liquefactioninduced lateral spreading has been defined as the displacement of large, surficial blocks of soil as a result of liquefaction in a subsurface layer" (Liquefaction... 1985). As described by Bartlett and Youd (1992a; 1992b), liquefaction-induced lateral spreading occurs on mild slopes of 0.3 to 5% underlain by loose sands and a shallow water table. Such soil deposits are prone to pore pressure generation, softening, and liquefaction during large earthquakes. If liquefaction occurs, the unsaturated overburdened soil can slide as intact blocks over the lower, liquefied deposit. An illustration of the dilative-tendency mechanism observed in undrained cyclic laboratory tests is shown in Figure 1 [Arulmoli et al. 1992]. Similar response (Figure 1) was observed [Zeghal and Elgamal 1994] at the US Imperial County Wildlife Refuge site (1987 Superstition Hills earthquake records, see [Holzer et al. 1989]). Figure 1 depicts the mechanism of accumulation of cycle-by-cycle deformations. This cyclic mobility mechanism can significantly reduces the total accumulated shear strain due to liquefaction

Pore Pressure Dissipation and Densification Rule

During the time cycle between successive impacts, the pore pressure generated dissipates with time and densification occurs concurrently. The equation for pore pressure dissipation with time is given as;

$$\frac{du}{dt} = \mathrm{Cr}\left(\frac{\partial^2 u}{\partial r^2} + \frac{1}{r}\frac{\partial u}{\partial r}\right) + \mathrm{Cv}\frac{\partial^2 u}{\partial z^2}$$

Here u= pore water pressure, Cr and Cv are the coefficient of consolidation in the radial and vertical directions. During consolidation, the volumetric densification of a soil element is given by;

$$\varepsilon v = \int m_v \cdot \partial \sigma'$$

Where εv = volumetric strain, m_v= coefficient of volume compressibility, and σ' = effective stress.

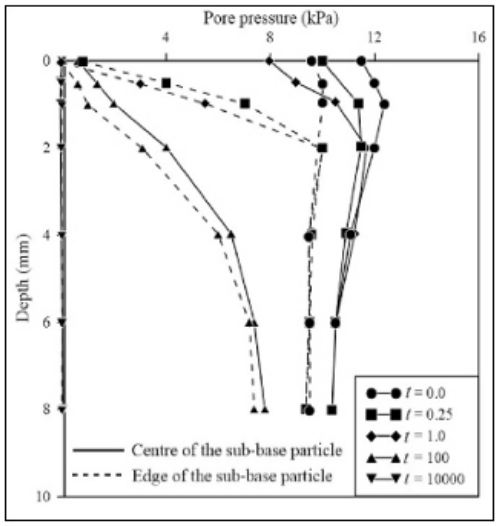

Fig 2: Depth Vs Pore Pressure

Conclusion

A new constitutive model is developed to model the cyclic shear behavior of liquefied soil. The underlying mechanisms are based on observed (medium-dense cohesionless soil) response during earthquakes, centrifuge experiments, and cyclic laboratory tests. The cyclic strain-based approach is less commonly used than the Cyclic stress-based approach as the cyclic strain amplitudes cannot be predicted as accurately as cyclic stress amplitudes, and due to the unavailability of equipment for cyclic strain-controlled testing. Though, the deterministic method of liquefaction potential is preferred by geotechnical professionals but, probabilistic evaluation is very much required in actual practice, which helps in taking risk-based design decisions. For making an unbiased evaluation of liquefaction potential, the uncertainty of the limit state boundary surface is to be determined for which rigorous reliability analyses are required.

References

1. Madabhushi SSC, Madabhushi SPG. Finite element analysis of floatation of rectangular tunnels following earthquake-induced liquefaction. Indian Geotech; c2015.

2. Robert DJ, Soga K, O'Rourke TD. Pipelines subjected to fault movement in dry and unsaturated soils; c2016.

3. Roy K, Hawlader B, Kenny S, Moore I. Uplift failure mechanisms of pipes buried in dense sand; c2018.

4. Castro G. Liquefaction and Cyclic Mobility of Saturated Sands, Journal of the Geotechnical Engineering Division, ASCE. 1975;101(GT6):551-569.

5. Castro G, Poulos SJ. Factors Affecting Liquefaction and Cyclic Mobility, Journal of the Geotechnical Engineering Division, ASCE. 1977 Jun;103(GT6):501516.

6. Iai S. A Strain Space Multiple Mechanism Model for Cyclic Behavior of Sand and its Application," Earthquake Engineering Research Note No. 43, Port and Harbor Research Institute, Ministry of Transport, Japan; c1991.

7. Kramer SL, Arduino P. Constitutive Modeling of Cyclic Mobility and Implications for Site Response," Proc. 2nd Intl. Conf. on Earthquake Geotechnical Engineering, Lisboa, Portugal, 21-25 June, Seco & Pinto (Ed.). 1999;2:895-900. Balkema.

8. Beaty M, Byrne P. An effective stress model for predicting liquefaction behaviour of sand", Geotechnical Earthquake Engineering and Soil Dynamics III ASCE Geotechnical Special Publication. 1998;75(1):766-777.

9. Sriskanda Kumar S. Cyclic loading response of frasersand for validation of numerical models simulating centrifugetests. Master's thesis, The University of British Columbia, Department of Civil

Engineering; c2004.

10. Seed HB, Martin PP, Lysmer J. The generation and dissipation of pore water pressures during soil liquefaction Earthquake Engineering Research Center, Report No. UCB/EERC. 2004;75-26:1975.

11. Kang GC, Tobita T, Iai S. Seismic simulation of liquefaction-induced uplift behavior of a hollow cylindrical structure buried in shallow ground. Soil Dyn. Earthquake Eng. 2014 Sep;64:85-94.

12. Pastor M, Zienkiewicz OC, Leung KH. Simple model for transient soil loading in earthquake analysis. II. Non-associative models for sands. Int J Number Anal Methods Geomech. 1985;9(5):477-498.

13. Liu H. Three-dimensional analysis of underground tunnels in liquefiable soil subject to earthquake loading. In Proc., GeoCongress 2012: State of the Art and Practice in Geotechnical Engineering; c2012.

14. Castro G. Liquefaction and cyclic mobility of saturated sands. J Geotech Engg ASCE. 1975;101(GT6):551-569.

15. Chen ZB, Chen YQ. Numerical Analysis of Dynamic Soil-Box Foundation Structure Interaction System, Journal of Asian Engineering; c2002. Architecture and Building

16. Ishihara K, Iwamoto S, Yasuda S, Takatsu H. Liquefaction of anisotropically consolidated sand, Proc. 9th Inter. Conf. on Soil Mech. and Found. Eng., Tokyo, Japan. 1977;2:261-264.

17. Ishihara K, Takatsu H. Effects of over consolidation and K0 conditions on the liquefaction characteristics of sands," Soils and Foundations. 1979;19(4);60-68.

18. Watanabe K, Sawada R, Koseki J. Uplift mechanism of opencut tunnel in liquefied ground and simplified method to evaluate the stability against uplifting; c2016.

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1. Original scientific paper (giving the previously unpublished results of the author's own research based on management methods).

2. Survey paper (giving an original, detailed and critical view of a research problem or an area to which the author has made a contribution visible through his self-citation);

3. Short or preliminary communication (original management paper of full format but of a smaller extent or of a preliminary character);

4. Scientific critique or forum (discussion on a particular scientific topic, based exclusively on management argumentation) and commentaries. Exceptionally, in particular areas, a scientific paper in the Journal can be in a form of a monograph or a critical edition of scientific data (historical, archival, lexicographic, bibliographic, data survey, etc.) which were unknown or hardly accessible for scientific research.

Professional articles:

1. Professional paper (contribution offering experience useful for improvement of professional practice but not necessarily based on scientific methods);
2. Informative contribution (editorial, commentary, etc.);
3. Review (of a book, software, case study, scientific event, etc.)

Language

The article should be in English. The grammar and style of the article should be of good quality. The systematized text should be without abbreviations (except standard ones). All measurements must be in SI units. The sequence of formulae is denoted in Arabic numerals in parentheses on the right-hand side.

Abstract and Summary

An abstract is a concise informative presentation of the article content for fast and accurate Evaluation of its relevance. It is both in the Editorial Office's and the author's best interest for an abstract to contain terms often used for indexing and article search. The abstract describes the purpose of the study and the methods, outlines the findings and state the conclusions. A 100- to 250-Word abstract should be placed between the title and the keywords with the body text to follow. Besides an abstract are advised to have a summary in English, at the end of the article, after the Reference list. The summary should be structured and long up to 1/10 of the article length (it is more extensive than the abstract).

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Keywords are terms or phrases showing adequately the article content for indexing and search purposes. They should be allocated heaving in mind widely accepted international sources (index, dictionary or thesaurus), such as the Web of Science keyword list for science in general. The higher their usage frequency is the better. Up to 10 keywords immediately follow the abstract and the summary, in respective languages.

Acknowledgements

The name and the number of the project or programmed within which the article was realized is given in a separate note at the bottom of the first page together with the name of the institution which financially supported the project or programmed.

Tables and Illustrations

All the captions should be in the original language as well as in English, together with the texts in illustrations if possible. Tables are typed in the same style as the text and are denoted by numerals at the top. Photographs and drawings, placed appropriately in the text, should be clear, precise and suitable for reproduction. Drawings should be created in Word or Corel.

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Footnotes are given at the bottom of the page with the text they refer to. They can contain less relevant details, additional explanations or used sources (e.g. scientific material, manuals). They cannot replace the cited literature.
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Notes