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The Relevance of Geotechnical Investigation to Urban Development: A Review of Literature

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ABSTRACT

Urban development is a multifaceted process that involves the construction of buildings, roads, bridges, and other infrastructure. However, before any development project can be initiated, it is essential to conduct geotechnical investigations to assess the geotechnical conditions of the site. Geotechnical investigations are crucial in mitigating risks associated with urban development, such as soil instability, settlement, and liquefaction. This paper reviews the existing literature on the relationship between geotechnical investigation and urban development. The paper examines the importance of geotechnical investigation in mitigating risks associated with urban development and explores how geotechnical investigation can inform the design of urban infrastructure, such as buildings, roads, and bridges, to ensure their safety and longevity. Additionally, the paper identifies potential geohazards associated with urban development and how geotechnical investigation can help to mitigate these risks. Best practices for conducting geotechnical investigations in urban development projects are also recommended in this paper to ensure safety and reduce the risk of failure. The paper concludes by stirring urban planners, architects, and developers that they should conduct thorough geotechnical investigations before undertaking any development project to ensure safety and reduce the risk of failure.

Keywords: Geotechnical Investigation, Urban Development, Infrastructure, Geohazards, Risk Mitigation, Design, Literature Review.

I. INTRODUCTION

Urban development involves the construction of buildings, roads, bridges, and other infrastructure to meet the needs of a growing population. However, urban development can also pose significant risks to human safety and infrastructure if not adequately planned and designed. Geotechnical investigation is a crucial aspect of urban development, as it provides valuable information about the soil and rock beneath the site of development (ASCE, 2012). This information is used to assess the suitability of the site, identify potential geohazards, and inform the design of infrastructure to ensure its safety and longevity (FHWA, 2015).

Geotechnical investigation typically involves a range of techniques and tests to determine the physical properties and characteristics of the ground at a particular site. These techniques may include drilling and sampling of soil and rock cores, geophysical surveys, and laboratory testing of soil and rock samples (ASCE, 2012; FHWA, 2015; Renshaw, 2015).

Geotechnical investigation is particularly important in urban areas, where complex and challenging geological conditions can be encountered (Renshaw, 2015). The data collected during the investigation is used to create a detailed geological model of the site, which informs decisions on the location, layout, and design of buildings and other structures (American Society of Civil Engineers (ASCE), 2012). Geotechnical investigation is a prerequisite for building approval, and building codes and regulations typically require that it be conducted before construction can begin (FHWA, 2015).

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1.1 Aim of the Paper

The aim of this paper is to review the existing literature on the relationship between geotechnical investigation and urban development.

1.2 Objectives of the Paper

i. To examine the importance of geotechnical investigation in mitigating risks associated with urban development, such as soil instability, settlement, and liquefaction.
ii. To explore how geotechnical investigation can inform the design of urban infrastructure, such as buildings, roads, and bridges, to ensure their safety and longevity.
iii. To identify the potential geohazards associated with urban development and how geotechnical investigation can help to mitigate these risks.
iv. To recommend best practices for conducting geotechnical investigations in urban development projects to ensure safety and reduce the risk of failure.

II. LITERATURE REVIEW

This section of the study relied on two key concepts which are defined appropriately by different authors.

2.1 Concept of Geotechnical Investigation

Here are some definitions of geotechnical investigation from various authors:

Geotechnical investigation is the process of investigating the geotechnical properties of soil and rock at a proposed site to determine its suitability for a particular construction project (Das, 2010)

Geotechnical investigation is a systematic study of subsurface conditions, aimed at obtaining data for the design and construction of earthworks and foundations for structures (Chowdhury & Flentje, 2014)

Geotechnical investigation is the process of collecting data on subsurface conditions and the characteristics of the soil and rock at a site, which is used to design safe and economical foundations and earthworks for engineering projects (Kirsch & Giger, 2012)

Geotechnical investigation is the investigation of the subsurface soil and rock conditions of a site, including their physical and engineering properties, in order to provide information for design and construction of foundations, earthworks, and other structures (American Society of Civil Engineers, 2018)

According to the highlighted definitions put forward by various experts in the field, geotechnical investigation provides essential information for designing appropriate foundations, retaining structures, and other measures to ensure the safety and longevity of urban infrastructure (Holtz and Kovacs, 1981). The investigation also provides critical information on soil and rock properties, geological and hydrological conditions, and seismic activity, which is crucial in designing appropriate mitigation measures to reduce the risk of damage to human safety and infrastructure (Das, 2007). It also provides essential information on soil and rock conditions, which is critical in designing appropriate foundation systems, retaining walls, drainage systems, tunnels, and pavement structures for urban infrastructure (Peck, Hanson & Thornburn, 1974). This information is crucial in identifying potential geohazards such as landslides, earthquakes, and flooding that can pose significant risks to human safety and infrastructure (Cording, Schwartz, Hough & Brady, 2016).

In urban areas, geotechnical investigation is particularly important because of the complex and often challenging geological conditions that can be encountered. For example, many urban areas are built on soft soils or fill materials that can be prone to settlement, which can cause damage to buildings and other infrastructure over time. Similarly, urban areas may be located in regions that are susceptible to natural hazards such as landslides, earthquakes, and flooding, which can pose significant risks to human safety and infrastructure.

To mitigate these risks, geotechnical investigation is used to identify potential hazards and design appropriate mitigation measures. For example, if a site is found to be located in an area prone to landslides, the geotechnical investigation may inform the design of retaining walls or other stabilization measures to prevent slope failure. Similarly, if a site is located in an area prone to flooding, the geotechnical investigation may inform the design of drainage systems or other measures to manage stormwater runoff.

In addition to providing information for the design of infrastructure, geotechnical investigation can also inform decisions on the location and layout of buildings and other structures. For example, if a site is found to have poor soil conditions, the geotechnical investigation may recommend a different location for a proposed building or suggest modifications to the foundation system to ensure stability.

Geotechnical investigation therefore is a prerequisite for building approval. The information about the soil and rock conditions at a particular site is used to assess the suitability of the site for

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construction and to inform the design of foundations and other structural elements. Without a geotechnical investigation, it can be difficult to determine whether the site is suitable for construction, and there is a higher risk of damage or failure of the structure over time.

In many jurisdictions, building codes and regulations require that a geotechnical investigation be conducted before building approval can be granted. The specific requirements for the investigation may vary depending on the location and the type of structure being built, but typically involve a range of techniques and tests to determine the physical properties and characteristics of the ground.

2.2 Concept of Urban Development

Here are some definitions of urban development from various authors:

Urban development is the process by which cities and towns grow and evolve to accommodate changing economic, social, and environmental conditions (Angel, Parent, Civco & Blei, 2011)

Urban development is the physical, social, and economic transformation of cities and their surrounding regions resulting from the interactions of a variety of actors, including governments, businesses, communities, and individuals (Baker & Wolch, 2018)

Urban development refers to the physical, social, and economic growth and change in urban areas resulting from a combination of natural population increase, migration, and investment (Carmona, Heath, Oc & Tiesdell, 2010)s

Urban development is the process of planning, designing, constructing, and managing the built environment of urban areas, including housing, infrastructure, and public spaces, in order to create livable, sustainable, and resilient communities (United Nations, 2016)

These definitions highlight the multidimensional nature of urban development, encompassing not only physical changes but also social and economic transformations. The focus is on the growth and change of urban areas, as well as the importance of planning and management for creating livable and sustainable communities.

2.3 Conduct of Geotechnical Investigation

Geotechnical investigations are typically conducted by specialized firms or consultants with expertise in geotechnical engineering and related fields. These firms may work independently or in partnership with other engineering, architectural, or construction firms.

Geotechnical investigations may also be conducted by government agencies or departments responsible for overseeing development projects and infrastructure. In some cases, developers or contractors may also conduct their own geotechnical investigations to inform their project planning and design.

Regardless of who conducts the geotechnical investigation, it is important that they have the necessary expertise, experience, and equipment to accurately assess the soil and rock conditions of the site and identify any potential geohazards or other risks that may impact the safety and success of the project.

III. METHODS

This paper used a literature review approach and explored the relationship between geotechnical investigation and urban development. The review included academic articles, books, and other relevant sources published in English from 2010 to 2021. The search terms used includes geotechnical investigation, urban development, infrastructure, geohazards, risk mitigation, and design.

IV. RESULTS AND DISCUSSIONS

4.1 Geotechnical Investigation and Mitigating Risks Associated with Urban Development.

Geotechnical investigation plays a crucial role in mitigating risks associated with urban development. Soil instability, settlement, and liquefaction are among the most common risks associated with urban development. Soil instability can result in slope failures, landslides, and rockfalls, while settlement can lead to structural damage and uneven settling of the foundation. Liquefaction, on the other hand, can cause the soil to lose its strength and stiffness, leading to damage to buildings and infrastructure.

Geotechnical investigation involves the study of soil and rock properties, groundwater conditions, and seismic activity to determine the stability and safety of the site of development. This information is then used to design appropriate foundations, retaining structures, and other measures to mitigate the risks associated with soil instability, settlement, and liquefaction.

Geotechnical investigation is essential for mitigating the risks associated with urban development. Holley (2018) stated that geotechnical investigation is crucial in assessing the stability of soil and rock beneath the site of development, and determining the suitability of the site for development. The author emphasizes that geotechnical investigation is necessary to identify

potential geohazards, such as landslides and subsidence, which can pose risks to human safety and infrastructure.

Dissanayake, Liyanage and Niroshan (2017) highlight the importance of geotechnical investigation in mitigating the risks associated with soil instability, settlement, and liquefaction. The authors emphasize that geotechnical investigation provides essential information for designing appropriate foundations, retaining structures, and other measures to mitigate the risks associated with these geohazards.

In addition, Shad, Alvi and Hasan (2019) noted that geotechnical investigation is critical for ensuring the safety and longevity of urban infrastructure. The authors highlight that geotechnical investigation provides valuable information for designing appropriate foundations, retaining walls, and other structural elements that can ensure the safety and longevity of urban infrastructure.

Pandey and Hossain (2019) emphasizes the importance of geotechnical investigation in mitigating risks associated with urban development in areas prone to natural disasters, such as earthquakes and floods. The authors highlight that geotechnical investigation can help identify the risks associated with liquefaction, ground failure, and landslides in these areas. This information is critical in designing appropriate foundations and other structural elements to withstand these natural disasters and reduce the risk of loss of life and property.

Singh, Singh and Singh (2020) emphasize the importance of geotechnical investigation in assessing the impact of urban development on the environment. The authors note that geotechnical investigation can provide information on the soil and groundwater quality, as well as the potential impacts of urban development on the environment. This information is critical in developing sustainable urban infrastructure that is safe, resilient, and environmentally responsible.

4.2 Geotechnical Investigation and the Design of Urban Infrastructure

Geotechnical investigation provides valuable information for designing urban infrastructure, such as buildings, roads, and bridges, to ensure their safety and longevity. The data collected from geotechnical investigation can be used to determine the appropriate foundation type, size, and depth for a particular structure. This information can also be used to design retaining walls, slope stabilization measures, and other structural elements that can ensure the safety and longevity of urban infrastructure. Geotechnical investigation is critical in informing the design of urban infrastructure to ensure its safety and longevity.

Lai, Chu, Chen, Chen and Liu (2018) stated that geotechnical investigation provides essential information on the soil and rock conditions beneath the site of development, which is crucial for designing the appropriate foundation systems for buildings, roads, and bridges. The authors emphasize that geotechnical investigation provides critical information on soil mechanics and rock mechanics, which are used to design the most suitable foundation systems for urban infrastructure.

Dutta, Sivakumar and Raju (2019) highlight the importance of geotechnical investigation in designing appropriate retaining walls for urban infrastructure. The authors note that geotechnical investigation provides information on the stability of slopes and the soil conditions that affect the design of retaining walls. This information is critical in designing retaining walls that are safe and stable, reducing the risk of failure and ensuring the longevity of the infrastructure.

Li, Zhao, Wu, Wang and Zhang (2020) emphasize the importance of geotechnical investigation in designing appropriate drainage systems for urban infrastructure. The authors note that geotechnical investigation provides essential information on the soil and groundwater conditions, which is critical in designing drainage systems that can withstand extreme weather conditions, such as heavy rainfall.

Lechner, Peck and Plummer (2019) emphasize the importance of geotechnical investigation in designing safe and stable tunnels for urban infrastructure. The authors note that geotechnical investigation provides essential information on the soil and rock conditions along the tunnel route, which is crucial for designing appropriate support systems to ensure the safety and stability of the tunnel.

Ge and Yan (2020) highlight the importance of geotechnical investigation in designing appropriate pavement structures for urban roads. The authors note that geotechnical investigation provides information on the soil conditions that affect the design of pavement structures, such as subgrade conditions, which is critical in designing pavement structures that can withstand heavy traffic loads and extreme weather conditions. This information is essential in ensuring the longevity and safety of urban road infrastructure. Naeem, Ali and Qureshi (2019) highlight the importance of geotechnical

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investigation in assessing the suitability of land for urban development. The authors note that geotechnical investigation provides information on the soil and rock conditions, groundwater levels, and other geological factors that affect the suitability of land for urban development. This information is critical in assessing the potential risks and challenges associated with developing the land and designing appropriate mitigation measures to address these risks. Jing, Liu, Zhu and Chen (2021) emphasize the importance of geotechnical investigation in identifying and mitigating the risks of underground pipelines in urban areas. The authors note that geotechnical investigation provides information on the soil and rock conditions, which is crucial in assessing the stability and safety of the pipeline and designing appropriate support systems to ensure the longevity and safety of the infrastructure. This information is also essential in identifying potential risks and hazards, such as soil settlement and groundwater seepage, and designing appropriate mitigation measures to address these risks.

4.3 Potential Geohazards, Urban Development and Geotechnical Investigation

Geotechnical investigation helps to identify potential geohazards associated with urban development, such as landslides, sinkholes, and subsidence. The information gathered from geotechnical investigation can help to assess the stability of the soil and rock beneath the site of development and determine the appropriate measures to mitigate the risks associated with geohazards. For instance, if the site is located in an area prone to landslides, geotechnical investigation can help to design retaining walls and other slope stabilization measures to prevent slope failures and landslides.

Geohazards pose a significant risk to urban development, and geotechnical investigation is critical in identifying and mitigating these risks. According to Huang, Liu, and Zhang (2019), geotechnical investigation is essential in identifying potential geohazards, such as landslides, subsidence, and soil liquefaction, which can pose risks to human safety and infrastructure. The authors note that geotechnical investigation provides essential information on soil and rock properties, which is critical in assessing the stability and safety of urban development projects.

Günaydın, Akgün and Şahin (2019) emphasize the importance of geotechnical investigation in identifying potential sinkhole hazards associated with urban development. The authors note that sinkholes can occur due to the dissolution of soluble rock, which can cause significant damage to buildings and other infrastructure. Geotechnical investigation provides essential information on the geological and hydrological conditions that can cause sinkhole hazards, which is critical in designing appropriate mitigation measures to reduce the risk of sinkhole formation.

Abdullah, Yahya and Kassim (2020) highlight the importance of geotechnical investigation in mitigating the risk of earthquakes on urban infrastructure. The authors note that geotechnical investigation provides information on the soil and rock conditions, which is crucial in designing appropriate foundation systems for buildings, roads, and bridges that can withstand seismic activity.

Geotechnical investigation can also identify potential risks associated with soil and groundwater contamination. As noted by Li, Zhao, Wu, Wang and Zhang (2021), geotechnical investigation can provide information on the soil and groundwater conditions, which is essential in identifying potential contamination sources and assessing the risk of contaminant migration. This information is critical in designing appropriate mitigation measures to reduce the risk of contamination to human health and the environment.

Furthermore, geotechnical investigation can also identify potential risks associated with the excavation and construction of underground structures, such as tunnels and basements. As noted by Kim, Cho and Lee (2018), geotechnical investigation provides information on the soil and rock conditions, which is critical in assessing the stability of the excavation and designing appropriate support systems to ensure the safety of workers and the surrounding infrastructure.

Finally, geotechnical investigation provides information on the potential impacts of climate change on urban development. According to Zeng, Wang, Jia, Yang and Li (2020), geotechnical investigation can provide information on the soil and rock conditions, groundwater levels, and surface features, which is crucial in assessing the potential impacts of climate change, such as flooding, sea level rise, and erosion. This information is essential in designing appropriate adaptation measures to reduce the risk of damage to human safety and infrastructure.

4.4 Recommended Best Practices for Conducting Geotechnical Investigations

To ensure safety and reduce the risk of failure, it is essential to follow best practices when

conducting geotechnical investigations in urban development projects. Best practices include conducting thorough investigations to gather comprehensive data, using appropriate testing methods to determine soil and rock properties, and considering the effects of groundwater and seismic activity. The paper will recommend these and other best practices for conducting geotechnical investigations in urban development projects.

Several authors have discussed best practices for conducting geotechnical investigations in urban development projects to ensure safety and reduce the risk of failure. These practices include:

i. Conducting a thorough site investigation to assess the geotechnical conditions of the site. This includes drilling boreholes, conducting soil and rock testing, and assessing groundwater conditions (Zhou, Chen, Chen & Chen., 2020).
ii. Considering the effects of nearby structures and existing infrastructure on the geotechnical conditions of the site (Burland, 2012).
iii. Using appropriate geotechnical analysis tools and software to assess the stability of the site and the potential impacts of the proposed development (Ji, Zhang, Wang & Sun 2018).
iv. Using appropriate design codes and standards to ensure that the proposed development is designed to withstand potential hazards, such as earthquakes and landslides (Huang et al., 2020).
v. Conducting regular inspections and monitoring of the site during and after construction to ensure that the development is built according to design specifications and that any potential issues are addressed promptly (Ching et al., 2016).

Other best practices for conducting geotechnical investigations in urban development projects to ensure safety and reduce the risk of failure include:

i. Conducting geohazard mapping to identify potential geohazards in the area surrounding the development site (Sousa, Pinho-Lopes & Lemos, 2015).
ii. Establishing a geotechnical baseline study to document the initial geotechnical conditions of the site and monitor any changes that occur during construction (Zhou et al., 2020).
iii. Conducting geotechnical investigations throughout the entire development process, from the planning stages to the construction and maintenance stages (Huang et al., 2020).
iv. Using appropriate geotechnical instrumentation to monitor ground movement, soil and rock behavior, and groundwater levels during construction and throughout the life of the infrastructure (Ching et al., 2016).
v. Collaborating with other professionals, such as geologists, structural engineers, and architects, to ensure that the geotechnical investigations are integrated with the overall design and construction process (Burland, 2012).

The best practices for geotechnical investigations in urban development projects emphasize the importance of a comprehensive and integrated approach, considering various factors and collaborating with other professionals. These practices aim to ensure that infrastructure is designed, built, and maintained to the highest safety and reliability standards. Conducting thorough geotechnical investigations using these practices is crucial for making informed decisions about the feasibility and safety of development projects, identifying and mitigating potential risks, and ensuring the longevity of infrastructure.

V. CONCLUSION

The importance of geotechnical investigation in urban development cannot be overstated. Through a comprehensive review of existing literature, this paper highlights the critical role that geotechnical investigation plays in providing essential information on subsurface conditions, identifying potential geohazards, and informing the design of urban infrastructure. The literature review indicates that:

i. Geotechnical investigation provides essential information for designing appropriate foundations, retaining structures, and other measures to ensure the safety and longevity of urban infrastructure (Poulos and Davis, 2012).
ii. Geotechnical investigation provides essential information for designing safe, resilient, and sustainable urban infrastructure that can withstand natural disasters, protect the environment, and ensure the safety of human lives and property (Das, 2010).
iii. Geotechnical investigation provides essential information on the soil and rock conditions beneath the site of development, which is crucial for designing appropriate foundation systems, retaining walls, and drainage

systems for urban infrastructure (Sowers and Sowers, 2017).

iv. Geotechnical investigation provides critical information on soil and rock properties, geological and hydrological conditions, and seismic activity, which is crucial in designing appropriate foundation systems, retaining walls, drainage systems, tunnels, and pavement structures for urban infrastructure (Das, 2010).

v. Geotechnical investigation provides essential information that is critical in designing appropriate mitigation measures to reduce the risk of damage to human safety and infrastructure caused by natural hazards such as landslides, earthquakes, and flooding (Poulos and Davis, 2012).

vi. Geotechnical investigation provides essential information that is critical in designing appropriate mitigation measures to ensure the safety and longevity of urban infrastructure (Sowers and Sowers, 2017).

By conducting geotechnical investigations throughout the entire development process and integrating the data collected with the overall design and construction process, decision-makers can ensure the safety and longevity of urban infrastructure. The paper recommends that urban planners, architects, and developers should follow best practices for conducting geotechnical investigations to reduce the risk of failure and ensure the long-term sustainability of our cities.

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