Numerical Analysis of the Deflection of a Building on Sandy Clay Soil: Application to a Building in the City of Douala

Guillaume Hervé Poh'sié
Department of Mechanical Engineering, College of technology, University of Buea , Buea, Cameroon
Department of Civil Engineering, Higher Institute of Advanced Technologies (ISTA-IUG), Douala, Cameroon

Jacques Sylvain Mbemmo Fotso
Laboratory of Applied Sciences and Technology (LTSA), Department of Industrial and Maintenance Engineering (GIM), University Institute of Technology (IUT), University of Douala, Douala, Cameroon

Arsène Nguepnang Noume
Department of Mechanical Engineering, College of technology, University of Buea , Buea, Cameroon

Martial Nde Ngnihamye
Department of Civil Engineering, National Advanced School of Public Works, P.O. Box 510, Yaoundé, Cameroon

Bienvenu Mananga
Department of Civil Engineering, Advanced Teachers Training College of the Technical Education, P.O. Box 1872, University of Douala, Cameroon

Fabien Kenmogne
Department of Civil Engineering, Advanced Teachers Training College of the Technical Education, P.O. Box 1872, University of Douala, Cameroon

Emmanuel Yamb Bell
Department of Civil Engineering, Advanced Teachers Training College of the Technical Education, P.O. Box 1872, University of Douala, Cameroon

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Abstract

This study presents a numerical analysis of the deflection of a reinforced concrete building founded on sandy clay soil in the city of Douala. To conduct this research, two numerical simulations were performed. The first consisted of a simulation in MATLAB based on mathematical and mechanical models of the building and the soil. The second consisted of a finite element simulation of the building and the soil using COMSOL Multiphysics. The result obtained for the structural deflection after the MATLAB simulation was 0.0026 mm for elastic soil and 4.1 nanometers when the soil plasticity was taken into account. These results show that the rigidity of the structure and the elastoplastic nature of certain sandy clay soils play a very significant role in the stability of the building. Furthermore, the numerical simulation in COMSOL Multiphysics yielded a deflection of 2.2 mm for both elastic and elastoplastic soils. This is explained by the fact that, under steady-state conditions, the structure settles under its self-weight and live load, which, combined with the rigidity of the structure, resists large displacements and considerably reduces deflection. In addition, during the COMSOL simulation, the threshold stresses of the building were 0.16 MPa for elastic soil and 0.20 MPa for elastoplastic soil. These values represent limits beyond which structural deflection could cause damage to the frame.

Keywords: numerical analysis, deflection, building, sandy clay soil.

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1. Introduction

The rapid urbanization observed in many developing countries, particularly in sub-Saharan Africa, is largely driven by rural exodus and economic concentration in major cities. In Cameroon, this trend is especially pronounced in Douala, the country's economic capital, where population growth has significantly increased the demand for housing. As a result, numerous reinforced concrete structures are being constructed, often on poorly characterized and mechanically unstable soils such as sandy clay formations. These soils exhibit complex geotechnical behavior due to their heterogeneity, variable water content, and sensitivity to loading conditions, making them highly susceptible to deformation and settlement. Consequently, several cases of structural distress and even building collapse have been reported in recent years, highlighting the importance of understanding soil–structure interaction in such environments (Abanda & Fokwa, 2018; Dsonwa et al., 2021; National Institute of Statistics of Cameroon, 2015).

Despite the growing body of research on structural stability and geotechnical behavior, the mechanisms governing the deflection of buildings founded on sandy clay soils remain insufficiently understood, particularly when considering nonlinear soil behavior. Previous studies have explored progressive collapse mechanisms and differential settlement using both analytical and numerical approaches. For instance, Abanda et al. (2016) investigated building collapse through numerical simulation, while Basmaji et al. (2016) demonstrated that incorporating elastoplastic soil behavior significantly affects predicted deflections and stress distribution. Similarly, El Kahi et al. (2019) emphasized the importance of soil plasticity in the transmission of ground movements affecting structures. However, discrepancies still exist between simplified analytical models and more advanced finite element approaches, leading to the following research question: how does the consideration of soil behavior, particularly the transition from elastic to elastoplastic regimes, influence the predicted deflection and mechanical response of reinforced concrete structures?

The novelty of this study lies in the combined use of two complementary numerical approaches to investigate the deflection of a reinforced concrete building on sandy clay soil. Unlike many previous works that rely on a single modeling framework, this research integrates an analytical–numerical model based on beam theory and soil interaction (implemented in MATLAB) with a finite element simulation carried out using COMSOL Multiphysics. This dual methodology enables a more comprehensive understanding of soil–structure interaction by allowing comparison between simplified and advanced models while accounting for constitutive laws and realistic boundary conditions. The general objective of this work is therefore to analyze the vertical deflection and mechanical response of a reinforced concrete structure founded on sandy clay soil in Douala. More specifically, the study aims to (i) model soil–structure interaction using appropriate analytical and numerical approaches, (ii) evaluate the influence of elastic and elastoplastic soil behavior on structural deflection, and (iii) compare the results obtained from MATLAB and COMSOL simulations to identify the most reliable predictive approach (Basmaji et al., 2014; Terzaghi, 1943).

To achieve these objectives, the work is structured into several stages. First, the study area and the characteristics of the soil and structure are defined based on available geotechnical and structural data (Ossende, 2011; Zoa et al., 2017). Next, analytical modeling is conducted using established soil–structure interaction theories such as the Pasternak model and beam theory, followed by numerical implementation using a finite difference method in MATLAB. In parallel, a finite element model is developed in COMSOL Multiphysics, incorporating appropriate material behavior laws such as the Mohr-Coulomb criterion and the Modified Cam-Clay model.

The results obtained from both approaches are then analyzed and compared in terms of deflection profiles and stress distribution. Finally, the findings are discussed in light of existing literature, leading to conclusions and recommendations aimed at improving the design and stability of buildings constructed on sandy clay soils.

2. Materials and methods

In this section, two numerical simulations were performed. The first simulation was carried out using MATLAB software and is based on mathematical models of the soil and the building. The second simulation was performed using COMSOL Multiphysics software through graphical modeling of the system, while accounting for loads and material behavior laws.

2.1 Presentation of the area and modeling of the chosen study specimen

2.1.1 Presentation of the study area

The study site is located between the J block intersection and the Bonamoussadi mosque intersection in the Douala 5th district. The Kotto neighborhood is bordered to the south by Bonamoussadi, to the north by Mbangue, to the east by Logpom, and to the west by the Wouri River. The climate in the city of Douala is a northern coastal equatorial type with two seasons. The average monthly rainfall over 56 years (1951 to 2006) shows that it is abundant, averaging around 3230.12 mm per year [25].

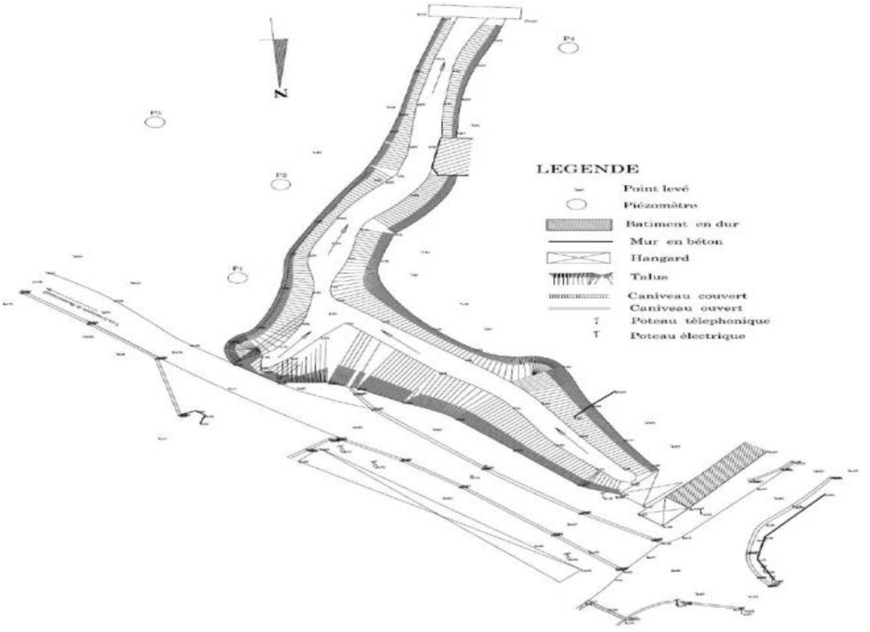

Figure 1 : Plan view of the Kotto Ravine and its surroundings (scale: 1:25000) [25]

2.1.2 Geological characteristics of the site

Table 2.1 presents the geological characteristics of the site, drawn from previous work carried out by geology researchers.

Table 1: *Physical characteristics of the site [32]*

Geological parameters	Symbols	Values and units
Dry soil density	γ_d	15.60 kN.m $^{-3}$
Specific gravity of solid particles	γs	25.80 kN.m $^{-3}$
Unit weight of water	γ_h	18.25 kN.m $^{-3}$
saturated soil unit weight	γ_{sat}	19.55 kN.m $^{-3}$
Submerged unit weight	γ'	9.60 kN.m $^{-3}$
Void ratio	e	0.654
Permeability coefficient (Darcy)	k	1.47 $^{\times 10^{-6}}$ ms^{-1}

Porosity	n	39.5%
Degree of saturation	Sr	67.1%
Water content	Wnat	16.99%
Young's modulus	E	10000 kPa
Poisson’s ratio	υ	0.38
Effective cohesion	c	20.52 kPa
Effective friction angle	ϕ	22.20°
Excavation depth	From 0.3m to 5.7m	
Soil type	Sandy clay with a yellowish color and some traces of reddish colors.	

2.1.3 Presentation of the study specimen

The chosen study specimen is the reinforced concrete frame of a two-story building (ground floor + 2 floors) anchored in compressible soil. This building was modeled as a frame to facilitate understanding of the work and to find satisfactory solutions to our research. Figure 2.2 shows the 3D model of the frame.

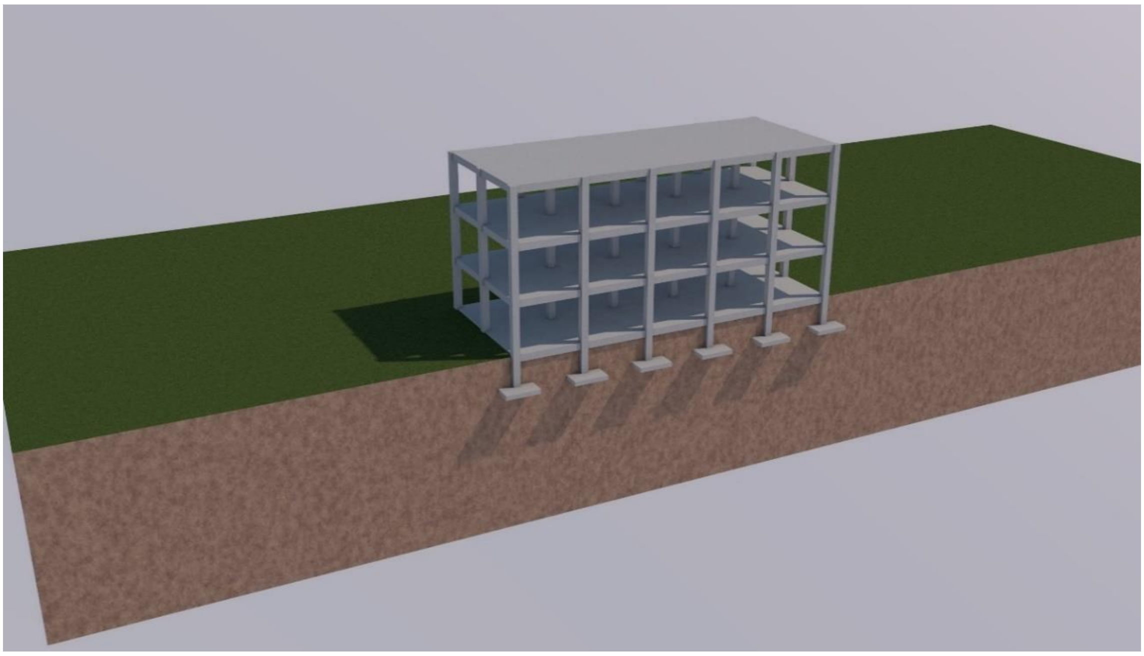

Figure 2.2: 3D *modeling of the specimen study frame*

2.1.4 Characteristics of the reinforced concrete frame

The frame is anchored in compressible soil at a depth of 2.00 m. It is built to a height of 9.00 m, with a length of 20.40 m and a width of 8.40 m. Table 2.2 presents the parameters and dimensions of the structure.

Table 2.2: Parameters *and dimensions of the* ***frame structure***

Settings	**Dimensions in (m)**
Columns	0.4m × 0.4m
Beams	0.15m × 0.4m
Slabs	e = 0.15m

Footings	2m × 2m
Anchoring depth	2m

Therefore, Figure 2.3 shows the longitudinal section of the frame and the soil layer with the appropriate dimensions.

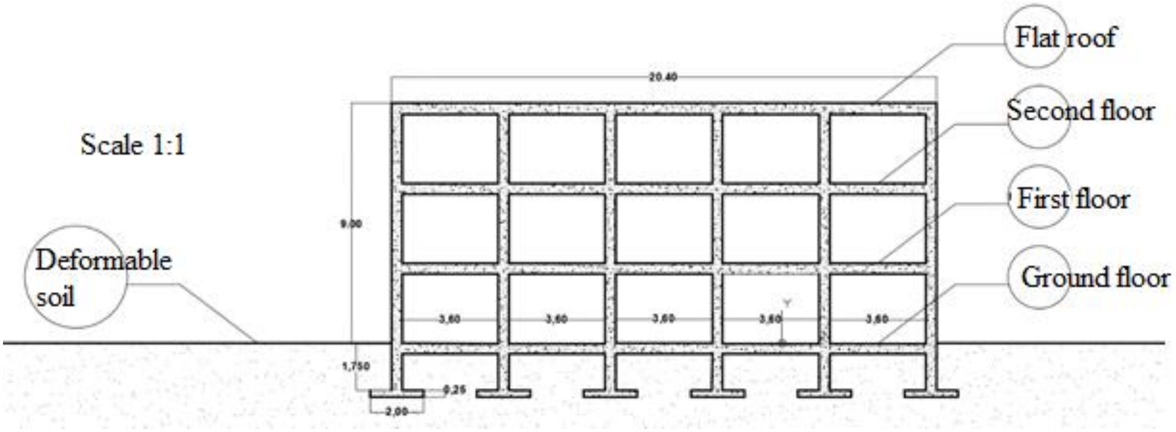

Figure 2.3: Longitudinal section of the specimen frame

2.2 Presentation of soil-structure interaction models

2.2.1 Application to deformable soils

In order to highlight the mechanical properties related to sandy clay soils and the deflection of concrete buildings in the city of Douala, a mathematical analysis based on empirical and experimental models is carried out in order to achieve the stated objectives.

- **Sandy clay soil with elastic deformation**

Table 2.3 presents the different mathematical models assimilated to soils and structure.

Table 2.3: *Elements of study and mathematical models*

Elements of study	Mathematical models
Ground	Pasternak's Model
Structure	Timoshenko beam model

The Pasternak soil model allows for the consideration of the soil's shear modulus, which the Winkler model does not. Furthermore, the Timoshenko beam model allows for the consideration of shear stress within the building during displacement. Figure 2.6 illustrates the structural deformation principle.

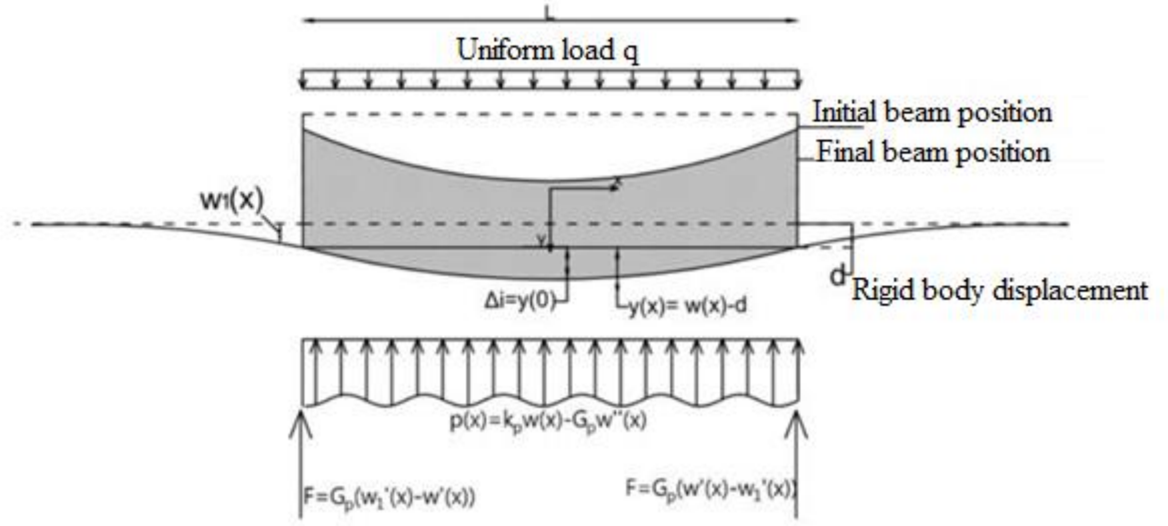

Figure 2.4: *Deformation of the building on an elastic ground (Pasternak model) [5]*

Through this Figure, the equation and boundary conditions are given as follows:

- Building displacement or deflection (shear stress taken into account):

$$\frac{d^2y(x)}{dx} = -\frac{M(x)}{EI} - \frac{3V'(x)}{2AG} \qquad (2.1)$$

With: y(x) = deflection after deformation of the beam, M(x) = bending moment of the Timoshenko beam, EI = stiffness of the structure, V(x) = shear force of the beam, A = cross-section of the beam, G = shear modulus of the beam.

- Soil reaction (Pasternak model without separation under the structure):

$$P(x) = K_PBW(x) - GpBW''(x) \qquad (2.2)$$

With: P(x) = soil reaction, Kp and Gp = soil shear modulus, B = beam width, and W(x) soil displacement.

At a state of equilibrium between the structure and the ground, the governing equation is as follows

$$\frac{d^4y(x)}{dx} = -\frac{q}{EI} - \frac{P(x)}{EI} - \frac{3(q-P(x))''}{2AG} \qquad (2.3)$$

With: M(x) = q – P(x) and V'(x) = $\frac{d}{dx}\left(-\frac{dM(x)}{dx}\right)$ (2.4)

Based on the equation of non-interpenetration between building and ground, and differentiating it 4 times, we obtain the equation $\frac{d^4y}{dx} = \frac{d^4w}{dx}$ (2.5)

Therefore, we obtain the final equation (2.3) for the deflection of the structure:

$$\left(\frac{3EI}{2AG}Gp + EI\right)\frac{d^4w}{dx} - \left(GpB + \frac{3EI}{2AG}Kp\right)\frac{d^2w}{dx} + KpBw(x) = q \qquad (2.6)$$

- Boundary conditions:

Unlike Winkler's model, Pasternak's model takes into account ground displacements outside the structure's area of action. Therefore, the boundary conditions are as follows:

- The beam deflection at the ends is zero:

$$y\left(\frac{L}{2}\right) = y\left(-\frac{L}{2}\right) = 0 \qquad (2.7)$$

- The bending moment of the beam is zero at the ends:
  $2AGy''\left(\frac{L}{2}\right) = -3V'\left(\frac{L}{2}\right)$ (2.8)
- The shear forces in the beam are zero at the ends:

$$2AGy'''\left(\frac{L}{2}\right) = -3V''\left(\frac{L}{2}\right) \quad (2.9)$$

Within the scope of this work, and given the established objectives, determining the soil deformation *W1* (*x*) *outside the building was not essential*, as it was not a critical step for the subsequent work. To solve the differential equation (2.6) while considering its boundary conditions (2.7), (2.8), and (2.9), we employed a numerical method based on finite differences, and the resulting simulation was performed using MATLAB code.

- **Sandy clay soil with perfect elastoplastic deformation**

This section focuses on taking into account soil plasticity, in the soil-structure interaction in order to provide notable indicators and to compare the results obtained.

In this case study, we observe that $P(x) > Pult$. Thus, the new equation for the building's deflection becomes:

$$\left(\frac{3EI}{2AG}Gp + EI\right)\frac{d^4w}{dx} + Pult = q \text{ (plastic domain).} \quad (2.10)$$

With Pult = soil bearing capacity:

$$\mathrm{Pult} = \mathrm{cN_c} + 0.5\mathrm{B}\gamma_1.\mathrm{N}_\gamma + (\mathrm{q} + \gamma_2\mathrm{D})\mathrm{N_q} \text{ [28].} \quad (2.11)$$

The boundary conditions are as follows:

- The beam deflection at the ends is zero:
  $y\left(\frac{L}{2}\right) = y\left(-\frac{L}{2}\right) = 0$ (2.12)
- The bending moment of the beam is zero at the ends:
  $2AGy''\left(\frac{L}{2}\right) = -3V'\left(\frac{L}{2}\right)$ (2.13)
- The shear forces in the beam are zero at the ends:
  $2AGy'''\left(\frac{L}{2}\right) = -3V''\left(\frac{L}{2}\right)$ (2.14)

Just like differential equation (2.6), the solution of this fourth-order differential equation was made possible by the numerical method of finite differences, and the result obtained was simulated through a MATLAB code.

2.2 Numerical simulation on COMSOL Multiphysics

Following the research work carried out above, a numerical simulation of the deflection of the reinforced concrete building is carried out using the COMSOL Multiphysics finite element software, in order to take into account the laws of materials and to compare the results obtained with those from the simulation on MATLAB.

2.2.1 Modeling principle

The study specimen, geometrically modeled in COMSOL, is the reinforced concrete frame presented in the preceding paragraphs (Figure 2.3). The ground is modeled as a large block measuring 100 m long and 30 m high. The work is carried out in 2D to obtain valid results and compare them with those of previous researchers. Figure 2.5 shows the specimen on the COMSOL interface.

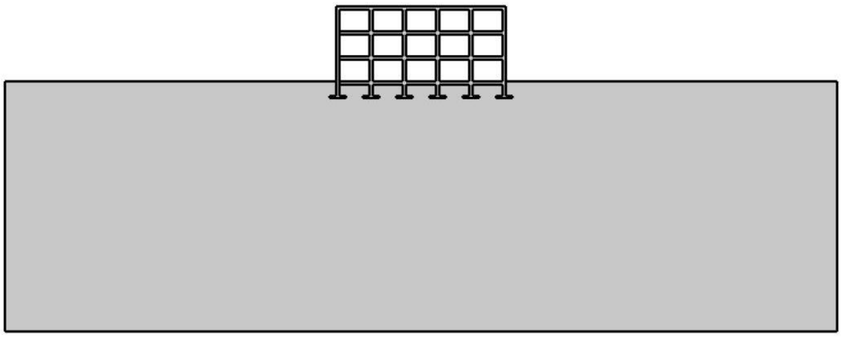

Figure 2.5: *Modeling of the reinforced concrete frame using COMSOL Multiphysics*

The columns, beams, and slabs are modeled using the material concrete. The dimensions of the load-bearing elements are always the same as those stated in Table 2.2. The supporting soil is modeled using the material soil.

2.3.2 Properties and mechanical behavior of the materials used

2.3.2.1 Mechanical properties of materials

The mechanical properties of the concrete used are those resulting from the work of previous researchers in the field of cementitious materials mechanics [8]. Table 2.4 presents the mechanical properties of the concrete used for this work.

Table 2.4: *Values of the mechanical properties of concrete [10]*

Properties	Symbols	Values and units
Density	ρ	2300 kg/ m^3
Young's modulus	E	25×10^{9} Pa
Poisson’s ratio	ν	0.2
Coefficient of thermal expansion	α	10^{-6} / K
Thermal conductivity	λ	1.8 W/(mK)
Constant pressure thermal capacity	CP	880 J/(kg.K)
Mechanical compressive strength at 28 days	f_{c28}	20 Mpa
28-day tensile strength	f_{t28}	1.80 Mpa

The mechanical properties of the soil used for this simulation are those presented in Table 2.1 of this section.

2.3.2.2 Mechanical behavior of materials

The concrete used in the simulation has a nonlinear elastic constitutive law with three parameters [31]. This constitutive law model is translated by equation (2.15) [13]:

$f_\sigma = c_1 I_1 + c_2 r(\theta)\sqrt{J_2} + c_3 J_2 - 1$ (2.15)

With $r(\theta) = \frac{4(1-e^2)cos^2\Theta(2e-1)^2}{2(1-e^2)\cos\Theta+(2e-1)\sqrt{4(1-e^2)cos^2\Theta+5e^2-4e}}$ (trace of the delimited surface in the spherical coordinate system). (2.16)

Furthermore, θ = 0° (pure tension) and θ = 60° (pure compression), $c_1, c_2, c_3 = f(\sigma_{cs}, \sigma_{ts}, \sigma_{bs})$

Which depend on the characteristics of the material, I_1= first invariant of the stress tensor, J_2= second invariant of the deviatoric tensor and e = [0.5, 1.0] (position of the vectors in the spherical frame).

The soil is characterized by the modified Cam-Clay constitutive law for elastoplastic deformations and described by equation (2.17)

F (cr) = $q^2 + M^2 . [P'^2 - P' . P'c]$ [26]. (2.17)

With F(cr) = critical load function, M = coefficient of friction, P' and q represent the spherical and deviatoric parts of the stress tensor, P'c = pre-consolidation pressure which is defined by equation (2.18)

$$P'c = P'co \exp\left[\left(\frac{1+e}{\lambda-k}\right)\varepsilon_v^p\right] \text{ [20].} \qquad (2.18)$$

With: P'co = initial consolidation pressure, e = void ratio, λ = slope of the normal consolidation line, k = slope of the swelling line, ε_v^p = plastic component of deformation.

The Mohr-Coulomb constitutive law was used to evaluate the behavior of the soil-structure interface and to predict failure of the supporting soil. This constitutive law is defined by equation (2.19).

$\tau = c + \sigma . \tan\phi$ (2.19)

With: τ = shear stress at break, c = cohesion of the material, σ = normal stress, ϕ = internal friction.

During the resolution process, the global model or direct method was chosen. This numerical model enables the analysis of the entire system in a single step.

2.3.3 Mesh and refinement

The mesh chosen for this work is an extra-fine mesh with linear triangular mesh elements (three sides), consisting of 3 nodes and 6 degrees of freedom per geometric element. Figure 2.6 shows the mesh of the specimen frame and the soil layer.

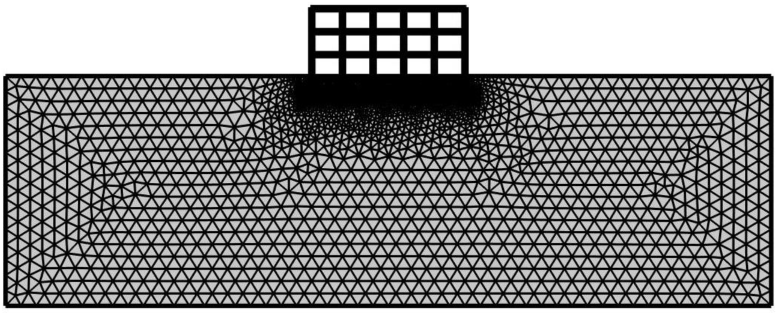

Figure 2.6: *Mesh of the frame and soil layer*

The mesh of this system was created according to the geometric and mathematical rules of the finite element method [11]. The modeling, carried out on a 2D plane, results in 4875 domain elements and 726 boundary elements.

Regarding the refinement, the foundation footings and the beam and column connection points were inspected and verified to ensure no detail was overlooked in the final calculation. Figure 2.7 illustrates the refinement performed on the structure.

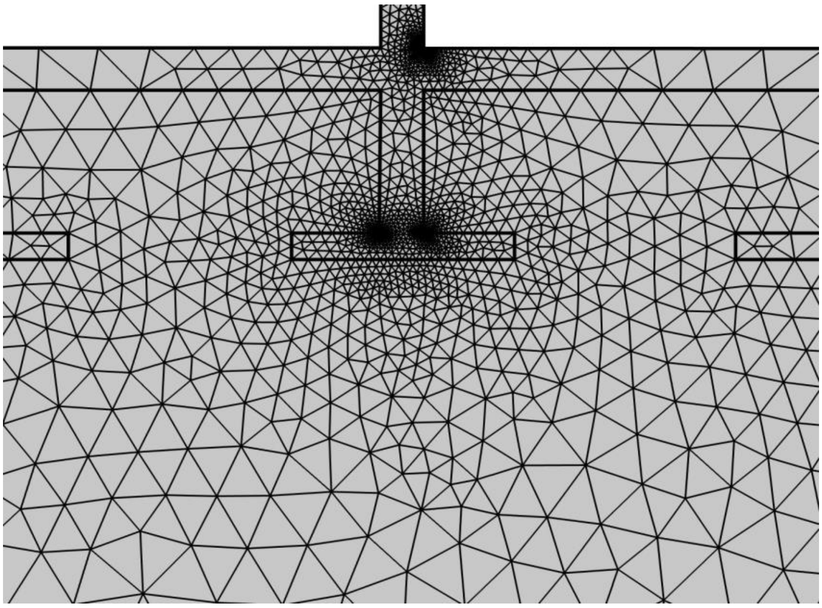

Figure 2.7: *Mesh refinement*

2.3.4 Loading and boundary conditions

Before applying the load, the various soil boundaries associated with the study were fixed to prevent any displacement of the supporting soil. Thus, along the X and Y axes, the displacements U(x) = U(y) = 0.

The load applied to the frame consists of its own weight following a load transfer, as well as live loads. The study and calculation process are defined as follows: A steady-state numerical simulation of the concrete frame on an elastic and elastoplastic soil, with observations of the structure's deflection and the stresses released.

3. Results and Discussion

3.1 Results of numerical simulations

In this section, the results obtained are presented succinctly according to the objective of the research.

3.1.1 Deflection of the building obtained by numerical simulation in MATLAB

Solving the differential equation (2.6) and its boundary conditions (2.7), (2.8), (2.9) using the iterative finite difference method yielded the vertical deflection of the building. The curve in Figure 3.1 represents this deflection as a function of the soil layer thickness.

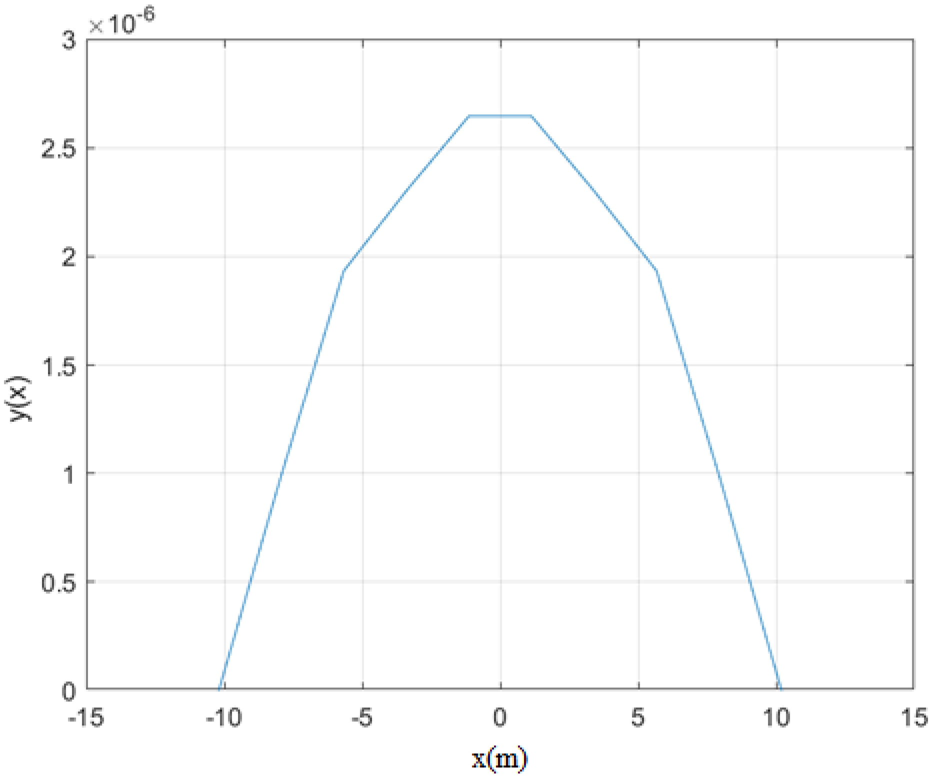

Figure 3.1: *Deflection curve of the building on an elastic ground*

This graph shows that the building's deflection curve has the shape of an inverted parabola. Furthermore, it decreases as the soil layer thickness increases. Thus, we observe that at the starting point x = 0 m, the deflection is $y = 2.646 \times 10^{-6}$ m, and at the point x = 10.1 m we have y = 0 m. These values, however small, are justified by the structure's high rigidity and large footprint. To verify this numerical soil-structure interaction model, a numerical simulation was performed in COMSOL to compare the results obtained.

3.1.2 Deflection of the building obtained by numerical simulation in COMSOL

Initially, numerical simulation of the structure's deflection on elastic soil allowed us to determine the steady-state settlement stress. This is shown in Figure 3.2 below.

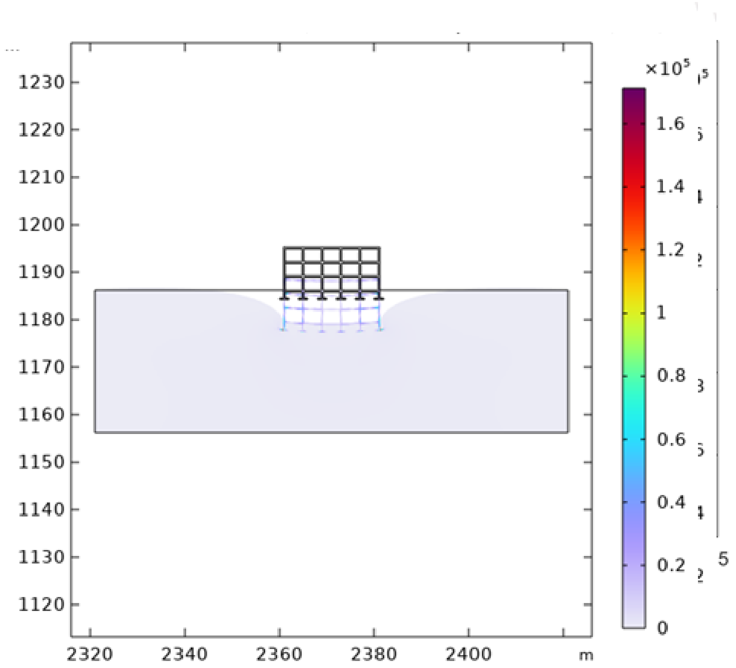

Figure 3.2 ***Von Mises stress at Gauss points (N/m²)***

The highest value of the stress released during settlement was observed to be 1.6 × 10^5 N /m². Thus, the finite element method allows us to determine the settlement threshold beyond which certain structural damage could occur within the structure. Furthermore, the building's displacement as a function of the depth of the deformable soil layer was obtained. Therefore, the curve in Figure 3.3 illustrates the building's deflection on elastic soil after simulation in COMSOL.

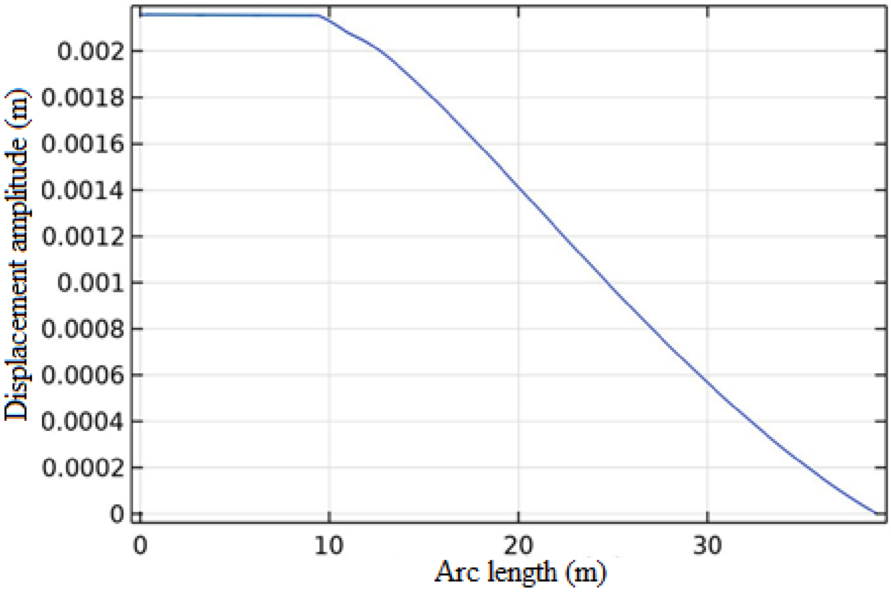

Figure 3.3: *Deflection curve of the building with respect to an elastic ground*

Using this simulation, we observe that the maximum displacement amplitude is on the order of 0.0022 m, or 2.2 mm. As mentioned above, we note that the deeper we go into the soil layer, the more the deflection value decreases, reaching zero beyond a depth of 30 m. Therefore, we can understand that over a range of 0 to 9.85 m, the deformation value is constant and does not vary (elastic range), but beyond this depth, it gradually decreases. This can be explained by the soil's bearing capacity, which increases with depth, and the rigidity of the structure. Consequently, the numerical simulation in COMSOL is somewhat similar to the simulation performed in MATLAB, as the values obtained are indeed very different (0.0026 mm for MATLAB and 2.2 mm for COMSOL, a difference of 2.197 mm), but on the order of a millimeter. This difference stems from the consideration of constitutive laws in the COMSOL simulation, the calculation methods, and the overall solution system. Consequently, it becomes clearer that the numerical method based on simulation (in general) provides a more accurate understanding of the deflection of reinforced concrete structures on elastic soil as a function of the load and the properties of the materials used.

3.1.3 Deflection of the building taking into account the plasticity of the soil by simulation on MATLAB

Solving equation (2.10) for the structure's deflection, taking into account the soil's plasticity and boundary conditions, has shed further light on the issue of building settlement. Therefore, the curve in Figure 3.4 describes the structure's deflection, considering the plasticity of the soil layer.

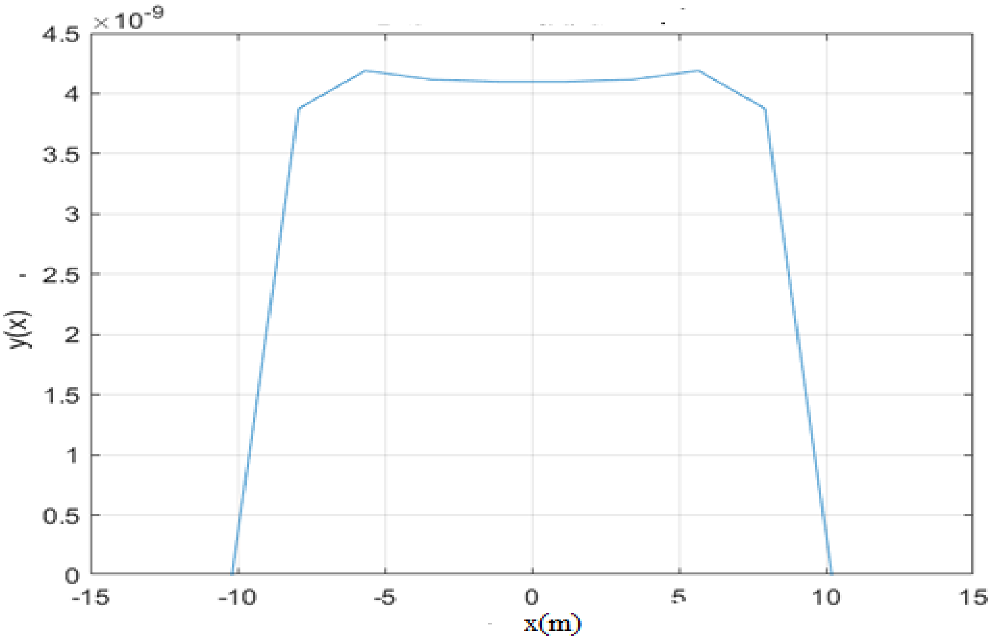

Figure 3.4: *Deflection of the building taking into account its plasticity*

We observe that the displacement (deflection) of the structure is very minimal, almost non-existent. This is due to the fact that, taking into account the plasticity of the soil, the deformations become very small and are limited to the elastic range. Furthermore, we also observe that the displacement does not exceed 10.2 m in thickness.

3.1.4 Numerical simulation in COMSOL of the building's deflection, taking into account soil plasticity

Using the COMSOL finite element software, a simulation was performed to support the results obtained above (Figure 3.4). Figure 3.5 illustrates the settlement stress of the structure on an elastoplastic soil.

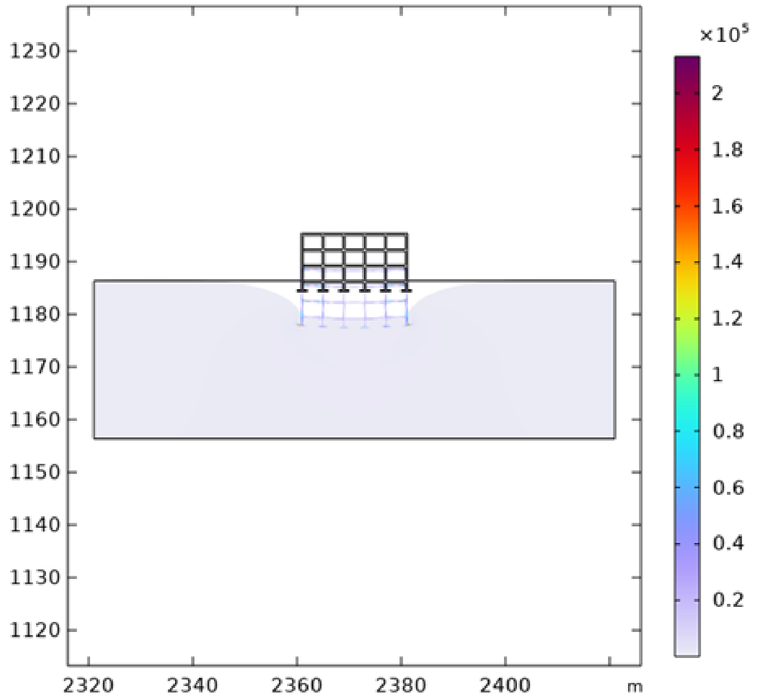

Figure 3.5: *Structural settlement stresses taking into account soil plasticity*

We observe that the deformations obtained are similar to those of an elastic soil; moreover, this case exhibits a slightly higher settlement stress compared to the previous one. This increase can be explained by the fact that, during its movement, the building generates mechanical stresses significant enough to deform the soil. Furthermore, we note that the soil deformation propagates beyond the building's area of influence. It is also noteworthy that the numerical method provides good accuracy in determining the stress present during the elastoplastic interaction.

Therefore, the curve in (Figure 3.6) shows the amplitude of the deflection of the building when taking into account soil plasticity.

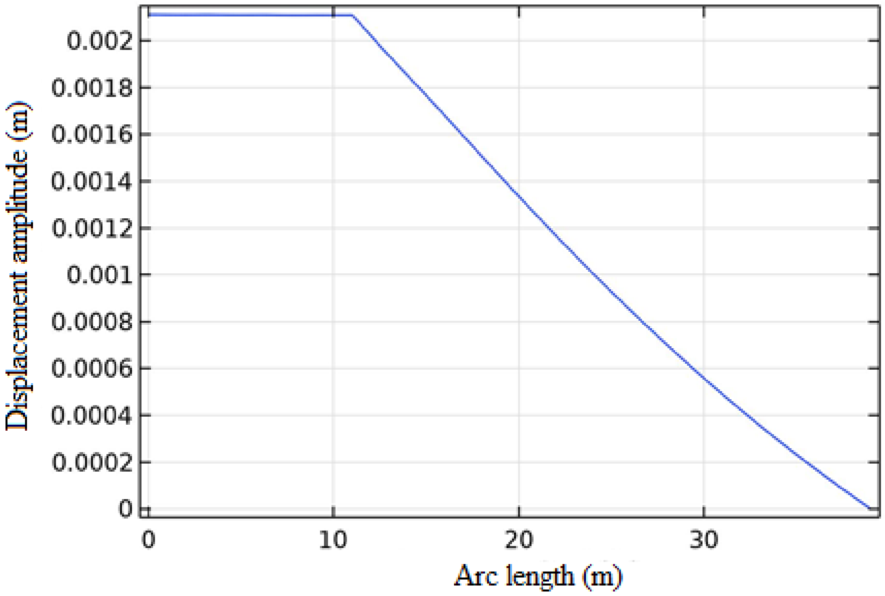

Figure 3.6: *Deflection curve of the building with respect to an elastoplastic soil*

From this result, we observe that at the initial point x = 0m, the displacement amplitude is y = 0.0022m. This value remains constant up to the point x = 10.2m and beyond this point, it gradually decreases until the final points x = 39m and y = 0m. This can be explained by the fact that, over the interval [0; 10.2m], the structure rests on soil that deforms until a stable deflection amplitude is reached. Once this interval is crossed, the displacement amplitude decreases because the soil resists deformation (deflection). Mechanically, this curve can be interpreted as an elastoplastic curve. Initially, there is a constant load and deformation, and then, beyond a threshold value, the load remains constant, but the deformation amplitude curve gradually decreases (plastic range of the soil).

3.2 Discussion

In light of the results presented above, and in order to verify them, they will be compared and discussed with the work of previous researchers.

Thus, we observe that the deflection curve of the building on elastic soil, obtained after simulation in MATLAB (Figure 3.1), has a maximum value of $y = 2.646 \times 10^{-6}$ m and is shaped like an inverted parabola. This curve has the same shape and is quite similar to the research and results found by [6]. Indeed, they worked on the influence of considering soil shear on the final deflection of the building. In the case of this article, the peak values found are different because the soil and the geometry of the structure are not the same. Furthermore, the finite element numerical simulation of the building on elastic soil using COMSOL Multiphysics (Figure 3.2) confirmed the results found on the settlement of a concrete building on compressible soil.

Furthermore, the vertical displacement of the structure on an elastoplastic soil (Figure 3.4) after simulation in MATLAB yielded a maximum value of $y = 4.2 \times 10^{-9}$ m. The representative curve has the shape of an inverted convex parabola. Thus, we observe that the results found here are very close to those of [16]. Indeed, they conducted research on the influence of soil plasticity on the transmission of ground movements affecting soil-structure interaction. Therefore, we note that the results obtained in this simulation lead to the same conclusion as theirs, namely that taking into account elastoplastic behavior influences the evaluation of ground movement transmission. In the equilibrium state, and depending on the condition of no interpenetration between the structure and the soil, the ground movement will also cause deflection of the building. Therefore, the numerical simulation on COMSOL Multiphysics (Figure 3.6) supports the results obtained with precision and taking into account the laws of material behavior.

Regarding mechanical responses, it is noted that the deflection simulation on an elastic soil (Figure 3.2) yielded a maximum settlement stress of 0.16 MPa and 0.2 MPa for an elastoplastic soil. These values are supported by the work of [2], who conducted research on the numerical simulation of a building collapse on sandy clay soil in the city of Douala, Cameroon. They obtained a failure value of 0.1 MPa and concluded that the collapse occurs following a localized failure of the soil, the appearance and subsequent propagation of cracks in the structure, before the domino effect of the entire building collapsing. In this research, and based on the results obtained, they also concluded that beyond these mechanical responses, the structure will progressively exhibit damage and tend towards collapse.

4. Conclusion

This study focused on the numerical analysis of the vertical deflection and mechanical response of a reinforced concrete structure founded on sandy clay soil, with application to a typical building in Douala. To achieve this objective, two complementary numerical approaches were implemented: an analytical–numerical model based on soil–structure interaction theories solved using MATLAB, and a finite element model developed in COMSOL Multiphysics. These approaches made it possible to evaluate the influence of soil behavior, particularly the transition from elastic to elastoplastic regimes, on the structural response.

The results obtained highlight a significant difference between the two modeling approaches. The MATLAB simulation, based on simplified analytical assumptions, yielded very low deflection values (on the order of micrometers and nanometers), reflecting the high rigidity of the structure and the limitations of purely theoretical models. In contrast, the finite element simulation performed in COMSOL Multiphysics provided more realistic results, with deflections on the order of millimeters, taking into account material constitutive laws, stress distribution, and boundary conditions. Furthermore, the analysis showed that the consideration of elastoplastic soil behavior reduces deformation amplitudes while increasing settlement-induced stresses, thereby confirming the critical role of soil plasticity in soil–structure interaction.

From a mechanical standpoint, the study demonstrated that the structure remains globally stable under the considered loading conditions, with stress levels (0.16 MPa to 0.20 MPa) remaining within acceptable limits. However, these values also indicate potential thresholds beyond which structural damage may occur, especially in the case of unfavorable soil conditions or inadequate design practices. These findings are consistent with previous studies and confirm that soil characteristics, particularly compressibility and plasticity, strongly influence the performance and durability of buildings constructed on sandy clay soils.

In perspective, several avenues can be explored to extend this work. First, a three-dimensional numerical modeling approach could be developed to better capture the spatial variability of soil properties and structural behavior, which is only partially represented in the current two-dimensional analysis. Second, future studies could incorporate dynamic loading conditions, such as seismic effects or cyclic loads, in order to evaluate the long-term performance and resilience of structures founded on compressible soils. Additionally, experimental validation through in situ measurements or laboratory testing would further improve the reliability of the numerical models and contribute to the development of more robust design guidelines adapted to local geotechnical conditions.

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