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Performance of Foundations during Earthquake

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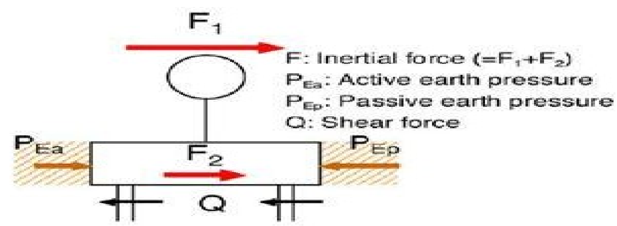
***Abstract-* Structures suffer damage when they shake as a result of seismic waves, as is widely known. The damage may be influenced by the characteristics of the soil in the affected region. The study aims to show how different foundation types, including shallow, mat/raft, pile, and structures like gravity dams and arch dams, among others, were impacted by the earthquake. The phrase "soil structure interaction" describes how the soil reacts to a building's loading when there is an earthquake disturbance, which is characterised by deflection. Shallow foundations' bearing capacity is decreased and their rate of settlement is increased due to the ground moving during the earthquake. In seismic zones, the mat foundations experience overturning moments due to kinematic interactions have been seen. Pile foundations are affected by kinematic and inertial interactions, which commonly lead to failures. The complex oscillating arrangement of acceleration and ground motion in a gravity dam, which creates ephemeral dynamic stresses owing to the inertia of the dam and confined water, is what causes the seismic activity created in these dams. The foundations of the arch dam undergo effects of inertia and flexibility due to the propagation of seismic waves.**

Keywords: earthquake effect, soil structure interaction, shallow, mat, pile foundation, gravity dam, arch dam.

I. INTRODUCTION

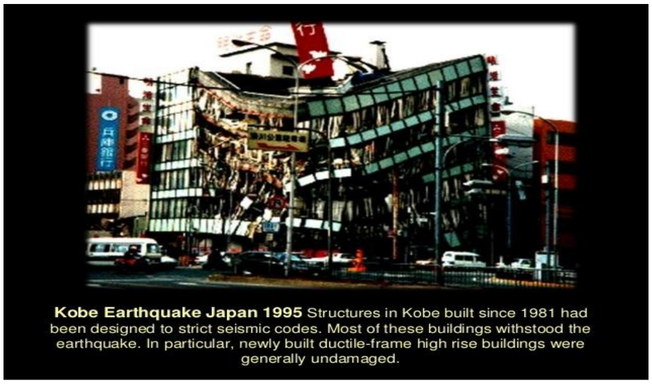
An element of a structure that connects it to the ground and disperses loads to the soil is its foundation. There are numerous foundation types for diverse causes. Modern foundations come in two varieties: Deep foundation and Shallow foundation. The distribution of forces on the foundation is shown in Figure 1.a. Foundations are constructed to be able to carry a specific amount of weight depending on the kind of subsoil supporting the foundation. When a foundation settles below the level of initial construction to the point that harm has already been done, it is said to have failed. In an earthquake-affected location, the behaviour of the soil affects how much damage an earthquake does. Here, the bottom surface is moving significantly and continuously as a result of the damage, which is brought on by the soil's overall vulnerabilty. For instance, as a result of earthquake-induced vibrations, granular soil deposition is squeezed, leading to sizeable and uneven surface settlements. The loose granular particles that make up the soil cause buildings to teeter and shift during earthquakes. Figures 1.b and 1.c provide examples of the harm this cause has resulted in. Figure 1.b depicts a Chilean island that experienced partial inundation as a result of the 1960 earthquake's dual impacts of ground settlement and tectonic plate movement brought on by compaction. The transmitted settling of a bridge's backfill during the 1964 Nagasaki earthquake is shown in Figure 1.c. 1Soil-structure interaction (SSI) has an impact on a structure's seismic response. According to assessments made after the 1964 Niigata earthquake, the 1995 Kobe earthquake (Figure 1.d), and the 2001 Bhuj earthquake2 (Figure 1.e), structures sitting on piles in damp soils frequently fall following earthquakes. The use of site-specific SSI analysis to ground motion is presented in this study. Shallow foundations are frequently employed for small-scale constructions in earthquake-prone regions. The bearing capacity of a shallow foundation is diminished by horizontal loads and rocking moments.



Figures: 1 a

Figures: 1 b

Figures: 1 c



Figures: 1 d

Figures: 1 e

1.1 Historic foundation types

These can be classified as Rubble Trench foundations, Pad Stone foundations, Stone foundations, Earth Fast foundations, or Post in Ground Constructions.

1.2 Modern foundation types

These foundation types are now typically employed in building.
These fall into the categories of shallow and deep foundations.
The objectives and duties of a foundation are as follows: - A foundation is a structure constructed underneath the soil to support the weight of a structure that is above it. It promotes lateral stability by providing the structure with an even, solid surface to distribute the weight to. A bed of stable earth serves as the foundation's support. To maintain the structure within its safe bearing capacity, the foundation's primary objective is to disperse the structure's weight over a sizable bearing area. It also ensures a secure foundation for building activities, improves the stability of the overall structure, and inhibits lateral movement of the supporting material.

II. FAILURE OF FOUNDATION

The soil next to the structure may move laterally, the subsoil may settle unevenly, the structure may topple over due to lateral pressure, the masonry may settle unevenly; the soil beneath the foundation may contract due to moisture removal, atmospheric action, or lateral soil escape, among other factors, leading to foundation failure.

Sagging flooring, cracked walls, and displaced moldings are a few effects of foundation failures. Examples of exterior indicators include wall rotation, a damaged or cracked foundation, separation around a garage door, window, or wall, and cracked bricks. While interior indicators include fractures in the flooring, disorganized doors and windows, and broken sheetrock.

The structure is totally destroyed by the ongoing ground deformations. Some choices for foundation design can tolerate these persistent earth deformations. Ground movement is mostly responsible for a building's deterioration. The building's foundations shake together with the surrounding ground when the earth at the construction site trembles. A building's reaction to an earthquake movement takes a few seconds. At this point, a variety of seismic wave types combine to cause the building to shake in a clear, identifiable manner. Additionally, each site suffers different total shaking due to its specific geological features, differences in fault seepage, and a diversity of rocks through which the waves flow.

Depending on the research method, configuration, age, architectural style, and degree of construction, every structure has unique features. The aforementioned elements have an effect on the building's reaction. Contrary to the complex nature of the interactions between the structure and ground within the few seconds of movement, there is a comprehensive understanding of how different building types can perform under different situations. Neither the structure displacements nor the ground displacements are independent of one another during an earthquake when no external forces are being applied to the system.

Figures-2a

III. SOIL STRUCTURE INTERACTION

Ground-structure interaction (SSI) is the relationship between the ground (soil) and a building built on it. The kind of ground and the type of structure both have an effect on the movement of the ground-structure system, which is fundamentally the outcome of a reciprocal stress exchange. This is relevant, particularly in seismically active areas. Movement and the resulting damage might be increased or decreased depending on the soil and structural configuration.

In comparison to buildings on rigid ground, buildings on pliable ground often absorb less damage. The second interaction impact connected to the mechanical properties of the soil is the sinking of foundations, which is aggravated by a seismic event. This phenomenon is known as soil liquefaction.

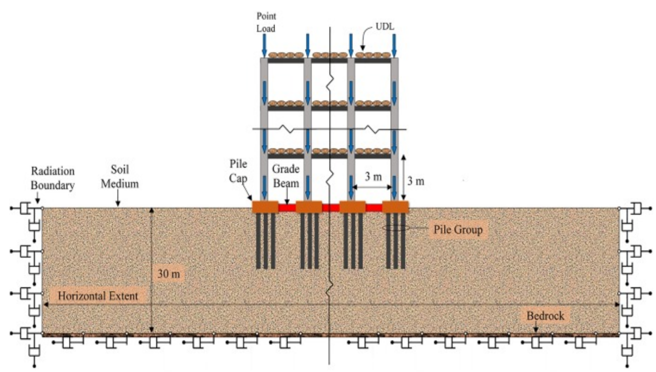
A structural element that is in direct touch with the ground is a common feature of civil engineering structures. When external forces, such as earthquakes, impinge on these systems, the structure and ground displacements are not independent of one another. Soil-structure interaction (SSI) is the process by which the structure's motion is influenced by the soil's response and the soil's response is impacted by the structure's motion. The effects of SSI are disregarded by conventional structural design methods. Neglecting SSI is possible for light structures on relatively stiff soil, such as uncomplicated rigid retaining walls and low-rise buildings. Nuclear power plants, big buildings, and elevated roadways are examples of large constructions supported by relatively soft soils that are more significantly affected by SSI.

Recent earthquake damage, such that caused by the Kobe earthquake in 1995, has also drawn attention to the fact that a structure's seismic behaviour is highly impacted by the reaction of the foundation and the surrounding ground in addition to the response of the superstructure. Because of this, modern seismic design codes, such as Standard Specifications for Concrete Structures: Verifying Seismic Performance JSCE 2005, mandate that the response analysis be performed while taking the entire structural system, including the superstructure, foundation, and ground, into account.

IV. SHALLOW FOUNDATION- MAT

It is common practise to evaluate architecture's earthquake resistance under the supposition that its foundation is firmly anchored to the ground below. According to this evaluation, the mat foundation will be elevated during the earthquake because the anticipated base overturning moment will be larger than the permissible overturning resistance caused by gravity force. A reinforced concrete mat foundation is a typical form of foundation utilised in many different projects. They are a sort of shallow foundation that transfers loads to the soil at the foot of the structure to make use of the earth's capacity to support weights. A mat foundation totally or partially encloses a building's footprint as opposed to discrete spread footings. Unless the load criteria and soil cause severe settling in each and every spread footing, a deep foundation design is preferred. Most often, a mat foundation is used to mitigate uplift pressures that could occur when constructions have significant overturning moments or to disperse the bearing load across a large area. Another typical case for a mat foundation is enormous, close-together spread footings. Effective soil structure issues have been explored by taking into account the fixed foundation. Despite research indicating that many architectural systems have been susceptible to foundation excitation during big earthquakes, solid bodies or clusters of solid bodies provide great examples of buildings overturning.

Most engineering structures have flexible foundations and regularly experience foundation uplift. Aside from especially rigid bodies, structural flaws and tensions are what reduce the uplift, according to Chopra and Yim. Shallow foundations commonly exhibit nonlinear reverberation under sideways periodic loads, which includes soil yielding, foundation elation, settling, sliding, and rocking. The principal mechanism for the dispersion of seismic energy through the process of soil yielding beneath the foundation is the nonlinear behaviour of shallow foundations under high amplitude earthquake-induced loads.



Figures-4a

V. PILE FOUNDATION

When constructing pile foundations, the majority of seismic design rules simply take inertial forces into account. However, the piles curve as a result of the seismic waves, which results in a bending moment over their whole length.

When studying pile foundations for seismic loading, one must consider both how to interpret the kinematic interactions that come from the pile and the surrounding soil shaking and the inertial load that results from the pile and soil working together. The reduction in stiffness brought on by seismic stress is also explained by the related soil-pile interaction.

The interaction between the soil and the pile was examined using the findings of a ground reaction study that was compiled from multiple experiments. On soft ground, kinematic and inertial interactions have an impact on pile foundation systems. The effect of these two interactions during earthquakes is pile forces. Numerous failures in pile foundations were brought on by the application of strong inertia forces to the base. The calculation of kinematic curvature, which results from sideward movements and displacements created on the pile as a result of ground movement and inertial forces, has an impact on the cap mass.

Due to the impacts of earth pressures on the foundation and the integrated pile, pseudo static analysis is performed to evaluate the maximum moment distribution in the pile. The maximum moment is, in general, equal to the arithmetic sum of the two stresses brought on by the inertial and kinematic causes. As The kinematic interaction between the soil and the pile, the induced seismicity of the pore-water pressures (PWP), the varied reactivity of the soils to dynamic seismic vibrations and the inertial interaction between the pile foundation and the structure are all aspects of the pile foundation's earthquake reaction.

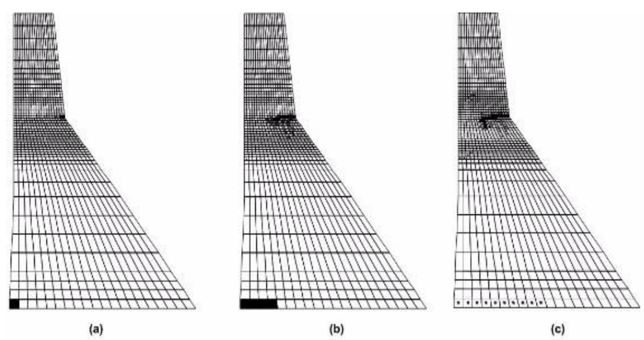
To forecast how a building will react to an earthquake, it is typically believed that the support motion at the foundation level is just that of the free-field. However, the higher structure interacts with its foundation and the surrounding soil to cause additional soil deformities, which contribute to those created by the movement of seismic waves, causing the movement near to the foundation to differ greatly from that of the free-field.

VI. GRAVITY DAMS

Concrete gravity dams are built with comfort in mind when an indigenous foundation is available at the dam site and is strong enough to withstand the massive weight of the dam. Waves produced by an earthquake have the potential to shake the dam in all directions. An earthquake has the same impact as accelerating the foundations of the dam in the direction in which the wave is now travelling. Acceleration can be divided into two categories:

Horizontal Acceleration $(\alpha_h) = K_h \times g$
Vertical Acceleration $(\alpha_v) = K \times g$

Since a concrete gravity dam is a complex, submerged structure that is created in such a way that its own weight overcomes external pressures, it has attracted a lot of research attention regarding how it behaves during tectonic movements caused by earthquakes. These buildings are sturdy, effective, and almost ever need maintenance. Unexpected tragedies like the abrupt release of reservoir water and the elimination of local ecological variety might result from such a dam breach. Figure shows how the Fujinuma Dam in Sukagawa City, Fukushima Prefecture, Japan, crumbled when the whole reservoir overtopped/overflowed the dam's crest 20 to 25 minutes after the Thoku earthquake. Figure 6.a depicts a few of the elements that went towards the terrible calamity that resulted from the stored water overflowing. As a result, the safety of dams has become a major worry in a number of regions of the world in recent years. In order to apply mitigation measures and boost the dam's strength at the right moment, preventing the collapse of dams in earthquake-prone areas, the behaviour of the dam at any age during its existence is determined. Therefore, it is essential to use a logical dynamic analysis technique while creating and securely analysing an earthquake-resistant dam. This study evaluates the interaction between concrete gravity dams and reservoir dams in reaction to seismic movements brought on by earthquakes. The gravity dam rupture scenarios are depicted in Figures 6 c and 6 d at six distinct time intervals. The dam's upstream face shows the rupture or cracking conditions within the structure at six different occasions. The nature of a bare fracture in an exceptionally accurate component is depicted by colouring or shadowing the whole component area. Little dots in the straightforward text stand in for the incomplete crack instances. The core elements that have never been softened are not highlighted in the illustration. Since the foundation may be permanently fixed, the force applied per unit area causes the bottom of the dam to fracture. Cracks were initially made by the dam's heel, and they spread to the toe.



Figures-6 a, b, c

Arch dams are particularly difficult to assess because they should be considered as three-dimensional systems that take into consideration the reservoir's semi-unconstrained dimension and the domain of the foundation rock. The interaction between the dam and the foundation rock, wave absorption at the reservoir border, the interaction between the dam and the water, the compressibility of the water, the interaction between the dam and the water, the interaction between the dam and the foundation rock, and structural variations in the ground surface movement over the canyon are some of the factors that should be considered in an effective arch dam analysis. Nonlinear dynamic analyses may be necessary because vertical structural joints might move or open up during powerful earthquake shocks, causing the concrete to break. The "Kariba Dam"The Kariba Gorge of the Zambezi River is seen in Figure 7 a. The basin between Zambia and Zimbabwe poses a severe threat to the million people that live in the area. The primary problems with the dam are the geological heterogeneity of the south bank abutment and the conduct of concrete in wet weather. Another potential threat to the complex is the unstable weathered material lying on clay seams downstream of the wall.It is expected to collapse in three years. See Figure 7.b until it is corrected, forever. If the dam were to fail, a huge surge of water would rip a wide valley apart along the Zambezi River's course to the Indian Ocean. The little stress rise in the arch dam contrasts with the concrete gravity dam's interaction drop.

Figure 7 a

Figure 7 b

VII. CONCLUSIONS

How an earthquake impacts the foundation of different architectural projects depends heavily on the properties and behavior of the soils in the impacted area. Despite advancements in engineering, if a structure's foundation is erected on soft soil, the whole thing might collapse during an earthquake. However, the foundation and structure of the building can interact with seismic wave's substantially better thanks to geotechnical engineers.

The solutions to prevent the damage are:-

(1). The superstructure and base are joined together, allowing the entire building to work as a single unit.

(2). Another approach is base isolation, in which the structure is raised above the ground.

As a result, the structure experiences far less deformation and damage and lateral acceleration is decreased. The structure can nevertheless receive a set amount of vibrational energy under seismic stress even with a base isolation system in place. The amount of energy that the structure can really absorb depends on how ductile the material was that was used in its construction.

Buildings today employ materials like rubber-and-steel plate combinations to absorb seismic vibration. These are a few strategies we may employ in the future to prevent certain earthquake-related losses. Even if earthquakes cannot be stopped, we can learn more about them in the hopes of developing new defences against their damaging effects. Simple steps are the most effective ways to lessen earthquake damage.

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