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Study on Modeling Nonlinear Lateral Pile-Soil Interaction Effects On RC Bridges

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ABSTRACT

Structural models, when used in conjunction with iterative MMRS investigations, have the ability to replicate the nonlinear behaviour of the isolation system as well as the effects of SSI .Purpose of simulating the superstructures of bridges, three-dimensional beam components are utilised. The SSI impacts are considered by adjusting the adaptability at the foundation of the buildings. There are a few ways to deal with model this soil adaptability in view of rearranged or thorough models. The models make the assumption that there is full composite action between the slab and the girders. Each of the nodal points that connect the many different segments that constitute the superstructure is where the mass of the superstructure is consolidated.

Keywords: *Modeling , Nonlinear , Lateral Pile-Soil , Interaction , RC Bridges*

I. INTRODUCTION

Elevated highways and bridges are crucial parts of the infrastructure of modern civilizations because of their increased traffic capacity. Due to the significance of the vast majority of these structures, it is unacceptable for them to suffer a loss of functioning as a result of an earthquake. This is a performance criterion that cannot be accepted. Concern was expressed among members of the bridge engineering community over the performance of structures during the Northridge and Kobe earthquakes, which occurred in 1994 and 1995 respectively. As a consequence of this, they started looking into various methods of design in order to decrease the seismic risk associated with bridge building. One of these design techniques is called seismic isolation, and it is one that, when contrasted with the usual design philosophy, has shown to have a great potential to increase seismic performance. [Citation needed] A. Kelly 1986; Buckle and Mayes 1990; Martelli et al. 1993; Soong and Constantinou 1994; Tsopelas et al. 1996a,b; Tsopelas and Constantinou 1997, to name just a few of the numerous studies that were done on this topic. However, it is important to keep in mind that seismic isolation is not a panacea, and that poorly designed seismically isolated bridges have the potential to sustain significant damage, as was the case with the Bolu Viaduct during the 1998 Duzce Earthquake, Roussis et al. (2003), or even collapse completely in the event of a seismic event. This was the case with the Bolu Viaduct.

Bridge Structural Models

For the purpose of constructing and analysing structural models of the bridges, the programme SAP2000 is utilised . The structural models for Bridge-I, both with and without SSI effects, are depicted in Figure 1. The Bridge-IIs are comparable to one another. These structural models, when used in conjunction with iterative MMRS investigations, have the ability to replicate the nonlinear behaviour of the isolation system as well as the effects of SSI.

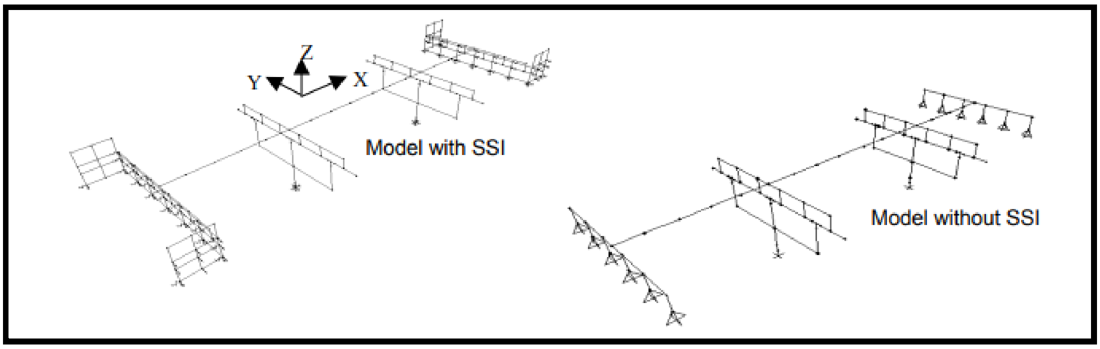

Fig. 1 Bridge-I structural models with and without SSI effects

Geometry of RC Bridge

One of the well-known and recently restored bridge modules in the Middle Zone of the Kingdom of Saudi Arabia (KSA), the Al-Fahs Bridge can be found to the northeast of Riyadh, Saudi Arabia. It serves as a study case because of its prominence in the region. The scaffolding is a cast-in-concrete bracing construction of two different lengths that is intended to survive for a long time. Figure 1 demonstrates that the two moderate bents each consist of three separate components, with a cross shaft positioned above the assembly. The scaffold, segment properties, and foundation characteristics have been computed and reported in Table 1 in consideration of the General Authority for Roads and Bridges, KSA, which is the owner of the present expansion. There is no shadow of a doubt that the safety provided by the separate underlying model of the fundamental core extension components is adequate to satisfy the requirements for heaps and relocation.

As can be seen in Figure 1, the extension is made up of a multi-range continuous deck that is held up by a line that runs in the direction of the detachment. The basis of the scaffolding is composed of docks constructed of reinforced concrete and non-bendable extensions. In the zones of projection and wharf, the separation direction is given in place of the typical line that runs between the superstructure and the substructure. This framework was constructed on a fairly commercial PC programme, but it is enhanced in the exact restricted component mode utilising professional seismic separation PC code and nonlinear static analysis carried out using SAP 2000.

Figure 2 Side view of the Al-Fahs bridge and view of the lower deck, respectively (Riyadh, KSA).

Superstructure Modeling

For the purpose of simulating the superstructures of both bridges, three-dimensional beam components are utilised. The models make the assumption that there is full composite action between the slab and the girders. Each of the nodal points that connect the many different segments that constitute the superstructure is where the mass of the superstructure is consolidated. To simulate the considerable in-plane translational stiffness of the bridge decks, transverse rigid bars are utilised. These bars are attached to the superstructure at the piers and abutments and have a length that is equivalent to the width of the bridge. These stiff bars are used to model the dynamic interaction that occurs between the movements of the bridge's superstructure, bearings, and substructures.

Isolation Bearings Modeling

At the locations of the girders, the isolation bearings are conceived of as three-dimensional beam components that link the substructures and superstructures. It is assumed that pin connections will be present at the joints that link the bearings to the substructures. Combining the results of many MMRS studies with the ELS of the bearings allows for the simulation of the nonlinear behaviour of the bearings.

Substructures Modeling

For the purpose of representing the pier components of both bridges, three-dimensional beam elements have been employed. In order to replicate the wall's width for Bridge-II, a horizontal stiff bar that is attached to the top of the wall is employed. This is done under the premise that the wall's cross-section will remain planar after it has been deformed. The load-bearing components were able to be attached to the wall as a result of this development. In addition, in order to accurately evaluate the effect that seismic pressures have on the soil or piles, the footings of both bridges have been modelled as vertical stiff beam components. This has been done in order to make the analysis as accurate as possible. In the structural model that does not account for the effects of SSI, the pier bases are hardcoded to remain unchanged. In the model that accounts for the SSI effects, there are a total of six boundary springs that are secured at the bottom of the piers to represent the interaction that occurs between the soil and the foundation.

In most cases, the abutments are not taken into account when structural models of bridges that do not account for SSI effects are created. As a result, it is believed that the conditions of the support at the abutment will be somewhat stiff. In the structural model that takes into account the impacts of SSI, the abutments are modelled as a grid of three-dimensional beam components. This helps to ensure that the model is as accurate as possible. In order to mimic the SSI effects, the model utilises boundary springs that are coupled at the interface nodes that are located between the abutment, the backfill, and the piles.

OBJECTIVES OF THE STUDY

1. To study on Backfilll-Abutment Interaction Modelling
2. To study on Modeling Pile-Soil Interaction

Modeling Pile-Soil Interaction

In order to create an accurate representation of the flexibility of the piles, two lateral and one vertical translational boundary spring have been attached to the base of the abutments at each pile site on both bridges. In order to replicate the flexibility of the complete foundation system at Bridge-II while also taking into consideration the group impact of the piles, six boundary springs, three translational and three rotational, have been attached to the bottom of the piers.

Modeling Nonlinear Lateral Pile-Soil Interaction Effects

A two-step technique is utilised in order to integrate the impacts of nonlinear lateral pile-soil interaction into the seismic assessments of the bridges. In the first step, nonlinear static pushover studies are carried out without the bridge in order to determine the correlations between the lateral forces exerted and the displacements caused by the pile foundations. In the second phase, you will use these nonlinear relationships and an iterative MMRS analysis procedure to formulate ELSs for the lateral translational springs. These ELSs will represent the lateral stiffness of the piles and will be used in the second step. The nonlinear lateral behaviour of the piles may thus be accounted for in the research thanks to this.

An iterative MMRS analysis technique is used to construct the ELS, as previously described by Dicleli. The ELS is defined as the slope of the secant line that extends from the origin to the point that represents the seismic lateral force of the piles on the lateral force-displacement curve of the piles. This slope is determined by the seismic lateral force of the piles. In the global X and Y directions of the bridge, the equivalent length span of the piles for Bridges I and II

Sitting Pile-Soil Interaction Modelling

Affects On It is to be anticipated that the vertical stiffness of the steel H-piles of Bridge-I, which are supported by hard sandstone, will be equivalent to their axial stiffness and will not be impacted by the characteristics of the soil in any way. The method developed by Novak [9] is utilised in order to calculate the vertical stiffness of the floating piles that make up Bridge-II. The vertical stiffness of the Bridge-I and Bridge-II piles, often known as the piles' stiffness in the global Z-direction

Simulating The Pile Group's Torsional and Rotational Stiffness

Determining the stiffness of the rotational springs for the rocking and torsional motion of the Bridge-II pier footings is accomplished by first applying a unit rotation about the global X, Y, and Z axes at the geometric centre of the pile group and then computing the moment of the generated elastic pile forces about the geometric centre of the pile group. Both of these steps take place at the geometric centre of the pile group. Dicleli offers further information and specifics on the calculation of the stiffness. The rotational stiffnesses of the piling group located at the piers of Bridge II.

Backfilll-Abutment Interaction Modelling

Longitudinal Direction

For the purpose of simulating the passive resistance of the backfill, a series of translational springs have been fastened to the nodes of a single abutment in the longitudinal direction, as There are no springs attached to the other abutment because seismic pressure that is delivered longitudinally causes just one abutment to be pushed towards the backfill while the other is pulled away from it. For the purpose of determining how the bridge will behave in the event of an earthquake, two separate structural models will be built with springs attached to the left and right abutments, respectively. Using the relationship that Clough outlined for the change in the earth pressure coefficient as a function of the abutment movement, the horizontal subgrade constant, ksh, for the backfill is found as a function of the depth from the top of the abutment. Next, estimate the stiffness of the boundary springs at the abutment-backfill interface nodes by multiplying ksh by the area tributary to the node.

Transverse Direction

Translational springs are attached to the nodes of just one of the wingwalls at each abutment in order to mimic the effect of the passive resistance of the backfill in the transverse direction. This is necessary owing to the fact that seismic forces have caused the other wingwall to be pushed away from the backfill. Once more, the area that is connected to the wingwall node's node is multiplied by ksh in order to determine the springs' level of stiffness. The model takes a cautious approach by ignoring the influence of embankment soil.

In addition, translational springs are secured to each abutment node in order to approximate the shear stiffness of the backfill. The shear stiffness of the backfill is estimated based on the premise that, when the bridge moves in a transverse direction, the only part of the backfill that will experience shearing deformation is the one that is located between the wing walls. When determining the stiffness of the transverse boundary springs at the abutment, the calculated shear stiffness is first distributed evenly over the interface nodes.

The SSI impacts are considered by adjusting the adaptability at the foundation of the buildings. There are a few ways to deal with model this soil adaptability in view of rearranged or thorough models. A few notable improved on models for catching the nonlinear way of behaving of the soil-foundation framework are the Beam on Nonlinear Winkler technique (BNWM), the lumped spring models or the constitutive models. One of the constitutive models, which is alluded to as a large scale component, has been generally examined in a few works. This approach can catch the nonlinear way of behaving of the soil with lumped hubs. A displaying choice gives an effective model somewhat hardly any expected boundaries contrasted with different models like 3D.

Albeit the full scale component idea has for sure been totally utilized, it has not yet been carried out in new quake designing programming. To do as such, relationship review with accessible trial tests are expected to show the model exhibition as demonstrated by Ramirez et al. In this work, some soil hypoplastic materials have been mathematically tried to be executed in open-source programming like OpenSees. In addition, explicit calculations to display this approach ought to likewise be created. In Hyeon Chai and Kwon, they were momentarily presented. By and by, this isn't the objective of the current work. Thusly, for this situation, two of the most well-known approaches have been utilized to show the SSI: an improved and a comprehensive methodology, the BNWM and the direct, separately.

The BNWM has been acknowledged in designing practice because of its overall straightforwardness and simplicity of adjustment. It depends on the demonstrating foundation's components as well as reproducing the nonlinear way of behaving of the soil through a bunch of inelastic springs. These mama terials were initially proposed for the analysis of heaps. Truth be told, there are a few chips away at the assurance of heaps conduct (segregated) thinking about these components. By the by, to the best of the creators' information, there are not many examinations that model the whole framework's way of behaving (soil + heap + structure).

The BNWM materials have been likewise evolved to be utilized in shallow foundations examinations. In Rajeev and Tesfamariam, delicacy bends for ideal RC exposed outline structures were acquired thinking about the SSI. The delicacy bends got from the fixed-model contrast from the SSI models relying upon the idea of the structure. They presumed that to get dependable outcomes, these investigations ought to be completed thinking about the qualities and the setup of the current buildings. A solitary shallow foundation was tentatively and numerically surveyed remembering soil vulnerabilities in Raychowdhury and Jindal. The outcomes showed that the precision in anticipating the reaction of the balance relies intensely upon the boundaries determination: both the soil and the balance's mathematical qualities. The SSI was closed to demolish the exhibition of primary individuals from ideal RC uncovered outline designs in Behnamfar and Banizadeh. The mid-and the tall structures were the most impacted.

The comprehensive demonstrating of the soil can be founded on an immediate or a substructure strategy. For this situation, the immediate methodology has been utilized. This decides the reaction of the soil and the structure all the while in a solitary advance, giving quicker and less difficult examinations. It presents a few novel elements: the soil and the structure can be discretised by limited component models, the limits should get extraordinary treatment, the pressure in the soil can be processed effectively and 3D nonlinear analysis is conceivable. The substructure technique isolates the SSI issue into a progression of less difficult issues following superposed advances. It prompts more com-plex examinations as various angles ought to be borne at the top of the priority list (one-layered arrangements of the site reaction issue, kinematic interac-tion issues, coupled soil-structure framework among others). Additional data of every strategy can be found in Maslenikov et al.. The immediate displaying of the soil is accomplished by utilizing limited and limit components strategies. The seismic weakness of skyscraper RC buildings was examined in Karapetrou et al.. The creators called attention to that the complex nonlinear way of behaving of the soil under the structure could present extra interpretation and turn impacts. Additionally, they presumed that the direct displaying of the soil could prompt temperamental outcomes. These outcomes were likewise acquired in Cayci et al. For this situation, the creators made and figured the RC structures naturally, utilizing an enormous information base, however the demonstrating was not done completely.

It tends to be seen that there is a need to consider the SSI impacts in the seismic investigations of structures. All the more so assuming that these examinations are nonlinear, which are the sort of investigations suggested in buildings' seismic weakness evaluations. By including the SSI contemplations, the seismic weakness examinations could become dreary because of the complicated technique expected to characterize them. Besides, there is an absence of studies and direction in the codes on the SSI appraisal. As a matter of fact, albeit the EC8 recognizes the structures for which the SSI should be remembered for designing practices, it indicates no rule for their evaluation. Henceforth, the advancement of methodology to break down the SSI issues, which can be straightforward yet genuinely exact, emerges as a chance to further develop the seismic weakness investigations.

II. CONCLUSION

The utilization of inelastic reaction spectra can prompt hardships in the understanding of results while directing pushover investigation on the grounds that, for expanding pliability factor, the interest removal some of the time diminishes. The SSI impacts are considered by adjusting the adaptability at the foundation of the buildings. There are a few ways to deal with model this soil adaptability in view of rearranged or thorough models. The exactness of the N2 and DCM strategies is lessening for SDOF frameworks in the short-time frame range. In the transitional period range the techniques give in everyday acceptable appraisals of seismic requests. The base shear was determined acceptably in the greater part of the cases with the exception of the short-time frame frameworks. Anyway the evaluations were unconservative inferring that the N2 and DCM technique might prompt dangerous plan or appraisal. The pushover bends will quite often underrate the real disseminated energy inferring that appraisal of harm in structures could be incorrect.

REFERENCES

[1]. Chaudhary, Muhammad. (2016). Effect of soil-foundation-structure interaction and pier column non-linearity on seismic response of bridges supported on shallow foundations. Australian Journal of Structural Engineering. 17. 1-20. 10.1080/13287982.2015.1116178.

[2]. Wankhade, Rajan & Ghugal, Yuwaraj. (2016). Study on Soil-Structure Interaction: A Review. International Journal of Engineering Research. 5. 737-741. 10.17950/ijer/v5i3/047.

[3]. Falamarz-Sheikhabadi, Mohammad Reza & Zerva, A.. (2016). Effect of numerical soil-foundation-structure modeling on the seismic response of a tall bridge pier via pushover analysis. Soil Dynamics and Earthquake Engineering. 90. 10.1016/j.soildyn.2016.08.020.

[4]. Pinho, Rui & Casarotti, Chiara & Antoniou, Stelios. (2007). A comparison of single-run pushover analysis techniques for seismic assessment of bridges. Earthquake Engineering & Structural Dynamics. 36. 1347 - 1362. 10.1002/eqe.684.

[5]. Nakhaei, Mofid & Ghannad, Mohammad Ali. (2008). The effect of soil–structure interaction on damage index of building. Engineering Structures - ENG STRUCT. 30. 1491-1499. 10.1016/j.engstruct.2007.04.009.

[6]. Islam, Md.Halim & Dutta, Atanu. (2021). Pushover Analysis of R.C.C. Building Including 3D Soil–Structure Interaction. 10.1007/978-981-33-6564-3_34.

[7]. Dok, Gökhan & kırtel, Osman & Aktas, Muharrem. (2014). Effect of Foundation Geometry and Soil Class in Nonlinear Pushover Analysis of Two Dimensional RC Frames Considering Soil-Structure Interaction.

[8]. Astley, R. J. (2000) “Infinite elements for wave problems: A review of current formulations and an assessment of accuracy", International Journal for Numerical Methods in Engineering, 49: 951–976.

[9]. Bazyar, M. H (2007) “Dynamic soil-Structure Interaction analysis using the Scaled boundary Finite-Element Method”, Ph. D Thesis, School of Civil and Environmental Engineering, The University of New South Wales, Sydney, Australia, June.

[10]. Bentley, K. J. and El Naggar, M. H. (2000). “Numerical analysis of kinematic response of single piles”, Canadian Geotechnical Journal 37: 1368-1382.

[11]. Bettess, P. And Zienkiewicz, O. C. (1977) “Differaction and refraction of surface waves using finite and infinite elements. International Journal for Numerical Methods in Engineering, 11:1271–1290.

[12]. Buragohain, D. N. and Shah, V. L. (1977) “Curved interface elements for interaction problems”, Proc. Int. Symposium on Soil-Structure-Interaction, Roorkee, India, pp 197-202.

[13]. Cai, Y. X., Gould, P. L. and Desai, C. S. (2000) “Nonlinear analysis of 3D seismic interaction of soil–pile–structure systems and application”, Engineering Structures 22, 191–199.