Analysis of Piled Raft Foundation

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Abstract- *M3-dimensional finite part technique as a general technique to unravel complicated issues is one in all the foremost powerful numerical strategies which might be used for heaped-up groundwork analysis. These models will think about the complicated interaction between soil and structure. Among on the market 3D FEM1 software package for modelling pield raft foundations, during this paper Midas GTS is employed because of its varied part kind and modeling skills. during this article, completely different pile modeling techniques in Midas GTS software package (like pile modeling by solid components, modeling by beam components connected to soil components and modeling by EPM2) area unit compared with a true pile loading take a look at information. Results showed that each one 3 strategies have wonderful compatibility with the results of loading take a look at within the linear space of the load-settlement curve, and SEM3 and EPM unbroken their conformity any within the non-linear space still. one in all the foremost crucial issues in 3D FEM modeling method of heaped-up raft foundations with SEM was a rise within the variety of components once the quantity of piles will increase which results in model's slowness and convergence downside. Piles modeling by EPM desires abundant lower elements; victimization this technique, skin friction resistance, tip resistance and displacement between pile and soil will be simply tag with a pile loading take a look at information that facilitates heaped-up raft analysis with an outsized variety of piles. when examination completely different pile modeling techniques through Midas GTS software package, the power of the software package for modeling heaped-up raft foundations had been verified; Results show acceptable agreement between software package output and monitored values and additionally outputs from alternative strategies.*

Keywords- Piled-raft foundation, Raft foundations, SEM models , EPM models , Modeling strategies.

I. INTRODUCTION

This For a protracted time, designers accustomed think about 2 separate choices for foundation design; shallow foundation consisting of base and deep foundations. However, in recent years they need pointed out that combining these 2 systems and at the same time victimisation the capability of pile cluster and raft (in contact with the soil), would cause economical style while not losing potency and safety. These foundations area unit known as raft foundations strengthened by piles or cumulous raft foundations. Bearing capability of cumulous raft foundations is influenced by a fancy interaction between soil below the structure and cumulous raft parts. There area unit four interactions between totally different parts that area unit shown in Figure one : • Soil Pile Interaction • Pile Pile Interaction (the distance between piles influences the behavior of pile cluster; whether or not piles reach failure in singular or group mode) • Raft Soil Interaction • Pile Raft Interaction (imposed load from the raft over the soil causes a lot of confinement and, consequently, will increase the bearing capability of the piles) Being conscious of these interactions and also the use of analytical ways is vital for the reliable style of cumulous raft foundations. Different ways had been developed for the analysis of cumulous raft foundations, which may be concisely classified as follow : • ways supported Simplified calculations • laptop based mostly Approximate ways • a lot of Rigorous laptop based mostly ways Simplified ways comprises Davis and Poulos , Randolph, van impe& clerk and Berland ways. every of those ways has simplifications within the modeling profile and raft bearing. Computer based mostly approximate ways comprises the subsequent groups: • the strategy that is predicated on" strip on spring" during which raft is shapely as a collection of strip foundations and piles as springs (for example, Poulos) • ways that area unit supported "plane on string" during which raft is taken into account as a flexural plane and piles as springs (for example Clancy& Randolph, Poulos) More Rigorous laptop based mostly ways area unit as follow:

Simplified finite part analysis : These models sometimes take into account foundation system as plane strain (Desai)or considers it as Associate in Nursing axis trigonal system (Hooper), and finite distinction analysis ways forward plane A. Abdolrezayi, N. Khayat/ process Engineering and Physical Modeling 4-1 (2021) 19-36 twenty one strain or axis-- symmetric conditions in business programs like FLAC, ar placed during this class. (for example Hewitt &Gue) • 3D--finite part and 3D--finite distinction analysis : Used in business software package like PLAXIS 3D, FLAC 3D, ABAQUS, MIDAS GTS, and PLAXIS 3D FOUNDATION • Boundary

components methods: (like Butterfiled and Banerji, Sinha)
•
Combined methods: Methods that mix boundary components ways for piles and finite components ways for rafts.(for example Hain and Lee, tantalum and little, Franke et al.)

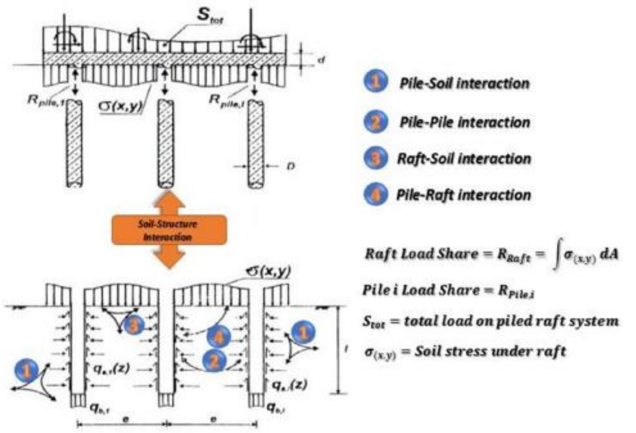

Fig. 1. cumulous raft foundations that are accommodates bearing components of soil, raft and pile swap and interactions between these nil components.

Simplified ways and computer--based approximate ways each have simplifications for considering the interaction between components and soil behavior modeling. thus mistreatment these ways perpetually have some errors. Therefore, these ways ar used as Associate in Nursing initial estimation in style so use on the market 3D-FEM software package for reliable results. 3D finite part ways ar of the foremost reliable ways for the analysis of cumulous raft foundations which might take into account 22 A. Abdolrezayi,

N. Khayat/ process Engineering and Physical Modeling 4-1 (2021) 19-36 complex interaction between components in these systems. Figure 2 shows a outline of the various ways of cumulous understructure analysis

II. CASE STUDY

Now . Sinha and Hanna (2016) performed a constant study on cumulous raft foundations mistreatment ABAQUS software package and also the changed Drucker— Prager essential law. The analysis aim was to look at the result of the governing parameters on the performance of cumulous raft foundations. Deb and Kumar Pal (2019) used ABAQUS software package package to check the response of a cumulous understructure beneath combined lateral and vertical loading and analyses the influence of vertical load on the lateral response of a cumulous understructure. Mali and Singh (2018) simulated an oversized cumulous raft through 3--D finite part modeling with PLAXIS 3D. the target of this study was to research the result of pile spacing, pile length, pile diameter and raft--soil stiffness magnitude relation on the settlement, load--sharing, bending moments, and shear force behavior of huge piled--raft foundation.

Deb and Kumar Pal (2020) used 3D finite part modeling by ABAQUS FEM package to check the complicated load sharing behavior because of the presence of interaction effects. supported this study they projected a simplified model for the planning of the heaped-up fundament considering each the security and usefulness conditions. One of the most issues in applying 3D FEM programs for analysis of heaped-up raft foundations is that these models square measure terribly time intense once the quantity of piles and components increase, it ends up in convergence issues for the numerical model. during this analysis, the capabilities of recent mythical being GTS package for heaped-up fundament analysis had been mentioned. completely different pile modeling techniques by numerous components during this package are mentioned and compared. mythical being GTS has several skills for pile modeling and conjointly incorporates a wide selection of components which might analyze the heaped-up fundament quick and accurately. 2. analysis technique Since mythical being GTS package is employed during this analysis, initially package options square measure shortly discussed; it's a comprehensive program for finite part analysis with second and 3D modeling ability that is employed for modeling of geotechnical operations like tunnels construction, foundations, excavations, leak studies, Slope stability, retentive structures, and consolidation then on. it's an in depth library of rock and soil behaviour models (15 models) and can also perform numerous analyses. In this package, pile modeling is accessible exploitation SEM models, BSCM and EPM that considerably scale back the analysis time compared to solid components and ancient pile modeling strategies. normally finite components package packages like ABAQUS shrewd axial forces and bending moments in every pile needs writing and implementing a python code. However, mythicalbeing GTS introduces Gauging Shell to estimate the instant, that is less complicated and axial forces and bending moments in every pile square measure calculated mechanically. solely many numbers of programs have such skills. In summary, there square measure 3 strategies for pile modeling during this software: • SEM models for piles • BSCM4 model • EPM (or in different words line to solid interface model) 2.1. Models with solid components In Figure three the ideas of this model square measure shown, soil and piles square measure each sculptural by solid components. In these models, the association between external nodes at the surface of the pile and soil is critical (the interface). 4 Beam-Solid property technique 24 A. Abdolrezayi, N. Khayat/ procedure Engineering and Physical Modeling 4-1 (2021) 19-36

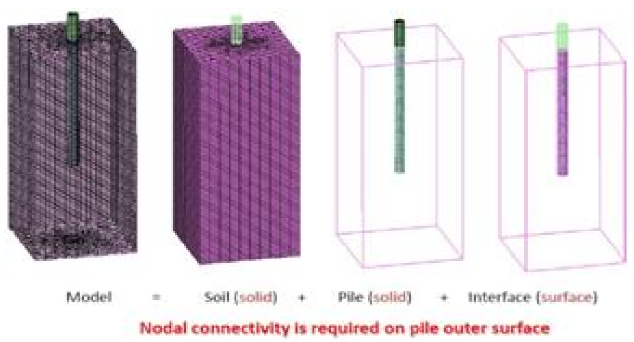

Fig. 3. Shcematic of a 3D model of pile with solid components. If it's required to think about the displacement between pile and soil and a discount in touch resistance between pile and soil in these models, surface interface components as its shown in Figure four will be used for connecting solid components.

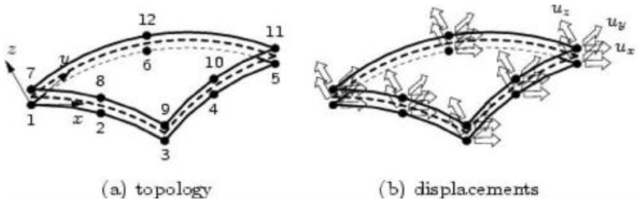

Fig. 4. Shcematic of Surface interface components for solid to solid components association. Some limitations of those models square measure as mentioned below: • process the pure mathematics of the model and meshing mechanism is sophisticated and time consuming. • several components square measure created in these models that need tons of computing time; especially in heaped-up raft foundations with several piles leading to a substantial computing time that is impractical for constant studies. • Axial Forces and bending moments in piles aren't on the market directly for the user and should be calculated by the user that makes it troublesome for constant heaped-up raft foundation analysis.

BSCM models In these models, as its shown in Figure five, soil is modelled as solid components, however pile is modelled as a beam or a linear part, and if its required to think about displacement between piles and soil or scale back the contact friction between them, line interface components that is shown in Figure six A. Abdolrezayi, N. Khayat/ procedure Engineering and Physical Modeling 4-1 (2021) 19-36 twenty five can be applied; in these models nodal property between pile and soil on the pile length is required. Some of the disadvantages in beam-solid property models • Nodal property demand makes the geometrical modeling and soil meshing processes troublesome, though in mythical being GTS it's done mechanically by automatic meshing feature that solely needs investigation regarding mesh quality. • For heaped-up raft foundations with an oversized range of piles, this modeling technique ends up in bigger models with a lot of computing time, though computing time in these models is much less than SEM models for piles.

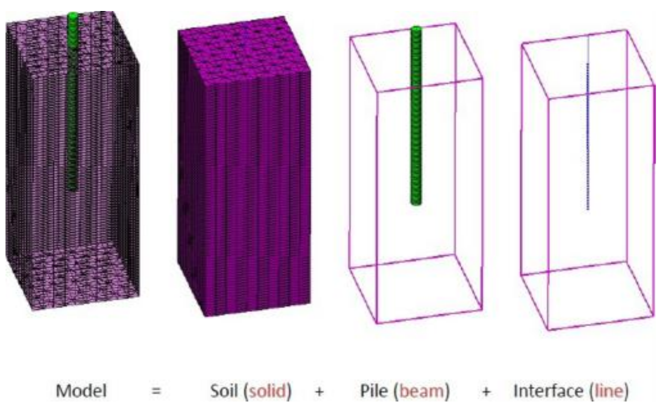

Fig. 5. Shcematic of 3D model of the pile with beam- solid property elements

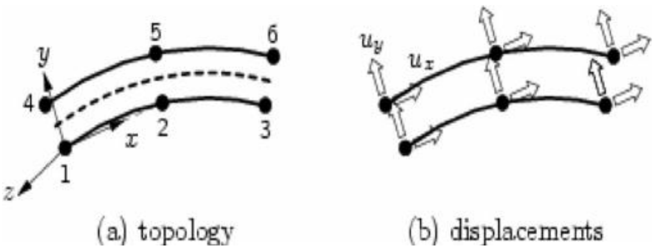

Fig. 6. Shcematic of Line interface components for connecting beam part to solid element.

III. METHODOLOGY

EPM models (line to solid interface model) In these models, as it's shown in Figure seven, the soil is modelled by solid components and therefore the piles with a beam or line interface part. For modeling slippage between pile and soil and modeling friction resistance line to solid interface is employed, that is shown in Figure eight, and for modeling tip bearing capability, purpose to solid interfaces square measure used, as shown in Figure nine, that square measure applied by choosing "create pile element" choice within the package.

making these 2 components is achieved by defining the min contact surfaces set between embedded pile part and soil part. The 26 A. Abdolrezayi, N. Khayat/ procedure Engineering and Physical Modeling 4-1 (2021) 19-36 first kind of a 'contact surface' that's used may be a 'line to solid' interface that's used for modeling the friction between Pile and soil and lateral capability and displacements at pile's sides. Another type of 'contact surfaces' that's used is 'point to solid interface' that is employed for modeling the tip bearing capability and displacement between soil and pile at the tip of the pile. during this manner by defining connecting surface parameters and components, it's doable to think about the displacement between pile and soil. In these models, nodal property between beam and soil components isn't required, and soil meshing will be done singly from pile meshing that makes these models suitable for big heaped-up raft foundations.

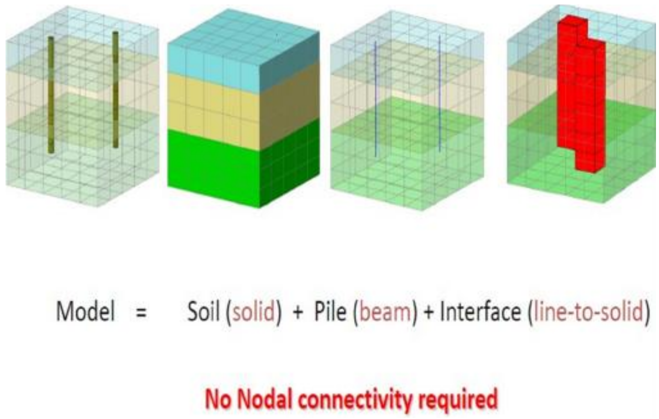

Fig. 7. Shcematic of 3D model of piles with embedded piles or line to solid interface.

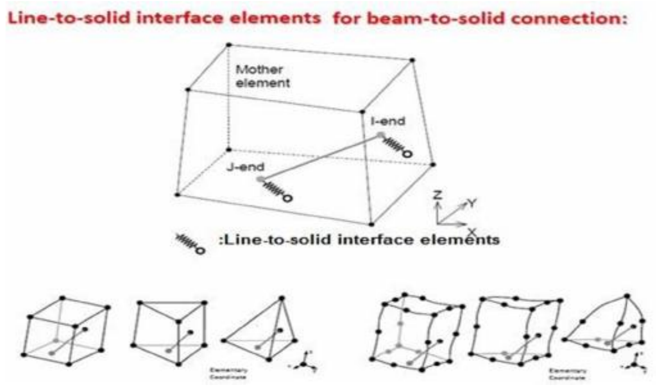

Fig. 8. Line interface components for lateral friction

. Abdolrezayi, N. Khayat/ procedure Engineering and Physical Modeling 4-1 (2021) 19-36 twenty seven In these models exploitation purpose to solid interface components offers U.S. the power for modeling tip bearing capability. Figure eight shows these elements; it's sort of a spring that connects the soil to the tip of the pile.

Features of modeling by embedded pile element: •

Geometrical definition and pile--soil meshing will be done singly and severally. • Crossing and intersection between line interfaces (beam association components) and soil elements will be calculated mechanically. • it's doable to model slippage with nonlinear friction--slip properties for line interface components. • Mesh refinement for the soil in these models is minimum that eventually decreases the calculations. The outline of the comparison between 3 modeling strategies for lateral skin friction and tip bearing capability of piles square measure given in tables 1&2, severally.

Table1
Comparison between three kinds of models for side friction modeling.

Model Type	SEM	BSCM	Embedded piles or Line-to-solid interface model
Interface type	Surface	Line	Line - to - Solid
Nodal connectivity	Required	Required	Not required
Shear law	Coulomb friction plasticity	Defining the relation between friction and slippage per length	Defining the relation between friction and slippage per length
Friction stress – settlement displacement.	local	Averaged over circumference	Averaged over circumference
Transversal behaviour	Gap opening Possible	Rigid(high elastic stiffness)	Rigid(high elastic stiffness)
Variation over pile circumference	Considered	Not considered	Not considered

Table 2
Comparison between three kinds of models for pile tip bearing capacity.

Model Type	SEM	BSCM	Embedded piles or Line-to-solid interface model
Interface type	Surface	Point spring	Point - to - solid
Nodal connectivity	Required	Required	Required
Tip failure	(High refinement required)	Is considered by defining a relation between tip reaction and settlement	Is considered by defining a relation between tip reaction and settlement
Bearing stress - settlement displacement.	local	Averaged over tip surface	Averaged over tip surface
lateral behaviour	Coulomb friction Over pile section	Slipping	Slipping
Variation over the surface of the pile's tip	Considered	Not considered	Not considered

IV. RESULTS AND DISCUSSION

Figure ten shows the results of pile loading check in FRG that is performed on a set pile in pre strengthened clay in city . The groundwater is found three.5m below the ground's level; piles have a diameter of one.5 m and length of nine.5 m and placed during a consolidated clay layer. Loading system consists of two hydraulic jack that generates force over a reaction beam. This beam is supported by sixteen anchors; they're placed vertically at a depth of sixteen twenty meters and a distance of four meters from piles below loading that minimizes the interaction between the pile and also the system. Loading is completed stepwise, and also the quantity of load at every step is fastened till the settlement rate is tiny. Applied load and connected displacement ar measured at the highest of the pile. Also, the soil settlement is measured at totally different depths close to the piles. additionally, loading cells that ar mounted at the highest of the piles, ar capable of direct measurement of the forces. The calculated total load settlement curve and also the connected fragmentation for facet and tip resistance ar shown in Figure eleven.

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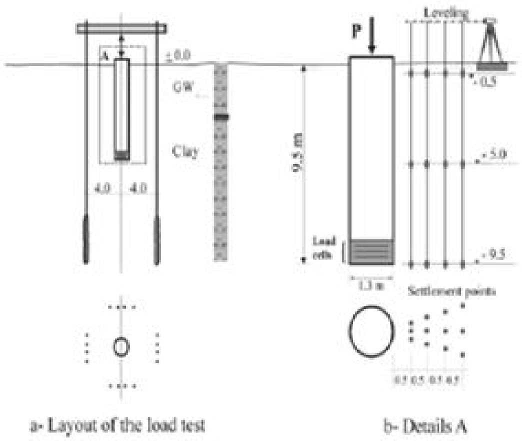

Fig. 10. Details of the pile loading test [15].

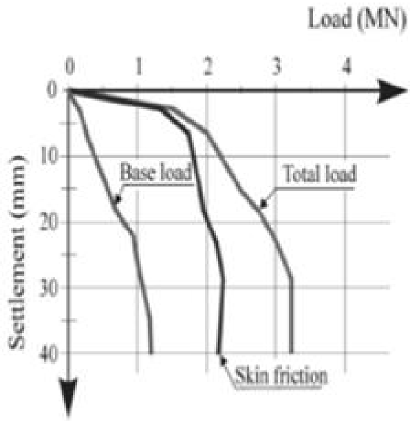

Fig. 11. Load-settlement curves for pile loading test [15].

Table 3.represents the material properties and constitutive model used in 3D-finite element models.

Table 3

Features of the behavioral model and materials in the pile's 3d loading test.

Constitutive model	Mohr coulomb	
Type of behavior	Drained	
Unsaturated soil density	γ_{unsat}	20 kN/m^3
Saturated soil density	γ_{sat}	20 kN/m^3
Soil Elastic modulus	E	6×10^4 kN/m^2
Poisson Ratio	ν	0.3
Cohesion	C	20 kN/m^2
Friction Angle	Φ	22.5
Soil dilatancy angle	Ψ	0
At rest lateral pressure coefficient	k_0	0.6

Figure 12 represent the model dimensions and number of elements and nodes for FEM modelling of pile using SEM and EPM methods. The mesh refinement was chosen as medium for both models.

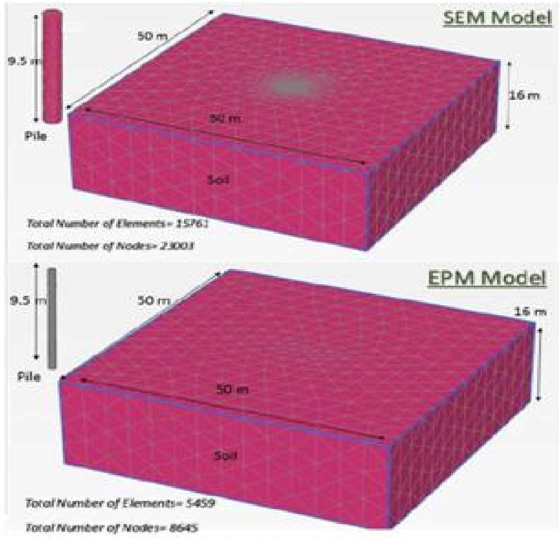

Fig. 12. Model properties for SEM and EPM models.

Figure 13 represents the comparison between total load-settlement curves indifferent pile modeling techniques and pile's loading test measurements.

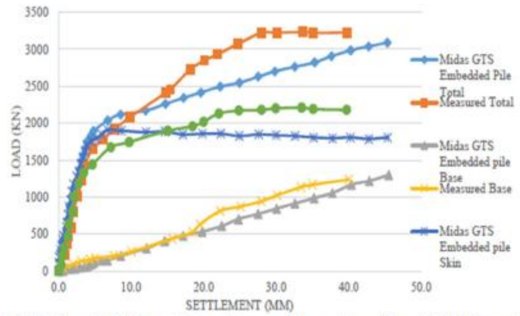

Fig. 14. Calibration and validation of skin resistance and base resistance for embedded piles model using the load-settlement curve of the pile loading test.

As it can be seen, there is a very good agreement between modeling results in embedded piles and pile loading test measurements.

As it is seen, all models showed acceptable consistency inside the linear a part of the load settlement curve. once nonlinear behaviour of different models started, beam model (beam connected to solid elements) shows a lot of rigid behaviour. the rationale behind this is often the very fact that surface interface parts aren't used for facet resistance reduction and slippage modeling between pile and soil that finally results in a lot of rigidity within the load settlement curve of this model. However, within the following section through examples that ar used for validation of heaped-up groundwork modeling, it is determined that the results of the beam property model shows acceptable consistency with the results obtained by different models that are engineered by distinguished researchers.

As it's mentioned earlier regarding examination completely different pile modeling approaches, in EPM techniques, the facet resistance and tip bearing capability don't seem to be thought- about as a part of the analysis results and instead applied as model's inputs. additionally before applying the min heaped-up groundwork models, these 2 parameters and different parameters for the pile soil interface model ought to be graduated via pile loading check results. once activity is finished modeling heaped- up rafts with an outsized variety of piles is done terribly simply and quickly and in contrast to pile modeling with solid parts, the values of forces, moments and plenty of different parameters ar offered at post processing section of Midas GTS package and doesn't need any calculation from users.

Figure fourteen shows the results of fragmentation of load settlement curves (pile skin resistance and base resistance) that are used for activity and validation of EPM models.

V. VALIDATION

3.1.1. First example

This example had been analysed by different authors like Poulos & Davis [1], Randolph [3], Sinha [12] (a combination of boundary and finite elements) and Ta& Small [14] (finite elements) via different techniques and different software like Plaxis3D, GARP, and GASP. Figure 15 shows the model's definition and geometry.

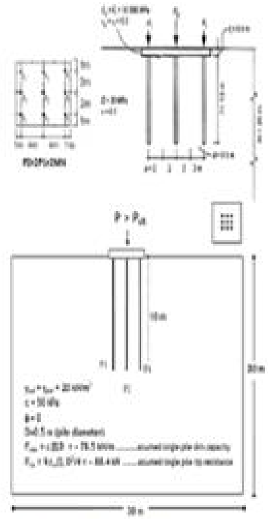

Fig. 15. Definition of hypothetical example by Poulos [1] which is used for software validation.

The average settlement value calculated by MIDAS GTS is 30 mm in this research. Figure 16 shows the comparison of MIDAS GTS settlement value with the value of settlement calculated by other methods and researches.

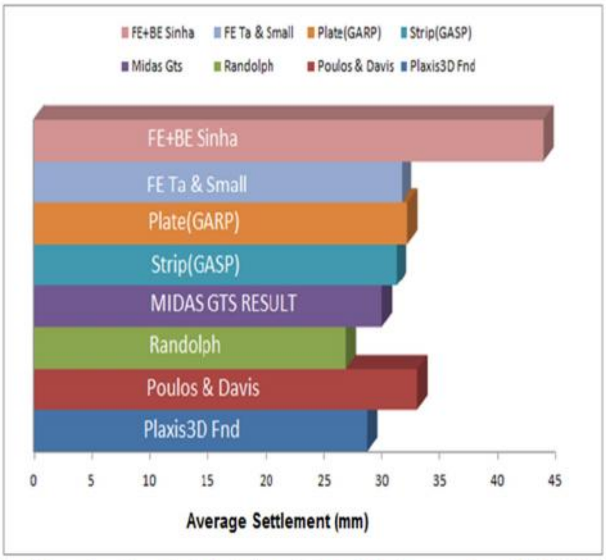

Fig. 16. Comparison of the results calculated using methods with calculated average settlement in MIDAS GTS for Poulos's hypothetical problem.

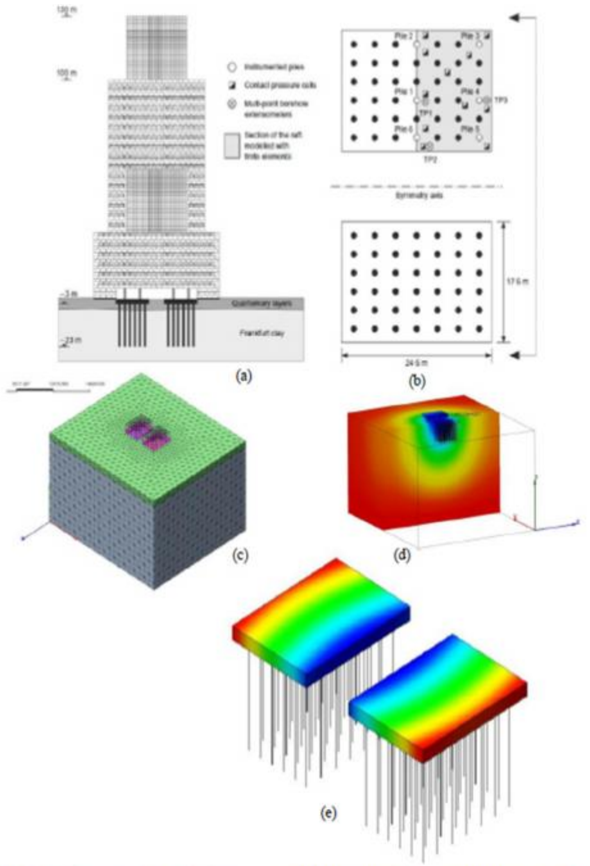

Fig. 17. (a), (b)Geometry details for Torhaus tower[26] (c), (d) and (e) validation process and result for Torhaus tower in MIDAS GTS software.

The second example is that the validation method for Torhaus der Messe tower building; this building is made on a concentrated groundwork with a dimension of seventeen.5 *24.5 m, every raft carries the 200MN load. Overly, during this concentrated groundwork, there square measure eighty four piles with diameter and length of zero.9 and twenty meters, severally [26]. Figure seventeen shows the model's definition, pure mathematics and results. the most measured settlement is a hundred and forty metric linear unit, and also the most settlement that is calculated in mythical being GTS computer code is 166mm that indicates acceptable conformation with the measured settlement of the building.

VI. CONCLUSION

Implementation of contemporary pile modeling strategies like EPM or BSCM would cause a major reduction in pure mathematics quality and calculation time as compared to the traditional pile modeling techniques that square measure supported the employment of SEM within the modeling (e)(b)(c)(d)(a). A. Abdolrezayi, N. Khayat/ procedure Engineering and Physical Modeling 4-1 (2021) 19-36 thirty five process. In these strategies, pile forces and moments square measure calculated within the code, and there would be no would like for manual calculations, not like SEM-- based models. 3 pile modeling techniques that comprises solid component, BSCM and EPM square measure mentioned and compared in section three, and therefore the following results have obtained: the most distinction between SEM and therefore the 2 alternative strategies is that the significantly additional significant quantity of calculations needed in SEM; conversely, in SEM, pile forces and moments aren't calculated within the code and will be calculated manually (which is extraordinarily tedious for an outsized variety of piles).

In EPM, parameters associated with load--bearing capability at skin, base, and slippage square measure thought of as model's inputs. As a result, EPM is completely different during this issue with alternative strategies. previous inputting these parameters for heaped- up substructure modeling, they ought to be calibrated; If the results of a pile loading take a look at square measure on the market, this standardisation can cause the straightforward application of heaped-up raft modeling techniques and therefore the needed time for computations and analysis would be abundant lower as compared with SEM.

For examination the results of 3 pile modeling strategies, they're compared with the particular information of a pile load—settlement take a look at that showed an appropriate agreement within the linear space of loading--settlement curve.

In this analysis the mythical being GTS code is verified for heaped-up substructure modeling; results show acceptable conformation for code outputs and monitored values. mythical being GTS has calculated the settlement with but eighteen % of error. The code is additionally verified with Poulos theoretical example that has been investigated by several researchers ANd strategies; the quantity of Settlement was an inacceptable agreement with settlement calculated by alternative methods and code; the settlement was nearly adequate the values computed by Plaxis3D foundation software.

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