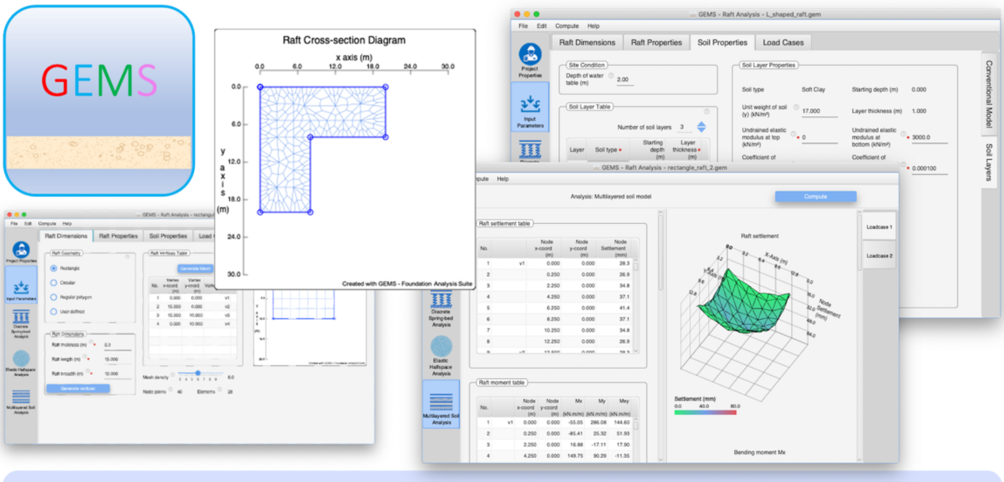
Geotechnical Engineering Modelling Software (GEMS)

Raft Foundation Analysis



www.gemsoftware.org

GEMS Overview

Geotechnical Engineering Modelling Software (GEMS) develops advanced and intuitive Computer Aided Design & Engineering (CAD & E) software for foundation analysis & design.

Our software is designed to streamline the complex process of geotechnical engineering, enabling engineers to work more efficiently and effectively. GEMS foundation analysis suite employs modern finite element modelling techniques for analysis & design of shallow and deep foundations. The foundation analysis suite includes modules for

- Beam foundations
- Raft foundations
- Comprehensive Pile Foundation Analysis (Land, Bridge & Waterfront Structures)
- Pile Group Settlement Analysis
- Offshore pile foundations




GEMS foundation analysis suite is available for download on Windows, MacOS based computers. It is also available on the cloud (for use online using a browser).

Windows 10

Mac

Revolutionizing Raft Foundation Analysis with GEMS

In the realm of construction engineering, the selection of raft or mat foundations is often driven by the need to efficiently distribute structural loads across large building footprints or to navigate challenging soil conditions. The analysis and design of raft foundations demand meticulous attention to detail, encompassing the assessment of immediate and long-term settlements at various column locations, as well as bending moments and shear forces in the raft structure

To address these complexities, GEMS (Geotechnical Engineering Modelling Software) offers advanced solutions tailored to streamline the analysis and design process.

Advanced Modelling Techniques

The GEMS Raft Foundation software utilizes cutting-edge finite element modelling techniques, ensuring accurate analysis and design. The analysis is carried out by idealizing the raft as an elastic plate of finite rigidity resting on soil sub grade. Our software offers multiple models for idealizing the soil support, including:

- **Discrete Spring Bed Model (Winkler Model)**: Utilizing modulus of subgrade reaction to simulate soil support.
- **Elastic half–space model:** Representing the subsoil as an elastic, homogeneous, isotropic, and semi-infinite medium, considering elastic modulus and Poisson ratio.
- **Multi-layer subsoil system:** Accounting for the actual subsoil profile by incorporating layers such as clay, sand, and rock, using property data obtained from field and laboratory investigations.

Complexity Simplified

The settlement and bending behaviour of a raft depend significantly on its thickness and the nature of soil support. The differential equation governing the flexure of a thin raft is

$$D\left(\frac{\partial^4 w}{\partial x^4} + 2\frac{\partial^2 w}{\partial x^2}\frac{\partial^2 w}{\partial y^2} + \frac{\partial^4 w}{\partial y^4}\right) = q - p_s$$

Where:

$D = \frac{Eh^3}{12(1-\nu^2)}$ is the flexural rigidity of the plate

E is the Young's modulus

ν being Poisson ratio

h signifies the raft thickness.

p_s denotes the soil reaction.

q represents the external load on the plate.

When the raft gets thicker the governing equations become much more complex. Hence for practical problems analytical solution will be impractical and recourse has to be taken to numerical solution.

Solution through Numerical Method

Here, GEMS shines with its implementation of finite element modelling based on Mindlin's plate theory. The raft foundation is discretized into number of bilinear quadrilateral plate elements, with each of its node having three degrees of freedom, vertical displacement and rotations about x and y axis sufficient to represent the deformed shape of the raft. Our software facilitates the consideration of thick or thin plates of various geometric configurations, load scenarios, and soil-structure interactions. Concentrated vertical loads, and moments and distributed vertical loads can be imposed on the raft. Different soil support models could be combined with the raft and the integrated system analysed considering effects of soil- structure interaction. Furthermore, automatic mesh generation capabilities simplify usage, ensuring seamless integration into engineering workflows while delivering accurate and reliable results.

With GEMS Raft Foundation analysis software, engineers are equipped to conquer the complexities of foundation analysis and design, empowering them to realize their vision for safe, resilient, and sustainable structures.

Method of Analysis

Finite element formulation is used in which raft is divided in to a number of quadrilateral plate elements. Division into quadrilateral elements enables raft of different shapes - rectangular, circular, polygonal, user-defined to be considered. The soil support stiffness is obtained based on the selected soil model. Both structural and soil stiffness are combined to obtain the overall stiffness of the system. The equilibrium equations are then solved where the knowns are the applied loads and the unknowns are the raft displacements.

Analysis and design of a raft foundation involves consideration of flexural rigidity of the raft and nature of sub-soil profile at the site. The raft is modelled as a plate in structural analysis. Raft foundation transfers stresses to greater depths in soil and the deformation properties of soil with in the zone of influence need to be considered. Below mentioned three types of soil support models are supported by the software.

Soil Models

Subgrade reaction theory based on discrete spring-bed model

In the discrete spring-bed model, the soil support is idealized as a linear spring bed. The stiffness of the soil support is characterized by the equation $p_s = k_s w$, where k_s represents the modulus of subgrade reaction. This model, also known as the Winkler model, does not fully account for the continuity present in the soil mass. Due to the extended stressed zone beneath the raft, selecting a representative value for k_s is necessary.

Elastic half-space model

In this approach the subsoil is replaced by a homogeneous, isotropic elastic half-space characterised by an elastic modulus and a Poisson ratio. This model considers the continuous nature of the soil medium and determines the soil support stiffness based on Boussinesq's equation for vertical displacement. Similarly, due to the deep stressed zone beneath the raft, choosing representative values for the Young's modulus and Poisson ratio for the underlying soil becomes imperative.

Multi-layered soil model

Raft foundations transfer stresses to greater depths within the soil, necessitating the consideration of deformation properties of all soil layers within the zone of influence.
The 'Multi-layer soil model' is based on the sub-surface soil profile at the location and utilizes data obtained from comprehensive field and laboratory investigations.

The settlement s may be expressed as

$$s = \int_0^H \varepsilon_z \, dz$$

Where:
ε_z represents the vertical strain at depth z.
H denotes the depth at which the settlement becomes insignificant.

For elastic behaviour ε_z is calculated as:

$$\varepsilon_z = \frac{1}{E}\left(\sigma_z - \upsilon(\sigma_x + \sigma_y)\right)$$

Sand and rock layers are modelled by using appropriate values of elastic modulus and Poisson ratio for each layer.

In clay layers immediate behaviour is modelled by using un-drained elastic modulus E_u and un-drained Poisson ratio $\upsilon_u = 0.5$. The long term behaviour in clay layers is modelled by using the following conventional equation

$$\varepsilon_z = m_v \sigma_z$$

In which m_v is coefficient of volume compressibility of the clay and σ_z is the increase in the vertical stress. The settlement can then be computed by summation across all layers (n):

$$s_j = \sum_{i=1}^{n} \varepsilon_{zi} H_i$$

Key Features

- Rafts with different geometries (Rectangular, circular, regular polygon, user-defined) can be considered.
- Modelling of soil layers using
  a. Discrete spring-bed model
  b. Elastic half space model
  c. Multi-layered soil model
- Multiple loading scenarios could be defined.
- The loading may consist of several concentrated loads & moments applied at various points on the raft
- Uniform load applied on the raft can be specified.
- Self-weight may be included if required.
- Immediate term and long-term settlement can be determined.
- Automatic Mesh Generation
- Graphical representation of the raft along with finite element grid used for computation.
- Graphical representation of loading for each case.
- One click computation and analysis for all load cases and models.
- Export results to MS Word, Excel PDF
- Data can be input in either SI units or 'Commonly used American units' (*kips for force and foot for length*).
- Supported on Windows, Mac and Cloud
- Analysis results include tabular & graphical representation of
  a. Raft settlement
  b. Bending & twisting moment
  c. Shear forces
  d. Soil pressure

Figure: Cross-section diagram

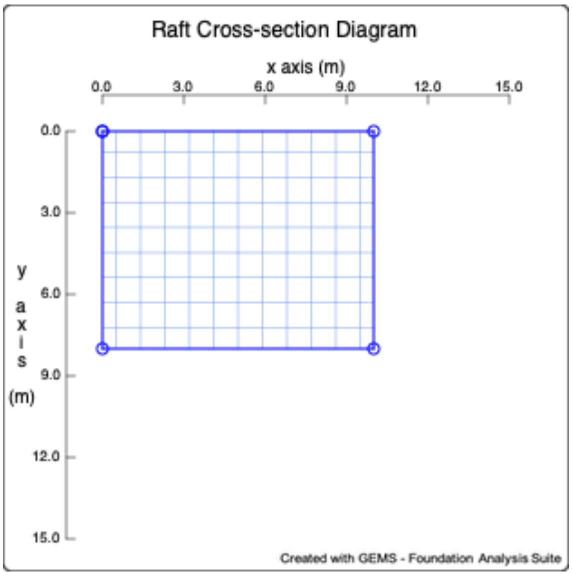
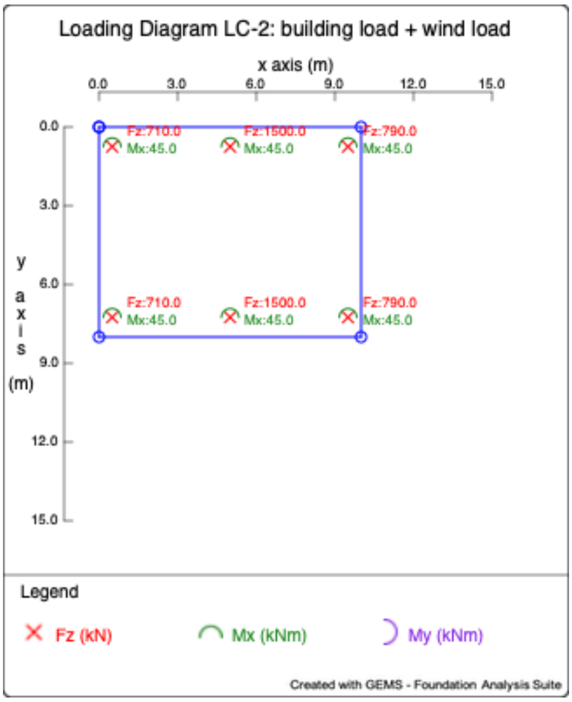


Figure: Loading diagram



Analysis

Results of analysis for are shown in separate panes for each of the load cases. The analysis consists of

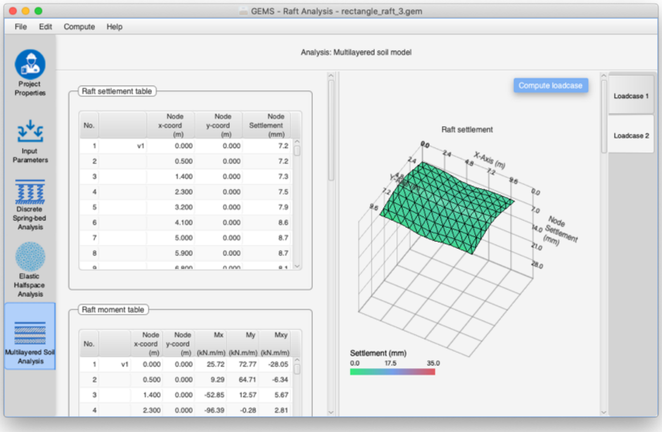
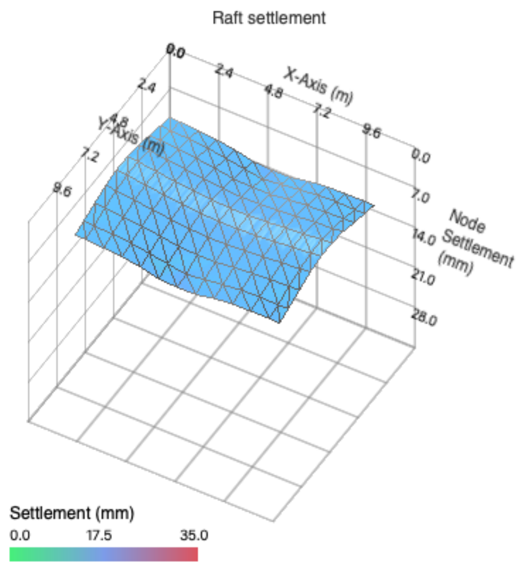
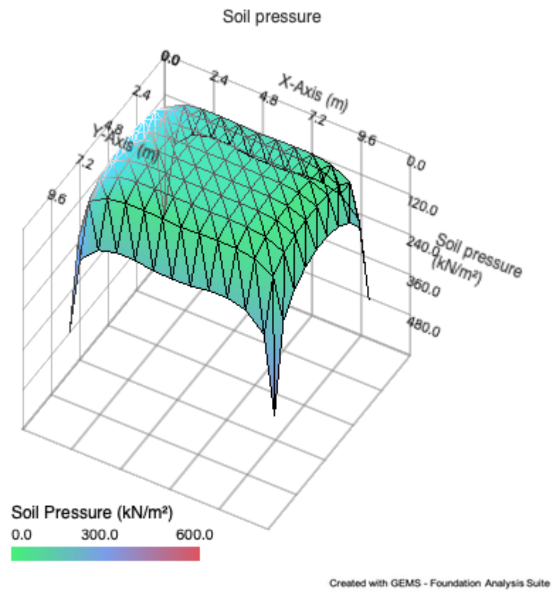


Figure: Analysis Pane

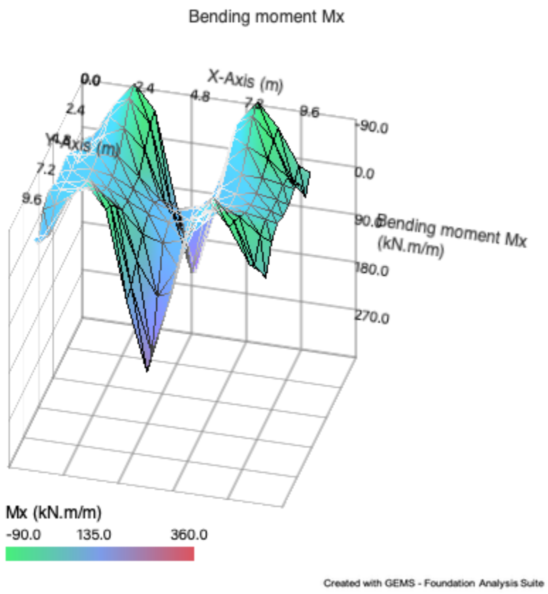
Tabulated values of settlement of the raft, and graphical representations of them.

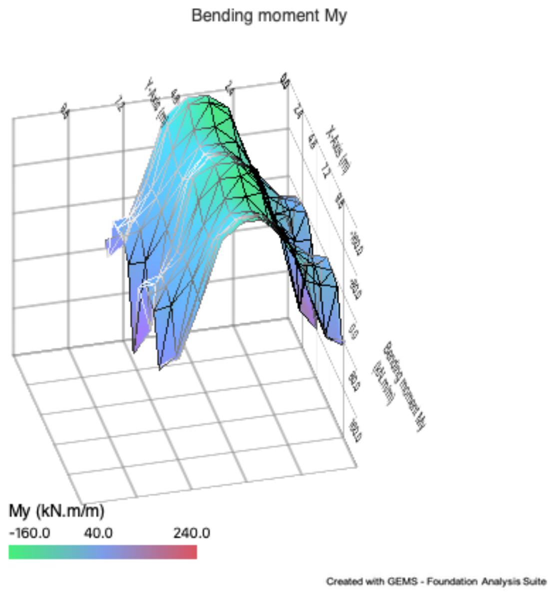


Values of soil pressure under the raft and graphical representation of the same

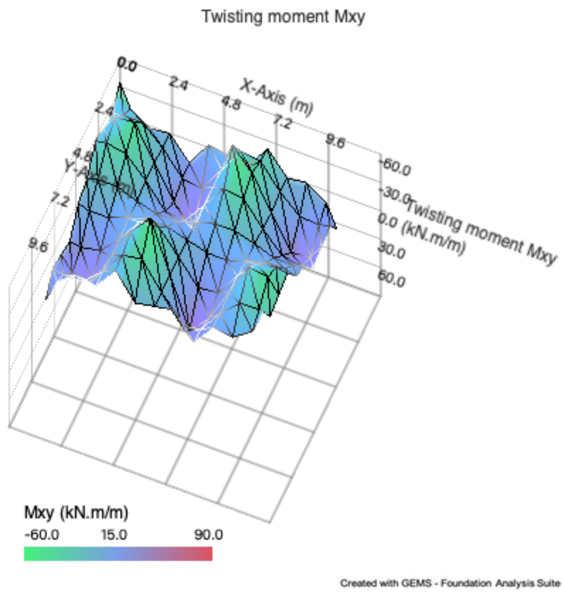


Tabulated values and graphical representation of the Bending moment Mx along the x-axis, My along the y-axis





Torsional moment Mxy along the z-axis and graphical representation of the same



Tabulated values of shear forces experienced by the raft

Tabulated values of slope at various nodal points on the raft.

Contact & Enquiries

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