Introduction

The Benchmarks and Verifications manual for the GTS NX is intended to demonstrate the performance and capabilities of the GTS NX solver in solving a wide range of finite element analysis problems in geotechnical engineering. The selected problems cover static and dynamics analyses as well as seepage and consolidation analyses. Both linear and nonlinear problems are included. The individual chapters are organized in terms of analysis types as summarized in Table 1.1.

Table 1.1 Summary of problems in chapters

Chapter	Description
2	*Element performances, linear static problems*
3	*Material nonlinear problems*
4	*Time history, free vibration, response spectrum*
5	*Steady-state and transient seepage problems, consolidation problems, seepage-stress sequential problems*
6	*Slope stability problems*
7	*Hysteresis models*
8	*Heat Transfer models*

The selected benchmark problems are widely recognized and accepted as standard problems for testing the performance of general finite element programs. These include problems from the suite of NAFEMS[1] benchmarks. Also many problems are selected from refereed journal papers and technical publications as well as books from established authors. The benchmark and verification problems organized in terms of their sources are presented in Table 1.2.

Due to the characteristics of individual finite element type, a given set of elements tend to yield superior performance for certain kind of problems while results for other types of problems may exhibit poor performance in comparison. One of the objectives of this manual is to transparently provide both the performance and some of the limitations of GTS NX solver. To this end, results obtained using various types of element models in terms of their geometry and formulations are provided especially in chapter 2 where performance of elements are extensively tested. For these problems, only a small number of elements are used to obtain the results even though further mesh refinement significantly enhances the solution accuracy.

[1] National Agency for Finite Element Methods and Standards, National Engineering Laboratory, Glasgow, U.K.

Each problem section is conveniently organized in three parts; section header, problem description and result summary. The section header includes the reference, type of elements tested and the GTS NX files used to solve the problem. The results are provided in tables and figures. Many problems contain tables organized in terms of the element types used to obtain the results. Table 1.3 summarizes the element groups and element types that are referenced in the individual problem sections.

Table 1.2 Summary of benchmark problems in terms of their references

Reference type / Analysis	NAFEMS benchmarks	Journal papers	Books and other sources	Total
Element performance	*7*	*6*	*9*	*22*
Nonlinear materials		*11*	*9*	*20*
Dynamics problems	*8*	*4*	*2*	*14*
Seepage and consolidation		*3*	*7*	*10*
Slope stability		*3*		*3*
Hysteresis models			*10*	*10*
Heat Transfer models	*3*	*1*	*3*	*7*
Total	*18*	*28*	*40*	*86*

Table 1.3 Element groups and element types

Element group	**Element type (element geometry-N)***
Beam and truss	*BEAM-2, TRUSS-2*
Plane strain, plane stress, and shell	*TRIA-3, TRIA-6, QUAD-4, QUAD-8* TRIA: triangular, QUAD: Quadrilateral
Solid	*TETRA-4, TETRA-10, PYRAM-5, PYRAM-13, PENTA-6, PENTA-15, HEXA-8, HEXA-20* TETRA: tetrahedral , PYRAM: pyramid, PENTA: Pentahedral, HEXA: Hexahedral
Axisymmetric solid	*TRIAX-3, TRIAX-6, QUADX-4, QUADX-8*

**N: number of element nodes*