Section 1 Overview

GTS NX is a program developed for the detailed analysis of ground and tunnel systems. It is founded on the C++ based Finite Element Analysis engine. Various analysis methods such as static analysis, dynamic analysis, seepage analysis, stress-seepage coupled analysis, consolidation analysis, construction stage analysis, slope stability analysis, are provided (Table 1.1.1) and various specialized elements are provided to accurately model the ground or tunnel to perform effective analysis.

Table 1.1.1 GTS NX Analysis Types

Analysis Types
Linear static analysis
Nonlinear static analysis
Construction stage analysis
Consolidation analysis
Fully Coupled Stress-Seepage analysis
Seepage(steady-state) analysis
Seepage(transient) analysis
Eigenvalue analysis
Response spectrum analysis
Linear time history(modal/direct) analysis
Nonlinear time history analysis
1D/2D equivalent linear analysis
Slope stability(SRM/SAM)
Nonlinear time history + SRM

This manual is mainly composed of theoretical and technical information that make up the base of detailed analysis for the effective usage of the GTS NX program. The contents of each chapter are as follows:

Chapter 2: Node and Coordinate system
Chapter 3: Elements for modeling
Chapter 4: Material models for detailed ground or structural analysis
Chapter 5: Algorithms used to perform analysis
Chapter 6: Load and Boundary condition

This manual contains all the functions of GTS NX, but the range of usable functions may be different depending on the version.

Section 2 Unit System

The physical quantities such as structure size, material properties etc. needed to define the analysis model is generally defined with reference to a particular unit system. With GTS NX, the unit conversion for force/length/time is possible and the user can change the unit system during modeling when defining the analysis model. Before running the analysis, the units for force/length/time need to be unified in a single unit system, either the English unit system or the SI unit system.

Table 1.2.1 Units used in the English/SI unit system

Physical quantity	English	SI
Position, Length, Displacement	Inch	meter
Modulus of Elasticity	lbf/inch^2	Newton/meter^2
Moment	inch-lbf	Newton-meter
Force	lbf	Newton
Mass	lbf-sec^2/inch	kilogram
Time	second	second
Stress	lbf/inch^2	Newton/meter^2

The unit system used for modeling in GTS NX is converted to the M-K-S (meter, kilogram, second) unit system for analysis. The analysis results are automatically converted to the unit system used in the modeling process.

Section 3

File system

During finite element analysis on the GTS NX, several files need to be created or saved and various temporary files are created or deleted. The files used on the GTS NX and their content are as follows.

Table 1.3.1 Main files in GTS NX

File name	Form	Content
ModelName.GTS	Binary	Model data file
ModelName_AnalysisName.mec	ASCII	Interpreter input file
ModelName_AnalysisName.log	ASCII	Analysis execution record file
ModelName_AnalysisName.out	ASCII	Analysis result data file
ModelName_AnalysisName_usr.out	ASCII	History result data file
ModelName_AnalysisName.nfxp	Binary	Analysis result data file (Post-processing)
ModelNmae_AnalysisName _ConstructionStageName.RST	Binary	Construction stage analysis restart data file

The result files available the GTS NX are ASCII form .out files and binary form .nfxp files. Fundamentally, the results are included in the .nfxp and used for result interpretation using the interpreter. The ASCII result .out file can also include results like the .nfxp file and the degree of inclusion can be controlled by the user options. For construction stage analysis, which takes longer than other types of analysis, the analysis can be terminated forcefully due to user inattention or system instability. As a provision, the .RST file contains the restart data that allows continued analysis from the shut down construction stage.

The temporary files created during the analysis process of GTS NX and their content are as follows.

Table 1.3.2 Files created during numerical analysis

File name	Point of creation/Content
InputName.DASM#.bin	Generation, finite element related information for all analyses
InputName.FACT#.bin#	Generation, matrix information when selecting the multi frontal method
InputName.EIGS#.bin#	Lancoz resampling information when selecting eigenvalue analysis
InputName.MSTO#.bin	Large scale matrix, vector related information internally recorded in the disk

The temporary files created during analysis are created in the scratch folder. The default value of the scratch folder is the same as the model file position.

Section 4 Notation System

This manual uses both the matrix notation and component notation. The matrix notation is very useful in expressing tensors and is hence used when possible.

The values needed for theory development are scalar, vector, second order tensor or matrix, fourth order tensor etc. The matrix notation is expressed as follows.

Table 1.4.1 Matrix notation

Value	Notation
Scalar	u
Vector	$\mathbf{u}$, $\{*\}$
Second order tensor, matrix	$\mathbf{A}$, $[*]$
Fourth order tensor	$\mathbf{C}$

The notation for vectors and tensors are the same when bold fonts are used, so the two need to be distinguished by their content. Matrix notation is very effective when understanding the relationship between physical quantities or their physical meaning. However, it is better to use the component notation when performing complex arithmetic operations or calculations between components, which are hard to express using the matrix notation. The component notation is based on coordinate systems. Each system can be defined by a basis vector. Base vectors are expressed in the 3D space as $\mathbf{e}_i$, $(i = 1, 2, 3)$ and may not be perpendicular to each other. When using a basis vector, an arbitrary vector $\mathbf{u}$ can be expressed as follows.

$$\mathbf{u} = u^1\mathbf{e}_1 + u^2\mathbf{e}_2 + u^3\mathbf{e}_3 \tag{1.4.1}$$

$\mathbf{e}_i$: displacement

u^j : stress

In the component notation, the subscript i represents the covariant basis vector or component in a strict sense. The superscript j represents the contravariant basis vector or component. Generally, the two are the same in the orthonormal coordinate system and hence not separated.
When using the component notation, it is convenient to use the summation convention on repetitive indexes as shown below.

$$\mathbf{u} = u^i\mathbf{e}_i \tag{1.4.2}$$

Similarly, second order tensors and fourth order tensors can be represented using the component notation as shown below:

$$\mathbf{A} = A^{ij}\mathbf{e}_i\mathbf{e}_j\ , \quad \mathbf{C} = C^{ijkl}\mathbf{e}_i\mathbf{e}_j\mathbf{e}_k\mathbf{e}_l \tag{1.4.3}$$

This manual assumes that the summation convention is applied unless otherwise specified.

Section 5 Sign Specification

GTS NX uses the following sign conventions on stress and pore pressure to provide consistency in result generation.

Positive(+) normal stress represents tension (Figure 1.5.1).
Positive (+) pore stress also represents tension
Positive (+) pore water pressure represents compression (Figure 1.5.2).

Here, the pore stress is stress defined by the pore water pressure development and only has value in the normal direction. Hence, the pore water pressure and pore stress have opposite signs according to the sign convention.

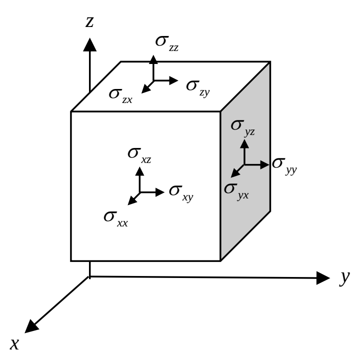

Figure 1.5.1 Positive stress direction

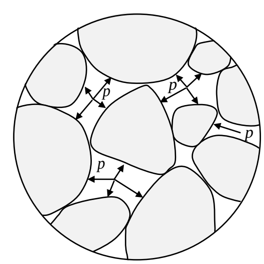

Figure 1.5.2 Positive pore water pressure