



Second-order Direct Analysis Method to Code of Practice for the Structural Use of Steel 2011

Dr. Y.P. Liu & NIDA Research Team
The Hong Kong Polytechnic University

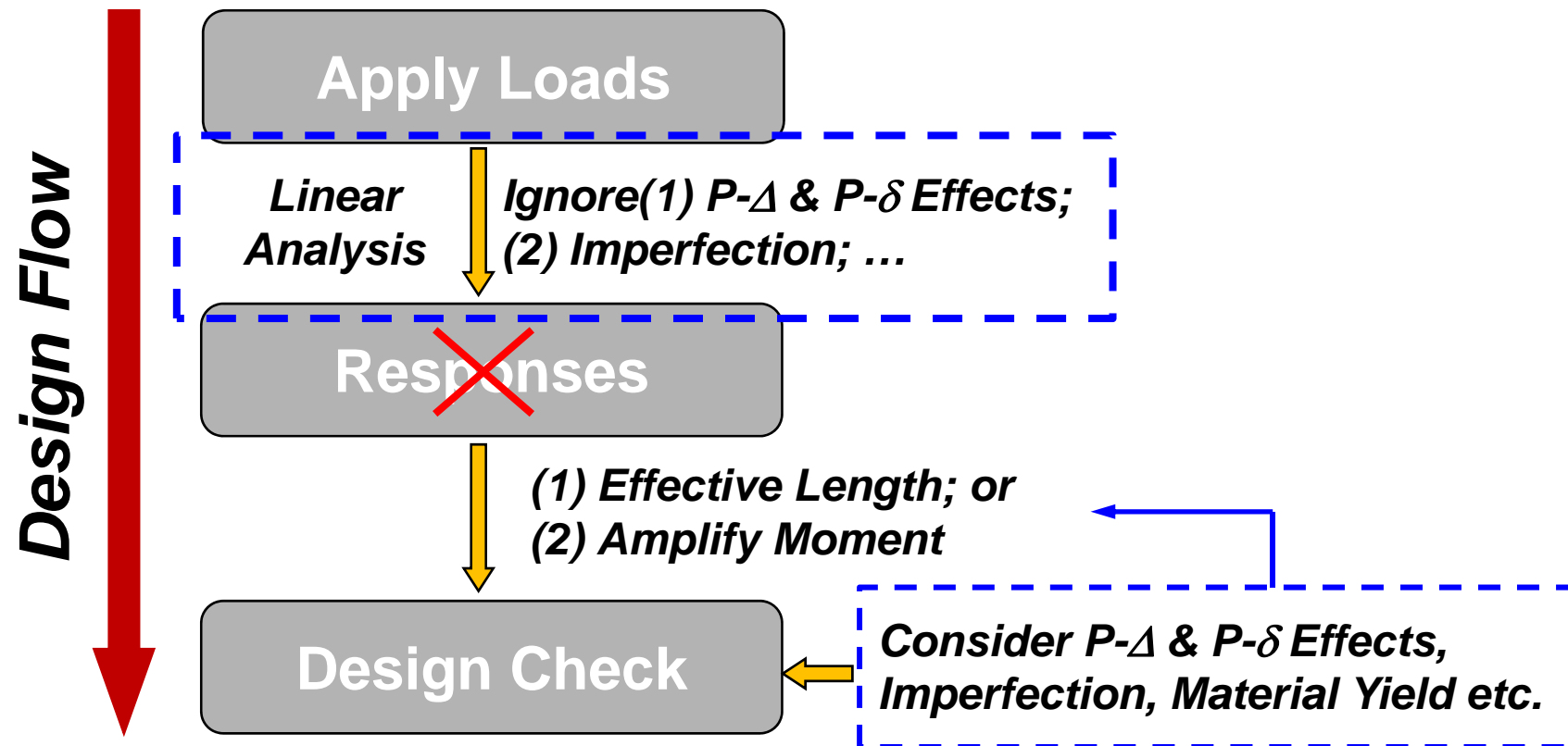
24 May 2013

Contents

- ***Second-Order Analysis vs. First-Order Analysis***
- ***What's NIDA***
- ***General Procedures & Settings***
- ***Most Frequently Asked Questions***
- ***New Features***

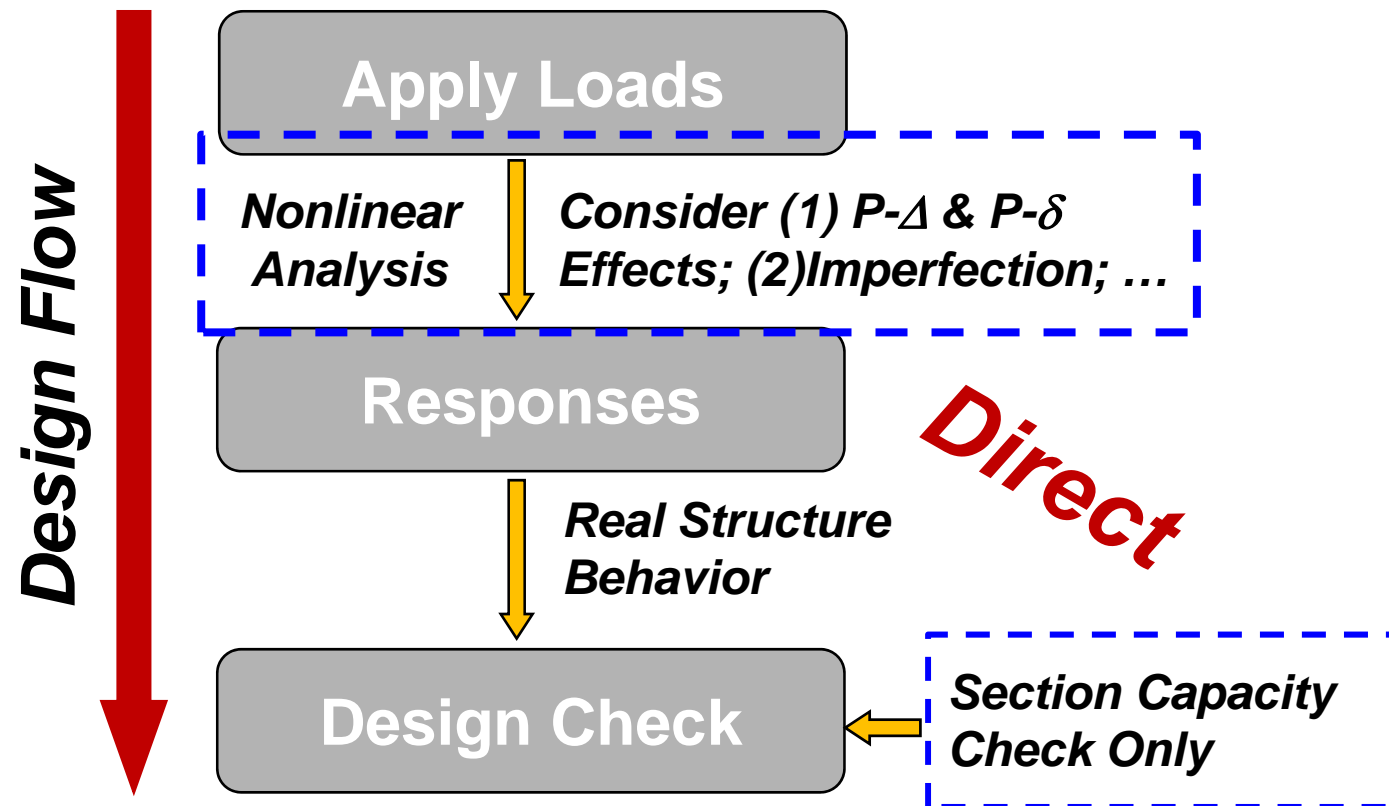
Second-Order Analysis vs. First-Order Analysis

➤ ***First-Order Linear Analysis & Design***

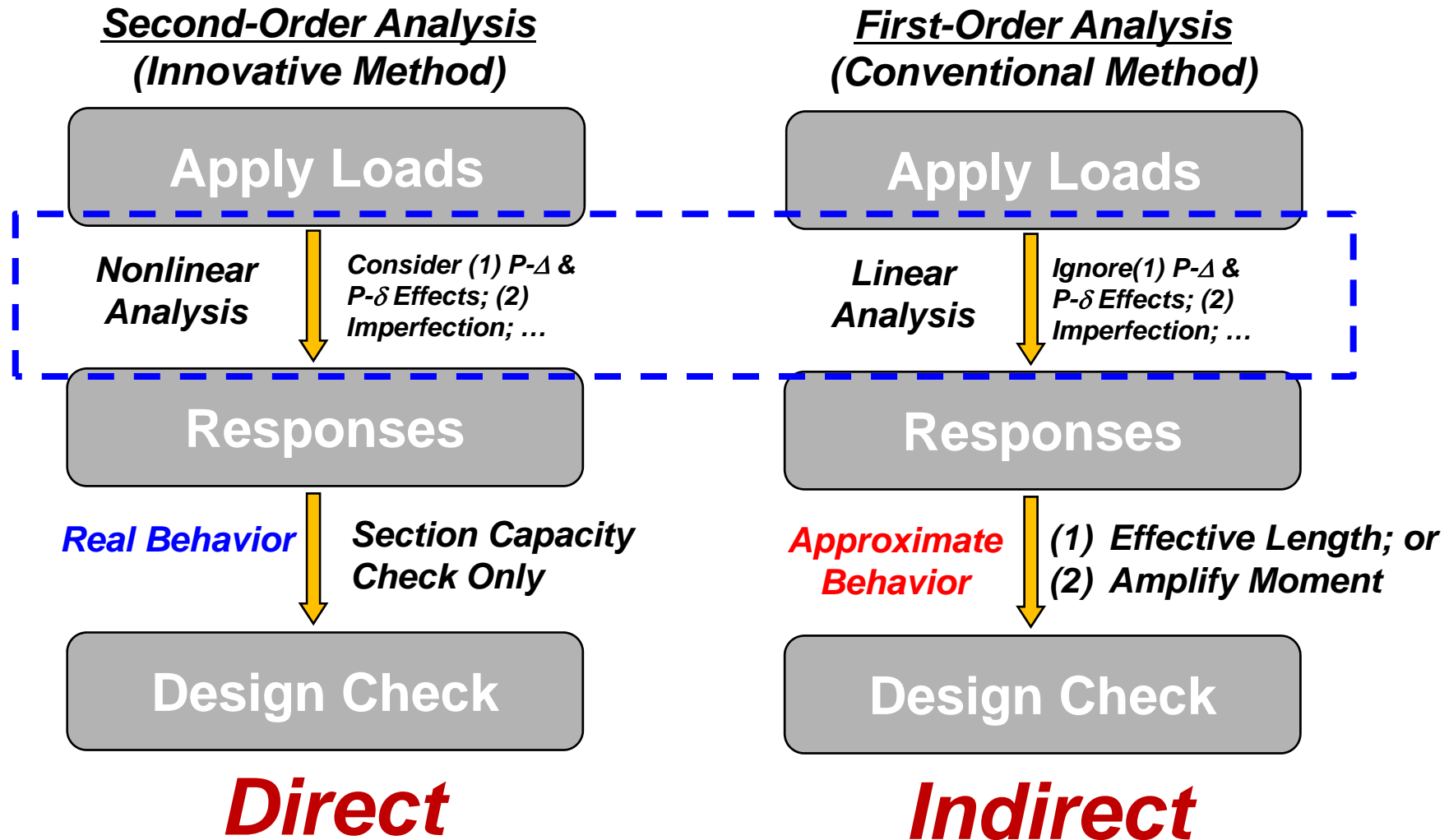


Second-Order Analysis vs. First-Order Analysis

➤ ***Second-Order Direct Analysis & Design***



Second-Order Analysis vs. First-Order Analysis



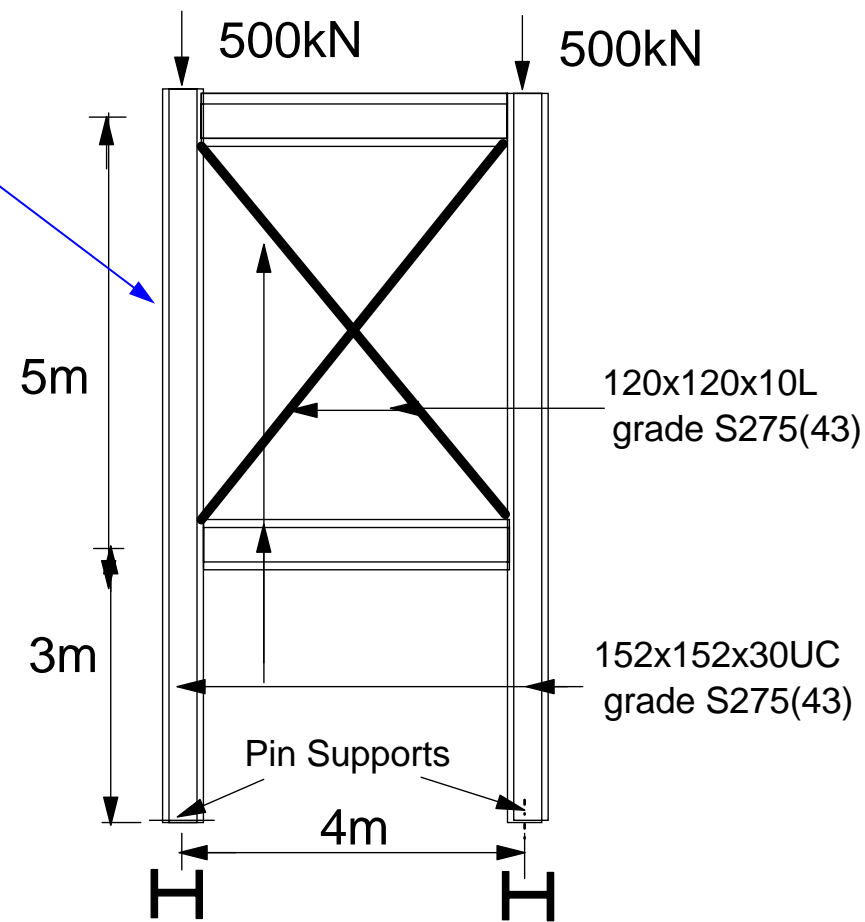
Second-Order Analysis vs. First-Order Analysis

Advantages of Direct Analysis:

- No need to assume effective length;
- Frame classification is not needed;
- More safer and more economic;
- Wider applications (*performance-based seismic design, load & construction sequences, structural fire engineering, progressive collapse analysis, ...*);
- Recommended in modern design codes (*Eurocode3, LRFD, New GB50017*);

Second-Order Analysis vs. First-Order Analysis

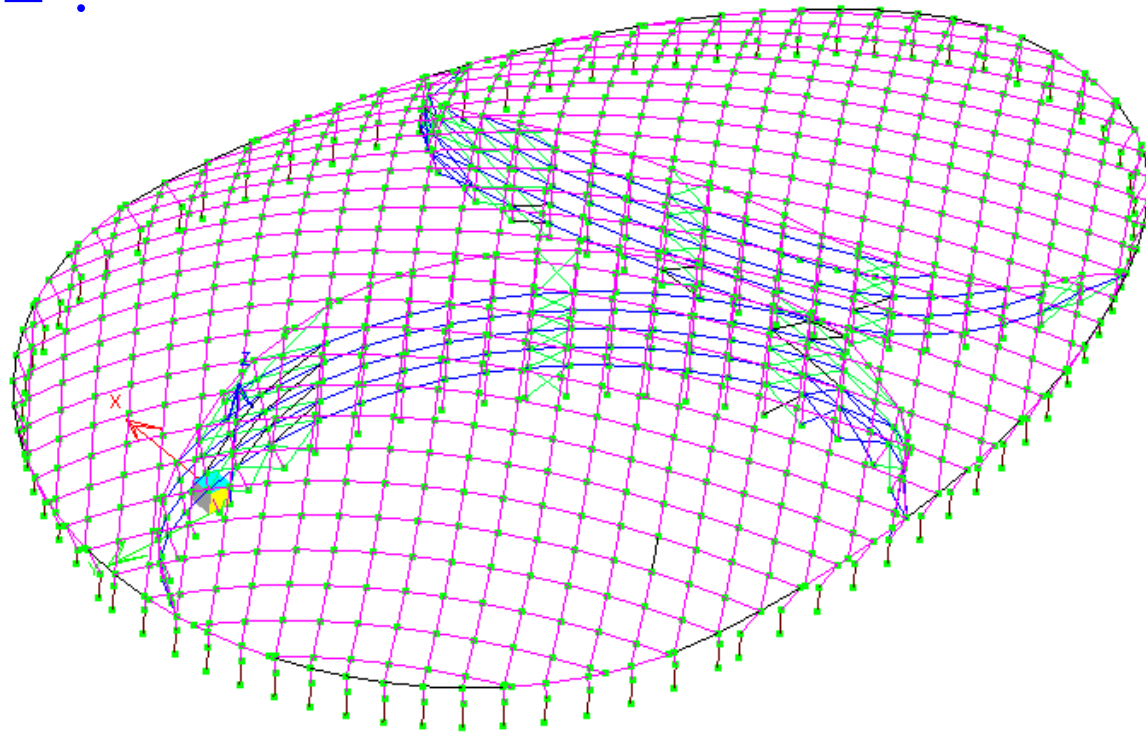
Effective Length = ?



Second-Order Analysis vs. First-Order Analysis

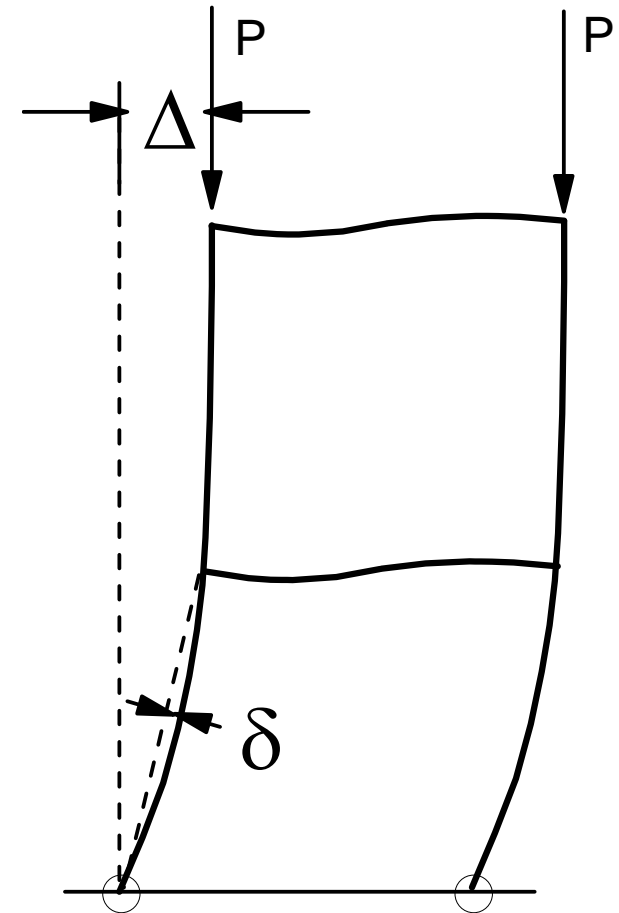
When under snow loads, snap-through buckling may take place.

Effective Length = ?



Major Concerns of Direct Analysis

- **$P-\Delta$ Effect** (*frame sidesway*)
- **$P-\delta$ Effect** (*member curvature*)
- **Imperfection** ($P-\Delta_0$ & $P-\delta_0$)



Initial Imperfection

No perfect structure exists in the world. Realistic imperfections should be included in the second-order analysis.

(1) Frame Imperfection (out-of-plumbness)

- a) Notional horizontal force (0.5% vertical forces)
- b) First eigen-value bucking mode ($H/200$)

(2) Member Imperfection (out-of-straightness, residual stresses)

- a) Perry-Robertson formulae (Linear analysis only)
- b) **Initial member bowing** (e.g. $L/500$)

Second-Order Analysis vs. First-Order Analysis

Without Imperfection

Project: Nida3
Unit: kN, m



Undeformed

Axial Shortening

With Imperfection

Project: Nida3
Unit: kN, m

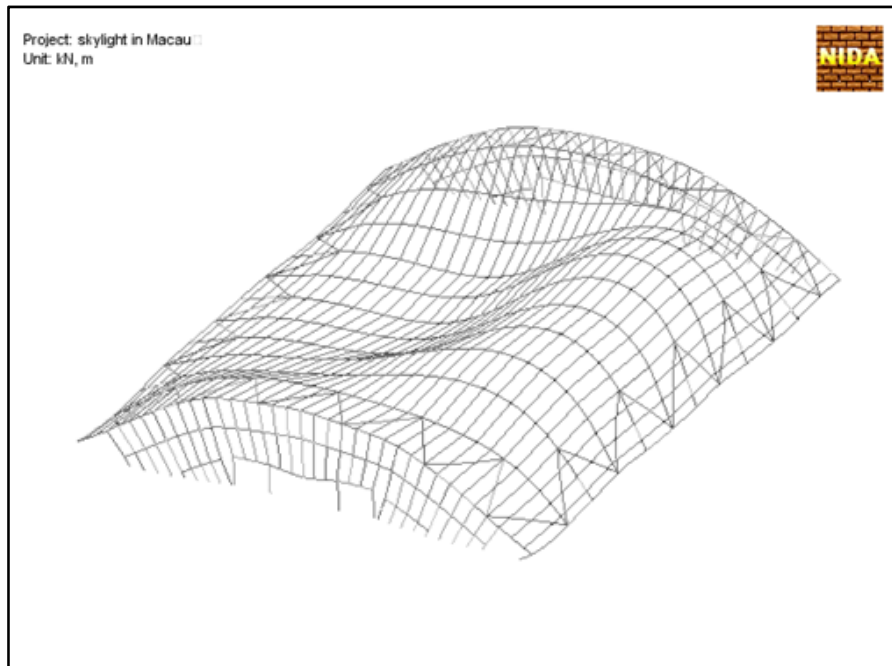


Undeformed

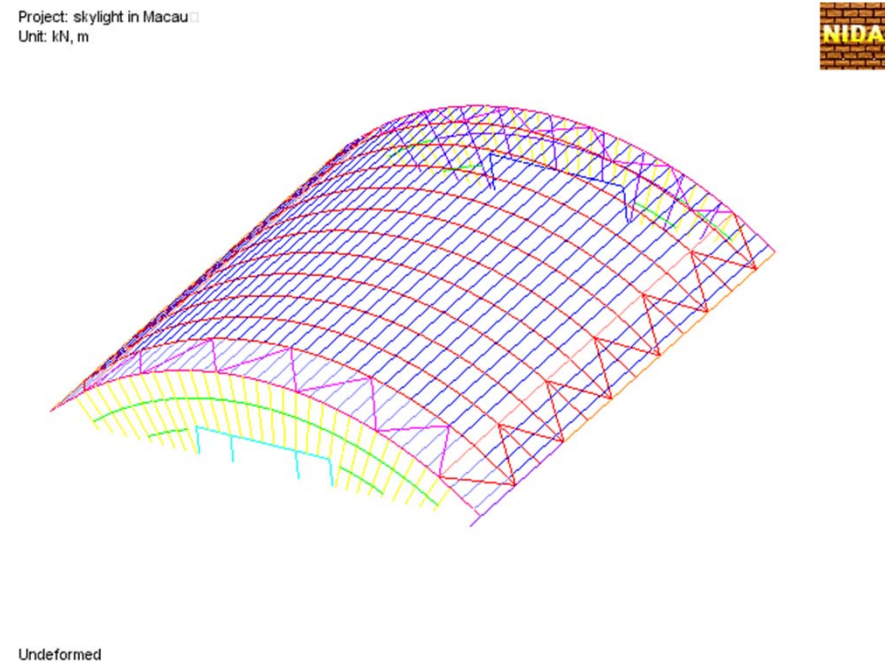
Axial Shortening + Bending

Second-Order Analysis vs. First-Order Analysis

Imperfection Shape



Deformed Shape



What's NIDA — *Nonlinear Integrated Design & Analysis*

- *NIDA is specially developed for second-order direct analysis.*
- *BD Pre-accepted Structural Programme Reference – [S0844](#) (**NIDA 9.0**)*
- *NIDA has been used for the structural design of many projects.*

What's NIDA — *Nonlinear Integrated Design & Analysis*

Analysis Capabilities of NIDA :

- **First-Order Linear Analysis**

- **Second-Order Nonlinear Analysis**

→ *Daily Design (ULS, SLS)*

- **Eigenvalue Buckling Analysis**

→ *Elastic Buckling Load Factor, λ_{cr}*

- **Modal Analysis**

→ *Natural Frequency & Vibration Mode*

- **Response Spectrum Analysis**

- **Time History Analysis**

→ *Seismic Design*

What's NIDA — *Nonlinear Integrated Design & Analysis*

Analysis Capabilities of NIDA :

- **Second-Order Nonlinear Analysis**

**Special &
Professional**

- **Time History Analysis**

*Advanced beam-column elements;
Robust numerical methods;
Meet code requirements;*

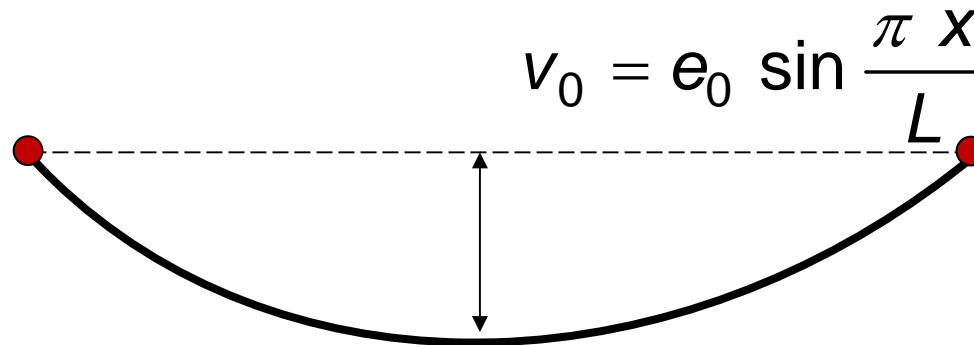
What's NIDA — *Nonlinear Integrated Design & Analysis*

Conventional Straight Element:

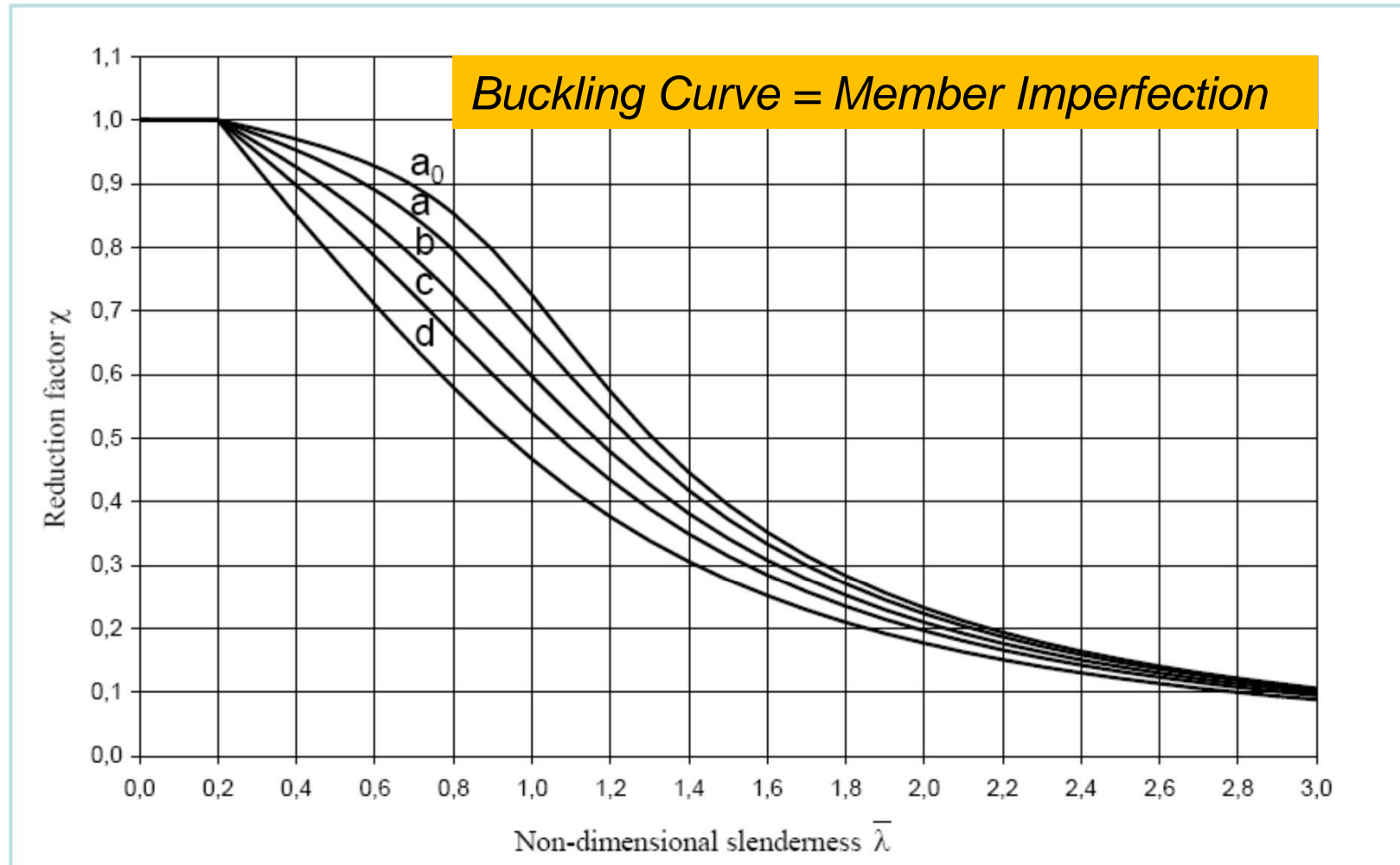


Innovative Curved Element (NIDA):

— One Element per Member



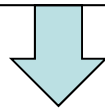
What's NIDA — *Nonlinear Integrated Design & Analysis*



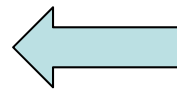
What's NIDA — *Nonlinear Integrated Design & Analysis*

Taking both global frame and local member imperfection into account, only section capacity check is needed.

$$\frac{P}{p_y A} + \frac{(M_y + P\Delta_y + P\delta_y)}{M_{cy}} + \frac{(M_z + P\Delta_z + P\delta_z)}{M_{cz}} = \phi \leq 1$$

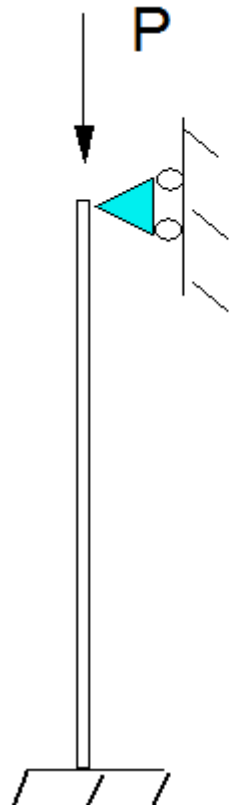


*Global stability;
Member stability;*



~~*Effective Length*~~

What's NIDA — *Nonlinear Integrated Design & Analysis*



Length = 5m

Section: CHS 88.9x3.2

Steel grade: S275

Method	Buckling resistance P_c (kN)	Error
1st order linear with $L_e/L=0.7$	108.9	N.A.
2nd order with imperfection $L/500$ to code	102.2	-6%
2nd order with imperfection $L/1000$ (not to code)	113.4	+4%
No imperfection	$p_y A = 234$	+118%

General Procedures & Settings in NIDA

Second-Order Analysis Procedure:

- Create Model (***Node, Member, Material, Section, Boundary Condition, End Condition, Load Case, Load Combination, ...***), or Import from SAP2000/Etabs/Staad/Strand7/GSA/PKPM or DXF/Revit;
- Check Member Imperfection Associated with Section;
- Create Analysis Cases (ULS & SLS) with Consideration of Frame Imperfection;
- Check Maximum Section Capacity Factors < 1 ;
- Check Building Drift and Member Deflection by Code;
- Export Results & Prepare Design Report

General Procedures & Settings in NIDA

Section

General Members

Name: [B2b]O114.3x5.0 Import ...

Type: 4. CHS[Pipe] Customize...

Material: S355

Section Properties (Analysis)

Cross Sectional Area (A): 1.7200e-003

Shear Area Correction Factor: 0

Second Moment of Area (Iy): 2.5700e-006

Second Moment of Area (Iz): 2.5700e-006

Torsional Constant (J): 5.1400e-006

Section Modulus (Design)

About y-axis (Zy): 4.5000e-005 Use Elastic(Z)

About z-axis (Zz): 4.5000e-005 Use Plastic(S)

About y-axis (Sy): 5.9800e-005

About z-axis (Sz): 5.9800e-005

Dimensions

B: 0.1143

D: 0

Tf: 0.005

tw: 0

B2: 0

Tf2: 0

ds: 0

Recalculate

☒ Rolled Section ☐ Fabricated Section ☐ Cold-formed

Suppress Frame Eigen-Imperfection: ☐ Yes ☒ No

Imperfection along Minor y-axis: L/500 Elastic Plastic

along Major z-axis: L/500

Stress Type: Square-root of Stress Advanced ...

OK Cancel Apply

Member
Imperfection

General Procedures & Settings in NIDA

[ULS01]1.4(DL+WX1)

Second-Order Analysis | Applied Loads | Construction Sequence

Name: [ULS01]1.4(DL+WX1)

Type: Second-order Analysis + Design

☒ PEP Element ☐ Curved Stability Function

☐ Enable Plastic Advanced Analysis ☐ Plastic Element ☒ Plastic Hinge

Total Load Cycles : 1

☒ Target Load Factor : 1.000

Maximum Iterations for each Load Cycle : 100

Number of Iterations for Tangent Stiffness Matrix : 1

Numerical Method

☒ Newton-Raphson (Constant Load) Method

☐ Single Displacement Control (Constant Disp.) Method

☐ Arc Length Method + Minimum Residual Displacement Method

Iterative & Incremental Parameters :

Incremental Load Factor : 1

Minimum Member Imperfection * L / 1000 : 1

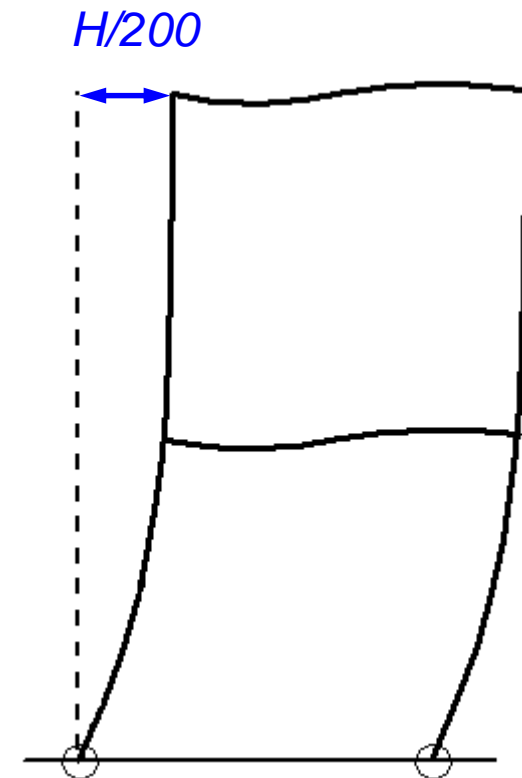
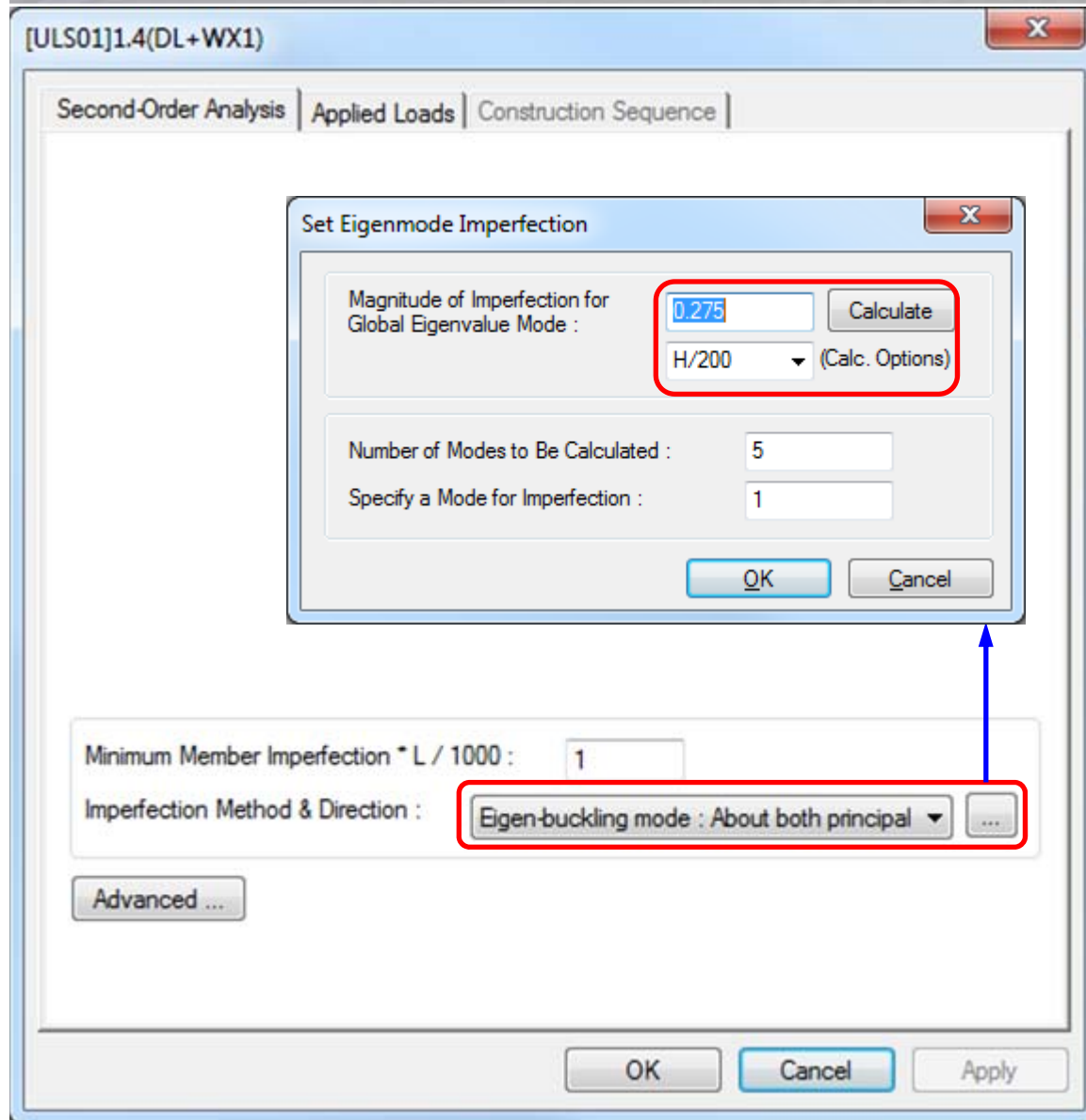
Imperfection Method & Direction : Eigen-buckling mode : About both principal

Advanced ...

OK Cancel Apply

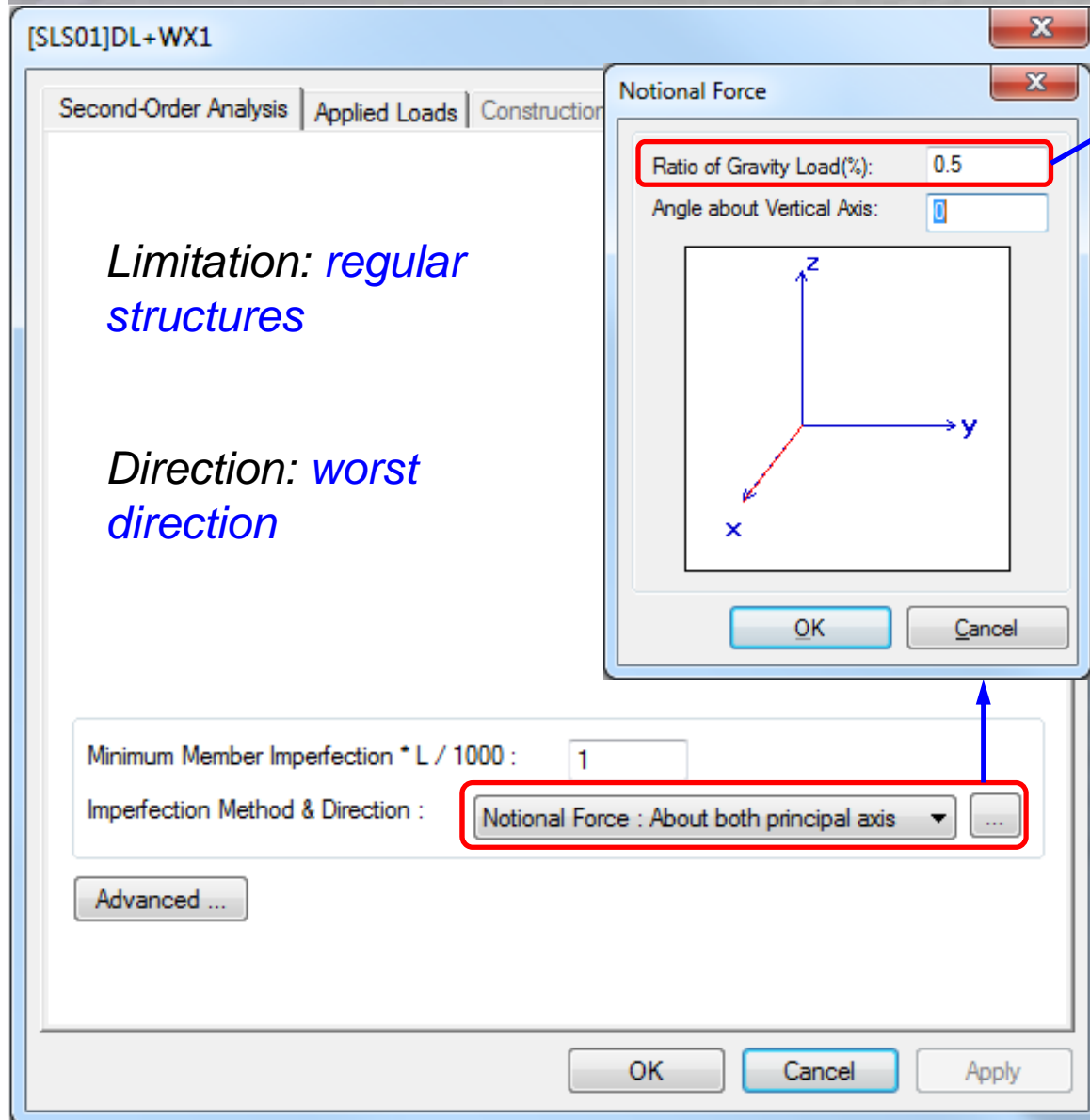
- To determine global imperfection (shape, magnitude);
- To determine the direction of member imperfection.

General Procedures & Settings in NIDA

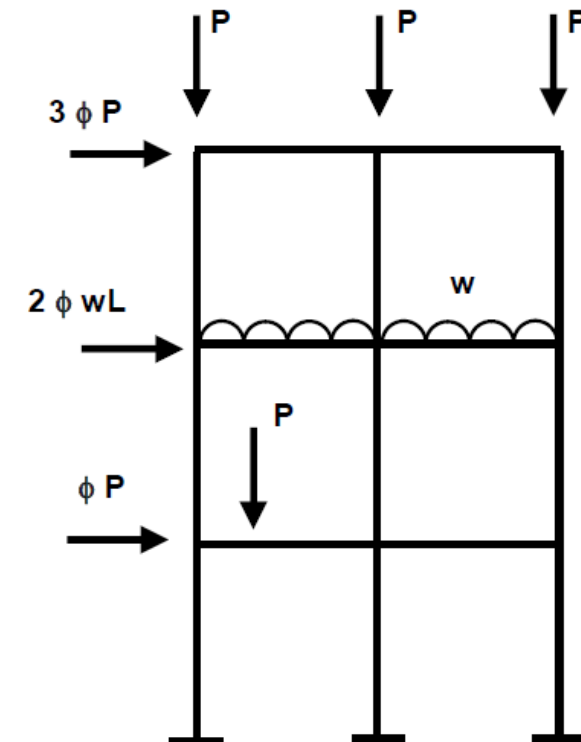


Global Imperfection
(Geometry Approach)

General Procedures & Settings in NIDA



$$\phi = 0.5\%$$



**Global Imperfection
(Notional Force Approach)**

Most Frequently Asked Questions

Q1: About Elastic Buckling Load Factor **– Why λ_{cr} is very small ?**

- Local member buckling (*large axial force, high slenderness ratio*);
- End releases (*moment release with torsional release*);
- Inconsistent unit system ("*N,mm*" – *MPa / kPa*);

Most Frequently Asked Questions

Q1: About Elastic Buckling Load Factor

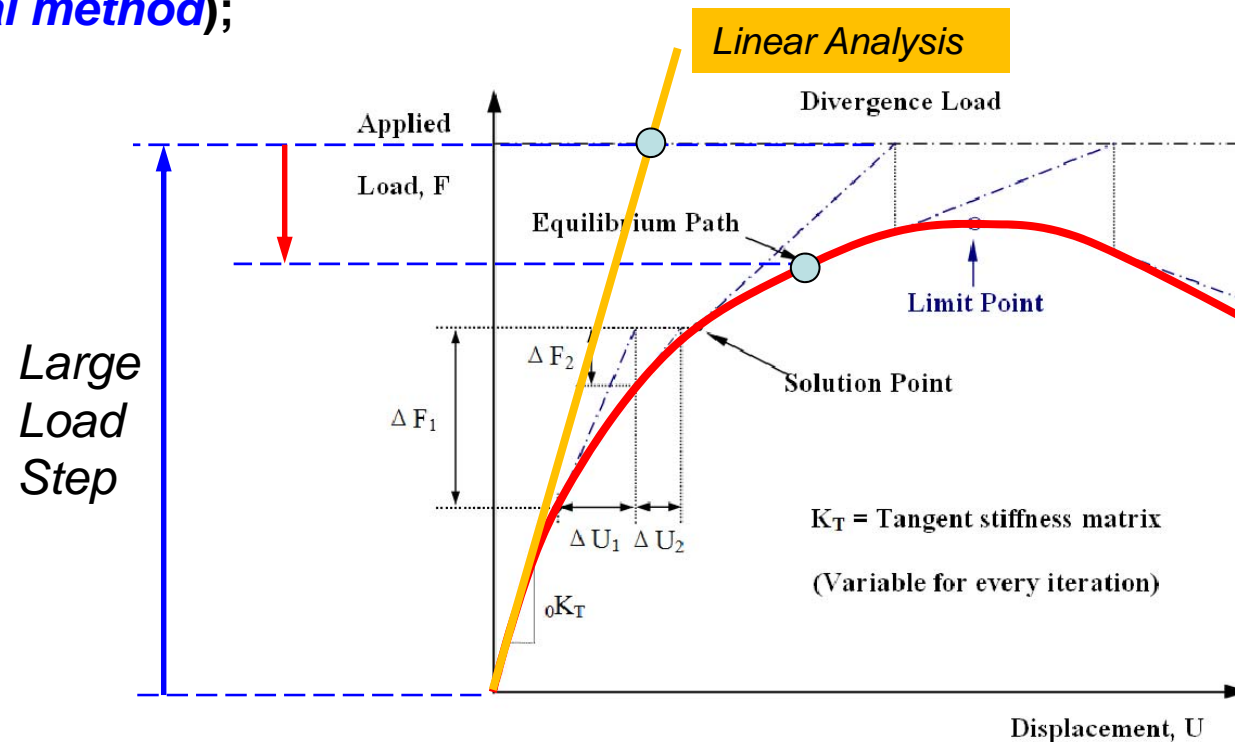
– Why λ_{cr} is different from other software ?

- Generally the difference of λ_{cr} from different software is very small due to same linear theory background;
- Improperly consider end releases in many software;

Most Frequently Asked Questions

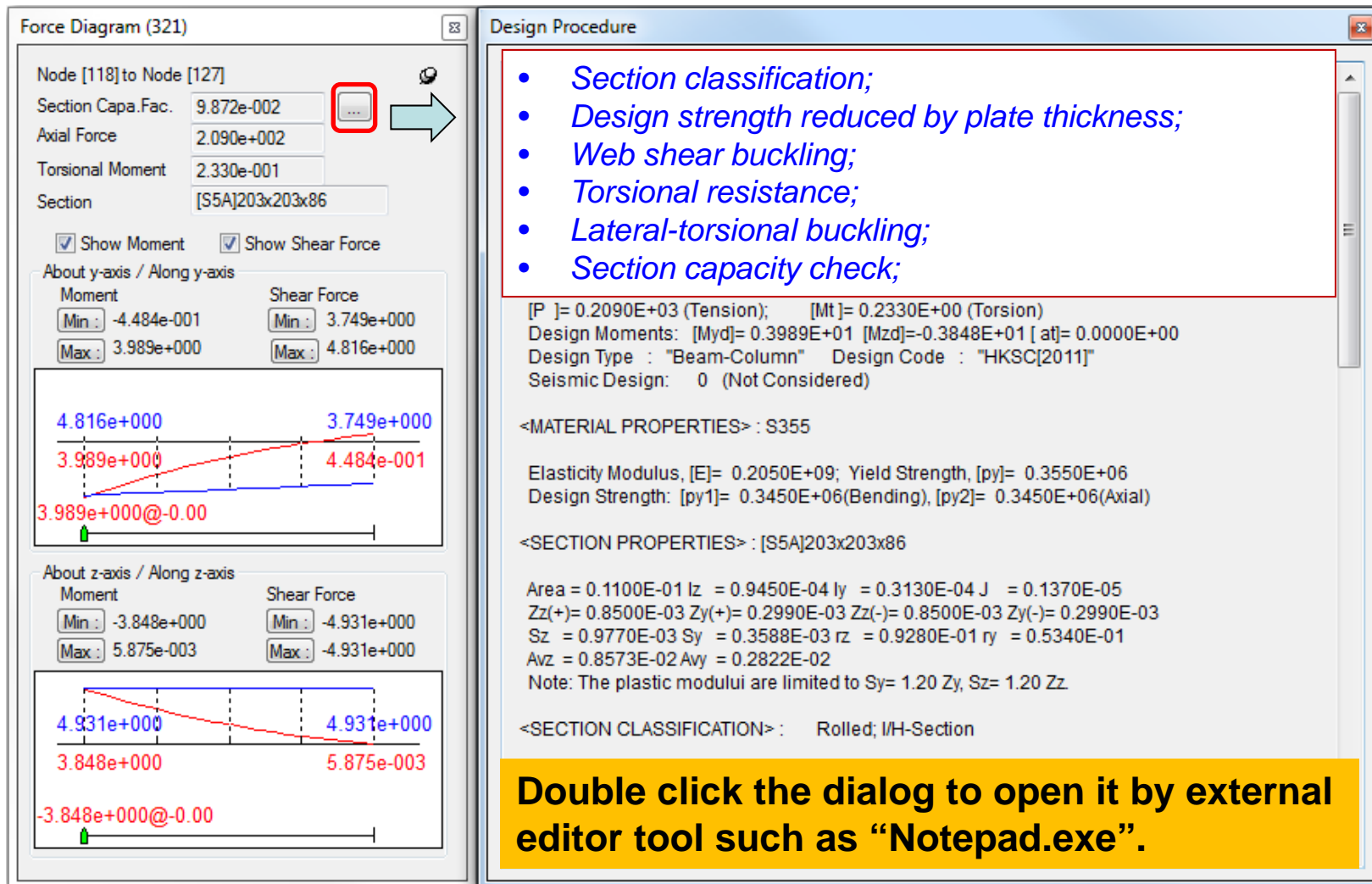
Q2: Why second-order analysis diverges ?

- Load increment is too large (*reduce load size, check deflection and strengthen the location with large deflection, change numerical method*);



New Features

1. Design procedure for every member



Force Diagram (321)

Node [118] to Node [127]

Section Capa.Fac. 9.872e-002

Axial Force 2.090e+002

Torsional Moment 2.330e-001

Section [S5A]203x203x86

☒ Show Moment ☒ Show Shear Force

About y-axis / Along y-axis

Moment

Min: -4.484e-001 Max: 3.989e+000

Shear Force

Min: 3.749e+000 Max: 4.816e+000

About z-axis / Along z-axis

Moment

Min: -3.848e+000 Max: 5.875e-003

Shear Force

Min: -4.931e+000 Max: -4.931e+000

Design Procedure

- Section classification;
- Design strength reduced by plate thickness;
- Web shear buckling;
- Torsional resistance;
- Lateral-torsional buckling;
- Section capacity check;

[P] = 0.2090E+03 (Tension); [Mt] = 0.2330E+00 (Torsion)
Design Moments: [Myd] = 0.3989E+01 [Mzd] = -0.3848E+01 [at] = 0.0000E+00
Design Type : "Beam-Column" Design Code : "HKSC[2011]"
Seismic Design: 0 (Not Considered)

<MATERIAL PROPERTIES> : S355

Elasticity Modulus, [E] = 0.2050E+09; Yield Strength, [py] = 0.3550E+06
Design Strength: [py1] = 0.3450E+06 (Bending), [py2] = 0.3450E+06 (Axial)

<SECTION PROPERTIES> : [S5A]203x203x86

Area = 0.1100E-01 Iz = 0.9450E-04 Iy = 0.3130E-04 J = 0.1370E-05
Zz(+) = 0.8500E-03 Zy(+) = 0.2990E-03 Zz(-) = 0.8500E-03 Zy(-) = 0.2990E-03
Sz = 0.9770E-03 Sy = 0.3588E-03 rz = 0.9280E-01 ry = 0.5340E-01
Avz = 0.8573E-02 Avy = 0.2822E-02
Note: The plastic moduli are limited to Sy = 1.20 Zy, Sz = 1.20 Zz.

<SECTION CLASSIFICATION> : Rolled; I/H-Section

Double click the dialog to open it by external editor tool such as "Notepad.exe".

New Features

2. Imperfection of Combined Member – An individual member



*A member divided
into 4 elements*



*Imperfection for
each element*



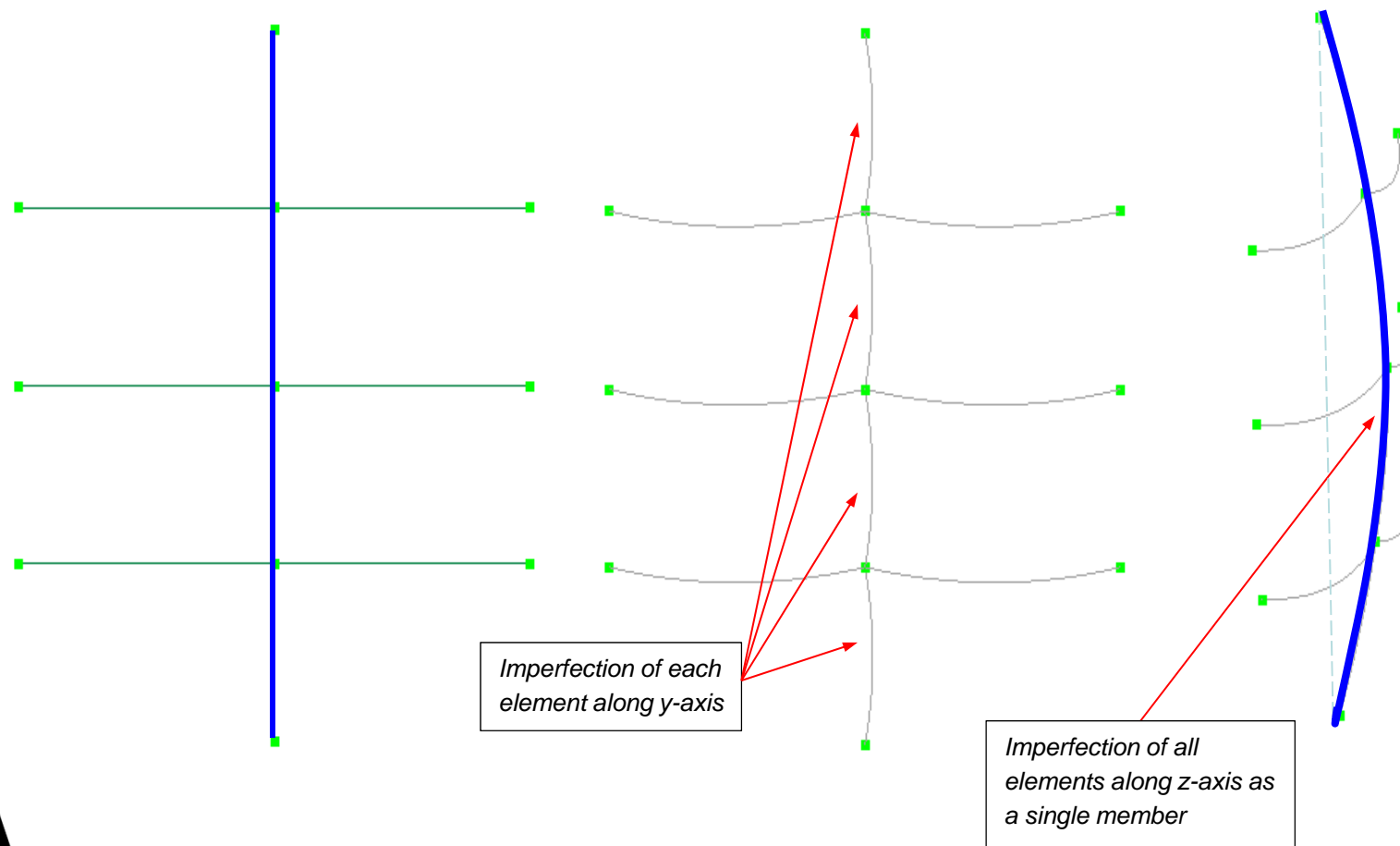
*Imperfection for
combined member*

New

New Features

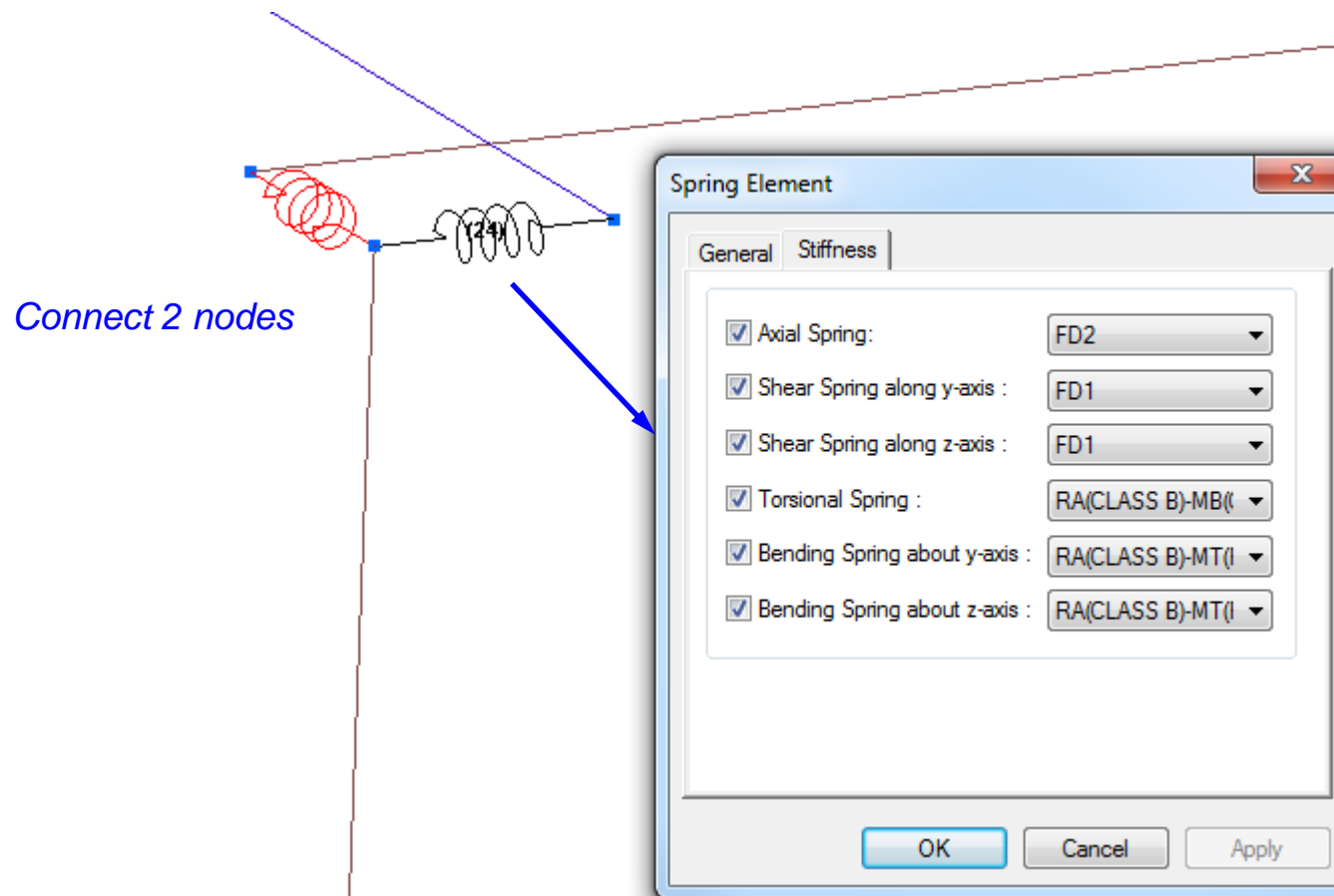
2. Imperfection of Combined Member (Cont'd)

- A member with intermediate members



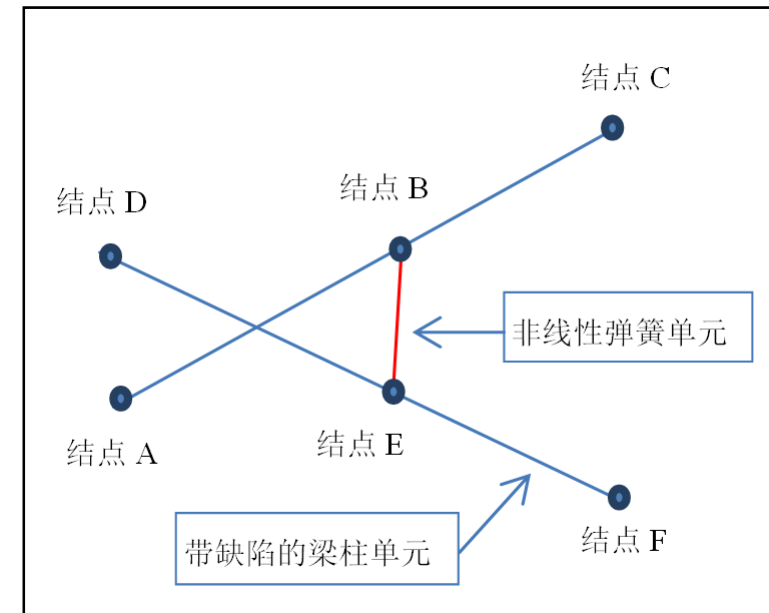
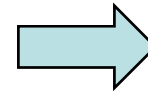
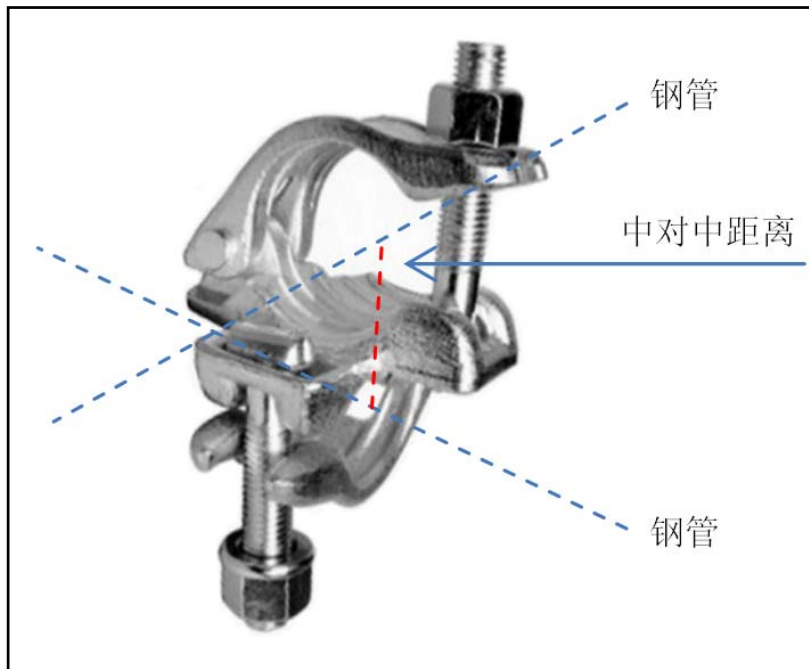
New Features

3. Nonlinear Spring Element



New Features

3. Nonlinear Spring Element (Cont'd)



To model right-angle couplers of scaffold system (**Application**)



New Features

- 4. Nonlinear Support Spring***
- 5. Node Local Axes***
- 6. More steel design codes***
- 7. More response spectrum functions***
- 8. More functions of time history analysis***
- 9. Many improvements ...***

More NIDA Products

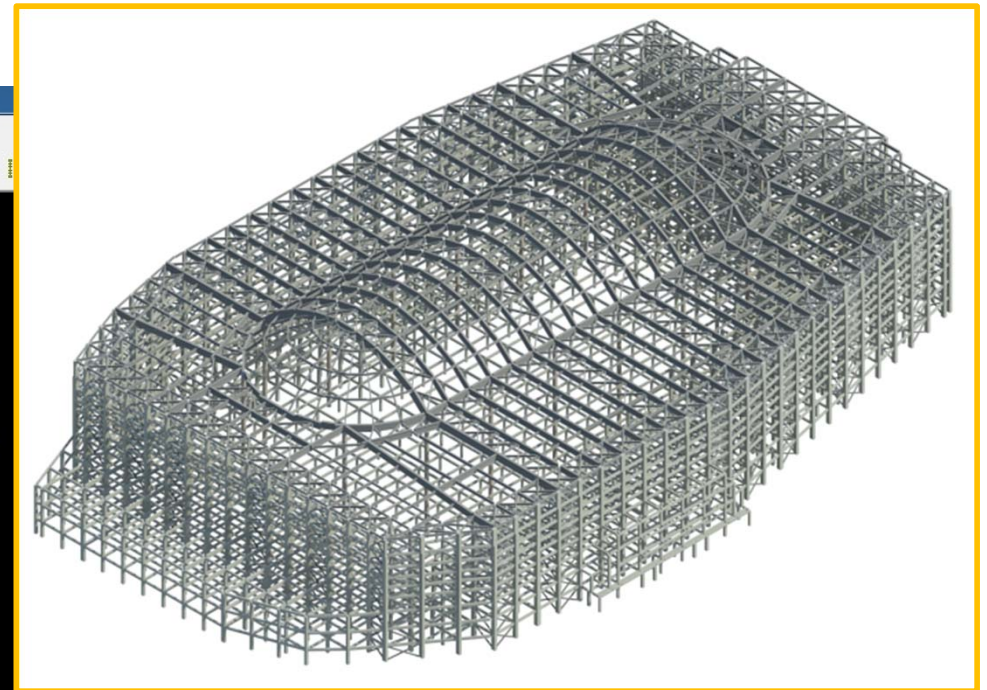
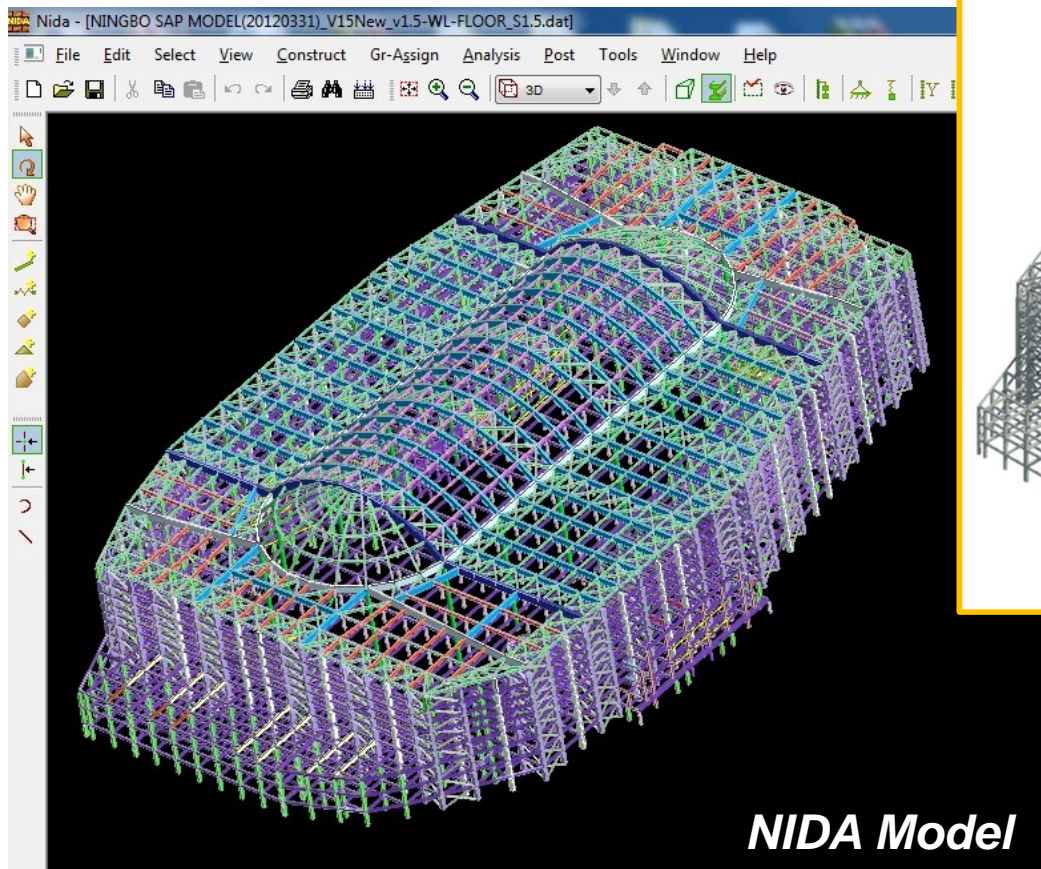
I. Nida x Revit 2012 – [Link to BIM](#)



- **Export from Revit to create a new NIDA model;**
- **Import from NIDA to create a new Revit model;**
- **Export from Revit to update an existing NIDA model;**
- **Export from NIDA to update an existing Revit model;**

More NIDA Products

I. Nida x Revit 2012 – [Link to BIM](#) (Cont'd)

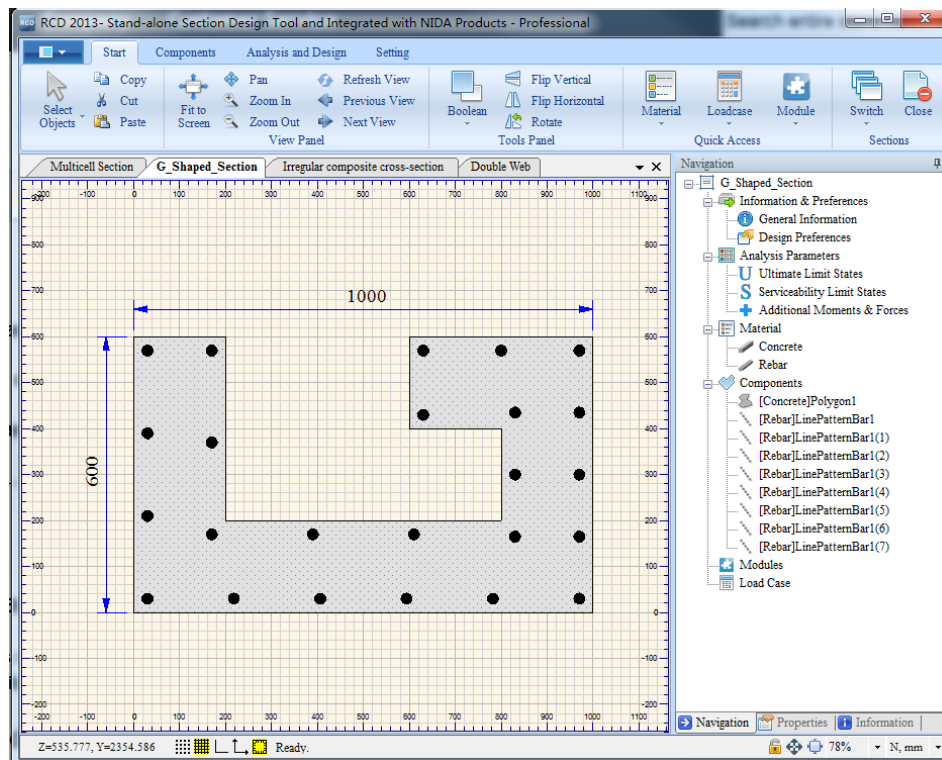


Revit Model

More NIDA Products

II. RCD 2013 — RC & Composite Section Design

RCD 2013 is advanced and technology-leading cross-section analysis and design software, a product of NIDA family.



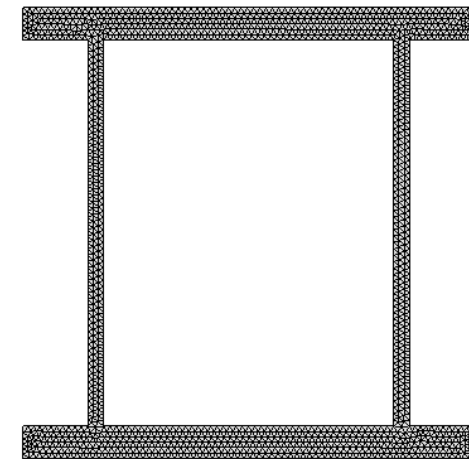
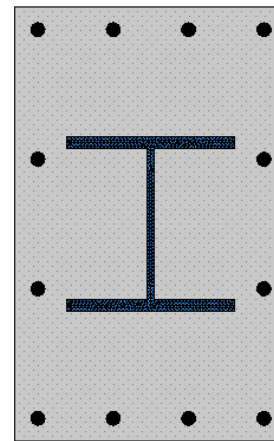
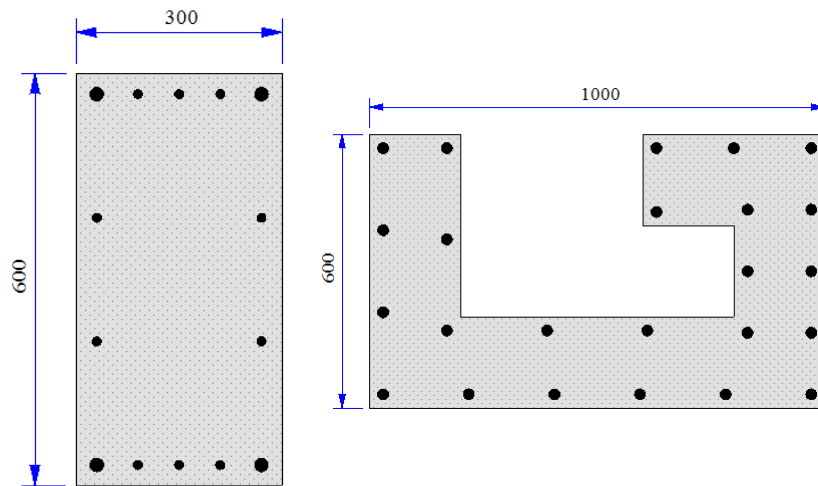
Updates from RCD 2009:

- *New User Interface (Ribbon);*
- *Multi-Documents Supported;*
- *Composite Sections Supported;*
- *Many Improvements ...*

More NIDA Products

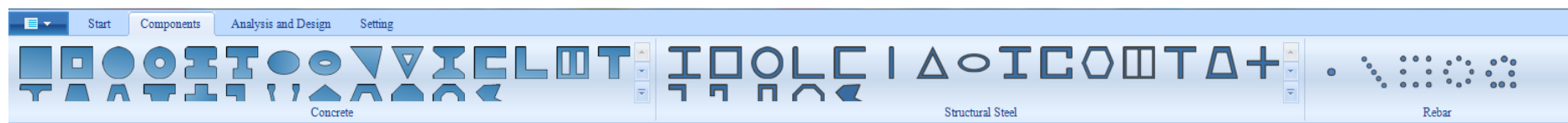
Features of RCD 2013

- Capable for analysis of *arbitrary composite*, *RC* and *built-up* steel sections; more faster & powerful



Automatically mesh into fibers

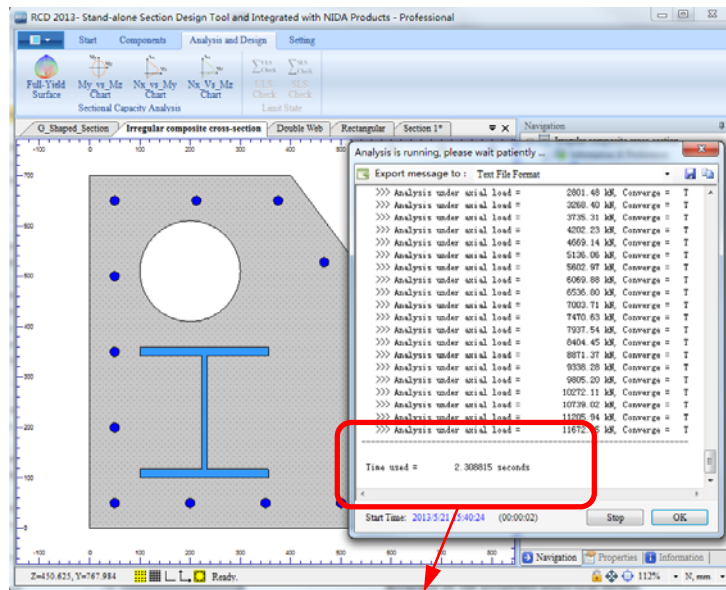
Over 50 common shapes for direct use!



More NIDA Products

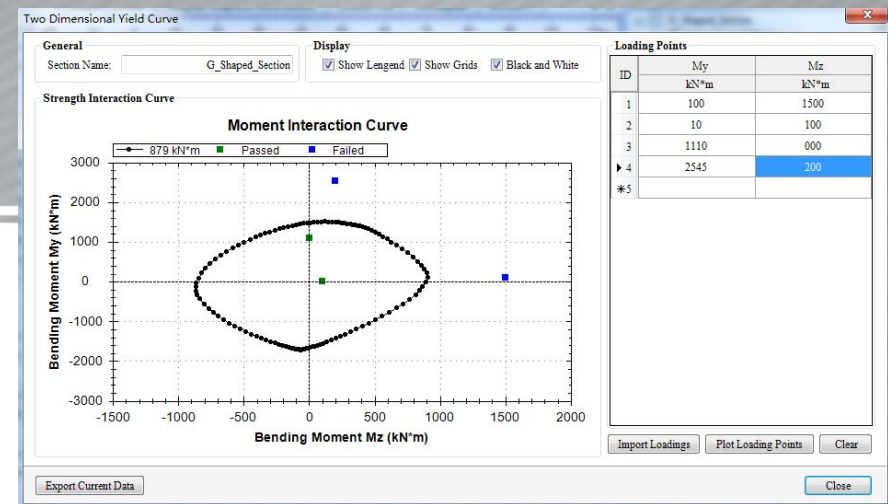
Features of RCD 2013

➤ New core-engine and results viewer

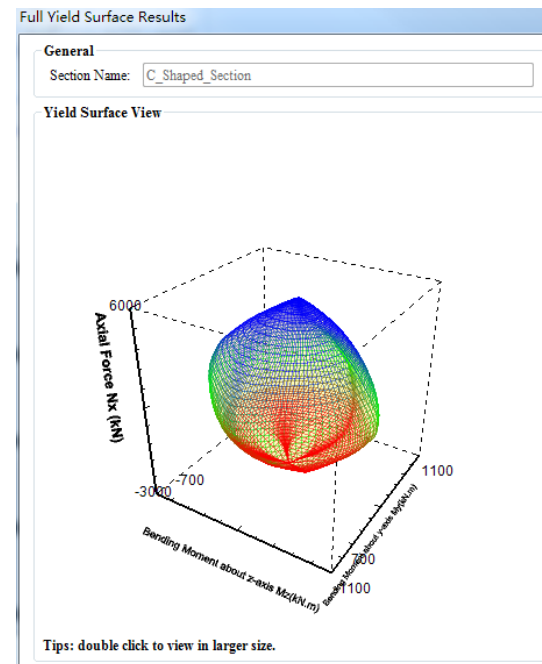


Time used = 2.308815 seconds

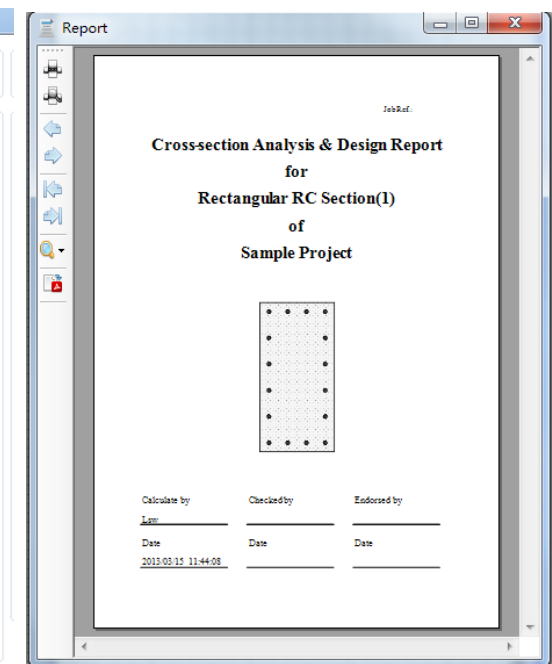
Only 2.3s for this section!



Two dimensional curve



3D View for Yield Surface



Output PDF Report

More NIDA Products

III. NIDA-MNN (Special version for **M**oving **N**ode **N**et)

- Large deflection analysis of net made of polygonal and line elements with internal nodes moving along their sides

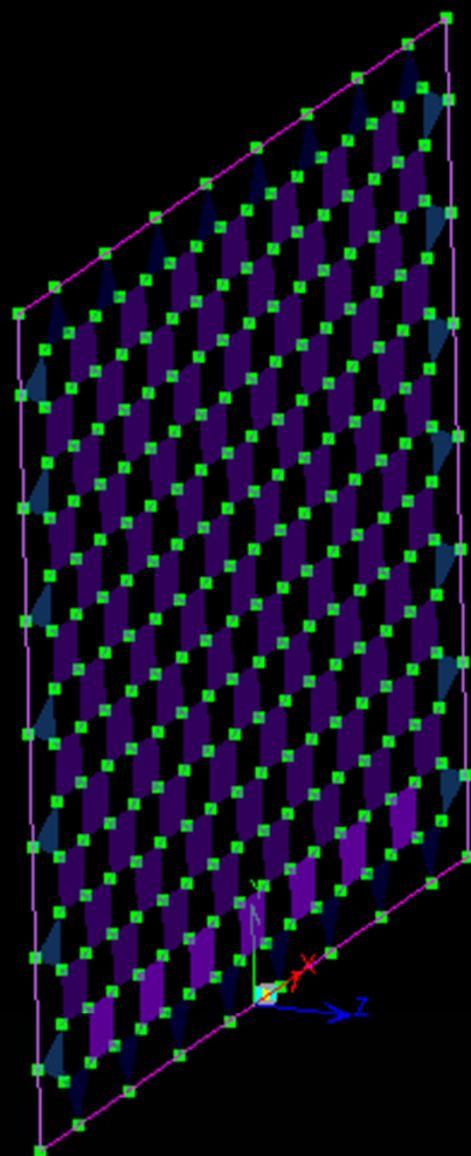


Flexible Barriers:

widely used as protection systems against natural hazards, such as rockfalls, landslides and debris flows.

Project: Rock fall slide NoEdge

Unit: kN, mm

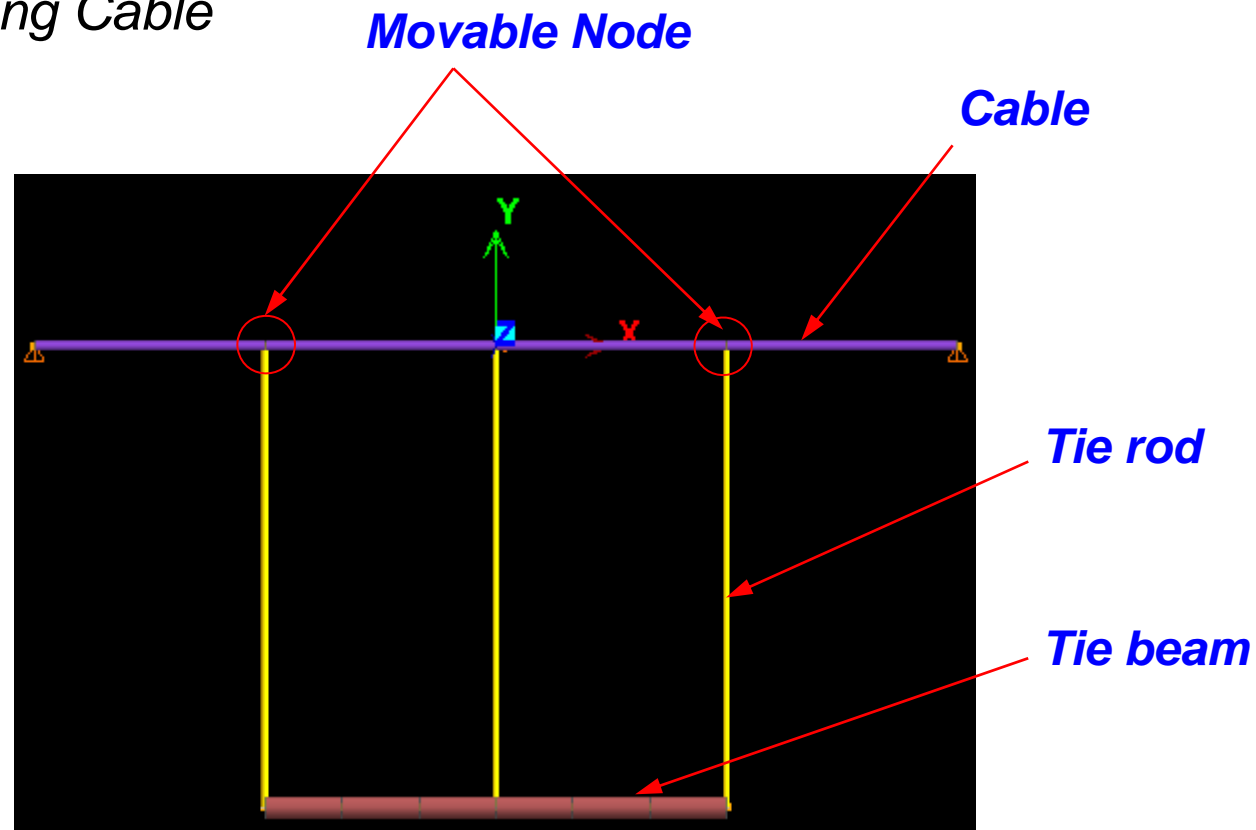


Undeformed

More NIDA Products

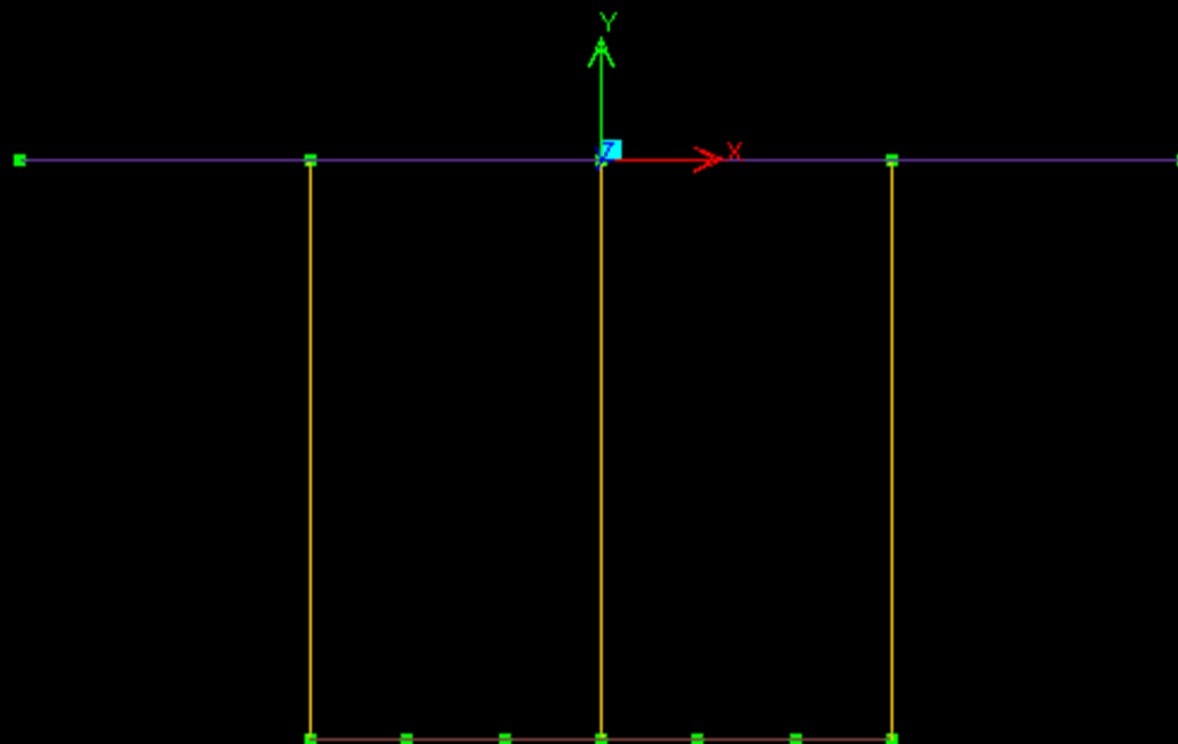
III. NIDA-MNN (Cont'd)

Model – Sliding Cable



Project: 2Csuspend

Unit: kN, mm

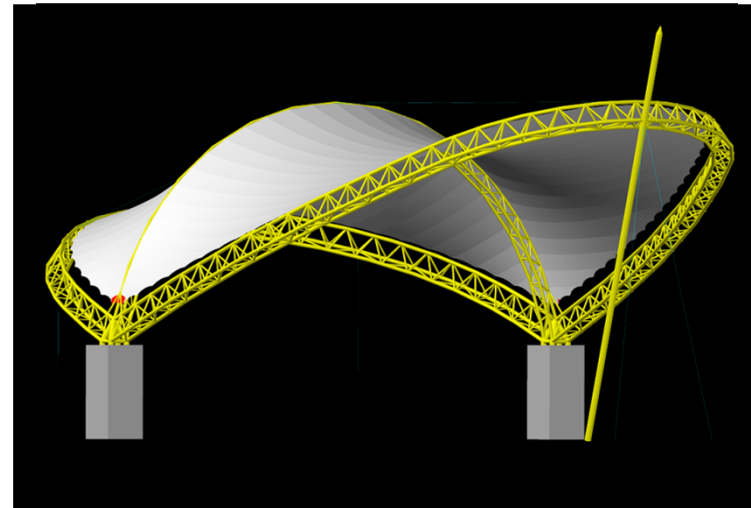


Undeformed

More NIDA Products

IV. NIDA-TMS (Special version)

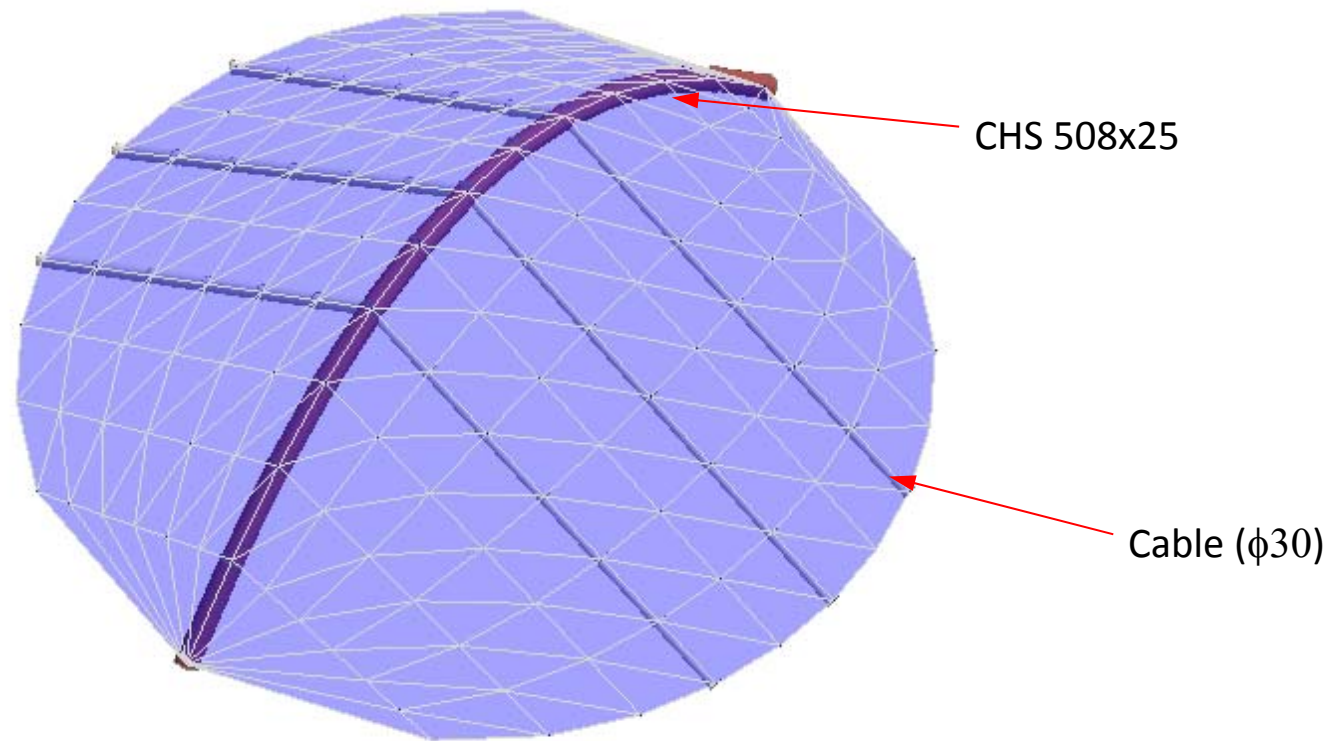
— Large deflection analysis of Tensioned Membrane Structure



*Amphitheatre in Hong Kong
Science Park Phase 2*

More NIDA Products

IV. NIDA-TMS (Cont'd)





感谢您的关注

Thank you

[http:// www.nidacse.com](http://www.nidacse.com)