NIDA Since 1996
Nonlinear Integrated Design and Analysis

Department of Civil & Environmental Engineering
The Hong Kong Polytechnic University

香港
鋼結構學會
Hong Kong Institute of
Steel Construction

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

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24 May 2013

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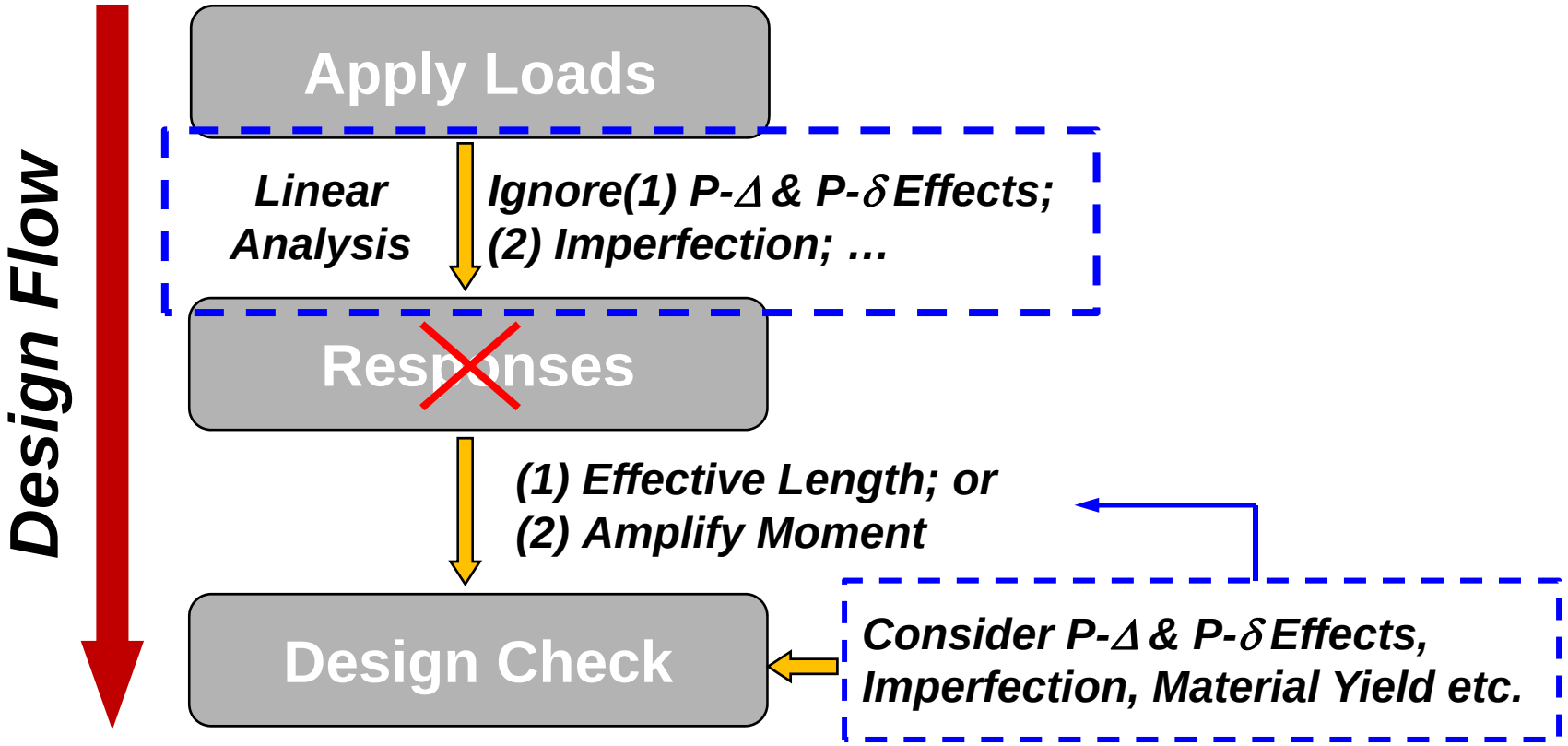
NiDA

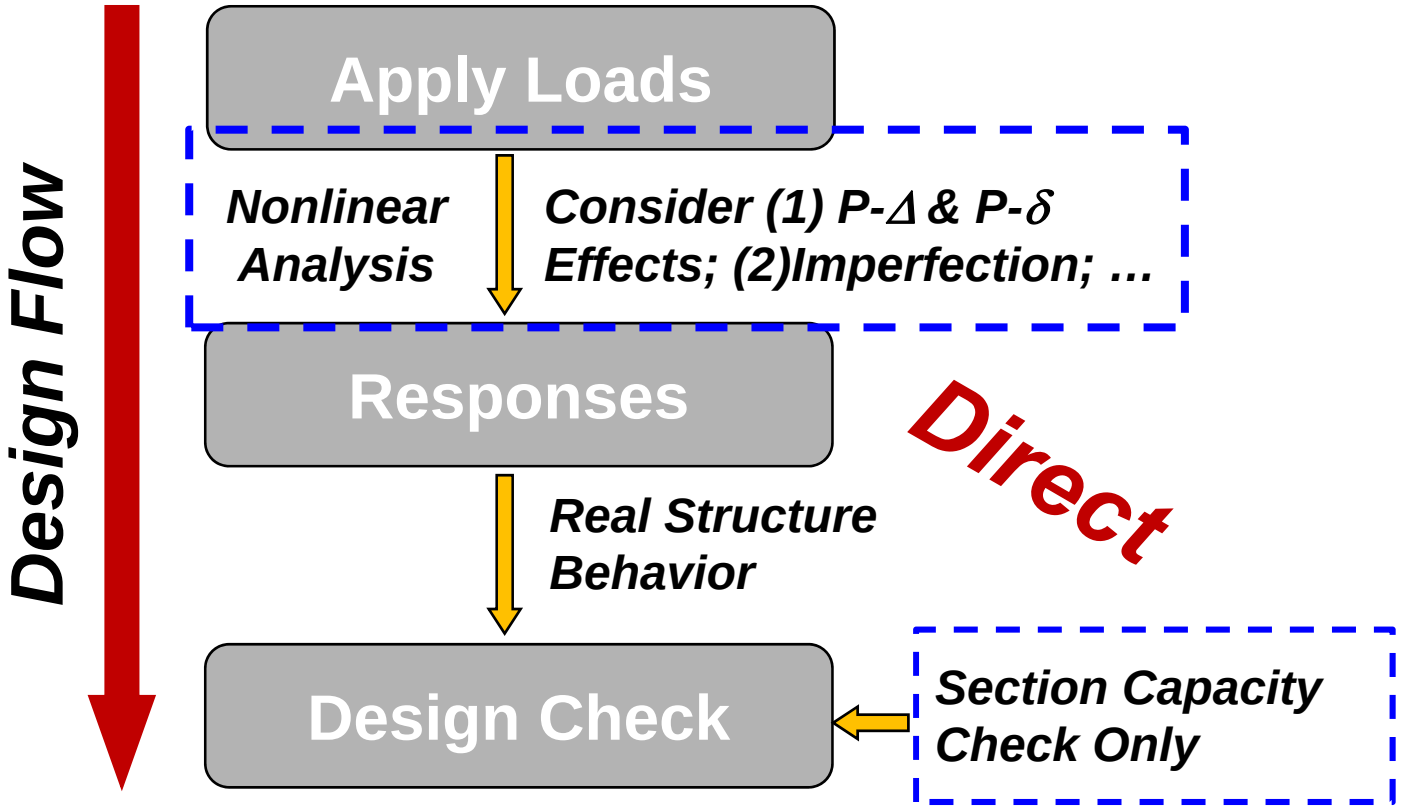
Second-Order Analysis vs. First-Order Analysis

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



Second-Order Analysis vs. First-Order Analysis

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



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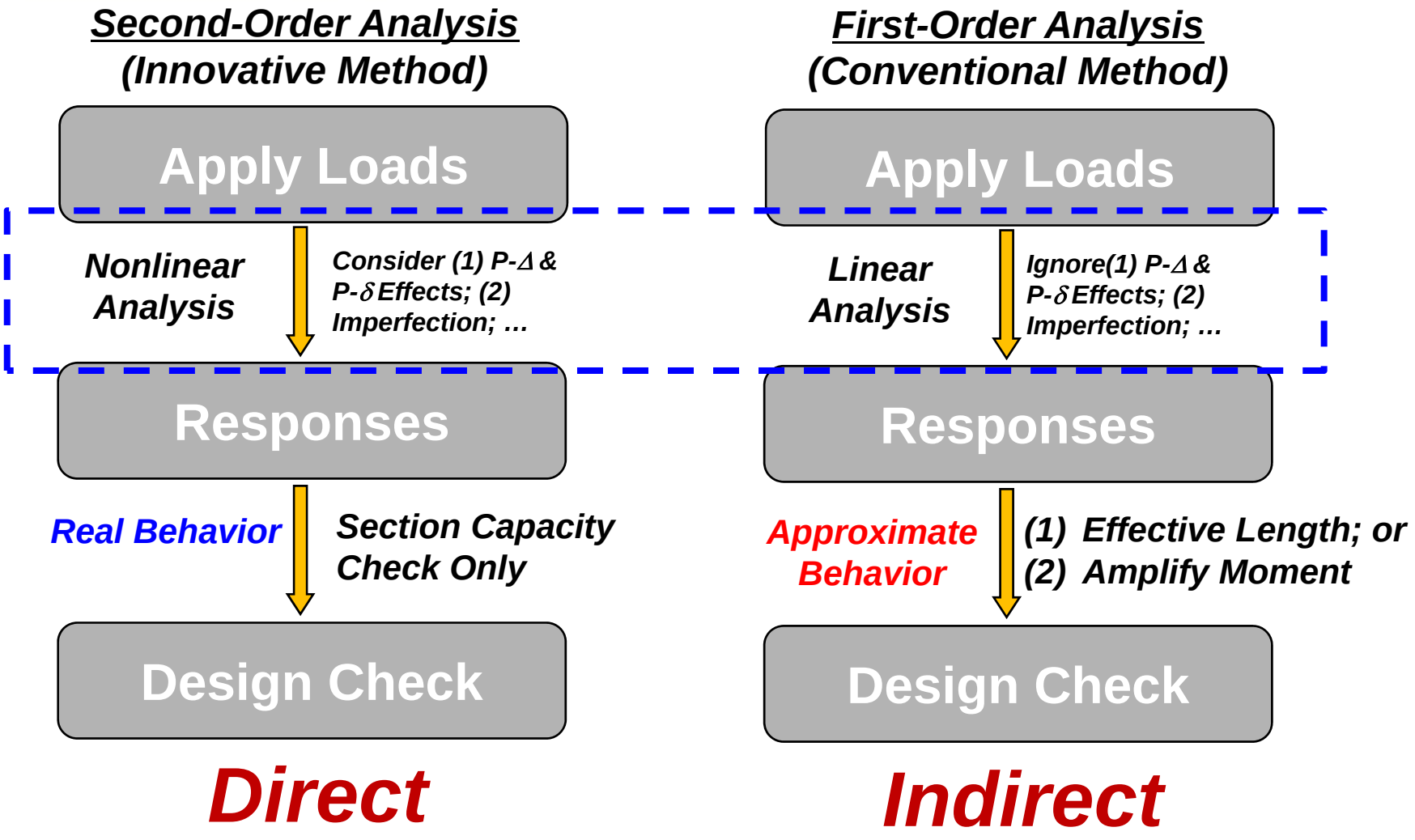
Second-Order Analysis vs. First-Order Analysis



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*);**

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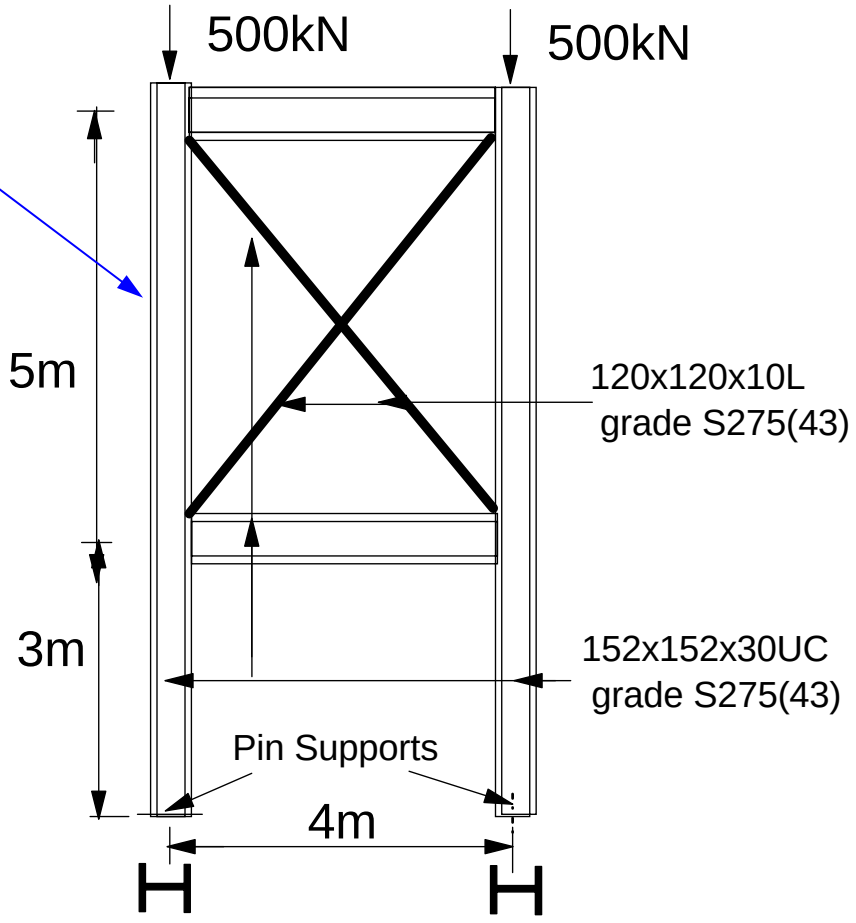
Second-Order Analysis vs. First-Order Analysis

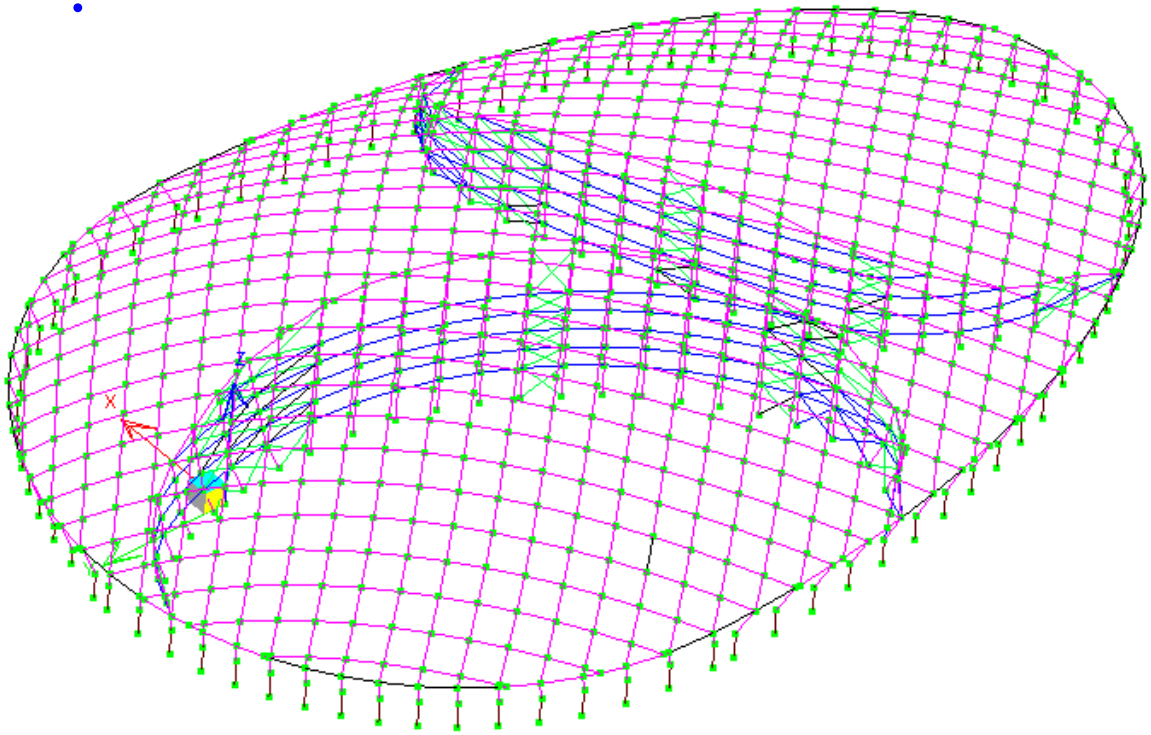
Effective Length = ?



Second-Order Analysis vs. First-Order Analysis

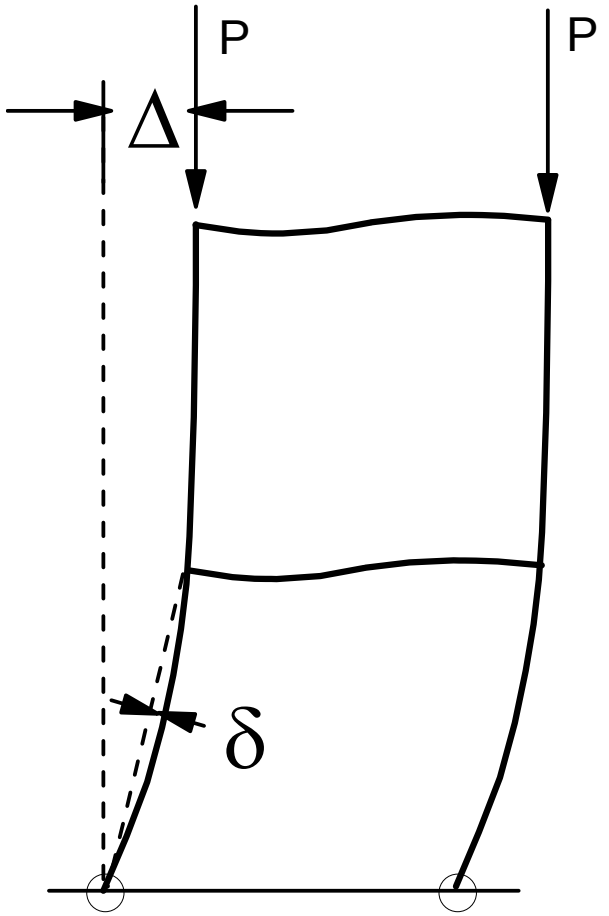
When under snow loads, snap-through buckling may take place.

Effective Length = ?



Major Concerns of Direct Analysis

- ***P-Δ Effect (****frame sidesway****)***
- ***P-δ Effect (****member curvature****)***
- ***Imperfection (****P-Δ_0 & P-δ_0 ****)***



The P-Δ and P-δ Effects

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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)

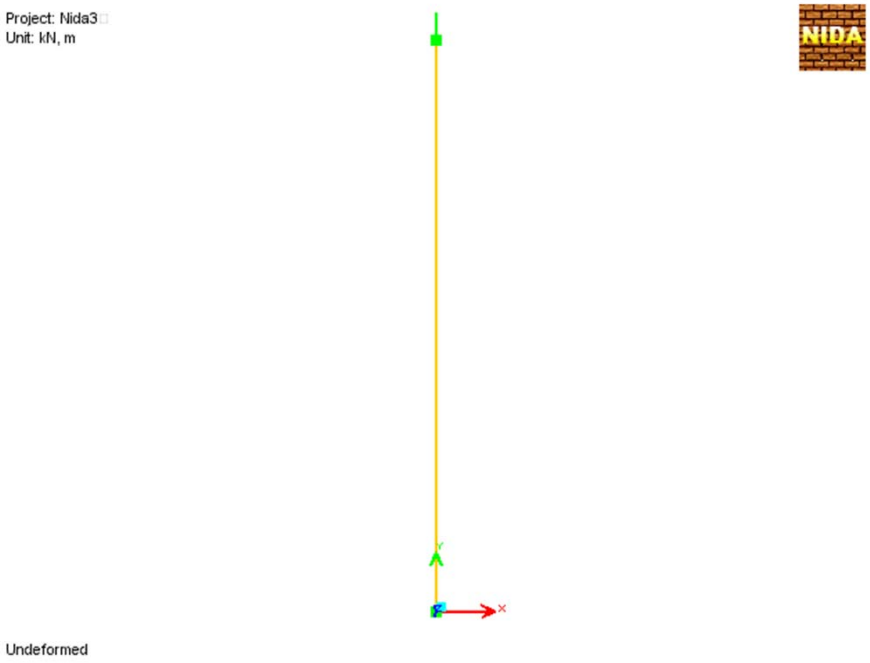
(2) ***Member Imperfection*** *(out-of-straightness, residual stresses)*

a) Perry-Robertson formulae (Linear analysis only)

b) Initial member bowing (e.g. L/500)

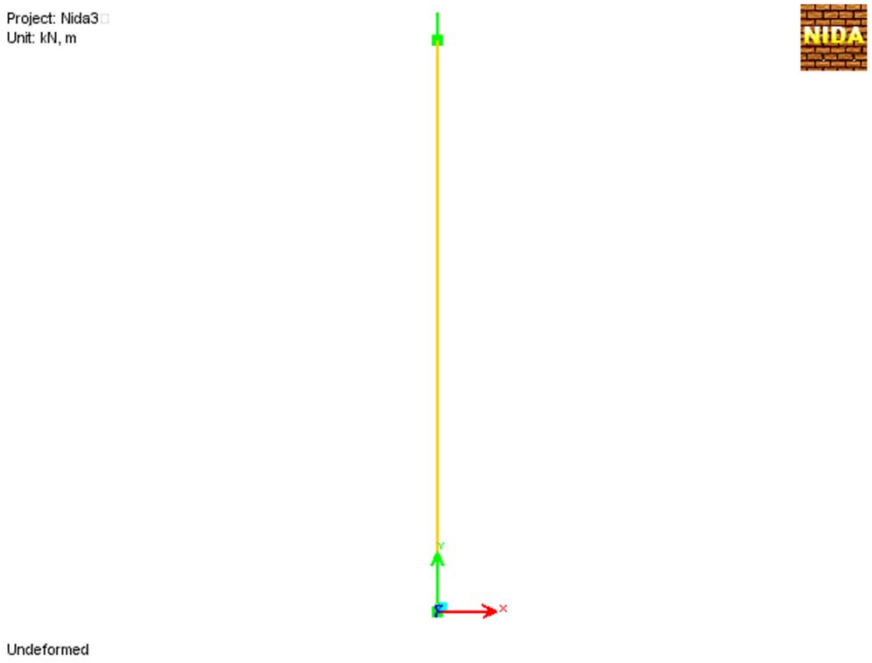
Second-Order Analysis vs. First-Order Analysis

Without Imperfection



Axial Shortening

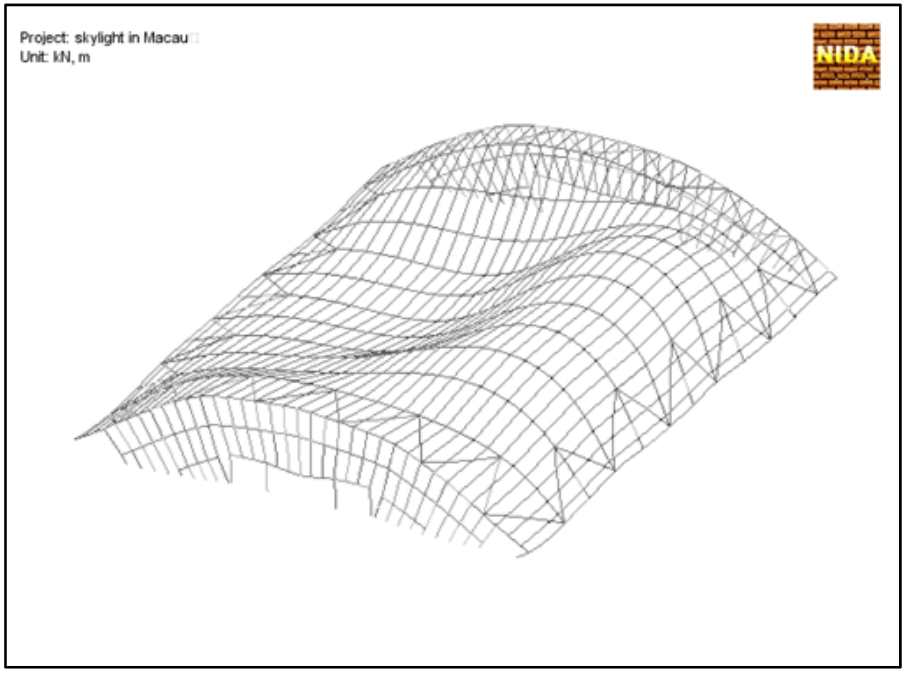
With Imperfection



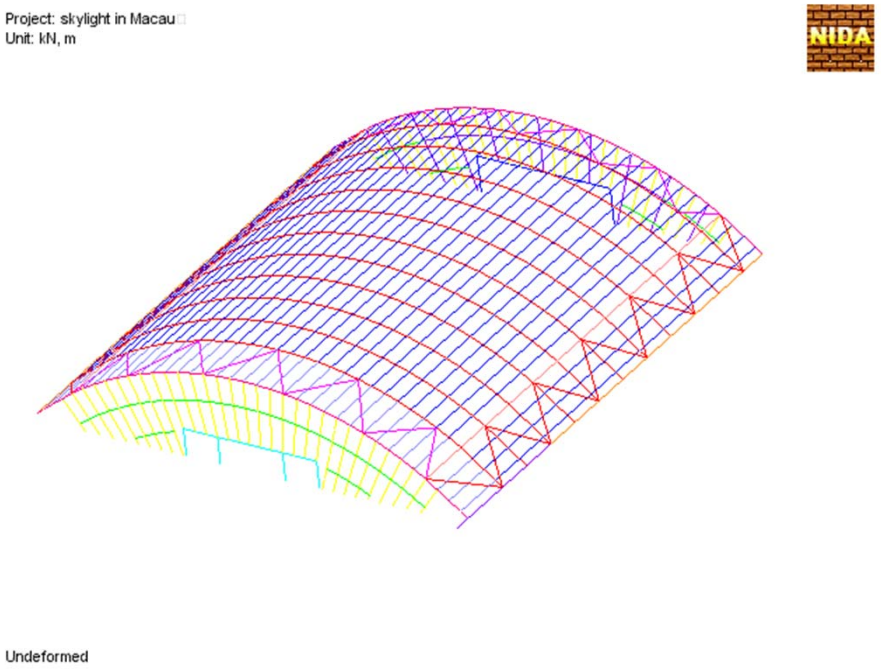
Axial Shortening + Bending

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.*

Analysis Capabilities of NIDA :

- **First-Order Linear Analysis**
- **Second-Order Nonlinear Analysis**

→ *Daily Design (ULS, SLS)*

- **Eigenvalue Buckling Analysis**

→ *Elastic Buckling Load Factor, λcr*

- **Modal Analysis**

→ *Natural Frequency & Vibration Mode*

- **Response Spectrum Analysis**
- **Time History Analysis**

→ *Seismic Design*

Analysis Capabilities of NIDA :

- **Second-Order Nonlinear Analysis**

Special & Professional

- **Time History Analysis**

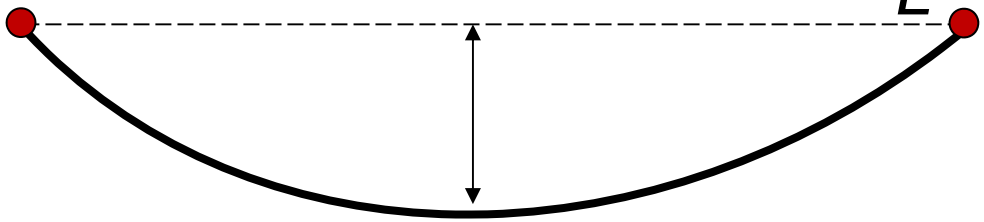
Advanced beam-column elements;
Robust numerical methods;
Meet code requirements;

Conventional Straight Element:

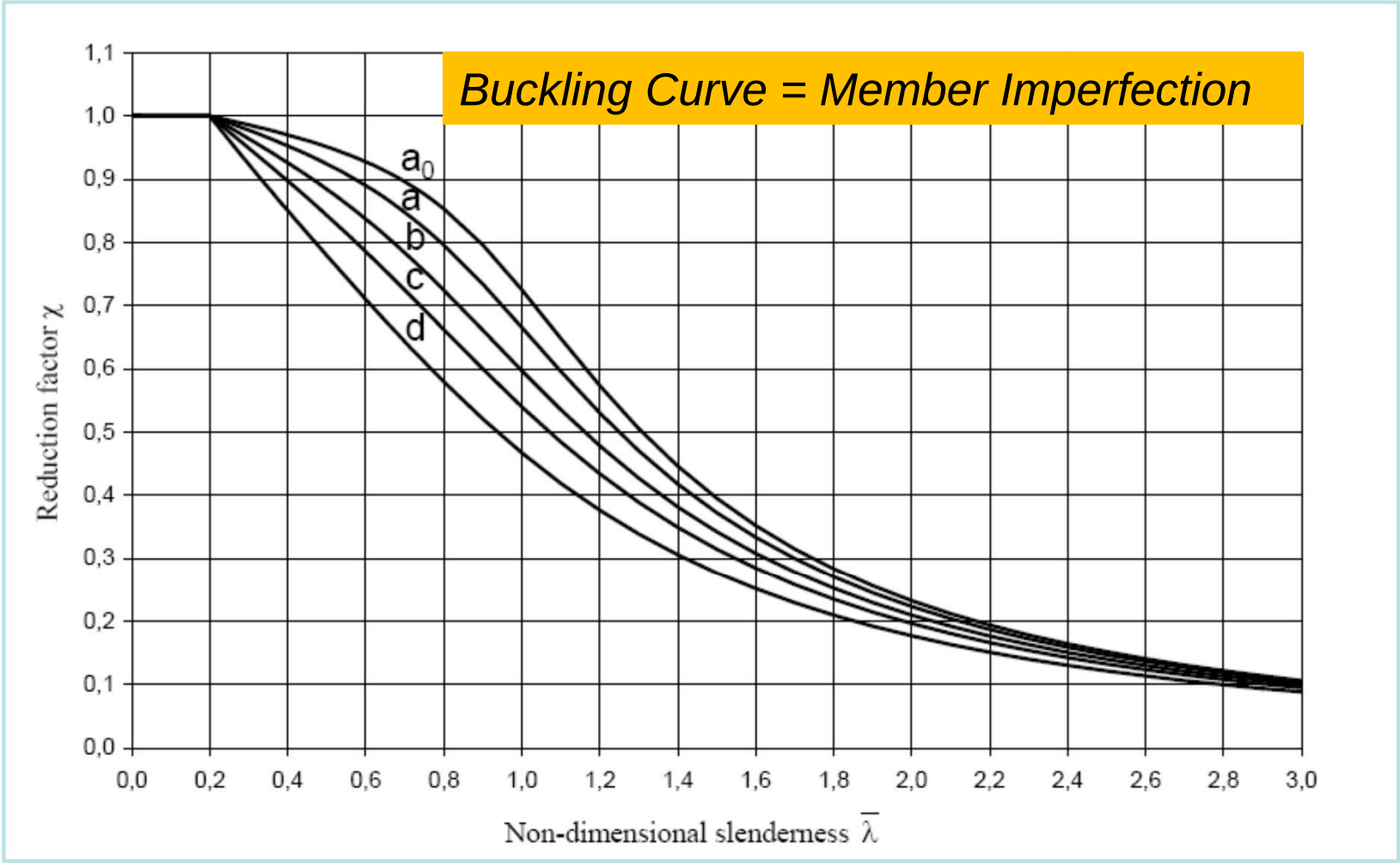
Innovative Curved Element (NIDA):

– One Element per Member

$$v_0 = e_0 \sin \frac{\pi x}{L}$$



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



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

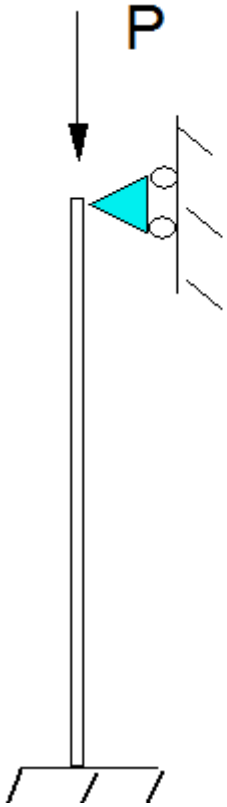
Taking both global frame and local member imperfection into account, only section capacity check is needed.

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

Global stability;
Member stability;

Effective Length

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



Length = 5m

Section: CHS 88.9x3.2

Steel grade: S275

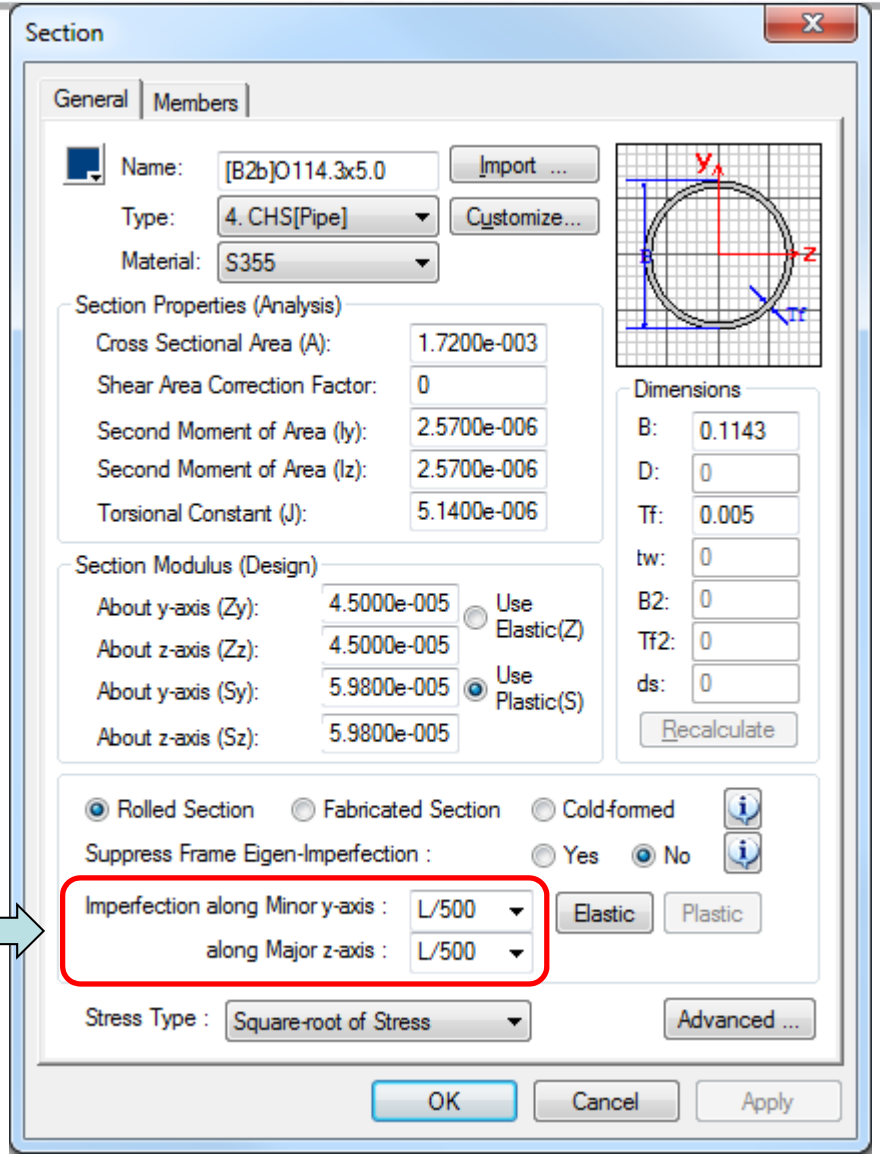
Method	Buckling resistance Pc (kN)	Error
1st order linear with L_e/L=0.7	108.9	N.A.
2nd order with imperfection L/500 to code	102.2	-6%
2nd order with imperfection L/1000 (not to code)	113.4	+4%
No imperfection	pyA = 234	+118%

Second-Order Analysis Procedure:

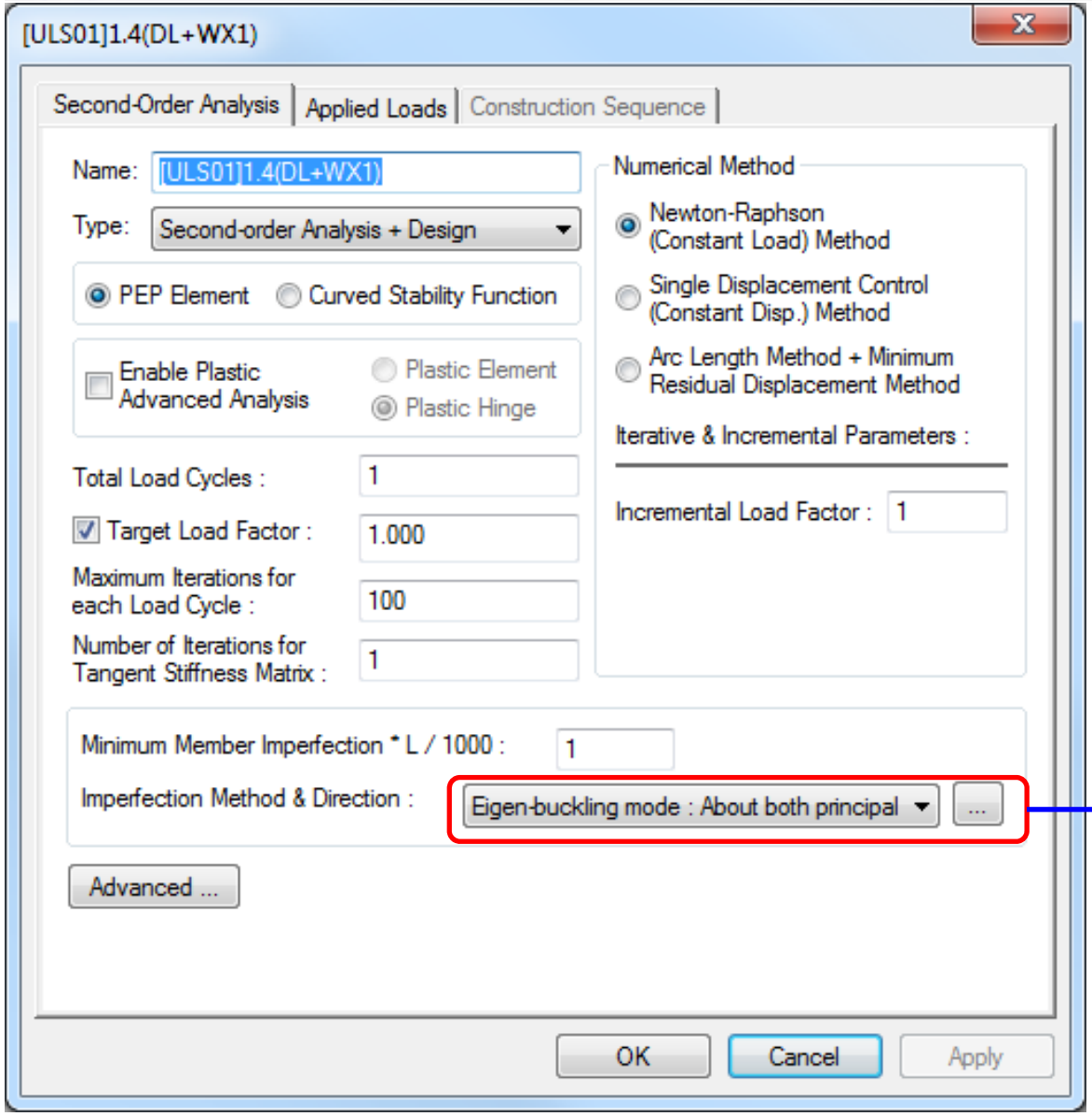
- **Create Model (*Node, Member, Material, Section, Boundary Condition, End Condition, Load Case, Load Combination, …*), or Import from SAP2000/Etabs/Staad/Strand7/GSA/PKPM or DXF/Revit;**
- **Check Member Imperfection Associated with Section;**
- **Create Analysis Cases (ULS & SLS) with Consideration 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

Member Imperfection

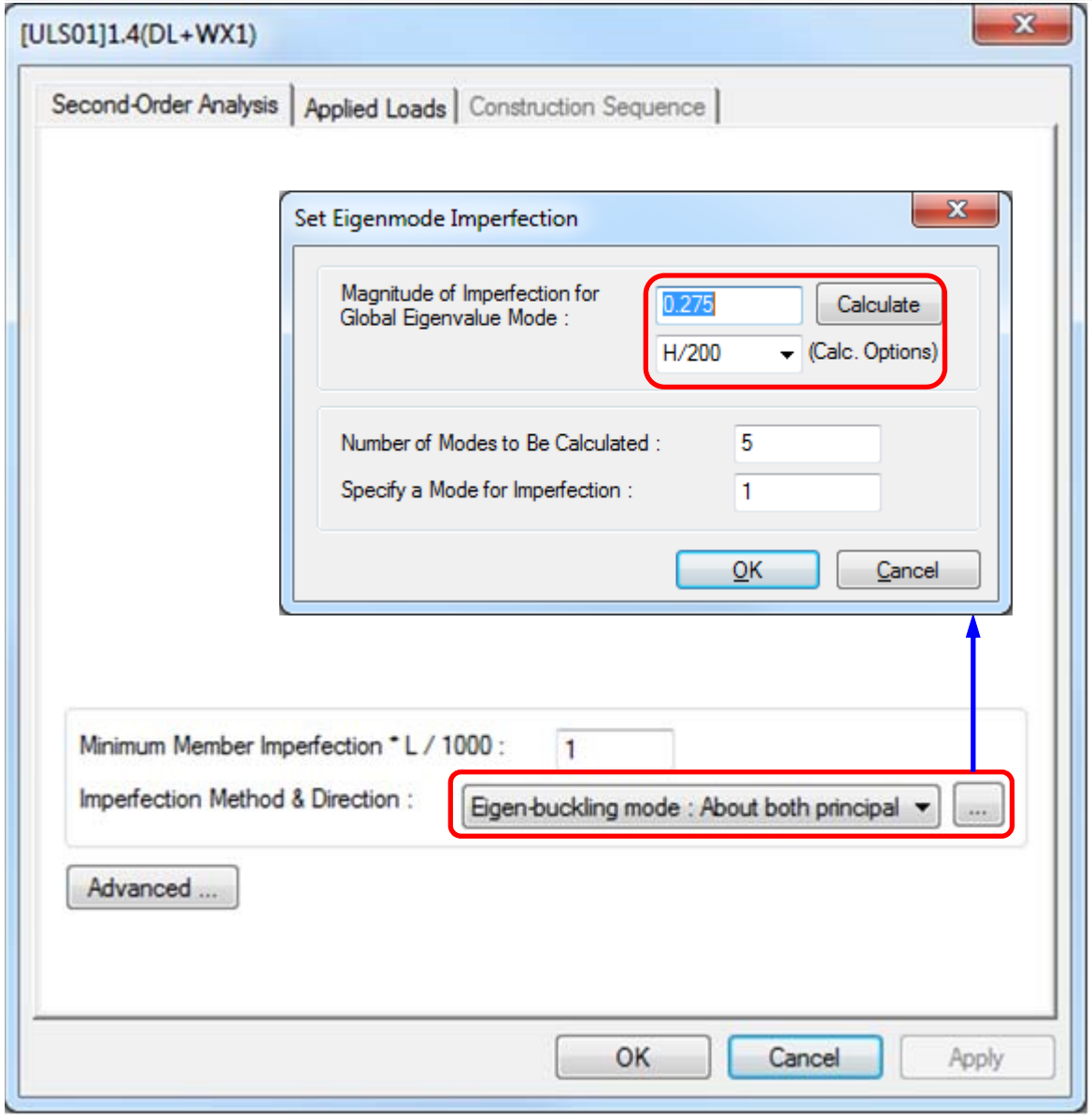


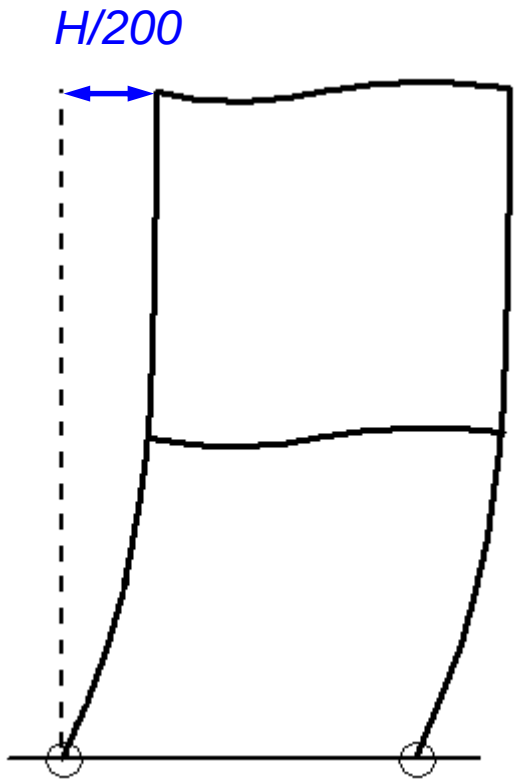
General Procedures & Settings in NIDA



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

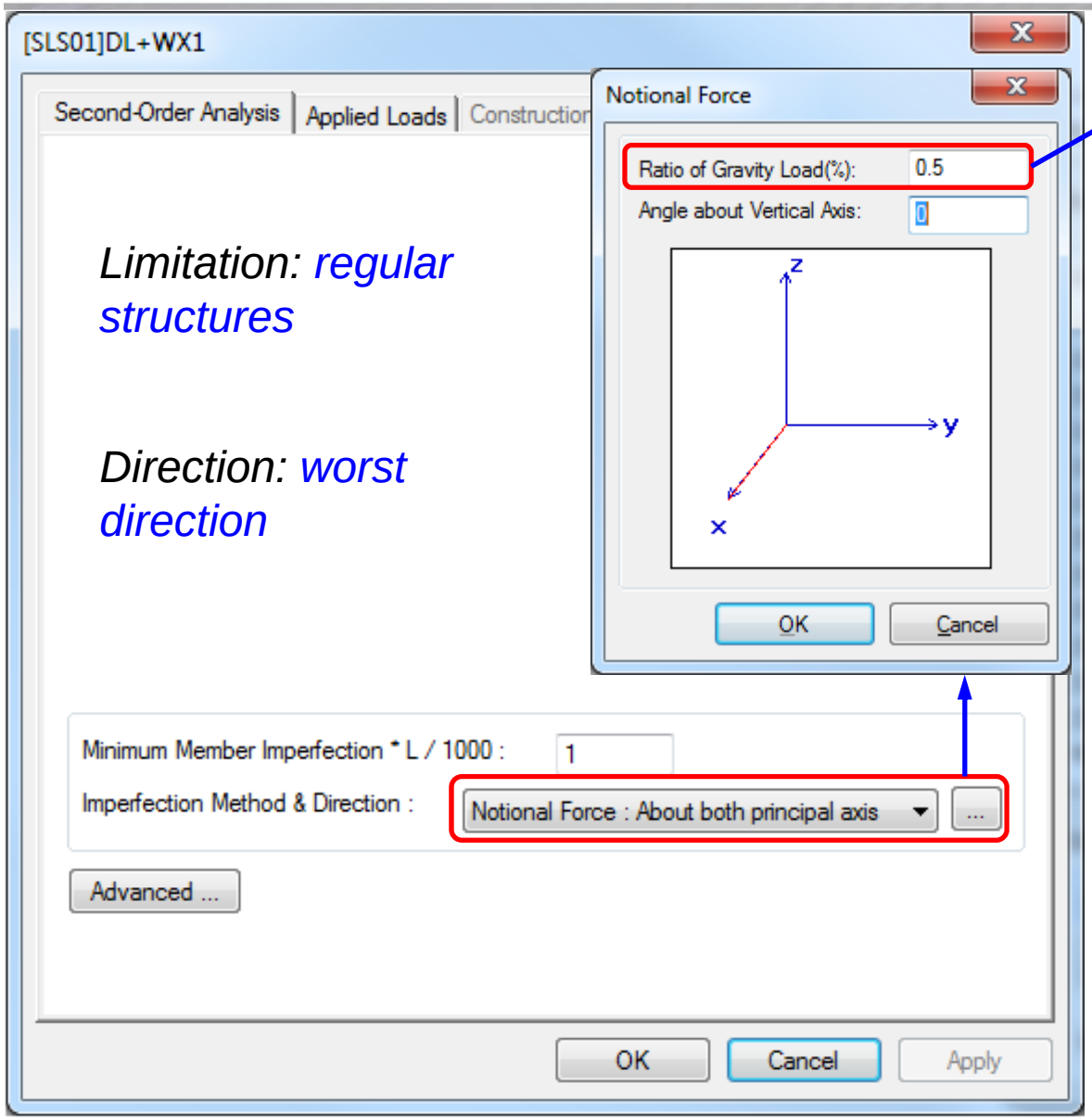
General Procedures & Settings in NIDA





Global Imperfection
(Geometry Approach)

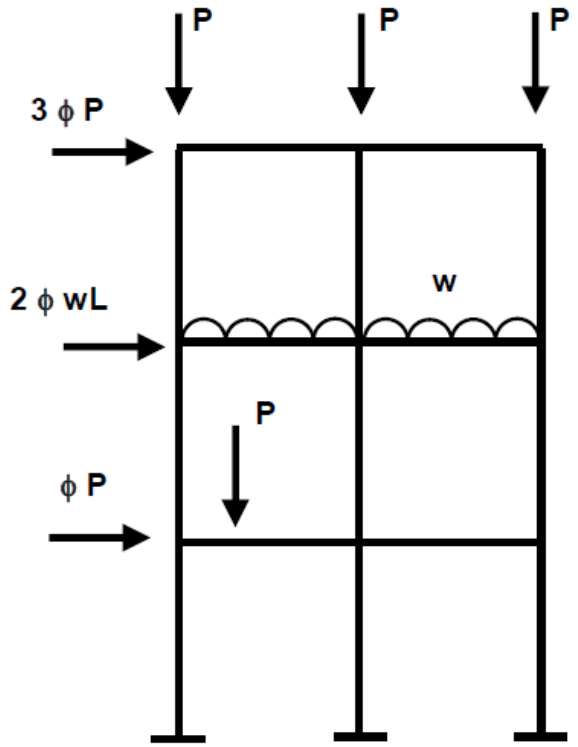
General Procedures & Settings in NIDA



Limitation: regular structures

Direction: worst direction

$\phi = 0.5\%$



Global Imperfection
(Notional Force Approach)

Most Frequently Asked Questions

Q1: About Elastic Buckling Load Factor

– Why λcr 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

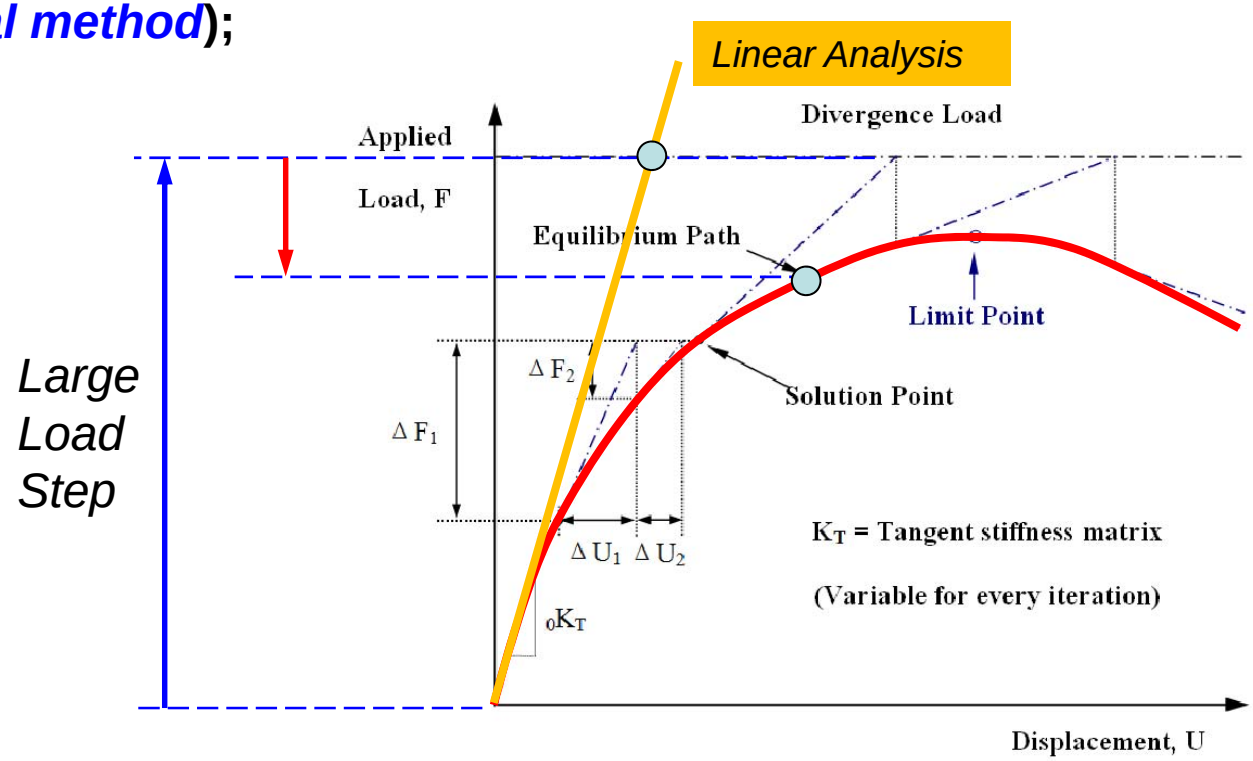
Q1: About Elastic Buckling Load Factor

– Why λcr is different from other software ?

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

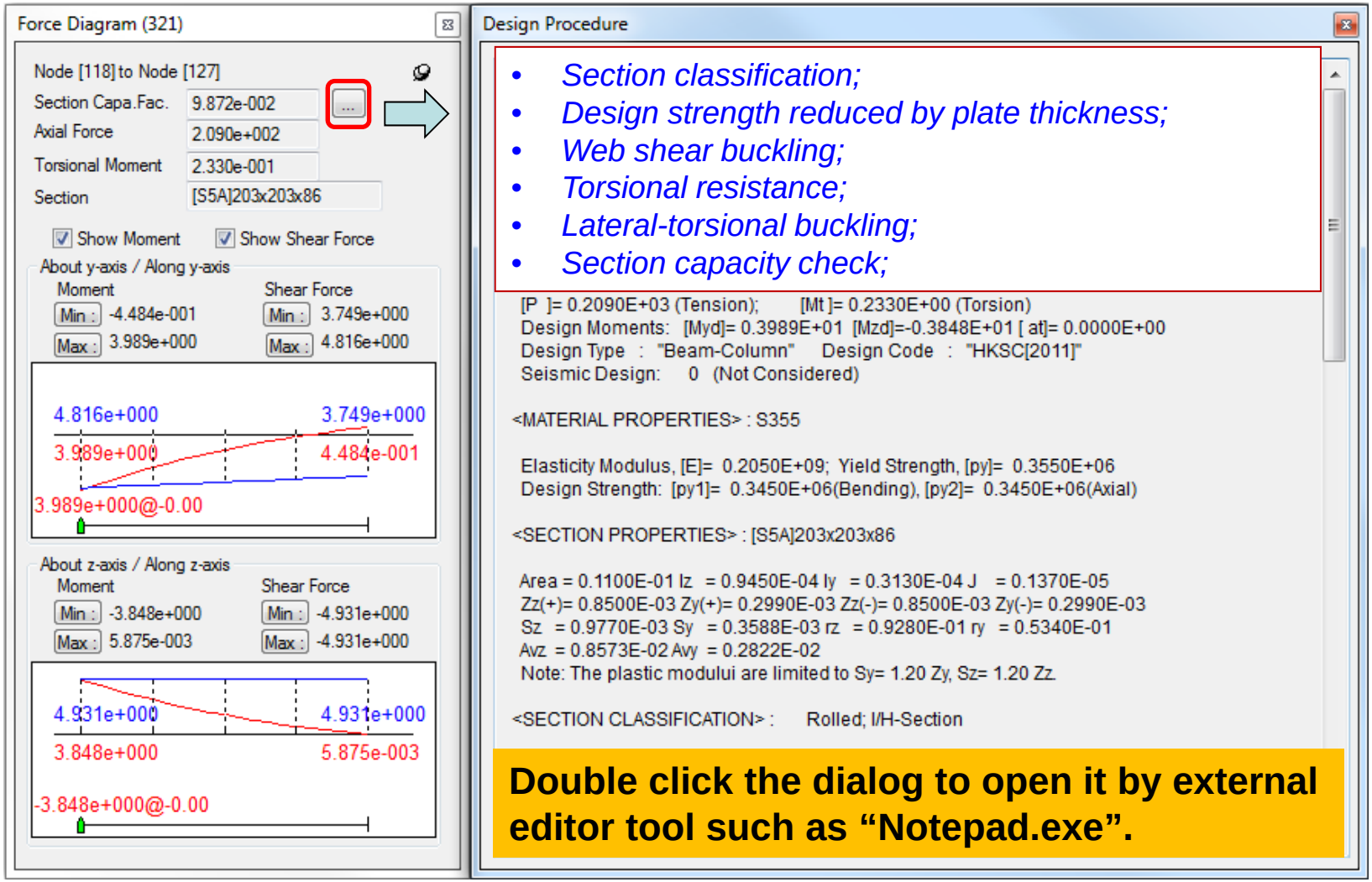
Q2: Why second-order analysis diverges ?

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



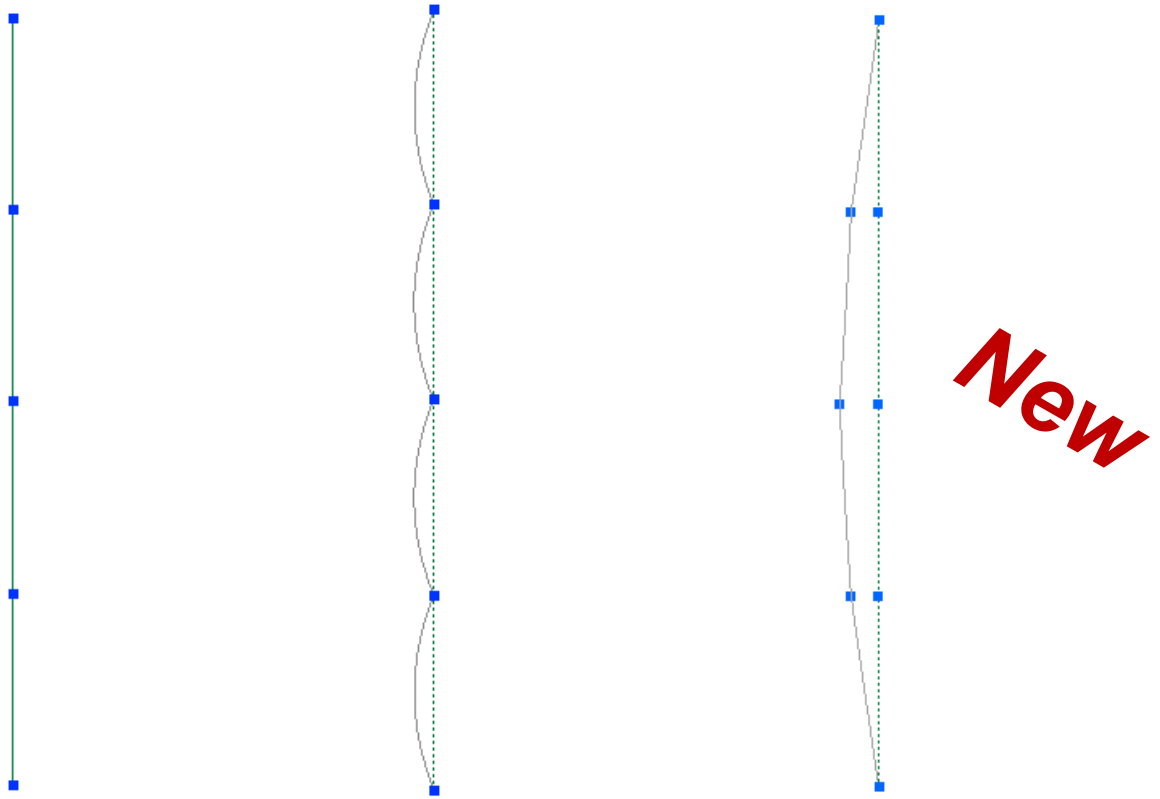
New Features

1. Design procedure for every member



2. Imperfection of Combined Member

– An individual member



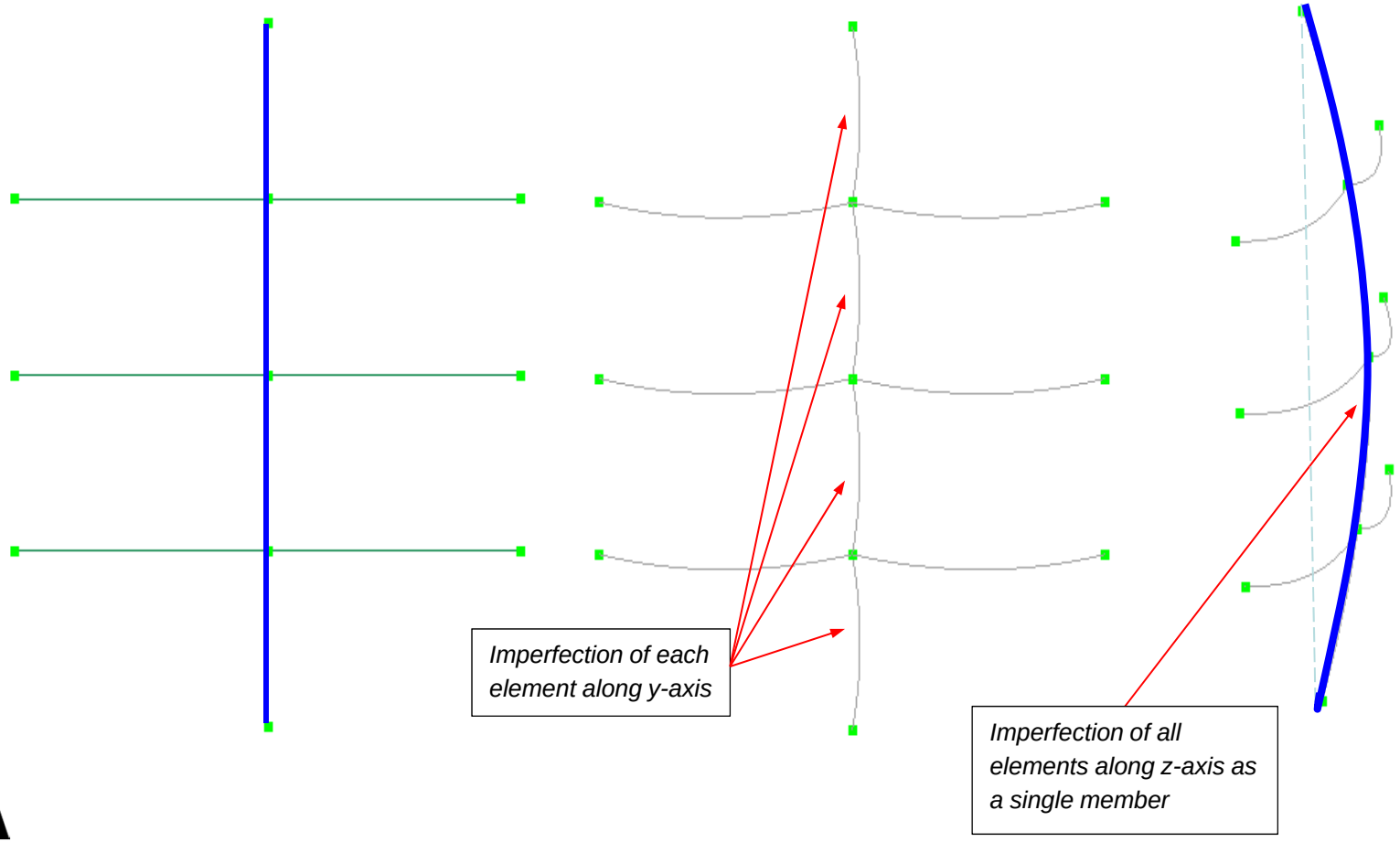
A member divided into 4 elements

Imperfection for each element

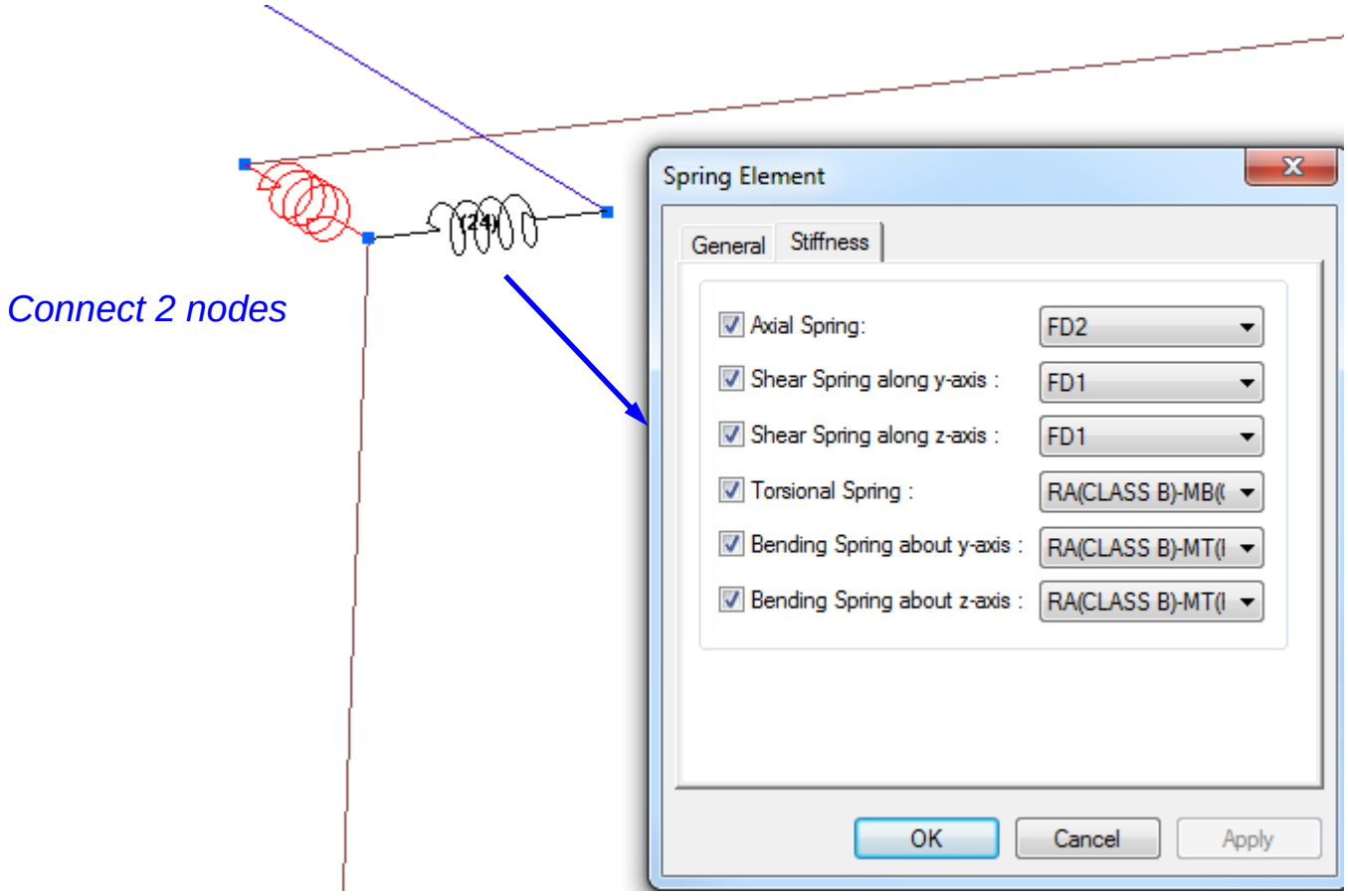
Imperfection for combined member

2. Imperfection of Combined Member (Cont'd)

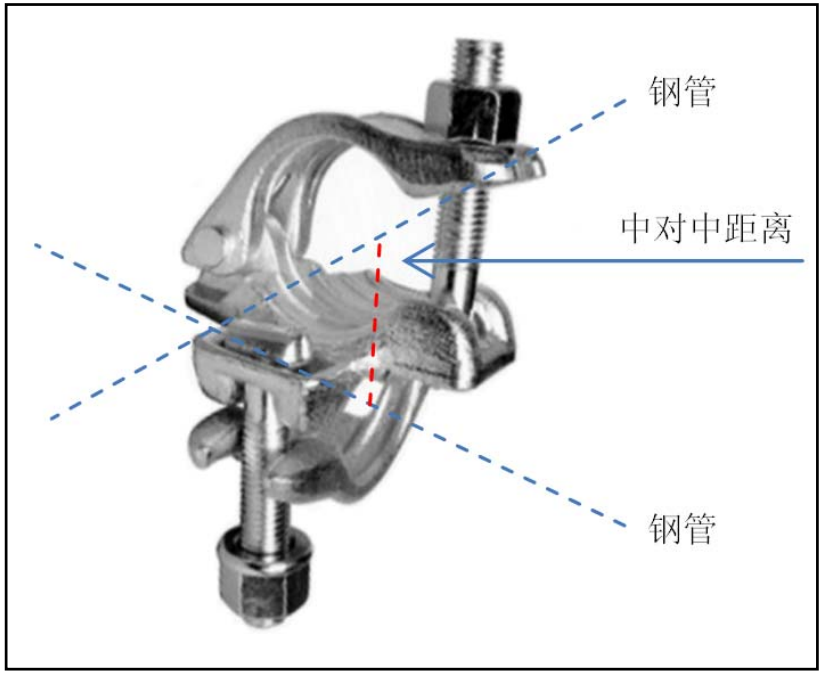
– A member with intermediate members

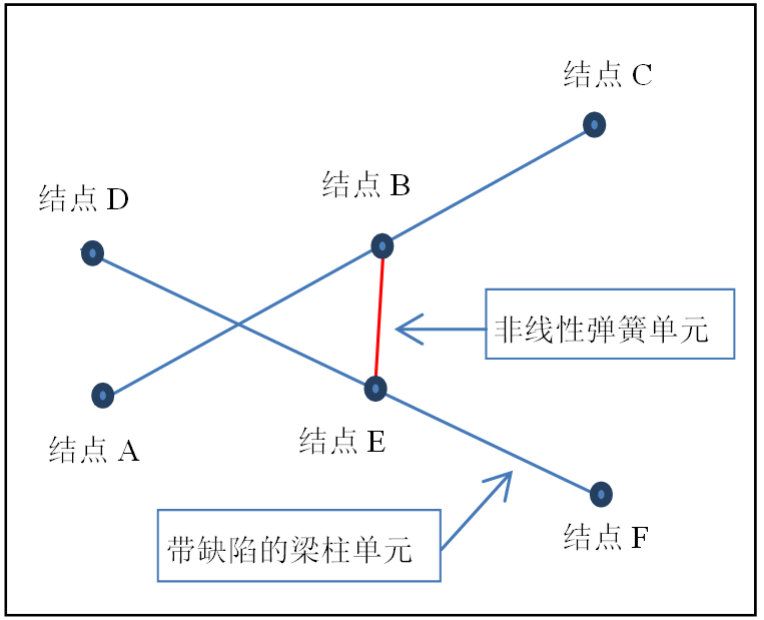


3. Nonlinear Spring Element



3. Nonlinear Spring Element (Cont'd)





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

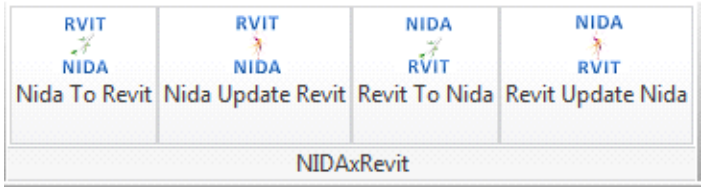



New Features

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

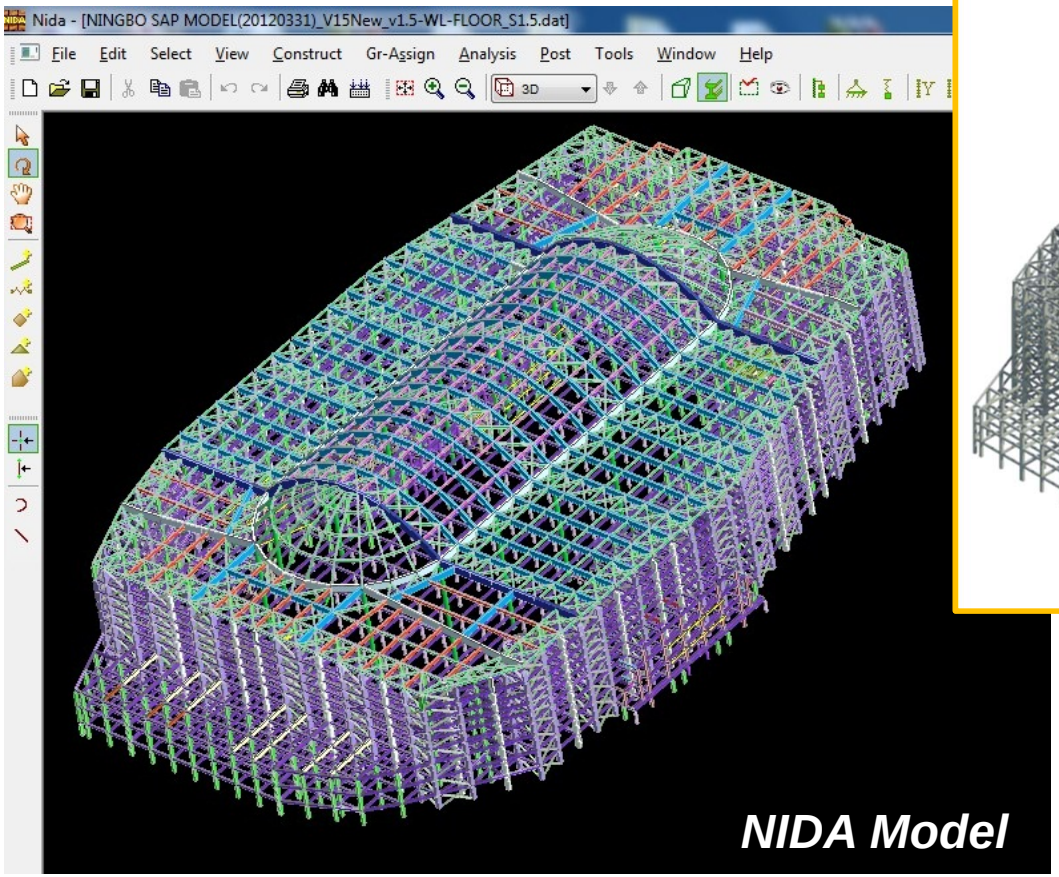
I. Nida x Revit 2012 – Link to BIM



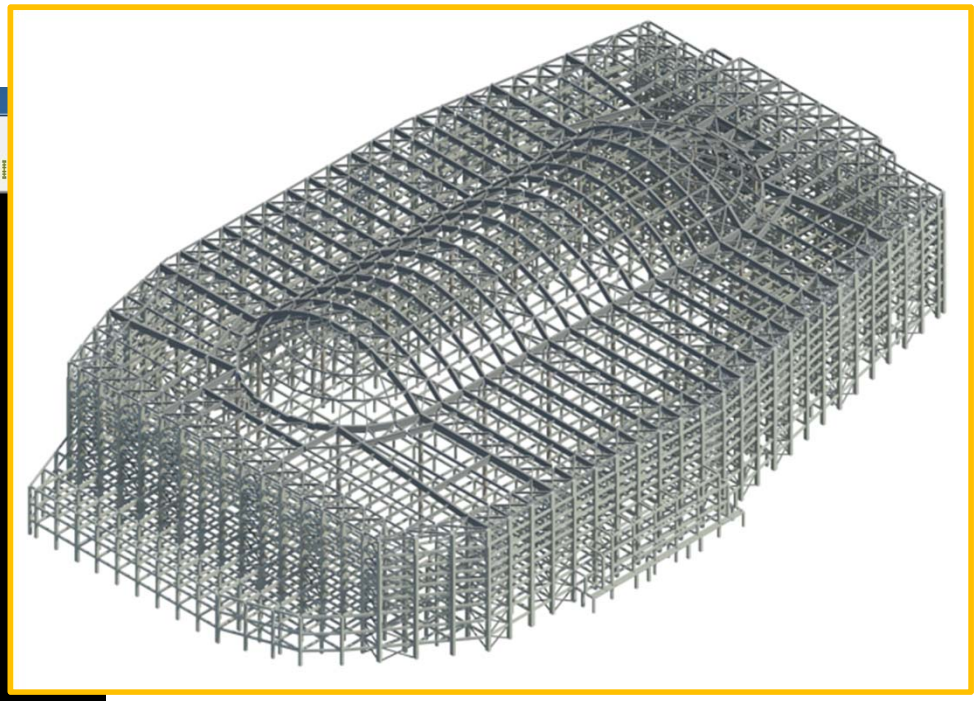
- **Export from Revit to create a new NIDA model;**
- **Import from NIDA to create a new Revit model;**
- **Export from Revit to update an existing NIDA model;**
- **Export from NIDA to update an existing Revit model;**

More NIDA Products

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



NIDA Model

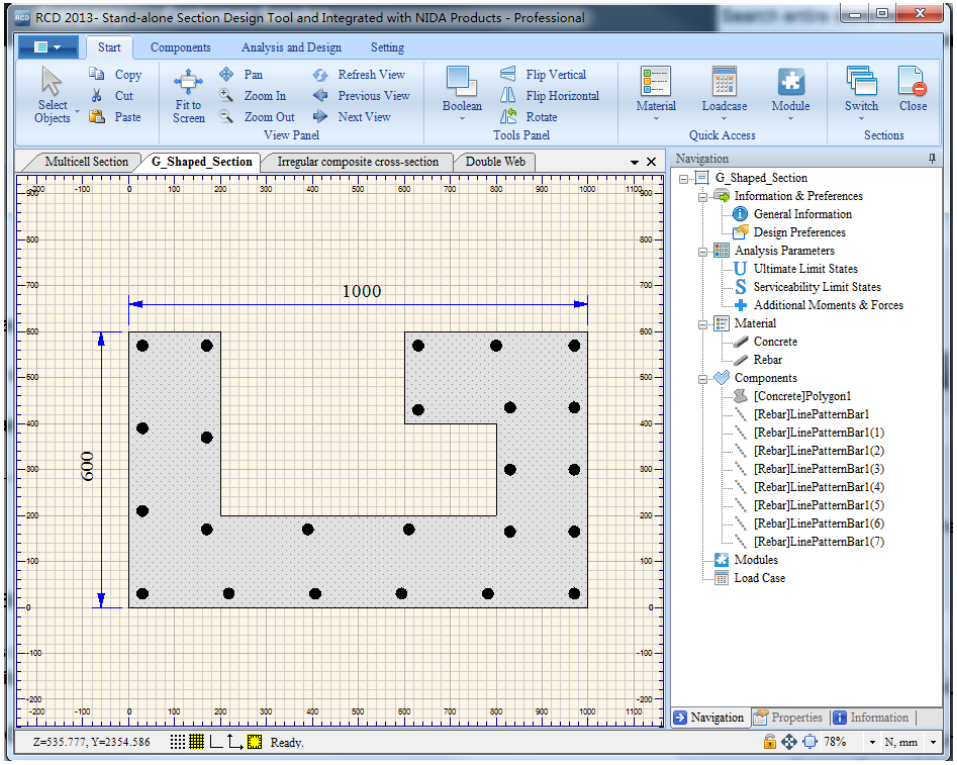


Revit Model

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.



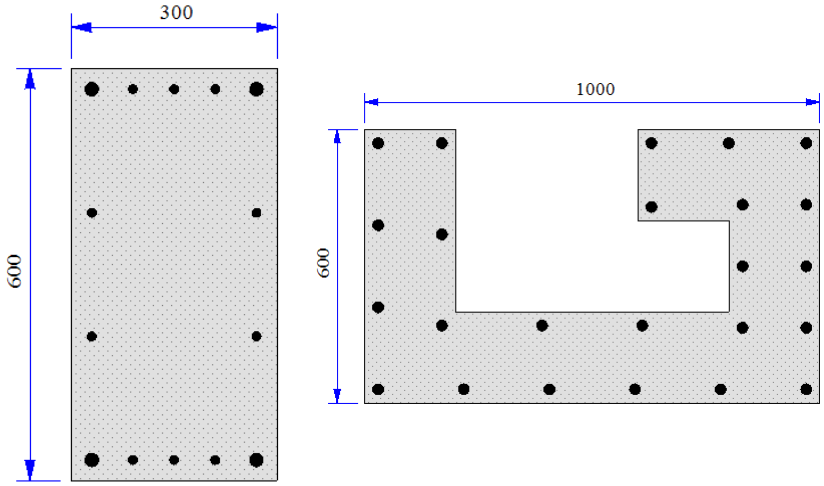
Updates from RCD 2009:

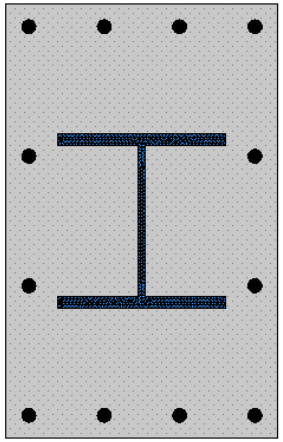
- *New User Interface (Ribbon);*
- *Multi-Documents Supported;*
- *Composite Sections Supported;*
- *Many Improvements …*

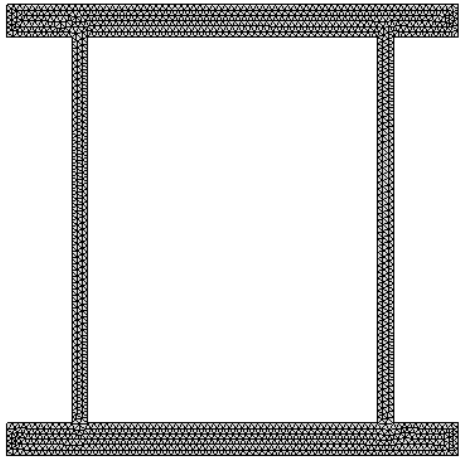
More NIDA Products

Features of RCD 2013

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







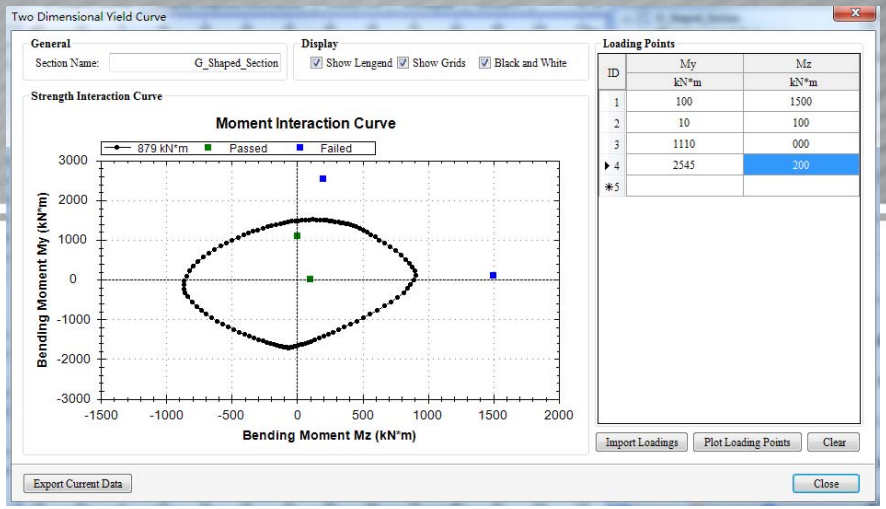
Automatically mesh into fibers

Over 50 common shapes for direct use!

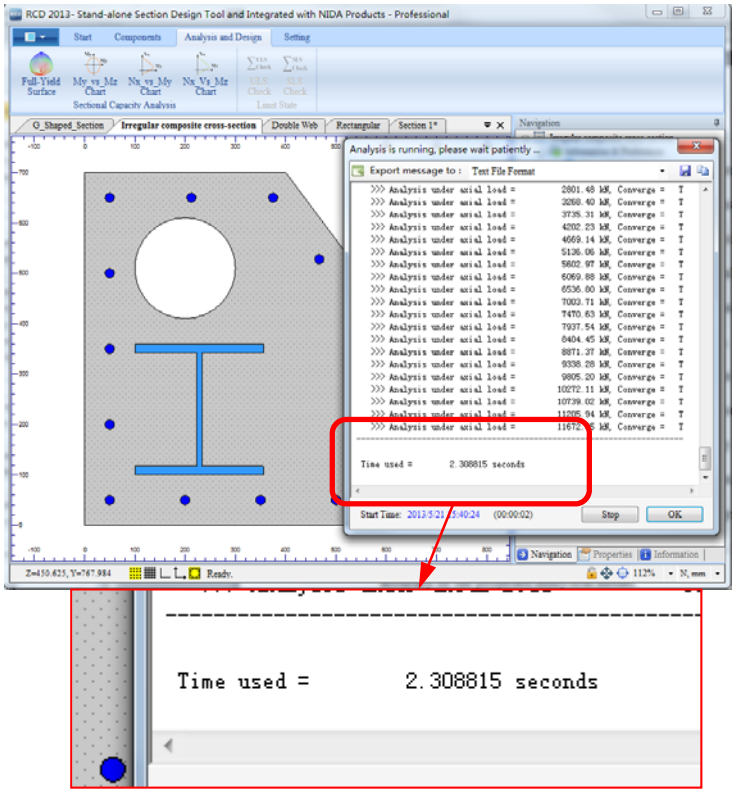
More NIDA Products

Features of RCD 2013

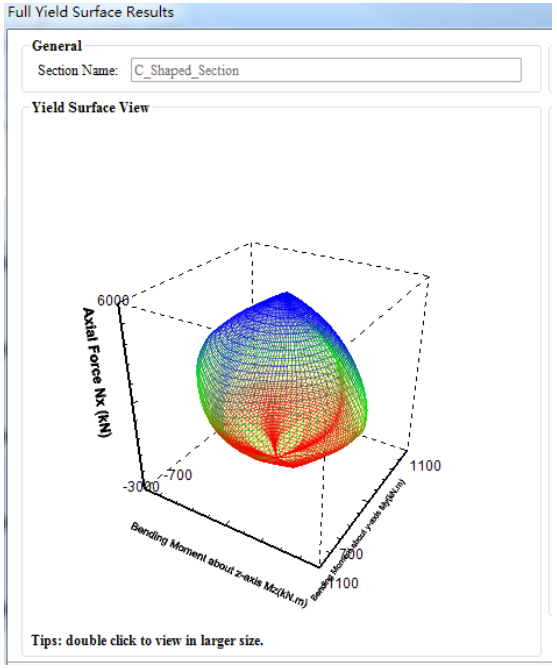
- *New core-engine and results viewer*



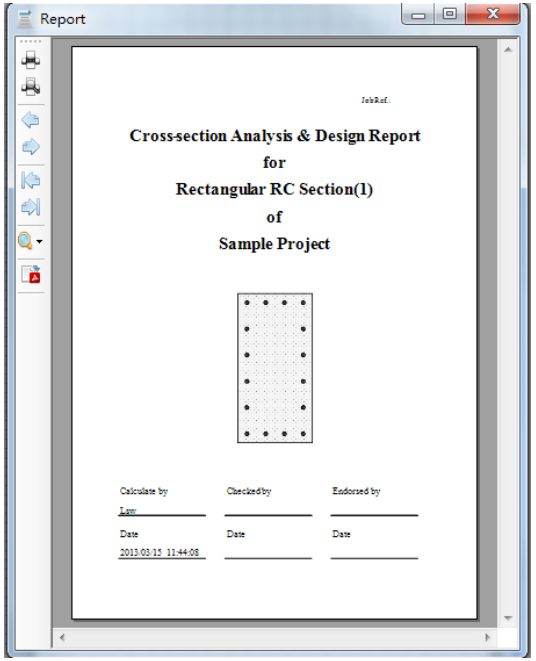
Two dimensional curve



Only 2.3s for this section!



3D View for Yield Surface



Output PDF Report

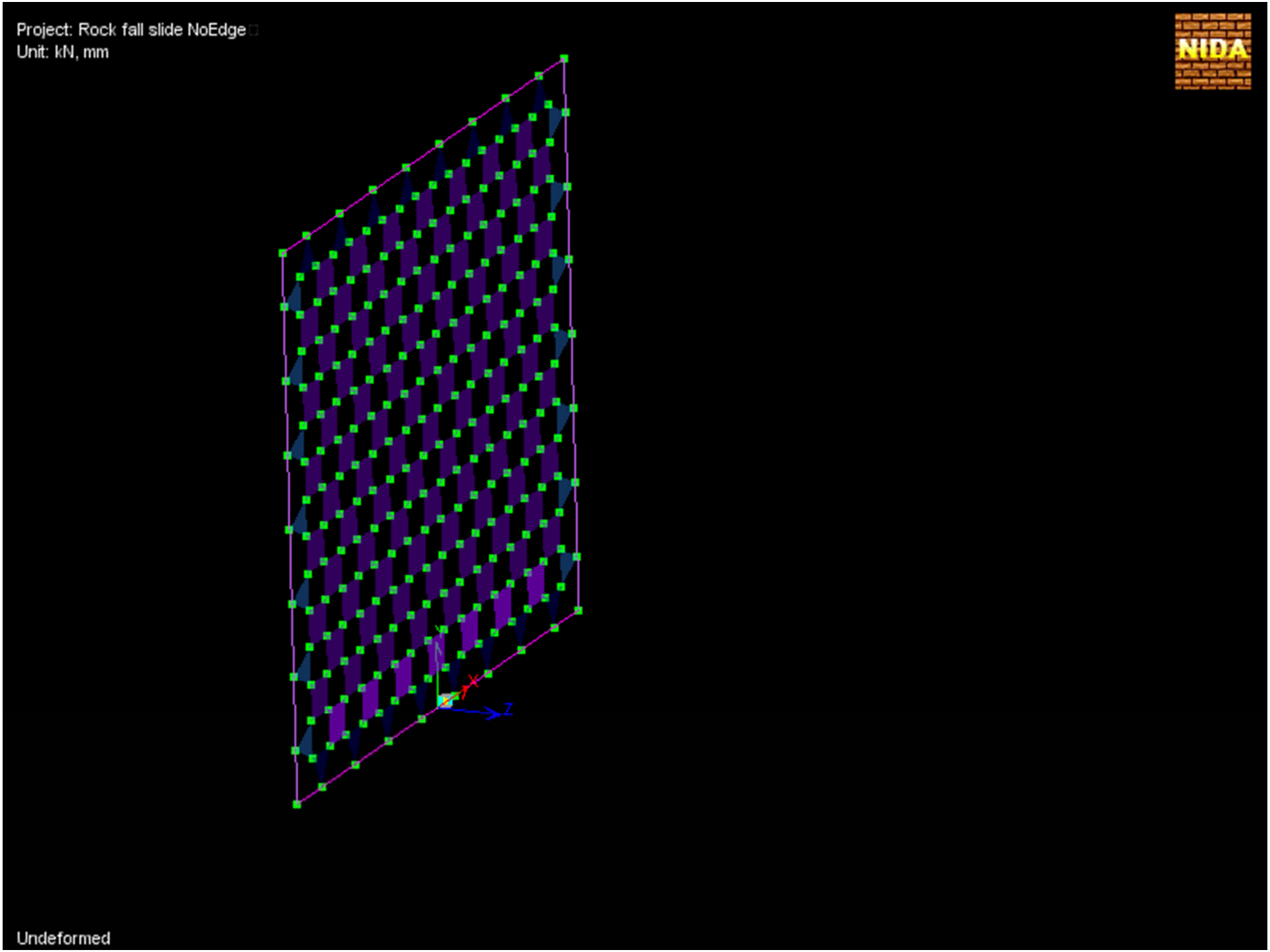
More NIDA Products

III. NIDA-MNN (Special version for Moving Node Net)

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

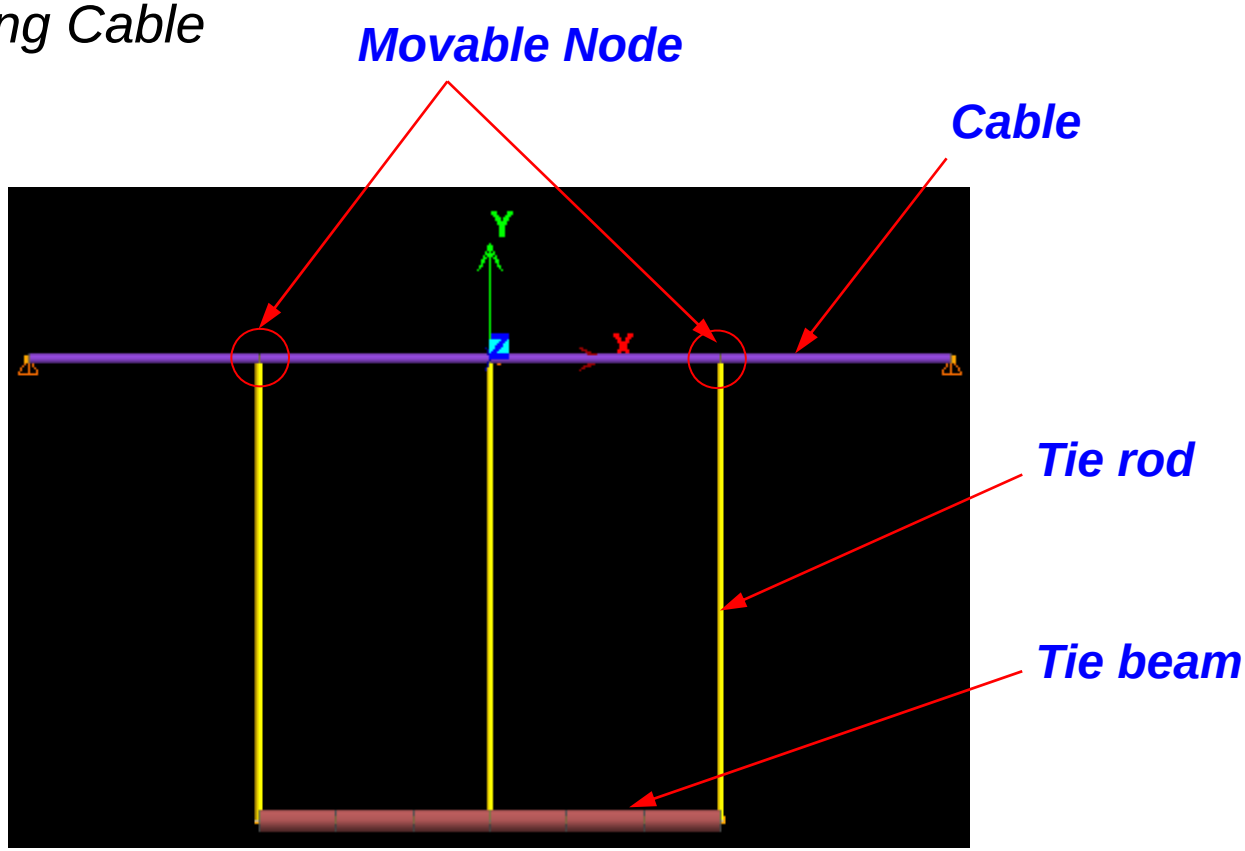
Flexible Barriers:
widely used as protection systems against natural hazards, such as rockfalls, landslides and debris flows.

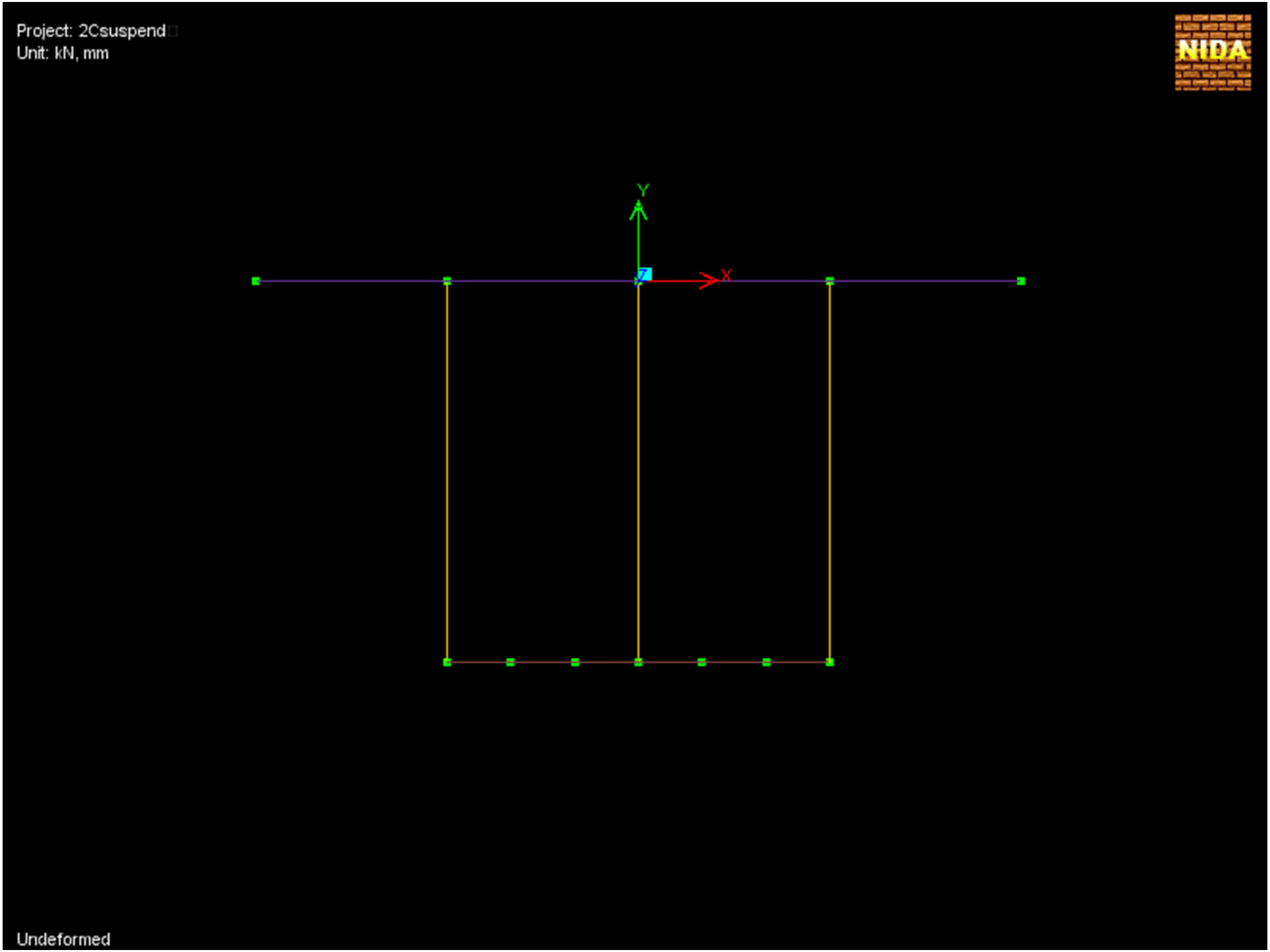
NIDA


Project: Rock fall slide NoEdge
Unit: kN, mm
NIDA
Y
X
Z
Undeformed

III. NIDA-MNN (Cont'd)

Model – Sliding Cable

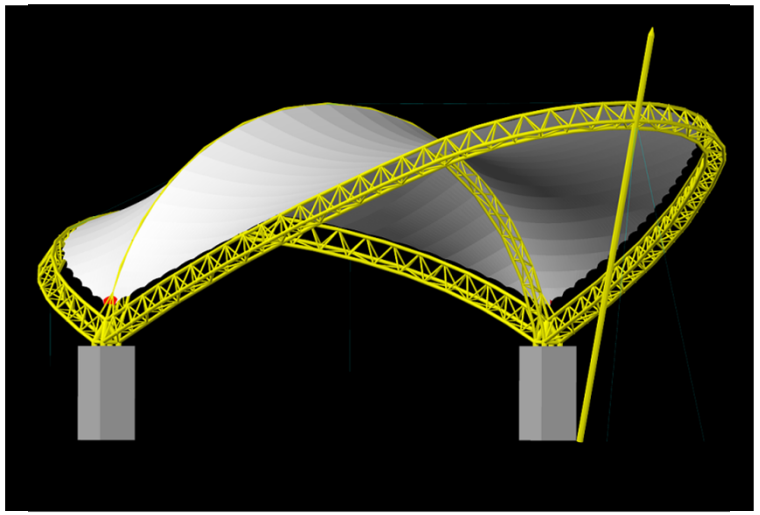



Project: 2Csuspend
Unit: kN, mm
NIDA
Y
X
Z
Undeformed

More NIDA Products

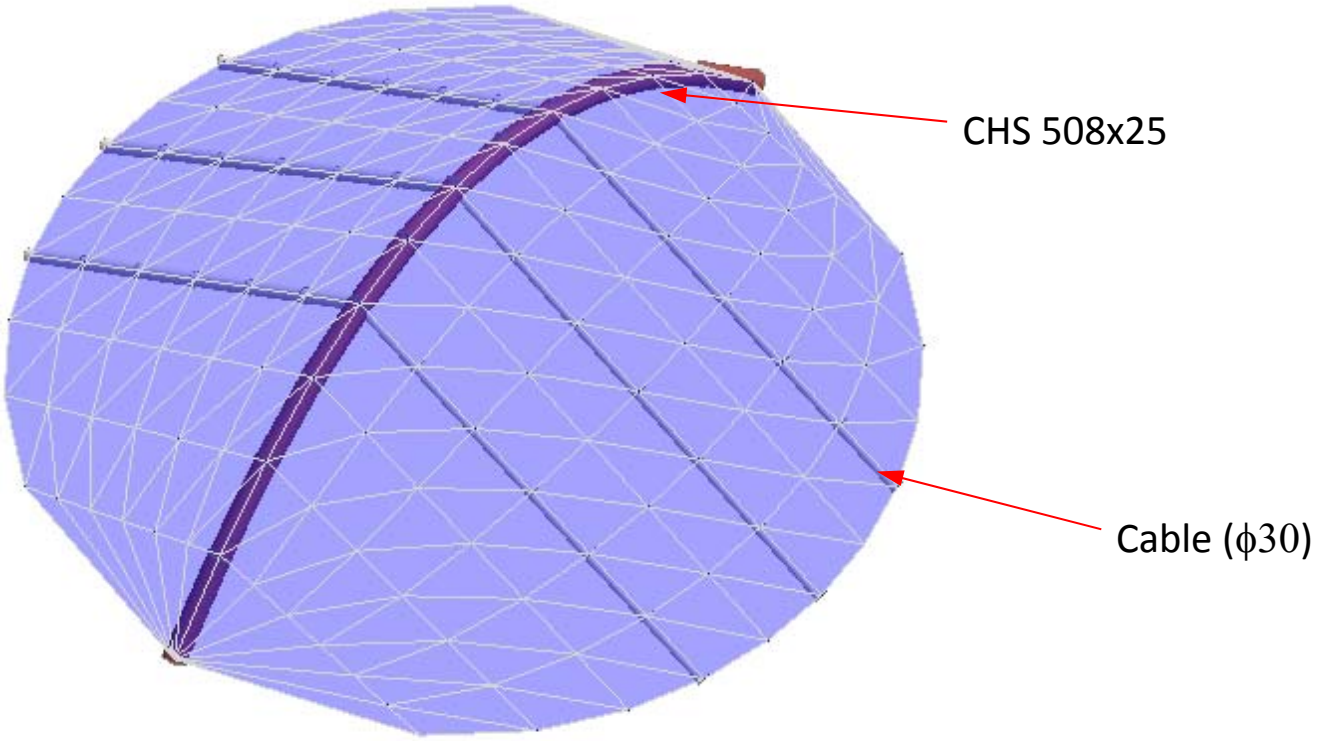
IV. NIDA-TMS (Special version)

– **Large deflection analysis of Tensioned Membrane Structure**



Amphitheatre in Hong Kong Science Park Phase 2

IV. NIDA-TMS (Cont'd)



NIDA Since 1996
Nonlinear Integrated Design and Analysis

Department of Civil & Environmental Engineering
The Hong Kong Polytechnic University

香港
鋼結構學會
Hong Kong Institute of
Steel Construction

感谢您的关注

Thank you

http:// www.nidacse.com