Package ‘civilR’

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Type Package

Title Civil Engineering R package

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Description Civil Engineering R package

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devtools,
dplyr,
writexl

Suggests knitr,
rmarkdown

VignetteBuilder knitr

R topics documented:

`axial_compression_force`

Calculate the axial compression force

Description

Compute Axial Compression Force, N_{ed} $[kN]$, for member without including Temperature effect. Used as trial for the top level strut where temperature changes could not be neglected. As well can be used to calculate final N_{ed} for struts from low levels of excavation, where temperature effect could be neglected.

Usage

```
axial_compression_force(isTopLevel = T, DL = 1, LL = 1, L = 12.5,
  P = 247, theta = 90, spacing = 6, Lcry = 12.7, Lcrz = 1,
  steel_grade = "S355", member_type = "UB", alpha_T = 1.2e-05,
  delta_T = 10, k_T = 0.8, E = 210, IL = 50, gamma = 1.35)
```

Arguments

`isTopLevel`	Is member located at top level? [boolean]
`DL`	Dead load / self-weight of member $[kN/m]$
`LL`	Live load / imposed load $[kN/m]$
`L`	Total length of member $[m]$
`P`	Axial compression force of member per meter $[kN/m]$
`theta`	Angle to wall $[deg]$
`spacing`	spacing $[m]$
`Lcry`	critical length major axis $[m]$
`Lcrz`	critical length minor axis $[m]$
`steel_grade`	steel_grade $[N/mm^2]$, categorical: 'S355' or 'S275'
`member_type`	member_type, categorical: 'UC' or 'UB'
`alpha_T`	Thermal coef. of expansion $[degC]$
`delta_T`	Change in temperature from the Installation temperature $[degC]$

k_T	Coefficient Of Temperature Effect [dimensionless]
E	Young's Modulus of Elasticity [GPa]
IL	Accidental Impact Load [kN/m]
gamma	Partial factor for action [dimensionless], as per EN 1990:2002 standard

Details

First of all function check which combination govern in ULS (Ultimate Limit State) without including Temperature load, TL [kN]. Then include TL calculations for Load Combinations applying partial factors based on the Table A1.2(B), EN1990-2002, p53 Compare maximum from ULS and ALS to define which mistake could govern.

Value

N_{ed} Axial compression force [kN], TL Temperature Load [kN]

`calculated_NEd` *Generate calculated NEd*

Description

Generate calculated N_{E_d}, $N_{E_{d_c}}$ [kN].

Usage

```
calculated_NEd(N_b_Rd, Ieff, MEd, h0, A)
```

Arguments

N_b_Rd	Overall buckling resistance of the struts about the axis [kN]
Ieff	Effective second moment of area [mm^4]
MEd	Second order moment [$kN.m$]
h0	Distance between centroids of chords [m]
A	Cross-section area of strut [cm^2]

Value

$N_{E_{d_c}}$ Calculated N_{E_d} [kN]

`check_local_buckling_resistance_about_zz_axis`
Perform check #3, calculating the local buckling resistance of struts about minor $z - z$ axis

---

Description

Calculate the local buckling resistance of member about minor $z - z$ axis, based on EC3 Approach.

$$L_e = kL_{ch}$$

$[mm]$ where L is the critical length for buckling about minor axis $z - z$ Steps of the check performed for laced struts:

1. Plastic resistance of the cross-section to compression $[kN]$

$$N_{pl,R_d,ch} = 2(A\,fy)$$

2. The Euler buckling load $[kN]$

$$N_{cr,ch} = \frac{\pi^2\,E\,I_{zz}}{{L_e}^2}$$

3. Relative slenderness [dimensionless]

$$\bar{\lambda_{ch}} = \sqrt{\frac{N_{pl,R_d,ch}}{N_{cr,ch}}}$$

4. Calculate Φ_{ch} parameter for slenderness reduction factor

$$\Phi_{ch} = 0.5\left[1 + \alpha\left(\bar{\lambda_{ch}} - 0.2\right) + \bar{\lambda_{ch}}^2\right]$$

5. Slenderness reduction factor [dimensionless]

$$X_{ch} = \frac{1}{\Phi_{ch} + \sqrt{{\Phi_{ch}}^2 - \bar{\lambda_{ch}}^2}}$$

6. Output overall buckling resistance of the struts about $z - z$ minor axis $[kN]$

$$N_{b,R_d,ch} = X_{ch}\,N_{pl,R_d,ch}$$

The partial factors γ_M that are applied to resistance of members to instability: $\gamma_{M_1} = 1$

Usage

```
check_local_buckling_resistance_about_zz_axis(trial_member_size,
  member_type, steel_grade, k, Lch, E)
```

Arguments

`trial_member_size`	Trial member size
`member_type`	member_type, categorical: 'UC' or 'UB'
`steel_grade`	steel_grade $[N/mm^2]$, categorical: 'S355' or 'S275'
`k`	Coefficient [dimensionless]
`Lch`	Length of chord $[mm]$
`E`	Young's Modulus of Elasticity $[GPa]$

Value

$N_{b,Rd,X}$ Local buckling resistance of struts about $z-z$ axis $[kN]$, f_y, N_{pl,R_d}, N_{cr}, $\bar{\lambda}$, α_{yy}, X

`check_overall_buckling_resistance_about_yy_axis`
Perform check #1, calculating the overall buckling resistance of member about major $y-y$ axis

---

Description

Calculate the overall buckling resistance of member about $y-y$ axis, based on EC3 Approach.

$$L_e = kL$$

$[mm]$ where L is the critical length for buckling about major axis $y-y$ Steps of the check performed for laced struts:

1. Plastic resistance of the cross-section to compression $[kN]$
$$N_{pl,R_d} = 2(A\,fy)$$
2. The Euler buckling load $[kN]$
$$N_{cr,X} = \frac{\pi^2\,E\,I_{yy}}{{L_e}^2}$$
3. Relative slenderness [dimensionless]
$$\bar{\lambda_X} = \sqrt{\frac{N_{pl,R_d}}{N_{cr,X}}}$$
4. Calculate Φ_X parameter for slenderness reduction factor
$$\Phi_X = 0.5\left[1 + \alpha\left(\bar{\lambda_X} - 0.2\right) + \bar{\lambda_X}^2\right]$$
5. Slenderness reduction factor [dimensionless]
$$X_x = \frac{1}{\Phi_X + \sqrt{{\Phi_X}^2 - \bar{\lambda_X}^2}}$$
6. Output overall buckling resistance of the struts about $y-y$ axis $[kN]$
$$N_{b,R_d,X} = X_X\,N_{pl,R_d}$$

The partial factors γ_M that are applied to resistance of members to instability: $\gamma_{M_1} = 1$

Usage

```
check_overall_buckling_resistance_about_yy_axis(trial_member_size,
  member_type, steel_grade, k, L, E)
```

Arguments

`trial_member_size`
: Trial member size

`member_type`
: member_type, categorical: 'UC' or 'UB'

`steel_grade`
: steel_grade [N/mm^2], categorical: 'S355' or 'S275'

`k`
: Coefficient [dimensionless]

`L`
: Total length of member [m]

`E`
: Young's Modulus of Elasticity [GPa]

Value

$N_{b,Rd,X}$ Overall buckling resistance of struts about major y-y axis [kN], $N_{b,R_d,X}$, f_y, N_{pl,R_d}, $N_{cr,X}$, $\bar{\lambda_X}$, α_{yy}, X

`check_overall_buckling_resistance_about_zz_axis`
Perform check #2, calculating the overall buckling resistance of struts about major $z - z$ axis

---

Description

Calculate the overall buckling resistance of member about $z - z$ axis, based on EC3 Approach.

$$L_e = k\,L$$

[mm] where L is the critical length for buckling about major axis $z - z$ Steps of the check performed for laced struts:

1. Plastic resistance of the cross-section to compression [kN]

$$N_{pl,R_d} = 2(A\,fy)$$

2. The Euler buckling load [kN]

$$N_{cr,Y} = \frac{\pi^2\,E\,I_{eff}}{{L_e}^2}$$

3. Relative slenderness [dimensionless]

$$\bar{\lambda_Y} = \sqrt{\frac{N_{pl,R_d}}{N_{cr,Y}}}$$

4. Calculate Φ_Y parameter for slenderness reduction factor

$$\Phi_Y = 0.5\left[1 + \alpha\left(\bar{\lambda_Y} - 0.2\right) + \bar{\lambda_Y}^2\right]$$

5. Slenderness reduction factor [dimensionless]

$$X_Y = \frac{1}{\Phi_Y + \sqrt{{\Phi_Y}^2 - \bar{\lambda_Y}^2}}$$

6. Output overall buckling resistance of the struts about $z - z$ axis $[kN]$

$$N_{b,R_d,Y} = X_Y \, N_{pl,R_d}$$

The partial factors γ_M that are applied to resistance of members to instability: $\gamma_{M_1} = 1$

Usage

```
check_overall_buckling_resistance_about_zz_axis(trial_member_size,
  member_type, steel_grade, k, L, E, h0)
```

Arguments

`trial_member_size`	Trial member size
`member_type`	member_type, categorical: 'UC' or 'UB'
`steel_grade`	steel_grade $[N/mm^2]$, categorical: 'S355' or 'S275'
`k`	Coefficient [dimensionless]
`L`	Total length of member $[m]$
`E`	Young's Modulus of Elasticity $[GPa]$
`h0`	Distance between centroids of chords $[mm]$

Value

$N_{b,Rd,Y}$ Overall buckling resistance of struts about z-z axis $[kN]$, $N_{b,R_d,Y}$, f_y, N_{pl,R_d}, I_{eff}, $N_{cr,Y}$, $\bar{\lambda_Y}$, α_{yy}, X

`civilR` *Package civilR*

Description

Civil Engineering package.

compute_output_table *Export output table to Excel file*

Description

Export output table to Excel file.

Usage

```
compute_output_table(file_name = "tables/input/output_processed_table.xlsx")
```

Arguments

`file_name`	Path and file name of the output table

Value

None

convert_member_dimensions_string_to_elements *Convert individual member dimensions to a string*

Description

Convert individual member dimensions to a string.

Usage

```
convert_member_dimensions_string_to_elements(s)
```

Arguments

`s`	String of the member dimensions

Value

- h Member height $[mm]$
- b Member width $[mm]$
- m Member weight $[kg/m]$

`convert_member_dimensions_to_string`
Convert the member size individual dimensions to a standard string

Description

Generate a combined string from given three individual elements, separated by "x".

Usage

```
convert_member_dimensions_to_string(h, b, m)
```

Arguments

h	Member height [mm]
b	Member width [mm]
m	Member mass [kg/m]

Value

String of the member dimensions

`effective_length_of_member`
Calculate the effective length of member

Description

Calculate the effective length of member, L_e [m].

Usage

```
effective_length_of_member(k, L)
```

Arguments

k	Effective lengh coefficient [dimensionless]
L	Length of strut between restraints [m]

Value

L_e Effective length of strut [m]

`effective_second_moment_of_area` *Calculate the effective second moment of area*

Description

Compute the effective second moment of area $[mm^4]$. I_{eff} is a function of the distance between the centroids of the chords and the section area of a chord, calculated as $I_{eff} = 0.5\,{h_0}^2\,A$.

Usage

```
effective_second_moment_of_area(h0, A)
```

Arguments

`h0`	Distance between centroids of chords $[mm]$
`A`	Cross-section area of strut $[cm^2]$

Value

I_{eff} Effective second moment of area $[mm^4]$

`Euler_buckling_load` *Calculate the Euler buckling load*

Description

Calculate the Euler buckling load $[kN]$

$$N_{cr,ch} = \frac{\pi^2\,E\,I}{{L_e}^2}$$

Usage

```
Euler_buckling_load(Le, E, I)
```

Arguments

`Le`	Effective length of strut $[mm]$
`E`	Young modulus $[MPa$ or $MN/m^2]$
`I`	- check 1: I_{yy}, second moment of area Axis $y-y$ $[cm^4]$. Check 2: I_{eff}, Effective second moment of area $[mm^4]$. Check 3: I_{eff} or I_{zz} $[mm^4]$

Value

N_{cr} Euler buckling load $[kN]$

`extract_member_dimensions` *Extract dimensions from reference table*

Description

Function that looks into the Blue Book https://www.steelforlifebluebook.co.uk/ for dimensions and properties.

Usage

```
extract_member_dimensions(h, b, m, member_type)
```

Arguments

`h`	Member height $[mm]$
`b`	Member width $[mm]$
`m`	Member mass $[kg/m]$
`member_type`	Member type, 'UB' or 'UC'

Value

- A Area of section $[cm^2]$
- tw Thickness of web $[mm]$
- tf Thickness of flange $[mm]$
- Iyy Second moment of area axis $y - y$ $[cm^4]$
- sh Depth of section $[mm]$
- sb Width of section $[mm]$
- Izz Second moment of area axis $z - z$ $[cm^4]$

`imperfection_factor_yy` *Calculate the imperfection factor α_yy for rolled section [dimensionless]*

Description

Calculate the imperfection factor α_{yy} for rolled section [dimensionless].

Usage

```
imperfection_factor_yy(h, b, tf)
```

Arguments

`h`	Member height $[mm]$
`b`	Member width $[mm]$
`tf`	thickness of the flange $[mm]$

Value

α_{yy} Imperfection factor for $y - y$ axis [dimensionless]

`imperfection_factor_zz` *Calculate the imperfection factor α_zz for rolled section*

Description

Calculate the imperfection factor α_{zz} for rolled section.

Usage

```
imperfection_factor_zz(h, b, tf)
```

Arguments

`h`	Member height $[mm]$
`b`	Member width $[mm]$
`tf`	thickness of the flange $[mm]$

Value

α_{zz} Imperfection factor for $z - z$ axis [dimensionless]

`maximum_shear_force_in_the_lacing` *Calculate the maximum shear force in the lacing*

Description

Calculate the maximum shear force in the lacing, V_{E_d} $[kN]$ (for a laced strut subject to a compressive axial force only)

$$V_{E_d} = \pi \frac{M_{E_d}}{L}$$

Usage

```
maximum_shear_force_in_the_lacing(MEd, L)
```

Arguments

`MEd`	Second order moment $[kN.m]$
`L`	Length of strut between restraints $[m]$

Value

V_{E_d} Maximum shear force in the lacing $[kN]$ (for a laced strut subject to a compressive axial force only)

`max_compressive_axial_force_in_chords`
Maximum compressive axial force in the chords

Description

Determine maximum compressive axial force in the chords at mid-length of the strut, N_{ch,E_d} $[kN]$

Usage

```
max_compressive_axial_force_in_chords(trial_member_size, member_type,
  steel_grade, k, L, n, Ad, Lch, E, h0, Ned)
```

Arguments

`trial_member_size`	Trial member size
`member_type`	member_type, categorical: 'UC' or 'UB'
`steel_grade`	steel_grade $[N/mm^2]$, categorical: 'S355' or 'S275'
`k`	Coefficient of length as function of wall rigidity [dimensionless]
`L`	Length between two restraints $[m]$
`n`	Number of lacing planes, default $[n = 2]$
`Ad`	Section area of diagonal (lacing), $[cm^2]$
`Lch`	Length of chord of betwen restrains (lace points) $[m]$
`E`	Young modulus $[GPa$ or $GN/m^2]$
`h0`	Distance between centroids of chords $[m]$
`Ned`	Axial compression Force $[kN]$

Value

N_{ch,E_d} Maximum compressive axial force in the chords $[kN]$, S_v, $N_{cr,ch}$, M_{E_d}

`overall_buckling_resistance_about_axis`
Calculate the overall buckling resistance of the memeber about the axis

---

Description

General case to compute the overall buckling resistance of the member, N_{b,R_d} $[kN]$, about the axis, calculated as:

$$N_{b,R_d} = X\,N_{pl,R_d}$$

Usage

```
overall_buckling_resistance_about_axis(X, N_pl_Rd)
```

Arguments

`X`	Slenderness reduction factor [dimentionless]
`N_pl_Rd`	Plastic resistance of the cross-section to compression [kN]

Value

N_{b,R_d} Overall buckling resistance of the struts about the axis [kN]

`plastic_resistance_of_cross_section_to_compression`

Calculate the plastic resistance of the cross-section to compression

---

Description

Calculate the plastic resistance of the cross-section to compression [N], based on cross-section area A and yield strength f_y.

Usage

```
plastic_resistance_of_cross_section_to_compression(A, fy)
```

Arguments

`A`	Cross-section area of the strut [cm^2]
`fy`	Yield strength [kN/mm^2]

Value

N_{pl,R_d} Plastic resistance of the cross-section to compression [N]

`process_input_table` *Process input table*

Description

Process input table.

Usage

```
process_input_table()
```

Value

Processed table, adding computed outputs:

read_input_table — *Read input table from given Excel file*

Description

Read input table from given Excel file.

Usage

```
read_input_table(file_name = "tables/input/trial1_kotik.xlsx")
```

Arguments

`file_name`	Path and file name of the input table

Value

Input table

relative_slenderness — *Calculate the relative slenderness*

Description

Calculate the relative slenderness [dimensionless]

$$\bar{\lambda} = \sqrt{\frac{N_{pl,R_d}}{N_{cr}}}$$

Usage

```
relative_slenderness(N_pl_Rd, Ncr)
```

Arguments

`N_pl_Rd`	Plastic resistance of the cross-section to compression $[kN]$
`Ncr`	Euler buckling load $[kN]$

Value

$\bar{\lambda}$ Relative slenderness [dimentionless]

second_order_bending_moment
Calculate the second order bending moment

Description

Compute the second order bending moment, M_{E_d} $[kN.m]$. The maximum bending moment, including the bow imperfection and the second order effects, calculated as:

$$M_{E_d} = \frac{N_{E_d}\, e_0 \,+\, {M_{E_d}}^I}{1 - \frac{N_{E_d}}{N_{cr,Y}} - \frac{N_{E_d}}{S_v}}$$

Usage

```
second_order_bending_moment(L, Ned, Sv, Ncr)
```

Arguments

L	Length of strut between restraints $[mm]$
Ned	axial_compression_force $[kN]$
Sv	Shear stiffness for K-shape lacing $[kN]$
Ncr	Euler buckling load from check #2 global zz $[kN]$

Value

M_{E_d} Second order moment $[kN.m]$

shear_stiffness *Calculate the shear stiffness for K-shape lacing*

Description

Calculate the shear stiffness for K-shape lacing $[kN]$. The expression of shear stiffness is:

$$S_v = \frac{n\, E\, A_d\, L_{ch}\, {h_0}^2}{d^3}$$

Usage

```
shear_stiffness(n = 2, Ad, Lch, E, h0)
```

Arguments

n	Number of planes of lacing, default $[n = 2]$
Ad	Section area of diagonal (lacing), $[cm^2]$
Lch	Length of chord of betwen restrains (lace points) $[m]$
E	Young modulus $[GPa$ or $GN/m^2]$
h0	Distance between centroids of chords $[m]$

Value

S_v Shear stiffness for K-shape lacing $[kN]$

`slenderness_reduction_factor` *Calculate the slenderness reduction factor*

Description

Calculate the slenderness reduction factor X [dimentionless] for the general case.

$$\Phi = 0.5\left[1 + \alpha\left(\bar{\lambda} - 0.2\right) + \bar{\lambda}^2\right]$$

$$X = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}}$$

Usage

```
slenderness_reduction_factor(alpha, lambda_bar)
```

Arguments

`alpha`	Check #1: imperfection factor α_{yy} for rolled section [dimentionless]. Check 2 & 3: imperfection factor α_{zz} for rolled section [dimentionless]
`lambda_bar,`	Relative slenderness $\bar{\lambda}$ [dimentionless]

Value

X Slenderness reduction factor [dimentionless]

`temperature_load` *Calculate the temperature load*

Description

Calculate Temperature Load as a function of a surface changes of temperature, TL [kN]. Usually used for calculation of Axial Compression Force for the top level member.

$$TL = \alpha_T\, \delta_T\, k_T\, E\, A$$

Usage

```
temperature_load(alpha_T = 1.2e-05, delta_T = 10, k_T = 0.8,
  E = 210, A = 94.4)
```

Arguments

`alpha_T`	Thermal coefficient of expansion [$degC$]
`delta_T`	Change in temperature from the Installation temperature [$degC$]
`k_T`	Coefficient Of temperature effect [dimensionless]
`E`	Young's Modulus of Elasticity [GPa or $GN/m2$]
`A`	Sectional area from table for given member size [cm^2]

Value

TL Temperature load [kN]

`trial_member_size` *Determine member size*

Description

Find optimized designation [height (mm) x width (mm) x mass (kg/m)] (also called member size) for given Axial Compression Force and critical length for major and minor axis. Searching into the tables based on the 'Compression' tables of the Blue Book https://www.steelforlifebluebook.co.uk/

Usage

```
trial_member_size(Lcry, Lcrz, Ned, steel_grade, member_type)
```

Arguments

`Lcry`	critical length major axis $[m]$
`Lcrz`	critical length minor axis $[m]$
`Ned`	Axial compression force $[kN]$
`steel_grade`	steel_grade $[N/mm^2]$, categorical: 'S355' or 'S275'
`member_type`	member_type, categorical: 'UC' or 'UB'

Value

Member size [height (mm) x width (mm) x mass (kg/m)]

`yield_strength` *Calculate the yield strength*

Description

Calculate the yield strength, f_y $[N/mm^2]$

Usage

```
yield_strength(tw, tf, steel_grade)
```

Arguments

`tw`	Thickness of the web $[mm]$
`tf`	Thickness of the flange $[mm]$
`steel_grade`	steel_grade $[N/mm^2]$, categorical: 'S355' or 'S275'

Value

f_y Yield strength $[N/mm^2]$

Examples

```
yield_strength(tw=47.6, tf=77, steel_grade="S355")
```

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