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| Plate Buckling Analysis | |
| User Manual | |
| April 25, 2018 | |



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# INTRODUCTION

Dynacard data program evaluates the analytics application performs the following:

* The guidance for service delivery in section XX
* The user manual for developer in section XX

The document contains the following:

* Guidance notes for business users in Sub-section 2.1
* Guidance notes for service delivery in Sub-section 2.2
* Guidance notes for developer in Sub-section 2.3

# THEORY

## Introduction

Also, can we draw a picture of the plate and show the loading, stiffners, etc. We already have examples in SEWOL and codes. But how can we communicate this to a common user on internet?!?

## DNV C201

Buckling of flat plates may be experienced when the plate is excessively stressed in compression along opposite edges, or in shear uniformly distributed around all edges of the plate or a combination of both. This necessitates establishment of values for the critical buckling stress in compression (a) and in shear (G).

### Failure Modes.

This recommended practice addresses failure modes for unstiffened and stiffened plates, which are not covered by the cross sectional check of members. Such failure modes are:

* Yielding of plates in bending due to lateral load.
* Buckling of slender plates (high span to thickness ratio) due to in-plane compressive stresses or shear stresses.

Guidance for determining resistance is given both for individual plates (unstiffend plates), stiffened plates and for girders supporting stiffended plate panels. For stiffened panels the recommendations cover panel buckling, stiffener buckling as well as local buckling of stiffener and girder flanges, webs and brackets.

### Boundary and loading conditions.

The Serviceability and Ultimate are the loading conditions that will also change some factors and hence the results.

* Loading conditions
  + Serviceability.
  + Ultimate.

The simply supported and sides clamped are the boundary condition that will also change the results. We have to capture this as well by repeating the calculation.

* Boundary conditions.
  + Simply supported.
  + And sides clamped.

### Limits.

### Plate Size limits:

The plate size limits for a given load such as the plate length or breadth becomes longer, it will fail. So we can find the plate thickness, plate size limits for a given loading on a plate for any component. There are 3 variations and this will be 3-D surface plot if we try find the result.

### Load Limits:

The load limits for a given plate size are the loads (longitudinal, transverse, shear) that can be varied to find the limiting loads on a given plate. There are 3 variations and this will be 3-D surface.

CAN You DO THIS

## Serviceability limit states.

Check of serviceability limit states for slender plates relatedto out of plane deflection may normally be omitted if the smallest span of the plate is less than 120 times the plate

thickness.

CAN You DO THIS

## Validity.

This Recommended Practice is best suited to rectangularplates and stiffened panels with stiffener length being larger than the stiffener spacing ( l > s ). It may also be used for girders being orthogonal to the stiffeners and with the girder having significant larger cross-sectional dimensions than the stiffeners.

- Example Code

Input Function

The following shows how to determine the inputs for a plate buckling calculations and these inputs have been read through munch module.

* import munch
* plateGData1 = {'PlateLength': 2.69, 'PlateLength\_unit' : 'm',
  + 'PlateBreadth' : 0.70, 'PlateBreadth\_unit' : 'm',
  + 'PlateThickness' : 0.014, 'PlateThickness\_unit' : 'm',
  + 'AverageWaterDepth' : 40, 'AverageWaterDepth\_unit' : 'm',
  + 'YieldStrength' : 34 , 'YieldStrength\_unit' : 'ksi',
  + 'PoissionsRatio' : 0.30,
  + 'YoungsModulus' : 30450, 'YoungsModulus\_unit' : 'ksi'}
* plateGDataFT1 = {'PlateLength': 8.82, 'PlateLength\_unit' : 'ft',
  + 'PlateBreadth' : 2.30, 'PlateBreadth\_unit' : 'ft',
  + 'PlateThickness' : 0.046, 'PlateThickness\_unit' : 'ft',
  + 'AverageWaterDepth' : 131.23, 'AverageWaterDepth\_unit' : 'ft',
  + 'YieldStrength' : 34 , 'YieldStrength\_unit' : 'ksi',
  + 'PoissionsRatio' : 0.30,
  + 'YoungsModulus' : 30450, 'YoungsModulus\_unit' : 'ksi'}
* plateGLoading1 = {'LongtudinalStress' : 0.5, 'LongtudinalStress\_unit' : 'ksi',
  + 'TransverseStress' : 0.5, 'TransverseStress\_unit' : 'ksi',
  + 'ShearStress' : 0.7, 'ShearStress\_unit' : 'ksi'}

# How to access objects from above dictionaries (also same for JSON format files)

* constantGvalue1 = {'BucklingFactor' : 0.26,

'BCedges\_simplysupported\_long': 4,

'BC\_sideclamped\_long' : 7.00,

'Resulting material factor': 1.15,

'H4' : 101325,

'H5' : 1025 ,

'H6' : 9.81,

'H7' : 0.000145038,

'H8' : 0.001,

'BR\_transversedirection' : 1,

'Integralfactor' : 0,

'BA\_sheardirection' : 1}

The script below shows how to read above inputs through munch module.

* constantGvalue = munch.munchify(constantGvalue1)
* plateGData = munch.munchify(plateGData1)
* plateGDataFT = munch.munchify(plateGDataFT1)
* plateGLoading = munch.munchify(plateGLoading1)
* l\_G = plateGDataFT["PlateLength"]
* s\_G = plateGDataFT["PlateBreadth"]
* t\_G = plateGDataFT["PlateThickness"]
* d\_G = plateGDataFT["AverageWaterDepth"]
* f\_G = plateGDataFT["YieldStrength"]
* p\_G = plateGDataFT["PoissionsRatio"]
* E\_G = plateGDataFT["YoungsModulus"]
* L\_G = plateGData["PlateLength"]
* S\_G = plateGData["PlateBreadth"]
* T\_G = plateGData["PlateThickness"]
* D\_G = plateGData["AverageWaterDepth"]
* σG\_xx = plateGLoading["LongtudinalStress"]
* σG\_yy = plateGLoading["TransverseStress"]
* τ\_G = plateGLoading["ShearStress"]
* k4\_G = constantGvalue["BucklingFactor"]
* c\_xx = constantGvalue["BCedges\_simplysupported\_long"]
* cxx = constantGvalue["BC\_sideclamped\_long"]
* ϒ\_M = constantGvalue["Resulting material factor"]
* x7 = constantGvalue["H4"]
* x8 = constantGvalue["H5"]
* x9 = constantGvalue["H6"]
* x10 = constantGvalue["H7"]
* x11 = constantGvalue["H8"]
* C\_τ = constantGvalue["BR\_transversedirection"]
* ci\_1 = constantGvalue["Integralfactor"]
* C\_τe2 = constantGvalue["BA\_sheardirection"]

Calculation

The following first line indicates how to take parametric inputs from the input line.

* from DataProvision.parameters\_Col\_All import \*
* from math import sqrt

# How to access objects from above dictionaries (also same for JSON format files)

* σG\_xx,σG\_yy,τ\_G
* x1=s\_G/l\_G
* x2=l\_G/s\_G
* c=(2-x1)
* x3=t\_G/s\_G
* x4=s\_G/t\_G
* x5=l\_G/t\_G

Buckling strength analyses shall be based on the characteristic buckling strength for the most unfavourable buckling mode. The characteristic buckling strength shall be based on the

lower 5th percentile of test results.

# FEA Analysis Stress (No Reduction Factor is used in Spreadsheet)

* σ\_e1=sqrt(σG\_xx\*\*2+σG\_yy\*\*2-(σG\_yy\*σG\_xx)+(3\*τ\_G\*\*2)) # Vonmises Stress (σe)

# Characteristic Material Resistance, σk

* σ\_kx=f\_I
* σ\_ky=f\_I
* τ\_k=f\_I/sqrt(3)
* σ\_e=f\_I

# Edges Simply supported - Uniform Loading

* c\_yy=(1+x1\*\*2)\*\*2
* c\_τ=(5.34+4\*x1\*\*2)

# Elastic Buckling Resistance for each stress direction

* x6=3.14159\*\*2\*E\_I/12/(1-p\_I\*\*2) # PI()^2\*G38/12/(1-G37^2)
* σExx\_Simp=x6\*c\_xx\*x3\*\*2
* σEyy\_Simp=x6\*c\_yy\*x3\*\*2
* τE\_simp=x6\*c\_τ\*x3\*\*2

# Reduced Slenders ratio # σG\_xx,σG\_yy,τ\_G

* λx\_simp=round(sqrt(σ\_kx/σExx\_Simp),2)
* λy\_simp=sqrt(σ\_ky/σEyy\_Simp)
* λτ\_simp=sqrt(τ\_k/τE\_simp)
* λe\_simp=sqrt(f\_I/σ\_e1\*((σG\_xx/σExx\_Simp)\*\*c+(σG\_yy/σEyy\_Simp)\*\*c+(τ\_G/τE\_simp)\*\*c)\*\*(1/c))

# Characteristic Buckling Resistance for serviceability

* σscrx\_simp=σ\_kx/sqrt(1+λx\_simp\*\*4)
* σscry\_simp=σ\_ky/sqrt(1+λy\_simp\*\*4)
* σscrz\_simp=τ\_k/sqrt(1+λτ\_simp\*\*4)
* σescr\_simp=f\_I/sqrt(1+λe\_simp\*\*4)

# Usage factor for serviceability check, Simply Supported.

* ηsx\_simp=σG\_xx/σscrx\_simp
* FALSE=σG\_yy/σscry\_simp
* ηsz\_simp=τ\_G/σscrz\_simp
* ηse\_simp=σ\_e1/σescr\_simp

# Characteristic Buckling Resistance for Ultimate check.

* σucrx\_simp1=(σ\_kx/(sqrt(1+λx\_simp\*\*4)))
* σucrx\_simp2=σ\_kx/sqrt(2)/λx\_simp
* if(λx\_simp<1):
* print("The value of σucrx\_simp1 is ",σucrx\_simp1)
* else:
* print("The value of σucrx\_simp2 is",σucrx\_simp2)
* σucry\_simp1=(σ\_ky/(sqrt(1+λy\_simp\*\*4)))
* σucry\_simp2=σ\_ky/sqrt(2)/λy\_simp
* if(λy\_simp<1):
* print("The value of σucry\_simp1 is ",σucry\_simp1)
* else:
* print("The value of σucry\_simp2 is",σucry\_simp2)
* σucrz\_simp1=(τ\_k/(sqrt(1+λτ\_simp\*\*4)))
* σucrz\_simp2=τ\_k/sqrt(2)/λτ\_simp
* if(λτ\_simp<1):
* print("The value of σucrz\_simp1 is ",σucrz\_simp1)
* else:
* print("The value of σucrz\_simp2 is",σucrz\_simp2)
* σeucr\_simp1=(σ\_e/(sqrt(1+λe\_simp\*\*4)))
* σeucr\_simp2=σ\_e/sqrt(2)/λe\_simp
* if(λe\_simp<1):
* print("The value of σeucr\_simp1 is ",σeucr\_simp1)
* else:
* print("The value of σeucr\_simp2 is",σeucr\_simp2)

# Usage factor for ultimate check, , Simply Supported.

* ηux\_simp=σG\_xx/σucrx\_simp1
* ηuy\_simp=σG\_yy/σucry\_simp2
* ηuz\_simp=τ\_G/σucrz\_simp1
* ηue\_simp=σ\_e1/σeucr\_simp2

# Sides clamped - Uniform Loading

* cyy=(1+2.5\*x1\*\*2+5\*x1\*\*4)
* cτ=(9+5.6\*x1\*\*2)

# Elastic Buckling Resistance for each stress direction.

* σExx\_Simp=x6\*cxx\*x3\*\*2
* σEyy\_Simp=x6\*cyy\*x3\*\*2
* τE\_Simp=x6\*cτ\*x3\*\*2

# Reduced Slenders ratio.

* λx\_side=sqrt(σ\_kx/σExx\_Simp)
* λy\_side=sqrt(σ\_ky/σEyy\_Simp)
* λτ\_side=sqrt(τ\_k/τE\_Simp)
* λe\_side=sqrt(f\_I/σ\_e1\*((σG\_xx/σExx\_Simp)\*\*c+(σG\_yy/σEyy\_Simp)\*\*c+(τ\_G/τE\_Simp)\*\*c)\*\*(1/c))

# Characteristic Buckling Resistance for serviceability.

* σscrx\_side=σ\_kx/sqrt(1+λx\_side\*\*4)
* σscry\_side=σ\_ky/sqrt(1+λy\_side\*\*4)
* σscrz\_side=τ\_k/sqrt(1+λτ\_side\*\*4)
* σescr\_side=f\_I/sqrt(1+λe\_side\*\*4)

# Usage factor for serviceability check, Sides Clamped.

* ηsx\_side=σG\_xx/σscrx\_side
* ηsy\_side=σG\_yy/σscry\_side
* ηsz\_side=τ\_G/σscrz\_side
* ηse\_side=σ\_e1/σescr\_side

# Characteristic Buckling Resistance for Ultimate Check.

* σucrx\_side1=σ\_kx/(sqrt(1+λx\_side\*\*4))
* σucrx\_side2=σ\_kx/sqrt(2)/λx\_side
* if(λx\_side<1):
* print("The value of σucrx\_side1 is ",σucrx\_side1)
* else:
* print("The value of σucrx\_side2 is",σucrx\_side2)
* σucry\_side1=σ\_ky/(sqrt(1+λy\_side\*\*4))
* σucry\_side2=σ\_ky/sqrt(2)/λy\_side
* if(λy\_side<1):
* print("The value of σucry\_side1 is ",σucry\_side1)
* else:
* print("The value of σucry\_side2 is",σucry\_side2)
* σucrz\_side1=τ\_k/(sqrt(1+λτ\_side\*\*4))
* σucrz\_side2=τ\_k/sqrt(2)/λτ\_side
* if(λτ\_side<1):
* print("The value of σucrz\_side1 is ",σucrz\_side1)
* else:
* print("The value of σucrz\_side2 is",σucrz\_side2)
* σeucr\_side1=σ\_e/(sqrt(1+λe\_side\*\*4))
* σeucr\_side2=σ\_e/sqrt(2)/λe\_side
* if(λe\_side<1):
* print("The value of σeucr\_side1 is",σeucr\_side1)
* else:
* print("The value of σeucr\_side2 is",σeucr\_side2)

# Usage factor for ultimate check, Sides Clamped.

* ηux\_side=σG\_xx/σucrx\_side1
* ηuy\_side=σG\_yy/σucry\_side2
* ηuz\_side=τ\_G/σucrz\_side1
* ηue\_side=σ\_e1/σeucr\_side2

# Buckling resistance stress in longitudinal direction.

Buckling checks of unstiffened plates in compression shall be made according to the effective width method. The reduction in plate resistance for in-plane compressive forces is expressed by a reduced (effective) width of the plate which is multiplied by the design yield strength to obtain the design resistance.

The design buckling resistance of an unstiffened plate under longitudinal compression force may be calculated as.

* λ\_p=0.525\*x4\*sqrt(f\_I/E\_I)
* Cx=(λ\_p-0.22)/λ\_p\*\*2
* if(λ\_p>0.673):
* print("The value for slendrness grater than equal to (0.673)",Cx)
* else:
* print("The value is",1)
* σxrd=Cx\*f\_I/ϒ\_M

# Buckling resistance stress in Transverse direction.

In case of linear varying transverse stress the capacity check can be done by use of the design stress value at a distance l1 from the most stressed end of the plate, but not less than 0.75

of maximum σy,Sd.

The design buckling resistance of a plate under transverse compression force may be found from:

* λ\_c=1.1\*x4\*sqrt(f\_I/E\_I)
* µ=0.21\*(λ\_c-0.2)
* k1=1 # if(l\_c<=0.2): print("the value of k",k)
* k2=1/(2\*λ\_c\*\*2)\*((1+µ+λ\_c\*\*2)-sqrt((1+µ+λ\_c\*\*2)\*\*2-4\*λ\_c\*\*2))
* k3=1/(2\*λ\_c\*\*2)+0.07
* p\_Sd\_pa=101325+1025\*D\_G\*x9
* p\_Sd\_ksi=p\_Sd\_pa\*x10\*x11
* x12= 2\*(x3\*\*2)\*f\_I #x7=2\*(t\_G/s\_G)^2\*f\_y
* #IF(0.05\*G43-0.75<0,0,0.05\*G43-0.75)
* h\_α1=0.05\*x4-0.75
* h\_α2=0.05\*x4-0.75
* if(h\_α1<0):
* print(" The value of h\_α1 is",0)
* else:
* print(" The value of h\_α is",h\_α2)
* Kp1=1
* Kp2=1-h\_α2\*((p\_Sd\_ksi/f\_I)-2\*x3\*\*2)
* if(p\_Sd\_ksi<=p\_Sd\_pa):
* print(" The value of Kp is",Kp1)
* else:
* print(" The value of Kp is",Kp2)
* σy\_R=(1.3\*t\_G/l\_G\*sqrt(E\_I/f\_I)+k4\_G\*(1-1.3\*t\_G/l\_G\*sqrt(E\_I/f\_I)))\*f\_I\*Kp1
* σy\_rd=σy\_R/ϒ\_M

# Buckling resistance stress in Shear direction.

* kl\_1=5.34+4\*(x1)\*\*2
* kl\_2=5.34\*x1\*\*2+4
* if(x1<1):
* print("The value of kl\_1 is",kl\_1)
* else:
* print("The value of kl\_2 is",kl\_2)
* λ\_w=0.795\*x4\*sqrt(f\_I/(E\_I\*kl\_1))
* if(λ\_w>1.2):
* print(0.9/λ\_w)
* if(λ\_w>0.8):
* print(1-0.625\*(λ\_w-0.8))
* else:
* print("The value of C\_τ is",C\_τ)
* τ\_rd=C\_τ/ϒ\_M\*f\_I/sqrt(3)

# Buckling resistance stress in Bi-axial with Shear direction.

A plate subjected to biaxially loading with shear should fulfil the following requirement where if both σx,Sd and σy,Sd is compression (positive) then ci\_2=(1-s\_G/(120\*t\_G)) for s/t <= 120

And ci\_2=0 for s/t > 120.

If either of σx,Sd and σy,Sd or both is in tension (negative), then ci = 1.0.

In order to perform cross sectional checks for members subjected to plate buckling the local buckling effects can be accounted for by checking the resistance by using the effective width.

* ci\_2=(1-s\_G/(120\*t\_G))
* if(x4>120):
* print("The value of ci\_1",ci\_1)
* else:
* print("The value of ci\_2",ci\_2)
* k\_l=kl\_1
* λ\_w=λ\_w
* C\_τe1=(1-0.8\*(λ\_w-0.8))
* if(λ\_w>1.25):
* print(1/λ\_w\*\*2)
* if(λ\_w>0.8):
* print("The value of C\_τe1 is",C\_τe1)
* else:
* print("The value of C\_τe2 is",C\_τe2)
* τrd=C\_τe2/ϒ\_M\*f\_I/sqrt(3)
* σ\_xrd=σxrd
* σ\_yrd=σy\_rd
* τ\_rd=τrd
* x15=(σG\_xx/σ\_xrd)\*\*2+(σG\_yy/σ\_yrd)\*\*2-ci\_2\*(σG\_yy/σ\_xrd)\*(σG\_yy/σ\_yrd)+(τ\_G/τ\_rd)\*\*2

# DNV-RP-C201 Usage factor

* Longitudinal=σG\_xx/σxrd
* Transverse=σG\_yy/σy\_rd
* Shear=τ\_G/τ\_rd
* Biaxial=sqrt(x15)