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



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# INTRODUCTION

# THEORY

When the external loads are defined, the size of the plate is defined, we may need to increase the thickness of the plate. Alternatively, we can also add a stiffener. The limiting size of the plate for a given thickness is also important.

## 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)

# Buckling of plates.

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 (σcr) and in shear ().

## In Edge Compression.

This critical compressive stress of a plate when subject to compression (σcr) can be found from the following.

Where:

E = modulus of elasticity in compression (Steel = 30,000,000 psi)

t = thickness of plate, inches

b = width of plate, inches

a = length of plate, inches

v = Poisson's ratio (for steel, usually = 0.3)

k = constant (depends upon plate shape (b/a) and support of sides).

If the resulting critical stress (σcr) from this formula is below the proportional limit (σy), buckling is said to be elastic and is confined to a portion of the plate away from the supported side thus does not mean complete collapse of the plate at this stress. This is

Represented by the portion of the C to. D .If the resulting value (σcr) is the Proportional limit. (σp), indicated by the portion of the curve A to C, buckling is said to be inelastic. Here, the tangent modulus (Et) must be used in some form to replace Young's or secant modulus (E) in the formula for determining (σcr).

This problem can be simplified by limiting the maximum value of the critical buckling stress (σcr) to the yield strength (σε) However, the value of the critical buckling stress (σcr) may be calculated if required.

Above the proportional limit (σp), the ratio no longer constant, but varies, depending upon the type of steel (represented by its stress-strain diagram) and the actual stress under consideration (position on the stress-strain diagram).

|  |  |
| --- | --- |
| **Values for plate factor (k) to be used in formula** | **Critical stress on plate to cause Buckling** |
| K=0.425 |  |
| K=1.277 |  |
| K=4.00 |  |
| K=5.42 |  |
| K= 6.97 |  |

Table 3‑1 Compression on load plate.

Above the proportional limit (σP) the modulus of elasticity (E) must be multiplied by a factor (A) to give the tangent modulus (Et). The tangent modulus (Et) is still the slope of the stress-strain diagram and but it varies.

If it is assumed that the plate is isotropic" (i.e., having the same properties in both directions x and y), the critical buckling formulas becomes. Where

If it is assumed that the plate has "anisotropic" behaviour (i.e. not having the same properties in both directions x and y), the tangent modulus (Et) would be used for stress in the x direction when the critical stress (σcr) is above the proportional limit (σp) .However, the modulus of elasticity (E) would be used in the y direction because any stress in this direction would be below the proportional limit (σp). In this case, the above formula would be conservative and the following would give better results.

For the steel becomes

If the critical buckling stress (σcr) is less than the Proportional limit (σcr) then and

formula #4 could be used directly in solving for critical stress (σcr).

However, if the critical buckling stress (σcr) is Greater than the proportional limit (σp), then and formula #4 cannot be used directly. It would be better to divide through by and express the formula as

From the value of will give the value of (σcr) .Obtain proper value for the plate

factor (k) from Table 1 or 3.

### Tangent modulus factor.

Blecich in "Buckling Strength” of Metal Structures" gives the following expression for this factor .

Where:

(σy) = Yield Point

(σp) = Proportional Limit

(σcr) = Critical Buckling stress.

If we use a ratio of the expression becomes.

Then, multiply through by

|  |  |
| --- | --- |
| Values for plate factor (k) to be used in formula | Critical stress on plate to cause Buckling(τ’cr) |
|  |  |
|  |  |

Table 3‑2 Shear on load plate.

## Buckling of plates under shear.

The critical buckling shearing stress (τcr) of a plate when subject to shear forces (τ t) may be expressed by the formula. (Similar to that used for the critical buckling stress for plates in edge compression).

Where:

E = modulus of elasticity in compression (Steel = 30,000,000 psi)

t = thickness of plate, inches

b = width of plate, inches

a = length of plate, inches(a is always the larger of the plate dimensions)

v = Poisson's ratio (for steel, usually = 0.3)

k = constant (depends upon plate shape (b/a) and edge restraint and also accounts for the modulus of elasticity in shear Ea).

It is usual practice to assume the edges simply supported .Shear yield strength (τ) is usually considered as of the yield strength or .58

Since the plate constant (k) can be adjusted to contain the 3 factor this becomes.

Since

|  |  |
| --- | --- |
| Values for plate factor(k) to be used in formulas | Critical stress (τ’cr) and (σ’cr) |
| When  When |  |
| When  When |  |
| When  When |  |
| When  When |  |

Table 3‑3 Critical stress for rectangular plates on 4 sides

As before in the buckling of plates by compression, in the inelastic range the critical stress (σcr)

exceeds the proportional limit (σp) and the tangent modulus (Et) is introduced by the factor .Therefore, formulas #5 and #6 would be used also in the buckling of plates by shear.

Proper values for the plate factor (k) are obtained from Table 2 for pure shear load, and Table 3, for shear load, combined with compression.

|  |  |
| --- | --- |
| **Values for plate factor (k) to be used in formulas** | **Critical stress (τ’cr) and (σ’cr)** |
| When    Where |  |
| When    Where |  |
| When    Where    Where |  |

3‑1 Critical stress for rectangular plates on 4 sides

## Summary.

1. The value of the plate factor (k) to be used in formula #5 comes from Tables 1, 3 or 3, adapted from "Buckling Strength of metal Structures", Bleich, pp 330, 395, 410.
2. Solve for from formula #5.

a. If this is the value of σcr, so go to step 4.

b. If go to step 3.

1. Insert this value in to the formula 6, and solve for the critical buckling stress (σcr).

4. After the critical stress (σcr) has been determined, the critical buckling stress of the given plate

Is (σcr or τcr) determined from the relationship shown in the right-hand column of Tables 1, 3, or 3.

## Buckling stress curves (Compression)

In regard to plates subjected only to compression or only to shear, H , M. Priest and J. Gilligan in their "Design Manual for High Strength Steels" show the curve patterns, Figure 5 (compression) and Figure 10 (shear). They have divided the buckling curve into three distinct portions (A-B, B-C, and C-D), and have lowered the critical stress values in the elastic buckling

region by 25% to more nearly conform to actual test results.

Values indicated on this typical curve are for ASTM A-7 (mild) steel, having a yield strength of

33,000 psi. The buckling curve (dashed line) of Figure2 has been superimposed on the Priest-Gillizan curve for comparison.

The horizontal line (A to B) is the limit of the yield strength (σcr) .Here (σcr) is assumed equal to (σy). The curve from C to D is expressed by.

|  |  |
| --- | --- |
| **Factor** | **Critical buckling compressive stress(σcr) determined by** |
|  |  |
|  | Where |
|  |  |

Table 3‑4 Buckling stress formulas.

Where

The curve from C to D is 75% of the critical buckling stress formula. Figure 1 or:

All of this is expressed in terms of the factor

Factors needed for the formula^ of curves in Figure 5, for steels of various yield strengths, are given in Table 5.

Figure 6 is just an enlargement of Figure 5, with additional steels having yield strengths from 33,000 psi to 100,000 psi.

For any given ratio of plate width to thickness (b/t), the critical buckling stress (σcr) can be read directly from this figure.

## Factor of safety.

A suitable factor of safety must be used with these values of b/t since they represent ultimate stress values for buckling. Some structural specifications limit the ratio (b/t) to a maximum value (point B) at which the critical buckling stress (σcr) equal to the yield strength (σy) . By so doing, it is not necessary to calculate the buckling stress. These limiting values of b/t, as specified

by several codes, are given in Table 6.

In general practice, somewhat more .liberal values of b/t are recognized. Table 7, extended to higher yield strengths, lists these limiting values of b/t.

## Effective width of plates in compression.

The 20" X 1/4" plate shown in Figure 7, simply supported along both sides, is subjected to n compressive load.

Under 'these conditions, the critical buckling compressive stress (σcr) as found from the curve (σy=33,000 psi) in Figure 6 is

Since the ratio is 40.0 and thus exceeds the value of 31.5 for point C, the following formula

must be used.

At this stress, the middle portion of the plate would be expected to buckle, Figure 8. The compressive load at this stage of loading would be

The over-all plate should not collapse since the portion of the plate along the supported sides could still be loaded up to the yield point (σy) before ultimate collapse. This portion of the plate, called the "effective width" can be determined by finding the ratio b/t when (σcr) is set equal to yield strength (σy) or point B.

Since (Both sides simply supported),the ratio

Since the plate thickness

This is the effective width of the plate which may be stressed to the yield point (σy) before ultimate collapse of the entire plate.

The total compressive load at this state of loading would be as shown in Figure 9.

The total compressive load here would be.

Another method makes no allowance for the central buckled portion as a load carrying member, it being assumed that the load is carried only by the supported portion of the plate. Hence the total compression load would be.

## Buckling stress curves shear.

The Priest & Cilligan curve, corresponding to Figure 5, when applied to the buckling of plates in shear is shown in Figure 10.

The curve is expressed in terms of see Table 8. Comparison of Figure 10 and Table 8 with Figure 5 end Table 4 reveals the parallelism of critical buckling stress for compression (σcr) and for shear (τcr).

Figure is just an enlargement of Figure, with additional steels having yield strength from 33,000 psi to 100,000 psi. Factors needed for the formulas of curves in figure are given in Table 9.

For any value of the critical buckling shear stress (τcr) can be read directly from the curves of

this figure.

A suitable factor of safety must be used with these values since they represent ultimate stress values for buckling.

By holding the ratio of to the value at point B (τcr=τy) and it will not be necessary to compute the critical shear stress (τcr) assuming the edges are simply supported the value of Then using just the three values of b/a as 1 (a square panel),1/2 (the length twice the width of panel) and zero (or infinite length), the required b/t value is obtained from Table 10 for steels of various yield strengths. The plate thickness is then adjusted as necessary to meet the requirement.

Notice in Figure 10 and Table 8 that the critical buckling stress in shear is given directly as.In Tables 2 and 3 it is given first as (σcr) and then changed to (τcr).