

Fatigue Design Basics in Accordance with the Canadian Code and the EuroCode

by:

Caroline (Lai Yung) Ngan

requirements in accordance with the Canadian Code as well as the EuroCode were also summarized and compared. The two design requirements are generally the same by using S-N curves developed based on different details. The prevalent difference between the two codes is the explicit use of safety factor in the EuroCode. Calculations were done using formatted spreadsheet to compare results from the two different codes. It was found that the results from the EuroCode can be similar to the Canadian code depending on the safety factor chosen for EuroCode design.

Abstract

This report presented background information with regards to fatigue and fatigue design. The fatigue process from crack initiation, crack growth, crack propagation, to final rupture were briefly discussed. The two types of fatigue problems, namely, low cycle fatigue and high cycle fatigue were also introduced with a description of Wohler's characteristic S-N curves. The design

Table of Content

Abstract 1
 2.0 Characteristics of Fatigue 4
 2.1 Phases in the fatigue process..... 4
 2.2 Fatigue Behavior 6
 3.0 Fatigue Design in Accordance with the Canadian Code 9
 3.1 General Specification..... 9
 3.2 Design Criteria 10
 4.0 Fatigue Design in Accordance with the EuroCode..... 14
 4.1 General Specification..... 14
 4.2 Design Criteria 16
 5.0 Comparison of CAN/CSA S16 and EuroCode3 and tools available 18
 5.1 Formatted spreadsheets for fatigue calculations 18
 5.2 Web-based tool for fatigue calculation using EC3 21
 6.0 Conclusion 23
 Reference 24

1.0 Introduction

A material subjected to repetitive or fluctuating stress will fail at a stress much lower than that required to cause fracture on a single application of load. Failures occurring under this condition of dynamic loading are called fatigue failure. Fatigue accounts for at

least 90 percent of all service failures due to mechanical causes. Fatigue failures are generally more dangerous than other types of failures because they occur suddenly without significant prior deformations.

Fatigue phenomena describe the progressive and localized structural damage that occurs when a material is subjected to cyclic loading, discovered during the XIXth century. The most important problems of failure by fatigue were found around 1850 during the development of the European railroad. The first explanation was that metal crystallizes under the action of the repeated loads. This idea originated from the coarsely crystalline appearance of many surfaces of parts broken by fatigue.

This report will first present some basic background information about fatigue followed by methods used for fatigue design in accordance with the Canadian Code and the Eurocode. Fatigue

calculations based on these two different codes will be compared by using formatted spreadsheets and web-based tools that are available.

2.0 Characteristics of Fatigue

Fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The maximum stress values are less than the ultimate tensile stress limit, and may be below the yield stress limit of the material. Under repeated stresses, materials undergo some internal progressive, permanent structural changes. The damage from cyclic loading is cumulative and materials do not recover when rested.

2.1 Phases in the fatigue process

The process of fatigue failure starts with dislocation movements, eventually forming persistent slip bands that nucleate short cracks. The essential conditions for fatigue failure are cyclic tensile loads, stress levels above a threshold value, and a flaw in the material.

The phases of fatigue, as illustrated by Figure 1, are:

1. Crack initiation

2. Crack growth
3. Crack propagation
4. Final rupture

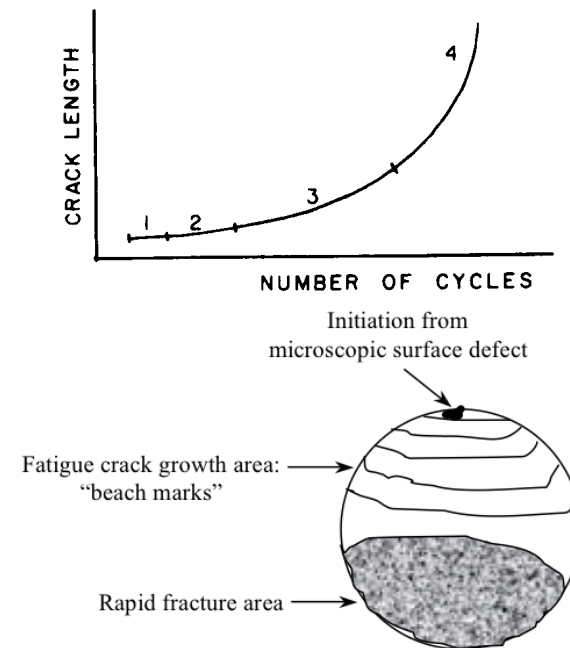


Figure 1 Stages to fatigue failure from (1) crack initiation, (2) crack growth, (3) crack propagation, to (4) Final rupture

Fatigue cracks usually originate on a free surface at a point of high stress concentration in the material. Sources of high stress

concentrations may be from abrupt changes in cross section (e.g. threads), flaws in the material, or surface scratches cause by handling or tooling of the material. As the member is subjected to repeated loading, the material around stress concentration undergoes a slip mechanism, which is a movement of dislocation, or displacement of the atomic matrix. When the cyclic load is repeated several times, reverse slip on adjacent slip planes may lead to the formation of extrusions and intrusions at the surface. Cracks will begin to grow along the slip plane and will eventually change direction until it is growing in a plane perpendicular to the principle tensile stress. Under repeated shear, torsional, or tensile loads, fatigue cracks will propagate. As stress levels increase, crack grows become more rapid. The process of crack growth is repeated until the crack reaches some critical length at which time a sudden failure would occur.

Fatigue failure can easily be recognized by examining the fracture. A fatigue fracture will have two distinct regions as shown in Figure 1. One part of the surface will be smooth or burnished as a result of the rubbing of the bottom and top of the crack as it is growing. The other part will be rather granular due to the rapid failure of the material. Other features of a fatigue fracture are Beachmarks and Striations. Beachmarks may be seen in fatigue failures of materials where the materials have been used for a period of time, allowed to rest for an equivalent time period and then loaded again. Striations can often only be seen through a microscope. They are thought to be steps in crack propagation, where the distance depends on the stress range. Beachmarks may contain thousands of striations as shown in Figure 2.



Figure 2 Example of Beachmarks and striations found in fatigue fracture

2.2 Fatigue Behavior

The dimensioning of a structure to fatigue is more difficult than with static loads because ruptures by fatigue depend on localized stresses. Since the fatigue stresses are in general too low to produce a local plastic deformation and with the redistribution associated with the stresses, it is necessary to carry out a detailed analysis which takes into account at the same time the total model of the stresses and the strong localized stresses due to the concentrations. On the other hand, analysis of static stresses requires only the definition of the total stress field and the high localized stresses

being redistributed by local deformation. The three fundamental steps necessary are the definition of the loads, detailed analysis of the stresses, and the consideration of the statistical variability of the loads and the properties of materials. Fatigue damage depends strongly on the oscillatory components of the load, its static component and the order of application of loads.

There are two types of fatigue problems; namely, low cycle fatigue and high cycle fatigue. During low cycle fatigue, the stresses are usually high enough for plastic deformation to occur. In that case, the account in terms of stress is less useful and the strain in the material offers a simpler description. The main interest in low cycle fatigue is the crack initiation life. The approach used in low cycle fatigue is strain-life approach or the study of cyclic work hardening.

On the contrary, high cycle fatigue is most focused on situation that require more than 10^4 cycles to failure where stress is low and deformation is primarily elastic. The main interest in this case is crack propagation life and the fatigue life is estimated by fracture mechanics method.

The material's performance is commonly characterized by Wohler's S-N curves, which is a graph of the magnitude of cyclical stress (S) against the logarithmic scale of the number of repeated cycles of loading (N) that a material will undergo before it fails (Figure 3)

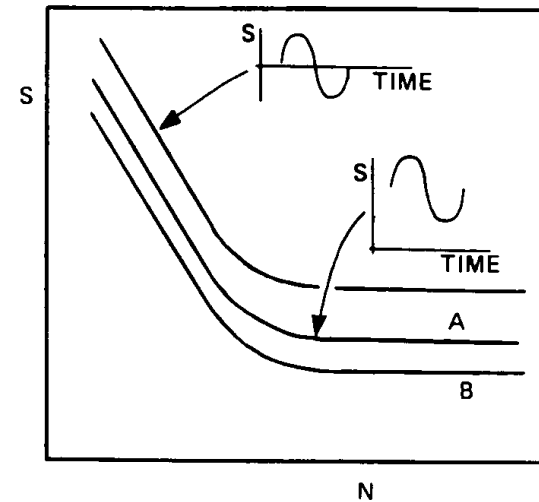


Figure 3 Wohler's characteristic S-N Curves

The S-N curves are derived from tests on samples of the material to be characterized where a regular sinusoidal stress is applied by a testing machine which also counts the number of cycles to failure. Each test generates a point on the plot. In general, the higher the fatigue stress level, the fewer number of loading cycles required to cause failure. The major factors that effect fatigue life are:

1. Shape of the connection

2. Magnitude of stress variations
3. Mean stress level
4. Choice of material

The fatigue life of a material is also influenced by factors such as temperature, surface finish, presence of oxidizing or inert chemicals, residual stresses, contact, etc. As shown by the plateau at the tail of the S-N curve in Figure 3, some materials exhibit a theoretical fatigue limit below which continued loading does not lead to failure.

3.0 Fatigue Design in Accordance with the Canadian Code

According to the Canadian Code, CAN/CSA S16, fatigue limit state is the limiting case of the slow propagation of a crack within a structural element that can result either from live load effects directly or as the consequence of local distortion within the structure due indirectly to live load effects. These two cases are referred to as live-load induced fatigue and distortion-induced fatigue, respectively. The limit state of fatigue is checked at load levels expected to occur many times during the life of the structure. Clause 26 of the CAN/CSA S16 specifies the requirement for fatigue design. This section will outline the calculations required for load-induced fatigue effect. Distortion-induced fatigue effects will not be included because this phenomenon arises from the relative movement of connected parts of an assemblage in such a way that large localized strains are produced. Since this condition is not usually included in design calculations, the only requirement

under distortion-induced fatigue is that “members and connections shall be detailed to minimize distortion-induced fatigue that may occur in regions of high strain at the interconnection of members undergoing differential displacements”.

3.1 General Specification

For fatigue calculations under live load induced effect, specified loads shall be used. A specified load less than the maximum specified load but acting with a greater number of cycles may govern and hence needs to also be considered. In general, members and connections subjected to fatigue loading need to be designed, detailed, and fabricated so as to minimize stress concentrations and abrupt changes in cross section. Unless otherwise stated, the design life of the structure is taken to be 50 years.

The controlling stress feature considered for live load induced fatigue is the range of stress to which the element is subjected. In most cases, ordinary elastic analysis and the principles of mechanics of materials are sufficient to obtain the stresses associated with the element. However, sophisticated analysis may be required for conditions such as major access holes and cut-outs. The stress range is simply the algebraic difference between the maximum and minimum stress at a given location. It should also be noted that fatigue calculations are only necessary for locations with net applied tensile stress. Stress ranges that are completely in compression need not be investigated for fatigue.

3.2 Design Criteria

According to Clause 26.3.2, the fatigue resistance, F_{sr} , needs to be greater than or equal to the calculated stress range at detail due to passage of the fatigue load, f_{sr} .

$$F_{sr} \geq f_{sr}$$

Equation 1

The fatigue resistance in turn is defined as:

$$F_{sr} = \left(\frac{\gamma}{nN} \right)^{\frac{1}{3}} \geq F_{srt}$$

Equation 2

where

- γ = fatigue life constant
- n = number of stress range cycles at given detail for each application of load
- N = number of applications of load
- F_{srt} = constant amplitude threshold stress range

The fatigue life constant (γ), number of stress range cycles (n), and number of applications of load (N), are defined in Table 10 in the code and according to different detail category. The detail categories are specified in Table 9 with illustrative examples in

Figure 2 of Section 26. A sample of the detail category and constants are shown in Figure 4 and Figure 5.

Table 9
Detail Categories for Load-Induced Fatigue
(See Clauses 26.3.1 and 26.3.4.)

General condition	Situation	Detail category	Illustrative example (see Figure 2)
Plain members	Base metal	A	1, 2
	<ul style="list-style-type: none"> with rolled or cleaned surfaces. Flame-cut edges with a surface roughness not exceeding 1000 (25 µm) as defined by CSA Standard B95 		
	<ul style="list-style-type: none"> of unpainted weathering steel 	B	
	<ul style="list-style-type: none"> at re-entrant corners of geometric discontinuities such as copes, cuts, or block-outs 	B	2a
Built-up members	at net section of eyebar heads and pin plates	E	
	Base metal and weld metal in components, without attachments, connected by		3, 4, 5, 7
	<ul style="list-style-type: none"> continuous full-penetration groove welds with backing bars removed, or continuous fillet welds parallel to the direction of applied stress 	B	

(Continued)

Figure 4 Detail categories for load-induced fatigue in CAN/CSA S16 Table 9

Table 10
Fatigue Constants for Various Detail Categories
(See Clauses 26.3.3 and 26.3.4.)

Detail category	Fatigue life constant, γ , MPa	Constant amplitude threshold stress range, F_{wt} , MPa	nN'	Fatigue life constant, γ' , MPa
A	8190×10^9	165	1.82×10^6	223×10^{15}
B	3930×10^9	110	2.95×10^6	47.6×10^{15}
B1	2000×10^9	83	3.50×10^6	13.8×10^{15}
C	1440×10^9	69	4.38×10^6	6.86×10^{15}
C1	1440×10^9	83	2.52×10^6	9.92×10^{15}
D	721×10^9	48	6.52×10^6	1.66×10^{15}
E	361×10^9	31	12.1×10^6	0.347×10^{15}
E1	128×10^9	18	21.9×10^6	0.0415×10^{15}

Figure 5 Fatigue constants for various detail categories in CAN/CSA S16 Table 10

Table 10

Alternatively, the values shown in Table 10 of the CAN/CSA S16 can be obtained from the series of parallel straight lines, the S-N curves, with slopes of 1/3 presented in Figure 6.

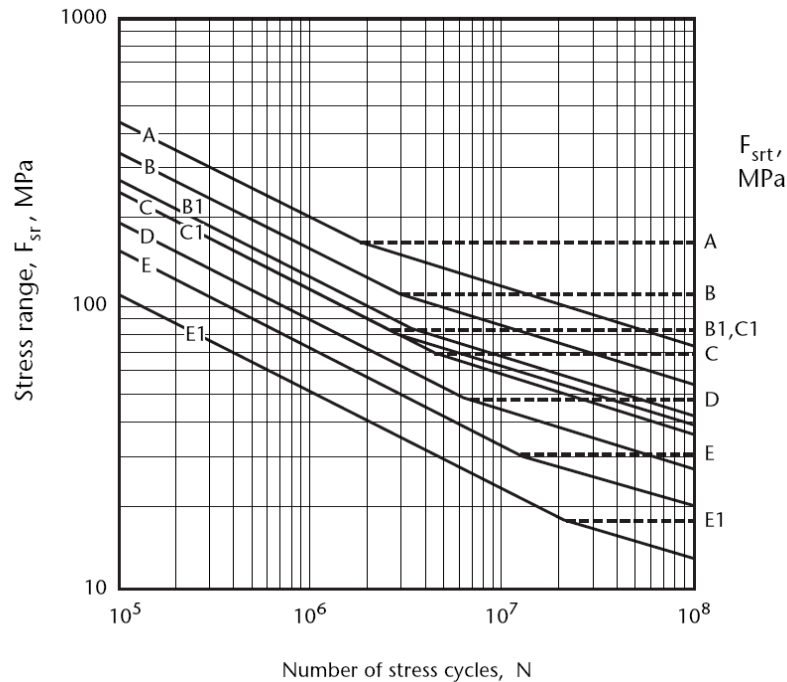


Figure 6 Characteristic S-N curves in CAN/CSA S16 for various detail categories

Each line has been established from a series of constant amplitude fatigue tests on details representative of the category at the mean minus two standard deviations on the fatigue life. The horizontal

dashed lines represent the constant amplitude threshold stress ranges as listed in Figure 5.

To calculate the fatigue resistance, the designer must estimate the number of applications (N) of the live load over the design life of the structure as well as the number of applications (n) of the stress range for each passage of the load.

For elements with stresses not applied at constant amplitude, the total damage from different fatigue loadings need to be calculated.

This can be done so by:

$$\sum \left[\frac{(nN)_i}{N_{fi}} \right] \leq 1.0$$

Equation 3

where $(nN)_i$ = number of expected stress range cycles at stress range level i

N_{fi} = number of cycles that would cause failure at stress range level i

The use of the above equations for fatigue design calculations will be demonstrated in an example in Section 5.0.

4.0 Fatigue Design in Accordance with the EuroCode

Eurocode is a set of pan-European model building codes developed by the European Committee for Standardization. Eurocode 3, EC3, contains details for designs of steel structures and Part 1.9 of EC3 deals with the fatigue strength of steel structures.

4.1 General Specification

According to Eurocode 3, the aim of designing a structure against the limit state of fatigue is to ensure, with an acceptable level of probability, that its performance is satisfactory during its entire design life, such that the structure is unlikely to fail by fatigue or to require repair of damage caused by fatigue. The required safety level is obtained by applying the appropriate partial safety factors.

In EC3, it is stated that no fatigue assessment is normally required for building structures except:

- members supporting lifting appliances or rolling loads
- members subject to repeated stress cycles from vibrating machinery
- members subject to wind-induced oscillations
- members subject to crowd-induced oscillations.

Moreover, no assessment is required if:

$$\gamma_{Ff} \Delta\sigma_p \leq \frac{\Delta\sigma_D}{\gamma_{Mf}}$$

Equation 4

where γ_{Ff} = partial safety factor for fatigue loads
 γ_{Mf} = partial safety factor for fatigue strength
 $\Delta\sigma_p$ = stress range caused by the loads for the fatigue assessment
 $\Delta\sigma_D$ = constant amplitude fatigue limit

The partial safety factor for fatigue loads (γ_{FF}) accounts for uncertainties in:

- the applied load levels
- the conversion of these loads into stresses and stress ranges
- the equivalent constant amplitude stress range from the design stress range spectrum
- the design life of the structure, and the evolution of the fatigue loading within the required design life of the structure.

The value of the partial safety factor for fatigue load is typically taken to be 1.0.

The partial safety factor for fatigue strength (γ_{Mf}), on the other hand, accounts for uncertainties in the fatigue resistance and the effects of:

- the size of the detail
- the dimensions, shape and proximity of the discontinuities

- local stress concentrations due to welding uncertainties
- variable welding processes and metallurgical effects

The value of this partial safety factor depends on the safety concepts considered and is summarized in Table 1.

Table 1 Partial safety factor for fatigue strength according to EC3

Safety Concept	Consequence of failure	
	Low consequence	High consequence
Damage tolerant concept	1.00	1.15
Safe life concept	1.15	1.25

The damage tolerant concept is based on limiting the growth of fatigue cracking and its consequence by means of a mandatory inspection program whereas the safe life concept is based on the calculation of damage during the structure design's life using standard lower bound endurance data (characteristic S-N curves) and an upper bound estimate of fatigue loading.

4.2 Design Criteria

In accordance with EC3, stresses are determined by an elastic analysis of the structure under fatigue loading where dynamic response of the structure or impact effect shall be considered when appropriate. In parent material, stresses are nominal stress ranges, modified nominal stress ranges or geometric stress ranges. For penetration or fillet welded joints, the forces transmitted by a unit length of weld shall be resolved into component transverse (normal stress) and parallel (shear stress) to the longitudinal axis of the weld.

Generally, the safety verification may be carried out in terms of the damage equivalent stress range for 2 million cycles by comparing it with the fatigue strength.

The fatigue strength of a material is defined for normal stresses by a series of $\log \Delta\sigma_r - \log N$ curves (S-N curves), each applying to a typical detail category.

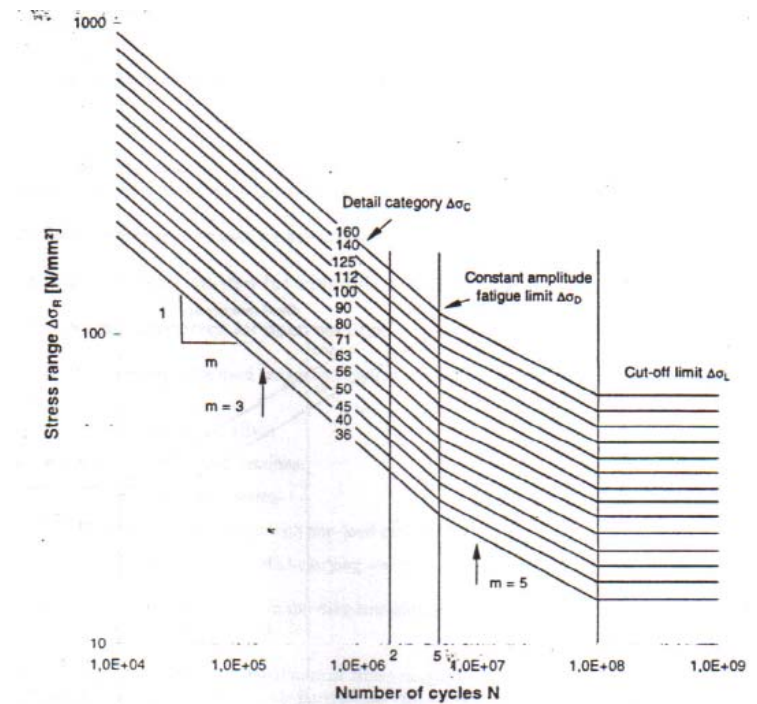


Figure 7 Characteristic S-N curves in EC3

These curves are based on representative experimental investigations and thus include the effects of:

- Local stress concentrations due to the weld geometry
- Size and shape of acceptable discontinuities
- Stress direction
- Residual stresses
- Metallurgical conditions
- In some cases, the welding process and post-weld improvement procedures

The plots shown in Figure 7 is similar to that used in the Canadian code as shown in Figure 6, except that the detail categories are now designated by a number which represents, in N/mm^2 , the reference value $\Delta\sigma_c$ of the fatigue strength at 2 million cycles. Also, another difference is that the S-N curves used in EC3 consist of two sloped section before the plateau of infinite life. Namely, the parallel curves have a slope of $m = 3$ until a constant amplitude fatigue limit $\Delta\sigma_D$, after which the

slope becomes $m = 5$ until the cut-off limit of $\Delta\sigma_L$. In the Canadian code, the curve has a slope of $m = 3$ until the infinite life plateau.

Similar to the Canadian Code, cumulative damage needs to be calculated if the member is subjected to a number of stress ranges using Equation 3. The calculations based on EC3 will be demonstrated in an example in Section 5.0.

5.0 Comparison of CAN/CSA S16 and EuroCode3 and tools available

There are pre-built tools available for the fatigue design calculations based on both the CAN/CSA S16 and the EuroCode3. The two tools that will be described in this section are a spreadsheet developed by M. Gedig and S.F. Stiemer and a web-based tool developed by D. Kern using Java script.

5.1 Formatted spreadsheets for fatigue calculations

In the formatted spreadsheet, the cumulative damage of a member subjected to one or more fatigue loadings can be calculated based on both the Canadian code and EC3. The user's input includes the stress ranges and the corresponding number of cycles in each stress range. Also the user needs to specify the various constants required as per the Canadian and EC3 for the specific detail

category the calculation is for. For the Canadian code, the constants input are the fatigue life constant (γ), constant amplitude threshold stress range (F_{srt}), and the slope of the S-N curve (m).

These values can be obtained from Table 10 of Section 26 as described earlier. For EC3, the constants needed are the constant amplitude fatigue limit ($\Delta\sigma_D$), cut off limit ($\Delta\sigma_L$) and the slopes for the two sections of the curve (m_1 and m_2). Figure 8 is a screen capture of the input section of the spreadsheet.

36					
37	General information:				
38	Canadian Code:				
39	Detail Category A				
40	Fatigue Life constant	y	=	8.19E+12	
41	constant amplitude threshold stress	F _{st}	=	165	Mpa
42	normal stress	m	=	3.0	
43	EC3				
44	Detail Category 160				
45	Constant of category 160	ΔσD	=	117	
46	Constant of category 160	ΔσL	=	64	
47	slope when Δσ ₁ > Δσ ₁ /γ _M	m1	=	3	
48	ΔσL/γ _M	m2	=	5	
49	Input:				
50	Stress ranges 1	Δσ1	=	220	Mpa
51	Stress ranges 2	Δσ2	=	90	Mpa
52	Stress ranges 3	Δσ3	=	45	Mpa
53	number of cycles in stress range 1	n1	=	200000	cycles
54	number of cycles in stress range 2	n2	=	3000000	cycles
55	number of cycles in stress range 3	n3	=	100000000	cycles
56	Calculations:				
57	Canadian Code:				
58	Allowable number of cycles in s.r.	N1	=	if(Δσ1>F _{st} /2, γ(Δσ1) ^m D)	769159 cycles
59	Allowable number of cycles in s.r.	N2	=	if(Δσ2>F _{st} /2, γ(Δσ2) ^m D)	11234568 cycles
60	Allowable number of cycles in s.r.	N3	=	if(Δσ3>F _{st} /2, γ(Δσ3) ^m D)	0 cycles
61	damage 1	d1	=	if(N1>0, n1/N1, 0)	0.26
62	damage 2	d2	=	if(N2>0, n2/N2, 0)	0.27
63	damage 3	d3	=	if(N3>0, n3/N3, 0)	0.00
64	Miner's rule	n	=	d1+d2+d3	0.53 OK
65	EC3				
66	Partial safety factor 1	γ _M 1	=	1.00	
67	Allowable number of cycles in sr1a	N1ag1	=	if(N1bg1>0, IF(Δσ1>=ΔσL/γ _M 1, 5E+6*((ΔσD/γ _M 1)/(Δσ1)) ^m 1, 0)	752072 cycles
68	Allowable number of cycles in sr1b	N1bg1	=	if(Δσ1>=ΔσL/γ _M 1, IF(ΔσD/γ _M 1>Δσ1, 5E+6*((ΔσD/γ _M 1)/(Δσ1)) ^m 2, 0), 0)	0 cycles
69	Allowable number of cycles in sr1c	N1cg1	=	IF(Δσ1<ΔσL/γ _M 1, INF, "0")	0 cycles
70	Allowable number of cycles in sr2a	N2ag1	=	if(N2bg1>0, IF(Δσ2>=ΔσL/γ _M 1, 5E+6*((ΔσD/γ _M 1)/(Δσ2)) ^m 1, 0)	0 cycles
71	Allowable number of cycles in sr2b	N2bg1	=	if(Δσ2>=ΔσL/γ _M 1, IF(ΔσD/γ _M 1>Δσ2, 5E+6*((ΔσD/γ _M 1)/(Δσ2)) ^m 2, 0), 0)	0 cycles

Figure 8 Formatted spreadsheets for calculating cumulative damage of a member

The calculation as per the Canadian Code is rather straight forward using equations as outlined in Section 3. Namely, the first step is to check if the stress range is below the constant amplitude threshold stress range. If it is, the number of cycles will be finite

and the damage level will be zero. If the stress range is higher than the constant amplitude threshold stress range, calculations will be carried out to determine the allowable number of cycles in each stress range by using Equation 2. The damage level in each stress range is calculated by taking the actual number of cycles, specified by the designer, divided by the allowable number of cycles calculated. The cumulative damage level is simply taken as the sum of the damage level from each stress range. Whether the design is safe or not is checked by using Equation 3; namely, it is safe if the total damage is less than or equal to 1.

For designing in conformity with EC3, the user must first define the required partial safety factor based on Table 2 according to the safety concept used and the consequence of failure. The calculations for EC3 are slightly more complicated because of the 2-sloped S-N curves as described in Section 4.2. Calculations must first be done to decide if the user specified stress ranges are

in the first part of the curve with $m = 3$, second part of the curve with $m = 5$, or below the constant amplitude threshold. The allowable number of cycles to failures is then calculated accordingly. The damage level for each stress range and the cumulative damage are calculated similar to that described for Canadian Code.

Depending on the various safety factor chosen, different cumulative damage will be obtained. Table 3 is a summary of results obtained as a comparison of the two codes based on the three stress levels as shown in Figure 8: (i) 220 MPa with 0.2 million cycles (ii) 90 MPa with 3 million cycles, and (iii) 45 MPa with 100 million cycles.

Table 2 Comparison of results using formatted spreadsheets

	Cumulative Damage
Canadian Code	0.53 (OK)
EC3	
Partial safety factor = 1 (Damage tolerant concept – low consequence)	0.44 (OK)
Partial safety factor = 1.15 (Damage tolerant concept – high consequence, or Safe life concept – low consequence)	0.74 (OK)
Partial safety factor = 1.25 (Safe life concept – high consequence)	1.02 (FAIL)

From Table 2, it is obvious that the cumulative damage level and whether the design is safe or not, is highly dependent on the safety concept considered and the level of consequence for EC3. In the Canadian Code, the safety level is incorporated into the calculations and the user does not have the option to adjust the factor. Based on the comparison in Table 2, it seems that the implicit safety factor used in the Canadian Code is approximately 1.1.

5.2 Web-based tool for fatigue calculation using EC3

Another tool available is a web-based tool developed by D. Kern, which provides explanations and calculations for EC3 fatigue part.

Figure 9 shows a screen capture of the front page of the website.

(http://www.sigi.ca/engineering/subsites/steel_eurofatigue/introduction.html)

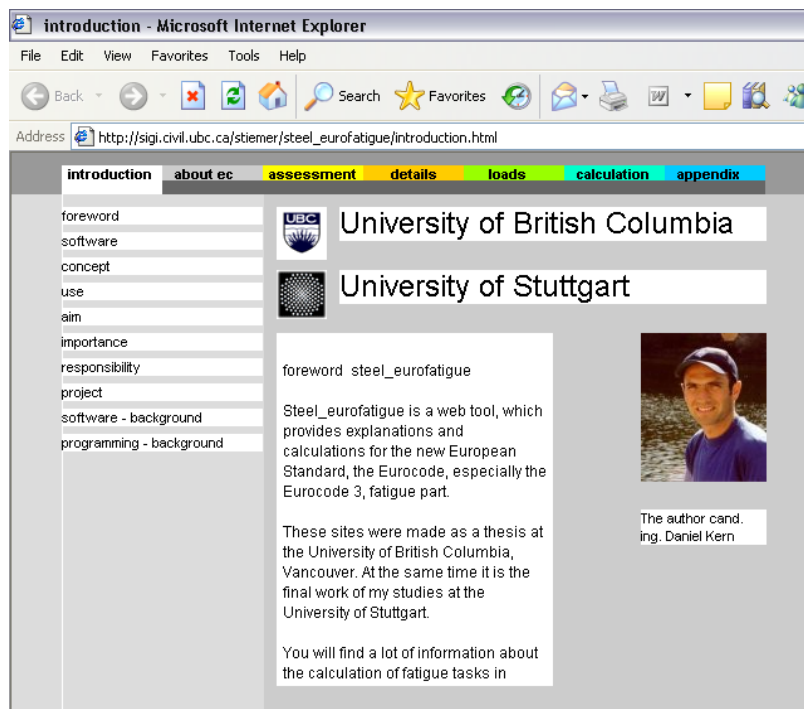
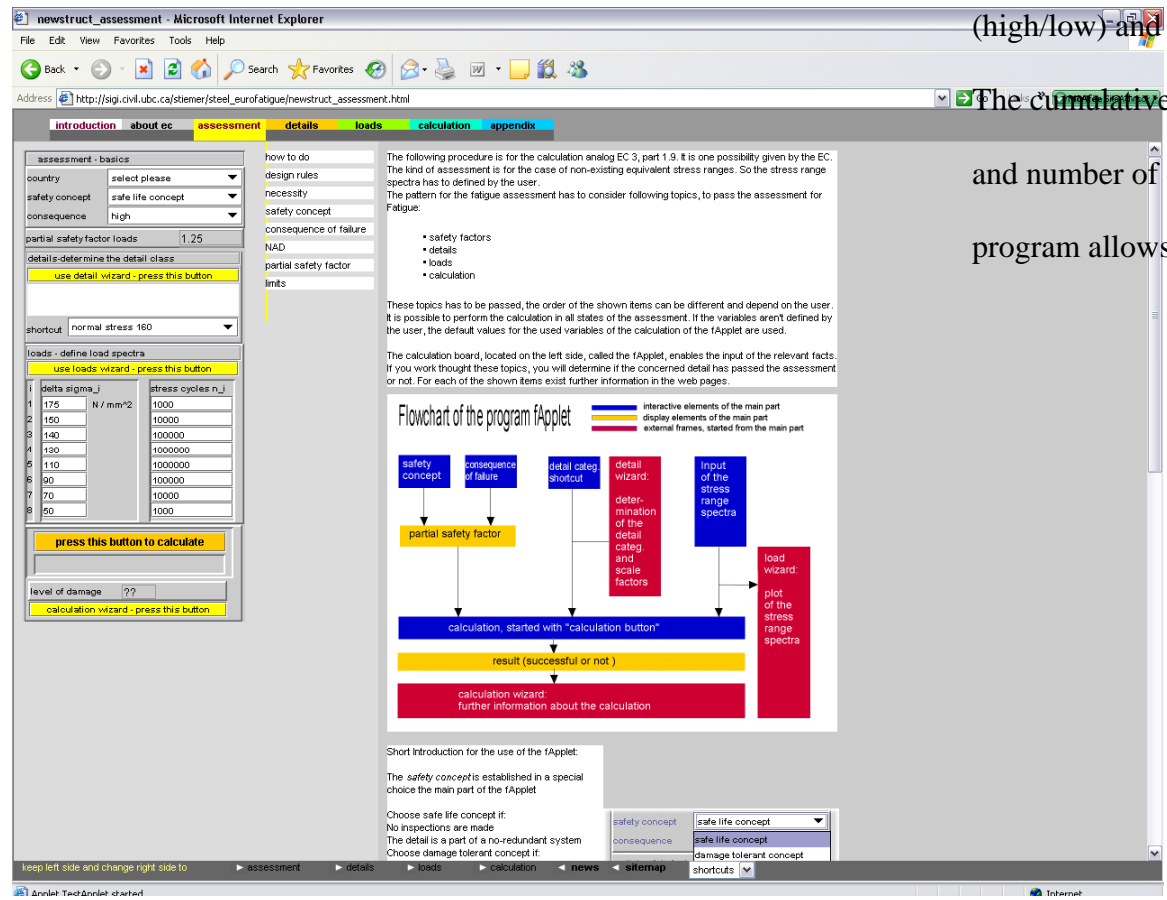


Figure 9 Home page for the web-based tool for fatigue calculation based on EC3

On the website, one can find a lot of information about the calculation of fatigue in general, information about details under cycling stress, a calculation program, and further information about metal fatigue. Under “Assessment” in the menu bar across the top of the page (yellow), one can perform the same calculation as was done with the formatted spreadsheet (Figure 10).



(high/low) and the detail category of the detail (normal stress level).

The cumulative damage is calculated after the various stress ranges and number of cycles in each stress range are entered. The program allows for up to 8 different stress ranges.

Figure 10 Cumulative Fatigue calculation page under “Assessment”

In this case, user does not need to enter the constant individually.

These constants are automatically generated when the user specifies the safety concept being used, the consequence

6.0 Conclusion

This report presented the basic concepts of the fatigue phenomenon for members subjected to repeated numbers of cyclic tensile loading. In general, one is concerned with high cycle fatigue and the performance of the member is assessed using characteristic S-N curves. The specific conditions for fatigue failure to occur were outlined and should be taken into consideration for designs. Fatigue failure should be avoided if possible because of its sudden failure behavior.

The design calculations in compliance with the Canadian Code CAN/CSA S16 and the Eurocode EC3 were also summarized. The basic concepts used for the two codes are generally the same. Namely they make use of the Wohler's characteristic S-N curves developed for different detail categories. The prevalent difference between the two codes is the explicit use of safety factor for the

Eurocode. Based on different safety factor chosen for EC3, the calculated damage level can be similar or drastically different from that calculated using the Canadian code.

Reference

Canadian Institute of Steel Construction. 2003. Handbook of Steel Construction, 8th Edition.

European Committee for Standardization. 2000. Eurocode 3: Design of steel structures. European Prestandard

Kern, D. 2000. Steel Eurofatigue.

http://www.sigi.ca/engineering/subsites/steel_eurofatigue/introduction.html

Lalanne, C. 2002. Fatigue Damage. Mechanical Vibration and Shock, Volume IV. pp 69 – 110.

Meisl, C. 2003. Fatigue Failure of Bolted Connections. University of British Columbia term project