Andy Matthews

Senior Bridge Engineer

Taking Dreams and turning them into Reality

It's a hard job at times

Overview

- DCC Structure
- The switch to Eurocodes
- Typical Projects
- Summary

Background

Plymouth Uni 1988 – 1992 B.Eng Hons

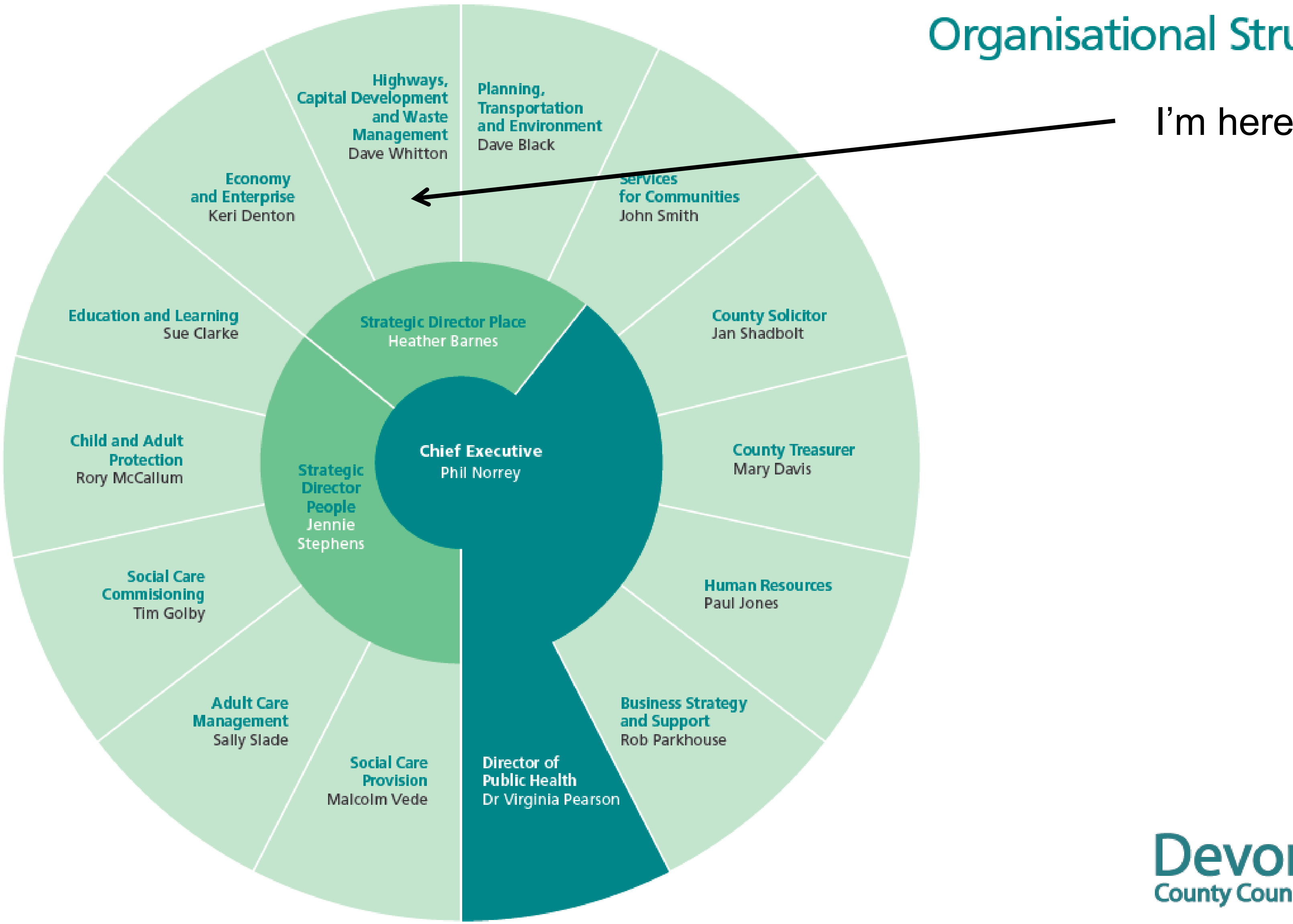
Private Sector 93 to 97

Devon County from there on

Chartered with the Institute of Structural Engineers 2003

Marking Examiner for CM IStrucE Exam

Organisational Structure



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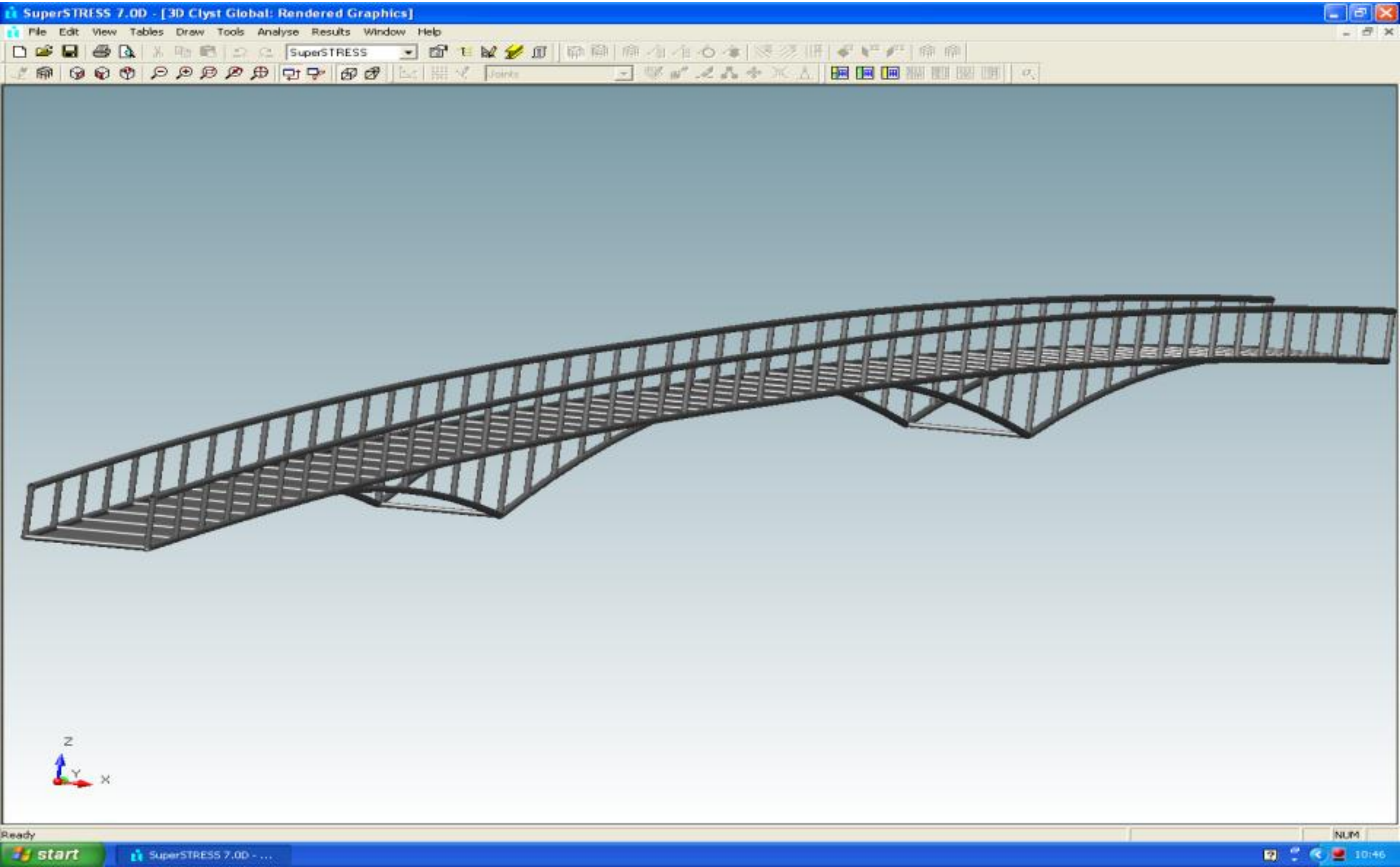
What does EDG do?

- Over 5000 bridges to look after
- Lots of retaining walls
- Cycle path development
- Technical approval process from Developers
- Recycling Centre's
- And the odd new highway bridge

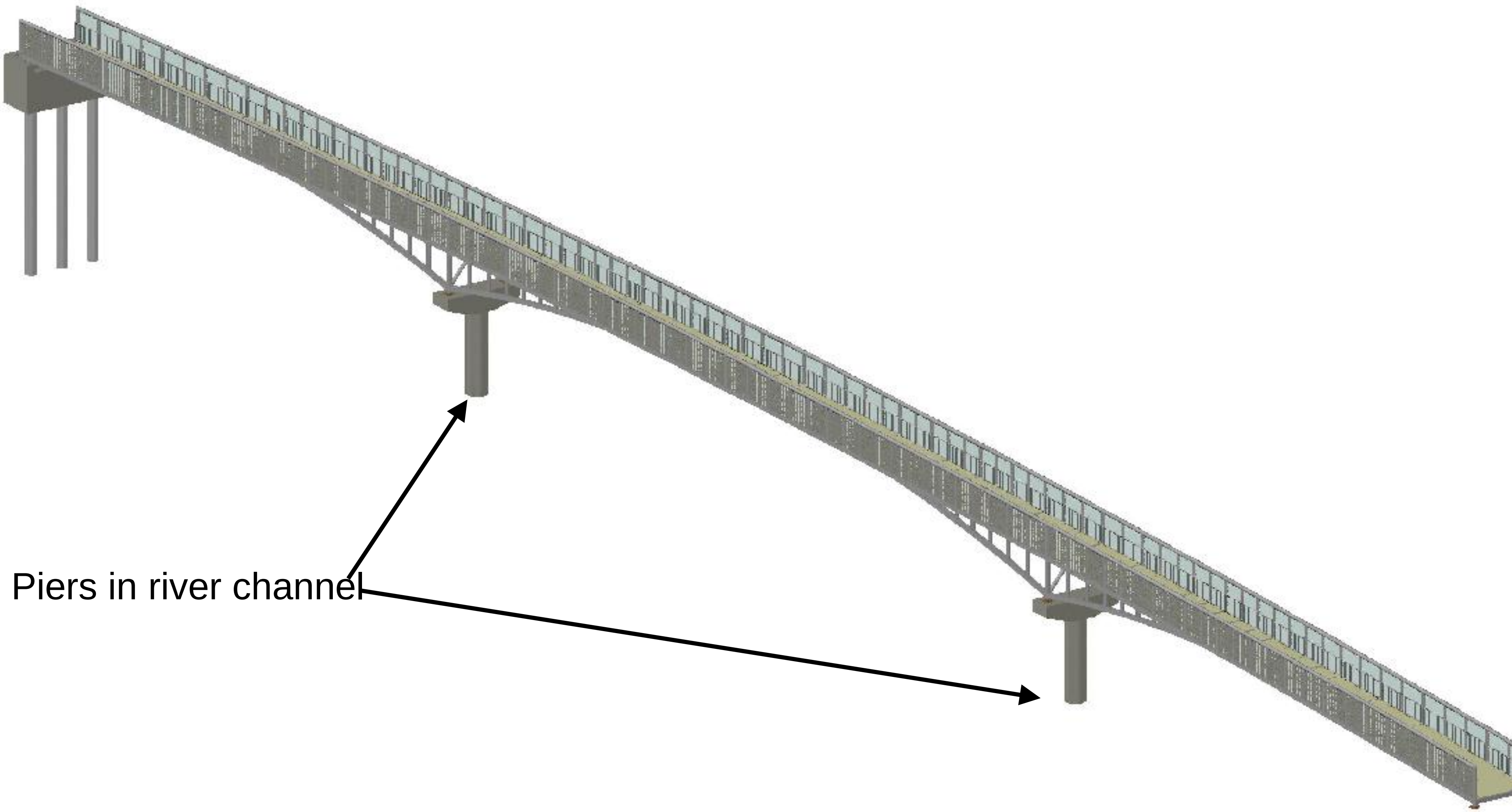
Training of staff

- Chef Engineer Decision to switch to Eurocode Design
- 3 Day Bridge Design training course for 12 in 2009
- Afternoon workshops in house – on going
- Graduates – Student extracts

First Eurocode Design 2009



Clyst Bridge



Clyst Bridge What did we learn?

- EC3-1-8 Connection Design very useful
- Need PD6695-2
- BS checks need to run along side (Ready Reckoners)
- Scheme Cost Estimate £2,8M ; approx £0,7M on temp works
- To costly the Dream never became a Reality

EC3-2 against BS5400 Pt3 Comparison

<u>3-2 6.3.4.2 (6) Calculation of Ncrit</u>

Smeared stiffness of internal u-frames c :-

$c = C_d / l_u$; $\gamma = c L^4 / E I$

For flexible end frames m is modified by PD 6695-2 Cl 9

$N_{crit} = m N_e$ 2383 kN 71% $A_g f_y$

3-1-1 6.3.1.1 Buckling resistance

$N_{b;Rd} = \chi A f_y / \gamma_{M1}$ 1645 kN (uls)

Back work to calculate true l_e

$l_e = \sqrt{(\pi^2 E I_y / N_{crit})}$ 8874 mm

<u>Pt 3 Cl 9.6.4.1.1.2 Discrete lateral restraints</u>

Check restraints are effective?

$\delta_e < l_R^3 / 40EI_c$ YES

$l_e = k_2 * k_3 * k_5 * (E * I_c * l_u * \delta_R)^{1/4}$ but not less than $k_3 * l_u$

$l_e = 8864$ mm

So N_{Ed} = 1118 kN (ULS B) < N_{Rd} so all okay ?

EC3-2 U-Frame flow chart

Step 1 Determine Stiffness of internal frame

Step 2 Determine Stiffness of end frame

Step 3 Select appropriate value of m depending if end frames are stiff or flexible and calculate Ncrit

Step 4 Calculate le from Ncrit and check against value determined by BS5400 Pt 3

Step 5 Calculate NRd Top chord compression resistance

Step 6 Calculate NEd in Top Chord at Midspan

Step 7a Calculate FEd forces acting on intermediate torsion restraints

Step 7b Calculate FEd forces acting on intermediate lateral restraints

Step 7c Check variance of NEd along top chord

Step 8 Calculate Fc forces acting on intermediate U-Frames

Step 9 Calculate design effects on U-frames vert braces (Primary My,Ed)

Step 10 Check MRd > MEd on U-frame vert braces

EC3-2 U-Frame flow chart

Step 11 Calculate design effects on U-frame trans deck member (Primary My,Ed)

Step 12 Check MRd > MEd on U-frame trans deck member

Step 13 Calculate Fs forces at the supports

Step 14 Calculate design effects on end frame (Axial + bi-axial bending)

Step 15a Check MRd > MEd on end U-frames

Step 15b Calculate Vp,Rd of vert end frame

Step 15c Calculate NRd of vert end frame

Step 15d Carry out M; N & V Interaction check
Step 16 Calculate design effects on end U-frame trans deck member (Primary My,Ed)
Step 17 Check MRd > MEd on end U-frame trans deck member
Step 18 Calculate Fcr of structure
Step 19 Check Fcr / FEd > 10
Step 20 Calculate Mz,Ed on Top Chord
Step 21a Calculate MRd of top chord
Step 21b Calculate Vp;Rd of top chord
Step 21c Carry out M; N & V Interaction check on top chord
Step 22 Review top chord size

Step 23 Grab a beer to celebrate!

Now where do I put the crane?

Combinations of Actions to EN 1990 : 2002

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6.4.3.2 Combinations of Actions for persistent or transient design situation ULS

Eq 6.10

Design Effect

Factored prestress

$$E_d = E\{\Sigma_{j\geq 1}\,\gamma_{G,j}\,G_{k,j}\text{ “+” }\gamma_p P\text{ “+” }\gamma_{Q,1}\,Q_{k,1}\text{ “+” }\Sigma_{i>1}\,\gamma_{Q,i}\,\psi_{0,i}\,Q_{k,i}\}$$

Effect of

Sum of Factored permanent actions

Factored leading variable action

Sum of Factored accompanying variable actions

Note ! ψ_i isn't applied to the leading action

Hard Sums

Teign Crossing Cycle Bridge NCN 9

TCCB- Why Eurocode design opposed to British Standards

Prior to Eurocodes two principal C of P would have been used

- BS 5400 Pt 3 Design of Steel Highway Structures
- BD 37/01 Loads on Highway structures

TCCB - BS5400 Pt 3

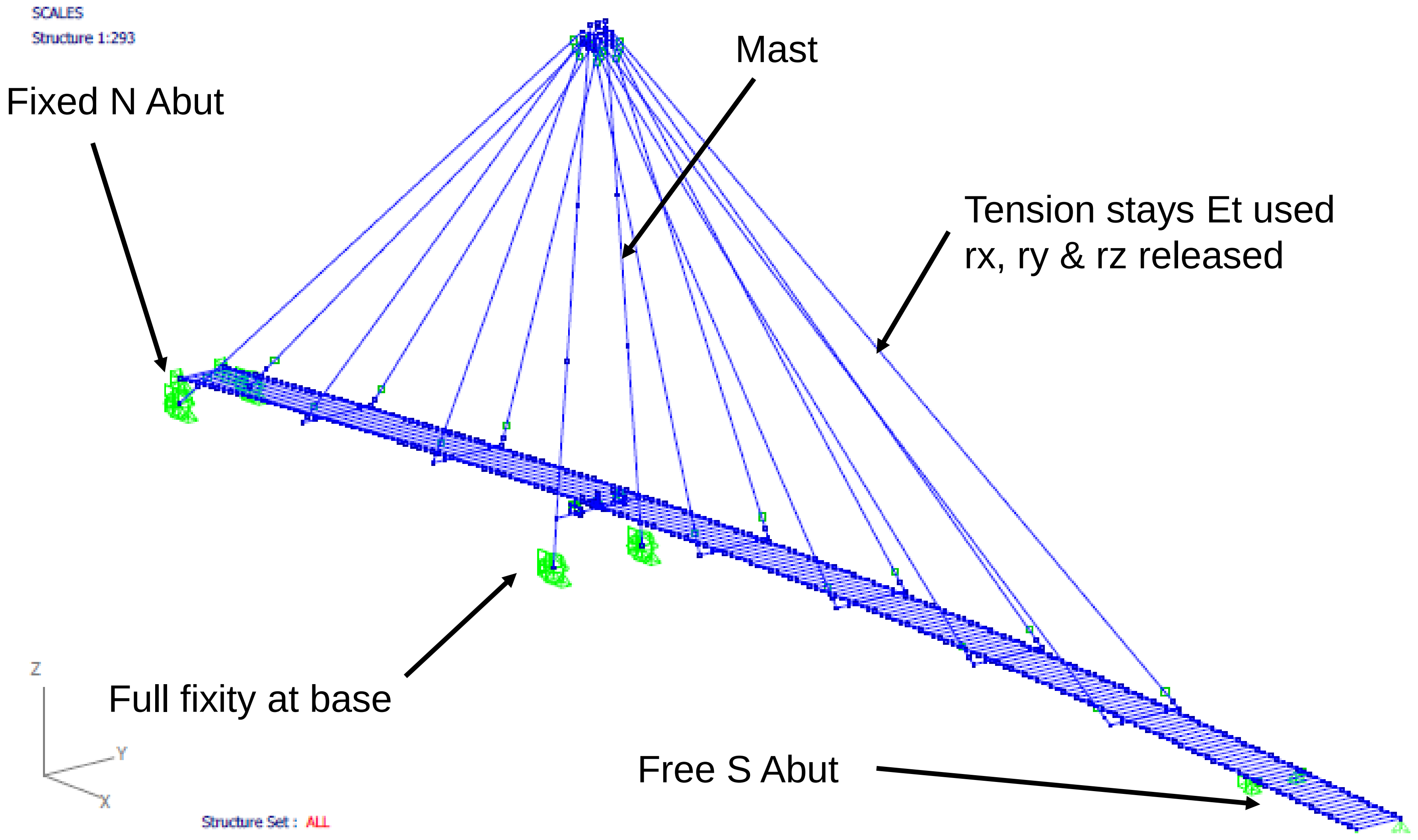
The BS for bridges for was primarily for :-

- Plate Girders
- Fabricated Box Structures

It doesn’t cover :-

- Cable stayed structures
- Hollow section connection design

TCCB – Modelling



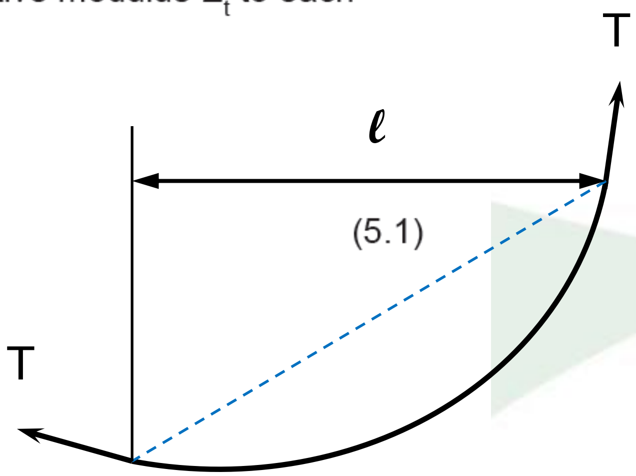
TCCB – Modelling Stays

Stays are subject to non linear behaviour EC3-1-11 is most helpful!

5.4.2 Catenary effects

(1) Catenary effects may be taken into account by using the effective modulus E_t to each cable or its segment:

$$E_f = \frac{E}{1 + \frac{w^2 \ell^2 E}{12\sigma^3}} \qquad (5.1)$$



E	is the modulus of elasticity of the cable in N/mm²
w	is the unit weight according to Table 2.2 in N/mm³
ℓ	is the horizontal span of the cable in mm
σ	is the stress in the cable in N/mm². For situations according to 5.3 it is σ_{G+P}.

TCCB- Eurocode Actions - Dynamics

BD 37/01 is limited in terms of dynamic analysis

- Only one person is considered to cross the bridge at a time!

- EC1-2 states:-

 “Appropriate dynamic models of pedestrian loads and comfort criteria should be defined”

And that’s about it!

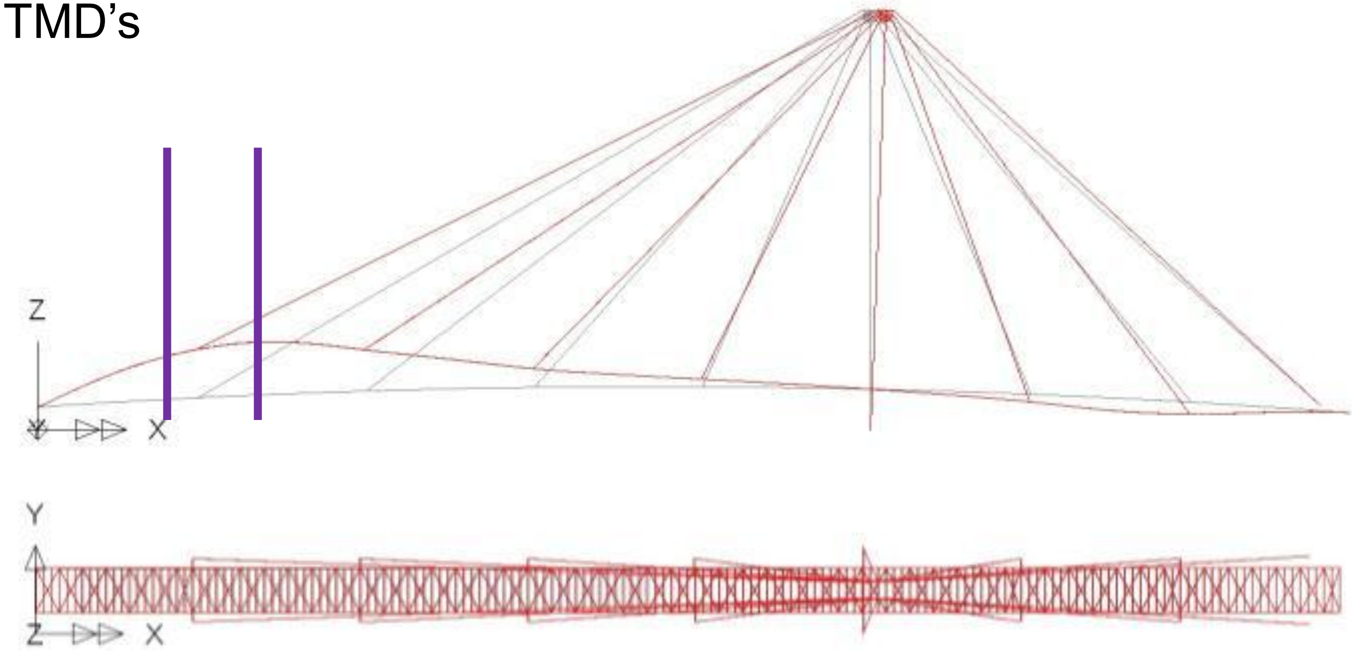
- NA to EC1-2 gives 3 load cases to consider

TCCB – Dynamics First Vertical Natural Frequency f_{n1}

Theory fn1 = 1,88 Hz
Measured = 2,1 Hz

Calculated a_{max} = 2,65 ms^{-2} (Joggers)
Limit = 1,3 ms^{-2}

Positions of 2 TMD's



Teign Crossing Cycle Bridge NCN 9

TCCB In summary

Full Eurocode Design

Designed In House

Independent Design Check (Jacobs)

TMD's required

Shortlisted for IStrucE Awards

9 months detailed design

Could have done it a lot quicker with EC+

Footbridge Dynamics causes headaches

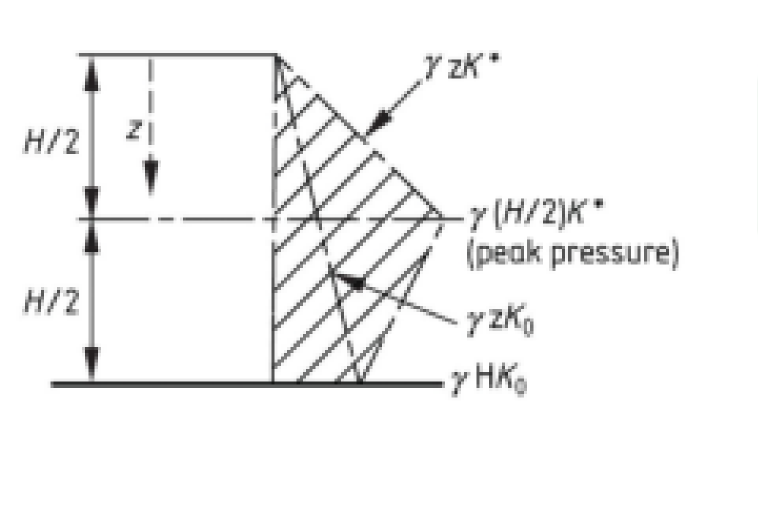
It’s not always big and glamorous

Crediton Link Road

Fully integral deck designed using EC+

Shortcomings in EC7

PD6694-1 is a real life saver



Earth pressures

Crediton Link Road

Devon County Council

Crediton Link Road

Crediton Link Road

Fully Designed to Eurocodes using EC+

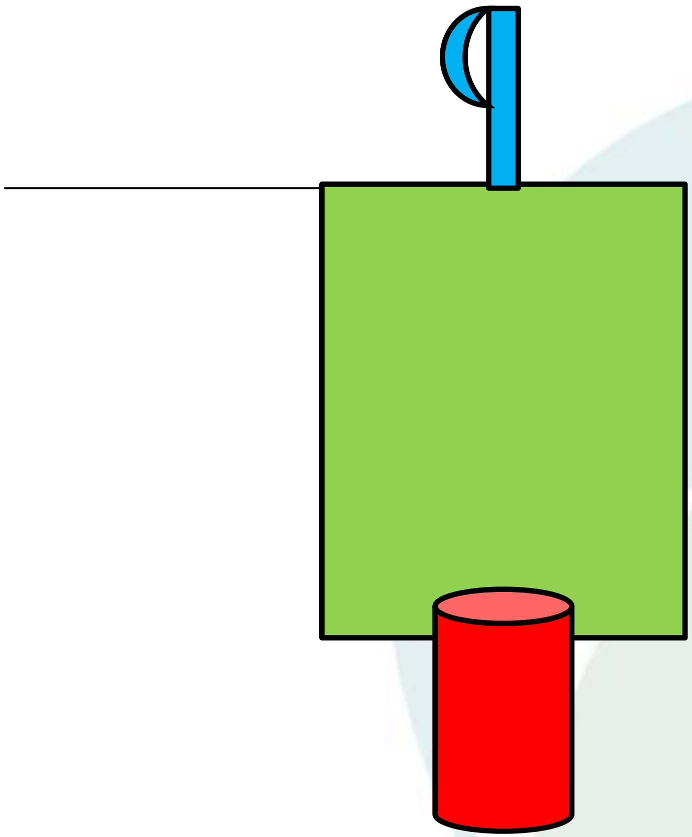
New Highway loading approx 30% more than HA

(Highway Loading isn’t 2 No 40t trucks)

Pre stressed Concrete Design little change

Getting to grips with best practise

Road Restraint Example



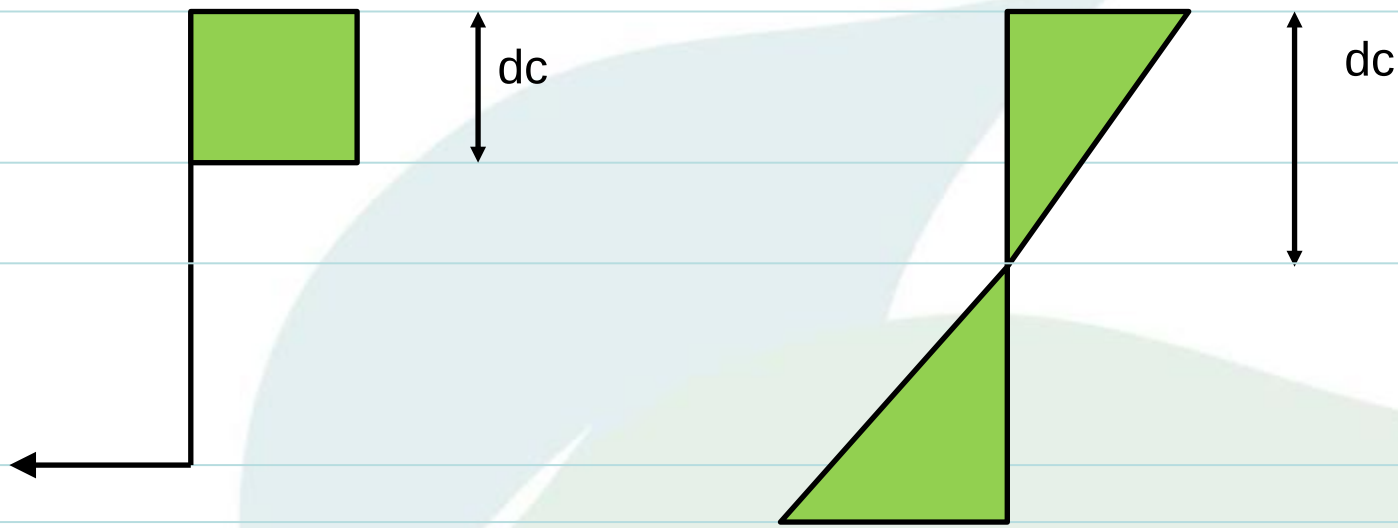
External Design

900 wide 1200 deep

Reinforced 24 B32’s (1,8 %)

“Satisfy crack checks”

Road Restraint Example



ULS Stress Block

Concrete in tension ignored

SLS Stress Block

Un cracked

As,min is based on the area of concrete in tension before the crack forms!

Eurocodes – The old way

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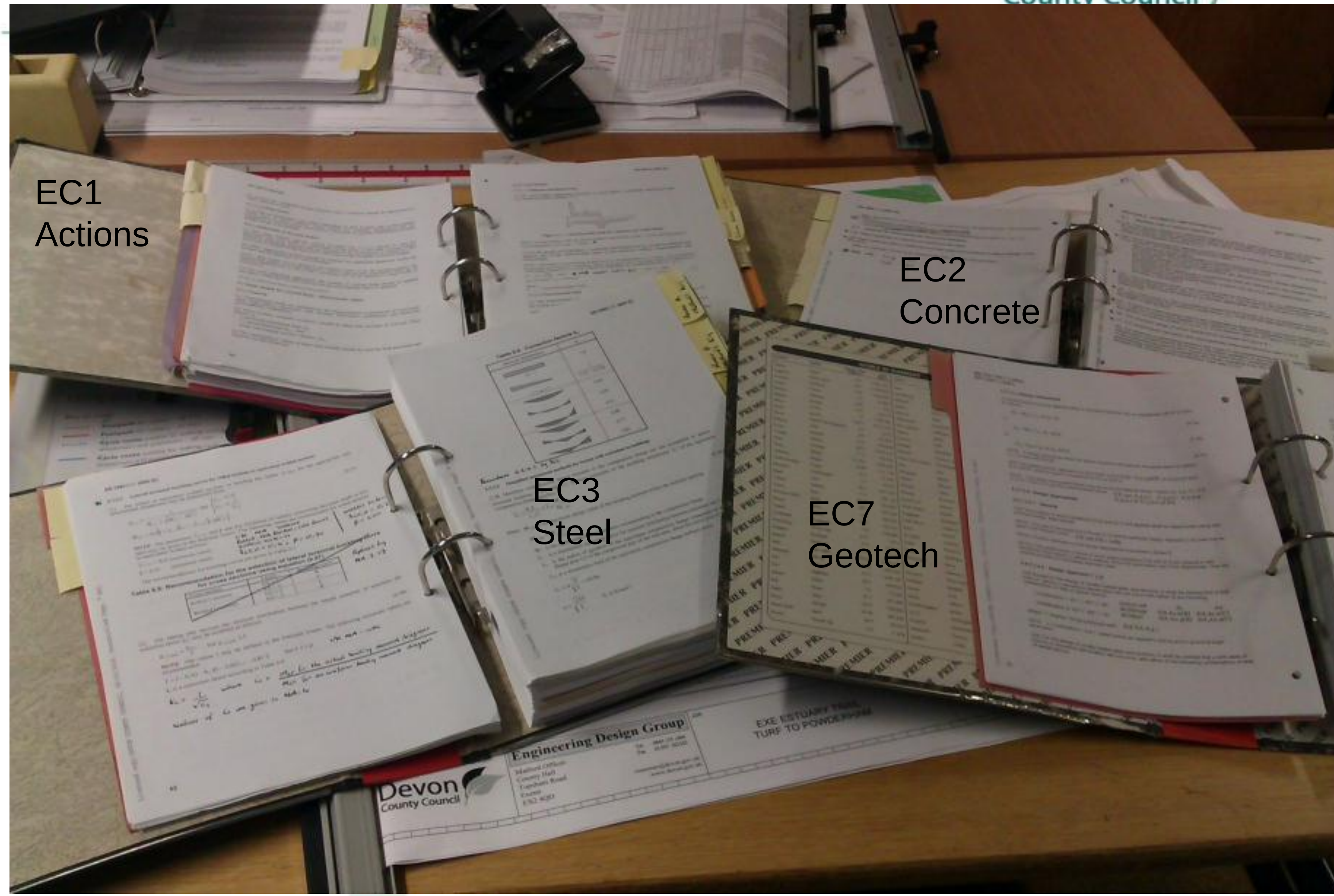

Eurocodes – The old way

- Paper copies from PDF format
- UK NA requirements had to be manually inserted
- Need a lot of book marks or fingers!
- A lot of paper
- Significant time required to produce
- Are you using the latest version?

Thank you for hanging in there

Any Questions?