

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

Project Title	Job No.
Discipline Structural	File Ref.
Review Date	Reviewer
Project Stage	Circulation

<b>Abbreviations</b>	<b>Legend</b>	<input type="checkbox"/>
ES = Every Storey	RPT-G = Reports → Single Default Reports → Graphical	Pass <input checked="" type="checkbox"/>
VSS = View Single Level Structure	RPT-T = Reports → Single Default Reports → Tabular	Fail <input type="checkbox"/>
VFS = View Full Structure	DAS = Differential (Elastic, Creep, Shrinkage) Axial Shortening	Not Applicable <input type="checkbox"/>
BMVC = Building Model Validity Check	RDS = Results Display Settings	
LTD <sub>1</sub> = VFS → Loading → Tributary Loads → Regenerate Tributaries (Adjusting for Transfer Floors) → Recalculate Loads		
LTD <sub>2</sub> = VSS → FEM → Automatic Mesh Generation → Analyse Structure [Apply F <sub>z</sub> (Vertical) Gravity Load Cases Only: LTD <sub>1</sub> ] (ES)		
BA = VFS → FEM → Automatic Mesh Generation → Analyse Structure		
FEFA = VSS → FEM → Automatic Mesh Generation → Analyse Structure		

Building SLS Load (MN)   Undecomposed   BA   LTD <sub>1</sub>   BA+LTD <sub>1</sub> Foundation				
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## Checklist Inclusions and Exclusions

EQ Checks Included	Wall / Column Nodal Loads and Live Load Reduction Checks Included	Hinged Beam Checks Included
Wall / Column Clear Height, Effective Height and Base Support Checks Included	Transferred Wall / Column on Transfer Beam / Slab Checks Included	
Section Properties, Torsion and Horizontal Framing Checks Included	Method of Slab Analysis, Beam Load Application and Frame Analysis Checks Included	
Redundant Slab, Beam and Wall / Column Analysis and Design Checks Included	Rare Slab, Beam and Wall / Column Analysis and Design Checks Included	
Pad Footing Checks Included	Strip Footing Checks Included	Raft / Piled Raft Footing Checks Included
		Pile Footing Checks Included

Note that in this document, the terms steel, rebar and reinforcement refer to steel reinforcement bars associated with **RC** or **PT** construction, whilst the term tendon refers to tendons associated with **PT** construction.

ITEM	CONTENT		√
<b>1.0</b>	<b>COMPANY STANDARD TEMPLATE CHECKS</b>		
<b>1.1</b>	<b>General</b>		
1.11	Company standard template used → MultiStorey-EQ <input type="checkbox"/> MultiStorey-NoEQ <input type="checkbox"/>		<input type="checkbox"/>
1.12	Date of release of company standard template.		<input type="checkbox"/>
<b>1.2</b>	<b>Variations to Company Standard Template</b>		
1.21	VFS → RPT-T → Structural Geometry → Slab Regions/Beams/Walls/Columns → check concrete grade for slab/beam/wall/column. VFS → Select by Type → select Beam → Modify Item Properties → check Beam Tab uncracked stiffnesses (M11, M22, M33) to 1.00 and VFS → Select by Type → select Slab Region → Modify Item Properties → check Slab Region Tab uncracked stiffnesses (M11, M22) to 1.00. VFS → Select by Type → select Beam → Modify Item Properties → check Beam Tab cracked stiffnesses (M11, M22, M33) to 0.50 and VFS → Select by Type → select Slab Region → Modify Item Properties → check Slab Region Tab cracked stiffnesses (M11, M22) to 0.50. BA/LTD <sub>2</sub> /FEFA → select Uncracked Stiffness Modifier for Class 1 <b>PT</b> or Class 2 <b>PT</b> and Cracked Stiffness Modifier for <b>RC</b> or Class 3 <b>PT</b> .		<input type="checkbox"/>
1.22	Braced/unbraced wall/column.		<input type="checkbox"/>
1.23	Maximum beam/wall/column rebar diameter.		<input type="checkbox"/>
1.24	Adoption of (unique) design links at beam supports.		<input type="checkbox"/>
1.25	Beam section cuts (span only – once for every beam or once for every axis).		<input type="checkbox"/>
1.26	RigidZones None.	RigidZones None	<input type="checkbox"/>
1.27	Compatibility torsion (M11=1.0) for transfer / edge beams for Class 1 <b>PT</b> or Class 2 <b>PT</b> . Compatibility torsion (M11=0.5) for transfer / edge beams for <b>RC</b> or Class 3 <b>PT</b> .		<input type="checkbox"/>
1.28	Foundation load combinations S+G+Q load factor (1.00, 1.02, 1.05, 1.10).		<input type="checkbox"/>
1.29	Etcetera.		<input type="checkbox"/>

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ITEM	CONTENT	✓																				
<b>1.3</b>	<b>Variations to Material Properties</b>																					
1.31	<p>For <b>RC</b> models with EQ loads stabilised by moment frames or (framed) tubes, as per capacity design concepts of BS EN1998-1 (i.e. the optimum location and sequence of attainment of member capacity with the attainment of primary seismic beam plastic moment capacity prior to the attainment of primary seismic column plastic moment capacity), for simplicity, the steel reinforcement strength of primary seismic column longitudinal bars should be reduced with respect to the steel reinforcement strength of primary seismic beam longitudinal bars by the following factors: -</p> <table border="1"> <thead> <tr> <th colspan="4">Capacity Design Concepts (Optimum Location and Sequence of Attainment of Member Capacity)</th> </tr> <tr> <th>Ductility Class</th> <th>Element</th> <th>BS EN1998-1 Clause</th> <th>ADAPT-Builder Representation</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Ductility Class Medium (DCM) and Ductility Class High (DCH)</td> <td>Primary Seismic Beam</td> <td rowspan="2">cl.4.4.2.3 <math>\Sigma M_{RC} \geq 1.3 \Sigma M_{Rb}</math></td> <td>Maintain longitudinal bar strength grade at <math>f_y</math></td> </tr> <tr> <td>Primary Seismic Column</td> <td>Reduce longitudinal bar strength grade to <math>f_y / 1.3</math></td> </tr> </tbody> </table>	Capacity Design Concepts (Optimum Location and Sequence of Attainment of Member Capacity)				Ductility Class	Element	BS EN1998-1 Clause	ADAPT-Builder Representation	Ductility Class Medium (DCM) and Ductility Class High (DCH)	Primary Seismic Beam	cl.4.4.2.3 $\Sigma M_{RC} \geq 1.3 \Sigma M_{Rb}$	Maintain longitudinal bar strength grade at $f_y$	Primary Seismic Column	Reduce longitudinal bar strength grade to $f_y / 1.3$	<input type="checkbox"/>						
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1.32	<p>For <b>RC</b> models with EQ loads stabilised by moment frames or (framed) tubes, as per capacity design concepts of BS EN1998-1 (i.e. the favourable mechanism of deformation with the primary seismic beam and primary seismic column elemental attainment of ductile plastic moment capacity prior to elemental attainment of brittle shear capacity), for simplicity, the steel reinforcement strength of primary seismic beam and primary seismic column shear links should be reduced with respect to the steel reinforcement strength of primary seismic beam and primary seismic column longitudinal bars by the following factors: -</p> <table border="1"> <thead> <tr> <th colspan="4">Capacity Design Concepts (Favourable Mechanism of Deformation)</th> </tr> <tr> <th>Ductility Class</th> <th>Element</th> <th>BS EN1998-1 Clause</th> <th>ADAPT-Builder Representation</th> </tr> </thead> <tbody> <tr> <td rowspan="2">Ductility Class Medium (DCM)</td> <td>Primary Seismic Beam</td> <td>cl.5.4.2.2 <math>\gamma_{Rd} = 1.0</math></td> <td rowspan="2">Reduce shear link strength grade to <math>f_{yv} / 1.1</math></td> </tr> <tr> <td>Primary Seismic Column</td> <td>cl.5.4.2.3 <math>\gamma_{Rd} = 1.1</math></td> </tr> <tr> <td rowspan="2">Ductility Class High (DCH)</td> <td>Primary Seismic Beam</td> <td>cl.5.5.2.1 <math>\gamma_{Rd} = 1.2</math></td> <td rowspan="2">Reduce shear link strength grade to <math>f_{yv} / 1.3</math></td> </tr> <tr> <td>Primary Seismic Column</td> <td>cl.5.5.2.2 <math>\gamma_{Rd} = 1.3</math></td> </tr> </tbody> </table>	Capacity Design Concepts (Favourable Mechanism of Deformation)				Ductility Class	Element	BS EN1998-1 Clause	ADAPT-Builder Representation	Ductility Class Medium (DCM)	Primary Seismic Beam	cl.5.4.2.2 $\gamma_{Rd} = 1.0$	Reduce shear link strength grade to $f_{yv} / 1.1$	Primary Seismic Column	cl.5.4.2.3 $\gamma_{Rd} = 1.1$	Ductility Class High (DCH)	Primary Seismic Beam	cl.5.5.2.1 $\gamma_{Rd} = 1.2$	Reduce shear link strength grade to $f_{yv} / 1.3$	Primary Seismic Column	cl.5.5.2.2 $\gamma_{Rd} = 1.3$	<input type="checkbox"/>
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<b>2.0</b>	<b>ARCHITECTURAL DESIGN INTENT CHECKS</b>																					
<b>2.1</b>	<b>General</b>																					
2.11	File → Import → DWG/DXF → import architectural drawing and check consistency of wall/column positions (ES).	<input type="checkbox"/>																				
2.12	File → Import → DWG/DXF → import architectural drawing and check consistency of slab/beam drops (ES).	<input type="checkbox"/>																				
2.13	File → Import → DWG/DXF → import architectural drawing and check consistency of slab edges and openings (ES).	<input type="checkbox"/>																				
2.14	Build → Construction Aids → Level Assignment → check storey labels, storey heights, h (m) including stump depth ( $h_{St01} >$ deepest beam to ensure correct wall/column base shears) and define base level as St00.	<input type="checkbox"/>																				
2.15	Build → Construction Aids → Level Assignment → check total building elevation, $H_T$ (m).	<input type="checkbox"/>																				
<b>3.0</b>	<b>FRAMING AND LOADING CHECKS</b>																					
<b>3.1</b>	<b>Framing Intent</b>																					
3.11	<p>Check floor framing intent (i.e. simple support, continuous, cantilever) is visually comprehensible.            Check staircase framing intent (i.e. longitudinal, transverse, stiffener) is visually comprehensible.            Check joint scheme (contraction, expansion, settlement and sway joints) is visually comprehensible.            Check frame sizes by VSS → RPT-G → Plan Geometry → compare: -</p> <p>(i) slab sizes w.r.t. span to depth ratios (<b>30 RC, 40 PT</b>), ULS bending stress <math>M_{ULS}/bh^2 \approx 1N/mm^2 \ll 5N/mm^2</math> and FEFA deflections, with <math>M_{ULS}</math> checked based on <b>1.4 x tributary width x (15.0-25.0kPa) x L<sup>2</sup>/12</b>,</p> <p>(ii) beam sizes w.r.t. span to depth ratios (<b>20 RC, 30 PT</b>), ULS shear stress <math>V_{ULS}/bh \approx 3N/mm^2 \ll 5N/mm^2</math> and ULS bending stress <math>M_{ULS}/bh^2 \approx 3N/mm^2 \ll 5N/mm^2</math> and FEFA deflections, with <math>M_{ULS}</math> and <math>V_{ULS}</math> checked based on <b>1.4 x tributary width x (15.0-25.0kPa) x L/2</b>, respectively with <math>A_{s,prov} \approx 3000 \cdot M_{ULS}</math> (kNm) / d (mm),</p> <p>(iii) shear wall <b>#A</b> sizes w.r.t. scheme design ratios (for 0.4% steel, <math>A_c \approx F_{ULS} / [15@C35; 17@C40; 19@C45; 21@C50; 23@C55; 25@C60]</math> <b>#B1, #B2</b> effectively equalising axial stress at every level to cater for <b>DAS #C</b>) and shear wall detailing <b>capacity tables</b>, with <math>F_{ULS}</math> checked based on <b>1.4 x tributary area x no. of storeys x (15.0-25.0kPa) #D</b>,</p>	<input type="checkbox"/>																				

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ITEM	CONTENT	✓
	<p>(iv) transfer beam sizes w.r.t. ULS shear stress <math>V_{ULS}/bh \approx 3N/mm^2 \ll 5N/mm^2</math> and ULS bending stress <math>M_{ULS}/bh^2 \approx 3N/mm^2 \ll 5N/mm^2</math>, ULS punching shear transfer column face stress <math>V_{eff}/ud \approx 4N/mm^2 \ll 5N/mm^2</math> (applicable when transfer beam width &gt; column width), <b>deep beam design #E1</b> and <b>BA and LTD<sub>2</sub> deflections</b>, with <math>M_{ULS} = F_{ULS}.L/4</math> and <math>V_{ULS} = F_{ULS}/2</math> #F1 computed from <math>F_{ULS}</math> checked based on <b>1.4 x tributary area x no. of storeys x (15.0-25.0kPa) #D</b>,</p> <p>(v) transfer slab sizes w.r.t. ULS shear stress <math>V_{ULS}/bh @ 1.0d \approx 1.0N/mm^2 [RC] \text{ to } 1.5N/mm^2 [PT] \ll 5N/mm^2</math> and ULS bending stress <math>M_{ULS}/bh^2 \approx 1.5N/mm^2 [RC] \text{ to } 2.5N/mm^2 [PT] \ll 5N/mm^2</math>, ULS punching shear transfer column (or transfer column head where applicable) and transferred walls/columns face stress <math>V_{eff}/ud \approx 4N/mm^2 \ll 5N/mm^2</math>, ULS punching shear transfer column (or transfer column head where applicable) and transferred walls/columns first perimeter stress <math>V_{eff}/ud @ 1.5d \approx 0.6N/mm^2 [RC] \text{ to } 1.0N/mm^2 [PT]</math>, <b>deep beam design #E2</b> and <b>CBAFE deflections</b>, with <math>M_{ULS} = F_{ULS}.L/4</math> and <math>V_{ULS} = F_{ULS}/2</math> #F2 computed from <math>F_{ULS}</math> checked based on <b>1.4 x tributary area x no. of storeys x (15.0-25.0kPa) #D</b>,</p> <p>(vi) column #A sizes w.r.t. scheme design ratios (for 2.0% steel, <math>A_c \approx F_{ULS} / [20@C35; 22@C40; 24@C45; 26@C50; 28@C55; 30@C60]</math> #B1, #B2 effectively <b>equalising axial stress</b> at every level to cater for <b>DAS #C</b>), with <math>F_{ULS}</math> checked based on <b>1.4 x tributary area x no. of storeys x (15.0-25.0kPa) #D</b>,</p> <p>(vii) lateral stability frame size and extent w.r.t. scheme design ratios (<b>height / 10</b>) whilst confirming the <b>braced/unbraced</b> wall/column conditions based on the <b>lateral stability system</b>, the <b>Moment Ratio Check</b> and/or the <b>Sway Susceptibility Check</b> (NHF / wind: non-sway with <math>Q/1.4 \leq 0.05</math> and sway with <math>Q/1.4 \leq 0.25</math> with default stiffness parameters; EQ: non-sway with <math>q.Q/0.7 \leq 0.05</math> and sway with <math>q.Q/0.7 \leq 0.25</math> with default stiffness parameters),</p> <p>(viii) lateral stability frame size and extent w.r.t. <b>lateral stability base shear magnitude distribution #G</b> and <b>lateral stability base moment magnitude distribution #H</b>, and</p> <p>(ix) lateral stability frame size and extent w.r.t. lateral deflections to NHF / wind #I (<math>\delta_{total}/2 \leq H_{total}/500</math> and <math>\Delta\delta_{storey,I}/2 \leq h_{storey,I}/500</math> with default stiffness parameters) and EQ #I (<math>q.\delta_{total} \leq H_{total}/250</math> and <math>q.\Delta\delta_{storey,I} \leq h_{storey,I}/250</math> (with fundamental period <math>T_1/\sqrt{2}</math>) with default stiffness parameters), (ES).</p> <p><b>#A:</b> Note check wall/column for <b>Reference Planes Storeys Intervals <math>\geq 1</math></b> and perform <b>BMVC</b>.</p> <p><b>#B1 [Textual]:</b> Note check VSS <math>\rightarrow</math> RPT-T <math>\rightarrow</math> Structural Geometry <math>\rightarrow</math> Walls/Columns for sectional area, <math>A_c</math> and BA/LTD<sub>2</sub> <math>\rightarrow</math> VSS <math>\rightarrow</math> RPT-T <math>\rightarrow</math> Wall/Column Reactions (<b>max</b>) <b>enveloping</b> ULS combinations axial load, <math>F_{ULS}</math> to calculate ULS axial stress <math>F_{ULS}/A_c</math> (<b>BA / LTD<sub>2</sub></b>). Note calculate <b>% steel <math>\ll 2\%</math></b>(shear wall vertical steel % limit for avoidance of through-thickness links)/<b>5%</b>(column vertical steel % limit) manually.</p> <p><b>#B2 [Visual]:</b> Note check BA/LTD<sub>2</sub> <math>\rightarrow</math> VSS <math>\rightarrow</math> RPT-G <math>\rightarrow</math> Wall/Column Reactions (<b>max</b>) <b>enveloping</b> ULS combinations axial load, <math>F_{ULS}</math> to calculate ULS axial stress <math>F_{ULS}/A_c</math> (<b>BA / LTD<sub>2</sub></b>) manually or BA/LTD<sub>2</sub> <math>\rightarrow</math> VSS <math>\rightarrow</math> RDS <math>\rightarrow</math> Wall/Column <math>\rightarrow</math> Actions (Diagram) <math>\rightarrow</math> Axial Force selecting <b>Envelope Strength</b> combinations axial load, <math>F_{ULS}</math> to calculate ULS axial stress <math>F_{ULS}/A_c</math> (<b>BA / LTD<sub>2</sub></b>) manually. Note check LTD<sub>1</sub> <math>\rightarrow</math> VSS <math>\rightarrow</math> RDS <math>\rightarrow</math> Load Takedown <math>\rightarrow</math> Cumulative Loads <b>manually factoring</b> S, G and Q for ULS combinations axial load, <math>F_{ULS}</math> to calculate ULS axial stress <math>F_{ULS}/A_c</math> (<b>LTD<sub>1</sub> only</b>) manually. Note calculate <b>% steel <math>\ll 2\%</math></b>(shear wall vertical steel % limit for avoidance of through-thickness links)/<b>5%</b>(column vertical steel % limit) manually.</p> <p><b>#C:</b> Note check BA <math>\rightarrow</math> VSS <math>\rightarrow</math> RDS <math>\rightarrow</math> Wall/Column <math>\rightarrow</math> Deformation <math>\rightarrow</math> Z-Translation for <b>DAS</b> and BA <math>\rightarrow</math> VSS <math>\rightarrow</math> RDS <math>\rightarrow</math> Wall/Column <math>\rightarrow</math> Deformation <math>\rightarrow</math> rr/ss-Translation for lateral deflection (<b>sway</b>) of the building due to DL+SDL+LL+PT. The SLS load combination inherently includes the effects of differential (elastic, creep, shrinkage) axial shortening. Staged construction analysis may be performed to reduce the magnitude of the effects of differential (elastic, creep, shrinkage) axial shortening.</p> <p><b>#D:</b> Note check BA <math>\rightarrow</math> VSS <math>\rightarrow</math> RDS <math>\rightarrow</math> Vibration for <b>animated deflections</b> for spurious members and BA <math>\rightarrow</math> VFS <math>\rightarrow</math> RDS <math>\rightarrow</math> Wall/Column <math>\rightarrow</math> Actions (Diagram) <math>\rightarrow</math> Axial Force <b>ensuring gradual wall/column axial load increment</b> and check BA/LTD<sub>2</sub> <math>\rightarrow</math> VSS <math>\rightarrow</math> RPT-T <math>\rightarrow</math> Wall/Column Reactions for <b>minimal discrepancy between BA and LTD<sub>2</sub> wall/column axial load take down</b> by ensuring minimal differential beam support (i.e. wall/column point) settlement (due to DAS and differential transfer floor deflection) in BA/FEFA <math>\rightarrow</math> VSS <math>\rightarrow</math> RDS <math>\rightarrow</math> Wall/Column <math>\rightarrow</math> Deformation <math>\rightarrow</math> Z-Translation !. The ULS load combinations inherently include the effects of differential (elastic, creep, shrinkage) axial shortening. Staged construction analysis may be performed to reduce the magnitude of the effects of differential (elastic, creep, shrinkage) axial shortening.</p> <p><b>#E1:</b> Note check (a) transfer beam / transferred wall <b>strut and tie truss analogy design</b> for the transferred wall (acting as the diagonal compression element with the provision of horizontal steel equivalent to <math>1/4</math> of the required vertical steel) and transfer beam (acting as the tension element with the provision of rebar of <math>0.95f_y.A_{s,prov}</math> to resist <math>F_{ULS}/4</math> over the transfer beam depth of span/3), (b) transfer beam <b>deep beam design</b> with <math>A_{s,prov} \approx 3800 \cdot M_{ULS} \text{ (kNm)} / h \text{ (mm)}</math>, (c) transfer beam <b>longitudinal shear within web and between web and flanges</b> and (d) transfer beam <b>torsion design</b>.</p> <p><b>#E2:</b> Note check (a) transfer slab / transferred wall <b>strut and tie truss analogy design</b> for the transferred wall (acting as the diagonal compression element with the provision of horizontal steel equivalent to <math>1/4</math> of the required vertical steel) and transfer slab (acting as the tension element with the provision of rebar of <math>0.95f_y.A_{s,prov}</math> to resist <math>F_{ULS}/4</math> over the transfer slab depth of span/3), (b) transfer slab <b>deep beam design</b> with <math>A_{s,prov} \approx 3800 \cdot M_{ULS} \text{ (kNm)} / h \text{ (mm)}</math> and (c) transfer slab</p>	

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	<p><b>longitudinal shear within web.</b></p> <p><b>#F1:</b> Note check BA/LTD<sub>2</sub> → VSS → RDS → Beam → Actions (Diagram) → Moment About zz for <b>minimal discrepancy between BA and LTD<sub>2</sub> transfer beam bending moments</b> by ensuring minimal differential transfer beam support (i.e. wall/column point) settlement (due to DAS) !. The ULS load combinations inherently include the effects of differential (elastic, creep, shrinkage) axial shortening. Staged construction analysis may be performed to reduce the magnitude of the effects of differential (elastic, creep, shrinkage) axial shortening.</p> <p><b>#F2:</b> Note check BA/LTD<sub>2</sub> → VSS → RDS → Slab → Actions (Contour Map) →  M<sub>xx</sub> + M<sub>xy</sub>  and  M<sub>yy</sub> + M<sub>xy</sub>  for <b>minimal discrepancy between BA and LTD<sub>2</sub> transfer slab bending moments</b> by ensuring minimal differential transfer slab support (i.e. wall/column point) settlement (due to DAS) !. The ULS load combinations inherently include the effects of differential (elastic, creep, shrinkage) axial shortening. Staged construction analysis may be performed to reduce the magnitude of the effects of differential (elastic, creep, shrinkage) axial shortening.</p> <p><b>#G:</b> Note check VSS → RPT-T → Structural Geometry → Walls/Columns for sectional area, A<sub>c</sub> and BA → VSS → RPT-T → Wall/Column Reactions (<b>max</b>) enveloping ULS combinations shear force, V<sub>ULS</sub> to calculate ULS shear stress <math>\tau = V_{ULS}/A_c \approx 3N/mm^2</math> (based on nominal link provision for vertical elements loaded to 40%<i>f<sub>cu</sub></i> at ULS i.e. the capacity for a 0.4% steel reinforced vertical element) &lt;&lt; <b>5N/mm<sup>2</sup></b> for all stability base shear resisting elements i.e. shear walls above transfer and shear walls / mega columns below transfer.</p> <p><b>#H:</b> Note ensure <b>no foundation uplift</b>.</p> <p><b>#I:</b> Note check <b>on-plan torsional twist</b> due to NHF, wind and EQ loads.</p>	✓
<b>3.2</b>	<b>Slab Loads</b>	
3.21	VSS → Loading → Add Load → Patch Load Wizard → add slab LL (ES). VSS → RPT-G → Loading → Live Load → check slab LL (ES).	<input type="checkbox"/>
3.22	VSS → Loading → Add Load → Patch Load Wizard → add slab SDL (ES). VSS → RPT-G → Loading → Dead Load → check slab SDL (ES).	<input type="checkbox"/>
3.23	VSS → Loading → Add Load → Point, Line and Patch Load → add slab point, line and partial patch load (ES). VSS → RPT-G → Loading → Live Load and Dead Load → check slab point, line and partial patch loading visually (ES).	<input type="checkbox"/>
<b>3.3</b>	<b>Beam Loads</b>	
3.31	VSS → Loading → Add Load → Line Load → add beam internal cladding line load (ES). VSS → RPT-G → Loading → Dead Load → check beam internal cladding line load visually (ES).	<input type="checkbox"/>
3.32	VSS → Loading → Add Load → Line Load → add beam external cladding line load (ES). VSS → RPT-G → Loading → Dead Load → check beam external cladding line load visually (ES).	<input type="checkbox"/>
3.33	VSS → Loading → Add Load → Line Load → add beam user defined line loads (ES). VSS → RPT-G → Loading → Live Load and Dead Load → check beams with user defined line loads visually (ES).	<input type="checkbox"/>
<b>3.4</b>	<b>Wall/Column Loads</b>	
3.41	VSS → Loading → Add Load → Point Load → add wall/column user defined point loads (ES). VSS → RPT-G → Loading → Live Load and Dead Load → check wall/column user defined point loads visually (ES).	<input type="checkbox"/>
<b>3.5</b>	<b>Lateral Loads</b>	
3.51	VSS → Loading → Add Load → Patch Load Wizard → add NHF loads (ES). VSS → RPT-G → Loading → User Defined Load Cases → check NHF loads (ES). VFS → Loading → Add Load → Wind Load Wizard → add wind loads (ES). VSS → RPT-G → Loading → User Defined Load Cases → check wind loads (ES).	<input type="checkbox"/>
3.52	VFS → Loading → Add Load → Seismic Load Wizard → add EQ loads (ES). VSS → RPT-G → Loading → User Defined Load Cases → check EQ loads (ES).	<input type="checkbox"/>
<b>3.6</b>	<b>Imposed Load Reduction</b>	
3.61	Loading → Live Load Reduction → check live load reduction factors. Note that live load reduction option must also be checked on the Load Combination table for applicability.	<input type="checkbox"/>
<b>3.7</b>	<b>Load Combination Cases</b>	
3.71	Note for EQ ULS load combination cases, if required by cl.4.3.3.5.2 BS EN1998-1 i.e. if a <sub>vg</sub> is greater than 0.25g, then the vertical component of the seismic action will need to be incorporated as follows: - $1.0DL+1.0SDL+\psi_{2i}LL+HYP\pm 1.0EQ_x\pm 0.3EQ_y\pm 0.3EQ_z$ $1.0DL+1.0SDL+\psi_{2i}LL+HYP\pm 0.3EQ_x\pm 1.0EQ_y\pm 0.3EQ_z$ by enhancing G to G+0.3EQ <sub>z</sub> where EQ <sub>z</sub> is the total EQ base shear in Z and G is DL+SDL, and for $1.0DL+1.0SDL+\psi_{2i}LL+HYP\pm 0.3EQ_x\pm 0.3EQ_y\pm 1.0EQ_z$ by enhancing G to G+1.0EQ <sub>z</sub> where EQ <sub>z</sub> is the total EQ base shear in Z and G is DL+SDL. Note for EQ SLS load combination cases, if required by cl.4.3.3.5.2 BS EN1998-1 i.e. if a <sub>vg</sub> is greater than 0.25g, then the vertical component of the seismic action will need to be incorporated as follows: - $1.0DL+1.0SDL+\psi_{2i}LL+PT\pm 1.0EQ_x\pm 0.3EQ_y\pm 0.3EQ_z$	<input type="checkbox"/>

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	√															
	$1.0DL+1.0SDL+\psi_{zi}LL+PT\pm 0.3EQ_x\pm 1.0EQ_y\pm 0.3EQ_z$ by enhancing G to $G+0.3EQ_z$ where $EQ_z$ is the total EQ base shear in Z and G is DL+SDL, and for $1.0DL+1.0SDL+\psi_{zi}LL+PT\pm 0.3EQ_x\pm 0.3EQ_y\pm 1.0EQ_z$ by enhancing G to $G+1.0EQ_z$ where $EQ_z$ is the total EQ base shear in Z and G is DL+SDL. Note effectively both the DL+SDL and LL components within the dynamic weight W is lumped into the enhanced load factor for G.	√															
3.72	Note for EQ ULS load combination cases, as required by cl.6.4.3.4 BS EN1990, the combination coefficient for variable action, $\psi_{zi}$ will need to be recalculated as per T.A1.1 BS EN1990. $1.0DL+1.0SDL+\psi_{zi}LL+HYP\pm 1.0EQ_x$ $1.0DL+1.0SDL+\psi_{zi}LL+HYP\pm 1.0EQ_y$ $1.0DL+1.0SDL+\psi_{zi}LL+HYP\pm 1.0EQ_x\pm 0.3EQ_y\pm 0.3EQ_z$ $1.0DL+1.0SDL+\psi_{zi}LL+HYP\pm 0.3EQ_x\pm 1.0EQ_y\pm 0.3EQ_z$ $1.0DL+1.0SDL+\psi_{zi}LL+HYP\pm 0.3EQ_x\pm 0.3EQ_y\pm 1.0EQ_z$ Note for EQ SLS load combination cases, as required by cl.6.4.3.4 BS EN1990, the combination coefficient for variable action, $\psi_{zi}$ will need to be recalculated as per T.A1.1 BS EN1990. $1.0DL+1.0SDL+\psi_{zi}LL+PT\pm 1.0EQ_x$ $1.0DL+1.0SDL+\psi_{zi}LL+PT\pm 1.0EQ_y$ $1.0DL+1.0SDL+\psi_{zi}LL+PT\pm 1.0EQ_x\pm 0.3EQ_y\pm 0.3EQ_z$ $1.0DL+1.0SDL+\psi_{zi}LL+PT\pm 0.3EQ_x\pm 1.0EQ_y\pm 0.3EQ_z$ $1.0DL+1.0SDL+\psi_{zi}LL+PT\pm 0.3EQ_x\pm 0.3EQ_y\pm 1.0EQ_z$	□															
<b>4.0</b>	<b>BOUNDARY CONDITION CHECKS</b>																
<b>4.1</b>	<b>Beam/Column Releases</b>																
4.11	VFS → Select by Type → select Beam → Modify Item Properties → check Beam Tab releases are unselected (ES).	□															
4.12	Check beams on corbels are defined with hinged ends (ES).	□															
4.13	Check stepped secondary beams across primary beams are defined with hinged ends for steps of a dimension greater than the width of the primary beam (ES).	□															
4.14	Check beams of depths significantly larger than the thickness of the supporting wall (orientated perpendicular to the longitudinal beam direction) e.g. basement retaining wall or lift core wall and beams of widths significantly larger than the thickness of the supporting wall (orientated parallel to the longitudinal beam direction) are defined with hinged ends with a nominal 50% of span steel defined at the hinged supports (ES).	□															
<b>4.2</b>	<b>Wall/Column Clear Height</b>																
4.21	<table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <thead> <tr style="background-color: #333; color: white;"> <th colspan="3">Wall/Column Clear Height Calculation</th> </tr> <tr style="background-color: #333; color: white;"> <th>Item</th> <th>Wall Clear Height</th> <th>Column Clear Height</th> </tr> </thead> <tbody> <tr> <td><b>Beam Depths</b></td> <td>Not Included</td> <td>Not Included</td> </tr> <tr> <td><b>Beam Drops or Elevation Vertical Offset</b></td> <td>Included only if a corresponding Vertical Offset definition is specified for the wall in the particular storey and the storey above</td> <td>Included only if a corresponding Offset-z definition is specified for the column in the particular storey and the storey above</td> </tr> <tr> <td><b>Multiple Storey Wall/Column Spans</b></td> <td>Included only if the number of storeys that the wall spans is specified in Reference Planes Storeys Intervals #<sup>A</sup></td> <td>Included only if the number of storeys that the column spans is specified in Reference Planes Storeys Intervals #<sup>A</sup></td> </tr> </tbody> </table> <p>#A: VFS → RPT-T → Structural Geometry → Walls/Columns → check walls/columns Reference Planes Storey Intervals definition indirectly by checking walls/columns length, noting that <b>only walls/columns that are strutted/tied in both directions may be considered Reference Planes Storeys Intervals = 1 (ES)</b>. Struts/ties should be capable of resisting <b>2.5% of the design ultimate vertical load</b> that the wall/column is designed to carry at the point of lateral support as stipulated by cl.3.9.2.3 BS8110-1. Note that the struts/ties should be at least <b>1/10<sup>th</sup></b> of the stiffness of the columns, i.e. <math>\Sigma I_{beam}/L_{beam} \geq 0.10[\Sigma I_{column}/L_{column}]</math> to be effective as suggested by cl.2.5.4 BS8110-2 and is to be fully restrained by a <b>horizontal diaphragm</b> (floor slab, note that flat slab also constitutes a horizontal diaphragm), failing which the summation of beam stiffnesses of at least <b>1/10<sup>th</sup></b> of the summation of column stiffnesses is mandatory.</p>	Wall/Column Clear Height Calculation			Item	Wall Clear Height	Column Clear Height	<b>Beam Depths</b>	Not Included	Not Included	<b>Beam Drops or Elevation Vertical Offset</b>	Included only if a corresponding Vertical Offset definition is specified for the wall in the particular storey and the storey above	Included only if a corresponding Offset-z definition is specified for the column in the particular storey and the storey above	<b>Multiple Storey Wall/Column Spans</b>	Included only if the number of storeys that the wall spans is specified in Reference Planes Storeys Intervals # <sup>A</sup>	Included only if the number of storeys that the column spans is specified in Reference Planes Storeys Intervals # <sup>A</sup>	□
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<b>Multiple Storey Wall/Column Spans</b>	Included only if the number of storeys that the wall spans is specified in Reference Planes Storeys Intervals # <sup>A</sup>	Included only if the number of storeys that the column spans is specified in Reference Planes Storeys Intervals # <sup>A</sup>															
4.22	<table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <thead> <tr style="background-color: #333; color: white;"> <th colspan="3">Recognition of Reference Planes Storeys Intervals ≥ 2 Wall/Column As Beam Supports for Beams Not on the Wall/Column Defined Storey</th> </tr> <tr style="background-color: #333; color: white;"> <th>Item</th> <th>BA</th> <th>FEFA</th> </tr> </thead> <tbody> <tr> <td><b>Wall</b></td> <td>Recognized</td> <td>Recognized</td> </tr> <tr> <td><b>Column</b></td> <td>Recognized</td> <td>Recognized</td> </tr> </tbody> </table>	Recognition of Reference Planes Storeys Intervals ≥ 2 Wall/Column As Beam Supports for Beams Not on the Wall/Column Defined Storey			Item	BA	FEFA	<b>Wall</b>	Recognized	Recognized	<b>Column</b>	Recognized	Recognized	□			
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Item	BA	FEFA															
<b>Wall</b>	Recognized	Recognized															
<b>Column</b>	Recognized	Recognized															
<b>4.3</b>	<b>Wall/Column Effective Length Factor</b>																
4.31	Check <b>Braced</b> adopted for walls/columns in a lateral stability system (ES): -	□															

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	✓
	<p>(i) that exist in a <b>coupled shear wall (minor plane only) / outrigger frame (outrigger columns only) / (framed) tube flange / (framed) tube web (minor plane only)</b> lateral stability system (cl.3.8.1.5 BS8110-1), <b>and</b></p> <p>(ii) that have a <b>total (of all walls/columns in question) gross stiffness</b> <math>\leq 1/12^{\text{th}}</math> of the total gross stiffness of the bracing elements resisting lateral movement of that storey (cl.6.2.5 ACI 318-14), <b>and</b></p> <p>(iii) that exhibit a <b>total (of all walls/columns in question) magnitude of shear force and bending moment (excluding the bending moment back-calculated by multiplying the push-pull axial forces of the walls/columns at the frame extremity)</b> based on the <b>Moment Ratio Check</b> <math>\leq 1/12^{\text{th}}</math> of the <b>total magnitude of shear force and bending moment (including ditto)</b> of the bracing elements resisting lateral movement of that storey (inferred from cl.6.2.5 ACI 318-14), <b>and</b></p> <p>(iv) that are within a <b>sway storey</b> (exhibiting <math>Q \leq 0.25</math> or <math>\lambda \geq 4.0</math>) based on the <b>Sway Susceptibility Check</b> but with elastic second-order analysis / P-<math>\Delta</math> analysis / lateral loads (wind, EQ) amplification with the amplified sway factor, <math>m = \lambda/(\lambda-1)</math> performed (cl.6.2.6 and cl.R6.7.1.2 ACI 318-14), <b>or (albeit unconservatively)</b></p> <p>(v) that are within a <b>non-sway storey</b> (exhibiting <math>Q \leq 0.05</math> or <math>\lambda \geq 20</math>) based on the <b>Sway Susceptibility Check</b> (based on cl.6.6.4.3(b) ACI 318-14).</p> <p>Note that for <b>significant buildings</b>, based on a (vertical load take down, base lateral load distribution and lateral drift verified) CSI.Etabs model, a <b>first principle eigenvalue buckling analysis</b> should be performed to confirm the <b>global building buckling</b> characteristics (requiring <math>\lambda \geq 4.0</math> to cl.R6.2.6 ACI 318-14 and to verify the value for m in <math>m = \lambda/(\lambda-1)</math>) and <b>local mega column buckling</b> characteristics ((requiring <math>\lambda \geq 1</math>).</p>	✓
4.32	<p>Check <b>Unbraced</b> adopted for walls/columns in a lateral stability system (ES): -</p> <p>(i) that exist in a <b>coupled shear wall (major plane only) / moment frame / outrigger frame (except outrigger columns) / (framed) tube web (major plane only)</b> lateral stability system (cl.3.8.1.5 BS8110-1), <b>or</b></p> <p>(ii) that have a <b>total (of all walls/columns in question) gross stiffness</b> <math>&gt; 1/12^{\text{th}}</math> of the total gross stiffness of the bracing elements resisting lateral movement of that storey (cl.6.2.5 ACI 318-14), <b>or</b></p> <p>(iii) that exhibit a <b>total (of all walls/columns in question) magnitude of shear force or bending moment (excluding the bending moment back-calculated by multiplying the push-pull axial forces of the walls/columns at the frame extremity)</b> based on the <b>Moment Ratio Check</b> <math>&gt; 1/12^{\text{th}}</math> of the <b>total magnitude of shear force or bending moment (including ditto)</b> of the bracing elements resisting lateral movement of that storey (inferred from cl.6.2.5 ACI 318-14), <b>and (albeit unconservatively)</b></p> <p>(iv) that are within a <b>sway storey</b> (exhibiting <math>Q &gt; 0.05</math> or <math>\lambda &lt; 20</math>) based on the <b>Sway Susceptibility Check</b> (based on cl.6.6.4.3(b) ACI 318-14).</p> <p>Note that for <b>significant buildings</b>, based on a (vertical load take down, base lateral load distribution and lateral drift verified) CSI.Etabs model, a <b>first principle eigenvalue buckling analysis</b> should be performed to confirm the <b>global building buckling</b> characteristics (requiring <math>\lambda \geq 4.0</math> to cl.R6.2.6 ACI 318-14 and to verify the value for m in <math>m = \lambda/(\lambda-1)</math>) and <b>local mega column buckling</b> characteristics ((requiring <math>\lambda \geq 1</math>).</p>	☐
4.33	<p>Check <b>manually</b> Edited Bracing adopted for walls/columns in structures with <b>transferred</b> lateral stability (e.g. <b>braced shear wall</b> residential block on an <b>unbraced moment frame</b> car park podium, noting that should the car park podium floors be constructed in flat slabs instead of in beams and slabs, the unbraced mega columns beneath the transfer floor would effectively resist a primary stability base shear induced vierendeel moment over its height from the transfer floor to a base level that can effectively transfer the stability base shear into the foundations unless, and as highly recommended, a certain proportion of the existing shear walls are continued below the transfer floor to the foundations or if new shear walls are introduced below the transfer floor, yielding a scenario akin to the core and outrigger form of stability whereby the stability base moment is resolved into axial forces into the then <b>braced</b> (provided cl.6.2.5 <b>and conservatively</b> cl.6.6.4.3(b) ACI 318-14 are satisfied for a non-sway storey) mega columns and the stability base shear is transferred by the transfer floor diaphragm to the shear walls beneath the transfer floor into the foundations; note that even if the car park podium floors were constructed in beams and slabs, it is likely that the stability base shear will migrate to the usually stiffer shear walls if they are provided; note that a <b>ULS shear stress check</b> should be done on all stability base shear resisting elements) (ES).</p>	☐
<b>4.4</b>	<b>Wall/Column Base Support Conditions</b>	
4.41	<p>RPT-T → Structural Geometry → Releases and Restraints → check user-defined supports (Build → Support → Point and Line Supports → introduce lateral and rotational flexibility): -</p> <p><b>Pad, Strip, Raft, Piled Raft Foundations</b></p> <ul style="list-style-type: none"> <li>- Introduce lateral flexibility in both directions in accordance with soil stiffness.</li> <li>- Introduce zero rotational flexibility in both planes.</li> </ul> <p><b>Piled Foundations (with Dropped or Integrated Pile Caps)</b></p> <ul style="list-style-type: none"> <li>- Introduce lateral flexibility in both directions in accordance with soil stiffness.</li> <li>- Introduce rotational flexibility in both planes for single-pile pile caps and one plane for double-pile pile caps.</li> </ul>	☐
4.42	Check <b>stepped</b> foundations levels relative to St00 (e.g. general pile cap level compared to the lift pit pile cap level) defined with -ve Offset-z (bot) upwards in the St01 wall/column definitions.	☐
4.43	Check <b>stepped</b> foundations levels relative to St0i where $i \geq 1$ defined with -ve Offset-z (bot) upwards and Point and Line Supports defined in St0i+1 wall/column definitions (check user-defined supports) noting that user-	☐

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	√																								
	defined support types are defined in Build → Support → Point and Line Supports. Alternatively, wall/column definitions at St0i+1 where i≥1 may be defined with Reference Planes Storeys Intervals ≥ 2 and -ve Offset-z (bot) upwards defined to extend beyond the storey height(s).	<input type="checkbox"/>																								
<b>5.0</b>	<b>MODELLING CHECKS</b>																									
<b>5.1</b>	<b>General</b>																									
5.11	Check all elements modelled with their <b>analytical footprint</b> matching their <b>physical footprint</b> (ES).	<input type="checkbox"/>																								
5.12	Check that secondary beam spans <b>break</b> at primary beam crossings and that primary beam spans <b>break</b> at wall/column crossings (ES). Check that <b>offset beams</b> (which are secondary beams that frame into the beam in question within the footprint of the wall/column) <b>are avoided as far as it is practical</b> (ES).	<input type="checkbox"/>																								
5.13	Check 3D visualization (Adapt Solid Modelling) for <b>accuracy of modelling</b> in particular: - <ul style="list-style-type: none"> <li>slab and beam drops and soffit continuity (ES).</li> <li>consistency of inter-storey wall/column setting out (ES).</li> <li>multi-storey (Reference Planes Storeys Intervals &gt; 1) wall/column element spans, noting that <b>only walls/columns that are strutted/tied in both directions may be considered Reference Planes Storeys Intervals = 1</b> (ES).</li> </ul>	<input type="checkbox"/>																								
5.14	Check validity of slab contributing to floor diaphragm for all dropped slabs, inclined slabs, slabs near inclined walls/columns and conservatively slabs near basement retaining walls to ensure that the stability base shear is resisted by the walls/columns supporting the superstructure (ES).	<input type="checkbox"/>																								
5.15	Check all cantilever beams are identified as such (ensuring the correct cantilever reinforcement detailing and the correct deflection assessment based on cantilever span / depth ratios) (ES).	<input type="checkbox"/>																								
5.16	Check all similar storeys are defined with their correct storey height to ensure that wall/column clear heights are accurately calculated.	<input type="checkbox"/>																								
<b>5.2</b>	<b>Section and Material Properties</b>																									
5.21	<b>% Reduction in Rigidity in BA #A</b>	<input type="checkbox"/>																								
	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr style="background-color: #333; color: white;"> <th style="width: 30%;">Action</th> <th style="width: 35%;">Slab/Beam</th> <th style="width: 35%;">Wall/Column</th> </tr> </thead> <tbody> <tr> <td style="background-color: #333; color: white;">ULS DL, SDL, LL (V) #B</td> <td style="background-color: #333; color: white;"><b>Class 1 PT or Class 2 PT</b> 50%{EA} Uncracked, Creep 50%{EI} Uncracked, Creep 50%{GAs} Uncracked, Creep 50%{GJ} Uncracked, Creep kE=1.0, kI=1.0, kJ=1.0, kA=1.0 [2.0 x Default Parameters]</td> <td style="background-color: #333; color: white;"><b>Class 1 PT, Class 2 PT, RC or Class 3 PT</b> 50%{EA} Uncracked, Creep 50%{EI} Uncracked, Creep 50%{GAs} Uncracked, Creep 50%{GJ} Uncracked, Creep kE=1.0, kI=1.0, kJ=1.0, kA=1.0 [Default Parameters]</td> </tr> <tr> <td style="background-color: #333; color: white;">ULS NHF (H) #B</td> <td style="background-color: #333; color: white;"><b>RC or Class 3 PT</b> 50%{EA} Uncracked, Creep 25%{EI} Cracked, Creep 50%{GAs} Uncracked, Creep 25%{GJ} Cracked, Creep kE=1.0, kI=0.5, kJ=0.5, kA=1.0 [Default Parameters]</td> <td style="background-color: #333; color: white;"><b>Class 1 PT, Class 2 PT, RC or Class 3 PT</b> 50%{EA} Uncracked, Creep 25%{EI} Cracked, Creep 50%{GAs} Uncracked, Creep 25%{GJ} Cracked, Creep kE=1.0, kI=0.5, kJ=0.5, kA=1.0 [~0.5 x Default Parameters]</td> </tr> <tr> <td style="background-color: #333; color: white;">ULS Wind (H) #B</td> <td style="background-color: #333; color: white;"><b>RC or Class 3 PT</b> 50%{EA} Uncracked, Creep 25%{EI} Cracked, Creep 50%{GAs} Uncracked, Creep 25%{GJ} Cracked, Creep kE=1.0, kI=0.5, kJ=0.5, kA=1.0 [Default Parameters]</td> <td style="background-color: #333; color: white;"><b>Class 1 PT, Class 2 PT, RC or Class 3 PT</b> 50%{EA} Uncracked, Creep 25%{EI} Cracked, Creep 50%{GAs} Uncracked, Creep 25%{GJ} Cracked, Creep kE=1.0, kI=0.5, kJ=0.5, kA=1.0 [~0.5 x Default Parameters]</td> </tr> <tr> <td style="background-color: #333; color: white;">SLS DL, SDL, LL (V) #C</td> <td style="background-color: #333; color: white;"><b>Class 1 PT or Class 2 PT</b> 50%{EA} Uncracked, Creep 50%{EI} Uncracked, Creep 50%{GAs} Uncracked, Creep 50%{GJ} Uncracked, Creep kE=1.0, kI=1.0, kJ=1.0, kA=1.0 [2.0 x Default Parameters]</td> <td style="background-color: #333; 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# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

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	<p style="text-align: center;"><b>RC or Class 3 PT</b></p> <p>100%{EA} Uncracked, No Creep                      50%{EI} Cracked, No Creep                      100%{GA<sub>s</sub>} Uncracked, No Creep                      50%{GJ} Cracked, No Creep                      k<sub>E</sub>=2.0, k<sub>I</sub>=0.5, k<sub>J</sub>=0.5, k<sub>A</sub>=1.0                      [2.0 x Default Parameters]</p>	[2.0 x Default Parameters]
<b>SLS EQ (H)</b> #C, #D, #F	<p style="text-align: center;"><b>Class 1 PT or Class 2 PT</b></p> <p>100%{EA} Uncracked, No Creep                      100%{EI} Uncracked, No Creep                      100%{GA<sub>s</sub>} Uncracked, No Creep                      100%{GJ} Uncracked, No Creep                      k<sub>E</sub>=2.0, k<sub>I</sub>=1.0, k<sub>J</sub>=1.0, k<sub>A</sub>=1.0                      [4.0 x Default Parameters]</p> <hr/> <p style="text-align: center;"><b>RC or Class 3 PT</b></p> <p>100%{EA} Uncracked, No Creep                      50%{EI} Cracked, No Creep                      100%{GA<sub>s</sub>} Uncracked, No Creep                      50%{GJ} Cracked, No Creep                      k<sub>E</sub>=2.0, k<sub>I</sub>=0.5, k<sub>J</sub>=0.5, k<sub>A</sub>=1.0                      [2.0 x Default Parameters]</p>	<p style="text-align: center;"><b>Class 1 PT, Class 2 PT, RC or Class 3 PT</b></p> <p>100%{EA} Uncracked, No Creep                      50%{EI} Cracked, No Creep                      100%{GA<sub>s</sub>} Uncracked, No Creep                      50%{GJ} Cracked, No Creep                      k<sub>E</sub>=2.0, k<sub>I</sub>=0.5, k<sub>J</sub>=0.5, k<sub>A</sub>=1.0                      [~1.0 x Default Parameters]</p>
<b>ULS Sway Susceptibility (NHF) (H)</b> #E	<p style="text-align: center;"><b>Class 1 PT or Class 2 PT</b></p> <p>100%{EA} Uncracked, No Creep                      70%{EI} Uncracked, No Creep                      100%{GA<sub>s</sub>} Uncracked, No Creep                      70%{GJ} Uncracked, No Creep                      k<sub>E</sub>=2.0, k<sub>I</sub>=0.7, k<sub>J</sub>=0.7, k<sub>A</sub>=1.0                      [~2.8 x Default Parameters]</p>	<p style="text-align: center;"><b>Class 1 PT, Class 2 PT, RC or Class 3 PT</b></p> <p>100%{EA} Uncracked, No Creep                      70%{EI} Uncracked, No Creep                      100%{GA<sub>s</sub>} Uncracked, No Creep                      70%{GJ} Uncracked, No Creep                      k<sub>E</sub>=2.0, k<sub>I</sub>=0.7, k<sub>J</sub>=0.7, k<sub>A</sub>=1.0                      [~1.4 x Default Parameters]</p>
<b>ULS Sway Susceptibility (Wind) (H)</b> #E	<p style="text-align: center;"><b>RC or Class 3 PT</b></p> <p>100%{EA} Uncracked, No Creep                      35%{EI} Cracked, No Creep                      100%{GA<sub>s</sub>} Uncracked, No Creep                      35%{GJ} Cracked, No Creep                      k<sub>E</sub>=2.0, k<sub>I</sub>=0.35, k<sub>J</sub>=0.35, k<sub>A</sub>=1.0                      [~1.4 x Default Parameters]</p>	<p style="text-align: center;"><b>Class 1 PT, Class 2 PT, RC or Class 3 PT</b></p> <p>100%{EA} Uncracked, No Creep                      70%{EI} Cracked, No Creep                      100%{GA<sub>s</sub>} Uncracked, No Creep                      70%{GJ} Cracked, No Creep                      k<sub>E</sub>=2.0, k<sub>I</sub>=0.7, k<sub>J</sub>=0.7, k<sub>A</sub>=1.0                      [~1.4 x Default Parameters]</p>
<b>ULS Sway Susceptibility (EQ) (H)</b> #E, #F	<p style="text-align: center;"><b>Class 1 PT or Class 2 PT</b></p> <p>100%{EA} Uncracked, No Creep                      70%{EI} Uncracked, No Creep                      100%{GA<sub>s</sub>} Uncracked, No Creep                      70%{GJ} Cracked, No Creep                      k<sub>E</sub>=2.0, k<sub>I</sub>=0.7, k<sub>J</sub>=0.7, k<sub>A</sub>=1.0                      [~2.8 x Default Parameters]</p> <hr/> <p style="text-align: center;"><b>RC or Class 3 PT</b></p> <p>100%{EA} Uncracked, No Creep                      35%{EI} Cracked, No Creep                      100%{GA<sub>s</sub>} Uncracked, No Creep                      35%{GJ} Cracked, No Creep                      k<sub>E</sub>=2.0, k<sub>I</sub>=0.35, k<sub>J</sub>=0.35, k<sub>A</sub>=1.0                      [~1.4 x Default Parameters]</p>	<p style="text-align: center;"><b>Class 1 PT, Class 2 PT, RC or Class 3 PT</b></p> <p>100%{EA} Uncracked, No Creep                      35%{EI} Cracked, No Creep                      100%{GA<sub>s</sub>} Uncracked, No Creep                      35%{GJ} Cracked, No Creep                      k<sub>E</sub>=2.0, k<sub>I</sub>=0.35, k<sub>J</sub>=0.35, k<sub>A</sub>=1.0                      [~0.7 x Default Parameters]</p>

**#A:** These values of k<sub>E</sub>, k<sub>I</sub>, k<sub>J</sub> and k<sub>A</sub> within the table are formulated based on the premise that the elastic modulus, E value has been reduced to account for creep effects as the default. The reduction to the elastic modulus, E of 0.50 for typical office / residential buildings as stipulated by cl.14.5.2 of Report 110 Design of RC Flat Slabs to BS8100 (CIRIA) pp.34 is adopted.

**#B:** **RC** or **Class 3 PT** stiffness values for ULS design governed by 1.00I<sub>g</sub> (wall, column) and 0.50I<sub>g</sub> (slab) of TR.64 Guide to the Design and Construction of RC Flat Slabs (The Concrete Society) pp.31 and by cl.14.5.4 of Report 110 Design of RC Flat Slabs to BS8100 (CIRIA) pp.35 are adopted. The **RC** or **Class 3 PT** ratio of relative stiffness for ULS design between (wall, column) : (slab, beam) elements of 1.00 : 0.50 is also suggested by cl.6.6.3.1.1 ACI 318-14, i.e. in 0.70 : 0.35 although the stiffness reduction factor 0.70 is not adopted here as would have a somewhat negligible effect on the ULS effects. Creep on the other hand is included for ULS effects to cater for the additional effects generated by differential (elastic, creep, shrinkage) axial shortening of walls/columns.

**#C:** **RC** or **Class 3 PT** stiffness values for SLS design governed by 0.70I<sub>g</sub> (wall, column), 0.35I<sub>g</sub> (beam) and 1.00A<sub>g</sub> (beam, wall, column) of cl.6.6.3.1.1 ACI 318-14 together with a 1.4 multiplier stipulated within cl.6.6.3.2.2 ACI 318-14 resulting in 1.00I<sub>g</sub> (wall, column), 0.50I<sub>g</sub> (beam) and 1.00A<sub>g</sub> (beam, wall, column) are adopted. Similar **RC** or **Class 3 PT** stiffness values for SLS design of 1.00I<sub>g</sub> (wall, column) and 0.50I<sub>g</sub> (slab) are also suggested by TR.64 Guide to the Design and Construction of RC Flat Slabs (The Concrete Society) pp.31 and by cl.14.5.4 of Report 110 Design of RC Flat Slabs to BS8100 (CIRIA) pp.35.

**#D:** The elastic modulus, E value incorporating creep effects is still adopted for ULS NHF / ULS wind / ULS EQ as part of the ULS load combination cases involving vertical loads (even though wind / EQ are short-term phenomena), as the effect of which is deemed negligible as the ratio of stiffness between (wall, column) and (slab, beam) elements is similar to their ratio of

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	✓																														
	<p>stiffness without incorporating creep effects. On the other hand, for SLS NHF / SLS wind / SLS EQ / SLS vibration design, the elastic modulus, E without incorporating creep effects is employed.</p> <p><b>#E:</b> RC or Class 3 PT stiffness values for ULS design governed by 0.70I<sub>g</sub> (wall, column), 0.35I<sub>g</sub> (beam) and 1.00A<sub>g</sub> (beam, wall, column) of cl.6.6.3.1.1 ACI 318-14 are adopted. Further, it is given in cl.R6.6.4.3 ACI 318-14 that if the lateral load deflections of the frame are calculated using service loads and the service load moments of inertia given in cl.6.6.3.2.2, it is permissible to calculate Q using 1.2 times the sum of the service gravity loads, the service load story shear, and 1.4 times the first order service load story deflections.</p> <p><b>#F:</b> Note that in certain circumstances, it may be deemed more appropriate to employ cracked 0.50I<sub>g</sub> (wall, column) stiffness properties for ULS EQ or SLS EQ effects due to the large displacements involved as suggested by T.9.1 of the Manual for the Seismic Design of Steel and Concrete Buildings to EC8 (IStructE) pp.61.</p>	<input checked="" type="checkbox"/>																														
5.22	Check slab cover 25mm internal and 40mm external (e.g. ground, podium deck, swimming pool, water tank, roof) (ES).	<input type="checkbox"/>																														
5.23	VFS → Select by Type → select Beam → Modify Item Properties → check Beam Tab torsional stiffness M11 (i.e. the torsional constant factor) = { <b>0.01</b> Class 1 PT or Class 2 PT   <b>0.01</b> RC or Class 3 PT} for models <b>without equilibrium torsional</b> beams.	<input type="checkbox"/>																														
5.24	VFS → Select by Type → select Beam → Modify Item Properties → check Beam Tab torsional stiffness M11 (i.e. the torsional constant factor) = { <b>1.00</b> Class 1 PT or Class 2 PT   <b>0.50</b> RC or Class 3 PT} for models <b>with equilibrium torsional</b> beams (e.g. curved beams and straight beams that frame eccentrically to columns (especially heavily loaded beams in transfer floors)). Torsional stiffness may also be considered for: - (i) heavily loaded <b>straight</b> transfer beams, and (ii) <b>straight</b> edge beams in regular buildings experiencing significant <b>compatibility torsion</b> .	<input type="checkbox"/>																														
5.25	<table border="1" style="width: 100%; text-align: center;"> <thead> <tr> <th colspan="3">Equilibrium and Compatibility Torsion</th> </tr> <tr> <th>Scenario</th> <th>Equilibrium Torsion</th> <th>Compatibility Torsion</th> </tr> </thead> <tbody> <tr> <td><b>Straight (Between Columns) Continuous Primary Beams</b></td> <td>Not Generated</td> <td>Generated</td> </tr> <tr> <td><b>Facetted (Between Columns) Continuous Primary Beams</b></td> <td>Generated</td> <td>Generated</td> </tr> <tr> <td><b>Curved (Between Columns) Continuous Primary Beams</b></td> <td>Generated</td> <td>Generated</td> </tr> </tbody> </table>	Equilibrium and Compatibility Torsion			Scenario	Equilibrium Torsion	Compatibility Torsion	<b>Straight (Between Columns) Continuous Primary Beams</b>	Not Generated	Generated	<b>Facetted (Between Columns) Continuous Primary Beams</b>	Generated	Generated	<b>Curved (Between Columns) Continuous Primary Beams</b>	Generated	Generated	<input type="checkbox"/>															
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5.26	For models with EQ loads stabilised by moment frames, as per the requirements of BS EN1998-1, the following geometrical constraints need to be achieved: - (a) as per cl.5.4.1.2.1 and cl.5.5.1.2.1, primary seismic beam eccentricity, $e \leq \text{column orthogonal dim, } b_c / 4$ (DCM, DCH) primary seismic beam width, $b_w \leq \min \{ \text{column orthogonal dim, } b_c + \text{beam depth, } h_w, 2b_c \}$ (DCM, DCH) primary seismic beam width, $b_w \geq 200\text{mm}$ (DCH) (b) as per cl.5.4.1.2.2 and cl.5.5.1.2.2, primary seismic column width, $h_c \geq (\text{column clear height, } l_d / 2) / 10$ (DCM, DCH) primary seismic column width, $h_c \geq 250\text{mm}$ (DCH)	<input type="checkbox"/>																														
5.27	For models with EQ loads stabilised by stability walls, as per the requirements of BS EN1998-1, the following geometrical constraints need to be achieved: - (a) as per cl.5.4.1.2.3 and cl.5.5.1.2.3, ductile wall thickness, $b_{wo} \geq \max \{ 150\text{mm, clear storey height, } h_s / 20 \}$ (DCM, DCH) (b) as per cl.5.4.3.4.2 and cl.5.5.3.4.5, ductile wall boundary element requirements (DCM, DCH)	<input type="checkbox"/>																														
<b>5.3</b>	<b>Element Horizontal Framing</b>																															
5.31	<table border="1" style="width: 100%; text-align: center;"> <thead> <tr> <th colspan="5">Requirement of Element to Frame Horizontally (Within the Same Storey) onto Element Insertion Point / Line (or Simply Within the Element Footprint on Plan)</th> </tr> <tr> <th>Element</th> <th>Slab</th> <th>Beam</th> <th>Wall</th> <th>Column</th> </tr> </thead> <tbody> <tr> <td><b>Slab</b></td> <td>N/A</td> <td>Not Required #A</td> <td>Not Required #B</td> <td>Not Required #C</td> </tr> <tr> <td><b>Beam</b></td> <td>N/A</td> <td>Not Required #D</td> <td>Not Required #E</td> <td>Not Required #E</td> </tr> <tr> <td><b>Wall</b></td> <td>N/A</td> <td>N/A</td> <td>Not Required #F</td> <td>Not Required #F</td> </tr> <tr> <td><b>Column</b></td> <td>N/A</td> <td>N/A</td> <td>N/A</td> <td>N/A</td> </tr> </tbody> </table> <p><b>#A:</b> Check slab footprint frame need only frame onto (<b>or through</b>) footprint of beam (ES).  <b>#B:</b> Check slab footprint frame need only frame onto (<b>or through</b>) footprint of wall (ES).  <b>#C:</b> Check slab footprint frame need only frame onto (<b>or through</b>) footprint of column (ES).  <b>#D:</b> Check secondary beam footprint need only frame onto footprint of primary beam (ES).  <b>#E:</b> Check primary beam footprint need only frame onto footprint of wall/column (ES).  <b>#F:</b> Check wall footprint need only frame onto footprint of wall/column (ES).            Note that in all cases above, no element may frame through the other element (but instead only onto element insertion point/line or within the element footprint), unless specifically denoted otherwise.</p>	Requirement of Element to Frame Horizontally (Within the Same Storey) onto Element Insertion Point / Line (or Simply Within the Element Footprint on Plan)					Element	Slab	Beam	Wall	Column	<b>Slab</b>	N/A	Not Required #A	Not Required #B	Not Required #C	<b>Beam</b>	N/A	Not Required #D	Not Required #E	Not Required #E	<b>Wall</b>	N/A	N/A	Not Required #F	Not Required #F	<b>Column</b>	N/A	N/A	N/A	N/A	<input type="checkbox"/>
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# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

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5.42	Check employment of <b>FE Shell Model</b> (with <b>mesh size</b> being reduced until convergence of the wall axial forces and bending moments) idealisation (Mid-Pier idealisation N/A) for transferred walls at the transfer level for a greater distribution of load and the realistic adoption of the wall contribution to the load transfer.	<input type="checkbox"/>																																													
5.43	Check for transferred walls framing across multiple transfer walls / transfer columns / transfer beams along the same axis that the <b>FE Shell Model</b> idealisation (Mid-Pier idealisation N/A) is used.	<input type="checkbox"/>																																													
5.44	Check transfer wall / transfer beam and <b>transferred wall</b> are modelled with their analytical footprint matching their physical footprint and centroid <b>coincident</b> with each other as beam torsions due to any relative offset <b>will not be</b> generated as beam rigid links are not created. Check transfer column / transfer beam and <b>transferred column</b> are modelled with their physical footprint centroid <b>coincident</b> with each other.	<input type="checkbox"/>																																													
5.45	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr style="background-color: #004a7c; color: white;"> <th colspan="5" style="text-align: center;">Modelling of Transferred Walls</th> </tr> <tr style="background-color: #004a7c; color: white;"> <th style="width: 15%;">Transfer red Wall</th> <th style="width: 15%;">Transfer Wall/ Column #C</th> <th style="width: 10%;">Rigid Zones</th> <th style="width: 10%;">Overlap #A</th> <th style="width: 50%;">Remark</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">Wall #B</td> <td style="text-align: center;">Wall #B</td> <td style="text-align: center;">None</td> <td style="text-align: center;">No Overlap</td> <td style="color: green;">• Correct <b>flexible</b> representation of transfer beam bending moment and shear force effects</td> </tr> <tr> <td style="text-align: center;">Wall #B</td> <td style="text-align: center;">Column</td> <td style="text-align: center;">None</td> <td style="text-align: center;">No Overlap</td> <td style="color: green;">• Correct <b>flexible</b> representation of transfer beam bending moment and shear force effects</td> </tr> <tr> <td style="text-align: center;">Wall #B</td> <td style="text-align: center;">Wall #B</td> <td style="text-align: center;">None #D</td> <td style="text-align: center;">Full / Partial Overlap</td> <td style="color: green;">• Correct <b>flexible</b> representation of transfer beam bending moment and shear force effects</td> </tr> <tr> <td style="text-align: center;">Wall #B</td> <td style="text-align: center;">Column</td> <td style="text-align: center;">None</td> <td style="text-align: center;">Full / Partial Overlap</td> <td style="color: green;">• Correct <b>flexible</b> representation of transfer beam bending moment and shear force effects</td> </tr> <tr> <td style="text-align: center;">Wall #B</td> <td style="text-align: center;">Wall #B</td> <td style="text-align: center;">Max</td> <td style="text-align: center;">No Overlap</td> <td style="color: red;">N/A</td> </tr> <tr> <td style="text-align: center;">Wall #B</td> <td style="text-align: center;">Column</td> <td style="text-align: center;">Max</td> <td style="text-align: center;">No Overlap</td> <td style="color: red;">N/A</td> </tr> <tr> <td style="text-align: center;">Wall #B</td> <td style="text-align: center;">Wall #B</td> <td style="text-align: center;">Max #D</td> <td style="text-align: center;">Full / Partial Overlap</td> <td style="color: red;">N/A</td> </tr> </tbody> </table>	Modelling of Transferred Walls					Transfer red Wall	Transfer Wall/ Column #C	Rigid Zones	Overlap #A	Remark	Wall #B	Wall #B	None	No Overlap	• Correct <b>flexible</b> representation of transfer beam bending moment and shear force effects	Wall #B	Column	None	No Overlap	• Correct <b>flexible</b> representation of transfer beam bending moment and shear force effects	Wall #B	Wall #B	None #D	Full / Partial Overlap	• Correct <b>flexible</b> representation of transfer beam bending moment and shear force effects	Wall #B	Column	None	Full / Partial Overlap	• Correct <b>flexible</b> representation of transfer beam bending moment and shear force effects	Wall #B	Wall #B	Max	No Overlap	N/A	Wall #B	Column	Max	No Overlap	N/A	Wall #B	Wall #B	Max #D	Full / Partial Overlap	N/A	<input type="checkbox"/>
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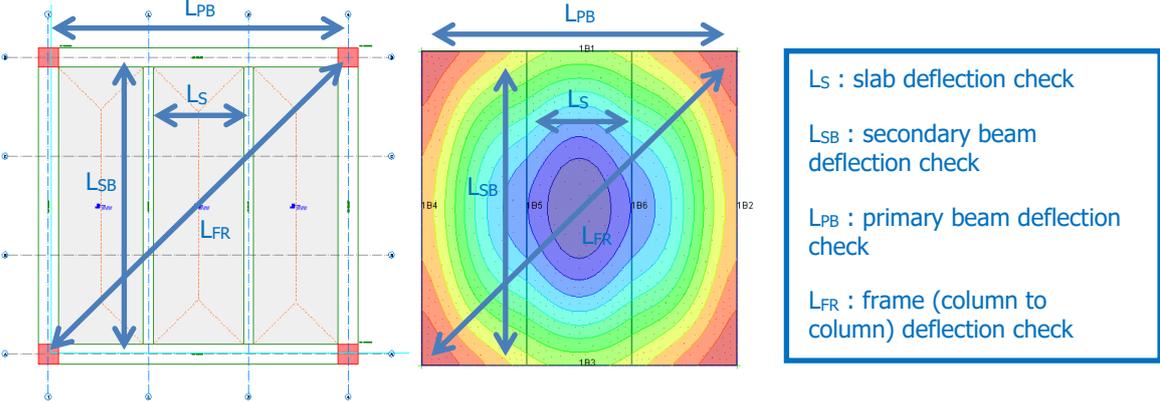
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<b>5.5</b>	<b>Housekeeping</b>																				
5.51	VFS → Select by Type → select Slab Region / Beam → Tools → Reset Labels → All → re-label all slabs and beams independently between storeys.	<input type="checkbox"/>																			
5.52	VFS → Select by Type → select Wall / Column → Tools → Reset Labels → For Column/Wall Stacks → re-label all walls and columns consistently between storeys.	<input type="checkbox"/>																			
<b>5.6</b>	<b>Model Integrity</b>																				
5.61	VSS → Select/Set View Items → select Slab Region/Beam/Wall/Column ID → check for overlapping slabs/beams/walls/columns (ES). BMVC → VFS → Build → Preprocessing → Establish Component Connectivity.	<input type="checkbox"/>																			
5.62	BMVC → VFS → Build → Preprocessing → Connect Beams to Columns and Walls.	<input type="checkbox"/>																			
<b>6.0</b>	<b>METHOD OF ANALYSIS CHECKS</b>																				
<b>6.1</b>	<b>Method of Slab Analysis and Design</b>																				
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Flat Slab-Column with Shear Wall	Supported <sup>#A</sup>	Partially Supported <sup>#C</sup>																			
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6.32	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr style="background-color: #333; color: white;"> <th rowspan="2" style="width: 30%;">Method of Frame Analysis</th> <th colspan="2" style="text-align: center;">Transferred Beam/Slab on Transferred Wall/Column on Transfer Beam/Slab</th> </tr> <tr style="background-color: #333; color: white;"> <th style="width: 35%;">ULS and SLS Effects on Transferred</th> <th style="width: 35%;">ULS and SLS Effects on Transfer</th> </tr> </thead> <tbody> <tr> <td></td> <td></td> <td></td> </tr> </tbody> </table>	Method of Frame Analysis	Transferred Beam/Slab on Transferred Wall/Column on Transfer Beam/Slab		ULS and SLS Effects on Transferred	ULS and SLS Effects on Transfer				<input type="checkbox"/>											
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# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT						✓																			
1	BA	Beam or Wall/Column		Slab	Beam		Slab																			
		Beam or Wall/Column	Slab in Vicinity		Beam	Slab in Vicinity																				
		Supported #A, #B	Supported #A, #B	Supported #A, #B	Supported #C	Supported #D	Supported #D																			
2	LTD <sub>2</sub>	Not Supported #A	Not Supported	Not Supported	Supported #C	Supported #D	Supported #D																			
<p><b>#A:</b> Check that the <b>envelope effects</b> of both Method 1 and Method 2 are used in the design of transferred beams, transferred slabs in vicinity, transferred slabs and transferred walls/columns, noting that Method 1 supports the effects of <b>differential support settlement</b> on superstructure beams, superstructure slabs in vicinity and superstructure slabs supported on walls/columns on <b>transfer beams or transfer slabs</b> or due to <b>DAS</b> of adjacent walls/columns. Note that the actual results (which can be predicted by a staged construction analysis) fall in between the effects produced by the two methods. The ULS load combinations inherently include the effects of differential (elastic, creep, shrinkage) axial shortening. Staged construction analysis may be performed to reduce the magnitude of the effects of differential (elastic, creep, shrinkage) axial shortening.</p> <p><b>#B:</b> Check that Method 1 is adopted to cater for the effects of <b>differential support settlement</b> of transferred beams, transferred slabs in vicinity, transferred slabs and transferred walls/columns on <b>transfer slabs</b>.</p> <p><b>#C:</b> Check that Method 2 is used to evaluate the effects on the <b>transfer beams</b> as Method 2 <b>does not</b> allow for the flexibility of the transfer beam resulting in larger action effects (forces, moments) on the transfer beam.</p> <p><b>#D:</b> Check that Method 2 is used to evaluate the effect of walls/columns on <b>transfer slabs</b> and on <b>slabs in the vicinity of walls/columns on transfer beams</b> as Method 2 <b>does not</b> allow for the flexibility of the transfer slab / transfer beam resulting in larger action effects (forces, moments) on the transfer slab / slabs in the vicinity of transfer beams.</p>																										
6.33	<table border="1"> <thead> <tr> <th rowspan="3">Item</th> <th colspan="2">Method of Frame Analysis</th> </tr> <tr> <th>Method 1</th> <th>Method 2</th> </tr> <tr> <th>BA</th> <th>LTD<sub>2</sub></th> </tr> </thead> <tbody> <tr> <td>Effect of Continuity on Beam Loading Tributary</td> <td>Supported</td> <td>Supported</td> </tr> <tr> <td>Effect of Flat Slabbing in Beam-Column Vertical Load Functional Framing</td> <td>Supported</td> <td>Supported</td> </tr> <tr> <td>Pattern Loading</td> <td>Not Supported</td> <td>Not Supported</td> </tr> <tr> <td>Effect of Slabs in Resisting Torsion of Beams</td> <td>Supported</td> <td>Supported</td> </tr> </tbody> </table>						Item	Method of Frame Analysis		Method 1	Method 2	BA	LTD <sub>2</sub>	Effect of Continuity on Beam Loading Tributary	Supported	Supported	Effect of Flat Slabbing in Beam-Column Vertical Load Functional Framing	Supported	Supported	Pattern Loading	Not Supported	Not Supported	Effect of Slabs in Resisting Torsion of Beams	Supported	Supported	<input type="checkbox"/>
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<b>7.0</b>	<b>SLAB ANALYSIS AND DESIGN CHECKS</b>																									
<b>7.1</b>	<b>General</b>																									
7.11	In <b>RC</b> models, check sufficiency of rebar in orthogonal directions to fully mesh slab (ES). In <b>PT</b> models, check sufficiency of tendons (and rebar) in orthogonal directions to fully mesh slab (ES).						<input type="checkbox"/>																			
<b>7.2</b>	<b>Conventional Codified BS8110 Coefficients Method</b>																									
7.21	Manually check sufficiency of rebar based on conventional codified BS8110 coefficients method in <b>RC</b> models (ES).						<input type="checkbox"/>																			
<b>7.3</b>	<b>Full FE Method Design Method</b>																									
7.31	VFS → Select by Type → select Beam → Modify Item Properties → check Beam Tab uncracked stiffnesses (M11, M22, M33) to 1.00 and VFS → Select by Type → select Slab Region → Modify Item Properties → check Slab Region Tab uncracked stiffnesses (M11, M22) to 1.00. VFS → Select by Type → select Beam → Modify Item Properties → check Beam Tab cracked stiffnesses (M11, M22, M33) to 0.50 and VFS → Select by Type → select Slab Region → Modify Item Properties → check Slab Region Tab cracked stiffnesses (M11, M22) to 0.50. FEFA → select Uncracked Stiffness Modifier for Class 1 <b>PT</b> or Class 2 <b>PT</b> and Cracked Stiffness Modifier for <b>RC</b> or Class 3 <b>PT</b> (ES).						<input type="checkbox"/>																			
7.32	<table border="1"> <thead> <tr> <th colspan="3">Positive and Negative Moment Factors for FEFA Effects</th> </tr> <tr> <th></th> <th>Positive Moment Factor</th> <th>Negative Moment Factor</th> </tr> </thead> <tbody> <tr> <td>(Less conservative) elasto-plastic slab design (assuming conditions of cl.3.5.2.3 BS8110-1 satisfied)</td> <td>1.2</td> <td>0.8</td> </tr> <tr> <td>(More conservative) elastic slab design (assuming conditions of cl.3.5.2.3 BS8110-1 satisfied)</td> <td>1.0</td> <td>1.0</td> </tr> <tr> <td>(More conservative) elastic slab design with equivalent pattern loading</td> <td>1.2</td> <td>1.0</td> </tr> </tbody> </table>						Positive and Negative Moment Factors for FEFA Effects				Positive Moment Factor	Negative Moment Factor	(Less conservative) elasto-plastic slab design (assuming conditions of cl.3.5.2.3 BS8110-1 satisfied)	1.2	0.8	(More conservative) elastic slab design (assuming conditions of cl.3.5.2.3 BS8110-1 satisfied)	1.0	1.0	(More conservative) elastic slab design with equivalent pattern loading	1.2	1.0	<input type="checkbox"/>				
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# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	✓
	(assuming conditions of cl.3.5.2.3 BS8110-1 not satisfied)	
7.33	FEFA → VSS → RDS → Vibration → check animated deflections for modelling accuracy (ES).	<input type="checkbox"/>
7.34	<p><b>PT Tendon Modelling</b>            Build → Tendon → Create Tendon / Map Tendon Banded / Map Tendon Distributed → check tendons based on prestress force and eccentricity required for load balancing and prestress force for average precompression (ES).</p> <p><b>RC or PT Deflection Checks</b>            FEFA → VSS → RDS → Slab → Deformation → Z-Translation → check <math> TLS = DL+PT </math> <b>deflections</b> ≤ <math>\{[\text{span}/500 \text{ to } \text{span}/350].C_1, 20\text{mm}\}</math> (ES).            FEFA → VSS → RDS → Slab → Deformation → Z-Translation → check <math>SLS=DL+SDL+LL+PT</math> <b>deflections</b> ≤ <math>[\text{span}/250].C_1</math> (ES).            FEFA → VSS → RDS → Slab → Deformation → Z-Translation → check <math>k_c.(DL+SDL)+LL+k_{c,PT}.PT</math> <b>deflections</b> ≤ <math>\{[\text{span}/500 \text{ to } \text{span}/350].C_1, 20\text{mm}\}</math>, note the creep term also includes the <b>total</b> (elastic, creep, shrinkage) axial shortening of the <b>one</b> storey in question (ES).            FEFA → VSS → RDS → Slab → Deformation → Z-Translation → check <math>k_c.(DL+SDL)+LL+k_{c,PT}.PT</math> <b>deflections</b> at façade beams ≤ <math>\{[\text{span}/1000].C_1, 20\text{mm}\}</math>, note the creep term also includes the <b>total</b> (elastic, creep, shrinkage) axial shortening of the <b>one</b> storey in question (ES).            Note <math>C_1 = \{0.8 \text{ for flanged beams, } 10.0/\text{span(m)} \text{ for spans } &gt; 10.0\text{m, } 0.9 \text{ for flat slabs}\}</math>. Note deflection criteria to cl.3.4.6.3 and cl.3.4.6.4 BS8110-1 and cl.3.2.1.1 and cl.3.2.1.2 BS8110-2. Note creep factor, <math>k_c</math> calculated from equating <math>0.5.(1-0.4)DL+1.0SDL=k_c.(DL+SDL)</math> based on multiplying factor 0.5 for the total DL creep deflection component (as opposed to the instantaneous deflection component) to (1-0.4) for the remaining 60% component of DL creep deflection after 1 month (cl.7.3 BS8110-2), giving <math>k_c=[0.3DL+1.0SDL]/[DL+SDL]</math>. Note likewise creep factor, <math>k_{c,PT}</math> calculated as <math>(1-0.5/K_{LT}.K_{ST}).(1-0.4)=0.2625</math>.</p>  <p>In <b>RC</b> models, note if necessary, the simulation of the beneficial effect of additional reinforcement in controlling deflections can be made by factoring down the exhibited deflections by the ratio of the modified span / effective depth to the ratio of the basic span / effective depth (cantilever 7.0, simply supported 20.0, continuous 26.0) (ES).</p>	<input type="checkbox"/>
7.35	<p><b>PT Tendon Modelling</b>            Build → Tendon → Create Tendon / Map Tendon Banded / Map Tendon Distributed → check tendons based on prestress force and eccentricity required for load balancing and prestress force for average precompression (ES).</p> <p><b>RC or PT Design Strip Support Lines, RC or PT Design Strip Tributaries and RC or PT Design Strip Design Sections Frequency</b>            VSS → Strips → Create Support Lines → check design strip support lines in X/Y directions (ES).            VSS → select Support Lines → Modify Item Properties → check Support Line Tab direction, criteria, rebar layer, maximum number of design sections per span to 10, distance of design section from face of column to 50mm, selecting display design sections and display results (ES).            VSS → Strips → Create Splitters → check design strip support lines splitters spanning between defined support lines for voids (e.g. lift and staircase) (ES).            VSS → RPT-G → Design Plans → Support Lines X/Y-Directions → check design strip support lines in X/Y directions (ES).            VSS → Strips / FEM → Generate Design Sections Automatically → Regenerate Tributaries → check design strip tributaries in X/Y directions and design strip design sections frequency for <b>RC</b> (column and middle design strip) or <b>PT</b> (full tributary width design strip) (ES).            VSS → RPT-G → Design Plans → Design Strips X/Y-Directions → check design strip tributaries in X/Y directions (ES).</p> <p><b>FE Analysis Method RC Analysis and Design</b>            FEFA → VSS → check <b>RC analysis and design</b> in X/Y directions (ES) → RDS → Slab</p>	<input type="checkbox"/>

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	✓
	<p>→ Actions (Contour Map) → <math> M_{xx} + M_{xy} </math> and <math> M_{yy} + M_{xy} </math> → check <b>ULS bending</b> effects <math>M_{ULS,E/E}</math>, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.            → manually check <b>ULS shear</b> effects <math>V_{ULS,E/E}</math>, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.</p> <p><b>RC Design Strip Design Sections FE Analysis Method Integration of Effects Analysis and RC Design Strip Design Sections Design</b></p> <p>FEFA → VSS → FEM → Design the "Design Section(s)" → Investigate (does not add rebar even if required) / Design (does add rebar if required) → check design strip design sections <b>RC analysis and design</b> in X/Y directions (ES) → RDS → Design Sections</p> <p>→ Actions → Bending → check <b>ULS bending</b> effects <math>M_{ULS,E/E}</math> based on <math>1.4 \times</math> tributary width <math>\times</math> (15.0-25.0kPa) <math>\times</math> <math>L^2/12</math>, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.            → Actions → Shear → check <b>ULS shear</b> effects <math>V_{ULS,E/E}</math> based on <math>1.4 \times</math> tributary width <math>\times</math> (15.0-25.0kPa) <math>\times</math> <math>L/2</math>, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.            → manually check <b>rebar areas (to resist ULS bending) required</b> <math>\{A_s(d)_{xx}, A_s(d)_{yy}\}</math>, noting minimum steel.            → manually check <b>ULS shear capacity</b>, <math>V_u</math> is greater than ULS shear effects <math>V_{ULS,E/E}</math> together with the associated <b>required shear links</b> <math>A_{sv,req}/S</math>.</p> <p>FEFA → VSS → FEM → Generate Rebar Drawing → check <b>rebar (to resist ULS bending) required</b> in X/Y directions (ES).</p> <p><b>FE Analysis Method PT Analysis and Design</b></p> <p>FEFA → VSS → check <b>PT analysis and design</b> in X/Y directions (ES) → RDS → Slab</p> <p>→ Actions (Contour Map) → <math> M_{xx} + M_{xy} </math> and <math> M_{yy} + M_{xy} </math> → check <b>TLS/SLS bending</b> effects <math>M_{TLS/SLS,E/E}+M_{TLS/SLS,E/L}</math> are minimal.            → Actions (Contour Map) → <math> M_{xx} + M_{xy} </math> and <math> M_{yy} + M_{xy} </math> → check <b>ULS bending</b> effects <math>M_{ULS,E/E}+M_{ULS,S/E}</math>, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.            Note by convention, +ve bending moment is sagging and -ve bending moment is hogging (<i>consistent</i> with ADAPT-Builder).</p> <p>→ Stress (Contour Map) → Mid-Depth Along XX/YY → check <b>TLS/SLS average precompression</b> 0.7-2.5N/mm<sup>2</sup> for slab and 2.5-4.5N/mm<sup>2</sup> for beam.            → Stress (Contour Map) → Top Fibre Along XX/YY → check <b>TLS top stress</b> <math>f'_{min,t} \leq f'_t \leq f'_{max,t}</math>            BM:   <math>-1.0 \leq f'_t \leq 0.50f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_t \leq 0.50f_{ci}</math> [CL2]   <math>-0.25f_{ci} \leq f'_t \leq 0.50f_{ci}</math> [CL3]              FS:   <math>-1.0 \leq f'_t \leq 0.24f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_t \leq 0.24f_{ci}</math> [CL2]   <math>-0.45\sqrt{f_{ci}} \leq f'_t \leq 0.24f_{ci}</math> [CL3]              → Stress (Contour Map) → Bottom Fibre Along XX/YY → check <b>TLS bottom stress</b> <math>f'_{min,b} \leq f'_b \leq f'_{max,b}</math>            BM:   <math>-1.0 \leq f'_b \leq 0.50f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_b \leq 0.50f_{ci}</math> [CL2]   <math>-0.25f_{ci} \leq f'_b \leq 0.50f_{ci}</math> [CL3]              FS:   <math>-1.0 \leq f'_b \leq 0.33f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_b \leq 0.33f_{ci}</math> [CL2]   <math>-0.45\sqrt{f_{ci}} \leq f'_b \leq 0.33f_{ci}</math> [CL3]              → Stress (Contour Map) → Top Fibre Along XX/YY → check <b>SLS top stress</b> <math>f_{min,t} \leq f_t \leq f_{max,t}</math>            BM:   <math>-0.0 \leq f_t \leq 0.33f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_t \leq 0.33f_{cu}</math> [CL2]   <math>-&lt;.....&gt; \leq f_t \leq 0.33f_{cu}</math> [CL3]              FS:   <math>-0.0 \leq f_t \leq 0.33f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_t \leq 0.33f_{cu}</math> [CL2]   <math>-0.45\sqrt{f_{cu}} \leq f_t \leq 0.33f_{cu}</math> [CL3]              Note <math>-&lt;.....&gt; = \text{MAX} \{-0.25f_{cu}, (0.7-1.1) \cdot (-0.58\sqrt{f_{cu}} \text{ to } -0.82\sqrt{f_{cu}}) - 4\text{N/mm}^2/1.0\%</math>.            → Stress (Contour Map) → Bottom Fibre Along XX/YY → check <b>SLS bottom stress</b> <math>f_{min,b} \leq f_b \leq f_{max,b}</math>            BM:   <math>-0.0 \leq f_b \leq 0.40f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_b \leq 0.40f_{cu}</math> [CL2]   <math>-&lt;.....&gt; \leq f_b \leq 0.40f_{cu}</math> [CL3]              FS:   <math>-0.0 \leq f_b \leq 0.24f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_b \leq 0.24f_{cu}</math> [CL2]   <math>-0.45\sqrt{f_{cu}} \leq f_b \leq 0.24f_{cu}</math> [CL3]              Note <math>-&lt;.....&gt; = \text{MAX} \{-0.25f_{cu}, (0.7-1.1) \cdot (-0.58\sqrt{f_{cu}} \text{ to } -0.82\sqrt{f_{cu}}) - 4\text{N/mm}^2/1.0\%</math>.            Note by convention, +ve stress is compressive and -ve stress is tensile (<i>inconsistent</i> with ADAPT-Builder).</p> <p><b>PT Design Strip Design Sections FE Analysis Method Integration of Effects Analysis and PT Design Strip Design Sections Design</b></p> <p>FEFA → VSS → FEM → Design the "Design Section(s)" → Investigate (does not add rebar even if required) / Design (does add rebar if required) → check design strip design sections <b>PT analysis and design</b> in X/Y directions (ES) → RDS → Design Sections</p> <p>→ Deformation → Z-Translation → check <b>TLS= DL+PT  deflections</b> <math>\leq \{[\text{span}/500 \text{ to } \text{span}/350].C_1, 20\text{mm}\}</math>.            → Deformation → Z-Translation → check <b>SLS=DL+SDL+LL+PT deflections</b> <math>\leq [\text{span}/250].C_1</math>.            → Deformation → Z-Translation → check <math>k_c \cdot (\text{DL}+\text{SDL})+\text{LL}+k_{c,PT} \cdot \text{PT deflections}</math> <math>\leq \{[\text{span}/500 \text{ to } \text{span}/350].C_1, 20\text{mm}\}</math>, note the creep term also includes the <b>total</b> (elastic, creep, shrinkage) axial shortening of the <b>one</b> storey in question.            → Deformation → Z-Translation → check <math>k_c \cdot (\text{DL}+\text{SDL})+\text{LL}+k_{c,PT} \cdot \text{PT deflections}</math> at façade beams <math>\leq \{[\text{span}/1000].C_1, 20\text{mm}\}</math>, note the creep term also includes the <b>total</b> (elastic, creep, shrinkage) axial shortening of the <b>one</b> storey in question.            Note <math>C_1 = \{0.8 \text{ for flanged beams, } 10.0/\text{span(m)} \text{ for spans } &gt; 10.0\text{m, } 0.9 \text{ for flat slabs}\}</math>. Note deflection criteria to cl.3.4.6.3 and cl.3.4.6.4 BS8110-1 and cl.3.2.1.1 and cl.3.2.1.2 BS8110-2. Note creep factor, <math>k_c</math> calculated from equating <math>0.5 \cdot (1-0.4)\text{DL}+1.0\text{SDL}=k_c \cdot (\text{DL}+\text{SDL})</math> based on multiplying factor 0.5 for the total DL creep deflection component (as opposed to the instantaneous deflection component) to (1-0.4) for the remaining 60% component of DL creep deflection after 1 month (cl.7.3 BS8110-2), giving <math>k_c=[0.3\text{DL}+1.0\text{SDL}]/[\text{DL}+\text{SDL}]</math>. Note</p>	

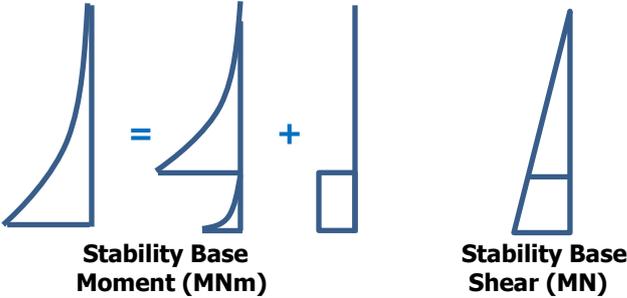
# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	✓								
	<p>likewise creep factor, <math>k_{c,PT}</math> calculated as <math>(1-0.5/K_{LT} \cdot K_{ST}) \cdot (1-0.4) = 0.2625</math>.</p> <p>→ Balanced Loading → check percentage of <b>DL+SDL load balancing</b> is approximately 70-100%.</p> <p>→ Actions → Bending → check <b>TLS/SLS bending</b> effects <math>M_{TLS/SLS,E/E} + M_{TLS/SLS,E/L}</math> are minimal.</p> <p>→ Actions → Bending → check <b>ULS bending</b> effects <math>M_{ULS,E/E} + M_{ULS,S/E}</math> based on <math>1.4 \times</math> tributary width <math>\times (15.0-25.0 \text{ kPa}) \times L^2/12</math> and hyperstatic effects, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.</p> <p>Note by convention, +ve bending moment is sagging and -ve bending moment is hogging (<i>consistent</i> with ADAPT-Builder).</p> <p>→ Actions → Shear → check <b>TLS/SLS shear</b> effects <math>V_{TLS/SLS,E/E} + V_{TLS/SLS,E/L}</math> are minimal.</p> <p>→ Actions → Shear → check <b>ULS shear</b> effects <math>V_{ULS,E/E} + V_{ULS,S/E}</math> based on <math>1.4 \times</math> tributary width <math>\times (15.0-25.0 \text{ kPa}) \times L/2</math> and hyperstatic effects, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.</p> <p>Note an arbitrary sign convention adopted for shear force (<i>inconsistent</i> with ADAPT-Builder).</p> <p>→ Stresses → Average (Precompression) → check <b>TLS/SLS average precompression</b> <math>0.7-2.5 \text{ N/mm}^2</math> for slab and <math>2.5-4.5 \text{ N/mm}^2</math> for beam.</p> <p>→ Stresses → Top → check <b>TLS top stress</b> <math>f'_{min,t} \leq f'_t \leq f'_{max,t}</math>            BM:   <math>-1.0 \leq f'_t \leq 0.50f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_t \leq 0.50f_{ci}</math> [CL2]   <math>-0.25f_{ci} \leq f'_t \leq 0.50f_{ci}</math> [CL3]              FS:   <math>-1.0 \leq f'_t \leq 0.24f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_t \leq 0.24f_{ci}</math> [CL2]   <math>-0.45\sqrt{f_{ci}} \leq f'_t \leq 0.24f_{ci}</math> [CL3]  </p> <p>→ Stresses → Bottom → check <b>TLS bottom stress</b> <math>f'_{min,b} \leq f'_b \leq f'_{max,b}</math>            BM:   <math>-1.0 \leq f'_b \leq 0.50f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_b \leq 0.50f_{ci}</math> [CL2]   <math>-0.25f_{ci} \leq f'_b \leq 0.50f_{ci}</math> [CL3]              FS:   <math>-1.0 \leq f'_b \leq 0.33f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_b \leq 0.33f_{ci}</math> [CL2]   <math>-0.45\sqrt{f_{ci}} \leq f'_b \leq 0.33f_{ci}</math> [CL3]  </p> <p>→ Stresses → Top → check <b>SLS top stress</b> <math>f_{min,t} \leq f_t \leq f_{max,t}</math>            BM:   <math>-0.0 \leq f_t \leq 0.33f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_t \leq 0.33f_{cu}</math> [CL2]   <math>-&lt;.....&gt; \leq f_t \leq 0.33f_{cu}</math> [CL3]              FS:   <math>-0.0 \leq f_t \leq 0.33f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_t \leq 0.33f_{cu}</math> [CL2]   <math>-0.45\sqrt{f_{cu}} \leq f_t \leq 0.33f_{cu}</math> [CL3]              Note <math>-&lt;.....&gt; = \text{MAX} \{-0.25f_{cu}, (0.7-1.1) \cdot (-0.58\sqrt{f_{cu}} \text{ to } -0.82\sqrt{f_{cu}}) - 4 \text{ N/mm}^2 / 1.0\%</math>.</p> <p>→ Stresses → Bottom → check <b>SLS bottom stress</b> <math>f_{min,b} \leq f_b \leq f_{max,b}</math>            BM:   <math>-0.0 \leq f_b \leq 0.40f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_b \leq 0.40f_{cu}</math> [CL2]   <math>-&lt;.....&gt; \leq f_b \leq 0.40f_{cu}</math> [CL3]              FS:   <math>-0.0 \leq f_b \leq 0.24f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_b \leq 0.24f_{cu}</math> [CL2]   <math>-0.45\sqrt{f_{cu}} \leq f_b \leq 0.24f_{cu}</math> [CL3]              Note <math>-&lt;.....&gt; = \text{MAX} \{-0.25f_{cu}, (0.7-1.1) \cdot (-0.58\sqrt{f_{cu}} \text{ to } -0.82\sqrt{f_{cu}}) - 4 \text{ N/mm}^2 / 1.0\%</math>.</p> <p>Note by convention, +ve stress is compressive and -ve stress is tensile (<i>inconsistent</i> with ADAPT-Builder).</p> <p>→ manually check <b>rebar areas (to resist SLS tensile stress) required</b> <math>\{A_s(d)_{xx}, A_s(d)_{yy}\}</math>, noting minimum steel.</p> <p>→ Investigation → Moment Capacity with Demand → check <b>ULS moment capacity</b>, <math>M_u</math> is greater than ULS bending effects <math>M_{ULS,E/E} + M_{ULS,S/E}</math>.</p> <p>→ manually check <b>ULS shear capacity</b>, <math>V_u</math> is greater than ULS shear effects <math>V_{ULS,E/E} + V_{ULS,S/E}</math> together with the associated <b>required shear links</b> <math>A_{sv,req}/S</math>.</p> <p>FEFA → VSS → FEM → Generate Rebar Drawing → check <b>rebar (to resist SLS tensile stress) required</b> in X/Y directions (ES).</p>									
	<p><b>RC or PT Method of Slab Detailing</b></p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr style="background-color: #004a7c; color: white;"> <th colspan="2" style="text-align: left;">RC or PT Method of Slab Detailing</th> </tr> </thead> <tbody> <tr> <td style="width: 25%;"><b>Method 1:</b> Automatic Specification of Reinforcement Bars</td> <td><b>Automatic</b> specification of (<b>top</b> and <b>bottom</b>) reinforcement <b>bars</b> based on slab rebar setting Criteria → General → One-Way or Two-Way Slab → Preferred Reinforcement Size and Material → Preferred Steel Bar Size T16 (T) and T10 (B) and Crack Control Bar Spacing 300mm. Note in this method, only the 1/3<sup>rd</sup> span hogging regions will be automatically reinforced, manual addition required for top steel throughout.</td> </tr> <tr> <td><b>Method 2:</b> Semi-Automatic Specification of Reinforcement Mesh / Bars</td> <td><b>Automatic</b> specification of (<b>top</b>) reinforcement <b>mesh / bars</b> based on slab rebar setting Criteria → General → One-Way or Two-Way Slab → Preferred Reinforcement Size and Material → Preferred Steel Bar Size T16 (T) and T10 (B) and Crack Control Bar Spacing 300mm and subsequent manual equivalent mesh substitution (where possible). Note in this method, only the 1/3<sup>rd</sup> span hogging regions will be automatically reinforced, manual addition required for top steel throughout. <b>Manual</b> specification of (<b>bottom</b>) reinforcement <b>mesh / bars</b> based on FEFA rebar areas required <math>\{A_s(d)_{xx}, A_s(d)_{yy}\}</math> for slab panels (Method 3).</td> </tr> <tr> <td><b>Method 3:</b> Manual Specification of Reinforcement Mesh / Bars</td> <td><b>Manual</b> specification of (<b>top</b>) reinforcement <b>mesh / bars</b> based on FEFA rebar areas required <math>\{A_s(d)_{xx}, A_s(d)_{yy}\}</math> for slab panels. Note in this method, since it is a manual method, either only the 1/3<sup>rd</sup> span hogging regions may be reinforced or alternatively top steel may be provided throughout. <b>Manual</b> specification of (<b>bottom</b>) reinforcement <b>mesh / bars</b> based on FEFA rebar areas required <math>\{A_s(d)_{xx}, A_s(d)_{yy}\}</math> for slab panels.</td> </tr> </tbody> </table>	RC or PT Method of Slab Detailing		<b>Method 1:</b> Automatic Specification of Reinforcement Bars	<b>Automatic</b> specification of ( <b>top</b> and <b>bottom</b> ) reinforcement <b>bars</b> based on slab rebar setting Criteria → General → One-Way or Two-Way Slab → Preferred Reinforcement Size and Material → Preferred Steel Bar Size T16 (T) and T10 (B) and Crack Control Bar Spacing 300mm. Note in this method, only the 1/3 <sup>rd</sup> span hogging regions will be automatically reinforced, manual addition required for top steel throughout.	<b>Method 2:</b> Semi-Automatic Specification of Reinforcement Mesh / Bars	<b>Automatic</b> specification of ( <b>top</b> ) reinforcement <b>mesh / bars</b> based on slab rebar setting Criteria → General → One-Way or Two-Way Slab → Preferred Reinforcement Size and Material → Preferred Steel Bar Size T16 (T) and T10 (B) and Crack Control Bar Spacing 300mm and subsequent manual equivalent mesh substitution (where possible). Note in this method, only the 1/3 <sup>rd</sup> span hogging regions will be automatically reinforced, manual addition required for top steel throughout. <b>Manual</b> specification of ( <b>bottom</b> ) reinforcement <b>mesh / bars</b> based on FEFA rebar areas required $\{A_s(d)_{xx}, A_s(d)_{yy}\}$ for slab panels (Method 3).	<b>Method 3:</b> Manual Specification of Reinforcement Mesh / Bars	<b>Manual</b> specification of ( <b>top</b> ) reinforcement <b>mesh / bars</b> based on FEFA rebar areas required $\{A_s(d)_{xx}, A_s(d)_{yy}\}$ for slab panels. Note in this method, since it is a manual method, either only the 1/3 <sup>rd</sup> span hogging regions may be reinforced or alternatively top steel may be provided throughout. <b>Manual</b> specification of ( <b>bottom</b> ) reinforcement <b>mesh / bars</b> based on FEFA rebar areas required $\{A_s(d)_{xx}, A_s(d)_{yy}\}$ for slab panels.	
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	<p><b>RC or PT Analysis and Design Summary Report</b></p>									

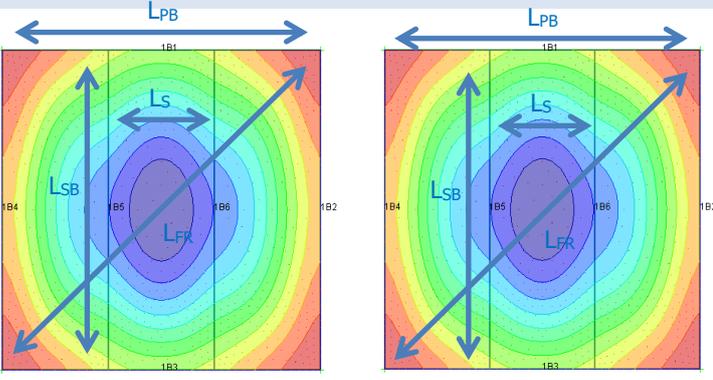
# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	√
	VSS → RPT-T → Design Section Data → Design Section Forces Tabular Report → check design strip design sections forces (ES). VSS → RPT-T → Design Section Data → Design Section Rebar Tabular Report → check design strip design sections rebar (ES). VSS → RPT-T → Design Section Data → Design Section Moment Capacities → check design strip design sections moment capacities (ES). VSS → RPT-T → Design Section Data → Design Section Dimension → check design strip design sections dimensions (ES). VSS → RPT-T → Design Section Data → Design Section Geometry → check design strip design sections geometry (ES). VSS → RPT-G → Tendon/Rebar Plan → check tendon and rebar plans (ES).	√
7.36	Manually check ULS shear stresses and shear design at beam/wall supports of heavily loaded slabs (ES).	<input type="checkbox"/>
7.37	VSS → FEM → Punching Shear Check → check <b>ULS punching shear</b> at wall/column supports of flat slabs (ES). VSS → RPT-T → Punching Shear Design → Punching Shear Stress Check Result → check punching shear stress results (ES). VSS → RPT-T → Punching Shear Design → Punching Shear Stress Check Parameters → check punching shear stress parameters (ES). VSS → RPT-T → Punching Shear Design → Punching Shear Reinforcement → check <b>punching shear reinforcement</b> (ES).	<input type="checkbox"/>
<b>8.0</b>	<b>BEAM AND WALL/COLUMN ANALYSIS AND DESIGN CHECKS</b>	
<b>8.1</b>	<b>Building Analysis Method</b>	
8.11	BA → VSS → RDS → Vibration check skeletal FE model correctly discretises the sectional model by checking animated deflections for modelling accuracy ensuring that all primary beams do frame onto their supporting columns (also displaying the primary beam ULS bending moments for clarity by selecting BA → VSS → RDS → Beam → Actions (Diagram) → Moment About zz) (ES).	<input type="checkbox"/>
8.12	BA → VSS → RDS → Beam → Deformation → Z-Translation → check $ T_L S  =  DL + PT $ deflections $\leq \{[\text{span}/500 \text{ to } \text{span}/350].C_1, 20\text{mm}\}$ (ES). BA → VSS → RDS → Beam → Deformation → Z-Translation → check $SLS = DL + SDL + LL + PT$ deflections $\leq [\text{span}/250].C_1$ (ES). BA → VSS → RDS → Beam → Deformation → Z-Translation → check $k_c.(DL + SDL) + LL + PT$ deflections $\leq \{[\text{span}/500 \text{ to } \text{span}/350].C_1, 20\text{mm}\}$ (ES). BA → VSS → RDS → Beam → Deformation → Z-Translation → check $k_c.(DL + SDL) + LL + PT$ deflections at façade beams $\leq \{[\text{span}/1000].C_1, 20\text{mm}\}$ (ES). Note $C_1 = \{0.8 \text{ for flanged beams, } 10.0/\text{span(m)} \text{ for spans } > 10.0\text{m, } 0.9 \text{ for flat slabs}\}$ . Note deflection criteria to cl.3.4.6.3 and cl.3.4.6.4 BS8110-1 and cl.3.2.1.1 and cl.3.2.1.2 BS8110-2. Note creep factor, $k_c$ calculated from equating $0.5.(1-0.4)DL + 1.0SDL = k_c.(DL + SDL)$ based on multiplying factor 0.5 for the total DL creep deflection component (as opposed to the instantaneous deflection component) to $(1-0.4)$ for the remaining 60% component of DL creep deflection after 1 month (cl.7.3 BS8110-2), giving $k_c = [0.3DL + 1.0SDL]/[DL + SDL]$ .	<input type="checkbox"/>
8.13	BA → VSS → RDS → Beam → Actions (Diagram) → check magnitude and shape of ULS effects (axial forces, shear forces, bending moments, torsional moments) (ES).	<input type="checkbox"/>
8.14	BA → VFS → RDS → Wall/Column → Actions (Diagram) → perform the <b>Moment Ratio Check</b> to comprehend the building primary lateral stability elements by <b>both</b> : - (i) comparing the <b>relative magnitude</b> of the coupled shear wall / moment frame / outrigger frame / tube ( <b>shear mode</b> ) <b>equivalent global bending moment</b> (back-calculated by multiplying the push-pull axial forces of the walls/columns at the frame extremity with the frame extremity lever arm, noting that the effectiveness of the coupling beams / moment beams / outrigger beams / (framed) tube web spandrel beams in contributing to the base moment resisting lateral stability is measured from the existence of significant push-pull axial forces in the walls/columns at the frame extremity, from the existence of significant local zig-zag bending moments in the walls/columns (except outrigger columns and tube flange columns) or from the existence of significant zig-zag bending moments in the coupling beams / moment beams / outrigger beams / (framed) tube web spandrel beams themselves) <b>with</b> the magnitude of the shear wall ( <b>bending mode</b> ) <b>cumulative bending moment</b> (exhibited as cumulative bending moments in the shear walls or as push-pull axial forces within the flanges of flanged shear walls) from lateral loads only (noting that the summation of which shall match the <b>stability base moment</b> ) (ES), <b>and</b> (ii) comparing the <b>relative magnitude</b> of the <b>summation</b> of the coupled shear wall / moment frame / outrigger frame (except outrigger columns) / (framed) tube (except tube flange columns) wall/column ( <b>shear mode</b> ) <b>shear forces</b> (which cause the local zig-zag bending moments in the walls/columns, noting that the effectiveness of the coupling beams / moment beams / outrigger beams / (framed) tube web spandrel beams in contributing to the base shear resisting lateral stability is measured from the existence of significant shear forces in the walls/columns (except outrigger columns and tube flange columns) or from the existence of significant shear forces in the coupling beams / moment beams / outrigger beams / (framed) tube web spandrel beams themselves) <b>with</b> the magnitude of the shear wall ( <b>bending mode</b> ) <b>cumulative shear force</b> from lateral loads only (noting that the summation of which	<input type="checkbox"/>

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	<p>shall match the <b>stability base shear</b> (ES).            Note that the effect to the <b>stability base moment</b> and <b>stability base shear</b> of a <b>transfer floor</b> (defined as a horizontal level at which the more extensive vertical elements on plan become discontinuous on elevation ensuing in less extensive vertical elements on plan) is <b>firstly</b>, the resolution of the stability base moment at the transfer level to <b>constant</b> push-pull axial forces in the walls/columns at the transfer frame extremity (somewhat akin to the effect of an outrigger) below the transfer level and <b>secondly</b>, the redistribution of stability base shear to different stability elements.</p> 	✓
8.15	<p>BA → VSS → RDS → Wall/Column → Deformation → Z-Translation → and FEFA → VSS → RDS → Wall/Column → Deformation → Z-Translation → check <b>differential beam support SLS settlement</b> (i.e. SLS settlement at the wall/column points) due to DAS of adjacent walls/columns (as a result of non-uniform column sections areas or non-uniform axial loading due to say differing building heights) and/or due to uneven flexibility of transfer beams below <math>\leq \text{span}/400</math> (ES). Note that significant differential beam support (i.e. wall/column point) settlement is also characterised by a significant lateral deflection (sway) of the building due to DL+SDL+LL+PT alone to the side undergoing greater elastic shortening or to the side supported by walls/columns on more flexible transfer beams (thus check for lateral movement of the floor plate on plan due to DL+SDL+LL+PT alone is <math>\leq \text{span}/500</math>). The SLS load combination inherently includes the effects of differential (elastic, creep, shrinkage) axial shortening. Staged construction analysis may be performed to reduce the magnitude of the effects of differential (elastic, creep, shrinkage) axial shortening. Finally, significant differential beam support (i.e. wall/column point) settlement is also characterised by <b>large discrepancies in the load take down, transfer beam bending moments</b> and the <b>higher levels beam bending moments</b> predicted between the BA and LTD<sub>2</sub> methods of frame analysis. The ULS load combinations inherently include the effects of differential (elastic, creep, shrinkage) axial shortening. Staged construction analysis may be performed to reduce the magnitude of the effects of differential (elastic, creep, shrinkage) axial shortening. Since it is difficult to reduce elastic shortening significantly, a better strategy is to limit the DAS by designing all walls/columns to the same axial stress level, maintain long clear spans between different structural types, i.e. between lightly-loaded cores and shear walls on the one hand and heavily loaded columns on the other or introduce settlement joints / pour strips between areas subject to large DAS (ES).</p>	☐
8.16	<p>Manually check that the bending moment design, ultimate shear force (ultimate shear stress) check and shear force design of beams with incoming offset beams (i.e. secondary beams that frame into the beam in question within the footprint of the wall/column) with a physical width that protrudes beyond the wall/column footprint is sufficiently enhanced (ES).</p>	☐
8.17	<p>Manually check beams (especially heavily loaded beams / transfer beams) with widths larger than the supporting wall/column width for ultimate shear and design shear within a beam width equal to the supporting wall/column width, notwithstanding the reverse analogy to multi column footing foundation shear design where the full width of the footing beam contributes to the ultimate and design shear capacity. These beams need also be manually checked for ULS punching shear (ES).</p>	☐
8.18	<p>Manually check ULS shear stresses and shear design at transferred walls on transfer beams.</p>	☐
8.19	<p>Manually check ULS punching shear at transferred walls/columns on transfer beams.</p>	☐
<b>8.2</b>	<b>Load Take Down Method</b>	
8.21	<p>VSS → Select by Type → select Beam → Modify Item Properties → check (transfer) Beam Tab uncracked stiffnesses (M11, M22, M33) to <math>(2/3^{\text{rd}}).(1.00) \approx 0.66</math> and VSS → Select by Type → select Slab Region → Modify Item Properties → check (transfer) Slab Region Tab uncracked stiffnesses (M11, M22) to <math>(2/3^{\text{rd}}).(1.00) \approx 0.66</math>, note the further <math>2/3^{\text{rd}}</math> reduction factor applied to simulate the additional deflection due to creep to storage loading instead of normal loading (i.e. creep coefficient, <math>\phi=2</math> for storage loading instead of <math>\phi=1</math> for normal loading).            VSS → Select by Type → select Beam → Modify Item Properties → check (transfer) Beam Tab cracked stiffnesses (M11, M22, M33) to <math>(2/3^{\text{rd}}).(0.50) \approx 0.32</math> and VSS → Select by Type → select Slab Region → Modify Item Properties → check (transfer) Slab Region Tab cracked stiffnesses (M11, M22) to <math>(2/3^{\text{rd}}).(0.50) \approx 0.32</math>, note the further <math>2/3^{\text{rd}}</math> reduction factor applied to simulate the additional deflection due to creep to storage loading instead of normal loading (i.e. creep coefficient, <math>\phi=2</math> for storage loading instead of <math>\phi=1</math> for normal loading).            LTD<sub>2</sub> → select Uncracked Stiffness Modifier for Class 1 PT or Class 2 PT and Cracked Stiffness Modifier for RC or Class 3 PT.</p>	☐
8.22	<b>PT Tendon Modelling</b>	☐

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ITEM	CONTENT	✓
	<p>Build → Tendon → Create Tendon / Map Tendon Banded / Map Tendon Distributed → check tendons based on prestress force and eccentricity required for load balancing and prestress force for average precompression.</p> <p><b>RC or PT Deflection Checks</b></p> <p>LTD<sub>2</sub> → VSS → RDS → Slab → Deformation → Z-Translation → check <math> TLS = DL+PT </math> <b>deflections</b> ≤ {[span/500 to span/350].C<sub>1</sub>, 20mm}.</p> <p>LTD<sub>2</sub> → VSS → RDS → Slab → Deformation → Z-Translation → check <math>SLS=DL+SDL+LL+PT</math> <b>deflections</b> ≤ [span/250].C<sub>1</sub>.</p> <p>LTD<sub>2</sub> → VSS → RDS → Slab → Deformation → Z-Translation → check <math>k_c.(DL+SDL)+LL+k_{c,PT}.PT</math> <b>deflections</b> ≤ {[span/500 to span/350].C<sub>1</sub>, 20mm}, note the creep term also includes the <b>total</b> (elastic, creep, shrinkage) axial shortening of the <b>one</b> storey in question.</p> <p>LTD<sub>2</sub> → VSS → RDS → Slab → Deformation → Z-Translation → check <math>k_c.(DL+SDL)+LL+k_{c,PT}.PT</math> <b>deflections</b> at façade beams ≤ {[span/1000].C<sub>1</sub>, 20mm}, note the creep term also includes the <b>total</b> (elastic, creep, shrinkage) axial shortening of the <b>one</b> storey in question.</p> <p>Note deflections above refer to deflections of all transfer slabs and slabs in the vicinity of transfer beams.          Note C<sub>1</sub> = {0.8 for flanged beams, 10.0/span(m) for spans &gt; 10.0m, 0.9 for flat slabs}. Note deflection criteria to cl.3.4.6.3 and cl.3.4.6.4 BS8110-1 and cl.3.2.1.1 and cl.3.2.1.2 BS8110-2. Note creep factor, k<sub>c</sub> calculated from equating (1-0.32).(1-0.4)DL+1.0SDL=k<sub>c</sub>.(DL+SDL) based on multiplying factor (1-0.32) for the total DL creep deflection component (as opposed to the instantaneous deflection component) to (1-0.4) for the remaining 60% component of DL creep deflection after 1 month (cl.7.3 BS8110-2), giving <math>k_c=[0.4DL+1.0SDL]/[DL+SDL]</math>. Note likewise creep factor, k<sub>c,PT</sub> calculated as (1-0.32/K<sub>LT</sub>.K<sub>ST</sub>). (1-0.4)=0.375.</p> <div data-bbox="220 840 1391 1220" style="border: 1px solid black; padding: 10px;">  <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p>L<sub>s</sub> : slab deflection check</p> <p>L<sub>sb</sub> : secondary beam deflection check</p> <p>L<sub>pb</sub> : primary beam deflection check</p> <p>L<sub>fr</sub> : frame (column to column) deflection check</p> </div> </div> <p>In <b>RC</b> models, note if necessary, the simulation of the beneficial effect of additional reinforcement in controlling deflections can be made by factoring down the exhibited deflections by the ratio of the modified span / effective depth to the ratio of the basic span / effective depth (cantilever 7.0, simply supported 20.0, continuous 26.0).</p>	✓
8.23	<p>Note here that in the following subsection, slab refers to transfer slab and slabs in the vicinity of transfer beams and beam refers to transfer beam.</p> <p><b>PT Tendon Modelling</b></p> <p>Build → Tendon → Create Tendon / Map Tendon Banded / Map Tendon Distributed → check tendons based on prestress force and eccentricity required for load balancing and prestress force for average precompression.</p> <p><b>RC or PT Design Strip Support Lines, RC or PT Design Strip Tributaries and RC or PT Design Strip Design Sections Frequency</b></p> <p>VSS → Strips → Create Support Lines → check design strip support lines in X/Y directions.</p> <p>VSS → select Support Lines → Modify Item Properties → check Support Line Tab direction, criteria, rebar layer, maximum number of design sections per span to 10, distance of design section from face of column to 50mm, selecting display design sections and display results.</p> <p>VSS → Strips → Create Splitters → check design strip support lines splitters spanning between defined support lines for voids (e.g. lift and staircase).</p> <p>VSS → RPT-G → Design Plans → Support Lines X/Y-Directions → check design strip support lines in X/Y directions.</p> <p>VSS → Strips / FEM → Generate Design Sections Automatically → Regenerate Tributaries → check design strip tributaries in X/Y directions and design strip design sections frequency for <b>RC</b> (column and middle design strip) or <b>PT</b> (full tributary width design strip).</p> <p>VSS → RPT-G → Design Plans → Design Strips X/Y-Directions → check design strip tributaries in X/Y directions.</p> <p><b>FE Analysis Method RC Analysis and Design</b></p> <p>LTD<sub>2</sub> → VSS → check <b>RC analysis and design</b> in X/Y directions → RDS → Slab</p> <p>→ Actions (Contour Map) → <math> M_{xx} + M_{xy} </math> and <math> M_{yy} + M_{xy} </math> → check <b>ULS bending</b> effects <math>M_{ULS,E/E}</math>, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.</p>	□

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	✓
	<p>→ manually check <b>ULS shear</b> effects <math>V_{ULS,E/E}</math>, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.</p> <p><b>RC Design Strip Design Sections FE Analysis Method Integration of Effects Analysis and RC Design Strip Design Sections Design</b></p> <p>LTD<sub>2</sub> → VSS → FEM → Design the "Design Section(s)" → Investigate (does not add rebar even if required) / Design (does add rebar if required) → check design strip design sections <b>RC analysis and design</b> in X/Y directions → RDS → Design Sections</p> <p>→ Actions → Bending → check <b>ULS bending</b> effects <math>M_{ULS,E/E}</math> based on 1.4 x tributary width x (15.0-25.0kPa) x <math>L^2/12</math>, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.</p> <p>→ Actions → Shear → check <b>ULS shear</b> effects <math>V_{ULS,E/E}</math> based on 1.4 x tributary width x (15.0-25.0kPa) x <math>L/2</math>, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.</p> <p>→ manually check <b>rebar areas (to resist ULS bending) required</b> <math>\{As(d)_{xx}, As(d)_{yy}\}</math>, noting minimum steel.</p> <p>→ manually check <b>ULS shear capacity</b>, <math>V_u</math> is greater than ULS shear effects <math>V_{ULS,E/E}</math> together with the associated <b>required shear links</b> <math>A_{sv,req}/S</math>.</p> <p>LTD<sub>2</sub> → VSS → FEM → Generate Rebar Drawing → check <b>rebar (to resist ULS bending) required</b> in X/Y directions.</p> <p><b>FE Analysis Method PT Analysis and Design</b></p> <p>LTD<sub>2</sub> → VSS → check <b>PT analysis and design</b> in X/Y directions → RDS → Slab</p> <p>→ Actions (Contour Map) → <math> M_{xx} + M_{xy} </math> and <math> M_{yy} + M_{xy} </math> → check <b>TLS/SLS bending</b> effects <math>M_{TLS/SLS,E/E}+M_{TLS/SLS,E/L}</math> are minimal.</p> <p>→ Actions (Contour Map) → <math> M_{xx} + M_{xy} </math> and <math> M_{yy} + M_{xy} </math> → check <b>ULS bending</b> effects <math>M_{ULS,E/E}+M_{ULS,S/E}</math>, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.</p> <p>Note by convention, +ve bending moment is sagging and -ve bending moment is hogging (<i>consistent</i> with ADAPT-Builder).</p> <p>→ Stress (Contour Map) → Mid-Depth Along XX/YY → check <b>TLS/SLS average precompression</b> 0.7-2.5N/mm<sup>2</sup> for slab and 2.5-4.5N/mm<sup>2</sup> for beam.</p> <p>→ Stress (Contour Map) → Top Fibre Along XX/YY → check <b>TLS top stress</b> <math>f'_{min,t} \leq f'_t \leq f'_{max,t}</math>            BM: <math>-1.0 \leq f'_t \leq 0.50f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_t \leq 0.50f_{ci}</math> [CL2]   <math>-0.25f_{ci} \leq f'_t \leq 0.50f_{ci}</math> [CL3]              FS: <math>-1.0 \leq f'_t \leq 0.24f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_t \leq 0.24f_{ci}</math> [CL2]   <math>-0.45\sqrt{f_{ci}} \leq f'_t \leq 0.24f_{ci}</math> [CL3]  </p> <p>→ Stress (Contour Map) → Bottom Fibre Along XX/YY → check <b>TLS bottom stress</b> <math>f'_{min,b} \leq f'_b \leq f'_{max,b}</math>            BM: <math>-1.0 \leq f'_b \leq 0.50f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_b \leq 0.50f_{ci}</math> [CL2]   <math>-0.25f_{ci} \leq f'_b \leq 0.50f_{ci}</math> [CL3]              FS: <math>-1.0 \leq f'_b \leq 0.33f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_b \leq 0.33f_{ci}</math> [CL2]   <math>-0.45\sqrt{f_{ci}} \leq f'_b \leq 0.33f_{ci}</math> [CL3]  </p> <p>→ Stress (Contour Map) → Top Fibre Along XX/YY → check <b>SLS top stress</b> <math>f_{min,t} \leq f_t \leq f_{max,t}</math>            BM: <math>-0.0 \leq f_t \leq 0.33f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_t \leq 0.33f_{cu}</math> [CL2]   <math>-&lt;.....&gt; \leq f_t \leq 0.33f_{cu}</math> [CL3]              FS: <math>-0.0 \leq f_t \leq 0.33f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_t \leq 0.33f_{cu}</math> [CL2]   <math>-0.45\sqrt{f_{cu}} \leq f_t \leq 0.33f_{cu}</math> [CL3]              Note <math>-&lt;.....&gt; = \text{MAX}\{-0.25f_{cu}, (0.7-1.1) \cdot (-0.58\sqrt{f_{cu}} \text{ to } -0.82\sqrt{f_{cu}}) - 4\text{N/mm}^2/1.0\%\}</math>.</p> <p>→ Stress (Contour Map) → Bottom Fibre Along XX/YY → check <b>SLS bottom stress</b> <math>f_{min,b} \leq f_b \leq f_{max,b}</math>            BM: <math>-0.0 \leq f_b \leq 0.40f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_b \leq 0.40f_{cu}</math> [CL2]   <math>-&lt;.....&gt; \leq f_b \leq 0.40f_{cu}</math> [CL3]              FS: <math>-0.0 \leq f_b \leq 0.24f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_b \leq 0.24f_{cu}</math> [CL2]   <math>-0.45\sqrt{f_{cu}} \leq f_b \leq 0.24f_{cu}</math> [CL3]              Note <math>-&lt;.....&gt; = \text{MAX}\{-0.25f_{cu}, (0.7-1.1) \cdot (-0.58\sqrt{f_{cu}} \text{ to } -0.82\sqrt{f_{cu}}) - 4\text{N/mm}^2/1.0\%\}</math>.</p> <p>Note by convention, +ve stress is compressive and -ve stress is tensile (<i>inconsistent</i> with ADAPT-Builder).</p> <p><b>PT Design Strip Design Sections FE Analysis Method Integration of Effects Analysis and PT Design Strip Design Sections Design</b></p> <p>LTD<sub>2</sub> → VSS → FEM → Design the "Design Section(s)" → Investigate (does not add rebar even if required) / Design (does add rebar if required) → check design strip design sections <b>PT analysis and design</b> in X/Y directions → RDS → Design Sections</p> <p>→ Deformation → Z-Translation → check <math> TLS = DL+PT </math> <b>deflections</b> <math>\leq \{[\text{span}/500 \text{ to } \text{span}/350].C_1, 20\text{mm}\}</math>.</p> <p>→ Deformation → Z-Translation → check <math>SLS=DL+SDL+LL+PT</math> <b>deflections</b> <math>\leq [\text{span}/250].C_1</math>.</p> <p>→ Deformation → Z-Translation → check <math>k_c \cdot (DL+SDL)+LL+k_{c,PT} \cdot PT</math> <b>deflections</b> <math>\leq \{[\text{span}/500 \text{ to } \text{span}/350].C_1, 20\text{mm}\}</math>, note the creep term also includes the <b>total</b> (elastic, creep, shrinkage) axial shortening of the <b>one</b> storey in question.</p> <p>→ Deformation → Z-Translation → check <math>k_c \cdot (DL+SDL)+LL+k_{c,PT} \cdot PT</math> <b>deflections</b> at façade beams <math>\leq \{[\text{span}/1000].C_1, 20\text{mm}\}</math>, note the creep term also includes the <b>total</b> (elastic, creep, shrinkage) axial shortening of the <b>one</b> storey in question.</p> <p>Note <math>C_1 = \{0.8 \text{ for flanged beams, } 10.0/\text{span(m)} \text{ for spans } &gt; 10.0\text{m, } 0.9 \text{ for flat slabs}\}</math>. Note deflection criteria to cl.3.4.6.3 and cl.3.4.6.4 BS8110-1 and cl.3.2.1.1 and cl.3.2.1.2 BS8110-2. Note creep factor, <math>k_c</math> calculated from equating <math>0.5 \cdot (1-0.4)DL+1.0SDL=k_c \cdot (DL+SDL)</math> based on multiplying factor 0.5 for the total DL creep deflection component (as opposed to the instantaneous deflection component) to (1-0.4) for the remaining 60% component of DL creep deflection after 1 month (cl.7.3 BS8110-2), giving <math>k_c=[0.3DL+1.0SDL]/[DL+SDL]</math>. Note likewise creep factor, <math>k_{c,PT}</math> calculated as <math>(1-0.32/K_{LT} \cdot K_{ST}) \cdot (1-0.4)=0.375</math>.</p> <p>→ Balanced Loading → check percentage of <b>DL+SDL load balancing</b> is approximately 70-100%.</p>	

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	✓
	<p>→ Actions → Bending → check <b>TLS/SLS bending</b> effects <math>M_{TLS/SLS,E/E} + M_{TLS/SLS,E/L}</math> are minimal.</p> <p>→ Actions → Bending → check <b>ULS bending</b> effects <math>M_{ULS,E/E} + M_{ULS,S/E}</math> based on <math>1.4 \times</math> tributary width <math>x</math> (<math>15.0-25.0 \text{ kPa}</math>) <math>\times L^2/12</math> and hyperstatic effects, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.</p> <p>Note by convention, +ve bending moment is sagging and -ve bending moment is hogging (<i>consistent</i> with ProtaStructure).</p> <p>→ Actions → Shear → check <b>TLS/SLS shear</b> effects <math>V_{TLS/SLS,E/E} + V_{TLS/SLS,E/L}</math> are minimal.</p> <p>→ Actions → Shear → check <b>ULS shear</b> effects <math>V_{ULS,E/E} + V_{ULS,S/E}</math> based on <math>1.4 \times</math> tributary width <math>x</math> (<math>15.0-25.0 \text{ kPa}</math>) <math>\times L/2</math> and hyperstatic effects, note w.o./w. the <b>differential</b> (elastic, creep, shrinkage) axial shortening of <b>adjacent</b> supports.</p> <p>Note an arbitrary sign convention adopted for shear force (<i>inconsistent</i> with ADAPT-Builder).</p> <p>→ Stresses → Average (Precompression) → check <b>TLS/SLS average precompression</b> <math>0.7-2.5 \text{ N/mm}^2</math> for slab and <math>2.5-4.5 \text{ N/mm}^2</math> for beam.</p> <p>→ Stresses → Top → check <b>TLS top stress</b> <math>f'_{min,t} \leq f'_t \leq f'_{max,t}</math>            BM:   <math>-1.0 \leq f'_t \leq 0.50f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_t \leq 0.50f_{ci}</math> [CL2]   <math>-0.25f_{ci} \leq f'_t \leq 0.50f_{ci}</math> [CL3]              FS:   <math>-1.0 \leq f'_t \leq 0.24f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_t \leq 0.24f_{ci}</math> [CL2]   <math>-0.45\sqrt{f_{ci}} \leq f'_t \leq 0.24f_{ci}</math> [CL3]  </p> <p>→ Stresses → Bottom → check <b>TLS bottom stress</b> <math>f'_{min,b} \leq f'_b \leq f'_{max,b}</math>            BM:   <math>-1.0 \leq f'_b \leq 0.50f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_b \leq 0.50f_{ci}</math> [CL2]   <math>-0.25f_{ci} \leq f'_b \leq 0.50f_{ci}</math> [CL3]              FS:   <math>-1.0 \leq f'_b \leq 0.33f_{ci}</math> [CL1]   <math>-0.36\sqrt{f_{ci}} \leq f'_b \leq 0.33f_{ci}</math> [CL2]   <math>-0.45\sqrt{f_{ci}} \leq f'_b \leq 0.33f_{ci}</math> [CL3]  </p> <p>→ Stresses → Top → check <b>SLS top stress</b> <math>f_{min,t} \leq f_t \leq f_{max,t}</math>            BM:   <math>-0.0 \leq f_t \leq 0.33f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_t \leq 0.33f_{cu}</math> [CL2]   <math>-&lt;.....&gt; \leq f_t \leq 0.33f_{cu}</math> [CL3]              FS:   <math>-0.0 \leq f_t \leq 0.33f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_t \leq 0.33f_{cu}</math> [CL2]   <math>-0.45\sqrt{f_{cu}} \leq f_t \leq 0.33f_{cu}</math> [CL3]              Note <math>-&lt;.....&gt; = \text{MAX} \{-0.25f_{cu}, (0.7-1.1) \cdot (-0.58\sqrt{f_{cu}} \text{ to } -0.82\sqrt{f_{cu}}) - 4 \text{ N/mm}^2 / 1.0\%</math>.</p> <p>→ Stresses → Bottom → check <b>SLS bottom stress</b> <math>f_{min,b} \leq f_b \leq f_{max,b}</math>            BM:   <math>-0.0 \leq f_b \leq 0.40f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_b \leq 0.40f_{cu}</math> [CL2]   <math>-&lt;.....&gt; \leq f_b \leq 0.40f_{cu}</math> [CL3]              FS:   <math>-0.0 \leq f_b \leq 0.24f_{cu}</math> [CL1]   <math>-0.36\sqrt{f_{cu}} \leq f_b \leq 0.24f_{cu}</math> [CL2]   <math>-0.45\sqrt{f_{cu}} \leq f_b \leq 0.24f_{cu}</math> [CL3]              Note <math>-&lt;.....&gt; = \text{MAX} \{-0.25f_{cu}, (0.7-1.1) \cdot (-0.58\sqrt{f_{cu}} \text{ to } -0.82\sqrt{f_{cu}}) - 4 \text{ N/mm}^2 / 1.0\%</math>.</p> <p>Note by convention, +ve stress is compressive and -ve stress is tensile (<i>inconsistent</i> with ADAPT-Builder).</p> <p>→ manually check <b>rebar areas (to resist SLS tensile stress) required</b> <math>\{A_s(d)_{xx}, A_s(d)_{yy}\}</math>, noting minimum steel.</p> <p>→ Investigation → Moment Capacity with Demand → check <b>ULS moment capacity</b>, <math>M_u</math> is greater than ULS bending effects <math>M_{ULS,E/E} + M_{ULS,S/E}</math>.</p> <p>→ manually check <b>ULS shear capacity</b>, <math>V_u</math> is greater than ULS shear effects <math>V_{ULS,E/E} + V_{ULS,S/E}</math> together with the associated <b>required shear links</b> <math>A_{sv,req}/S</math>.</p> <p>LTD<sub>2</sub> → VSS → FEM → Generate Rebar Drawing → check <b>rebar (to resist SLS tensile stress) required</b> in X/Y directions.</p>	✓
8.24	<p>Note here that in the following subsection, slab refers to transfer slab and slabs in the vicinity of transfer beams and beam refers to transfer beam.</p> <p><b>RC or PT Analysis and Design Summary Report</b></p> <p>LTD<sub>2</sub> → VSS → RPT-T → Design Section Data → Design Section Forces Tabular Report → check design strip design sections forces.</p> <p>LTD<sub>2</sub> → VSS → RPT-T → Design Section Data → Design Section Rebar Tabular Report → check design strip design sections rebar.</p> <p>LTD<sub>2</sub> → VSS → RPT-T → Design Section Data → Design Section Moment Capacities → check design strip design sections moment capacities.</p> <p>LTD<sub>2</sub> → VSS → RPT-T → Design Section Data → Design Section Dimension → check design strip design sections dimensions.</p> <p>LTD<sub>2</sub> → VSS → RPT-T → Design Section Data → Design Section Geometry → check design strip design sections geometry.</p> <p>LTD<sub>2</sub> → VSS → RPT-G → Tendon/Rebar Plan → check tendon and rebar plans.</p>	☐
8.25	Manually check ULS shear stresses and shear design at beam/wall supports of transfer slabs.	☐
8.26	<p>LTD<sub>2</sub> → VSS → FEM → Punching Shear Check → check <b>ULS punching shear</b> at wall/column supports of transfer slabs.</p> <p>LTD<sub>2</sub> → VSS → RPT-T → Punching Shear Design → Punching Shear Stress Check Result → check punching shear stress results.</p> <p>LTD<sub>2</sub> → VSS → RPT-T → Punching Shear Design → Punching Shear Stress Check Parameters → check punching shear stress parameters.</p> <p>LTD<sub>2</sub> → VSS → RPT-T → Punching Shear Design → Punching Shear Reinforcement → check <b>punching shear reinforcement</b>.</p>	☐
8.27	Manually check ULS shear stresses and shear design at transferred walls on transfer slabs.	☐
8.28	Manually check ULS punching shear at transferred walls/columns on transfer slabs.	☐

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	✓
<b>8.3</b>	<b>FE Model III-Conditioning</b>	
8.31	<p><b>Building Analysis Method</b> BA → Reports → Export Tributary Loads Check → check consistency between the applied un-decomposed loads tables and the reactions presented in the FEM loads tables.</p> <p><b>Load Take Down Method</b> LTD<sub>1</sub> → Reports → Export Tributary Loads Check → check consistency between the applied un-decomposed loads tables and the reactions presented in the cumulative loads tables.</p>	<input type="checkbox"/>
<b>8.4</b>	<b>Load Take Down</b>	
8.41	BA/LTD <sub>1</sub> → Reports → Export Tributary Loads Check → check SLS load ≈ 15.0-25.0kPa for typical concrete residential and commercial buildings (ES). Note check load take down calculation for <b>BA / LTD<sub>1</sub></b> .	<input type="checkbox"/>
8.42	<p>BA → VFS → RDS → Wall/Column → Actions (Diagram) → filtering out beams to only show walls/columns, check Axial Force in all walls/columns to visually inspect the sensibility of the load take down, e.g. only compression loads in walls/column, no zero loads to ensure <b>no erroneous unattached walls/columns</b> and no tension loads to ensure <b>no erroneous hanging walls/columns</b>.</p> <p>BA → VSS → RPT-G → Wall/Column Reactions → enable display of Axial Force, Moment and Shear for appropriate Loading Combinations <b>to visually display Bottom loading effects</b>, noting that directions rr and ss refer to the local axes (i.e. axis direction rr and ss, respectively) → check Axial Force (ensuring no uplift) for all walls/columns and Axial Force (ensuring no uplift), Moment and Shear for stability walls/columns (ES but primarily above the transfer floor and foundations). In addition for EQ combination cases, EQ base shear force for foundations to be calculated with the lateral and vertical EQ loads in the EQ combination cases enhanced by the overstrength and multiplicative factors, <math>\gamma_{Rd} \cdot \Omega</math> as per cl.4.4.2.6 BS EN1998-1. Note perform load take down calculation and likewise foundation SLS load combinations reporting for <b>BA only</b>.</p> <p>LTD<sub>1</sub> → VSS → RDS → Load Takedown → Cumulative Loads <b>to visually display Bottom loading effects</b> → check axial force (moment and shear N/A) for all walls/columns. Note perform load take down calculation and likewise foundation SLS load combinations reporting for <b>LTD<sub>1</sub> only</b>.</p>	<input type="checkbox"/>
<b>8.5</b>	<b>Sway Susceptibility (NHF, Wind, EQ)</b>	
8.51	<p>Check Sway Classification Report <math>Q \leq 0.05</math> for <math>\lambda \geq 20</math> for <b>BA / LTD<sub>2</sub></b>, else amplify lateral loads (wind, EQ) with the amplified sway factor, <math>m = \lambda/(\lambda-1)</math> to a maximum of <math>m = 1.33</math> corresponding to <math>Q \leq 0.25</math> and <math>\lambda \geq 4.0</math> as the limit of linearity of the static analysis (cl.R6.2.6 ACI 318-14).</p> <ul style="list-style-type: none"> <li>ULS sway susceptibility to NHF / wind load combinations should be analysed with modified default stiffness parameters {Class 1 <b>PT</b> or Class 2 <b>PT</b> slab/beam: <math>k_E=2.0, k_I=0.7, k_J=0.7</math>; <b>RC</b> or Class 3 <b>PT</b> slab/beam: <math>k_E=2.0, k_I=0.35, k_J=0.35</math>; wall/column: <math>k_E=2.0, k_I=0.7, k_J=0.7</math>} and other lateral load combinations (EQ) <b>deleted</b>.</li> <li>ULS sway susceptibility to EQ load combinations should be analysed with modified default stiffness parameters {Class 1 <b>PT</b> or Class 2 <b>PT</b> slab/beam: <math>k_E=2.0, k_I=0.7, k_J=0.7</math>; <b>RC</b> or Class 3 <b>PT</b> slab/beam: <math>k_E=2.0, k_I=0.35, k_J=0.35</math>; wall/column: <math>k_E=2.0, k_I=0.35, k_J=0.35</math>} and other lateral load combinations (NHF, wind) <b>deleted</b>. Further, the lateral EQ displacements from the SLS EQ load combinations are to be enhanced by the <b>adopted behaviour factor, q</b> as per cl.4.3.4 BS EN1998-1.</li> </ul>	<input type="checkbox"/>
<b>8.6</b>	<b>Lateral Deflections / Torsional Twist</b>	
8.61	BA → VSS → RDS → Wall/Column → Deformation → rr/ss-Translation → <b>optionally</b> check total building lateral deflections to <b>NHF</b> , $\delta_{total} \leq H_{total}/500$ and relative storey drift, $\Delta\delta_{storey,I} \leq h_{storey,I}/500$ (ES). NHF load combinations should be analysed with modified default stiffness parameters {Class 1 <b>PT</b> or Class 2 <b>PT</b> slab/beam: $k_E=2.0, k_I=1.0, k_J=1.0$ ; <b>RC</b> or Class 3 <b>PT</b> slab/beam: $k_E=2.0, k_I=0.5, k_J=0.5$ ; wall/column: $k_E=2.0, k_I=1.0, k_J=1.0$ }, NHF load factors reset to 1.0, other lateral load combinations (wind, EQ) <b>deleted</b> and as a last resort adopting <b>flanged beam sections</b> in lieu of rectangular beam sections.	<input type="checkbox"/>
8.62	BA → VSS → RDS → Wall/Column → Deformation → rr/ss-Translation → <b>optionally</b> check on-plan torsional twist due to <b>NHF</b> indicating if the offset between the centre of gravity / mass and centre of stiffness is $\leq$ span/500 (ES). NHF load combinations should be analysed with modified default stiffness parameters {Class 1 <b>PT</b> or Class 2 <b>PT</b> slab/beam: $k_E=2.0, k_I=1.0, k_J=1.0$ ; <b>RC</b> or Class 3 <b>PT</b> slab/beam: $k_E=2.0, k_I=0.5, k_J=0.5$ ; wall/column: $k_E=2.0, k_I=1.0, k_J=1.0$ }, NHF load factors reset to 1.0, other lateral load combinations (wind, EQ) <b>deleted</b> and as a last resort adopting <b>flanged beam sections</b> in lieu of rectangular beam sections.	<input type="checkbox"/>
8.63	BA → VSS → RDS → Wall/Column → Deformation → rr/ss-Translation → check total building lateral deflections to <b>wind</b> , $\delta_{total} \leq H_{total}/500$ and relative storey drift, $\Delta\delta_{storey,I} \leq h_{storey,I}/500$ (ES) to cl.3.2.2.2 BS8110-2. SLS wind load combinations should be analysed with modified default stiffness parameters {Class 1 <b>PT</b> or Class 2 <b>PT</b> slab/beam: $k_E=2.0, k_I=1.0, k_J=1.0$ ; <b>RC</b> or Class 3 <b>PT</b> slab/beam: $k_E=2.0, k_I=0.5, k_J=0.5$ ; wall/column: $k_E=2.0, k_I=1.0, k_J=1.0$ }, wind load factors reset to 1.0, other lateral load combinations (NHF, EQ) <b>deleted</b> and as a last resort adopting <b>flanged beam sections</b> in lieu of rectangular beam sections.	<input type="checkbox"/>
8.64	BA → VSS → RDS → Wall/Column → Deformation → rr/ss-Translation → check on-plan torsional twist due to <b>wind</b> indicating if the offset between the centre of elevation and centre of stiffness is $\leq$ span/500 (ES). SLS wind load combinations should be analysed with modified default stiffness parameters {Class 1 <b>PT</b> or Class 2 <b>PT</b> slab/beam: $k_E=2.0, k_I=1.0, k_J=1.0$ ; <b>RC</b> or Class 3 <b>PT</b> slab/beam: $k_E=2.0, k_I=0.5, k_J=0.5$ ; wall/column: $k_E=2.0, k_I=1.0, k_J=1.0$ }, wind load factors reset to 1.0, other lateral load combinations (NHF, EQ) <b>deleted</b> and as a last	<input type="checkbox"/>

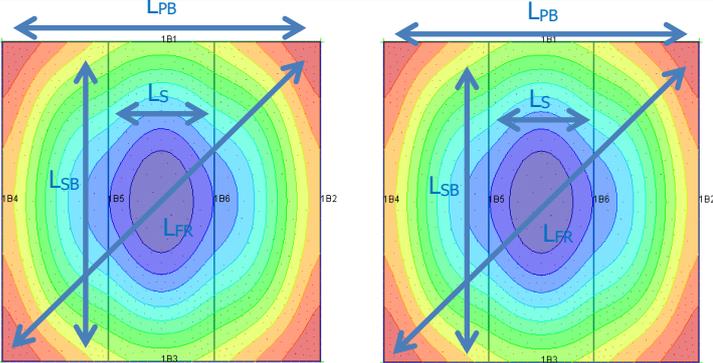
# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	√
	resort adopting <b>flanged beam sections</b> in lieu of rectangular beam sections.	
8.65	BA → VSS → RDS → Wall/Column → Deformation → rr/ss-Translation → check total building lateral deflections to <b>EQ</b> , $v.q.\delta_{total} \leq H_{total}/250$ and relative storey drift, $v.q.\Delta\delta_{storey,I} \leq h_{storey,I}/250$ (ES) as per cl.4.4.3.2 BS EN1998-1. SLS EQ load combinations should be analysed with modified default stiffness parameters {Class 1 <b>PT</b> or Class 2 <b>PT</b> slab/beam: $k_E=2.0, k_I=1.0, k_J=1.0$ ; <b>RC</b> or Class 3 <b>PT</b> slab/beam: $k_E=2.0, k_I=0.5, k_J=0.5$ ; wall/column: $k_E=2.0, k_I=0.5, k_J=0.5$ } and other lateral load combinations (NHF, wind) <b>deleted</b> . Further, the lateral EQ displacements from the SLS EQ load combinations are to be enhanced by the <b>adopted behaviour factor, q</b> as per cl.4.3.4 BS EN1998-1.	<input type="checkbox"/>
8.66	BA → VSS → RDS → Wall/Column → Deformation → rr/ss-Translation → check on-plan torsional twist due to <b>EQ</b> indicating if the offset between the centre of gravity / mass and centre of stiffness is $\leq \text{span}/500$ (ES). SLS EQ load combinations should be analysed with modified default stiffness parameters {Class 1 <b>PT</b> or Class 2 <b>PT</b> slab/beam: $k_E=2.0, k_I=1.0, k_J=1.0$ ; <b>RC</b> or Class 3 <b>PT</b> slab/beam: $k_E=2.0, k_I=0.5, k_J=0.5$ ; wall/column: $k_E=2.0, k_I=0.5, k_J=0.5$ } and other lateral load combinations (NHF, wind) <b>deleted</b> . Further, the lateral EQ displacements from the SLS EQ load combinations are to be enhanced by the <b>adopted behaviour factor, q</b> as per cl.4.3.4 BS EN1998-1.	<input type="checkbox"/>
<b>8.7</b>	<b>Beam Design</b>	
8.71	Check design status of <b>RC</b> beams (ES). Check design status of <b>PT</b> beam design strips design sections (ES).	<input type="checkbox"/>
8.72	In <b>RC</b> models, check beam rebar design for <b>BA / LTD<sub>2</sub></b> (ES). In <b>PT</b> models, check beam design strip design sections tendons (and rebar) design for <b>BA / LTD<sub>2</sub></b> (ES).	<input type="checkbox"/>
8.73	In <b>RC</b> models, check <b>common beam details</b> in all similar storeys and between similar beams within the storey (ES). In <b>PT</b> models, check <b>common beam details</b> in all similar storeys and between similar beams within the storey (ES).	<input type="checkbox"/>
8.74	In <b>RC</b> models, check % steel $\ll 4\%$ and design shear stress $\approx 3N/mm^2 \ll 5N/mm^2$ for <b>BA / LTD<sub>2</sub></b> (ES including similar storeys). In <b>PT</b> models, check design shear stress $\approx 3N/mm^2 \ll 5N/mm^2$ for <b>BA / LTD<sub>2</sub></b> (ES including similar storeys).	<input type="checkbox"/>
8.75	In <b>RC</b> models, check beam detailed design report for <b>BA / LTD<sub>2</sub></b> (ES including similar storeys). In <b>PT</b> models, check beam detailed design report for <b>BA / LTD<sub>2</sub></b> (ES including similar storeys).	<input type="checkbox"/>
8.76	In <b>RC</b> and <b>PT</b> models, manually perform <b>ULS longitudinal shear</b> check within web and between web and flanges for heavily loaded transfer beams if ULS shear stresses are greater than those stipulated on T.5.5 BS8110-1 for <b>BA / LTD<sub>2</sub></b> . Manually perform deep beam design for the transfer beam should the span to depth ratio be $\leq 2.0$ simply-supported or 2.5 continuous (CIRIA Guide 2). Manually perform strut and tie truss analogy design for the transferred wall (acting as the diagonal compression element) and transfer beam (acting as the tension element).	<input type="checkbox"/>
8.77	In <b>RC</b> models, manually check compliance to the deflection criteria for non-prismatic beams by recalculating the actual span / depth ratio based on the total beam span instead of the segmented beam span for <b>BA / LTD<sub>2</sub></b> (ES).	<input type="checkbox"/>
8.78	<b>Building <b>RC</b> and <b>PT</b> beam final comprehensive design check (ES) <sup>#A</sup></b>	
8.781	BA → check design → % steel $\ll 4\%$ → $\tau \approx 3 \ll 5N/mm^2$ →	<input type="checkbox"/>
8.782	LTD <sub>2</sub> → check design → % steel $\ll 4\%$ → $\tau \approx 3 \ll 5N/mm^2$ →	<input type="checkbox"/>
	<b>#A</b> Note for models with EQ loads, ULS EQ load combinations should be analysed on models with the following modified default stiffness parameters {Class 1 <b>PT</b> or Class 2 <b>PT</b> slab/beam: $k_E=1.0, k_I=1.0, k_J=1.0$ ; <b>RC</b> or Class 3 <b>PT</b> slab/beam: $k_E=1.0, k_I=0.5, k_J=0.5$ ; wall/column: $k_E=1.0, k_I=0.5, k_J=0.5$ }.	
8.79	Manual modification of <b>RC</b> and <b>PT</b> beam detailing as follows: - (a) incorporation of outer perimeter torsion links at heavily loaded transfer beam sections. (b) elongation of rebar and links for the portions of transfer beam beneath transferred walls. (c) inclusion of additional shear links / hooks for very wide beams to satisfy the 150mm maximum spacing requirement of cl.3.12.7.2 BS8110-1 (ES). (d) appropriate enhancement to non-prismatic beams (ES). (e) search for single rebar specification, e.g. 1T12, 1T16, 1T20, 1T25, 1T32 or 1T40 within the beam dxfs (ES). (f) for models with EQ loads stabilised by moment frames, enhancement to the primary seismic beam maximum link spacing, s should be provided based on cl.5.4.3.1.2 BS EN1998-1 (DCM) which states $s = \min \{\text{beam depth} / 4; 24 \times \text{link diameter}; 225\text{mm}; 8 \times \text{longitudinal bar diameter}\}$ and cl.5.5.3.1.3 BS EN1998-1 (DCH) which states $s = \min \{\text{beam depth} / 4; 24 \times \text{link diameter}; 175\text{mm}; 6 \times \text{longitudinal bar diameter}\}$ (ES).	<input type="checkbox"/>
<b>8.8</b>	<b>Wall/Column Design</b>	
8.81	Check design status of walls/columns (ES).	<input type="checkbox"/>
8.82	Check for <b>both frame analysis methods</b> and <b>both column design theories</b> , i.e. BA + cl.3.8.4.5 BS8110-1 theory, BA + biaxial bending theory, LTD <sub>2</sub> + cl.3.8.4.5 BS8110-1 theory and LTD <sub>2</sub> + biaxial bending theory (ES). Note that the cl.3.8.4.5 BS8110-1 theory is more conservative (less economic) compared to the biaxial bending	<input type="checkbox"/>

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	✓
	theory. Note that the design of walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	
8.83	Check reinforcement only increases down the building and decreases up the building (in general).	<input type="checkbox"/>
8.84	Check <b>common column details</b> between similar columns within the storey (ES).	<input type="checkbox"/>
8.85	Check % steel for walls (i.e. sections without through-thickness shear links) << <b>2%</b> and design shear stress $\approx$ <b>3N/mm<sup>2</sup></b> << <b>5N/mm<sup>2</sup></b> for <b>both frame analysis methods</b> and <b>both column design theories</b> , i.e. BA + cl.3.8.4.5 BS8110-1 theory, BA + biaxial bending theory, LTD <sub>2</sub> + cl.3.8.4.5 BS8110-1 theory and LTD <sub>2</sub> + biaxial bending theory (ES). Note that the design of walls to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
8.86	Check % steel for columns (i.e. sections with through-thickness shear links) << <b>5%</b> and design shear stress $\approx$ <b>3N/mm<sup>2</sup></b> << <b>5N/mm<sup>2</sup></b> for <b>both frame analysis methods</b> and <b>both column design theories</b> , i.e. BA + cl.3.8.4.5 BS8110-1 theory, BA + biaxial bending theory, LTD <sub>2</sub> + cl.3.8.4.5 BS8110-1 theory and LTD <sub>2</sub> + biaxial bending theory (ES). Note that the design of columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
8.87	Check wall/column detailed design report → search for {< 15.0 or > 15.0} for walls/columns that are to be correctly defined as braced and {< 10.0 or > 10.0} for walls/columns that are to be correctly defined as unbraced (ES).	<input type="checkbox"/>
8.88	<b>Building wall/column final comprehensive design check (ES)</b> <sup>#B, #C</sup>	
8.881	BA → BS8110-1 theory → check design → % steel << 2%/5% <sup>#A</sup> → $\tau \approx 3$ << 5N/mm <sup>2</sup> →	<input type="checkbox"/>
8.882	BA → biaxial bending theory → check design → % steel << 2%/5% <sup>#A</sup> → $\tau \approx 3$ << 5N/mm <sup>2</sup> →	<input type="checkbox"/>
8.883	LTD <sub>2</sub> → BS8110-1 theory → check design → % steel << 2%/5% <sup>#A</sup> → $\tau \approx 3$ << 5N/mm <sup>2</sup> →	<input type="checkbox"/>
8.884	LTD <sub>2</sub> → biaxial bending theory → check design → % steel << 2%/5% <sup>#A</sup> → $\tau \approx 3$ << 5N/mm <sup>2</sup> →	<input type="checkbox"/>
	<p><b>#A</b> Note for models with EQ loads stabilised by moment frames, the maximum primary seismic column % steel is 4%, not 5%.</p> <p><b>#B</b> Note for models with EQ loads, ULS EQ load combinations should be analysed on models with the following modified default stiffness parameters {Class 1 <b>PT</b> or Class 2 <b>PT</b> slab/beam: <math>k_E=1.0, k_I=1.0, k_J=1.0</math>; <b>RC</b> or Class 3 <b>PT</b> slab/beam: <math>k_E=1.0, k_I=0.5, k_J=0.5</math>; wall/column: <math>k_E=1.0, k_I=0.5, k_J=0.5</math>}.</p> <p><b>#C</b> Note enhance walls/columns as appropriate for accidental loads (e.g. car park vehicular impact loads) and as disproportionate collapse key elements.</p> <p>Note that the design of walls/columns to resist the cumulative moment and shear for LTD<sub>2</sub> N/A.</p>	
8.89	Manual modification of wall/column detailing as follows: - (a) manual addition of nominal through-thickness links in column-like vertical elements detailed as walls (ES). (b) for models with EQ loads stabilised by moment frames, enhancement to the primary seismic column maximum link spacing, s should be provided based on cl.5.4.3.2.2 BS EN1998-1 (DCM) which states $s = \min \{(\text{minimum column dimension excluding cover and half link diameter}) / 2; 175\text{mm}; 8 \times \text{longitudinal bar diameter}\}$ and cl.5.5.3.2.2 BS EN1998-1 (DCH) which states $s = \min \{(\text{minimum column dimension excluding cover and half link diameter}) / 3; 125\text{mm}; 6 \times \text{longitudinal bar diameter}\}$ (ES).	<input type="checkbox"/>
<b>9.0</b>	<b>FOUNDATION CHECKS</b>	
<b>9.1</b>	<b>General</b>	
9.11	Check Allowable Soil Stress Ultimate Strength Factor = $(1.4DL+1.4SDL+1.6LL)/(DL+SDL+LL)$ , 1.4 being conservative.	<input type="checkbox"/>
<b>9.2</b>	<b>Pad Footing</b>	
9.21	Check Footing Depth, Surcharge Height and Allowable Stress of Soil. Note perform load take down calculation for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
9.22	Perform a detailed design check of all pad footings for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
<b>9.3</b>	<b>Strip Footing</b>	
9.31	Check allowable stress of soil (kPa). Check coefficient of subgrade reaction (kN/m <sup>3</sup> ).	<input type="checkbox"/>
9.32	Check range of Subgrade Coefficients, Footing Width and Footing Depth. Note perform load take down calculation for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
9.33	Perform a detailed design check of all strip footings for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
9.34	Check (strip footing) beam detailed design report for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
<b>9.4</b>	<b>Raft / Piled Raft Footing</b>	
9.41	Check allowable stress of soil (kPa). Check coefficient of subgrade reaction (kN/m <sup>3</sup> ). Check pile SWL and vertical Pile Spring Coefficient. Ensure no uniformly distributed SDL or LL on the raft / piled raft as this will not translate into bending or shear effects on the raft / piled raft, instead employ point loads with their spacing distributed to depict reality.	<input type="checkbox"/>

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	✓
9.42	Check raft / piled raft analysis by choosing <i>not to Ignore Bearing Capacity of Soil</i> . Note perform load take down calculation for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
9.43	<p>Check raft / piled raft SLS rotations <math>\leq 1/250</math> to BS8110-2 cl.3.2.1.1 (note the Stiffness Factors (i.e. factor for bending rigidity EI) for (raft strip) beam and (raft) slab elements <b>should</b> be set to <b>(2/3<sup>rd</sup>).(0.50)≈0.32</b> (the further 2/3<sup>rd</sup> reduction factor applied to simulate the additional deflection due to creep to storage loading instead of normal loading (i.e. creep coefficient, <math>\phi=2</math> for storage loading instead of <math>\phi=1</math> for normal loading))). Note perform load take down calculation for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD<sub>2</sub> N/A.</p> <p>Check raft / piled raft SLS tilt <math>\leq 1/400</math> (note that tilt is unaffected by E and I values but instead is dependent only on the loading magnitude and distribution and the soil stiffness). Note perform load take down calculation for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD<sub>2</sub> N/A.</p> <div style="display: flex; align-items: center; justify-content: center;">  <div style="border: 1px solid blue; padding: 5px; margin-left: 20px;"> <p style="color: blue;">L<sub>s</sub> : (raft) slab deflection check</p> <p style="color: blue;">L<sub>sB</sub> : secondary (raft strip) beam deflection check</p> <p style="color: blue;">L<sub>pB</sub> : primary (raft strip) beam deflection check</p> <p style="color: blue;">L<sub>FR</sub> : frame (column to column) deflection check</p> </div> </div> <p>Note if necessary, the simulation of the beneficial effect of additional reinforcement in controlling deflections can be made by factoring down the exhibited deflections by the ratio of the modified span / effective depth to the ratio of the basic span / effective depth (cantilever 7.0, simply supported 20.0, continuous 26.0).</p>	<input type="checkbox"/>
9.44	Check raft / piled raft $ M_{xx} + M_{xy} $ and $ M_{yy} + M_{xy}  \rightarrow$ manually check rebar areas required $\{As(d)_{xx}, As(d)_{yy}\}$ , noting minimum steel. Note perform load take down calculation for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
9.45	Check raft / piled raft soil pressure. Note perform load take down calculation for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
9.46	Manually check raft ULS shear stresses and shear design at beam/wall framing. Note perform load take down calculation for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
9.47	Check raft ULS punching shear at wall/column framing. Note perform load take down calculation for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
9.48	Check (raft strip) beam detailed design report for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
9.49	Check factored pile forces (ensuring no tension due to uplift) against the factored pile capacity (especially for stability walls attracting significant moments obscuring the obvious adequacy of the pile group capacity). Note perform load take down calculation for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
<b>9.5</b>	<b>Pile Footing</b>	
9.51	Check pile SWL, Pile Size, vertical pile Spring Coefficient, Pile Cap Depth and Surcharge Height. Note perform load take down calculation for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
9.52	Perform a detailed design check of all pile footings for <b>BA / LTD<sub>2</sub></b> for all load combinations. Note that the design of foundations for walls/columns to resist the cumulative moment and shear for LTD <sub>2</sub> N/A.	<input type="checkbox"/>
9.53	Note for pile caps with complex geometries (i.e. more than 4 pile pile-groups), employ the concepts of piled raft analysis and design choosing <i>to Ignore the Bearing Capacity of Soil</i> and incorporating the soil surcharge loads into the (pile cap) slab superimposed dead loads.	<input type="checkbox"/>
<b>10.0</b>	<b>QUANTITY CHECKS</b>	
<b>10.1</b>	<b>General</b>	
10.11	VFS $\rightarrow$ RPT-T $\rightarrow$ Quantity and Cost $\rightarrow$ check estimate of the concrete volume (m <sup>3</sup> ). Check estimate of the formwork area (m <sup>2</sup> ).	<input type="checkbox"/>

## FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

ITEM	CONTENT	✓
	VFS → RPT-T → Quantity and Cost → check estimate of the steel / tendon quantity (kg).	
10.12	<p>In <b>RC</b> or <b>PT</b> models, check concrete quantity to typical concrete equivalent floor thicknesses (<math>m^3/10^3m^2</math>) → 250-500.</p> <p>In <b>RC</b> or <b>PT</b> models, check formwork quantity to typical formwork rates (<math>m^2/m^2</math>) → 1.5-2.5.</p> <p>In <b>RC</b> models, check rebar quantity to typical rebar tonnages (<math>kg/m^3</math>) → one-way or two-way slabs 75-100, flat slabs 125-175, transfer slabs 150-350, beams 125-250, transfer beams 150-350, walls 100, columns 150-300, pile caps 150-200.</p> <p>In <b>PT</b> models, check tendon quantity to typical tendon tonnages (<math>kg/m^3</math>) → slabs 20-25, transfer slabs 20-25, beams 40-50. In <b>PT</b> models, check rebar quantity to typical rebar tonnages (<math>kg/m^3</math>) → slabs 20-35, transfer slabs 40-70, beams 40-70.</p>	<input type="checkbox"/>

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

## Appendix A: PT Permissible Stress

Permissible Stress [N/mm <sup>2</sup> ] [BS8110, TR.43]						
	Serviceability Class 1 No Flexural Tensile Stresses		Serviceability Class 2 Flexural Tensile Stresses, Uncracked (No Visible Cracking)		Serviceability Class 3 Flexural Tensile Stresses, Cracked	
	Top	Bottom	Top	Bottom	Top	Bottom
<b>TLS comp</b> $f'_{max,t/b}$	$0.50 f_{ci} \text{ #A1}$ $0.24 f_{ci} \text{ #A2}$	$0.50 f_{ci} \text{ #A1}$ $0.33 f_{ci} \text{ #A2}$	$0.50 f_{ci} \text{ #A1}$ $0.24 f_{ci} \text{ #A2}$	$0.50 f_{ci} \text{ #A1}$ $0.33 f_{ci} \text{ #A2}$	$0.50 f_{ci} \text{ #A1}$ $0.24 f_{ci} \text{ #A2}$	$0.50 f_{ci} \text{ #A1}$ $0.33 f_{ci} \text{ #A2}$
<b>TLS tensile</b> $f'_{min,t/b}$	$-1.0 \text{ #B}$	$-1.0 \text{ #B}$	$-0.36 \sqrt{f_{ci}} \text{ #B}$	$-0.36 \sqrt{f_{ci}} \text{ #B}$	$-0.25 f_{ci} \text{ #B1}$ $-0.45 \sqrt{f_{ci}} \text{ #B2}$	$-0.25 f_{ci} \text{ #B1}$ $-0.45 \sqrt{f_{ci}} \text{ #B2}$
<b>SLS comp</b> $f'_{max,t/b}$	$0.33 f_{cu} \text{ #C1}$ $0.33 f_{cu} \text{ #C2}$	$0.40 f_{cu} \text{ #C1}$ $0.24 f_{cu} \text{ #C2}$	$0.33 f_{cu} \text{ #C1}$ $0.33 f_{cu} \text{ #C2}$	$0.40 f_{cu} \text{ #C1}$ $0.24 f_{cu} \text{ #C2}$	$0.33 f_{cu} \text{ #C1}$ $0.33 f_{cu} \text{ #C2}$	$0.40 f_{cu} \text{ #C1}$ $0.24 f_{cu} \text{ #C2}$
<b>SLS tensile</b> $f'_{min,t/b}$	$-0.0 \text{ #D}$	$-0.0 \text{ #D}$	$-0.36 \sqrt{f_{cu}} \text{ #D}$	$-0.36 \sqrt{f_{cu}} \text{ #D}$	$-\langle \dots \rangle \text{ #D1}$ $-0.45 \sqrt{f_{cu}} \text{ #D2}$	$-\langle \dots \rangle \text{ #D1}$ $-0.45 \sqrt{f_{cu}} \text{ #D2}$

#A1: Note beam, one-way slab or two-way slab option to cl.4.3.5.1 BS8110.

#A2: Note flat slab option to T.2 TR.43 and cl.6.10.2 TR.43.

#B: Note beam, one-way slab, two-way slab or flat slab option to cl.4.3.5.2 BS8110.

#B1: Note beam, one-way slab or two-way slab option to cl.4.3.5.2 BS8110.

#B2: Note flat slab option to T.2 TR.43 and cl.6.10.2 TR.43 based on **full tributary width** design strip.

#C1: Note beam, one-way slab or two-way slab option to cl.4.3.4.2 BS8110.

#C2: Note flat slab option to T.2 TR.43.

#D: Note beam, one-way slab, two-way slab or flat slab option to cl.4.3.4.3 BS8110.

#D1: Note beam, one-way slab or two-way slab option to cl.4.3.4.3 BS8110. Note  $-\langle \dots \rangle = \text{MAX} \{-0.25f_{cu}, (0.7-1.1) \cdot (-0.58\sqrt{f_{cu}} \text{ to } -0.82\sqrt{f_{cu}}) - 4\text{N/mm}^2/1.0\%$  as the code allows for an increase in the tensile stress limit from 1% of longitudinal steel (untensioned reinforcement) onwards ( $-4\text{N/mm}^2$  for every 1% of longitudinal steel (untensioned reinforcement), increasing proportionally, up to the specified upper limit of  $-0.25f_{cu}$ ).

#D2: Note flat slab option to T.2 TR.43 based on **full tributary width** design strip.

Table 4.2 – Design Hypothetical Flexural Tensile Stresses for Class 3 Members [N/mm<sup>2</sup>]

Group	Limiting Crack Width [mm]	Design Stress for Concrete Grade		
		30	40	50
Grouted Post-Tensioned Tendons	0.1	3.2	4.1	4.8
	0.2	3.8	5.0	5.8

Table 4.3 – Depth Factors for Design Tensile Stresses for Class 3 Members

Depth of Member [mm]	Factor
≤ 200	1.1
400	1.0
600	0.9
800	0.8
≥ 1000	0.7

Permissible Stress [N/mm<sup>2</sup>] [ACI318]

	Serviceability Class U Uncracked		Serviceability Class T Transition		Serviceability Class C Cracked	
	Top	Bottom	Top	Bottom	Top	Bottom
<b>TLS comp</b> $f'_{max,t/b}$	$0.60 f_{ci}' \text{ #A}$	$0.60 f_{ci}' \text{ #A}$	$0.60 f_{ci}' \text{ #A}$	$0.60 f_{ci}' \text{ #A}$	$0.60 f_{ci}' \text{ #A}$	$0.60 f_{ci}' \text{ #A}$
<b>TLS tensile</b> $f'_{min,t/b}$	$-0.25 \sqrt{f_{ci}'} \text{ #B}$	$-0.25 \sqrt{f_{ci}'} \text{ #B}$	$-0.25 \sqrt{f_{ci}'} \text{ #B}$	$-0.25 \sqrt{f_{ci}'} \text{ #B}$	$-0.30 f_{ci}' \text{ #B1}$ $-0.50 \sqrt{f_{ci}'} \text{ #B2}$	$-0.30 f_{ci}' \text{ #B1}$ $-0.50 \sqrt{f_{ci}'} \text{ #B2}$

## FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

<b>SLS comp</b> $f_{max,t/b}$	$0.60 f_c' \#C$	$0.60 f_c' \#C$	$0.60 f_c' \#C$	$0.60 f_c' \#C$	$0.60 f_c' \#C$	$0.60 f_c' \#C$
<b>SLS tensile</b> $f_{min,t/b}$	$\frac{-0.62 \sqrt{f_c' \#D1}}{-0.50 \sqrt{f_c' \#D2}}$	$\frac{-0.62 \sqrt{f_c' \#D1}}{-0.50 \sqrt{f_c' \#D2}}$	$\frac{-1.00 \sqrt{f_c' \#D1}}{-0.50 \sqrt{f_c' \#D2}}$	$\frac{-1.00 \sqrt{f_c' \#D1}}{-0.50 \sqrt{f_c' \#D2}}$	$\frac{-0.30 f_c' \#D1}{-0.50 \sqrt{f_c' \#D2}}$	$\frac{-0.30 f_c' \#D1}{-0.50 \sqrt{f_c' \#D2}}$

**#A:** Note beam, one-way slab, two-way slab or flat slab option to cl.24.5.3.1 ACI318.

**#B:** Note beam, one-way slab, two-way slab or flat slab option to cl.24.5.3.2 ACI318.

**#B1:** Note beam, one-way slab or two-way slab option analogous to cl.4.3.5.2 BS8110.

**#B2:** Note flat slab option to cl.24.5.3.2.1 ACI318 based on **full tributary width** design strip.

**#C:** Note beam, one-way slab, two-way slab or flat slab option to cl.24.5.4.1 ACI318.

**#D1:** Note beam, one-way slab or two-way slab option to cl.24.5.2.1 ACI318 and analogous to cl.4.3.4.3 BS8110.

**#D2:** Note flat slab option to cl.24.5.2.1 ACI318 based on **full tributary width** design strip.

Permissible Stress [N/mm <sup>2</sup> ] [AS3600]						
	Serviceability Class U Uncracked		Serviceability Class T Transition		Serviceability Class C Cracked	
	Top	Bottom	Top	Bottom	Top	Bottom
<b>TLS comp</b> $f'_{max,t/b}$	$0.50 f_{ci}' \#A$	$0.50 f_{ci}' \#A$	$0.50 f_{ci}' \#A$	$0.50 f_{ci}' \#A$	$0.50 f_{ci}' \#A$	$0.50 f_{ci}' \#A$
<b>TLS tensile</b> $f'_{min,t/b}$	$-0.25 \sqrt{f_{ci}' \#B}$	$-0.25 \sqrt{f_{ci}' \#B}$	$-0.60 \sqrt{f_{ci}' \#B}$	$-0.60 \sqrt{f_{ci}' \#B}$	$\frac{-0.30 f_{ci}' \#B1}{-0.60 \sqrt{f_{ci}' \#B2}}$	$\frac{-0.30 f_{ci}' \#B1}{-0.60 \sqrt{f_{ci}' \#B2}}$
<b>SLS comp</b> $f_{max,t/b}$	$0.50 f_c' \#C$	$0.50 f_c' \#C$	$0.50 f_c' \#C$	$0.50 f_c' \#C$	$0.50 f_c' \#C$	$0.50 f_c' \#C$
<b>SLS tensile</b> $f_{min,t/b}$	$-0.25 \sqrt{f_c' \#D}$	$-0.25 \sqrt{f_c' \#D}$	$-0.60 \sqrt{f_c' \#D}$	$-0.60 \sqrt{f_c' \#D}$	$\frac{-0.30 f_c' \#D1}{-0.60 \sqrt{f_c' \#D2}}$	$\frac{-0.30 f_c' \#D1}{-0.60 \sqrt{f_c' \#D2}}$

**#A:** Note beam, one-way slab, two-way slab or flat slab option to cl.8.1.6.2 AS3600.

**#B:** Note beam, one-way slab, two-way slab or flat slab option to cl.8.6.2 and cl.9.4.2 AS3600.

**#B1:** Note beam, one-way slab or two-way slab option analogous to cl.4.3.5.2 BS8110.

**#B2:** Note flat slab option to cl.9.4.2 AS3600 based on **column strip tributary width** design strip.

**#C:** Note beam, one-way slab, two-way slab or flat slab option to cl.8.1.6.2 AS3600.

**#D:** Note beam, one-way slab, two-way slab or flat slab option to cl.8.6.2 and cl.9.4.2 AS3600.

**#D1:** Note beam, one-way slab or two-way slab option analogous to cl.4.3.4.3 BS8110.

**#D2:** Note flat slab option to cl.9.4.2 AS3600 as an alternative to cl.6.9.5.3 AS3600 based on **column strip tributary width** design strip.

Permissible Stress [N/mm <sup>2</sup> ] [EC2 and TR.43-2]						
	Serviceability Class U Uncracked		Serviceability Class T Transition		Serviceability Class C Cracked	
	Top	Bottom	Top	Bottom	Top	Bottom
<b>TLS comp</b> $f'_{max,t/b}$	$\frac{0.50 f_{ci}' \#A1}{0.30 f_{ci}' \#A2}$	$\frac{0.50 f_{ci}' \#A1}{0.40 f_{ci}' \#A2}$	$\frac{0.50 f_{ci}' \#A1}{0.30 f_{ci}' \#A2}$	$\frac{0.50 f_{ci}' \#A1}{0.40 f_{ci}' \#A2}$	$\frac{0.50 f_{ci}' \#A1}{0.30 f_{ci}' \#A2}$	$\frac{0.50 f_{ci}' \#A1}{0.40 f_{ci}' \#A2}$
<b>TLS tensile</b> $f'_{min,t/b}$	$\frac{-0.21 f_{ci}'^{2/3} \#B1}{-0.09 f_{ci}'^{2/3} \#B2}$	$\frac{-0.30 f_{ci}' \#B1}{-0.27 f_{ci}'^{2/3} \#B2}$	$\frac{-0.30 f_{ci}' \#B1}{-0.27 f_{ci}'^{2/3} \#B2}$			
<b>SLS comp</b> $f_{max,t/b}$	$\frac{0.60 f_c' \#C1}{0.40 f_c' \#C2}$	$\frac{0.60 f_c' \#C1}{0.30 f_c' \#C2}$	$\frac{0.60 f_c' \#C1}{0.40 f_c' \#C2}$	$\frac{0.60 f_c' \#C1}{0.30 f_c' \#C2}$	$\frac{0.60 f_c' \#C1}{0.40 f_c' \#C2}$	$\frac{0.60 f_c' \#C1}{0.30 f_c' \#C2}$
<b>SLS tensile</b> $f_{min,t/b}$	$\frac{-0.21 f_c'^{2/3} \#D1}{-0.09 f_c'^{2/3} \#D3}$	$\frac{<.....> \#D2}{-0.27 f_c'^{2/3} \#D3}$	$\frac{<.....> \#D2}{-0.27 f_c'^{2/3} \#D3}$			

**#A1:** Note beam, one-way slab or two-way slab option to cl.5.8.2 TR.43-2.

**#A2:** Note flat slab option to T.4 TR.43-2 and cl.5.8.2 TR.43-2.

**#B1:** Note beam, one-way slab or two-way slab option to cl.5.8.2 TR.43-2 and analogous to cl.4.3.5.2 BS8110.

**#B2:** Note flat slab option to T.4 TR.43-2 and cl.5.8.2 TR.43-2 based on **full tributary width** design strip.

**#C1:** Note beam, one-way slab or two-way slab option to cl.5.10.2.2 EC2.

**#C2:** Note flat slab option to T.4 TR.43-2.

**#D1:** Note beam, one-way slab or two-way slab option analogous to cl.5.8.2 TR.43-2.

**#D2:** Note beam, one-way slab or two-way slab option to cl.5.8.1 TR.43-2. Note  $<.....> = \text{MAX} \{-0.30f_c', (-0.40f_c'^{2/3} \text{ to } -0.50f_c'^{2/3}) - 4N/mm^2/1.0\%$  as the code allows for an increase in the tensile stress limit from 1% of longitudinal steel (untensioned reinforcement) onwards ( $-4N/mm^2$  for every 1% of longitudinal steel (untensioned reinforcement), increasing proportionally, up to the specified upper limit of  $-0.30f_c'$ ).

**#D3:** Note flat slab option to T.4 TR.43-2 based on **full tributary width** design strip.

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### Appendix B: **PT** Prestress Strand Types

<b>PT Prestress Strand Types</b>	$\phi_s$ [mm]	$A_s$ [mm <sup>2</sup> ]	$E_p$ [GPa]	$f_{pk}$ [N/mm <sup>2</sup> ]	$F_{pk}$ [kN]
[ASTM A416] Grade 270 $\phi_s = 12.7$ mm Strand	12.70	98.71	186.0	1860	183.7
[ASTM A416] Grade 270 $\phi_s = 15.24$ mm Strand	15.24	140.00	186.0	1860	260.7
[BS5896] 7-Wire Super $\phi_s = 12.9$ mm Strand	12.90	100.00	195.0	1860	186.0
[BS5896] 7-Wire Super $\phi_s = 15.7$ mm Strand	15.70	150.00	195.0	1860	279.0

### Appendix C: **PT** Tendon Duct Dimensions

<b>PT Tendon Ducts Horizontal <math>D_{T,H}</math> and Vertical <math>D_{T,V}</math> External Dimensions</b>					
Maximum Number of Prestress Strands in Each Tendon, $N_s$	Default for 0.5" Strands		Default for 0.6" Strands		Remark
	$D_{T,H}$ (mm)	$D_{T,V}$ (mm)	$D_{T,H}$ (mm)	$D_{T,V}$ (mm)	
3	55	23	55	23	Default refers to flat ducts
5	75	23	90	23	Default refers to flat ducts
7	55	55	70	70	Default refers to round ducts
12	80	80	85	85	Default refers to round ducts
19	95	95	100	100	Default refers to round ducts
27	100	100	115	115	Default refers to round ducts
37	115	115	135	135	Default refers to round ducts
42	125	125	145	145	Default refers to round ducts

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

## Appendix D: RC or PT Load Combination Cases

Load Combo	Description	Load Factor								
		PT	HYP	DL	SDL	LL	WL <sub>x</sub>	WL <sub>y</sub>	NHL <sub>x</sub>	NHL <sub>y</sub>
<b>Ultimate Limit State (ULS)</b>										
ULS01	1.4DL+1.4SDL+1.6LL+HYP #A, #B	-	1.0	1.4	1.4	1.6	-	-	-	-
ULS02	1.4DL+1.4SDL±1.0NHL+HYP #A, #C	-	1.0	1.4	1.4	-	-	-	±1.0	-
		-	1.0	1.4	1.4	-	-	-	-	±1.0
ULS03	1.0DL+1.0SDL±1.0NHL+HYP #A	-	1.0	1.0	1.0	-	-	-	±1.0	-
		-	1.0	1.0	1.0	-	-	-	-	±1.0
ULS04	1.2DL+1.2SDL+1.2LL±1.0NHL+HYP #A, #C	-	1.0	1.2	1.2	1.2	-	-	±1.0	-
		-	1.0	1.2	1.2	1.2	-	-	-	±1.0
ULS05	1.4DL+1.4SDL±1.4WL+HYP #A	-	1.0	1.4	1.4	-	±1.4	-	-	-
		-	1.0	1.4	1.4	-	-	±1.4	-	-
ULS06	1.0DL+1.0SDL±1.4WL+HYP #A	-	1.0	1.0	1.0	-	±1.4	-	-	-
		-	1.0	1.0	1.0	-	-	±1.4	-	-
ULS07	1.2DL+1.2SDL+1.2LL±1.2WL+HYP #A	-	1.0	1.2	1.2	1.2	±1.2	-	-	-
		-	1.0	1.2	1.2	1.2	-	±1.2	-	-
<b>Transfer Limit State (TLS)</b>										
TLS01	1.0DL+1.15PT #D	1.15	-	1.0	-	-	-	-	-	-
<b>Serviceability Limit State (SLS)</b>										
SLS01	1.0DL+1.0SDL+1.0LL+PT #A	1.0	-	1.0	1.0	1.0	-	-	-	-
SLS02	1.0DL+1.0SDL+1.0LL±1.0NHL+PT #A	1.0	-	1.0	1.0	1.0	-	-	±1.0	-
		1.0	-	1.0	1.0	1.0	-	-	-	±1.0
SLS03	1.0DL+1.0SDL+1.0LL±1.0WL+PT #A	1.0	-	1.0	1.0	1.0	±1.0	-	-	-
		1.0	-	1.0	1.0	1.0	-	±1.0	-	-

#A For 3D building finite element models, the load combinations inherently include the effects of differential (elastic, creep, shrinkage) axial shortening. For 2D floor plate models on the other hand, these load combinations shall be appended with a 30-year differential (elastic, creep, shrinkage) axial shortening load case based on a 10-day per floor staged construction analysis of the load combination case 1.4DL+1.4SDL, 1.2DL+1.2SDL or 1.0DL+1.0SDL as appropriate. Calculation of the elastic, creep and shrinkage components of the axial shortening shall be based on cl.3.1.4 EC2.

#B Note that it is ensured that the construction load combination is less onerous than ULS 01.

#C Note that the load combination case 1.4DL+1.4SDL±1.0NHL+HYP need not be applied if it is deemed to be always less onerous than 1.2DL+1.2SDL+1.2LL±1.0NHL+HYP. This will be the case always as long as  $[DL+SDL]/[DL+SDL+LL] \leq 0.85$ .

#D Note that for transfer storeys, the TLS load combination case only considers the self-weight of the particular storey (and not the self-weight from any upper storey) in its dead load case, DL.

Load Combo	Description	Load Factor							
		PT	HYP	DL	SDL	LL	EQ <sub>x</sub>	EQ <sub>y</sub>	EQ <sub>z</sub>
<b>Ultimate Limit State (ULS)</b>									
EQ ULS01	1.0DL+1.0SDL+ $\psi/2$ LL±1.0EQ <sub>x</sub> +HYP 1.0DL+1.0SDL+ $\psi/2$ LL±1.0EQ <sub>y</sub> +HYP	-	1.0	1.0	1.0	$\psi/2$	±1.0	-	-
		-	1.0	1.0	1.0	$\psi/2$	-	±1.0	-
EQ ULS02	1.0DL+1.0SDL+ $\psi/2$ LL+HYP ±1.0EQ <sub>x</sub> ±0.3EQ <sub>y</sub> ±0.3EQ <sub>z</sub> 1.0DL+1.0SDL+ $\psi/2$ LL+HYP ±0.3EQ <sub>x</sub> ±1.0EQ <sub>y</sub> ±0.3EQ <sub>z</sub> 1.0DL+1.0SDL+ $\psi/2$ LL+HYP ±0.3EQ <sub>x</sub> ±0.3EQ <sub>y</sub> ±1.0EQ <sub>z</sub>	-	1.0	1.0	1.0	$\psi/2$	±1.0	±0.3	±0.3
		-	1.0	1.0	1.0	$\psi/2$	±0.3	±1.0	±0.3
		-	1.0	1.0	1.0	$\psi/2$	±0.3	±0.3	±1.0

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	Serviceability Limit State (SLS)								
EQ SLS01	$1.0DL+1.0SDL+\psi/2LL\pm 1.0EQ_x+PT_{\#A}$	1.0	-	1.0	1.0	$\psi/2i$	$\pm 1.0$	-	-
	$1.0DL+1.0SDL+\psi/2LL\pm 1.0EQ_y+PT_{\#A}$	1.0	-	1.0	1.0	$\psi/2i$	-	$\pm 1.0$	-
EQ SLS02	$1.0DL+1.0SDL+\psi/2LL+PT_{\#A}$ $\pm 1.0EQ_x\pm 0.3EQ_y\pm 0.3EQ_z_{\#A}$	1.0	-	1.0	1.0	$\psi/2i$	$\pm 1.0$	$\pm 0.3$	$\pm 0.3$
	$1.0DL+1.0SDL+\psi/2LL+PT_{\#A}$ $\pm 0.3EQ_x\pm 1.0EQ_y\pm 0.3EQ_z_{\#A}$	1.0	-	1.0	1.0	$\psi/2i$	$\pm 0.3$	$\pm 1.0$	$\pm 0.3$
	$1.0DL+1.0SDL+\psi/2LL+PT_{\#A}$ $\pm 0.3EQ_x\pm 0.3EQ_y\pm 1.0EQ_z_{\#A}$	1.0	-	1.0	1.0	$\psi/2i$	$\pm 0.3$	$\pm 0.3$	$\pm 1.0$

**#A** Note that the lateral EQ loads in the EQ SLS combination cases here are **not** enhanced by the adopted behaviour factor, q as per cl.4.3.4 BS EN1998-1 as these EQ SLS combinations are required for PT SLS design and also represent the foundation load combination cases. The evaluation of EQ deflections should be based on an amplified (by the factor q) deflection value instead.

### Appendix E: RC or PT Design Strip Design Sections Equivalent Frame Method Integration of Effects Analysis vs FE Analysis Method Integration of Effects Analysis

RC or PT Design Strip Design Sections Equivalent Frame Method Integration of Effects Analysis	RC or PT Design Strip Design Sections FE Analysis Method Integration of Effects Analysis
Does not consider the flat slab hogging moment stress concentrations, unconservatively	Does consider the flat slab hogging moment stress concentrations, conservatively
Does not inherently consider external loads and tendons outside of the design strip (but still offers an effect), unconservatively	Does inherently consider external loads and tendons outside of the design strip (but still offers an effect), conservatively

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

## Appendix F: **PT** Additional Detailing Requirements

The following additional detailing requirements are required: -

- (i) the provision of minimum longitudinal steel (untensioned reinforcement) for unbonded tendon construction [cl.6.10.6 TR.43]
- (ii) the provision of flexural and restraining longitudinal and transverse steel (untensioned reinforcement) near restraining walls

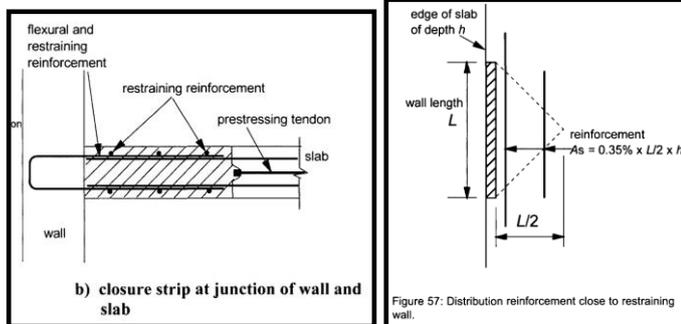
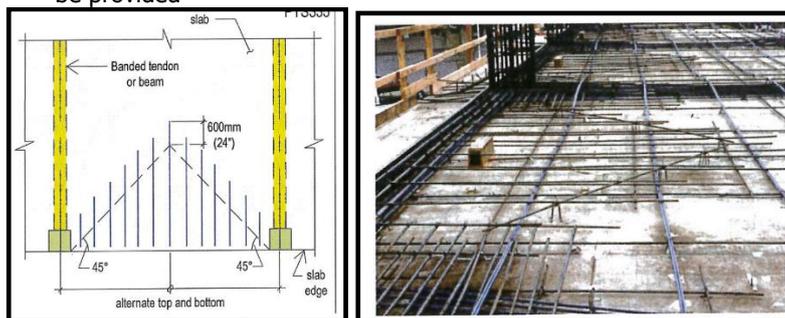


Figure 57: Distribution reinforcement close to restraining wall.

- (iii) the provision of longitudinal and transverse steel (untensioned reinforcement) between tendon anchorages at flat slab edges [cl.6.13 TR.43]
  - parallel to the edge, untensioned and/or tensioned reinforcement to resist the ULS bending moment for a continuous slab spanning  $l_a$ , which is the centre to centre distance between (groups of) anchorages, evenly distributed across a width of  $0.7l_a$  should be provided, and
  - perpendicular to the edge, untensioned reinforcement greater than  $0.13\%bh$  and  $1/4$  x parallel reinforcement, evenly distributed between the anchorages and extending  $\text{MAX}(l_a, 0.7l_a + \text{anchorage})$  should be provided



- (iv) the provision of minimum longitudinal steel (untensioned reinforcement) at column positions for all flat slabs of at least  $0.075\%$  of the gross concrete cross-sectional area, concentrated between lines that are 1.5 times the slab depth either side of the width of the column and extending  $0.2L$  into the span,  $L$  [cl.6.10.6 TR.43]

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

## Appendix G: PT Dual-Cast Construction

Dual-cast construction may be simplistically simulated by: -

- (i) first, performing the first-cast PT structural analysis after
  - modelling the structure corresponding to the first-cast (e.g. a transfer storey structure with a reduced initial thickness without any upper storey superstructure walls that may provide a stiffening effect)
  - modelling the PT tendons corresponding to the first-cast only whilst **excluding** that of the second-cast (e.g. a transfer storey structure with PT tendons within the first-cast initial thickness only)
  - applying external superimposed dead and live loads corresponding to the first-cast (e.g. a transfer storey structure with external self-weight of the additional second cast included as superimposed dead load and construction live load)
  - defining a **standard** TLS load combination case, e.g. 1.0S+1.15PT
  - defining standard SLS/ULS load combination cases with PT load combination cases
- (ii) second, performing the first-cast PT design TLS/SLS/ULS checks whilst
  - recording the **representative** SLS stress at bottom face which should be positive (i.e. compressive) for the dual-cast construction method to be effective, however negative (i.e. tensile) stresses should be considered and recorded if indeed that is the case (noting that by convention, positive stress is compressive and negative stress is tensile)
- (iii) third, performing the second-cast PT structural analysis after
  - modelling the structure corresponding to the second-cast (e.g. a transfer storey structure with an increased final thickness and upper storey superstructure walls potentially providing a stiffening effect)
  - modelling the PT tendons corresponding to the second-cast only whilst **excluding** that of the first-cast (e.g. a transfer storey structure with PT tendons within the second-cast final thickness only)
  - modelling the additional first-cast PT tendon area as equivalent [factored by  $f_{pk}/f_y$ ] bottom longitudinal steel (untensioned reinforcement) area for the PT design ULS bending and shear checks, although for any quantity take-off purposes, the second-cast bottom longitudinal steel (untensioned reinforcement) quantity should then be factored down and for completion, the second-cast PT tendon quantity factored up to include the first-cast PT tendon quantity
  - applying external dead, superimposed dead and live loads corresponding to the second-cast (e.g. a transfer storey structure with external dead, superimposed dead and live loads from the particular storey and all upper storeys)
  - defining a **non-standard** TLS load combination case to exclude the beneficial effect (of counteracting the prestressing equivalent load) of the self-weight of the second-cast structure section which can no longer be considered as it has already been considered in the bending of the first-cast structure section, e.g. 0.0S+1.15PT, noting that all **transfer storeys** should thus be designated as such so that the dead load (self-weight of the structure) case, S within the TLS load combination case (thus defined when the type of load combination case is designated by the user as **initial**) will refer to the self-weight of only the particular storey (and not the self-weight from any upper storey)
  - defining standard SLS/ULS load combination cases with PT load combination cases, noting that the effect of the self-weight of the second-cast structure section can conservatively be double-counted, the effect being marginal in practice as it would be resisted by the full second-cast structure section elastic section modulus  $Z_{t/b}$  and would form only a fraction of the full SLS load combination cases whilst ensuring that the correct external load effects are maintained for presentation purposes and other PT design SLS/ULS checks
- (iv) fourth, performing the second-cast PT design TLS/SLS/ULS checks whilst
  - subtracting the recorded first-cast **representative** SLS stress at bottom face from the criteria  $f_{min}'/f_{min}$  and  $f_{max}'/f_{max}$

# FEM Design Verification Checklist for ADAPT-Builder 2017 (Summary)

## Appendix H: PT Multi-Stage Stressing

Multi-stage stressing may be simplistically simulated by: -

- (i) first,
  - modelling the structure corresponding to the first stressing stage,  $STG(i=1)$  (e.g. a transfer storey structure with a reduced total number of upper storeys above the transfer storey)
  - modelling the PT tendons corresponding to the first stressing stage,  $STG(i=1)$  (e.g. a transfer storey structure with a reduced total number of PT tendons)
  - applying external superimposed dead and live loads corresponding to the first stressing stage,  $STG(i=1)$  (e.g. a transfer storey structure with external loads consistent with the reduced total number of upper storeys above the transfer storey)
  - defining a **standard** TLS load combination case, e.g.  $1.0S+1.15PT$ , noting that all **transfer storeys** should thus be designated as such so that the dead load (self-weight of the structure) case, S within the TLS load combination case (thus defined when the type of load combination case is designated by the user as **initial**) will refer to the self-weight of only the particular storey (and not the self-weight from any upper storey)
  - defining standard SLS/ULS load combination cases with PT load combination cases
  - performing the PT structural analysis
  - performing the PT design TLS/SLS/ULS checks corresponding to the first stressing stage,  $STG(i=1)$
- (ii) second,
  - modelling the structure corresponding to the second stressing stage,  $STG(i=2)$  (e.g. a transfer storey structure with an increased total number of upper storeys above the transfer storey)
  - modelling the PT tendons corresponding to the second stressing stage,  $STG(i=2)$  (e.g. a transfer storey structure with an increased total number of PT tendons)
  - applying external superimposed dead and live loads corresponding to the second stressing stage,  $STG(i=2)$  (e.g. a transfer storey structure with external loads consistent with the increased total number of upper storeys above the transfer storey)
  - defining a **non-standard** TLS load combination case to include the effects of the self-weight from the upper storeys corresponding to the preceding stressing stage (pre-calculated and applied as superimposed dead load), e.g.  $1.0S+1.0S_{UPPER\ STOREYS\ OF\ STG(i=1)}+1.15PT$
  - defining standard SLS/ULS load combination cases with PT load combination cases
  - performing the PT structural analysis
  - performing the PT design TLS/SLS/ULS checks corresponding to the second stressing stage,  $STG(i=2)$
- (iii) third and thereafter, repeating the second step corresponding to the third and thereafter stressing stages,  $STG(i=3, 4, 5, \text{etc.})$