Verification Summary

This verification record presents a like-for-like comparison of PTKalc against RAPT for the analysis, ultimate design and serviceability assessment of a continuous post-tensioned concrete beam with a flanged section. Equivalent geometry, section properties, material parameters, support conditions, tendon profile, prestress force, applied loads and design combinations have been used wherever applicable, allowing differences in the calculated response to be traced to the respective analysis and design methodologies.

Structural Analysis

The individual self-weight, superimposed dead load, live load and prestress load cases have been compared directly. The resulting bending-moment and shear-force diagrams demonstrate close agreement between PTKalc and RAPT in both distribution and magnitude. In the prestressed benchmark, agreement of the prestress-only response also provides an independent check of the tendon geometry, equivalent tendon loading and resulting global prestress actions.

The corresponding ultimate and permanent-load combinations have also been compared and show consistent structural response. This provides verification of the fundamental PTKalc finite-element analysis, including member stiffness, continuity, support conditions, load application and load-combination procedures.

Ultimate Design

The resulting ultimate flexural and shear design requirements, including the contribution of prestressing to section behaviour, have been compared with the corresponding RAPT results. The governing regions and overall reinforcement demand are consistent between the two programs.

The graphical presentation differs because PTKalc reports governing reinforcement envelopes while RAPT displays a number of the underlying demand, minimum reinforcement and capacity components separately. The comparison is therefore made on the governing engineering result rather than graphical presentation alone.

Deformation and Cracked-Section Behaviour

Deflection requires a more detailed comparison because PTKalc and RAPT use different methods for representing cracking, tension stiffening and long-term concrete behaviour.

RAPT results are presented using the Eurocode 2, Branson, RAPT Modified Concrete Tensile Modulus and No Tension Stiffening approaches. PTKalc uses an effective-stiffness finite-element procedure in which cracking is assessed locally and the structure is re-analysed using the resulting spatially varying stiffness.

Three PTKalc sensitivity cases are presented:

Educational Example Only – Refer to current Australian Standards and project-specific requirements before design.

- Age Adjustment = 1.00; Rupture Stress = 3.39 MPa — reference cracking response.
- Age Adjustment = 0.76; Rupture Stress = 3.39 MPa — demonstrates the influence of the adopted long-term age-adjustment treatment.
- Age Adjustment = 1.00; Rupture Stress = 1.00 MPa — demonstrates sensitivity to reduced concrete tensile resistance and earlier cracking.

These cases are not intended to reproduce the individual RAPT methods on a one-to-one basis. They demonstrate the sensitivity of PTKalc to the principal assumptions governing cracked and long-term stiffness and provide context for the range of deformation predictions obtained using the alternative RAPT formulations.

A detailed description and comparison of the PTKalc and RAPT deflection methodologies is provided in Appendix A.

Conclusion

For the benchmark presented, PTKalc demonstrates close agreement with RAPT for the fundamental elastic and prestress analysis, with consistent governing behaviour for ultimate flexural and shear design.

The deformation comparison demonstrates that predicted long-term deflection is dependent on the assumptions adopted for cracking, tension stiffening, creep, shrinkage and load history. Differences between PTKalc and individual RAPT deformation results should therefore be interpreted in the context of these differing theoretical formulations rather than as differences in the underlying elastic structural analysis.

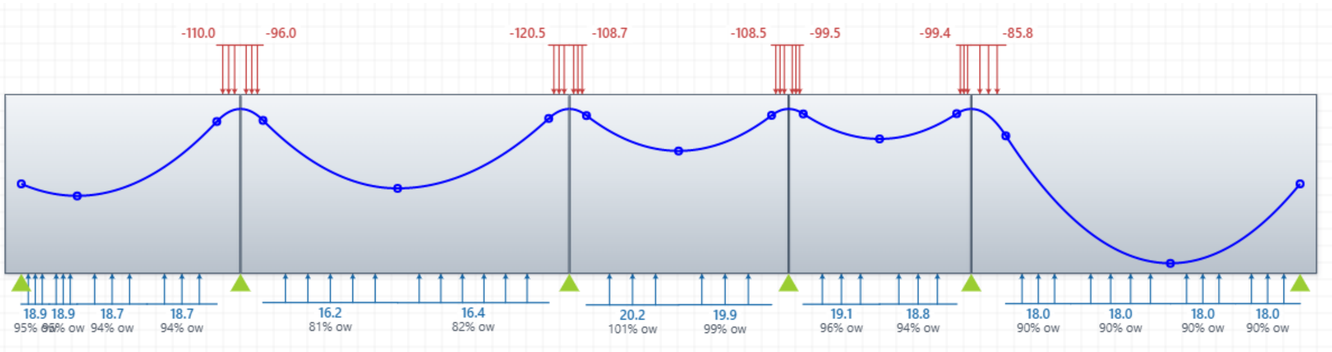
Overall, the verification demonstrates that PTKalc provides a mechanically consistent analysis and design response, with results that can be independently benchmarked against established structural analysis and serviceability methods.

This verification record is an educational benchmarking example. It does not establish numerical equivalence between PTKalc and RAPT and does not replace assessment against the applicable Australian Standards or project-specific engineering requirements.

Educational Example Only – Refer to current Australian Standards and project-specific requirements before design.

RKALC STRUCTURAL ENGINEERING — LEARNING CENTRE	Flanged (T) PT Section	By	RK
	PTKalc	Sheet No. 1	Date 8/26

Benchmark Beam



Span ID.	Length	Section	Left Support	Right Support	Cols Under?	Cols Over?	Profile Type	ZL	Zc	Zr	C	Cantilever?
Span#1	6	T2000x200-1000x600	Pin	Pin	☐	☐	Type1-Parabolic	300	260	550	1510	☐
Span#2	9	T2000x200-1000x600	Pin	Pin	☐	☐	Type2-Parabolic	550	285	550	4300	
Span#3	6	T2000x200-1000x600	Pin	Pin	☐	☐	Type2-Parabolic	550	410	550	2990	
Span#4	5	T2000x200-1000x600	Pin	Pin	☐	☐	Type2-Parabolic	550	450	550	2490	
Span#5	9	T2000x200-1000x600	Pin		☐	☐	Type1-Parabolic	550	35	300	5450	☐

Materials & Criteria

Beam Type	PT
f'cp (N/mm²) - *at transfer*	20
f'c (N/mm²) - *final*	40
ft (N/mm²) Conc. Tension Stress	3.39
Basic Creep Coef. φcc.b	2.8
Shringkage Strain εcs (30 Years)	800E-6
Age Adjustment Factor	0.76
fy (N/mm²) - *flexure*	500
fyv (N/mm²) - *shear*	500
fpb (N/mm²) - *strands*	1870
fpb reduction (clause 3.3.1)	0.82
Strand *(7 Wire Ordinary AS/NZS 4672.1)*	12.7
No. of Strands (Per Tendon)	3
No. of Tendons (even spacing)	1
Reverse Parabola Radius (mm)	5000
Stressing Location	Left
Top Cover mm (Min)	30
Bottom Cover mm (Min)	30
Environment (Clause 3.1.8.3)	Interior
Load Application - days	10
Draw In Magnitude mm	6
μ (friction coef. - clause 3.4.2.4)	0.2
βb (wobble effects - cl. 3.4.2.4)	0.024

Member type: Beam

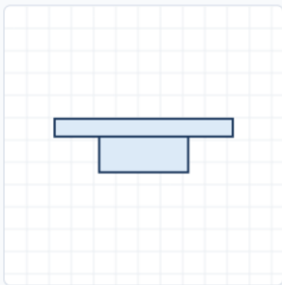
Section shape: T-section

Dimensions

Flange width, b_f	2000 mm
Flange thickness, D_f	200 mm
Web width, b_w	1000 mm
Overall depth, D	600 mm

Add section | Clear

Section preview

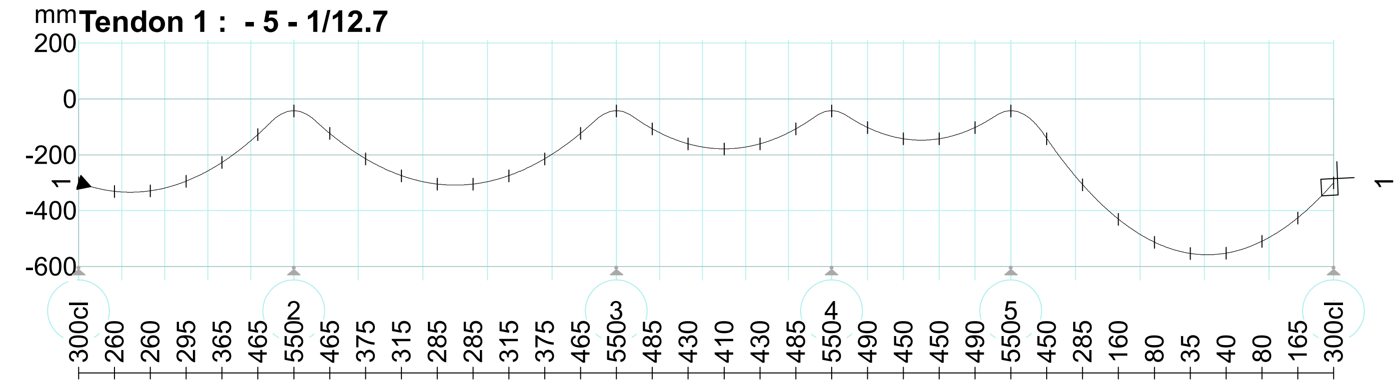


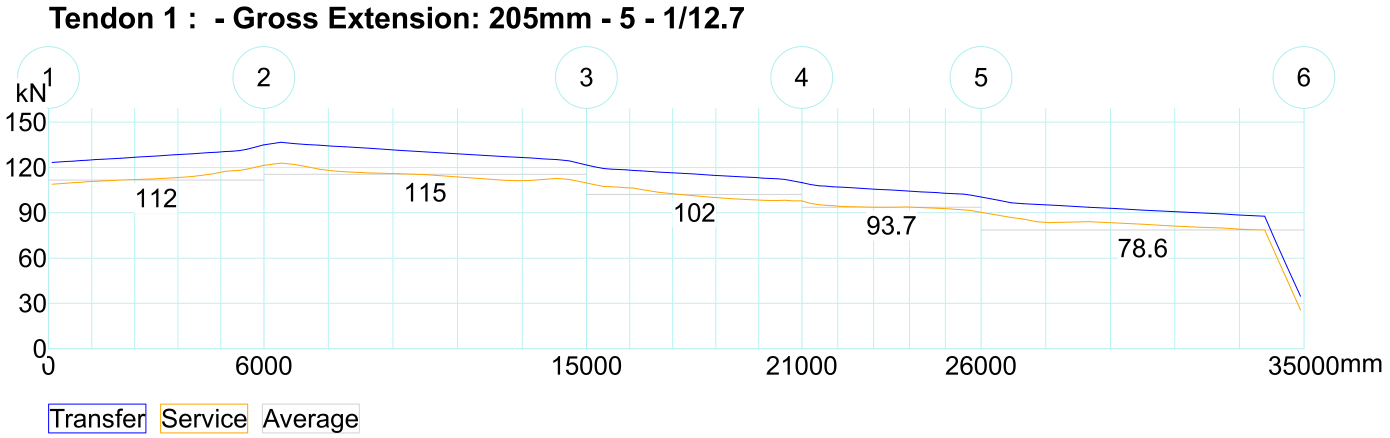
T-section: bf 2,000, bw 1,000, Df 200, D 600 mm

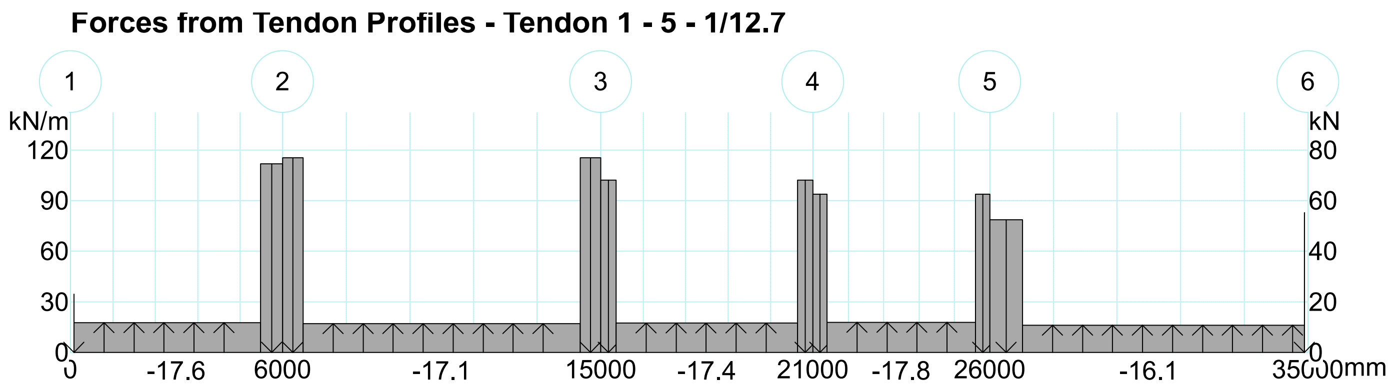
Educational Example Only – Refer to current Australian Standards and project-specific requirements before design.

RAPT

PT Geometry and Loads

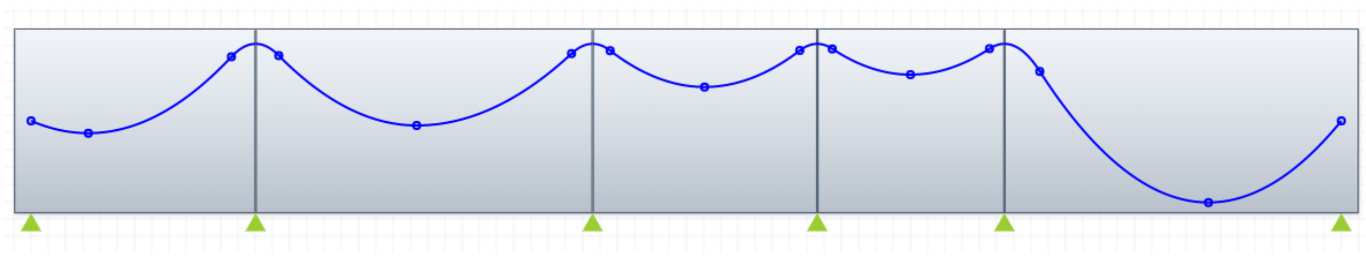


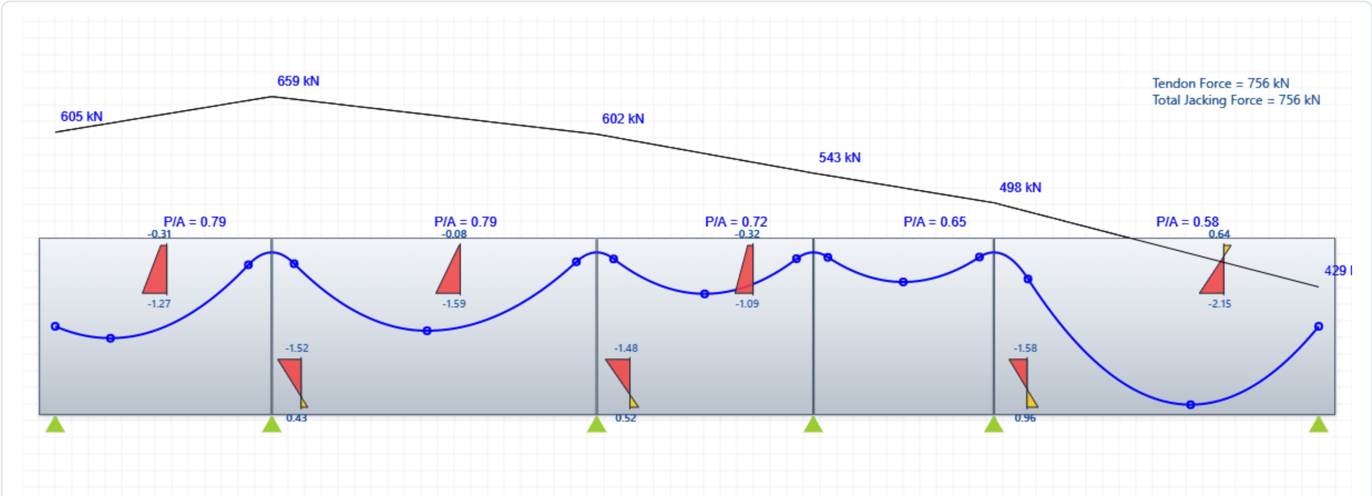


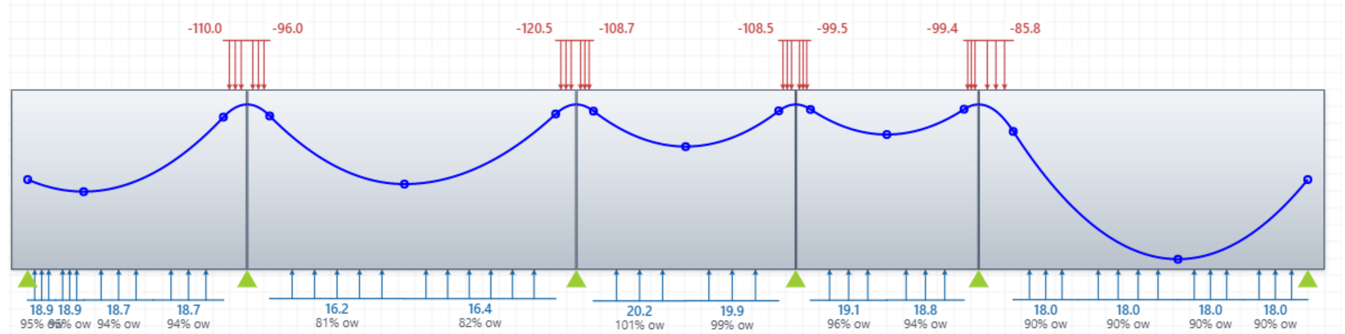


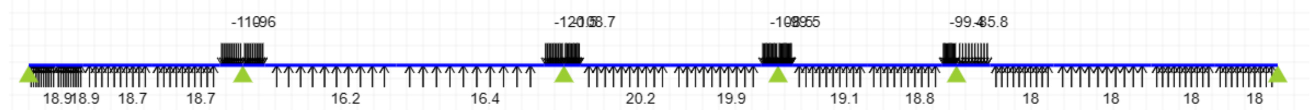
PTKalc

PT Geometry and Loads





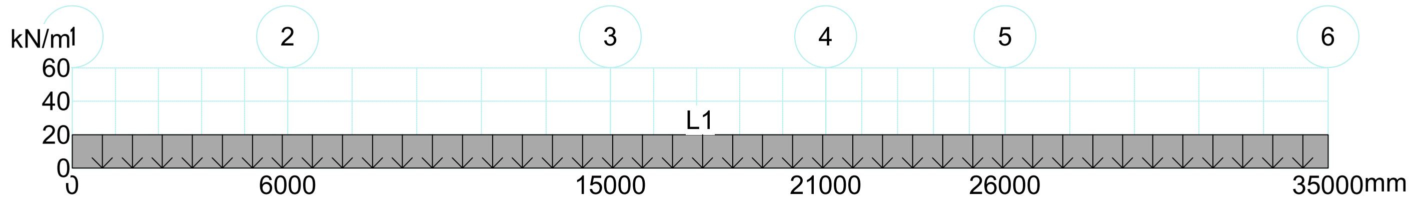




RAPT

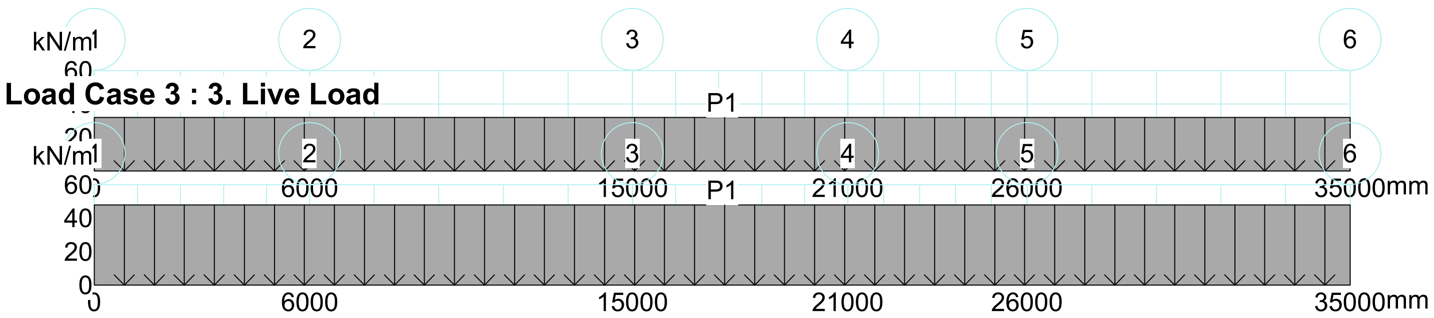
Applied raw load cases

Load Case 1 : 1. Self Weight



Load Case 2 : 2. Extra Dead Load

Load Case 3 : 3. Live Load



1. Self Weight - Line

Load	Left End Reference Column	Left end of load from reference column	Load at left end	Right End reference column	Right end of load from reference column	Load at right end	Description
	#	mm	kN/m	#	mm	kN/m	A
1	1	0	20	6	0	20	

2. Extra Dead Load - Panel

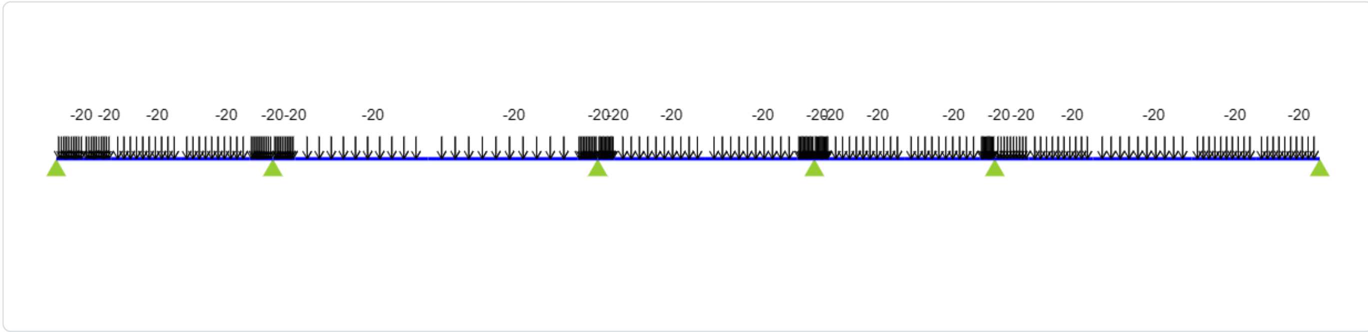
Load	Left End reference column	Left end of load from reference column	Load at left end	Right End reference column	Right end of load from reference column	Load at right end	Description
	#	mm	kN/m2	#	mm	kN/m2	A
1	1	0	16	6	0	16	

3. Live Load - Panel

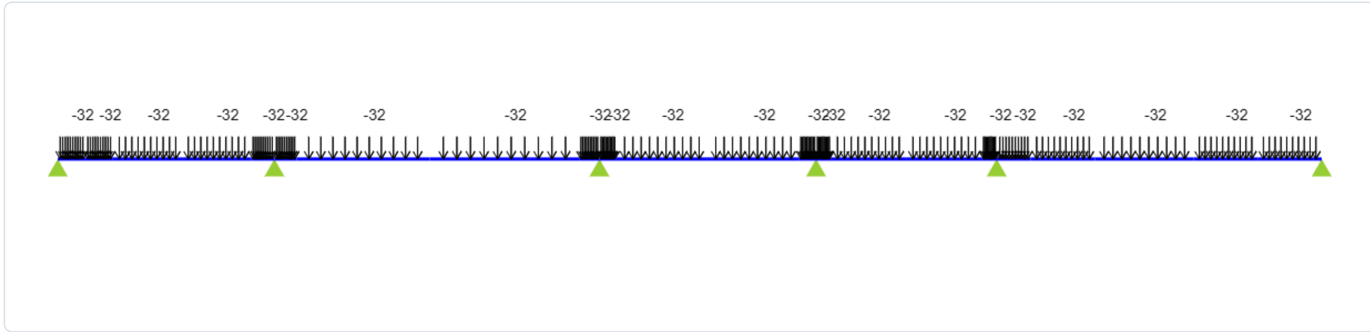
Load	Left End reference column	Left end of load from reference column	Load at left end	Right End reference column	Right end of load from reference column	Load at right end	Live Load reduction	Description
	#	mm	kN/m2	#	mm	kN/m2	#.#	A
1	1	0	24	6	0	24	1	

PTKalc

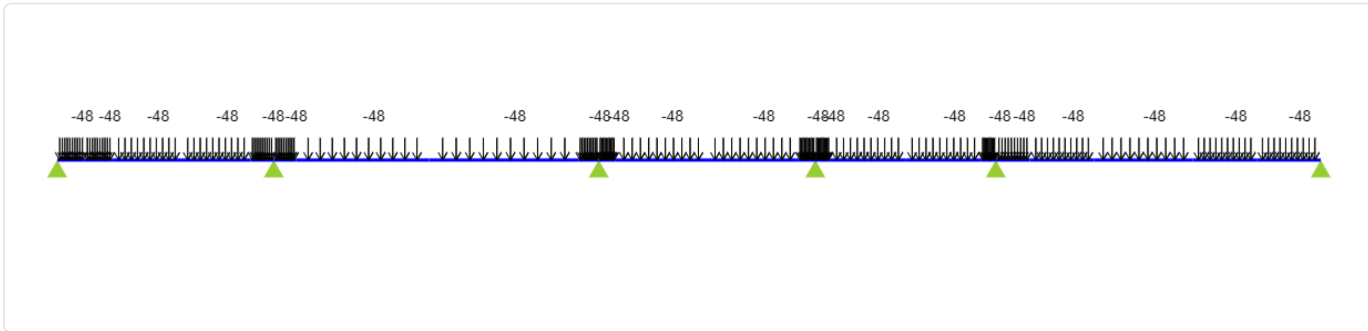
Applied raw load cases



Load Case 2 — OW



Load Case 3 — SDL

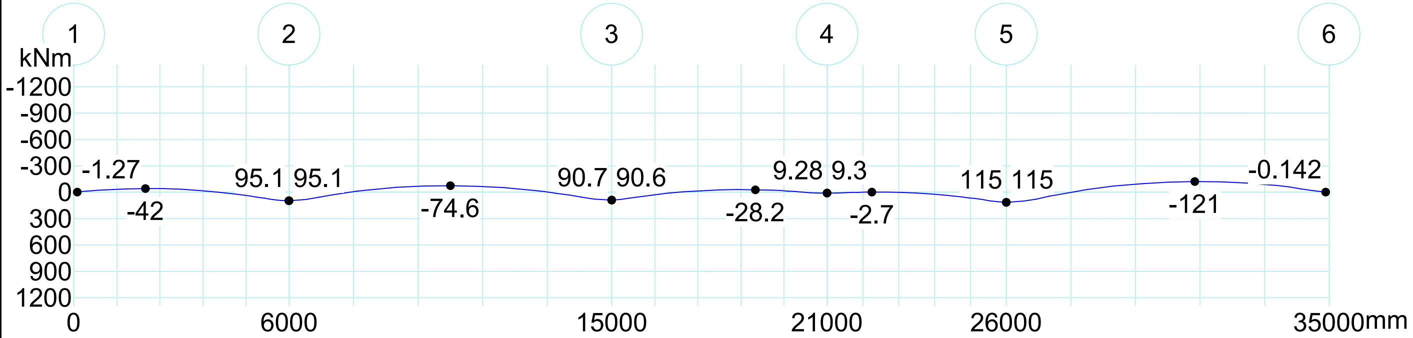


Load Case 4 — LL

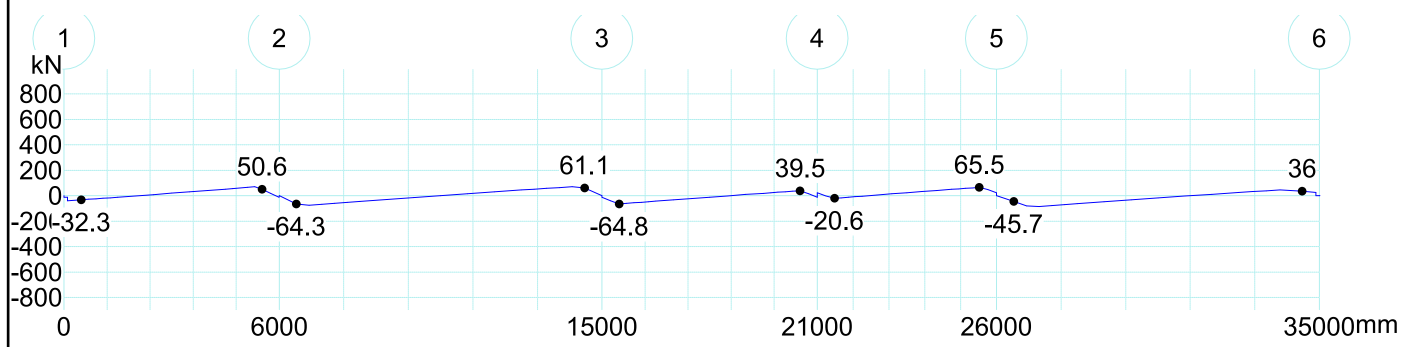
LEARNING CENTRE	PTKalc Verification Record	Flanged (T) PT Section	By	RK
		PTKalc	*Sheet No.* 1	*Date* 8/26

RAPT

Moment and shear digram for PT load case



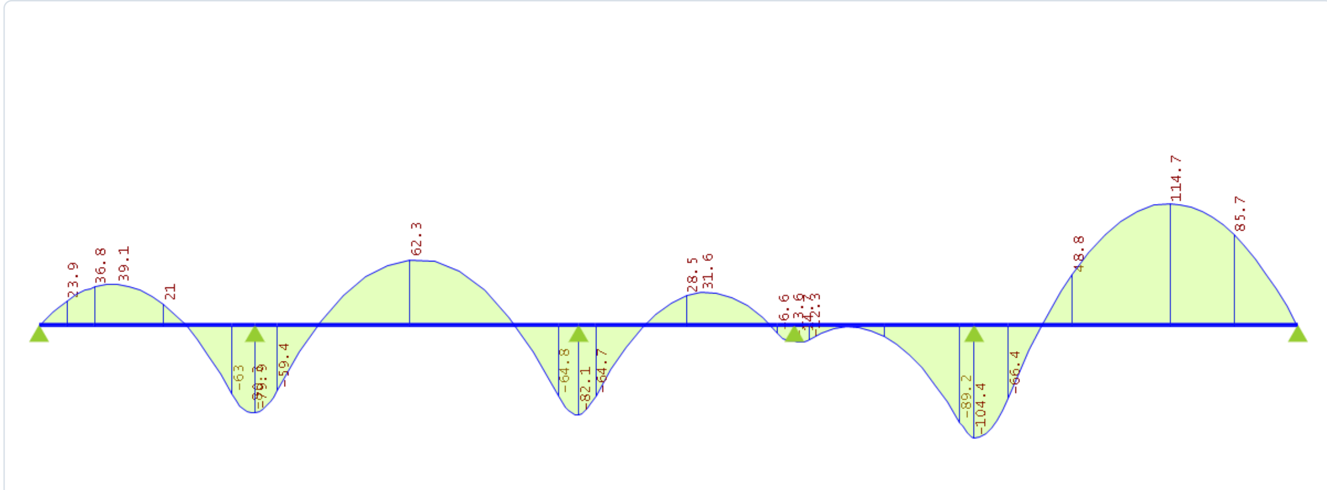
Moment



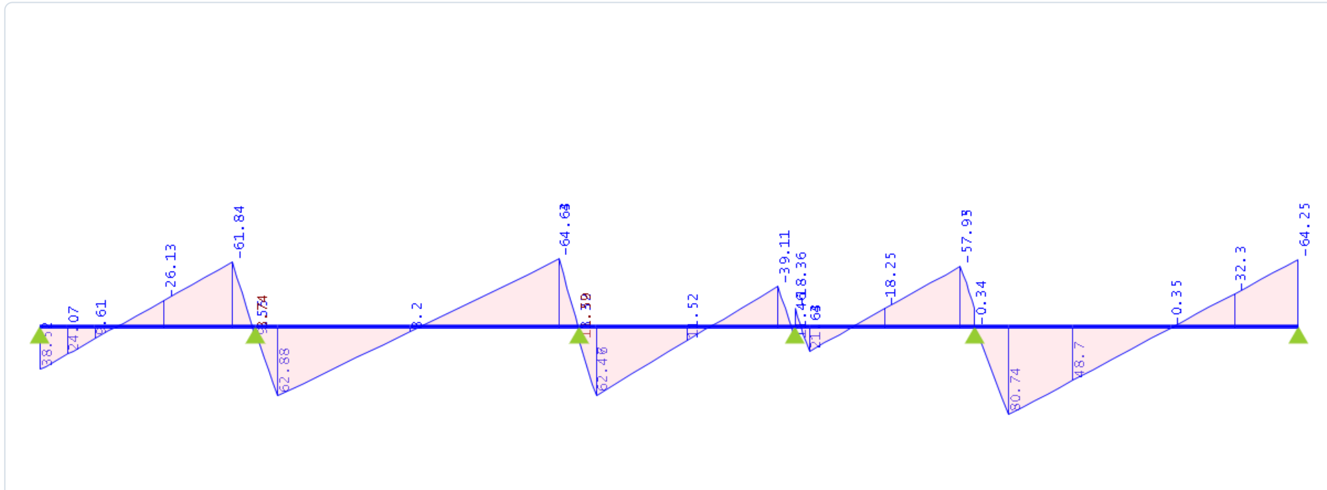
Shear

PTKalc

Moment and shear digram for PT load case



Bending Moment Diagram - KN.m / PT

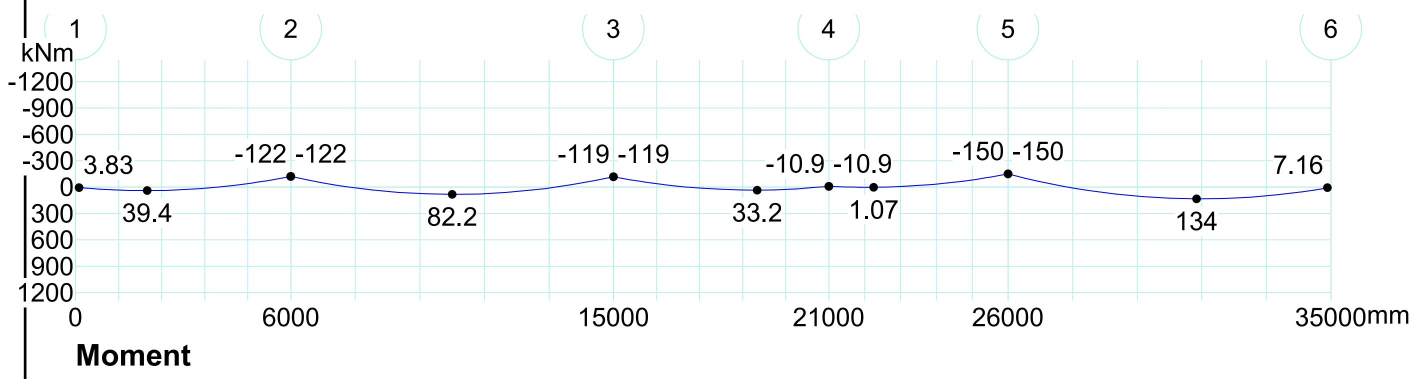


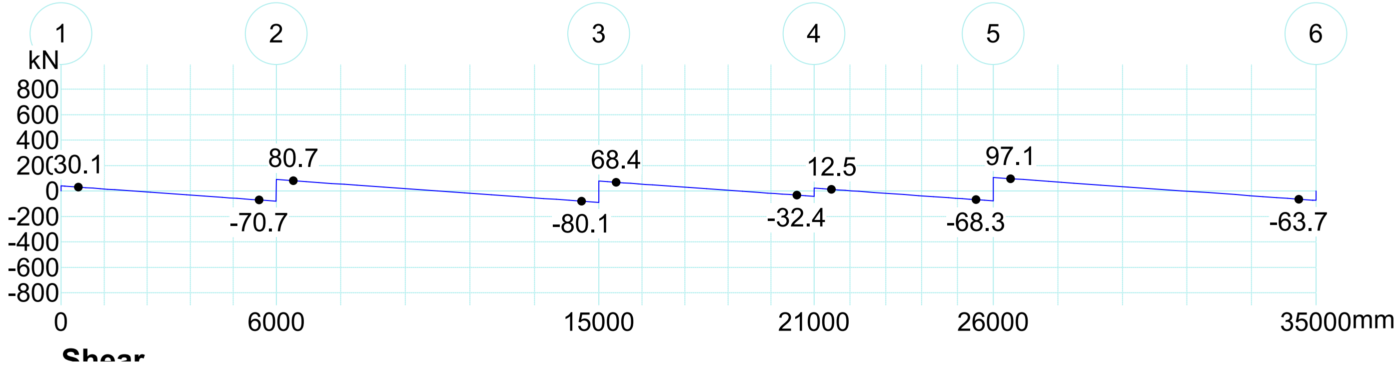
Shear Force Diagram - KN , m / PT

LEARNING CENTRE	PTKalc Verification Record	Flanged (T) PT Section	By	RK
		PTKalc	Sheet No. 1	Date 8/26

RAPT

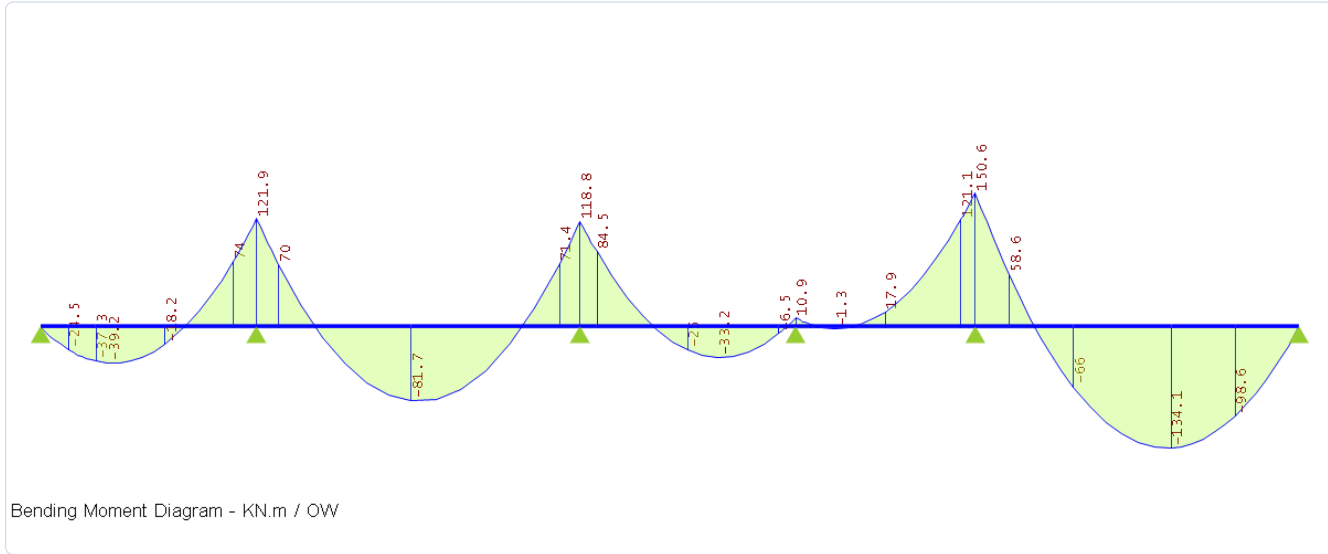
Moment and shear digram for OW load case

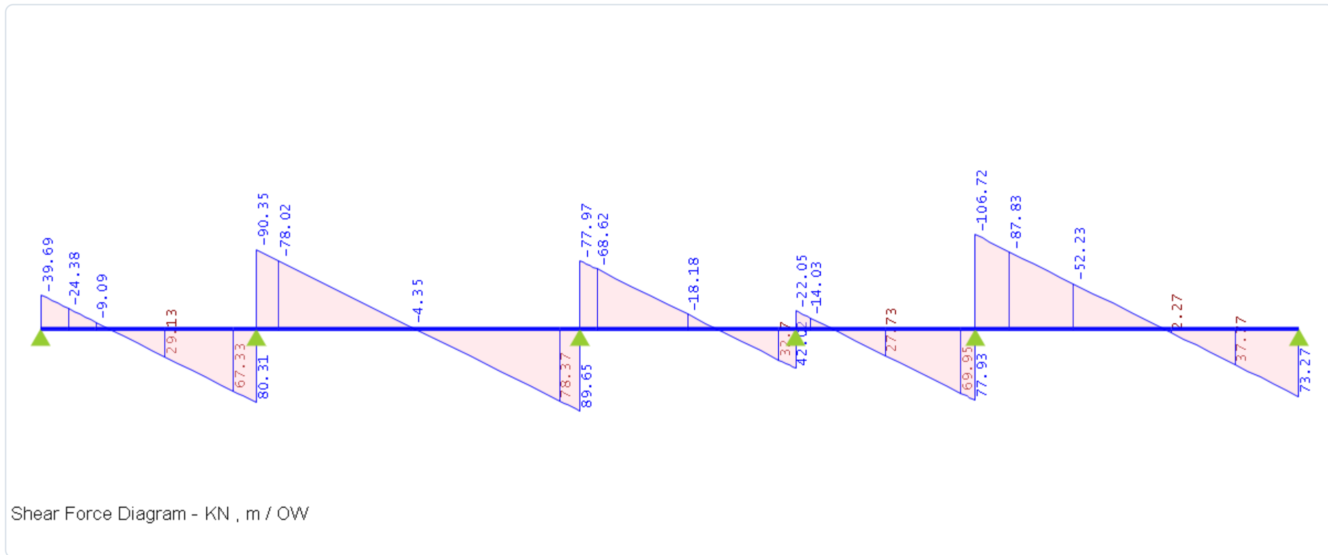




PTKalc

Moment and shear digram for OW load case





Educational Example Only – Refer to current Australian Standards and project-specific requirements before design.

LEARNING CENTRE	PTKalc Verification Record	Flanged (T) PT Section	By	RK
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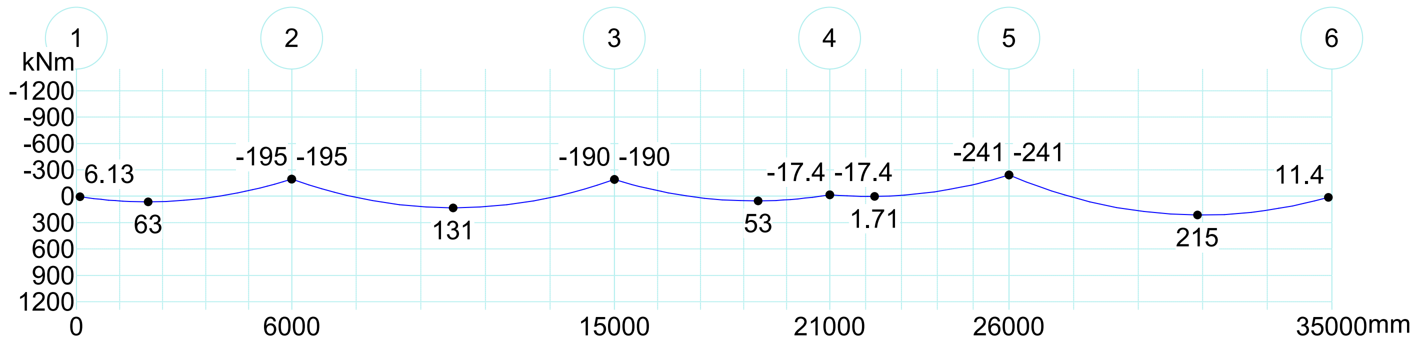
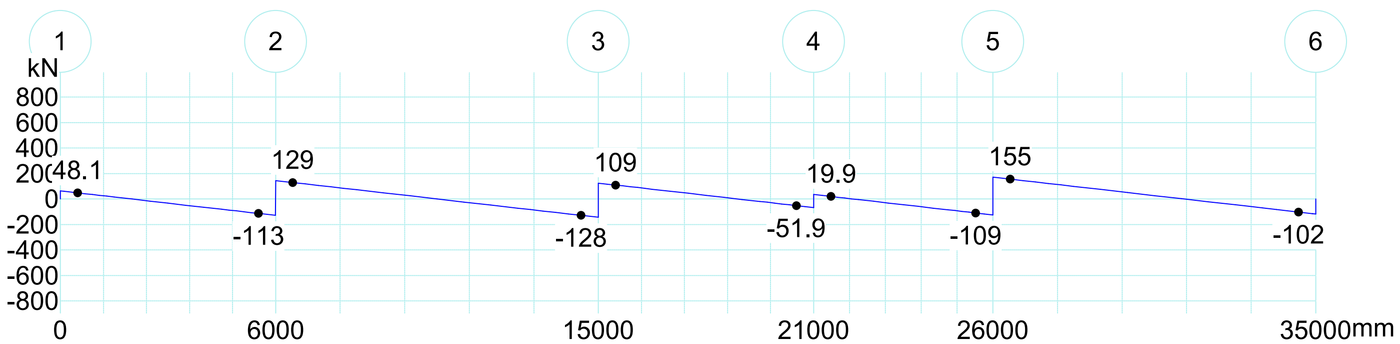
RAPT

Moment and shear digram for SDL load case



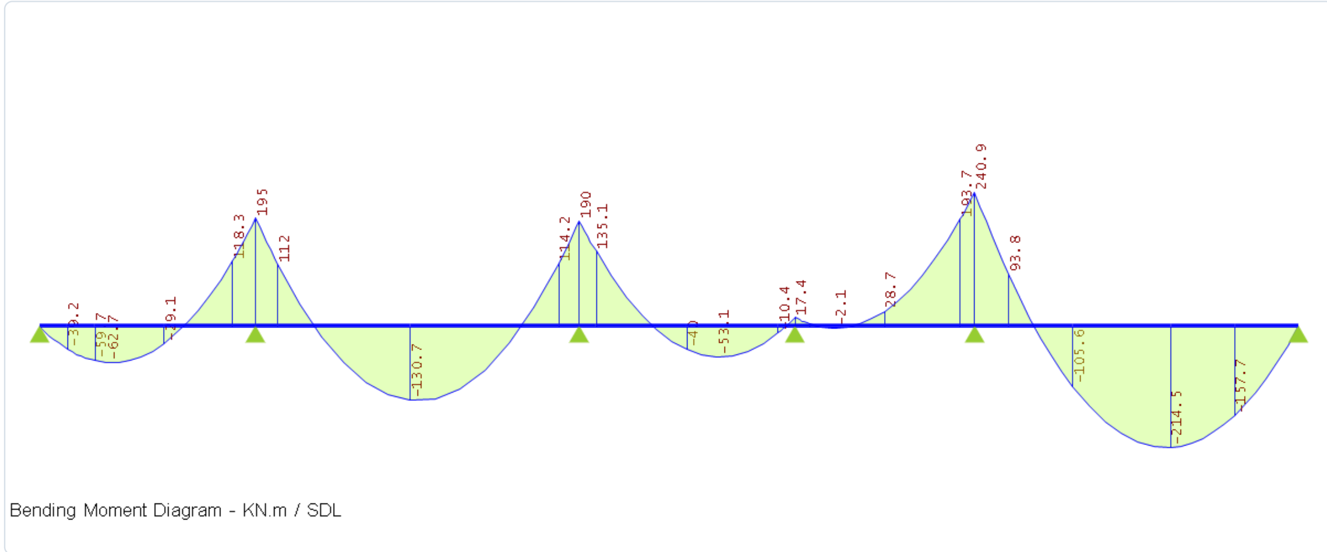
Moment



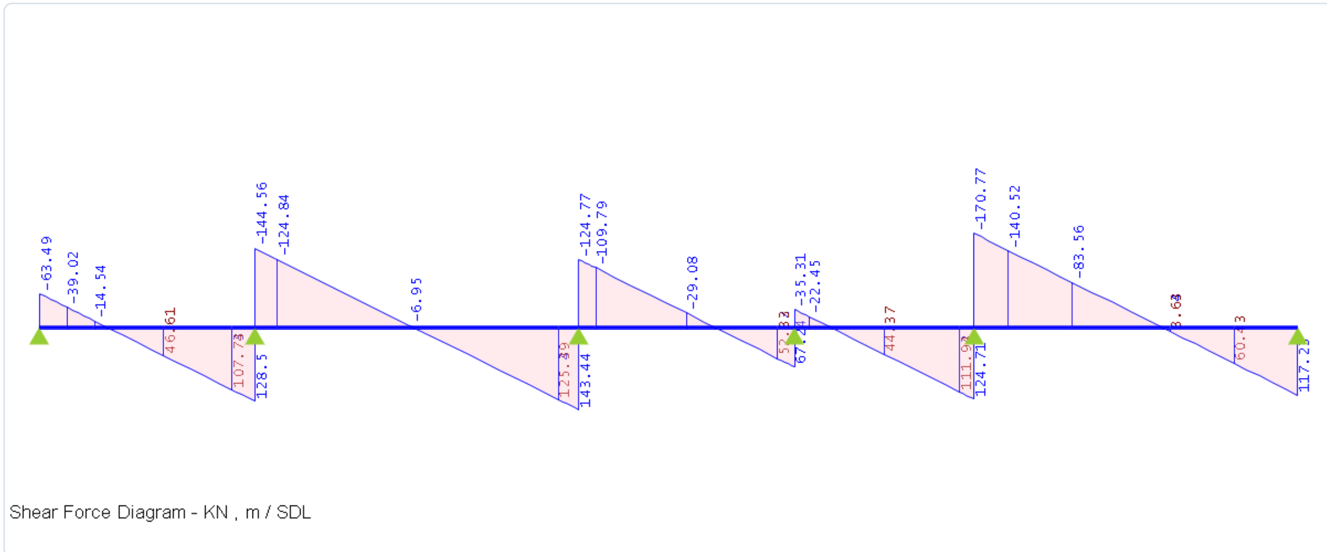
Shear

PTKalc

Moment and shear digram for SDL load case



Bending Moment Diagram - KN.m / SDL



Shear Force Diagram - KN , m / SDL

LEARNING CENTRE

PTKalc Verification Record

Flanged (T) PT Section	By	RK
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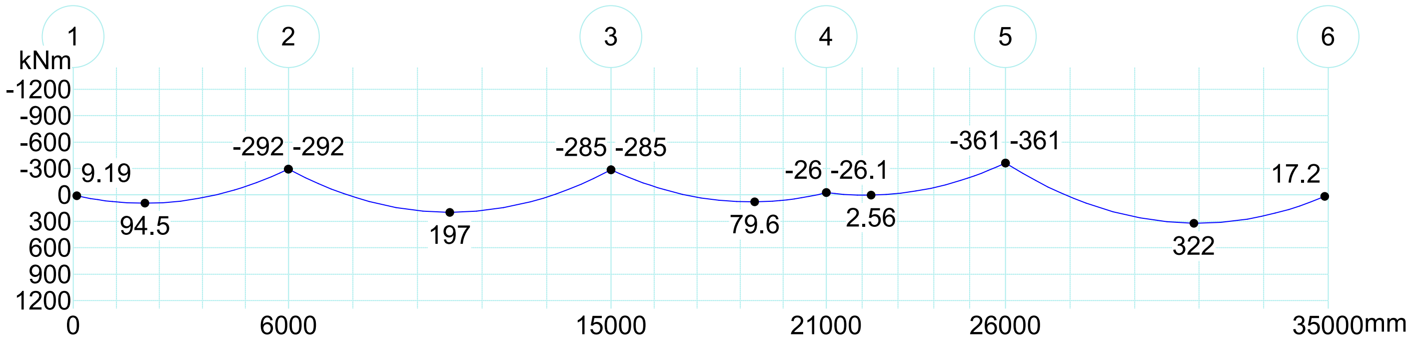
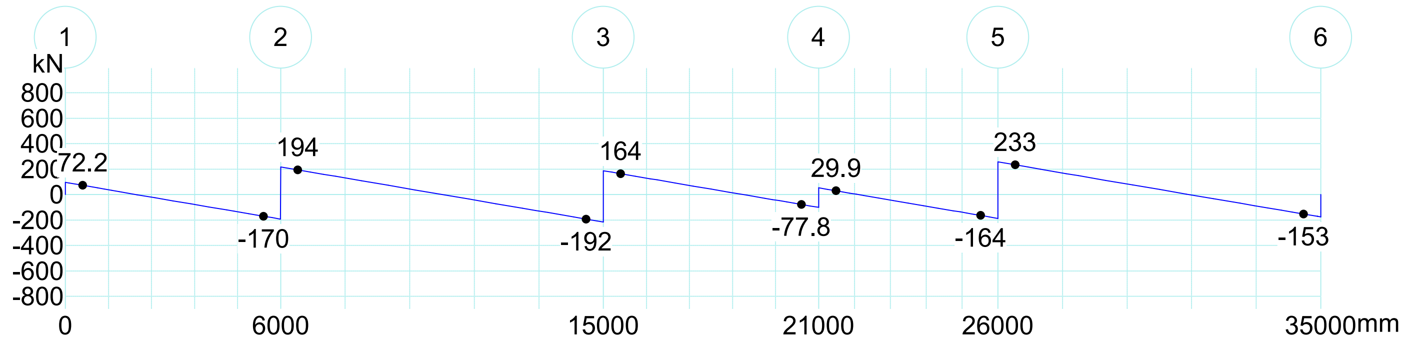
RAPT

Moment and shear digram for LL load case



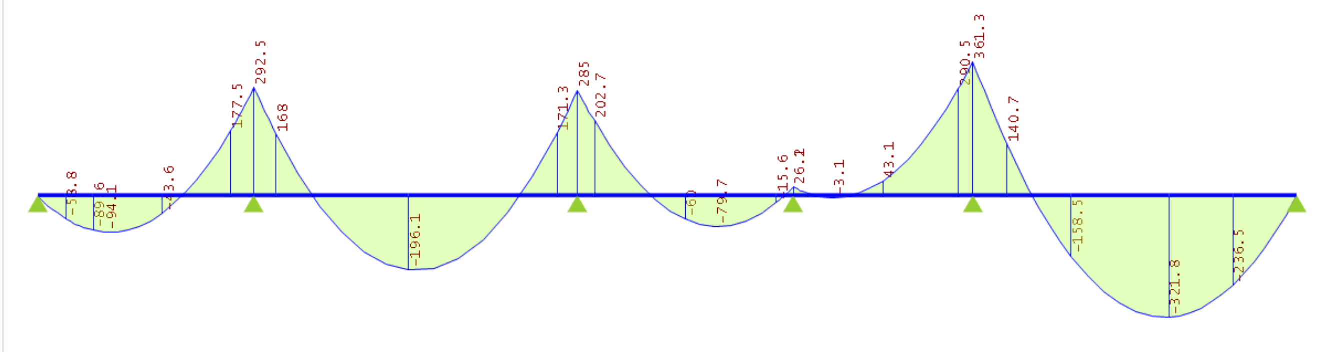
Moment



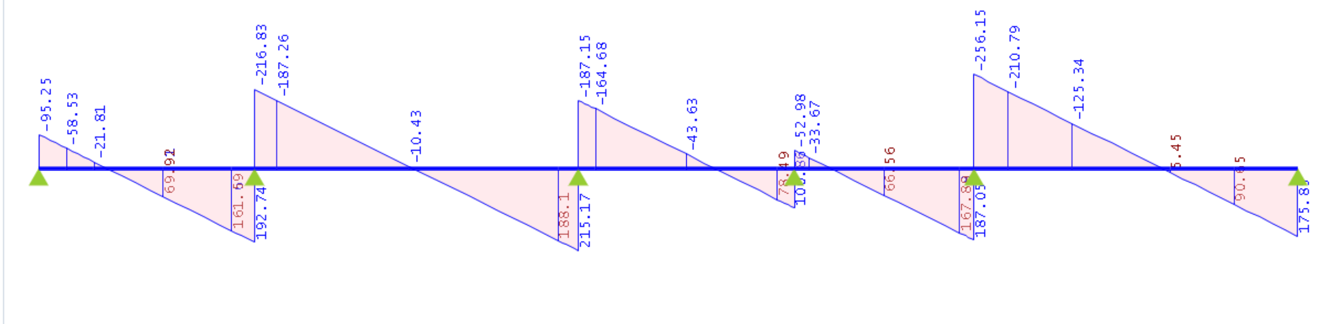
Shear

PTKalc

Moment and shear digram for LL load case



Bending Moment Diagram - KN.m / LL



Shear Force Diagram - KN , m / LL

Educational Example Only – Refer to current Australian Standards and project-specific requirements before design.

LEARNING CENTRE

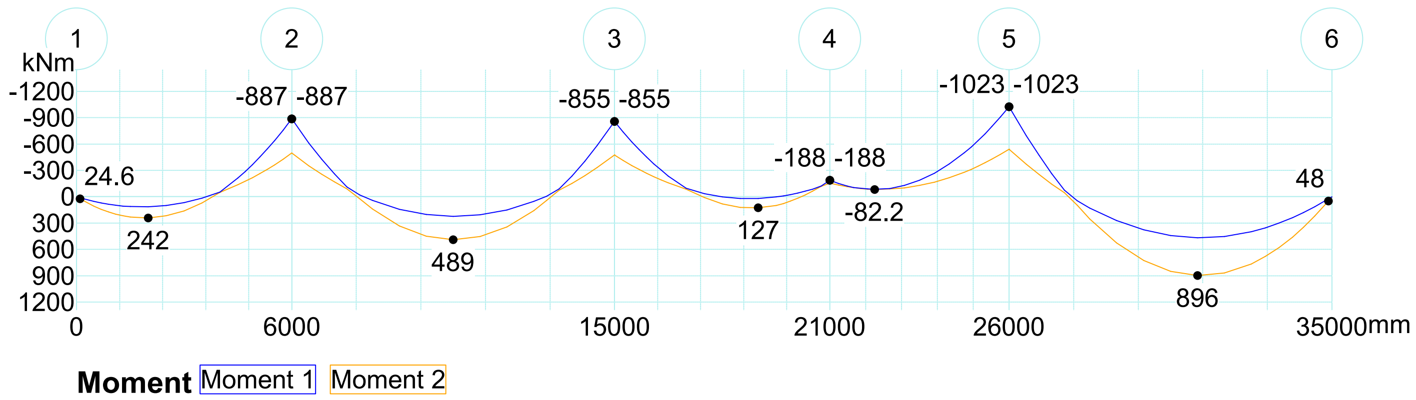
RKALC STRUCTURAL ENGINEERING

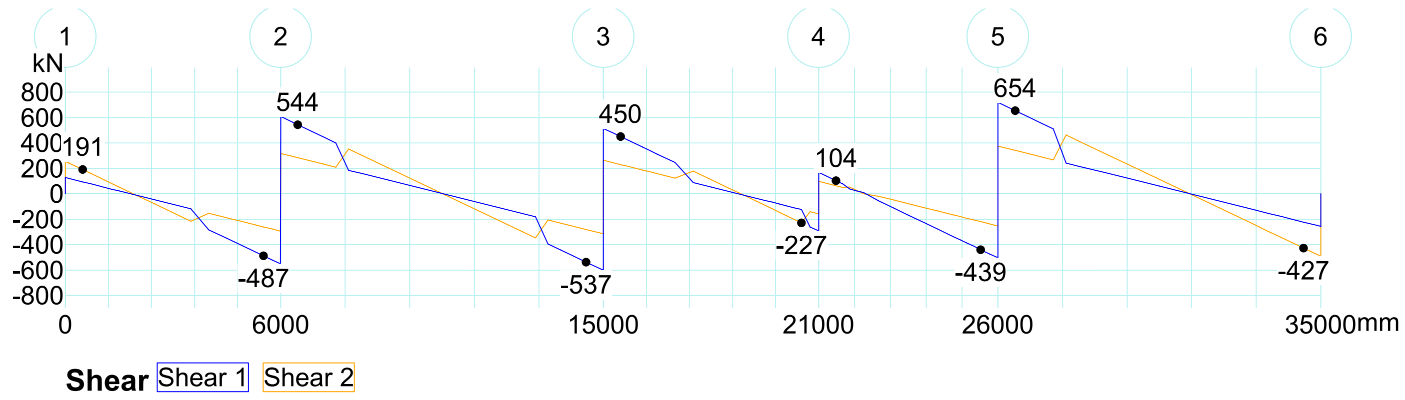
PTKalc Verification Record

Flanged (T) PT Section	By	RK
PTKalc	Sheet No. 1	Date 8/26

RAPT

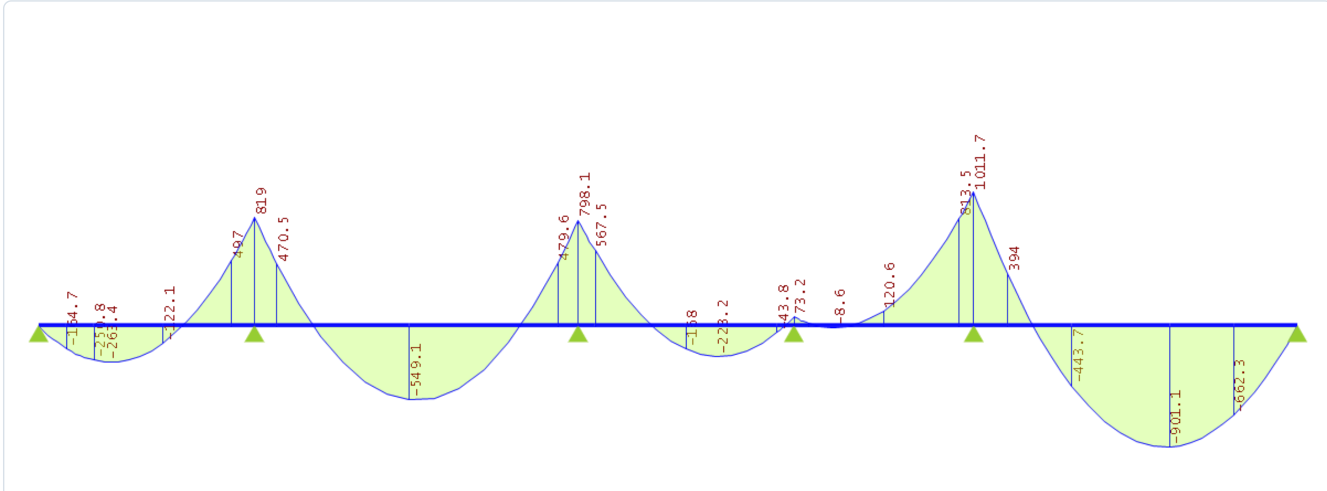
Moment and shear digram for Ultimate load case



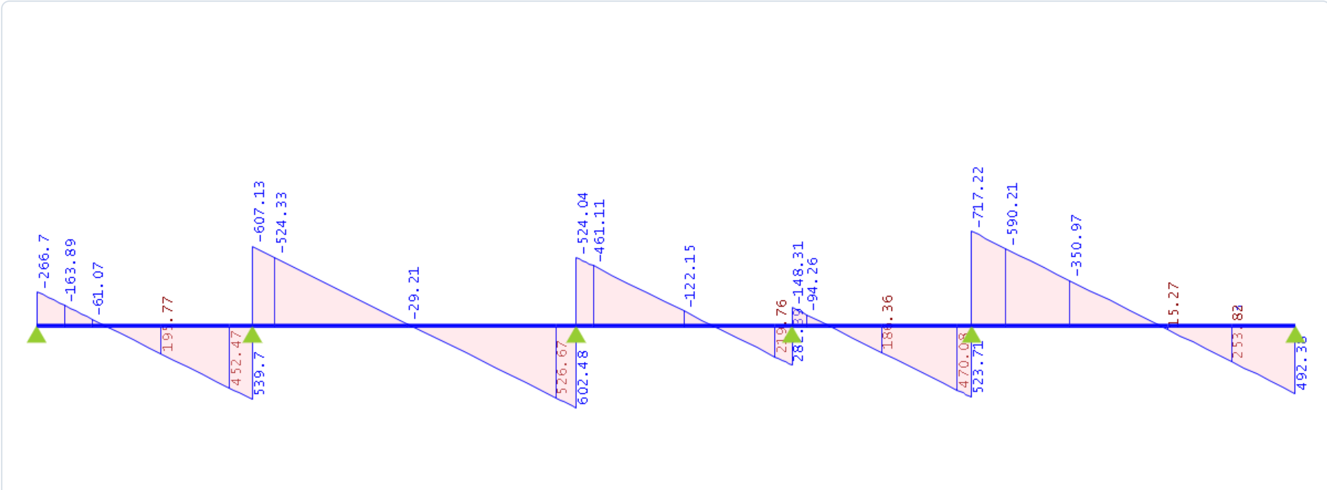


PTKalc

Moment and shear digram for 1.2DL+1.5LL load case



Bending Moment Diagram - KN.m / LC-1.2DL+1.5LL



Shear Force Diagram - KN , m / LC-1.2DL+1.5LL

Educational Example Only – Refer to current Australian Standards and project-specific requirements before design.

LEARNING CENTRE	PTKalc Verification Record	Flanged (T) PT Section	By	RK
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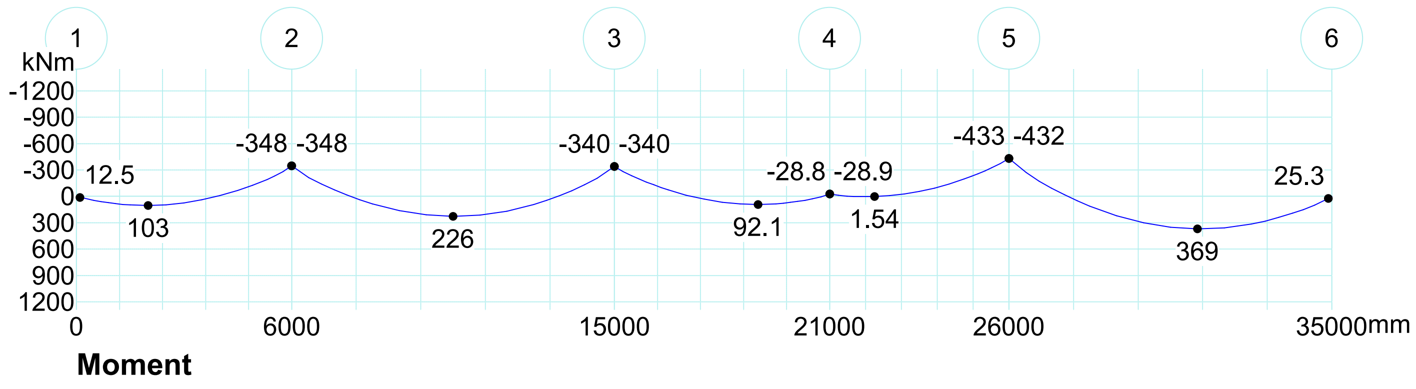
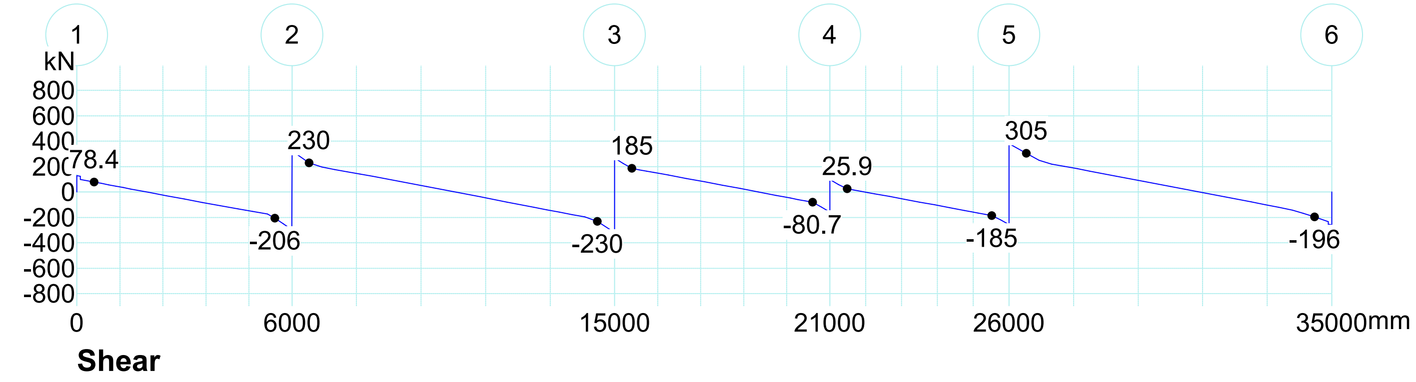
RAPT

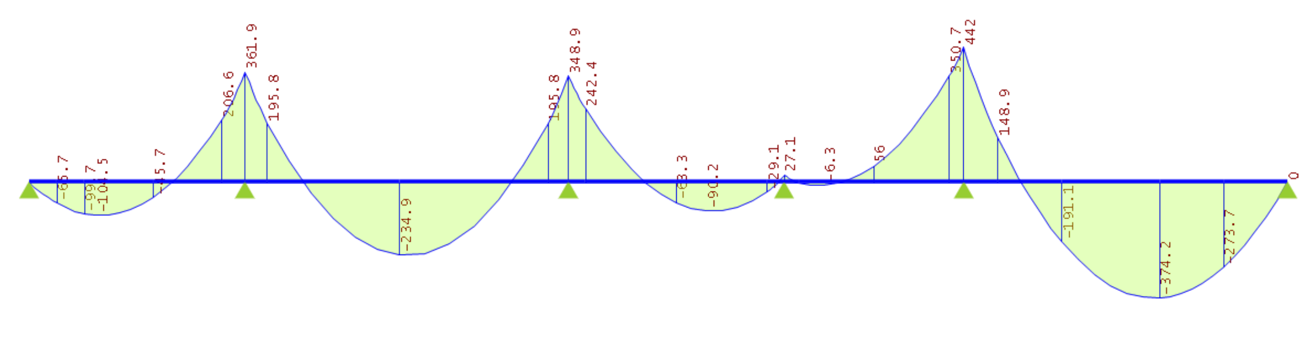
Moment and shear digram for Permanent Deflection load case



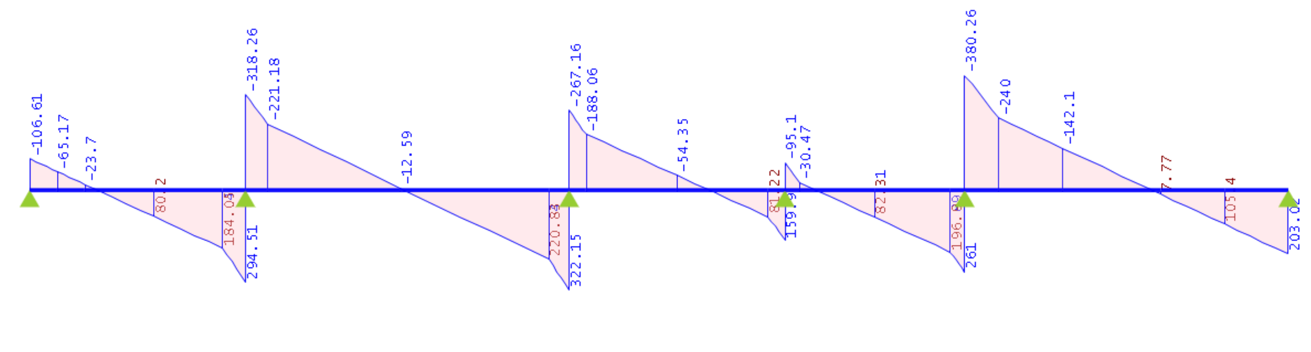


PTKalc

Moment and shear digram for DL + 0.4LL + 0.9PT load case



Bending Moment Diagram - KN.m / LC-1.0DL+0.4LL+PT

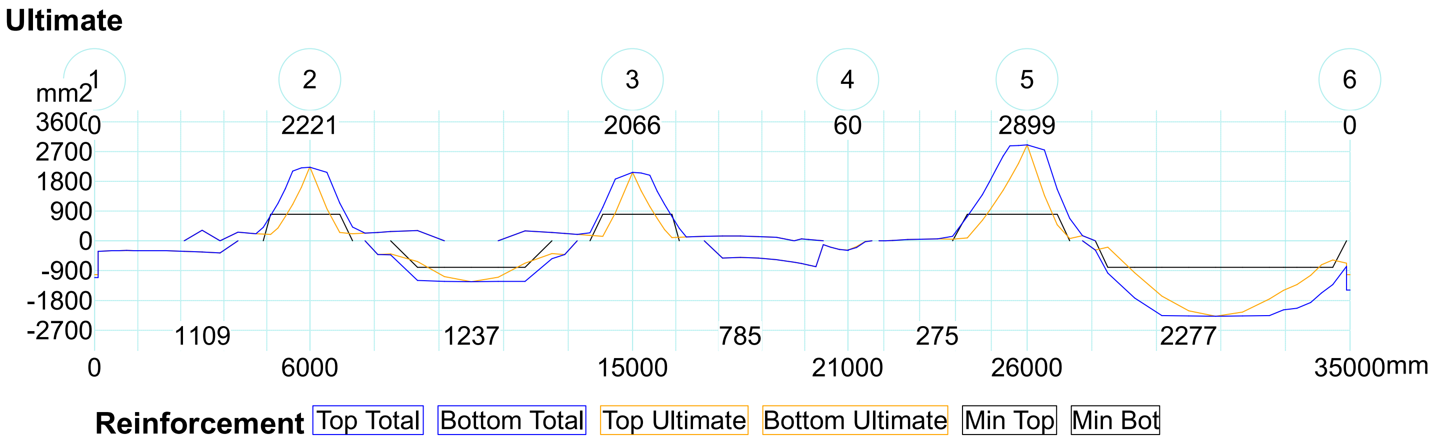


Shear Force Diagram - KN , m / LC-1.0DL+0.4LL+PT

Educational Example Only – Refer to current Australian Standards and project-specific requirements before design.

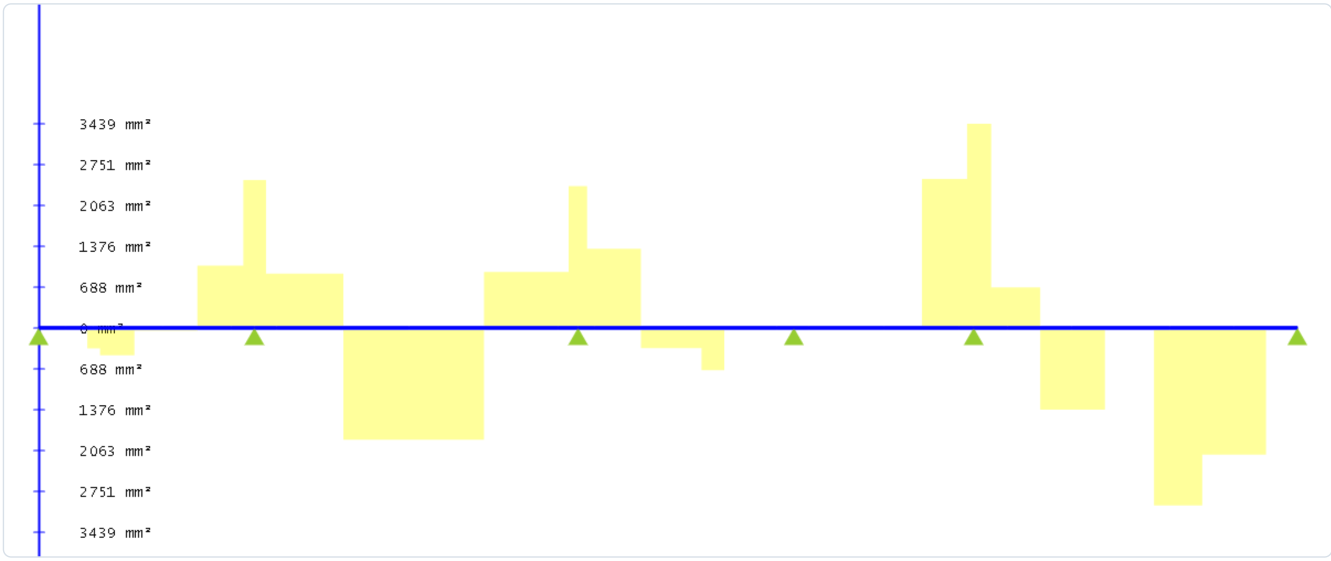
RAPT

Flexural Reinforcement



PTKalc

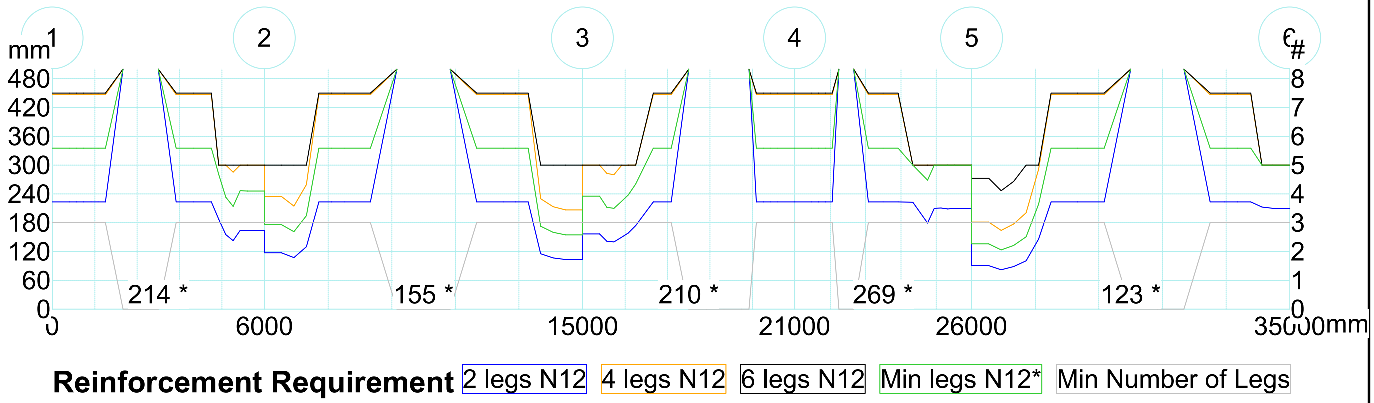
Flexural Reinforcement



Educational Example Only – Refer to current Australian Standards and project-specific requirements before design.

RAPT

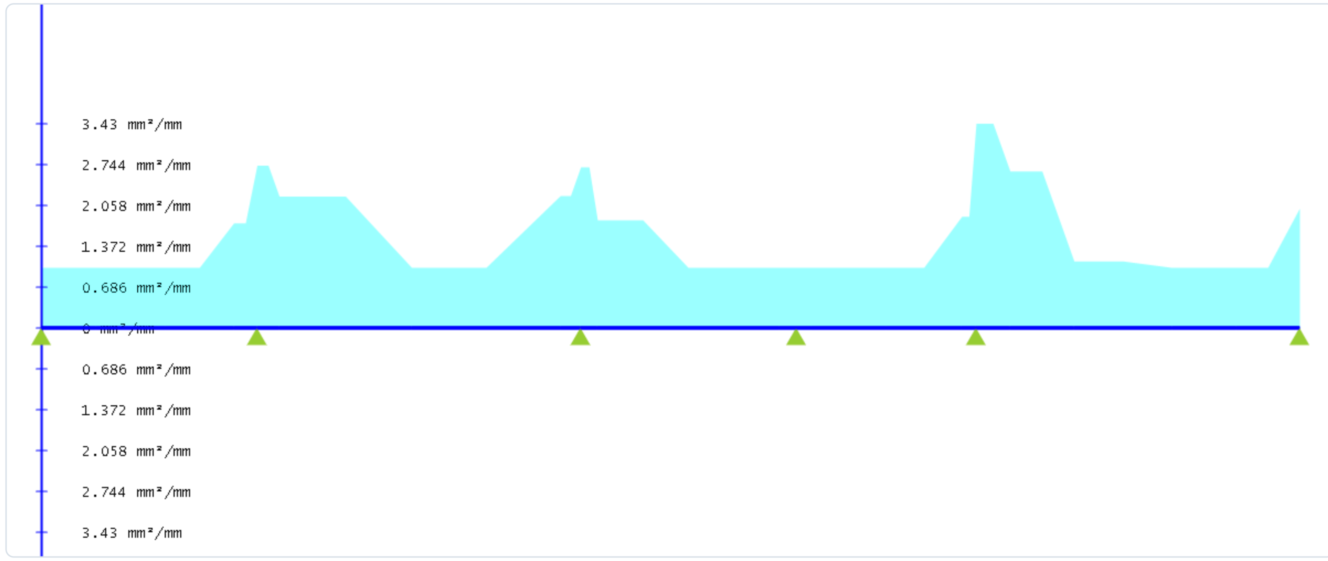
Shear Reinforcement



PTKalc

Shear Reinforcement

NOTE: PTKalc currently reports the adopted minimum shear reinforcement where minimum reinforcement governs, including regions where the calculated shear demand does not require additional shear reinforcement. The final detailing arrangement remains subject to the designer’s engineering judgement and the applicable code requirements.



LEARNING CENTRE

RKALC

PTKalc Verification Record

Flanged (T) PT Section	By	RK
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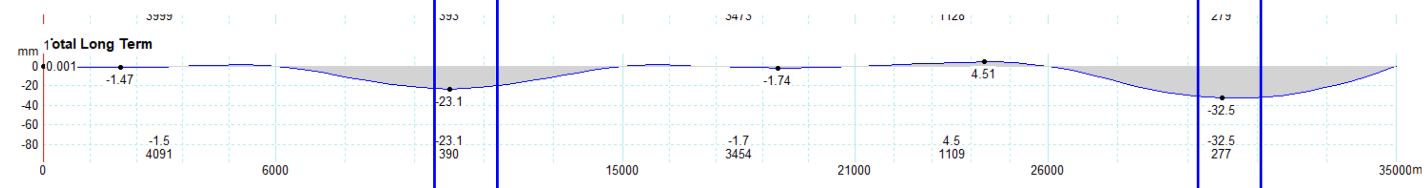
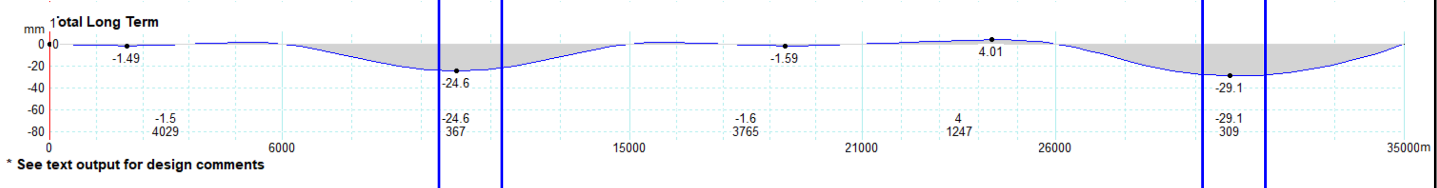
RAPT

Deformation

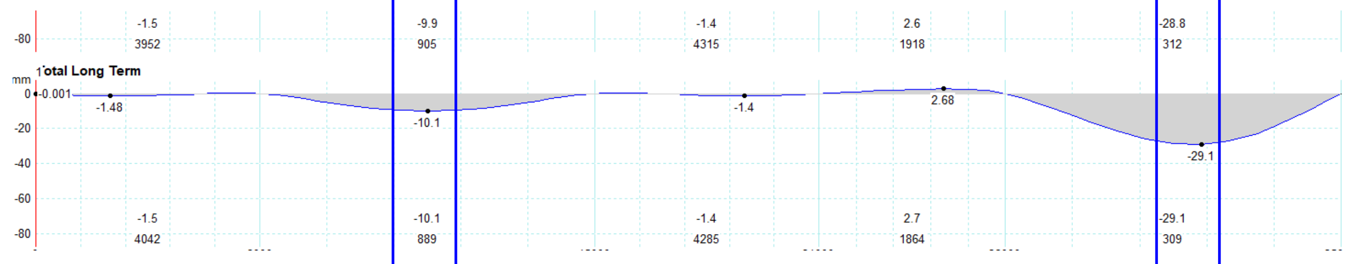
Eurocode formula



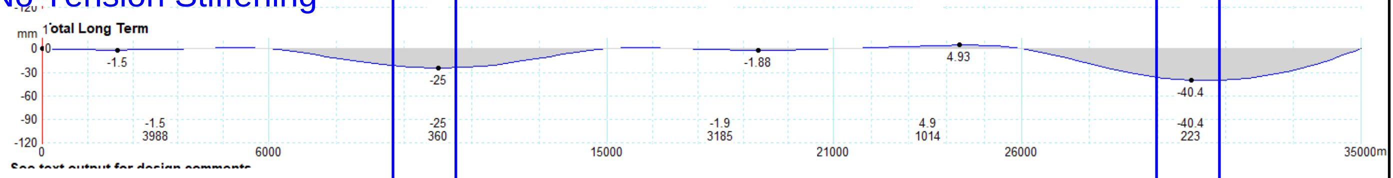
Branson formula



Rapt Modified Method



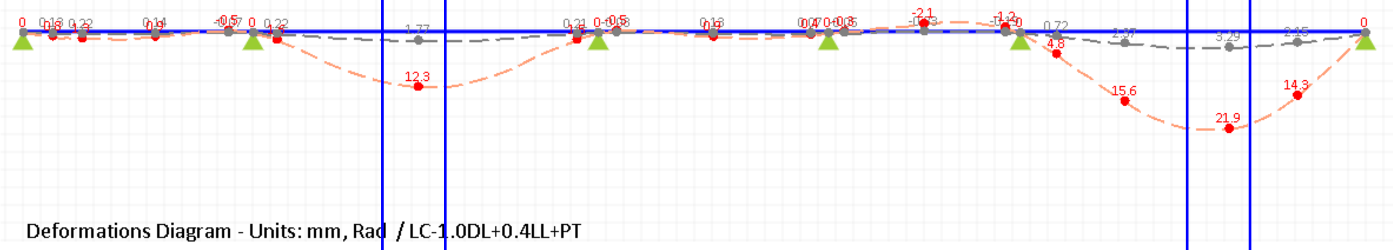
No Tension Stiffening



PTKalc

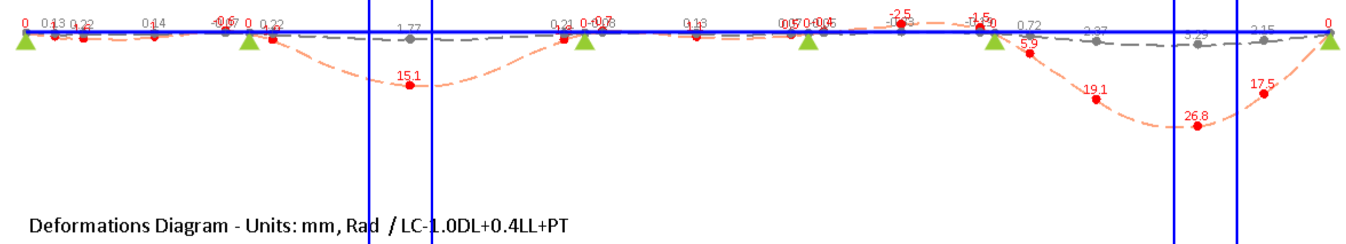
Deformation

Age Adjustment = 1
Rupture = 3.39

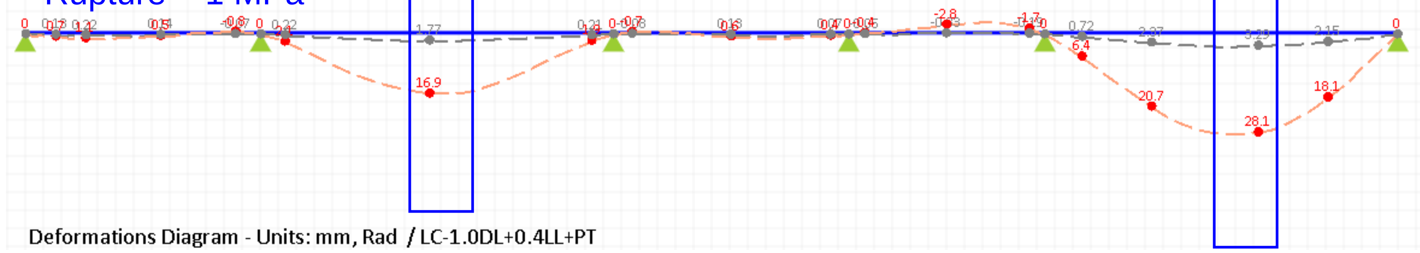


Deformations in grey are elasitc without allowance for cracking (full section)
Deformations in red include effective section properties after cracking and creep

Age Adjustment = 0.76
Rupture = 3.39



Age Adjustment = 1
Rupture = 1 MPa



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Appendix A — Detailed Deflection Methodology: PTKalc and RAPT

1. General approach

Prediction of reinforced and prestressed concrete deflection requires consideration of cracking, tension stiffening, reinforcement, prestress, creep and shrinkage. These effects cause flexural stiffness and curvature to vary both spatially along a member and with time.

PTKalc and RAPT both recognise these mechanisms, but incorporate them into the structural solution differently.

PTKalc adopts an effective-stiffness finite-element approach. Section behaviour is evaluated locally along the member and condensed into an effective flexural stiffness for each finite element. A second global finite-element analysis is then performed using these reduced stiffnesses. Consequently, changes in stiffness influence not only the calculated deformation but also the distribution of bending moments throughout a continuous structure.

RAPT adopts a section-curvature approach for its deflection calculations. Section curvature is calculated for prescribed loading and concrete-modulus conditions using strain compatibility. The resulting curvature distributions are subsequently used to determine the required short-term, incremental and long-term deflections.

This distinction is fundamental when comparing results. PTKalc represents cracking principally through a spatially varying effective EI within the global structural model, whereas RAPT evaluates the corresponding behaviour principally through section curvature under the relevant load and time condition.

2. PTKalc initial elastic analysis

PTKalc begins with a conventional linear-elastic finite-element analysis using the gross section properties.

This initial analysis establishes the bending moment distribution:

$$M_0(x)$$

together with the corresponding shear forces, reactions and elastic displacements.

The purpose of this first solution is not to provide the final long-term deflection. Instead, its bending moments provide the demand from which the cracking state and effective stiffness of individual sections are assessed.

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At the start and end of each finite element, PTKalc passes the signed service moment into its serviceability section calculation. Consequently, positive and negative bending regions are assessed separately and may develop different cracked properties.

This is particularly relevant to continuous beams, where a heavily cracked support region can have substantially different stiffness from an adjacent span region.

3. PTKalc transformed-section analysis

For each section being assessed, PTKalc establishes transformed uncracked and cracked section properties.

A creep-adjusted concrete modulus is first established and the reinforcement is transformed into equivalent concrete using the corresponding modular ratio:

$$n = \frac{E_s}{E_{c,\mathrm{eff}}}$$

The transformed uncracked section includes the concrete geometry and the additional transformed contribution of the reinforcement. PTKalc therefore uses a transformed uncracked inertia I_{uncr} rather than simply the gross concrete inertia I_g in its local cracking calculation.

For a cracked section, tensile concrete is excluded and equilibrium of the transformed section is used to determine the neutral axis. The cracked inertia is then obtained from the concrete compression region and transformed reinforcement:

$$I_{cr} = I_{c,\mathrm{compression}} + \sum n A_s (y_s - y_{NA})^2$$

For T- and L-sections, the calculation recognises whether the neutral axis lies within the flange or extends into the web.

This calculation is repeated locally rather than assigning one cracked inertia to the entire span.

4. PTKalc cracking moment

PTKalc determines the cracking resistance using the transformed uncracked section and explicitly incorporates the local prestress and shrinkage state.

In conceptual form:

$$M_{cr} = \frac{I_{uncr}}{y_t}\left[f_{ct} - \sigma_{cs} + \frac{P_e + N_c}{A_g}\right] + P_e e_p$$

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where P_e is the effective prestressing force, e_p is tendon eccentricity, N_c is additional axial compression and σ_{cs} represents the shrinkage-induced reinforcement stress.

Thus PTKalc does not determine cracking from external bending moment and concrete tensile strength alone. Prestress delays cracking through both axial compression and eccentric prestress, while shrinkage reduces the tensile reserve available before cracking.

The tendon eccentricity is evaluated from the actual draped tendon profile at the relevant finite-element location. The cracking resistance of a prestressed member can therefore vary along its length as the tendon profile varies.

5. PTKalc tension stiffening and effective inertia

After I_{uncr}, I_{cr} and M_{cr} have been established, PTKalc determines the degree of cracking from the ratio:

r_M = min(M_cr / |M_s|, 1)

and evaluates effective inertia using:

$$I_{eff} = \frac{I_{cr}}{\left[1 - \left(1 - \frac{I_{cr}}{I_{uncr}}\right) r_M\right]^2}$$

subject to the implemented upper and lower bounds.

The important engineering feature is the continuous transition:

$$I_{cr} \leq I_{eff} \leq I_{uncr}$$

rather than an abrupt switch from an uncracked section to a fully cracked section.

The resulting local stiffness reduction is:

$$R_I = \frac{I_{eff}}{I_{uncr}}$$

PTKalc calculates this independently at both ends of every finite element.

For the element itself:

$$R_{I,e} = \frac{R_{I,L} + R_{I,R}}{2}$$

This produces a piecewise-varying stiffness distribution along the complete beam.

6. RAPT treatment of tension stiffening

This is one of the major differences between the programs.

RAPT does not impose one unique tension-stiffening formulation. Its documentation provides three tension-stiffening methods, together with a no-tension-stiffening reference case:

1. Branson's Formula
2. Eurocode 2 Formula
3. Modified Concrete Tensile Modulus Method
4. No tension stiffening

The RAPT documentation identifies the Modified Concrete Tensile Modulus Method as its documented default and preferred method, with the intent of representing tension stiffening within the cracked-section analysis rather than through an averaging expression.

Branson method

The Branson approach determines an effective inertia representing the transition between uncracked and cracked behaviour.

For partially prestressed sections RAPT modifies the treatment to account for the prestress bending effect. The RAPT documentation states that the curvature needs to be brought back to the zero datum by subtracting the total prestress bending moment, with the decompression bending moment used as a conservative lower bound.

Of the documented RAPT alternatives, the Branson approach is conceptually the closest to PTKalc because both ultimately represent post-cracking behaviour through an effective stiffness; however, the interpolation formulations are different.

Eurocode 2 method

The Eurocode 2 option works principally through an effective curvature, interpolating between the uncracked and cracked section curvatures and incorporating coefficients associated with reinforcement bond and sustained loading.

Therefore, unlike PTKalc, the primary interpolated quantity is curvature rather than inertia.

RAPT Modified Concrete Tensile Modulus Method

The RAPT preferred method is more fundamentally different.

Rather than first determining I_{cr} and subsequently interpolating an effective inertia, RAPT modifies the Young's modulus of the concrete in tension to represent the residual tensile contribution of concrete between cracks.

The section is then solved using strain compatibility to establish equilibrium, neutral-axis depth, strain and ultimately curvature under the applied moment.

Thus:

PTKalc

$$M \rightarrow M_{cr} \rightarrow I_{cr} \rightarrow I_{eff} \rightarrow EI_{element}$$

whereas the RAPT Modified Method is more directly:

$$M \rightarrow \text{modified tensile concrete behaviour} \rightarrow \text{strain compatibility} \rightarrow \kappa$$

These are different recognised ways of representing the same physical phenomenon of tension stiffening.

7. Treatment of creep

Both programs use an effective-modulus concept, but again the complete implementations differ.

PTKalc incorporates creep at two levels.

First, a creep-adjusted concrete modulus is used in the transformed-section calculation. This changes the modular ratio and therefore affects the transformed neutral axis, I_{uncr} and I_{cr}.

Second, the element stiffness used in the final long-term finite-element analysis is reduced using the final creep coefficient and the age-adjustment factor.

In the present PTKalc formulation:

R_LT = R_I / (1 + phi / 0.76)

and therefore:

I_LT = I_g R_LT

where 0.76 is the adopted age-adjustment factor.

RAPT similarly employs a reduced effective concrete modulus to represent creep and provides an Age Adjustment Factor associated with the time of loading and rate at which stress develops. Its theory documentation identifies the treatment as Faber's Effective Modulus Method.

So the underlying concept is related, but the way the resulting long-term section response enters the global deflection calculation is not identical.

8. Treatment of shrinkage

Here there is a particularly important methodological distinction.

In the current PTKalc methodology, shrinkage enters primarily through the section cracking/effective-stiffness assessment. The shrinkage-induced reinforcement stress reduces the tensile reserve available before cracking, thereby reducing M_{cr} and potentially reducing I_{eff}.

RAPT explicitly calculates a shrinkage curvature based on shrinkage strain, modular ratio, reinforcement first moment and transformed section inertia:

$$\kappa_{cs} = f(\varepsilon_{cs}, n, S_s, I_t)$$

and adds that shrinkage curvature to its long-term curvature condition.

This is therefore a genuine theoretical difference and should be stated clearly in the comparison.

RAPT explicitly introduces shrinkage-induced curvature into the long-term deformation calculation. PTKalc, in its present documented formulation, incorporates shrinkage through its effect on cracking resistance and effective stiffness rather than as a separately integrated shrinkage-curvature field.

That difference can produce a systematic difference in predicted long-term deformation even when the two programs have essentially identical elastic moment diagrams.

9. PTKalc second finite-element analysis

This is a distinctive feature of the PTKalc approach.

After calculating the section stiffness reduction at each finite-element end and averaging the two end values, PTKalc reconstructs the global stiffness matrix.

For each element:

I_LT,e = I_g,e R_I,e / (1 + phi_e / 0.76) and a new element stiffness matrix is generated using that inertia.

The complete reduced-stiffness global system is then assembled and solved:

[K_LT]{d_LT} = {F}

The long-term deflection is therefore not obtained by multiplying the original elastic deflection by a creep or cracking factor.

It is a new structural solution.

This has an important consequence for continuous beams: changing the stiffness at one location changes the structural moment distribution.

A heavily cracked support region becomes less stiff and attracts less bending moment; adjacent less-cracked regions attract correspondingly more. The resulting force redistribution satisfies equilibrium and compatibility because it occurs through the global finite-element solution.

PTKalc therefore produces:

M_0(x) -> EI_eff(x) -> M_LT(x), v_LT(x)

The present procedure performs one explicit stiffness update. It does not repeatedly recalculate I_{eff} from the redistributed moments until convergence. It should therefore be described as a two-pass effective-stiffness analysis, not as a fully nonlinear iterative cracked analysis.

10. RAPT curvature and deflection cases

RAPT's procedure is organised differently.

The RAPT theory manual states that curvatures used for deflection are calculated using four combinations:

1. Short-Term Load with Short-Term Concrete Modulus
2. Permanent Load with Short-Term Concrete Modulus
3. Permanent Load with Long-Term Concrete Modulus plus shrinkage curvature
4. Initial Load with Short-Term Concrete Modulus

For each condition, strain compatibility establishes the section strain state and neutral-axis depth, from which curvature is determined.

RAPT then derives three reported deformation quantities from those curvature cases.

The maximum short-term deflection comes directly from Case 1.

The incremental deflection is obtained from:

delta_inc = delta_3 + (delta_1 - delta_2) - delta_4

and the long-term deflection is:

delta_LT = delta_3 + (delta_1 - delta_2)

RAPT specifically notes that long-term deflection is not simply the sum of initial and incremental deflection.

This staged load-history definition is more explicit in RAPT than in the current PTKalc methodology.

11. Fundamental comparison

The comparison can therefore be summarised as follows:

Aspect	PTKalc	RAPT
Initial structural analysis	FE analysis	Structural analysis
Local cracking assessment	Yes	Yes
Transformed cracked section	Yes	Yes
Prestress included	Yes	Yes
Tension stiffening	Effective inertia relationship	3 tension-stiffening methods + no-tension-stiffening reference
Branson option	No	Yes
Eurocode 2 option	No	Yes
Modified tensile modulus	No	Documented default/preferred method
PTKalc effective-I formulation	Yes	Not identical
Creep	Effective modulus + element EI reduction	Effective modulus/curvature

Aspect	PTKalc	RAPT
Age adjustment	0.76 in current formulation	User/calculated age adjustment
Shrinkage	Influences cracking/effective stiffness	Explicit shrinkage curvature
Spatial stiffness variation	Individual FE elements	Section curvature distribution
Global cracked-stiffness re-analysis	Yes	Different curvature-based deflection procedure
Moment redistribution from reduced EI	Explicitly captured by second FE solution	Not the defining mechanism of RAPT's documented deflection procedure
Short-term case	Available through structural analysis	Explicit curvature case
Incremental deflection	Different/current PTKalc framework	Explicit $3 + (1 - 2) - 4$
Long-term deflection	Reduced-stiffness FE solution	Explicit $3 + (1 - 2)$
Fully iterative cracking	No	Not equivalent to PTKalc iteration

12. Interpretation of the benchmark results

12.1 Purpose of the benchmark comparison

The benchmark comparison is intended to assess whether PTKalc produces a rational and consistent prediction of reinforced and prestressed concrete deformation when compared with recognised alternative serviceability formulations. It is not intended to demonstrate numerical identity with RAPT. The two programs use different methods to represent cracking, tension stiffening and long-term concrete behaviour, and these differences can legitimately produce different deflection magnitudes while retaining the same underlying structural mechanics.

The comparison should therefore be read in two stages. First, agreement of the gross-section bending moment and shear-force diagrams establishes that the same geometry, loading, support conditions and basic elastic structural response have been represented. Second, the deformation comparison examines the sensitivity of the calculated response to the assumptions used after cracking and time-dependent behaviour are introduced.

12.2 RAPT reference solutions

For the verification record, four RAPT deformation results are shown: the Eurocode 2 formulation, Branson's formula, the RAPT Modified Concrete Tensile Modulus Method, and a no-tension-stiffening reference case. These results are useful because they demonstrate that concrete deflection is not represented by one unique post-cracking solution. Different recognised assumptions regarding tension stiffening and section curvature produce a range of predicted deformations for the same beam, loading and material properties.

Accordingly, the RAPT curves are treated as independent reference solutions rather than as a single target curve that PTKalc is required to reproduce. Particular attention is given to the RAPT Modified Concrete Tensile Modulus Method because it is the principal RAPT formulation used in the comparison, while the other curves provide useful context for the influence of tension stiffening.

12.3 PTKalc sensitivity cases

Three PTKalc cases are presented to separate the influence of the age-adjustment treatment from the influence of concrete tensile resistance used in the cracking calculation. Only one parameter is changed relative to the reference case at a time, allowing the resulting change in deformation to be interpreted directly.

Case	Age adjustment	Rupture stress	Purpose
PTKalc Case 1 - Reference cracking response	1.00	3.39 MPa	Standard tensile resistance with no age-adjustment reduction.
PTKalc Case 2 - Age-adjusted long-term response	0.76	3.39 MPa	Isolates the influence of the adopted age-adjustment factor while retaining the same cracking resistance.
PTKalc Case 3 - Reduced tensile resistance	1.00	1.00 MPa	Isolates sensitivity to earlier cracking and reduced concrete tension contribution.

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12.4 Effect of the age-adjustment factor

Cases 1 and 2 retain the same rupture stress of 3.39 MPa. The cracking threshold and the basic tension-stiffening relationship are therefore unchanged, while the long-term stiffness treatment is altered through the age-adjustment factor. This comparison primarily demonstrates the influence of creep-related stiffness reduction on the magnitude of long-term deformation.

Where the two curves retain a similar overall shape but differ in magnitude, the result is consistent with the intended behaviour of the model: the same regions of the member are being identified as relatively stiff or cracked, but the long-term flexural rigidity assigned to those regions is reduced. The age-adjustment factor should therefore be interpreted as a time-dependent stiffness assumption, not as a change to the concrete cracking strength.

12.5 Effect of concrete rupture stress

Cases 1 and 3 retain an age-adjustment factor of 1.00 and vary only the concrete rupture stress from 3.39 MPa to 1.00 MPa. In PTKalc, the adopted tensile resistance enters the cracking-moment calculation and consequently affects the ratio of cracking moment to service moment used in the effective-inertia relationship.

Reducing the rupture stress therefore causes cracking to be recognised at a lower applied moment and reduces the contribution attributed to concrete tension between cracks. This can reduce the effective stiffness over a greater proportion of the member and increase the calculated deformation. The 1.00 MPa case is a sensitivity case representing reduced concrete tensile contribution; it is not mathematically equivalent to the RAPT no-tension-stiffening case, because PTKalc continues to use its own effective-inertia formulation and retains a finite tensile resistance.

12.6 Interpretation of PTKalc and RAPT results

The comparison demonstrates that predicted deformation is sensitive to the assumptions adopted after the gross elastic analysis. Agreement of the elastic moment and shear diagrams verifies the common structural basis of the models, while divergence between deflection curves primarily reflects the subsequent treatment of cracking, tension stiffening, creep, shrinkage and load history.

PTKalc should therefore not be assessed by selecting one RAPT curve as an absolute definition of the correct deflection. A more appropriate comparison is whether the PTKalc response is mechanically consistent, responds in the expected direction when the governing assumptions are varied, and has a technically explainable relationship to the alternative RAPT formulations.

The three PTKalc cases provide this sensitivity check. Reducing the age-adjusted long-term stiffness increases deformation without changing the adopted cracking strength, while reducing the rupture stress causes earlier cracking and a corresponding reduction in effective member stiffness. These trends are consistent with reinforced-concrete

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serviceability mechanics and help identify the source of differences between the two programs.

12.7 Scope and limitations

This comparison is a software verification exercise for the stated benchmark model. It does not imply that PTKalc and RAPT use identical algorithms, nor that one program is used as the definition of the other. Results are dependent on the selected material properties, reinforcement, prestress, load history, creep and shrinkage parameters, cracking assumptions and tension-stiffening model.

The numerical results shown are specific to the verification example and should be read together with the model input data, the applicable design standard and project-specific engineering requirements. The objective of the exercise is to demonstrate the transparency, consistency and sensitivity of the PTKalc deflection methodology against established alternative analysis approaches.

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