Switches and Crossings

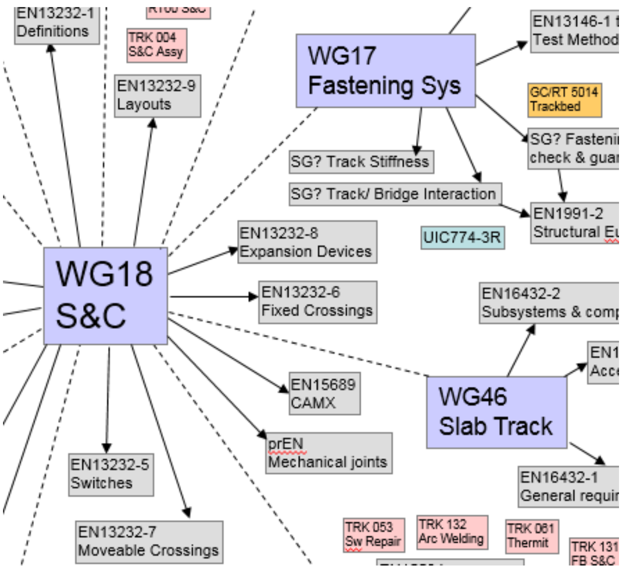
Knowledge, Processes and Experience

There is a series of logical steps to designing S&C. When CEN required a structure for the preparation of a series of standards, Andy Foan listed all the subject matter, distributed it into distinct subject groups, and presented this as the structure. Those present agreed and the groups became the nine parts of EN13232 Switches and crossings.

Not that EN13232 stands alone. It works alongside the standards for rail profiles and materials, fastening systems, sleepers and bearers (including hollow ones) and others to provide a framework for both design and assurance.

The process of writing and agreeing these standards reaches across different railway types and involves all those European nations with established railway technologies. Initially mandated to promote fair trade, a later mandate added interoperability, and now the standards are needed as a vehicle for translating the requirements of the Technical Specifications for Interoperability into a practical resource for producing workable designs.

The working group responsible for standards for switches and crossings is headed by Andy Foan. EN13232 covers geometrical layout, wheel/rail interaction, point operation, and requirements and tolerances for switches, fixed crossings, crossings with moveable parts, expansion devices and layouts. The group has also written a standard for cast manganese crossings, and a standard for mechanical joints has recently been released for comment.



Track stiffness through S&C is a weakness in the current portfolio because EN13481-7 doesn't provide rules for the wide variation in plate lengths; this assumes greater importance in nonballasted applications if more resilience is built into the platework. Forthcoming work includes addressing this issue in the standard for S&C fastening systems.

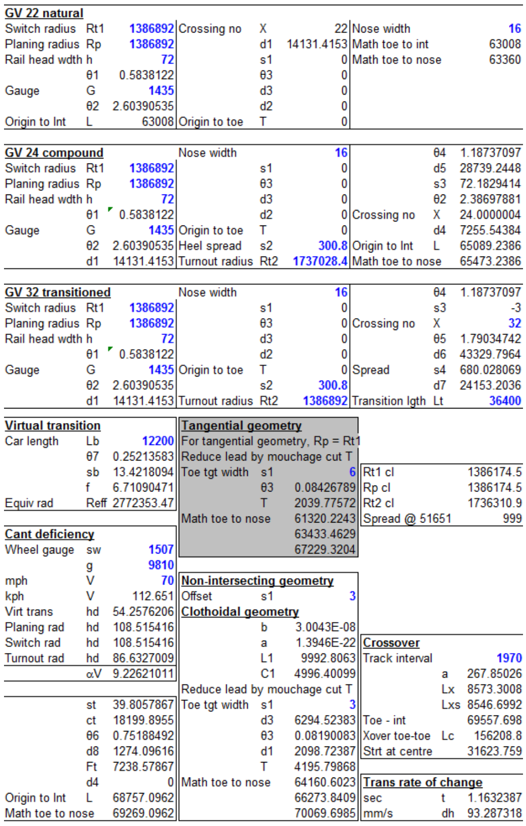
Getting involved in standards for S&C exposes the participants to different opinions about principles, why rules are as they are and whether they are based on evidence, which railways are investing in what technologies, and so on. Andy has enjoyed the education and networking opportunities too, for over 20 years as a manufacturer's representative and now as an independent specialist.

Andy takes the rules expressed in the standards, and the structured approach in the nine parts of EN13232, and makes them into tools for design and analysis of behaviour. Tools make the repetitive calculations more reliable and in some cases feasible when they wouldn't otherwise be.

The following explains some of them and demonstrates how they have been used by Andy Foan Limited to deliver evidence-based solutions.

Geometry Tools

Spreadsheets such as that illustrated are good for scoping out turnout families and use the appropriate fundamental geometric parameters.



GV 22 natural								
Switch radius	Rt1	1386892	Crossing no	X	22	Nose width		16
Planing radius	Rp	1386892		d1	14131.4153	Math toe to int		63008
Rail head wdth	h	72		s1	0	Math toe to nose		63360
	θ1	0.5838122		θ3	0			
Gauge	G	1435		d3	0			
	θ2	2.60390535		d2	0			
Origin to Int	L	63008	Origin to toe	T	0			

GV 24 compound			Nose width		16		θ4	1.18737097
Switch radius	Rt1	1386892		s1	0		d5	28739.2448
Planing radius	Rp	1386892		θ3	0		s3	72.1829414
Rail head wdth	h	72		d3	0		θ2	2.38697881
	θ1	0.5838122		d2	0	Crossing no	X	24.0000004
Gauge	G	1435	Origin to toe	T	0		d4	7255.54384
	θ2	2.60390535	Heel spread	s2	300.8	Origin to Int	L	65089.2386
	d1	14131.4153	Turnout radius	Rt2	1737028.4	Math toe to nose		65473.2386

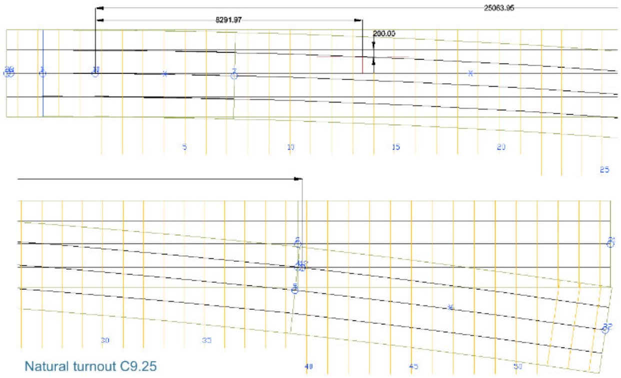
GV 32 transitioned			Nose width		16		θ4	1.18737097
Switch radius	Rt1	1386892		s1	0		s3	-3
Planing radius	Rp	1386892		θ3	0	Crossing no	X	32
Rail head wdth	h	72		d3	0		θ5	1.79034742
	θ1	0.5838122		d2	0		d6	43329.7964
Gauge	G	1435	Origin to toe	T	0	Spread	s4	680.028069
	θ2	2.60390535		s2	300.8		d7	24153.2036
	d1	14131.4153	Turnout radius	Rt2	1386892	Transition lgth	Lt	36400

Virtual transition			**Tangential geometry**					
Car length	Lb	12200	For tangential geometry, Rp = Rt1					
	θ7	0.25213583	Reduce lead by mouchage cut T					
	sb	13.4218094	Toe tgt width	s1	6	Rt1 cl		1386174.5
	f	6.71090471		θ3	0.08426789	Rp cl		1386174.5
Equiv rad	Reff	2772353.47		T	2039.77572	Rt2 cl		1736310.9
			Math toe to nose		61320.2243	Spread @ 51651		999
Cant deficiency					63433.4629			
Wheel gauge	sw	1507			67229.3204			
	g	9810						
mph	V	70	**Non-intersecting geometry**					
kph	V	112.651	Offset	s1	3			
Virt trans	hd	54.2576206	**Clothoidal geometry**					
Planing rad	hd	108.515416		b	3.0043E-08			
Switch rad	hd	108.515416		a	1.3946E-22	**Crossover**		
Turnout rad	hd	86.6327009		L1	9992.8063	Track interval		1970
	αV	9.22621011		C1	4996.40099		a	267.85026
			Reduce lead by mouchage cut T				Lx	8573.3008
	st	39.8057867	Toe tgt width	s1	3		Lxs	8546.6992
	ct	18199.8955		d3	6294.52383	Toe - int		69557.698
	θ6	0.75188492		θ3	0.08190083	Xover toe-toe	Lc	156208.8
	d8	1274.09616		d1	2098.72387	Strt at centre		31623.759
	Ft	7238.57867		T	4195.79868			
	d4	0	Math toe to nose		64160.6023	**Trans rate of change**		
Origin to Int	L	68757.0962			66273.8409	sec	t	1.1632387
Math toe to nose		69269.0962			70069.6985	mm/s	dh	93.287318

BLIPS is a geometry system designed for S&C. BLIPS stands for Basic Layout Intersection Points System. Wherever the rail running edge intersects a bearer centreline is a key datum for the definition of associated components. BLIPS creates these intersections.

BLIPS enables the user to draw track panels of any configuration and orientation, and by superimposing panels of different configuration and the same start point any type of special trackwork construction can be drawn.

BLIPS writes to .dxf file format, thereby creating drawings that can be opened in any CAD program.



Natural turnout C9.25

The user defines his requirements with a simple sequence of specially written commands. A BLIPS datafile is a text-only file which contains a sequence of building blocks. The datafile can be thought of as an audit trail for the layout drawing it produces.

```
mark, 1,
pstr, 26547.5608107412,
mark, 2,
shft, 3, -717.5,
shft, 5, -3.09405098533339,
mark, 4,
retn, 1,
shft, 3, 0,
pcir, 2, 245565.5, -6.18810197066679,
mark, 5,
retn, 4,
shft, 1, 148.000339014585,
mark, 12,
retn, 1,
shft, 2, 991.851941274932,
mark, 6,
shft, 1, 2623.2485726643,
mark, 10,
shft, 2, 0,
mark, 11,
retn, 10,
shft, 5, -0.524557064070709,
pcir, 2, 286533.5, -0.862732607278937,
mark, 7,
titl, 0, post-gtg add-ins,
titl, 0, define fronts as 4.5 spacings each 650,
titl, 0, ie 2925 less 180 from MP to joint,
titl, 0, datum point 1 is origin of switch curve,
titl, 0, datum point 10 is MP switch,
retn, 10,
shft, 5, 180,
pstr, 2745,
shft, 5, 180,
mark, 23,
titl, 0, datum point 2 is main road at heel,
retn, 2,
pstr, 9700,
mark, 21,
titl, 0, datum point 5 is turnout road at heel,
retn, 5,
pcir, 6, 245565.5, 9700,
mark, 22,
titl, 1, return to datum and start bearer domain,
retn, 10,
shft, 2, 2745,
dset, 1340, -1340,
bdst, 325, 3, 650,
bnm5, 1,
```

Each panel is automatically placed at the endpoint of the one previously drawn unless otherwise specified. Each panel can be drawn with just centreline and gauge lines, or with a partial or full set of rail footprint and plate footprint construction lines. Bearer centrelines are drawn in groups of identical spacing called domains, distributed either on a straight line or on a circular arc. Different spacings and special configurations are constructed by using several domains in sequence.

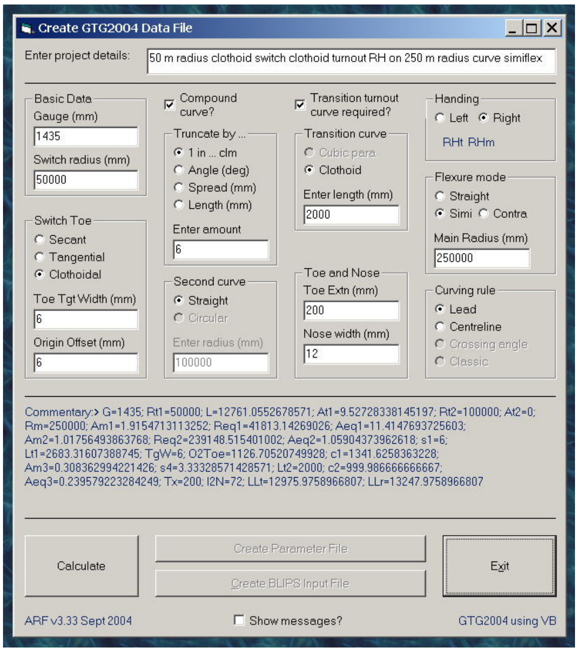
BLIPS was used to generate the original RT60 geometry layouts and footprint spreadsheets, and is used today by AFL to create and verify geometries graphically.

GTG is a graphical user interface for creating input datafiles for BLIPS. Less knowledge is needed to create original turnout geometries. Once GTG has generated the input datafile, extra detail for exit panels and bearer domains can be added manually to the input datafile.

GTG immediately calculates key turnout parameters, which can be checked against requirements. An alternative spreadsheet is used if a tabular reporting format is required. This has been used where a family of turnouts has to be optimised before committing to producing drawings. It caters for intersecting (secant), tangential and non-intersecting (clothoidal) geometry types.

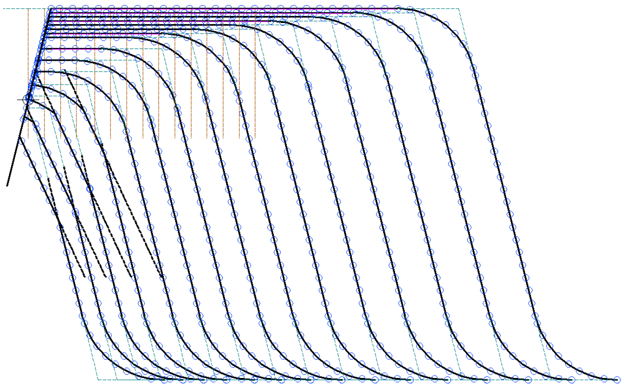
Apart from designing the standard turnout, GTG provides four methods of curving it to similar or contraflexure.

Classic invokes the simple equivalent curve rule, but this doesn't satisfy the preservation of the lead dimension. Curving on centreline and curving to preserve crossing angle are also provided.



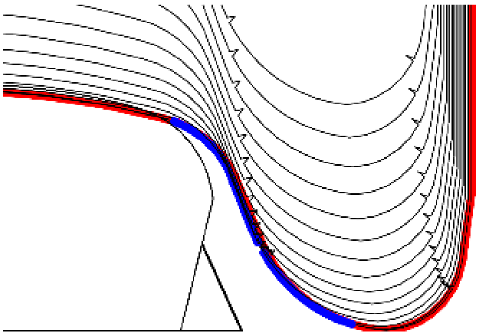
Wheel/Rail Interaction Tools

TopVB is an efficient and effective automated 2D process, based on a VB program, which draws switch profile cross-sections. It produces .dxf files directly and it can also be commanded to create a points cloud for each profile. Based on a simple cross-section of just the switch rail head, there are many functions which automate various aspects of geometry.



Time is saved in computing section parameter values, drawing the profiles and capturing the data points. Confidence in the results is assured by avoidance of manual number handling. Points data can be used in dynamic simulation and switch inspection.

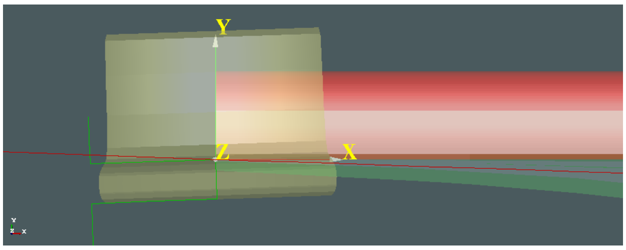
The three dimensions of a switch can be effectively separated and their rules dealt with individually. In plan, the locus of the centreline of the switch rail and the rail profile defines the unmachined raw material, while the switch rail running edge geometry is the reference line/curve for machining the outside headcut.



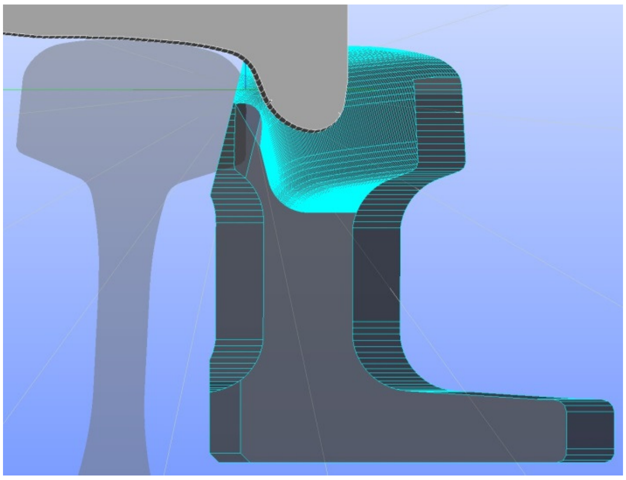
In elevation a top machining cut is made. It is defined by depths below the switch rail crown and by where it runs out on the switch rail centreline.

The third dimension is the shape of the machining cuts, defined by fillet radii and angles or slopes relative to the vertical plane.

The stock rail running edge may define the inside headcut, or it may be offset. A switch toe relief cut may be used if required. All these loci lie in the switch rail reference plane.

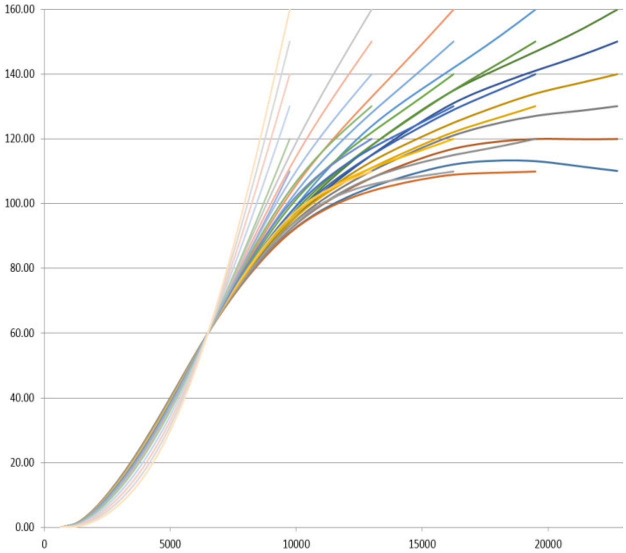


AFL has also developed 3D parametric modelling tools for switches and crossing wheel/rail visualisation, used for example to correct a wheel profile for angle of attack before superimposing it on a sequence of switch rail profiles to check for contact in the danger zone.

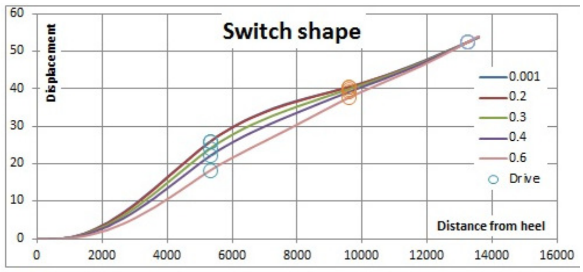


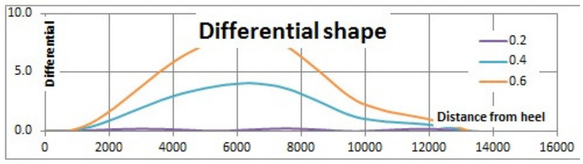
Point Operation Optimisation Tools

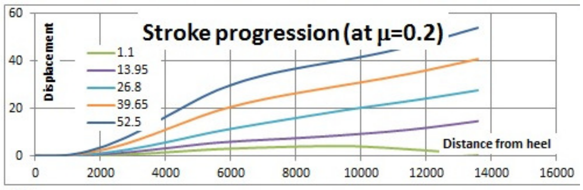
Design and optimisation of switch flexure is notoriously difficult and counterintuitive without computational methods. AFL uses a process developed over 20 years and based on a program written by Andy Foan called F-Melba, for Frictional Multi-element Beam Analysis.

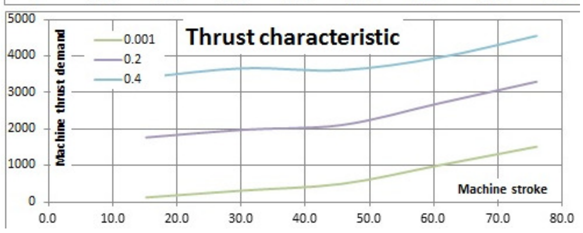


It has been used for short stiff switches through to long switches and for families of switches such as vertical full depth and shallow depth switches in CEN56 rails and clothoidal inclined switches in CEN60 profile.



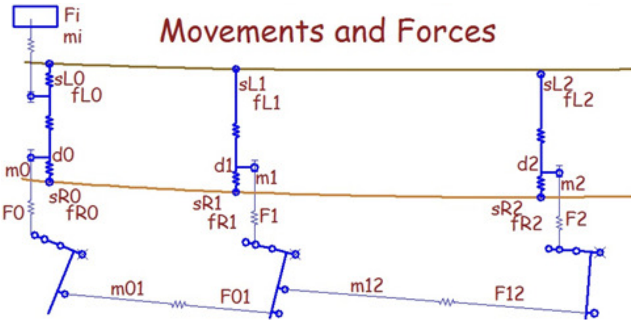






Physical testing is always recommended, however neither simulation nor physical testing alone are enough to explore all aspects of behaviour. F-Melba has shown close agreement with test data, and together the two facets have advanced the technique and added confidence. Its power to optimise behaviour, reduce failures, and identify obstruction detectability risk has often been demonstrated.

Where switch behaviour and point operating equipment behaviour are interactive, for example where mechanical supplementary drives introduce resilience, there is an additional risk of insufficient stroke to achieve proper switch closure. For supporting analyses F-Melba is embedded into a tool called FMCM (F-Melba Context Matrix) accompanied by functional diagrams.



Unlike stiff (multiple actuator) drives, the stroke at intermediate and rear drive positions isn't fixed. This shows in the switch shape and differential shape graphs generated by FMCM using F-Melba output data.

Tools for Structural Integrity

Desktop structural integrity calculations tend to be ad-hoc but a template for rail stress and deflection has been found to be useful.

Rail stress and deflection v3.02

Demonstration calculation

inputs:			*results:*		
resilient pad stiffness	k_{p1} (kN/mm)	70			
attrition pad stiffness	k_{p2} (kN/mm)	1400			
ballast stiffness	k_b (kN/mm/end)	100	sleeper modulus	k_s (kN/mm)	40
bearer spacing	(mm)	650	track modulus	k_T (N/mm^2)	61.538
support width	(mm)	285.2	foundation modulus	k_O (N/mm^3)	0.2158
E (rail)	(N/mm^2)	207000			
Ixx (rail)	mm^4	15700000	track stiffness	k_L (kN/mm)	83.44
			β		0.0015
axle load	tonnes	30	dynamic load factor		1.1988
speed	kph	80	vertical wheel load	L (kN)	147.15
			dynamic wheel load	L (kN)	176.4
			ballast pressure	(N/mm^2)	0.2965
			static vertical deflection	d (mm)	1.7636
			rail bending moment	(kNmm)	29897
Yfoot	(mm)	62.3	rail stress over bearer	(N/mm^2)	118.64
mid bed rail stress factor		1.2	max rail stress mid bed	(N/mm^2)	142.36

For modelling track system behaviour, AFL developed a beam grillage template using the finite element package Calculix, and a research variant has been configured for longitudinal stress modelling.

For 3D wheel and rail modelling and linear elastic stress analysis, AFL uses the open source finite element package Salome-Mech with parametric scripts using the coding language python.