

GUIDANCE AND PRINCIPLES

Document Title: Track Design Handbook: NR/L3/TRK/2049/mod01



User information

This Network Rail standard contains colour-coding according to the following Red–Amber–Green classification.

Red requirements – no variations permitted

- Red requirements are to be complied with and achieved at all times.
- Red requirements are presented in a red box.
- Red requirements are monitored for compliance.
- Non-compliances will be investigated and corrective actions enforced.

Amber requirements – variations permitted subject to approved risk analysis and mitigation

- Amber requirements are to be complied with unless an approved variation is in place.
- Amber requirements are presented with an amber sidebar.
- Amber requirements are monitored for compliance.
- Variations can only be approved through the national non-compliance process.
- Non-approved variations will be investigated and corrective actions enforced.

Green guidance – to be used unless alternative solutions are followed

- Guidance should be followed unless an alternative solution produces a better result.
- Guidance is presented with a dotted green sidebar.
- Guidance is not monitored for compliance.
- Alternative solutions should be documented to demonstrate effective control.

Amendment marks

- First document amendments are presented with a single black line to the right of the affected text.
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A.1.1: Track Layout Design

1 Establishing the Track Layout

The development of the track layout design should be undertaken in accordance with the company's procedures for the feasibility, development and authorisation of Track Renewals and other projects. It is important to follow the initial remit and scope to identify the critical requirements for speed and functionality. Due consideration must be given to the other aspects and constraints of the layout including 'operational flexibility' and speed, fixed points, matching the existing footprint, staging and phasing of the construction, reliability and ease of maintenance. Taking due account of the requirements set out in the appropriate Railway Group and Network Rail Standards, the design of the layout will be shaped by the speeds required on the through main and the turnout diverging route(s). The final design should represent the very best interpretation of the remit and scope and be the most effective engineering solution once the various constraints have been resolved.

2 Track Alignment

Where layouts include S&C units, these shall be placed on an established and proven designed through alignment of the main line.

Without this, it is impossible to obtain correct relationships between S&C combinations and the checking of maximum permissible speeds will be difficult.

Where Overhead Line Equipment is present, it is vital that the registration is taken into account; any departure from the permitted tolerances shall be agreed with the Route Asset Manager (Electrification & Plant) before implementation.

Similarly, where structures such as underbridges are affected by the scheme then any alteration to track position may need to be agreed by the responsible Network Rail Structures Engineer (or by the responsible Civil/Structures Engineer in the case of a bridge owned by a third party).

3 Plain Line Associated with S&C Renewal

Wherever S&C is to be renewed, between 10 metres and 40 metres of plain line should be renewed on each leg (length dependant on the track category). Ballast ramps should be installed in the plain-line sections to provide consistent track stiffness under the S&C.

4 Design of Layouts

Layouts should be designed to give consistent through alignment curvatures with a minimum number of steps in radii and avoid abrupt changes of cant deficiency.

When designing S&C layouts, the S&C should be kept clear (at least 200m) of embankments, viaducts, platforms, tunnels, vertical curves and at locations with a change of track stiffness wherever possible for ease of maintenance and to reduce the risk and consequence of train derailment. In addition, similar flexure switches with a turnout radius of 300m and below and a through route radius of 1000m and below are classed as high risk switches as they tend to experience high wear rates or uneven wear near the switch toe. Excessive wear at switch toes is the main cause of flange climb derailments at facing switches. For safety reasons, these switches should not be designed in. Standard layouts are preferred over complex layouts using slips and switch diamonds. Switch panels should preferably be separated by at least 20m. On higher category lines, individual leads should be separated by 80 metres of plain line to permit each lead to be tamped independently. On lower category lines 40 metres of plain line should be provided.

A.1.1: Track Layout Design (Continued)

When designing S&C for 'like-for-like' renewals, the designer should establish any inherent maintenance problems associated with the layout and, where practicable, design out the problems. Problems could include two-levelling designs which are difficult to design as well as maintain, persistent rail break/defect risk due to inherent high impact loading on higher speed sharp angled crossings etc. With a complex layout, the risk and serviceability of the layout should be assessed and the designer should consider spacing out the layout by extending the distance between individual leads as far as is reasonably practicable within the constraints of the existing signalling, geometry and OLE.

For notes relating to specific types of S&C unit, e.g. switch diamonds, see A.3.1.

A.1.2: Switch and Crossing Design Philosophy

Design of turnouts

By definition, a turnout is 'handed' left or right, the reference being to the direction of the 'turnout' line from the 'through' or 'main' line when looking from the switch toes towards the crossing. The creation of a track layout will define the hand of switches required, the turnout can then be designed by applying the various lead lengths of the standard elements. The hand of switches is always noted so that the 'set' of the stock rail is identified (in a LH turnout the LH stock-rail has a set).

In some instances where the through route is on a sharp curve the turnout may appear to be handed in the opposite direction. It is important that contra flexure and similar flexure turnouts are correctly identified and specified.

Measurement of lead lengths

See Sheet A.4.1

Basis of NR60 Series Geometry

Inclined NR60 geometry is identical to the earlier RT60 geometry. However, NR60 S&C uses components of a single *converged* design; whereas RT60 components varied between the S&C manufacturers. NR60 uses 60E2 rail profile, RT60 used CEN60E1 rail. CEN60E1A1 switch rail is used in both.

The NR60 series is a range of turnouts, crossovers and junctions incorporating principles of geometry which offer good ride quality while reducing impact forces. They have been optimised for mixed traffic including high speed tilting trains above 125mph.

The range of configurations is described in more detail on Sheets C.2.1, C.2.2, C.2.3 & C.2.4, and includes:-

- Transitioned turnouts - for turnouts, crossovers, and single and double junctions;
- Natural (and circular curve) turnouts - for turnouts and junctions where space is restricted or geometry dictates.

The main principles on which the range is based are as follows:-

- Switches have a clothoidal entry curve which minimises the angle of attack and consequently reduces lateral wheel impact forces.
- In the transitioned turnouts, a comfortable ride is assured by a clothoidal transition from the switch curve to the straight at the crossing; the crossing area is designed with straight alignment on all 4 legs - improving the ride through the crossover road.

Principles Adopted for Standard Turnout Configurations

1. Design maximum speeds are based upon useable increments in miles per hour (i.e. 25, 30, 35 mph etc.).
2. Maximum allowable cant deficiency values, as set out in NR/L2/TRK/2102 table 10 are used in the determination of switch radii and initial crossing angles.
3. Crossing angles are rounded up to the nearest $\frac{1}{4}$ of a whole number (e.g. 1 in 17, 1 in $17\frac{1}{4}$, 1 in $17\frac{1}{2}$ etc.).
However, many CEN56E1 and **all** NR60 crossing angles will be quoted as decimals (1 in 17.25, 1 in 17.5 etc.).
4. Based on the rounded-up crossing angle the final switch and turnout radii, transition and lead lengths, and general geometry are determined.

A.1.2: Switch and Crossing Design Philosophy (Continued)

General Parameters (NR/L2/TRK/2102 Table 5 to Table 11)

- Rails inclined at 1 in 20 and set at 1435mm nominal track gauge within fully welded layouts.
- Maximum allowable rate of change of cant deficiency values are set out in NR/L2/TRK/2102 table 11.
- The maximum rate of change of cant deficiency of 80mm/sec may only be applied between switch toe and the crossing IP.

A.1.3: Siting of S&C - 1

1 Straight through alignments

Wherever reasonably practicable (without major alterations which are incompatible with scheme scope), switches and crossings should always be positioned on straight through alignments on the 'main' route. There are several reasons for this:

- (i) the straight through alignment is easier to maintain and re-establish;
- (ii) the speed on the turnout or crossover on a curved main line will normally be reduced due to limiting cant or cant deficiency values;
- (iii) the switches and crossings will be standard; particularly, cast monoblock common crossings design, will also be off-the-shelf easily replaceable items, and in the NR60 transitioned turnout design, can be used left or right-handed. Standard crossings will be cheaper (easier to manufacture), and more readily obtainable;
- (iv) the absence of cant will assist in the correct seating of the rails and crossings onto the baseplates, and the correct fitting up of the switch drive mechanisms.

2 Curved through alignments (full curve)

Where it is unavoidable and necessary to locate S&C on curved through alignments, particular attention should be given to managing superelevation and in dealing with adverse or 'negative' cant on the turnout route, especially where tracks are tied together over through bearers. As a result the permissible speeds across the crossover or other layout will be significantly reduced from those available over a straight configuration (and as set out in the main tables within this document).

Particular should be paid to thoroughly investigating and checking the resulting speeds together with the rates of change of cant deficiency at each and every instantaneous change of radius. The requirement of through bearers will mean that the cant on both roads of a crossover would be the same.

3 Transitions

Switches and crossing layouts should not be located on through-alignment transition curves due to the complexity of the turnout geometry; and any necessary superelevation is likely to lead to track twists through the crossing area.

4 Vertical profile and alignment

S&C should not be located on vertical curves (either hogging or sagging) where the vertical curve radius is any sharper than 10 km. The consequences of doing so are to:

- (i) have crossings or switches not seated properly on their baseplates - this will exacerbate the breakage of baseplates and indeed rails;
- (ii) require every item to be pre-curved in the vertical plane, making them non-standard;
- (iii) make the switch detection difficult to achieve and maintain.

Individual items of S&C (turnouts, crossovers, etc.) shall be designed such that all bearers (sleepers) are at the same rake (regardless of any two-levelling of rails) throughout layout and 20 metres into any adjacent plain-line.

A.1.4: Siting of S&C - 2

1 Underline Structures

S&C should be positioned clear of any underbridge, viaduct or significant underline structure.

No rail joints, or discontinuity such as adjustment switches (other than structural expansion switches), should be permitted on or immediately adjacent to an underbridge.

Any deviation to the above shall have an appropriate Civil Engineer's design to take into account any lateral loading that would result from S&C or discontinuities being installed on top of the structure; and design acceptance. Any proposal to install new S&C on the bridge shall be approved by the Network Rail Route Asset Manager (Civil – Structures).

Any proposal to slew an alignment over an underline structure shall be approved by the Network Rail Route Asset Manager (Civil - Structure).

2 Over-line Structures

S&C should not be placed under, or immediately adjacent to, over-line structures.

In overhead electrification areas, the positioning of S&C either underneath or even close to an over-line structure can create problems (sometimes insurmountable) with wiring the layout.

3 Station Platforms

Occasionally there is a requirement to position a turnout within a platform. This might then require the shape of the platform edge to be altered to allow for the extra end throw of rolling stock negotiating the turnout. This can result in a large stepping distance into the train stopped across the turnout. Designs should optimise all aspects of any such scenario.

4 Overhead Line Equipment Considerations

The positioning of S&C is crucial as far as the relation to adjacent overhead masts is concerned. Sheets E.1.2 and E.1.3 give guidance on this point. However, when an existing crossover is being relayed, virtually like-for-like but in a new design of material, then the overall length of the crossover may well change by a small degree. To obtain the minimum disruption to the overhead catenary design, the new crossover should be spread equally around the centre-line of the previous crossover; i.e. do *not* keep one switch in its existing position and let the other move by the difference in overall length

A.2.1: Design Considerations - Speeds Through S&C

1 Determination of Speeds through S&C

The design speeds for turnouts and through any part of an S&C layout are determined for the centre-line radii of the tracks involved. This is considered to represent the path and curvatures experienced by vehicles - and passengers within them.

NB NR60 S&C speed values quoted throughout this document are for fully welded layouts on concrete bearers.

2 Speeds through Turnouts

When travelling over a turnout on the 'main' or through line, there will be no separate speed restriction, but when passing over the turnout on the 'branch' line, it is normal to expect a reduced speed restriction (for description, see Sheet A.1.2). Turnouts are designed to give specific maximum speeds from a straight main line; these speeds are limited by the maximum permitted cant deficiency and the maximum permitted rate of change of cant deficiency.

All turnout speeds should be recalculated when the main line is curved and/or canted (positively or negatively) - see paragraph 6. NR60 switch radii are tighter than CEN56E1 vertical equivalents, and in heavy use rapid side wear can result if high volumes of traffic, or concentrated heavy axle loads, can be expected on the turnout road. Consideration should always be given to providing a longer switch than that required for the operational speed in order to minimise wear and therefore maintenance intervention..

3 Speeds through Crossovers

Running line (a line shown as such in Appendix A of the relevant Sectional Appendix), timetabled-use crossovers should normally be designed using transitioned turnouts - this will give a smoother ride through the complete crossover, and give smaller lateral forces on the common crossing, giving longer life.

As in turnouts above, the permissible speed should be reassessed when the main lines are curved and/or canted. When curving crossovers turnout alignments may be improved by having a transitioned turnout on the similar flexure leg and a circular turnout on the contra-flexure leg.

4 Choice of Speed for Turnouts and Crossovers

The line speed in the vicinity of the S&C has a relevance if certain signalling restrictions are to be avoided.

'Approach Control', detailed in Group Standards allows there to be no signalling restriction to the branch line turnout/crossover provided the difference in speeds between the main line and the branch is 10 mph or less. For example, on a 90 mph main line, an 80 mph turnout would not need a signalled restriction of speed, whereas a 75 mph turnout would. This means the route required would not be cleared until the train had slowed to a particular speed at a specific position in advance of the junction. The non-provision of a signalled restriction of speed can be a significant factor in the time taken for trains to perform crossing movements, say from fast to slow lines. Ideally the crossover speed would need to be equal to, or at the most only 10 mph less than, the main line permitted speed.

5 Speeds through Junctions

The permissible speed through any form of junction work will be determined by the switch length cant, cant deficiency and the rates of change of cant and cant deficiency.

At each instantaneous change of radius, the rate of change of cant deficiency shall be checked using the formulae on Sheet A.7.1.

A.2.1: Design Considerations - Speeds Through S&C (Continued)

6 Curved Main Lines

Where any curve is present, all maximum permissible values of cant, cant deficiency, and rates of change of both, shall not be exceeded, and each value shall be individually checked. When a resultant figure for the speed is produced, this then shall be rounded down to the nearest 5 mph (e.g. 39.4 mph would need to become 35 mph). The figure shall not be rounded up, as this will result in the maximum permissible figures being exceeded.

A.3.1: Types of S&C Unit - 1

1 Turnouts

Standard length stock rail 'fronts' should be used in wherever possible. These are:

2745mm to the mathematical toe position or Mathematical Point (2670mm to the Switch Toe or Real Point or switch rail end) for NR60 switches.

3070mm to the Switch Toe position (2905mm to the physical toe extension) for Shallow Depth Vertical switches.

3070mm to the Switch Toe position for Full Depth Vertical switches.

Note: design lead lengths are quoted as Mathematical Point – IP for NR60 leads and Switch Toe – Nose for all other leads. Toe-Toe dimensions are quoted as Switch Toe and not Mathematical point for NR60 switches.

2 Crossovers

Transitioned crossovers should be used for all straight running line crossovers. For follow-on crossovers, and the permissible speeds through them, see Sheet Nos. A.7.3 & A.7.4.

3 Fixed Obtuse Crossings

The use of fixed obtuse crossings is generally *discouraged* as they involve the use of relatively short lengths of rail, which of course should be welded if at all possible. Fixed diamonds also tend to employ sharper check entry flares, although designs are now developed for cast manganese obtuse crossings with bolted on long flare checks. There is a prohibition on their use where the maximum speed is 110mph or greater (see NR/L2/TRK/2102). Their use is also governed by limiting track radii through the obtuse crossings.

4 Diamond Crossing Geometry

Based upon a **straight** through alignment of the 'main' route, by examination of the fine geometry the two obtuse crossings which form the diamond cannot be of exactly the same angle if either track is curved.

While previously this has been dealt with by assuming that both crossings have identical angles this approach is incompatible with CAD-based design processes. Therefore the new convention is that whole diamond configuration will be considered as having the exact angle (e.g. 1 in 8.25) obtained at the intersection of the two track centre-lines. This will produce the correct track radii, but results in minor difference in the two actual crossing angles (usually in the second decimal place of the 1 in N number).

These individual and exact differing angles should be used to calculate the lead lengths. For practical manufacturing purposes the minor variation in angle will not normally be significant within the normal range of angles used and can be ignored. For example, a 1 in 4.53 and a 1 in 4.47 crossing would both be made as 1 in 4.5.

However, for angles sharper than about 1 in 3, the geometry of the individual crossings shall be determined and manufactured.

For **curved** through alignments of the 'main' route determine the geometry appropriate lead lengths and radii from 'first principles', using the centres of the circles and basic geometrical formulae.

It is not sufficiently accurate, for example, to use the 'standard' lead lengths and centre-line radii (adjusted for equivalent radius) produced by the tables on Sheet Nos C.1.7 & C.2.7.

A.3.1: Types of S&C Unit – 1 (Continued)

5 Switch Diamonds

The use of switch diamonds in layouts is also discouraged, for a number of reasons. From the physical design of a switch diamond, it is very difficult technically to restrain relative longitudinal movement between the switch and wing rails in the hot weather situation, and because of this phenomenon, adjustment switches (with their additional maintenance liability) are often placed on all four legs of the diamond to help alleviate the problem. Special strengthening by 'back' rails and blocks also assists, but the maintenance of exact track gauge at the knuckle becomes difficult due to the overturning tendency of the head of the wing rail with higher temperature. The use of high manganese common crossings in the diamond (the current norm) with their attendant greater expansion coefficient only serves to exacerbate the problem. There are two principal sites where switch diamonds are commonly used:.

- (i) 3-line crossovers (turnout/diamond/turnout), where the alternative provision of two follow-on crossovers with sufficient space between them should always be investigated and encouraged.
- (ii) double junctions, where the alternative layout would be a turnout, and a crossover followed by a turnout. Where switch diamonds are used they are to be of the Full Depth Vertical design.

A.3.2: Types of S&C Unit - 2

1 Double Junctions

As far as possible, the junctions shown on Sheet Nos C.1.9 & C.2.6 should be used, as these have been designed to give as near as possible constant radii right through the junction, so resulting in constant cant deficiency.

The possible splitting up of the double junction into a turnout, a crossover, and a further turnout, to eliminate the diamond, should be investigated and encouraged. Attention should be given to maintaining the required six-foot spacing/passing clearances right round the junction, bearing in mind all potential/possible types of rolling stock likely to use the lines.

This is achieved by staggering the relative positions of the two sets of switches, normally by a minimum of two bearer spacings.

2 Tandem Turnouts

Tandems, where one turnout is interlaced in the same direction with a second turnout, (see diagrams on Sheet C.1.10), should not be used in main running lines due to the fact that it is not possible to strengthen them for CWR, or indeed to weld them up. Their use in terminal station track layouts is accepted where space is of a premium, or in sidings or depots.

Tandem turnouts are not available in NR60.

3 Scissors Crossovers

Wherever possible, scissors crossovers should be positioned on straight parallel tracks, to facilitate the use of standard cast manganese crossings. Current designs are based on a 1970mm six-foot spacing.

4 Single and Double Slips

Single and double slips are not available in NR60.

A.3.3: Rail Joints, Bearers and Checking Arrangements in S&C

1 Joints/Welds

The inherent SD value, and maintenance intervention period, in S&C can be reduced by the elimination of bolted rail joints and it is beneficial to weld up the complete layout. It is desirable to complete the welding of the new layout before trains run. Where temporary back-hole fished joints are used prior to welding, there is an increased risk of the track gaining a ballast memory in as little as 2 or 3 days, as the position of the joint is not completely lost after welding, and eventual deterioration in the track bed can result.

The need for insulated joints is accepted, and their positioning should be in accord with Sheet C.1.10; the avoidance of positioning insulated joints directly on the switch fronts should be considered a priority.

Six-hole insulated joints should be used wherever practicable.

2 Bearers

Bearers are normally concrete, although hardwood or steel may be specified. The standard bearer spacing is 650mm between centre-lines in NR60 and generally 710mm in Vertical S&C. (see REPW drawings for dimensions).

The overall construction depth from rail head to underside of bearer shall remain constant throughout an S&C layout that is not subject to two-levelling.

The longest concrete bearers are nominally 8500mm; requirements for longer lengths may be satisfied by 'tying' two shorter bearers together by an approved method.

3 Checking Arrangements

Check rails in S&C have been standardised. The designs for NR60 are now in four separate speed bands, and each end of a check rail should be considered separately, such that if a particular check is used at speed in one direction only, then the trailing end would have shorter flare.

Bi-directional lines shall have the same flare at both ends of the check rail.

For **NR60** Inclined S&C the nominal check rail gauge is 1394mm (+3/-0); this is the main controlling dimension for check flange-ways within S&C. With a nominal track gauge of 1435mm through the S&C this gives a flange-way width of 41mm (+3/-0) in both the crossing wing rails **and** the cover check rails.

Full details of checking arrangements are shown on Sheet E.8.5, but the above principles should be kept in mind.

In **Vertical** S&C the nominal check rail gauge is 1391mm (+3/-0); since the nominal track gauge through the S&C is 1432mm, the resultant flange-way width is 41mm (+3/-0) in both the crossing wing rails **and** the cover check rails. Details of check rail lengths and positions are shown on Sheets E.8.1 and E.8.3.

In curves sharper than 200m radius where continuous check-rails are required, they should extend 20m beyond the <200m radius curve into the next geometrical element to enable the bogie wheel sets to be properly aligned when joining or leaving the checked portion.

Continuous check rails should be lubricated.