

# TRACKWORK... *doing it right*

A clinic by Rich Kolm • 2006 PCR Convention "River City Express" in Sacramento

## INTRODUCTION

Whether you are new to model railroading or have been around for a while, this quick review of **trackwork design and construction** should give you some useful ideas and insights. It covers the things that are important for reliable, trouble-free operation of trains while creating a more-realistic appearance. The purpose is enjoyment of this great hobby.

Dimensions are given for HO scale, but the information applies to the other scales as well. Track planning handbooks and the NMRA standards and recommended practices cover all the popular scales. The mention of proprietary products and specific publications is only for information and does not represent any endorsement.

Information regarding trackwork design and construction is on the Internet and experience with trackwork design and construction is shared at various online discussion groups.

### **Reliable operation is many things**

- **Trackwork**, even when carefully designed and properly constructed, is only one of the things that can affect reliable, trouble-free operation of trains. The other important things (not covered in this clinic) include the following:

- **Equipment**. Locomotives must be mechanically in good working order; passenger and freight cars should be of optimum weight based on standard formulas; wheels must be true and properly gauged; truck-mounting screws must be adjusted for good tracking without car wobble; and couplers should be installed at the correct height and working properly.

- **Electrical**. Provide enough electrical connections to the track to assure no loss of power; feed the rails from electrical buss wires under the layout, especially with DCC; don't depend on rail joiners for electrical connections; turnouts should not have any electrical breaks nor potential for short circuits; track has to be kept clean; and good electrical pickup on locomotives is a must. If your control system is DCC, turnouts that are DCC friendly are an advantage.

- **Maintenance**. Track and turnouts should be checked for proper gage and flangeway widths, especially at switch points, frogs, and guard rails; be sure rail joints are smooth and aligned; mounting of trucks and couplers on cars and locomotives must be periodically checked and readjusted if necessary; and the wheels of locomotives and cars should be kept clean.

## TRACKWORK DESIGN

### Curves

Just as with real railroads, there are several factors that have to be considered in laying out curves: **minimum radius, spiral curves, superelevation, and s-curves**.

- **Minimum Radius**. If prototypical radii were used for a model railroad, the space required would be tremendous. In HO scale, the minimum radii would be:

Mainlines	130"
Mainlines in mountains	100"
Branch lines	70"
Sidings and yards	50"

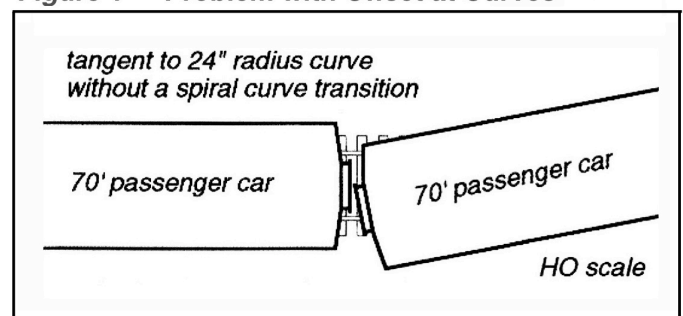
Obviously, there has to be a compromise. Larger radii would be closer to the prototypical dimensions, would give a realistic appearance, and would provide smooth operation. For example, in HO scale a radius of 48" or larger would be ideal. However, we have to use smaller radii to accommodate the limited space confronting most layouts. The following criteria apply in HO scale:

Preferred minimum radius	32"
Conventional radius	24"
Sharp curve radius	18"

- **Spiral Easements**. A train making the sudden change from a tangent (straight track) to a curve (fixed radius) looks unrealistic. The locomotive may lurch, especially steam. The ends of longer passenger and freight cars will have a significant lateral offset, as shown in Figure 1. This is especially true with the smaller radii curves we use on model railroads. Wheels may not track smoothly and car-mounted couplers can be significantly misaligned, causing derailment.

Train operation will look more realistic and will be smoother by creating a spiral easement — a curve of gradually

Figure 1 • Problem with Offset at Curves



## Curves, continued

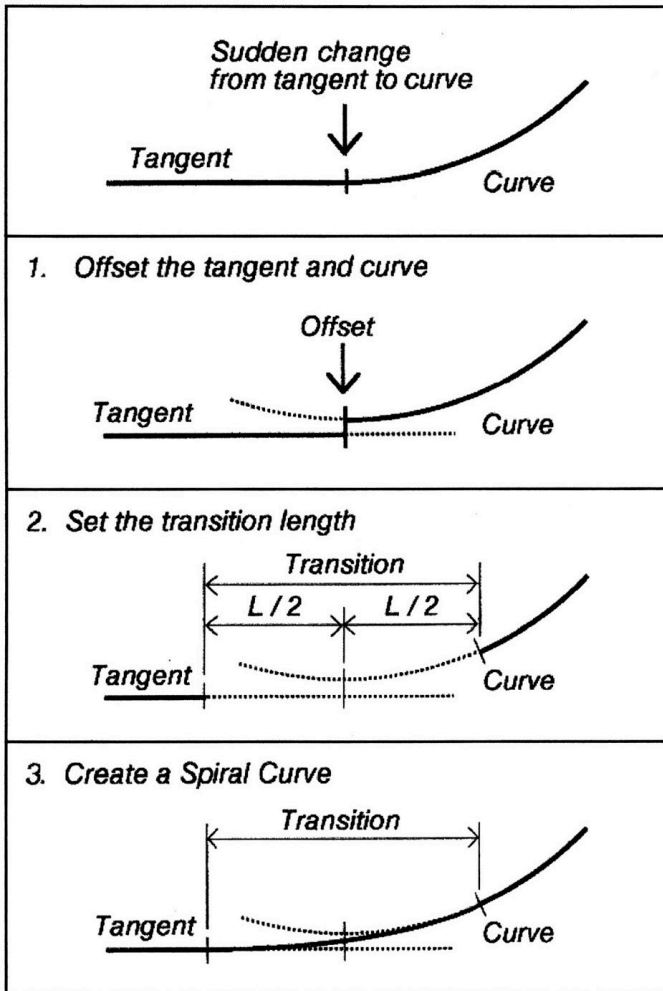
diminishing radius connecting the tangent (straight track) with the curve (fixed radius). NMRA Data Sheet D3c describes several ways of doing it — cubic spiral calculation (the prototype approach), tangent method, bent-stick method, and three-segment template method.

The bent-stick method is very simple, with the steps shown in Figure 2. Working with track centerlines, first offset the fixed-radius curve from the tangent and establish the transition length. Tack one end of the stick along the tangent and then bend the stick to match the fixed radius of the curve at the end of the transition length. The track centerline can then be drawn along the stick.

Spiral Easement Dimensions in HO Scale

Radius of Curve	Transition Length	Offset Distance
18"	12"	3/8"
24"	16"	7/16"
32"	20"	1/2"

Figure 2 • Creating a Spiral Curve



• **Superelevation.** You probably have observed the visual effect of superelevation or banking of curves on real railroads. The locomotive and train lean to the inside of the curve because the outer rail is raised higher than the inner rail to counteract the tendency of a train to overturn outward, especially at higher speeds. The prototype superelevation may be as much as 6" (0.069" for HO scale) but is usually less.

Superelevation is usually not important to the operation of model trains. However, it does add a lot to the realistic appearance of a train rounding a curve. The suggested superelevation is 0.030" in HO scale (about 1/32"), which seems small but is visually effective.

The subgrade and roadbed are installed with a level cross-section. Then the outside rail of the track can be raised with 1/32" wood strips or 0.030" styrene strips glued onto the roadbed under the ties. Flex track is also available with built-in superelevation. If the track subgrade is on risers, the tops of the risers can be cut or set at the appropriate very small angle, but this is difficult to control.

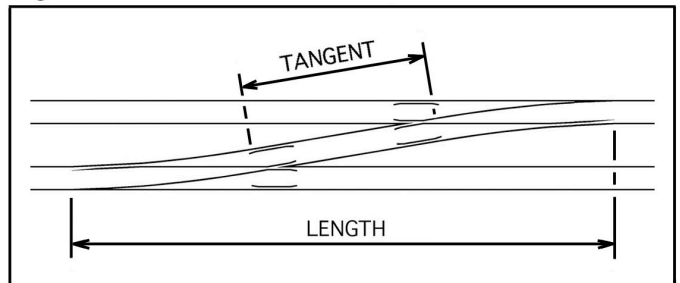
A gradual transition is required from no superelevation on the tangent to full superelevation on the curve. The location of this transition is the same as a spiral easement transition (see Figure 2).

• **S-Curves.** The problem of car ends being offset where the track changes from tangent to curve (Figure 1) can be compounded by an S-curve, particularly when the tangent (straight track) between the two curves is very short. It can also be a problem for longer wheelbase steam locomotives.

S-curves with very short tangents should be avoided in the design of trackwork, particularly with sharper curves. Ideally, the tangent should be at least as long as the longest freight or passenger car.

A crossover between two parallel tracks, as shown in Figure 3, is a tight S-curve that cannot be avoided. However, the tangent length between frogs can be increased for smoother train operation by using longer turnouts with a smaller frog angle and a larger closure radius. For example, with a #6 crossover the tangent is 5.7" which is increased to 7.4" with #8 turnouts. But at the same time, the space required—the length of the crossover in Figure 3—increases from 16.2" for #6 to 23.2" for #8.

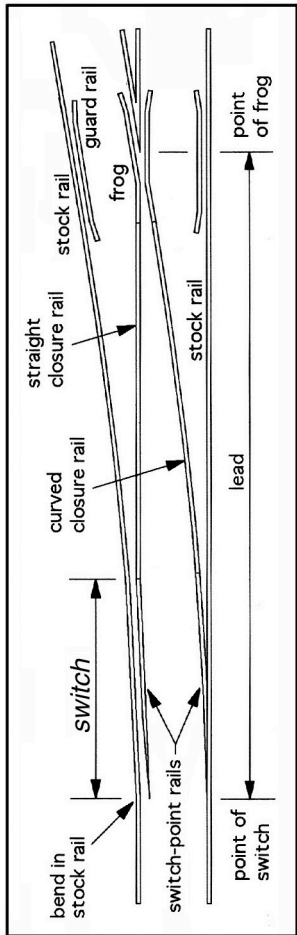
Figure 3 • S-Curve – Crossover



## Turnouts

When is a turnout a switch? “**Turnout**” is the term used in the railroad industry for the trackwork device that allows flanged wheels to move from one track to another. People operating the railroads refer to the “**switch**,” which is only the moveable switch-point rails—the route is changed by throwing the “switch”.

**Figure 4 • Turnout**



turnouts sometimes make the lead length shorter and thus the closure radius smaller than these standard dimensions.

Turnout Number	Lead Length	Frog Angle	Closure Radius
#4	5.06"	14° 15'	15"
#5	5.69"	11° 25'	26"
#6	6.25"	9° 32'	43"
#7	8.44"	8° 10'	49"
#8	9.00"	7° 09'	67"
#10	9.56"	5° 43'	117"
#12	10.06"	4° 46'	151"

Moveable switch point rails in the North American prototype are most-often fabricated with straight rails on both legs of the turnout. On the curved leg the switch point rail makes an angle of about 1° or 2° when the point is against the

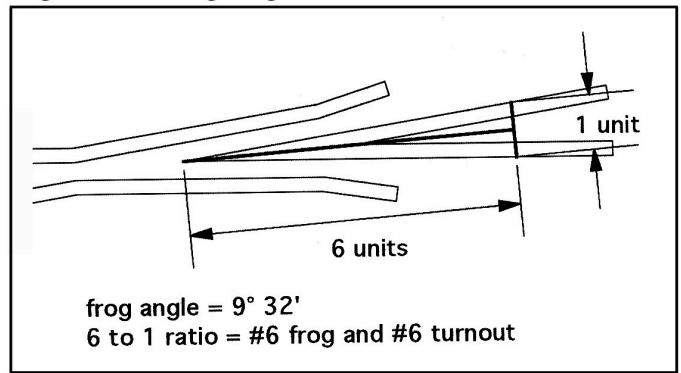
• **Size (number).** The size of a turnout is represented by a number (#4, #6, etc) which is determined by the angle at which the rails cross at the frog. How that number relates to the frog angle is shown in Figure 5.

• **Closure radius** is the centerline radius of the middle part of the curved leg between the switch point rail and the frog. The maximum possible closure radius for a given frog angle is a matter of geometry. It is an important consideration in the design of trackwork and ideally should not be less than the minimum radius your rolling stock will easily take.

• **Lead** is the length from the point of the frog to the point-end of the switch point rails (Figure 4).

• **NMRA dimensions.** The data in the table below are for HO scale based on the standard dimensions in NMRA RP-12.3. Manufacturers of model railroad

**Figure 5 • Frog Angle and Number**



straight stock rail, which is a sudden change for wheels. Model turnouts may have a slightly curved switch point rail on the curved leg because the turnouts are small compared to the prototype. Both rails are straight going through the frog.

• **Selecting turnouts** and their sizes to use on a model railroad takes into account a number of factors:

- era being modeled – what rail size and design?
- type of railroad – main line or branch line?
- appearance of trackwork – does it have the quality to look like the prototype?
- reliable train operation – does it properly fit the track configuration and the size of rolling stock?
- space available – what are the layout limitations?

Some prefabricated turnouts may not be “DCC friendly” (see Figure 17). This is not required, but does assure more-reliable operation of trains. It avoids momentary electrical shorts caused by metal wheels not tracking properly and assures a continuous power feed and control signal to locomotives. For more information see the websites listed on page 1.

• **Space Limitations.** The selection of turnouts for different layout situations is usually a compromise in model railroading because most layouts have limited space.

Comparison	Main Line	Yards
prototype turnout	#10 to #20	#8 or longer
typical model railroad	#6 to #8	#4 to #8

Longer turnouts (larger number) are more prototypical, have a more realistic appearance, and provide smoother operation on the curved leg. On the other hand, shorter turnouts (smaller number) can better utilize limited space and may be acceptable for operation of shorter engines and cars. Wye and curved turnouts and double-slip switches can be used to optimize the use of layout space, but on the prototype are usually used only where train speeds are slower such as in yard areas. Prefabricated turnouts may not always fit into the desired trackwork configuration; however, scratch-built turnouts can be crafted to provide exactly what’s needed.

## Turnouts, continued

• **Minimum size turnouts.** Considering appearance and reliable train operation, the *minimum* size turnouts for a model railroad are recommended as follows. Use longer turnouts if space permits.

main line crossovers	#8
main line sidings	#8
branch lines (shorter cars and engines)	#6
yards for 70'-85' cars	#8
yards for 40'-70' cars	#6
yards for shorter freight cars	#5
industrial sidings in tight places	#4

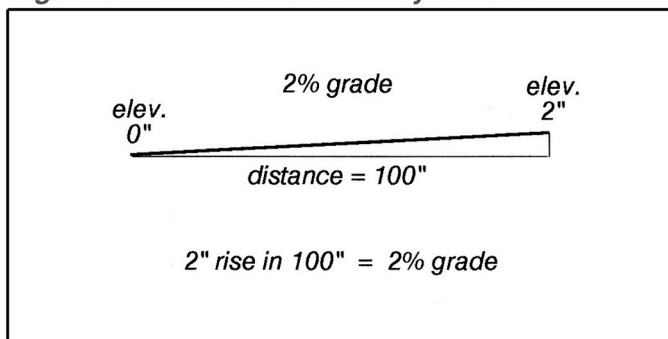
• **Location.** When designing a layout, the location of turnouts is very important for reliable and smooth operation and realistic appearance. Carefully determine and draw the configuration of track and turnouts on paper before building any trackwork. Be sure curved and tangent tracks will be properly aligned with each turnout. As with the prototype, the main line should be on the straight leg of a turnout whenever possible. Select and locate turnouts to avoid or minimize the effects of tight S-curves. Allow ample space in the layout plan for longer turnouts where needed. Trackwork design must also consider the space required under or next to a turnout for installation of the switch machine or other switch-throwing device.

• **Access.** Be sure to provide convenient access to turnouts and their switch-throwing devices for routine maintenance, occasional repairs, and future replacement. Don't bury them under non-removeable scenery and try to avoid tight areas directly under other trackwork.

## Grades

• **Layout Need.** Grades are usually required when designing a railroad. They are needed in hilly or mountainous terrain on the prototype being modeled, and to move trains between different levels of a model railroad where space is limited. We measure grades by percent, as shown in Figure 6.

Figure 6 • Grades Measured by Percent

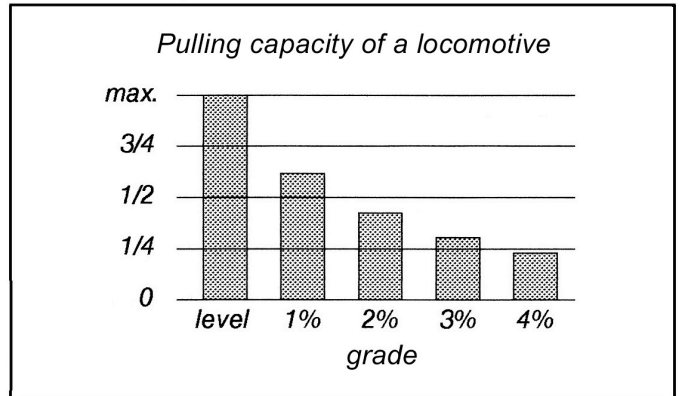


• **Operation.** The type of model railroad operation planned will determine the maximum grade:

Ideal maximum grade	1" in 100" or 1%
Main line maximum grade	2" in 100" or 2%
Branch line maximum grade	3" in 100" or 3%
Unusually steep grade	4" in 100" or 4%

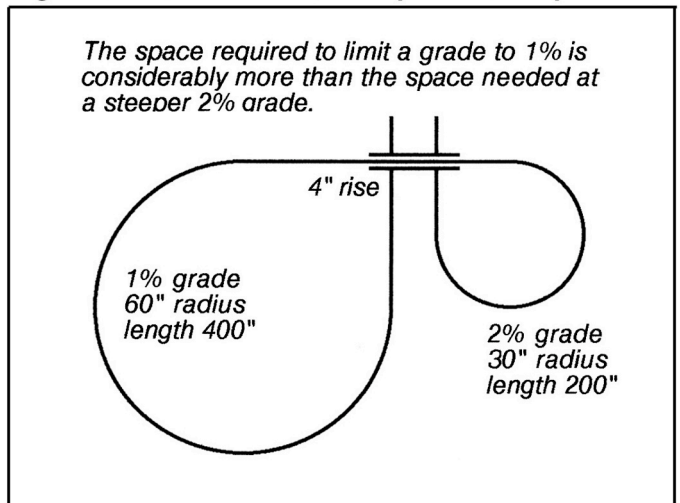
• **Limitations.** Steeper grades significantly reduce the pulling capacity of a locomotive, as illustrated in Figure 7.

Figure 7 • Operation on Grades



Another limitation is the space available on the layout for the length of track necessary to make a needed elevation change, as illustrated in Figure 8.

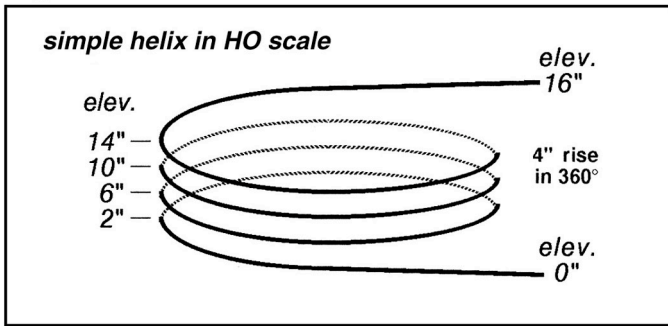
Figure 8 • Gentle Grades Require More Space



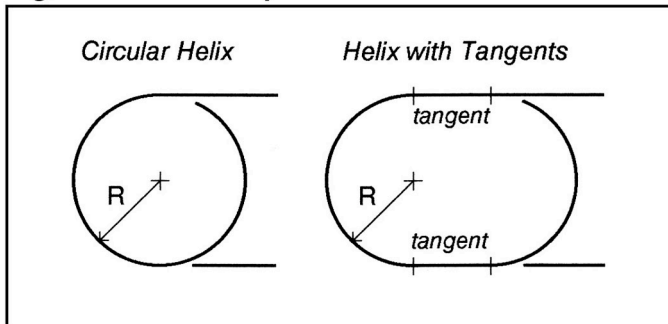
• **Helices.** A helix is a long grade wrapped into a relatively small space to achieve a significant change in elevation, as shown in Figure 9. It can be used to move trains between levels of a multilevel layout or to access hidden staging tracks at lower levels under the layout. Critical factors for train operation are the radius of curve, the grade, and vertical clearance between loops. A helix may be circular or a combination of curves and tangents, as shown in Figure 10.

**Grades, continued**

**Figure 9 • What is a Helix?**



**Figure 10 • Helix Options**

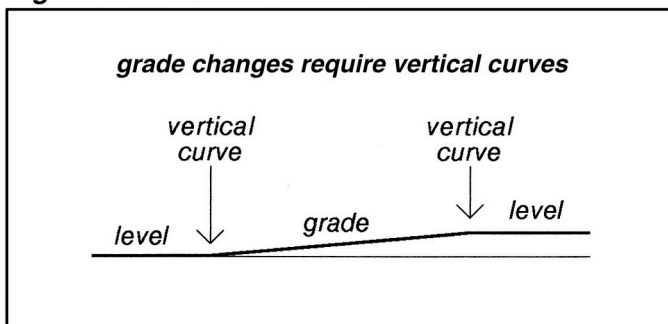


Examples of the effect of radius and tangent lengths on the grade of a helix are given in the following table, assuming for HO scale a 4" change in elevation for each 360° loop:

Radius of Curve	Circular Helix	Add 10" Tangents	Add 30" Tangents
28"	2.3%	2.0%	1.7%
32"	2.0%	1.8%	1.5%
36"	1.8%	1.6%	1.4%

• **Vertical Curves.** Where the grade changes, a vertical curve is needed for a gradual change as shown in Figure 11. A sudden change in grade could cause cars to uncouple or the pilot of a locomotive to drag on the track. In the prototype the radius of the vertical curve is calculated, but in the model we simply put a gradual bend in the roadbed or subgrade.

**Figure 11 • Vertical Curves**



**Clearances**

The last element of trackwork design is clearance around and above the track, and between parallel tracks.

A valuable tool for checking standard clearances is the NMRA Standards Gage, which is available in different scales (see Figure 15).

The traditional vertical clearance in HO scale is 3" above the top of rail. This effectively means a rail-to-rail vertical dimension of approximately 4" when one track crosses above another, allowing for the thickness of the subgrade or bridge structure supporting the upper track. The 4" dimension can be reduced if you are sure your locomotives and cars can tolerate less vertical clearance or if the subgrade supporting the upper track is reduced in thickness where the tracks cross.

A note of caution, though, if you model contemporary trains—some of the very large freight cars and tall passenger cars may require more clearance than determined by the NMRA Standards Gage.

Parallel tracks are set by centerline to centerline spacing. On the Southern Pacific, 14 feet was a common track spacing on tangents (straight track). This would be 1.93" in HO scale, and we use 2" as a standard. The spacing has to be increased at curves because of the overhang of long passenger and freight cars and long locomotives. The recommended minimum track spacing in HO scale is:

mainline tangents	2"
curves 18" radius	2-3/8"
24" radius	2-1/4"
32" radius	2-1/8"
yards (finger space)	2-1/4"

Present-day railroads with heavy traffic main lines tend to use wider spacing of tracks to safely facilitate maintenance and repair work.

**TRACKWORK CONSTRUCTION**

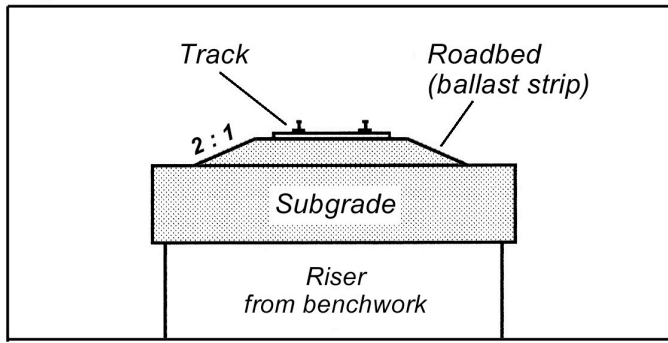
Ideally, trackwork should be easy to construct with readily available materials at a reasonable cost. The design has to accommodate the type of track and turnouts being installed. Trackwork should provide stability and a basis for realistic appearance and reliable operation.

In some parts of the country the seasonal effects of temperature and humidity on wood and other materials can be a problem and must be considered.

The basic elements of trackwork are shown in Figure 12. There are many different ways of constructing subgrade and roadbed, some of which are illustrated in Figures 16a through 16f. (Note that the benchwork necessary to support the trackwork is not part of this clinic.)

## Trackwork Construction, continued

**Figure 12 • Basic elements of trackwork**



• **Subgrade (sub-roadbed).** This provides the structural support and the alignment and grade for the trackwork. It is sometimes called sub-roadbed. It can be a broad table top or a narrower continuous support constructed on risers extending above the benchwork, providing a firm support for the roadbed and track. It should be designed to help limit the transfer of train noise. Available subgrade materials include:

- plywood – sheet or cut-outs
- boards – “1x”, 3/4” thick
- hardboard – flat, laminated
- spline – wood or hardboard, spaced with blocks
- spline – wood or hardboard, laminated
- spline – homasote, laminated (messy to cut)
- blue foam board (extruded Styrofoam)
- white foam terrain (manufactured components)
- homasote or celotex sheet on top of plywood, boards, or spaced spline

• **Roadbed.** This is the base for track and ballast. Roadbed should be uniform and smooth, facilitate track laying, and provide a realistic cross-section for ballast. Most commercially available HO scale roadbeds have 1:1 (45°) side slopes for the ballast shape, which should be flatter 2:1 slopes for prototypical appearance (see Fig. 12). Limiting the transfer of noise is a consideration in selecting roadbed material. If track is spiked down, the roadbed should be dense enough to hold spikes well, like soft wood or homasote, but not so hard that spikes are difficult to drive. Available roadbed materials include:

- |                        |                             |
|------------------------|-----------------------------|
| – cork                 | many different suppliers    |
| – homasote             | HomaBed, Calif. Roadbed Co. |
| – flexible foam        | Woodland Scenics            |
| – uncured butyl rubber | AMI Instant Roadbed         |
| – upson board          | Ribbonrail                  |
| – vinyl                | Vinylbed, Hobby Innovations |
| – wood                 | Tru-Scale Models            |

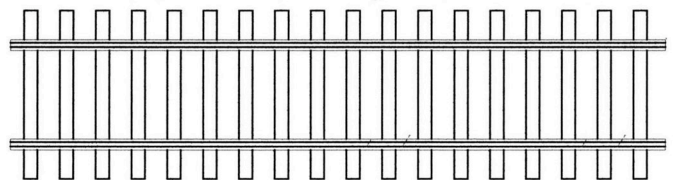
• **Track.** Track may be prefabricated (flexible track) or separate ties and rails (hand-laid track). Size of rail is a prime consideration (Figure 13). In HO scale, code 100 rail has been in common use for many years, but it represents a very heavy prototype rail which is oversize for most model railroads. In recent years the smaller code 83 rail has become very popular because it provides a more realistic appearance, even though it still represents a fairly heavy prototype rail. It works well with the RP-25 wheel flanges provided by manufacturers of locomotives and cars. Code 70 and Code 55 rail represent the lighter rail of earlier eras and in yards, and on branch lines, sidings, and narrow gauge railroads. With these smaller rails, more attention has to be paid to the size of wheel flanges and spikes to avoid interference. Code 75 rail is one of the sizes used by track manufacturer Peco.

**Figure 13 • Rail Sizes**

rail cross sections are shown larger than actual size					
code	100	83	75	70	55
height	0.100"	0.083"	0.075"	0.070"	0.055"
prototype weight per yard in HO scale	152#	140#	120#	100#	70#

Along with Code 83 rail, the manufacturers of prefabricated track improved the size and spacing of ties to look more realistic. The ties with Code 100 rail are oversized and spaced too far apart, being a scale 11” wide and spaced about 25” on center. Ties with Code 83 rail are a scale 8” wide and spaced 20” to 22” on center (depending on the track manufacturer), which is much closer to the prototype (see Figure 14). Prototype dimensions of ties vary with the era, type of track, and railroad. Present-day main line railroads use ties that are longer and may be concrete instead of wood.

• **Tracklaying.** Your layout has been designed, the benchwork has been built, the risers, subgrade, and roadbed are in place, and the last step in trackwork construction is to lay the track. It may be spiked, nailed, glued, or attached with an adhesive, depending on your preference and governed by the type of roadbed you are using.



## Trackwork Construction, continued

### Track and turnout installation should be done in the following sequence:

- carefully mark track and turnout locations and spiral easements, usually with centerlines
- install the turnouts first
- then fit the track to the turnouts

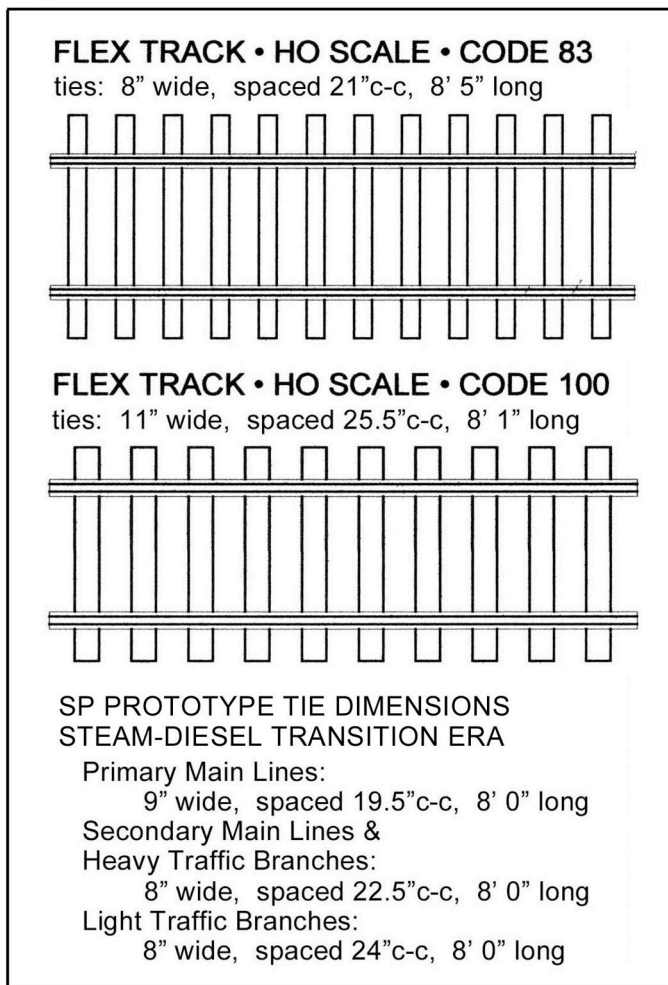
### In the process, pay attention to the following:

- using NMRA gage, check turnouts for gauge, flangeways, and switch-point spread and gauge
- provide small gaps at rail joints to allow for temperature expansion
- stagger the rail joints so that wheels on a common axle are not hitting joints at the same time

### Visually check the alignment of track and turnouts as they are being installed:

- get your eye down close and sight along the track
- do rail joints line up properly?
- are the tangents really straight?
- are the curves smooth?

**Fig. 14 • Tie dimensions of flex track**



### Other things to remember:

- if using track nails, don't push them in too tight because track gauge may be narrowed
- carefully place glue and ballast around switch points and throw rods
- stock rails adjacent to the switch points need extra spiking if the switch throwing device is forceful
- install wired connections from track power busses under the layout to every section of track

## NMRA STANDARDS AND RECOMMENDED PRACTICES

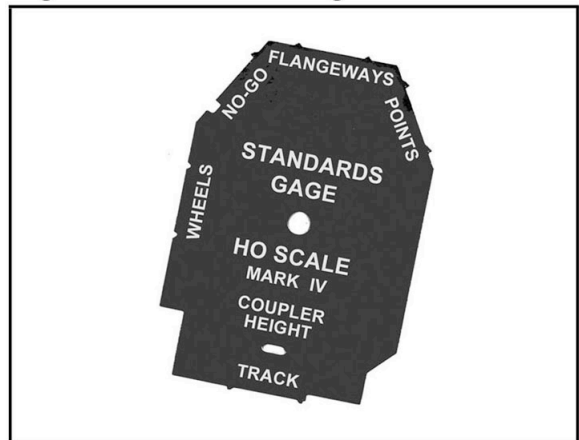
NMRA Standards were introduced in 1936 as the primary basis for interchange of model railroad equipment. Standards S-1, S-2, S-3, and S-4 provide the required dimensions for track gauge, track and wheel relationships, gage and clearances at frogs and switch-points, and wheel tires and flanges. They were updated in the 1980s and are being updated again this year. New Standards 9.1 and 9.2 were established for DCC in 1994.

NMRA Recommended Practices (RPs) have been around since 1957 to supplement the Standards. Details and additional dimensions for turnouts are covered by the RP-12 series for different scales and the RP-13 series for the various parts of frogs and guard rails. RP-25 specifies the well-known standard wheel contour designed with a tradeoff between optimum track holding ability and appearance. The DCC standards are supplemented by the RP-9 series.

The NMRA Standards Gage (Figure 15) is essential for checking trackwork, especially turnouts. RP-2 describes how to use the gage.

NMRA Standards and Practices can be purchased from the NMRA or can be viewed and printed from NMRA's website at <http://www.nmra.org>. The Standards Gage is also available from the NMRA and in many local hobby shops.

**Figure 15 • NMRA Gage**



## Different ways of constructing trackwork

Figure 16a

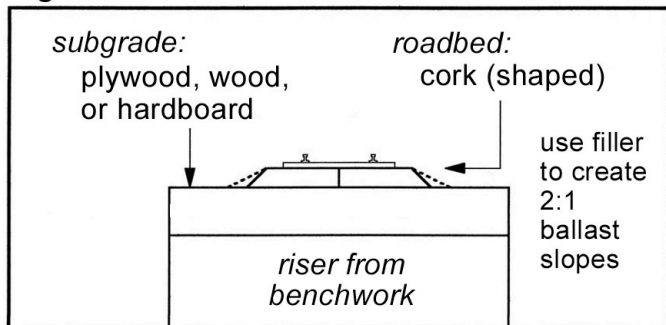


Figure 16b

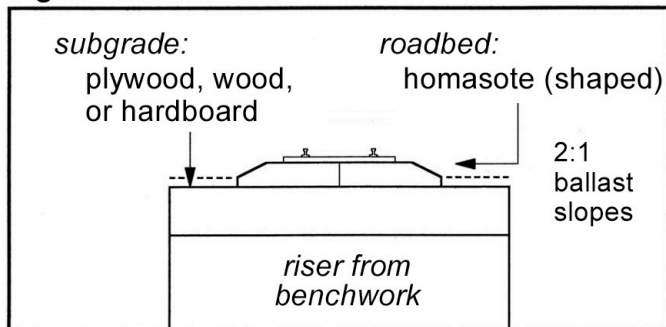


Figure 16c

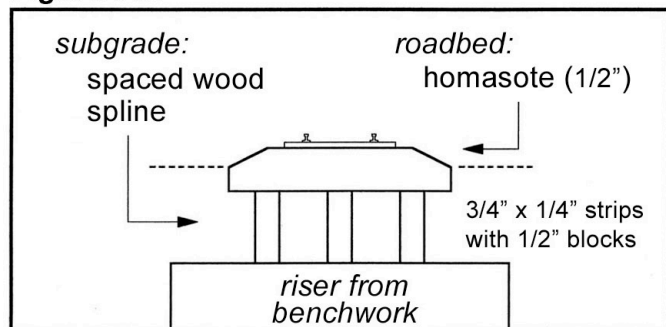


Figure 16d

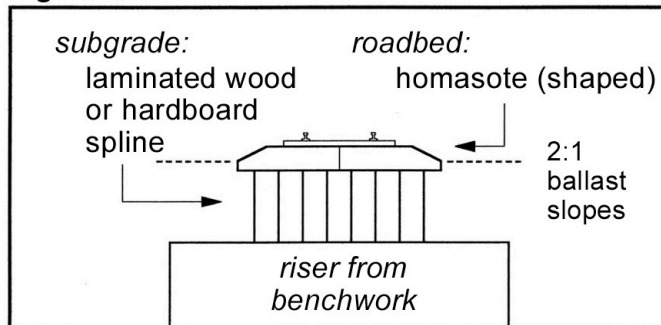


Figure 16e

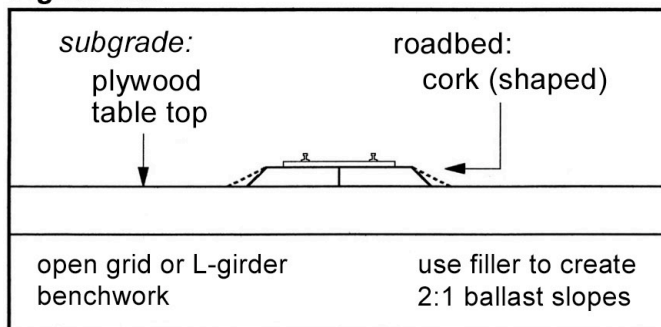
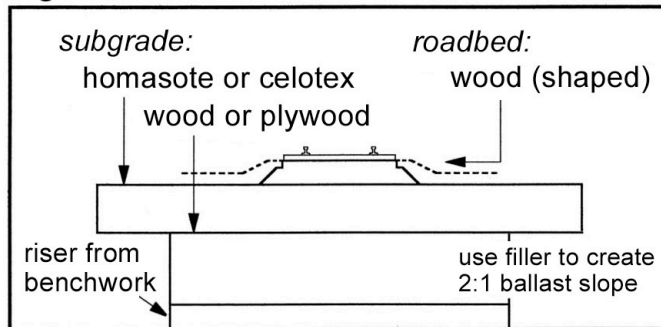


Figure 16f



## REFERENCES

- Magazines such as *Model Railroader*, *Railroad Model Craftsman*, *Narrow Gauge & Shortline Gazette*, *Model Railroading*, *Mainline Modeler*, *Railmodel Journal*, *Garden Railways*, and others.
- Annual publications such as *Model Railroad Planning* by Model Railroader Magazine.
- Books such as *Track Planning for Realistic Operation* by John Armstrong, *Creative Model Railroad Design* by John Armstrong, *Design Handbook of Model Railroads* by Paul Mallery, *Trackwork Handbook* by Paul Mallery, *How to Build Model Railroad Benchwork* by Linn H. Westcott, *The ABC's of Model Railroading*, *Practical Guide to HO Model Railroading*, and others.
- Publications of the Layout Design Special Interest Group (LDSIG) at <http://www.ldsig.org>.

Figure 17 • DCC friendly & ideal DC turnout

