General Layout Design and Trackwork

Introduction

This information is written for someone who is starting to design their track layout and who has limited on no experience in this work. It covers all the basics but does not go into some specific areas such as the building of switches (turnouts) or bridges.

Location

Your location should be large enough to allow the full size of the track plus at least several additional feet along both sides of the track. This allows for the width of the train equipment and the passengers. It is not recommended that the track be placed near trees, posts, edges of high walls, etc. because a derailment could cause the train and passengers to hit or fall over these objects.

You should select a location for your track that will prevent people and pets from having to be on, or tripping over, the track. If vehicles must cross the track you should try to develop a design that minimizes the number of crossings. Crossings located on straight sections of track, commonly called "tangent track", are always best. Completely avoid foot or vehicle crossings at switches or other complex trackwork.

Drainage

Consider the existing flow of water, both streams and runoff from rain or melting snow. Tracks are usually raised somewhat above the adjacent ground and can quickly become a dam. Small flows can use a culvert (pipe) under the track, Larger flows may require a bridge.

Ground that slopes towards the track will result in flow towards the track. If uncontrolled, this may wash mud or debris into the rock ballest making it unable to properly hold the track. The usual way of addressing this is to place a V-bottomed ditch along one or both sides of the track to turn the water flow parallel to the track and route it to a point where it will either flow away from the track or can be ran into a culvert, drain or stream. Lowering the track below the surrounding ground (commonly called a "cut") will require a ditch on both sides.

Curves

Curves are measured by the radius to the center of the track (half-way between the rails). You should always make any curve follow the largest possible radius that your space allows. Tight curves limit the types of equipment, especially steam locomotives, that you can operate. The actual minimum value depends on many factors. It is best to contact the manufacturer or designer of anything you plan to operate and to inquire as to the minimum radius they recommend.

For 1 1/2” scale, small locomotives such as a four wheeled switch engine can operate on curves as tight as a 10 foot radius (3 meters), but sometimes do so only at low speeds. Most home layouts try for a minimum radius of 30 to 40 feet (9 to 12 meters). Clubs often use 70 to 100 feet (21 to 30 meters). Smaller scale equipment can go somewhat tighter than this while larger equipment must have larger minimums. In each case areas that are only operated at low speeds or are not used very often may allow tighter minimums. Be sure that whatever minimum value you use is maintained everywhere since sudden kinks can develop when you are laying track and they will be much less than your minimum.

Cars are not discussed since most North American prototype cars use individual trucks and the minimum radius is determined mainly by the wheelbase (center to center distance between wheels) which is usually much smaller than a locomotive.

One issue to be aware of is what is known as a reverse curve (Figure 1). If you have a curve that turns first one way, then the other you can create a problem if the two sections of the curve are too close together. This is not an issue of wheelbase but of coupler swing between two cars (or a locomotive and car) and usually shows up with your longest car, especially if it is coupled to something much shorter. To prevent problems separate the two curves by the length of your longest car (X in the drawing). You can reduce this somewhat if you have a tight place, especially since such an area will probably be limited to low speeds. Also be aware that this applies to the curve within a switch followed by either another switch or curved track.

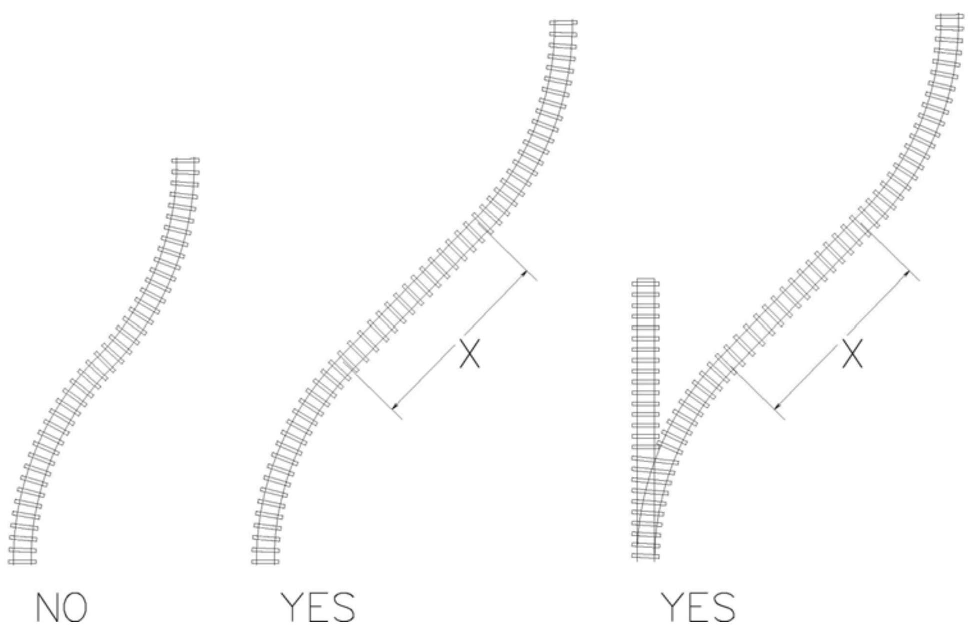

Figure 1 – S Curves

Track Gauge

The gauge of your track is the measurement from the inside edge of the head (top part) of one rail to the inside edge of the other. If you have equipment to operate on your planned layout your track gauge will be determined by that equipment. If you plan on taking your equipment to other layouts it must match whatever standards they have followed.

It has always been traditional to slightly widen the gauge used on tangent track when in a curve. This allows longer equipment more room to turn within the curve. As an example of this many 7 1/2" gauge layouts use 7 9/16" or 7 5/8" in curves. Using two gauges requires you to build track to both sizes and to also have sections that transition from one to the other. To simplify this many layouts simply use the wider gauge everywhere. Based on the experience of several large club layouts this does not seem to cause any problems.

Grade

Your location must also consider the "grade" of the track. Grade is defined as the amount of slope, or the change in elevation in a fixed distance. Grade is usually measured as a number of feet (meters) of rise or fall in 100 feet (meters) along the track with 1 in 100 being called one percent, etc. Most trains will operate best with a maximum grade of three percent, but a better layout will result with a maximum of two percent. Steep grades require very careful operation and tend to be difficult for children or visitors. In general, you will have a more relaxed and fun to operate railroad if you limit both grades and tight curves.

Grade is measured in distance along the track, not in a straight line. A track that curves back and forth takes a longer distance to reach another point but results in a lesser grade. This is often seen in the full size railroads.

You can check your selected location with a piece of string and a device known as a "line level" (a small bubble level that hangs on the string) available at most hardware stores. For large projects consider renting a surveyors transit.

If your grade is too steep, you should relocate your track if possible. Moving of dirt (cuts or fills), bridges, trestles, and tunnels may also be used.

Earthwork

With your layout design finished you will want to begin to move dirt. Large construction equipment does not work well on making the narrow widths we need for our roadbeds. You should consider smaller equipment such as rototillers and walk behind loaders that are commonly used in gardening. Be sure that fills (areas where dirt was added) are firmly compacted.

Slope the dirt away from the track either uphill or down as needed and try to keep this slope at a reasonable angle to limit erosion with rain or irrigation. Review the information above on drainage to include trackside ditches, culverts and similar work as needed. Consider the use of grass or other seeds to prevent erosion of disturbed areas. For very large areas local contractors offer a process known as hydroseeding that sprays on a mixture of seed, mulch and a binder that will hold the soil until the seed takes root.

Consideration must be given to preventing the growing of weeds in the ballest. Fabric like materials known as geotextiles are sold in home centers that can be placed between the dirt roadbed and the ballast rock. Being porous these materials will allow water to soak in but stop weeds from coming through. In cases where the soil is clay and may swell with moisture, or where frost heaving of frozen ground is common you may want to consider plastic sheeting to prevent water from reaching the soil under the ballest.

Construction of bridges, and similar features are beyond the scope of this paper but you must remember that they must be capable of supporting the weight of loaded trains. Bridges, tunnels, station platforms and other structures must allow sufficient room for trains and passengers, and meet all safety considerations.

Ties

The most common tie material is still wood. Most wood ties must be treated with a preservative to prevent deterioration in the ground. Preservatives to apply yourself are available from paint stores or home centers. Commercial treatments are applied by companies that do wood treatment (see the yellow pages).

Some woods such as heartwood redwood or cedar, and some tropical hardwoods do not require treatment. Purchasing pre-treated wood is generally a waste of money since the treatment is designed for the way in which the wood is used in new homes. The treatment is on the outer surfaces but does not go to the center of the wood. When cut and buried in the ground this untreated core rots the same as untreated wood.

There are new materials that replace wood in applications such as patio decks that are made of plastic or of compositions of wood fiber and plastics. Some of these can be buried in the ground, check with the supplier. These will last virtually forever but cost more.

In 7 1/2 or 7 1/4” gauge, ties of 2 by 4 lumber (actual size 1 1/2” by 3 1/2”) set on edge (so the 1 1/2” wide edge shows) are most common. These ties would be spaced 4” apart center-to-center. Tie length is usually 14”. 4 3/4”, 5” and 3 1/2” gauges often use 2 by 4 ties because this standard size wood is easily available and because it anchors the track well into gravel ballast. These would be shorter, typically 8” to 10” long but similarly spaced. Larger gauge layouts are usually 3 by 4 or 4 by 4 lumber, cut 24 to 30 inches long and spaced 8” to 12” apart.

Track Screws

The rail is most commonly attached to the ties using track screws. These typically have a 5/16" hex head and a self drilling point. While they are available in stainless steel the fact that it is not magnetic will slow installation since a magnetic bit cannot be used to hold the screws. Based on the experience of many clubs it has been found that stainless steel screws corrode about as soon as plain zinc plated ones rust so their much higher cost is not warranted.

Installation is best done with a power screwdriver (first choice) or power drill having a magnetic insert hex driver bit to fit the screws. They may also be installed by hand with a socket wrench, nut driver, or screwdriver.

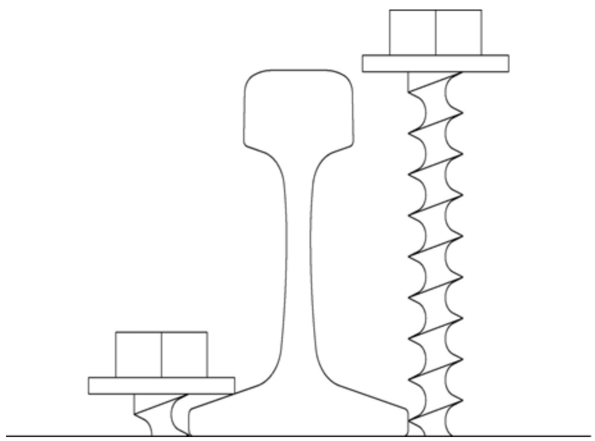

Figure 2 – Track Screw Installation

When installing track screws they should be placed vertically (see right side of Figure 2) and driven straight downwards. Since the base of the rail slopes it is natural to want to drive screws at that same angle but it is not recommended. Screws placed at an angle will allow the rail to move sideways out of gauge if they come loose. Screws driven vertically will maintain gauge even if loose. The screws should also be located so that the side of the screw does not cut into the edge of the rail. Install the screw until the head touches the base of the rail (left side of drawing). The screws should only slightly touch the rail. This allows the rail to slide through the tie as it expands and contracts with temperature.

Rail Joints

It is necessary to provide for rail expansion and contraction. How this is done depends on the design of the rail and its available joint bars. Vertical alignment of the rail must be maintained while horizontal movement is allowed.

The most basic method is to place the joint on a tie and to use track screws on both rail ends to hold them down to the tie. Use care in locating these track screws so that they do not interfere with the installation of the bolts and nuts that hold the joint bars.

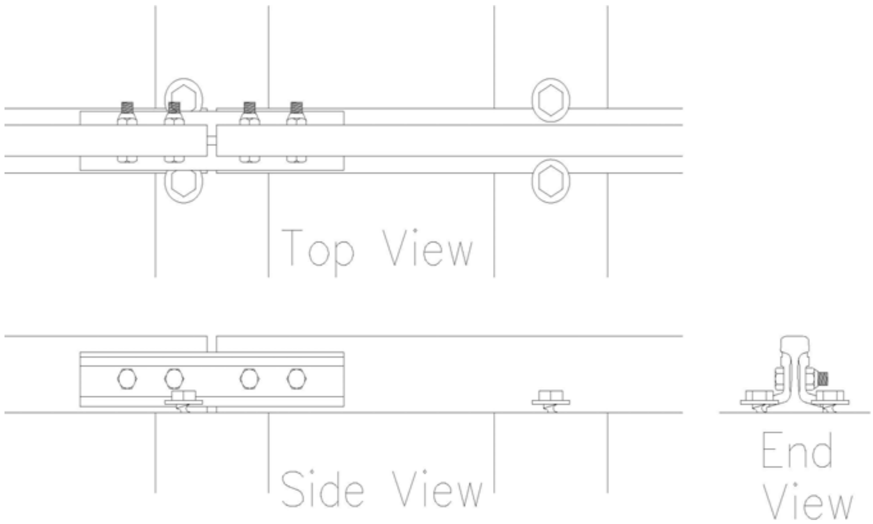

Figure 3 – Typical Rail Joints

If the joint bar has a scale profile, that is it fits into the side of the rail and fills the space between the underside of the head of the rail and the top of the base of the rail (Figure 3), it will maintain vertical alignment. Horizontal movement is then allowed by drilling the hole in the rail (but not the joint bar) considerably larger than the size of the bolt used to assemble the joint. This allows the joint bars to slide along the rail.

If this type of joint bar is not available then alignment must be maintained by the bolts through the joint bar and rail. This requires that the size of the hole in the rail in the vertical direction must be the same as the size of the bolt (and the hole in the joint bar), while the opening in the rail must be wider in the horizontal direction (i.e., a slot instead of a round hole). Producing these slots often requires the development of a special tool.

The oversize hole or slot must always be in the rail to prevent the bolt head or nut from catching on the edge of the hole or slot. This also keeps dirt out of the opening.

If installing a considerable amount of track it is usually best to put the holes or slots in both ends of all of the rail before assembling into track. The few cases where the rail must be cut and the holes or slots not used are offset by the relative ease of doing the work in a shop as opposed to in the field. For round holes you can set up a fixture on a drill press and pre-drill the holes.

The size of the screws or bolts used must match the joint bars and depends on the size of the rail. Small rails used for 5” gauge or less generally use a #4. 7 1/2” or 7 1/4” gauge use a #10. Larger rails use bolts of 1/4” or larger. The same considerations of stainless steel versus zinc plated steel apply as discussed for track screws.

Joint Bar Installation

When joining two rails you must estimate how much gap is needed depending on the temperature at time of installation. In general, it is better to have a gap too wide than too narrow. Rail will seldom pull itself up out of the ground at low temperatures while it can much more easily develop kinks due to high temperature expansion. As an example, on the hottest day of the year rail can be laid with little or no gap. If the temperature is half way between summer and winter, one half of the maximum gap may be assumed as a good starting place.

Joint bars are placed one on each side of the rail. Use a machine screw or hex head bolt through the holes with the heads located between the rails (so that the nuts will be on the outside). Install nylon insert type lock nuts on to the bolts. These nuts are self-locking and become harder to turn before they are fully tight. Make sure that all bolts are properly, but not overly tightened. You must allow the joint to move so make sure they are not excessively tight. These type of nuts are required since you cannot fully tighten them.

Track Panel Pre-Assembly and Installation

If you are going to lay more than a small amount of track you may want to take the time to build a fixture that holds the ties at the proper spacing and then holds the rails at the proper gauge. There are about as many ways to do this as there are people doing it so no design is given here but a visit to a local club will usually show what they do.

In most cases where a lot of track is being laid the minimum radius of the curves is fairly large. In this case you will usually only build a jig and track panels that are straight. This is because it is possible to “bow” a straight panel to the needed curve. In doing this the rail slips under the track screws to allow the curve to be formed (remember that the rail must be free enough to move with changes in temperature). When laying track this way start with a straight section and assemble panels as needed. When you come to a curve you should continue to assemble two or three more straight panels in a straight line. Then drag the track sideways as needed to make the curve. Leave about half the last panel straight to better join the next panels to be added and curve it after they are added. When bending the panels this way you will find one rail getting longer than the other, simply cut off the excess and then make new holes for the joint bars. Then add two or three more straight panels and repeat the operations as needed.

Rail Bending

If you are going to have tight curves you may need to bend rail before assembling it to the ties. Steel rail is much more likely to need pre-bending and is more difficult to bend than aluminum.

The easiest way to do bending is with a machine specifically intended for this. These are available from various suppliers or can be made.

You may also bend limited amounts of rail by making a template. Use a piece of plywood that is thin enough to fit into the side of the rail below the head and above the flange. Cut the edge of the plywood to a radius somewhat smaller than your final requirement. You need to allow for the fact that the rail will spring back by over bending it. Also, realize that you only need to come close as the final radius can be adjusted when laying using the natural spring of the rail. Use your plywood template by clamping the rail around the edge at one end and then working your way down the edge pushing the rail up against the edge of the plywood. The plywood template keeps you from making too tight a curve which would result in a kink. When you reach the end of the template, unclamp the rail, and reposition it to continue the bending further down the length of the rail.

Ballast Choice

Normally 7 1/2" or 7 1/4" gauge or larger trackwork uses a gravel referred to as "3/4 minus crush". Smaller gauges may use 3/8 minus crush. This material has a range of sizes that allow it to be compacted around and under the ties when leveling the track. Crushed rock has sharp corners and will hold much better than other types of rock. If using wood ties make sure that the ballast is under, as well as around the ties to allow water to drain completely away from them. It is not recommended that you use concrete, paved areas, or other hard surfaces to support your track as the ties will tend to slide on these surfaces and leveling will be difficult. Products such as rock dust or slag that will set up hard over time should not be used for ballast.

Road Crossings

There are many methods of making road or path crossings. However, many of these will result in an area that requires a lot of maintenance or produces unreliable operation. The method described in Figure 4 has been widely used and proven to work well.

Obtain steel angle (commonly called "angle iron") of about the same height as your rail. The type that is most desirable has a round edge profile as opposed to a sharp corner. You will use the top edge as the rail with the one side vertical and the bottom side horizontal, The bottom may turn in towards the other rail or outwards. Bolt or weld a flat bar across the bottom every few feet to hold two pieces in gauge.

This assembly is embedded in concrete at least 4" thick and extending well beyond the width of the track. When finishing the concrete it should be flush with the top of the angle. Form a groove for the wheel flange along the inside edges using a groove forming tool intended to make this shape in concrete work.

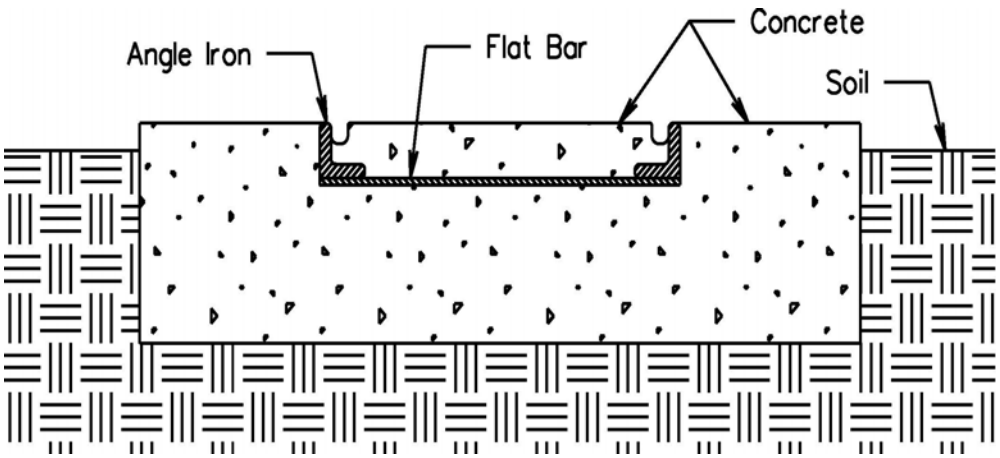

Figure 4 – Road Crosssing Construction

Laying Track

You will find that the simplest way to lay track panels is to place them directly on the dirt, geotextile, or plastic film of your roadbed. You should adjust curves and install joint bars to get a finished track before you install ballast.

Ballast can then simply be dumped over the track. Use a rod with a hook formed on its end (a sprinkler valve wrench from the hardware store makes a good starting place for this) to pull the track up through the ballast so that some rock is under the ties and use your judgment to establish the approximate level of the track. Add more ballast as needed and tamp the rock to hold the ties (the end of a shovel handle makes a good tamper). Use whatever levels or other equipment you have to gradually work the track into its desired slopes, curves, etc. When finished you should have ballest almost to the tops of the ties and extending at least a few inches wider than the length of the ties.

You should be careful to make sure the track is level from side to side. Variations up and down along the length of the track may look funny and will feel like a roller coaster but will generally not cause a derailment. Small variations from side to side on the other hand will cause all sorts of problems that are often hard for the beginner to find. Spend time and check this carefully.

Maintenance

You will find that newly laid track will settle no matter how careful you are in first laying it. Plan on some time to recheck and adjust your track during the first season of its operation. In areas where the ground freezes you must also plan on some work each spring as the ground thaws.