Introduction to Railroad Infrastructure
Jerry Rose
University of Kentucky

Topics
• Loadings and Track Basics
• Ballast and Subgrade
• Crossties
• Rail and Fastenings
• Special Trackwork
Basic elements of rail transportation

Traffic Control System
Safe, efficient operation of many trains on same tracks

Railroad Network
System operation affects efficiency and service reliability

Line & Terminal Operation
Timely and efficient train operation and use of equipment & personnel

Rail Cars
Design and size affect operating efficiency

Locomotive
Efficient conversion of energy into tractive force to pull train

Brake System
Safe stopping distance affects train spacing and line capacity

Track System
Structure & condition affects speed and maintenance requirements

Wheel/Rail Interface
Complex dynamics affect stability & speed
Basics of freight railcar weight and capacity

- The nominal capacity of a typical, 4-axle railcar today is 110 tons (formerly was 100 ton)
- Maximum Gross Rail Load (GRL) of a 110 ton, 4-axle railcar is 286,000 lbs. (weight of car + contents or “lading”)
- Nominal capacity = 220,000 lbs. or 110 tons
- Often referred to as a “110 ton” car or a “286K” car

Load or Lading

Nominal Capacity
Approx. 220,000 lbs
= 110 tons

Light weight or “tare” approx. 66,000 lbs = 33 tons

Gross Rail Load (GRL)

220,000 lbs.
+ 66,000 lbs.

286,000 lbs.

(actual light weight will vary somewhat depending on car size, consequently the weight-carrying capacity will vary inversely, i.e lighter car larger capacity)
Railcar weight per axle and per wheel

- Maximum GRL = 286,000 lbs. for a 4-axle car
- Typical car has two, 2-axle “trucks” (or “bogies”) supporting it
- Weight per axle = 286,000/4 = 71,500 lbs.
- Weight per wheel = 286,000/8 = 35,750 lbs.
- Each wheel and the rail it rides on must be able to support 35,750 lbs.
- Track system must be able to support and satisfactorily distribute these loads to the subgrade.
What is the load path from rail vehicle to track system?

- Loads are transferred from the carbody into truck and track structure via the:
  - center-bowl (1)
  - bolster (1)
  - spring-groups (2)
  - side frames (2)
  - bearing adaptors (4)
  - bearings (4)
  - axle journals (4)
  - wheels (4)
  - rails (2)
  - ties (many)
  - ballast
What is the size of the contact patch?
Which side of the wheel should the flange be on?

Flange on the inside is stable, rather than unstable, when there is a lateral force such as in curves.

Flanges on outside of tread

Lateral Disturbing Force

Disturbing force tends to lift guiding flange from rail

Flanges on inside of tread

Lateral Disturbing Force

Disturbing force tends to hold guiding flange down on rail
Cross-sectional view of wheel/rail interface and track system

• Principal components from top down
  – Rail
  – Tieplate
  – Fasteners (spikes)
  – Crossties
  – Ballast
  – Sub-ballast
  – Subgrade

• Loads are distributed downward through these components
Track

• Track is a dynamic system of interacting components that distributes the loads and provides a smooth, stable running surface for rail vehicles.

• System must provide **vertical, lateral and longitudinal stability**
Track Superelevation

- Needed to counter centrifugal force
  
  \[ e_a = 0.0007DV^2 \]

  where \( e_a \) = actual superelevation, inches
  
  \( D \) = degree of curvature
  
  \( V \) = train speed, MPH

- Results in balanced superelevation, equal force on each rail for given speed
  
  - Underbalance - Cars lean to high rail
  
  - Overbalance - Cars lean to low rail
Unbalanced Superelevation

- Required because of varying speeds
- Set for predominate traffic
- Faster trains can travel at speeds set by the unbalance
- \( V_{\text{max}} = \left( \frac{e_a + \text{unbalance inches}}{0.0007D} \right)^{1/2} \)

Examples:
  - U.S. DoD uses +2 inches unbalanced and a max of 4 inch superelevation because most trains travel less than posted speed and speeds are slow
  - FRA permits +3 inches unbalanced with a 7 inch max superelevation to allow for faster trains for Track Classes 3-5 (26-80 MPH) and 8 inch max for Classes 1 and 2 (0-25 MPH)
  - FRA permits +4 inches unbalanced for rolling stock meeting certain criteria
Superelevation Runoff and Spirals

- Transition from tangent to full curvature
Rail

- Rail is the single most valuable asset owned by the railroad industry
- It is probably the most critical element of track system
- Provides smooth, low-friction, running surface
- Wide, flat base distributes load across several crossties and allows fasteners and other stabilizing components to be attached
- Combined with fasteners and ties, provides a stable track gauge
- Three principal parts of rail:
  - Head
  - Web
  - Base

Tee Rail Data—Diagram

HT—Height
BW—Width of Base
HW—Width of Head
W—Web (at center point)
HD—Depth of Head
FD—Fishing
BD—Depth of Base
E—Bolt Hole Elevation
**AREMA* rail specifications**

- Rail specifications are maintained by AREMA
- Rail size is measured in lbs./yard.
- Most common new rail is 115 lb. and 141 lb.

* The American Railway Engineering and Maintenance of Way Association (AREMA) is the professional association of the North American railway engineering community and maintains the railroad industry track engineering standards.
Fasteners & tie plates

- The tie plate supports the rail and distributes the load over a larger section of the tie surface.
- Fasteners (cut spikes are the most common type in NA) hold the track in gauge. Cut spikes do not provide much vertical restraint.
- Ties may be made of wood, concrete, steel, and recently composite wood and recycled plastic materials
- Along with fasteners, ties provide gauge restraint and further distribute the load into the ballast.

Tie plate

Standard “cut” spike
Cross ties

- Crossties are the next step in load distribution
- Wooden crossties are the most common in North America because of their economy and performance
- Concrete and steel ties are commonly used overseas, and in certain specialized applications in North America
- Crossties from recycled plastic and various composites of scrap ties and other wood sources are also being tested by railroads and AAR
Types of ties

Timber
Plastic (and composite)

Concrete
Steel
Wood Tie Replacement Process

- Ties first marked for replacement
- Automated
- Accomplished by a "tie gang"
Ballast & sub-ballast cross-section*

- Ballast and sub-ballast are the final stages in load distribution.
- In addition to distributing vertical loads, ballast has a critical role maintaining longitudinal and lateral stability of track.
- Ballast and sub-ballast must provide adequate drainage.
- Ballast is subject to pulverization from loading and unloading as trains pass over, thereby generating fine particles that clog the ballast.

* AREMA recommended practice.
Track deflections under unloaded and loaded car

- Rolling load on elastic foundation results in repeated cycling of loads as wheels pass by.
- A 100 car train results in 200 cycles, one for each truck
Rail is a beam on an elastic foundation

Direction of movement

Wave action in loaded rail.

- As a load is applied, it results in both downward and upward forces on the rail and consequently the track structure.
- This “pumping” action as wheels pass over it tends to loosen, wear and damage track components.
“Pumping” has particularly serious consequences for ballast

- The repeated up and down cycling of loads on the ballast causes it to wear and become pulverized, creating “fines”
- These fines foul the ballast section and impede drainage
- It is a negative feedback loop
- The impaired drainage causes that area to hold water and soften the subgrade
- The poorer support results in a lower modulus leading to greater dynamic loads, leading to further deterioration of the ballast
- The solution is to replace the ballast, or “clean” it by removing it and separating fines from the remaining rock
Screw spikes and spring clips

- This “premium” system for fastening rail to ties is more expensive than conventional cut spike system
Premium fastening systems are used when economics justify the greater expense

- Concrete or steel ties
- Variety of spring fasteners
- Justification for their use is based on demands on the track system
- Tonnage, speed, maintenance objectives
- Ultimately a matter of economics
- Is it cost effective given the particular circumstance of construction and operation to invest in more costly, but better-performing components and systems?
- That is, if I spend more to build it, will I spend less maintaining it?
High-speed rail and rail transit systems need particularly high-performance track systems.

Why?
Advanced track systems: Slab track and ladder track

- Conventional track too soft and unstable
- These systems are being used overseas for high-speed rail and rail transit systems
- Starting to be used in North America
Q: What do railroads call the special trackwork that allows diverging moves?

• Answer: **Turnouts**

• They are comprised of:
  – **Switch** (diverts wheels from one track to the other)
    • points
    • operating and switch rods
    • switch machine or switch stand
  – **Frog**
    • point
    • wing rails
    • flangeway
    • heel
  – **Guard rails**
  – **Stock rail, closure rails and lead rail**
Principal Parts of a Turnout

Switch
Diverts wheels from one track to another when points are shifted

Rail braces

Switch rods or points

Curved stock rail

Curved closure rail

Switch

Straight closure rail

Lead

Head-block ties

Guard Rail
Prevents wheel flanges from taking wrong path at frog point

Frog
Allows wheel flanges to cross running rail

Point
Flangeway (1 7/8" wide)

Heel

Wing rail

Throw = 4 3/4"

Operating rod – to switch stand (hand throw) or switch machine (remote, power-throw)

No. 6

One unit

No. 20

Definition of angle or "number" of frog and turnout

6 units
Bolted rail joints versus continuously welded rail (CWR)
Rail joints

- No more “clickety clack”
- Most North American mainline track is now made of “continuously welded rail” (CWR)
- Eliminates dynamic loads at joints
- Improves ride, reduces maintenance requirements and extends roadbed and other track component life
CWR is an important improvement, but it is not without its drawbacks

- Bolted joints had some allowance for thermal expansion and contraction of rail
- In welded rail the resultant stress must be contained
- If localized lateral forces become too strong they may overwhelm the strength of the ballast to restrain the track, and result in what is variously known as a “track buckle” or “sun kink”
Rail anchors provide longitudinal restraint of rail

- Anchors are sprung clamps that attach to the rail
- They are mounted adjacent to ties
- With enough in place, they prevent rail from “running” due to thermal, tractive or braking forces
- Objective is homogeneous distribution of contained stress in rail
Confusing railroad “crossing” terminology

- **Crossing:** Two tracks crossing each other, sometimes referred to as a “railroad crossing at grade”. The combined hardware is also called a “diamond”.

- **Crossover:** Two turnouts on parallel tracks that allow trains to cross over from one track to the other.

- **Grade Crossing:** Where a railroad and highway cross at grade. Sometimes called a “Highway/Rail Intersection”
Crossings aka “diamonds”

Diamonds aren’t forever

Replaceable, manganese steel inserts are used to extend life
Double slips are only used in locations where space is limited.

How many can you find in this picture?
Double-slip switches are sometimes referred to as “Puzzle switches”

A combination of a Track Crossing and two Turnouts interconnected into one assembly.

- Because they are such a “puzzle” to figure out and maintain!
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Presentation Author
Jerry Rose
Professor
University of Kentucky
Department of Civil Engineering
261 Raymond Building
Lexington, KY 40506-0281
(859) 257-4278
<jrose@engr.uky.edu>

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