MIXED-USE CORRIDORS: DESIGN MEETING STANDARDS RESULTING IN TRACK DEFECTS

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INTRODUCTION TO MIXED USE RAIL CORRIDORS

Passenger

- Move people quickly
  - High frequency service
  - High speed service

Freight

- Move goods efficiently
  - Maximizing the load
  - Fuel economy

INTRODUCTION TO MIXED USE RAIL CORRIDORS

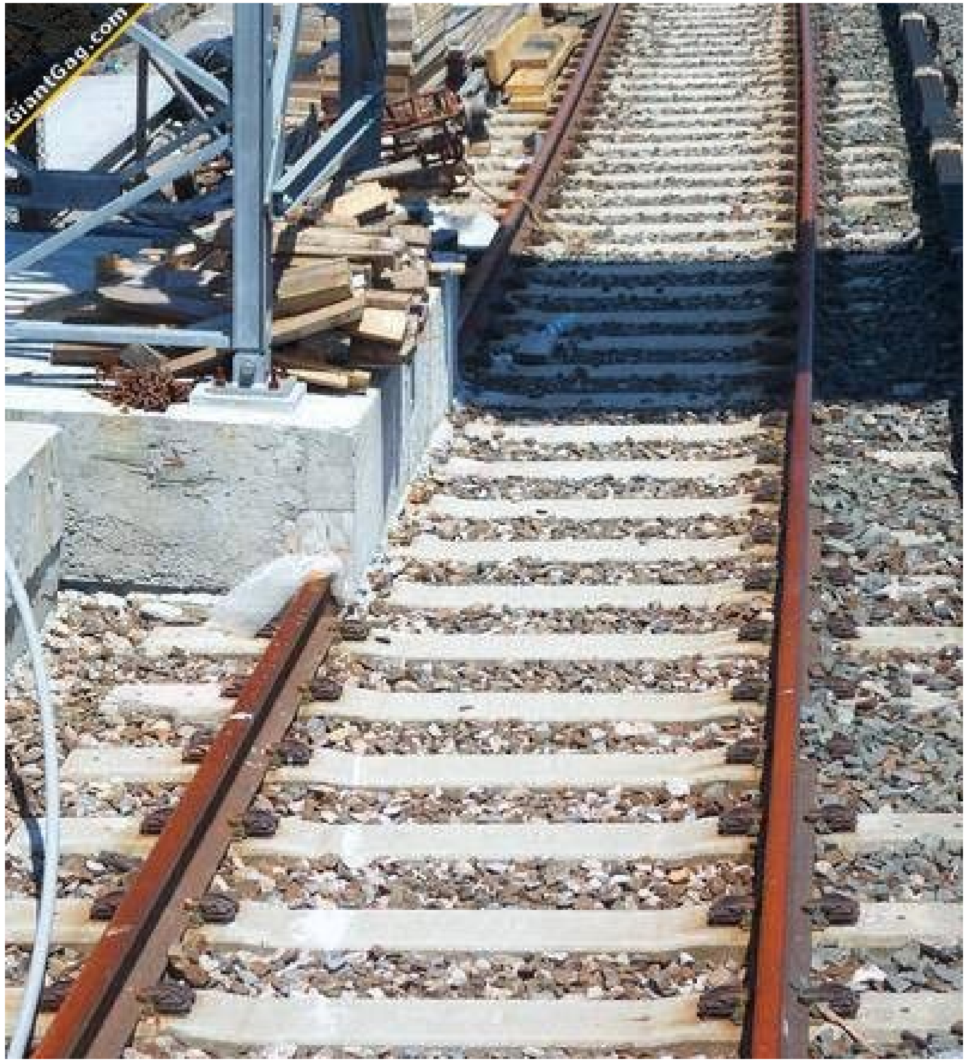
Mixed use

- Large speed differences
- Near design criteria limits

Result

- Tolerances play a larger factor
- Maintenance needs to be considered in design

IS EVERYONE WORKING TOGETHER?



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Track design ☑

Foundation design ☑

CASE STUDY

- Desire to increase operating speed
- 80 mph passenger, 60 mph freight
- Limited space available

INTRODUCTION

Degree of curve	1°30’
Super-elevation	3.75”
Passenger Unbalance	2.97”
Passenger Speed	80 mph
Freight Unbalance	0.03”
Freight Speed	60 mph

- Maximum passenger unbalance of 3.0”
- Cross-level construction tolerance of ¼”

PROBLEM

	Design	Constructed
Degree of curve	1°30’	1°30’
Super-elevation	3.75”	3.50”
Passenger Unbalance	2.97”	3.00”
Passenger Speed	80 mph	78.5 mph
Freight Unbalance	0.03”	0.28”
Freight Speed	60 mph	60 mph

- The curve was constructed ¼” under the design super-elevation
- The original design followed all recommended methods
- Verification with a geometry car revealed a maximum speed of 78.5 mph
- A TSO was required
- This location will always be susceptible to cross-level error

So what happened?

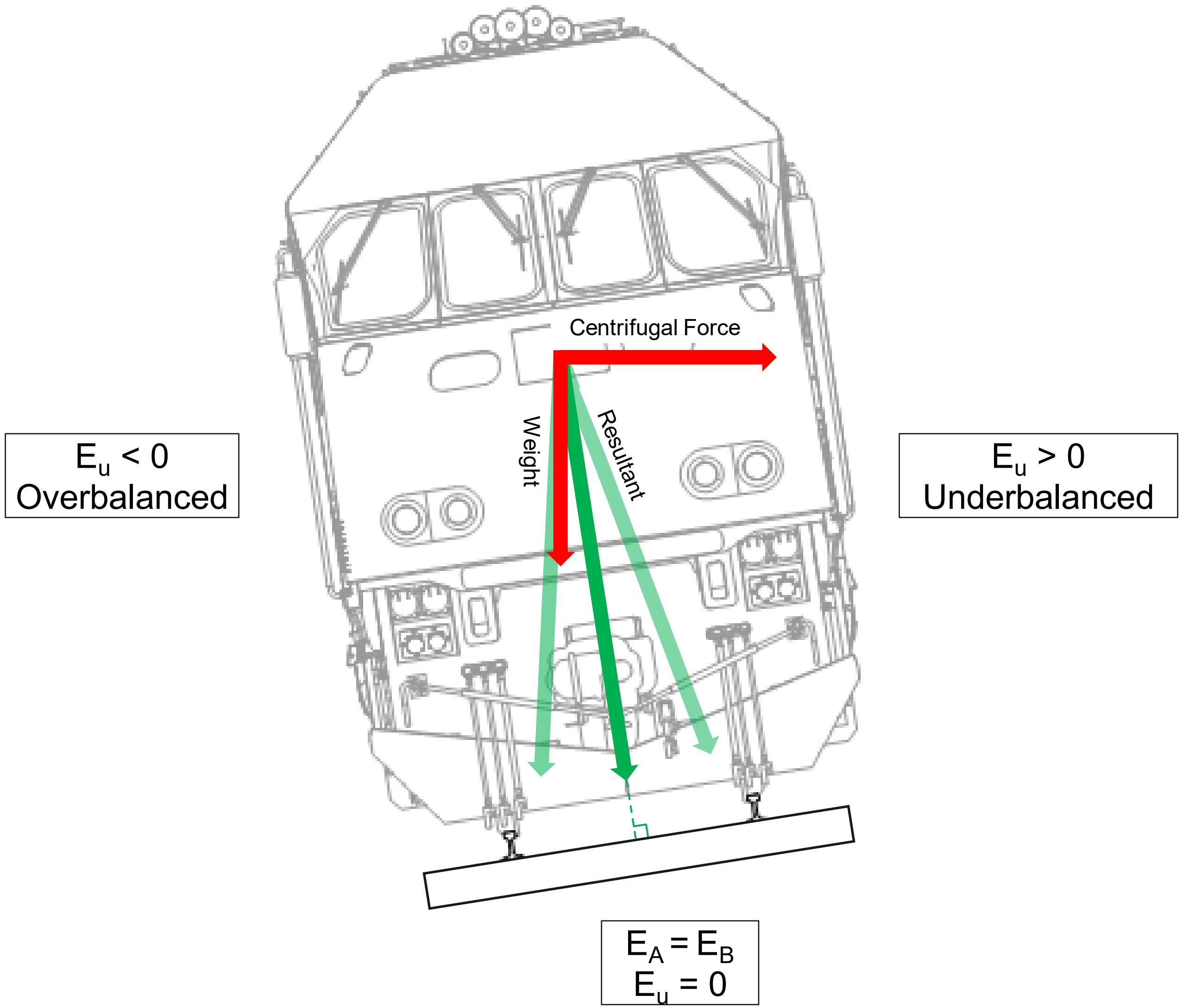
FUNDAMENTALS OF CURVE DESIGN

- Balanced super-elevation is the point at which the force on both of the rails is the same
- Balanced Super-elevation is calculated using the formula:

$$E_b = 0.0007\ x\ D_c\ x\ V^2$$

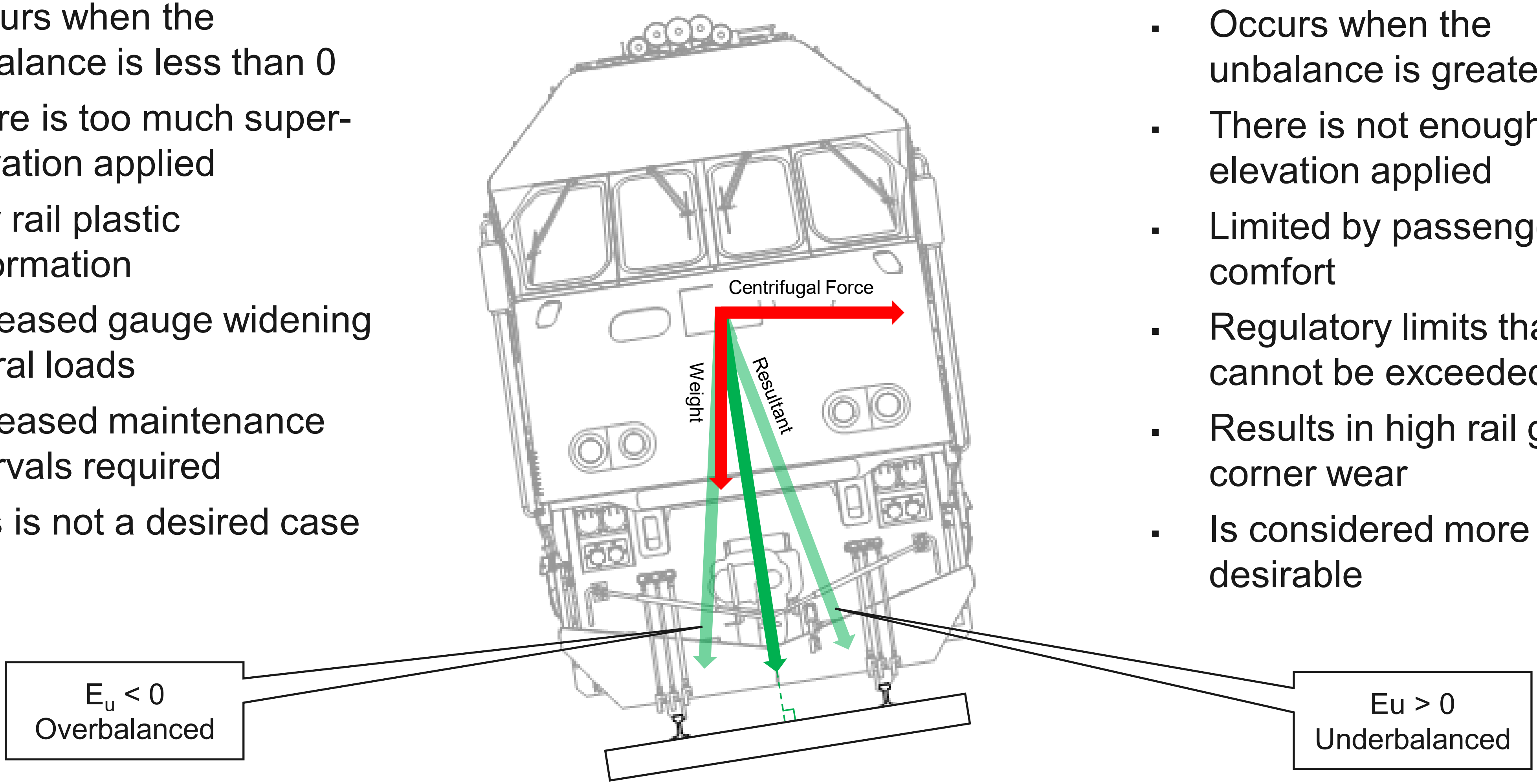
- The balanced super-elevation can be related to the actual and the unbalanced super-elevation through the following formula:

$$E_B = E_A + E_U$$



FUNDAMENTALS OF CURVE DESIGN

- Occurs when the unbalance is less than 0
- There is too much super-elevation applied
- Low rail plastic deformation
- Increased gauge widening lateral loads
- Increased maintenance intervals required
- This is not a desired case



- Occurs when the unbalance is greater than 0
- There is not enough super-elevation applied
- Limited by passenger comfort
- Regulatory limits that cannot be exceeded
- Results in high rail gauge corner wear
- Is considered more desirable

CONSTRUCTION AND MAINTENANCE TOLERANCES

Maintenance is governed by two key areas:

1. Cross-level deviation from design
   - Defects are “priority” or “urgent”
   - Allows for maintenance measures before introduction of a TSO
   - Avoids the reduction in track speed

Track Class	1	2	3	4	5
Speed	15/10	30/25	60/40	80/60	95/80
Priority	1”	1”	¾”	½”	½”
Urgent	3”	2”	1-¾”	1-¼”	1”

CONSTRUCTION AND MAINTENANCE TOLERANCES

Maintenance is governed by two key areas:

2. Vmax

- The balanced super-elevation formula is rearranged to yield maximum allowable speed

$$V_{MAX} = \sqrt{\frac{E_A + E_u}{0.0007\ D_C}}$$

- This formula has been adopted by both TC and FRA as a regulatory limit

Construction is governed by:

1. Cross-level deviation from design

- Typically varies by agency
- ±¼” is a common value

CONSTRUCTION AND MAINTENANCE TOLERANCES

Applying these two cases to the previous example:

- Passenger speed 80 mph, freight speed 60 mph
- Class 4 track
- Degree of curvature is 1°30’ and maximum unbalance is 3.0”
- Priority defect: ½”
- Urgent defect: 1-¼”

	Criteria 1 Cross-level from design
Design	3.75”
Construction Tolerance	3.50”
Priority Defect	3.25”
Urgent Defect	2.50”

} Maintenance action triggered
No reduction in speed required

CONSTRUCTION AND MAINTENANCE TOLERANCES

Applying these two cases to the previous example:

	Criteria 1 Cross-level from design	Criteria 2 V_{MAX}
Design	3.75”	80 mph
Construction Tolerance	3.50”	79 mph
Priority Defect	3.25”	77 mph
Urgent Defect	2.50”	72 mph

Criteria 1 (Priority Defect): Maintenance action triggered. No reduction in speed required

Criteria 2 (79 mph): Maintenance action triggered. Reduction in speed required

CAUSE

- Design speed close to the regulatory limits causes issues after construction
- Bypasses the priority and urgent defect classification
- Standards do not incorporate any tolerances in the design

Current industry standard is to “avoid the unbalance limits”, but how can this be quantified?

UNBALANCE UPPER LIMITS

- The upper limits in the field are defined by regulatory bodies
- Adding a maintenance buffer M_B reduces the likelihood of early intervention
- This reduces the maximum allowable unbalance in design

In the field...

$$V_{MAX} = \sqrt{\frac{E_A + E_u}{0.0007\ D_C}}$$

In Design...

$$V_{MAX,DESN} = \sqrt{\frac{E_{A,DESN} + E_{U,MAX} - M_{B,MAX}}{0.0007 D_C}}$$

$M_{B,MAX}$ Desired = ½”

$M_{B,MAX}$ Absolute = ¼”

UNBALANCE LOWER LIMITS

- There are no regulatory requirements for the minimum unbalance
- It's generally common practice to avoid negatives
- Desired case of zero unbalance
- Absolute case of -1" unbalance

In the field...

$$V_{MIN} = \text{Not Defined}$$

In Design...

$$V_{MIN,DESN} = \sqrt{\frac{E_{A,DESN} + M_{B,MIN}}{0.0007 D_C}}$$

$M_{B,MIN}$ Desired = ¼"

$M_{B,MIN}$ Absolute = -¾"

SOLUTION

$$V_{MIN,DESN} = \sqrt{\frac{E_{A,DESN} + M_{B,MIN}}{0.0007D_C}}$$

$M_{B,MIN}$ Desired = ¼”

$M_{B,MIN}$ Absolute = -¾”

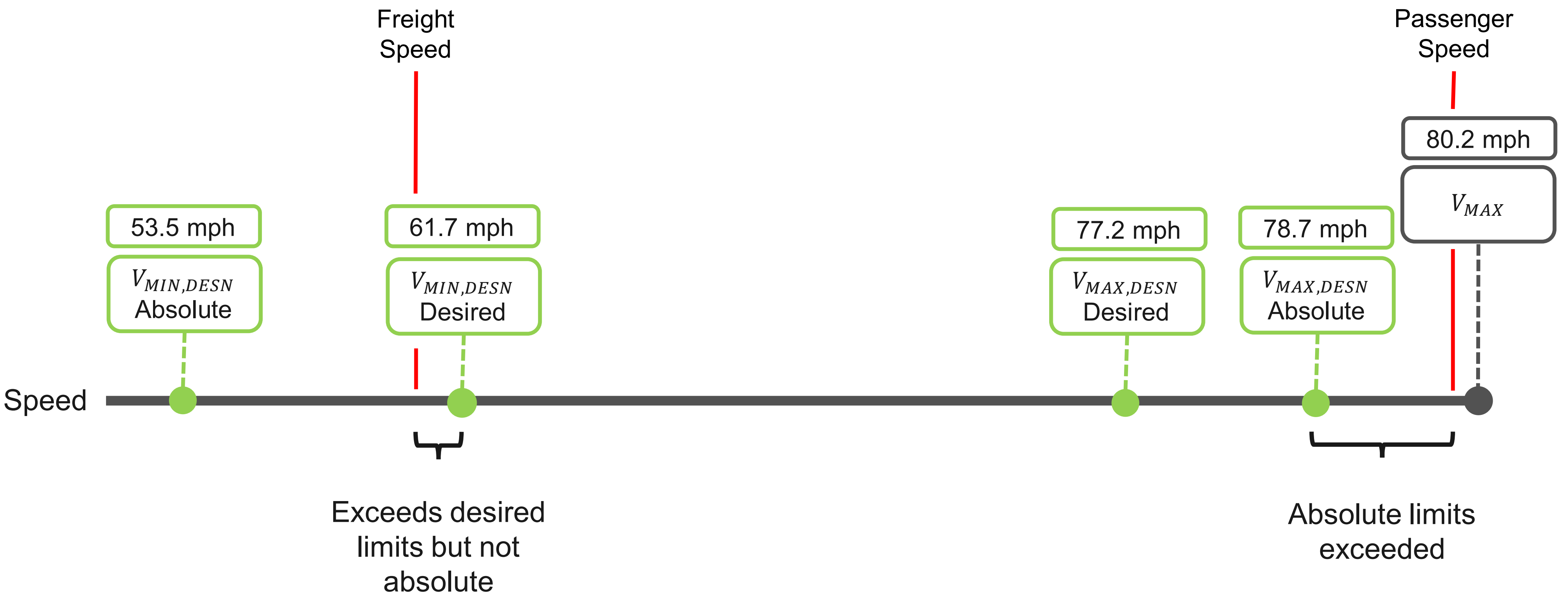
$$V_{MAX,DESN} = \sqrt{\frac{E_{A,DESN} + E_{U,MAX} - M_{B,MAX}}{0.0007D_C}}$$

$M_{B,MAX}$ Desired = ½”

$M_{B,MAX}$ Absolute = ¼”

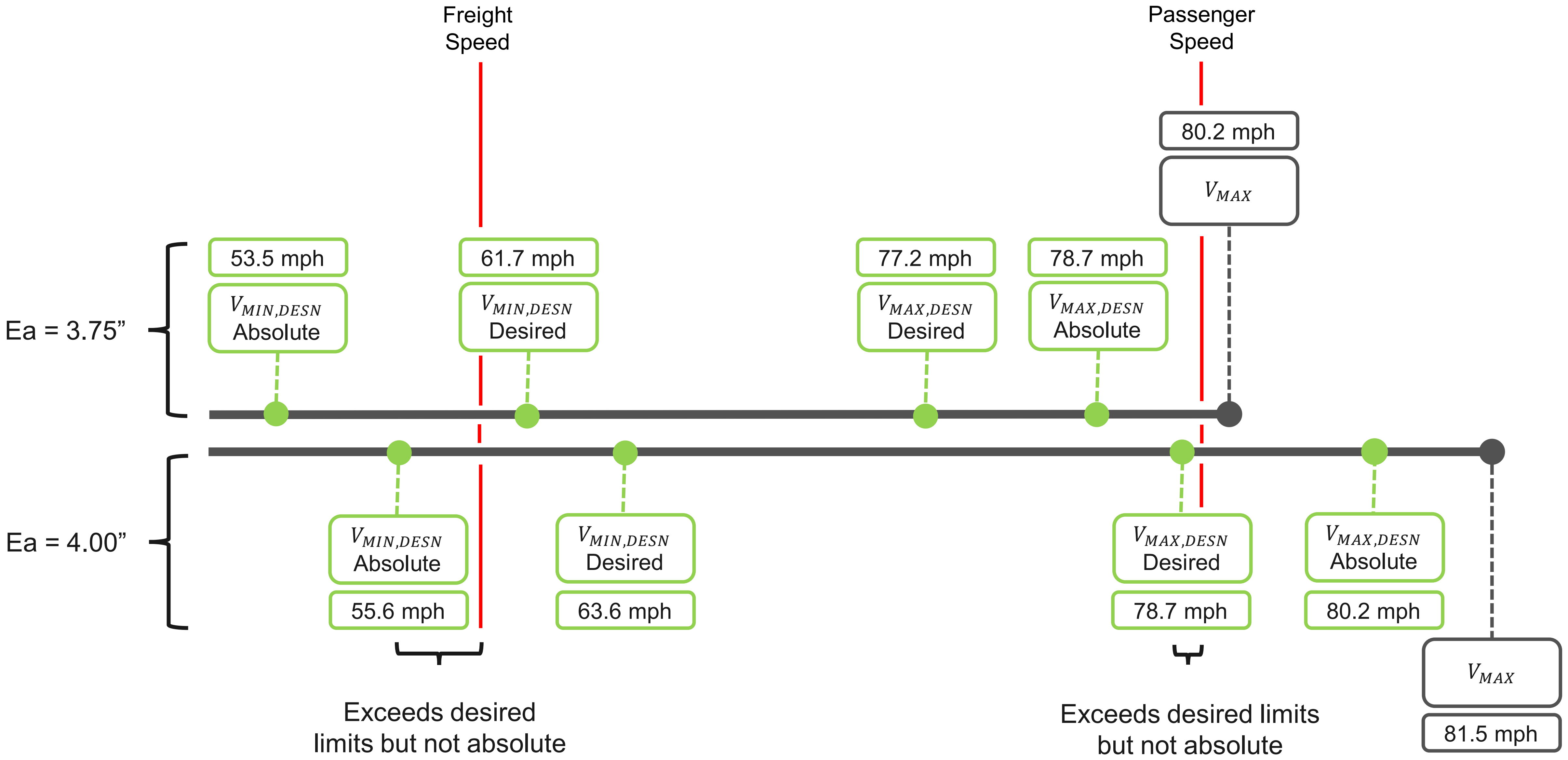
DESIGN LIMITS

Applying these to the previous example:

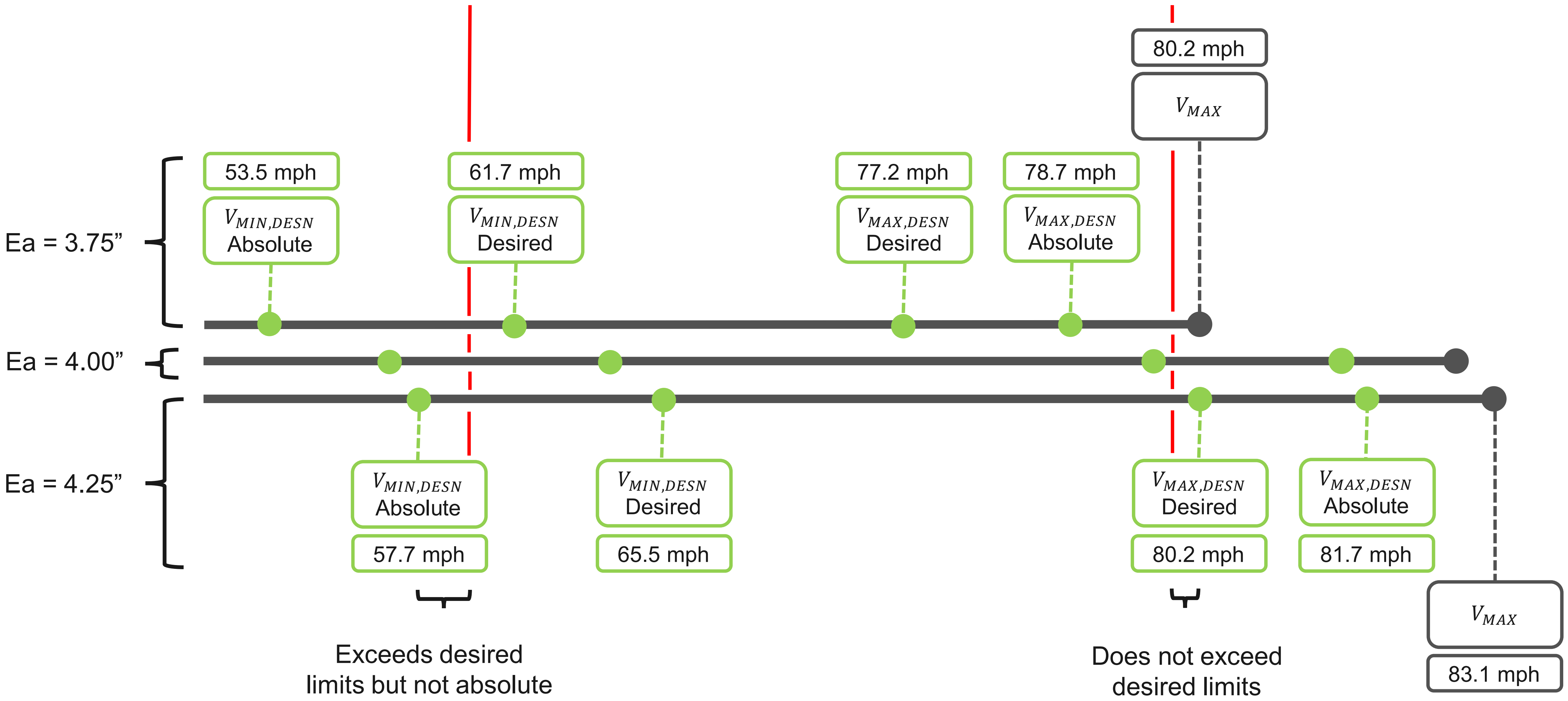


What if we adjust the super-elevation?

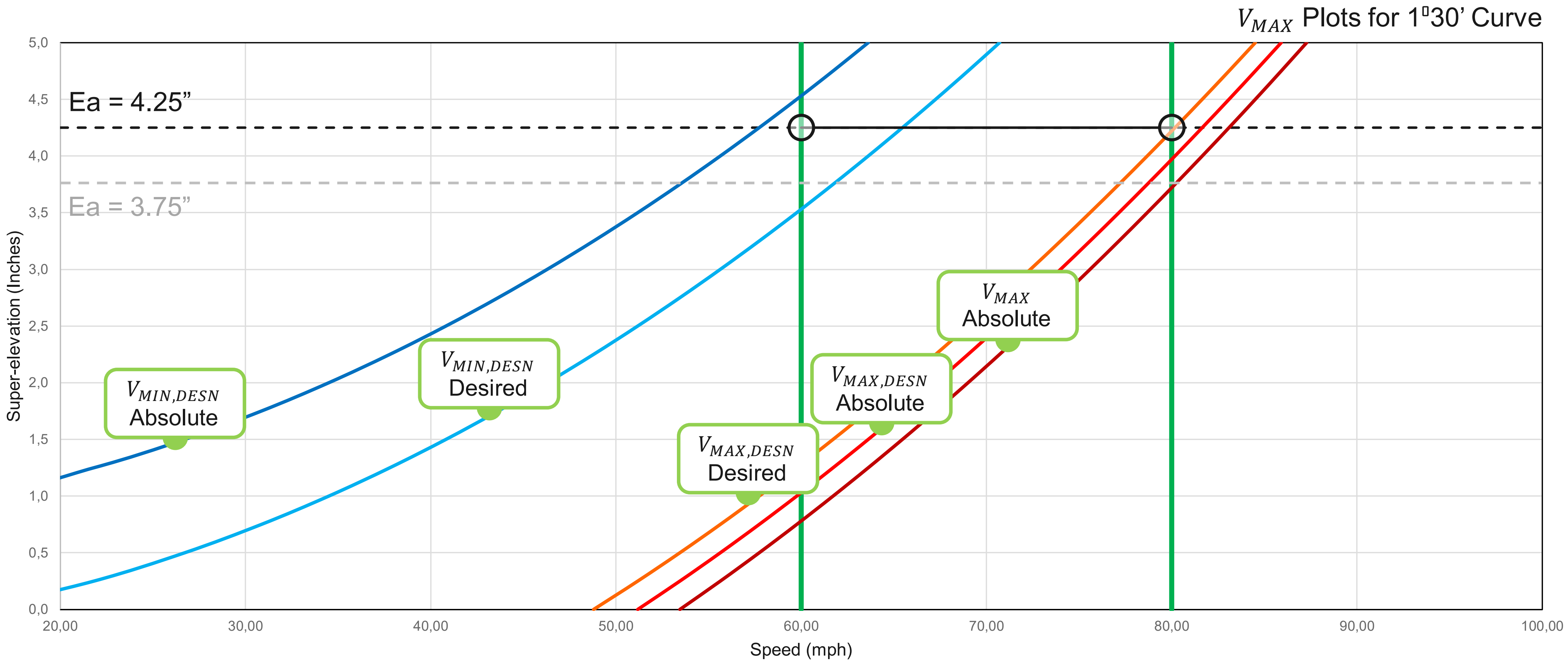
DESIGN LIMITS



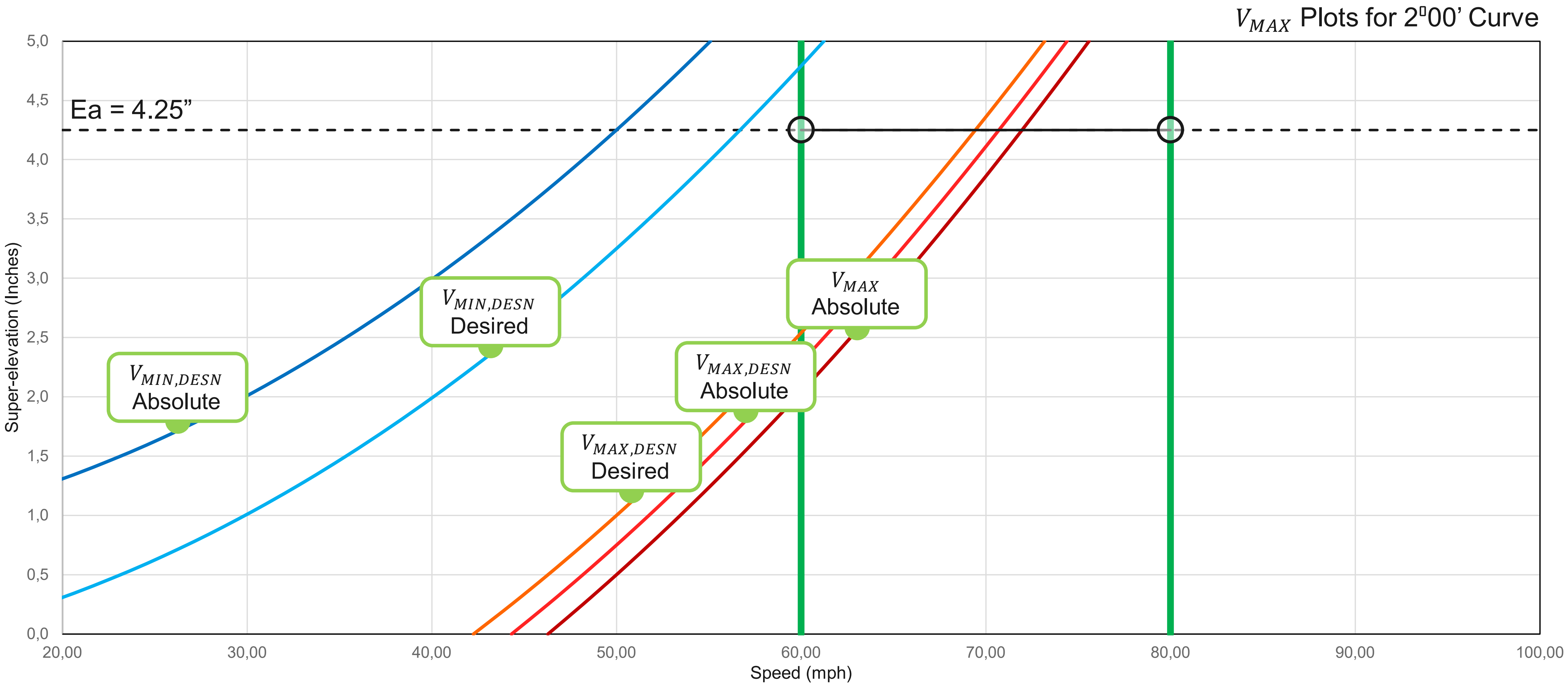
DESIGN LIMITS



GRAPHICAL REPRESENTATION



GRAPHICAL REPRESENTATION



SOLUTION

- Overbalanced case requires more maintenance and is not desired
- Regulatory limits on the allowable underbalance
- Common practice is to avoid the unbalance limits
- Vmax defects do not follow priority and urgent defect types and require immediate intervention
- Proposed formulas place design limits below the regulatory limits

$$V_{MAX,DESN} = \sqrt{\frac{E_{A,DESN} + E_{U,MAX} - M_{B,MAX}}{0.0007D_C}}$$

$M_{B,MAX}$ Desired = ½”

$M_{B,MAX}$ Absolute = ¼”

$$V_{MIN,DESN} = \sqrt{\frac{E_{A,DESN} + M_{B,MIN}}{0.0007D_C}}$$

$M_{B,MIN}$ Desired = ¼”

$M_{B,MIN}$ Absolute = -¾”

IMPLICATIONS

- Lower speeds considering tolerances
- Optimization of super-elevation
- Prioritization of traffic type
- Improvements in maintenance
- Selection of track type

QUESTIONS?

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