High Performance Steel Cost Comparison Study

ACEC / NCDOT Bridge Committee

HPS Bridge Workshop

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High Performance Steel Cost Comparison Study

Acknowledgements:

Joint Study between HDR Engineering and University of Nebraska at Lincoln

Sponsored by FHWA

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HPS Cost Comparison Study

HPS has been used successfully now on many projects in several states.

Tennessee – One of the first applications

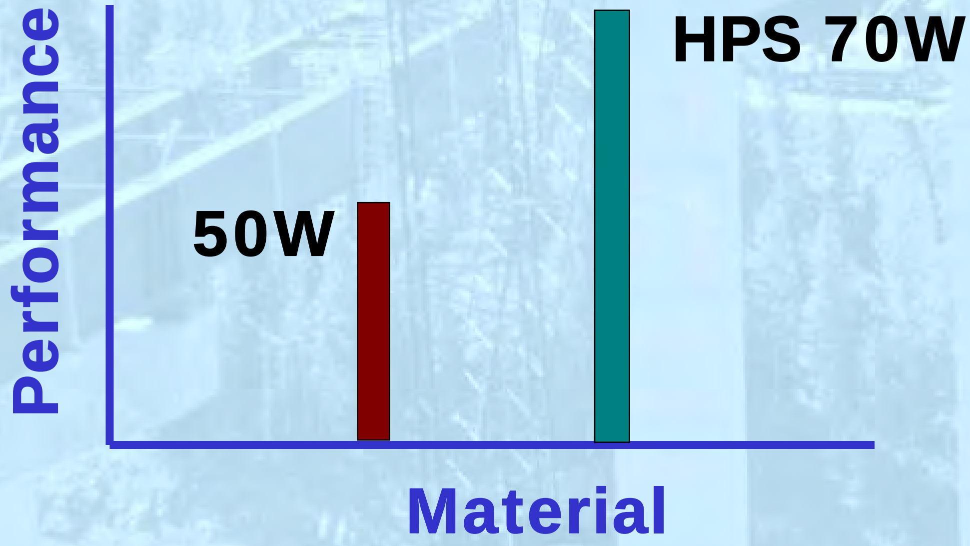
State Route 53 Bridge over Martin Creek, Jackson County

Weight Savings 24%

HPS Cost Comparison Study

HPS 70W provides significant advantages over conventional Grade 50W Steel.

- Strength
- Weldability
- Toughness
- Weathering



HPS Cost Comparison Study

HPS 70W material cost is greater than conventional Grade 50W Steel.

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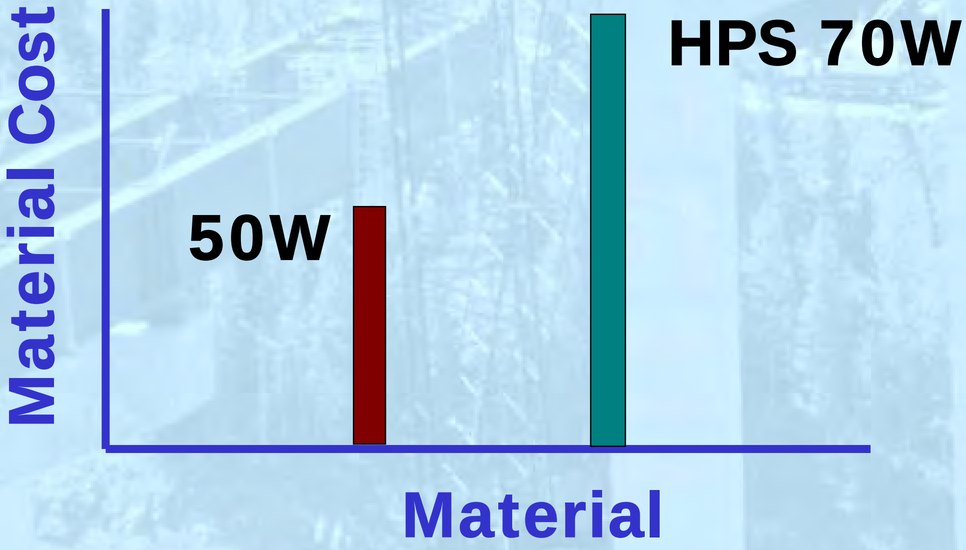
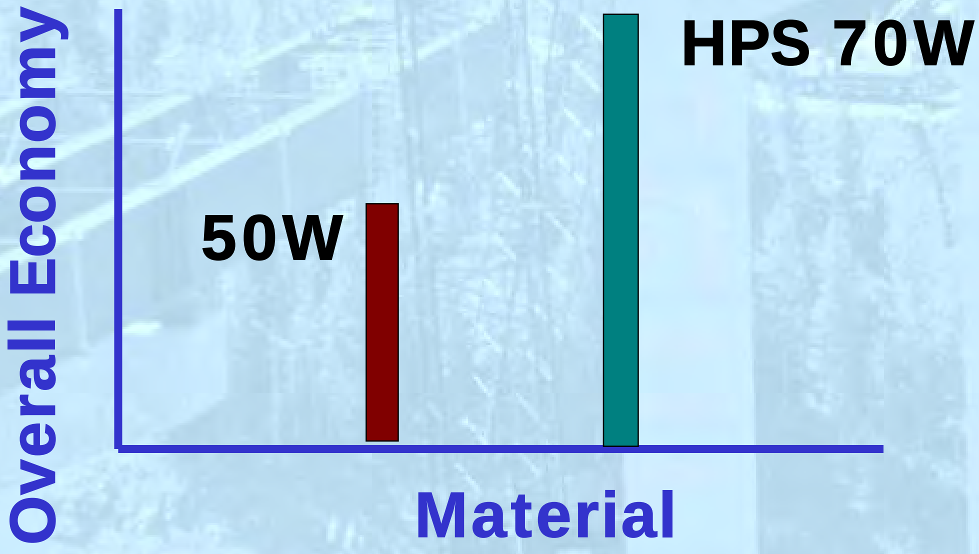


HPS Cost Comparison Study

When does greater strength and performance outweigh material unit cost to achieve overall economy?



Study showed the economy of hybrid girders.

HPS Cost Comparison Study

COST COMPARISON STUDY GOALS

Compare girder weight and fabrication cost associated with designs using Grade 50W and HPS 70W steel

Develop relative trends
Considering Variable:

- Span length
- Girder spacing
- Material combinations + Hybrids
- Girder depth

HPS Cost Comparison Study

COST COMPARISON STUDY GOALS

Develop fabrication cost comparisons with Fabricator input

Determine deflection effects (L/800)

Determine fatigue effects

Determine trends for box girders

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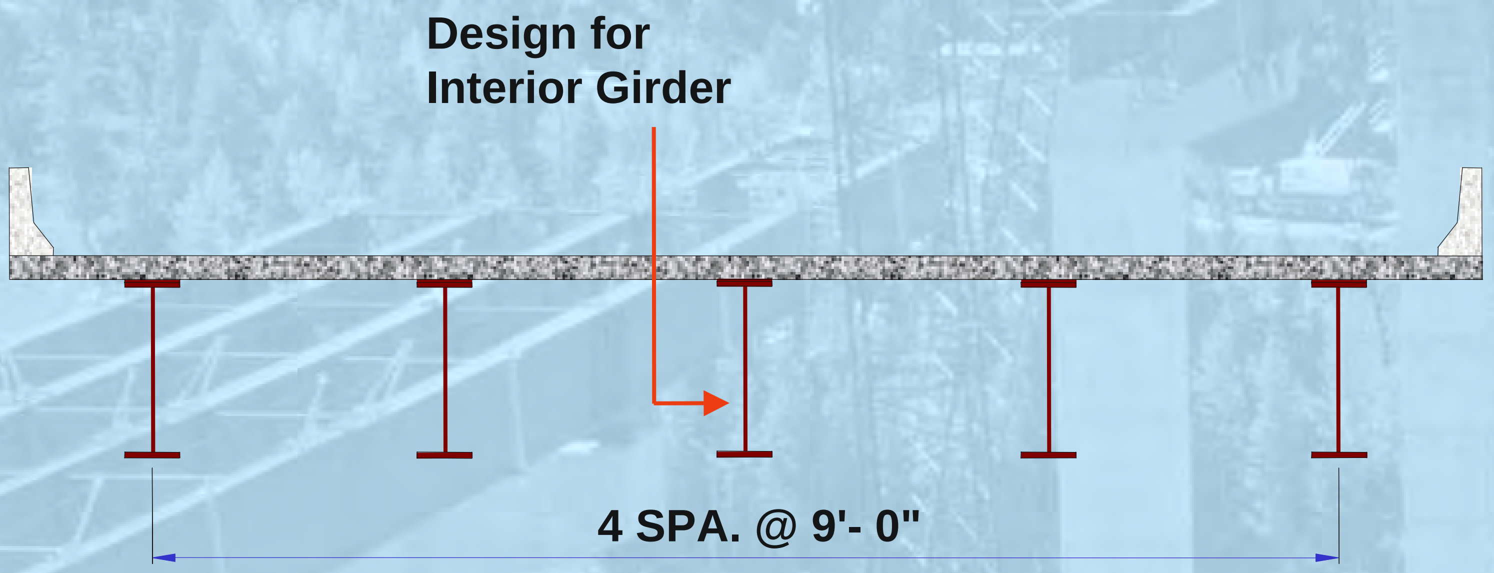
Two-Span bridge arrangement considered for study

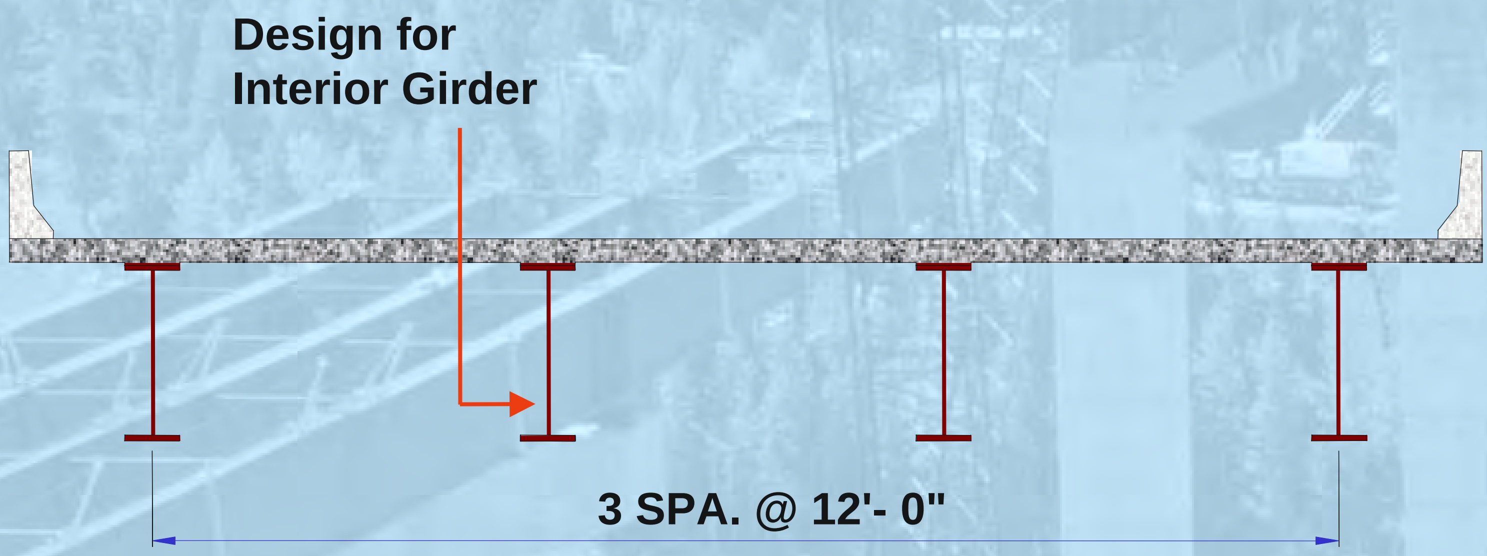
- **Positive and negative moment regions**
- **Simple design approach**
- **Popular grade separation structure**

HPS Cost Comparison Study

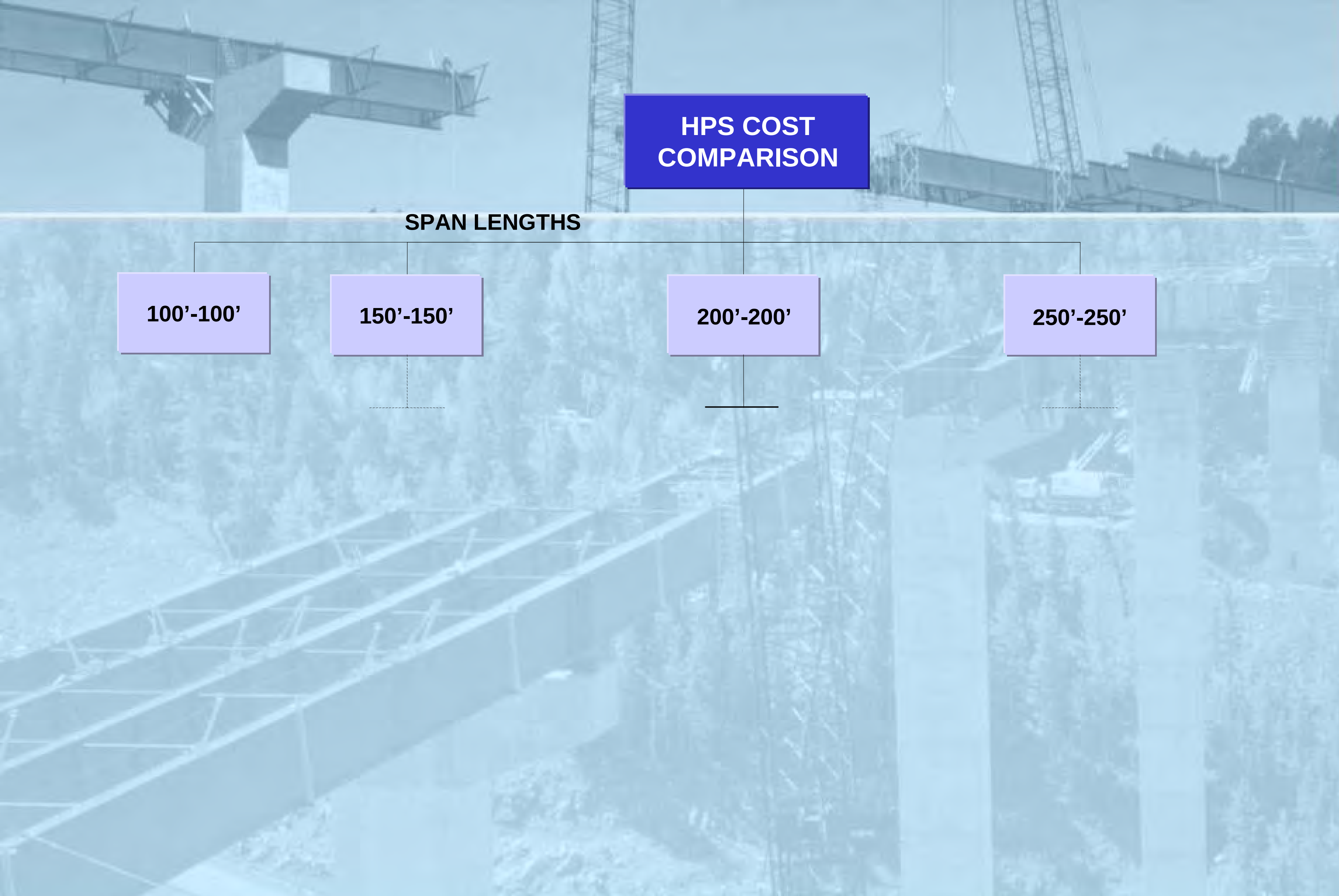


5 Girders @ 9’ Spacing

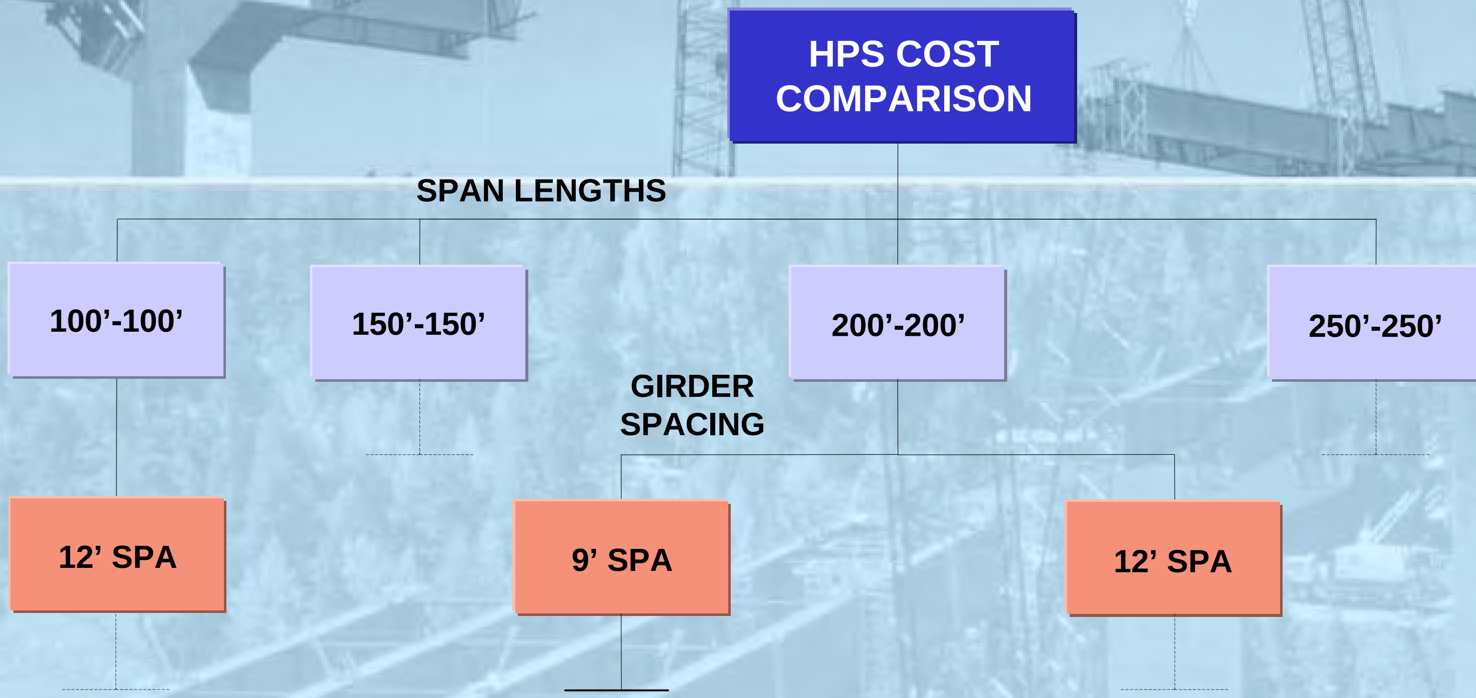
HPS Cost Comparison Study



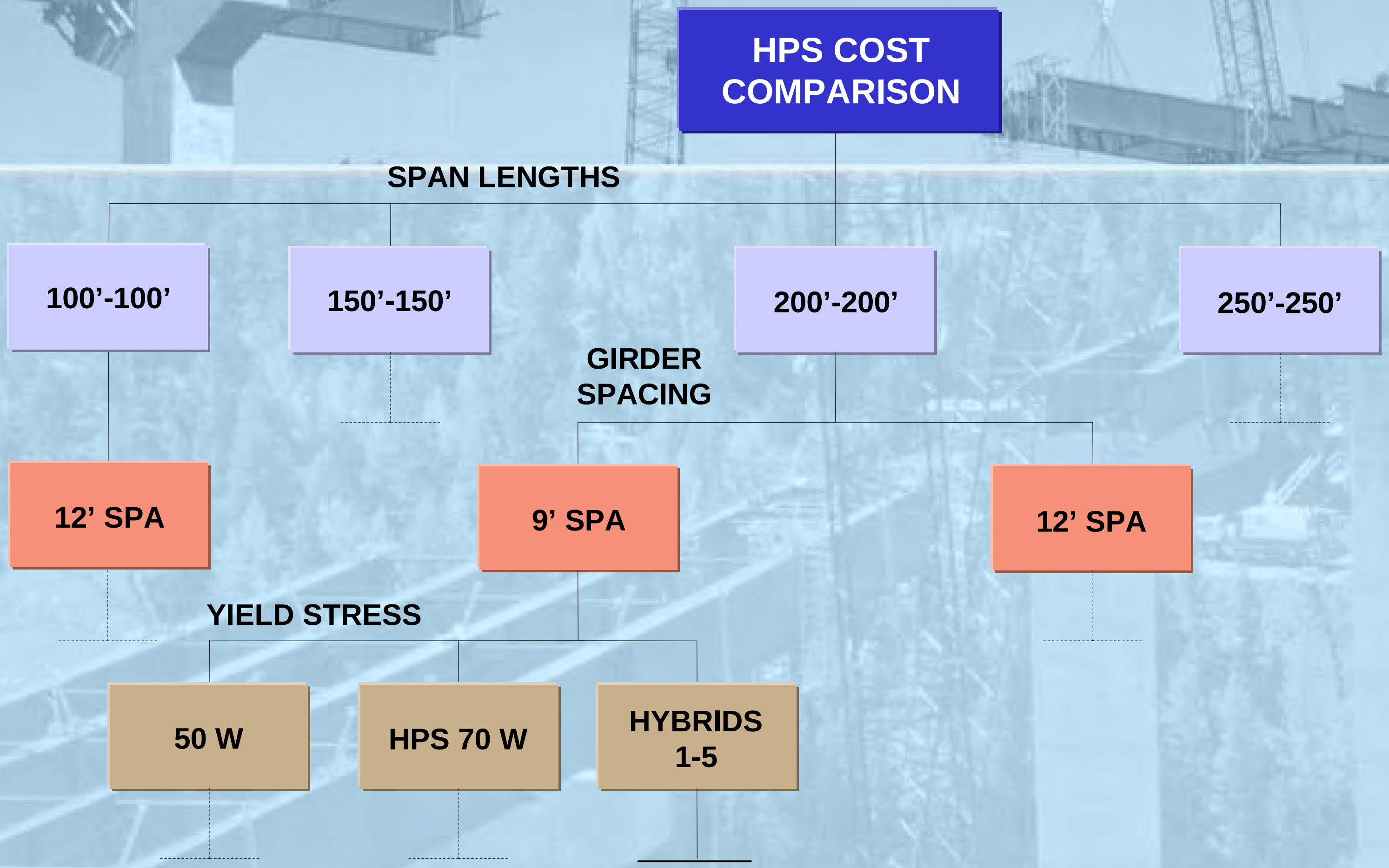
4 Girders @ 12’ Spacing



Design Flowchart



Design Flowchart



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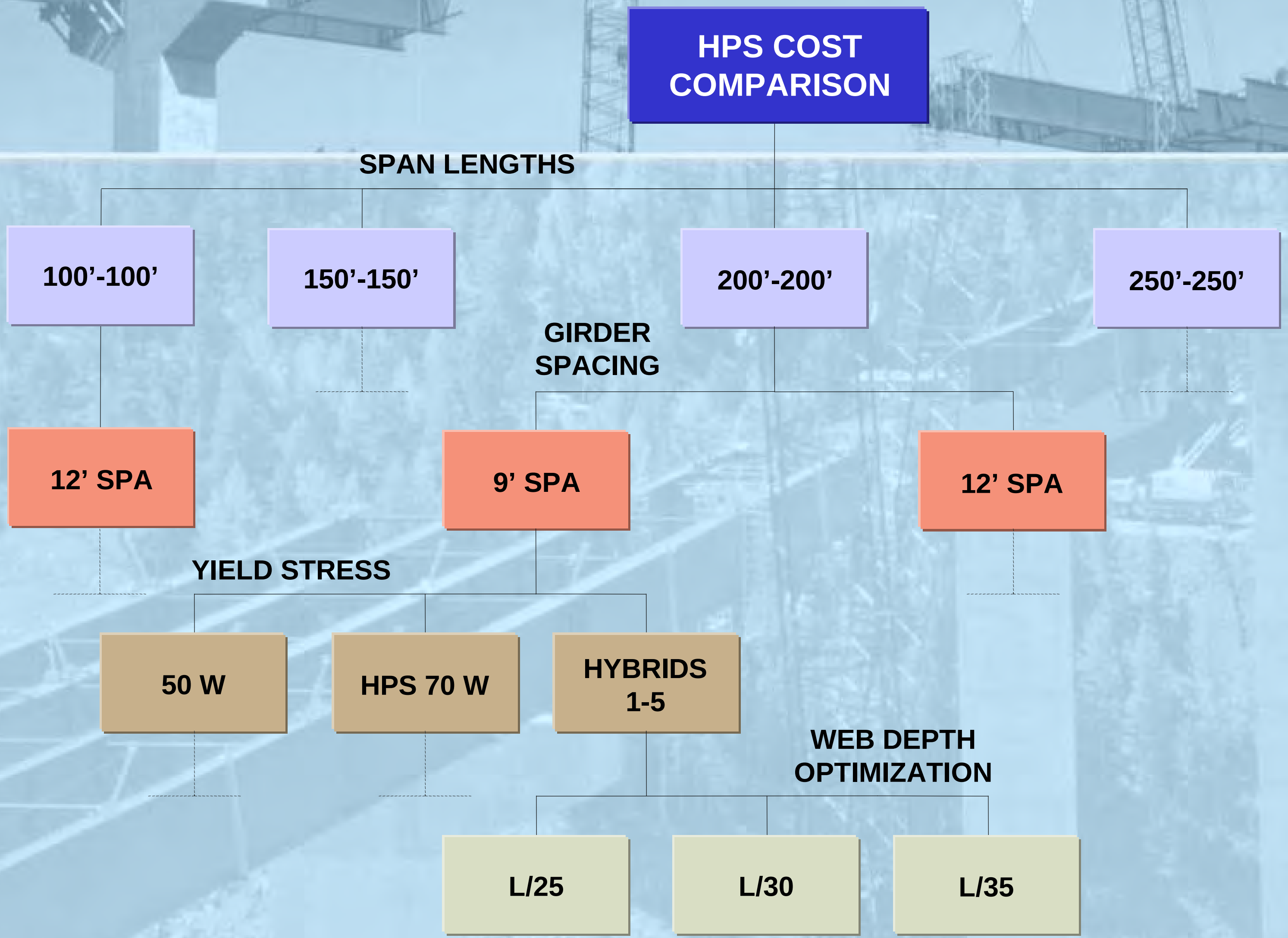
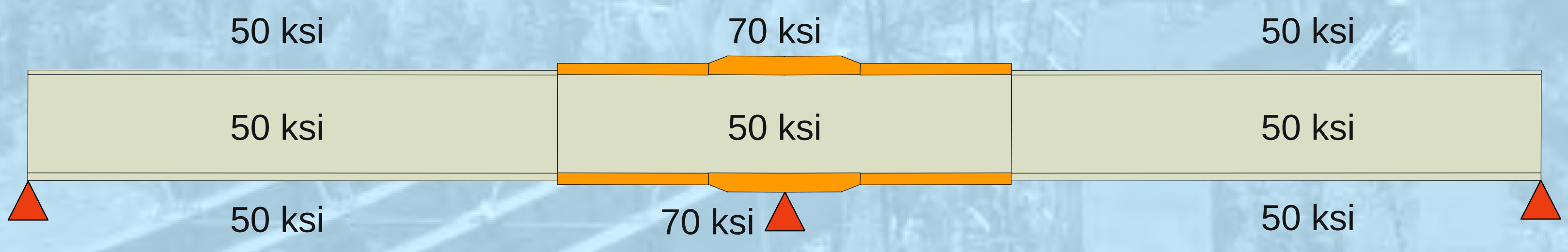


Design Flowchart

HPS Cost Comparison Study



HYBRID 1

Consider Hybrid 1 for shorter spans where Fatigue can control at positive moment bottom flanges.

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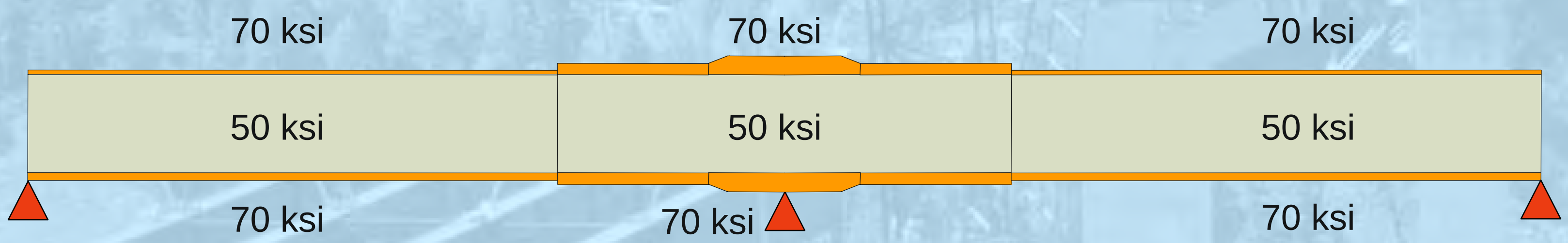

HYBRID 2

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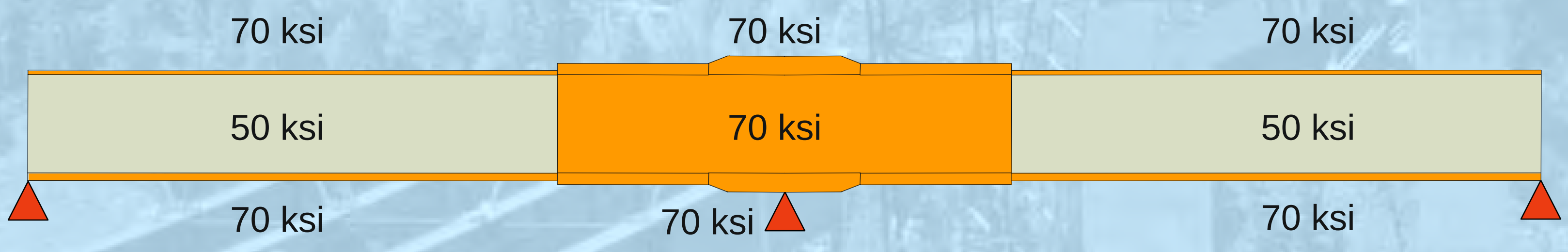
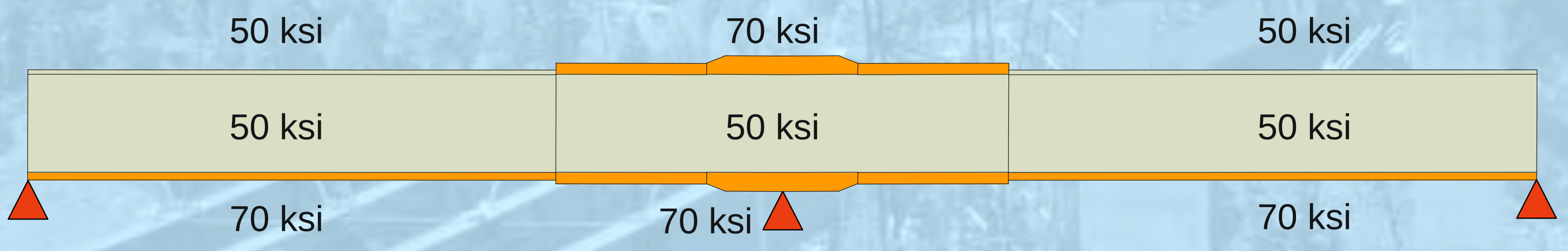


HYBRID 3

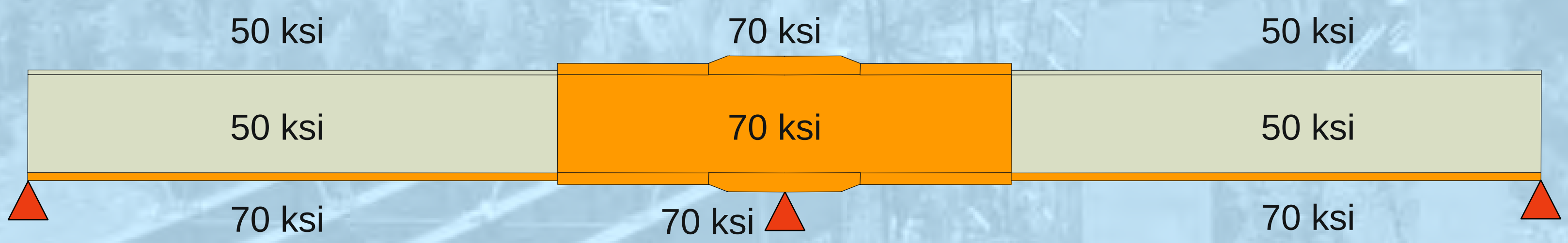
HPS Cost Comparison Study



HYBRID 4

Hybrid 4 was typically the most cost effective

HPS Cost Comparison Study

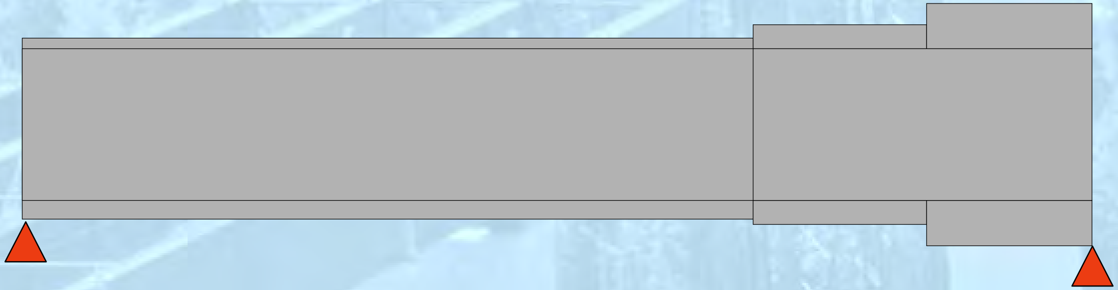


HYBRID 5

HPS Cost Comparison Study

Design Criteria

AASHTO LRFD 2nd Edition with 2000 Interim



Design parameters:

- Interior girder
- 25 ft. max cross frame spacing
- 12” x 3/4” minimum flange

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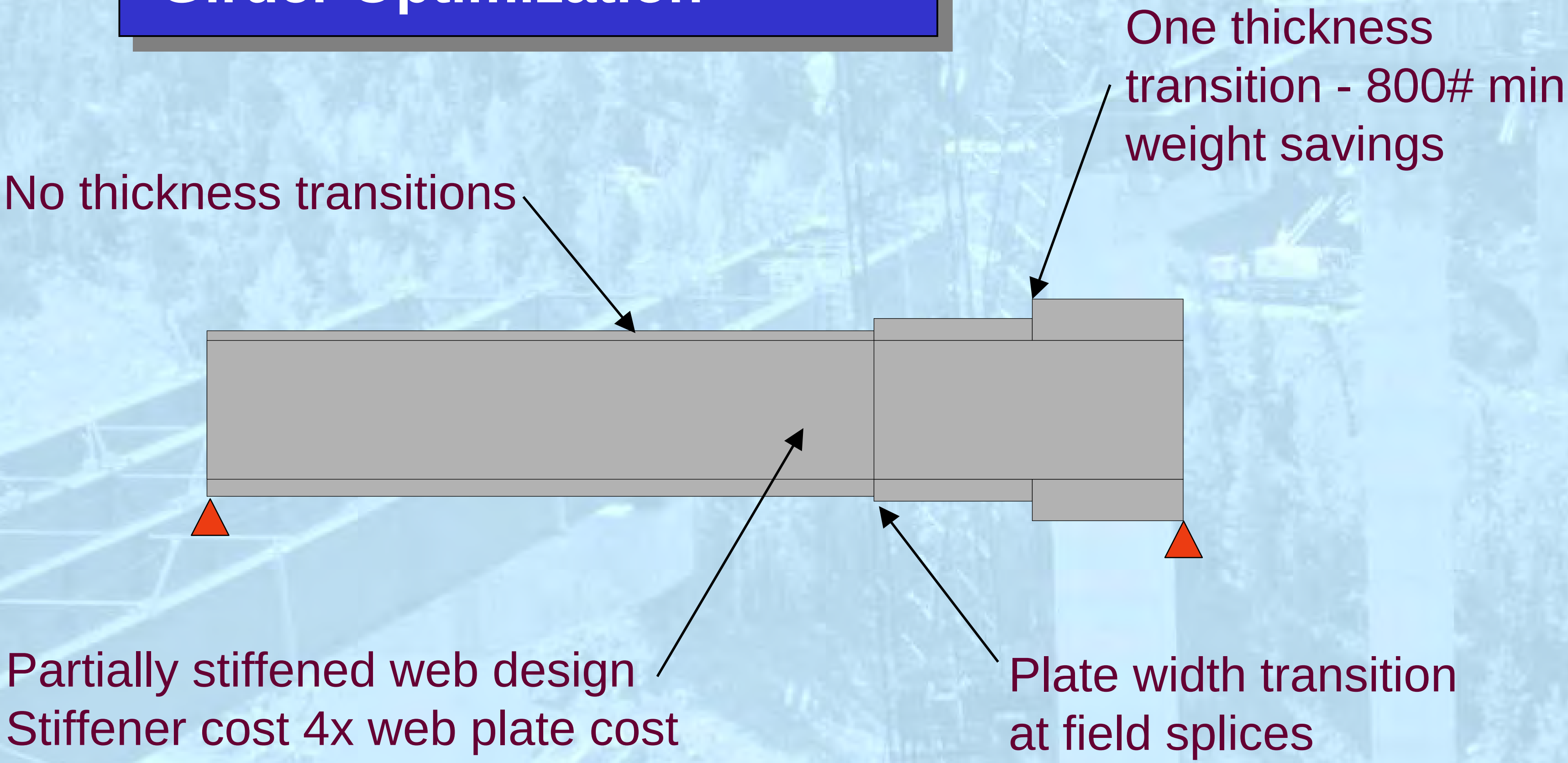
Girder Optimization



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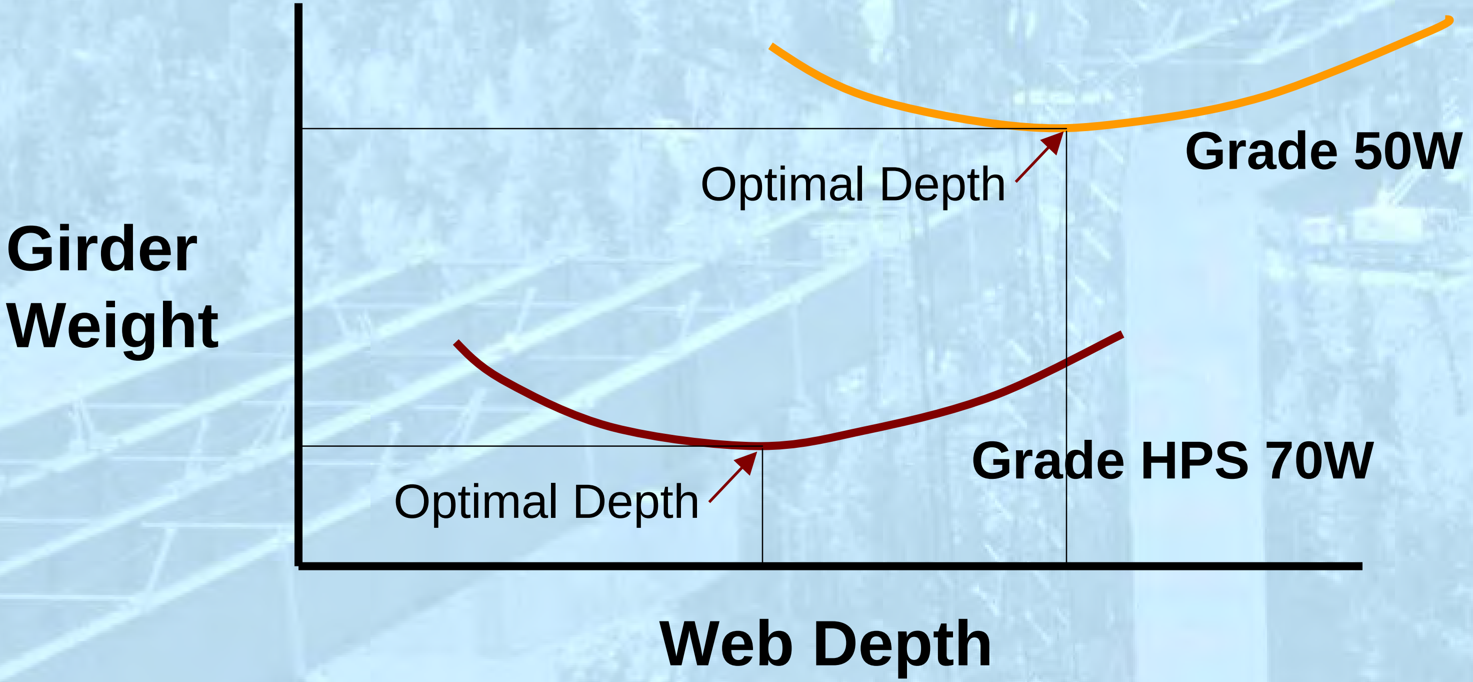
HPS 70W mill lengths

Thickness	Process	Length
<= 2”	Thermo Mechanical Controlled Processing (TMCP)	120’
> 2”	Quenching and Tempering (Q&T)	50’

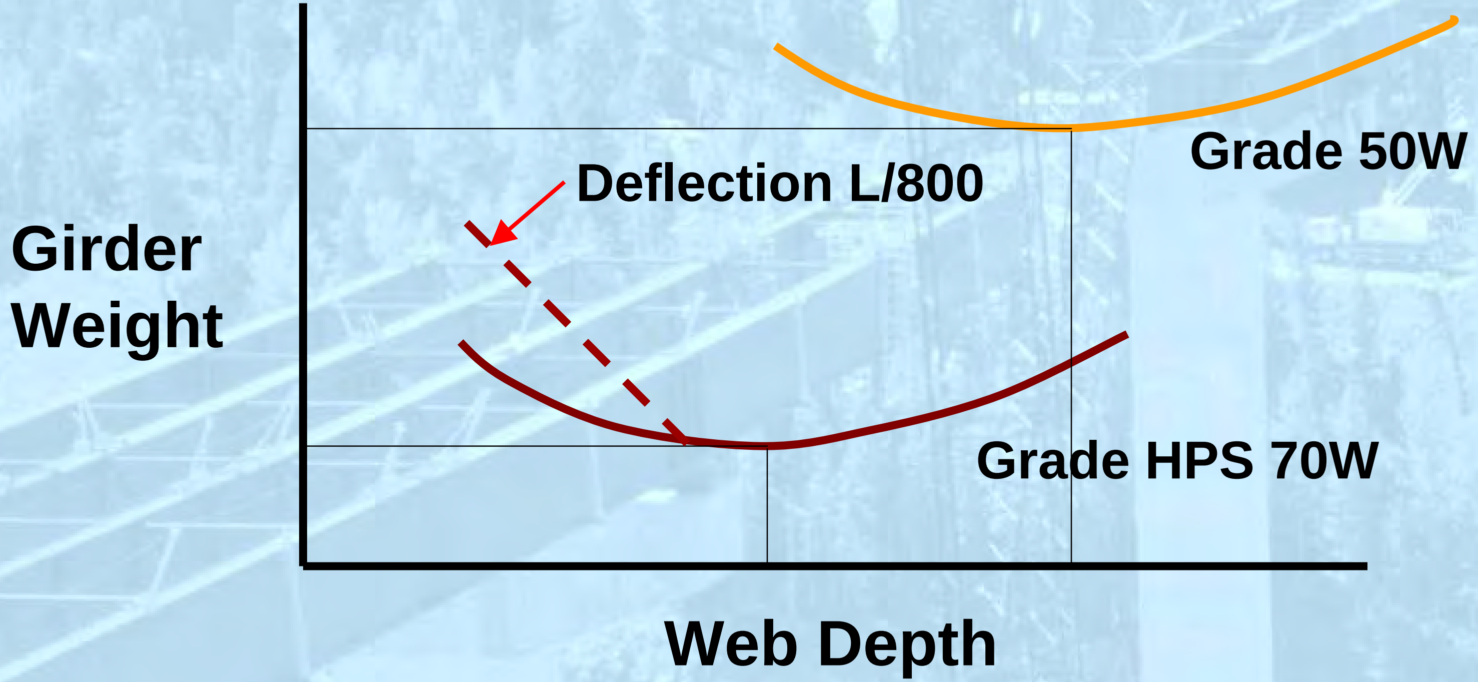
HPS Cost Comparison Study

Performance Characteristics



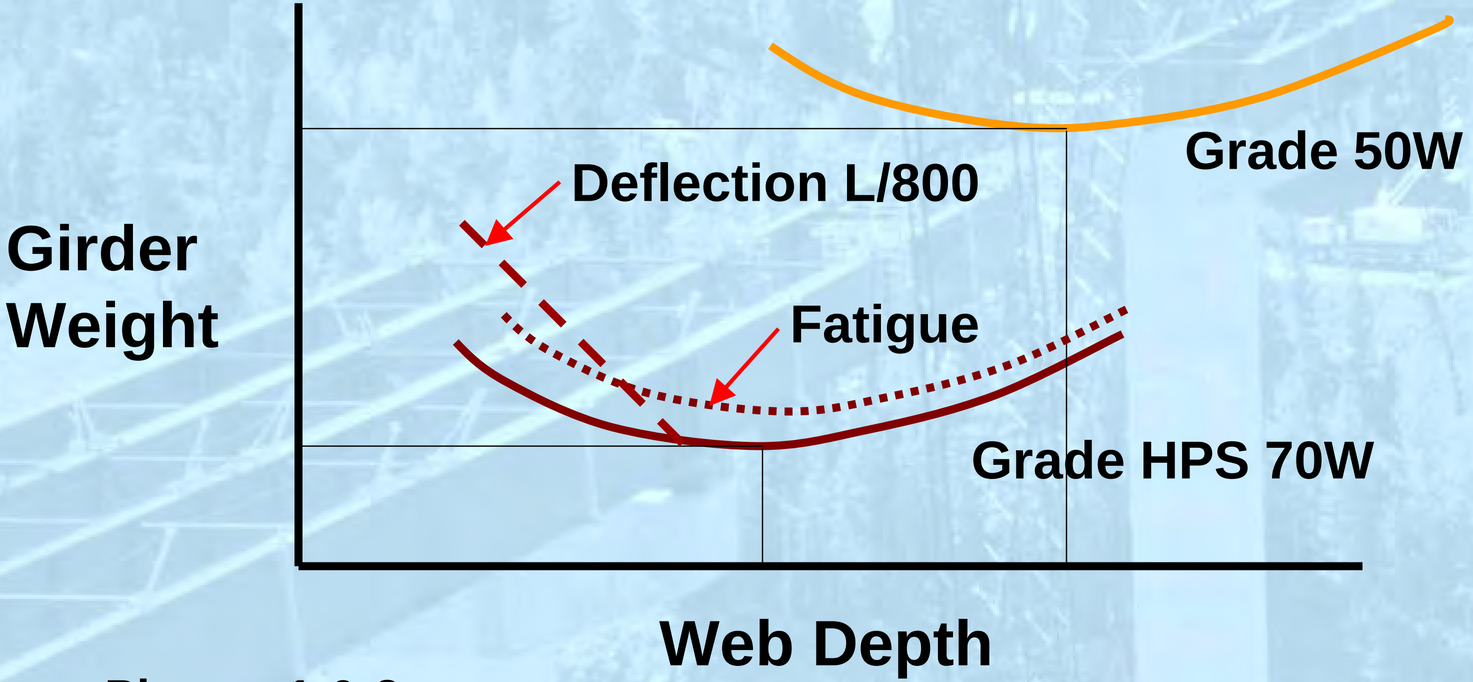
HPS Cost Comparison Study

Performance Characteristics



HPS Cost Comparison Study

Performance Characteristics

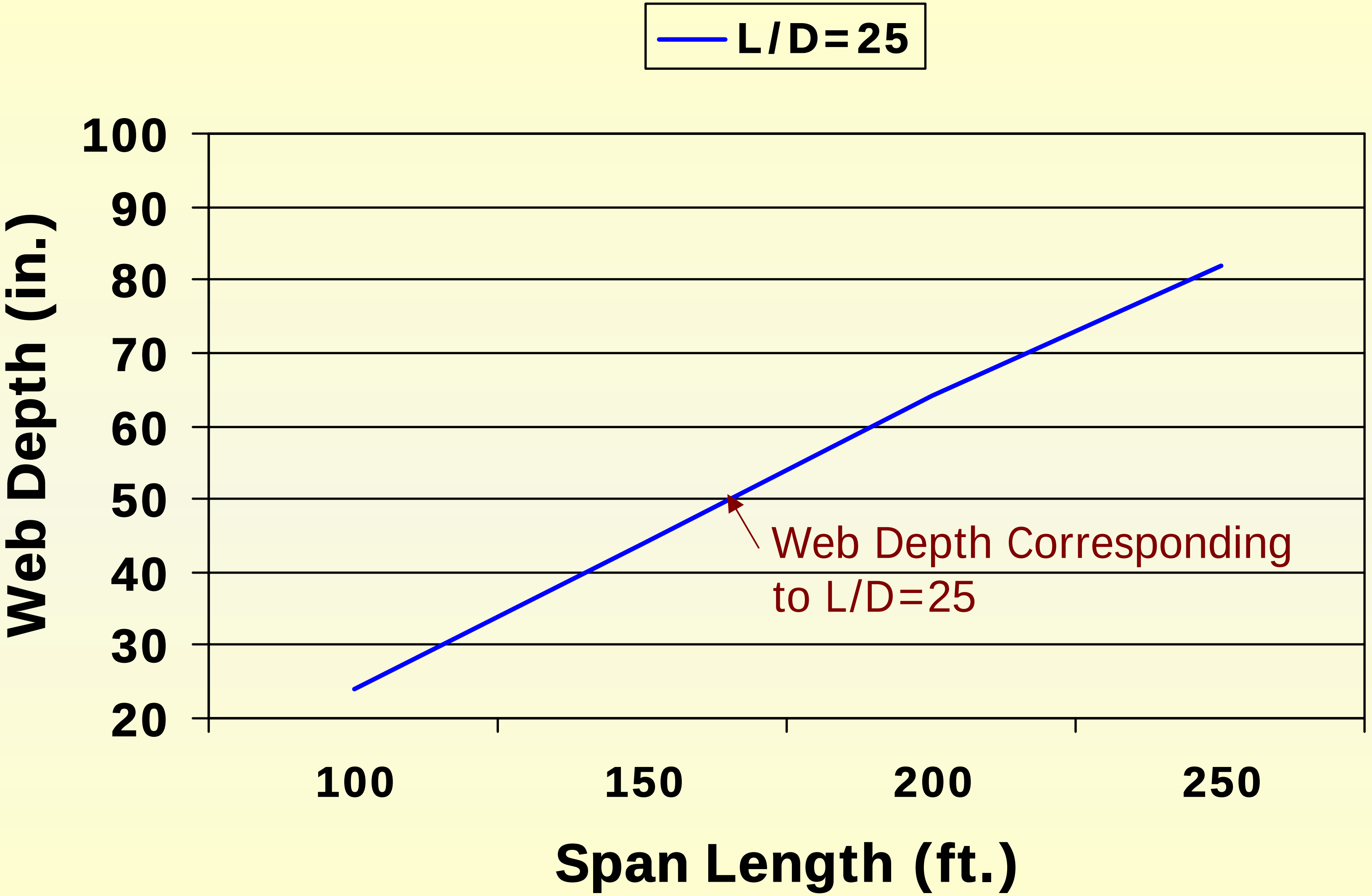


Phases 1 & 2

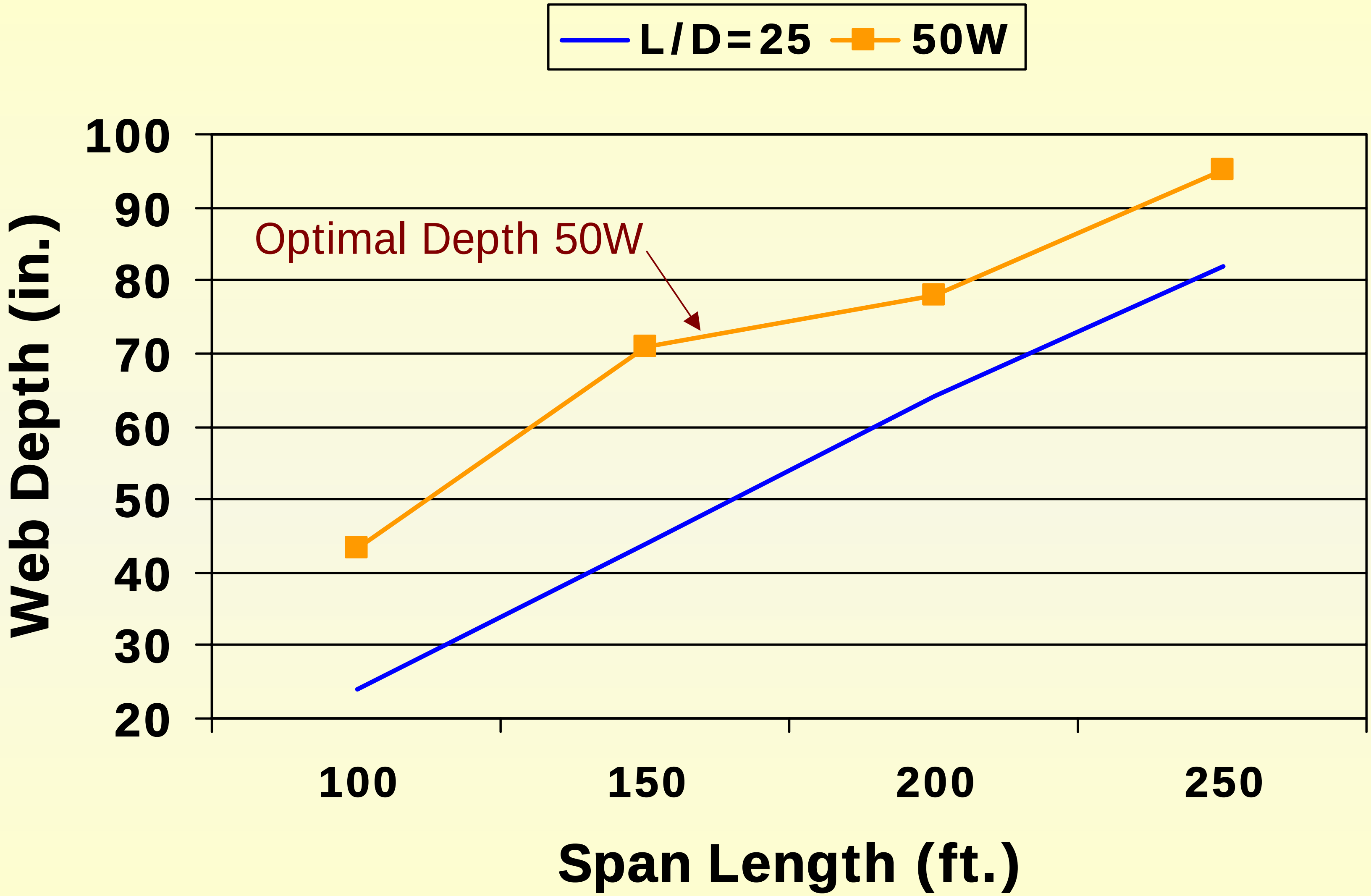
49 design combinations

170 girder designs

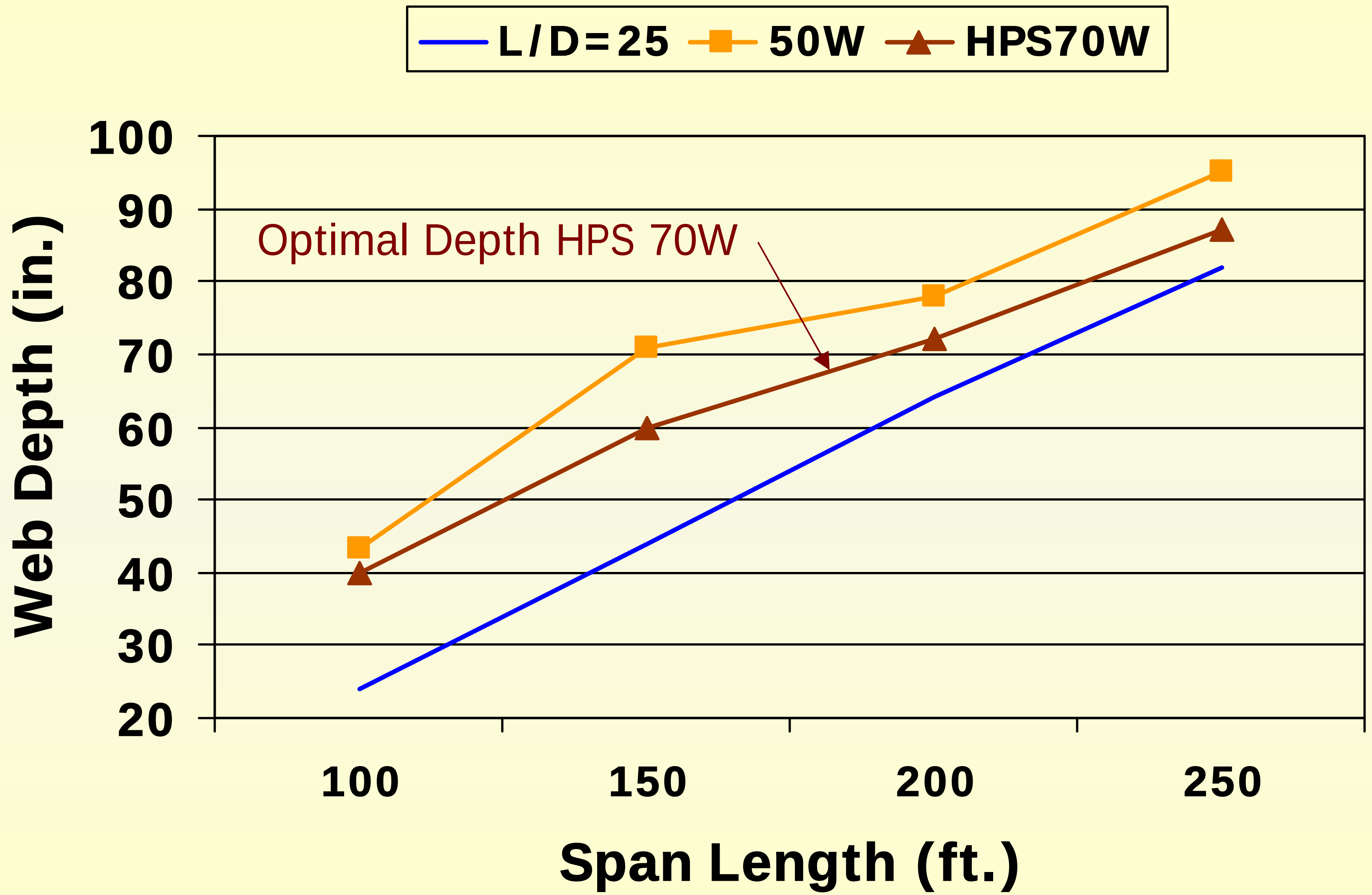
Optimal Depth and Deflection



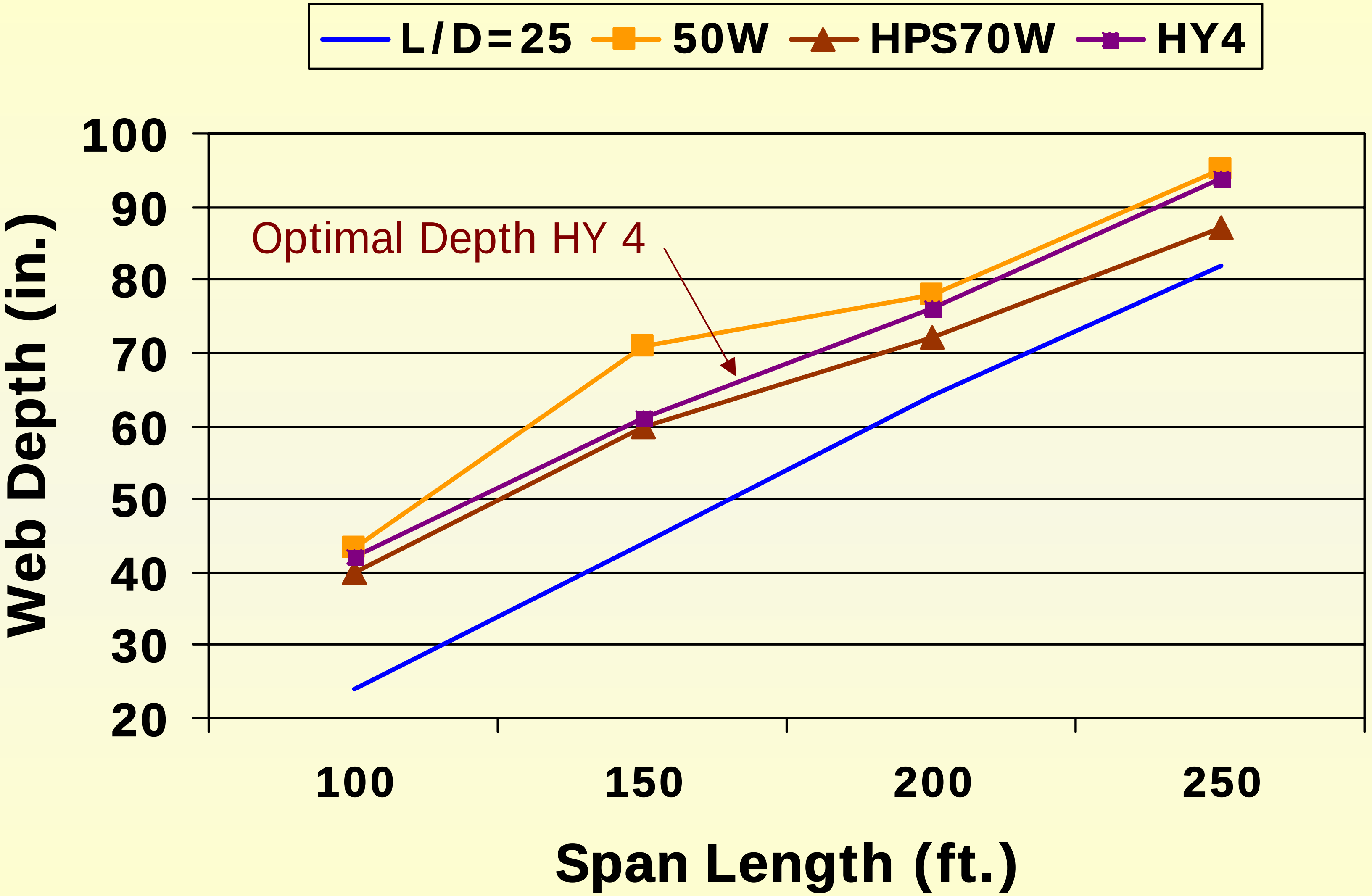
Optimal Depth and Deflection



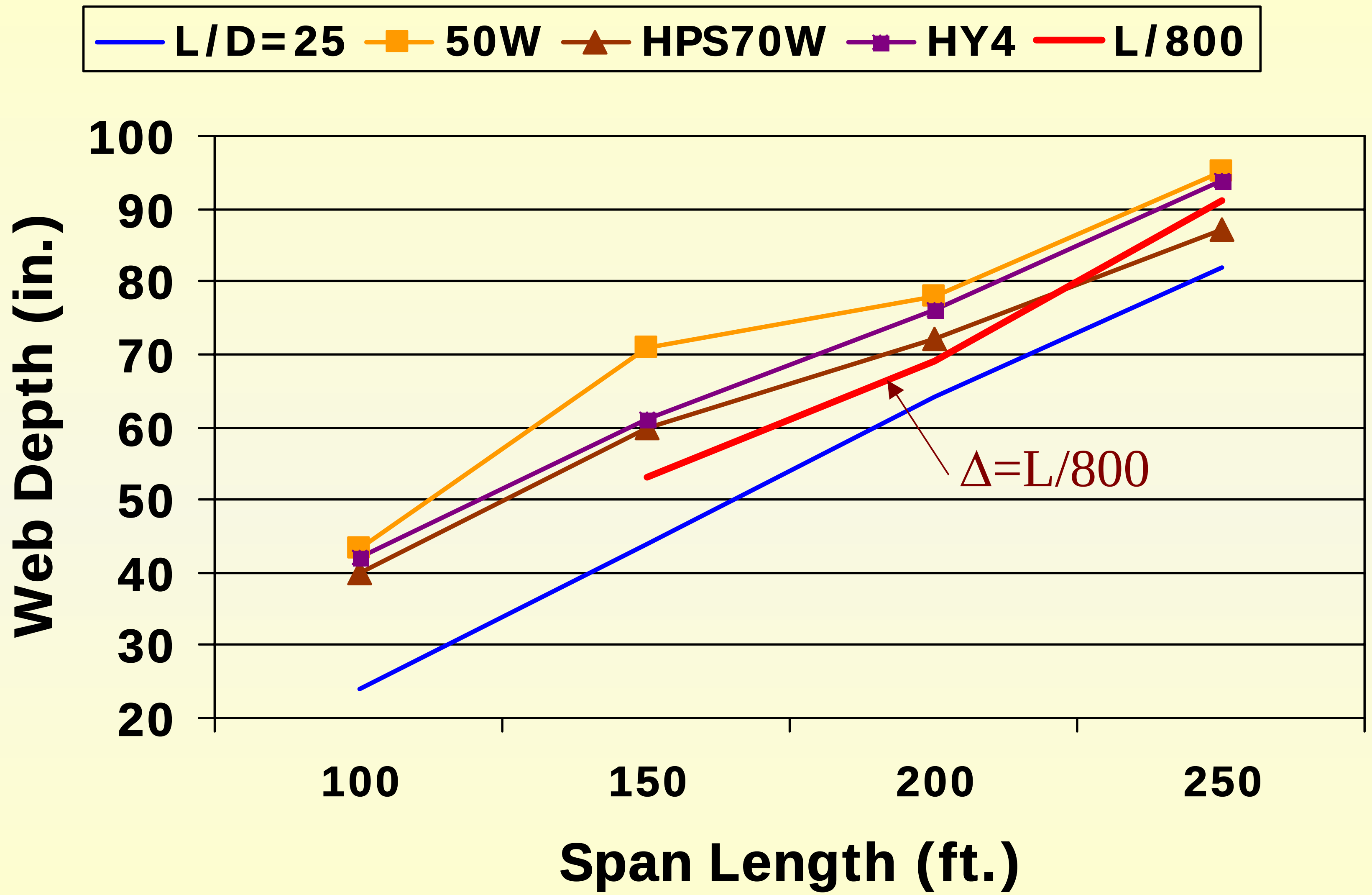
Optimal Depth and Deflection



Optimal Depth and Deflection



Optimal Depth and Deflection



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Optimal Girder Depths

Bridge Spans	Girder Spacing	50W	HPS 70W	Hybrid - 4
100'-100'	12'	42	40	41
150'-150'	9'	63	56	53
	12'	71	60	61
200'-200'	9'	76	70 (68)	72
	12'	78	72 (69)	76 (70)
250'-250'	9'	90	77 (84)	86 (86)
	12'	95	87 (91)	94 (93)

( ) – Depth where deflection equals L/800

HPS Cost Comparison Study

Fatigue

When does Fatigue affect the cost effectiveness of HPS 70W steel?

HPS Cost Comparison Study

Fatigue

When does Fatigue affect the cost effectiveness of HPS 70W steel?

Fatigue resistance is a variable based on:

- **detail category**
- **average daily truck traffic**

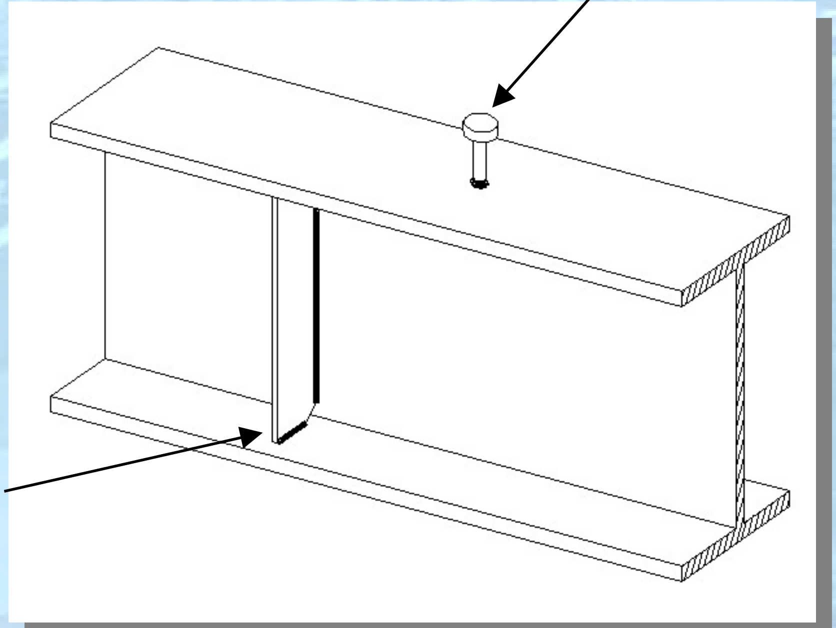
HPS Cost Comparison Study

Fatigue

Two Fatigue Detail Categories Considered

Stud Shear Connector

Category C



Welded Cross Frame Stiffener

Category C’

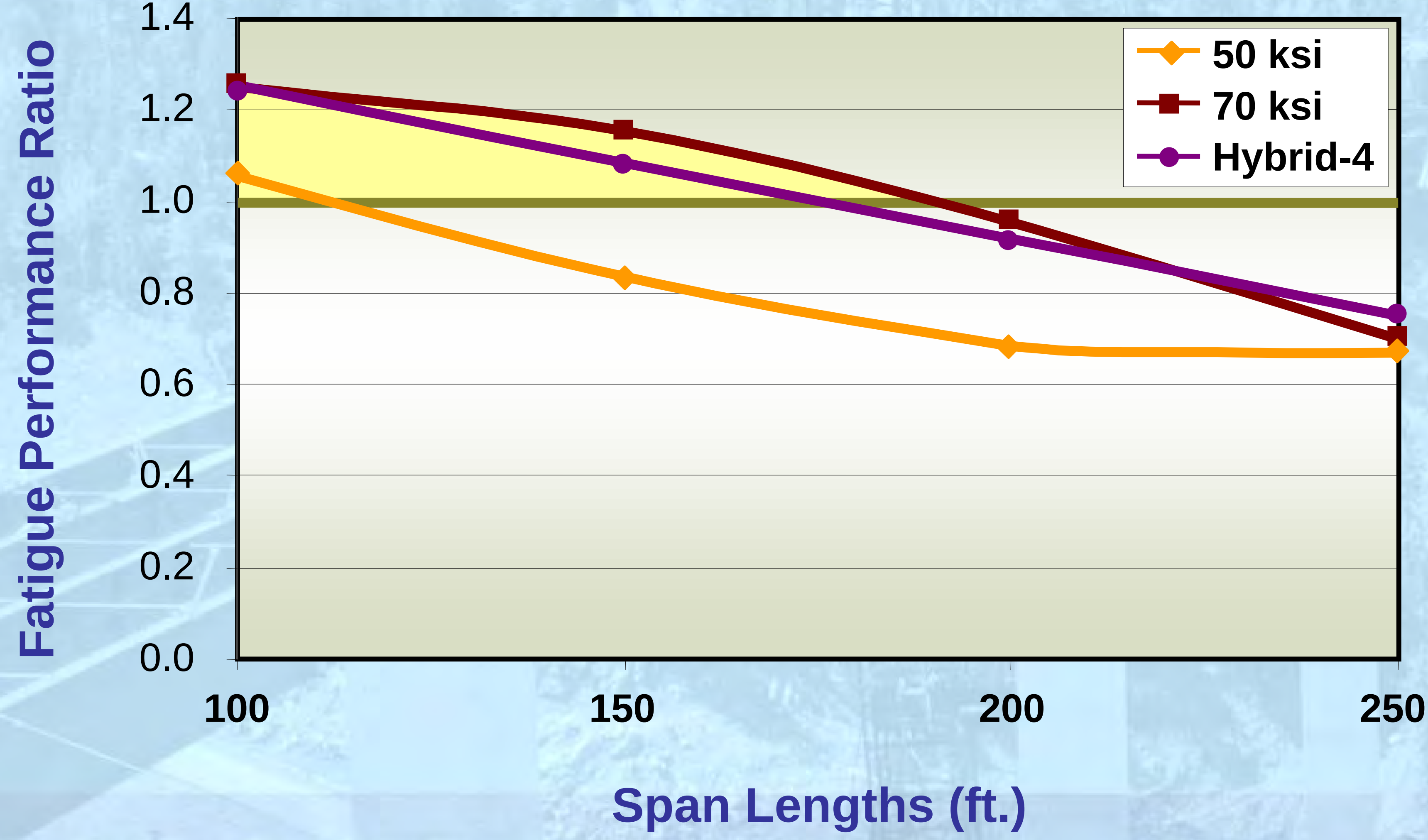
HPS Cost Comparison Study

Fatigue

Limiting value of Average Daily Truck Traffic (ADTT) used for study

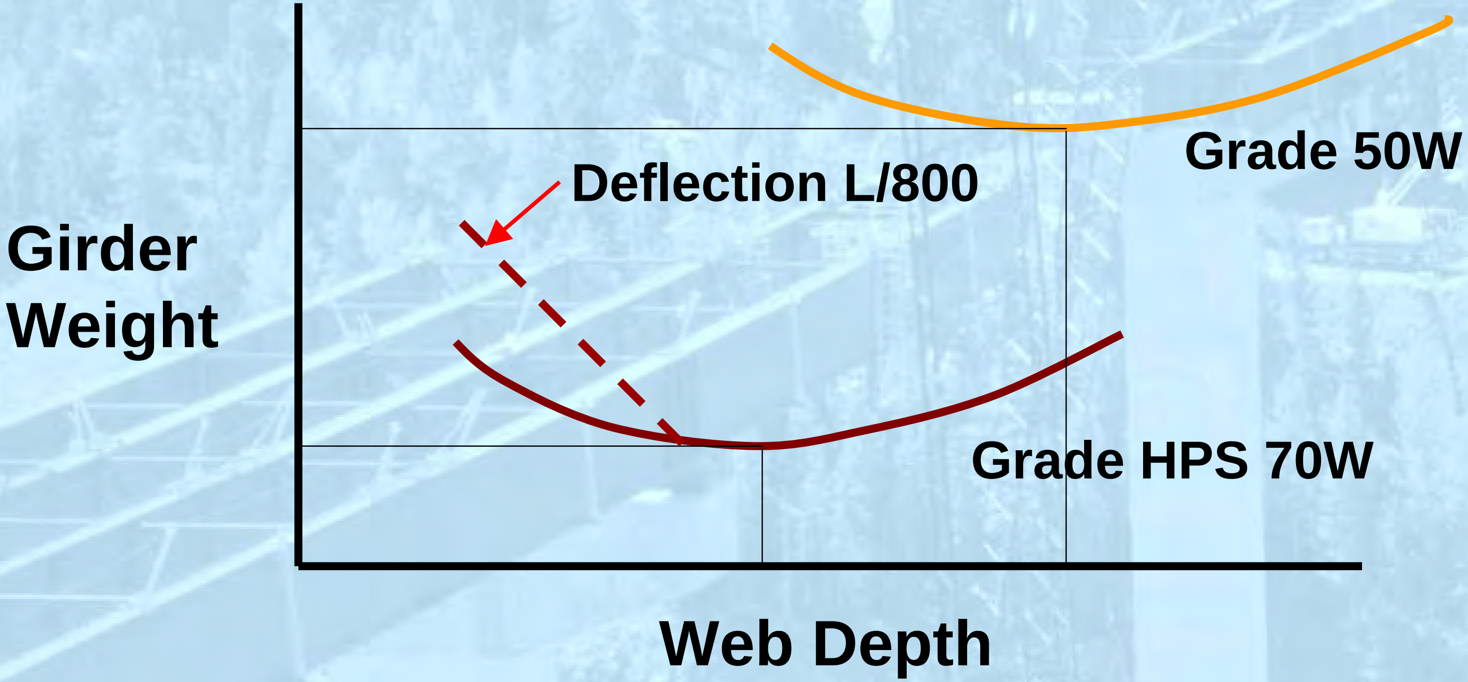
- **Results in conservative lower bound fatigue resistance.**
- **Corresponds to Interstate roadway or urban arterial.**
- **Ramps, overpasses, rural roads, etc. with lower ADTT will have higher fatigue resistance limits.**

Load Induced Fatigue
Bottom Category C' - 12 ft. Girder Spacing

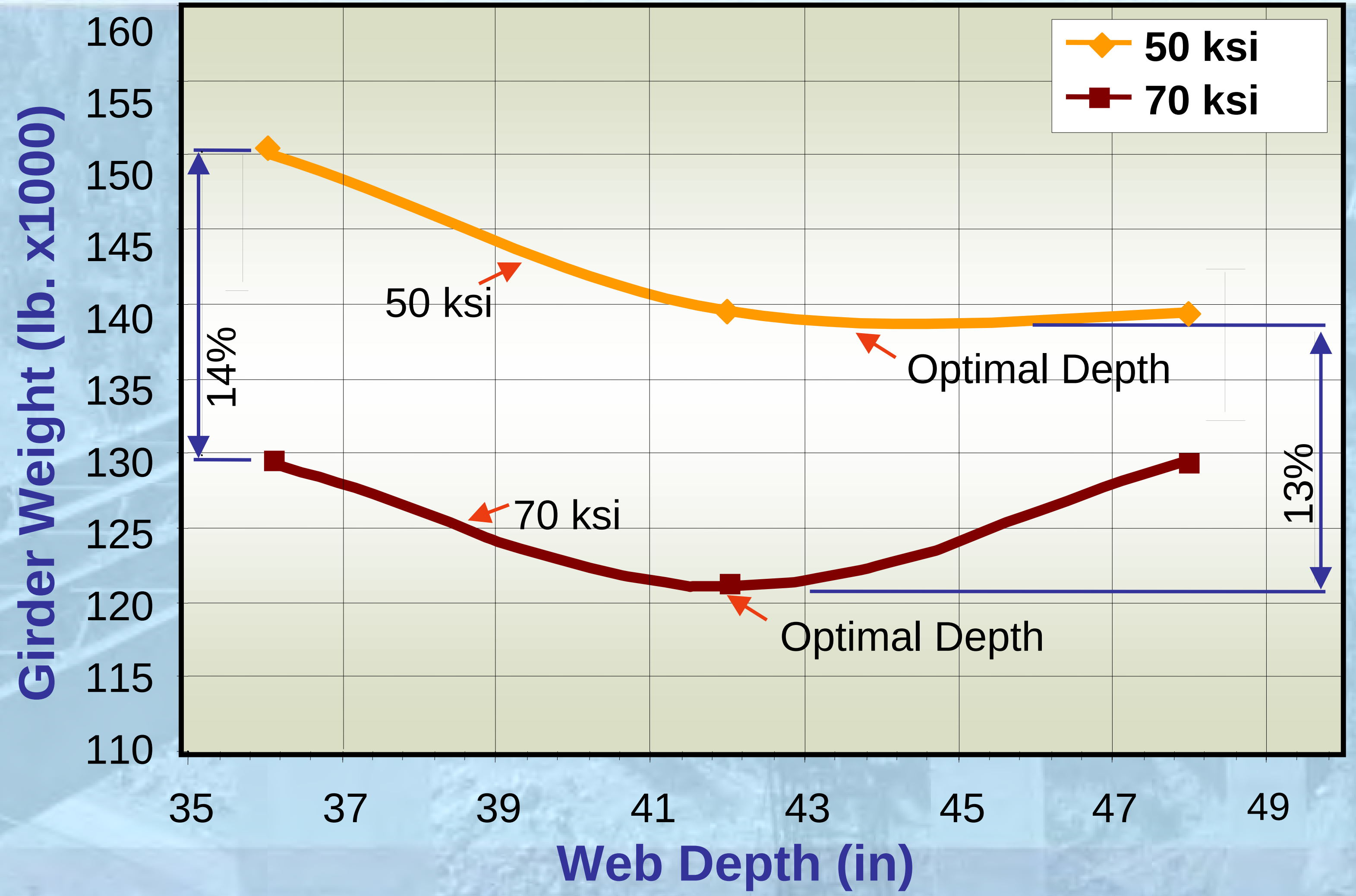


HPS Cost Comparison Study

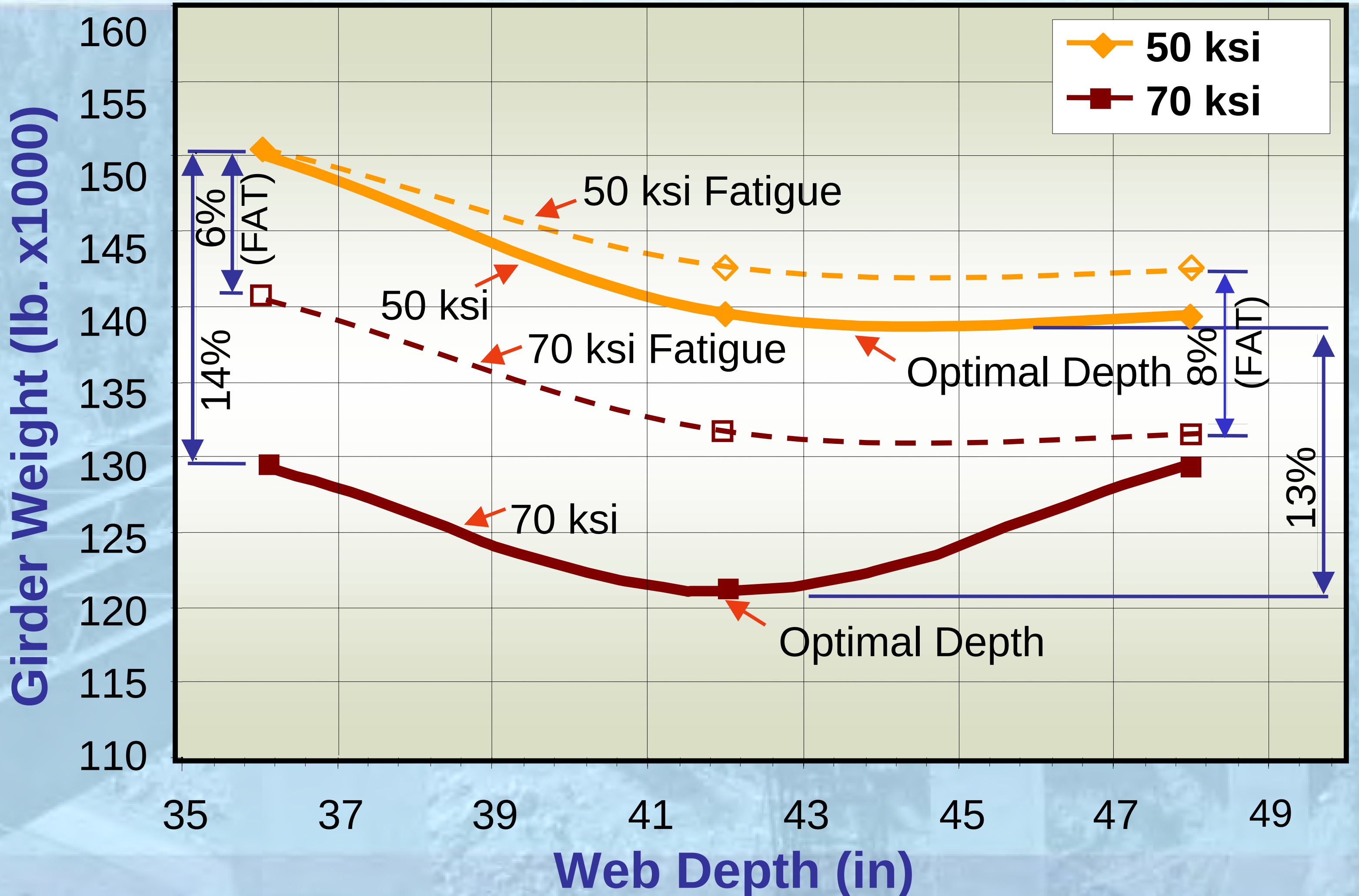
Girder Weight Comparisons



Girder Weight Comparisons
100 ft. Spans & 12 ft. Girder Spacing

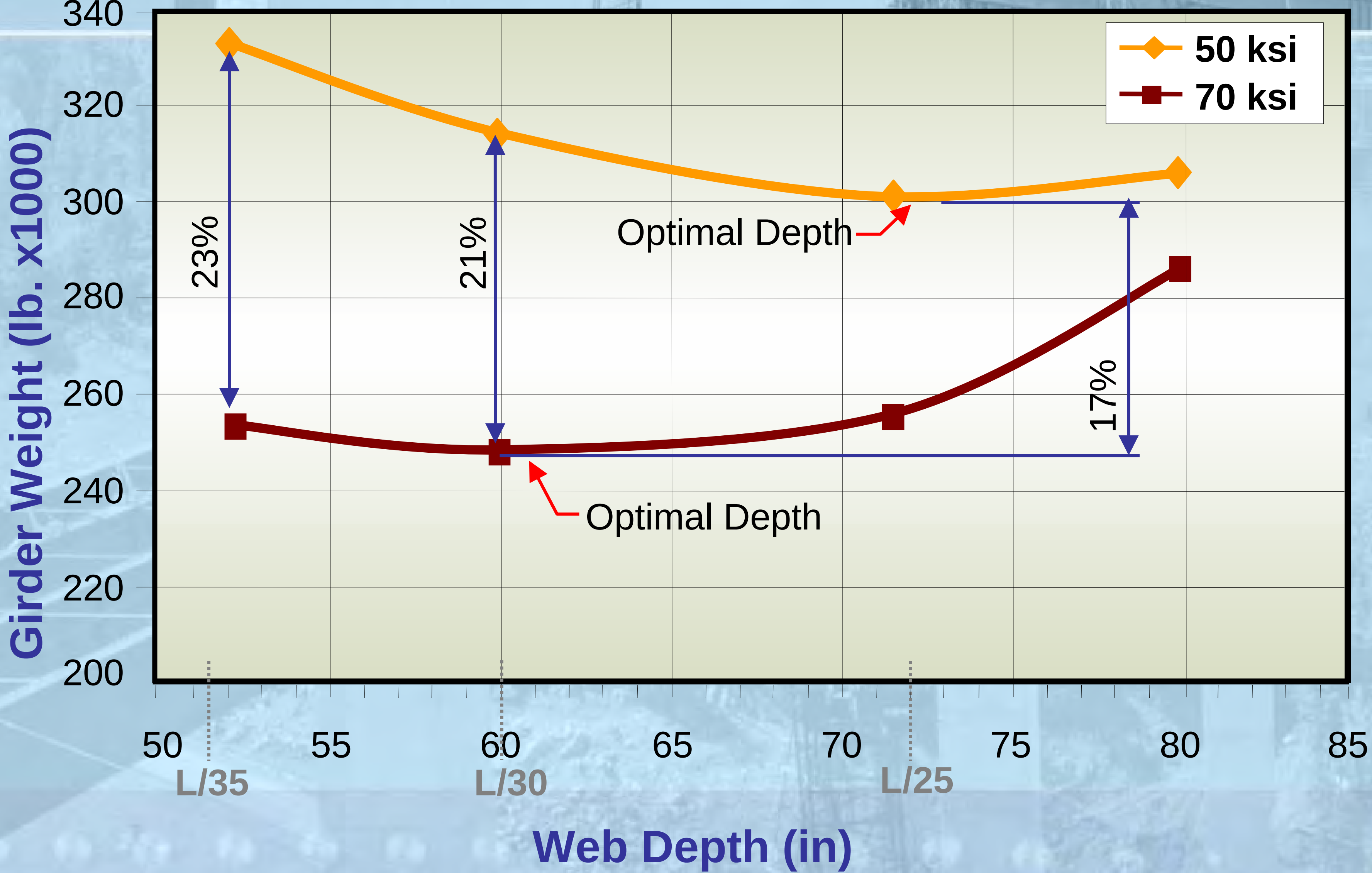


Girder Weight Comparisons
100 ft. Spans & 12 ft. Girder Spacing



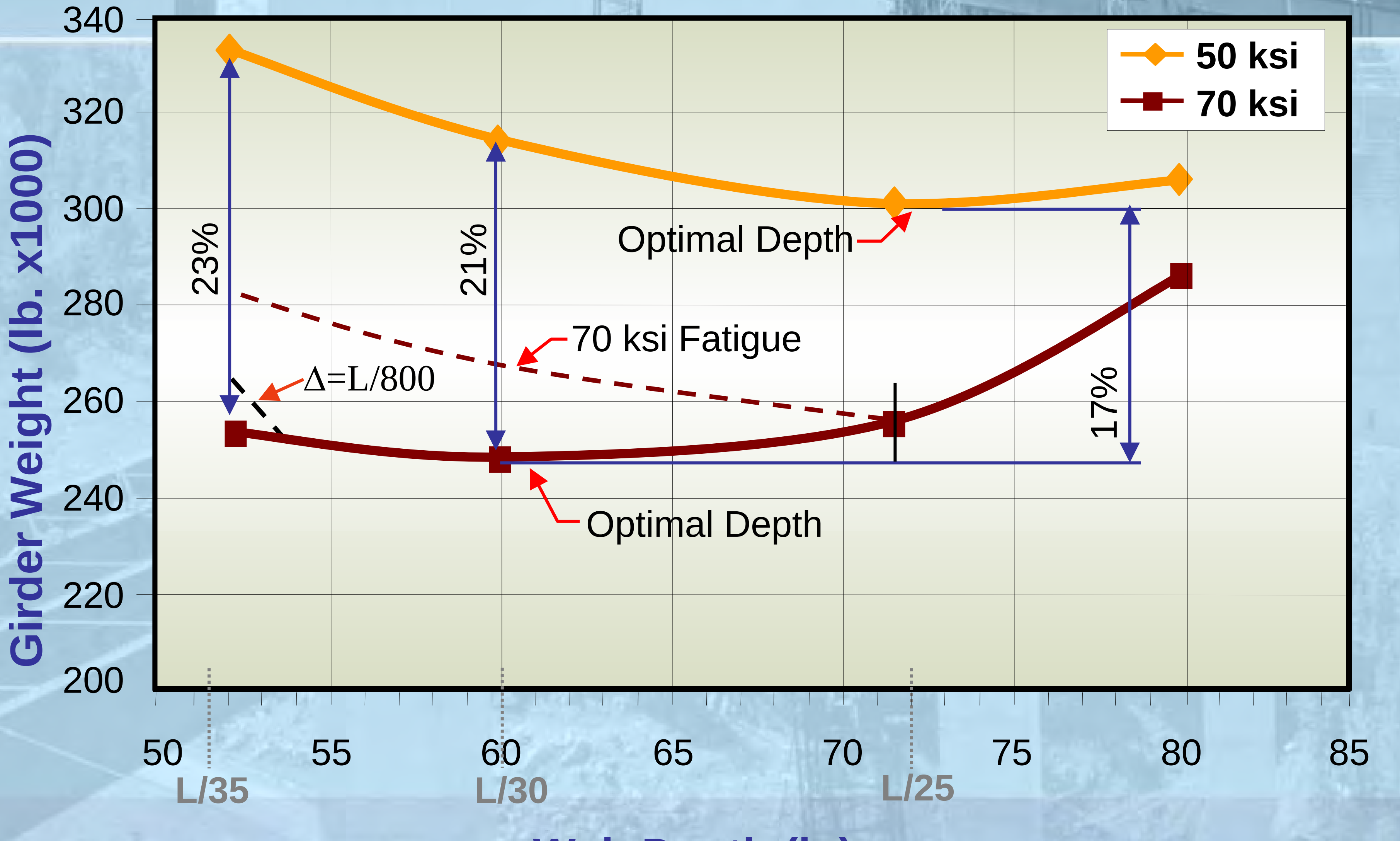
Girder Weight Comparisons

150 ft. Spans & 12 ft. Girder Spacing



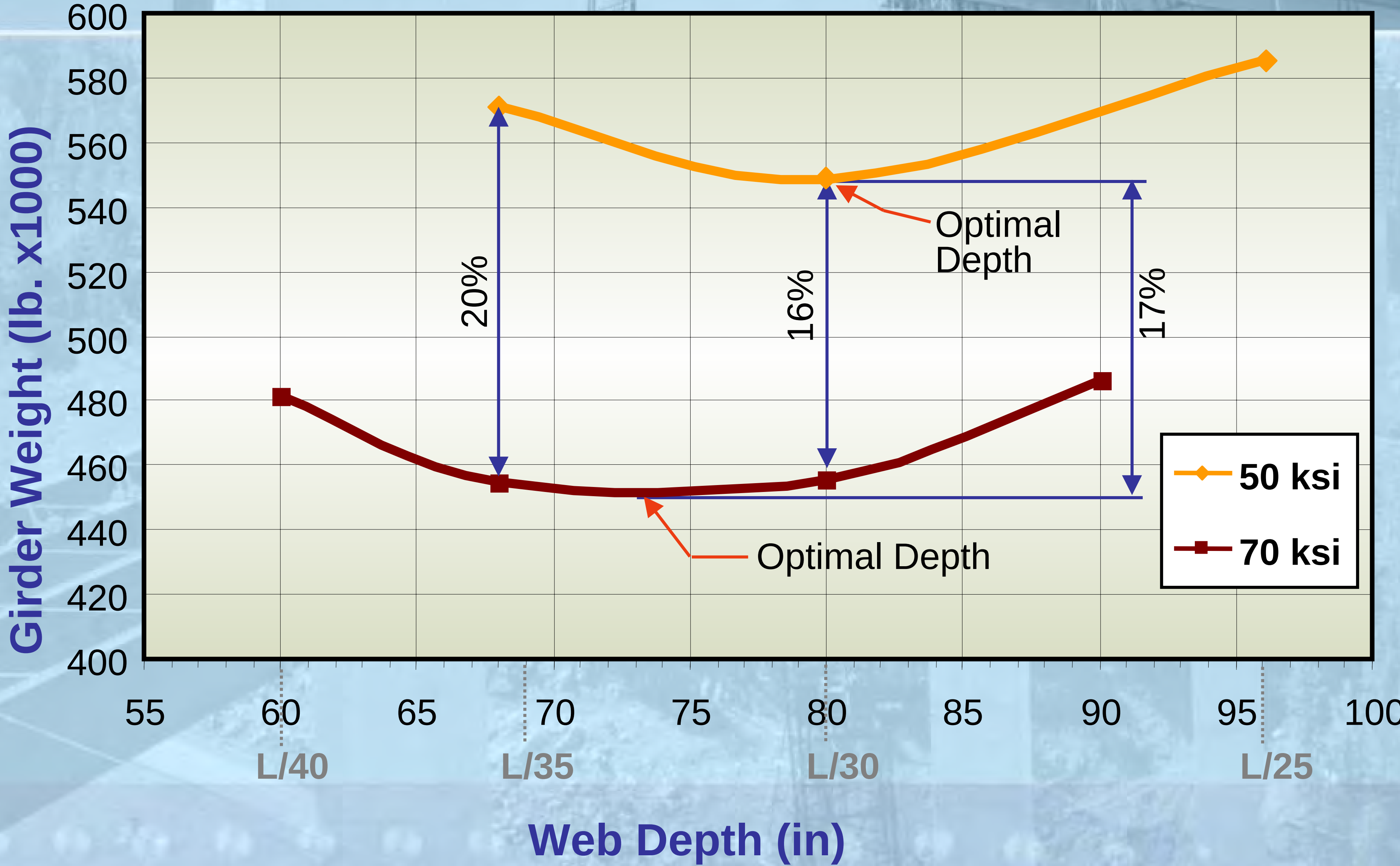
Girder Weight Comparisons

150 ft. Spans & 12 ft. Girder Spacing



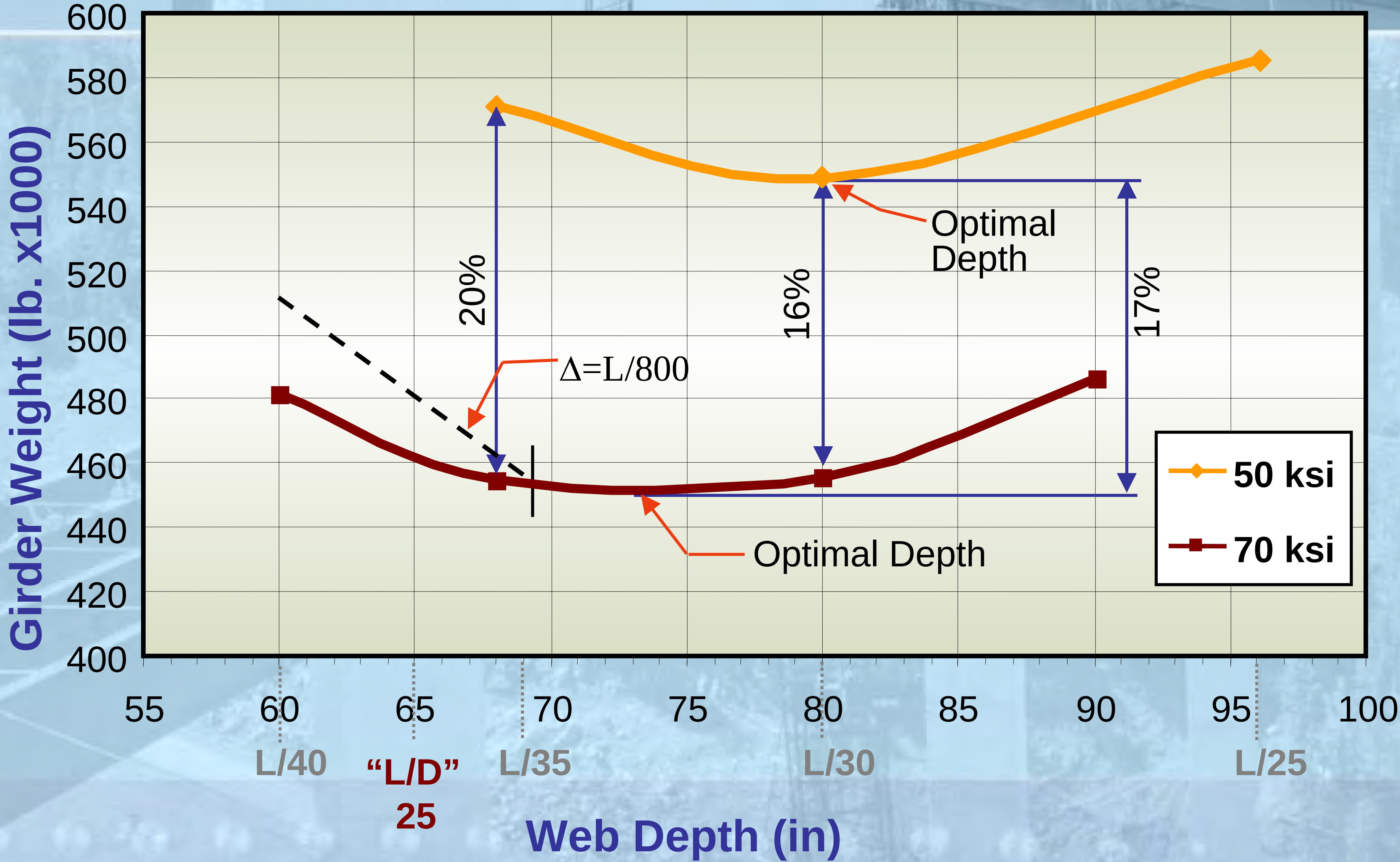
Girder Weight Comparisons

200 ft. Spans & 12 ft. Girder Spacing

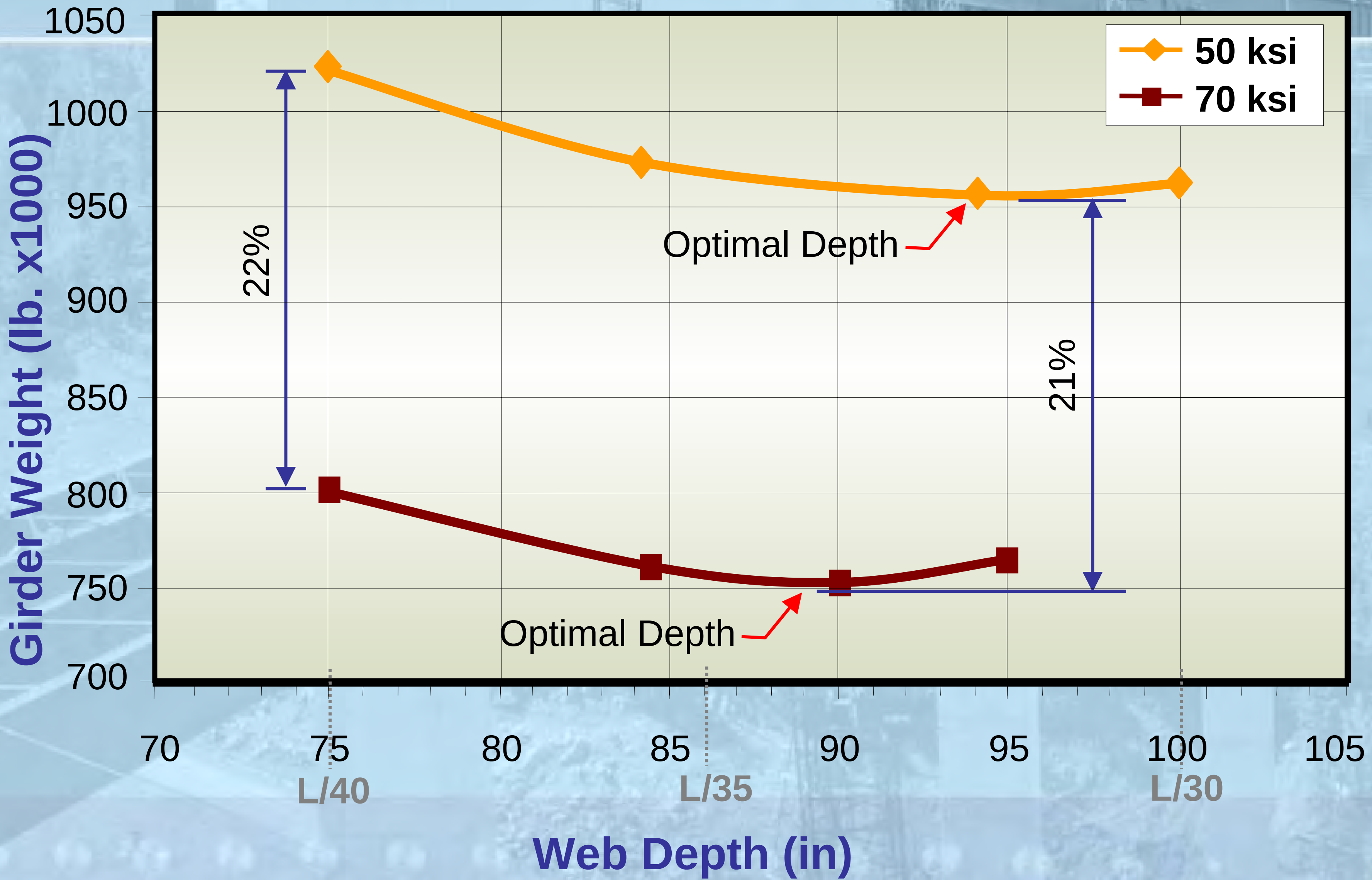


Girder Weight Comparisons

200 ft. Spans & 12 ft. Girder Spacing

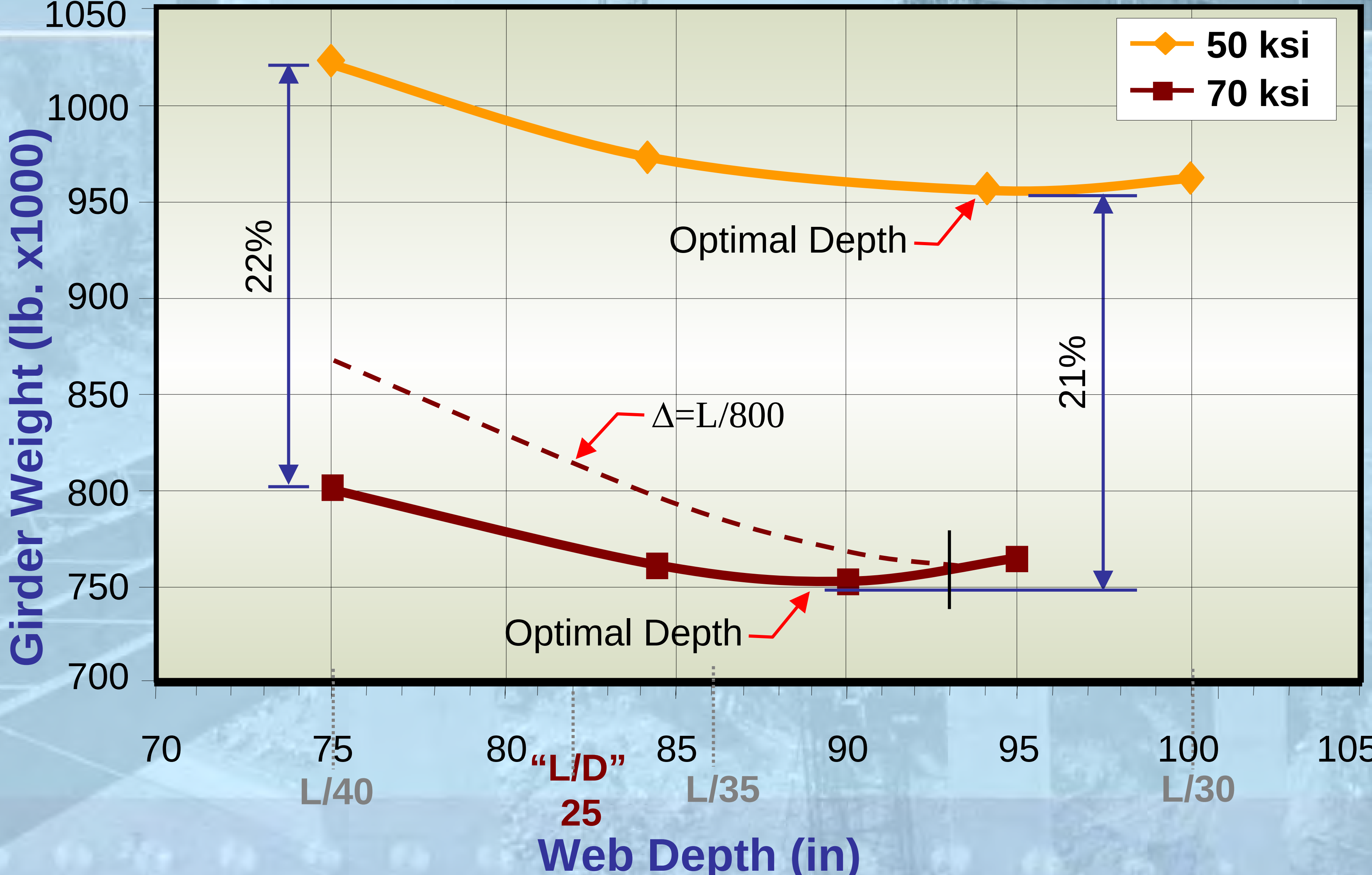


Girder Weight Comparisons
250 ft. Spans & 12 ft. Girder Spacing

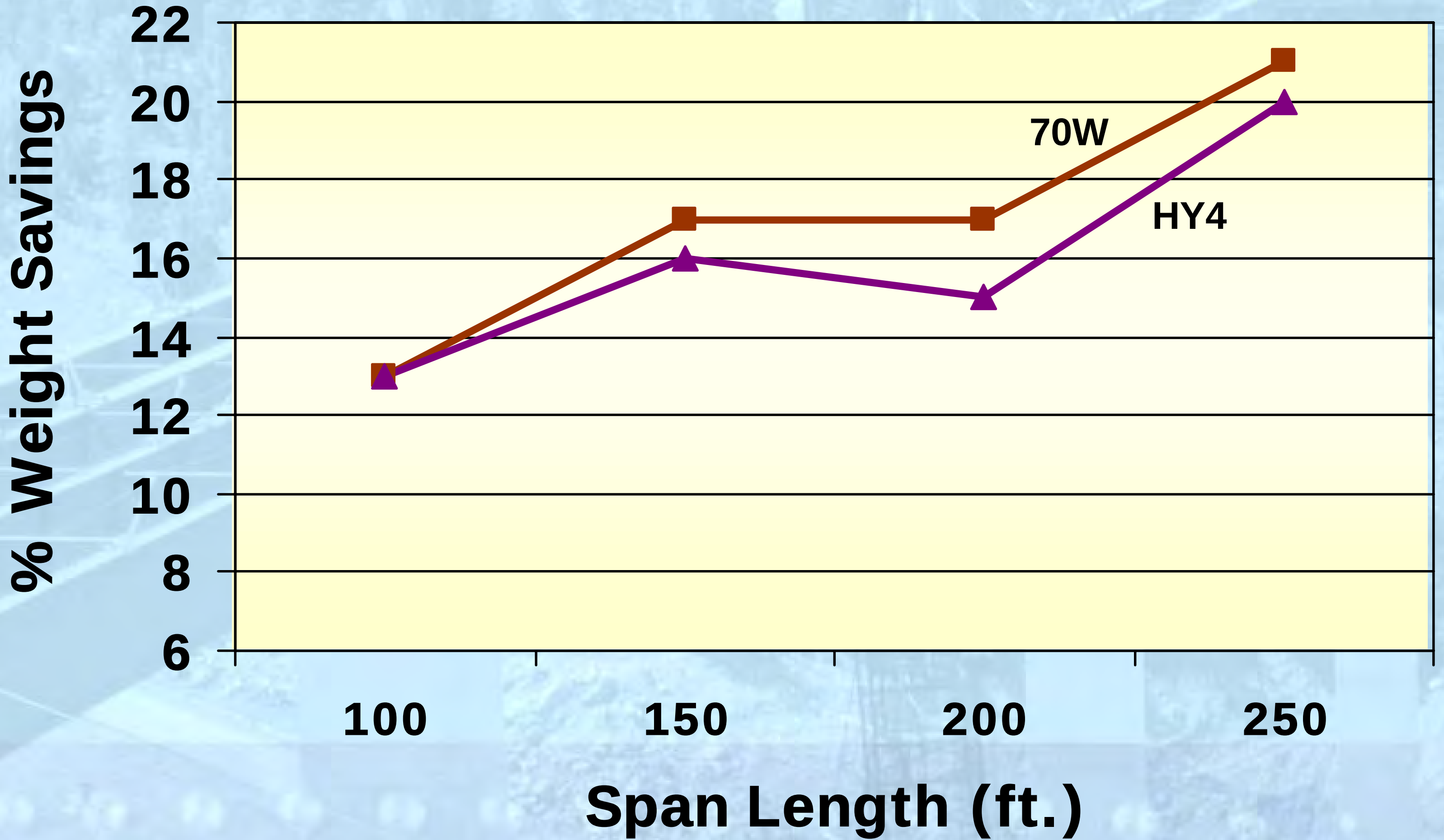


Girder Weight Comparisons

250 ft. Spans & 12 ft. Girder Spacing

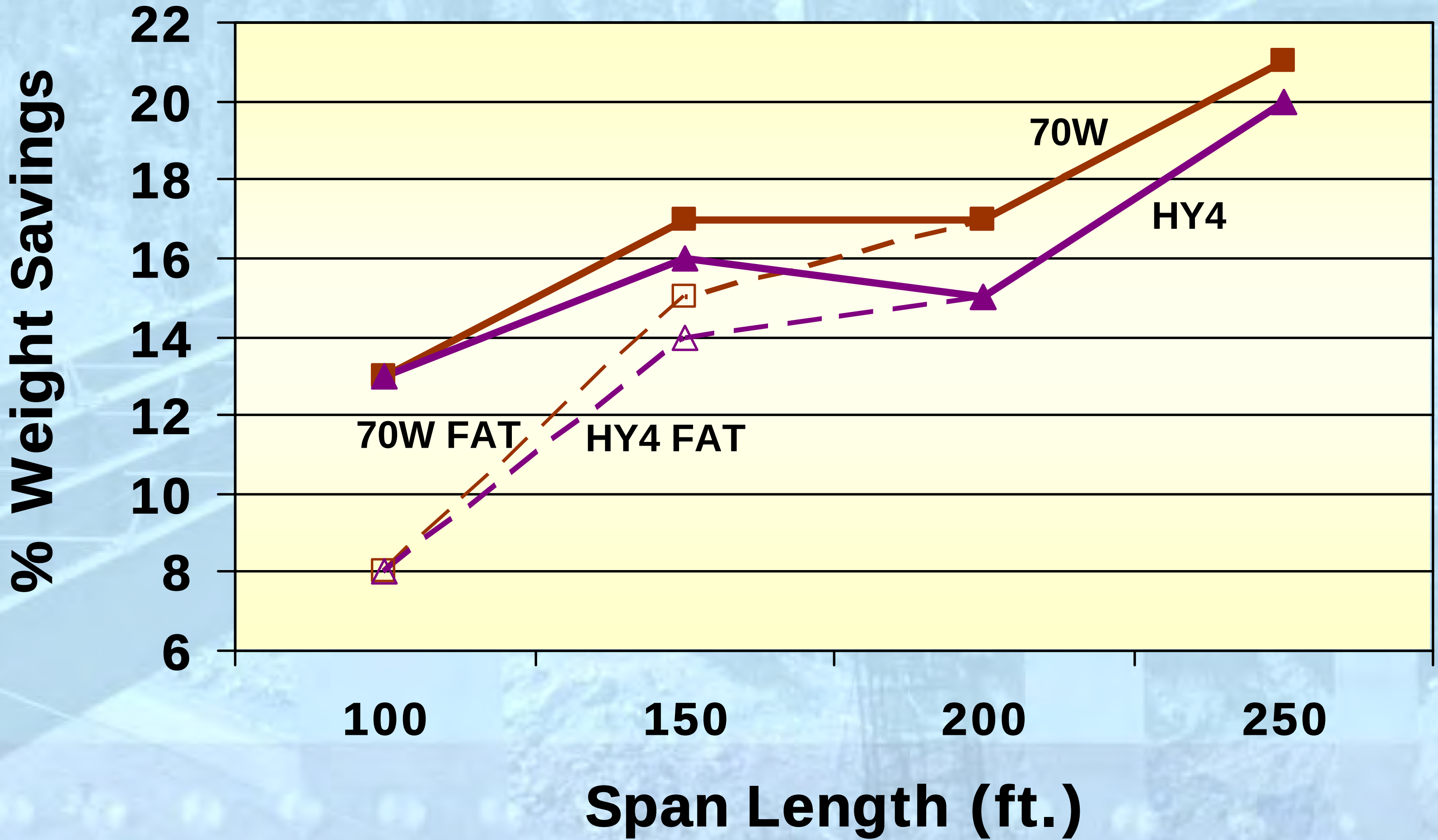


Girder Weight Comparisons
Weight Savings from 50W



Girder Weight Comparisons

Weight Savings from 50W



HPS Cost Comparison Study

Weight Savings at Optimal Depth from 50W

Bridge Spans	Girder Spacing	HPS 70W	Hybrid - 4
100'-100'	12'	13% (8%)	13% (8%)
150'-150'	9'	17% (13%)	11% (9%)
	12'	17% (15%)	16% (14%)
200'-200'	9'	17%	16%
	12'	17%	15%
250'-250'	9'	17%	13%
	12'	21% (19%)	20%

( ) - Weight savings considering fatigue

( ) - Weight savings considering deflection

HPS Cost Comparison Study

Fabricator Cost Estimates

Goal: Determine relative cost effectiveness of HPS 70W steel over Grade 50W

Fabricator participation requested for cost comparison

- Costs requested for 16 designs
- 10 Fabricators selected to represent entire country

Costs included material and labor

HPS Cost Comparison Study

Fabricator Cost Estimates

Fabricator Average Unit Costs ($/lb.)

Steel Grade	Phase I 2000	Phase II 2002	Phase III 2004	
			I-Girder	Box
50W	$0.61/lb	$0.52/lb	$0.70/lb	$0.78/lb
HPS 70W	$0.75/lb	$0.66/lb	$0.87/lb	$0.92/lb
Difference	$0.14/lb	$0.14/lb	$0.17/lb	$0.14/lb

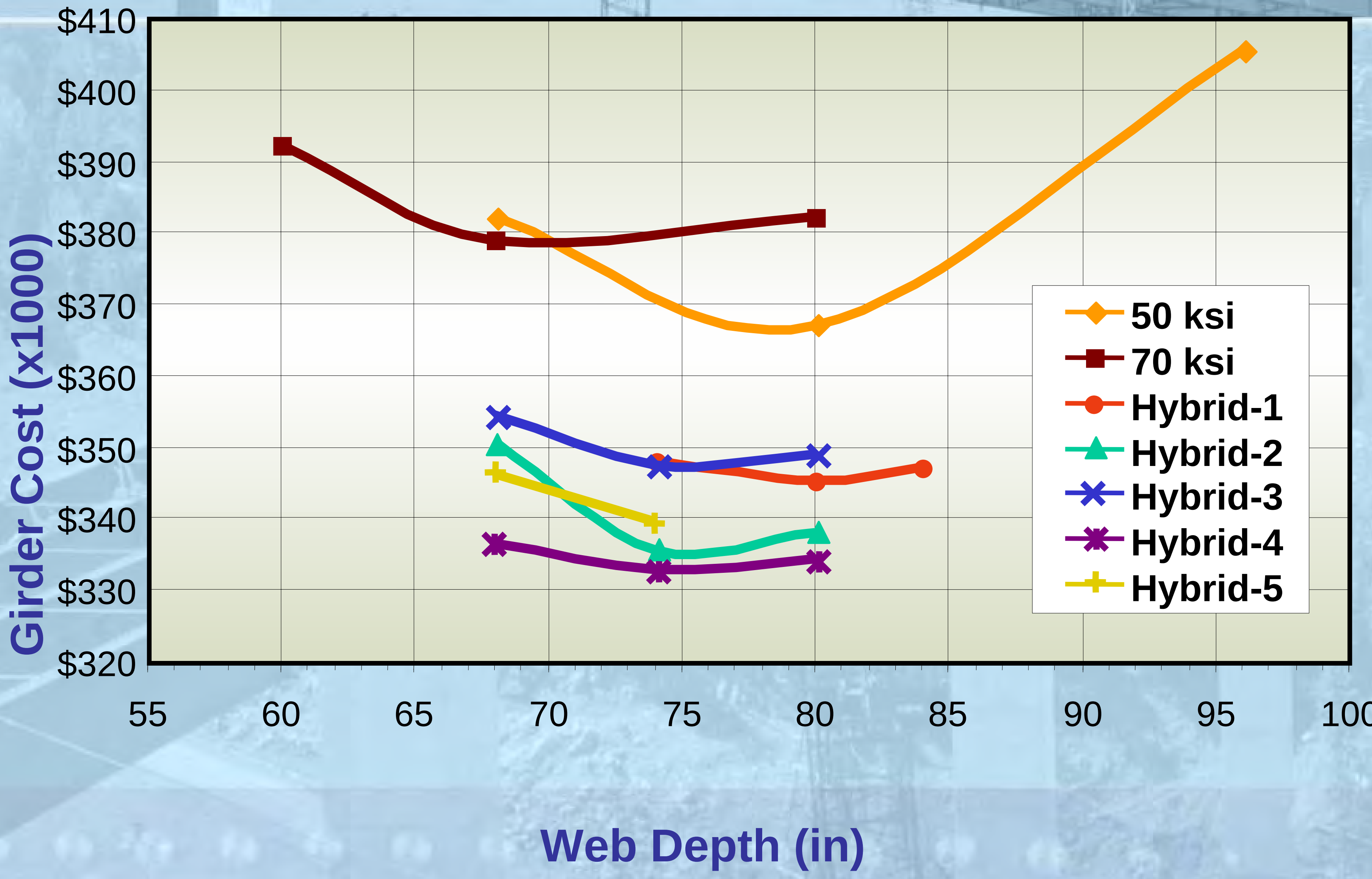
HPS Cost Comparison Study

Fabricator Average Cost Estimates ($/lb.)

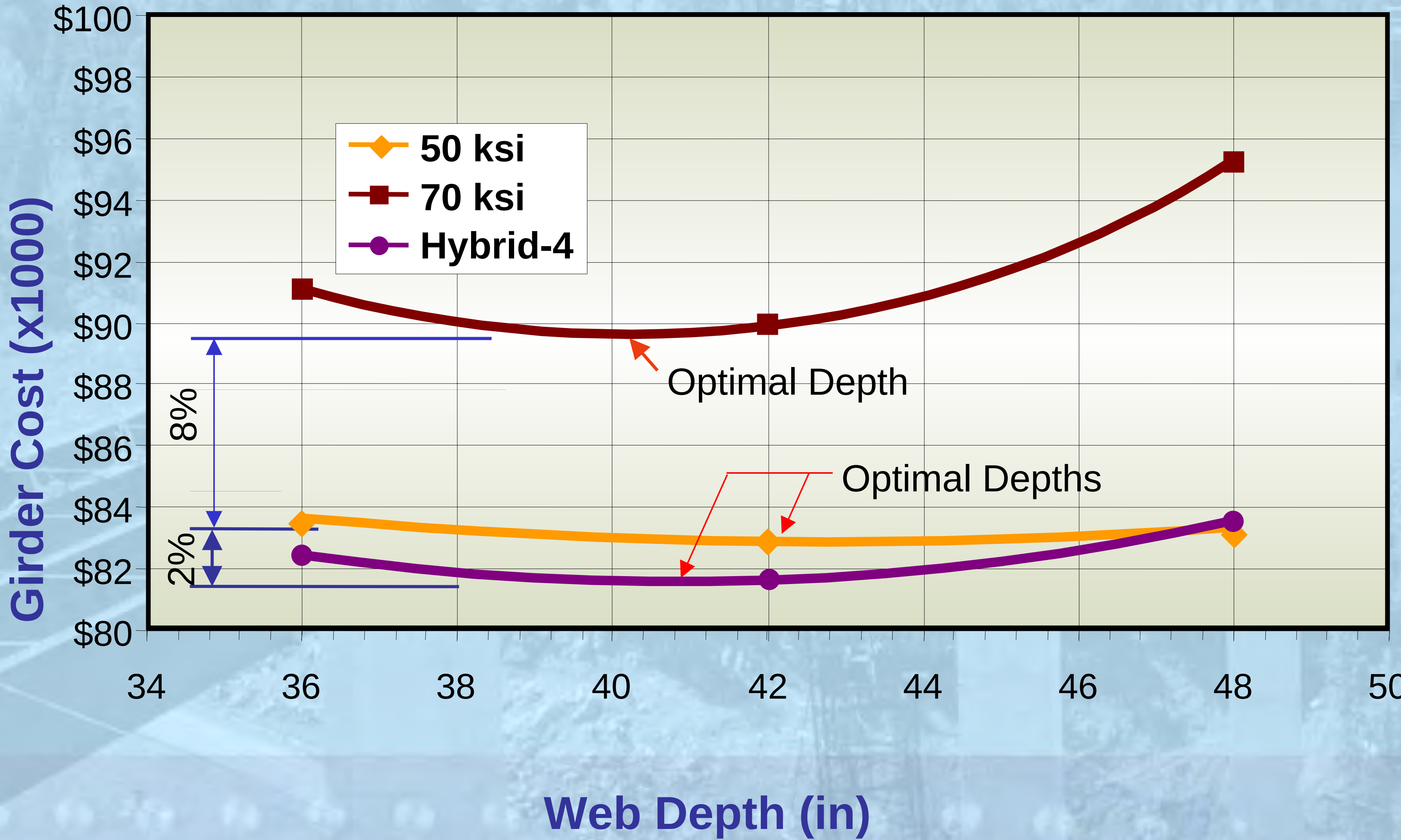
Bridge Spans	Girder Spacing	50W	HPS 70W
150' - 150'	9'	N.R.	N.R.
	12'	0.56	0.71
200' - 200'	9'	0.53	0.67
	12'	0.51	0.63
250' - 250'	9'	N.R.	N.R.
	12'	0.48	0.61
	Average	0.52	0.66

Girder Cost Comparisons

Typical Cost Comparison for All Hybrid Alternatives



Girder Cost Comparisons
100 ft. Spans & 12 ft. Girder Spacing



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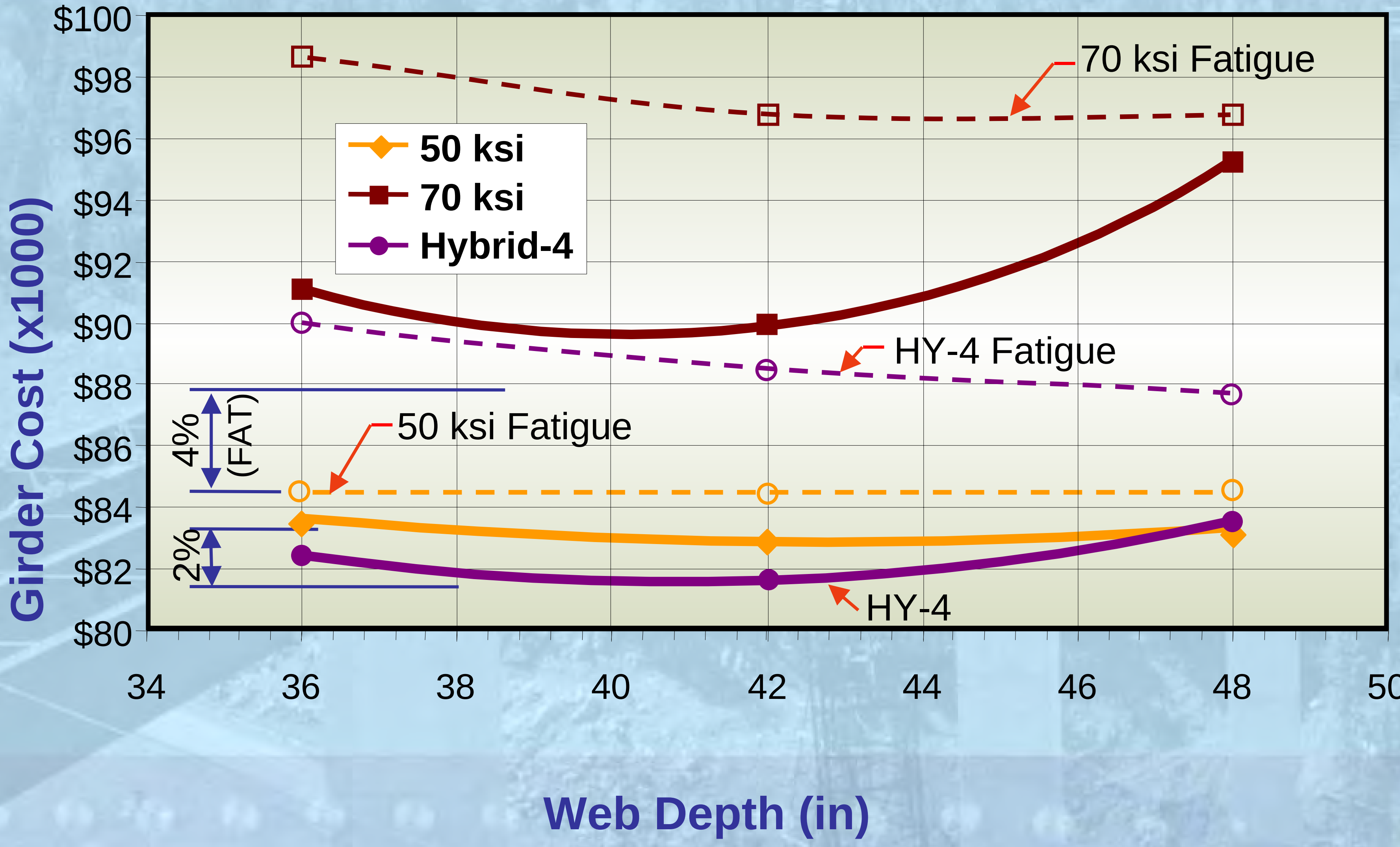
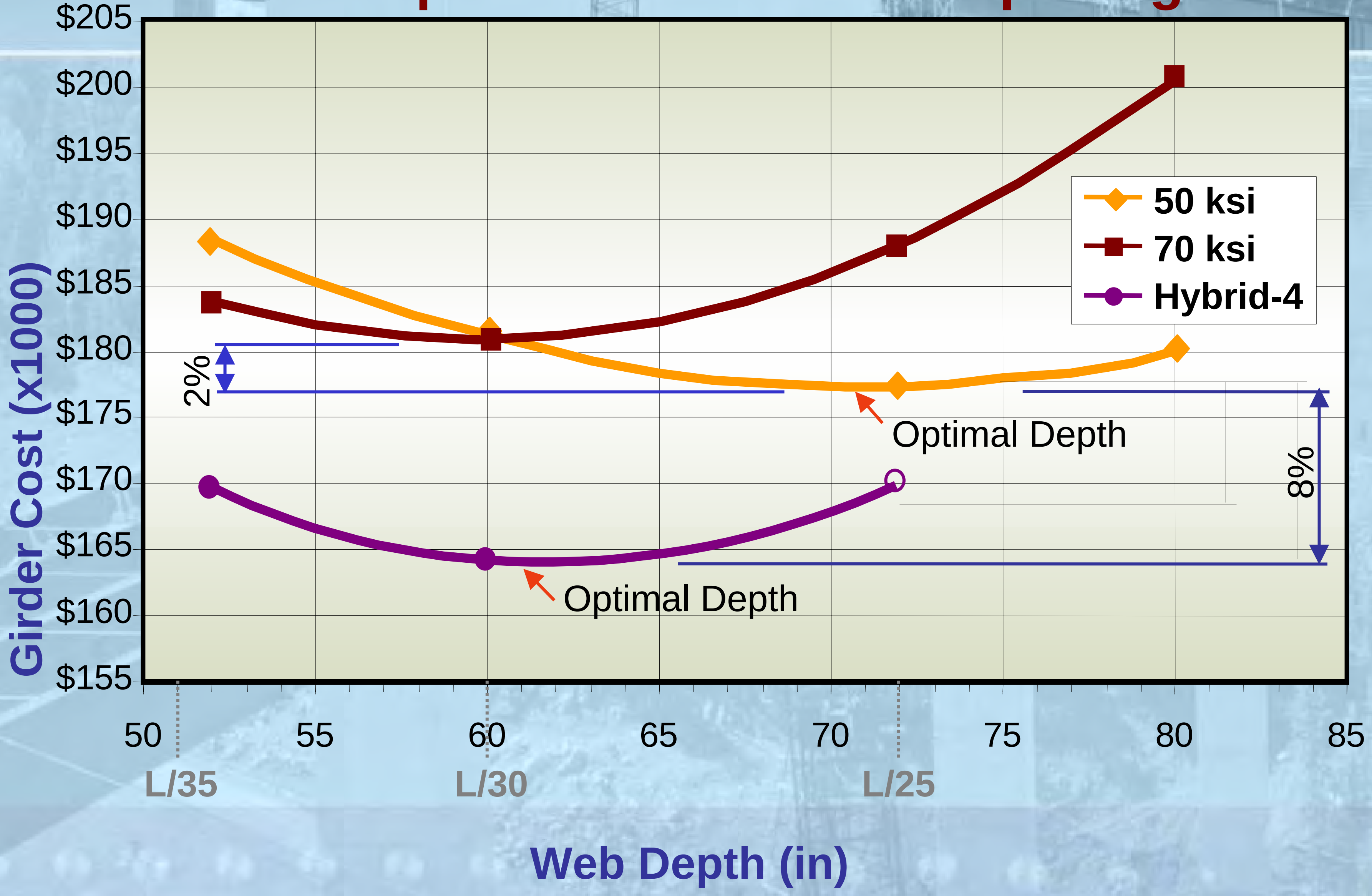


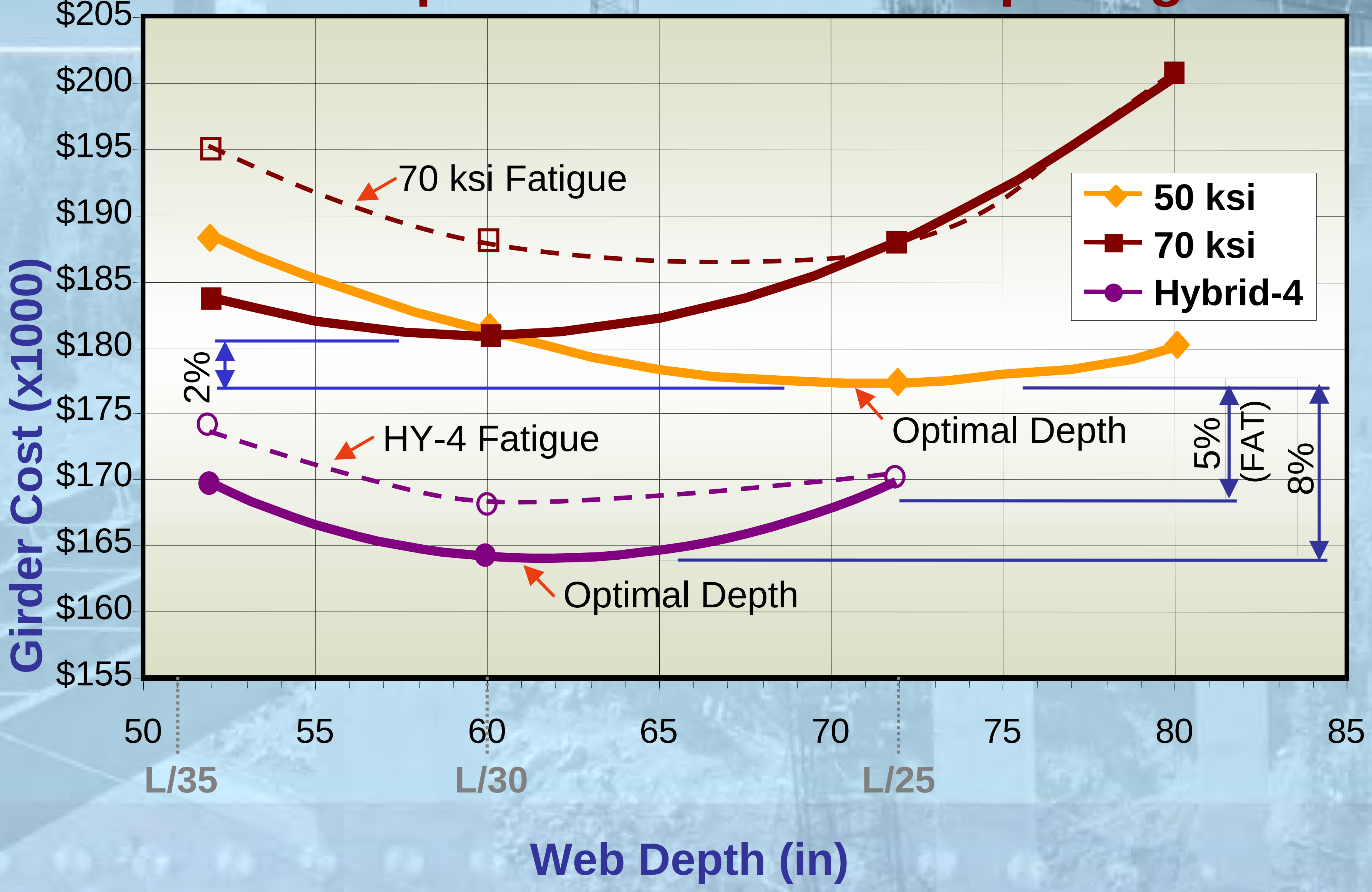
Girder Cost Comparisons

150 ft. Spans & 12 ft. Girder Spacing

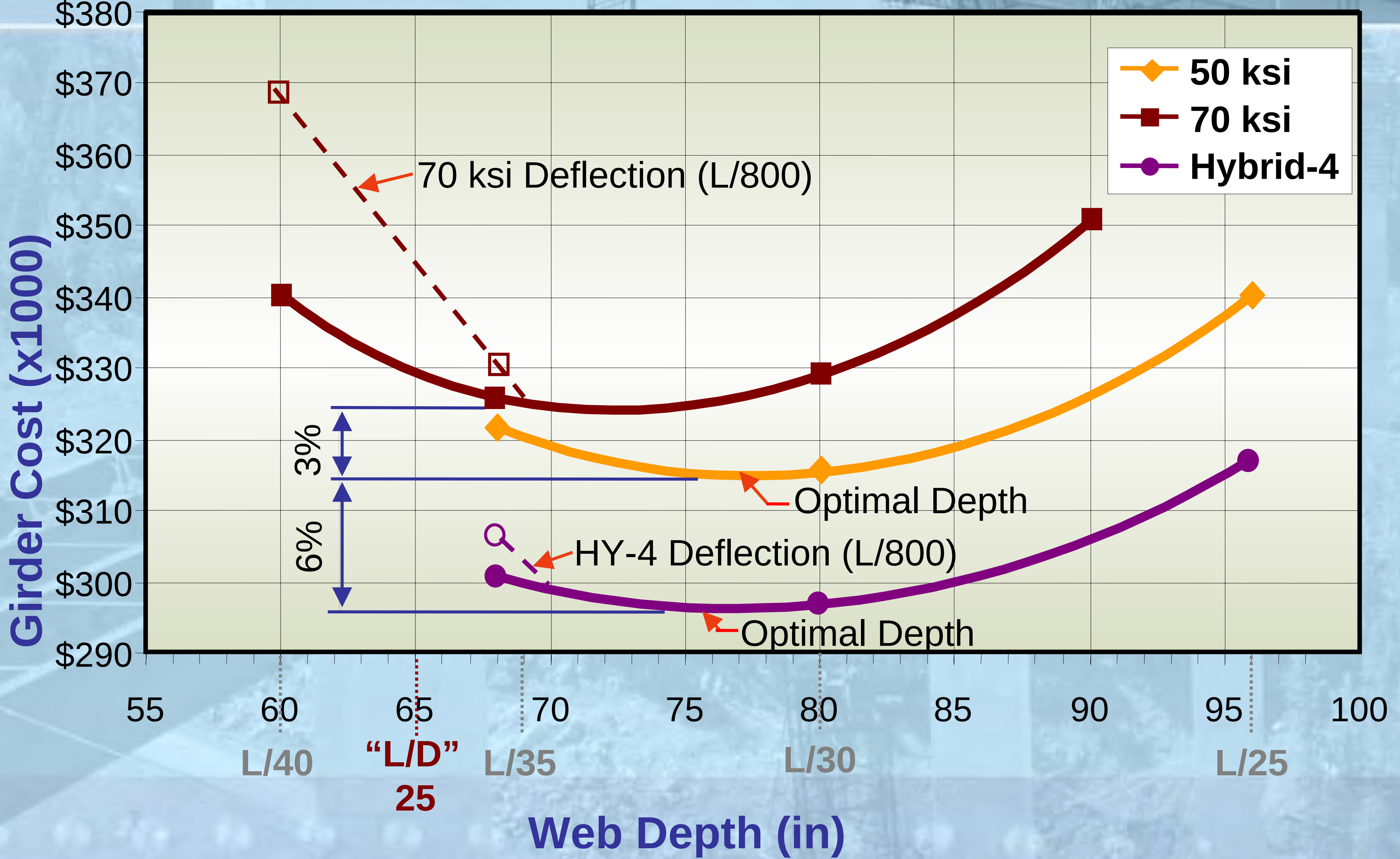


Girder Cost Comparisons

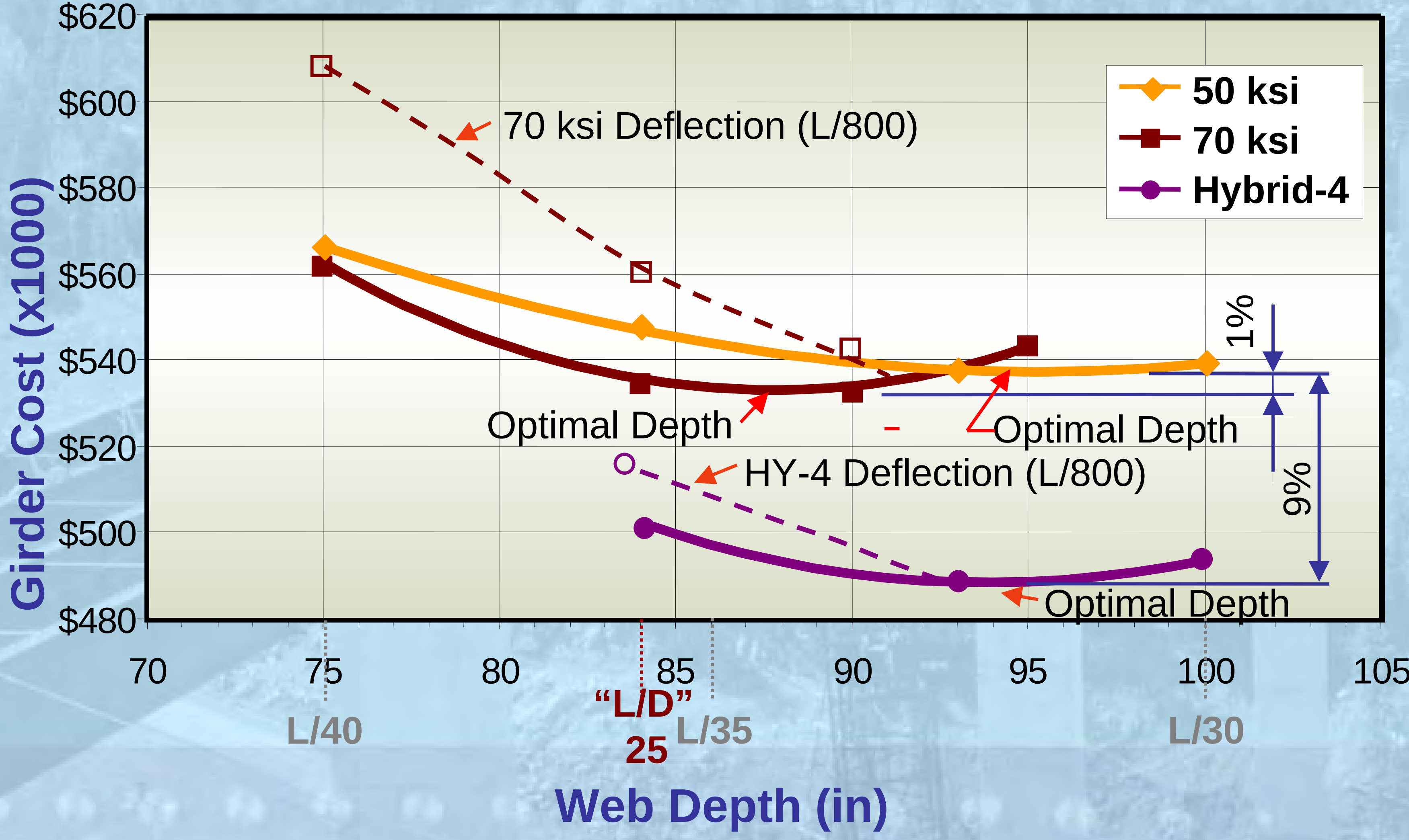
150 ft. Spans & 12 ft. Girder Spacing



Girder Cost Comparisons
200 ft. Spans & 12 ft. Girder Spacing

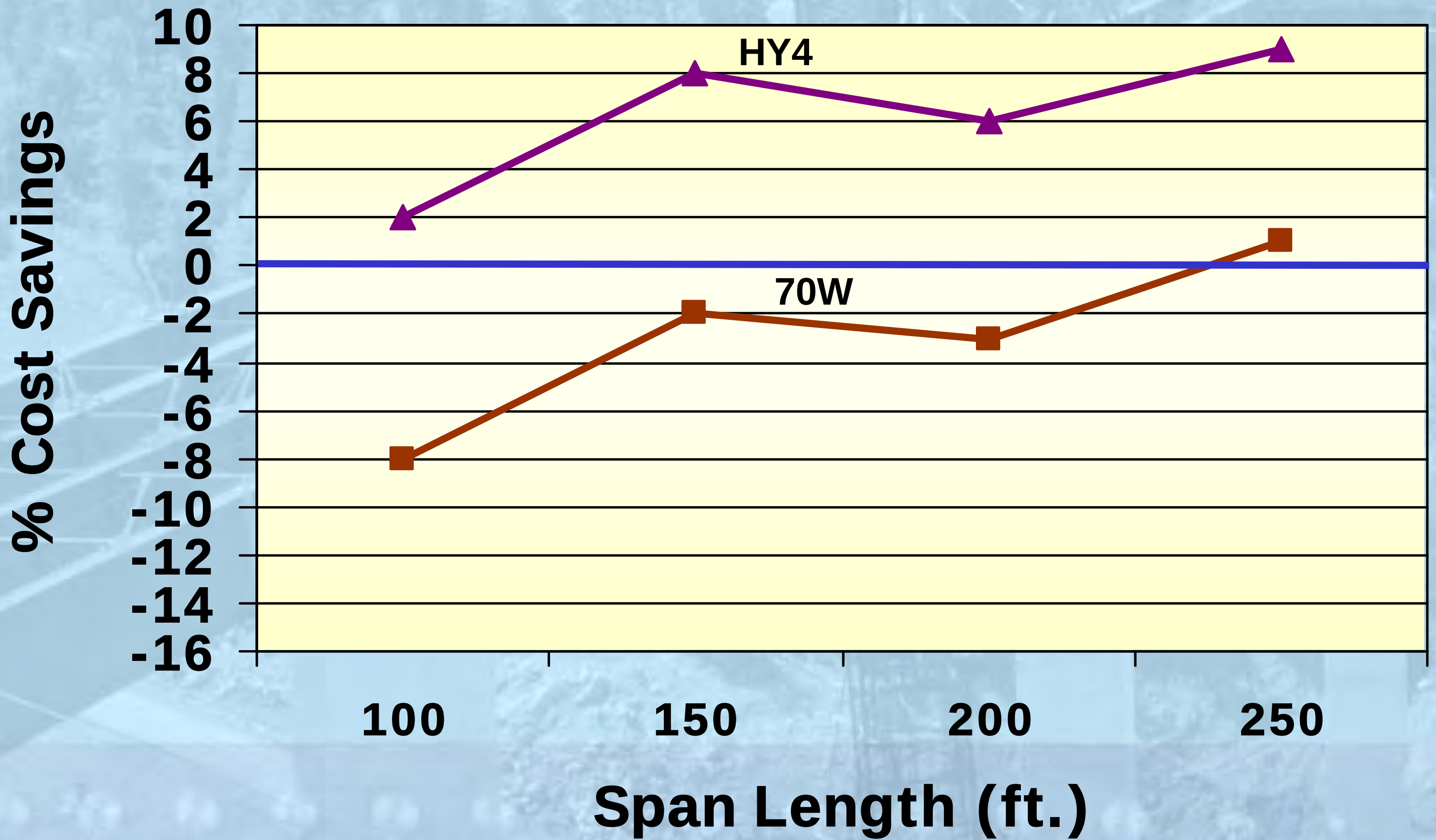


Girder Cost Comparisons
250 ft. Spans & 12 ft. Girder Spacing

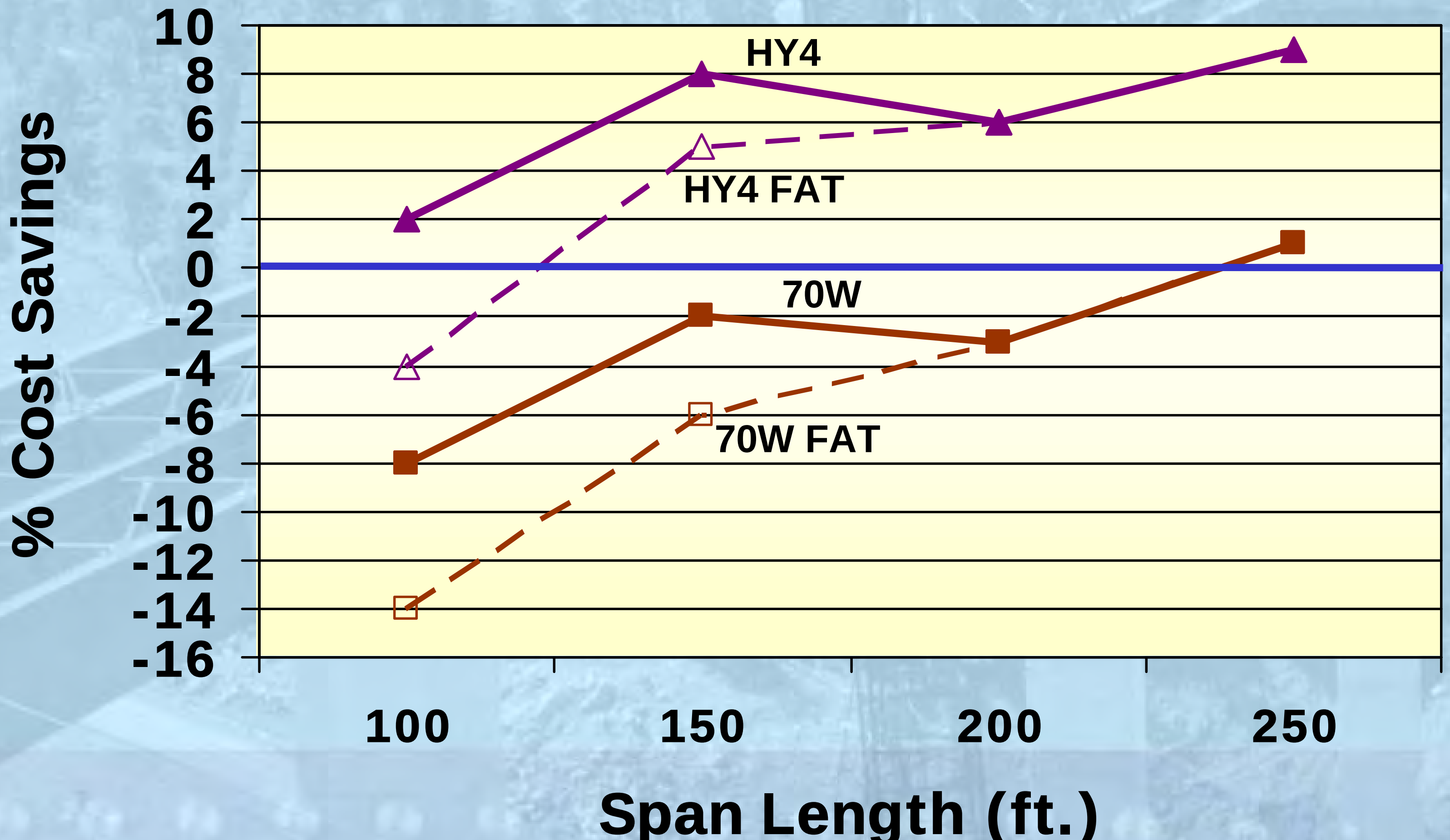


Girder Cost Comparisons

Cost Savings from 50W



Girder Cost Comparisons
Cost Savings from 50W



HPS Cost Comparison Study

Relative Girder Fabrication Cost Savings w.r.t. Grade 50W

Spans	Girder Spacing	HPS 70W	Hybrid - 4
100'-100'	12'	-8% (-14%)	2% (-4%)
150'-150'	9'	-4% (-8%)	4% (2%)
	12'	-2% (-6%)	8% (5%)
200'-200'	9'	-4%	7%
	12'	-3%	6%
250'-250'	9'	-3%	6%
	12'	1%	9%

( ) – Cost savings considering fatigue

HPS Cost Comparison Study

Summary and Conclusions

The study compared weight, depth and cost of 49 girder configurations for a range of span lengths, girder spacing, and steel types.

HPS Cost Comparison Study

Summary and Conclusions

Performance Issues:

- Use of homogenous HPS 70W steel resulted in weight savings of 13% to 20% relative to 50W. Hybrid 4 had 11% to 20% savings.
- Greater weight savings occur at shallower depths.
- Optimal girder depths were shallower by an average of 8% to 9% in all spans except 100’.
- Fatigue affected 100’ and 150’ spans. Truck volume is a factor.
- Deflection (L/800) affected 70W design at 250’ spans at optimal depth. In 200’ spans, depths below optimal were affected.

HPS Cost Comparison Study

Summary and Conclusions

Cost Issues:

• At optimal depths, homogenous Grade 50 designs were typically more economical than HPS 70W designs. Advantage reduces with span length.

• At shallower depths, HPS 70W designs were typically more economical.

HPS Cost Comparison Study

Summary and Conclusions

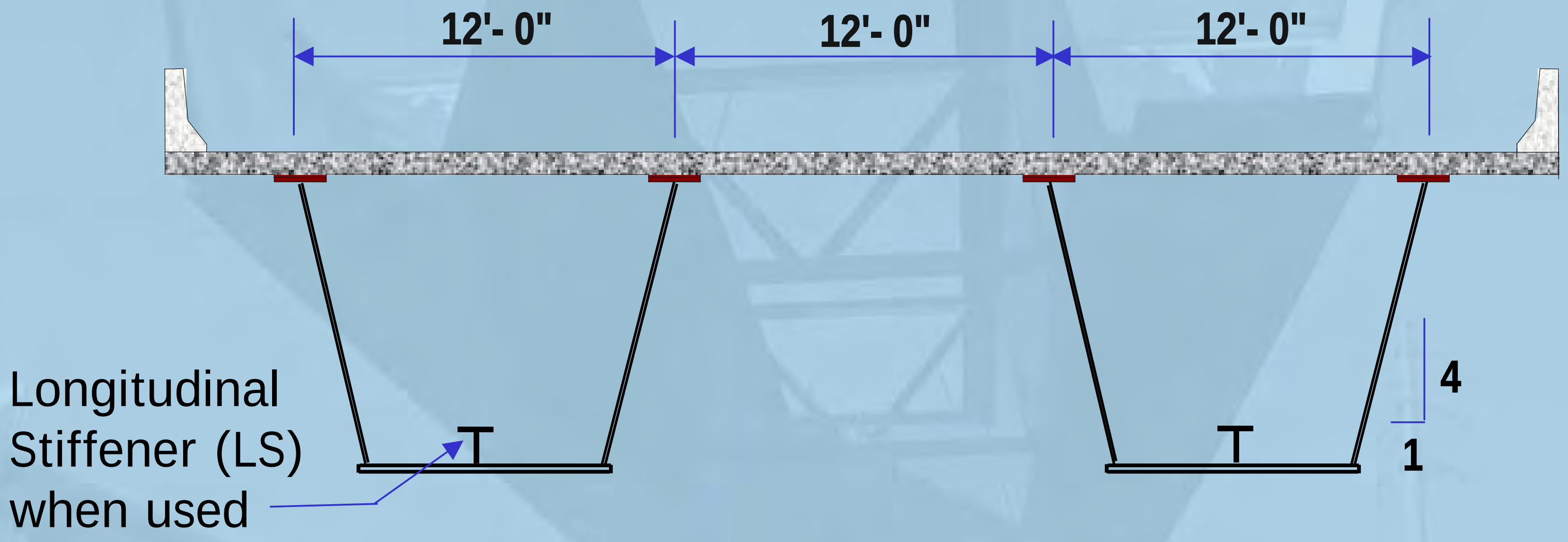
Cost Issues Continued:

- Hybrid designs were the most economical with cost savings of 2% to 9% at optimal depths. Savings increase with span length.
- Hybrid 4 was the most economical with:
  - HPS 70W top and bottom flanges in negative moment region
  - HPS 70W bottom flanges in positive moment region
  - Grade 50 top flanges in positive moment region and all webs

Additional cost savings can be realized with HPS 70W in shipping and erection, foundations, and reduced approach fill heights.

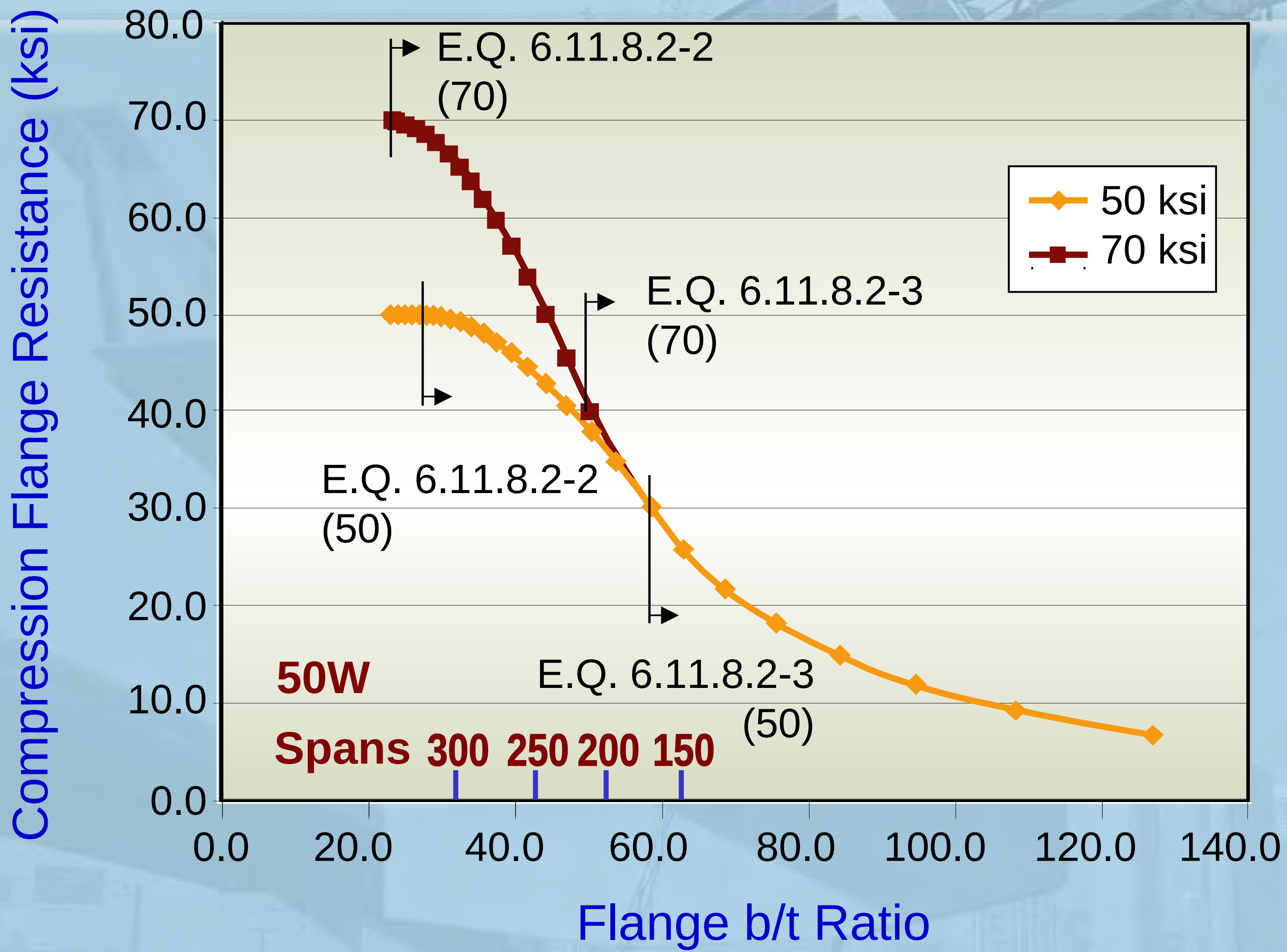
High Performance Steel Box Girder Study

HPS Box Girder Study



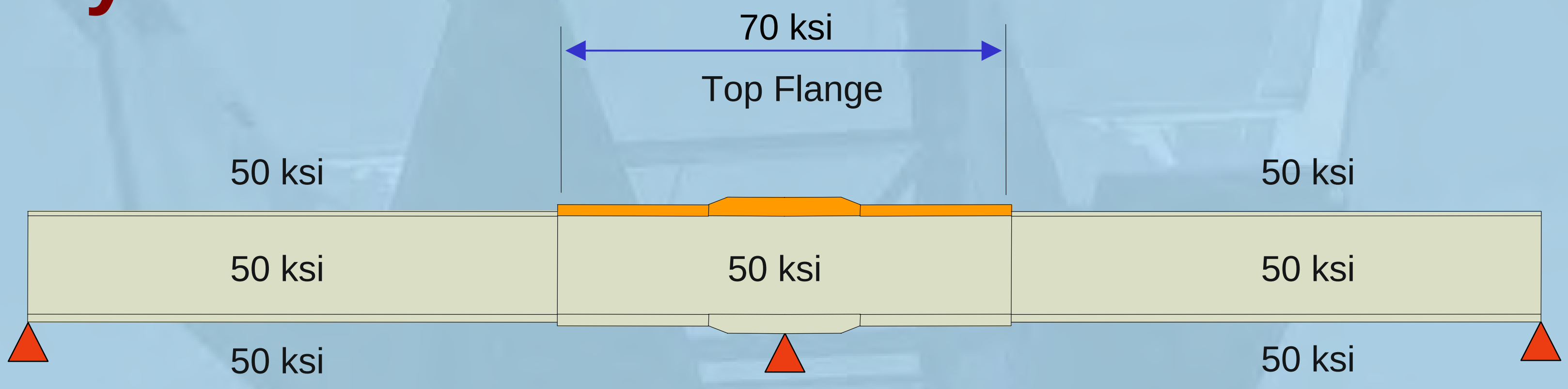
2 Box Girder Section

HPS Box Girder Study



HPS Box Girder Study

Hybrid B1



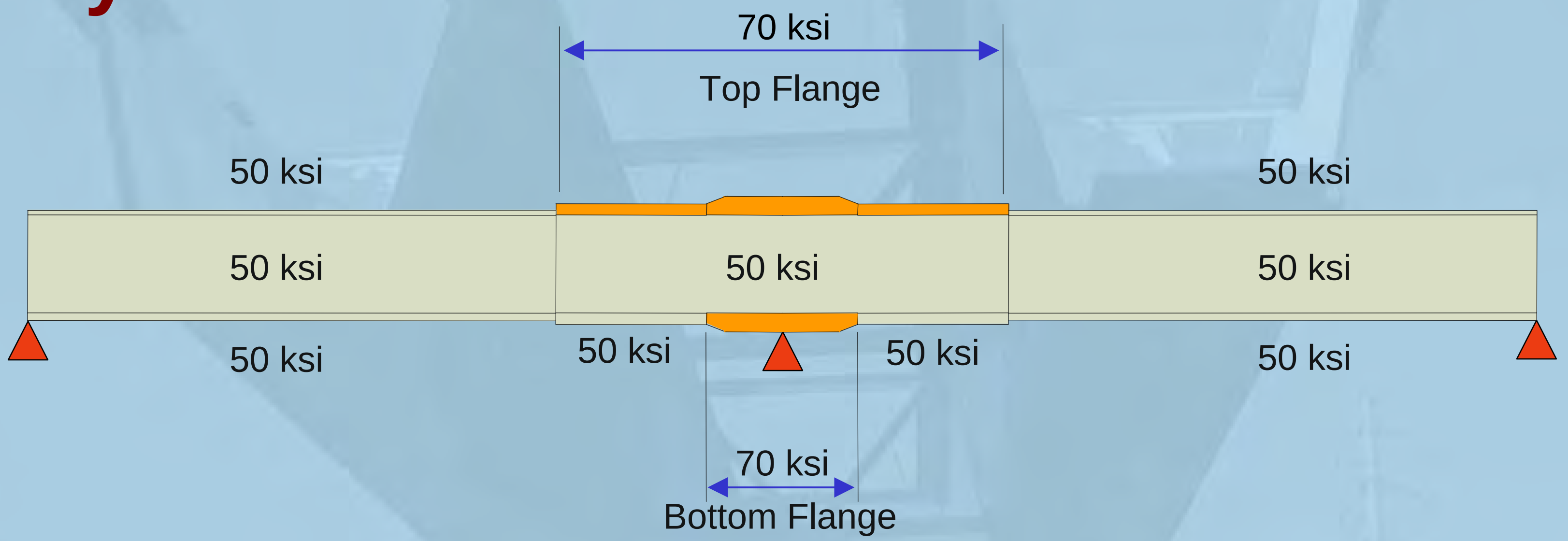
150 ft Spans – HY, HY LS

200 ft Spans – HY

250 ft Spans – HY

HPS Box Girder Study

Hybrid B2

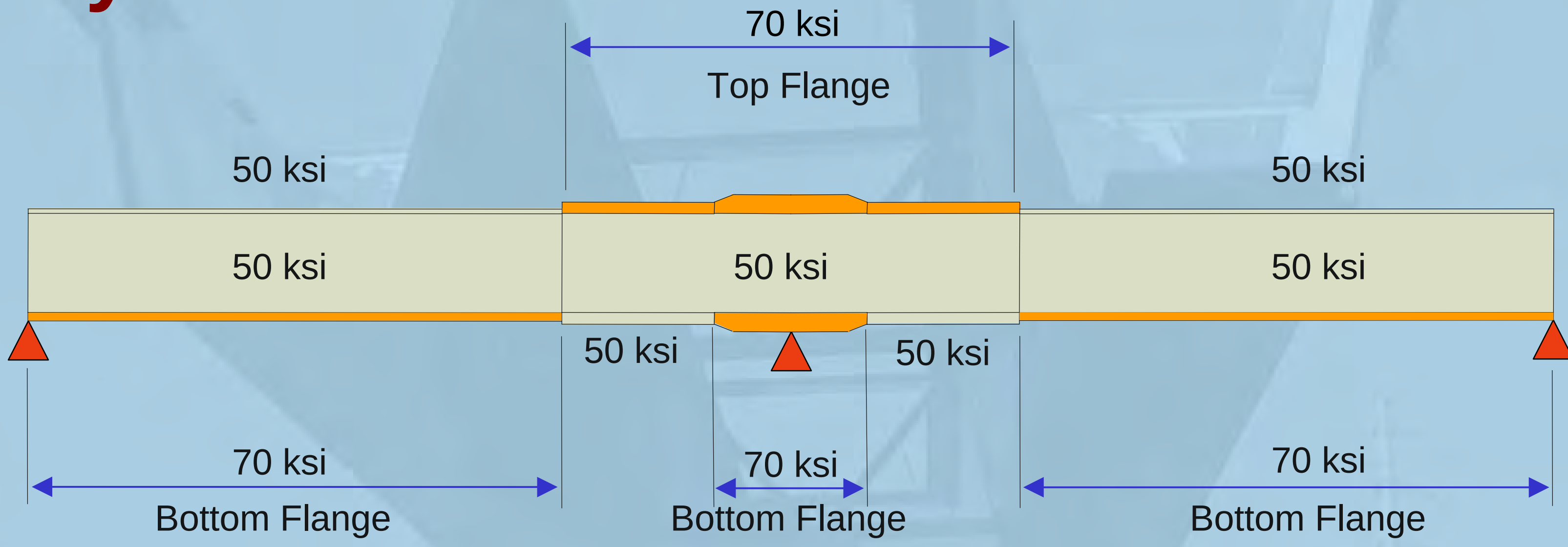


200 ft Spans – HY LS

250 ft Spans – HY LS

HPS Box Girder Study

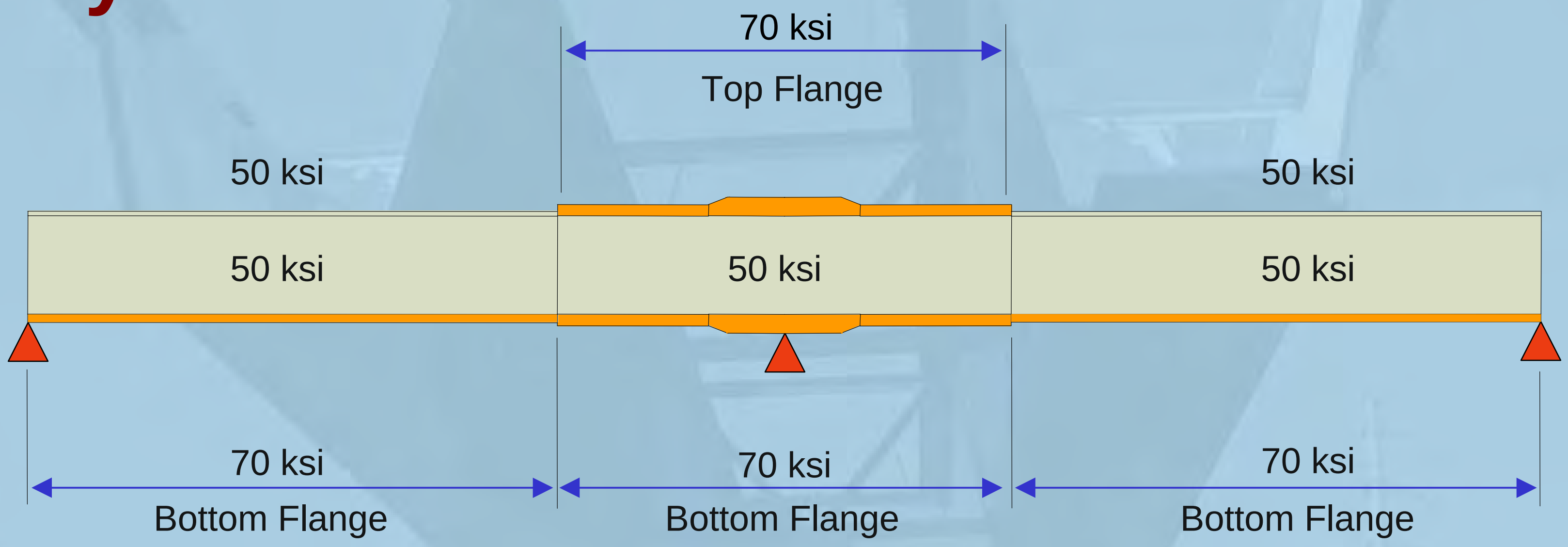
Hybrid B3



300 ft Spans – HY

HPS Box Girder Study

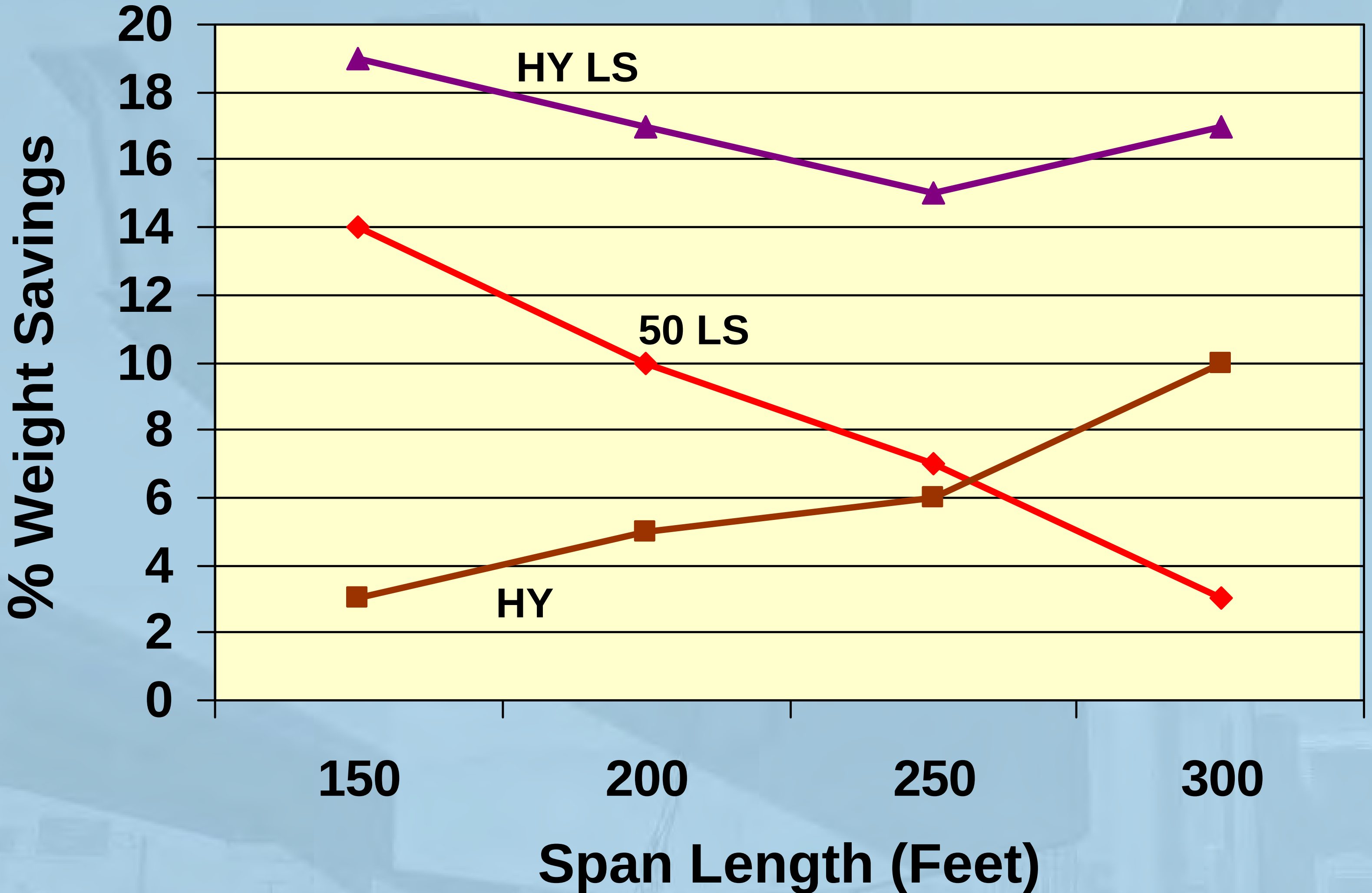
Hybrid B4



300 ft Spans – HY LS

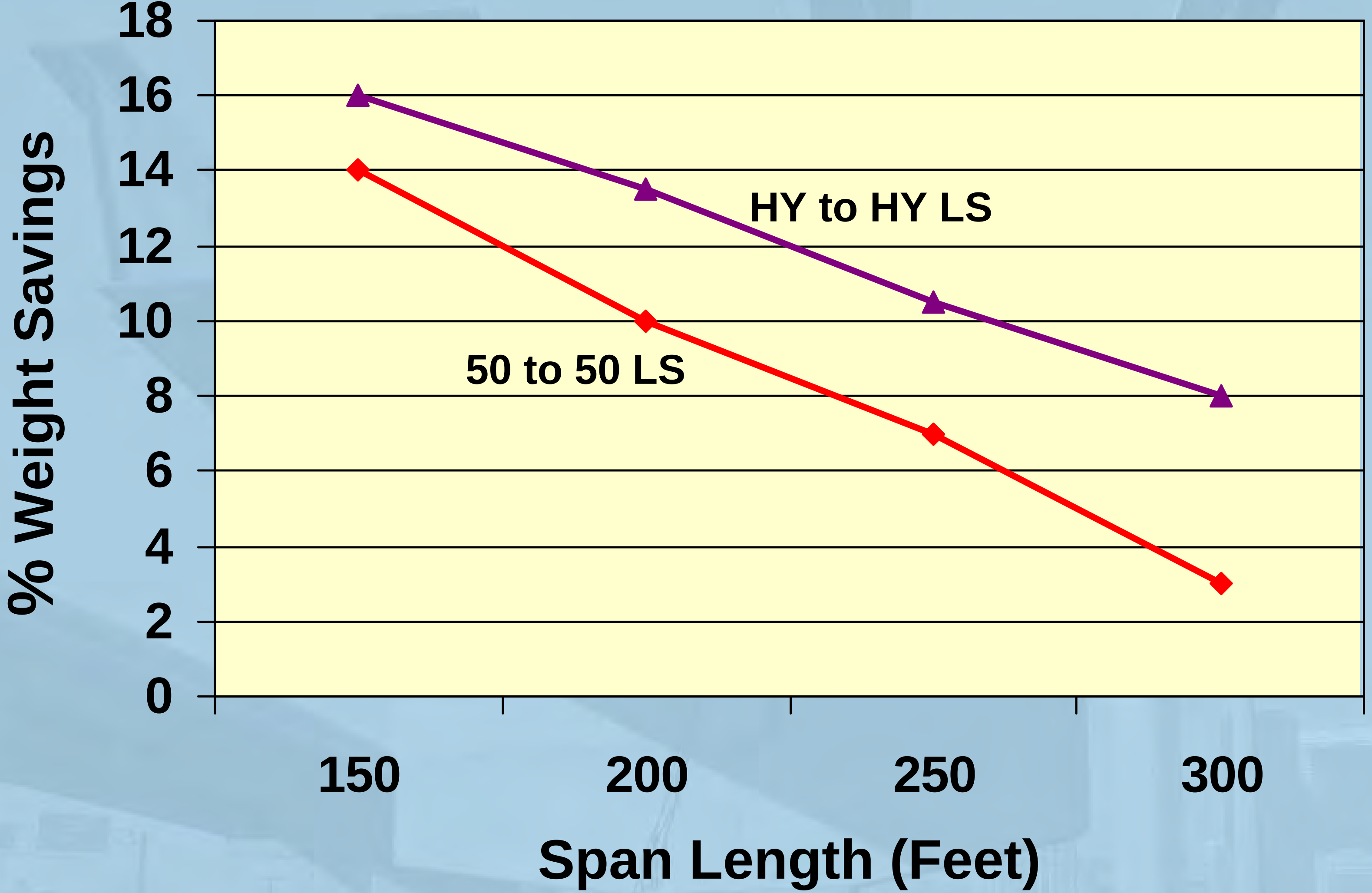
Box Girder Weight Comparisons

Weight Savings from 50W



Box Girder Weight Comparisons

Weight Savings with Longitudinal Stiffener



HPS Box Girder Study

Fabricator Cost Estimates

Fabricator participation requested for cost comparison

- **Costs obtained for 16 designs**
- **4 Fabricators participated**

Costs included material and labor

HPS Box Girder Study

Fabricator Cost Estimates

Fabricator Average Unit Costs ($/lb.)

Span	50W			HPS 70W		
	Material	Labor	Total	Material	Labor	Total
150 - 150	0.48	0.36	0.84	0.63	0.37	1.00
200 - 200	0.49	0.30	0.79	0.62	0.30	0.92
250 - 250	0.48	0.26	0.74	0.63	0.26	0.89
300 - 300	0.49	0.25	0.74	0.63	0.25	0.88
Average	0.49	0.29	0.78	0.63	0.29	0.92

HPS Box Girder Study

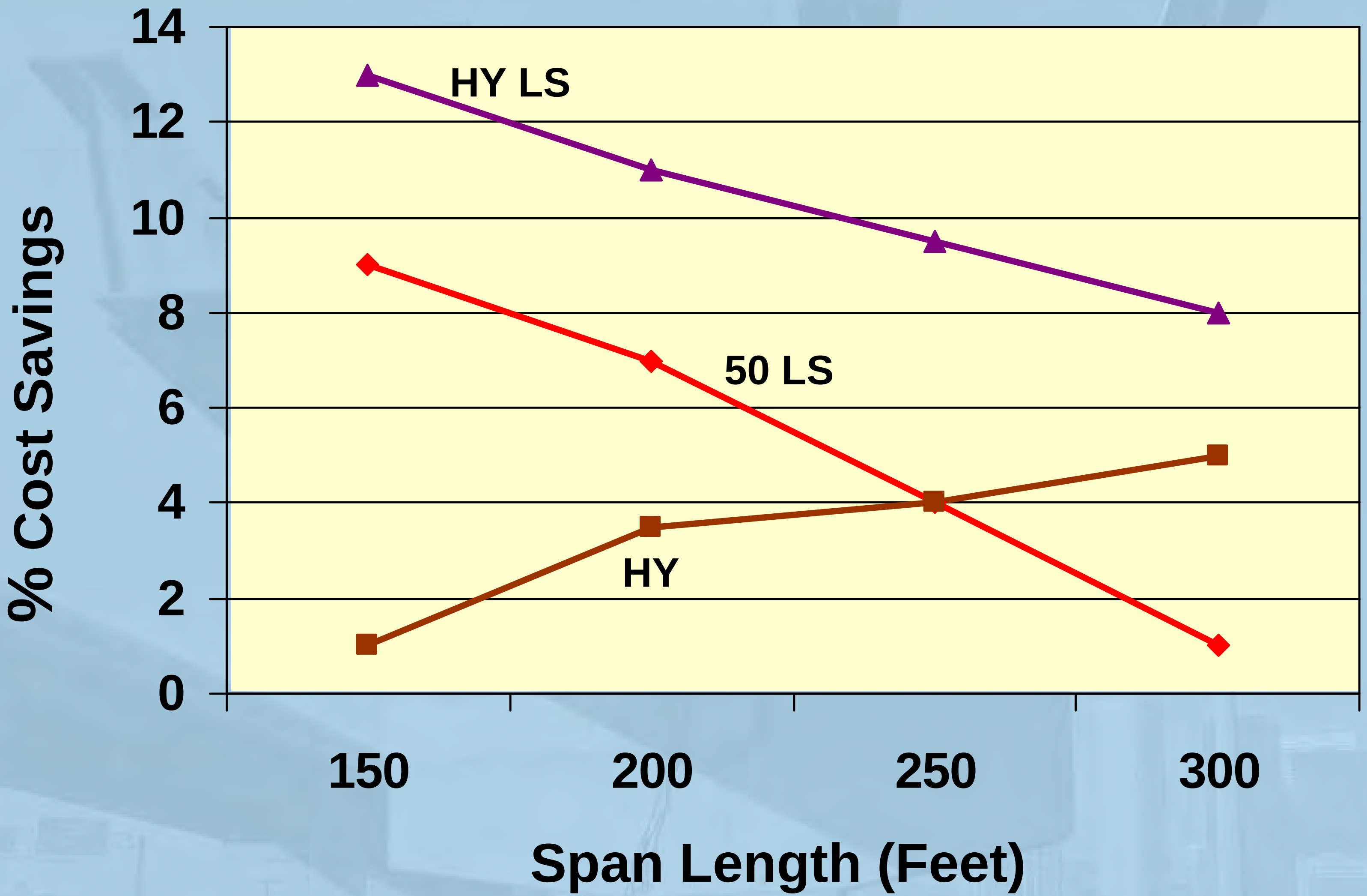
Fabricator Cost Estimates

Fabricator Average Unit Costs ($/lb.)

Steel Grade	Phase I 2000	Phase II 2002	Phase III 2004	
			I-Girder	Box
50W	$0.61/lb	$0.52/lb	$0.70/lb	$0.78/lb
HPS 70W	$0.75/lb	$0.66/lb	$0.87/lb	$0.92/lb
Difference	$0.14/lb	$0.14/lb	$0.17/lb	$0.14/lb

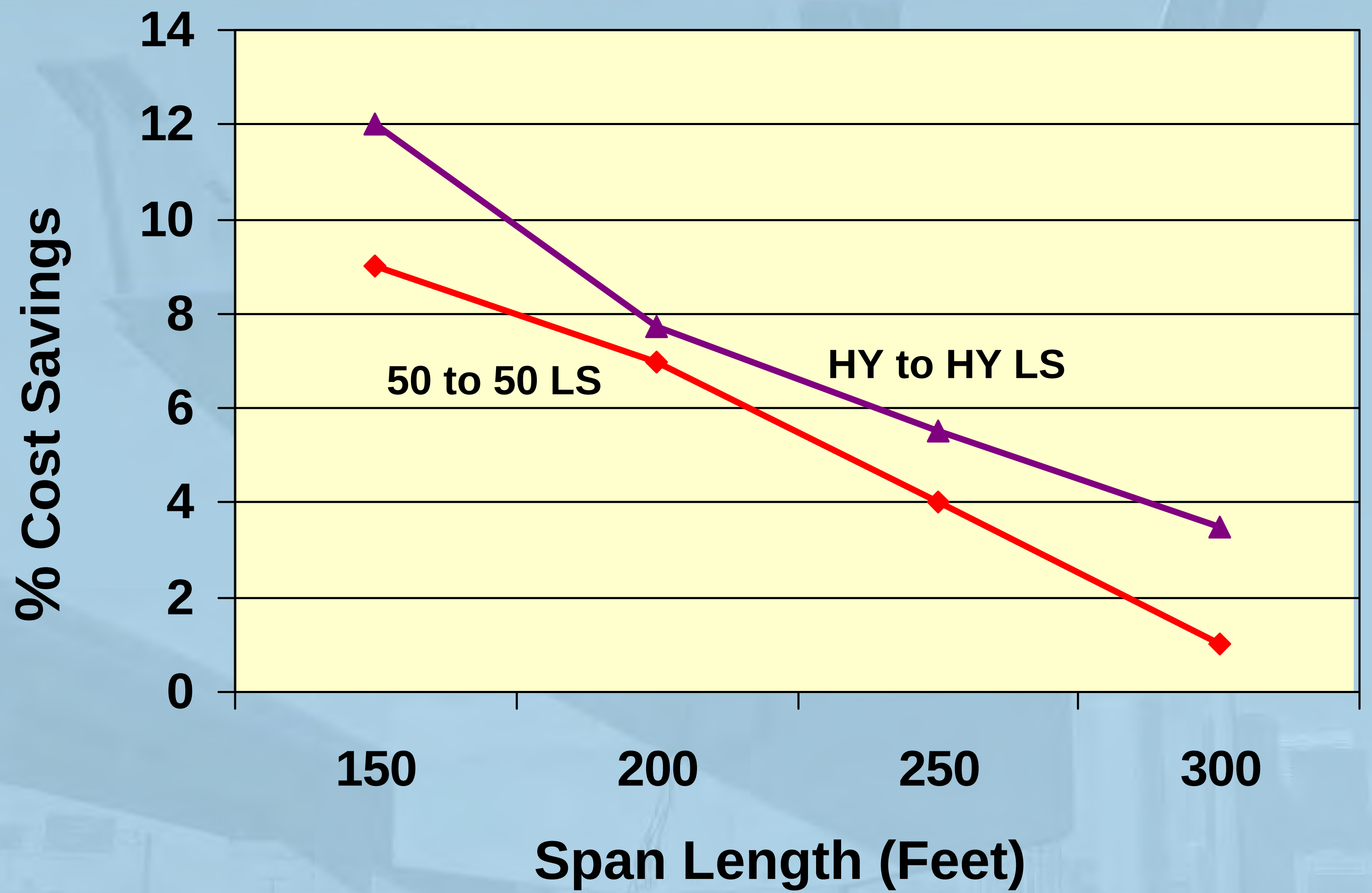
Box Girder Cost Comparisons

Cost Savings from 50W



Box Girder Cost Comparisons

Cost Savings with Longitudinal Stiffener



HPS Box Girder Study

Summary and Conclusions

- Hybrid design with bottom flange longitudinal stiffening is the most economical use of HPS 70W in box girders.
- Effectiveness of HY increases with increasing span length
- Effectiveness of bottom flange negative moment longitudinal stiffening decreases with increasing span length.
- The optimal HY combination varies. All optimal hybrids had HPS 70W in negative moment top flanges, and 50W for all webs. Bottom flanges had varying use of HPS 70W according to span length and use of bottom flange longitudinal stiffening.

High Performance Steel Cost Comparison Study

Questions?

DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA

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HDR

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