CT Innovations

TT-W005

TSS Structural Design Efficiency:

TOUGHTray

TOUGH
SUPPORT SAVINGS

1.0 ABSRACT

Structural design efficiency involves optimizing the use of materials and construction techniques to achieve a balance between the structural systems performance, cost, and sustainability.

This paper investigates the structural design practices that relate to cable ladder tray structural support systems. It reviews both industry standard design practices and manufacturer design recommendations.

We examine the design recommendations to determine their structural design efficiency, focusing on material optimization, engineering flexibility and innovative design practices.

Through comprehensive analysis we calculate and quantify those recommendations design efficiency. We identify the efficiencies that will minimize structural design complexity, structural materials and engineering hours.

This paper will review the following design practices:

a. *NEMA Standards Publication VE 2 : Cable Tray Installation Guidelines*

b. *CT Innovations TOUGH Support Savings : Design Recommendations for TOUGHTray*

This paper presents a series of *"Manufacturer Recommendations"* that have been developed and implemented. The paper contains a demonstration of the structural design efficiency gains available, when applied to a cable ladder tray project with approximated savings of 10,000 engineering hours.

2.0 INTRODUCTION

National energy security and environmental concerns are driving the energy transition, while societies adoption of new data technology is driving increased demand for products and services. These combined needs are driving increased demand for new electrical infrastructure that the construction industry must deliver against a backdrop of market constraints such as the availability and cost of experienced and skilled engineers.

Innovation and problem-solving is required to alleviate and overcome these market challenges. Manufacturers must provide solutions that customers can easily and efficiently implemented using minimal engineering resources.

Efficiency in structural design can lead to significant savings in materials and labor, reducing the overall environmental impact of construction projects. This paper focuses on design practices that provide the greatest engineering efficiency when designing a cable tray systems structural support system.

It is important that early consideration be given to cable tray support structure design practices that best mitigate structural engineering complexity and engineering design hours.

It is recommended this be considered and evaluated during front end engineering design.

3.0 DETERMINING DESIGN VALUE

To calculate structural design efficiency for a cable tray support application, we shall use the following formulae and factors to determine the efficiency gained implementing manufacturer recommendations.

3.1 Support Location Flexibility Factor

Each cable tray application support recommendation provides varying degrees of design flexibility in where to locate the structural support. Flexibility varies from 2ft to 20ft and are assigned the following multiplication factors.

- 2ft = 0.90
- 5ft = 0.75
- 10ft = 0.50
- 15ft = 0.25
- 20ft = 0.00

3.2 Design Efficiency Formulae

E = Design Efficiency %

D = Support Design Hours

Q = Application Support Quantity

F = Support Location Flexibility Factor

N = Industry Standard Practice NEMA VE 2 recommendation

T = Manufacturer TOUGH Support Savings (TSS) recommendation

$$E = \frac{D \times NQ \times NF \ (-) \ D \times TQ \times TF}{D \times NQ \times NF}$$

3.3 Design Efficiency Worked Example

$$E = \frac{2 \times 3 \times 0.9 \quad (-) \quad 2 \times 2 \times 0.9}{2 \times 3 \times 0.9} \longrightarrow \frac{5.4 \ (-) \ 3.6}{5.4} \longrightarrow 33\% \text{ TSS Design Efficiency}$$

By identifying and assigning a design efficiency value (%) to each cable tray support application, we can determine engineering design efficiency of the structural support locations provided by Industry Standard Practice NEMA VE 2 and Manufacturer Recommendations TOUGH Support Savings.

4.0 DESIGN PRACTICES

When determining the required location of structural steel supports for the cable tray system, standard practice will generally refer to industry standard NEMA VE 2 recommendations. It should be noted that the NEMA VE 2 recommendations are just that, recommendations not must dos; it simply provides design guidance.

How can we apply the recommendations of NEMA VE 2 efficiently? And can applying the guidance in blind obedience be detrimental to the cable tray systems structural support systems engineering design efficiency?

Let us start by considering what the recommendations are, and how they apply to the structural support system.

4.1 Cable Tray Supports

NEMA publication VE 2 Section 3.3.1 quote "*supports for cable trays should provide strength and working load capabilities sufficient to meet the load requirement of the cable tray wiring system. Consideration should be given to loads associated with future cable additions or any other additional loads applied to the cable tray system or the cable tray support system*" unquote.

It is evident from this quote, that structural support design must consider multiple factors to adequately support the cable tray system. Generally, the supports structural engineering design must consider:

a. Cable tray weights
- *Straight sections, fittings, covers (lbs/ft)*

b. Cable weight
- *Cable design load (lbs/ft)*

c. Future cable additions should refer to:
- *NEC Article 392 for allowable cable fill*
- *NEMA VE 1 for allowable cable tray loads*

d. Other additional tray loads applied to the structural support system are:
- *Dynamic wind and Seismic loads*
- *Static snow and Ice loads*

4.2 Recommended Support Locations for Fittings

Cable tray fittings are:
- *Horizontal Elbow, Tee, Cross, Wye, Reducer*
- *Vertical Elbow, Tee*

For each fitting type the recommended location of structural support is given by:
- *NEMA Standards Publication VE 2 Cable Tray Installation Guidelines*
- *Section 3.5.1 Recommended Support Locations for Fittings.*

Quote "*Recommended support locations follow, unless otherwise recommended by manufacturer*" unquote.
Therefore, the above statement provides the engineer with two options for the location of the cable tray fittings structural supports, being:
- *to follow NEMA VE 2 Section 3.5.1 recommendations and figures.*
- *to follow the cable tray manufacturer recommendations and figures "TOUGH Support Savings".*

4.3 Cable Tray Fittings Structural Support Locations

The following cable tray system support lopcation recommendations will be considered:

4.3a. Horizontal Elbow Support: NEMA VE 2 Figure 3.54 and TSS Figure 3.1B
4.3b. Horizontal Tee Support: NEMA VE 2 Figure 3.55 and TSS Figure 3.2B
4.3c. Horizontal Cross Support: NEMA VE 2 Figure 3.57 and TSS Figure 3.3B
4.3d. Vertical Elbow Support: NEMA VE 2 Figure 3.59 and TSS Figure 4.1C

4.3a Horizontal Elbow Support: VE 2 : Figure 3-54

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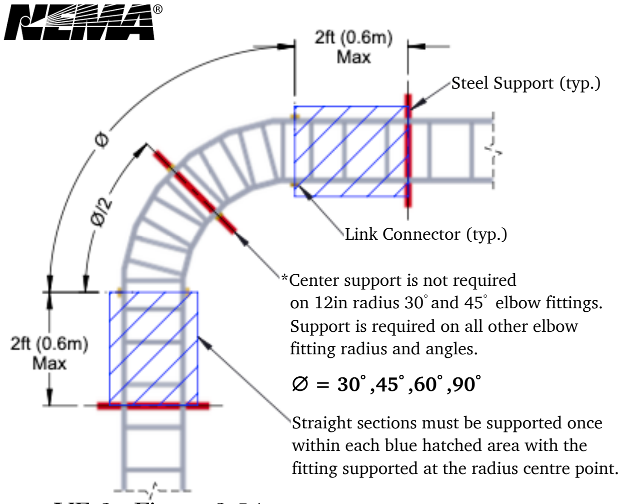

VE 2 : Figure 3-54

Industry Standard Practice : Support Locations		
VE 2	Support Quantity	Flexibility Factor
	3	0.9

4.3a Horizontal Elbow Support: TSS : Figure 3.1B

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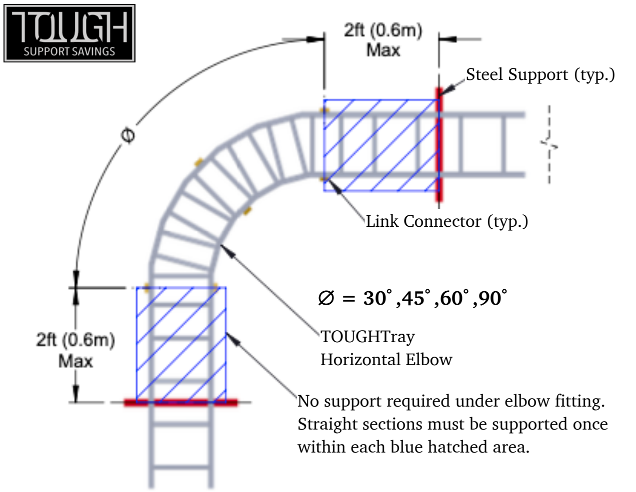

TSS : Figure TSS-3.1B

Manufacturer Recommended : Support Locations		
	Support Quantity	Flexibility Factor
	2	0.57

4.3b Horizontal Tee Support: VE 2 : Figure 3-55

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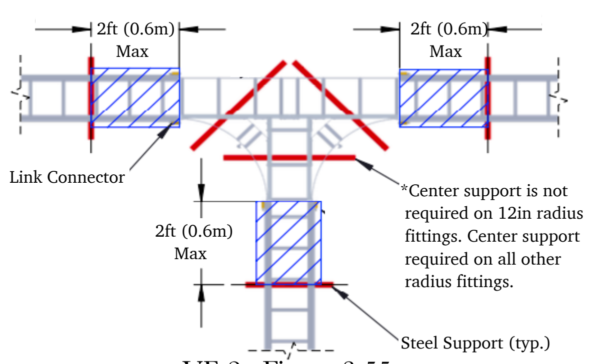
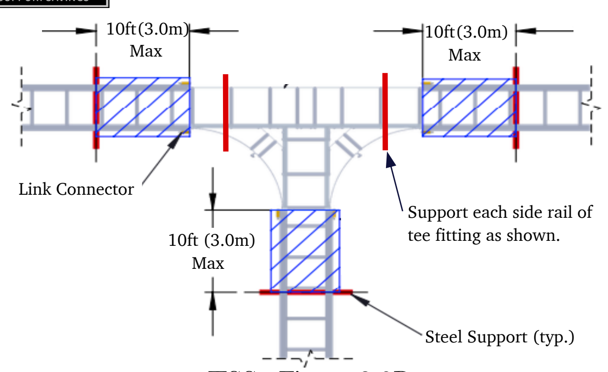


VE 2 : Figure 3-55

Industry Standard Practice : Support Locations		
VE 2	Support Quantity	Flexibility Factor
	6	0.9

4.3b Horizontal Tee Support: TSS : Figure 3.2B

TOUGH SUPPORT SAVINGS



TSS : Figure 3.2B

Manufacturer Recommended : Support Locations		
	Support Quantity	Flexibility Factor
	5	0.40

4.3c Horizontal Cross Support: VE 2 : Figure 3-55

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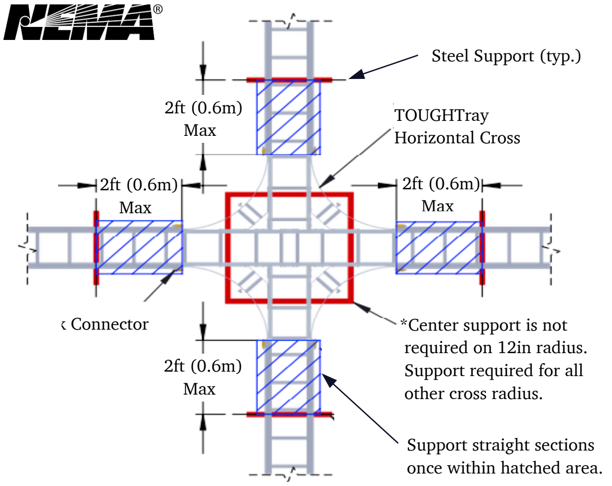
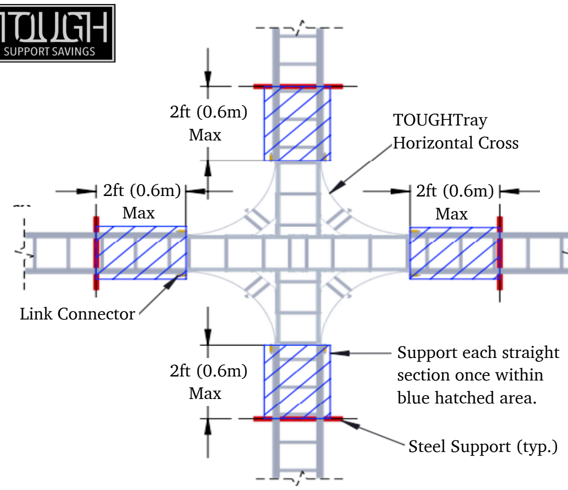


VE 2 : Figure 3-55

Industry Standard Practice : Support Locations		
VE 2	Support Quantity	Flexibility Factor
	8	0.9

4.3c Horizontal Cross Support: TSS : Figure 3.3B



TSS : Figure 3.3B

Manufacturer Recommended : Support Locations		
	Support Quantity	Flexibility Factor
	4	0.40

4.3d Vertical Elbow Support: VE 2 : Figure 3-59

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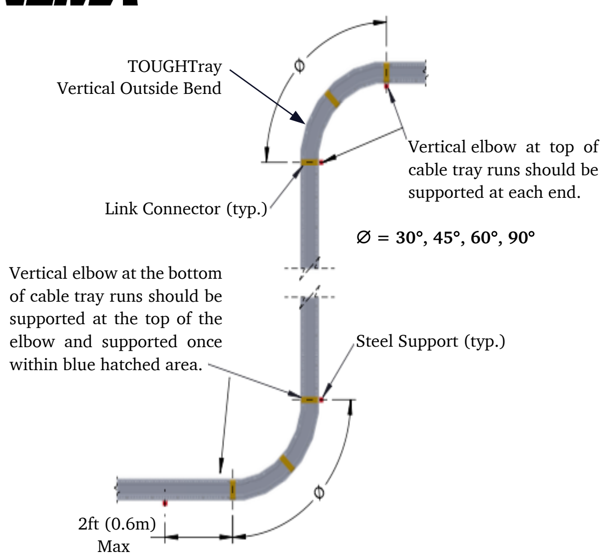
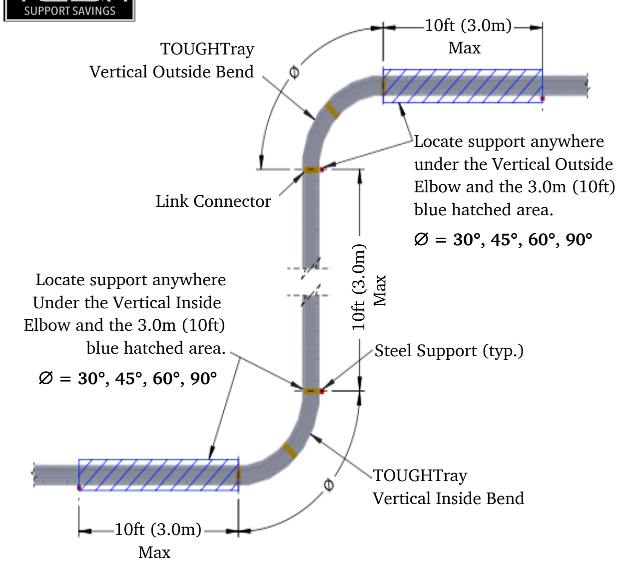


VE 2 : Figure 3-59

Industry Standard Practice : Support Locations		
VE 2	Support Quantity	Flexibility Factor
	4	0.9

4.3d Vertical Elbow Support: TSS : Figure 4.1C



TSS : Figure 4.1C

Manufacturer Recommended : Support Locations		
	Support Quantity	Flexibility Factor
	2	0.25

4.4 Expansion Joints

Cable tray continuous straight runs will thermally expand and contract under thermal dynamic loads.

Expansion joints are required to manage the thermal expansion/contraction, located and structurally supported in accordance with Industry Standard NEMA VE 2, Section 3.4.2.

Quote *"Supports should be located within 600 mm (2 ft) of each side of the expansion splice plates. Expansion splice joints should be designed and placed so as to maximize the rigidity of the cable tray, unless expansion splice plates are part of a system specifically designed for other placement, including over supports or mid-span"* unquote.

This recommendation raises questions concerning thermal expansion design. Clarifying these questions is important to ensure:

- *maximum rigidity of the cable tray.*
- *minimum quantity of structural supports.*

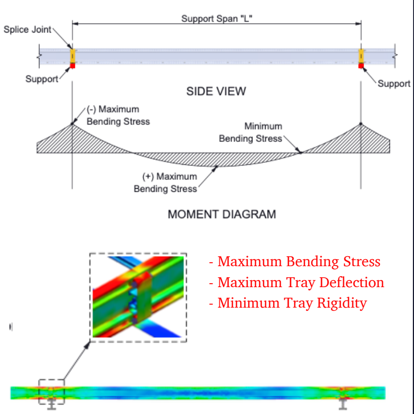
Questions:

A. *Rigidity : how do you design and place the expansion joint to maximize the rigidity of the cable tray?*
B. *Thermal : what are the expansion joints thermal performance implications?*
C. *Structure : what are the structural support design implications?*

Clarifications:
Let us consider the following expansion joint locations to analyze and answer questions A., B., C.

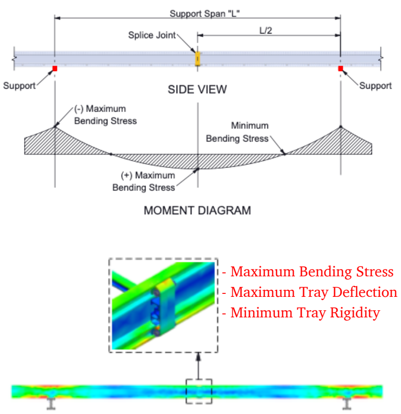
- *over support expansion joint location (4.4.1)*
- *mid-span expansion joint location (4.4.2)*
- *quarter-span expansion joint location (4.4.3)*

4.4.1 Over Support Location



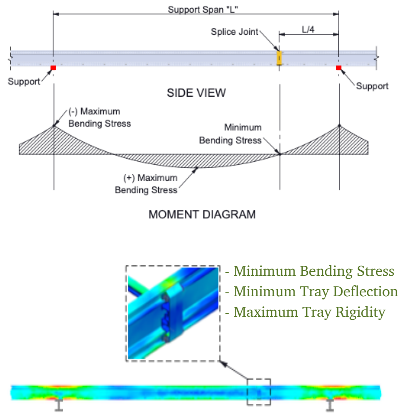
A. Rigidity:	Max. Bending Stress
B. Thermal:	Poor Performance
C. Structure:	No Additional Supports
Location is Not Recommended	

4.4.2 Mid-Span Location



A. Rigidity:	High Bending Stress
B. Thermal:	Poor Performance
C. Structure:	2 Additional Supports
Location is Not Recommended	

4.4.3 Quarter-Span Location



A. Rigidity:	No Bending Stress
B. Thermal:	Good Performance
C. Structure:	No Additional Supports
Location is Recommended	

4.4 Cable Tray Structural Support Locations

The following cable tray system support lopcation recommendations will be considered:

4.4a. Expansion Joint Support: NEMA VE 2 Figure 3.39 and TSS Figure 7.1B

4.4a. Expansion Joint Support Locations: VE 2 : Figure 3.39

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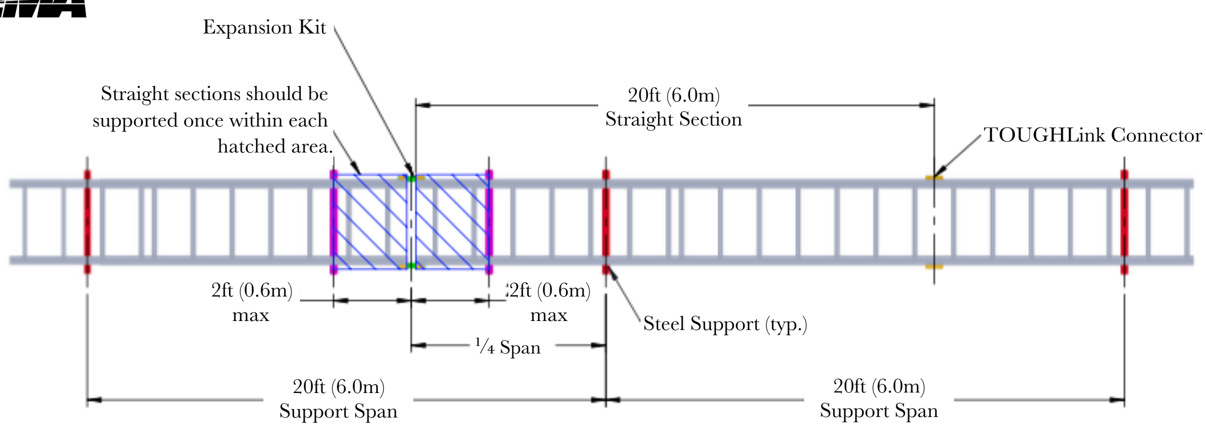
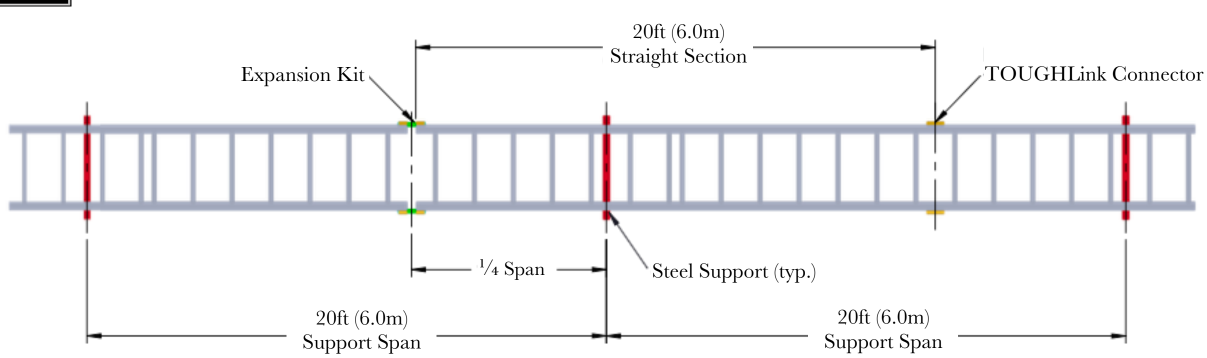


VE 2 : Figure 3-34

INDUSTRY STANDARD PRACTICE : SUPPORT LOCATIONS		
VE 2	SUPPORT QUANTITY	FLEXIBILITY FACTOR
	2	0.9

4.4a. Expansion Joint Support Locations: TSS TOUGH Support Savings

TOUGH SUPPORT SAVINGS



TSS : Figure 7.1B

MANUFACTURER RECOMMENDED : SUPPORT LOCATIONS		
	SUPPORT QUANTITY	FLEXIBILITY FACTOR
	0	0.00

5.0 TABULATION OF DESIGN PRACTICES

This tabulation provides a summary of the design practices detailed within Section 4.0. The below data shows if a design practice provides engineering design efficiency. Green colored cells indicate the design practice is efficient. Red colored cells indicate the design practice is less efficient.

Section #	Support Quantity		Flexibility Factor		Engineering Hours		Design Efficiency
	TSS	NEMA	TSS	NEMA	TSS	NEMA	TSS
4.3a	2	3	0.57	0.90	2.28	5.40	+57.78%
4.3b	5	6	0.40	0.90	4.00	10.80	+62.96%
4.3c	4	8	0.40	0.90	3.20	14.40	+77.78%
4.3d	2	4	0.25	0.95	1.00	7.60	+86.84%
4.4a	0	2	0.00	0.90	0.00	1.80	+100.00%

6.0 WORKED ENERGY PROJECT EXAMPLE

We now consider a cable tray projects structural support system requirements. Based on the Table 6.1 cable tray material take-off, we calculate the structural support system design efficiency when applying Industry Standard Practice Design Recommendations and Manufacturer Design Recommendations, refer to Table 6.2 analysis.

The calculations and comparisons will consider the following:

a) *Quantity of structural supports to be designed.*

b) *Structural support location design flexibility.*

c) *Time to engineer the structural supports.*

d) *Structural support design efficiency.*

TABLE 6.1 : CABLE TRAY SYSTEM MATERIAL TAKE-OFF				
Item #	Quantity	UOM	Cable Tray Description	NEMA VE 1
1.0	400	1-Pc	Horizontal Elbow 36"W 36"R	20C
2.0	150	1-Pc	Horizontal Tee 36"W 36"R	20C
3.0	100	1-Pc	Horizontal Cross 36"W 36"R	20C
4.0	250	1-Pc	Vertical Inside Elbow 36"W 36"R	20C
5.0	400	1-Pc	Vertical Outside Elbow 36"W 36"R	20C
6.0	1670	1-Pc	Expansion Joint Kit 36"W	20C

TABLE 6.2 : MATERIAL TAKE-OFF DESIGN PRACTICE EFFECIENCY ANALYSIS										
Item	Tray Description	UoM	Qty	Structural Support Quantity		Location Flexibility Factor		Engineering Design Hours		Design Efficiency
				NEMA	TSS	NEMA	TSS	NEMA	TSS	TSS
1.0	Horizontal Elbow 36"W 36"R	1-Pc	450	1350	800	0.90	0.57	2,430	912	+57.78%
2.0	Horizontal Tee 36"W 36"R	1-Pc	150	900	750	0.90	0.40	1,620	600	+62.96%
3.0	Horizontal Cross 36"W 36"R	1-Pc	100	800	400	0.90	0.40	1,440	320	+77.78%
4.0	Vertical IS Elbow 36"W 36"R	1-Pc	400	800	400	0.90	0.25	1,440	200	+88.9%
5.0	Vertical OS Elbow 36"W 36"R	1-Pc	400	800	400	1.00	0.25	1,600	200	+88.9%
6.0	Expansion Joint Kit 36"W	1-Pc	1100	2200	0	0.90	0.00	3,960	0	+100.0%
		TOTALS:		**6,850**	**2,750**			**12,490**	**2,232**	**+80.59%**

7.0 SUMMARY

With consideration to the data presented, we can summarize the available engineering design efficiencies:

a) NEMA VE 2 Industry Standard Practice Design Recommendations.
Industry Standard Practice does not reduce cable tray structural support quantities, nor the associated structural engineering design hours. It demonstrates low design flexibility and results in a low structural engineering design efficiency.

b) TOUGH Support Savings Manufacturer Design Recommendations.
Manufacturer Design Recommendations reduce the structural tray supports by 4,000 pieces, engineering design by 10,000 hours. It demonstrates excellent structural engineering design efficiency, a gain of 80.59%

8.0 CONCLUSIONS

Industry standard practices present design efficiency challenges which can be easily mitigated by the selection and implementation of alternate manufacturer recommendations. Based on the findings of this paper, we recommend:

a. Cable tray selection should consider the impact of the tray structural supports and the associated engineering design efficiency at the earliest possible stage of a project. This is recommended to be during project FEED.

b. Selecting a cable tray system designed to reduce support structure, that provides structural design flexibility and delivers quantifiable engineering design efficiency. This is recommended to be during project FEED.

9.0 REFERENCES & TOOLS

To aid the evaluation of cable ladder tray structural design efficiency, the following technical papers and quantification tools are available and recommended by the author. https://www.toughinnovations.com/resources

a. TOUGH Support Savings Calculator
b. TT-W004: Mitigating Critical Path Risks
c. TT-W006: Improved Installation Efficiency

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