Controlling Parameters in the design of Concrete slabs Reinforced with Non-metallic reinforcement

(FRP-RC Slabs)

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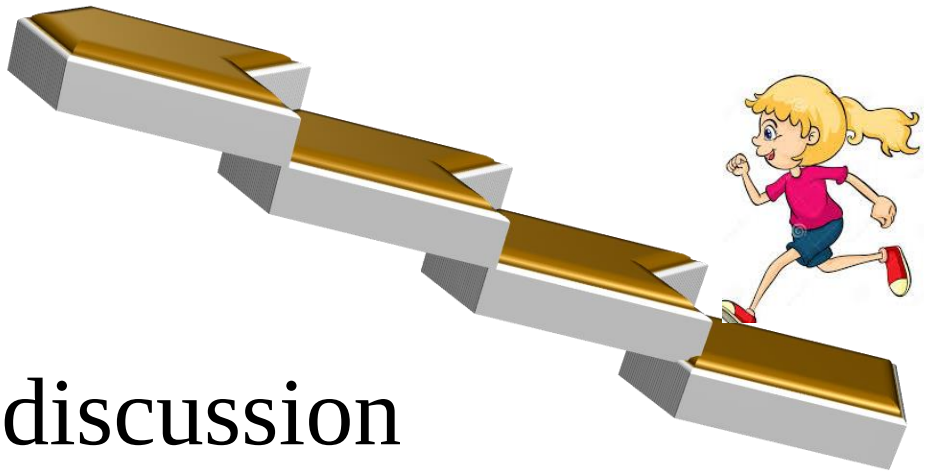
Contents

- Introduction
- Aim of Study
- Objectives
- Methodology
- Observations and discussion
- Conclusion



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INTRODUCTION

Introduction

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Introduction

- Reasons for limited use of FRP in the construction industry
  - Lower modulus of elasticity
  - No ductility
  - Possibly higher initial cost
  - Lack of design standards
  - Lack of confidence in designers

- Focus of FRP reinforcement in the past
  - Bridges
  - Strengthening of existing structures

Recent developments

- FRP material properties and aids
  - Improved modulus of elasticity
  - Improved bond performance
  - Improved manufacturing techniques
  - Availability of design guides
  - Improved confidence in designers
- Recent trends in the use of FRP
  - Transportation Engineering
  - Flat work

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AIMS & OBJECTIVES

Objectives

1. To understand the design issues in FRP RC slabs of residential buildings

2. Effects of lower modulus of elasticity of FRP bars and its impact on design of FRP RC slabs

3. To develop a relationship between thickness and span of FRP-RC one-way solid non-prestressed slabs

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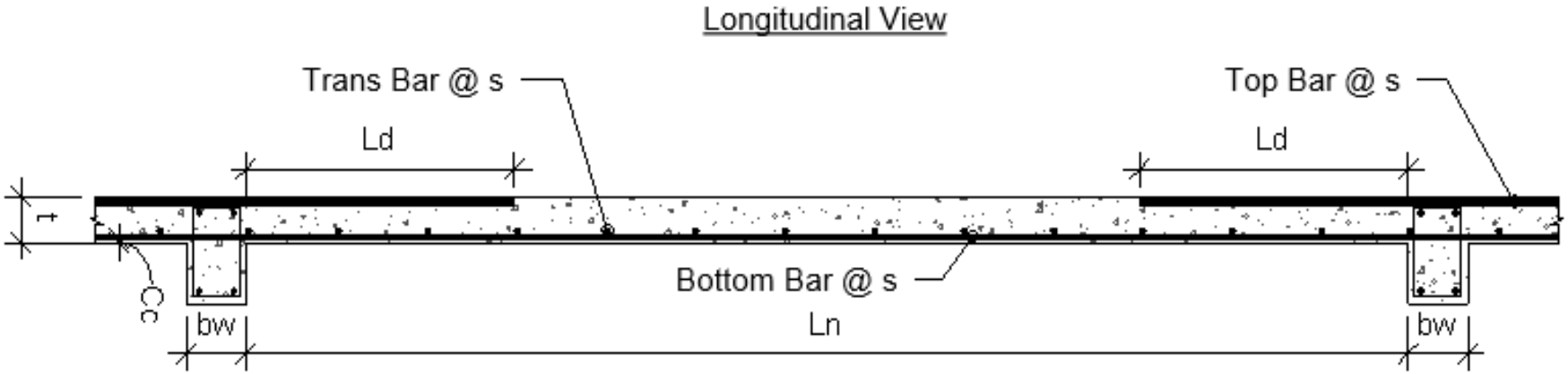
Methodology

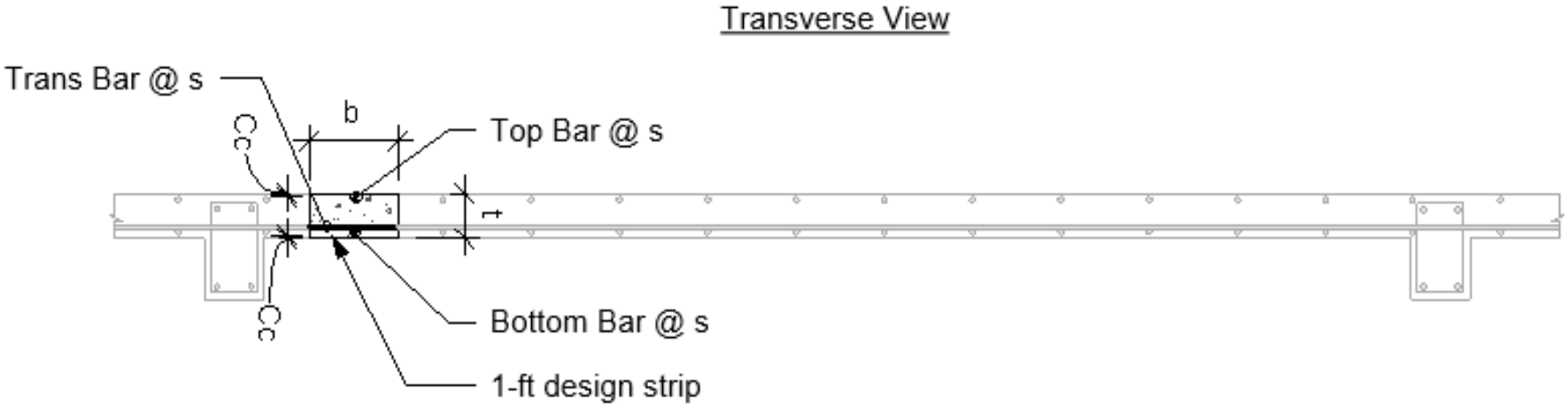
Methodology

- Slabs were designed with four end conditions
  1. Simply supported
  2. Both ends continuous
  3. One end continuous
  4. Cantilever

- Mathcad sheets were developed to analyze all the slabs

An Example of a continuous slab





Properties of Materials

Bar Designation	Diameter (in)	Area (in^2)	Elastic modulus (ksi)	Tensile strength (ksi)	Concrete strength (ksi)	Bond coefficient k_b	Concrete clear cover (in)
GFRP-04*	0.5	0.2	8,702	139.5	4.0	1.35	0.75
GFRP-05*	0.625	0.31		132			
GFRP-06*	0.75	0.44		130			
GFRP-04	0.5	0.2	6,500	108			
GFRP-05	0.625	0.31		94			
GFRP-06	0.75	0.44		93			

Observations & discussions

- Stresses in FRP reinforcement
- Development length
- Constructability issues
- Serviceability issues
- Effect of lower modulus of elasticity

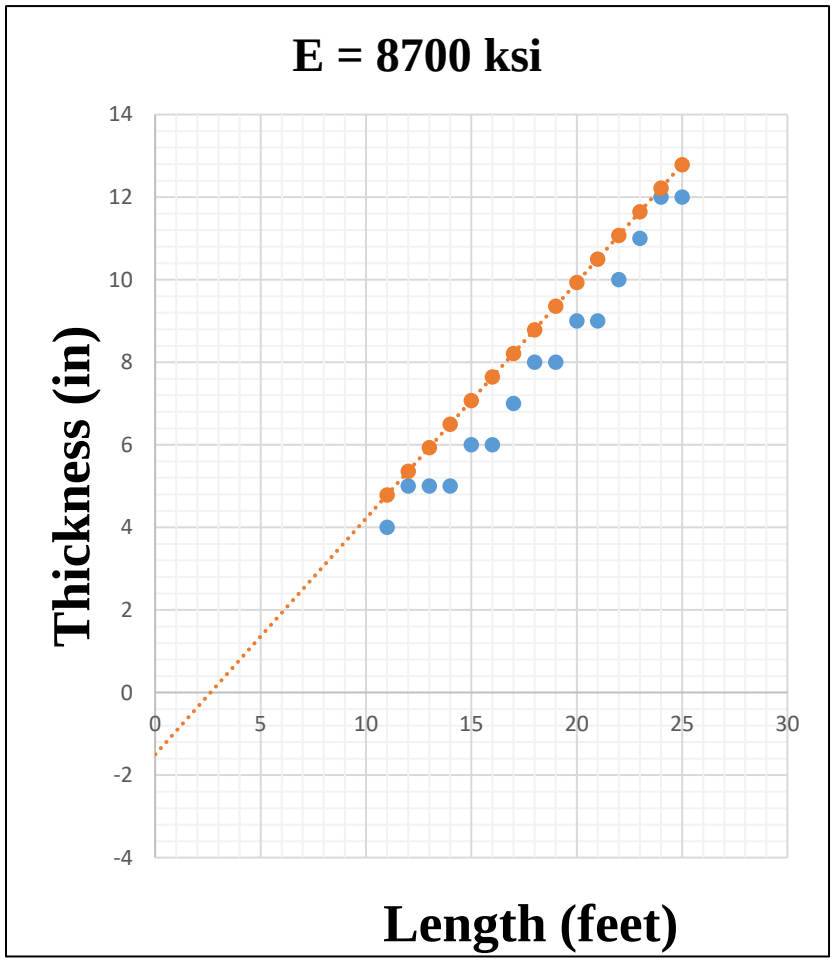
Simply supported slabs at max: reinforcement

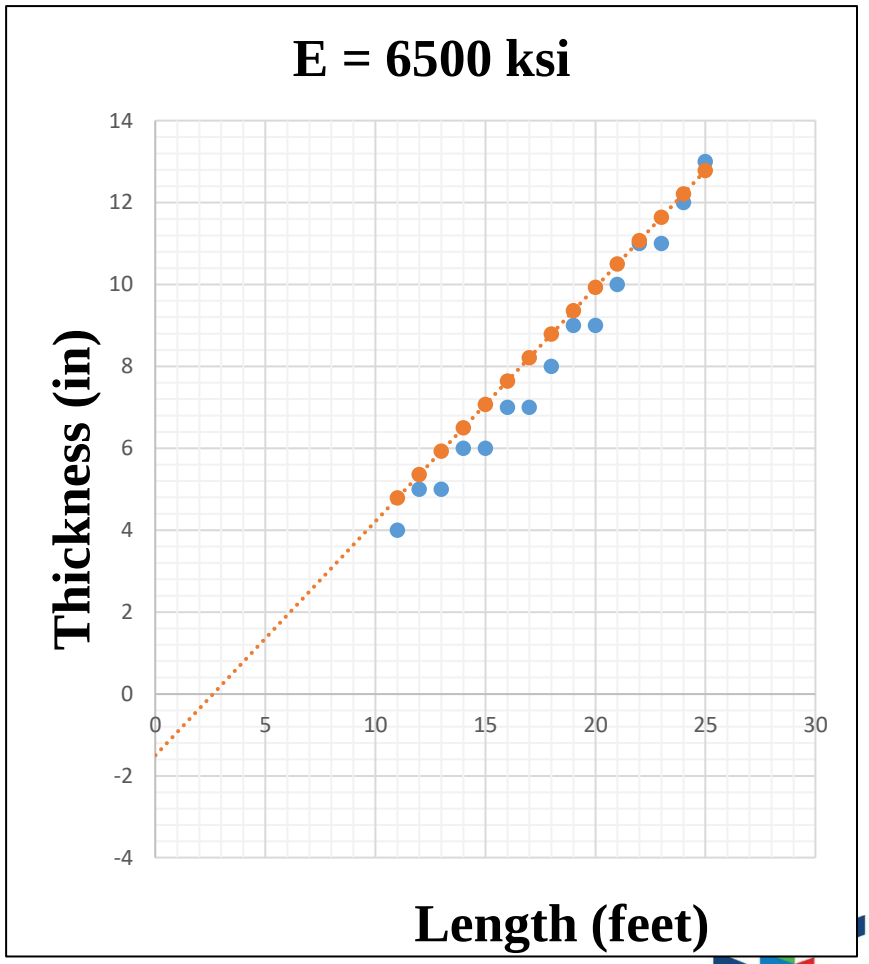
Designation	Clear span (feet)	*h* (in)	Bar size @ c/c	Req. Area (in^2)	Pro. Area (in^2)
F-12	12	5	#4@7.5	0.14	0.31
F-13	13	5	#4@6.5	0.14	0.36
F-14	14	5	#4@2.5	0.14	0.94
F-15	15	6	#4@5	0.18	0.47
F-16	16	6	#4@2.5	0.18	0.94

Simply supported slabs designed at A_{fmin}

Designation	Clear span (feet)	*h* (in)	Bar size @ c/c	Required Area (in^2)	Provided Area (in^2)
F-12	12	5	#4@7	0.14	0.31
F-13	13	6	#4@7	0.14	0.34
F-14	14	6	#4@7	0.14	0.34
F-15	15	7	#4@6	0.18	0.39
F-16	16	7	#4@6	0.18	0.39

New v/s old generation bars





Continuous slabs

- Positive and negative reinforcement
- More reinforcement at mid span
- The effect of more reinforcement at mid-span

$$I_e = 0.70 I_{e+} + 0.15(I_{e1-} + I_{e2-}) \qquad (24.2.3.6)$$

Continuous slabs at maximum reinforcement

Desig:	Clear span (ft)	*h* (in)	Negative Reinforcement	Req. Area (in^2)	Prov. Area (in^2)	Positive Reinforcement	Req. Area (in^2)	Prov. Area (in^2)
F-12	12	4	#4@8.5	0.17	0.28	#4@8.5	0.11	0.28
F-13	13	4	#4@8	0.17	0.29	#4@5	0.11	0.47
F-14	14	4	#4@7	0.17	0.34	#4@2.5	0.11	0.94
F-15	15	5	#4@7.5	0.21	0.31	#4@5	0.14	0.47
F-16	16	5	#4@7	0.21	0.34	#4@2.5	0.14	0.94

Continuous slabs at A_{fmin}

Desig:	Clear span (ft)	*h* (in)	Negative Reinforcement	Req. Area (in^2)	Pro. Area (in^2)	Positive Reinforcement	Req. Area (in^2)	Pro. Area (in^2)
F-12	12	4	#4@8	0.11	0.29	#4@8	0.11	0.29
F-13	13	4	#4@7	0.11	0.33	#4@7	0.11	0.33
F-14	14	4	#4@7	0.11	0.34	#4@7	0.11	0.37
F-15	15	5	#4@7	0.11	0.34	#4@7	0.14	0.37
F-16	16	6	#4@6	0.14	0.39	#4@6	0.14	0.39

Cantilever slabs

Designation	Clear span (feet)	*h* (in)	Bar size with center to center spacing			Req. Area (in^2)	Pro. Area (in^2)
GFRP-03	4	4	#4@10	#5@13	#6@15	0.11	0.24
GFRP-04	5	4	#4@7	#5@8	#6@10	0.114	0.34
GFRP-05	6	5	#4@6	#5@8	#6@9	0.143	0.36
GFRP-06	7	6	#4@5	#5@7	#6@9	0.172	0.43

Relationship between length and thickness

Support condition	*h* at maximum reinforcement	ACI-318-19	*h* A_{f_min}	*h* *at* A_{f_min} & $f`_c = 2500$
Simply supported	$\frac{l}{25}$	$\frac{l}{20}$	$\frac{l}{23}$	$\frac{l}{19}$
Both end Continuous slabs	$\frac{l}{32}$	$\frac{l}{28}$	$\frac{l}{26}$	$\frac{l}{22}$
One end continuous	$\frac{l}{30}$	$\frac{l}{24}$	$\frac{l}{28}$	$\frac{l}{22}$
Cantilever	$\frac{l}{13}$	$\frac{l}{10}$	$\frac{l}{12}$	$\frac{l}{9}$

Conclusions

Objectives

- Serviceability controls design
- More reinforcement and consequently more material is required for FRP-RC slabs
- Development length values may lead to constructability issues

Conclusions

- Improvements in material properties have impacted the design
- Large diameter bars be avoided
- Design of FRP-RC slabs should be limited to 18 feet


TOWARDS
SUSTAINABLE
FUTURE