STRUCTURAL STRENGTHENING WITH FRP.
AVAILABLE SYSTEMS AND CARBODUR SOFTWARE TOOL

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BUILDING TRUST

AGENDA

1. Understanding the Need for Structural Strengthening
   Explore the reasons behind reinforcing existing structures and the benefits it provides.

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2. Designing with FRP: Standards and Guidelines
   Review current industry standards and best practices for designing with Fiber-Reinforced Polymer (FRP) systems.

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3. Overview of FRP Systems and Applications
   Examine the types of FRP systems available and their practical uses in structural engineering.

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4. Introducing the Enhanced CarboDur Design Software
   Discover the latest features and improvements in the CarboDur software tailored for structural designers.

WHAT WE DO
BUILDING TRUST

- Sika is a specialty chemicals company with a leading position in the development and production of systems and products for bonding, sealing, damping, reinforcing and protecting in the building sector and motor vehicle industry.

SIKA AT A GLANCE

25,000	EMPLOYEES
100	COUNTRIES
300+	PLANTS WORLDWIDE
6	NEW & EXPANDED PLANTS IN 2020
83	NEW PATENTS IN 2020
1	ACQUISITION IN 2020
7.88 BN	NET SALES IN 2020 (IN CHF)

WE ARE THERE

Our products might not always be visible but the results they achieve bring clear added value to customers and society.

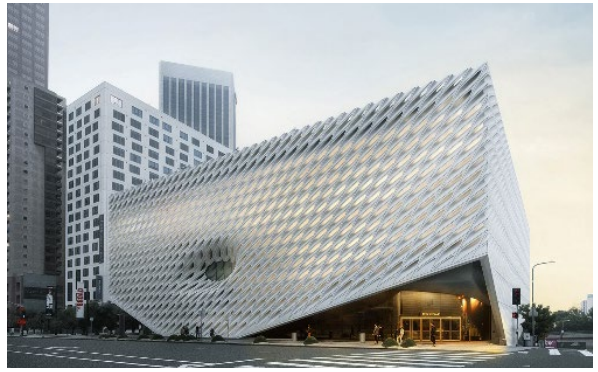
TARGET MARKETS – FOCUS ON ATTRACTIVE MARKETS
SOLUTIONS, LIFE-CYCLE MANAGEMENT, ONE STRONG BRAND

Concrete

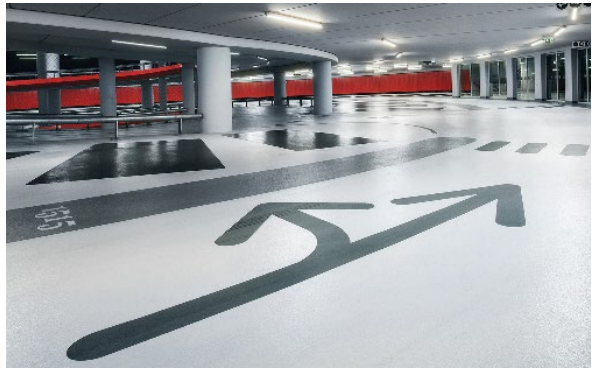
Waterproofing

Roofing

Building Finishing



Flooring & Coating



Sealing & Bonding

Engineered Refurbishment

Industry

UNDERSTANDING STRUCTURAL STRENGTHENING

Optional Subtitle

WHY DO STRUCTURES NEED STRENGTHENING

So that our structures are not zip-tied or strapped together to prevent failure!

WHY DO STRUCTURES NEED STRENGTHENING?

- Insufficient reinforcement
- Corrosion damage
- Change in use
- Structural damage
- Seismic upgrade

HEHOW ARE STRUCTURES STRENGTHENED
TYPICAL STRENGTHENING METHODS

Externally bonded FRP or Steel
Traditionally done with steel, most bonded strengthening is nowdays done with FRP

Section enlargement
Used frequently, this method is intrusive to the structure, adds a lot of weight, and takes longer to implement

External Post-tensioning
For cases where high-capacity contribution is required, external PT is great solution. Traditionally done with steel, PT strengthening can also be done with FRP

Supplemental Support
Supplemental supports are a great solution, though they take headspace and can be tricky to install.

WHAT ARE FRP SYSTEMS?

FABRIC

Fabrics are made from glass or carbon fiber.

RESIN

Most used resins to saturate the fabrics are epoxy and more recently PU.

REINFORCED CONCRETE

Reinforced concrete is a composite. Bonding FRP to it creates a complex system. Understanding how to design with it properly is critical for successful strengthening.

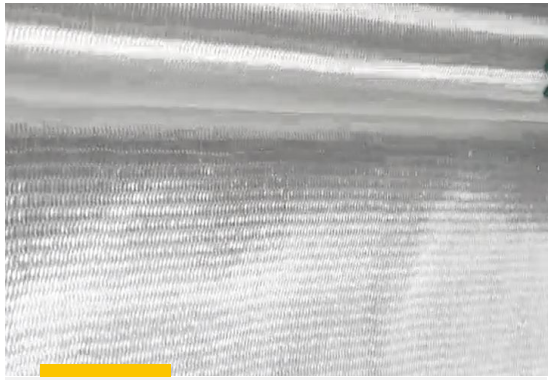
MOST COMMON FRP MATERIALS
GLASS VS CARBON

Carbon Systems (CFRP)

- Damp/wet conditions
- Stiffness driven
- Extreme alkaline conditions

Stronger, stiffer, more durable

CFRP



Glass Systems (GFRP)

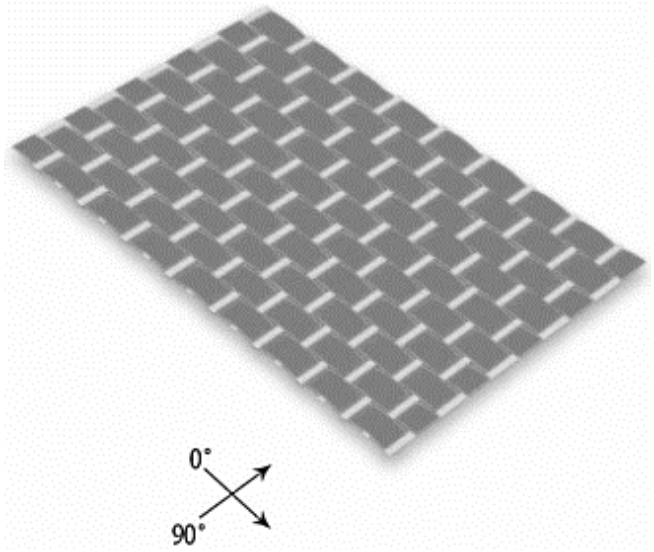
- Seismic strengthening
- Dry conditions
- Extreme acidic conditions
- Economical

Economical, used commonly for seismic retrofit

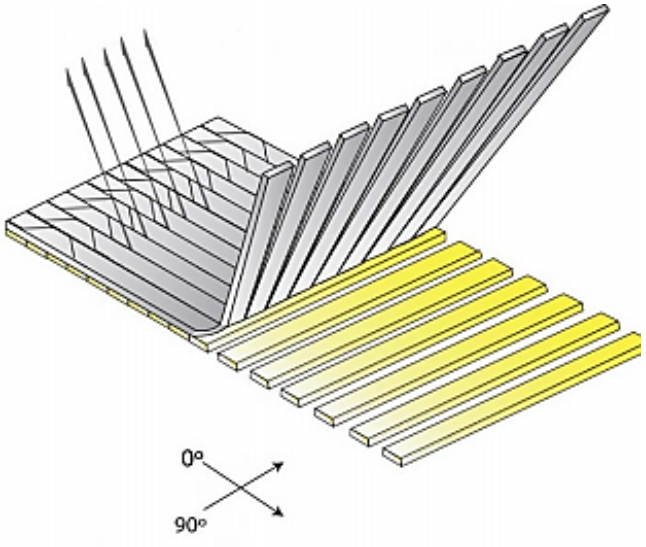
GFRP

FRP FABRIC TYPES

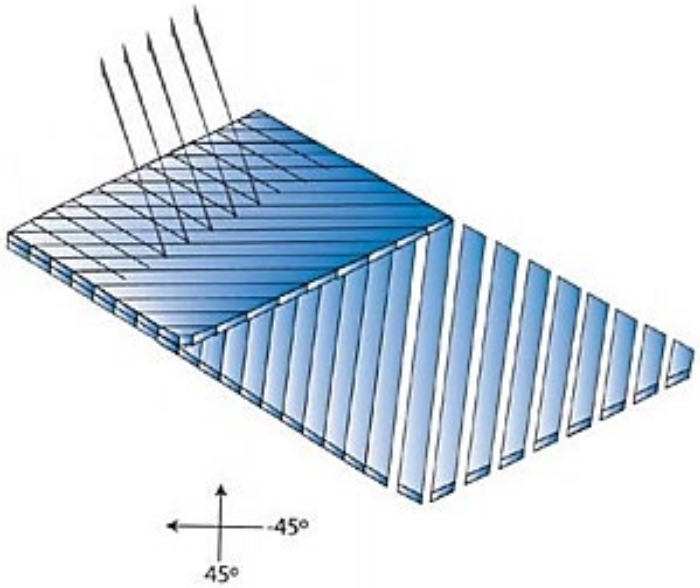
Uniaxial Fabrics



Biaxial Fabrics



+/-45d Fabrics



ADVANTAGES OF FRP REPAIRS

- Cost/scheduling benefits
- Reduced maintenance costs
- Light weight materials puts less strain on the structure
- Non-corrosive, designed for long-term performance
- Great for limited access

TYPICAL APPLICATIONS

Optional Subtitle

TYPICAL APPLICATIONS
PARKING STRUCTURES

- Shear Strengthening
- Corrosion Damage
- Column strengthening

TYPICAL APPLICATIONS
BUILDINGS

- Modifications (wall or slab openings)
- Change in use
- Seismic upgrades
- Wall strengthening

TYPICAL APPLICATIONS
BRIDGES

- Girder Strengthening
- Column Wrapping
- Pier Upgrades
- Pier cap strengthening
- Deck Stiffening

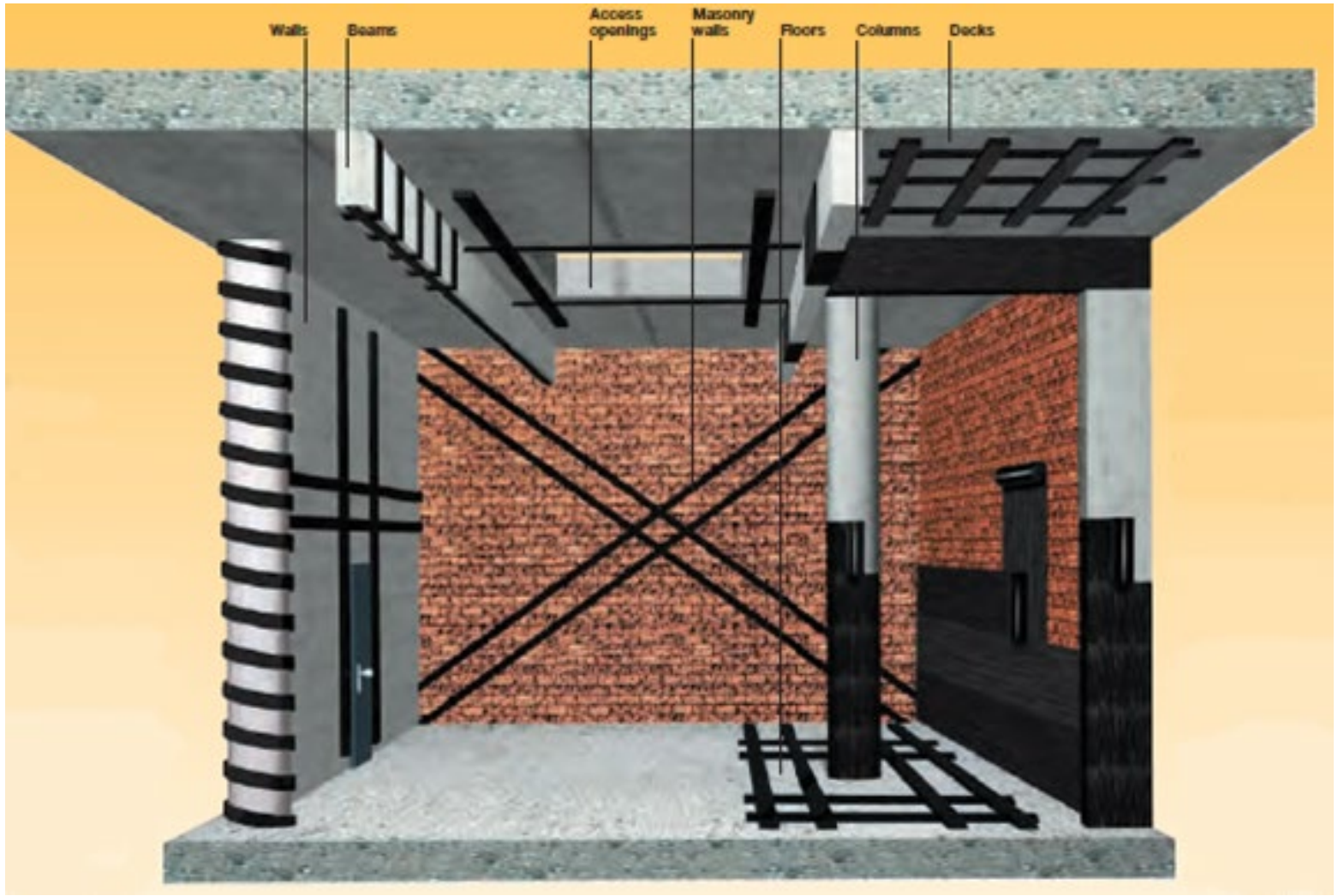
TYPICAL USAGE OF FRP MATERIALS

Flexural

Shear

Confinement

Seismic



TYPICAL USAGE OF FRP MATERIALS
SUMMARY

- Load Increases
- Increased live loads
- Increased traffic volumes on bridges
- Installation of heavy machinery in industrial buildings
- Vibrating structures
- Changes of building utilization

- Seismic Strengthening
- Column wrapping
- Masonry walls

- Damage to Structural Parts
- Aging of construction materials
- Vehicle impact
- Fire
- Blast resistance

- Change in Structural System
- Removal of walls or columns
- Removal of slab sections for openings

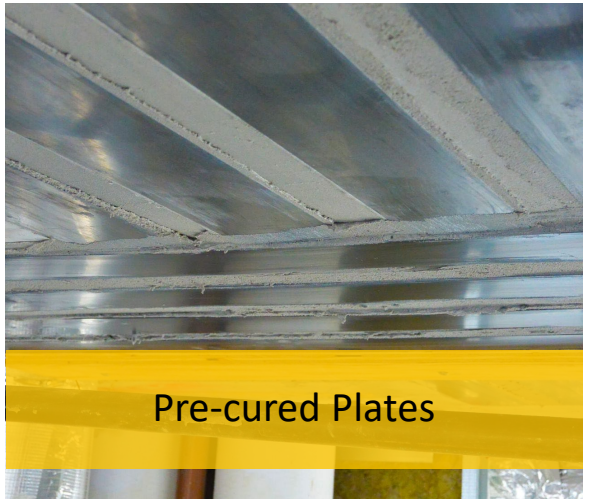
- Design or Construction Defects
- Insufficient reinforcements
- Insufficient structural depth

OVERVIEW OF FRP SYSTEMS AND APPLICATIONS

Optional Subtitle

AVAILABLE FRP SYSTEMS

Epoxy Wet Lay-up Systems



Pre-cured Plates

NSM Rods

FRP Anchorage

FRCM System

PRIMER APPLICATION FOR FRP SYSTEMS

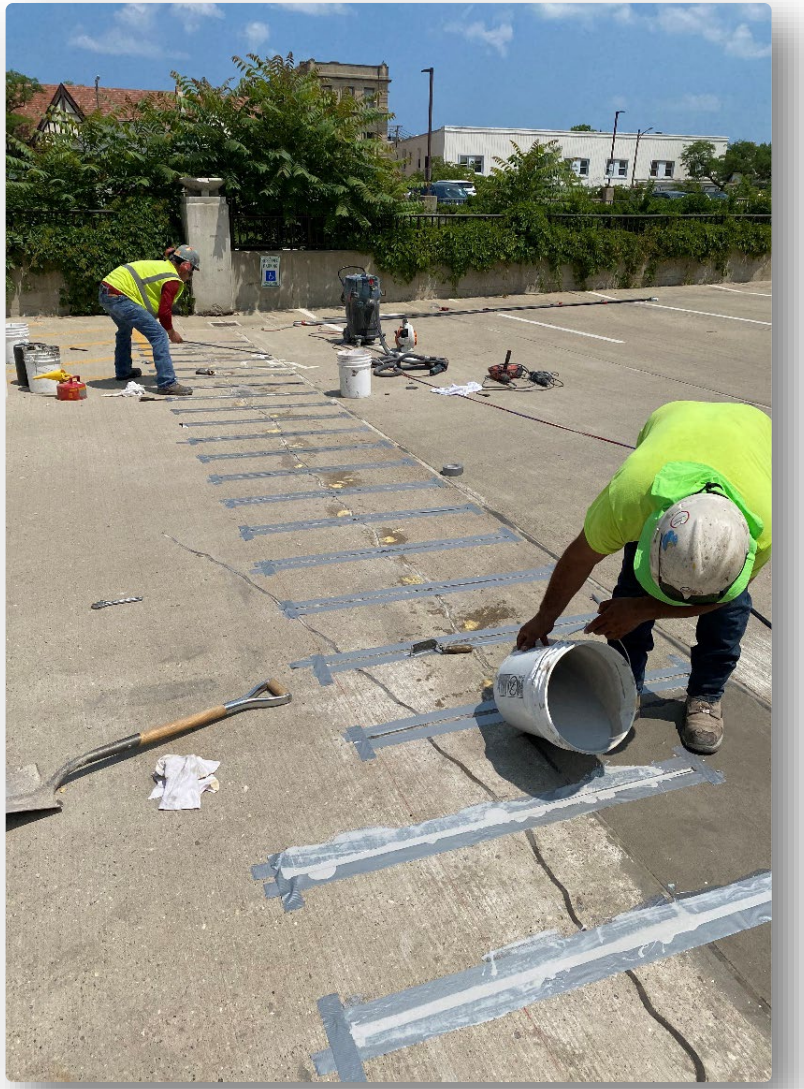
- Mix & Apply Epoxy Primer

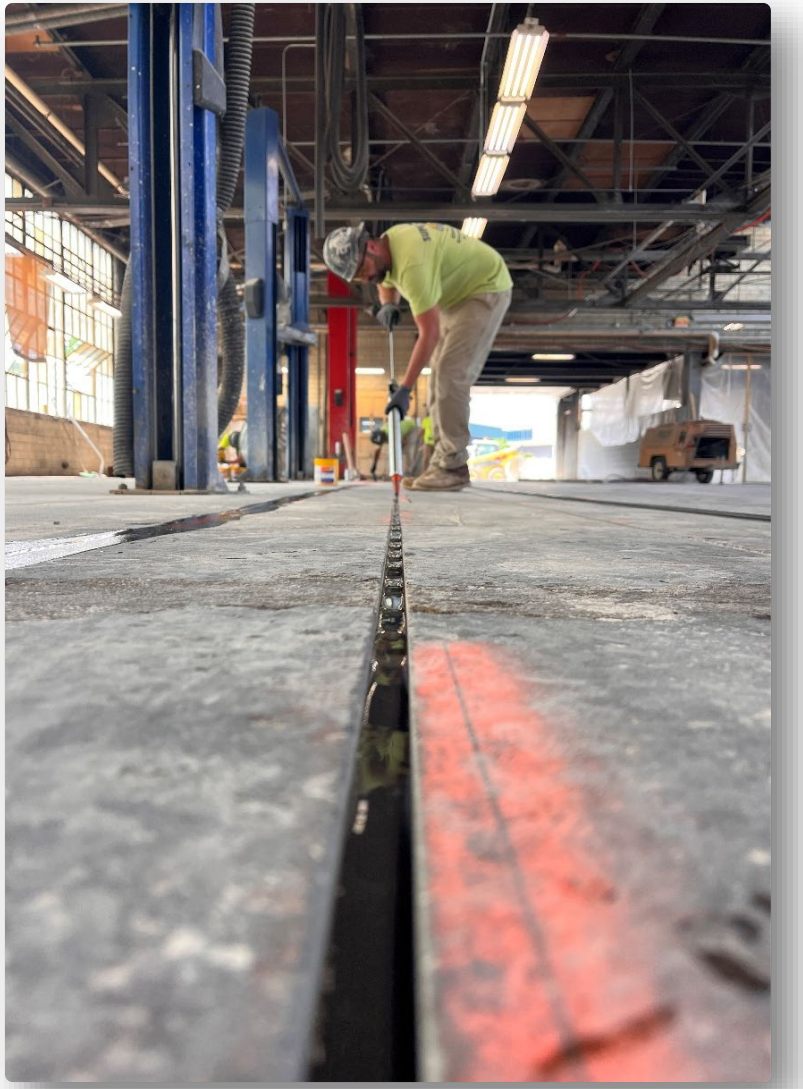



FIELD SATURATED FRP SYSTEMS
SATURATE FABRIC WITH RESIN – TABLE OR SATURATOR

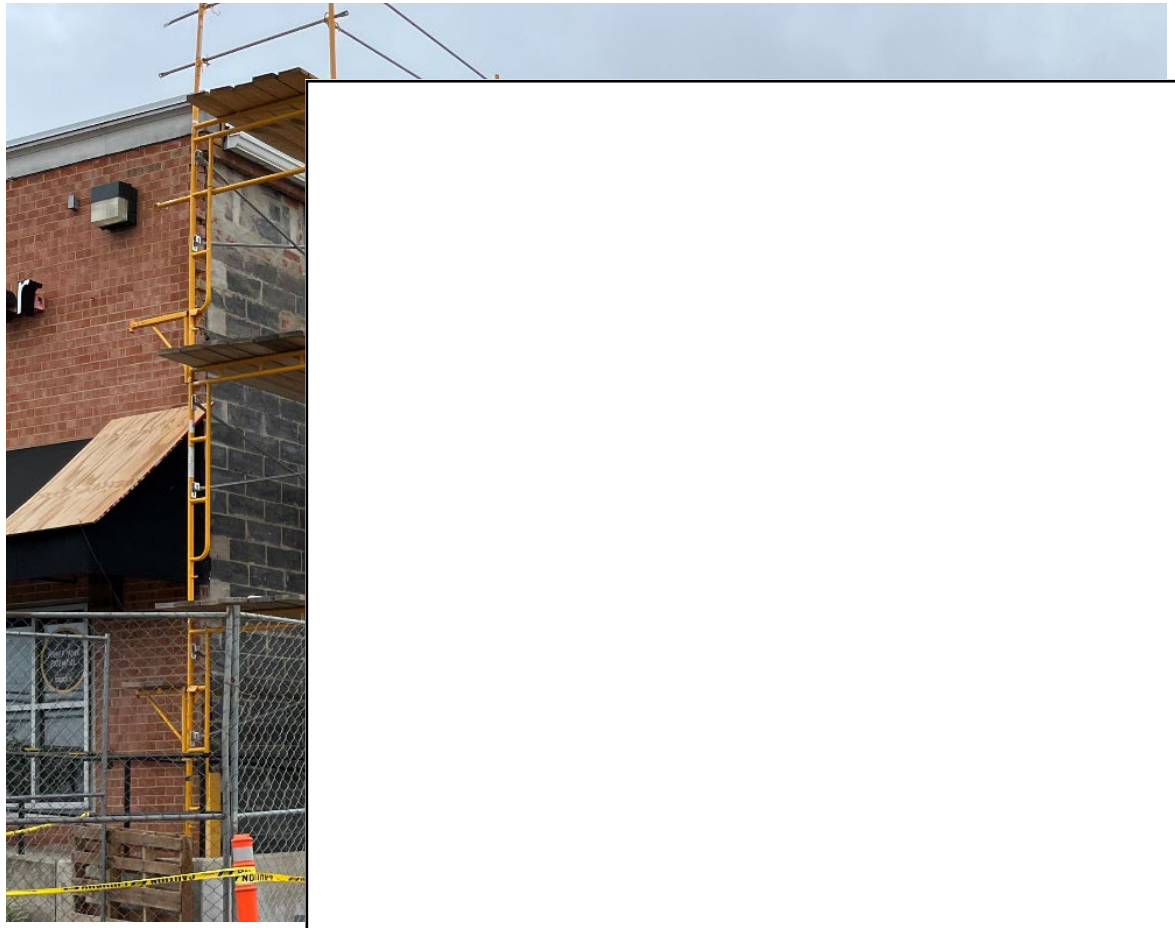
CFRP PLATES
CLEAN, CUT, AND INSTALL STRIPS

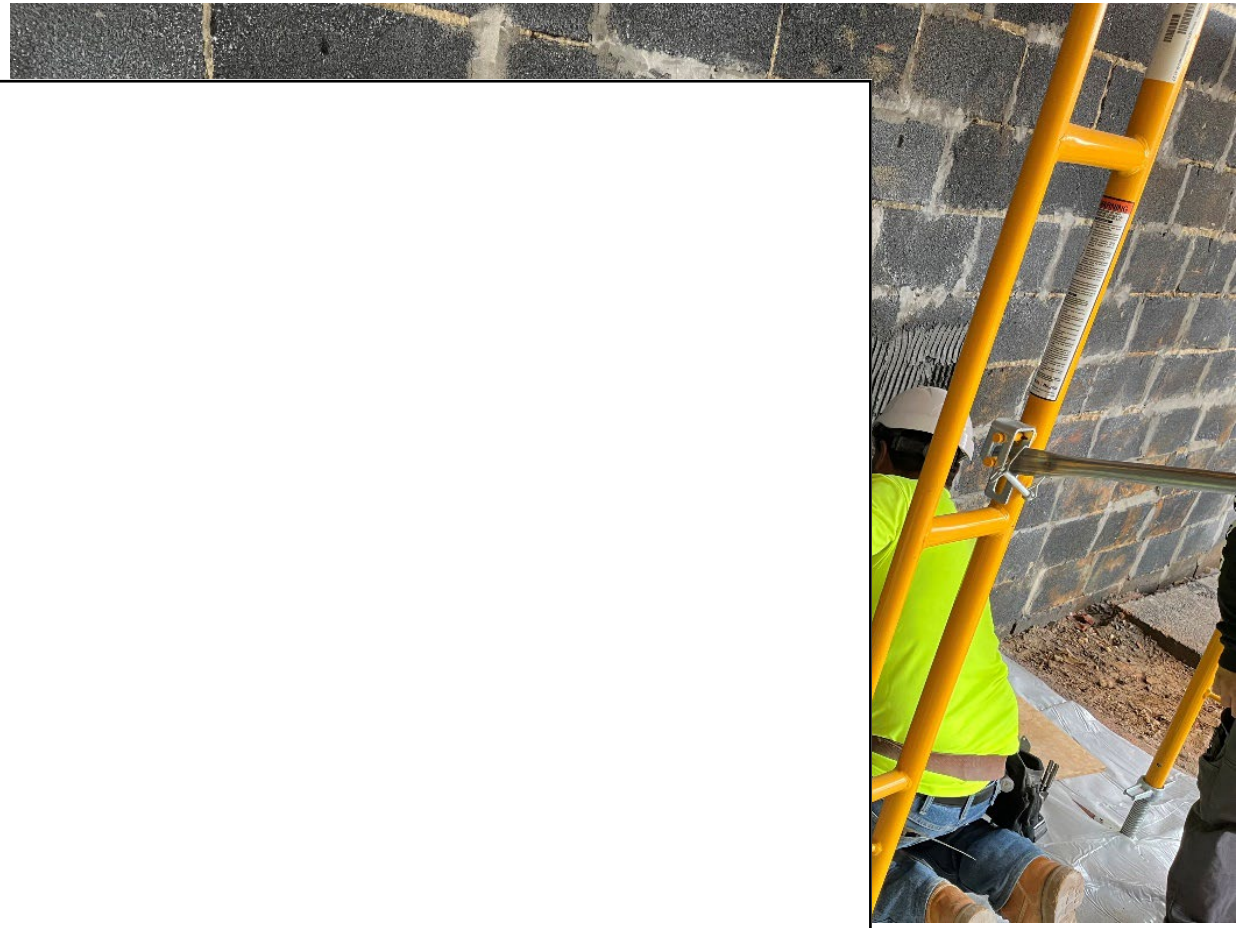
FRP RODS
NSM REINFORCEMENT





FRCM REINFORCEMENT





DESIGN GUIDES AND PRINCIPALS

Optional Subtitle

CODES AND STANDARDS
ACI & AASHTO

- ACI 440.2-23
  - Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures – Guide

- ACI 562-17
  - Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Buildings

- AASHTO Guide 2nd Ed

- ICC Evaluation Service Report

“SUPPLEMENTAL REINFORCEMENT”

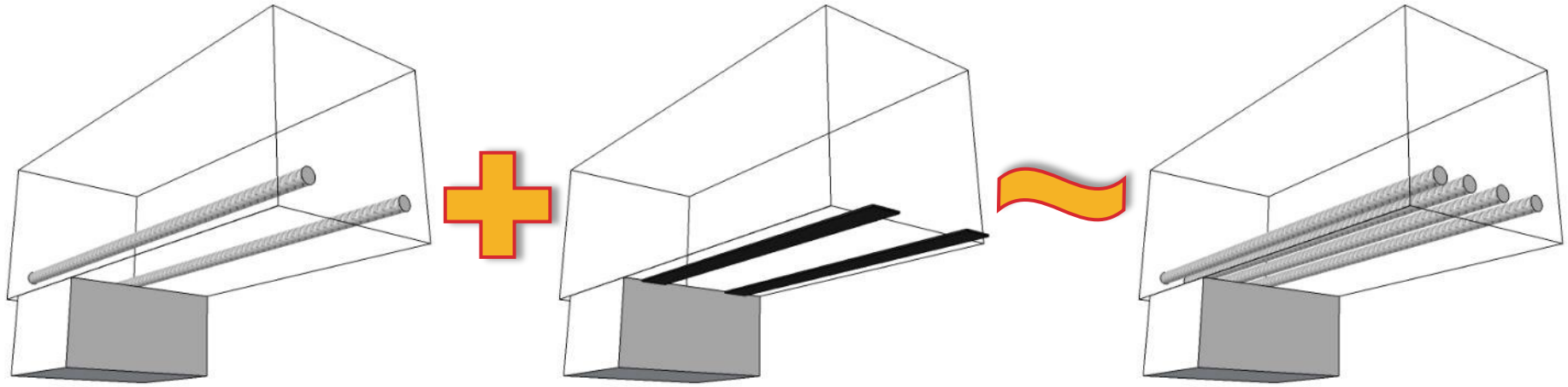
FRP Limitations

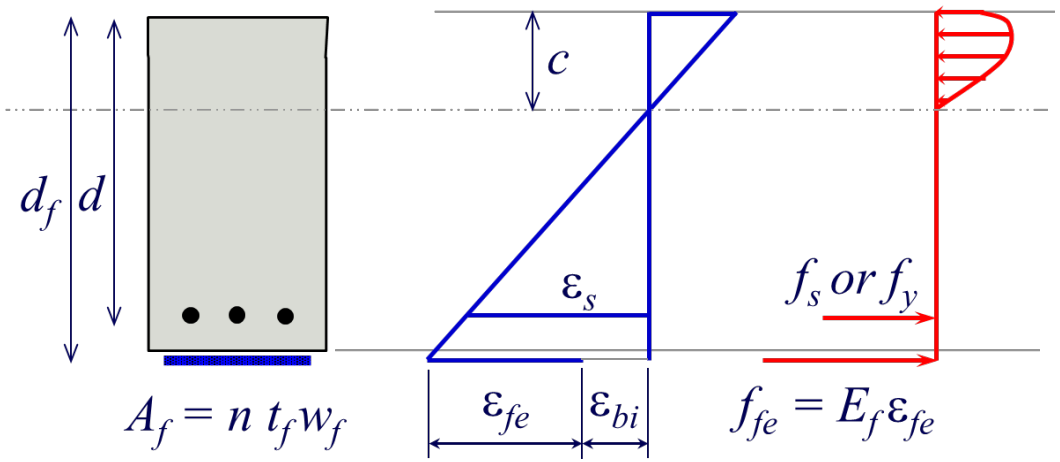
$$(\phi R_n)_{existing} \geq (1.1S_{DL} + 0.75S_{LL})_{new}$$

Existing Capacity ≥ Load demand:
1.1DL + .75LL

FLEXURAL REINFORCEMENT

HOW DOES CFRP AFFECTS A REINFORCED BEAM?
FLEXURAL STRENGTHENING





$$M_n = \underbrace{A_s f_s \left(d - \frac{\beta_1 c}{2} \right)}_{\text{Steel Contribution}} + \underbrace{\Psi_f A_f f_{fe} \left(d_f - \frac{\beta_1 c}{2} \right)}_{\text{FRP Contribution}}$$

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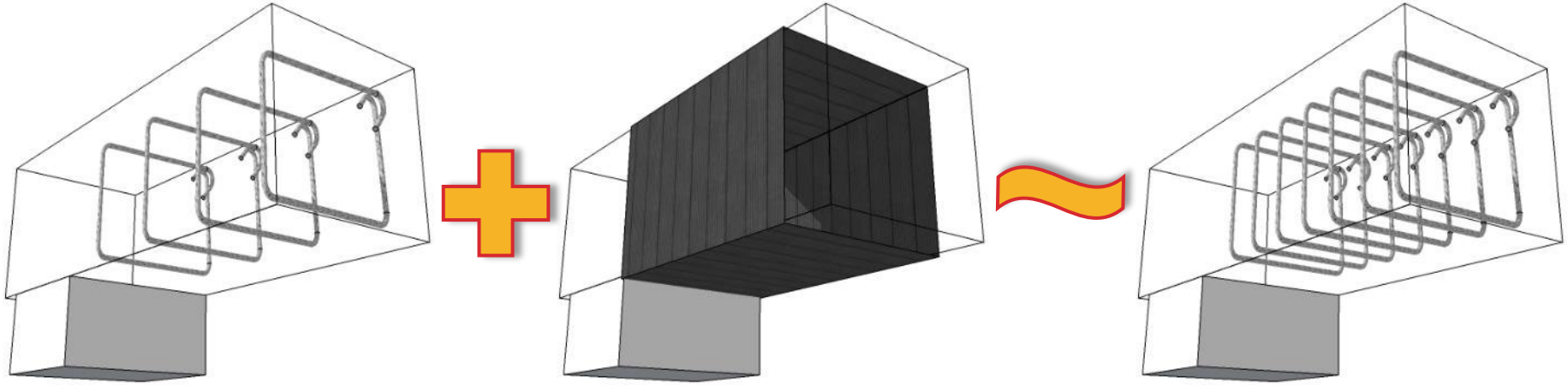
SHEAR REINFORCEMENT

HOW DOES CFRP AFFECTS A REINFORCED BEAM?
SHEAR STRENGTHENING

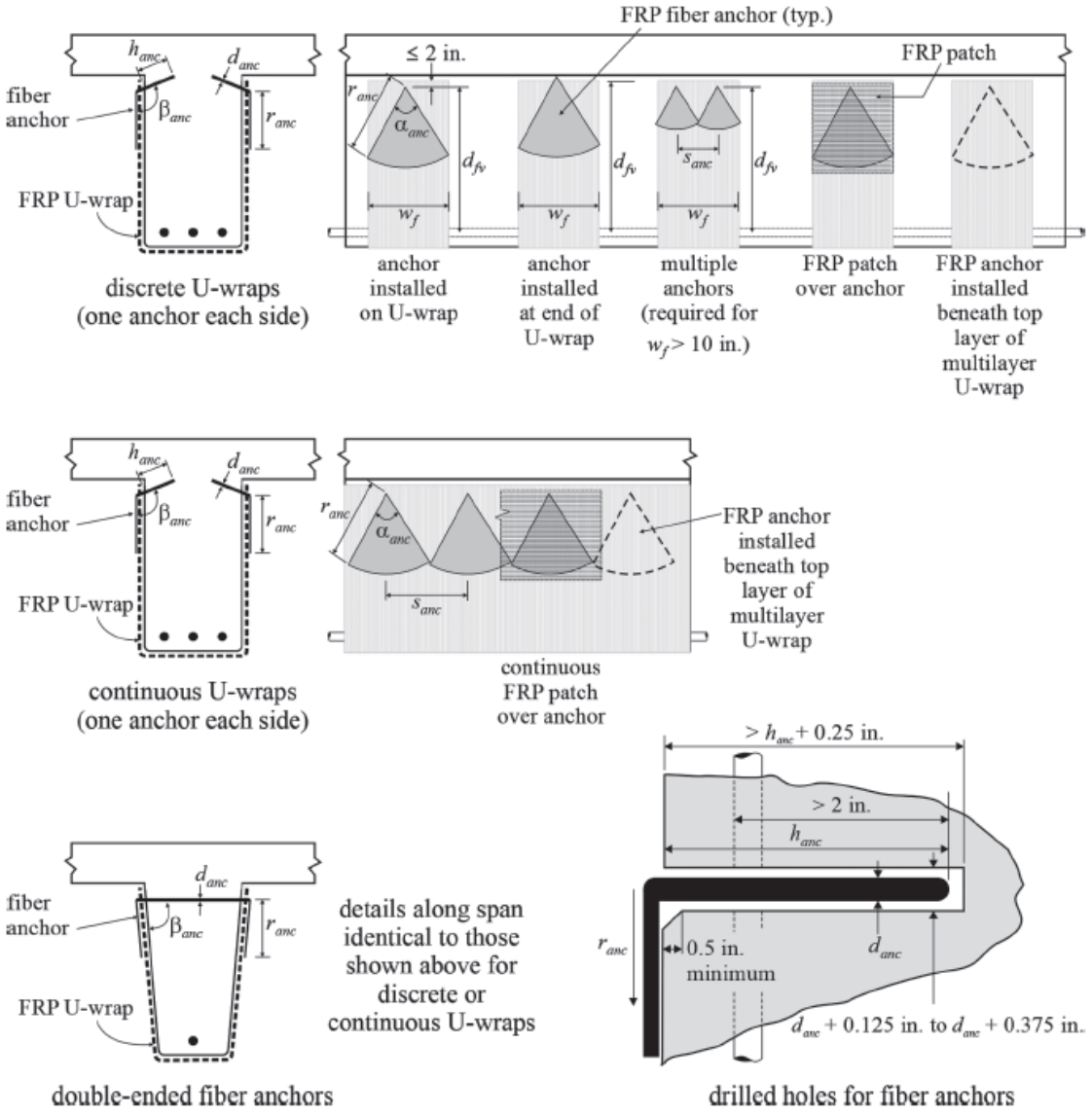


$$\phi V_n = \phi\left(V_c + V_s + \Psi_f V_f\right)$$

Steel and concrete contribution

FRP Contribution

U-WRAP ANCHORAGE – FIBER ANCHORS



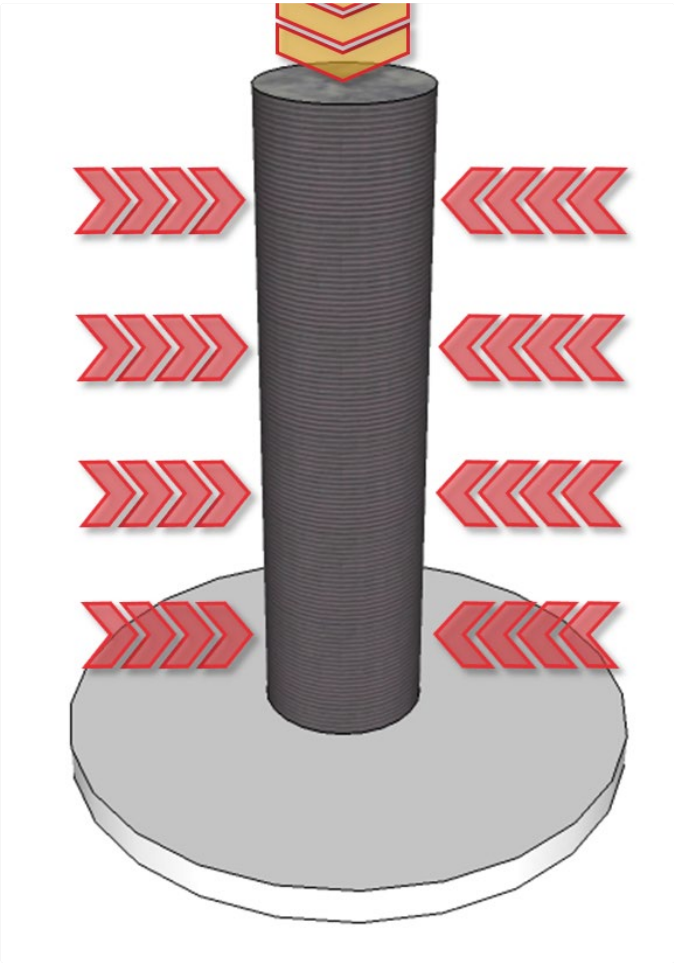
$$A_{anc} \geq R_A(Nt_f s_{anc})$$

Table 8.7.6.1—Fiber anchor design parameters and detailing requirements, in.-lb

s_{anc}, in.	U-wrap $NE_f t_f$, kip/in.	R_A 90 degrees	R_A 125 degrees	r_{anc}, in.	h_{anc}, in. 90 degrees	h_{anc}, in. 110 degrees	h_{anc}, in. 125 degrees < $\beta_{anc} \leq$ 180 degrees
≤ 4	$NE_f t_f \leq 288$						6.0
	$288 < NE_f t_f \leq 575$						6.0
	$575 < NE_f t_f \leq 863$						6.0
	$863 < NE_f t_f \leq 1150$						8.0
$4 < s_{anc} \leq 6$	$NE_f t_f \leq 288$						6.0
	$288 < NE_f t_f \leq 575$						6.0
	$575 < NE_f t_f \leq 863$						8.0
	$863 < NE_f t_f \leq 1150$						10.0
$6 < s_{anc} \leq 8$	$NE_f t_f \leq 288$						6.0
	$288 < NE_f t_f \leq 575$						8.0
	$575 < NE_f t_f \leq 863$						10.0
	$863 < NE_f t_f \leq 1150$						12.0
$8 < s_{anc} \leq 10$	$NE_f t_f \leq 288$						6.0
	$288 < NE_f t_f \leq 575$						8.0
	$575 < NE_f t_f \leq 863$						10.0
	$863 < NE_f t_f \leq 1150$						12.0

COLUMN CONFINEMENT

COLUMN STRENGTHENING
CONFINEMENT



- CFRP strengthening
- Increase in both axial and flexural strength
- Commonly used for seismic retrofitting
- Most efficient reinforcement in circular columns

CONFINEMENT DESIGN

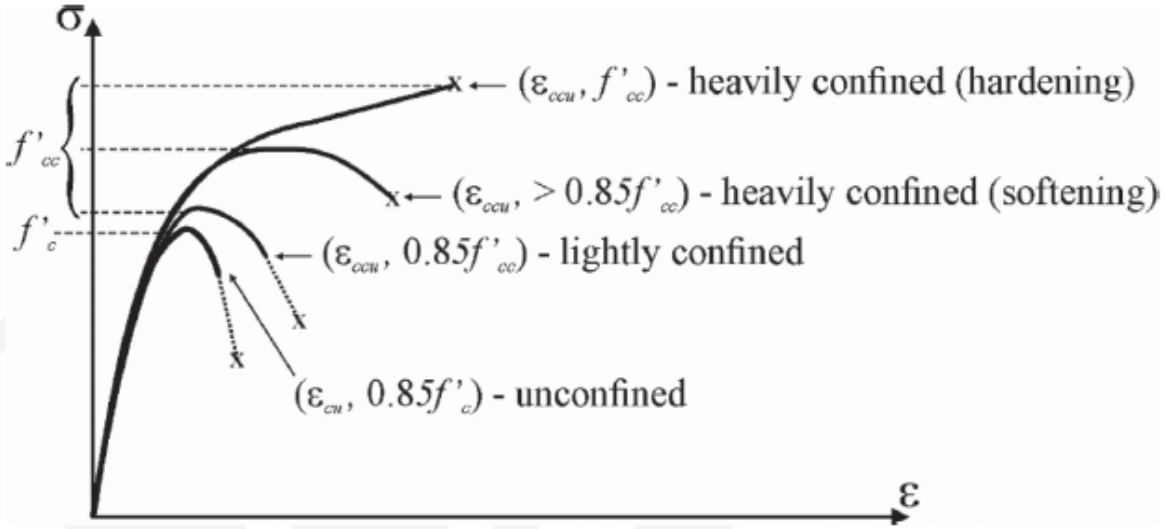


Fig. R9.2.4.1.3—Schematic stress-strain behavior of unconfined and confined reinforced concrete columns (after Rocca et al. [2006]).

Reduction factor for non-circular members

$$f'_{cc} = f'_c + \Psi_f 3.3 \kappa_a f_l$$

$$\varepsilon_{ccu} = \varepsilon'_c \left(1.5 + 12 \kappa_b \frac{f_l}{f'_c} \left(\frac{\varepsilon_{fe}}{\varepsilon'_c} \right)^{0.45} \right)$$

$$\phi P_n = 0.85 \phi \left[0.85 f'_{cc} \left(A_g - A_{st} \right) + f_y A_{st} \right]$$

CONFINEMENT DESIGN

- For combined axial compression and bending
- Axial-moment interaction for an FRP confined column is found based on strain compatibility and stress resultants.

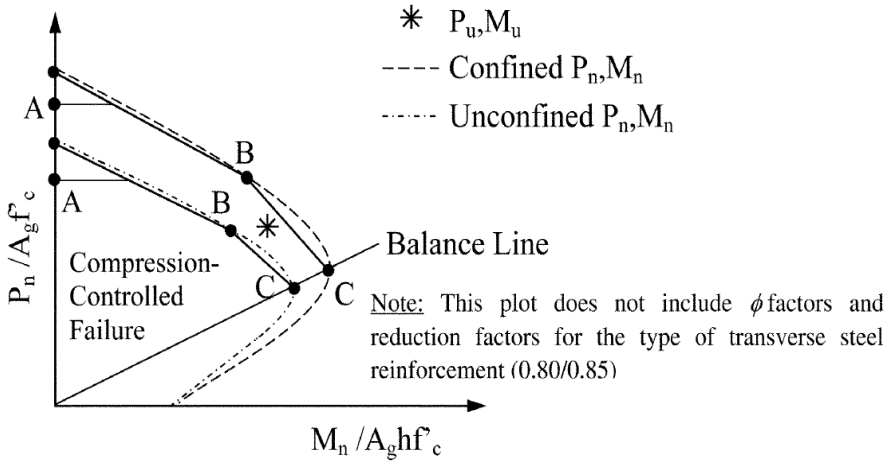
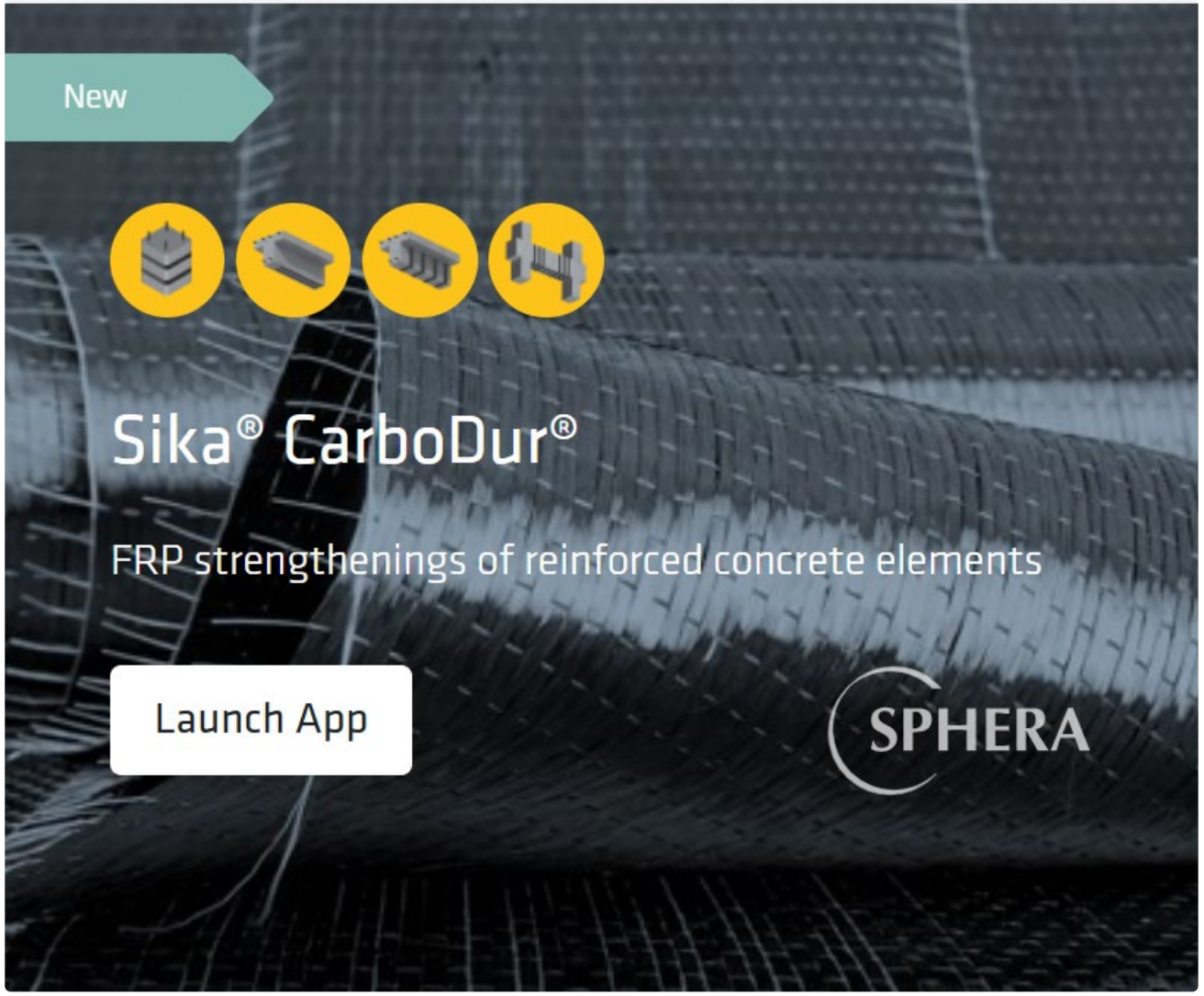


Figure 12.4 in ACI-440.2R

CARBODUR SOFTWARE

Optional Subtitle

SIKA CARBODUR SOFTWARE
NEW AND IMPROVED CLOUD BASED TOOL



Features of the new Sika® CarboDur® Software

- Free licensed, cloud-based software
- No installation needed
- Compatible with all web browsers
- Modernized interface and easy navigation
- User has full control of complete design process
- Available in multiple languages and design guidelines
- Supported by Sika technical assistance

SIKA® CARBODUR® SOFTWARE – CLOUD BASED

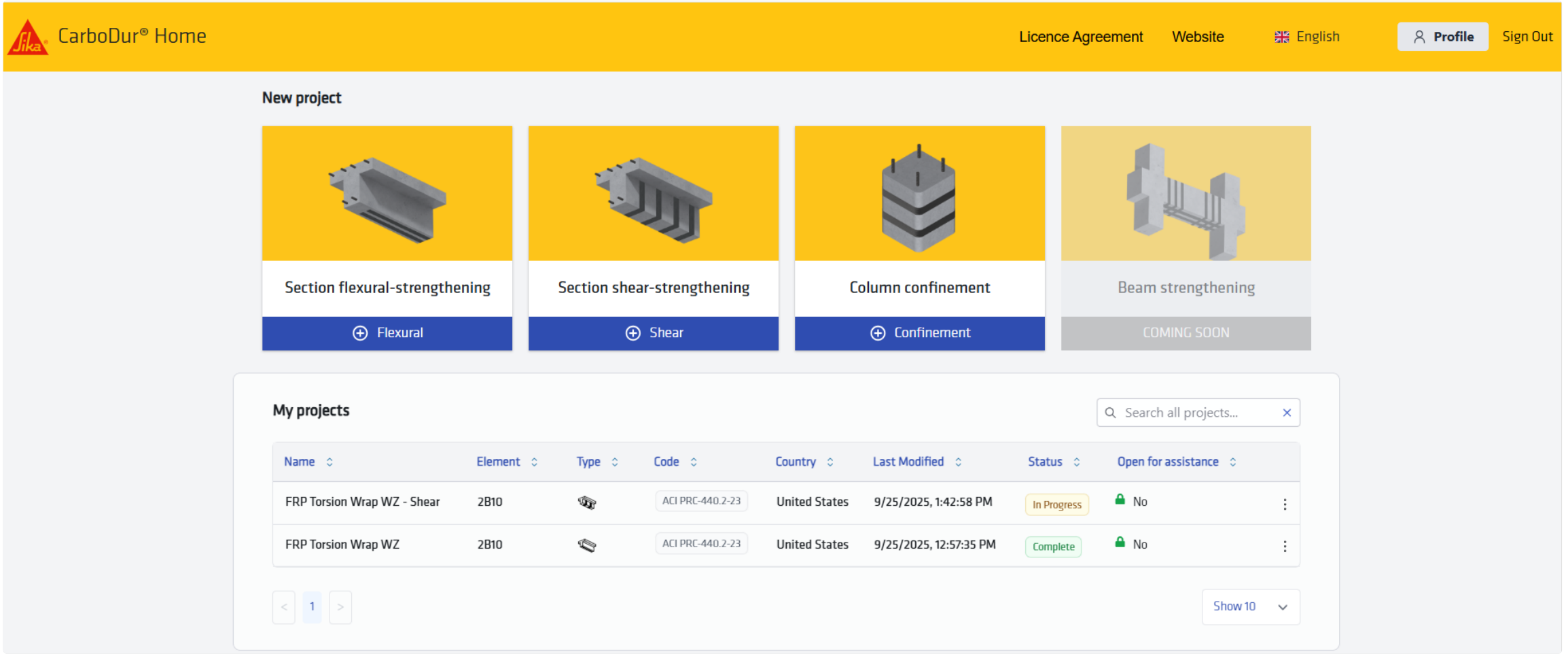
ADVANTAGES

- Powerful tool
- Free license
- Excellent user interface
- Multi language/ Multi design standard
- Cloud based. No installation needed
- Accessible from any internet connected device
- New functionalities

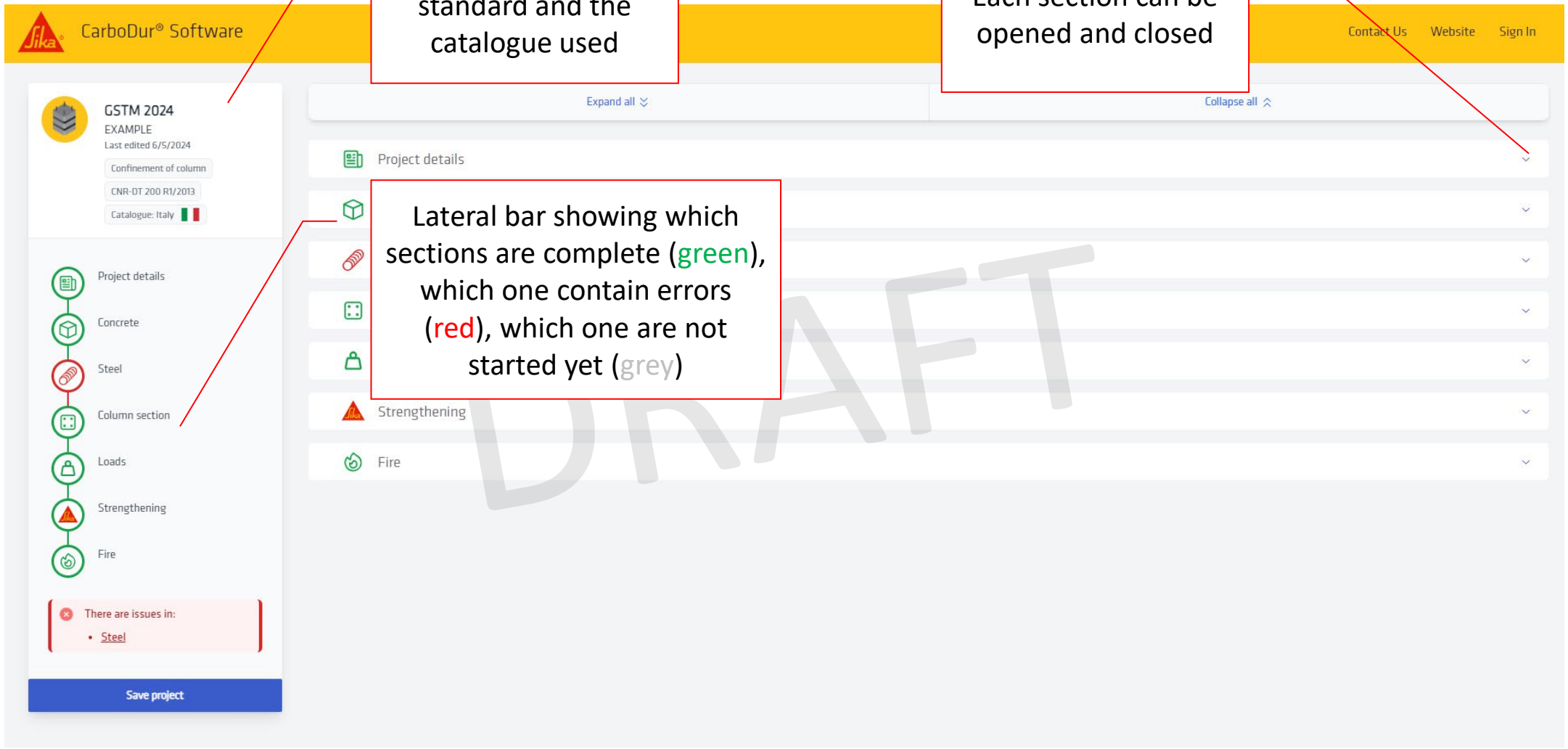
Old version:

- ~~Required installation~~
- ~~Several issues with firewall and antivirus~~
- ~~No control on the activities done by users~~
- ~~Not sure everybody works with latest version~~
- ~~License valid only on 1 single PC/laptop~~

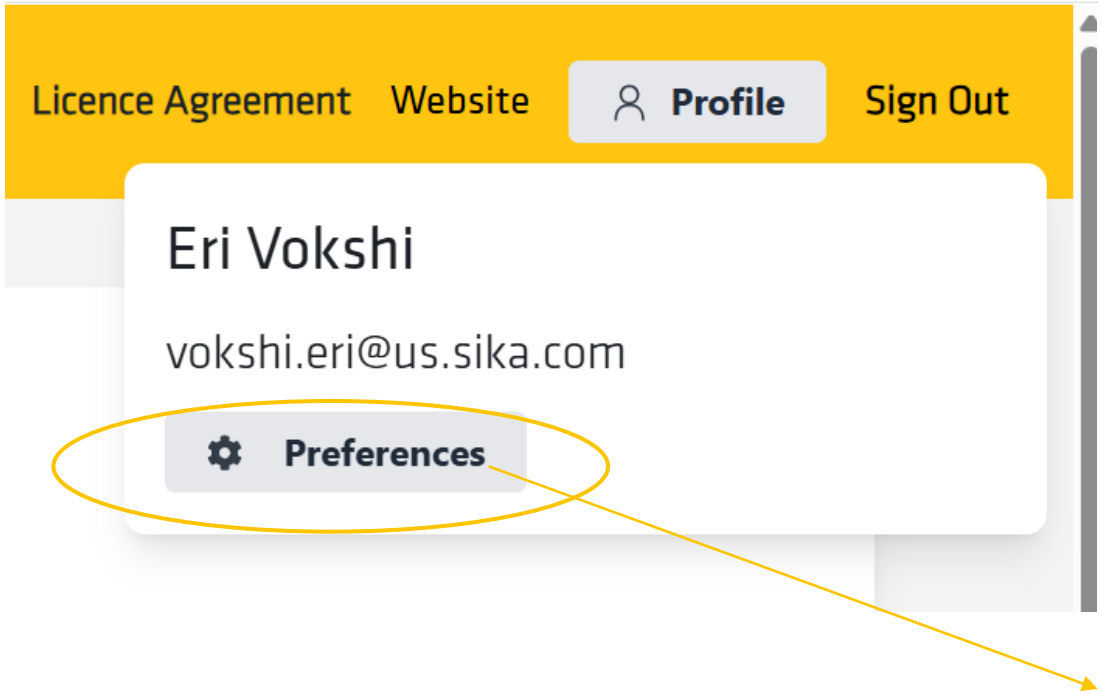
CARBODUR SOFTWARE
LANDING PAGE



NEW SIKA® CARBODUR® SOFTWARE



PROFILE PREFERENCES/UNITS



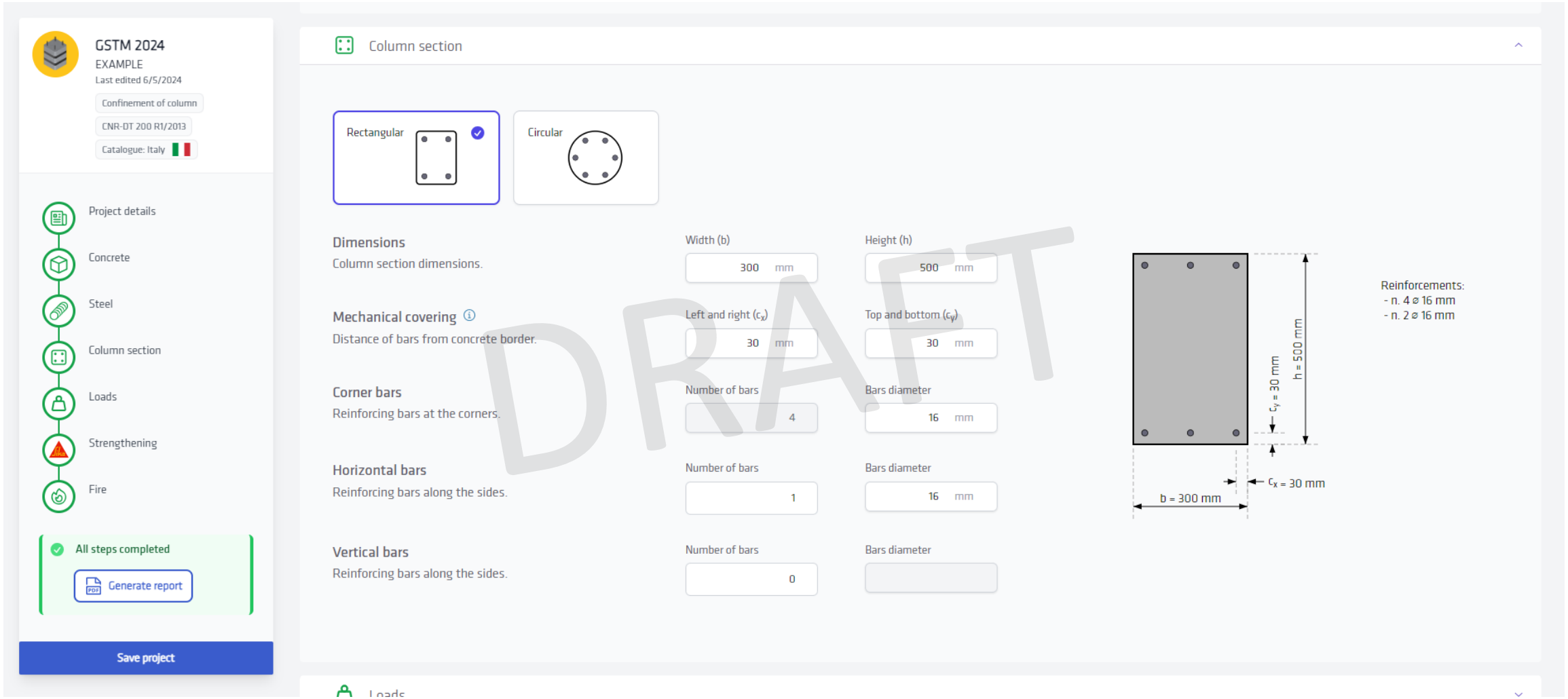
Preferences

Current System: ◯ International System ● US Customary

Units of measure:

	International System	US Customary
Plan length (e.g. length of beams, distance between uprights)	mm	ft.
Section length (e.g. width of a beam, thickness of a slab)	mm	in.
Plan area (e.g. area of slabs)	m²	ft²
Section area (e.g. cross-section of rebars)	mm²	in²
Torque (e.g. bending moment)	kNm	kip·ft
Force (e.g. point loads)	kN	lbf
Force per unit length (e.g. line loads)	kN/m	kip/ft
Force per unit area (e.g. uniform loads)	kN/m²	kip/ft²

NEW SIKA® CARBODUR® SOFTWARE – CLOUD BASED



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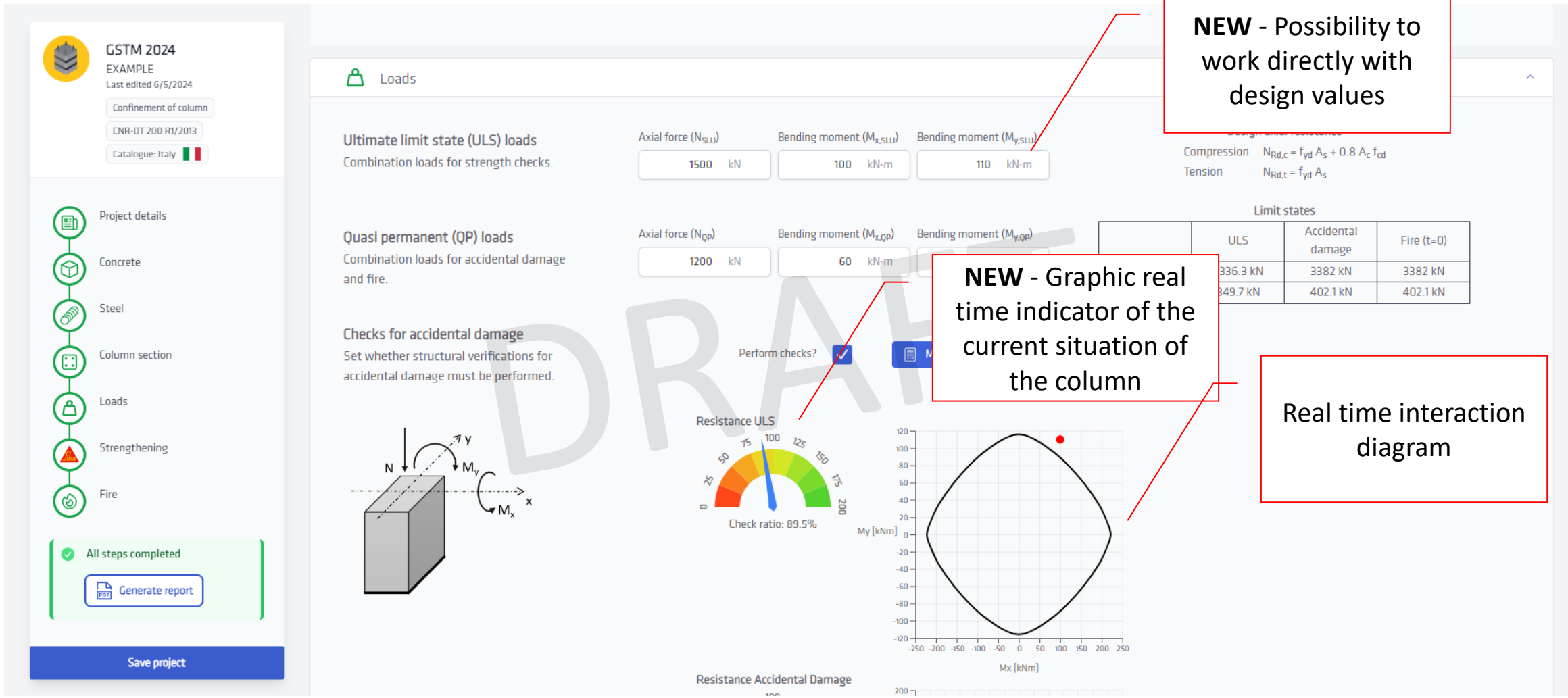
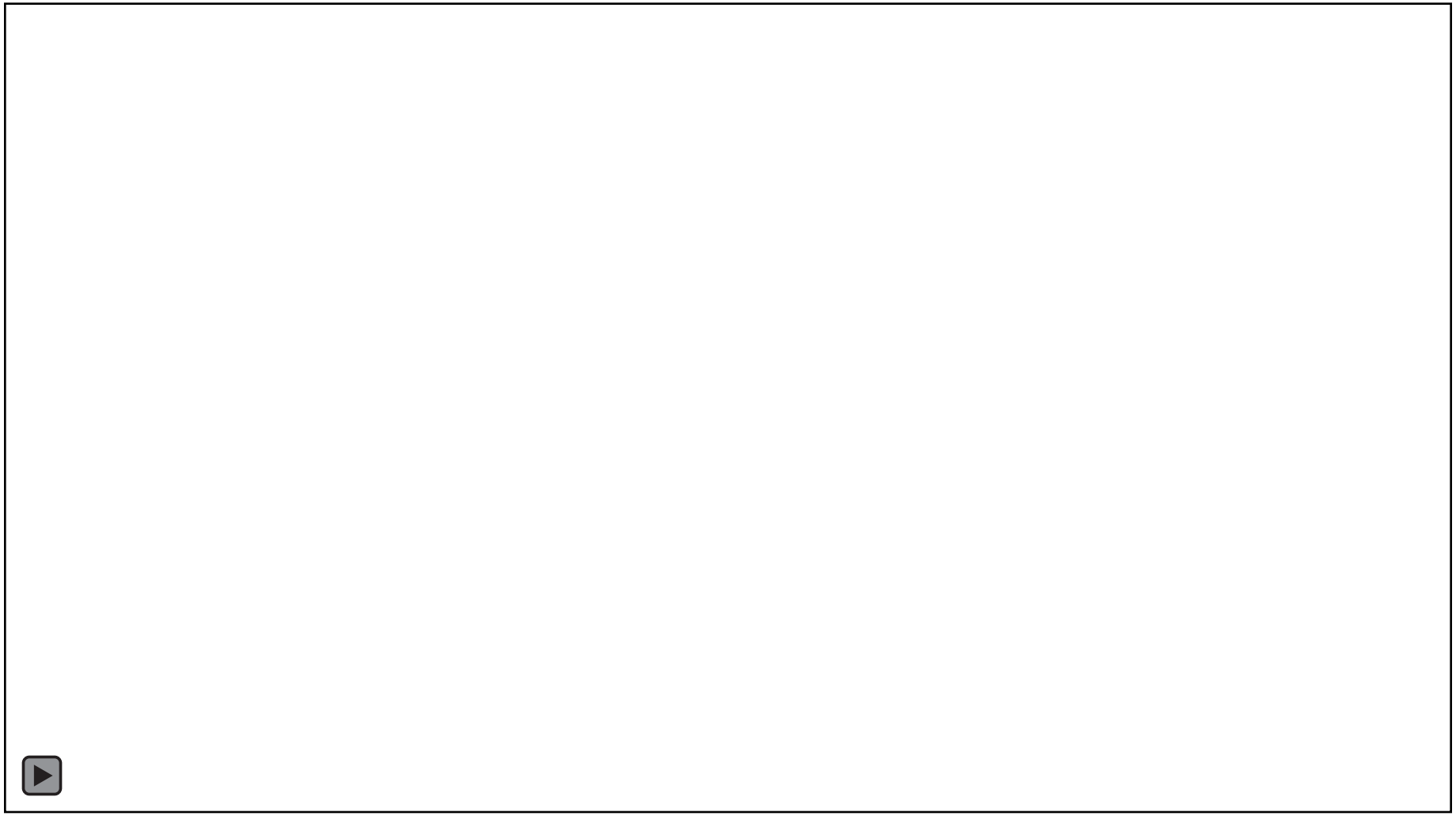


NEW - Possibility to work directly with design values

NEW - Graphic real time indicator of the current situation of the column

Real time interaction diagram

NEW SIKA® CARBODUR® SOFTWARE – CLOUD BASED



CONCLUSIONS

- FRP's are cost and time effective solutions for reinforcement of infrastructure
- Typical FRP strengthening applications in RC include flexural, shear, confinement, and seismic strengthening
- Proper repair and application is critical to ensure successful and long-lasting reinforcement
- Current FRP code and design guidelines are ACI CODE 440.13 and AASHT 2nd Ed.
- Sika new CarboDur cloud base software is a powerful design tool to help you with the design and specification process

THANK YOU.

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HEADLINE LOREM IPSUM
SUBHEADLINE LOREM IPSUM

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HEADLINE LOREM IPSUM
SUBHEADLINE LOREM IPSUM

Growth across multiple dimensions
Sika aims for organic growth fueled by innovative drive and entrepreneurial spirit. Growth is further strengthened by carefully targeted acquisitions that add complimentary technologies and increase our access to markets and channels. Sika always strives to ensure a smooth integration – paying close attention to the local corporate culture and needs of our new team members.

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HEADLINE LOREM IPSUM
SUBHEADLINE LOREM IPSUM

Caption

Sika aims for organic growth fueled by innovative drive and entrepreneurial spirit. Growth is further strengthened by carefully targeted acquisitions that add complimentary technol-ogies and increase our access to markets and channels.

Caption

Acquisitions have proven to be a major growth driver that allows us to increase market penetra-tion through market share, technology as well as channel access.

HEADLINE LOREM IPSUM
SUBHEADLINE LOREM IPSUM

HEADLINE LOREM IPSUM
SUBHEADLINE LOREM IPSUM

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SUBHEADLINE LOREM IPSUM

Topic 1
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Topic 2
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Topic 3
- Fusce nec leo non ipsum
- Blandit euismod eu eu leo
- Vivamus suscipit
- Finibus blandit
- Maecenas nunc sapien
- Vehicula eu tortor nec
- Euismod tristique massa.
- Integer id cursus turpis.
- Sed sed quam
- vitae velit euismod accumsan
- sit amet et lorem

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Name
Company

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Name Lastname
Company

INSERT YOUR VISION

THERE’S A GRADIENT ON THE IMAGE TO HELP WITH READABILITY.

EXAMPLE
TABLE ON WHITE BACKGROUND

IN €	2005	2006	2007	2008	2009	2010
LOREM	1.230	1.230	1.230	1.230	1.230	1.230
IPSUM	2.340	2.340	2.340	2.340	2.340	2.340
DOLOR	3.450	3.450	3.450	3.450	3.450	3.450
SIT	4.560	4.560	4.560	4.560	4.560	4.560
AMET	5.670	5.670	5.670	5.670	5.670	5.670

Table description big lorem ipsum dolor am, consectetur adipiscing elit. Crasek bibendum vehicula arcu. Sed qui massa. Nulla facilisi. Curabitur at nunc.

POTENTIAL CATEGORIES
DEFINITION OF THE CATEGORIES

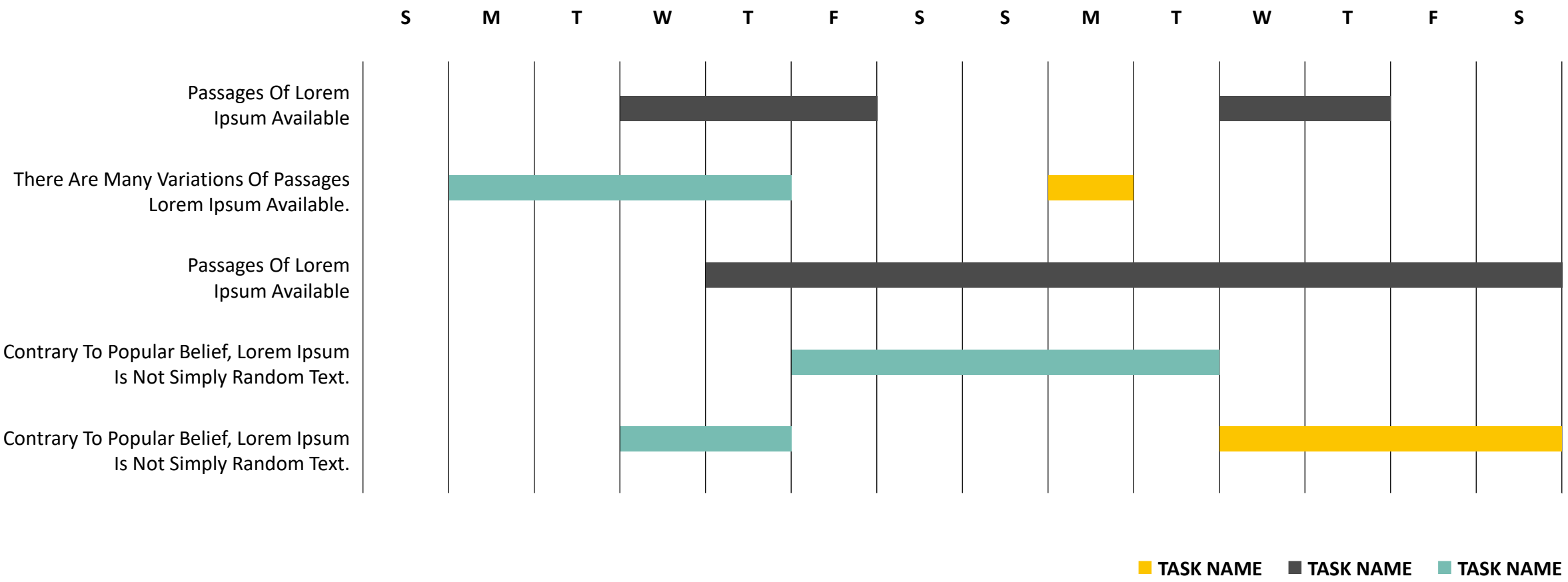
	LOREM IPSUM	LOREM IPSUM	LOREM IPSUM	LOREM IPSUM	LOREM IPSUM	LOREM IPSUM
Lorem	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo
Lorem	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo
Lorem	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo
Lorem	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo
Lorem	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo	Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempo

EXAMPLES
COMPARISON OF PRODUCT STRENGTHS

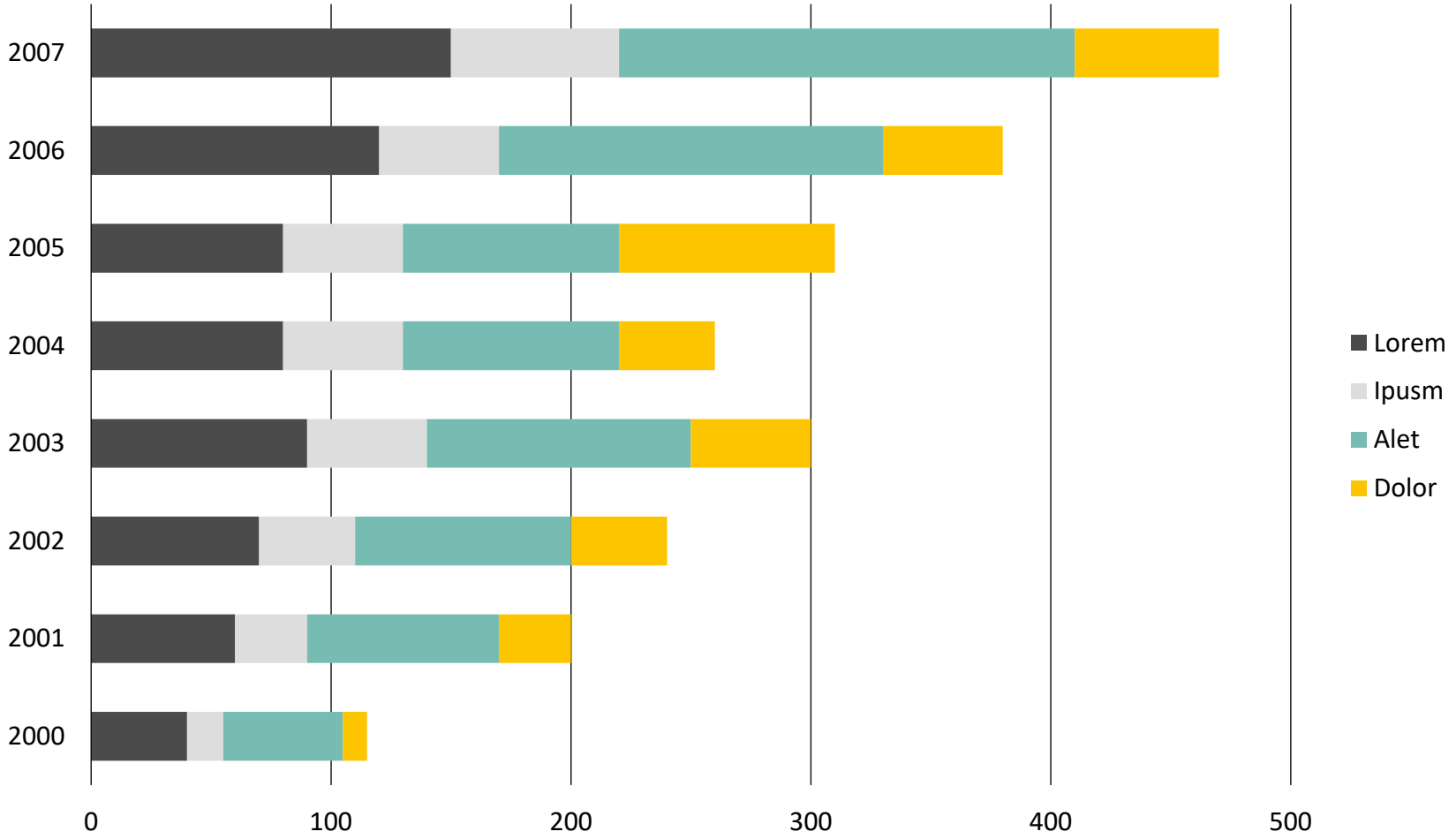
Fields of use	Sika Product A	Sika Product B	Sika Product C
Lorem ipsum dolor sit amet, consectetur adipiscing	●●●	●●●	●●
Lorem ipsum dolor sit amet, consectetur adipiscing	●	●●●	○
Lorem ipsum dolor sit amet, consectetur adipiscing	●●	●●	●●
Lorem ipsum dolor sit amet, consectetur adipiscing	●●●	○	●
Lorem ipsum dolor sit amet, consectetur adipiscing	●●●	●●	●●●

●●● **Optimal Solution** ●● **Feasible** ● **Feasible but there's something better** ○ **Solution not possible**

IMPLEMENTATION PROGRESS



EXAMPLE
BAR DIAGRAM (STACKED)



Caption
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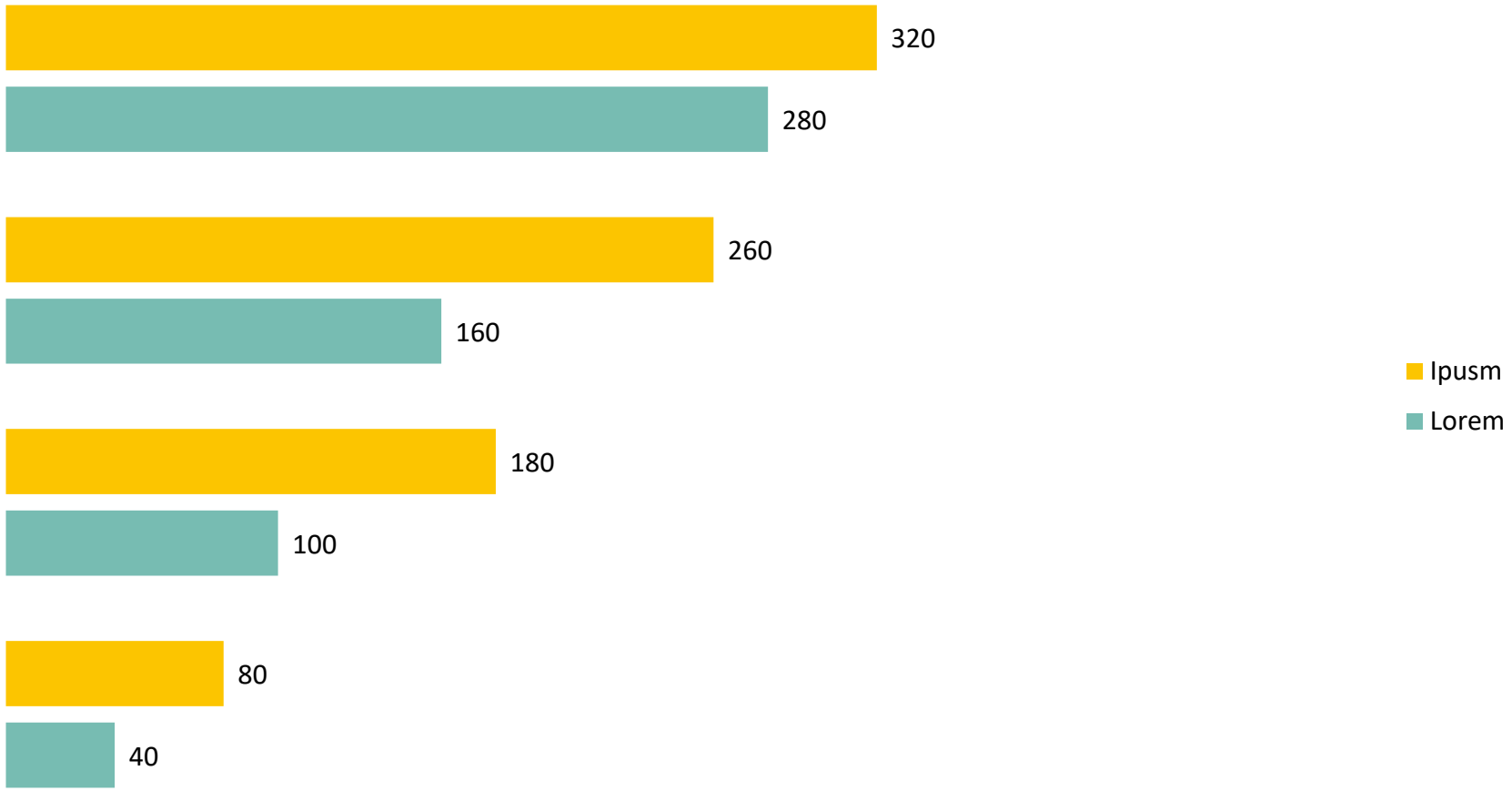
EXAMPLE
BAR DIAGRAM (GROUPED)



Caption
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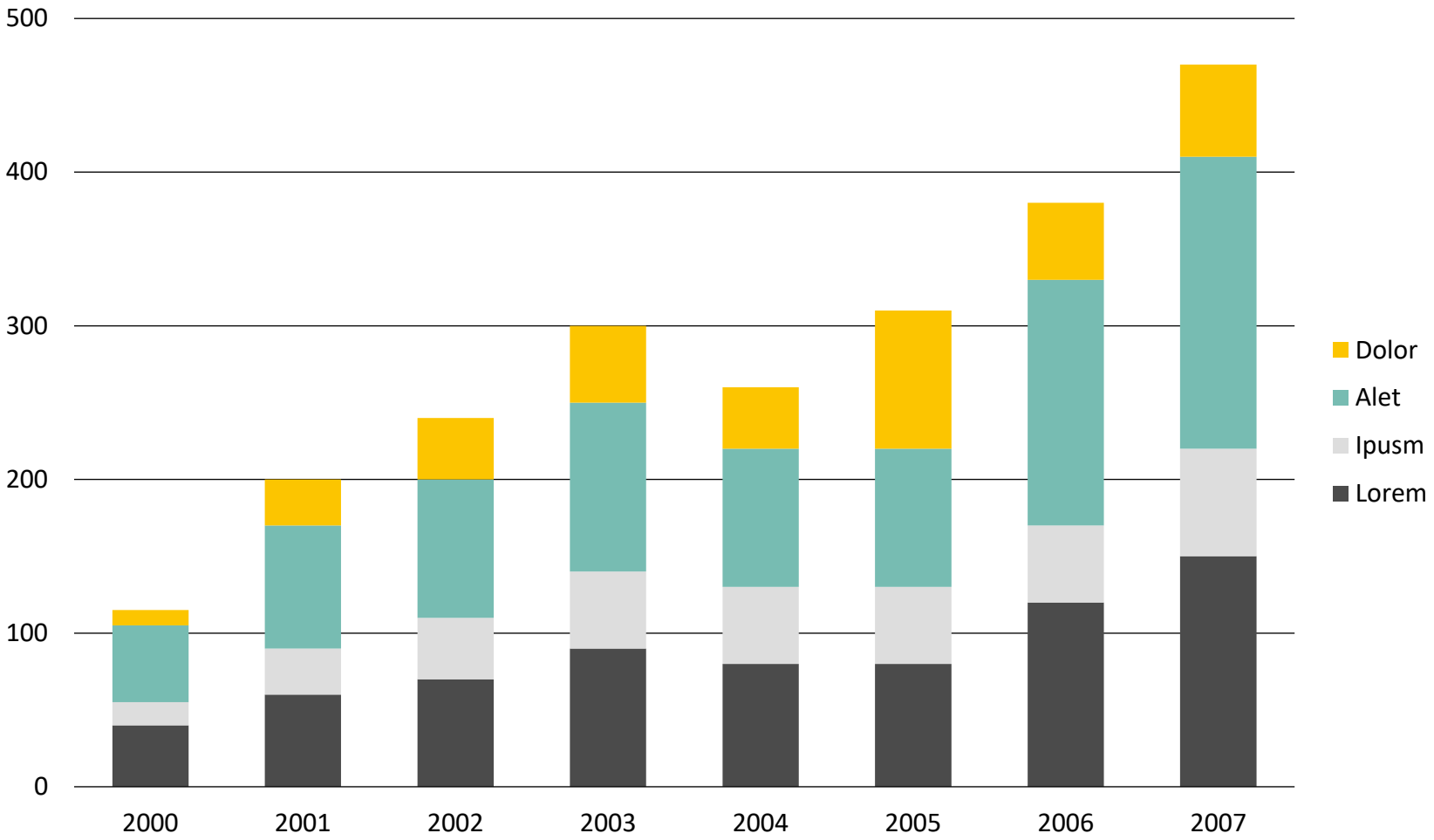
EXAMPLE
COLUMN DIAGRAM (STACKED)



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EXAMPLE
COLUMN DIAGRAM (GROUPED)

Caption
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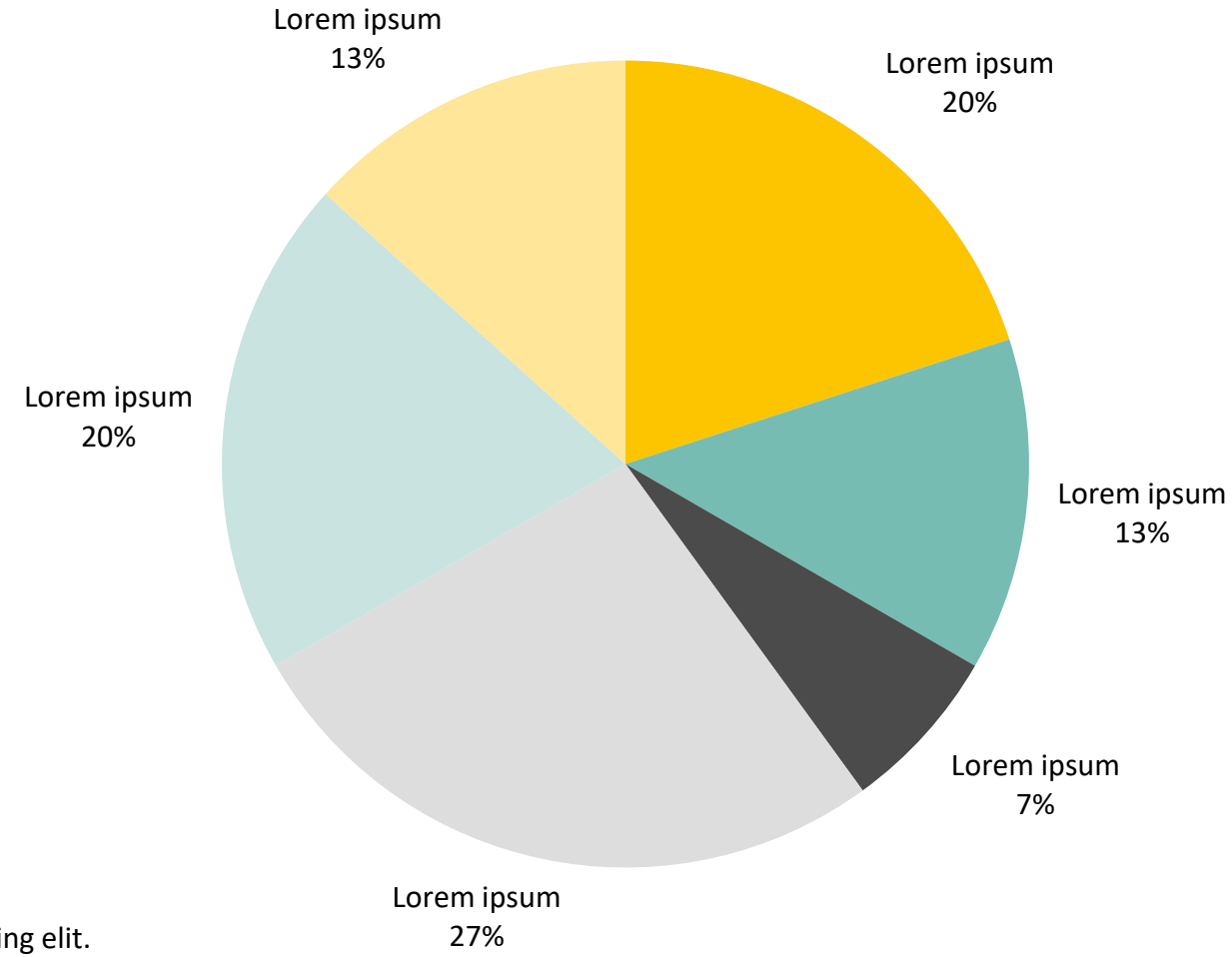
EXAMPLE
PIE CHART



Caption
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EXAMPLE
CIRCLE DIAGRAM

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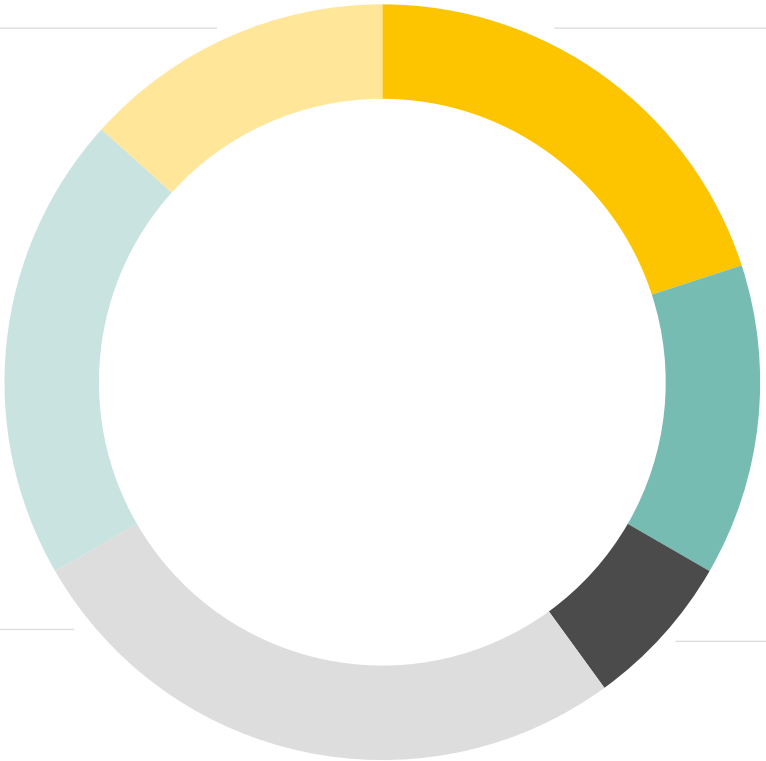
Lorem ipsum

XX%
Lorem ipsum



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EXAMPLE
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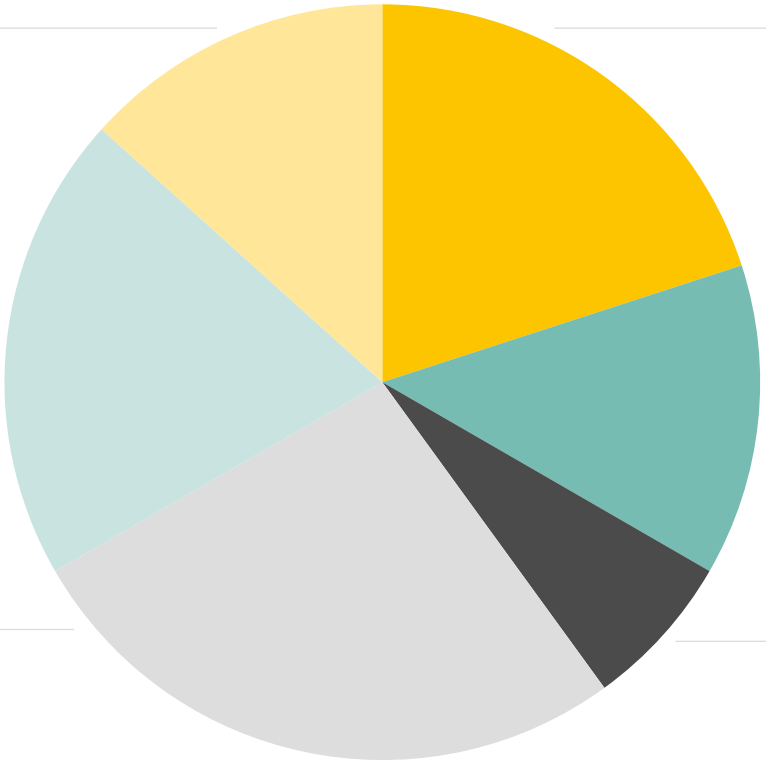

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EXAMPLE
PIE CHART

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HEADLINES FOR CATEGORIES
SUBHEADLINE LOREM IPSUM

Category 1

Category 2

Category 3

Category 4

Category 5

Category 6

Category 7

Category 8

HEADLINE E. G. FOR PRODUCTS
SUBHEADLINE LOREM IPSUM

Material A
- Lorem ipsum dolor
- Lorem ipsum dolor
- Lorem ipsum dolor

Lorem ipsum dolor
Product A

Material B
- Lorem ipsum dolor
- Lorem ipsum dolor
- Lorem ipsum dolor
- Lorem ipsum dolor

Lorem ipsum dolor
Product B

Material C
- Lorem ipsum dolor
- Lorem ipsum dolor

Lorem ipsum dolor
Product C

Material D
- Lorem ipsum dolor
- Lorem ipsum dolor
- Lorem ipsum dolor
- Lorem ipsum dolor

Lorem ipsum dolor
Product D

HEADLINE LOREM IPSUM
SUBHEADLINE LOREM IPSUM

Product A–D

Lorem Energy + 5.5 XX	Lorem Energy + 5.5 XX	Lorem Energy + 5.5 XX	Lorem Energy + 5.5 XX
			
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HEADLINES FOR CATEGORIES WITH DESCRIPTION
SUBHEADLINE LOREM IPSUM

Products max. 2 lines?	**Products**	**Products**	**Products**	**Products**
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Solution	Solution	Sika Waterbar®, SikaFuko® Swell-1, SikaInject®	Solution	Solution

PROCESS OVERVIEW

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Keyword Lorem
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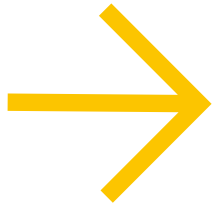

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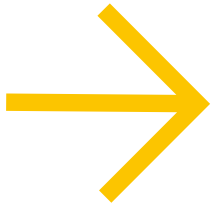

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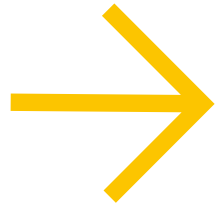

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PROCESS OVERVIEW

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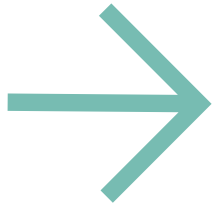

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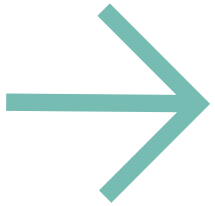

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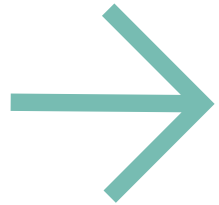

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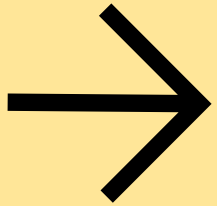

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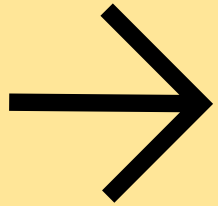

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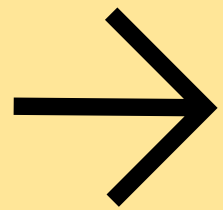

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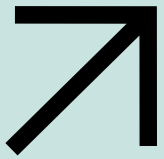

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PROCESS OVERVIEW

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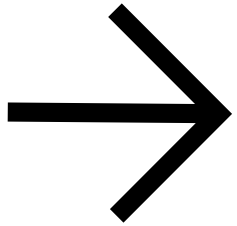

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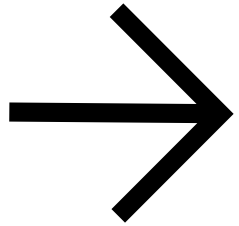

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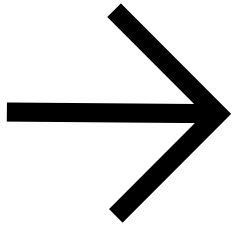

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PROCESS OVERVIEW

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