Fire Resistance of Reinforced Concrete Structures Utilising Mechanical Couplers

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Reinforced Concrete (RC)

1 Durability

Withstands harsh environmental conditions.

2 Cost-effectiveness

Affordable and widely available materials.

3 High Strength

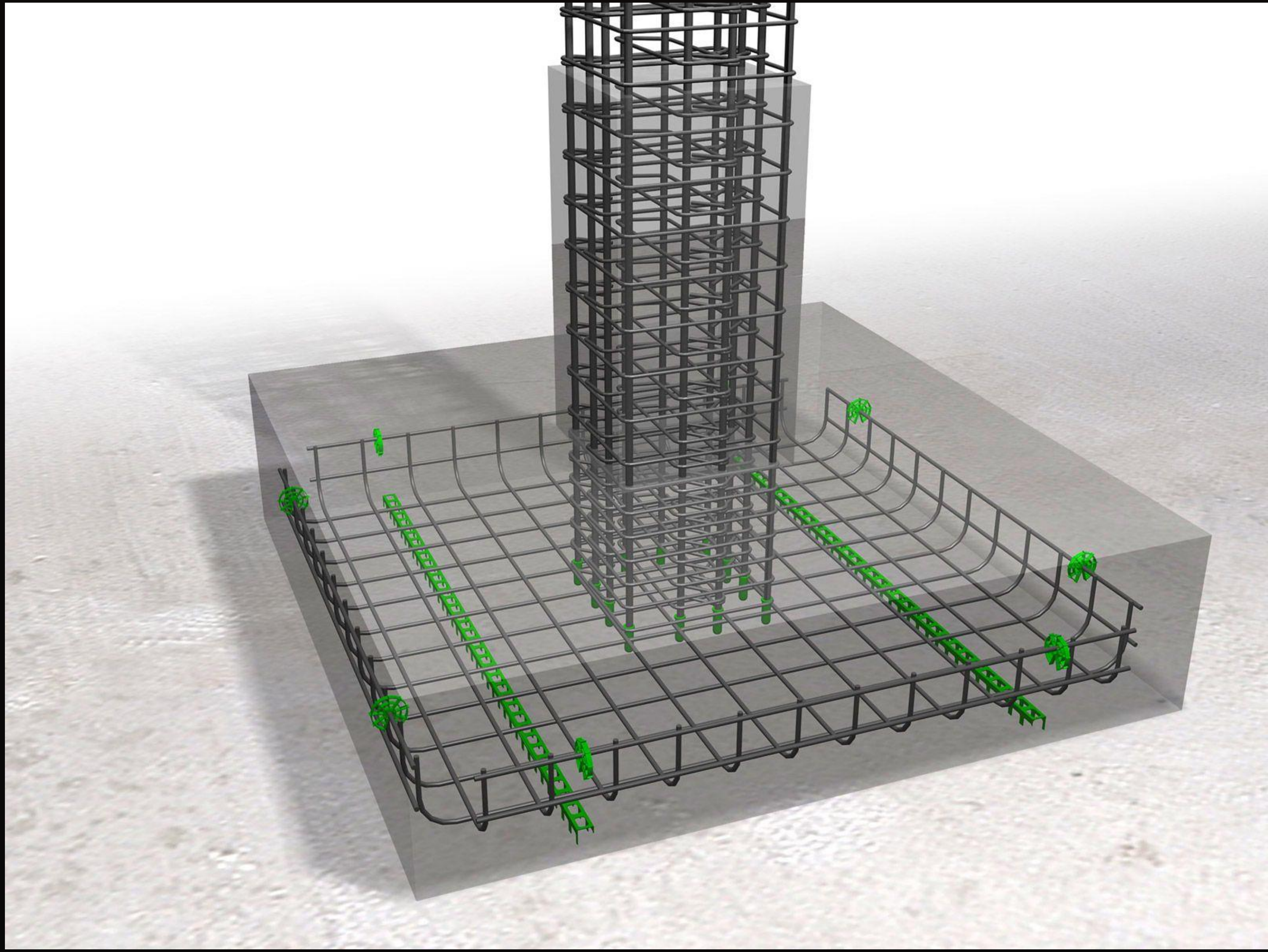
Strong in both compression and tension

4 Fire Resistance

Excellent performance in fire conditions

5 Long Lifespan

Low maintenance with extended service life



Presentation Overview

Why Couplers?

Reasons for using mechanical couplers in concrete structures.

Types

Different types of reinforcement couplers available.

Fire Impact

Problems with couplers exposed to fire conditions.

Numerical Analysis

Thermal analysis results using SAFIR software.

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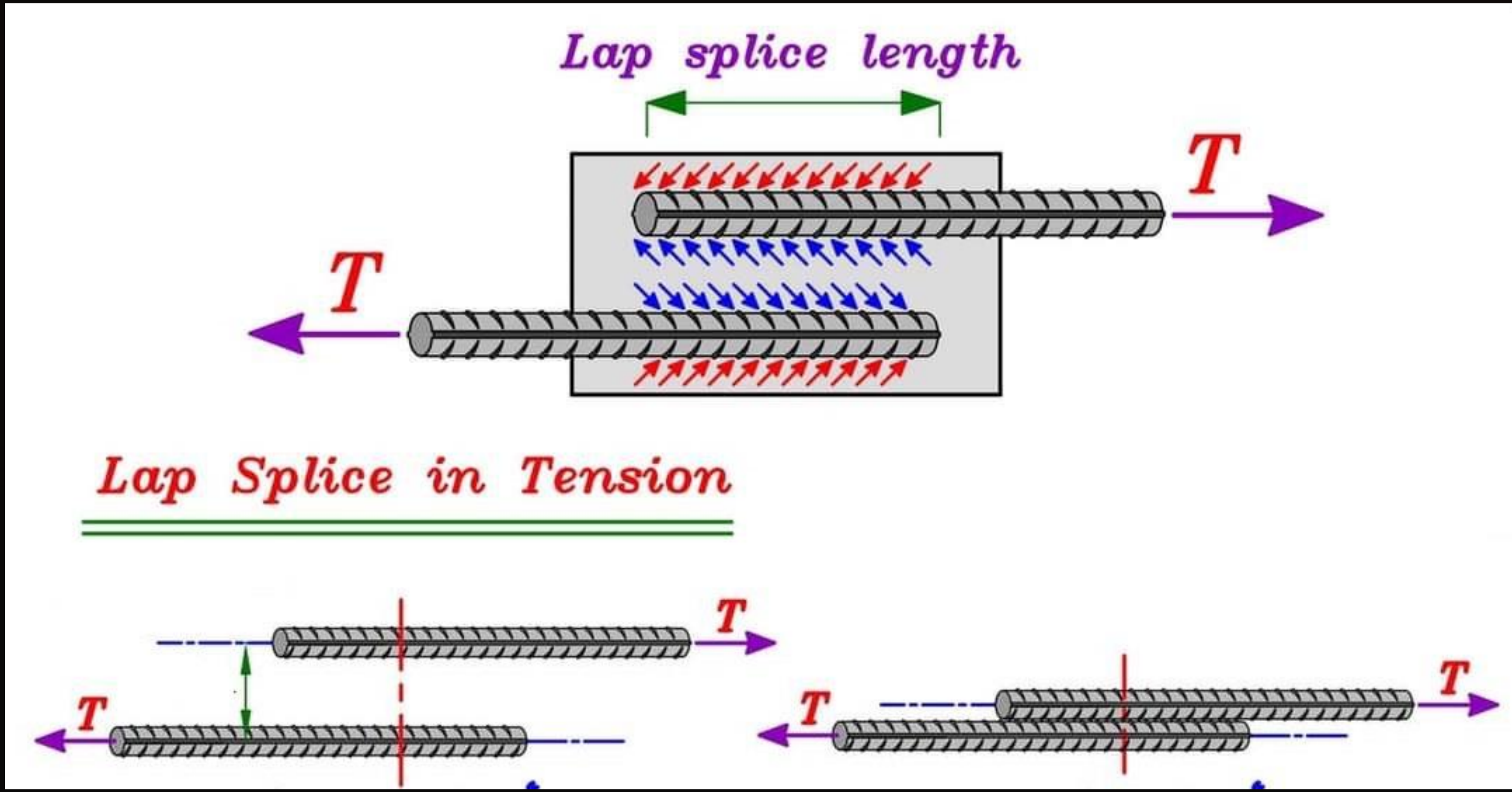
The Lapped Joints Method

1 **Time-consuming.**

Placing the lapped joints is difficult and time-consuming

2 **Requires more space**

Not adequate in the areas were the reinforcement is congested.



The Mechanical Coupler Method

1 **Efficient Load Distribution**

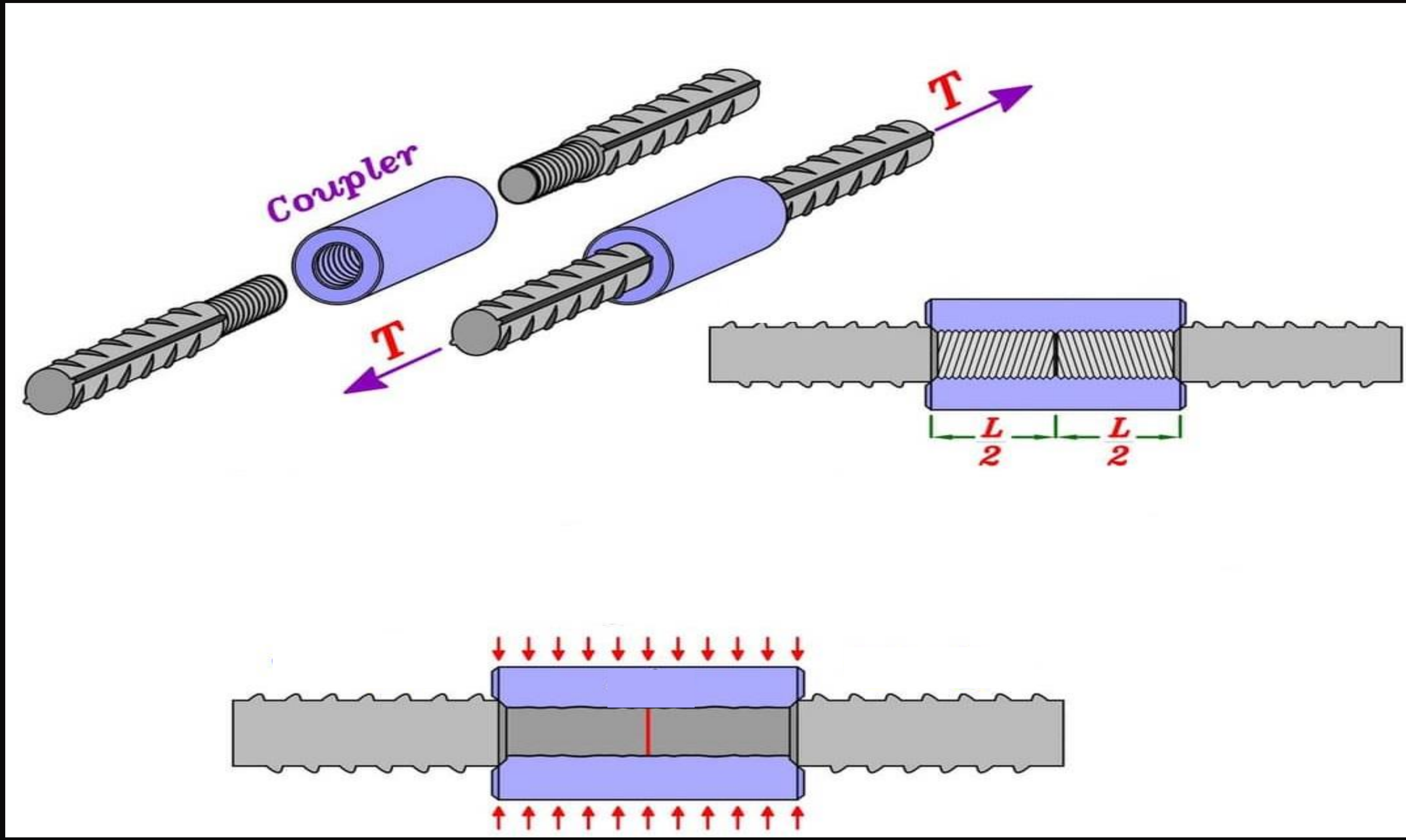
Couplers effectively transfer force between steel reinforcement bars.

2 **Structural Integrity**

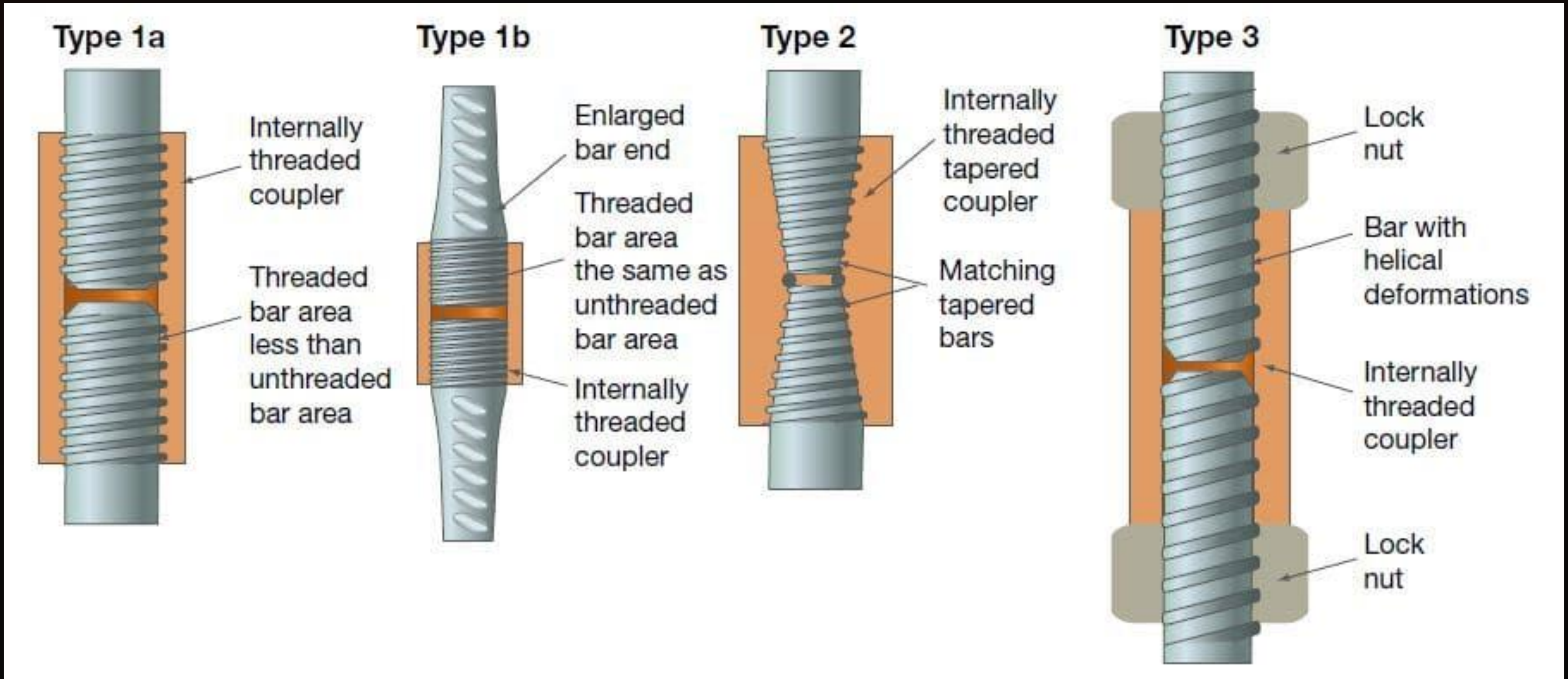
They ensure the structural integrity of concrete structures under various loads.

3 **Construction Efficiency**

Couplers allow for faster and easier assembly of reinforcement cages.



Types of Mechanical Couplers



Tapered Thread Couplers

Purpose

Designed for joining reinforcing bars in most applications.

Preparation

Rebar ends are cut square and tapered threads are cut to fit the coupler.

Installation

Sleeve is tightened onto the threaded bar using a calibrated torque wrench.

Standard Coupler Dimensions

Bar Diameter (mm)		12	16	20	25	32	40
External Dia. (mm)	*d*	22	25	30	36	48	60
Coupler Length (mm)	*l*	58	70	74	90	112	138
Weight (kg)		0.13	0.17	0.25	0.43	0.99	1.90
Torque (Nm)		60	110	165	265	285	330
Part No.		TTS12	TTS16	TTS20	TTS25	TTS32	TTS40

Bartec Plus Couplers

Purpose

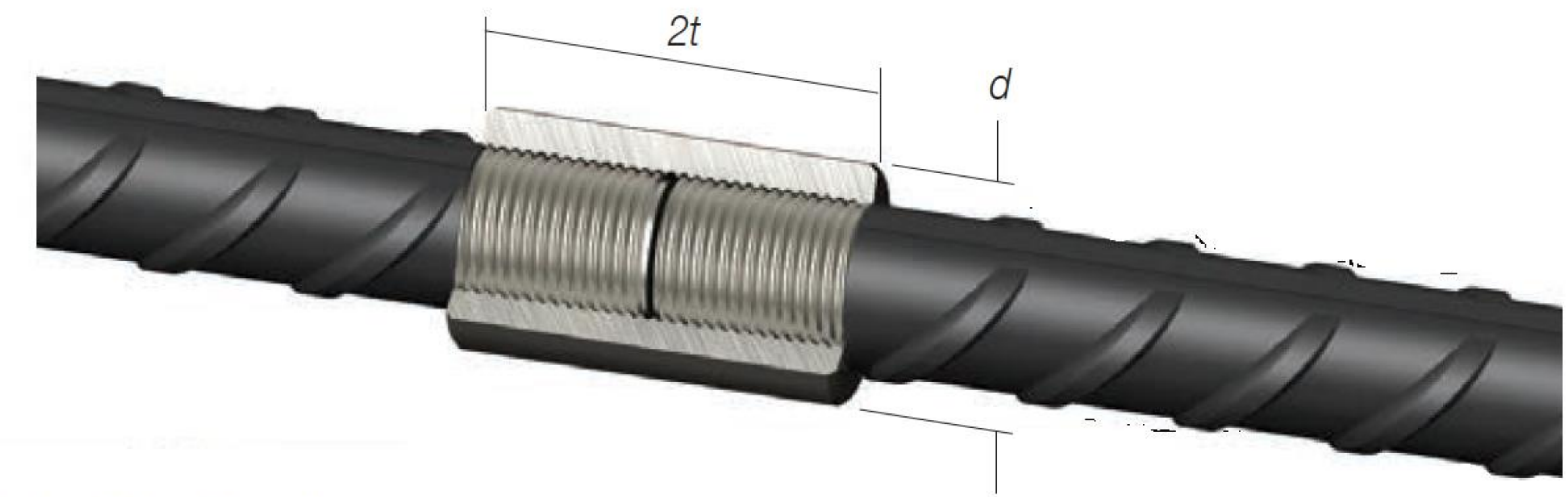
Provides a full-strength joint, ideal for fatigue-prone applications.

Preparation

Bar ends are cut square, slightly enlarged, with parallel threads rolled on.

Installation

Coupler is installed using a pipe or chain wrench; no calibrated torque wrench needed.



Bartec Plus Couplers

Bar Diameter (mm)		12	16	20	25	32	40
External Diameter (mm)	*d*	20.6	26.4	32.1	40.1	49.5	67.5
Coupler Length (mm)	*2t*	28	40	48	60	72	90
Thread Form		M14x2.0	M20x2.5	M24x3.0	M30x3.5	M36x4.0	M45x4.5
Weight (kg)		0.05	0.09	0.16	0.31	0.57	1.53
Coupler Reference		BTP12	BTP16	BTP20	BTP25	BTP32	BTP40

Other sizes are available on request. Contact us for more details. Thread incompatible with standard metric bolts/studs.

MBT Couplers

Purpose

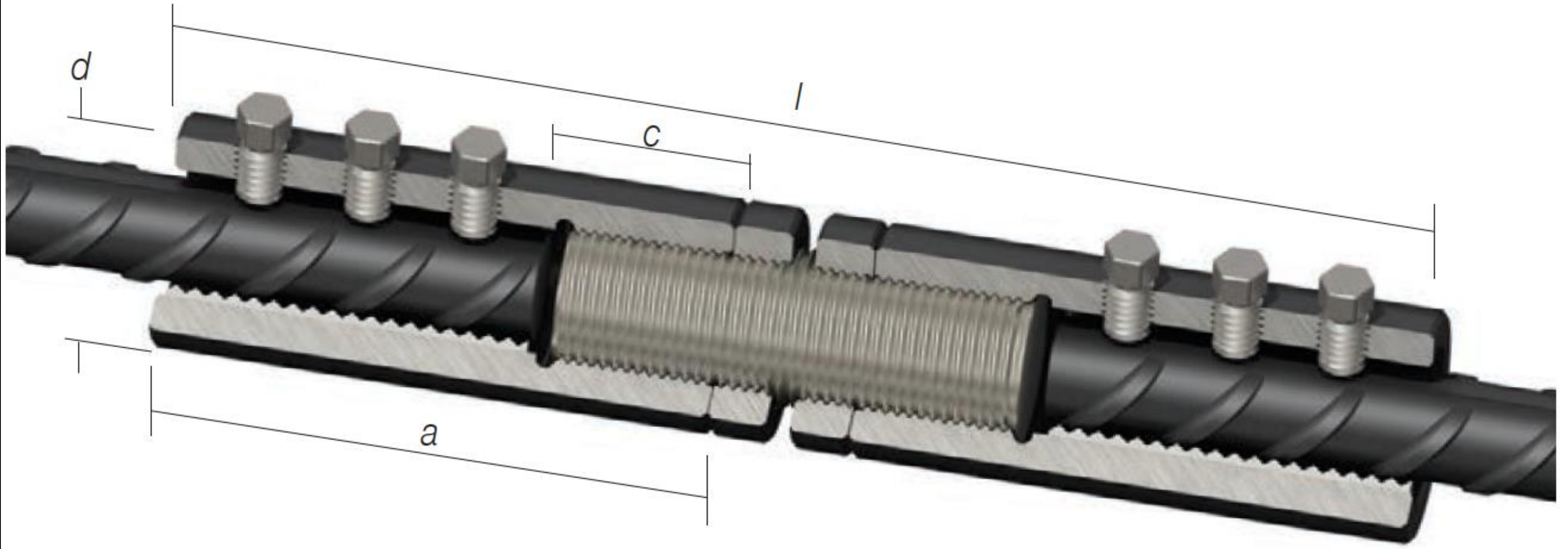
Suitable when bar ends aren't prepared for parallel or tapered thread couplers.

Preparation

Bars are supported by two serrated saddles within the coupler.

Installation

Locked in place with special lock shear bolts; heads shear off at the correct torque for visual confirmation.



Bar Diameter (mm)		12	16	20	25	32	40
External Diameter (mm)	d	33.4	42.2	48.3	54.0	71.0	81.0
Maximum Length (mm)	l	250	280	349	414	490	675
Female Component Length (mm)	a	100	115	147	177	214	300
Threaded Section (mm)	c	30	35	38	43	53	53
Socket Size A/F (ins)		1/2	1/2	1/2	5/8	5/8	3/4
No. of Bolts		6	6	8	8	10	14
Nail Plate Diameter x Thickness (mm)		75 x 5	75 x 5	75 x 5	100 x 5	100 x 5	127 x 5
Approx Weight (kg)		1.40	2.20	3.70	5.15	11.5	18.8
Torque (Nm)		55	108	108	275	360	525
Part No.		C12	C16	C20	C25	C32	C40

Eurocode: Concrete Cover in Fire Design

Eurocode: Concrete Cover in Fire Design

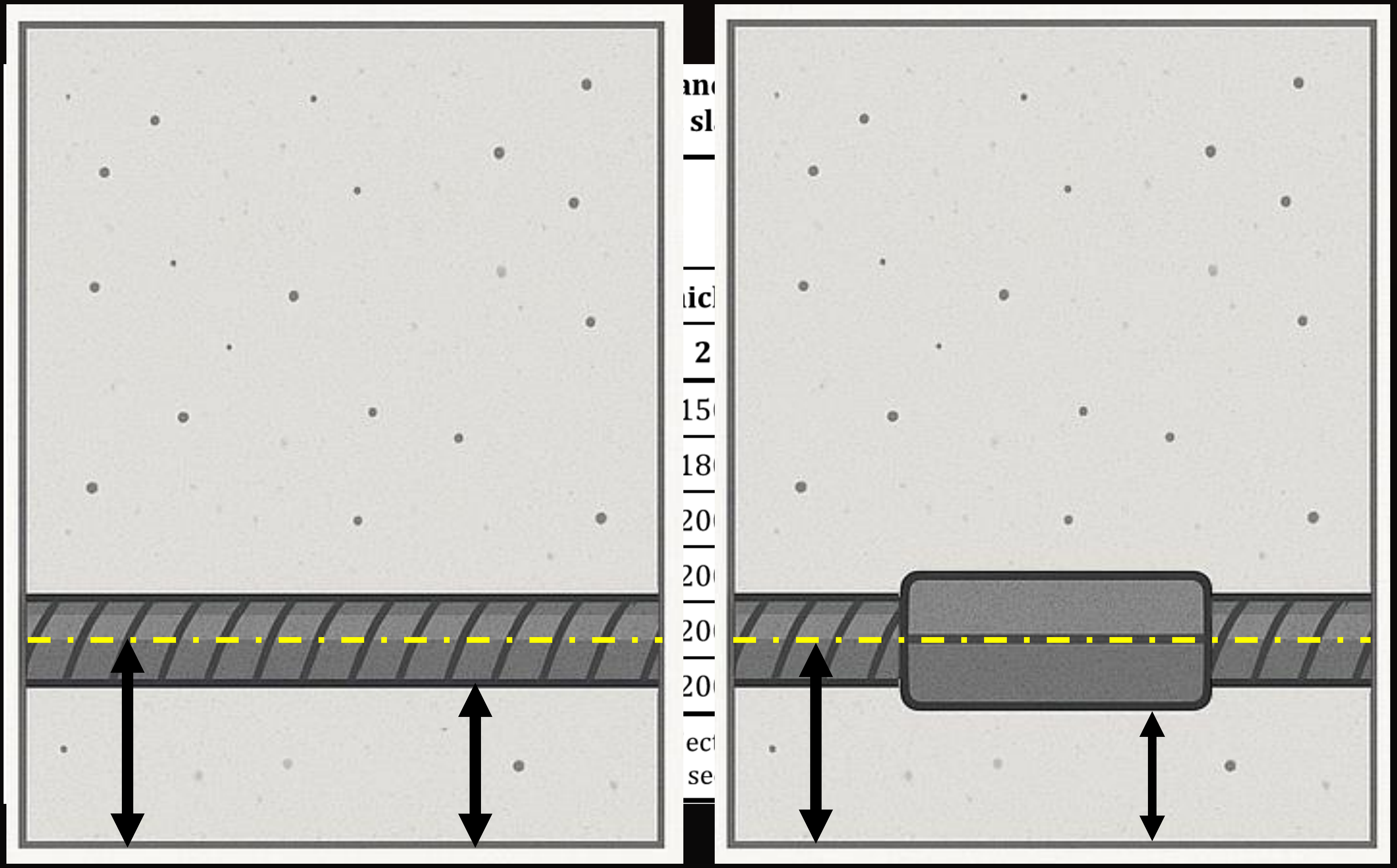
European code for fire design of concrete structures EN 1992-1-2

- Fire resistance based on "axis distance“
- Axis distance is the distance to the centre of the main reinforcement.

Mechanical couplers

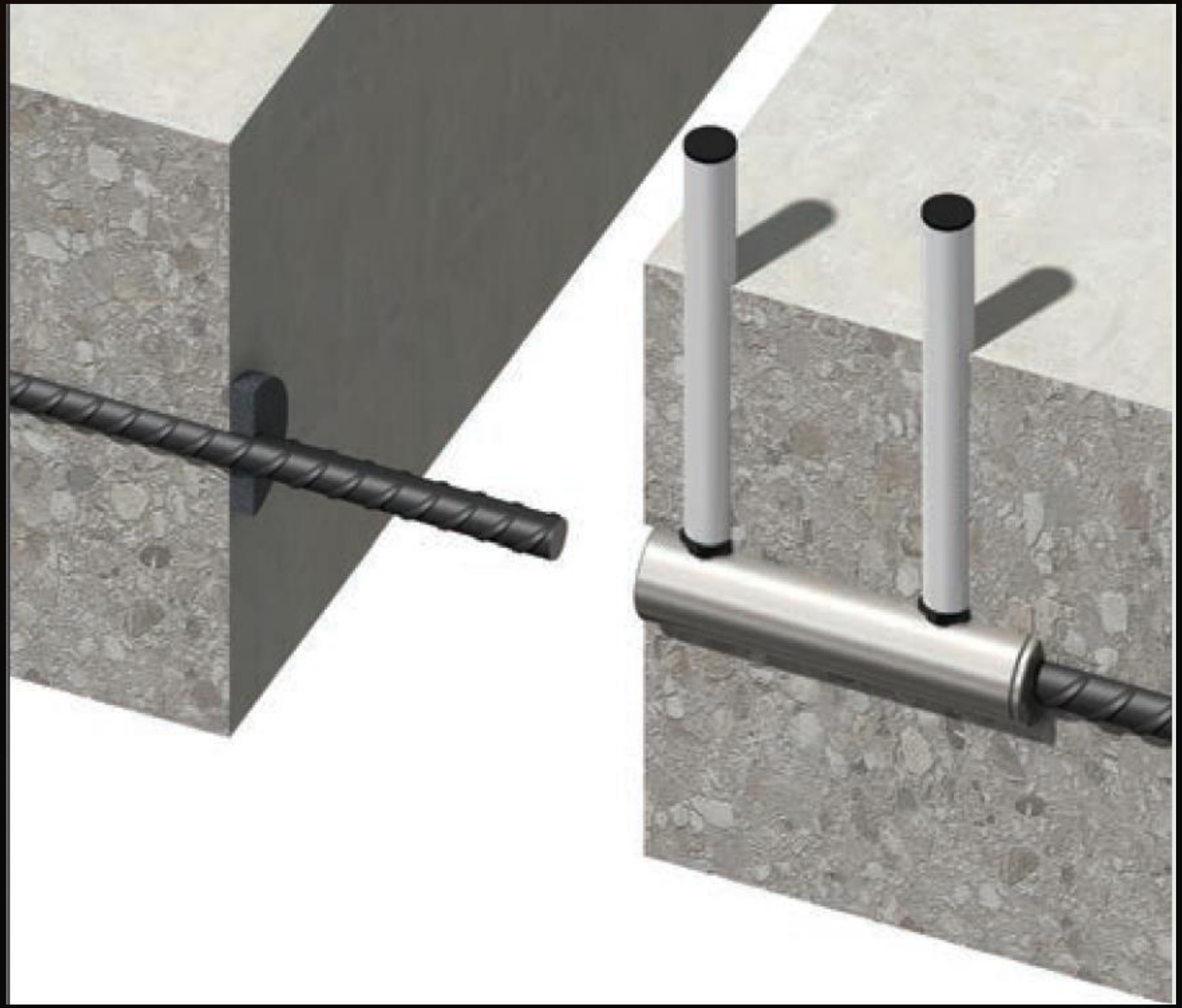
- Coupler typically concentric with the bar
- Coupler axis distance = bar axis distance

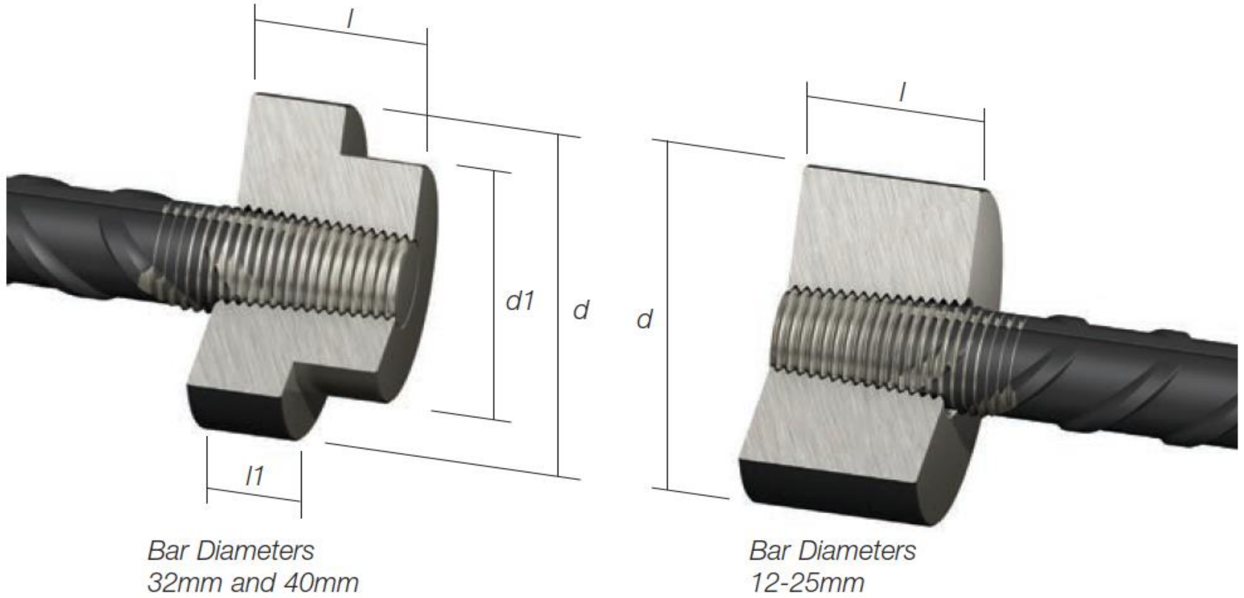
The clear cover to the coupler will be reduced compared to the steel bar



Couplers in Fire Conditions: Challenges

The coupler would typically have a reduced concrete cover due to its larger size compared to the rebar, and this has a direct influence on temperature development.





Tapered Thread Headed Anchor Dimensions

Bar Diameter (mm)		12	16	20	25	32	40
External Dia. (mm)	*d*	40	50	65	80	110	135
External Dia. (mm)	*d1*	-	-	-	-	78	78
Coupler Length (mm)	*l*	27.0	33.0	35.0	43.5	53.5	67.5
Coupler Length (mm)	*l1*	-	-	-	-	28.5	42.5
Weight (kg)		0.25	0.46	0.83	1.57	2.81	5.17
Torque (Nm)		60	110	165	265	285	330
Part No.		TTH12	TTH16	TTH20	TTH25	TTH32	TTH40

Note: *Where tapered thread headed anchors are used, the compressive strength of the concrete shall not be less than strength grade C32/40 (cylinder/cube).*

Thermal Analysis

Methodology

SAFIR Program

Thermal analysis simulation

Bar Sizes

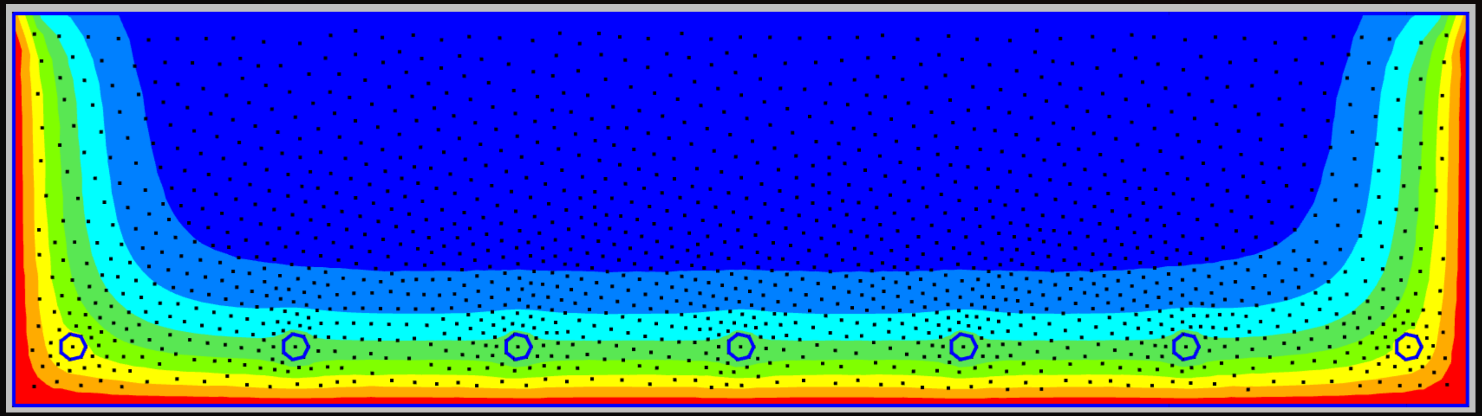
32mm and 40mm bars tested

Coupler Sizes

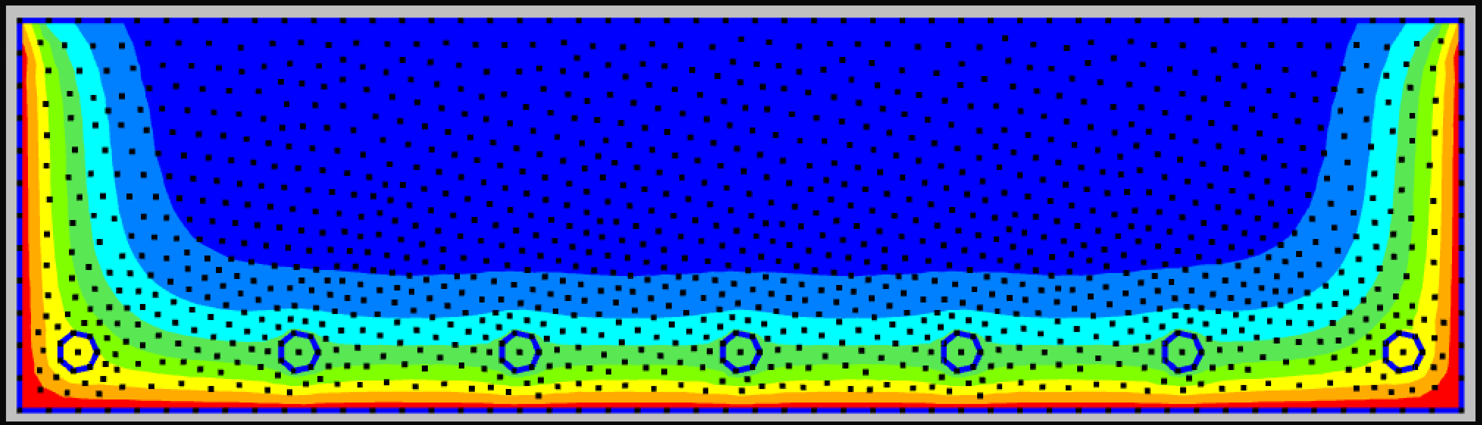
150% up to 300% larger than bars

Time Intervals

Tested at 3600s, 7200s, 9000s



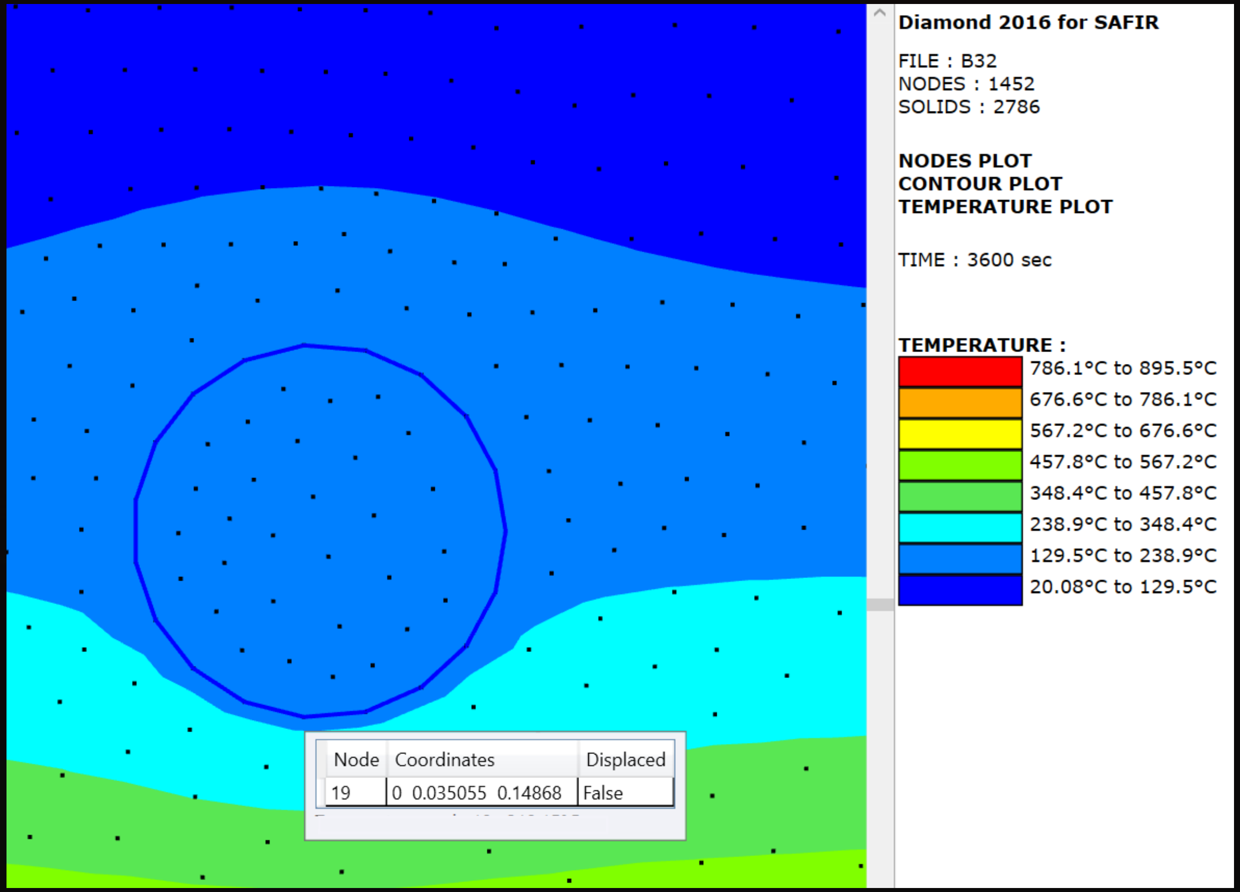
A) 32 mm bar without couplers



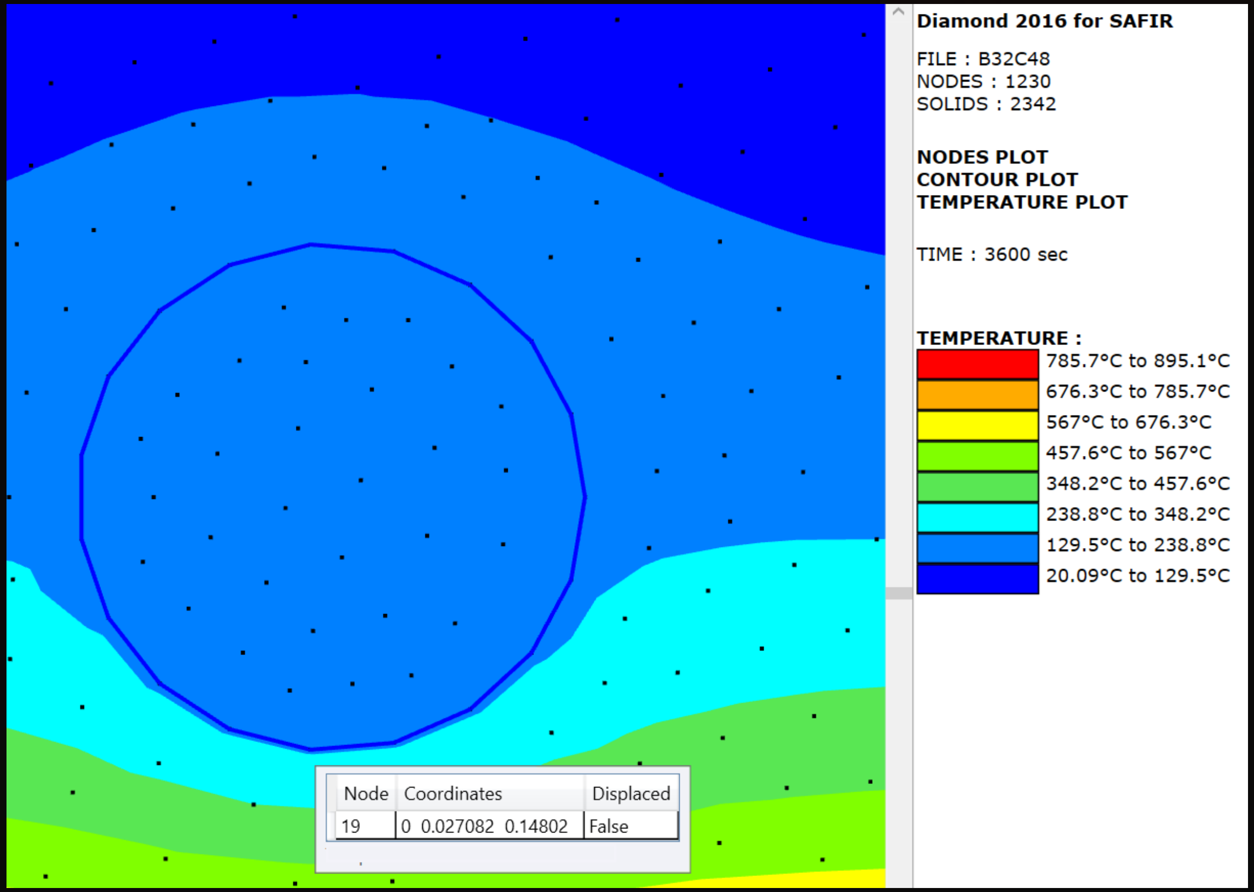
B) 32 mm bar with 48mm couplers

Results: Temperature

Time	Bar size 32 mm	Coupler size 48 mm	Change in T
3600 s	219 °C	230 °C	4.92 %
7200 s	392 °C	416 °C	6.12 %
9000 s	458 °C	487 °C	6.33 %



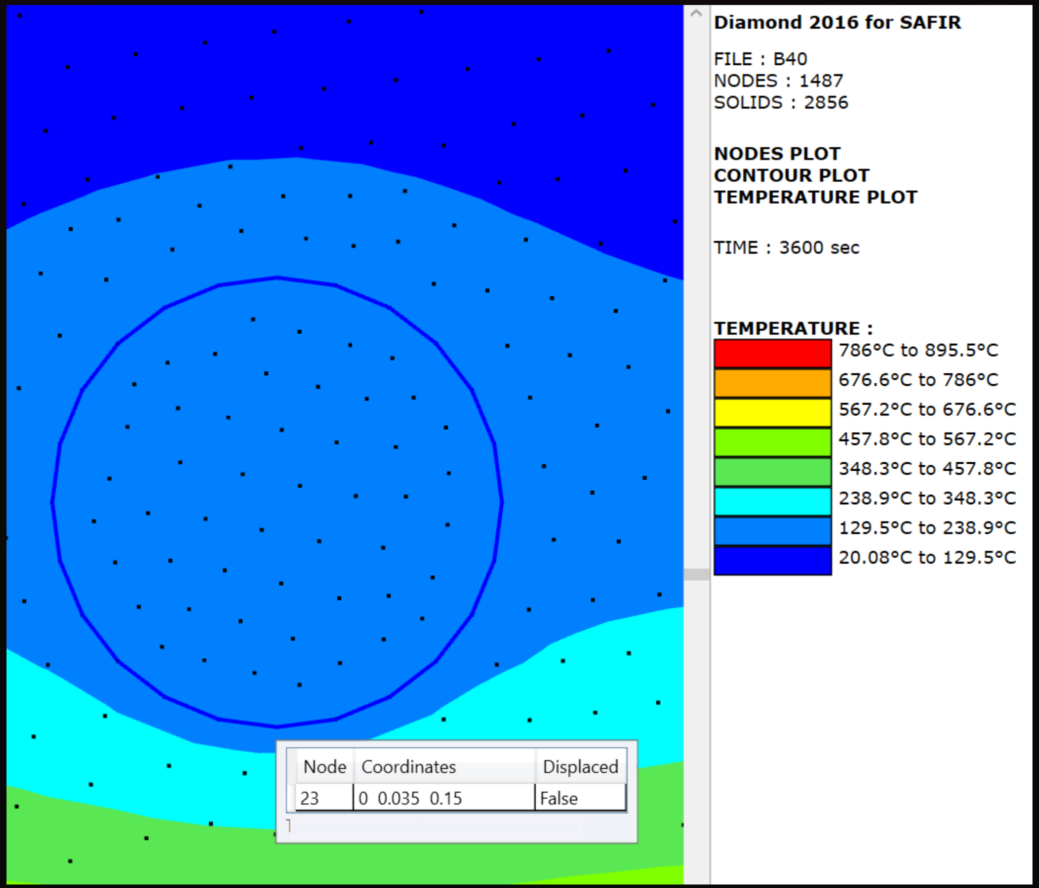
A) 32 mm bar without couplers



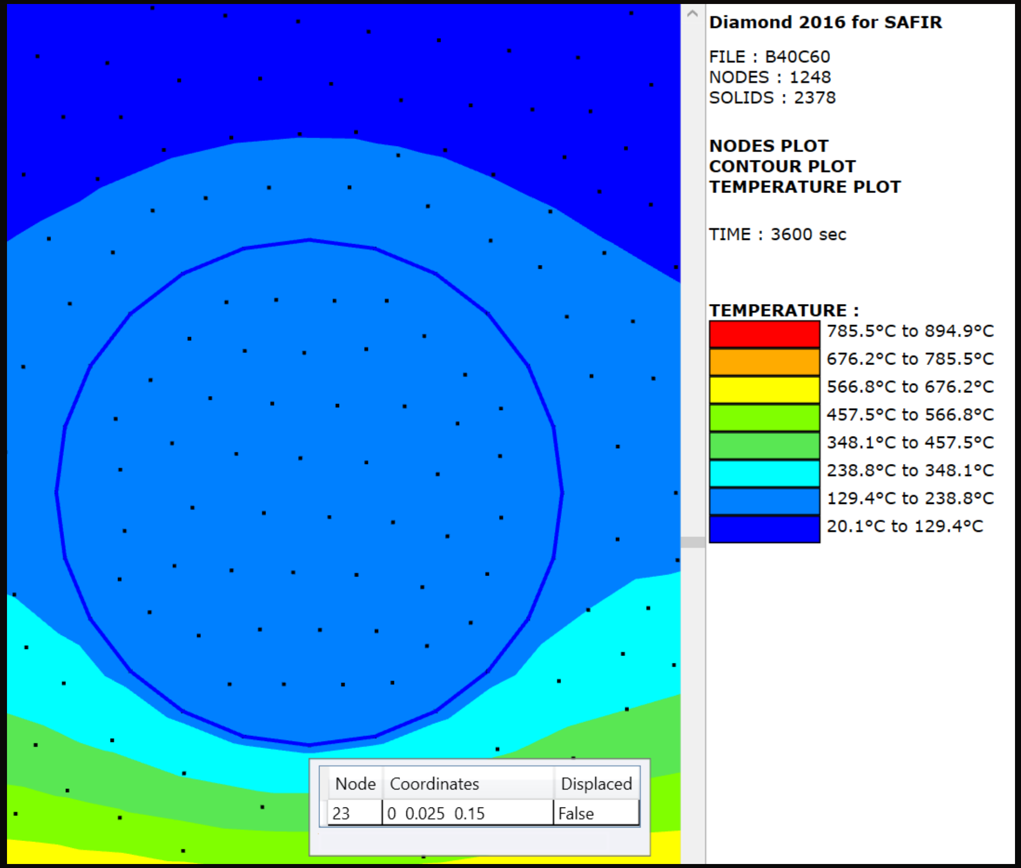
B) 32 mm bar with couplers

Results: Temperature

Time	Bar size 40 mm	Coupler size 60 mm	Change in T
3600 s	246 °C	264 °C	7.31 %
7200 s	418 °C	456 °C	9.08 %
9000 s	492 °C	536 °C	8.94 %

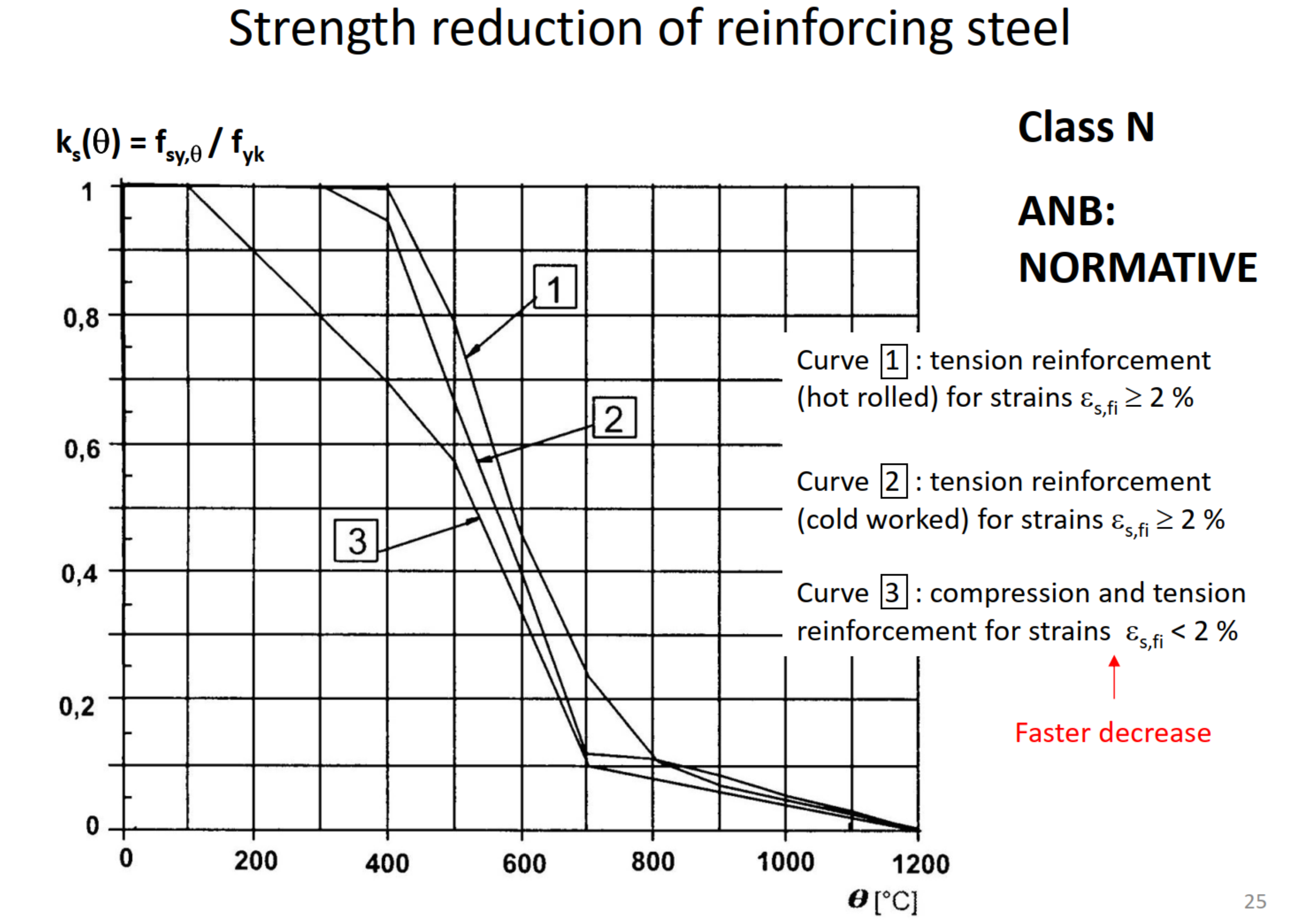


A) 40 mm bar without couplers



B) 60 mm bar with couplers

Strength reduction of reinforcing steel



[1] Effect of Elevated Temperatures on Mechanical Properties of Spliced and Non-Spliced Steel Reinforcements: Experimental Study

1.5 X

Time	Bar 32 mm	Ks	Coupler 48 mm	Ks	Change in T
3600 s	219 °C	1.00	230 °C	1.00	4.92 %
7200 s	392 °C	1.00	416 °C	0.98	6.12 %
9000 s	458 °C	0.95	487 °C	0.85	6.33 %

2.0 X

Time	Bar 32 mm	Ks	Coupler 64 mm	Ks	Change in T
3600 s	219 °C	1.00	252 °C	1.00	15.06 %
7200 s	392 °C	1.00	442 °C	0.96	12.7 %
9000 s	458 °C	0.95	509 °C	0.80	11.13 %

2.5 X

Time	Bar 32 mm	Ks	Coupler 80 mm	Ks	Change in T
3600 s	219 °C	1.00	290 °C	1.00	32.4 %
7200 s	392 °C	1.00	490 °C	0.85	25.0 %
9000 s	458 °C	0.95	563 °C	0.65	22.93 %

3.0 X

Time	Bar 32 mm	Ks	Coupler 96 mm	Ks	Change in T
3600 s	219 °C	1.00	381 °C	1.00	73.92 %
7200 s	392 °C	1.00	610 °C	0.45	55.61 %
9000 s	458 °C	0.95	682 °C	0.38	48.91 %

1.5 X

Time	Bar 40 mm	Ks	Coupler 60 mm	Ks	Change in T
3600 s	246 °C	1.00	264 °C	1.00	7.31 %
7200 s	418 °C	0.98	456 °C	0.90	9.08 %
9000 s	492 °C	0.82	536 °C	0.75	8.94%

2.0 X

Time	Bar 40 mm	Ks	Coupler 80 mm	Ks	Change in T
3600 s	246 °C	1.00	276 °C	1.00	12.19 %
7200 s	418 °C	0.98	466 °C	0.88	11.48 %
9000 s	492 °C	0.82	548 °C	0.65	11.38 %

2.5 X

Time	Bar 40 mm	Ks	Coupler 100 mm	Ks	Change in T
3600 s	246 °C	1.00	312 °C	1.00	26.82 %
7200 s	418 °C	0.98	521 °C	0.73	24.64 %
9000 s	492 °C	0.82	612 °C	0.44	24.39 %

Discussion

Coupler size impacts fire resistance

- Larger couplers (e.g., 96 mm) reach 682°C vs. 458°C for 32 mm bar alone.
- Strength drops significantly (Ks = 0.38 vs. 0.95 after 2.5 hrs).

Reduced cover increases heat transfer

- Challenges Eurocode’s axis distance concept.

Design implication

- Smaller couplers or more cover may be safer.

Limitation

- Simulations need experimental validation.

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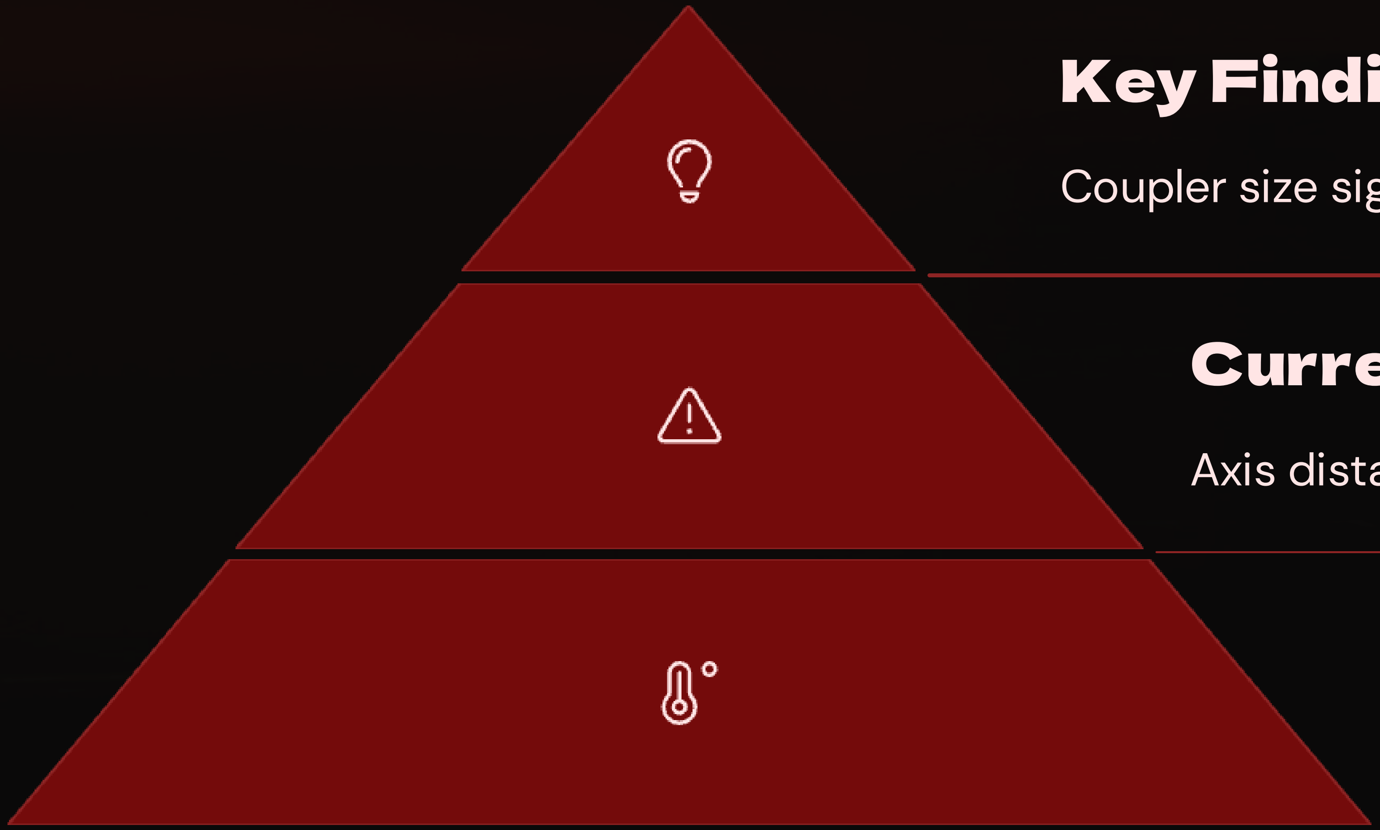
Conclusion



Key Finding

Coupler size significantly affects fire performance

Current codes may not suffice.

Axis distance overlooks size effect.

Future Research

Experimental testing needed for validation

Thank you

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