
BUNDREX®
Steel Fiber
Reinforced Concrete
Steel fiber reinforced concrete(SFRC) is the mixed material dispersing steel fiber randomly inside the concrete mixture to improve tensile strength, flexural performance, cracking resistance, ductility, shear strength and impact resistance of concrete structure.
in
You Tube
WWW.BUNDREX.COM

OVERVIEW

Bundrex, which combines the best steel fiber technology with stable and affordable quality, is widely used as a structural reinforcement for tunnel and precast.

BUNDREX®

BUNDREX® History

KOSTEEL Co., Ltd, a company that has made Korea strong,
is heading towards the world with its Steel Fiber.

1970-1980

Birth of KOSTEEL

1977.03 Establishment of KOSTEEL Co., Ltd.
1980.04 Opened the Pohang #1 Factory with Rolling mills for Wire-rod
1988.02 Acquired KS (Korea Standards) certification for Wire-rod

1990

Business Formation of KOSTEEL

1993.05 Opened the Pohang #2 Factory for Wire-processing
(Cold-drawn steel wire, Annealed wire & Nails)
2003.05 Opened the Eumsung Factory for Deck-plate
2003.12 Established KOSTEEL VINA in Vietnam
2005.12 Acquired "Steel Fiber Korea" (Steel fiber manufacturing company)

2000

Growth of KOSTEEL

2008.12 Accomplished 51% market share in the Korea low carbon wire rod market
2010.11 Won the President's Award at the 17th Business Innovation Awards
2012.01 Merged "Steel Fiber Korea" as Steel Fiber Division in KOSTEEL

2010

2020

BUNDREX New Growth

2013.12 Developed SFEED-PRO
(SFRC structural Design Program for SOG)
2014.09 Developed "Arched-Steel Fiber"
2018.09 Completed SFEED-PRO series
(SOG, SOP, Segment, General Structure)
2019.05 Opened 5th Exhibition booth at
"World Tunnel Congress"(since 2015)
2020.02 Opened 7th Exhibition booth at
"World of Concrete"(since 2014)

BUNDREX® PRODUCTS

Steel Fibers are added to the concrete mix to provide multidimensional reinforcement and is used to replace rebar or mesh.

Application



Responding with optimal solution by carrying full product line-up.

Steel Fiber

BUNDREX is an ideal concrete reinforcement which shifts the properties of concrete from brittleness to ductility, and increases toughness and resistance to cracking by drying shrinkage and Plastic shrinkage.

Products

SUPER BUNDREX

Tensile Strength (1,100~1,500MPa)

Arched Fiber,new shaped and patented steel fiber increasing the performance of concrete by up to 20% compared to conventional steel fiber products.

Ultra/ High BUNDREX

Tensile Strength : 1,500 ~ 2,200MPa

The recently developed steel fiber which has extremely high tensile strength, enabling higher concrete performance.

BUNDREX

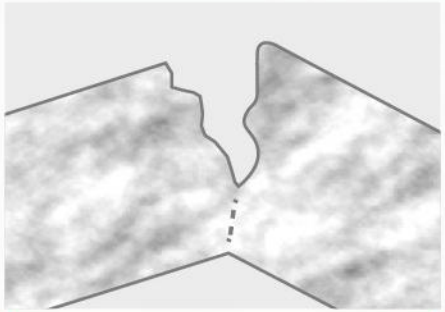
Tensile Strength (1,100~1,350MPa)

Standard type steel fiber with its quality and performance.

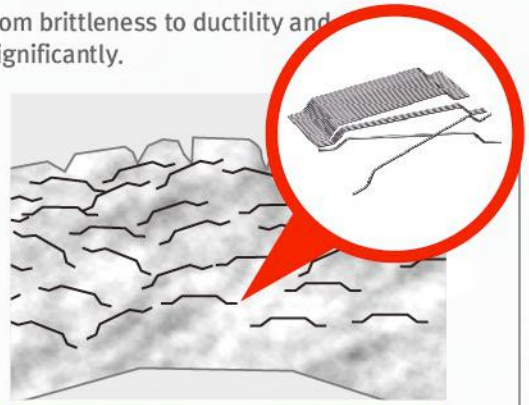
BUNDREX® General Feature of BUNDREX® Steel Fiber

Physical Property Change of the Concrete

BUNDREX induces concrete's property from brittleness to ductility and increases its toughness and durability significantly.



Normal Concrete(Brittle Fracture)



BUNDREX Reinforced Concrete (Ductile Fracture)

Expected Effects for Concrete

Following to each concrete properties,
Bundrex SFRC effects can be remarkably increased.

Concrete Properties	BUNDREX ® Effects
Modulus Rupture	Increased by up to 3 times
Shear Strength	Increased by up to 2 times
Torsional Strength	Increased by up to 2 times
Fatigue Resistance	Increased by up to 1.8 times
Abrasion and Corrosion	Increased by up to 1.4 times
Shock Absorption	Increased by up to 15 times

● Normal Concrete ● BUNDREX® reinforced concrete

Physical Property Comparison

Classification	General Concrete Slab	Steel Fiber Reinforced Concrete Slab
Workability	Decreased workability	Increased workability
Control of crack at initial drying shrinkage	Upper drying shrinkage crack	Decrease in upper drying shrinkage crack
Initial crack strength and maximum yield strength	Average	Excellent
	Concrete slab without rebar < Concrete slab with rebar< Concrete slab with steel fiber	
Fracture condition	Brittleness behavior	Ductility behavior

BUNDREX® General Feature of BUNDREX® Steel Fiber

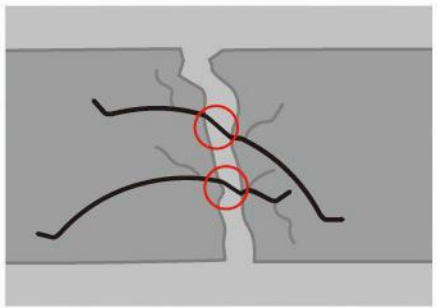
Distinctive Features

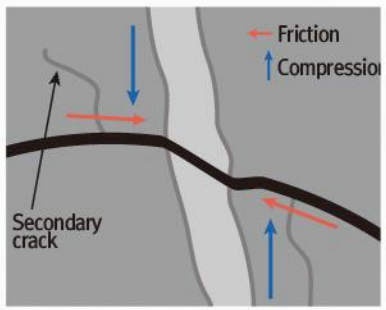
Adding Bundrex steel fibers to the concrete mix helps giving the concrete a higher tensile strength, together with improving flexural toughness and crack resistance.

Super BUNDREX®

BUNDREX® Features

- Increases fatigue resistance, flexural toughness, shear force, flexibility, percussion resistance, and fracture resistance of concrete
- Increases resistance to drying shrinkage
- Increases abrasion durability, erosion resistance and corrosion resistance
- Minimizes maintenance and repair expense
- Reduces section thickness of concrete by enhancing physical properties of the concrete
- Reinforces physical cohesion of concrete by even dispersion of steel fiber
- Improves constructability, cost-effectiveness and safety by not installing wire mesh
- Offers three-dimensional reinforcement effect within concrete





BUNDREX® PRODUCTS

Features of BUNDREX®

- Improves productivity by replacing partially or totally the rebar .
- Increases crack control, impact resistance and durability.
- Increases economic efficiency.

Product Code	D (mm)	L (mm)	Aspect Ratio (L/D)	Tensile Strength (Mpa)	Type	T/S of MassProduction	Country of Origin	CE
BUNDREX 65/35 CH	0.55	35	65	1,000~2,400	Collated	1,100 1,350 1,650 1,800	Korea	○ ○ ○ ○
BUNDREX 66/35 CH	0.53	35	66	1,000~2,000	Collated	1,250	Korea	○
BUNDREX 50/30 CH	0.60	30	50	1,000~2,000	Collated	1,200	Korea	○
BUNDREX 80/60 CH	0.75	60	80	1,000~2,000	Collated	1,100 1,250 1,500 1,800	Korea	○ ○ ○ ○
BUNDREX 67/60 CH	0.9	60	67	1,000~1,900	Collated	1,050 1,200 1,500	Korea	○ ○ ○
SUPER BUNDREX 80/60 CA	0.75	60	80	1,000~1,800	Collated	1,500 1,800	Korea	○
SUPER BUNDREX 65/35 CA	0.55	35	65	1,000~1,500	Collated	1,500 1,800	Korea	○
BUNDREX 50/50 LH	1.0	50	50	1,100	Loose	1,100	Vietnam	○

BUNDREX® CERTIFICATION

Proven Quality by International Standard

CE No.1020-CPR-010037679 | ISO 9001 | ISO 14001 | ASTM INTERNATIONAL Standards Worldwide

'KSEA(Korea)'
KOSTEEL Fiber Reinforced Concrete Design and Product

'KS(Korea)'
KOSTEEL Steel Fiber Product and Factory

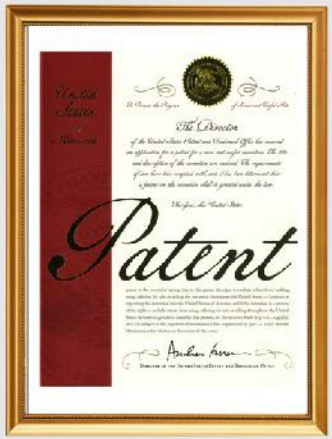
'CE(Europe)'
KOSTEEL Steel Fiber Product and Factory

'ISO9001'
KOSTEEL Steel Fiber Factory

'ISO 14001 certification
KOSTEEL Steel Fib
Factory

'ASTM(USA)'
KOSTEEL Steel Fiber Product

'Patent(Korea)'
New Shape Steel Fiber



'Patent(USA)'
New Shape Steel Fiber

BUNDREX®

Shotcrete

Advantages of BUNDREX®

Performance of BUNDREX®

Advantage of BUNDREX®

Benefits

- Increased reinforcement effects with wall of even thickness on a rugged surface
- Increased tensile strength, bending strength, shear strength of concrete; no hollowing-out ; reduction of wall thickness(20%)
- High resistance to cracking; increase in toughness (residual strength) after cracking
- Shotcrete construction possible right after excavation; drop in risk of cave-in disasters; rise in reinforcement effects and safety of permanent structures

Cost-effectiveness

- Reduces labor costs, as no reinforcement assembly process is required
- Reduces construction cost due to shortened construction period
- Reduced working hours and construction costs

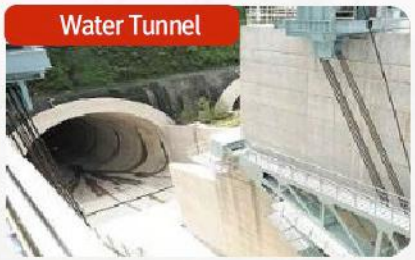
Quality

- Streamlined work process; rise in quality and safety

Shotcrete

Features of BUNDREX®

Other Applications for Shotcrete



Advantage of BUNDREX®

As fibers, especially steel fibers,
show better concrete performance and also safer and easier work, fibers are regarded as a better solution for reinforcement than mesh.

BUNDREX have supplied 450km long 500 tunnels (more than 200,000MT) with our steel fibers for sprayed concrete of NATM tunnels, which proves BUNDREX is the best solution for sprayed concrete.

Steel fiber reinforced sprayed concrete

Advantage of Steel fiber Reinforced Sprayed Concrete (vs. Mesh)

Mesh Reinforcement Sprayed Concrete	Steel Fiber Reinforced Sprayed Concrete
Difficult to install wire mesh in case of back break from excavation; decreased reinforcement effects.	Increased reinforcement effects with wall of even thickness on a rugged surface.
Decreased adhesion, layer splitting, hollowing-out due to vibration on wire mesh when placing shotcrete.	Increased tensile strength, bending strength, shear strength of concrete; no hollowing-out; reduction of wall thickness(20%).
High frequency of cracking in shotcrete and decreased reinforcement effects in case of cracking	High resistance to cracking; increase in toughness (residual strength) after cracking.
Shotcrete reinforcement needed right after excavation due to risk of cave-in disasters; decreased reinforcement effects due to delay of reinforcement.	Shotcrete construction possible right after excavation; drop in risk of cave in disasters; rise in reinforcement effects and safety of permanent structures.
Low constructability and complex work process.	Streamlined work process; rise in quality and safety.
Increased construction costs due to longer working hours.	Reduced working hours and construction costs.

Performance of BUNDREX®

- Experiences in all kinds of tunnel projects
  –Metro, High-speed train, Expressway
  –Hydro power, Underground & Electric line tunnel & Mining
- Overseas projects all around the world
  –Korea, Japan, Nepal, Taiwan
  –Canada, USA, Colombia, Peru, etc.

Shotcrete Construction Performance

- 500 tunnel projects in Korea with 97,117 MT
- Total length 450Km during 2001–2016
- 58 projects in 2017 and 62 projects in 2018

Performance of BUNDREX®

U. A .E AL MANDOUS PROJECT

World largest oil storage tunnel

ABU DHABI NATIONAL OIL COMPANY(ADNOC) is undertaking the construction of the **AL MANDOUS** oil storage terminal project in the **U.A.E.**

- It is big enough to store approx. 40 million barrels of oil contributing to oil price stabilization.
- The project "involves" the construction of 12 crude oil storage "caverns", water tunnels in D-shape, boreholes and access tunnels.
- It includes the construction of compressor units and access roads and the installation of temperature control machinery and safety systems.

All images and pictures shown are for illustration purpose only.

BUNDREX®
supplying
7,000tons
of steel Fiber
to M-Project
in U.A.E

KF 65/35 CH T/S ~1,300MPa

Diameter 0.55mm
Length 35mm

BUNDREX®

TBM

Advantages of BUNDREX®
Performance of BUNDREX®

Advantage of BUNDREX®

Benefits

- Improved productivity by reducing part/all of rebar giving effects of smooth dispersion of concrete and multi-directional reinforcement of steel Fiber
- Increases crack control, impact resistance and durability of the precast reducing crack or breakage of joint between the segments cause by jack thrust
- Secures refractory performance by combining with synthetic Fiber preventing high-strength concrete spalling and increasing residual strength after fire exposure

Cost-effectiveness

- Reduces labor costs, as no reinforcemen assembly process is required
- Reduces construction cost due to shortened construction period
- Reduced working hours and construction costs

Quality

- Streamlined work process; rise in quality and safety

Precast

Features of BUNDREX®

Other Application for Precast

Waterway Culvert

Railroad Sleeper

Tunnel Lining Support

Residential

Advantage of BUNDREX®

SFRC precast segment for TBM

Shield TBM method is widely used to drill a tunnel where it is under sea, it has weak ground or blasting is not possible.

The method is to install precast segment lining after excavating ground with TBM (Tunnel Boring Machine).

In the past, rebar was mainly used for reinforcement of precast segment but as the performance of steel fiber is enhanced a lot recently, rebar is being replaced with steel fiber.

BUNDREX offers steel fibers that fits well to precast segment.

Advantage of SFRC Precast Segment for TBM	
Improvement of productivity	Reduces time, space and labor used for installing rebar during segment precast manufacturing.
Improvement of durability	Increases crack control and breakage joints between segments caused by jack thrust through the effect of 3-dimensional dispersion of steel fiber.
Improvement of cost-efficiency	Reduces cost of steel material for reinforcement and labor cost Reduces maintenance cost by better durability.

Advantage of BUNDREX®

SFRC Precast Segment Manufacturing Process

The production of segment is a lot simpler because rebar cage process is not required.

Productivity is improved and production cost is reduced.

Segment Manufacturing Process

Performance of **BUNDREX®**

Precast Tunnel Segments in Concrete Reinforced with BUNDREX_Steel Fibers

TBM projects performed in Korea, Japan, US, Canada and others.

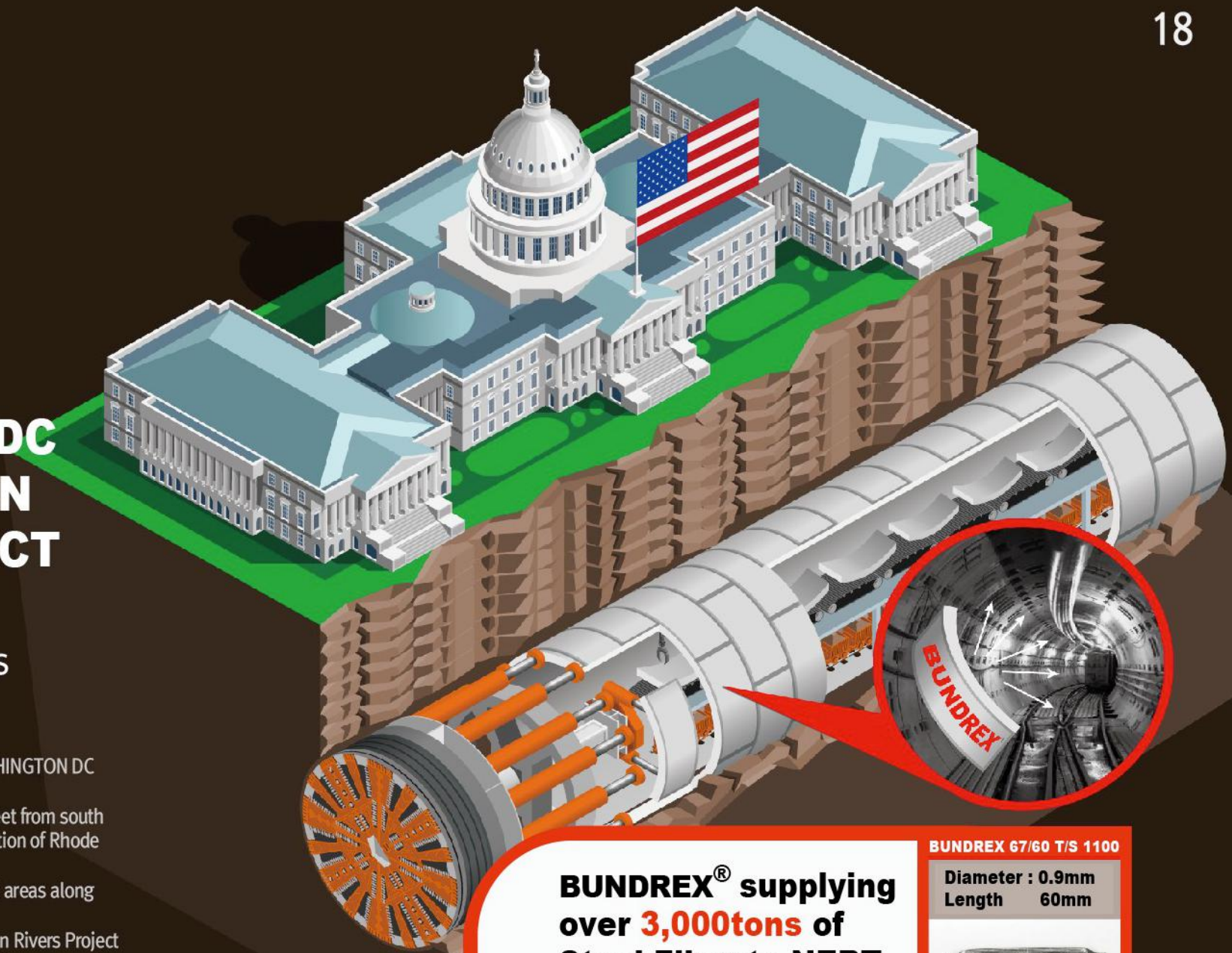
TBM Construction Performance

Performance of **BUNDREX®**

U.S.A WASHINGTON DC WATER'S CLEAN RIVERS PROJECT

The biggest WASHINGTON DC water's clean rivers tunnel

- The NEBT is the biggest component of WASHINGTON DC Water's Clean Rivers Project.
- 50–160 feet below ground and run 27,000 feet from south of Robert F. Kennedy Stadium to the intersection of Rhode Island Avenue.
- Aligned to intersect the existing chronic flood areas along Rhode Island Avenue.
- Effects: Once it is connected to the other Clean Rivers Project tunnels, the NEBT will help reduce combined sewer overflows to the Anacostia River by 98 percent and the chance of flooding in the areas it serves from about 50 percent to 70 percent in any given year.



BUNDREX® supplying over 3,000tons of Steel Fiber to NEBT Project in USA

BUNDREX 67/60 T/S 1100

Diameter : 0.9mm
Length 60mm

BUNDREX®

Slab On Grade(SOG)

Advantages of BUNDREX®
Performance of BUNDREX®

Advantage of BUNDREX®

Benefits

- Reduce frequency of defects that must be remedied due to its excellent shock resistance, fatigue strength, and wear resistance

Cost-effectiveness

- Reduce labor costs as no reinforcement assembly process is required
- Reduce construction cost due to shortened construction period
- Reduce cost of concret by decreasing thickness of slab

Constructability

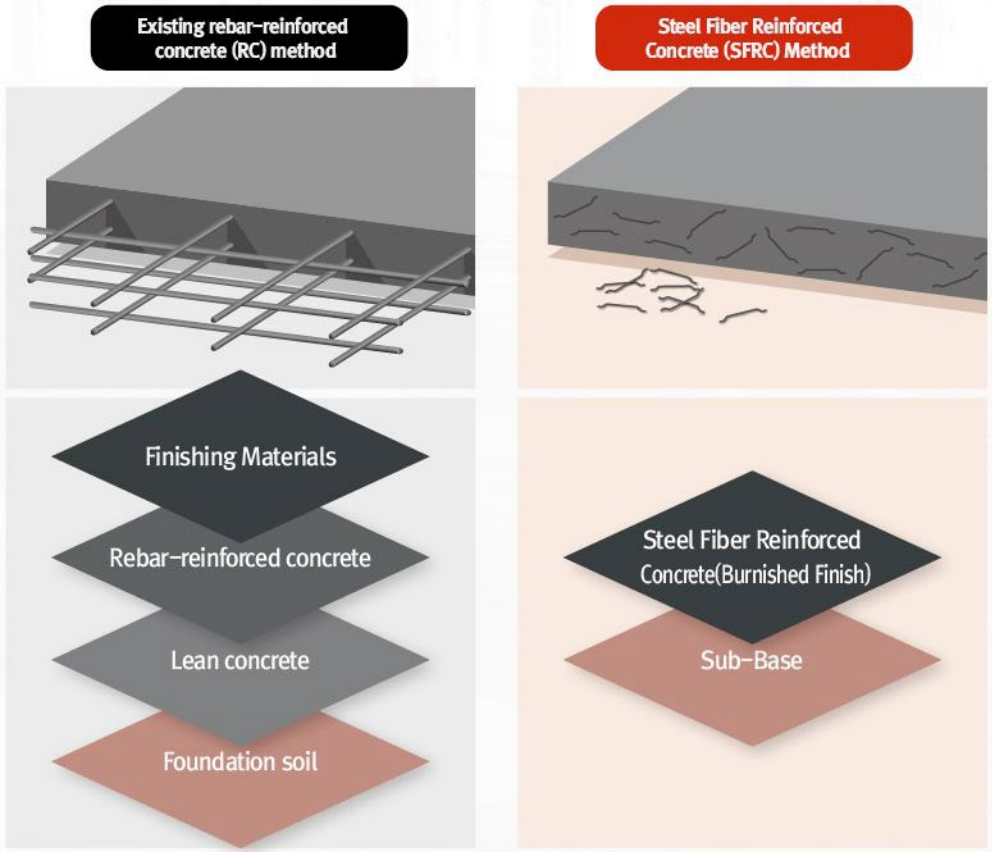
- Accelerate schedule by eliminating rebar and mesh placement
- Able to use large laser screed equipment

Quality

- Achieve a high level of ground top smoothness
- Help control cracking better the rebar concrete method

Rebar Vs. Steel Fiber

Improve 10~20% of overall performance compared with usual type provide high quality product for SOG & SOP



Reduced thickness by 20%/Reduced construction period by 40%/Reduced cost by 20%

Advantage of BUNDREX®

Applications

Applied to floor slab construction of building and civil engineering structures such as factories, warehouses, container terminal, gas stations, residential foundation slabs and airport taxiways.

Plant

- Site Name : Kia Mobis Mexico Plant (Mexico)
- Slab Thickness : 250 mm
- Concrete Strength : 27 MPa
- Steel Fiber Input : 20 kg/m^3

Warehouse

- Site Name : CUMMINS Warehouse Project (India)
- Slab Thickness : 250 mm
- Concrete Strength : 30 MPa
- Steel Fiber Input : 25 kg/m^3

Gas Station

- Site Name : Caltex Truck Stop (Australia)
- Slab Thickness : 200 mm
- Concrete Strength : 24 MPa
- Steel Fiber Input : 25 kg/m^3

Residential Foundation Slab

- Site Name : Lakeside Park for Persimmon Homes (UK)
- Slab Thickness : 200 mm
- Concrete Strength : 21 MPa
- Steel Fiber Input: 40 kg/m^3

Airport lanes

- Site Name : McCarran International Airport (USA)
- Slab Thickness : 400 mm
- Concrete Strength : 30 MPa
- Steel Fiber Input : 50 kg/m^3

Container Terminal

- Site Name : Algeciras Harbour Project (Spain)
- Slab Thickness : 320 mm
- Concrete Strength : 30 MPa
- Steel Fiber Input : 35 kg/m^3

Comparison (R.C Slab Vs. SFRC Slab)_1

The SFRC method can reduce slab thickness under the same design conditions, reducing construction cost by 20% and construction period by 40% compared to the RC method.

Structural Design Comparison

OOO New Construction	
Purpose	• Industrial Building • Factory
Basic Design	• RC FLOOR • Epoxy Paint
Changed Design	• SFRC FLOOR • Permeability surface reinforcing agent
Scope of Application	• For all of 1st Floor
Area	• About 15,000m²

Classification	R.C – SLAB	S.F.R.C – SLAB
Coefficient of subgrade reaction for foundation	0.05 N/mm³	0.05 N/mm³
Concrete Strength	24MPa	24MPa
Live Load	30 kN/m²	30 kN/m²
Wheel Load	2.5 kN/wheel	2.5 kN/wheel
Design Method	Elastic Design (Strength design method)	Plastic Design (Limit state design method)
Slab Thickness	250 mm	200 mm
Steel fiber input volume	–	25 kg/m²
Rebar reinforcement volume	2-HD13@200(SD 400, upper & lower, two-way)	–
Cost of construction	100	80

Comparison (R.C Slab Vs. SFRC Slab)_2

Classification	R.C – SLAB	S.F.R.C – SLAB
Construtions	 Rebar installation involve in a great deal of time and involve in the use of pumps to protect placed rebar.	 This requires no rebar installation as the steel fiber reinforced concrete can be placed directly from a concrete mixer truck
Flatness	• Must be checked manually during construction. • Less than FM3 from TR-34 (poor)	• Operate laser Screeding (automatically checks for flatness). • More than FM2 from TR-34 (good)
Crack	 Unable to reinforce total area of slab due to 2-dimensional reinforcement → Durability and usability is poor, with many cracks	 Able to reinforce total area of slab due to multidimensional reinforcement → Prevents cracking in order to increase durability and improve usability
Joint	Spalling due to wooden formwork	No spalling due to buried steel formwork
Construction Period	**Total construction period 23 days** 4 days Sub-Slab Concrete 5 days Rebar Installation 8 days Pouring & Plastering 6 days epoxy finish	**Total construction period 14 days** 2 days Prepare for placement 8 days SFRC 4 days Placing surface reinforcing agent 40% reduction in construction period

S.F.R.C

Better Concrete Quality

+

More Cost Efficiency

=

Optimal Industrial Floor Solution

Comparison (R.C Slab Vs. SFRC Slab)_3

Advantages of steel fibe campared with rebar or mesh	
Crack control	As steel fibers are 3-dimensionly distributed into the concrete, SFRC shows better crack control performance.
Flatness	FM1 or FM2 class can be acquired by TR-34 standards. (FM3 or FM4 class with rebar or mesh)
Impact & Fatigue	Better impact resistance and higher fatigue resistance.
Construction time	40% of construction time is saved by reduced construction process.
Construction cost	As slab thickness is normally reduced by 20% and labor work for rebar placement is skipped, total cost can be saved up to 20%.
Easy to work	No concrete pumping/ No rabar work/ No pre lean concrete placement.

Performance of BUNDREX®

- Construction of Sampyo Hwa-sung factory
- Construction of Ssangyong Ciffcon factory
- Construction of Guri Logistics Center
- Construction of MH Pyeonggok Logistics Center
- Construction of Hyuandai Mobis Ulsan factory
- Construction of Gyeongsan Tyco factory
- Construction of Hyorim Gyeongsan factory
- Construction of National Agricultural Cooperative Federation Miryang Logistics Center
- Construction of Sam Shin Chemical factory
- Construction of SungShin Hysco factory
- Construction of Gyeongsan DYC Logistics Center
- Construction of Namyang Nynexmo Hwasung factory
- Construction of Icheon, Maegok-ri Logistics Center
- Construction of AK Logistics Center
- Hanwha S-ONE Project
- Construction of Yong-in Bae Bong-ri Logistics Center
- Construction of Cheonan E-Land Logistics Center
- Construction of Mapei Cheonan factory
- Construction of Pyeongtaek Chun-il Logistics Center
- Construction of Seo Yi Chun Cha Logistics Center
- Construction of Woojin Industrial Systems Railroad car factory
- Construction of Ishin textile plant
- Construction of Renault-Samsung Busan Sola
- Construction of Mercedes-Benz Parts Logistics Center (Korea)
- Construction of Ulsan Exhibit Convention Center

Office Depot Warehouse (USA)

CUMMINS Warehouse (India)

Nimetech Project (Finland)

Fresenius Medical Care SOG Project (Colombia) generating parking lot

- Construction of Deokpyeong Hu-med Logistics Center

Industrial Slab for Hitachi Fortune Transformer nc-New Plant (Taiwan)

SFRC SOG construction Performance

From 2014 to 2020, we provided design support to 308 Domestic South korea sites and supplied BUNDREX steel fiber products to 134 SFRC floor slab construction sites.

Renault-Samsung Busan Sola generating parking lot construction

Mapei Cheonan factory construction

Mercedes-Benz Parts Logistics Center construction (Korea)

Deokpyeong Hu-med Logistics Center construction

Cheonan E-Land Logistics Center construction

Daimler Colombia Mercedes Benz SOG Project (South America)

Kia Mobis India factory construction (India)

Coca Cola Plant Project (South America)

Design supported - **308 sites**
Fibers supplied - **134 sites**
Supplied quantity - **6,000 Tons**

BUNDREX®

Slab On Pile(SOP)

Advantages of BUNDREX®
Performance of BUNDREX®

Advantage of BUNDREX®

Constructability

- Reduce construction time by omitting the rebar installation process
- Construct in fast-track method using Laser Screed equipment

Cost-effectiveness

- Material cost reduced due to skip the process for sub-slab concrete
- Reduce maintenance cost due to multidimensional reinforcement

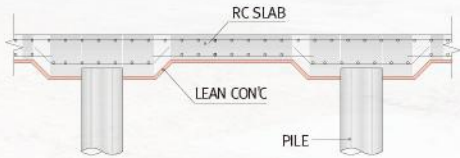
Quality

- Increase flexural strength of concrete through high tensile steel fiber
- Increase crack suppressing effect compared to RC method (Multidimensional reinforcement)
- Reduce dry shrinkage cracks due to separation of piles and slabs

Rebar Vs. Steel Fiber

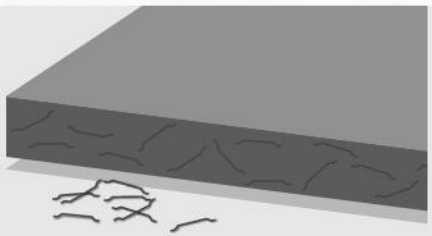
Improve 10~20% of overall performance compared with usual type
Provide high quality product for SOG & SOP

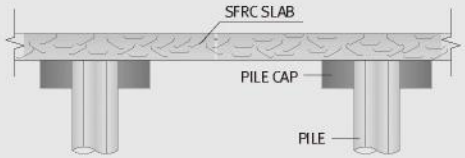
Conventional Rebar-reinforced Concrete (RC) method



Improved Quality / Reduced construction period / Reduced cost

Steel Fiber Reinforced Concrete (SFRC) Method





Advantages of BUNDREX®

SFRC

Floor slab method

Steel fiber reinforced concrete, which was widely used for shotcrete, is now widely used for floor slabs and precast.
High quality SOG (Slab On Grade) and the SOP (Slab On Pile) steel fiber reinforced concrete floor slab method is applied on various sites in the world.

Overview of Construction Method

1 External Load Factor Analysis

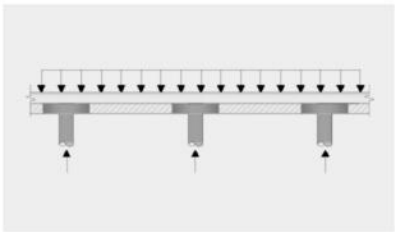
Racking System

Dynamic Load

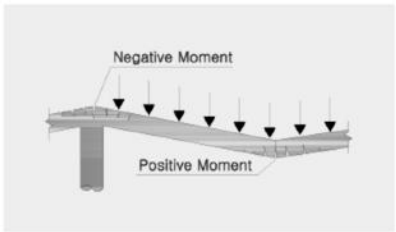
Crack Control

Stock Load

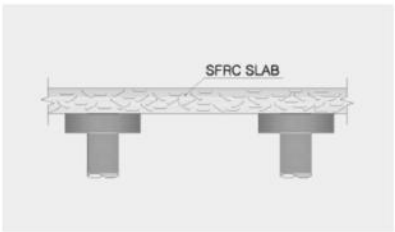
2 SOP Design



Input load



Examine Flexural Resistance



Container Terminal

3 SFRC SOP Construction

Pile Ground Reinforcement ▸

Concrete Pouring ▸

Flattening Work ▸

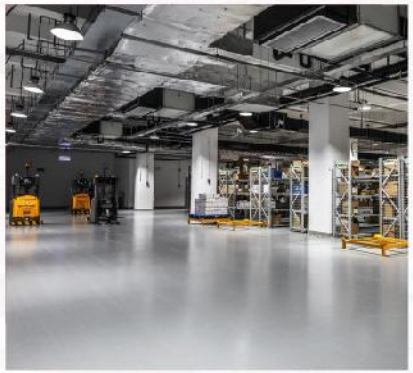
Completed

Advantage of
BUNDREX®

Applications

Applied to floor slab construction of building and civil engineering structures such as factories, warehouses, container terminal, gas stations, residential foundation slabs and airport taxiways.





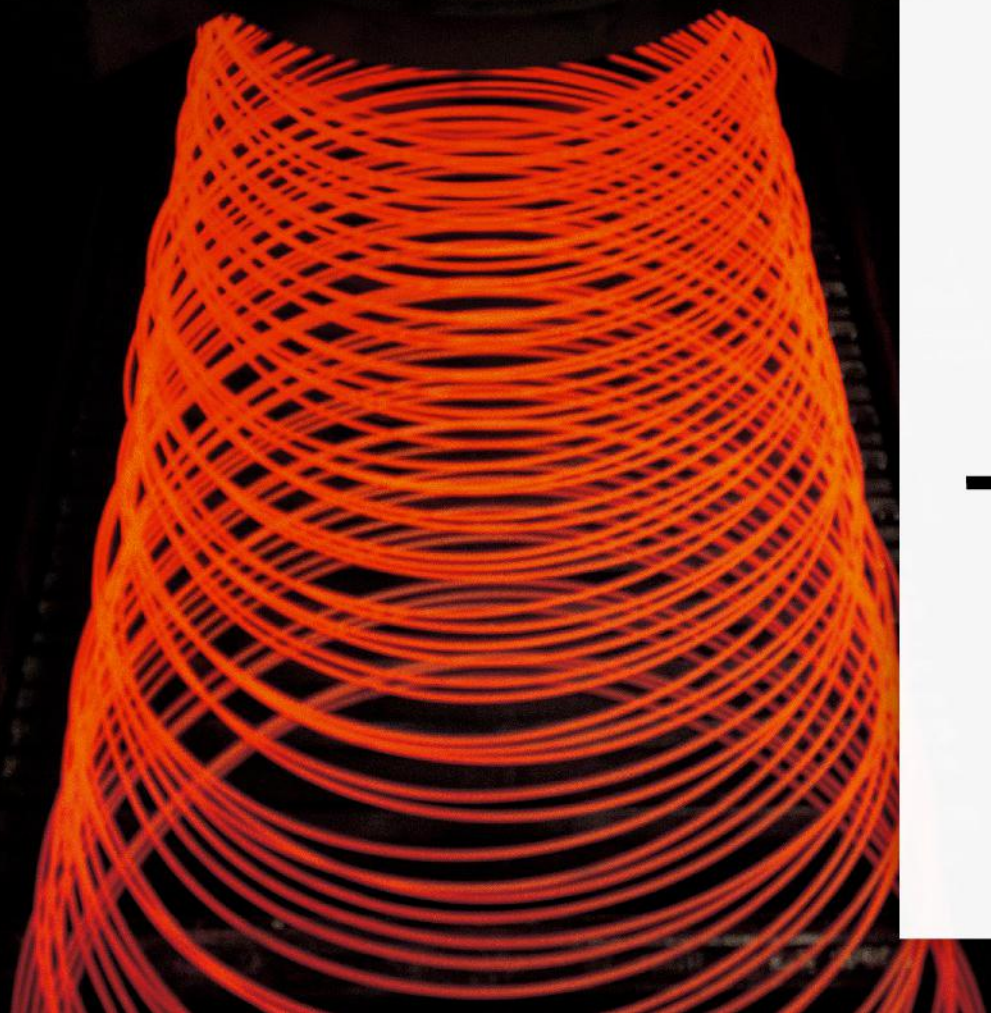
Advantages of BUNDREX®

Integration

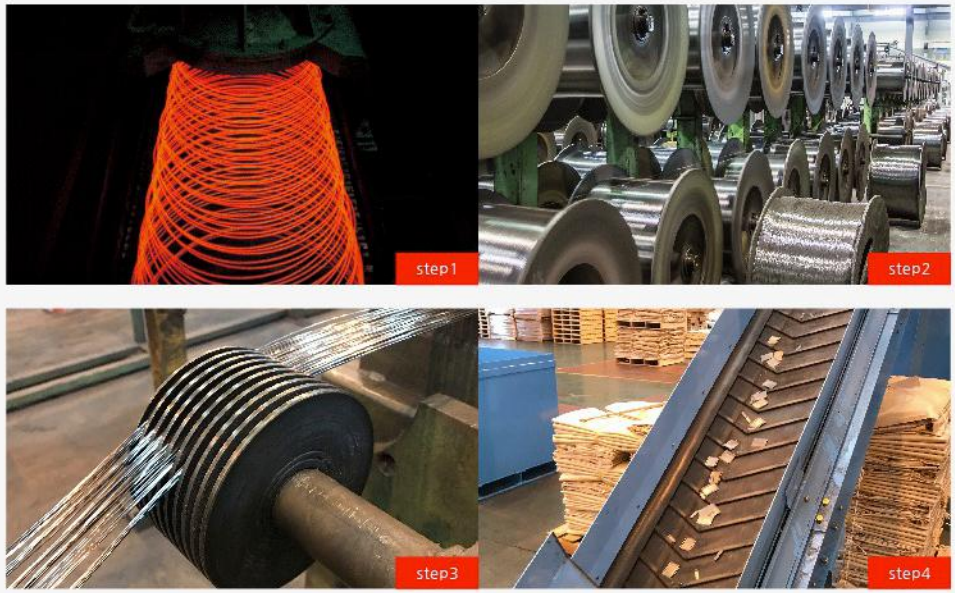
Super Bundrex
SFEED PRO

Excellency of **BUNDREX®**

BUNDREX is an ideal concrete reinforcement which shifts the properties of concrete from brittleness to ductility, and increases toughness and resistance to cracking by drying shrinkage and plastic shrinkage.



Excellency in Production



Competitive advantages in quality and cost through integrated production from wire rod to steel fiber.

Excellency in Market Performance

- No.1 M/S in steel fiber market in Korea
- Continuous growth in overseas market 2021 Forecast Q'ty : 20,000 ton

Excellency in Technology

- Proven quality by International Standard
- Advanced technical support as a solution provider
- Continuous investment

BUNDREX® Production Flow

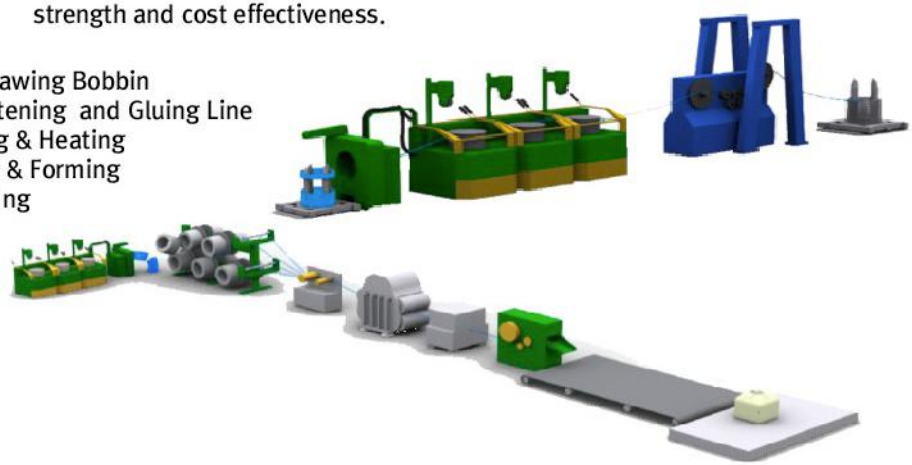
Factory 1

1. Heating Furnace
2. Rough Rolling
3. Concurrent Heating Furnace
4. Intermediate Rolling
5. Block Mill
6. Post-treatment Line

Factory 3

Due to integrated process from raw material to steel fiber, BUNDREX® is favored by steel fiber users for our technical strength and cost effectiveness.

1. Wire Drawing Bobbin
2. Straightening and Gluing Line
3. Bonding & Heating
4. Cooling & Forming
5. Packaging



BUNDREX® Production Flow

Heating Furnace

Factory 1

1. Heating Furnace
2. Rough Rolling
3. Concurrent Heating Furnace
4. Intermediate Rolling
5. Block Mill
6. Post-treatment Line

Rough Rolling

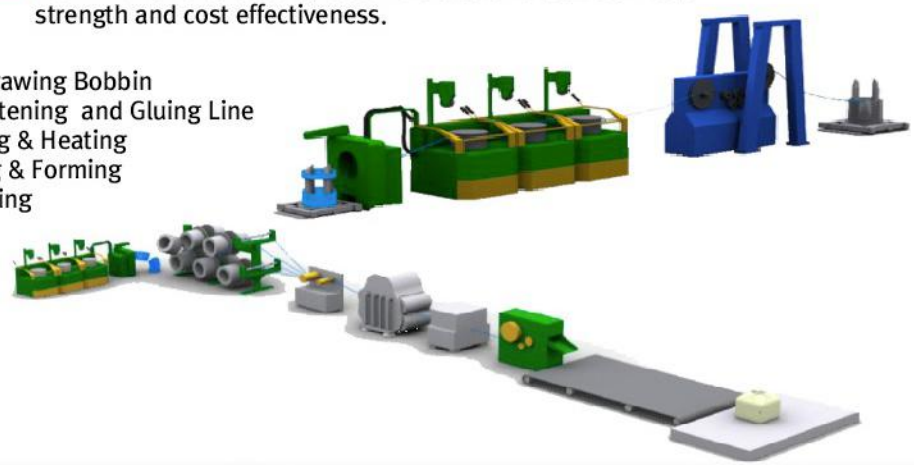
Intermediate Rolling

Block Mill

BUNDREX® Production Flow

Factory 3 Due to integrated process from raw material to steel fiber, BUNDREX® is favored by steel fiber users for our technical strength and cost effectiveness.

1. Wire Drawing Bobbin
2. Straightening and Gluing Line
3. Bonding & Heating
4. Cooling & Forming
5. Packaging



Wire Drawing Bobbin

Straightening and Gluing Line

Bonding & Heating

Packaging

BUNDREX® to the World

Technical Strength & Cost Effectiveness!

Advantages of **BUNDREX®**

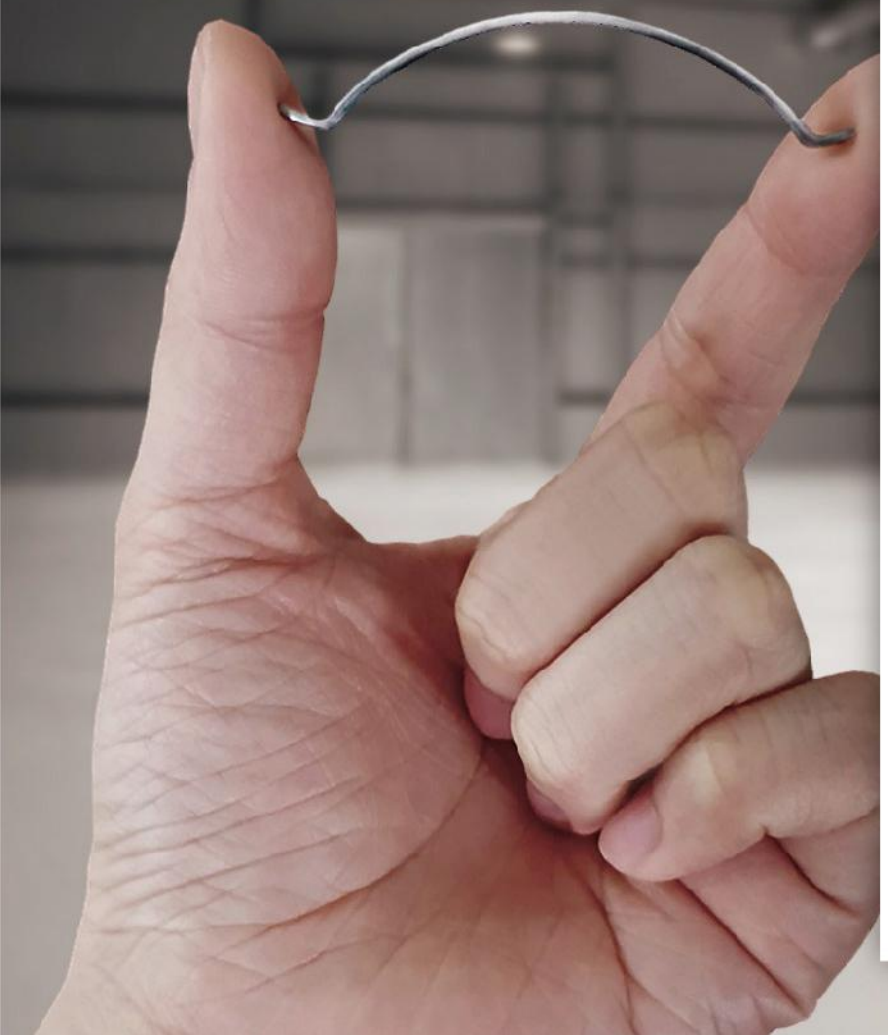
Integration

Super Bundrex

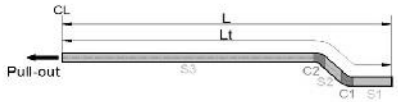
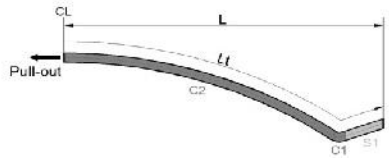
SFEED PRO

Pull-out test of SUPER BUNDREX®

Performance enhancement of arched steel fiber is caused by improving of its pull-out energy.



SUPER BUNDREX® Pull-out mechanism

Classification	Existing type (A-type)	SUPER BUNDREX®
Type		
Pull-out mechanism	 Overall resistance length(Lt) is shorter than B-type"C" section with a large resistance is less than B-type.	 Overall resistance length(Lt) is longer than A-type "C"section with a large resistance is greater than A-type
Pull-out test view		

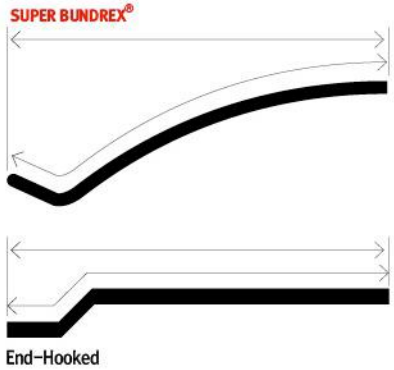
Pull-out test Result SUPER BUNDREX®

Performance enhancement of arched steel fiber is caused by improving of its pull-out energy.

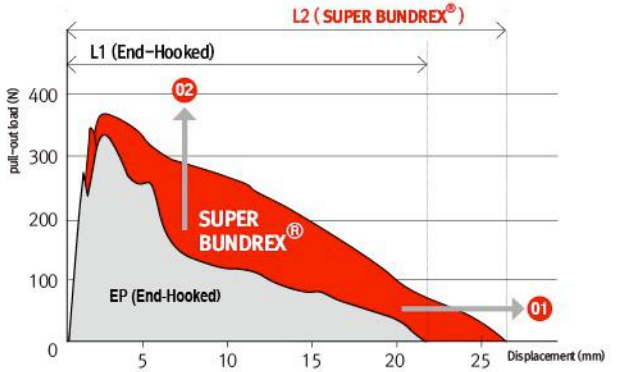
Patent No.
15510305
(USA)

Pull-out test Result SUPER BUNDREX®

More mechanical resistance

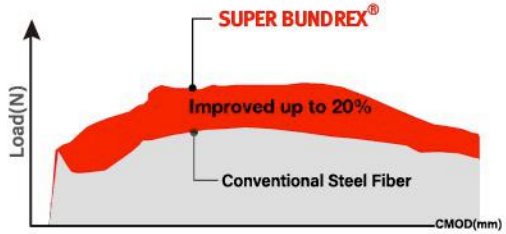


More Pull-Out Energy with SFRC Performance Up to 20%

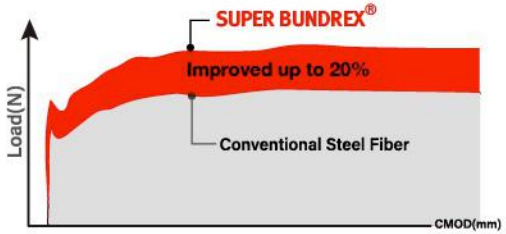


More SFRC Performance Up to 20% SUPER BUNDREX®

SUPER BUNDREX® 65/35 40kg/m³



SUPER BUNDREX® 80/60 40kg/m³



Advantages of **BUNDREX®**

Integration System Bundrex

Super Bundrex

SFEED PRO

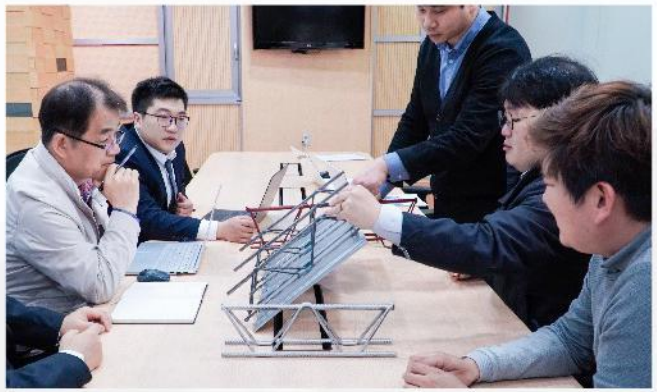
SFEED-PRO

Steel Fiber Enhanced Engineering Design Program

SFEED-PRO, developed by KOSTEEL, is a unique design program that provides customers with accurate, modern, structural design solutions, and has been certified by Korean Structural Engineering Association Institute of Construction and Structural Technology (KSEA) for the superior performance of **BUNDREX®** steel fibers.

R&D team of BUNDREX

SFEED-PRO, developed by **BUNDREX® Institute of KOSTEEL** reflecting state of the art construction design standard of EU & US, provides the best structural design solution to our customers in order to realize the superior performance of our steel fiber.



Feature

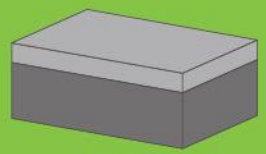
- Enter various variables for requirements such as materials, loads, safety factors and environmental conditions
- Case simulation by varying slab thickness and concrete strength
- Perform case-by-case safety check and economic analysis through the above process
- Apply flexural toughness value reinforced with **BUNDREX®** steel fiber

SFEED-PRO

Steel Fiber Enhanced Engineering Design Program

SFEED-Pro-GSS

Grade Supported Slab

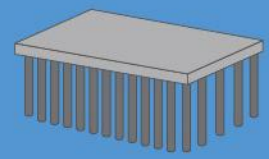


SFEED-Pro-GSS is design program for SOG.
The often times, the Kosteel design allows for a reduction in the lab thickness and steel fiber usage can be calculated based on the load and ground conditions.

Design Criteria: TR-34, ACI 360
SFRC Performance Parameters: $R_{e,3}$

SFEED-Pro-PSS

Pile Supported Slab



SFEED-Pro-PSS is an SOP design program used in conditions where the ground is very unstable to support concrete slabs. BUNDREX PRIME has been developed to solidify slab under conditions of pile support with the appropriate amount of steel fiber.

- Design Criteria: TR-34, ACI 360
- SFRC Performance Parameters: CMOD

SFEED-Pro-SEG

Segmenta Lining

SFEED-PRO-SEG is a program to design segmental lining for tunnel. **BUNDREX®** keeps updating the program reflecting the state of the art technology to satisfy customers' needs.

- Design standards: RILEM, ITA, ACI 544
- Unit: SI
- SFRC performance parameter: CMOD value

SFEED-Pro-GSS	SOG
SFEED-Pro-PSS	SOP
SFEED-Pro-SEG	TBM

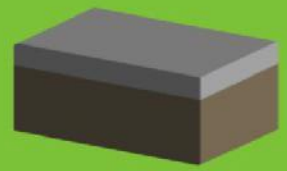
SFEED-PRO

Steel Fiber Enhanced Engineering Design Program

SFEED PRO
Steel Fiber Enhanced Engineering Design PROgram

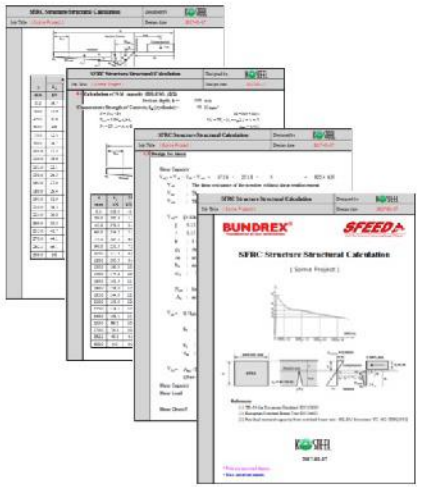
- Improve productivity by reducing all of rebar
- Increase crack control, impact resistance and durability
- Increase economic efficiency

SFEED Pro - GSS
Ground Supported Slab



SFEED Pro - PSS
Pile Supported Slab

SFEED Pro - SEG
Segmental Lining



SFEED-PRO (Steel Fiber Enhanced Engineering Design Program)

SFEED PRO
Steel Fiber Enhanced Engineering Design PROgram

Classification	Input	Design Calculation	Output
Material	• Concrete: Designate initial design strength, incremental value, number of cases (*) • Steel fiber: Choose size of Bundrex®	Calculate various cases of structural designs by concrete strength (*) and slab thickness (**) based on the given conditions ⋮ Calculate the $R_{e,3}$ values for each case ⋮ Calculate steel fiber dosages for each case with the appropriate $R_{e,3}$ ⋮ Cost analysis based on amounts of concrete and steel fiber (***)	Select the most economical case and provide output of structural calculations for each case
Slab	• Region: Designate number and area of region • Thickness: Designate initial thickness, incremental value, number of cases (*)		
Dowel	• Enter loading condition at joints • Enter load transfer rate (%)		
Load	• Enter load conditions • Concentrated load, linear load, uniform load • Rack • Uniform • Mezzanine • Fork Lift • Wall • Truck		
Safety factor	• Enter safety factor for loads and materials		
Environmental Factor	• Enter temperature difference between top and bottom of slab		
Sub-base	• FEnter coefficient of friction between slab and sub-base • Enter modulus of sub-grade reaction (k)		
Unit Cost	• Enter unit cost for concrete and steel fiber (***)		

SFEED-PRO (Steel Fiber Enhanced Engineering Design Program)

SFEED PRO
Steel Fiber Enhanced Engineering Design PROgram

vs Other Program

Classification	Other Program	SFEED Pro
Economic Feasibility Analysis	• No analysis of economic feasibility available • No analysis of economic feasibility function • Unable to provide optimum design case	• Analysis of economic feasibility available • Cost analysis for economic feasibility function available for concrete & steel fiber • Easy to case analysis for optimal design
Convenience of Design	• Only 1 concrete thickness and strength input is allowed • Separate calculation where there is 'no good' design • Long time required for design calculation	• Up to 5 concrete thicknesses and strength inputs are allowed • Recursive calculation available at once with minimum time (up to 25 cases) • Reduce structural design time
KSEA Certification	• Other programs (Bekart, Arcelomithal, and Macaferries) claim to follow the TR-34 guide as a standard for calculation • However, there has been no approval by a qualified third party	• Following TR-34 guide as standard for its calculation • Approval by KSEA, who has the top professional in this field • KSEA(Korea Structural Engineering Association)
Details and Specification	• No construction guide or details available • Contractor or design engineers must produce additional specifications or detailed drawings	• Construction guide or details available for SFRC SOG • Provide standard construction specification • Provide convenience to contractor or designer in performing their work

Appendix BUNDREX® _1

Capacity

Organization

Exhibition

CAPACITY
BUNDREX®

We are the only one steel fiber manufacturer in the world who manufactures wire rod to steel fiber in-house, which makes us competitive in cost and quality.

Pohang #.3 factory

Place	Pohang Steel Industrial complex Korea
Production Capacity:	Approx. 24,000 tons /year
Main Products	Steel Fiber
Site area	23,358㎡
No. of employees	50
Daily shift / 5 days a week	Total Capacity of BUNDREX: 45,000 MT

Daily shift / 5 days a week

- Subcontractors (domestic use)
- Contract Vol./Month: 1,750 MT
- Contract Vol./Year: 21,000MT

ORGANIZATION
BUNDREX®

BUSINESS Five Main Business Division of KOSTEEL

Steel Material Business Division	Construction Material Business Division	Manufacturing & Quality Control Division	Strategy & MGMT. Division	CFO Division
Trading Team	BUNDREX	R&D Team	Accounting Team	Finance Team
Marketing Sales Team	Global Sales Team	Process Improvement Team	Legal Team	
	Domestic Sales Team	Production Management Team	IT Team	
	Technical Team	Health & Safety Team	HR Team	
	Deckplate Sales Team	Factory	Operation Supporting Team	


Pohang #1,2 Factory


Pohang #3 Factory


Eumsung Factory


Vietnam Factory

Pohang #1 Factory

POINTS OF CONTACT

BUNDREX®

Bundrex Division
Global Sales Team

Everywhere in your life!

Director

Joey Yeo
tel +82-2-2106-0278
e-mail mhyeo@kosteel.co.kr

Europe

Brandon Lee
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e-mail sh5021@kosteel.co.kr

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Dominica Lee
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e-mail dominica@kosteel.co.kr

Asia & Middle East

Kevin Baek
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e-mail kkjin432@kosteel.co.kr

Latin America

Antonio Kim
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e-mail shkim@kosteel.co.kr

Asia & Middle East

An, Tran Van
tel +82-2-2106-0127
e-mail antran91@kosteel.co.kr

2019.05.06 ~ 05.08

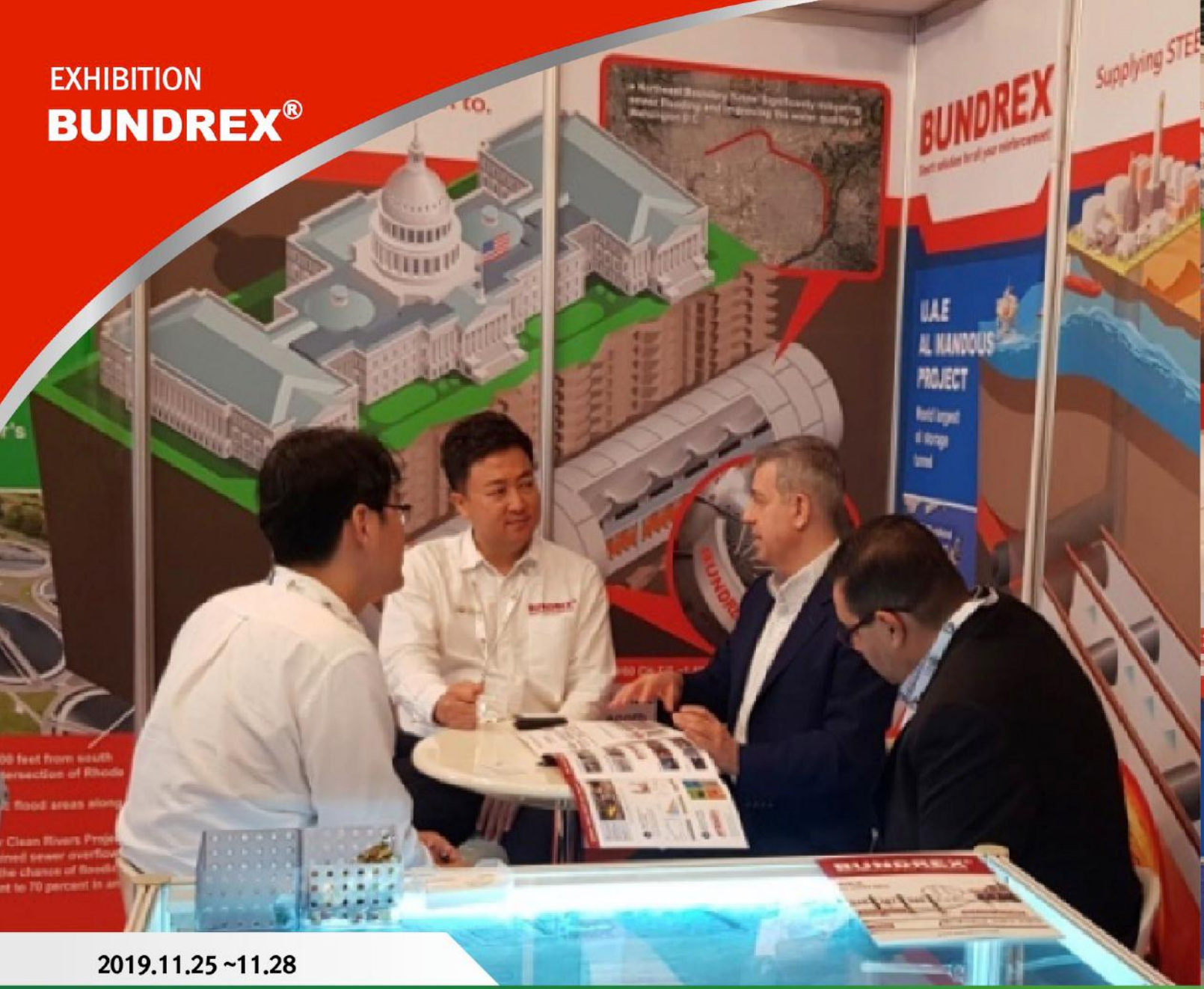
2019 Mostra D'Oltremare Exhibition Center – Naples, Italy

2019.05.06 ~ 05.08

2019 Mostra D'Oltremare Exhibition Center – Naples, Italy

2019.11.25 ~11.28

2019 **DUBAI** World Trade Center_ Dubai,UAE



2019.11.25 ~11.28

2019 **DUBAI** World Trade Center_ Dubai,UAE

2020.02.04 ~ 02.07

BUNDREX Steel Fiber at the **World of Concrete 2020**_ Las Vegas, USA

EXHIBITION

BUNDREX®

2020.02.04 ~ 02.07

BUNDREX Steel Fiber at the **World of Concrete 2020**_ Las Vegas, USA

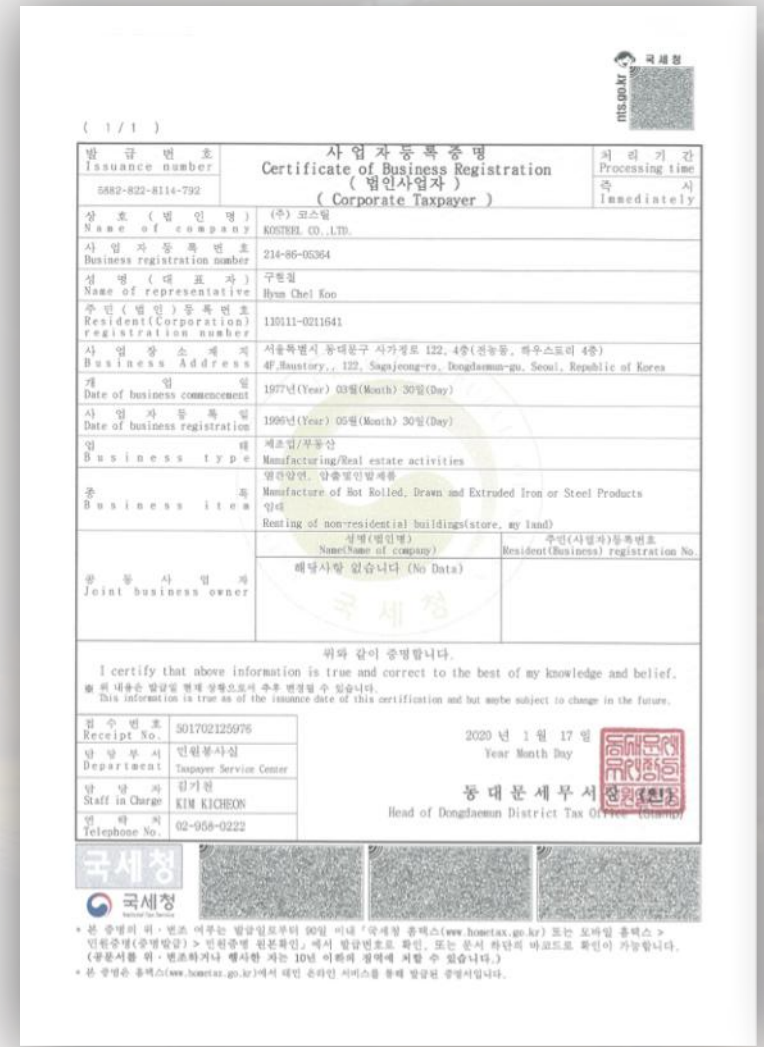

BUNDREX
Steel fiber
U.S.A
WASHINGTON DC
THE NEBT NORTHEAST
BOUNDARY TUNNEL PROJECT
09 Jan
WORLD OF CONCRETE®
WORLD OF CONCRETE 2020
EXHIBITS: FEBRUARY 4-7; EDUCATION: 3-7
LAS VEGAS CONVENTION CENTER

Appendix BUNDREX® _2

License & CE, 2020 POSCO Certified Innovilt, ISO certificate
Quality control documents

License & CE, ISO certificate

License



(1 / 1)

발급번호 Issuance number	사업자등록증명 Certificate of Business Registration (법인사업자) (Corporate Taxpayer)	처리기간 Processing time
5882-822-8114-792		즉시 Immediately

상호(법인명) Name of company	(주) 코스틸 KOSTEEL CO.,LTD.
사업자등록번호 Business registration number	214-86-05364
성명(대표자) Name of representative	구현철 Hyun Chel Koo
주민(법인)등록번호 Resident(Corporation) registration number	110111-0211641
사업장소재지 Business Address	서울특별시 동대문구 사가정로 122, 4층(전농동, 하우스토리 4층) 4F,Haustory,, 122, Sagajeong-ro, Dongdaemun-gu, Seoul, Republic of Korea
개업일 Date of business commencement	1977년(Year) 03월(Month) 30일(Day)
사업자등록일 Date of business registration	1999년(Year) 05월(Month) 30일(Day)
업태 Business type	제조업/부동산 Manufacturing/Real estate activities
종목 Business item	열간압연, 압출및인발제품 Manufacture of Hot Rolled, Drawn and Extruded Iron or Steel Products 임대 Renting of non-residential buildings(store, my land)
공동사업자 Joint business owner	성명(법인명) Name(Name of company): 해당사항 없습니다 (No Data) / 주민(사업자)등록번호 Resident(Business) registration No.

위와 같이 증명합니다.

I certify that above information is true and correct to the best of my knowledge and belief.

※ 본 내용은 발급일 현재 정보으로서 추후 변경될 수 있습니다.
This information is true as of the issuance date of this certification and but maybe subject to change in the future.

접수번호 Receipt No.	501702125976
담당부서 Department	민원봉사실 Taxpayer Service Center
담당자 Staff in Charge	김기천 KIM KICHEON
연락처 Telephone No.	02-958-0222

2020 년 1 월 17 일
Year Month Day

동대문세무서장 직인생략
Head of Dongdaemun District Tax Office (Stamp)

국세청 National Tax Service

* 본 증명의 위·변조 여부는 발급일로부터 90일 이내 「국세청 홈택스(www.hometax.go.kr) 또는 모바일 홈택스 > 민원증명(증명발급) > 민원증명 원본확인」에서 발급번호로 확인, 또는 문서 하단의 바코드로 확인이 가능합니다. (공문서를 위·변조하거나 행사한 자는 10년 이하의 징역에 처할 수 있습니다.)
* 본 증명은 홈택스(www.hometax.go.kr)에서 대한 온라인 서비스를 통해 발급된 증명서입니다.

C E

ZÚS

TECHNICKÝ A ZKUŠEBNÍ ÚSTAV STAVEBNÍ PRAHA, s.p.
Technical and Test Institute for Construction Prague

Akreditovaná zkušební laboratoř, Autorizovaná osoba, Notifikovaná osoba, Oznámený subjekt, Subjekt pro technické posuzování, Certifikační orgán, Inspekční orgán / Accredited Testing Laboratory, Authorized Body, Notified Body, Technical Assessment Body, Certification Body, Inspection Body. Prosecká 811/76a, 190 00 Praha 9 - Prosek, Czech Republic

Notified Body 1020

CERTIFICATE OF CONSTANCY OF PERFORMANCE

No. 1020 – CPR – 010037679

In compliance with Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 (the Construction Products Regulation or CPR), this certificate applies to the construction product

Steel fibres for concrete

Types:

Bundrex KF 60/30, KF 66/35, KF 50/30, KF 56/35, KF 71/50, KF 66/50, KF 60/60, KF 67/60, KF 80/60, KF 80/60 H, KF 65/35, KF 65/35 M, KF 65/35 H, KF 65/35 U, H 65/35MM, H 67/60ML, H 80/60MM, H 67/60HL, H 80/60UL and SUPER BUNDREX A 80/60HL, A 65/35HL

(all bundled: glued)

placed on the market under the name or trade mark of

KOSTEEL Co., Ltd.
40, Hodong-Ro 58 beon-gil, Nam-gu, Pohang-si, Gyeongsangbuk-do, Korea

and produced in the manufacturing plant

KOSTEEL Co., Ltd.
40, Hodong-Ro 58 beon-gil, Nam-gu, Pohang-si, Gyeongsangbuk-do, Korea

This certificate attests that all provisions concerning the assessment and verification of constancy of performance described in Annex ZA of the standard

EN 14889-1:2006

under system 1 for the performance set out in this certificate are applied and that the factory production control conducted by the manufacturer is assessed to ensure the

constancy of performance of the construction product.

This certificate was first issued on 15 February 2017 and will remain valid as long as neither the harmonised standard, the construction product, the AVCP methods nor the manufacturing conditions in the plant are modified significantly, unless suspended or withdrawn by the notified product certification body.

The stamp of the Notified Body 1020
Praha, 9 October 2020

TECHNICKÝ A ZKUŠEBNÍ ÚSTAV STAVEBNÍ PRAHA, s.p. ZÚS 1020

Ing. Iveta Jiroutová
Deputy Manager of the Notified Body

2020 POSCO Certified Innovilt

포스코가 인증한 강건재 생산기업
posco CERTIFIED
INNOVILT Alliance
POSCO INNOVILT ALLIANCE

INNOVILT

SUPER BUNDREX®
ARCHED

Scientific Shape, Innovation of SFRC structural stability

SUPER BUNDREX®

Steel Fiber Rinforced Concrete

Designed by : Kyeong Jin Cha
(Kosteel Chief Engineer)
☎ 02-2106-0196 / ✉chakj@kosteel.co.kr
www.bundrex.com

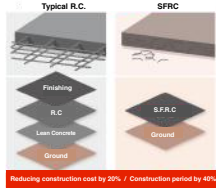
Technology Overview

SUPER BUNDREX® Arched

SUPER BUNDREX® Double Arched

SUPER BUNDREX®	SUPER BUNDREX® can replace Rebar/wire mesh to improve concrete bending performance, reduce construction period/ cost, and reduce cracks, plastic/ temperature/ dry shrinkage.
Technology Effect	The shape of the SUPER BUNDREX® arch has doubled adhesive strength (pull-out performance) compared to the conventional hook type and upto 30% improvement in concrete bending performance.
Technology Acquisition	The shape and performance of the SUPER BUNDREX® acquired Korean and Overseas patents and technology certifications. (Korean patent: 1 case / Overseas patent: 1 case / Korean patent application 1 case/ KSEA technology certifications (construction and design) 2 cases

Advantages and Effects



Structural Performance Improving	Doubled concrete adhesion strength, improved flexural toughness by 30%, increased limit load, and reduced concrete slab thickness.
Reducing Construction Period	60% reduction in construction time due to reduced pouring amount – No lean concrete, No rebar assembly and installation processing,
Reducing Construction Cost	Overall construction cost can be reduced by 30% through reduction of concrete slab thickness, and the labor cost by assembling, installation of rebars.
Crack Control	Reduced initial plastic/temperature/dry shrinkage cracking upto 29%. No settlement crack caused by rebar installation and assembly.

Track Record

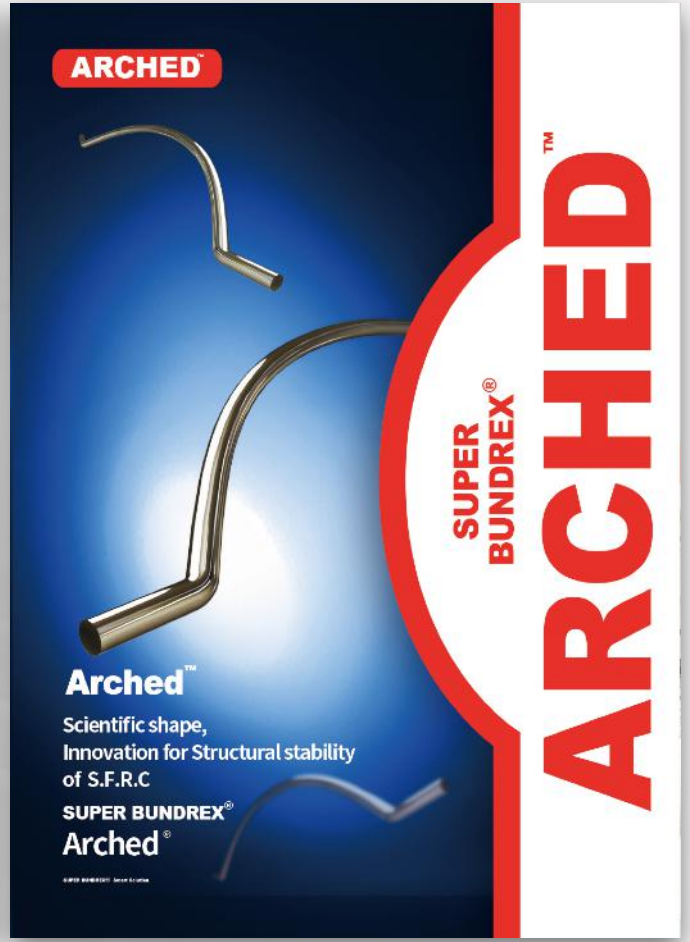
No	BUNDREX® Project	Year
1	Geumsan Gimje Logistics Center New Construction	2021
2	Gyeseong Construction Icheon Bubal-eup Logistics Center New Construction	2021
3	POSCO Yangji Collection and Delivery Center New Construction	2021
4	Gyeseong E&C Anseong Coupang Logistics Center New Construction	2020
5	Samwoo Steel Pyeongtaek factory floor reinforcement work	2020

Geumsan Gimje Logistics Center New Construction (2021)

POSCO Yangji Collection and Delivery Center New Construction (2021)

Gyeseong E&C Anseong Coupang Logistics Center New Construction (2020)

INNOVILT



License & CE, ISO certificate

ISO

CERTIFICATE OF APPROVAL

KOSTEEL Co., Ltd.

- 1ST FACTORY : 35, HODONG-RO, NAM-GU, POHANG-SI, GYEONGSANGBUK-DO, KOREA
- 2nd FACTORY : 40, HODONG-RO 588BEON-GIL, NAM-GU, POHANG-SI, GYEONGSANGBUK-DO, KOREA
- 3rd FACTORY : 675, DAEGEUM-RO, DAESO-MYEON, EUMSEONG-GUN, CHUNGCHEONGBUK-DO, KOREA

Korean Standards Association hereby certifies that the Quality Management System of the above organization has been assessed and found to meet the requirements of the standard and scope of certification detailed below:

CERTIFICATION No. QMS-3350

STANDARD KS Q ISO 9001:2015/ISO 9001:2015

SCOPE OF CERTIFICATION
SITE:Refer to the Appendix

VALID FROM 12 July, 2019

VALID UNTIL 11 July, 2022

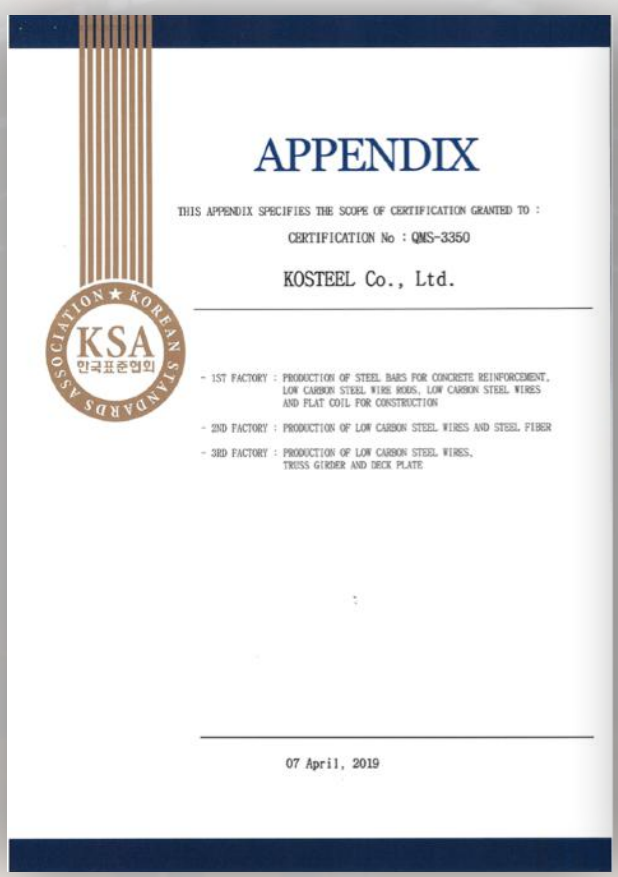
Original Certification Date : 12 July, 2010

Date of Issue : 07 April, 2019 PRESIDENT OF KSA

KOREAN STANDARDS ASSOCIATION

305, Teheran-Ro, Gangnam-Gu, Seoul, Korea

KSA has been accredited in respect of ISO 9001 covered by the KAB(Accreditation Certificate Number KAB-QC-30)



APPENDIX

THIS APPENDIX SPECIFIES THE SCOPE OF CERTIFICATION GRANTED TO :

CERTIFICATION No : QMS-3350

KOSTEEL Co., Ltd.

- 1ST FACTORY : PRODUCTION OF STEEL BARS FOR CONCRETE REINFORCEMENT, LOW CARBON STEEL WIRE RODS, LOW CARBON STEEL WIRES AND FLAT COIL FOR CONSTRUCTION
- 2ND FACTORY : PRODUCTION OF LOW CARBON STEEL WIRES AND STEEL FIBER
- 3RD FACTORY : PRODUCTION OF LOW CARBON STEEL WIRES, TRUSS GIRDER AND DECK PLATE

07 April, 2019

CERTIFICATE OF APPROVAL

KOSTEEL Co., Ltd.

- 1ST FACTORY : 35, HODONG-RO, NAM-GU, POHANG-SI, GYEONGSANGBUK-DO, KOREA
- 2nd FACTORY : 40, HODONG-RO 588BEON-GIL, NAM-GU, POHANG-SI, GYEONGSANGBUK-DO, KOREA

Korean Standards Association hereby certifies that the Environmental Management System of the above organization has been assessed and found to meet the requirements of the standard and scope of certification detailed below:

CERTIFICATION No. EMS-1325

STANDARD KS I ISO 14001:2015/ISO 14001:2015

SCOPE OF CERTIFICATION
PRODUCTION AND SERVICING OF STEEL FIBER

VALID FROM 11 May, 2018

VALID UNTIL 10 May, 2021

Original Certification Date : 11 May, 2015

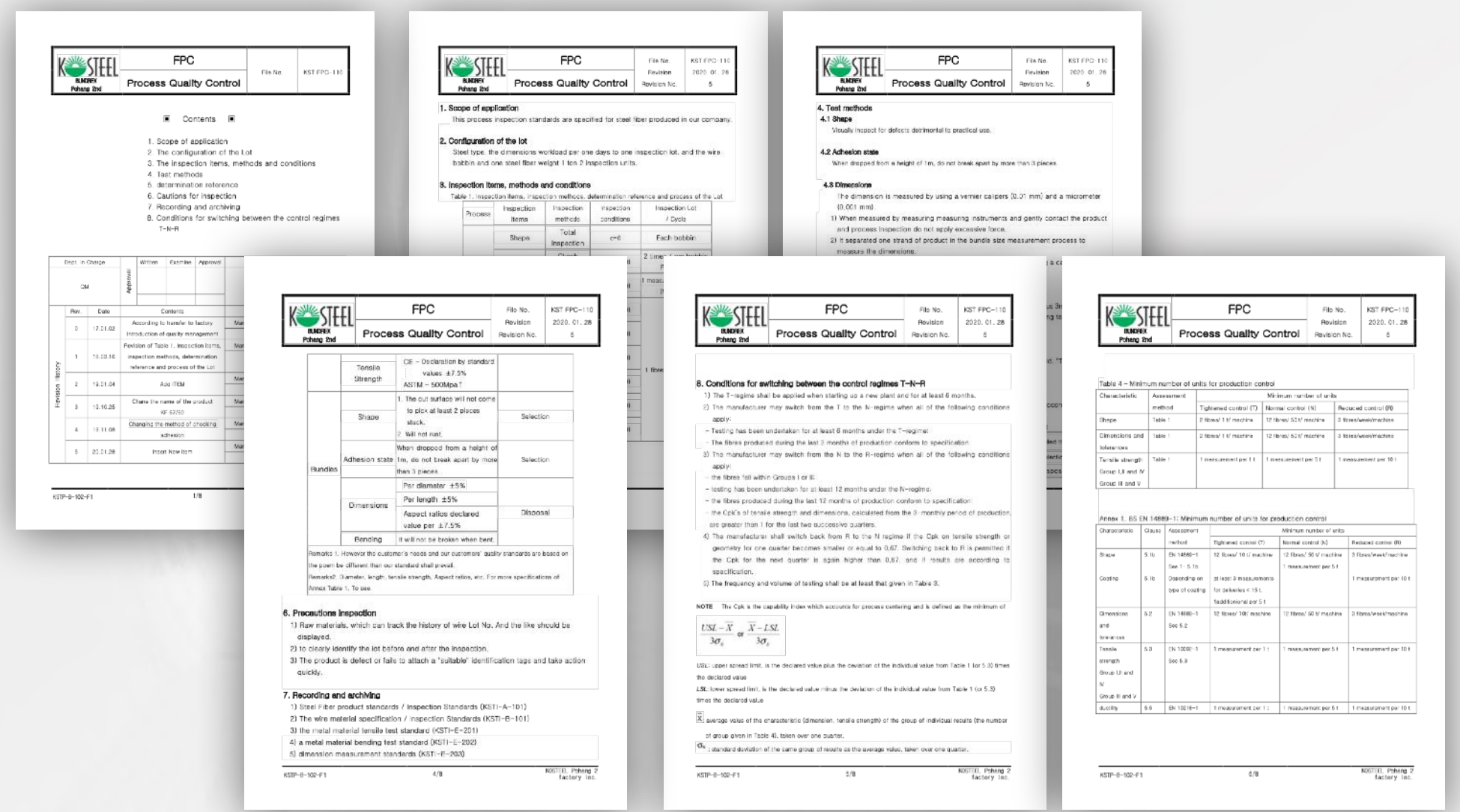
Date of Issue : 10 April, 2018 PRESIDENT OF KSA

KOREAN STANDARDS ASSOCIATION

305, Teheran-Ro, Gangnam-Gu, Seoul, Korea

Accredited by Member of the IAF MLA for EMS.
The Accreditation Mark (-) indicates accreditation in respect of those activities covered by the Accreditation Certification Number KAB-EC-11.

Quality control documents



FPC Process Quality Control — File No. KST FPC-110

■ Contents ■

1. Scope of application
2. The configuration of the Lot
3. The inspection items, methods and conditions
4. Test methods
5. determination reference
6. Cautions for inspection
7. Recording and archiving
8. Conditions for switching between the control regimes T-N-R

Revision history

Rev.	Date	Contents
0	17.01.02	According to transfer to factory Introduction of quality management
1	18.03.16	Revision of Table 1, inspection items, inspection methods, determination reference and process of the Lot
2	19.01.04	Add ITEM
3	19.10.25	Chane the name of the product KF 52/50
4	19.11.08	Changing the method of checking adhesion
5	20.01.28	Insert New Item

KSTP-B-102-F1 1/8

1. Scope of application
This process inspection standards are specified for steel fiber produced in our company.

2. Configuration of the lot
Steel type, the dimensions workload per one days to one inspection lot, and the wire bobbin and one steel fiber weight 1 ton 2 inspection units.

3. Inspection items, methods and conditions
Table 1. Inspection items, inspection methods, determination reference and process of the Lot

Process	Inspection Items	Inspection methods	Inspection conditions	Inspection Lot / Cycle
	Shape	Total Inspection	c=0	Each bobbin

4. Test methods
4.1 Shape
Visually inspect for defects detrimental to practical use.

4.2 Adhesion state
When dropped from a height of 1m, do not break apart by more than 3 pieces.

4.3 Dimensions
The dimension is measured by using a vernier calipers (0.01 mm) and a micrometer (0.001 mm).
1) When measured by measuring measuring instruments and gently contact the product and process inspection do not apply excessive force.
2) If separated one strand of product in the bundle size measurement process to measure the dimensions.

Bundles	Tensile Strength	CE – Declaration by standard values ±7.5% ASTM – 500Mpa↑	
	Shape	1. The cut surface will not come to pick at least 2 places stuck. 2. Will not rust.	Selection
	Adhesion state	When dropped from a height of 1m, do not break apart by more than 3 pieces.	Selection
	Dimensions	Per diameter ±5%	
		Per length ±5%	
		Aspect ratios declared value per ±7.5%	Disposal
	Bending	It will not be broken when bent.	

Remarks 1. However the customer's needs and our customers' quality standards are based on the point be different than our standard shall prevail.
Remarks2. Diameter, length, tensile strength, Aspect ratios, etc. For more specifications of Annex Table 1, To see.

6. Precautions inspection
1) Raw materials, which can track the history of wire Lot No. And the like should be displayed.
2) to clearly identify the lot before and after the inspection.
3) The product is defect or fails to attach a "suitable" identification tags and take action quickly.

7. Recording and archiving
1) Steel Fiber product standards / Inspection Standards (KSTI-A-101)
2) The wire material specification / Inspection Standards (KSTI-B-101)
3) the metal material tensile test standard (KSTI-E-201)
4) a metal material bending test standard (KSTI-E-202)
5) dimension measurement standards (KSTI-E-203)

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8. Conditions for switching between the control regimes T-N-R
1) The T-regime shall be applied when starting up a new plant and for at least 6 months.
2) The manufacturer may switch from the T to the N-regime when all of the following conditions apply:
– Testing has been undertaken for at least 6 months under the T-regime;
– The fibres produced during the last 3 months of production conform to specification.
3) The manufacturer may switch from the N to the R-regime when all of the following conditions apply:
– the fibres fall within Groups I or II;
– testing has been undertaken for at least 12 months under the N-regime;
– the fibres produced during the last 12 months of production conform to specification;
– the Cpk's of tensile strength and dimensions, calculated from the 3 -monthly period of production, are greater than 1 for the last two successive quarters.
4) The manufacturer shall switch back from R to the N regime if the Cpk on tensile strength or geometry for one quarter becomes smaller or equal to 0,67. Switching back to R is permitted if the Cpk for the next quarter is again higher than 0,67, and if results are according to specification.
5) The frequency and volume of testing shall be at least that given in Table 3.

NOTE The Cpk is the capability index which accounts for process centering and is defined as the minimum of

$$\frac{USL-\bar{X}}{3\sigma_s} \text{ or } \frac{\bar{X}-LSL}{3\sigma_s}$$

USL: upper spread limit, is the declared value plus the deviation of the individual value from Table 1 (or 5.3) times the declared value
LSL: lower spread limit, is the declared value minus the deviation of the individual value from Table 1 (or 5.3) times the declared value
$\bar{X}$ average value of the characteristic (dimension, tensile strength) of the group of individual results (the number of group given in Table 4), taken over one quarter.
σ_s : standard deviation of the same group of results as the average value, taken over one quarter.

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Table 4 – Minimum number of units for production control

Characteristic	Assessment method	Minimum number of units Tightened control (T)	Normal control (N)	Reduced control (R)
Shape	Table 1	2 fibres/ 1 t/ machine	12 fibres/ 5 t/ machine	3 fibres/week/machine
Dimensions and tolerances	Table 1	2 fibres/ 1 t/ machine	12 fibres/ 5 t/ machine	3 fibres/week/machine
Tensile strength Group I,II and IV Group III and V	Table 1	1 measurement per 1 t	1 measurement per 5 t	1 measurement per 10 t

Annex T. BS EN 14889-1: Minimum number of units for production control

Characteristic	Clause	Assessment method	Minimum number of units Tightened control (T)	Normal control (N)	Reduced control (R)
Shape	5.1b	EN 14889-1 Sec 1: 5.1b	12 fibres/ 10 t/ machine	12 fibres/ 50 t/ machine 1 measurement per 5 t	3 fibres/week/machine
Coating	5.1b	Depending on type of coating	at least 3 measurements for deliveries < 15 t. 1additional per 5 t		1 measurement per 10 t
Dimensions and tolerances	5.2	EN 14889-1 Sec 5.2	12 fibres/ 10t/ machine	12 fibres/ 50 t/ machine	3 fibres/week/machine
Tensile strength Group I,II and IV Group III and V	5.3	EN 10002-1 Sec 5.3	1 measurement per 1 t	1 measurement per 5 t	1 measurement per 10 t
ductility	5.5	EN 10218-1	1 measurement per 1 t	1 measurement per 5 t	1 measurement per 10 t

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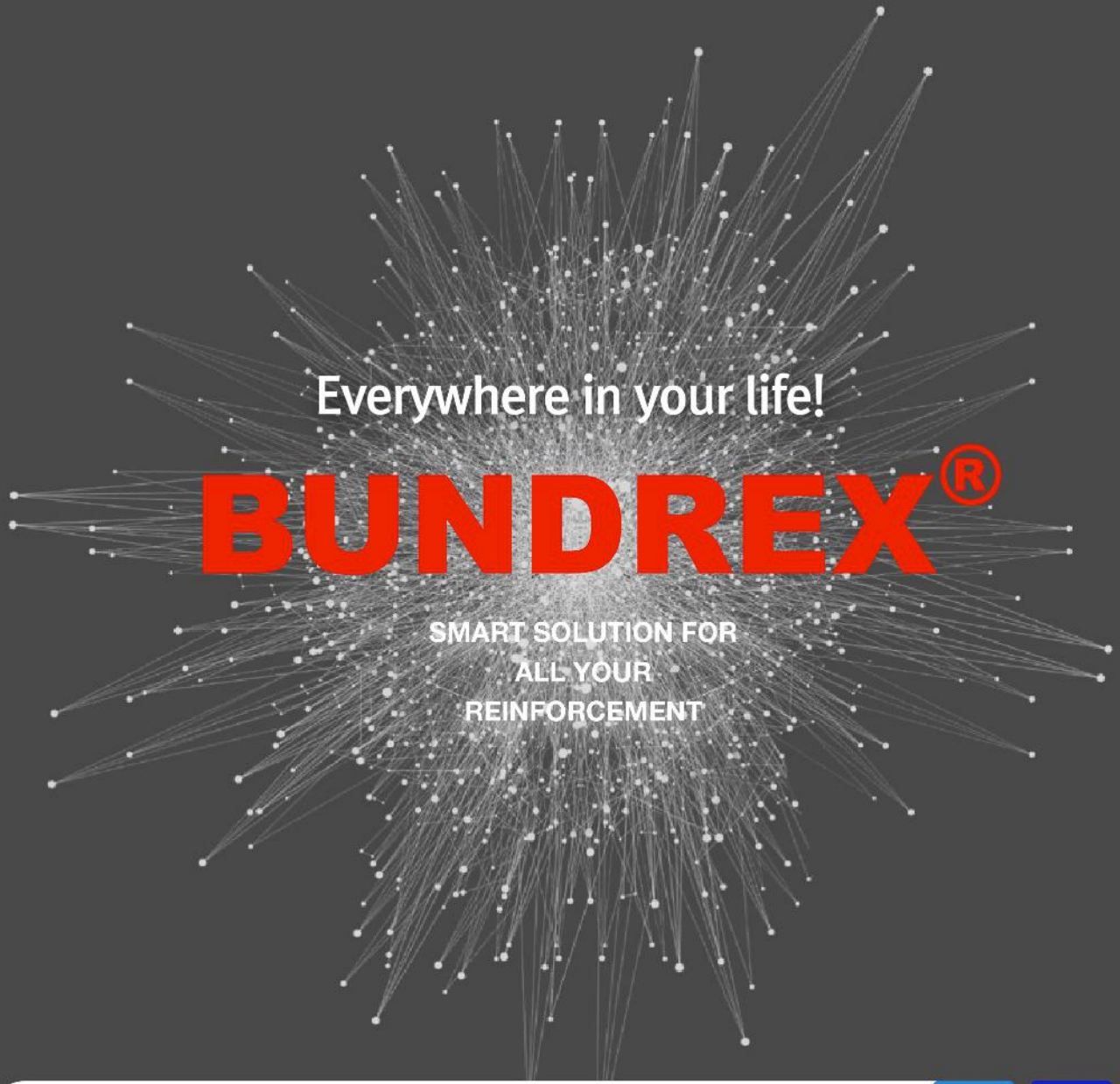

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