





MMFX STEEL DMCC
A Subsidiary of
MMFX TECHNOLOGIES CORPORATION

MMFX 2 STEEL Concrete Reinforcing Bars

TECHNICAL PRESENTATION – June 30, 2009

NACE - JUBAIL


















CORE OF THE TECHNOLOGY

- MMFX initial core technology was the result of 25 years of research at UC Berkeley and Lawrence Berkeley National Laboratory.
- MMFX's initial proprietary technology was developed at the University of California Berkeley under the guidance of world-renowned scientist and inventor, Professor Gareth Thomas.

The first high-voltage transmission Electron Microscope



Photo Courtesy of the National Center for Electron Microscopy




Corrosion of Conventional Pearlitic Steels

Schematic of Micro Galvanic Cells in the Ferrite-Iron Carbide Microstructure



Microgalvanic Cell Formation Between Iron-Carbide and Ferrite Phases

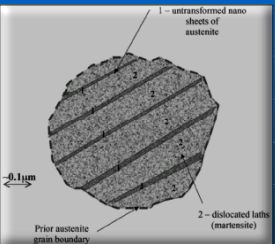
Transmission Electron Microscope (TEM) Micrograph of the Ferrite – Iron Carbide Microstructure



Corrosion Can Be Minimized By Avoiding Microgalvanic Cell Formation




MICROCOMPOSITE STEELS



Microcomposite Steels, Packet Lath Martensite

Dislocated laths of martensite enveloped by stable retained austenite films

CARBIDE FREE MICROSTRUCTURE to Eliminate Formation of Microstructural Galvanic Cells

What Makes MMFX 2 (ASTM A1035) Different?

1. Chemical Composition
Low-carbon
Chromium alloy

Element	ASTM A1035/A1035M Maximum Amount *	Typical MMFX2
Carbon	0.15%	0.08%
Chromium	8 to 10.9%	9%
Manganese	1.5%	0.5%
Nitrogen	0.05%	0.05%
Phosphorus	0.035%	0.035
Sulfur	0.045%	0.045%
Silicon	0.50%	0.50%

*Maximum unless range indicated

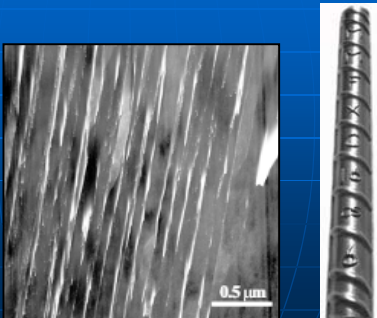
2. Processing

Controlled - rolling and production process



What Makes MMFX 2 (ASTM A1035) Different?

RESULTS IN NEW MICROSTRUCTURE



0.5 μ m

MMFX STEEL
A Green Commercial Reality



- Utilizes 90% recycled material
- Operates on hydroelectric power
- Less steel to accomplish the same job greatly reduces greenhouse emissions
- Lowest cost construction system





Designation: A 1035/A1035M - 07

Standard Specification for Deformed and Plain, Low-carbon, Chromium, Steel Bars for Concrete Reinforcement¹

This standard is issued under the designation A 1035/A1035M. The number 07 indicates the year of last revision. This standard was last revised in 2007. It is subject to revision at any time without notice. This standard is under the jurisdiction of the Technical Committee A10.3, Reinforcing Steel Bars for Concrete Reinforcement. This standard is the property of ASTM International. All rights reserved. No part of this standard may be reproduced without permission from ASTM International.

1.1 Scope
1.1.1 This specification covers low-carbon, chromium, steel bars, deformed and plain, for concrete reinforcement, in hot-rolled and cold-rolled condition. The standard size and dimensions of deformed bars and plain round reinforcement are given in Table 1. The use of this specification references steel and stainless steel reinforcement. This specification covers reinforcement bars in solid and twisted shapes and is not intended to apply to reinforcement in other shapes.

1.1.2 Bars of all sizes conforming to this specification shall be delivered in 12 nominal sizes: 1/4, 3/8, 1/2, 5/8, 3/4, 7/8, 1, 1 1/8, 1 1/4, 1 1/2, 1 3/4, and 2 inches (6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, 64, 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160, 162, 164, 166, 168, 170, 172, 174, 176, 178, 180, 182, 184, 186, 188, 190, 192, 194, 196, 198, 200, 202, 204, 206, 208, 210, 212, 214, 216, 218, 220, 222, 224, 226, 228, 230, 232, 234, 236, 238, 240, 242, 244, 246, 248, 250, 252, 254, 256, 258, 260, 262, 264, 266, 268, 270, 272, 274, 276, 278, 280, 282, 284, 286, 288, 290, 292, 294, 296, 298, 300, 302, 304, 306, 308, 310, 312, 314, 316, 318, 320, 322, 324, 326, 328, 330, 332, 334, 336, 338, 340, 342, 344, 346, 348, 350, 352, 354, 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4118, 4120, 4122, 4124, 41

Production and Availability

MMFX + Zamil Group → UNIROL

MMFX Steel Billets are produced at MMFX Steel Mill in Welland, Canada 400,000 Ton Capacity

MMFX Steel Billets Shipped to UNIROL Steel for rolling into different bar sizes per ASTM A1035 Specifications

MMFX steel bars and coils are stocked and distributed in Bahrain by UNIROL Steel

GRIP-TWIST 'XT' Mechanical Splices

BarSplice PRODUCTS INC. SUBSIDIARY OF FC INDUSTRIES, INC.

- FOR HIGH STRENGTH, LOW CARBON, CHROMIUM STEEL BARS, ASTM A 1035
- FAST, EFFICIENT INSTALLATION
- ELIMINATES LONG LAP LENGTHS, REDUCES CONGESTION
- DEVELOPS STRENGTH: $1.25 \times f_y$, GRADE 100
- ULTIMATE CAPACITY: $1.50 \times f_y$, GRADE 100

f_y = SPECIFIED YIELD OF REINFORCING BAR

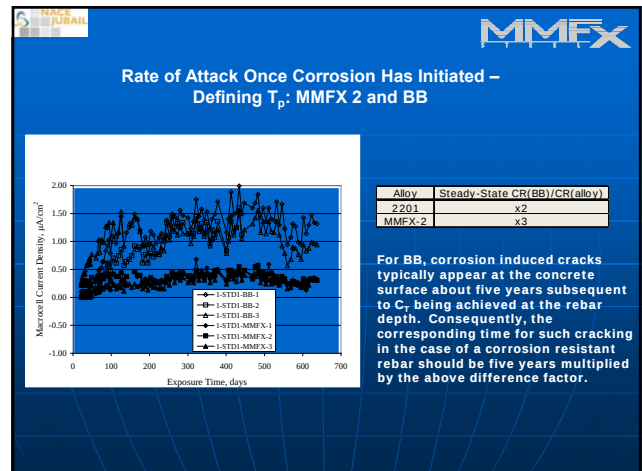
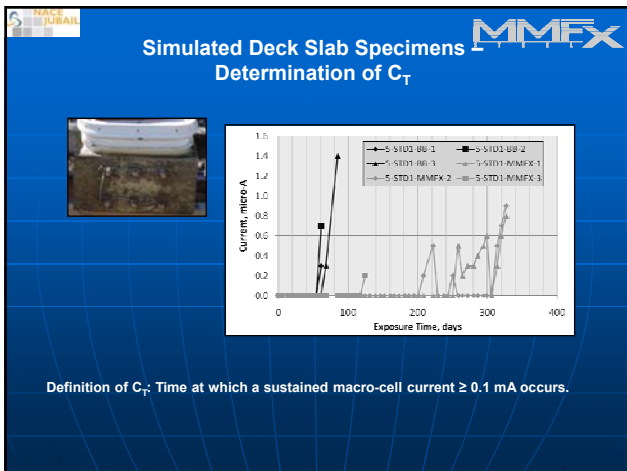
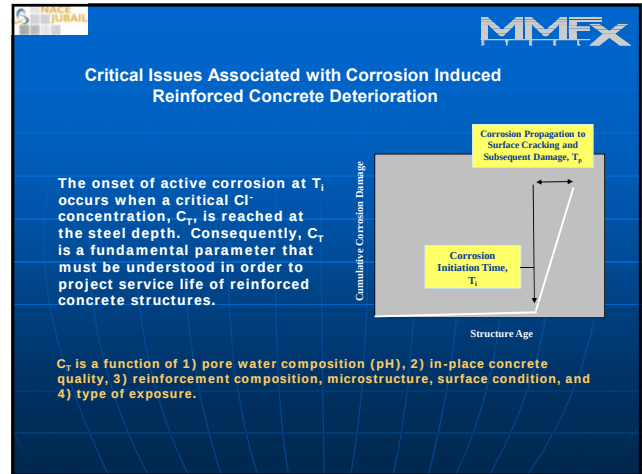
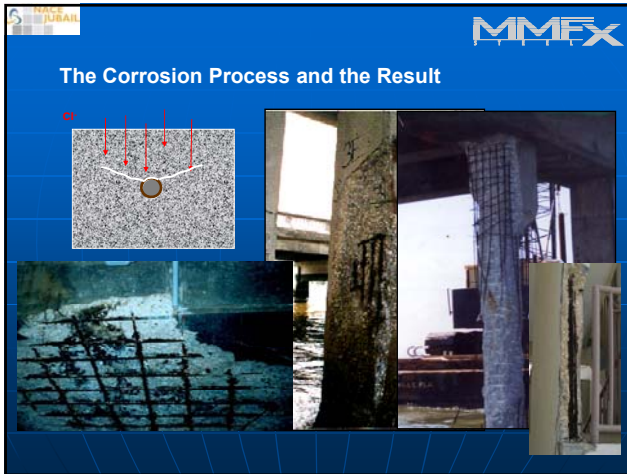
Dextra

BARTEC Parallel Thread Couplers

MMFX

MMFX 2 (ASTM A1035)

THE SOLUTION TO THE CORROSION PROBLEM



Life-Cycle Modeling

The universally accepted approach to calculating T_i is based upon Fick's second law for non steady-state diffusion:

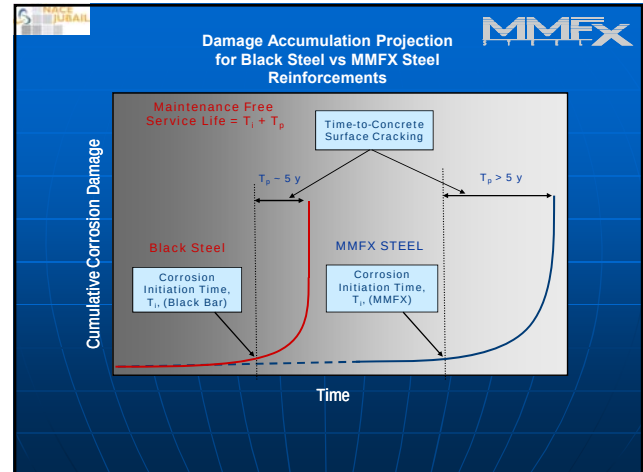
$$\frac{\partial^2 C}{\partial t^2} = \frac{\partial}{\partial x} \left[D \frac{\partial C}{\partial x} \right]$$

The one-dimensional solution to Fick's Second Law applied to defining the time at which corrosion initiates, T_i :

$$\frac{C_s - C_i}{C_i} = \text{erf} \left[\frac{x}{\sqrt{D_e \cdot T_i}} \right]$$

C_s = Surface [Cl]
 x = Reinforcement cover
 D_e = Effective diffusion coefficient

Time-to-Repair/Rehabilitation = $T_i + T_p$



Corrosion Properties

Based on macro-cell current in reinforced concrete slabs, ASTM A1035 corrosion rate is up to 20% of black steel bars.

ASTM A1035 Provides a four-fold enhancement of the chloride threshold and up to 5 fold reductions in wastage rate once corrosion initiates.

Corrosion performance compared to 2201 LDX Stainless Steels

Choice for corrosion applications requiring 75+ years service life at the lowest cost.

Service Life Projection Examples – Black Bar and MMFX 2

Black Steel:

C_r (black steel) ~ 1.0 kg / m³ (corresponds to 2% of steel having initiated corrosion)

Design Parameters:
 Cl⁻ Diffusion Coefficient 10⁻¹² m²/s
 Concrete Cover 63 mm.

Time-to-Corrosion: **12 years**

Time after corrosion initiation for surface cracks to appear: ~ 5 years

If repair commences 10 years later: Maintenance-free life: **~22 years**

MMFX 2:

C_r (MMFX 2) ~ 4x greater: 4.0 kg / m³ (corresponds to 2% of steel having initiated corrosion)

Design Parameters:
 Cl⁻ Diffusion Coefficient 10⁻¹² m²/s
 Concrete Cover 63 mm.

If corrosion rate, once initiated, is 3x less than for black bar, then time after initiation for surface cracks to appear: ~ 15 years

If repair commences 30 years later: Maintenance-free life: **62 years**




VTRC Recommendations

- "Corrosion protection for structures designed for a 100-year+ service life as currently recommended by FHWA, the report recommends that the Virginia Department of Transportation (VDOT) amend its specifications regarding the use of ECR to require the use of corrosion-resistant metallic reinforcing bars such as ASTM A1035, stainless steel clad, and solid stainless steel."
- "ASTM A1035 costs about the same as ECR but can extend the life of a deck approximately 5 times longer."
- "ASTM A1035 is clearly the most cost-effective reinforcement for the majority of VDOT decks."




CORROSION APPLICATIONS




CONNECTICUT DEPARTMENT OF TRANSPORTATION Church Street Extension Bridge over Metro North Railroad New Haven, CT








CALIFORNIA ACADEMY OF SCIENCES California Academy – Exhibition Education and Research Center, San Francisco, CA







MMEX

MARINELAND OF FLORIDA
Seawater Lagoon Dolphin Tank – Marineland, FL

MMEX

**US NAVY NAVAL FACILITIES ENGINEERING
COMMAND (NFSEC)**
Modular Hybrid Pier – San Diego, CA (Constructed - Tacoma, WA)

MMEX

MMFX 2 (ASTM A1035)
Solution to Congestion

MMEX

MMFX 2 (ASTM A1035) Solution to Congestion

**Using The MMFX 2 (ASTM A1035)
Strength And Corrosion Advantages**

The use of MMFX 2 (ASTM A1035) allows the structural engineer and design team to achieve the following:

- Reduce rebar congestion (at selected structural components)
- Reduce member dimensions (e.g. mat foundation thickness)
- Improves constructability
- Extends Service Life of Structure
- Deliver project cost savings

MAT FOUNDATION APPLICATIONS

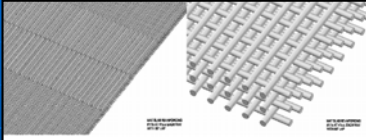


Figure 4 - 3D Rendering of #11@4" o.c. (A615 Grade 60 Reinforcing)

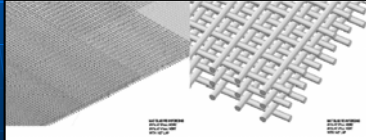


Figure 6 - 3D Rendering of #11@6" o.c. (MMFX Grade 100 Reinforcing)

**MMFX 2 (ASTM A1035)
CONFINEMENT**

Full-Size Replica of two columns:

Column in Back is reinforced with 60 ksi #5 confinement ties at 2-1/4" vertical spacing

Column in Front is reinforced with 690 (100ksi) ASTM A1035 #5 confinement ties at 4" vertical spacing



Confinement Application

3D Models of two columns:

Column on left is reinforced with 60 ksi #5 confinement ties at 4" vertical spacing

Column on right is reinforced with 690 (100ksi) ASTM A1035 #5 confinement ties at 4" vertical spacing (same spacing, but with almost half the number of cross ties)

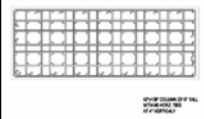


Figure 7 - A615 Gr. 60 Ties

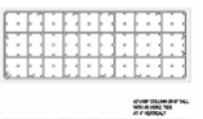


Figure 8 - MMFX 100ksi Ties




MMFX 2 (ASTM A1035) APPROVALS (Alternate Method of Construction per IBC)

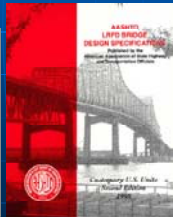
- City of Los Angeles, CA (LARR)
- City of Long Beach, CA
- City of San Diego, CA
- City of Irvine, CA
- Clark County, Nevada (Las Vegas Strip)
- Miami-Dade County, FL (incl. City of Miami)
- City of Orlando, FL
- Abu Dhabi, UAE
- JAFZA, UAE




MMFX - Proven, Credible, Effective

American Society of Testing Materials (ASTM)
American Association of State Highway and Transportation Officials (AASHTO)
American Concrete Institute (ACI)

FHWA validated – used by 24 state DOTs



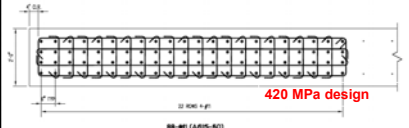
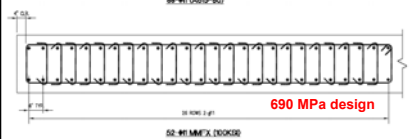


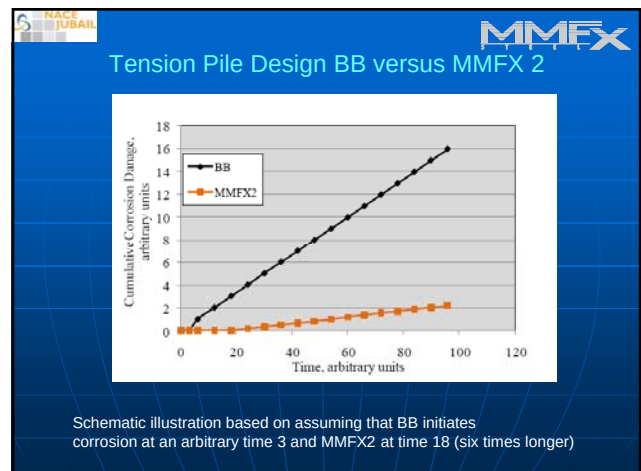
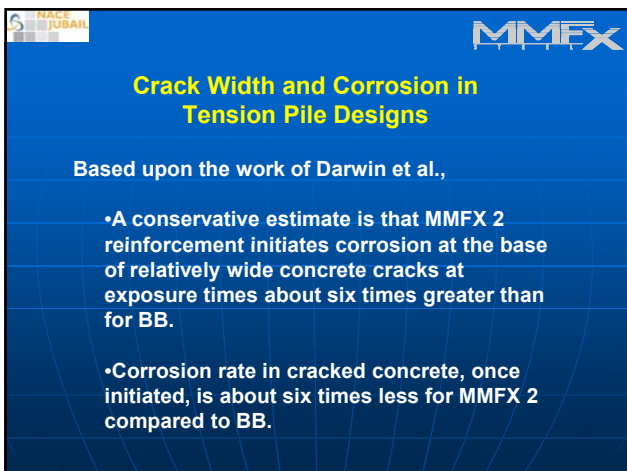
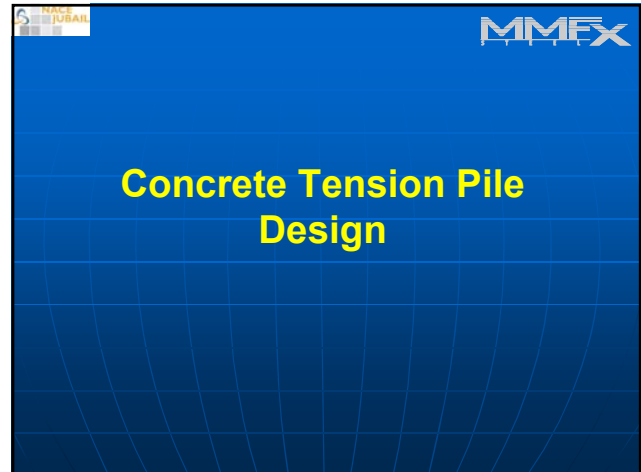
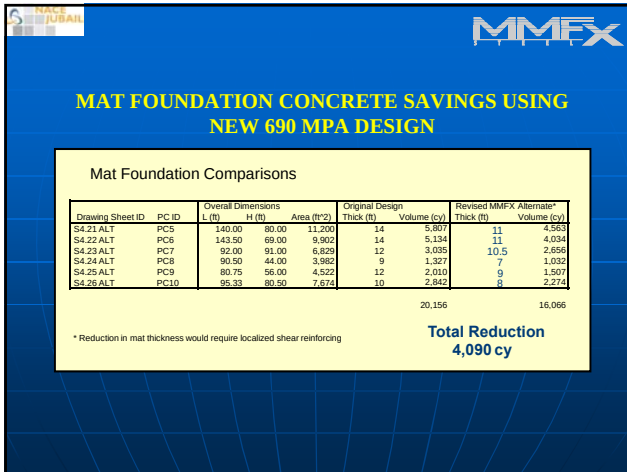
Project Cost Savings Utilizing MMFX 2 (ASTM A1035) Rebar

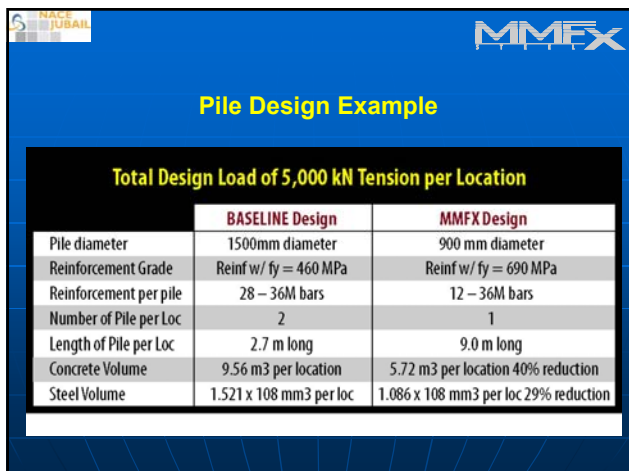
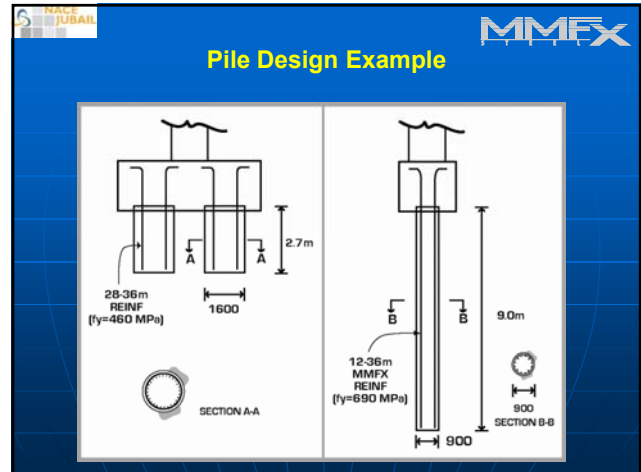
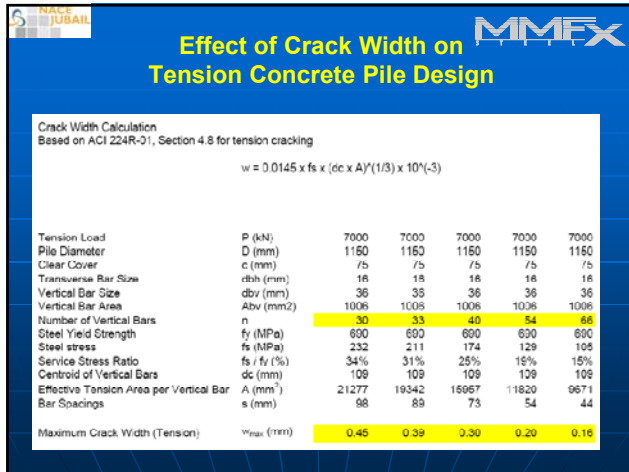



Example Project in Las Vegas

- Original Design with #11 jamb steel
- A1035 alternate design with 40% less #11 jamb steel
- Reduces or eliminates intermediate layers of jamb steel
- Reduces or eliminates intermediate cross ties
- LEADS TO MORE EFFICIENCY PLACEMENT \$\$\$





MMEX

The Tides – Chicago, IL
51 Floor Condominium Beams

MMEX

Project City Center - Pelli Tower – Las Vegas, NV
Load Transfer Beams

MMEX

HEAD COMPANIES
Mustique Condominiums, Gulf Shores, AL

MMEX

Coastal Residence – Malibu, CA
Drilled Pier Foundation




BRICKELL KEY LAST BAYFRONT SITE
BRICKELL FIRST 5-STAR CONDOMINIUM

- The use of A1035 allows flexibility in design by engineer. In this case, the engineer chose to utilize the high-strength property of MMFEX to reduce the thickness of the mat foundation.
- Preliminary Design Info:
 - Mat Foundation (under 1 level basement – below water table):
 - Thickness reduced by an average of 3' (2,500 cy total), at selected heavily-reinforced mats under the structural cores.
 - Reduced excavation, haul-out, dewatering, concrete volume, etc.
 - Tension Piles (36" diameter caissons):
 - Total of about 370 piles supporting mat foundation. Approximately 200 would be utilized as tension piles using MMFEX rebars, to resist high hurricane loading in the South Florida region.



ACI Innovation Task Group 6

Design Guide for the Use of High-Strength Steel Bars (ASTM A 1035-07) for Structural Concrete

A Document being developed by ITG - 6



Design Guide

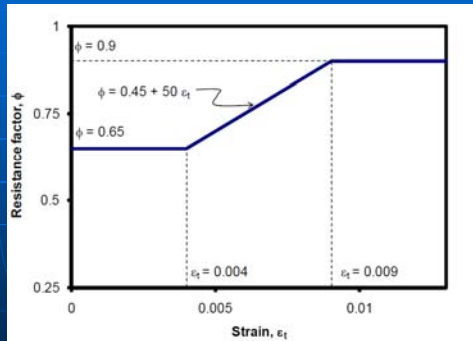
- Use non-mandatory language
- Cover structural reinforced concrete members under low seismic regions (Category A, B and C):
 - Beams and Columns
 - One-way and two way slab systems
 - Walls and Footings
- Consider both strength and serviceability
- Limit application to slab systems, foundations, and members not designated as part of seismic-force-resisting system for moderate and high seismic regions (Category D, E, and F)
- Investigate use of high-strength bars as primary, secondary and confining reinforcement
- Address development length and anchorage issues



Tension- and Compression-Controlled Limits

STEEL TYPE	TENSION-CONTROLLED STRAIN LIMIT	COMPRESSION-CONTROLLED STRAIN LIMIT
ASTM A 615 Grade 60	0.005	0.002
ASTM A1035 Grade 100 Theoretical	0.0066	0.004
ASTM A1035 Grade 100 Idealized	0.009	0.004

Φ Factor of Simplified Design Method



Other Design Criteria

- Minimum Reinforcement Required by ACI 318-08
Use $f_y = 100,000$ psi [690 MPa] with Section 10.5 for flexural members and Section 7.12 for shrinkage and temperature
- No moment redistribution in continuous member
- Design Stress in Web Reinforcement
Use $f_y = 60,000$ psi [420 MPa] for crack control
Use $f_y = 80,000$ psi [550 MPa] if hairline cracking is not critical
- Compression Stress Limit
Use $f_y = 80,000$ psi [550 MPa] for flexure compression steel and column longitudinal steel in compression
Use $f_y = 100,000$ psi [690 MPa] for column longitudinal steel in tension and for column spirals
- Use moment magnification procedure for column slenderness effect

CONCLUSIONS

- Building Code and Municipality Recognition
- Effective in corrosive environment application, including marine, humidity, corrosive soil, etc.
- Effective in mitigating rebar congestion
- Allows design flexibility
- Same processes:
 - Steel making (made in conventional steel mills)
 - Fabrication (same equipment)
 - Design (same ACI equations)
 - Detailing (same bend radius)
 - Installation
- PROJECT COST SAVINGS

MMFX STEEL CORPORATION OF AMERICA



Proven, Credible, Effective

Thank you

