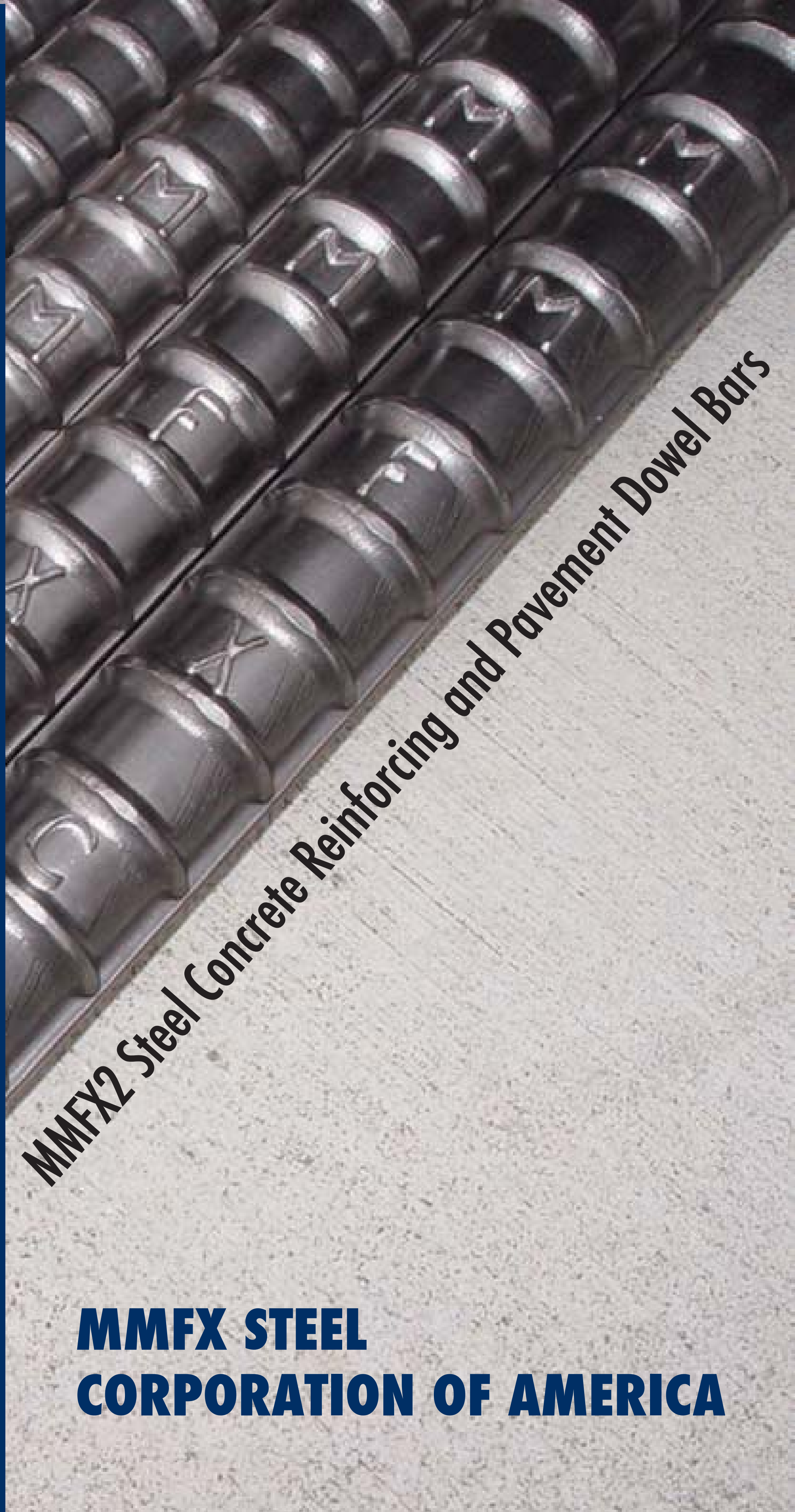
PRODUCT GUIDE



MMFX2 Steel Concrete Reinforcing and Pavement Dowel Bars

MMFX STEEL CORPORATION OF AMERICA

June 2007

The information and data in this document
are accurate to the best of MMFX's knowledge
and belief and are intended for general information only.

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MMFX 2 Steel Product Guide

Product Identification

Product Trade Name: *Microcomposite (MMFX 2) Steel Rebar and Dowel Bar*

Product Contact Information

Manufacturer: MMFX Steel Corporation of America (MMFX) - a subsidiary of MMFX Technologies Corporation

MMFX Steel contracts production of MMFX 2 steel products to pre-qualified steel mills and rebar rolling mills.

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I. Product Description

MMFX 2 steel bars are an uncoated, highly corrosion-resistant, steel, concrete reinforcing product that meet or exceed the mechanical properties of ASTM A1035 steel bars as well as ASTM A615 Grade 75, resulting from both its chemistry and manufacturing production process.

MMFX 2 Steel

Plain and Deformed Bar

II. Material Composition – Properties

Microcomposite (MMFX 2) steel is a low-carbon, chromium alloy steel that is produced as part of a controlled-rolling production process (i.e. rolling steel within a well-defined temperature range and cooled at a specific rate). The combination of MMFX 2 steel's chemical composition (see below) and manufacturing production process produce an economical, high-quality, finegrained steel with a reduced amount of impurities in comparison to that of standard carbon steels (Figure 1). MMFX 2 steel's unique composition provides the basis for its corrosion-resistant and high-strength material properties.

Typical MMFX Chemical Composition

No	Heat*	C	Mn	Si	S	P	Cu	Cr	Ni	Mo	V	Nb	N^2 PPM
1	810737	0.06	0.46	0.23	0.011	0.01	0.1	9.13	0.08	0.02	0.018	0.007	118
2	710778	0.06	0.46	0.25	0.012	0.01	0.07	9.17	0.07	0.01	0.18	0.007	108
3	809465	0.07	0.011	0.01	0.013	0.01	0.13	9.61	0.1	0.02	0.027	0.006	167
4	810736	0.08	0.43	0.22	0.007	0.01	0.1	9.4	0.08	0.02	0.023	0.007	154
5	710789	0.06	0.43	0.29	0.008	0.01	0.1	9.28	0.08	0.02	0.018	0.007	110
Heat Average		0.07	0.46	0.25	0.010	0.01	0.10	9.32	0.08	0.02	0.053	0.007	131
** Required		0.15	1.5	0.50	0.045	0.035	-	8 to 10.9	-	-	-	-	500

- Weight percentage of chemical constituents
- ASTM A1035 maximum weight percentages except for the Cr specification range.

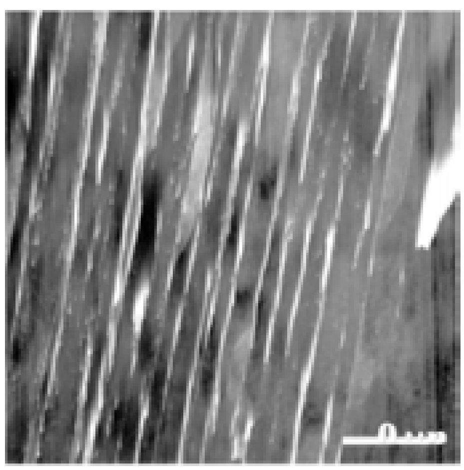
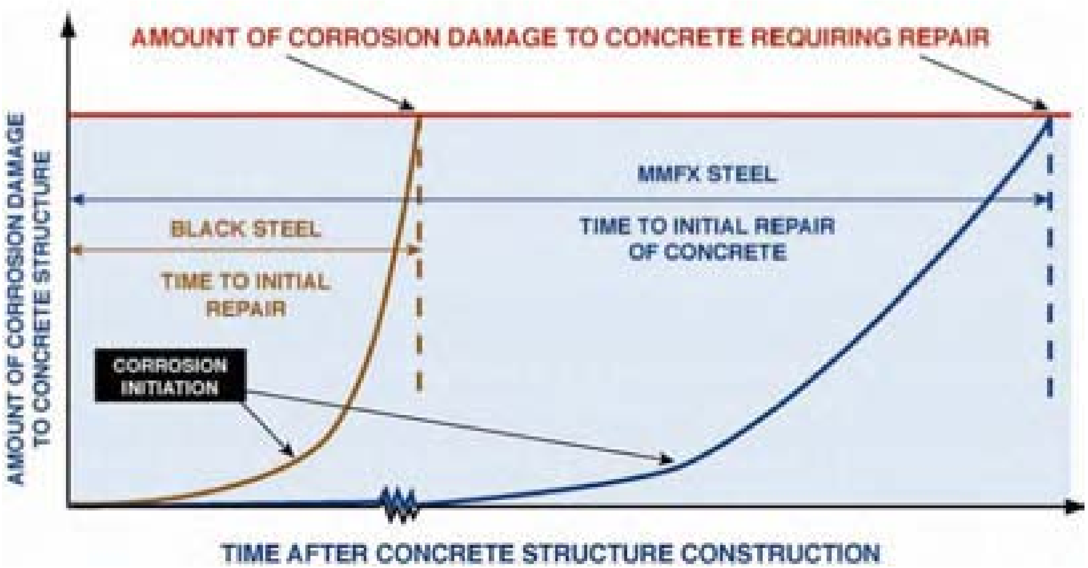


Figure 1: Electron Microscope Image of MMFX Steel – Highly magnified MMFX Steel microstructure viewed through the use of a special electron microscope procedure known as TEM (Transmission Electron Microscopy)

A. Corrosion Resistant Properties

MMFX 2 rebar's corrosion resistance has been tested at 5 to 6 times the Critical Chloride Threshold Level of ASTM A615 conventional carbon steel bar. Figure 2 is a schematic graphic illustration comparing MMFX Steel's corrosion protection to corrosive black steel bars and coated bars. MMFX Steel's corrosion resistance means that it takes a significantly longer time for corrosion to start and progress to the extent that requires repair to a structure, than it does for black steel or epoxy-coated rebar (ECR).



MMFX 2 rebar's corrosion resistance has been demonstrated by various organizations and agencies testing programs as illustrated by MMFX's Publications of Test Reports and Analysis. MMFX's corrosion resistance has been proven to provide project cost savings over the service life of those projects.

In addition, since the material itself provides the corrosion-resistance, field installation may be simplified in comparison to other corrosion resistant rebar products. MMFX 2 is monolithic composition means that:

- Storage methods and field handling will not damage MMFX 2 rebar, as can occur to coated products requiring field touch up of field damaged coatings as noticed by the special field handling requirements for both epoxy and stainless steel clad coated rebar products or special UV protection from sunlight required for epoxy-coated rebar.

- Standard field rebar fabrication procedures are possible with MMFX 2 vs. special requirements for offsite cutting and bending of (epoxy, cladded and galvanized) coated products and special requirements to place protective end caps for cladded products, or lap joint coupling of galvanized and black bars.

- No special field erection safety hazards exist for MMFX, unlike wet and slick epoxy-coated surfaces or sharp protrusions associated with galvanized rebars.

B. High-Strength Properties

MMFX 2 steel possesses tensile, yield strength, and elongation properties as shown in Table 2, Mechanical Tensile Test Properties.

TABLE 2 MECHANICAL TENSILE TEST PROPERTIES	
Tensile strength, min. psi [MPa]	150,000 [1030]
Yield strength (0.2% Offset), min. psi [MPa]	100,000 [690]
Stress corresponding to an extension under load of 0.0035 in./in. [0.0035 mm/mm], min. psi [MPa]	80,000 [550]
Elongation in 8 in. [203.2 mm], min %	
3 through 11 [10 through 36]	7
14, 18 [43,57]	6

MMFX 2 rebar is appropriate for use as concrete reinforcement in building, industrial, transportation and other reinforced concrete applications. MMFX 2 has been used in building slabs/bridge decks, beams/ girders, columns, abutments, footings, foundations, and other related cast-in-place and precast reinforced concrete members. In addition, MMFX 2 steel is also appropriate for use as concrete reinforcement (rebars) in retaining walls, sea walls, port ship fender systems, storm drainage culverts and headwalls, and pavement dowel bars, among other uses.

MMFX 2 steel rebar meets or exceeds the requirements of ASTM A615 Grade 75 and ASTM A1035.

- MMFX 2 rebar can be used with design yield strength of 80 ksi as ASTM A1035 rebar in accordance with design methodologies of ACI 318-05. 80 ksi MMFX 2 rebar designs can provide labor savings and steel quantity reduction of up to 25% in comparison to conventional reinforcing materials, resulting in reduced project construction times.

- Additional design efficiencies may be accomplished with MMFX 2 rebar, when using design yield strength of 100 ksi per ASTM A1035. MMFX 2 rebar 100 ksi designs are capable of providing potential labor savings of up to 50% and a steel quantity reduction of up to 40% in comparison to conventional reinforcing materials, resulting in an even further reduction of the project construction schedule. Design guidelines and methodologies for using MMFX steel bars at the higher design strengths can be obtained from the engineering support team of MMFX Technologies. MMFX Engineering support may be reached via the following:

  Tel: (866) 466-7878 (Toll Free)
  Fax: (949) 474-1130
  Email: engineering@mmfx.com

III. Manufacturing Quality Control / Material Certification

All MMFX 2 steel bars are produced in accordance with MMFX Technologies Quality Assurance Manual (Section V. C. Publications/Reports/Papers - Reference 3.), insuring that the manufacturing practices and tolerances, used in MMFX 2's production, provide both the certified chemical composition and mechanical properties are met or exceeded. Product traceability procedures by heat and rolling numbers assure the buyer, materials delivered at the point of purchase; conform to the material certification tags accompanying them.

All MMFX 2 steel bars are certified to both ASTM A615 Grade 75 and ASTM A1035 testing requirements to meet or exceed the chemical composition and mechanical provisions of these standard material specifications.

IV. Design and Construction Specification

The unique mechanical and corrosion-resistant properties of MMFX 2 rebars allow the designer/specifier to design more durable and safer structures. These structures are realized by mitigating the current problems facing the concrete construction industry, namely, corrosion and rebar congestion. Some of the applications using MMFX 2 rebars are described below:

Structures Exposed To Corrosive Environment

Corrosion-resistant MMFX 2 rebars are ideal for structural members and systems exposed to, or in direct contact with, corrosive environments, such as humid atmospheric conditions, high foundation water tables, or corrosive soil conditions. Possible applications exist in foundation piles and systems, marine structures, exposed balconies, etc.

Structural systems reinforced with MMFX 2 rebars have shown to provide extended service lives of 75 to 100 years, depending on the severity of the exposure.

Flexural Tension Application

Practical applications of MMFX 2 rebars in high-rise construction include, but are not limited to, tension piles, mat foundations, shearwalls and moment frames, etc. These structural components designed with the higher-yield-strength-property of MMFX 2 rebars have demonstrated to be cost-effective, improve constructability, and shorten construction schedules.

The design of concrete members reinforced with MMFX 2 rebars for flexure is analogous to the design of concrete reinforced with conventional steel bars. Experimental data of concrete members reinforced with MMFX 2 bars shows that flexural capacity can be calculated based on similar assumptions for members reinforced with conventional carbon steel rebars, taking into account the higher strength of the MMFX 2 rebars.

Based on the experimental results and the analysis conducted, the design of a concrete section reinforced with MMFX 2 rebars can be simplified by using the ACI 318 design philosophy and 690 MPa [100,000 psi] in tension, while limiting the stresses in compression up to 550 MPa [80,000 psi], corresponding to 0.35% strain.

Calculations involved in control of cracking should be made for the service load level. Research has shown that, in spite of service load steel stresses as high as 60,000 psi, the width of individual cracks can be held down to hair-line size by proper distribution of the bars (Malhas, F. 2002, El-Hasha, R. and Rizkalla, S. 2002). The strength characteristics of high-quality concretes along with the high-corrosion-resistance-properties of the high-strength steel will complement the structural properties of the MMFX 2 rebars, thus facilitating design development of attractive and economical structures.

Transverse Reinforcing

One application prompting the achievement of code recognition and market acceptance of high-strength reinforcing steel is its use as transverse reinforcement in columns, piles, and comparable vertical elements. There are indications worldwide suggesting that increased design requirements for transverse reinforcing steel especially in concrete columns and piles, are either exceeding the practical capacity of mild steel reinforcing bars, or are causing such a great amount of steel congestion that correct placement and consolidation of concrete is becoming complex.

There are further indications that this burden is adversely affecting the market for such reinforced concrete structures by making them prohibitively more expensive. As a result, alternative members such as structural steel rolled sections have replaced reinforced concrete as the material of choice in some parts of the world.

As a result, the newly published American Concrete Institute, ACI, 318-05 building code includes a new provision for allowing the use of higher design stresses for spiral transverse reinforcement in section 10.9.3 of the building code. The American Concrete Institute's ACI 318-05 building code commentary provides the following explanation for the acceptance of the use of the high-strength steel bars with yield strength of 100,000 psi for spiral reinforcement: "Confinement reinforcement often creates congestion in reinforced concrete structures. Research shows that 690 MPa (100,000 psi) yield strength reinforcement can be used for confinement (ACI, 2005). This will reduce congestion, thereby making structures safer, because concrete can be consolidated more easily, and will make structures more economical."

Furthermore, the upcoming ACI 318-08 building code extends the use of ASTM 1035 steel bars in transverse reinforcement ties for confinement purpose, for structural components subjected to high seismic load.

Product Guide Specification

A copy of the Product Guide Specification is attached for reference. This document outlines the properties of MMFX 2 rebars, as well as construction specifications.

For further questions regarding engineering design using MMFX 2 rebars, please contact our Engineering Department at (949)476-7600 or engineering@mmfx.com

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MMFX 2 Rebar – Product Guide Specification

Specifier Notes: This product guide specification is written in accordance with the Construction Specifications Institute (CSI) Format

The Engineer shall carefully review this specification to meet the requirements of the project and local building code and to coordinate with other specification sections and the drawings.

Delete all "Specifier Notes" after editing this section.

Specifier Notes: This section covers MMFX Microcomposite (MMFX 2) Steel uncoated, plain and deformed bars for concrete reinforcement.

One of the main reasons for considering MMFX 2 rebar for concrete reinforcement is that carbon steel reinforcing bars easily corrode in concrete when subjected to harsh environments, resulting in loss of strength and structural integrity or aesthetic appeal of the structure. Reinforced structures are prone to corrosion, when they are exposed to the outdoor environment and to deicing salts in colder climates or coastal ocean environments. MMFX 2 bars provide significant corrosion resistant properties in reinforced concrete applications.

MMFX 2's high strength also provides an opportunity to save on the quantity of rebar required for specific structural loading applications, allowing for reduced reinforcement congestion in heavily reinforced concrete structures.

MMFX 2 rebar meets ASTM A1035-06, ASTM A615 Grade 75 and AASHTO M31 Grade 75 requirements and provides enhanced corrosion resistance. Design Guidelines based on ACI 318-05 requirements can be used in designing concrete structures reinforced with MMFX 2 rebar. MMFX Technologies Corporation does not currently recommend use of its products outside of concrete.

MMFX Technologies Corporation offers its assistance in editing this specification section for specific project applications of MMFX 2 reinforcing bars.

Specifier Notes: Designers and engineers are referred to the documents noted below, regarding the application of MMFX 2 bars for concrete reinforcement. Engineers are also directed to technical papers posted in MMFX Steel 's Web site for additional information.

1. *ACI 318-05, "Building Code Requirements for Concrete" (2005), American Concrete Institute, Detroit, MI*
2. *"Placing Reinforcing Bars" (1997), Concrete Reinforcing Steel Institute, Schaumburg, IL.*

SECTION 03200

MICROCOMPOSITE (MMFX 2) STEEL UNCOATED, PLAIN AND DEFORMED BARS FOR CONCRETE REINFORCEMENT

PART 1 GENERAL

1.1 SPECIFICATION SCOPE

A. This specification covers MMFX Microcomposite (MMFX 2) steel uncoated, plain and deformed bars for concrete reinforcement in cast-in-place or pre-cast reinforced concrete.

Specifier Notes: Edit the following list as required for the project. List other sections with work directly related to the MMFX 2 bars.

1.2 RELATED WORK

A. Section 03300 – Cast-in-Place Concrete.

B. Section 03400 – Pre-cast Concrete.

Specifier Notes: List standards referenced in this section, complete with designations, dates and titles. This article does not require compliance with standards, but is mere a listing of those used in the preparation of this specification section.

1.3 REFERENCES

A. Codes and Standards

1. American Concrete Institute (ACI)

   a. Building Code Requirements for Reinforced Concrete (ACI 318-05).
   b. Details and Detailing of Concrete Reinforcement (ACI 315-99).
   c. ACI Detailing Manual – 1994 (ACI SP-66).
   d. Standard Tolerances for Concrete Construction and Materials (ACI 117-90).

2. American Society for Testing and Materials (ASTM)

   a. ASTM A 6/A 6M-02 Specification for General Requirements for Rolled Structural, Steel Bars, Plates, Shapes, and Sheet Piling
   b. ASTM A82-01 – Standard Specification for Steel Wire, Plain, for Concrete Reinforcement
   c. ASTM A370-02 – Test Methods and Definitions for Mechanical Testing of Steel Products
   d. ASTM A 510/A 510M-02 Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel
   e. A615/A 615M – 06a Specification for Deformed and Plain Carbon Steel Bars for Concrete Reinforcement

f. ASTM A1035-06 Specifications for Deformed and Plain Low-Carbon, Chromium Steel Bars form Concrete Reinforcement
g. ASTM E29-02 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

3. American Association of State Highway and Transportation Officials (AASHTO)

a. AASHTO M 31M/M 31-03 – Standard Specification for Deformed and Plain Billet Steel Bars for Concrete Reinforcement

4. Concrete Reinforcing Steel Institute (CRSI)

a. CRSI Manual of Standard Practice, 27th Edition, 2001
b. Placing Reinforcing Bars (CRSI PRB), 7th Edition, 1997

1.4 DESIGN REQUIREMENTS

Specifier Notes: MMFX 2 rebar conforms to the provisions of ASTM A1035-06, ASTM A615 Grade 75 and AASHTO M31 Grade 75 allowing for its design in accordance with ACI 318-05. MMFX 2 rebars can be used for spiral confinement up to 100,000 psi yield strength in accordance to ACI 318-05 requirements of 10.9.3. In addition, 100,000 psi yield strength can be used for design in tension as per "Application of ASTM A1035 MMFX Steel Reinforcement in Building Applications: An Appraisal" – S.K. Ghosh – April 2006 – S.K. Ghosh Associates.

A. Design of concrete structures reinforced with MMFX 2 bars shall be based in accordance with the provisions of ACI 318-05.

B. MMFX 2 reinforcing bars shall not be directly substituted for carbon steel Grade 40 or 60 reinforcing bars on an equal area basis, except as noted on the plans or approved by the Engineer.

Specifier Notes: MMFX Technologies Corporation does not currently recommend using the product outside of concrete.

1.5 SUBMITTALS

A. Comply with Specification – Submittal Procedures.

B. Product Data: Submit manufacturer's product data, including material and mechanical properties.

C. Test Reports: Submit manufacturer's mill certifications for material and mechanical properties for each bar size used by the project.

D. Placing Drawings: Submit MMFX 2 bar placing drawings in accordance with ACI SP-66.

E. Field Welding Procedures: MMFX 2 steel bars shall not be welded.

Specifier Notes: MMFX 2 steel bars should not be welded as currently no specific provisions have been included to enhance its weldability.

F. Mechanical Couplers: Submit manufacturer's product data for use with MMFX 2 steel bars.

Specifier Notes: Contact MMFX Steel Corporation for a list of qualified Mechanical Bar Splice Coupler Manufacturers.

1.6 DELIVERIES, STORAGE, AND HANDLING

A. General: Deliver, store, and handle MMFX 2 bars in accordance with manufacturer's instructions.

B. Storage:

1. Do not store MMFX 2 bars directly on ground to keep them free from dirt and mud and to provide easy handling.

2. Seams, surface irregularities, or mill scale oxidation shall not be cause for rejection, provided the weight, dimensions, and cross-sectional area of a hand-wired-brush test specimen are not less than the requirements of this specification.

PART 2 PRODUCTS

2.1 SUPPLIER

A. MMFX Steel Corporation of America, 6325 S Jones Blvd, Suite 300- Las Vegas, NV 89118, phone: (702) 247-1332, Fax (702) 247-1647
E-mail info@mmfx.com Web Site http://www.mmfx.com

2.2 MATERIAL

A. MMFX Microcomposite (MMFX 2) Steel Deformed and Plain Bars

1. General:

   MMFX 2 bars shall have a minimum chromium composition by weight of 8% and a minimum yield strength of 100,000 psi [690 MPa], measured by using the 0.2% offset test method of ASTM A370.

2. Manufacture Process and Bar Sizes:

   MMFX 2 bars shall be hot rolled from properly identified mold or strand cast steel using the electric-arc-furnace (EAF) process. Available bars are standard plain and deformed bar sizes #3 [10], thru #11 [36]. Bar sizes #14 [43] and #18 [57] can be special ordered.

3. Material Composition:

   MMFX 2 bars shall meet the requirements of Table 1.

Table 1– Maximum Chemical Constituents (Weight %)

Element	Carbon	Chromium	Manganese	Nitrogen	Phosphorus	Sulfur	Silicon
Maximum Amount[A]	0.15%	8 to 10.9%	1.5 %	0.05%	0.035%	0.045%	0.50%
Typical MMFX 2	0.08%	9%	0.5%				

Note A– Maximum unless range indicated

4. Bar Weight, Dimensions, and Deformation Spacing and Height:

   Deformed MMFX 2 bars shall conform to the weight, dimensions and deformation spacing, height, and gap requirements prescribed in Table 2.

Table 2
Deformed Bar Designation Numbers, Nominal Weights [Masses], Nominal Dimensions, and Deformation Requirements

Bar Designation No. [A]	Nominal Weight, LB/ft [Nominal Mass, kg/m]	Nominal Dimensions[B]			Deformation Requirements, in. [mm]		
		Diameter, in. [mm]	Cross-Sectional Area, In. ^{2} [mm ^{2}]	Perimeter in. [mm]	Maximum Average Spacing	Minimum Average Height	Maximum Gap (Chord of 12.5 % of Nominal Perimeter)
3[10]	0.376 [0.560]	0.375 [9.5]	0.11 [71]	1.178 [29.9]	0.262 [6.7]	0.015[0.38]	0.143[3.6]
4[13]	0.668 [0.994]	0.500 [12.7]	0.20 [129]	1.571 [39.9]	0.350 [8.9]	0.020[0.51]	0.191[4.9]
5[16]	1.043 [1.552]	0.625 [15.9]	0.31 [199]	1.963 [49.9]	0.437 [11.1]	0.028[0.71]	0.239[6.1]
6[19]	1.502 [2.235]	0.750 [19.1]	0.44 [284]	2.356 [59.8]	0.525 [13.3]	0.038[0.97]	0.286[7.3]
7[22]	2.044 [3.042]	0.875 [22.2]	0.60 [387]	2.749 [69.8]	0.612 [15.5]	0.044[1.12]	0.334[8.5]
8[25]	2.670 [3.973]	1.000 [25.4]	0.79 [510]	3.142 [79.8]	0.700 [17.8]	0.050[1.27]	0.383[9.7]
9[29]	3.400 [5.060]	1.128 [28.7]	1.00 [645]	3.544 [90.0]	0.790 [20.1]	0.056[1.42]	0.431[10.9]
10 [32]	4.303 [6.404]	1.270 [32.3]	1.27 [819]	3.990 [101.3]	0.889 [22.6]	0.064[1.63]	0.487[12.4]
11 [36]	5.313 [7.907]	1.410 [35.8]	1.56 [1006]	4.430 [112.5]	0.987 [25.1]	0.071[1.80]	0.540[13.7]
14 [43]	7.65 [11.38]	1.693 [43.0]	2.25 [1452]	5.32 [135.1]	1.185 [30.1]	0.085[2.16]	0.648[16.5]
18 [57]	13.60 [20.24]	2.257 [57.3]	4.00 [2581]	7.09 [180.1]	1.58 [40.1]	0.102[2.59]	0.864[21.9]

[A]Bar numbers are based on the number of eighths of an inch included in the nominal diameter of the bars [bar numbers approximate the number of millimeters of the nominal diameter of the bar].
[B]The nominal dimensions of a deformed bar are equivalent to those of a plain round bar having the same weight [mass] per foot [meter] as the deformed bar.

5. Bar Deformations:

a. Deformations shall be spaced along the bar at substantially uniform distances. The deformations on opposite sides of the bar shall be similar in size, shape, and pattern.

b. The deformations shall be placed with respect to the axis of the bar so that the included angle of the bar is not less than 45°. Where the line of deformation forms an included angle with the axis of the bar 45° to 70° inclusive, the deformations shall alternatively reverse in direction on each side or those on one side shall be reversed in direction from those on the opposite side. Where the line of deformations is over 70°, a reversal in direction shall not be required.

c. The average spacing or distance between deformations on each side of the bar shall not exceed seven tenths of the nominal diameter of the bar.

d. The overall length of deformations shall be such that the gap between the ends of the deformations on opposite sides of the bar shall not exceed 12½% of the nominal perimeter of the bar. Where the ends terminate in a longitudinal rib, the width of the longitudinal rib shall be considered the gap. Where more than two longitudinal ribs are involved, the total width of all longitudinal ribs shall not exceed 25% of the nominal perimeter of the bar; furthermore, the summation of gaps shall not exceed 25% of the nominal perimeter of the bar. The nominal perimeter of the bar shall be 3.14 times the nominal diameter.

6. Permissible Variation in Weight [Mass]:

a. Deformed reinforcing bars shall be evaluated on the basis of nominal weight [mass].The weight [mass] determined using the measured weight [mass] of the test specimen and rounding in accordance with ASTM E 29, shall be at least 94% of the applicable weight [mass] per unit length prescribed in Table 1. In no case shall overweight [excess mass] of any deformed bar be the cause for rejection. Weight [mass] variation for plain rounds shall be computed on the basis of permissible variation in diameter. For plain bars smaller than 3/8 in. [9.5mm], use ASTM A 510/A 510M. For larger bars up to and including 2.25 in. [57.2 mm], use ASTM Specification A 6/A 6M.

7. Tensile Properties:

a. MMFX 2 bars shall conform to the requirements for tensile properties prescribed in Table 3.

b. The yield strength shall be determined by the offset method (0.2% offset), described in Test Methods and Definitions A370. The strength corresponding to an extension under load of 0.0035 in./in. (0.0035 mm/mm) shall be minimum of 80,000 psi [550MPa].

Table 3
Tensile Properties Requirements

Tensile strength, min, psi [MPa]	150,000 [1030]
Yield strength (0.2% offset), min, psi [MPa]	100,000 [690]
Strength corresponding to an extension under load of 0.0035 in/in (0.0035 mm/mm), min, psi [MPa]	80,000** [550]
Elongation in 8 in. [203.2mm], min. %:	
Bar Designation No.	
3 through 11 [10 through 36]	7
14, 18 [43, 57]	6

*Specifier Notes: **Designers need to be aware that current design standards (ACI-318-05) limit the design strength to 80,000 [550 MPa], except for prestressing steel and for spiral transverse reinforcement. Members reinforced with bars with yield strengths that are considerably above 80,000 psi [550 MPa] may exhibit behavior that differs from that expected of conventional reinforced concrete members or may require special detailing to ensure adequate performance at service and factored loads. See MMFX Steel website for additional guidance for use of MMFX 2 rebars: "Application of ASTM A1035 MMFX Steel Reinforcement in Building Applications: An Appraisal" – S.K. Ghosh – April 2006 – S.K. Ghosh Associates.*

8. Bend Test Properties:

MMFX 2 bend test specimens shall withstand being bent around a pin without cracking on the outside radius of the bent portion. The requirements for degree of bending and sizes of pins are prescribed in Table 4. When material is furnished in coils, the test sample shall be straightened prior to placement in the bend tester.

Table 4
Bend Test Requirements

Bar Designation No.	Pin Diameter[A]
3, 4, 5, [10,13, 16,]	3½d[B]
6, 7, 8[19,22, 25]	5d
9,10,11 [29, 32, 36]	7d
14, 18 [43, 57] (90°)	9d

[A]Test bends 180° unless otherwise noted in ( ).

[B]d= nominal diameter of specimen.

9. Bar Identification:

MMFX 2 bars meet the requirements of both ASTM A615 Grade 75 and ASTM A1035 specifications. MMFX 2 bars, excepts plain round bars, which shall be tagged for grade, shall be identified by a distinguishing set of marks legibly rolled onto the surface of one side of the bar to denote the specification in the following order:

a. *Bar Identifier* – "MMFX" shall indicate a product produced for MMFX Steel meeting the chemical composition of Table 1.
b. *Point of Origin*- Letter or symbol established as the manufacturer's mill designation.
c. *Size Designation*- Arabic number corresponding to bar designation number of Table 2.
d. *Type of Steel*- Letters CS indicating that the bar was produced to ASTM A1035 specification.

e. *Minimum Yield Designation*- Either the number 100 [6] or three continuous longitudinal lines through at least five spaces offset each direction from the center of the bar.

Dual Specification

f. *Point of Origin*- Letter or symbol established as the manufacturer's mill designation.
g. *Size Designation*- Arabic number corresponding to bar designation number of Table 2.
h. *Type of Steel*- Letters S indicating that the bar was produced to ASTM A615 Grade 75 specification.
i. *Minimum Yield Designation*- Either the number 75 [5] or two continuous longitudinal lines through at least five spaces offset each direction from the center of the bar.

It shall be permissible to substitute: a metric size bar of for the corresponding inch pound size bar.

B. Bar Supports

1. Bar supports and spacers shall be per recommendations set forth by Chapter 3 of the CRSI Manual of Standard Practice.

2. Ferrous metal bar supports in concrete areas where soffits are exposed to view or are painted shall be Class 1 or Class 2, Types A or B; Class 3 is acceptable in other areas.

C. Tie Wire

1. Metallic ties shall be 16 gauge (1.5 mm diameter) or heavier, black-annealed ferrous metal wire.

2. Non-metallic ties shall be appropriate for the intended application.

D. Mechanical Bar Splice Couplers

1. Couplers shall be made from MMFX 2 steel bars or other approved carbon steel bar material and shall be approved for use with MMFX 2 rebars.

2.3 MATERIAL QUALITY CONTROL

A. Quality Control Testing:

MMFX 2 bars shall be furnished with material certifications in accordance with SECTION 1.5 SUBMITTALS.

PART 3 EXECUTION

3.1 EXAMINATION

A. Examine areas to receive MMFX 2 bars. Notify the Engineer if areas are not acceptable. Do not begin placing MMFX 2 bars until unacceptable conditions have been corrected.

B. Seams, surface irregularities, or mill scale oxidation shall not be cause for rejection, provided the weight, dimensions, and cross-sectional area of a hand-wired-brush test specimen are not less than the requirements of this specification.

3.2 PLACING DRAWINGS

A. Place MMFX 2 bars accurately in accordance with approved placing drawings, schedules, typical details, and notes.

Specifier Notes: Placing of MMFX 2 bars is performed similarly to that for uncoated steel reinforcing bars, and common practices should apply with some key exceptions, as specified below.

3.3 FABRICATION

A. Reinforcing steel shall be accurately fabricated to the dimensions shown in the Contract documents.

1. Bends shall conform to the dimensions and details in accordance with ACI 315-99 – Chapter 3, ACI SP-66 and/or CRSI Manual of Standard Practice – Chapter 6, unless otherwise shown, with fabricated bends conforming to Table 5 per ACI 315 – Table 7.2.

Table 5
Minimum Fabricated Bend Diameters

Bar Size	Minimum Bend Diameter
3, 4, 5, 6, 7, 8 [10,13, 16, 19,22, 25]	6d
9,10,11 [29, 32, 36]	8d
14, 18 [43, 57]	10d

2. Bars shall be bent cold, and shall not be bent or straightened in a manner that will injure the material. Heating of the bars to facilitate bending shall not be permitted.

3. Bar cutting shall be accomplished by shearing or with a water-cooled saw. Torch cutting shall not be permitted.

4. Bars shall be fabricated within the tolerances shown in the ACI 315-99 figures 8 and 9, and/or CRSI Manual of Standard Practice – Chapter 7 and/or CRSI PRB – Chapter 6.

B. Spirals

1. Provide one and one-half finishing turns top and bottom minimum.

2. Splice lap lengths shall be to the length shown on the contract documents.

3. Provide spacers per Chapter 5, Section 10 of the CRSI Manual of Standard Practice.

C. Field Welding as an aid to fabrication and/or installation shall not be permitted.

3.4 INSTALLATION

A. Placement:

Place MMFX 2 bars in accordance with CRSI PRB – Chapter 10, and to the tolerances given in ACI 117 and/or CRSI PRB, unless otherwise specified or approved by the Engineer. Bars shall be free from loose mill scale oxidation, dirt, oil or other deleterious coatings that could reduce bond with the concrete. When bars are moved more than one bar diameter to avoid interference with other reinforcement, conduits, or embedded items, the resulting arrangement of the bars shall meet the structural requirements of the project as approved by the Engineer.

B. Field Cutting and Bending:

When required, field cutting and bending of MMFX 2 bars shall be per SECTION 3.3 FABRICATION.
Reinforcing bars partially embedded in concrete shall not be field bent. Fabricated bent bars shall not be straightened and rebent in the field.

C. Securing:

Secure MMFX 2 bars in formwork to prevent displacement by concrete placement or workers.

D. Supports and Spacers:

Place and support MMFX 2 bars accurately using specified supports before concrete placement is started, and placed in accordance with the provisions of ACI 315 – Chapter 5 or CRSI PRB.

E. Splicing:

All splicing of reinforcement shall be as indicated in the Contract Documents, unless otherwise permitted. Concrete cover and bar spacing shall conform to ACI 318-05.

Mechanical connections shall be made only at locations shown in the Contract Documents or as permitted by the Engineer.

1. When required or permitted, mechanical coupler connections shall develop 125 percent of the specified minimum tensile strength of the bars being spliced; and shall be installed per coupler manufacturer's recommendations.

F. Fastening:

Fasten MMFX 2 bars with approved tie wire, or snap ties, in accordance with ACI 315.

G. Cleaning:

Remove form oil or other deleterious materials from MMFX 2 bars before placing concrete.

3.5 TESTING AND INSPECTION

A. Upon request, a certified copy of a mill certification report showing physical and chemical analysis for each heat of reinforcing bars delivered shall be provided.

B. Field inspection shall be in accordance with local Building Code or agency requirements.

END OF SECTION

V. Project Applications

Since 2001, MMFX 2 rebar has been, or is being, used in various public infrastructure / building and private development projects through out the United States, Puerto Rico and Canada. Following is a representative list of some of those projects with information concerning them along with pictures of them.

A. Public Infrastructure Projects

Item	Location/Project Description	Owner/Agency	Project Information
1	Vian, OK-Sequoya Co.- State Hwy. over Illinois River-Lake Tenkiller Spillway Channel Bridge	Army Corps of Engineers – Tulsa District	MMFX 2 used in the entire bridge structure except precast elements Constructed 2006
2	Bayonne, NJ – Bayonne Military Ocean Terminal Redevelopment	Bayonne Local Redevelopment Authority (BLRA)	Pier piles, caps and deck Under Construction 2007
3	Jensen Beach, FL Causeway Bridge over Intercostal Waterway	Florida DOT	Top and bottom mat of bridge deck – Constructed 2004
4	Port Orchard, WA – Intermodal Terminal	Kitsap Transit Authority	Floating ferry boat dock reinforcement – Constructed 2006
5	Swan River, MB – Province Highway 10 over East Favel River	Manitoba Highways Dept.	Top and bottom mat of bridge deck and curbs – Constructed 2002
6	Rio Arriba Co. – W/O Gobernador, NM – US 64 over Gobernador Arroyo River	New Mexico Dept. of Highways and Transportation	Entire Bridge Structure Abutments, piers, wingwalls, approach slabs and deck (100 ksi ductile failure design) Constructed 2005
7	Folsom. CA – Light Rail Bridge over Alde Creek	Sacramento Regional Transit District	Light rail bridge girders, abutments, and columns (100ksi design) Constructed 2004
8	Potter Co. Amarillo, TX – Washington Street Underpass I-40	Texas DOT	Columns, abutments, caps, top and bottom mat and parapets Constructed 2003
9	San Diego, CA – Modular Hybrid Pier	US Navy NFSEC (Naval Facilities Engineering Command)	MMFX 2 used through out structure Constructed 2004
10	Richland, WA - SR 240 – I -182 To Columbia Center Interchange	Washington DOT	1.5” diameter by 18” pavement dowel bars. Constructed 2007

ARMY CORPS OF ENGINEERS
Lake Tenkiller Spillway Bridge (State Highway 100) over Illinois River – Vivian, OK

Bayonne Pier Redevelopment - Bayonne, NJ Piles, Caps and Deck

FLORIDA DEPARTMENT OF TRANSPORTATION
Jensen Beach Causeway Bridge over Intercoastal Waterway – Jensen Beach, FL

KITSAP TRANSIT AUTHORITY
Intermodal Terminal – Port Orchard, WA



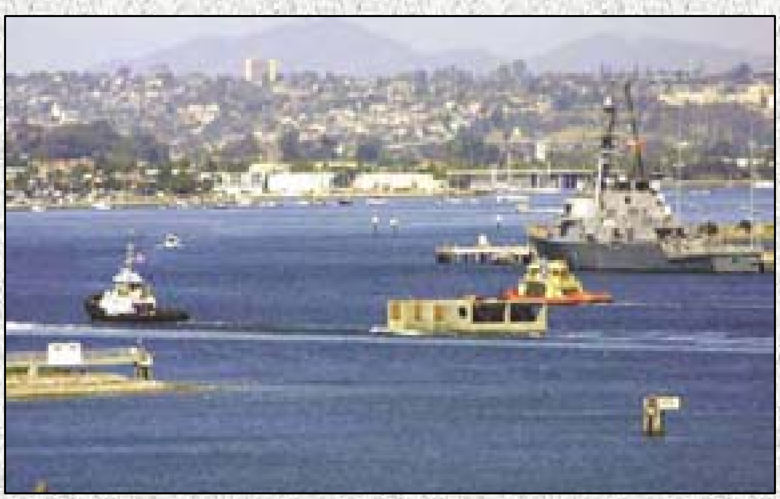

MANITOBA HIGHWAYS DEPARTMENT
Province Highway 10 over East Favel River – Swan River, MB

NEW MEXICO DEPARTMENT OF HIGHWAYS AND TRANSPORATION
US 64 Bridge over Gobernador Arroyo River – Rio Arriba County, NM

SACRAMENTO REGIONAL TRANSIT DISTRICT
Light Rail Bridge over Alder Creek – Folsom, CA

TEXAS DEPARTMENT OF TRANSPORTATION
Washington Street Overpass Bridge over I -40 – Amarillo, TX

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



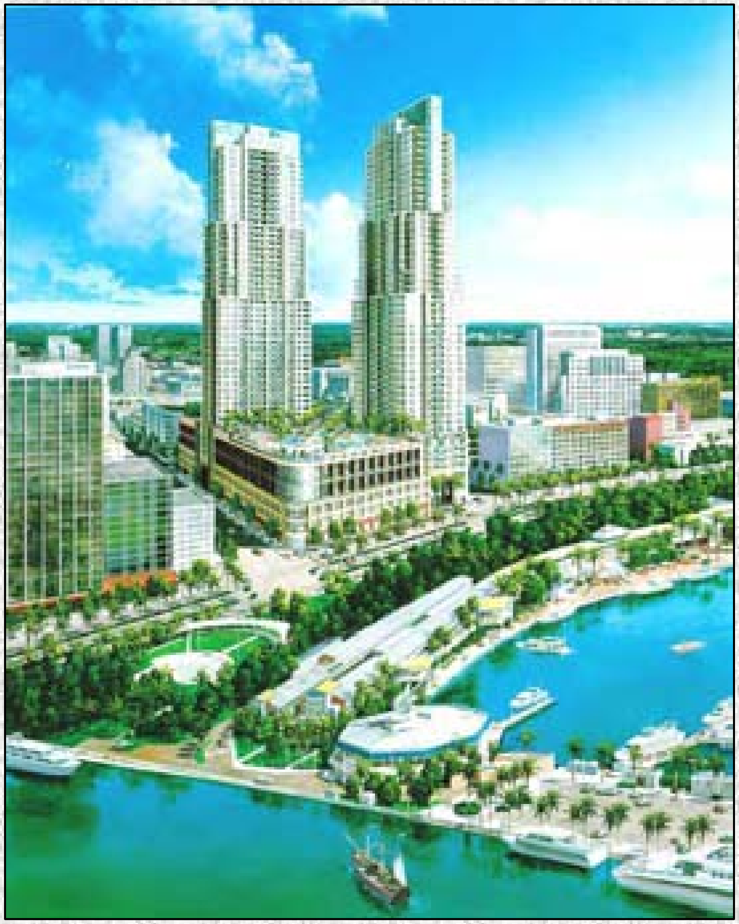
Washington Pavement Dowel Bar Insertion

B. Public and Private Building Development Projects

Item	Location/Project Description	Owner/ Agency	Project Information
1	St. Charles, MO – Ameristar Casino	Ameristar Casinos Inc.	Cast-in-place and Precast elevated pool deck Under Construction 2007
2	Miami, FL-Everglades on the Bay Condominiums	CABI Developers	49 Floor Condominium-Foundation Under Construction 2006
3	San Francisco, CA California Academy Exhibition, Education and Research Center	California Academy of Sciences	Building Foundation and Aquarium tank reinforcement Under Construction 2006
4	Gulf Shores, AL Mustique Condominiums	Head Companies	21 Floor Condominium - columns – stairway and elevator shafts – Under construction 2006
5	Brooklyn, NY - Kingswood Retail & Office Center	Kingswood Partners LLC	Mat foundation designed at 100ksi –Constructed 2005
6	Chicago, IL - The Tides	Magellan Development Group, Ltd.	51 Floor Condominium – Beams – Under Construction 2007
7	Marineland, FL – Seawater Lagoon Dolphin Tank	Marineland of Florida	Aquarium tank reinforcement Constructed 2005
8	Las Vegas, NV Las Vegas, NV – Project City Center Pelli Tower	MGM Mirage	60 Floor Hotel/Casino – Load Transfer Beams – Under Construction 2007
9	Malibu, CA - Coastal Residence	Private Residence	Building drilled pile foundations – 100 ksi Design – Under Construction 2007
10	Pebble Beach, CA – 4 story Coastal Residence	Private Residence	Building foundations, slabs, retaining walls and columns Under Construction 2006

Ameristar Casino – St. Charles, MO - Cast-in-Place and Precast Pool Deck

CABI DEVELOPERS
Everglades on the Bay Condominiums – Miami, FL



California Academy of Sciences – Exhibition, Education and Research Center – San Francisco, CA - Foundation and Aquarium Tank





HEAD COMPANIES
Mustique Condominiums, Gulf Shores, AL

KINGSWOOD PARTNERS LLC
Kingswood Retail and Office Center – Brooklyn, NY

The Tides – Chicago, IL 51 Floor Condominium Beams



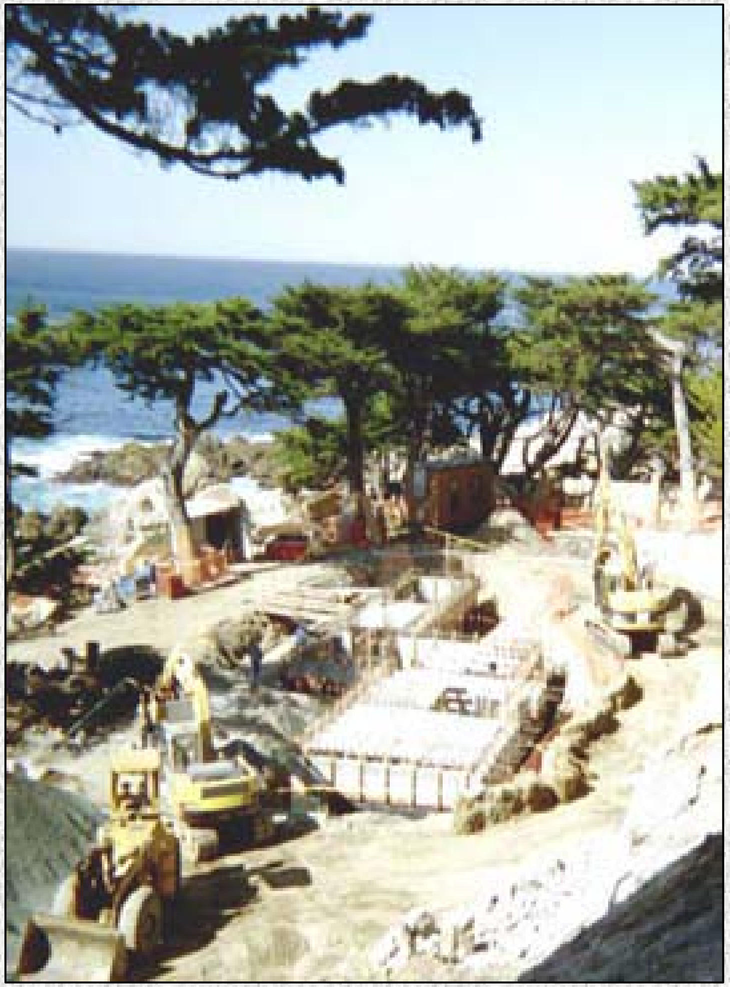


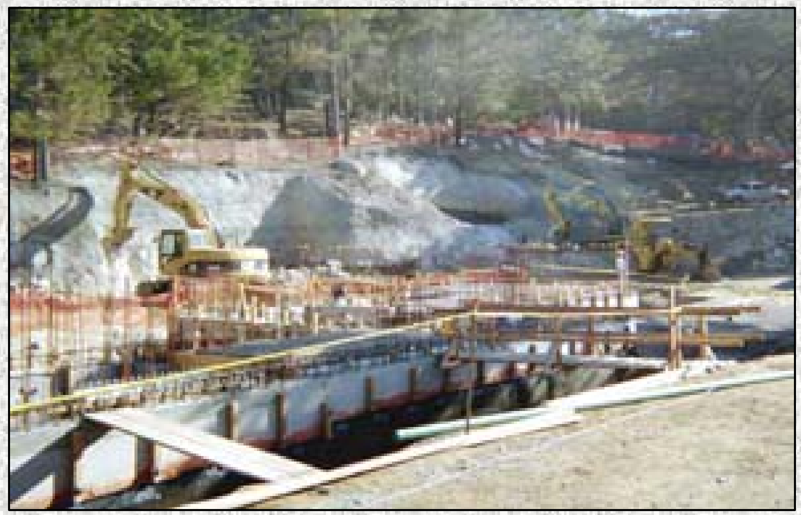
MARINELAND OF FLORIDA
Seawater Lagoon Dolphin Tank – Marineland, FL

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

Coastal Residence – Malibu, CA - Drilled Pier Foundation

PRIVATE RESISDENCE - CALIFORNIA
4 – Story Coastal Residence – Pebble, Beach, CA





VI. Agency Approvals

MMFX 2 rebar has been, or is in the process of being, used in various private development projects in: California, Florida, Nevada, New York, North Carolina, Georgia and Washington as: building slabs, foundations, columns, shear walls and beams designed to utilize the superior mechanical properties of the MMFX steel bars.

The following state transportation agencies have or are in the process of constructing both bridge deck, and other structural members, or using pavement dowel bars:

Arizona DOT	Kentucky Transportation Cabinet	South Carolina DOT
Connecticut DOT	Michigan DOT	Texas DOT
Delaware DOT	New Hampshire DOT	Utah DOT
Florida DOT	New Mexico DOH&T	Vermont DOT
Idaho DOT	North Carolina DOT	Virginia DOT
Iowa DOT	Oklahoma DOT	Washington DOT
Indiana DOT	Pennsylvania DOT	Wisconsin DOT

In addition, these government agencies also have used MMFX 2 rebar in their reinforced concrete structural elements:

Army Corps of Engineers – Tulsa District
Los Angeles County Department of Public Works
Manitoba Transportation and Government Services
Pennsylvania Turnpike Authority
Puerto Rico Departamento de Transportacion y Obras
Públicas Sacramento Regional Transit District
US Naval Facilities Command
Vancouver Organizing Committee for the 2010 Olympic and Paralympic Winter Games (VANOC)

A. State Transportation Departments

Name of Agency	Approval Date	Name & Phone Number of Contact
Alabama DOT	02-03-04	Billy Bullard (334) 206-2209
Colorado DOT	02-11-05	David Kotzer (303) 757-9421
Georgia DOT	12-11-03	Reggie Fry (404) 363-7619
Idaho DOT	07-30-04	Steve Loop (208) 334-2867
New Mexico Dept. of Highways and Transportation	10-23-02	Ernest Archulata (505) 827–5100
North Carolina DOT	Trial Basis 03-31-03	Azam Azimi, Ph D, PE (919) 250-4128
Texas DOT	(A) APEL 03-22-04	Randy Cox, P.E. (512) 416-2189
Utah DOT	(B) 04-25-05	Barry Sharp (801) 965-4314
Washington State DOT	(C) 06-24-05	John Livingston (360) 709-5472

Note: (A) APEL (ASSHTO Product Evaluation List)
(B) See APL (Approved Product List) page 42 of 66 Category N. "Rust Passivators" ID # 03-114
(C) Pavement Dowel Bars

B. Building Departments

The following building departments have approved the use of MMFX 2 in various flexural elements (i.e. mat foundation, shear walls etc.) as noted in their approval documents.

Name of Agency	Approval Date	Comment
City of Long Beach, California Planning and Building Department	03-17-06	Approved for 100 ksi foundation systems only
City of Los Angeles, California Department of Building and Safety	01-01-06	Approved for 100 ksi foundation systems only
City of Miami, Florida Building Department	09-08-06	Approved for 100 ksi foundation systems and superstructures
City of North Bay Village, Florida Building & Zoning Department	06-28-06	Approved for 100 ksi foundation systems and superstructures
City of Orlando, Florida Division of Building Safety	09-18-06	Approved for 100 ksi foundation systems and superstructures
City of San Diego, California Department of Development Services	05-10-05	Project approval 100 ksi foundation systems only
Clark County (Las Vegas), Nevada Department of Development Services	03-13-06	Approved for 100 ksi foundation systems and superstructures
Miami – Dade County, Florida Building Code Compliance Office	08-15-06	Approved for 100 ksi foundation systems and superstructures
Sarasota County, Florida Permitting Services	10-21-05	Approved for 100 ksi foundation systems and superstructures
City of Irvine, California	12-12-06	Approved for 100 ksi foundation systems

CITY OF LONG BEACH

DEPARTMENT OF PLANNING AND BUILDING

333 W. Ocean Blvd., Fourth Floor   Long Beach, CA 90802   Ph: 562-570-6651   Fax: 562-570-6753

BUILDING BUREAU / PLAN REVIEW DIVISION

March 17, 2006

Johnny Kwok, S.E. MBA	Case No.:	**ALT 2006-03-17 BU**
Assistant Director of Engineering	Location:	**N/A**
MMFX Technologies Corporation	Project No.:	**N/A**
2415 Campus Drive, Suite 100	Council District:	**N/A**
Irvine, CA 92612	Inspection District:	**N/A**

SUBJECT: REQUEST FOR ALTERNATE METERIALS AND METHODS OF CONSTRUCTION – HIGH STRENGTH REINFORCING STEEL

Dear Mr. Kwok,

This is in response to your letter dated December 1, 2005 requesting the Building Official to consider granting a request for a general approval to use high strength reinforcing steel pursuant to the alternate materials and methods of construction provisions of the building code.

The specific request under consideration is as follows:

"To allow the use of MMFX 2 ASTM A1035 deformed steel bars for use in reinforced concrete foundation systems using up to 100 ksi."

The requirements and prerequisites for granting a request for alternate materials and methods of construction are enumerated in Section 18.04.090 of the Long Beach Municipal Code. This Section provides in pertinent part as follows:

> *"B. The building official may approve any such alternate provided he finds that the proposed design is satisfactory and complies with the provisions of this title and that the materials, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this title in suitability, strength, effectiveness, fire resistance, durability, safety and sanitation.*
>
> *C. The building official shall require that sufficient evidence or proof be submitted to substantiate any claims that may be made regarding its use."*

After thorough consideration of the statements contained in your request letter, the report dated December 2005 and the back up testing data from various testing agencies, I find that the rational analyses to substantiate the claim as enumerated in Section 18.04.090 of the Long Beach Municipal Code have been established. The request is in conformity with the intent and purpose of the code.

Under the authority of Section 18.04.090 of the Long Beach Municipal Code, I hereby **APPROVE** your alternate materials and methods of construction request subject to the following terms and conditions:

1. This approval shall be in effect as long as the product has an active LA City Research Report, International Code Council Evaluation Services Report, or any other approval from a recognized national organization. The conditions contained in such acceptance reports shall be complied with as if specified herein. Where there is more than one approved acceptance report, the conditions stipulated in the more restrictive report shall be complied with.

2. A copy of this approval letter and the acceptance report indicated in condition #1 above shall be included with each set of building plans submitted to the Department of Planning and Building that utilize this product. Included shall be a wet stamp and signature of the Engineer of Record responsible for the project.

3. If the privilege authorized by this approval letter is utilized, the conditions stipulated herein immediately become effective and must be strictly complied with. The violation of any conditions imposed by the Building Official in connection with the granting of this request pursuant to the authority of Section 18.04.090 of the Long Beach Municipal Code shall constitute a violation and be subject to the same penalties as any other violations of the Code.

4. The Department reserves the right to impose additional corrective conditions, if, in the Building Official's opinion, such conditions are proven necessary for the protection of occupants of the building when actual design plans are submitted for review.

If you have any questions or concerns regarding this matter, please contact Mr. Truong Huynh, Engineering Plan Check Officer, at 562 570 6921.

Approved:
Lawrence Brugger
Superintendent of Building and Safety

BY:

Truong Huynh
Engineering Plan Check Officer
Department of Planning and Building
Building Bureau/Plan Review Division

LB:th
ALT 2006-03-17 BU High Strength Steel

CITY OF LOS ANGELES

CALIFORNIA

ANTONIO R. VILLARAIGOSA
MAYOR

DEPARTMENT OF
BUILDING AND SAFETY
201 NORTH FIGUEROA STREET
LOS ANGELES, CA 90012

ANDREW A. ADELMAN, P.E.
GENERAL MANAGER

RAYMOND CHAN
EXECUTIVE OFFICER

MMFX Technologies Corporation
2415 Campus Dive, Suite 100
Irvine, CA 92612

Attn: Johnny Kwok, S.E. MBA
(949) 476-7600

RESEARCH REPORT: RR 25598
(CSI #13120)

Expires: January 1, 2009

GENERAL APPROVAL -Renewal - MMFX 2 ASTM A1035 deformed steel bars for use in design of reinforced concrete mat and spread foundation systems using up to 100,000 psi yield strength.

DETAILS

MMFX 2 ASTM A1035 deformed steel bars shall meet the following specifications:
minimum yield strength for tension:100,000 psi 0.2 percent offset.
minimum yield strength for compression: 80,000 psi at 0.35 percent strain.

The approval is subject to the following conditions:

1. MMFX 2 ASTM A1035 deformed steel bars shall be used for design of reinforced concrete mat and spread foundation systems based on the following yield strength: Tension: 100,000 psi. Compression: 80,000 psi.

2. MMFX 2 ASTM A1035 deformed steel bars, when designed using higher yield strength, shall have proportionally longer development length and lap length based on 60,000 psi yield strength prescribed in 2002 Los Angeles City Building Code.

3. Test data from the mill or from a Los Angeles City approved testing agency shall verify the material in accordance with the above modified specifications for each job.

4. MMFX 2 ASTM A1035 deformed steel bars shall be distinctly dual marked for ASTM A615 Grade 75 and ASTM A1035 (100,000 psi) for field identification.

5. All steel materials shall be identified as - "LARR 25598" on bar tags.

6. Mechanical couplers to develop full strength require a separate approval

7. MMFX 2 ASTM A1035 deformed steel bars shall not be welded, unless the welding protocol is provided by manufacture for specific application and approved by Structural Plan Check.

DISCUSSION

This general approval of an equivalent alternate to the Code is only valid where an engineer and/or inspector of this Department has determined that all conditions of this approval have been met in the project in which it is to be used.

Addressee to whom this Research Report is issued is responsible for providing copies of it, complete with any attachments indicated, to architects, engineers and builders using items approved herein in design or construction which must be approved by Department of Building and Safety Engineers and Inspectors.

Yeuan Chou

YEUAN CHOU, Chief
Engineering Research Section
2319 Dorris Place
Los Angeles, CA 90031
Phone-(213) 485-2376
Fax-(213)847-0985

RB:elan
RR25598/wp8.0
R12/18/06
3C1/1903.5.3

CITY OF LOS ANGELES
CALIFORNIA

ANTONIO R. VILLARAIGOSA
MAYOR

DEPARTMENT OF
BUILDING AND SAFETY
201 NORTH FIGUEROA STREET
LOS ANGELES, CA 90012

ANDREW A. ADELMAN, P.E.
GENERAL MANAGER
RAYMOND CHAN
EXECUTIVE OFFICER

MMFX Technologies Corporation
2415 Campus Drive, Suite 100
Irvine, CA 92612

RESEARCH REPORT: RR 25619
(CSI # 03210)

Attn: Johnny Kwok, S.E. MBA
(949) 476-7600

Expires: July 1, 2009

GENERAL APPROVAL - Renewal - Barsplice Grip-Twist System® Type XT Couplers for Type 1 Mechanical Splice of MMFX 2 ASTM A 1035 100,000 psi deformed steel bars.

DETAILS

Barsplice Grip-Twist System® Type XT Couplers manufactured by Barsplice Products, Inc. made from steel conforming to ASTM A576 or A519, Grade 1018, for splicing #4 through # 11 MMFX 2 ASTM A1035 100,000 psi deformed steel bars.

The approval is subject to the following conditions:

1. Installation of the splices shall be in accordance with the manufacturer's specifications. A copy of which shall be available at each job site to all Deputy Inspectors on the job.

2. Continuous inspection by Deputy Inspectors shall be provided during installations of the splices.

   In addition to the normal duties, the Deputy Inspector shall:

   a) Verify the hardware and equipment.

   b) Verify the cleaning and condition of the bars in accordance with the specifications and the requirements herein.

   c) Verify the installation procedures in accordance with the specifications and the requirements herein.

3. Splice to be installed shall be selected at the job site by the Registered Deputy Inspector or the Building Inspector and shall be tested by a Los Angeles City Approved testing agency. The test shall be conducted on each different reinforcing bar size and the frequency of tests shall be as follows:

   1 out of the first 10 splices.
   1 out of the next 90 splices.
   1 out of the next 100 splices.

   Splices shall develop in tension or compression, as required, at least 125 percent of the specified yield strength of the bar.

4. If failure of the tested splice should occur prior to obtaining 125-percent of specified yield strength, then 25-percent of all couplers shall be tested.

   If failure of the tested splice occurs with testing of the 25-percent requirement, as stated above, then all couplers shall be rejected.

5. The fabricator, in processing steel for the couplers through his works, shall maintain identity of the material and shall maintain suitable procedures and records attesting that the specified coupler has been furnished. The ASTM or other specification designation shall be included near the erection mark on each shipping assembly or important construction component over any shop coat of paint prior to shipment from the fabricator's plant. The fabricator's identification mark system shall be established and on record prior to fabrication.

   Couplers which are not readily identifiable from marking and test records shall be tested to determine conformity to this report. The fabricator shall, when requested, furnish an affidavit of compliance. Test data shall be provided upon request.

6. Splice locations shall be fully detailed on the plans.

7. Requirements for concrete cover and space between bars or sleeves shall be applicable at splices.

DISCUSSION

The approval is based on tests.

Addressee to whom this Research Report is issued is responsible for providing copies of it, complete with any attachments indicated, to architects, engineers and builders using items approved herein in design or construction, and must be approved by Department of Building and Safety Engineers and Inspectors.

This general approval of an equivalent alternate to the Code is only valid where an engineer and/or inspector of this Department has determined that all conditions of this Approval have been met in the project in which it is to be used.

Yeuan Chou

YEUAN CHOU, Chief
Engineering Research Section
2319 Dorris Place
Los Angeles, CA 90031
Phone (213) 485-2376
Fax (213) 847-0985

YC YC:elem
RR25619/wp8.0
R07/16/07
3A4/5A1/1912.1/1912.14/1912.15

City of Miami

September 8, 2006

CORRECTED COPY

Johnny Kwok SE MBA
MMFX Technologies Corp.
2415 Campus Drive #100
Irvine, CA 92612

RE: **MMFX 2 Rebar (100 ICSI minimum yield strength)**
For reinforce concrete structure

Dear Mr. Kwok:

This is in response to your July 25, 2006 letter in which you request the use of MMFX 2 Rebar **(100 KSI** minimum yield strength) for reinforced concrete structures as an alternative material and method of construction in building design.

Our in-house staff has reviewed the package you submitted, supporting test documents, and specifications and they found that the MMFX 2 Rebar 100 KSI reinforcement can be accepted for all reinforced concrete structures with its limitation in longitudinal reinforcement as specified In ACI Section 21.2.5. We are of the opinion that thru proper design, this product will meet the current code requirements.

While you are currently proposing the use of this foundation level, please notify me in writing when you propose to use this for the building structure.

Very truly yours,

Jose L. Ferras
Building Official

c: Structural Plans Examiners
Central File

CITY OF ORLANDO
OFFICE OF PERMITTING SERVICES

September 25, 2006

Johnny Kwok S.E. MBA
Assistant Director of Engineering
MMFX Technologies Corporation
2415 Campus Drive, Suite 100
Irvine, CA 92612

Re: General Approval for use of MMFX 2 Rebar (100ksi minimum yield strength) in reinforced concrete structures

Dear Mr. Kwok:

This is in response to your letter dated July 18, 2006 requesting the Building Official to review and grant general approval for the use of MMFX 2 rebar, conforming to ASTM A1035, in design of reinforced concrete structures.

We have reviewed the submitted package and hereby accept the use of MMFX 2 rebar up to 100 ksi design yield strength in the design of reinforced concrete structures, as an alternate material and method of construction. It is our belief that the use of this innovative material would result in a better overall building product by relieving a common construction issue with rebar congestion and allowing proper consolidation of concrete, especially in foundation systems and shearwalls. In addition, the corrosion resistant nature of the rebar would provide a more durable structure.

If you have any question or concern regarding this matter, please feel free to contact me at 407-246-2525.

Sincerely yours,

Thomas D Hite

Thomas Hite
Building Official

Visit our website at: www.cityoforlando.net/permits

CITY HALL • 400 SOUTH ORANGE AVENUE • LOBBY FLOOR • P.O. BOX 4990 • ORLANDO, FLORIDA 32802-4990
PHONE 407-246-2271 • FAX 407-246-2882

THE CITY OF SAN DIEGO

RECEIVED
JUL 13 2005
KPFF - SAN DIEGO

July 11, 2005

Mr. Geoff Warcholick
KPFF Consulting Engineers
3131 Camino Del Rio North, Suite 1080
San Diego, CA 92108

Ref: Alternate Design Approach to allow the use of MMFX 100 KSI Reinforcing Steel in the Mat Foundation of Diamond View Tower office project located at 350 10th Avenue, (Case # 0542 Pts # 67757).

Dear Mr. Warcholick:

This letter is in response to your application submitted on June 13, 2005 where you requested acceptance of the use of Alternate Materials, Design, or Construction Methods per Section §129.0109 of the San Diego Municipal Code. More specifically you request an alternate design approach for the use of a type and grade of reinforcing steel not currently adopted into the current building code and the referenced concrete design standards.

Section 129.0109 of the San Diego Municipal Code (SDMC) authorizes the Building Official to grant approval for the use of any alternate material, design, or construction method when the Building Official determines that the proposed alternate material, design, or construction method complies with the Building, Electrical, Plumbing, or Mechanical Regulations; and that the proposed alternate material, design, or construction method is at least equivalent to the standards prescribed in the applicable regulation in terms of suitability, quality, strength, effectiveness, fire resistance, durability, safety, and sanitation. Additionally, the SDMC requires that sufficient evidence has been submitted to substantiate any claims that may be made regarding the use of any proposed alternate material, design, or construction method.

Your application, as well as documentation submitted in support of your request, show a concrete hi-rise building utilizing a steel braced frame system and supported on a continuous mat foundation. The frame columns will transfer their lateral loads into the floor diaphragm located above the first basement level and will continue concrete encased down to the mat foundation.

We have carefully reviewed the requirements of the 2001 California Building Code (CBC) in Section 1909.4 as well as the technical arguments put forward in your request, and hereby grant approval for the use of the proposed reinforcing steel only within the mat foundation as proposed:

1. The corrosion resistant properties of the MMFX reinforcing bars will provide better building performance from a serviceability standpoint. Any concealed and non-visible cracking in the

foundation may expose the reinforcing steel to unwanted moisture contact; the improved corrosion resistance will improve the longevity of the structure.

2. The MMFX steel reinforcing bars will not be used in flexural elements subjected to significant ductility demand as would be expected of ductile concrete moment frames or concrete shear wall boundary elements. Columns supported by the mat foundation typically transfer axial loads and vertical loads due seismic uplift of the frames above upper most basement level.
3. The use of steel reinforcing bars with a higher tensile yield strength will result in less reinforcing congestion and will therefore enhance performance of the foundation system due to improved consolidation of the poured in place concrete.
4. Substantiation has been provided by Robert F. Mast, past member of ACI committee 318 in 1971, and discusses why the 80,000 psi Fy limit for reinforcing steel bars remains in the concrete code. The primary concern was with axially loaded concrete elements such as columns and not flexural elements such as mat foundations. The Fy was limited such that the steel strain of .35% to be compatible with concrete strain of approximately .30%.

As a condition of granting this approval you are hereby requested to certify to the Building Official in writing that the proposed the alternative design has been implemented per this approval. This written certification must be submitted prior to final inspection and should be based on your site visit to confirm implementation and operation of the proposed alternatives.

A copy of this approval will be forwarded to the Structural Inspection Section of the Division of Building and Safety as well as Mohammad Heivand.

Please feel free to contact me at (619) 446-5406, or Ali Fattah at (619) 446-5092 should you need to discuss this matter further.

Sincerely,

Isam Hasenin, P.E., C.B.O.
Chief Building Official

AF:alm

cc: Isam Hasenin, Correspondence File
Joe Harris, Inspection Services
Mohammad Heivand, Plan Reviewer
DSD Geo File, Records Supervisor
Pete Fischer, Plan Review Supervisor
Senior Research Engineer

THE CITY OF SAN DIEGO

May 10, 2005

RECEIVED
MAY 13 2005
KPFF SAN DIEGO

Mr. Geoff Warcholick
KPFF Consulting Engineers
3131 Camino Del Rio North, Suite 1080
San Diego, 92108

Ref: Alternate Design Approach to Allow the Use MMFX 100 KSI Reinforcing Steel in the Mat Foundation of the Hard Rock Hotel Project Located at 275 5th Avenue (Case # 0524 PTS # 66851).

Dear Mr. Warcholick:

This letter is in response to your application submitted on March 11, 2005 where you requested acceptance of the use of Alternate Materials, Design, or Construction Methods per Section §129.0109 of the San Diego Municipal Code. More specifically you request an alternate design approach for the use of a type and grade of reinforcing steel not currently adopted into the current building code and the referenced concrete design standards.

Section 129.0109 of the San Diego Municipal Code (SDMC) authorizes the Building Official to grant approval for the use of any alternate material, design, or construction method when the Building Official determines that the proposed alternate material, design, or construction method complies with the Building, Electrical, Plumbing, or Mechanical Regulations; and that the proposed alternate material, design, or construction method is at least equivalent to the standards prescribed in the applicable regulation in terms of suitability, quality, strength, effectiveness, fire resistance, durability, safety, and sanitation. Additionally, the SDMC requires that sufficient evidence has been submitted to substantiate any claims that may be made regarding the use of any proposed alternate material, design, or construction method.

Your application, as well as documentation submitted in support of your request, show a concrete hi-rise building utilizing a shear wall system and supported on a continuous mat foundation.

We have carefully reviewed the requirements of the 2001 California Building Code (CBC) in Section 1909.4 as well as the technical arguments put forward in your request, and hereby grant approval for the use of the proposed reinforcing steel only within the mat foundation as proposed:

1. The corrosion resistant properties of the MMFX reinforcing bars will provide better building performance from a serviceability standpoint. Any concealed and non-visible cracking in the foundation may expose the reinforcing steel to unwanted moisture contact; the improved corrosion resistance will improve the longevity of the structure.
2. The MMFX steel reinforcing bars will not be used in flexural elements subjected to significant ductility demand as would be expected of ductile concrete moment frames or concrete shear wall

boundary elements

3. The use of steel reinforcing bars with a higher tensile yield strength will result in less reinforcing congestion and will therefore enhance performance of the foundation system due to improved consolidation of the poured in place concrete.
4. Substantiation has been provided by Robert F. Mast, past member of ACI committee 318 in 1971, and discusses why the 80,000 psi Fy limit for reinforcing steel bars remains in the concrete code. The primary concern was with axially loaded concrete elements such as columns and not flexural elements such as mat foundations. The Fy was limited such that the steel strain of .35% to be compatible with concrete strain of approximately .30%.

As a condition of granting this approval you are hereby requested to certify to the Building Official in writing that the proposed the alternative design has been implemented per this approval. This written certification must be submitted prior to final inspection and should be based on your site visit to confirm implementation and operation of the proposed alternatives.

A copy of this approval will be forwarded to the Structural Inspection Section of the Division of Building and Safety as well as the Fire Marshal's office. A copy of this approval letter must be presented to the combination building inspector prior to requesting an inspection.

Please feel free to contact me at (619) 446-5406, or Ali Fattah at (619) 446-5092 should you need to discuss this matter further.

Sincerely,

Isam Hasenin, P.E., C.B.O.
Chief Building Official

cc: Isam Hasenin, Correspondence File
Joe Harris, Inspection Services MS #1102B
Sam Oates, Fire and Life Safety Services, MS #603
DSD Geo File, Records Supervisor, MS #201
Plan Review Supervisor, Pete Fischer, MS #401
Plan Reviewer, John Diebold, MS #401
Senior Research Engineer, MS #401

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City of Irvine, One Civic Center Plaza, P.O. Box 19575, Irvine, California 92623-9575 (949) 724-6000

December 12, 2006

06VA1477

Mr. Johnny Kwok
MMFX Technologies Corporation
2415 Campus Drive, Suite 100
Irvine, CA 92612

SUBJECT: Approval for use of MMFX2 steel reinforcement conforming to ASTM A1035 in design of reinforced concrete mat foundations.

Dear Mr. Kwok

This is in response to your request for approval to use MMFX Technologies Corporation reinforcement steel conforming to ASTM A1035 in mat foundations, using a design yield strength of up to 100 ksi using the 0.2% offset method. The requested design yield strength of up to 100 ksi exceeds the code limit of 80 ksi per California Building Code (CBC) Section 1909.4.

Section 105 of the UAC authorizes the Building Official to grant approval for the use of any alternate material, design, or construction method when the Building Official determines that the proposed alternate material, design, or construction method complies with the Building, Electrical, Plumbing, or Mechanical Regulations; and that the proposed alternate materials, design, or construction method is at least equivalent to the standards prescribed in the applicable regulations in terms of suitability, quality, strength, effectiveness, fire resistance, durability, safety, and sanitation. Additionally, the UAC requires that sufficient evidence has been submitted to substantiate any claims that may be made regarding the use of any proposed alternate material, design or construction method.

The benefits of using steel reinforcing bars with higher yield strength, such as MMFX2 steel, include reducing reinforcing congestion. Reducing reinforcement congestion improves consolidation of the poured in place concrete. MMFX2 steel also has the benefit of having enhanced corrosion resistance.

After review of the requirements of the 2001 CBC as well as the submitted documentation including the report prepared by Dr. S.K. Ghosh of S.K. Ghosh and Associates, dated April 2006, the approval findings of the cities of Los Angeles, Long Beach and San Diego, reports of tests conducted on MMFX2 steel at various universities, the use of MMFX2 steel reinforcement conforming to ASTM 1035 is approved for use in thick reinforced concrete mat foundations subject to the following conditions:

1. MMFX2 steel reinforcement is permitted for use in mat foundations only.

2. The yield strength used in design calculations shall not exceed:
   a) 100 ksi in tension;
   b) 80 ksi in compression; and
   c) 60 ksi for shear reinforcement in tension.

3. MMFX2 steel reinforcing bars, when designed using higher yield strength, shall have proportionally longer development length and lap length than that based on 60 ksi yield strength.

4. MMFX2 ASTM A1035 deformed steel reinforcing bars shall be distinctly marked for field identification.

5. MMFX2 steel reinforcement bars shall not be welded unless the welding protocol is provided by manufacturer for the specific application and approved by the City of Irvine.

6. The MMFX steel reinforcing bars shall not be used in flexural elements subjected to significant ductility demand as would be expected of ductile concrete moment frames including grade beams or concrete shear wall boundary elements.

If you should have any questions, please contact Kam Chitalia, Principal Plan Check Engineer at (949) 724-6371.

Recommended by:

Kam Chitalia

KAM CHITALIA, S.E.
Principal Plan Check Engineer

Approved by:

Eric M. Tolles

ERIC M. TOLLES, S.E.
Chief Building Official

cc: file

VII. Reference Publications / Reports / Papers

The following reference documents are provided to allow the opportunity for a more detailed review of MMFX 2 rebar's corrosion and structural characteristics.

A. Corrosion Test Reports, Papers, and Analysis References

1. **Laboratory Evaluation of Corrosion Resistance of Steel Dowels in Concrete Pavement – January, 2007 – Final Report- John Harvey, PhD et al.- Pavement Research Center-Institute of Transportation Studies – UC Berkeley and Davis**: This pavement dowel corrosion report indicates that Microcomposite (MMFX 2) pavement dowel bar had approximately 35 times the polarization resistance of carbon steel dowels. The report noted that epoxy bars presented some risk of corrosion, recommending special care be taken in shipping, handling, and storage to prevent localized corrosion initiating holidays. It recommended that Microcomposite steel dowel be considered for locations with high corrosion exposure.

2. **Summary Report on the Performance of Epoxy-Coated Reinforcing Steel in Virginia Richard E. Weyers, Michael M. Sprinkel** , **Michael C. Brown** , **- VTRC Report 06-R29 - June 2006**: This report based on 14 years of research by VTRC of corrosion resistant reinforcing steel alternates states: "because ECR cannot provide adequate 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 amend its specifications regarding the use of ECR to require the use of corrosion-resistant metallic reinforcing bars such as MMFX 2, ..."

3. "**Comparative Performance of MMFX Microcomposite Reinforcing Steel and Other Types of Steel with Respect to Corrosion Resistance and Service Life Prediction in Reinforced Concrete Structures"** – **Dr. D. R. Morgan - AMEC Earth & Environmental - June 2006:** This report makes the following conclusion after evaluating 14 studies and reports concerning the corrosion resistance properties of MMFX2 (Microcomposite) Steel reinforcement and other products: *"Studies evaluated in this report indicate that MMFX corrosion resistance is similar to or better than that of certain stainless steels such as 2101 and 3Cr12. … stainless steels (i.e. SS304 and SS316 series) appear to be more effective than MMFX for use in bridge and other structures exposed to chlorides, the lack of availability in North America of many the types of stainless steel evaluated, and their high costs compared to MMFX, make them less attractive from a life-cycle cost perspective for most applications."*

4. **Job Site Evaluation of Corrosion-Resistant Alloys for Use as Reinforcement in Concrete - William H. Hartt, Rodney G. Powers et. al. Report No. FHWA-HRT-06-078, June 2006**: This Federal Highway Administration (FHWA) report revaluated various corrosion-resistant reinforcement materials in comparison to ECR (epoxy coated reinforcing steel), including MMFX 2 rebar, as used in FHWA's Innovative Bridge Research and Construction (IBRC) Program. This

report was based on input concerning 27 IBRC projects, 12 of which included MMFX2 rebar. The report noted: "… corrosion-resistant reinforcing steel can be incorporated into bridge construction with relative ease and placed with less difficulty than ECR. Thus, these reinforcements are a viable technical alternative to ECR."

5. **ASM Handbook, Volume 13C, Corrosion: Environments and Industries Corrosion in Bridges and Highways – 2006 ASM International – J. Tinnea, W. Hartt, F. Pianca et. al.** This handbook chapter discusses the various aspects of corrosion associated with bridge structural elements in corrosive environments and describes alternative corrosion-resistant reinforcement systems. ASTM A1035 (MMFX 2 Steel) is noted a having the same Cl^-/OH^- ratio of 4.9, as 316 stainless steel cladded reinforcement, as a measure of its corrosion resistance. (Copy of this reference is available from the American Society for Metals- ASM).

6. **Evaluation of corrosion resistance of different steel reinforcement types - Final Report • May 2006 - Iowa State University Bridge Center (CTRE Project 02-103):** Voltage and current results from field monitoring of a instrumented bridge constructed half with MMFX Steel and half with ECR indicated: 1. The MMFX half remained within the normal range at less than 100mV; appeared to have no ongoing corrosion activity. 2. In contrast, ECR unexpectedly had readings that were two times greater than MMFX, close to 200 mV. This lead to the report's speculation that defects in the coatings had occurred during construction.

7. **"New Technologies Proven in Precast Concrete Modular Floating Pier for U.S. Navy" – PCI Journal July-August 2005 - Michael W. LaNier, PE, FPCI, Preston S. Springston et.. al.:** This article notes that the Navy's Modular Hybrid Pier (MHP) project received Precast / Prestressed Concrete Institute's (PCI's) Henry N. Edwards award and updates - Preston Springston's ASCE paper. Project review procedures are discussed demonstrating why MMFX rebar was included in one of the project's two Navy MHP modules. The article noted that use of MMFX saved about $2.8 million over the original proposed design, while providing a 75-yr service life. MMFX's corrosion resistance performance was analyzed by the STADIUM computer model.

8. **Comparing the Chloride Resistances of Reinforcing Bars- Gerardo Clemeña Ph.D. and Paul Virmani Ph.D. – Concrete International - November 2004:** This article evaluates new, economical metallic reinforcement for its ability to withstand high salt concentration. The comprehensive study, on which the article is based shows that the chloride threshold of MMFX Microcomposite bars is about 5 to 6 times better than A615 steels and approximately 2 times chloride threshold of stainless steel 2101 LDX bars.

9. **A Critical Literature Review of High-Performance Reinforcements in Concrete Bridge Applications, Hartt, W.H., R.G. Powers, et. al. Report No. FHWA-HRT-04-093, July 2004:** This literature review was made high-performance reinforcement products, including MMFX 2 rebar, for concrete bridge applications. The report indicated that the high-performance alloys outperformed black steel from a corrosion resistance standpoint.

10. **ASCE Ports 2004 Conference Paper - Modular Hybrid Pier for Naval Ports Preston Springston, PE - Naval Facilities Engineering Service Center – May 2004:** This paper describes in part, how use of MMFX 2 rebar in the US Navy's Modular Hybrid Pier (MHP) program, can help to reduce operational repair costs of their piers by 80% over a 100 year service life. Service life of the pier's concrete exposed to seawater, using MMFX 2, was analyzed using a numerical model called STADIUM, Software for (modeling) Transport and Degradation in Un-Saturated Materials.

11. **2004 CBC Conference Paper - Characterization of Corrosion Resistant Reinforcement by Accelerated Testing – William Hartt Ph.D. et. al. - Florida Atlantic University – May 2004:** Wet-dry exposures and Cyclic Potentiodynamic Polarization (CPP) scans were performed on various corrosion resistant reinforcements. The corrosion rate for wet-dry exposure samples was calculated from both polarization resistance and weight loss measurements. Corrosion resistance for CPP scans was gauged in terms of the critical pitting potential. Results from preliminary experiments have been evaluated, and ultimately these will be compared with findings from ongoing long-term test yard exposure of concrete slabs fabricated with these same reinforcements.

12. **Accelerated Chloride Threshold Testing Part II - Corrosion Resistant Reinforcement –David Trejo Ph.D. and Radhakrishna Pillai - Texas A&M University, ACI Materials Journal January – February 2004:** This paper presents the results of testing MMFX 2 and two other corrosion resistant chrome alloy steel rebar materials using the ACT test procedure.

13. **Virginia Transportation Research Council (VTRC) Report 04-R7 - Gerardo Clemeña Ph.D. – December 2003:** This report describes testing, analysis and recommendations concerning various metallic bars, including MMFX 2, that were found to be more durable and corrosion resistant than epoxy-coated rebar, with the program's investigation serving as the basis for an ACI Materials Journal paper co-authored by VTRC's Dr. Gerardo Clemena and FHWA's Dr. Y. Paul Virmani. In conclusion the report recommends MMFX2 rebar for use by Virginia DOT in corrosive environments.

14. **CIAS (Concrete Innovations Appraisal Service) Report 03-2 "Appraisal Report High Corrosion Resistance MMFX Microcomposite Reinforcing Steels" – Prof. Paul Zia, Prof. Theodore Bremner, Dr. V. M. (Mohan) Malhotra, Morris Schupack, P.E., Paul G. Tourney, P.E. – May 31, 2003:** This document reports on the findings of the CIAS's MMFX corrosion panel's concluding that MMFX 2's corrosion resistance provides a longer service life and is more cost effective than A615 reinforcement.

15. **Accelerated Chloride Threshold Testing: Part I – ASTM A615 and A706 – David Trejo Ph.D. and Radhakrishna Pillai - Texas A&M University, ACI Materials Journal November – December 2003:** This paper presents the ACT (Accelerated Chloride Threshold) test method for measurement of critical chloride threshold levels of different steels in reinforced concrete, and provides test results on ASTM A615 and ASTM A706 reinforcing steels using the ACT test procedure.

16. **Evaluation of MMFX Corrosion-resistant Steel Dowel Bars in Concrete Pavements – Construction Report # WI-07-03 – July 2003 - Khader Abu al-eis - Wisconsin Department of Transportation:** This experimental study was initiated to evaluate MMFX corrosion-resistant steel dowel bars. The report makes the following conclusion concerning construction using MMFX 2 (ASTM A1035) pavement dowel bars: "Installing the MMFX steel dowel bars went very well with only minor, easily rectifiable problems encountered. The MMFX steel is superior in strength to that of standard steel."

17. **"Corrosion Evaluation of MMFX Reinforcing Steel" Preliminary Report – University of South Carolina - Branko Popov Ph.D. et. al. – May - 2002:** This report is based on corrosion testing, which included: MMFX 2, A615, and A706 rebar, was conducted in various test solutions, determining corrosion rates. MMFX 2 corrosion rate performance is indicated as being superior to A615 and A706 rebar.

18. **Corrosion Protection Strategies for Ministry Bridges - Final Report Amended July 31, 2000 - University of Waterloo - C.M. Hansson, R. Haas, R. Green, R.C. Evers, O.K. Gepraegs, and R. Al Assar**: This report states: "Major concerns exist with the inability of maintaining a flaw-free coating on ECR during handling, placement and compaction of the concrete, and with disbondment of the coating ... In turn, concern exists that this provides easy access to chlorides and, thus, allows corrosion at flaws and along the bar under the disbonded coating. … There is additional concern regarding the difficulty of monitoring the condition of ECR and of repair/rehabilitation cycles over the 75 years." …. "The conclusion is that options involving ECR present no cost or performance advantages over BSR [Black Steel Reinforcement]. … the further use of ECR is not recommended on the basis of both technical and life cycle cost analysis."

B. Structural Test Reports, Papers, and Analysis References

1. **Behavior of High Performance Steel as Shear Reinforcement for Concrete Structures – Final Report – North Carolina State Univ. – Constructed Facilities Laboratory – M. Sumpter, S. Rizkalla, P. Zia – June 2007 (91 pages):** This report concludes that: 1. "Direct replacement of conventional Grade 60 longitudinal reinforcement with MMFX [ASTM A1035] longitudinal reinforcement showed an optimum design by further increasing the shear strength and enhancing serviceability." 2. "The use of MMFX [ASTM A1035] steel, with a yield strength of 80 ksi, increases the allowable service stress level to 48 ksi. Shear crack widths measured for all tested beams reinforced with MMFX steel were within the allowable limit specified by the ACI Code."

2. **Evaluation of Bond Characteristics of MMFX Steel – North Carolina State Univ. – Constructed Facilities Laboratory, Technical Report No. RD-07-02 – H. Seliem, A. Hosny, S. Rizkalla – June 2007 (71 pages):** This report concludes that: A. Stress levels of 90 and 70 ksi can be achieved by No. 8 and No. 11 ASTM A1035 spliced bars without the use of transverse reinforcement (confinement). B. Spliced bar transverse reinforcement was able to develop a stress of 150 ksi for No. 8 and No. 11 A1035 bars and increased the ultimate load and ductility of the beams. C. Increasing the splice length, proportional to the square root of the ratio of the splice length and the bar diameter, increased the strength of the splice. D. Increasing the concrete cover by the square root of the ratio of the cover to the bar diameter, increases the stress developed in the spliced bars. E. Use of ACI 408 equation provides better prediction of stresses and less scatter than use of the ACI 318-05 equation.

3. **Effect of Confinement and Gauging on the Performance of MMFX High Strength Reinforcing Bar Tension Lap Splices - University of Texas (Austin) – K. Hoyt – May 2007 (60 pages):** This program reports on testing of beam-splice specimens using ASTM A1035 No. 8 bar splices in a constant moment region, with varied amounts of No. 4 Grade 60 transverse reinforcement and spacing. It was found that: 1. ACI 408 equation provided a good estimate of failure stresses at high stress levels, but with predicted lower strengths than measured in beams with confinement. 2. The linear nature of the current development length code equation is acceptable. 3. Behavior of the interior splices were nearly identical to that of the exterior splice. 4. High steel stresses resulted in greater crack widths than currently acceptable for service load stresses using Grade 60 steel. The equation used to determine serviceability limits only appears to be effective for stress levels of 60 ksi or less.

4. **Performance of Tension Lap Splices with MMFX High Strength Reinforcing Bars - University of Texas (Austin)– G. Glass – May 2007 (141 pages):** This paper reports on tests from beam-splice specimens at the University of Texas, North Carolina State University, and the University of Kansas, making the following conclusions concerning ASTM A1035 reinforcement: A. A1035 lap splices developed bar stresses up to 155 ksi. B. ACI 408 development length equation provided relatively accurate estimates of failure stresses for splices with and without confining transverse reinforcement. C. ACI 318 and AASHTO LRFD development length equations provided unconservative calculated failure stresses for unconfined splices, while providing reasonable calculated failure stresses for confined splices. D. The addition of confining transverse reinforcement provided an increase in failure stress and was greater than predicted by either the ACI 408 or ACI 318 equation. E. The addition of confining transverse reinforcement provided an increase in beam deflections at failure; and was greater than proportional to the increase in confining reinforcement. F. Service level crack widths were greater than the limits used as a basis for serviceability provisions included in pre-1999 editions of ACI 318. G. Bar splices with stresses greater than 75 ksi should be designed using the ACI 408 development length equation with the modification factor, ϕ, equal to 0.82. H. A minimum level of transverse reinforcement should be included for all splices above 75 ksi except for those with No. 5 or smaller bars with large bar spacing and cover.

5. **Behavior of Minimum Length Splices of High-Strength Reinforcement – University of Texas (Austin) – K. Donnelly – 2007 (35 pages):** This paper reports on testing of spliced No. 5 ASTM A1035 longitudinal bars with varying levels of confinement. It found that ACI 408 stress values were more accurate than ACI 318, particularly when transverse reinforcement (confinement) was present within the splice length. It was noted that a proportional increase in splice strength can no longer be gained after a certain amount of transverse reinforcement (confinement) has been added to a splice.

6. **Fatigue Behaviour of MMFX Corrosion-Resistant Reinforcing Steel Siebren J. DeJong and Colin MacDougall Department of Civil Engineering, Queen's University, Ontario, Canada 7th International Conference on Short and Medium Span Bridges, Montreal, Canada, 2006.** This study indicated that MMFX was tested to have a fatigue life of 1 x 10^6 cycles at a stress range of approximately 310 MPa [45 ksi], compared to conventional steel 1 x 10^6 cycles at a stress range of approximately 166 MPa [24 ksi]. The study made the following conclusion: "Thus, MMFX exhibits superior fatigue resistance under constant amplitude loading in an air environment than conventional steel reinforcing bars."

7. **Bond Characteristics of High-Strength Steel Reinforcement - ACI Structural Journal Vol. 103, No. 6 November - December 2006 -- R. El-Hacha, H. El-Agroudy, S. Rizkalla.** This paper summarizes the findings of a study concerning the bond characteristics of MMFX 2 steel bars, based on testing of a series of beam end specimens, comparing MMFX 2 bars to A615 Grade 60. The bond behavior of the MMFX 2 bars was found to be similar to that of A615 Grade 60 ksi steel up to the proportional limit of 80 ksi, using splice length to bar diameter (L_s/d_b) of 30 db. A splice length of 45 d_b was found to be adequate for a MMFX 2 bar yield strength of 110 ksi.

8. **"Seismic Behavior of Bridge Columns Built Incorporating MMFX Steel" – University of California, San Diego – Report No. SSRP – 2003/09 – Bernd Stephan , Jose Restrepo, Frieder Seible – October 2003:** Testing was performed on two similar column units constructed using ASTM 706 Grade 60 and MMFX 2 reinforcing bars. The ASTM unit was designed according to the CALTRANS Bridge Design Specifications (July 2002) and MMFX unit incorporated MMFX's design strength resulting in approximately half the steel requirement of the ASTM unit. The tests conclusively showed that both units can be designed to form ductile flexural plastic hinges and can sustain drift levels of approximately 4% without failure and complied with CALTRANS column seismic failure criteria. (See also – "**Seismic Testing of Bridge Columns Incorporating High-Performance Materials" – ACI Structural Journal Vol. 103, No. 4 July-August 2006 -- J. I. Restrepo, F. Seible, B. Stephan, M. J. Schoettler**.)

9. **"Shear Behaviour of Concrete Beams Reinforced With MMFX Steel Without Web Reinforcement" - Constructed Facilities Laboratory - North Carolina State University – April 2006 – R. El-Hacha and S. Rizkalla** This program tested four beams with shear span-to-depth (a/d) ratio of 1.79 using a clear span of 10 ft. and two beams were tested with shear span-to-depth (a/d) ratio of 2.6 using a clear span of 14.5 ft to failure. Despite the reduction of the longitudinal reinforcement area (40 percent less) of MMFX steel used, the shear capacity of the beams with a/d ratio of 1.79 and reinforced with MMFX steel was 80 percent higher than those reinforced with grade 60 steel. For the beams with a/d ratio of 2.6, the beam reinforced with MMFX steel had a capacity of 12 percent more than the beam reinforced with conventional Grade 60 steel. The higher failure loads achieved by the beams reinforced with MMFX steel compared to the beams reinforced with Grade 60 steel is due to the high-strength characteristics of the MMFX steel which is more than twice of the Grade 60 steel.

10. **Behavior of Concrete Bridge Decks Reinforced with MMFX Steel - Hatem Seliem, Gregory Lucier, Sami Rizkalla and Paul Zia – Proceedings for Structural Faults & Repair 2006, Edinburgh, Scotland – June 2006:** This paper states the following conclusions based on testing of full scale bridge deck sections at North Carolina State University: "The ultimate load carrying capacity of the three bridge decks tested in this investigation was eight to ten

times the service load specified by AASHTO Design Specifications (1998). Bridge decks reinforced with 33 percent less MMFX steel [90 ksi design yield strength] developed the same ultimate load carrying capacity and deflection at service load as those reinforced with Grade 60 steel. This is attributed to the higher strength of the MMFX steel compared to Grade 60 steel."

11. **Application of ASTM A 1035 MMFX Steel Reinforcement in Building Applications: An Appraisal – S.K. Ghosh - April 2006 - S.K. Ghosh Associates Inc. :** This report examines various design aspects for use of MMFX 2 rebar in building structural applications, relating the design to appropriate ACI 318 Sections. Conclusions of the report describe considerations for: a. allowable flexural tension design at 100 ksi, 80 ksi in flexural compression, and 60 ksi for shear strength, and b. one-way slab tension design at 100 ksi limitations, among design aspects presented.

12. **MMFX Rebar Evaluation for I-95 Service Road Bridge 1-712-B – Center for Innovative Bridge Engineering - University of Delaware – March 2005 - M. McNally, M. Chajes et al.** The following is a summary of results from the four point bending tests of the standard beam [60 ksi yield design], MMFX4 beam [same reinforcement as 60 ksi yield design], MMFX2 beam [100 ksi yield design], and the CFRP beam [ACI ACI 440.1 R-01 design guideline]. Both ultimate loads and mode of failure were predicted with good accuracy using traditional equations for the MMFX reinforced beams. Yield deflection calculations were smaller and load at L/800 calculations were greater than the actual measured yield deflection and load at L/800 values for all beams. This may have been due to early cracking. All beams cracked at a similar load level. Both MMFX beams failed in the desired mode. For both beams, the MMFX rebar yielded prior to failure.

13. **Evaluation of MMFX Steel For NCDOT Concrete Bridges – FHWA/NC/2006-31, NCDOT Report 2004-27 – S. Rizkalla, P. Zia et. al. – December 2005** This publication states the following conclusions based on testing of full scale bridge deck sections and corrosion tests at North Carolina State University: "1. Substituting MMFX steel directly for Grade 60 steel in a design … is an overly-conservative approach. 2. MMFX steel [ASTM A1035] can be used as the main flexural reinforcement for cast-in-place concrete bridge decks at a reinforcement ratio corresponding to 33% less than that required for Grade 60 steel. Therefore, a design of reinforced concrete bridge decks using MMFX steel may utilize an equivalent yield stress of 90 ksi for the MMFX steel bars. 3. Design of concrete bridge decks utilizing the high tensile strength characteristics of the MMFX steel should satisfy all minimum reinforcement ratios required by the AASHTO LRFD Bridge Design Specifications as well as the serviceability requirements of the specifications. 4. MMFX steel [ASTM A1035] has a much lower corrosion rate compared to conventional Grade 60 steel. Therefore, the use of MMFX steel could increase the service life of concrete bridges and lower repair costs."

14. **Tensile Test – Coupled Reinforcing Steel Bars (w/ Stress vs. Strain Graphs) – Smith Emery Laboratories – February 2005:** This report covers the successful testing of #4, #8, #9, #10, and #11 MMFX Bars fitted with Barsplice® couplers. The report covers test results and photographs of tested samples.

15. **Smith Emery Laboratories – Certificates of Compliance**
ASTM A615/615M Grade 75 Deformed Reinforcing Steel – February 2003
ASTM A1035/A1035M Deformed Reinforcing Steel - August 2004
Smith-Emery Laboratories – P. John Latiolait: These test results took place at an ICC (International Code Council) certified commercial material testing laboratory; and confirm that MMFX 2 rebar meets or exceeds the requirements for ASTM A615/615M Grade 75 and ASTM A1035/A1035M for bar sizes 4 through 11.

16. **Tensile Testing of Mechanical Bar Splices for MMFX Steel– Florida DOT - Antonis Michael - February 2004:** Two types of commercially available mechanical splices for #6 bars were tested to establish compatibility with MMFX 2 rebar. Both splice types exceeded the capacity of the MMFX bar and failure occurred in the steel bar. The average stress in the bars at failure was 173.6 ksi.

17. **"Seismic Behavior of Bridge Columns Built Incorporating MMFX Steel" – University of California, San Diego – Report No. SSRP – 2003/09 – Bernd Stephan , Jose Restrepo, Frieder Seible – October 2003:** Testing was performed on two similar column units constructed using ASTM 706 Grade 60 and MMFX 2 reinforcing bars. The ASTM unit was designed according to the CALTRANS Bridge Design Specifications (July 2002) and MMFX unit incorporated MMFX's design strength resulting in approximately half the steel requirement of the ASTM unit. The tests conclusively showed that both units can be designed to form ductile flexural plastic hinges and can sustain drift levels of approximately 4% without failure and complied with CALTRANS column seismic failure criteria. (See also – "**Seismic Testing of Bridge Columns Incorporating High-Performance Materials" – ACI Structural Journal Vol. 103, No. 4 July-August 2006 -- J. I. Restrepo, F. Seible, B. Stephan, M. J. Schoettler**.)

18. **Reinforcement Alternatives for Concrete Bridge Decks - Research Report KTC-03-19/SPR-215-00-1F Issam Harik, Ph.D. et. al. Kentucky Transportation Center July 2003:** This report investigates the application of various reinforcement types in concrete bridge decks as potential replacements or supplements to conventional steel reinforcement. Traditional epoxy coated reinforcement (ECS), stainless steel clad (SSC) reinforcement, MMFX microcomposite reinforcement, and carbon fiber reinforced polymer (CFRP) reinforcement were evaluated. Tests were conducted to determine the material properties of each reinforcement type. Full-scale two-span reinforced concrete deck specimens were load tested to evaluate their

performance.

19. **"Development Length of Micro-Composite (MMFX) Steel Reinforcing Bars Used In Bridge Deck Applications" - University of Massachusetts Amherst – June 2003 - Sean Peterfreund ...** This program tested "…Three reinforced concrete beams containing #4 MMFX bars for tensile reinforcement, and three beams containing #5 MMFX bars were loaded and examined under flexural failure. The tests were evaluated to determine the adequacy of the development length code equation contained in ACI318-02 (Equation 6-1) when designing with MMFX bars. The 0.2 percent offset method was applied to tensile testing data to obtain a yield stress of approximately 120 ksi. This value was then used in equation 6-1 to determine a theoretical development length. The theoretical length was compared to strain data obtained from the beam tests. From this data, it was concluded that the theoretical length was more than adequate to develop the flexural capacity of the beam."

20. **"Behaviour of MMFX-2 Microcomposite Steel and Stainless Steel Rebars In Uniaxial Axial Tension" – Constructed Facilities Laboratory - North Carolina State University - November 2002 – R. El-Hacha and S. Rizkalla** Testing was performed … **"**to evaluate the tensile behaviour of the #4 MMFX rebars loaded and unloaded in tension at different stress levels, and to determine the stress-strain characteristics of #6 stainless steel rebars." [MMFX's] "…average offset yield strength using three specimens was found to be 117ksi with a standard deviation equal to 4ksi. The average ultimate strength using three specimens was found to be 159ksi with a standard deviation equal to 1ksi. MMFX steel rebars were unloaded at different selected stress values then reloaded to failure, the curve continued upward to the point at which unloading started during the first loading cycle then followed the same path as the original stress-strain curve of the specimen tested to failure without unloading."

21. **Fundamental Material Properties of MMFX Steel Rebars", North Carolina State University, NCSU-CFL Report No. 02-04, Raafat El-Hacha Ph.D. and Sami Rizkalla Ph.D., July 2002:** This report provides preliminary data for the fundamental mechanical material properties of MMFX steel reinforcing rebars. The testing focused on the mechanical properties in tension and in compression, shear strength, fatigue strength, effect of bend on tensile strength of the bent rebar (stirrup), bond strength and development length, and the behavior of MMFX rebars as compression steel in reinforced concrete columns.

22. **Experimental Investigation of the Flexural Behavior of Reinforced Concrete Beams Using MMFX Steel, Final Report, University of North Florida - Faris A. Malhas, Ph.D.. – July 2002:** Test program indicated that all MMFX reinforced beams exhibited a ductile behavior with the steel strained significantly, when the crushing strain of the concrete was reached. No other mode of failure was observed in any of the tests. Stiffness of the

beams was significantly reduced after cracking and was more pronounced when compared to the computed behavior of regular steel. Service load testing for all specimens indicated that live load deflection would most probably satisfy the ACI Code, and at no time it was excessive. Comparison with control beams have shown that other than the reduced flexural stiffness, the MMFX beams were comparable in behavior to regular steel and the replacement of regular steel without compromising the structural characteristics of the flexural components.

23. **Bending Behavior of Concrete Beams Reinforced with MMFX Steel Bars, Constructed Facilities Center, West Virginia University - Vijay P.V., Ph.D. et. al - July 2002:** Theoretical moments can be predicted very well using current theories. Beams exhibited significant amount of elongation before compression failures (secondary) occurred. Deflection values can be well approximated up to a stress level of 75 ksi (within the serviceability stress limits) using actual stiffness of the bar at a given stress level and also by accounting the corresponding increase in strain as compared to Es = $29x10^6$ psi. The crack width values evaluated by using stress in tension steel and also by accounting for the corresponding strain value at that stress level led to very good prediction of crack widths.

24. "**A Comparative Bond Study of MMFX Reinforcing Steel in Concrete**" **Michigan Technologies University, CSD-2002-03 Final Report, Tess Ahlborn Ph.D. and Tim DenHartigh -July 2002:** This study contains the results of one hundred thirty bond tests were performed with beam-end specimens similar to ASTM A944 specimens. Statistical comparisons of MMFX reinforcement test results were made to predict values for bond strength of MMFX and A615 reinforcement. Test results indicated that no modifications were suggested when estimating the development length of MMFX reinforcement as a one-to-one replacement for ASTM A615 ASTM Gr. 60 reinforcement, No. 4 to No. 6 bars, using standard development relationships

25. **"Investigation into the Structural Performance of MMFX Reinforcing" (Preliminary Draft) – Florida Dept of Transportation – Structures Research Center – June 21, 2002 – Marc Ansley** A series of 4 sets of beams were tested to determine the structural performance of MMFX reinforcing steel compared to standard Grade 60 reinforcing (ASTM A615). In general the MMFX steel performed well providing capacity that exceeded the standard reinforcing in all cases. The only concern was that to insure ductile behavior changes in detailing would be required with MMFX reinforcing due to its greater tensile capacity and lack of a distinctive yield point.

26. **Standard Specification for Deformed and Plain, Low-carbon, Chromium, Steel Bars for Concrete Reinforcement:** This specification covers low-carbon, chromium, steel bars, deformed and plain concrete reinforcement in cut lengths and coils. Bars are of two minimum yield strength levels as defined in namely, 100 000 psi [690 MPa], and 120 000 [830 MPa] designed as Grade 100 [690] and Grade 120 [830], respectively.

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