Comparative Cost Analysis of MMFX Bars in Indian Scenario

Virendra Kumar Paul, Salman Khursheed and Md. Asif Akbari

Abstract In this research work, an attempt has been made to do a comparative study of MMFX bars in place of Fe-500 bars which are used extensively in building construction industry these days. The average tensile strength of which vary from 620 to 1030 MPA as compared to the tensile strength of conventional Fe-500 bars which is in the range of 500 MPA. As in the case of normal Fe-500 bars, the main issue was of rusting hence to overcome this high chromium content is mixed for making the MMFX bars. The chloride content is also taken four times higher in case of MMFX bars than the normal carbon steel bars. An attempt has been made to check the savings in quantity of steel by providing reinforcement with higher capacity as compared to Fe-500. At the same time, a cost model is also tried to work out to check its overall feasibility as per Indian condition. The findings of this report will benefit the cost consultants as well as researchers who have keen interest to implement and encourage the use of smart materials for building smart cities.

Keywords MMFX bars · Fe-500 bars · Smart materials for smart cities · New construction materials · Emerging material · Cost comparison · Optimization in RCC structure cost

1 Introduction

The main goal is to have a sustainable economic growth by improving the life of citizen. For this, the terms sustainable cities, smart cities or new technology communities are coined. There are many components of a smart city like energy, governance, environment, mobility and building and services. The use of advanced

V. K. Paul · S. Khursheed (✉) · Md. A. Akbari
Department of Building Engineering and Management,
School of Planning and Architecture, New Delhi, India
e-mail: salman.khursheed@spa.ac.in

V. K. Paul
e-mail: vk.paul@spa.ac.in

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material as one of the parameters is for judging the smart city network [1]. As per [2] the smart building is defined as a component of smart city and for that focus is given on the selection of innovative materials. As per [3] apart from sustainable environment, smart communication spaces, smart devices and smart cities also refer to a city using smart material. The smart material refers to a material having superior strength, ductility, toughness, initial and life cost efficiencies, ease of manufacture and application [4]. As per [5] smart structure is defined as the key component of smart city which apart from fulfilling technical criteria must also fulfil economic, sustainability and environment criterion. Therefore, there is a need to look beyond conventional steel and RCC framed structure and focus on those advanced construction technologies and materials which have better properties in terms of durability, sound insulation, earthquake resistance, strength and at the same time the project can be completed in lesser time with cost feasibility. As per [6] in his research titled “Smarter Material for Smart Cities” there are eleven smart materials defined, TMT bars was one of those. It is manufactured primarily from recycled scrap. Reinforcement with this higher capacity could provide various benefits by reducing member cross sections and reinforcement quantities, leading to savings in material, shipping, and placement costs. MMFX2 rebar can be found in the world’s best-engineered construction projects. Since 2002, this revolutionary steel product has been specified in public infrastructure and public/private development projects throughout the USA, Canada, Mexico and the Middle East.

2 Methodology

The methodology involves exploratory research on MMFX bars. To achieve the objective a building is modelled on ETABS 2016 using MMFX as well as Fe-500 bars as per case study. The ETABS 2016 model is then analysed for various structural properties and a relationship is defined among structural parameters of design and cost modelling after taking values of the various loading conditions according to the case study model. Then, at last a cost model is obtained from the relationship established.

3 Comparison with Stainless Steel Rebars

MMFX bars were invented at the University of California by Prof. Gareth Thomas [7]. The organisation based in USA, producing MMFX bars is the MMFX Steel Corp [8]. The MMFX bars have higher strength, fatigue resistance and ductility as compared to other high-strength bars because of its microstructure laminated lathe structure. Because of these changes at microstructure level MMFX bars has longer service life as well as lower construction cost. In terms of corrosion resistance, MMFX is similar to stainless steel. Comparing service life span both MMFX bars and SS rebars gives 100 years of service life but cost-wise MMFX is not even half of the cost of SS rebars if comparatively similar strength bars is selected as per American scenario [9]. As per Virginia Transportation Research Council (VRTC), the MMFX products are designated as the most cost-effective solution [10].

Further, MMFX rebar can be handled just like conventional steel bars, without the special handling requirements associated with SS bars. For example, MMFX is not considered dissimilar to carbon steel for galvanic corrosion purposes. Therefore, MMFX does not need to be isolated from carbon steels in construction, as SS bars do.

The drawback to reinforcing steel is its susceptibility to corrosion. One of the potential alternative to this problem is MMFX bars. MMFX bars do not corrode and come in many different forms that lend themselves to both exterior application for rehabilitation of existing RC columns and use as internal reinforcement to extend initial design life. As per [11] MMFX bars reduce the vulnerability of reinforcement to corrosion and works as an effective high-strength bar. The MMFX bars as compared to the conventional steel when used in an experiment provided better crack control after the yielding [12]. MMFX bars have the yield strength of approximately 828 N/mm^2 [13].

4 Structural Modelling of six Storey Commercial Block

The case study of a building considered is a super structure with the plan as shown in Fig. 1 Structural plan of building considered for case study. The building is modelled using ETABS 2016 having dimensions of 19 × 13.5 m and it is of six storey (G + 5). The building in the study considered is a commercial block with column, beam and slab type framed structure with shear walls. Since the effect of MMFX bars is being checked, the building is first modelled using Fe-500 conventional bars and then using MMfx bars. The building has non-uniform grid in both the directions. There are three different types of column which are 22 in numbers along with three different types of beams. The shear wall is provided in the lift core.

The structural model of building is prepared, analysed and designed in ETABS 2016 version. The load combination for different types of forces is applied on the structure. The member sizes and details are fixed by analysing the structure. Analysis is performed and results are compared for base shear, support reactions, storey drift, mode shapes, etc. The following criteria are assumed while analysing the building:

- The floor diaphragm is assumed to be rigid.
- Dynamic analysis to be performed using response spectrum method.
- All dimensions are in m, unless otherwise specified.
- The size of the framing plan is 19 m × 13.5 m.
- The framing plan is assumed to be Special Moment Resisting Frame (SMRF) (Table 1).

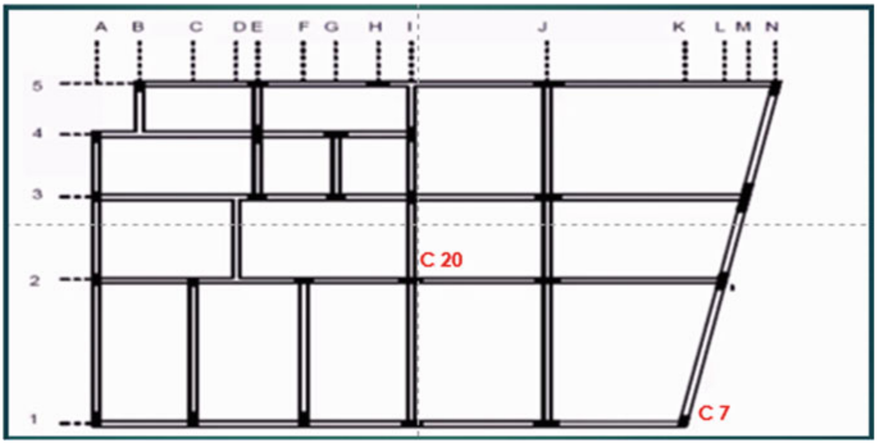

Fig. 1 Structural plan for building considered for case study showing columns C7 and C20

Table 1 Structural modelling of building

Modelling details of building		Remarks
Area	13.5 m × 19 m	
Storey details	Ground + 5 storeys	
Frame type	SMRF (Special Moment Resisting Frame)	Table 9, IS:1983:2016, part-I
Height of basement	5 m	
Height of ground storey	3 m	
Height of typical storey	3 m	
Purpose	Mercantile	IS:875:1987 part -II
Foundation support system	Fixed	
Seismic zone	Zone-IV	IS:1983:2016, part-I
Zone factor (*z*)	0.24	IS:1983:2016, part-I
Type of soil	Medium	IS:1983:2016, part-I
Damping ratio	5%	IS:1983:2016, part-I
Response reduction factor (*R*)	5	IS:1983:2016, part-I
Importance factor (*I*)	1	IS:1983:2016, part-I
Time period in *X* direction	0.319 s [clause 7.6.2, IS:1893: 2002, part-I]	IS:1983:2016, part-I
Time period in *Y* direction	0.378 s [clause 7.6.2, IS:1893: 2002, part-I]	IS:1983:2016, part-I

(continued)

Table 1 (continued)

Modelling details of building		Remarks
Material properties		
Grade of reinforcement (longitudinal/main)	Fe-500	MMFX grade 100 (690 MPA) for second building
Grade of reinforcement (shear/ties)	Fe-415	
Concrete		
Grade of concrete (beam, slab, staircase)	M25	
Grade of concrete (column, shear wall)	M30	
Density (M25)	25 KN/Cum	
Density (M30)	30 KN/Cum	
Poisson's ratio	0.20	
Structural members		
Thickness of slab	160 mm	
Thickness of sun-shade	125 mm	
Thickness of staircase	250 mm	
Thickness of shear wall	115 mm and 230 mm	
Thickness of shear wall	230 mm	
Dimension of beam	230 mm × 500 mm	
	300 mm × 600 mm	
	300 mm × 450 mm	
Dimension of column	230 mm × 400 mm	
	230 mm × 600 mm	
	300 mm × 600 mm	
Dead load intensities		
For 230 mm thick wall	12.34 KN/m	IS:875:1987 part-I
For 115 mm thick wall	6.82 KN/m	IS:875:1987 part-I
For parapet wall	5.14 KN/m	IS:875:1987 part-I
For slab	5.24 KN/sqm	IS:875:1987 part-I
For terrace	6.64 KN/sqm	IS:875:1987 part-I
For staircase	10.54 KN/sqm	IS:875:1987 part-I
Imposed load		
On every floor except terrace	5 KN/sqm	IS:875 part-II
On terrace	1.5 KN/sqm	IS:875 part-II

The modelling design and analysis are done using ETABS 2016 software. The building is analysed and designed for conventional Fe-500 and MMFX bars. The effect of brickwork is also taken into account along with the portal frame.

The storey and grid systems are defined and then the material properties of different items taken in the structural modelling followed by the load cases, then the earthquake resistant design parameters.

5 Modelling Results

It deals with both the structural comparative analysis was done using ETABS 2016 as well as cost comparative analysis of building modelled using Fe-500 and MMFX grade 100 bars. The below-mentioned graphs are showing storey drifts when the rebar is changed for Fe-500 to MMFX grade 100 rebars.

It is observed from Fig. 2 that storey drift for building with Fe-500 is more than building modelled using MMFX bars. The changes in the properties of MMFX bars in comparison to Fe-500 may be the reason behind this (Figs. 3 and 4).

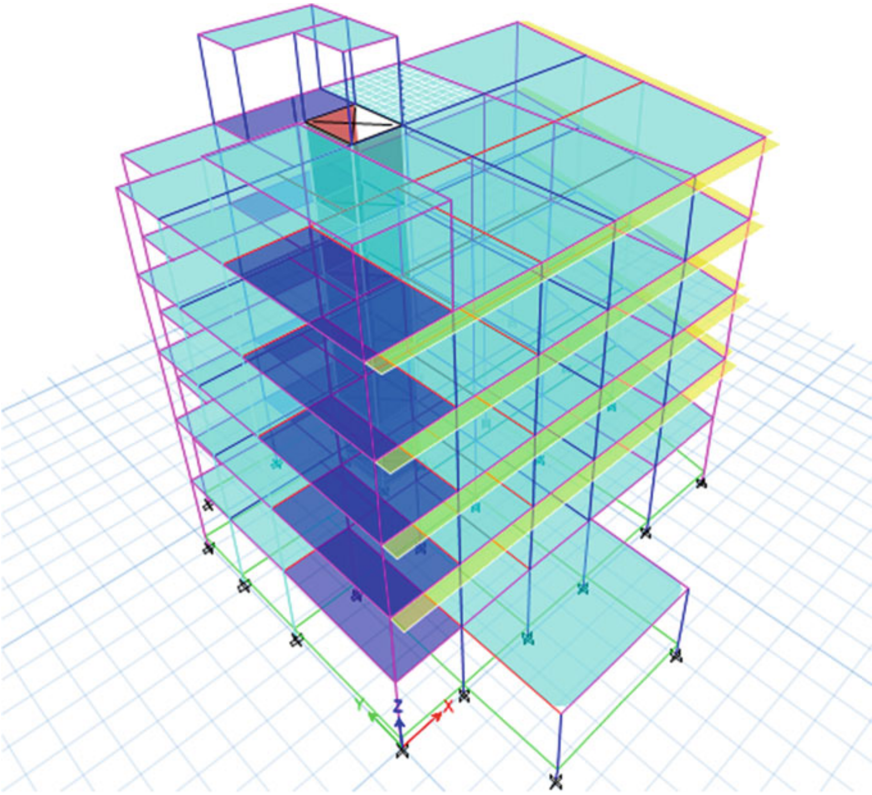

Fig. 2 3D view of commercial block modelled in ETABS 2016

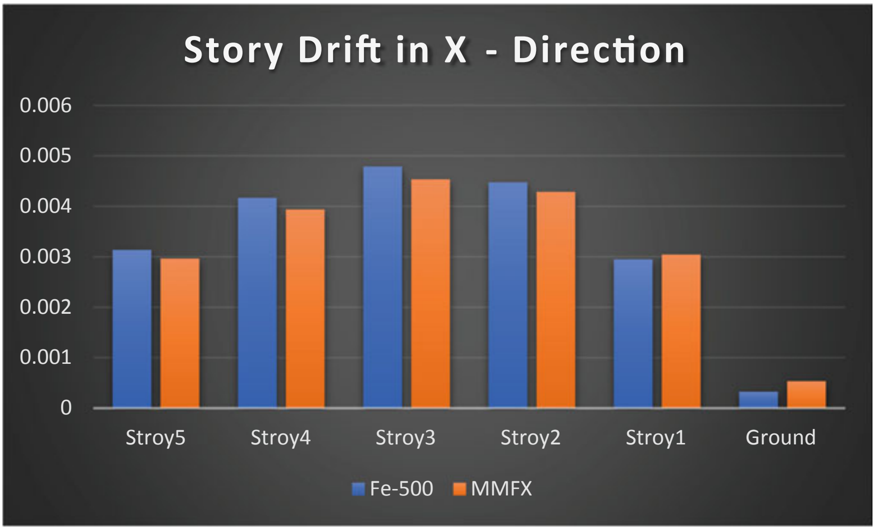

Fig. 3 Representation of storey drift in *X* direction when the rebar is changed for Fe-500 to MMFX grade 100 rebars

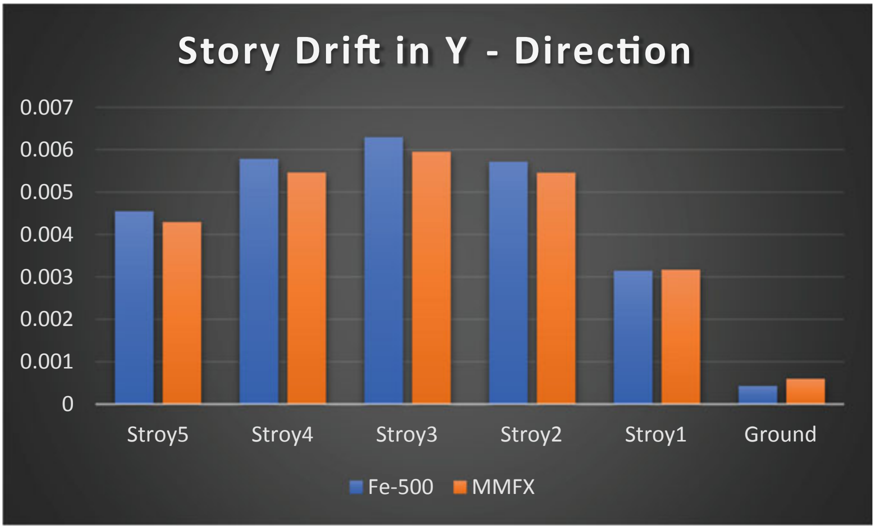

Fig. 4 Storey drift in *Y* direction for Fe-500 and MMFX grade 100 rebars

The same happened with storey drift in *Y* direction, because of the changes in the material properties of MMFX bars as compared to conventional FE_500 bars (Figs. 5 and 6).

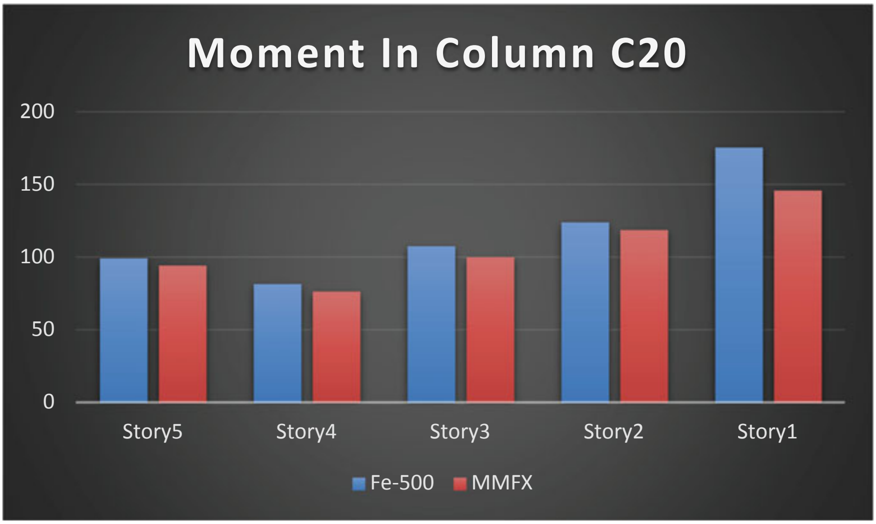

Fig. 5 Percentage variation of moment in column C20 (middle column)

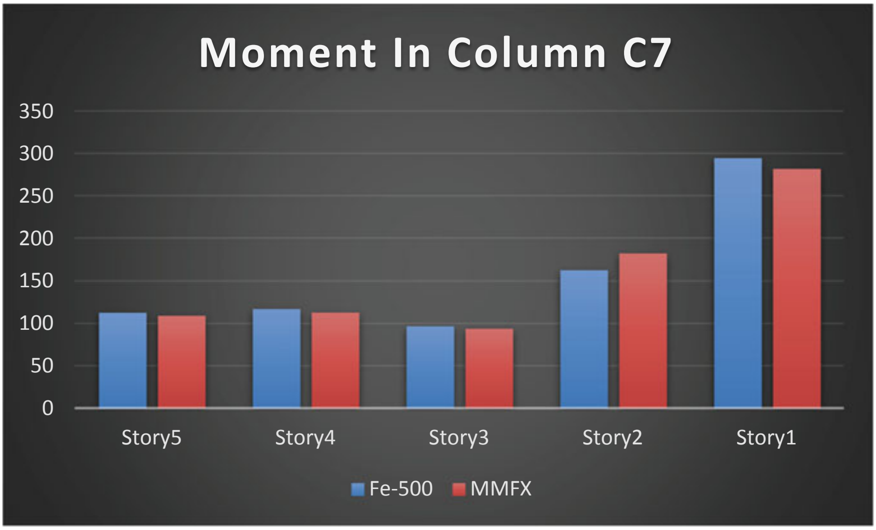

Fig. 6 Percentage variation of moment in column C7 (front right corner)

As per the architectural plan shown in Fig. 1, the middle column (C20) and the front corner column (C7). The variation in moment is about 5–17% on different stories for the same column modelled using Fe-500 and MMFX bars. The variation in moment is due to the different properties of Fe-500 and MMMFX bars (Table 2).

Table 2 Weight of steel obtained in building modelled using Fe-500

Members	Weight (kg)
Beam (longitudinal reinforcement)	
Subtotal	18,557
Beam (shear reinforcement)	
	2.94 kg/m
Subtotal (shear reinforcement)	2682
Total reinforcement in beam	21,539
Column (longitudinal reinforcement)	
Subtotal (longitudinal reinforcement)	8409.45
Column (shear reinforcement)	
Average weight of shear reinforcement per metre length of column	13.5 kg/m
Subtotal (shear reinforcement)	4333.5
Total reinforcement in column	12,742.95
Total weight of reinforcement used in building with conventional bars (Fe-500)	34,281.95

6 Reinforcement Quantity Calculation and Comparison

The area of reinforcement calculated by ETABS is further modified after the detailing done by using conditional formatting function of MS-Excel and the actual area which is got at the end is used for further calculation of cost. The same procedure is repeated for building modelled both using Fe-500 bars as well as MMFX bars. The total quantity of reinforcement thus obtained is summarised in Table 3 as follows in and the summary of total quantity if reinforcement for MMFX bars is made in Table 4.

Table 3 Weight of steel used in building modelled using MMFX grade 100 bars

Members	Weight (kg)
Beam (longitudinal reinforcement)	
Subtotal	16,082
Beam (shear reinforcement)	
	2.94 kg/m
Subtotal (shear reinforcement)	2682
Total reinforcement in beam	18,764
Column (longitudinal reinforcement)	
Subtotal (longitudinal reinforcement)	6280.55
Column (shear reinforcement)	
Average weight of shear reinforcement per metre length of column	13.5 kg/m
Subtotal (shear reinforcement)	4333.5
Total reinforcement in column	10,614.05
Total weight of reinforcement used in building with conventional bars (Fe-500)	29,378.05

Table 4 Cost of importing MMFX rebars at Delhi location

Particulars	Quantity	Unit
The weight obtained from structural detailing	19,684	kg
Rate in Dubai per ton	47,034	Rs.
Approximate fright charge (via sea) [14]	68,058.36	Rs.
Fright charge per ton	3402.918	Rs.
Total cost at Kolkata port/ton	50,436.92	Rs.
Import duty at Kolkata port for 20 ton [15, 16]	14,276	Rs.
Import duty per ton	713.8	Rs.
Total cost in India per ton	51,150.72	Rs.
Transportation cost to Delhi/ton [17]	3971.7	Rs.
Total cost at Delhi location/ton	55,122.42	Rs.
Total cost at Delhi location/Kg	56.12	Rs.

Table 5 Cost comparison of Fe-500 and MMFX bars

Sl. No.	Particulars	Unit	Quantity	Rate/Kg	Cost
1	Fe-500	Kg	29,948.5	33.56	1,005,070
2	MMFX	Kg	22,362.6	56.12	1,254,986

7 Cost Comparison

The rate of the Fe-500 bars is taken for Delhi location from site with the brand name of TATA Tiscon TMT Steel Bars. The rate is ₹33,560/ton, which is ₹33.56/Kg. Similarly, the rate for MMFX bars is taken from the site negotiated rate at Dubai location which is 2600 Dirhams/ton.

Excluding Fe-415 bars which are used for shear reinforcement, as per Table 5, the total quantity of Fe-500 and MMFX grade 100 bars are as follows.

The cost of MMFX bars is higher than the cost of Fe-500 by 25%. Hence, the benefit–cost ratio comes out to be negative which shows non-feasibility for such scale projects.

8 Inferences

The following inferences are drawn from the study done in this research:

- The MMFX bars have superior strength and corrosion resisting property than conventional Fe-500 bars due to its nanostructural arrangement.
- The exploratory study shows that there is no such Indian Standard code which defines the use of MMFX bars in Indian context.
- The density of MMFX bars is slightly more than that of Fe-500 bars (negligible).

- The minimum yield strength of MMFX bars used in this case is 690 MPA and that of Fe-500 is 500 MPA. The former is 38% more than the later one. This results in stiffer structure.
- The quantity of reinforcement obtained in the modelling done using MMFX bars is 29,378 kg and the quantity of reinforcement consumed in building modelled using Fe-500 bars is 34,281 kg. The quantity of reinforcement saved in the modelling done using MMFX bars approximately 16.69%.
- The cost of reinforcement obtained in the modelling done using MMFX bars is INR 1005069 and the cost of reinforcement obtained in building modelled using Fe-500 bars is INR 1254986. The cost difference of 25% is seen as per the study.

9 Conclusions

As seen from the above results, the MMFX bars are better for storey drifts in both *X* and *Y* direction. The case study considered in this research is of a mercantile building with six storey. Even after saving 16.69% of reinforcement as compared to Fe-500 bars, the import cost shows that the cost of reinforcement is approximately 25% higher if we opt for MMFX rebars. The possible reasons for this higher cost are that, in this case, the building is considered is of six storey only, and hence the lesser amount of reinforcement is used as compared to tall buildings in terms of total weight of reinforcement. The fright charge from Dubai to Kolkata and the transportation cost from Kolkata to Delhi may have decreased if we would have ordered the same MMFX bars in bulk against the present ordered quantity of just 20 ton. As the code does not takes into consideration of MMFX bars, this study is a kind of way forward for the use of MMFX bars in Indian context as an innovative material for building smart cities but can not be treated as recommendation for use of MMFX bars.

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