

Microstructural and Mechanical Properties of TMT/QST Steel Bars for Concrete Applications

Table 1 Typical process parameters for the quality control of TMT bars

Description	Manufacturing Line-1		Manufacturing Line-2				
	Diameter of bar (mm)	8	10	12	16	20	25
Speed of steel bars (m/s)	21	11.75	15	9	5.5	4	2.3
Water pressure (kg/cm ²)	14	12	10	9.5	9	7.5	13
Volume of water (per m ³)	4.9	4.9	5.2	5.2	6.7	6.7	15.3
Bore diameter (mm)	24	24	28	28	32	32	48
Width and depth of nozzle (mm)	75×24	75×24	75×28	75×28	75×32	75×32	90×48
Length of nozzle (mm)	247	247	247	247	247	247	247
Length of quenching box (m)	11	11	8.5	8.5	8.5	8.5	8.5



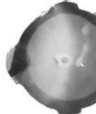






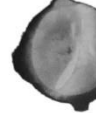
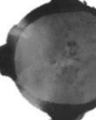



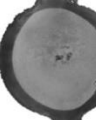
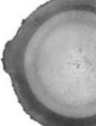


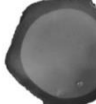
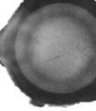





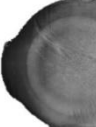
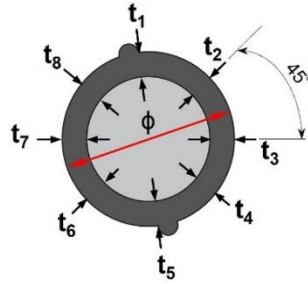
Brand	Diameter of bar (mm)				
	8	10	12	16	20
A					-
B		-			-
C					-
D					
E					
F					

Figure 1 CSPD of commercially available Fe 550D grade TMT/QST bars

Table 2 Measured thickness of TM-Ring of Fe 550D grade TMT/QST bars from commercially available brands



Brand	Diameter (mm)	Measured thickness (mm)										
		t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	$t_{min} (0.05\phi)$	$t_{avg} (0.085\phi)$	$t_{max} (0.15\phi)$
A	8	0.7	0.6	0.9	0.5	0.8	0.6	0.4	0.6	0.4 (0.4)	0.6 (0.68)	0.9 (1.2)
	10	0.9	0.9	1.0	1.1	1.0	1.0	1.2	0.7	0.7 (0.5)	0.9 (0.85)	1.1 (1.5)
	12	1.1	1.0	1.1	1.2	0.7	0.8	0.9	1.2	0.7 (0.6)	1.2 (1.02)	1.3 (1.8)
	16	1.5	1.4	1.3	1.6	1.5	1.5	1.6	1.5	1.3 (0.8)	1.4 (1.36)	1.6 (2.4)
	20	2.1	2.1	1.7	1.8	2.1	2.1	1.9	2.1	1.7 (1.0)	2 (1.7)	2.1 (3.0)
B	8	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.7	0.7 (0.4)	0.7 (0.68)	0.8 (1.2)
	12	0.9	1.0	0.8	0.5	0.9	1.1	1.0	0.9	0.5 (0.6)	0.9 (1.02)	1.1 (1.8)
C	10	0.8	0.8	0.7	0.8	0.7	0.7	0.7	0.7	0.7 (0.50)	0.7 (0.85)	0.8 (1.5)
	20	1.5	2.3	1.7	1.4	2.0	1.6	1.8	1.7	1.5 (1.0)	1.8 (1.7)	2.3 (3.0)
D	10	0.9	0.8	1.4	1.5	0.7	0.8	1.4	1.5	0.7 (0.5)	1.1 (0.85)	1.5 (1.5)
	12	1.0	1.2	1.3	1.3	1.2	1.3	1.1	1.1	1.0 (0.6)	1.1 (1.02)	1.3 (1.8)
	16	0.8	1.1	1.6	2.2	2.1	1.3	1.7	1.6	0.8 (0.8)	1.5 (1.36)	2.1 (2.4)
	20	2.1	2.1	2.1	1.9	1.9	2.0	1.7	2.1	1.7 (1.0)	1.9 (1.7)	2.1 (3.0)
E	10	0.8	0.8	0.7	0.8	0.8	0.7	0.8	1.0	0.7 (0.5)	0.8 (0.85)	1.0 (1.5)
	12	0.9	1.0	1.2	1.2	1.2	1.0	1.1	1.2	0.9 (0.6)	1.1 (1.02)	1.2 (1.8)
	16	1.6	1.7	1.6	1.7	1.7	1.4	1.4	1.6	1.4 (0.8)	1.6 (1.36)	1.7 (2.4)
	20	1.8	2.0	2.1	1.9	1.9	2.0	2.1	2.1	1.9 (1.0)	2.0 (1.7)	2.1 (3.0)
F	10	1.3	1.2	0.8	0.7	1.0	1.5	1.3	1.3	0.7 (0.5)	1.2 (0.85)	1.5 (1.5)
	12	1.3	1.2	1.3	1.3	1.3	1.1	1.1	1.1	1.1 (0.6)	1.2 (1.02)	1.3 (1.8)
	16	1.6	1.5	1.7	1.5	1.6	1.5	1.6	1.6	1.5 (0.8)	1.6 (1.36)	1.7 (2.4)
	20	2.5	2.5	2.6	2.4	2.4	2.1	2.3	2.4	2.1 (1.0)	2.4 (1.7)	2.6 (3.0)

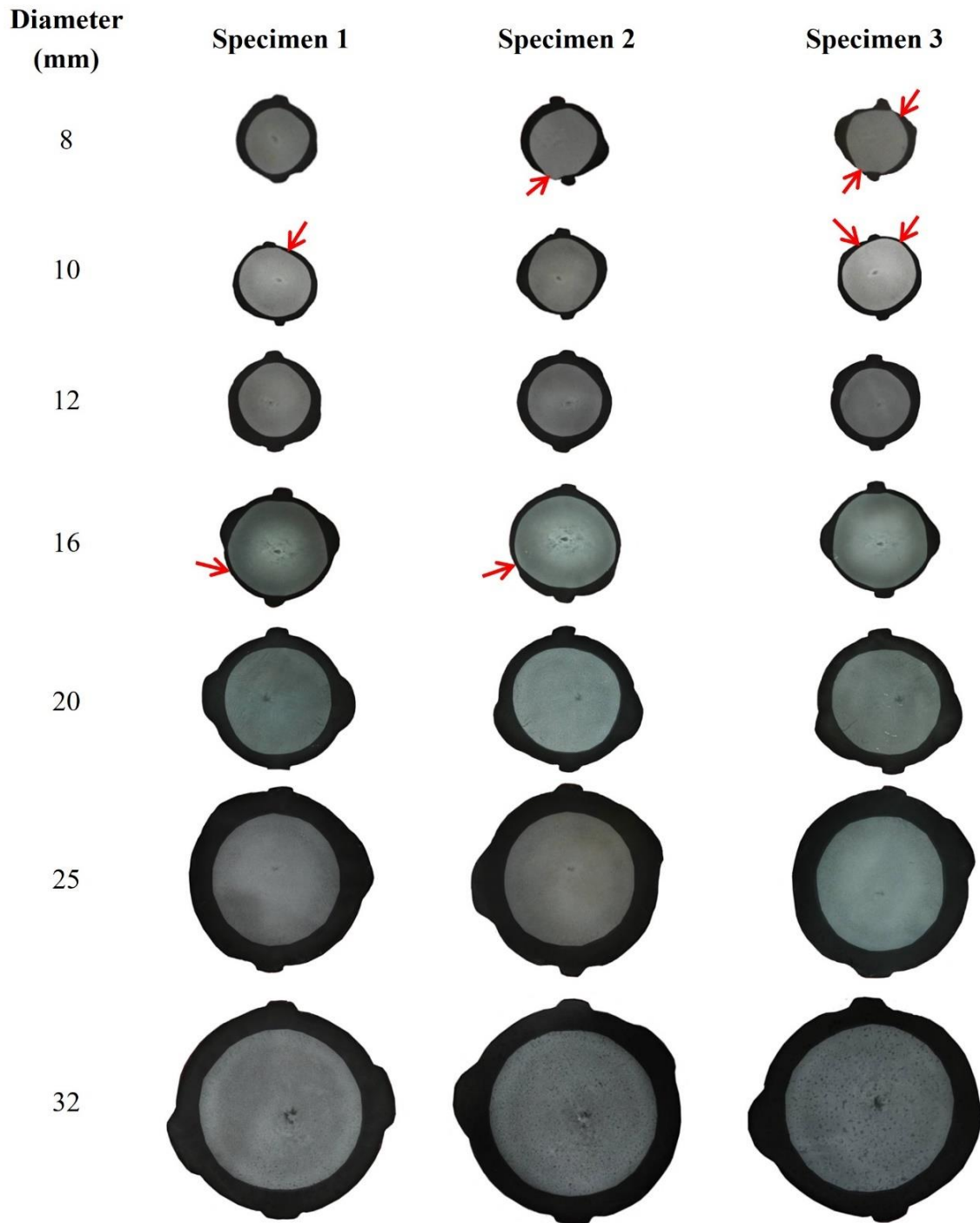
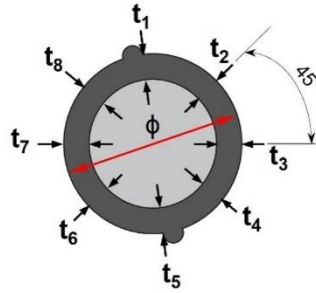


Figure 2 CSPD of Fe550D grade TMT/QST bars of diameters ranging from 8 to 32 mm

Table 3 Measured thickness of TM-Ring of Fe550D grade TMT/QST bars of diameters ranging from 8 to 32 mm



Diameter (mm)	Specimen no.	Measured thickness (mm)										
		t ₁	t ₂	t ₃	t ₄	t ₅	t ₆	t ₇	t ₈	t _{min} (0.05φ)	t _{avg} (0.085φ)	t _{max} (0.15φ)
8	1	0.82	0.68	0.27	0.76	0.85	0.86	0.54	0.6	0.27 (0.4)	0.67 (0.68)	0.86 (1.2)
	2	0.38	0.67	0.49	0.27	0.54	0.19	0.4	0	0 (0.4)	0.37 (0.68)	0.67 (1.2)
	3	0.52	0.7	0.7	0.38	0.38	0.53	0.1	0	0 (0.4)	0.41 (0.68)	0.7 (1.2)
10	1	0.68	0.49	0.39	0.83	0.98	1.12	0.49	0.64	0.39 (0.5)	0.70 (0.85)	1.12 (1.5)
	2	0.59	0.67	0.59	0.57	0.92	0.92	1	0.78	0.57 (0.5)	0.75 (0.85)	1 (1.5)
	3	0.64	0.54	0.36	0.53	0.51	0.54	0.46	0.53	0.36 (0.5)	0.51 (0.85)	0.64 (1.5)
12	1	0.78	0.69	1.08	1.07	1.26	1.36	1.25	1.25	0.69 (0.6)	1.09 (1.02)	1.36 (1.8)
	2	1.24	1.14	0.96	1.13	1.46	0.99	1.24	1.15	0.96 (0.6)	1.16 (1.02)	1.46 (1.8)
	3	1.1	1.54	1.15	0.93	1.15	1.1	1.17	1.03	0.93 (0.6)	1.15 (1.02)	1.54 (1.8)
16	1	0.66	0.42	0.56	0.73	0.47	0.5	0.68	0.7	0.42 (0.8)	0.59 (1.36)	0.73 (2.4)
	2	0.91	0.75	0.58	0.56	0.48	0.6	0.63	0.65	0.48 (0.8)	0.64 (1.36)	0.91 (2.4)
	3	0.92	0.71	0.49	0.59	0.62	0.61	0.67	0.48	0.48 (0.8)	0.64 (1.36)	0.92 (2.4)
20	1	1.76	1.72	1.82	1.92	2.11	1.82	1.93	1.86	1.72 (1.0)	1.87 (1.7)	2.11 (3)
	2	1.72	1.72	1.95	1.75	1.75	2.22	1.85	1.98	1.72 (1.0)	1.87 (1.7)	2.22 (3)
	3	1.8	1.81	1.84	1.88	1.9	1.85	1.85	2.32	1.8 (1.0)	1.91 (1.7)	2.32 (3)
25	1	2.91	2.87	2.96	3.1	3.15	3.26	3.08	3.17	2.87 (1.25)	3.06 (2.12)	3.26 (3.75)
	2	2.61	2.74	2.85	2.95	2.78	2.85	2.98	3.15	2.61 (1.25)	2.86 (2.12)	3.15 (3.75)
	3	2.52	2.66	2.67	2.84	2.95	3.15	3.22	3.21	2.52 (1.25)	2.90 (2.12)	3.22 (3.75)
32	1	3.39	3.46	3.33	3.43	3.41	3.27	3.11	3.54	3.11 (1.6)	3.37 (2.72)	3.54 (4.8)
	2	3.02	3.01	3.25	3.05	3.15	3.25	3.22	3.24	3.01 (1.6)	3.15 (2.72)	3.25 (4.8)
	3	2.91	2.95	2.98	3.01	3.15	3.04	3.15	2.95	2.91 (1.6)	3.01 (2.72)	3.15 (4.8)

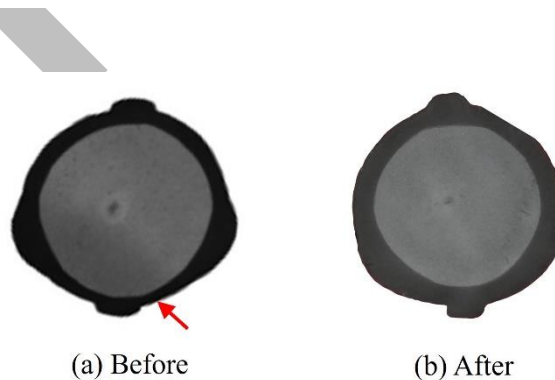


Figure 3 CSPD of TM-Ring showing the effect of cleaning the nozzle assembly during the manufacturing of TMT/QST bars of 12 mm diameter

Table 4 Data of tensile properties of good quality (GQ) bars and poor quality (PQ) TMT/QST bars (Nair (2017))

	Yield load	Ultimate load	Elongation		Yield load	Ultimate load	Elongation
	(kN)	(kN)	(%)		(kN)	(kN)	(%)
GQ1	74.3	84.1	22.5	PQ1	72.1	81.5	24.3
GQ2	74.1	84.1	25.7	PQ2	62.8	73.5	20.6
GQ3	73.4	83.6	20.0	PQ3	66.5	76.4	25.5
GQ4	71.8	84.5	22.2	PQ4	67.5	75.6	23.1
Mean	73.4	743.7	22.6	Mean	67.2	76.7	23.4
SD	1.0	3.3	2.3	SD	3.3	2.9	1.8
COV	1.3	0.4	10.3	COV	5.7	3.8	7.9