

Maintenance and Repair of Concrete Structures
Prof. Radhakrishna G. Pillai
Department of Civil Engineering
Indian Institute of Technology – Madras

Lecture – 05

TM-Ring Test for Assessing: The Quality of TMT / QST Steel Rebars

Hi, welcome to this short video on air quality control test for most of the rebars which are available in our country. Thermo mechanically treated steel or rather technically known as quenched and self-tempered steel. We use this steel a lot in our construction site. However, there are a lot of issues associated with the quality of this steel. Recently we developed and rather modified the test procedure on how to assess the quality or how to assess the tempered Martensite ring on TMT steel. And I have here Suraj Nair who is a masters student who worked on this project and then refined the test procedure. So I am actually handing over to him to explain the significance of this test, why it is necessary for our country and then explain the details of the test methods.

Hi, my name is Suraj and I worked as a graduate student at IIT Madras developing the TM ring test which is used to assess the quality of the TMT rebars in terms of its microstructure. Now as shown on the screen, the TMT rebars are special in having a cross section where a tempered Martensite ring and a ferrite pearlite (FP) core in it. The tempered Martensite ring is predominantly responsible for the strength that the TMT rebars have whereas the ferrite pearlite core gives it its ductility.

(Refer Slide Time: 02:08)

Shear stirrups with a bend angle of 135°

Must check the surface crack resistance if used for shear stirrups with a bend angle of 135°
(as in the case of earthquake resistant designs)

Nair and Pillai (2017), "TM-Ring test - A quality Control test for TMT (or GST) Steel reinforcing bars used in reinforced concrete systems," ICI Journal, April-June 2017

Because of its special feature, we use these in earthquake resistant designs where we need both strengths and used in ductility. These parts are used in stirrups and we bend it at 135 degrees. A typical 135 degree bent stirrup as being shown here. A good TMT rebar will show a non-cracked surface because the surface crack resistance is also good in these cases. But surprisingly as shown on the screen we found cracks in several rebars which have been tested in bending and this is being attributed to the inadequate microstructure that is present in it.

(Refer Slide Time: 02:46)

Poor TM-Ring can cause surface cracking

No cracking Severe cracking

When I say inadequate microstructure as shown on the screen, you can see that no cracking case shows a complete TM ring in it with a concentric FP core whereas a severe cracking case has an incomplete TM ring in it which shows cracking when it is being subjected to bending.

(Refer Slide Time: 03:09)

Rebars with discontinuities were observed predominantly in 8 and 12 mm diameter rebars (stirrups)

	A	B	C	D	E
8 mm					
12 mm					
16 mm					

Now we have tested this in several rebars of different diameters and different sources. So, on the screen we have several different rebars being tested and show us the TM and the FP areas in it. So in most of the cases we find that the microstructure is inadequate where the TM ring is discontinuous, or the FP core is eccentric, and this is predominantly seen in 8 mm and 12 mm rebars. Now if we don't ensure the proper microstructure is present it can result in premature failure in terms of strength or premature corrosion.

(Refer Slide Time: 03:48)

IS 1786 provides a "non-mandatory" specification to test the TM-ring in TMT rebars

IS 1786:2008
ANNEX A
(Foreword)
INFORMATION ON CONTROLLED COOLING PROCESS

4-1 The processing of reinforcing steel is usually through one or combination of processes which may include hot rolling after annealing, hot rolling followed by controlled cooling (TM process) and hot rolling followed by cold work.

Heat treatment is a thermal process undergone by the steel in the solid state. The most common practice is finishing after hot treatment which rolling, commonly known as thermomechanical treatment (TMT) process. After having the hot end of the rolling mill, the hot bar is quenched (rapidly cooled) in water from a final rolling temperature of about 910°C. The quenching is partial, only one surface layer has been transformed from austenite to steel phase stable only at very high temperatures to martensite (stable at temperatures below 200°C). This unrolled quenching is achieved in one or more water cooling devices through which the steel passes at a very high speed before reaching the cooling bed.

Because the quenching is only partial, a part of the original heat remains in the core of the steel and, on the cooling bed, this heat migrates towards the surface. This results in an austenite self-tempering process where the surface layer of martensite is tempered, this "tempering temperature" (or equivalent temperature) refers to the maximum temperature attained by the bar surface after quenching. Tempering enables a partial diffusion of carbon out of the surface to form ferrite and pearlite, thus relieving the inherent stresses locked

in during the sudden quenching of the hot bar end in cold water. The resulting tempered-martensite shows improved deformability compared to the un-quenched martensite.

The case of the heat treated reinforcing bar/wires consist of ferrite and pearlite - more ductile but less strong than the martensite. Compressive process needed is used to dependently adjust the more rapidly changing parameters depending on the chemical composition of the steel, the desired grade and size of the reinforcing bar/wire etc. For the larger diameter, small addition of microalloys is used.

Sometimes it becomes necessary to determine if a particular reinforcing bar/wire, or lot, has undergone proper heat treatment or is only a mild steel deformed bar. Because the two cannot be distinguished visually, the following field test may be used for purposes of identification. A small piece (about 12 mm long) can be cut and the transverse face lightly ground flat on progressively finer emery papers up to '0' size. The sample can be macroetched with mild (5 percent nitric acid in alcohol) at ambient temperature for a few seconds which should then reveal a darker annular region corresponding to martensite/bainite microstructure and a lighter core region. However, this test is not to be regarded as a criterion for rejection. The material conforming to the requirements of this standard for chemical and physical properties shall be considered acceptable.


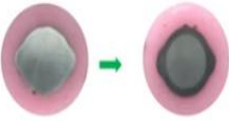
IS 1786 which regulates the strength characteristics of these bars do mention about doing a macro etching test which is non-mandatory to make sure that the TM ring and the FP core are

properly present in these rebars. But since it's not mandatory it's not usually followed or not used as an acceptance criteria in the specifications.

(Refer Slide Time: 04:12)

TM-Ring Test

- Ensure durability of steel
- Ensure proper heat treatment
- Easy and replicable
- Ideal for on-site qualification
- Macroetching
- Acceptance criteria




The slide features two logos in the top right corner: a circular emblem with a lamp and the text 'Jawahar Education Society's Institute of Technology' and the NPTEL logo.

This is where TM ring test comes into picture where it used to ensure the durability of the steel in terms of proper heat treatment. This test is easy and replicable to do on site and it involves macro etching in it. This is more of an enhanced version of macroetching.

(Refer Slide Time: 04:12)

Components/Parts of the TM-Ring test

- Specimen embedded in contrasting cold setting epoxy
- Polished specimen (80-220 or 100 grit size)
- Nital solution (nitric acid, ethyl alcohol) 5% by volume
- Image acquisition setup
 - Lighting conditions (350-450 lux)
 - Adjustable platform



The slide features two logos in the top right corner: a circular emblem with a lamp and the text 'Jawahar Education Society's Institute of Technology' and the NPTEL logo.

Coming to the test procedure, we have two parts, one is the specimen preparation and second one is the actual test procedure. For the specimen preparation we have a regular steel rebar which is cut into a small piece, this rebar will be polished using sandpapers of different grid sizes ranging

between 80 to 220. Once polished we embed the specimen in a cold mounting epoxy which in this case has a contrasting color, this will help at the end when we take the photograph.


Coming to the test setup, we have a camera which is set at the top, we have two adjustable lighting and then there is a movable platform. On the movable platform stays the specimen. The adjustable lighting is set at 350 to 450 lux light intensity to make sure that we have replicable results. The movable platform is set to make sure that the specimen is entirely in focus in the camera.

Next, we have the solution which we are going to use for macro etching which is 5% Nital solution. The Nital solution is being made using nitric acid and ethyl alcohol. 5% nitric acid by volume in ethyl alcohol is being used in here.

(Refer Slide Time: 06:24)

TM-Ring test procedure

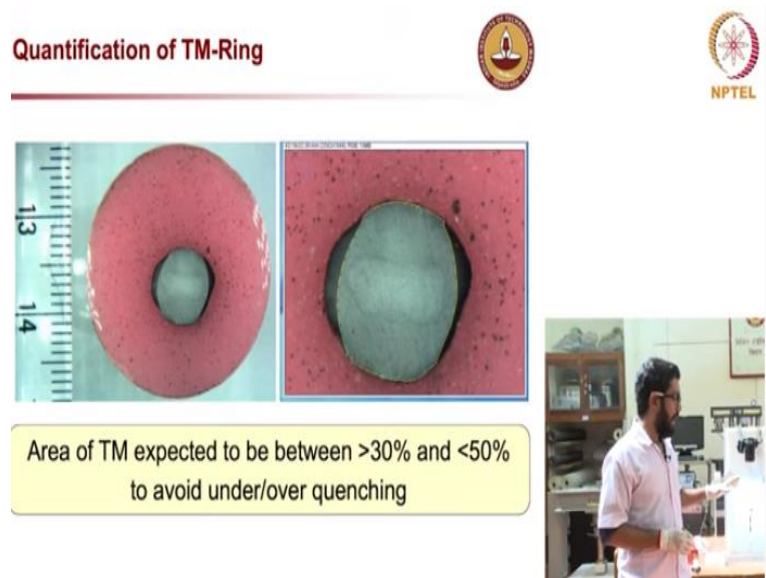
- Collect 2-3 mL Nital solution using micropipette
- Deposit the solution on the cold mounted sample surface
- Wait for 3-5 minutes for etching
- Absorb excess solution using paper towel after etching
- Take photo for analysis and quantification



Once a solution is ready, we collect it using a micro puppet, take 2 to 3 ML and pour it on the surface of the specimen. Once a specimen is exposed to the Nital solution, wait for 3 to 5 minutes within which the specimen is going to be etched. Having etched we will collect the excess solution on the surface of the specimen using paper towel or cloth. This is to make sure that the surface is non-reflective when you take the photo. So now the TM and FP areas are clearly visible and then we take a snap at the specified lighting condition and the proper focus level.

or the FP core is concentric. Level two is a much more extended analysis where we quantify the area of the tempered martensite using any image analysis software.

(Refer Slide Time: 08:07)



The quantified TM area is expected to be in the range of 30 to 50%, an under quench TMT rebar will have an area of tempered Martensite less than 30% which can result in premature strength failure or corrosion and an over quench case where tempered Martensite is greater than 50% of the area can compromise in ductility.

So we need to make sure that the area is within 30 to 50% and this can be done using the level two acceptance criteria. With that the test set up, the specimen preparation and the testing procedure has been explained and this is easy to follow on site and can be helpful to make sure that the quality of the TMT steel rebars are ensured. Thank you.