Establishment of Correlation Factor for the Carbon Steel Rods Tested Under Tensile Load and Three Point Bend Test

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ABSTRACT: Steel is one of the major construction material which plays an important role in the construction industry of Sri Lanka. The supply of construction materials with required quality is always identified as one of the major obstacles to improved construction in developing countries .Laboratory testing to verify the steel grade is very important before it is used in construction purposes.

BS 4449: 1997, Specification for Carbon Steel Bars for the Reinforcement of Concrete Specifies two grades of reinforced steel bars for the concrete:

a) Grade 460: commonly referred to as ribbed or tor steel
b) Grade 250: Commonly referred as plain steel.

When the specified steel grade is 460, it describes the characteristic strength which is measured in terms of yield/proof stress of 460 N/mm2.However, this standard was revised as BS 4449 : 2005, Specification for Steel for the Reinforcement of Concrete and that specifies three grades of reinforced steel bars as Grade B500A,B500B and B500C.Where A,B and C denotes different tensile / yield strengths and elongations. However, the BS 4449 specified the testing methods for the steel products, currently inadequacy of required machine capacity is the bottle neck. An alternative is proposed by the standard for larger diameters as to reduce samples could be tested but it does not provide the correlation factors applicable for specimens for the reduced sizes. Therefore, it is highly essential and could be economical also to develop relevant correlation for tensile parameters for the reduced specimens of steel.

Key Words: Reinforcement, Yield stress

1 INTRODUCTION

Steels are usually defined as alloys of iron and carbon, containing not more than 2% carbon, with or without other alloying elements. With more than 2% carbon, the material comes into the category of 'cast iron' Steel containing only carbon as the specific alloying element are known as carbon steels. These steels can also contain up to 1.2% manganese and 0.4% silicon. Residual elements such as nickel, chromium, aluminium, molybdenum and copper, which are unavoidably retained from raw materials, may be present in small quantities, in addition to 'impurities' such as phosphorous and sulphur.

Mild steel is the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. Low carbon steel contains approximately 0.05–0.15% carbon and mild steel contains 0.16–0.29% carbon, therefore it is neither brittle nor ductile. Mild steel has a relatively low tensile strength, but it is cheap and malleable; surface hardness can be increased through carburizing. It is often used when large quantities of steel are needed, for example as structural steel. The density of mild steel is approximately 7.85 g/cm3 (0.284 lb/in3) and the Young's modulus is 210,000 MPa (30,000,000 psi).Low carbon steels suffer from yield-point run out where the material has two yield points. The first yield point (or upper yield point) is higher than the second and the yield drops dramatically after the upper yield point. If low carbon steel is only stressed to some point between the upper and lower yield point then the surface may develop Louder bands.

Various types of steels (structural, plain, ribbed and tor steels) are produced in the country but quantity is not sufficient to satisfy the demand, hence many types of steels are imported to cover

the demand for construction industry. The reinforcement of concrete with steel rods is more safe, efficient and more economical. It has excellent bonding properties as well as high yield/proof stress and elongation. Generally, the strength and other properties of steel depend on carbon and other alloying elements present in it. Alloy additions are more expensive and hence cold working of hot rolled steel bars are usually done in Sri Lanka.

On the other hand most of the sales outlets do not provide information on the grade of steel. Hence laboratory testing to verify the steel grade is very important before it is used in construction purpose. Laboratory testing to verify the steel grade is based on British Standard and Sri Lanka Standards

If the structure has been designed to use steel reinforcement of more than 32 mm diameter of above grades it is necessary to verify/ estimate the strength grades of steel. Presently many construction projects demand the use of steel having larger cross sections and thereby facing doubts, on the decision regarding the compliance with respect to the requirements specified grades relevant standard.

The yield strength Re, stress ration Rm/ Re, and elongation at fracture , of steel obtained from test specimens selected, prepared and tested in accordance with the standard, shall be as specified in the table below. The specified tensile properties apply are as follow.

Table 01 Specified tensile properties.

Tensile Properties				
Grade	Yield strength (R_e) N/mm^2	Stress ratio (Rm/Re) Min.	Elongation at fracture A_5 (min.) %	Total elongation at maximum force A_{gt} [3] (min.) %
250	250	1.15	22	--
460 A[4)]	460	1.05	12	2.5
460 B[4)]	460	1.08	14	5

Following Standards are being used for laboratory testing:

i) SLS 375:2004
Specification for Ribbed Steel Bars for the Reinforcement of Concrete

ii) BS 4449:1997
Specification for Carbon Steel Bars for the Reinforcement of Concrete

In addition to the above mass per meter run to be check before use for the construction purpose. Specified mass per meter value are as follow.

1.1 Mass/ Meter run

Table 02 Tolerance limit for mass per meter run.

Tolerance limit	Bar diameter (mm)							
	6	8	10	12	16	20	25	32
Lower (kg)	0.202	0.369	0.577	0.848	1.509	2.359	3.677	6.026
Upper (kg)	0.242	0.421	0.657	0.928	1.651	2.581	4.023	6.594

1.2 Yield Strength

The yield strength or yield point of a material is defined in engineering and materials science as the stress at which a material begins to deform plastically. Prior to the yield point the material will deform elastically and will return to its original shape when the applied stress is removed. Once the yield point is passed some fraction of the deformation will be permanent and non-reversible. It is often difficult to precisely define yielding due to the wide variety of stress–strain curves exhibited by real materials.

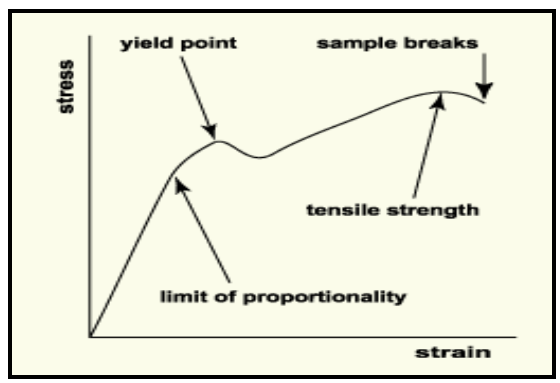

Fig 01 Stress-strain graph for a typical metal

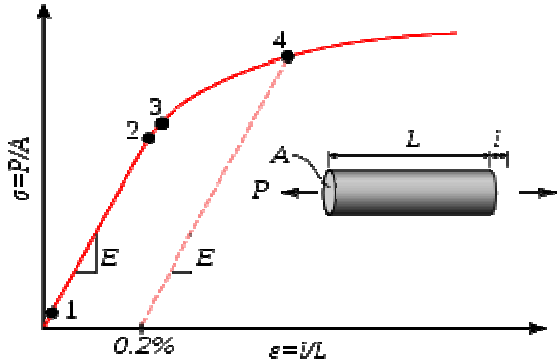

Fig 02 Stress-strain graph for a work harden steel

There are several possible ways to define yielding.

1: True elastic limit
2: Proportionality limit
3: Elastic limit
4: Offset yield strength

1.2.1 True elastic limit

The lowest stress at which dislocations move. This definition is rarely used, since dislocations move at very low stresses, and detecting such movement is very difficult.

1.2.2 Proportionality limit

Up to this amount of stress, stress is proportional to strain (Hooke's law), so the stress-strain graph is a straight line, and the gradient will be equal to the elastic modulus of the material.

1.2.3 Elastic limit (yield strength)

Beyond the elastic limit, permanent deformation will occur. The lowest stress at which permanent deformation can be measured. This requires a manual load-unload procedure, and the accuracy is critically dependent on equipment and operator skill

This is the most widely used strength measure of metals, and is found from the stress-strain curve as shown in the figure to the right. A plastic strain of 0.2% is usually used to define the offset yield stress, although other values may be used depending on the material and the application. The offset value is given as a subscript, e.g., Rp0.2=310 MPa. In some materials there is essentially no linear region and so a certain value of strain is defined instead. Although somewhat arbitrary, this method does allow for a consistent comparison of materials.

1.3 Upper yield point and lower yield point

Some metals, such as mild steel, reach an upper yield point before dropping rapidly to a lower yield point. The material response is linear up until the upper yield point, but the lower yield point is used in structural engineering as a conservative value. If a metal is only stressed to the upper yield point, and beyond, lauders bands can develop.

1.4 Bending properties of steel

Bending and re-bending Properties are determine as per BS or SLS Standard. Brittleness of material is determine in this methods. The test specimen shall show no sign of fracture or cracks on visual examination

2 OBJECTIVE OF THE STUDY

If the structure has been designed to use steel reinforcement of more than 32 mm diameter of above grades it is necessary to verify/ estimate the strength grades of steel. Presently many construction projects demand the use of steel having larger cross sections and thereby facing doubts, on the decision regarding the compliance with respect to the requirements specified grades relevant standard. Therefore it is very much important to develop a relation between tensile test and three point bend test to minimize cost involved for tensile test for bars of 32mm diameter and above.

3 METHODOLOGY

Since, there are limited facilities and expensive process is in preparation of reduced test specimens to required size and shapes as per BS standard an alternative is proposed to develop a correlation through the use of three point bending.

Three point test mostly is used for brittle material testing but bending and re-bending for carbon steel as per BS4449 is also a type of test that could be used to determine a brittleness of the samples. Therefore, this research study was focused to develop a relation by undertaking tensile test and three point test using identical samples. Test samples were Collected samples from reputed company which is having SLS mark Samples were Subjected to tensile test and three point bending test for 10 mm to 32 mm diameter bars. Only three point bend test carried out for 40 mm and 50 mm diameter bars.

4 RESULTS AND DISCUSSION

Few test samples were tested and observed the behavior of stress versus strain graph under three point bending. Samples were collected from only one reputed Company. Literature review shows that the production method and chemical additions will vary from manufacture to manufacture. Therefore , minimum three manufactures to be consisted before the final conclusion.

5 CONCLUSIONS

Test carried out showed that,

1. Behavior of the steel rods tested under tensile load and three point bending had similar patterns up to the maximum load.

2. Further analysis will be carried out to determine the correlation of yield stress in tensile and three point bending

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