University Of Khartoum
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PROPERTIES OF STEEL USED FOR STRUCTURAL PURPOSES IN BUILDINGS IN THE SUDAN

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This work deals with steel used for structural purposes in the Sudan. Most of this work is experimental; therefore I would like to thank the staff of Giad and IRC Laboratories for their help.

I wish to express my sincerest thanks to all those who have helped in executing this work. This includes my family.

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ABSTRACT

The study focuses on compliances with standard specifications of steel used for structural purposes in Sudan. To achieve this objective, the study was divided into two parts. The first one focuses on studying structural steel, including hot-rolled sections as universal beams, angles, hollow sections (circular, square and rectangular), sheet…etc. The second part studies cold-rolled sections, compound sections and reinforcing bars of both plain and deformed types. The study was limited to types used for building purposes, for a better focus on a vast subject, on the other hand, such types are divided into local and imported sections. The various properties of steel were studied. These included tensile strength, and yield strength and ductility through tests of tensile, hardness, impact and bending and rebending. A chemical analysis of sample sections was conducted to show percentage of carbon and other important elements such as sulfur and phosphorus. The study compare samples to standard specifications (BS, ASTM, EUR, JIS and DIN). A comparison was also done on the different sample sections of structural steel. The study findings show that most of the imported steel sections comply with specifications, while locally made steel varies as to compliance with specifications. This is discussed in detail in the study. We hope for the expanding of the study of structural steel and that such research takes a more specialized manner.

بسم الله الرحمن الرحيم

الخلاصة

تمت دراسة خواص الفولاذ المستعمل للأغراض الإنشائية فى السودان و مدى مطابقتها للمواصفات القياسية العالمية . و لتحقيق ذلك تم فصل الدراسة إلى جزئين: الجزء الأول دراسة الفولاذ الإنشائى وهو يتضمن المقاطع المسحوبة على الساخن (عارضات قياسية **I** ، زوى مقاطع مجوفة دائرية ومربعة و مستطيلة ، ألواح ..) و المقاطع المسحوبة على البارد و المقاطع المركبة ، و الجزء الثانى دراسة الأسياخ و هو يتضمن السيخ العادى و السيخ المشرشر. و نسبة لتوسع الموضوع فقد تم حصر الدراسة فى الأصناف المستخدمة فى المبانى الغير عالية ، من ناحية أخرى هذه الأنواع تنقسم إلى نوعين المستورد من خارج البلاد و المحلى. و تمت دراسة خواص الفولاذ المختلفة من مقاومة الشد القصوى و مقاومة الخضوع و المطيلية و ذلك عن طريق إختبارات الشد ، الصلادة ، مقاومة الصدم ، الإنحناء و إعادة الإنحناء ، و تم تحليل كيميائى للعينات المختلفة من الفولاذ و ذلك لتوضيح نسبة الكربون و العناصر الأخرى ذات الأهمية فى صناعة الفولاذ مثل الكبريت و الفسفور ... ، ومن خلال هذه الدراسة تم مطابقة الأصناف أعلاه من الفولاذ الإنشائى بالمواصفات القياسية العالمية مثل البريطانية BS و الأمريكية ASTM و الأوربية EURO و اليابانية JIS والألمانية DIN ، كما تم المقارنة بين الأنواع المختلفة للفولاذ الإنشائى . و قد أوضحت النتائج أن معظم الفولاذ المستورد مطابق للمواصفات بينما يتفاوت إنتاج المصانع المحلية فى مطابقته للمواصفات و قد تم تفصيل ذلك فى الدراسة. نأمل بتوسع البحث فى الفولاذ الإنشائى، و عمل دراسات متخصصة أكثر للأنواع المختلفة له.

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Notations

ASTM	American Society for Testing Materials
BS	British Standard
CR	Cold Rolled Sections
C_{eq}	Carbon Equivalent
DIN	German Standard
E	Young's Elasticity Modulus
F_u	Tensile Strength
F_y	Yield Strength
HR	Hot Rolled Sections
IRC	Industry Researches Centre
ISO	International Specifications Organization
JIS	Japan Standard
δ	Unit Stress
ε	Unit Strain

CHAPTER ONE
INTRODUCTION

1.1 General

The construction industry in the Sudan is suffering from lack of quality control regarding building materials. Steel is one of the most commonly used materials in the building construction. The versatility of steel in structural applications rests on the fact that it can be readily supplied at a relatively cheap cost in a wide range of different product forms, and with a useful range of material properties. The key to understanding the versatility of steel is its basic metallurgical behavior. Steel is an efficient material for structural purposes because of its high strength- to-weight ratio. So this study covers the metallurgy and strength of local and imported structural steel products in the Sudan.

1.2 Objectives

This work is carried out to cover the following objectives:

1. **Investigation of types of steel products available in the Sudan used for structural purposes.**
2. **Standard acceptance Tests which can be carried out in the Sudan according to international standards, BS, ASTM etc, for steel, both local and imported, used in Sudan and their compliance with standard specifications.**
3. **Comparison between the different types of structural steel products, both local and imported, used in Sudan their compliance with standard specifications.**

1.3 Scope of work

Steel is used in structural work as elements and products with different shapes. The properties of the steel used for structural purposes are mainly the material properties, which define the constituent of steel and the geometrical properties of the produced elements.. In this study, the material properties will be investigated in order to determine the adequacy of steel used in the Sudan, both imported and locally manufactured. The study was limited to types available in Sudan, and also to tests available in the country. Imported structural steel covered includes Ukrainian, Turkish, polish and Egyptian makes. The investigation will be limited to steel used in buildings.

1.4 Approach and Methodology

1.4.1 Data Collection

(a) Structural Steel Sections were collected from:

a- All local manufacturers

-The Malaysian Sudanese Factory

-The United Triple Factory

-The Metal Factory

b- Different types of imported Structural Steel Sections available in Sudan, including origin.

(Such as: Egypt, Boland, Turkey.. etc)

(b) Reinforcing Steel Bars

a- Imported Bars:

(Turkish, Egyptian, Ukrainian .. etc)

b- Bars produced locally:

- GIAD Factory

- Omdurman Factory

1.4.2 Experimental Work

Specimens of steel used for structural purpose were prepared in the Sudan University workshops according to standard specifications, in the required shapes and dimensions.

The following standard tests were carried out on structural steel specimens:

- **The Tensile Test (Yield Strength, Tensile Strength and Elongation)**
- **Hardness Test**
- **Impact Test**
- **Chemical composition**

Reinforcing Bars were prepared (in different labs) and tested for:

- **Tensile Test (Yield Strength, Tensile Strength and Elongation)**
- **Bending test**
- **Chemical composition**

Summary of the study illustrated in Fig. 1.1.

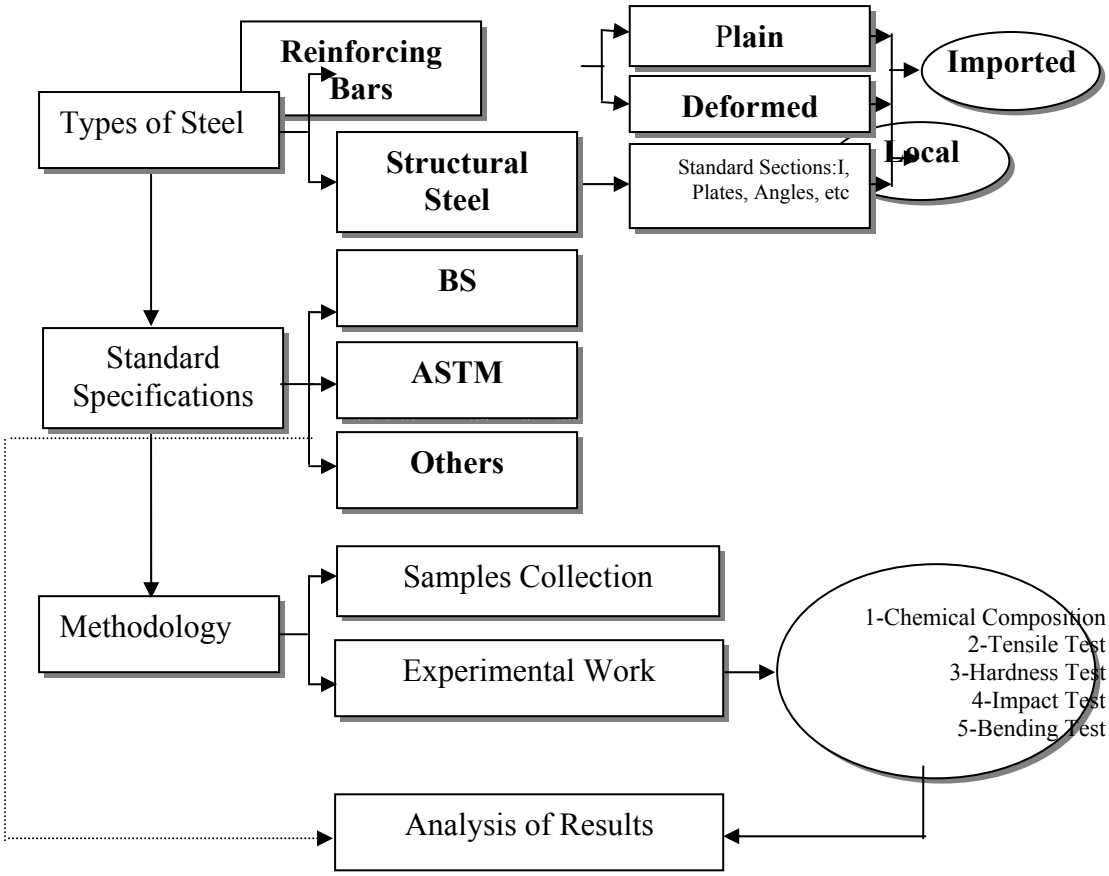


Fig.1.1 Flow Diagram for the Study

CHAPTER TWO
TYPES OF STRUCTURAL STEEL AND REINFORCING BARS

2.1 General

Steels are deformable alloys of iron with carbon and other elements. As a rule, the composition of steel includes carbon, manganese, silicon, sulfur, and phosphorus.

To make steels possessing special properties, the metal is alloyed with other additions, such as chromium, nickel, molybdenum, tungsten, copper, niobium, vanadium, etc. along with higher quantities of manganese and silicon.

Carbon is the principal element in the composition of steels. It determines, to an appreciable extent, the properties of steel depending on the content of carbon, all iron alloys are divided into steels and pig irons. If the carbon content is less than 1.7-2.0% iron alloys are called steels; with higher carbon concentrations, they are called pig irons. When carbon content is from 1.7% to 3.0 % they are called steel pig irons and common pig irons when they contain more carbon.

2.2 Classification of Steel

There is still no unique world – wide adopted classification of steel. Steels produced by various processes are extremely diverse in their properties. They can be classified by the following parameters:-

(a) Application

By this feature, the following main groups can be outlined : furnace and boiler steels, steels for railway transport (rail steels, tyre steels, etc.), structural steels (for making various building structures, such as building, bridges, various machine, etc.), ball-bearing, tool steels (for making various tools, cutters, rolling mill rolls, elements of pressing dies, etc.), spring steels, transformer steels, stainless steels, gun steels, tube steels, etc.;

(b)Quality

Steels are usually divided into plain quality and high-quality grades, the differences between these groups are due to the allowed concentration of harmful impurities (mainly sulfur and phosphorus), in special requirements of the content of non-metallic inclusions, etc. For instance, plain steels are allowed to contain up to 0.055-0.060% of sulfur or phosphorus, which is quality, and for high quality steels these impurities are limited to 0.040-0.045%, 0.020-0.030% respectively .

(c)Chemical Composition

Steels are grouped into carbon steels (low-, medium-, and high-carbon grades), low-, medium-, and high –alloyed steels (including chromium, manganese, chrome-nickel steels, etc.).

(d) The Nature Of Steel Solidification In Moulds

According to this classification, steels are divided into killed, semi- killed and rimming steels. The behavior of the metal during solidification in moulds depends on the degree of de-oxidation; more deeply deoxidized steel solidifies more quickly.

(e)The Manufacturing Process

in this respect, steels are classified to

(1) The type of steel making plant: converter steel (including oxygen-converter, Bessemer steel, basic Bessemer steel), open-hearth steel, electric steel, electro slag re-melted steel etc.

(2) The process proper: basic and acid open-hearth steel, basic and acid electric steel, vacuum- degassed steel, steel treated with synthetic slogs, inert-gas blown steel, etc.

(3) The state of the metal: in solid state (sponge iron, the product of direct reduction in electrolytic state (the product of electrolysis of iron- containing materials), in electrolytic state (the products of atomization of molten steel), in pasty state (the products of bloomer, finery, pudding, Aston- Byers process), in molten or cast state (the products of converter, open-hearth processes and the like).

2.3 Structural Steel Sections

2.3.1Geometric Properties

For a given member serial sizes, the geometric section properties are:-

(1) The exact section dimensions.

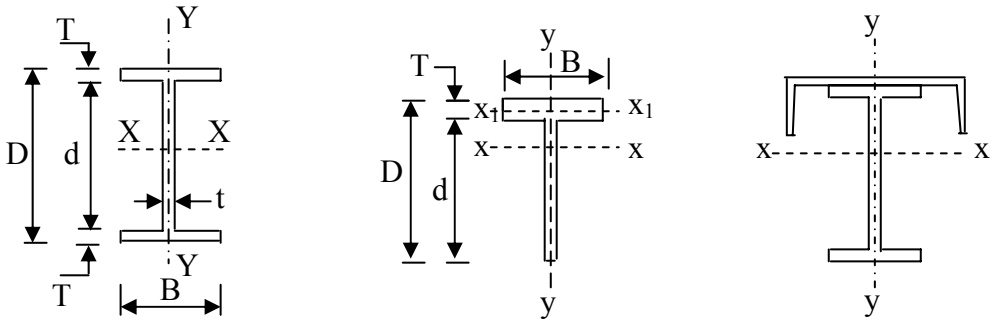
(2) The location of the centroid of the section.;

(3) Area of the cross section .

(4) Moments of inertia about principal axes.

(5) Radii of gyration about principal axes .

For compound and built–up sections, the properties must be calculated from first principles. The beam section for the symmetrical I-Section and unsymmetrical section is dimensioned as shown in Fig. 2.1



a) Symmetrical I-section **b) Unsymmetrical**

Fig. 2.1 Beam sections

2.3.2 Material Properties

The mechanical behavior of metals, including the resistance of metals to failure which caused by slip, fatigue, impact, flow or creep, stress rupture , corrosion, strength, ductility and elastic properties of steel influenced by three principle factors :

1) The carbon content.
2) The percentages of silicon, sulfur, phosphorus, manganese, and other alloying elements.
3) The heat treatment and mechanical working.

2.3.3 Hot-Rolled Sections

Hot-rolled sections are produced in steel mills from steel billets by passing them through a series of rolls. The main sections are shown in Fig. 2.2 and their principal properties and uses are briefly discussed herein after:-

(1) Universal Beams

These are very efficient sections for resisting bending moment about the major axis.

(2) Universal Columns

These are sections produced primarily to resist axial load with a high radius of gyration about the minor axis to prevent buckling in that plane.

(3) Channels

These are used as beams, bracing members, truss members and in compound members.

(4) Angles (Equal and Unequal)

These are used as bracing members, truss members and for purlins and sheeting rails.

(5) Structural Tees

The sections shown are produced by cutting a universal beam or column in to two parts. Tees are used as truss member, ties and light beams.

(6) Hollow Sections : Circular, Square and Rectangular

These sections are produced from flat plates. The circular shape is formed first and then converted to the square or rectangular shape. These sections make very efficient compression members, and they are also used in building frames, as purlins, sheeting rails, etc.

The range of usual serial sizes is given for the members shown in Figure (2.2). A number of different members are produced in each serial size by varying the flange, web, leg or wall thicknesses. The sizes and properties of these sections are given in a number of handbooks &publications such as:

-BS 4: Structural Steel Sections, Part 1: Hot –Rolled Sections

-BS 4848: Hot -rolled Structural Steel Sections,

Part 2: Hollow Sections ,

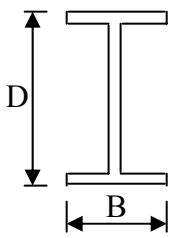
Part 4: Equal and Unequal Angles .

(7) Steel Sheet

Thin, flat-rolled Coiled sheet steel accounts for nearly one-half of all steel shipped domestically and is created in hot-strip mill by rolling a cast slab flat while maintaining the side dimensions. The malleable steel lengthens to several hundred meters as it is squeezed by the rolling mill. The most common differences among steel bars, strip, plate, and sheet are merely their physical dimensions of width and gauge thickness. Product classification by sized (BS4360:1986) is given in Table (2.1) .

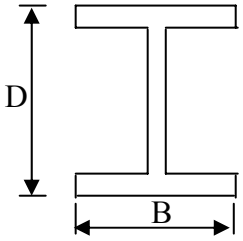
Table (2.1) Product Classification by Size (BS 4360:1986)

Specified **Thickness (Millimeters)**	*Specified Width (Millimeters)*				
	≤ 152	**≤ 203**	**≤ 304**	**≤ 1219**	**≥ 1219**
≥ 5.84	Bar	Bar	Plate	Plate	Plate
≥ 5.18	Bar	Bar	Plate	Plate	Plate
≥ 4.57	Strip	Strip	Strip	Sheet	Plate
≥ 1.14	Strip	Strip	Strip	Sheet	Sheet



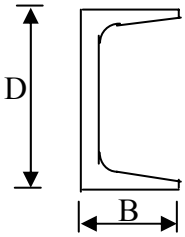
DxB 203x133 to

Universal



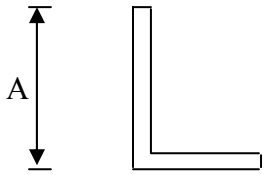
DxB 152x152 to

Universal



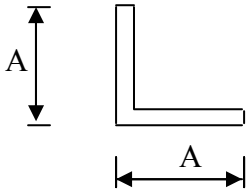
DxB 76x38 to 432x102

Channels



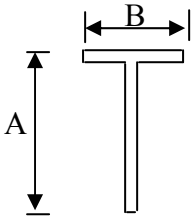
AxB 40x25 to 200x150

Unequal angles



AxA 25x25 to

Equal angles



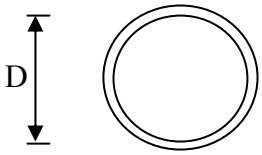
BxA 133x102 to

Structural

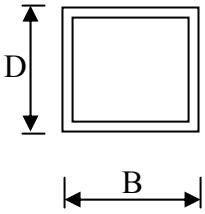
D 213 to 457

DxD 20x20 to 400x400

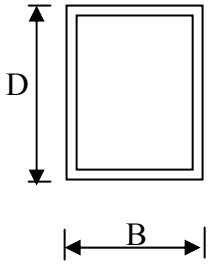
DxB 50x30 to 450x250



Circular Hollow Section



Square Hollow Section

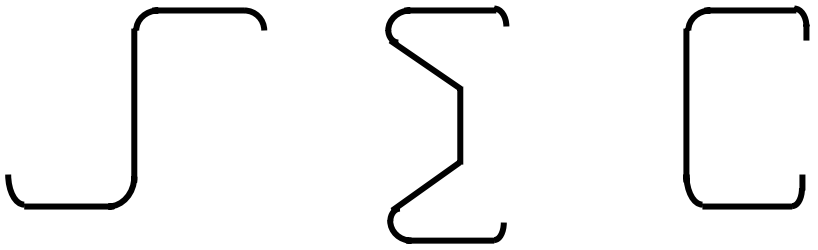


Rectangular Hollow Section

Fig. 2.2 Hot-Rolled Sections

2.3.4 Cold – Formed Sections

Thin steel plates can be formed into a wide range of sections by cold rolling. The most important uses for cold-rolled sections in steel structures are for purlins and sheeting rails. Three common sections- the zed, sigma and lipped channel- are shown in Figure (2.3). For the full range of sizes available internally and the sections properties, reference should be made to manufacturer's literature .



Zed Section **Sigma** **Lipped**

Fig. 2.3 Cold-Formed Sections

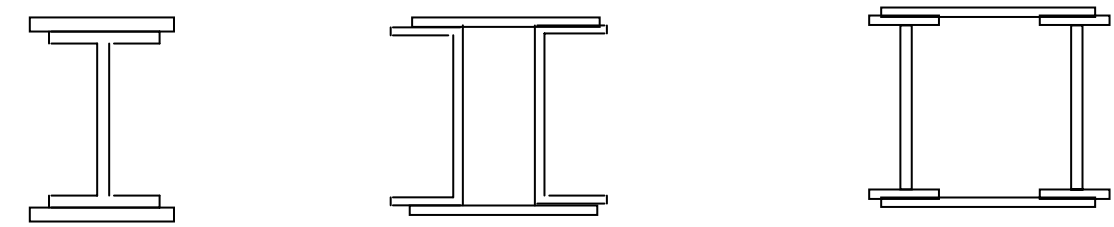
2.3.5 Compound Sections

Compound sections are usually formed by the following means :

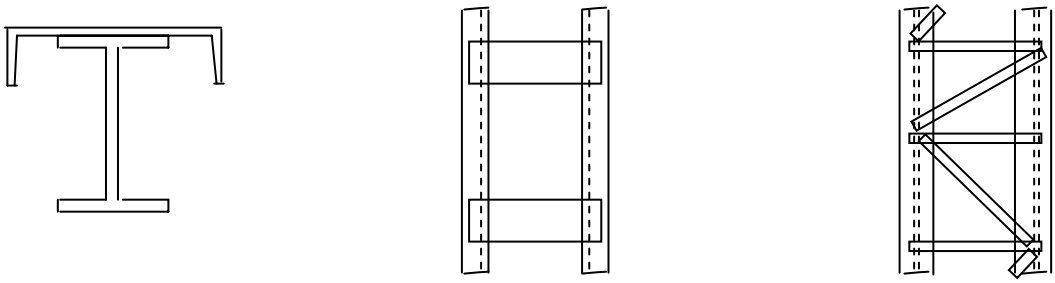
(1) Strengthening a standard rolled section , such as a universal beam, by welding on cover plates, as shown in Figure 2.4 (a) .

(2) Combining two separate rolled sections , as in the case of the crane girder shown in Figure 2.4 (b).

(3) Connecting two members together to form a strong combined member. Examples are battened and laced members shown in Figures 2.4 (c) and (d).



a) Compound Beam Sections



b) Crane Girder **c) Battened Member** **d) Laced Member**

Fig. 2.4 Compound Sections

2.3.6 Built-up Sections

Built-up sections are made by welding plates together to form I, H or box members which are known as plates girders, Built-up columns, box girders or columns, respectively. These sections are used where heavy loads have to be carried and, in the case of plate and box girders, where long spans are required. Examples of Built-up sections are shown in Figure 2.5

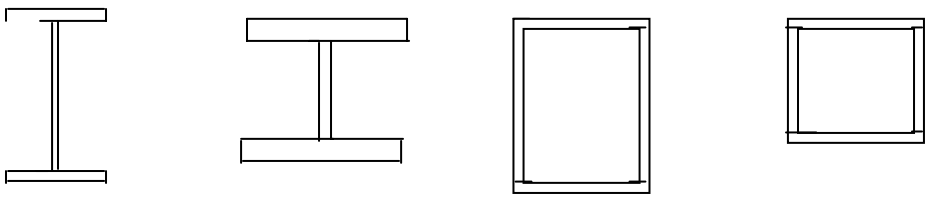


Plate Girder	Built-up Column	Box Girder	Box Column

2.3.7 Structural Steel Sections Manufactured Locally in the Sudan

Lists of Structural Steel Sections Manufactured Locally are presented in Appendix (A)

2.4 Reinforcing Bars

2.4.1 Size of Imported Reinforcing Bars

The preferred Sizes of reinforcing bars, according to BS 4449 (1997) and ASTM 615 (1978) are as shown in Table (2.2)

Table (2.2) Preferred Sizes of Reinforcing Bars

Size (diameter) (mm)	Cross – Sectional Area (mm^2)
6	28.2
8	50.2
10	78.5
12	113.0
16	201.0
20	314.0
32	804.0

The reinforcing bars of diameter 6mm and below, usually imported to market in the form of coils and cut according to the need. Sizes bigger than 6mm usually come in lengths

greater than 20m, but most of it of lengths 6m and 12m. Some dimensions of the type 18mm-32mm are rarely imported. They are imported only according to the needs.

2.4.2 Reinforcing Bars Produced Locally

There are two local Factories which produce reinforcing bars, namely:

i) GIAD Factory; which produces bars 10mm, 12mm, 16mm and 20mm in diameter.

ii) Omdurman Factory; which produces bars 10mm, 12mm and 16mm in diameter.

CHAPTER THREE

TESTING STEEL PRODUCTS

INCLUDED IN THIS STUDY

3.1 Introduction

Tests are conducted on construction materials in order to determine their quality and their suitability for specific use . It is necessary, for the producer, consumer, and the general public, to have tests for the determination of quantitative properties of materials such that the material may be properly selected, specified and designed. Tests are further needed to duplicate materials and to check upon the uniformity of different shipments.

Testing and evaluation of the many metals and alloys requires hundreds of tests and specifications. The BS, ISO, ASTM…etc, specifications, dealing with metals and their alloys , covers various standard tests for steel products.

The most common mechanical tests (for metals and metallic products) are listed in ASTM A370, (BS) and (ISO) as follows:

1- **ASTM E8: Tension Testing of Metallic Materials (BS 18 : 1987), (ISO 6892)**
2- **ASTM E10 : Test for Brinell Hardness of Metallic Materials.(BS 240 : 1986), (ISO 156)**
3- **ASTM E18 : Test for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials. (BS 891 : 1989), (ISO 6508)**

4- ASTM E23 : Notched – Bar Impact Testing of Metallic Materials. (BS 131 : 1989), (ISO R148, R83, R442)

5- ASTM E16 : Bend Testing of metals. (BS 1639 : 1989), (ISO 7438)

3.2 Steel Testing Facilities Available in The Sudan

The following types of Tests for steel are presently available in the Sudan:

Table (3.1) Steel Testing Facilities Available in The Sudan

Institute / Organization	Available Testing Facilities					
	Tensile Test		Hardness Test	Impact Test	Chemical Composition	Metallurgy
	TTM	Extenso - meter				
Faculty of Eng. Lab, U.of. K.	√***	√	√	√	-	√
IRC Lab (El-Halfaya)	√*	√	√	√	-	-
O.I.U Lab	√***	-	-	-	-	-
GIAD Factory Lab	√**	_	√	-	√	-

Maximum capacity (per Ton) : * 10 , ** 20 (Digital) ,* 50**

3.3 Tests for Structural steel

Tests to be performed shown in table (3.2) below :

Table (3.2) Tests to be performed for Structural steel

No.	Type of Test	Name of Lab. where tests were carried out
1	**Tensile Test (Extensometer)**	**- Faculty of Eng. Lab, U.of. K.** **- IRC Lab. (AL-Halfia)**
2	**Hardness Test**	**- IRC Lab. (AL-Halfia)**
3	**Impact**	**- IRC Lab. (AL-Halfia)**
4	**Chemical compositions**	**- Giad Factory Lab.**

3.3.1 Tensile Test

Apparatus

Extensometer, complying with (BS 18). All local factories import structural steel as rolled sheets and provided to form of required sections. Test samples were taken from the rolled sheets. Some standard sections; angles, square pipes and rectangular pipes were also tested. For any test three specimens were taken from each batch.

Table (3.3) Type of Sections of Test Samples

Factory	Steel sheets	Type of Sections	No
The Malaysian Sudanese Factory	**HR 1.0mm sheets** **HR 1.5mm sheets** **CR 0.6mm sheets** **CR 0.5mm sheets**	**Angles 50x50x4mm** **Square pipes (3mm thick)** **Rectangular pipes (1mm thick)**	**3**
The Metal Factory	**HR 1.0mm sheets** **CR 1.0mm sheets**	**Rectangular pipes (1mm thick)**	**3**
United Triple Factory	**HR 1.0mm sheets**	**Rectangular pipes (1mm thick)**	**3**

Most specifications for metals have requirements for physical properties as determined by the tensile strength. The tension test is one of the most important tests for determining the structural and mechanical properties of metals. These properties include the ultimate tensile strength, ductility, elongation, reduction in area, modulus of elasticity, yield point, yield strength, proportional limit, the elastic and inelastic range.

The tensile test is performed by gripping the opposite ends of specimen shown in Figure (3.1) called coupon and pulling it apart. Various standard ASTM coupons are shown in Figure (3.2) and BS coupons are shown in Figure (3.3) Standard test specimens are obtained from sheared blanked , sawed , trepanned, or oxygen – cut materials are being tested .In all cases, special attention should be taken to ensure the removal by machining all distorted cold – or heat-affected areas .Test specimens should be machined such that they have a reduced cross section at the mid point to localize the zone of fracture .In addition ,the specimen should be gauged and marked such that the percentage elongation may be determined .

When loading a metal specimen ,the rate of loading is usually unimportant but should not exceed 690MPa/min. Most modern testing machines are equipped with electronic strain gauges; otherwise, extensometers or foil gages (in conjunction with strain indicators and switching and balancing unit) may be employed .When the coupon is fastened in the machine and the strain gauge is fastened, the test begins. as the specimen is pulled apart, a load- strain (stress –strain) diagram may be

plotted (automatically if electronic strain gauges are used) as shown in Figure (3.4) from this various physical and /or mechanical properties be obtained.

In a tensile test it is customary to give the strength of a material in terms of stress or force per unit area. Also, the point at which yielding starts is expressed as stress.

Furthermore, in a tensile test, strain is measured as unit strain. Unit strain, in any direction, is the deformation per unit of length in that direction. If electronic strain gages are employed in a tensile test,

the plot on the stress-strain diagram is a function of the force per unit area versus the unit strain.

However, in some cases the unit strain cannot be obtained directly (as in the use of an extensometer), so the deformation, measured in any direction ,is the total change in the dimension of a member in that direction .When the loading is such that the unit strain is constant over the length of a member, it may be computed by dividing the deformation by the original length of the member (gauge length). Thus unit strain equals total strain divided by the gauge length.

Tensile Strength **: the tensile strength of metals is the maximum axial load (ultimate load),observed in a tension test,divided by the original cross-sectional area. The strength increases and reaches a maximum in mild steel, after extensive elongation and necking. As indicated, it is Characterized by the beginning of necking down, a decrease in cross sectional area of the specimen, or local instability.**

The tensile strength is the ultimate strength expressed in units of (psi) and as shown in Figure (3.4).

Ductility is the ability of a material to undergo large deformations without fracture. Thus, the material will deform in the inelastic (plastic)range. Ductility is measured by the elongation and reduction of area in a tension test and is expressed as a percentage:

Percent reduction =

$$Percent\ \text{reduction} = \frac{\text{Final length - orginal length}}{original\ length} x100 \qquad \textbf{(3.1)}$$

and

$$\text{Percent reduction area} = \frac{\text{original area - area after fracture}}{\text{original area}} x100 \qquad \textbf{(3.2)}$$

The slope of the straight–line portion of the stress- strain curve, gives the modulus of elasticity (E). It is a measure of the inherent rigidity or stiffness of a material. For given geometric configuration, a material with a larger E deforms less under the same stress.

The modulus of elasticity (Young's modulus) is the ratio of unit stress to unit strain in the elastic range of the stress-strain curve as follows:

$$E = \frac{\text{Stress (Mpa)}}{\text{Strain (mm./mm.)}} \quad (3.3)$$

Yield point at the end of the linear portion of the stress- strain cure, some materials (such as a low-carbon steels) develop a yield point. The yield point is the first load at which there is a marked increase in strain without an increase in stress. This behavior may be a consequence of inertia due to the effects of the testing machine and the deformation characteristics of the test specimen. The yield point is sometimes taken as the proportional limit and elastic limit, which is an incorrect practice. Most metals do not have a yield point, and thus an offset method is utilized.

Offset Yield Strength: The offset yield strength is defined as the stress corresponding to a permanent deformation. The offset method is usually used with materials that have a definite straight-line portion in their stress-strain curve. One measures the corresponding offset percentage on the stress-strain curve and projects upward a straight line parallel with the straight-line portion of the stress-strain curve. Where the line intersects the stress-strain curve, the value is read off as the offset yield strength.

In situations where the stress-strain curve does not exhibit a straight-line portion, the secant modulus or tangent modulus method may be used.

The proportional limit: is the greatest stress that a material is capable of without deviating from the law of proportionality of stress to strain (Hooke's law). Hooke's law is defined as

$$\sigma = E \times \varepsilon \qquad (3.4)$$

Where σ = unit stress

ε = unit strain

E = Young's modulus of elasticity

Metals are elastic within the proportional limit and thus the proportional limit has significance in the elastic stability of columns and shells.

Elastic Limit and Inelastic Range: The elastic limit is the largest unit stress that can be developed without a permanent set remaining after the load is removed. In most cases the elastic limit is difficult to determine, and many materials do not have a well-defined proportional limit, or even have one at all; thus, the offset yield

strength is used to measure the beginning of plastic deformation (inelastic range).

3.3.2 Rockwell Hardness Test

ASTM, E18 & BS 891 specifies the test for the determination of the Rockwell hardness and Rockwell superficial hardness of metallic materials. The Rockwell hardness method employs either a ball or measure depth of penetration accurately. Two superimposed impressions are made, one with a load of 22 Ib (10 kg) and the second with a load of 220 Ib (100 kg). The depth to which the major load drives the ball or cone below that depth to which the minor load has previously driven it is a measure of the hardness. This method is usually designated as Rockwell B, as the ball is used here. For the harder steels, greater accuracy is obtained by use of a diamond cone applied under a major load of 330 Ib (150 kg) and a minor load of 22 Ib (10 kg) and is designated as Rockwell C. Rockwell superficial hardness machines are also used for the testing of very thin shells or thin surface layers of materials. In this case the minor load is 6.6 Ib (3 kg) and the major load varies from 33 to 99 Ib (15 to 45 kg).

In all cases the Rockwell hardness number is read directly from the scales on the machine. The relationship of the Brinell and Rockwell hardness numbers to tensile strength is shown in Table (3.4).

Table (3.4).The relationship of the Brinell and Rockwell hardness numbers to tensile strength

Brinell Hardness Number			**Rockwell Hardness Number**			**Rockwell Superficial Hardness Number, Diamond Penetrator**		
Brinell Indentation Diameter (mm)	**Standard Ball**	**Tungsten Carbide Ball**	**B Scale**	**C Scale**	**15-N Scale**	**30-N Scale**	**45-N Scale**	**(Approximate) Tensile Strength(Mpa)**
2.50		601		57.3	89.0	75.1	63.5	2262
2.60		555		54.7	87.8	72.7	60.6	2055
2.70		514		52.1	86.5	70.3	47.6	1890
2.80		477		49.5	85.3	68.2	54.5	1738
2.90		444		47.1	84.0	65.8	51.5	1586
3.00	415	415		44.5	82.8	63.5	48.4	1462
3.10	388	388		41.8	81.4	61.1	45.3	1331
3.20	363	363		39.1	80.0	58.7	42.0	1220
3.30	341	341		36.6	78.6	56.4	39.1	1131
3.40	321	321		34.3	77.3	54.3	36.4	1055
3.50	302	302		32.1	76.1	52.2	33.8	1007
3.60	285	285		29.9	75.0	50.3	31.2	952
3.70	269	269		276	73.7	48.3	28.5	897
3.80	255	255		27.6	73.7	48.3	28.5	897
3.90	241	241	100.0	22.8	70.9	43.9	22.8	800
4.00	229	229	98.2	20.5	69.7	41.9	20.1	766
4.10	217	217	96.4					710
4.20	207	207	94.6					682
4.30	197	197	92.8					648
4.40	187	187	90.7					621
4.50	179	179	89.0					607
4.60	170	170	86.8					579
4.70	163	163	85.0					566
4.80	156	156	82.9					552
4.90	149	149	80.8					503
5.00	143	143	78.7					490
5.10	137	137	76.4					462

5.20	131	131	74.0	448
5.30	126	126	72.0	434
5.40	121	121	69.0	414
5.50	116	116	67.6	400
5.60	111	111	65.7	386

Rockwell Test Procedure

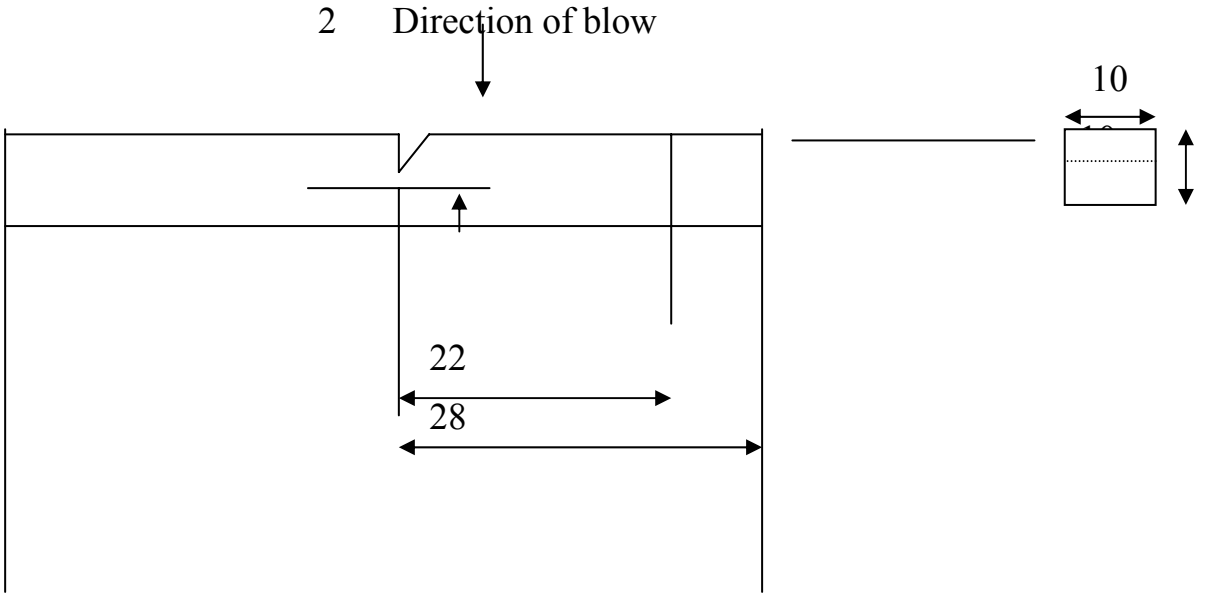
1- **Before starting test, the crank Handle is pulled for ward counter- clockwise as far as it .**
2- **Correct penetrator selected and plunger rod inserted.**
3- **Correct anvil placed on elevating screw.**
4- **Correct combination of weights selected and corresponding position of minor load weight.**
5- **Specimen or test block placed on the anvil.**
6- **Specimen raised into contact with the penetrator by turning capstan hand wheel clockwise. Continue motion until small pointer is near the dot. Continue until the large pointer is in a vertical position**
7- **The bezel of the dial gauge until the " SET" line is directly behind the large pointer.**
8- **The weights (MAJOR LOAD) released by tripping the crank handle backward. Do not force this crank handle. Allow the dash-pot to control the speed of test.**
9- **When the large pointer comes to rest return the crank handle to the starting position. This removes the major load. The minor load is still applied.**
10- **The scale letter and " ROCKWELL" number read from the dial gauge.**
11- **The MINOR LOAO is removed by turning the capstan handwheel counter-clockwise to lower the elevating screw and specimen so they clear the penetrator.**
12- **The specimen is removed or the test repeated.**

3.3.3 Notched-Bar Impact Test

Impact tests are performed primarily for two reasons:

1. To determine the ability of the material to resist impact under service conditions.
2. To determine the quality of the metal from a metallurgical standpoint.

Two types of impact tests are usually performed, the charpy and the lzod tests. Both apply a dynamic load by use of a pendulum that has enough kinetic energy to rupture the specimen in its path. Each specimen is prepared to standard shape as in Fig. (3.6).



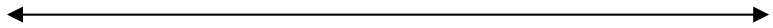


Fig. 3.6 Standard Dimensions of a sample for Impact Test

And used Izod Impact by a machine of 2.76 kg. M capasity.

3.3.4 Chemical Composition Test (Spectophotometer)

3.3.4.1 Objective of the Test

The objective of this test is to determine the percentages of the elements existing in the specimen

3.3.4.2 Apparatus

- Grinding Machine
- Spectrophotometer (with 10 digit accuracy and 4 decimal) for the following main elements: Carbon C, Manganese Mn, Silicon Si, Phosphor P, sulfur S, in addition to ; Molpedeim Mo, Vanadium V, chrome Cv, copper Cu, Nickel Ni , which are used in calculating the Carbon Equivalent.

3.3.4.3 Sampling

Number of specimen bars selected randomly to be tested for the chemical composition using the spectrophotometer for each test unit.

3.3.4.4 Preparation of Specimen

The specimen (composed of three randomly selected bars) is prepared to be plane-ended.

-The specimen surface is refined using the grinding machine.

-The surface of the specimen is cleaned , using a smooth dry paper.

-During the test, The specimen surface must be free from any active gas. with discharging rate not less than 30 m bar. The in- active gas surrounding the specimen should be 99.98% pure.

3.3.4.5 Testing of Specimen & Calculations

-Two analysis tests must be carried for the same bar and the average is determined, providing that the analysis is changed each time the test is carried.

-The result of analysis is considered only if the standard deviation is less than 1.0 (SD < 1.0) for the element under consideration.

The Carbon Equivalent (C_{Eq}) is calculated from:

$$C_{Eq} = C + Mn / 6 + (Mo + V + Cr) /5 + (Cu + Ni) / 15$$

3.3.4.6 Test Procedure

1. The specimens are prepared and cleaned using the specimen preparation Apparatus
2. Operate the computer corrected with the spectrophotometer analysis apparatus From the (Analyse) menu choose (Initialize instrument) and (READ Instrument) from the sub-menu.
3. Place the specimen which prepared as in (1) above in the champer and tidely close it.
4. The name and number the specimen is input to the program by checking an (Analyse)and choosing (Details). This operation will take about 30 seconds approximately.
5. For re-analysis, change the position the specimen in the chamber, then press (Analyse Again) and waiting for about another 30 seconds to perform the analysis.
6. The results are recorded in the spectrum Analysis test from (IT / 02) and the average reading is recorded at the end of

the day in the daily report of the laboratory (IT/03).

3.4 Tests for Reinforcing Bars

Tests to be performed are shown in table (3.5) below :

Table (3.5) Tests to be performed on Reinforcing Bars

No.	Type of Test	Name of Lab. Where Tests were carried out
1	**Tensile Test (Tensile Testing machine)**	**- Faculty of Eng. Lab, U.of. Kh** **- Giad Factory Lab.**
2	**Bending Test**	**- Giad Factory Lab.**
3	**Chemical compositions**	**- Giad Factory Lab.**

3.4.1 Tensile Test

Objective of the Test:

Determine the tensile strength, Yield stress and elongation of Reinforcing Bars by the methods described in BS 18.

Apparatus: Tensile Testing Machine

Sampling & Preparation

Three samples are taken from a batch manufactured at a certain time.. Each test unit will comprise 3 test specimens. Each sample is cut at a length of Min 30d and bars exhibiting isolated defects, which are not characteristic of the product, are excluded.

The following samples are obtained from the indicated factories and sources in Table (3.6):

Table (3.6) Type of Reinforcing Bars of Test Samples

	Source or Factory	Diameter available (mm)	Type	Number
Local	**Omdurman Factory**	**12,16**	**Deformed**	**3**
	GIAD	**10,12,16**	**Deformed**	**3**
Imported	**Ukraine**	**8,10,12,16,25,32**	**Deformed**	**3**
	Turkey	**10,12,16**	**Deformed**	**3**
	Egypt	**6,10,12,18,25**	**Deformed**	**3**
		20	**Plain**	**3**

Condition of Test Specimens

The tensile, bend and rebend tests shall be carried out on straight bars.

Determination of the effective cross-sectional area of deformed bars (as BS 4449)

For bars where the configuration is such that, by visual inspection. The cross-sectional area is substantially uniform along the length of the bar, the effective cross-sectional area,

A, shall be the gross cross-sectional area, in millimeters squared, determined by weighing and measuring to a precision of + 0.5% a length of not less than 0.5m and calculated as follows:

$$A = \frac{M}{0.00785L}$$

where

M is the mass of the bar (in kg)

L is the length of the bar(in m)

Test Procedure

(as BS 18)Insert a test piece in the grips of a suitable tensile testing machine and apply an increasing force to strain the test piece. Test continuously or with interruptions depending upon the tensile properties to be determined.

3.4.2 Bending Test

BS 4449 specifies both a test bend and rebend test. The diameter of former (or mandrel) around which a bar must

bent without any transverse rupture of the metal is twice the bar size for grade 250 and three times bar size for grade 460.

3.4.3 Chemical Compositions Test (Spectrophotometer)

The same procedure and steps indicated in sub-section 3.3.4 were repeated here .

CHAPTER FOUR

TEST RESULTS

4.1 General

This chapter presents the results of the different tests carried out to investigate the properties of structural steel used in Sudan.

The results are shown and tabulated in two groups:

The first **group contains the results for the structural steel sections. The tests carried out on tensile strength, hardness and chemical analysis tests.**

The second **group contains the test results for the reinforcing bars. The tests carried out for this group are tensile strength tests and the chemical composition test.**

The results are grouped and tablulated in a manner to show their overall significance. A diagramatical representations are also developed in following chapter to compare the results for different samples in each test group.

Hardness Test Results
Samples of Local Steel Sections

Sample :M/4

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	65
2		63
3		62

Sample :SM/4

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	94
2		96
3		93

Hardness Test Results
Samples of Local Steel Sections

Sample :M/1

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	79
2		81
3		86

Sample :M/2

Specimen No	Load (N)	Rockwell Hardness Number
1	1471.5	89
2		87
3		87

Sample 3U/1

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	63
2		60
3		61

Hardness Test Results
Samples of Local Steel Sections

Sample :SM/3

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	79
2		78
3		77

Sample :SM/6

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	49
2		50
3		53

Sample :3U/3

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	69
2		65
3		62

Hardness Test Results
Samples of Local Steel Sections

Sample :M/5

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	69
2		67
3		71

Sample :M/6

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	66
2		60
3		60

Sample :M/3

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	85
2		87
3		80

Hardness Test Results
Samples of Local Steel Sections

Sample :SM/1

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	85
2		85
3		87

Sample :SM/2

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	74
2		75
3		71

Sample :3U/2

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	80
2		78
3		75

Hardness Test Results
Samples of Imported Steel Sections

Sample :P/1

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	99
2		97
3		98

Sample :E/1

Specimen No	Load (N)	Rockwell Hardness Number
1	588.6	90
2		89
3		87

4.2 Results of Structural Steel Sections

Tensile Test Result
(Extensometer Test)
Sample of Local Steel Sections

Sample Number (M/1)

Specimen No	Area (mm)	Yield Strength (N/mm²)	Tensile St (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	16.65	259	342	24	HR Sheet	I.R.C.	M
2	16.93	278	342	17			
3	16.37	288	354	15			

Sample Number (M/2)

Specimen No	Area (mm)	Yield Strength (N/mm²)	Tensile St (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	21.38	321	413	20	HR Sheet	I.R.C	M
2	20.72	343	393	22			
3	20.30	329	406	29			

Sample Number (M/3)

Specimen No	Area (mm)	Yield Strength (N/mm²)	Tensile St (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	20.12	332	385	20	HR Sheet	I.R.C.	M
2	19.31	320	381	24			
3	22.97	290	316	22			

Tensile Test Result
(Extensometer Test)
Sample of Local Steel Sections

Sample Number (M/4)

Specimen No	Area (mm)	Yield Strength (N/mm²)	Tensile St (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	8.95	236	280	7	CR Sheet	I.R.C.	SM
2	8.88	271	309	12			
3	8.22	247	298	7			

Sample Number (M/5)

Specimen No	Area (mm)	Yield Strength (N/mm²)	Tensile St (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	18.19	205	243	14	CR Sheet	I.R.C	SM
2	14.29	251	309	13			
3	15.32	237	288	18			

Sample Number (M/6)

Specimen No	Area (mm)	Yield Strength (N/mm²)	Tensile St (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	13.12	247	322	13	CR Sheet	I.R.C.	M
2	15.16	194	269	15			
3		269	334	17			

Tensile Test Result
(Extensometer Test)
Sample of Local Steel Sections

Sample Number (SM/4)

Specimen No	Area mm^2	Yield Strength (N/mm²)	Tensile St (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	9.41	203	250	8	CR Sheet	I.R.C.	SM
2	9.08	238	292	18			
3	9.15	221	268	12			

Sample Number (SM/5)

Specimen No	Area mm^2 (mm)	Yield Strength (N/mm²)	Tensile St (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	11.24	358	384	9	CR Sheet	I.R.C	SM
2	12.97	333	363	21			
3	12.33	321	350	20			

Sample Number (SM/6)

Specimen No	Area (mm) mm^2	Yield Strength (N/mm^2)	Ultimate S (N/mm^2)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	10.67	239	294	14	CR Sheet	I.R.C.	SM
2	10.54	244	310	13			
3	12.28	212	260	15			

Tensile Test Result
(Extensometer Test)
Sample of Local Steel Sections

Sample Number (3U/1)

Specimen No	Area (mm) mm^2	Yield Strength (N/mm^2)	Ultimate S (N/mm^2)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	17.43	236	280	22	HR Sheet	I.R.C.	3U
2	17.44	271	309	20			
3	19.73	247	298	18			

Sample Number (3U/2)

Specimen No	Area (mm) mm^2	Yield Strength (N/mm^2)	Ultimate S (N/mm^2)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	18.83	279	380	19	HR Sheet	I.R.C	3U
2	22.93	252	312	18			
3	21.38	273	342	18			

Sample Number (3U/3)

Specimen No	Area (mm)	Yield Strength (N/mm²)	Ultimate S (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	17.99	280	315	19	HR Sheet	I.R.C.	3U
2	17.66	244	304	20			
3	18.30	299	330	18			

Tensile Test Result
(Extensometer Test)
Sample of Local Steel Sections

Sample Number (E/1)

Specimen No	Area (mm)	Yield Strength (N/mm²)	Ultimate S (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	39.71	279	390	21	HR Angle 2in	U. of K.	(1)
2	41.60	248	370	23			
3	39.74	321	405	20			

Sample Number (E/2)

Specimen No	Area (mm)	Yield Strength (N/mm²)	Ultimate S (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	39.80	281	394	21	HR Angle 2in	U. of K.	(1)
2	39.72	274	383	20			
3	39.91	269	377	23			

Sample Number (E/3)

Specimen No	Area (mm)	Yield Strength (N/mm²)	Ultimate S (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	39.90	301	406	21	HR Angle 2in	U. of K.	(1)
2	39.79	292	376	22			
3	39.88	271	379	22			

Tensile Test Result
(Extensometer Test)
Sample of Local Steel Sections

Sample Number (P/1)

Specimen No	Area (mm)	Yield Strength (N/mm²)	Ultimate S (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	57.65	297	434	32	HR Angle 2in	U. of K.	(1)
2	58.56	294	421	23			
3	58.32	291	425	24			

Sample Number (P/2)

Specimen No	Area (mm)	Yield Strength (N/mm²)	Ultimate S (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	28.29	295	426	34	HR Angle 2in	U. of K.	(1)
2	29.74	341	479	27			
3	28.74	320	466	26			

Sample Number (P/3)

Specimen No	Area (mm)	Yield Strength (N/mm²)	Ultimate S (N/mm²)	Elongation %	Remarks		
					Type of Sample	Testing Lab	Source of Sample
1	28.76	334	461	27	HR Angle 2in	U. of K.	(1)
2	28.52	314	453	34			
3	28.29	323	459	29			

4.3 Results of Reinforcing Bars

Tensile Test Result
Sample of Omdurman Steel R .B

Sample Number (O16/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	15.12	179.6	1.410	425	588	1.4	13	U. of K.	O
2	14.69	169.6	1.332	378	467	1.2	21		
3	15.49	188.6	1.481	347	621	1.8	17		

Sample Number (O16/2)

								Remarks

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Testing Lab	Source of Sample
1	15.21	181.84	1.427	365	553	1.52	14	U. of K.	O
2	15.15	180.41	1.416	323	475	1.47	14		
3	15.15	181.13	1.422	314	471	1.50	24		

Sample Number (O16/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	15.43	187.02	1.468	413	637	1.54	7	U .of K.	O
2	14.90	174.65	1.371	630	951	1.51	7		
3	15.25	182.69	1.434	482	711	1.48	7		

Tensile Test Result
Sample of Omdurman Steel R .B

Sample Number (O16/4)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample

1	15.43	187.02	1.468	413	637	1.54	7	U. of K	O
2	14.9	174.65	1.371	630	951	1.51	7		
3	15.25	182.69	1.434	482	711	1.47	7		

Sample Number (O16/5)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	11.6	9792	0.769	715	1068	1.49	7	U.of K.	O
2	11.8	98.2	0.771	720	1066	1.48	7		
3	11.44	102.83	0.807	660	974	1.47	7		

Tensile Test Result
Sample of Turkish 1-Steel R B

Sample Number (T 5.5/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	5.5	23.8	0.187	264	400	1.52	22	U. of K.	(3)
2	5.5	23.8	0.187	260	383	1.47	23		
3	5.5	23.8	0.187	354	523	1.48	22		

Sample Number (T5.5/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	5.5	23.8	0.187	264	420	1.59	22	U.of K	(3)
2	5.5	23.8	0.187	280	429	1.53	23		
3	5.5	23.8	0.187	280	412	1.47	22		

Sample Number (T5.5/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	5.5	23.8	0.187	257	361	1.40	14	U.of K	(3)
2	5.5	23.8	0.187	363	544	1.50	13		
3	5.5	23.8	0.187	301	420	1.40	18		

Tensile Test Result
Sample of Turkish 1-Steel R B

Sample Number (T6/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	6.0	28.3	0.222	298	423	1.42	17	U. of K.	(3)
2	6.0	28.3	0.222	277	395	1.43	18		
3	6.0	28.3	0.222	326	451	1.38	20		

Sample Number (T6/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	6.0	28.3	0.222	541	735	1.36	18	U.of K	(3)
2	6.0	28.3	0.222	541	742	1.37	14		
3	6.0	28.3	0.222	541	749	1.38	16		

Tensile Test Result
Sample of Turkish 1-Steel R B

Sample Number (T8/1)

Specimen	Actual Size	X - Sectional	Weight	Yield	Tensile St		Elongation	Remarks

NO	(mm)	Area (mm²)	(kg /ML)	Strength fy (N/mm²)	(N/mm²)	fu / fy	%	Testing Lab	Source of Sample
1	7.69	46.5	0.365	464	707	1.52	20	U.of K	(3)
2	7.76	45.5	0.357	464	701	1.51	20		
3	7.76	47.3	0.371	467	705	1.51	19		

Sample Number (T8/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	8.0	50.3	0.395	238	374	1.57	28	U.of K	(3)
2	8.0	50.3	0.395	230	374	1.63	31		
3	8.0	50.3	0.395	230	374	1.63	28		

Tensile Test Result
Sample of Turkish 1-Steel R B

Sample Number(T10/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	10.00	78.6	0.617	412	668	1.62	17	U.of K	(3)
2	10.03	79.0	0.620	428	652	1.52	19		
3	10.00	78.6	0.617	468	724	1.55	18		

Sample Number (T10/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	10.17	81.3	0.638	428	694	1.62	16	U. of K	(3)
2	10.17	81.3	0.638	428	694	1.62	17		
3	10.15	80.9	0.635	430	697	1.62	18		

Sample Number (T10/3)

Specimen	Actual Size	X - Sectional	Weight	Yield	Tensile St		Elongation	Remarks

NO	(mm)	Area (mm²)	(kg /ML)	Strength fy (N/mm²)	(N/mm²)	fu / fy	%	Testing Lab	Source of Sample
1	9.95	77.8	0.611	429	662	1.54	22	U.of K	(3)
2	9.63	72.9	0.572	437	713	1.63	20		
3	9.98	78.3	0.615	401	668	1.67	22		

Tensile Test Result
Sample of Turkish 1-Steel R B

Sample Number (T12/1).

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	12.13	115.7	0.908	432	672	1.56	24	U.of K	(3)
2	11.92	111.6	0.876	453	694	1.53	24		
3	12.27	118.3	0.929	415	634	1.53	21		

Sample Number (T12/2)

Specimen	Actual Size	X - Sectional	Weight	Yield	Tensile St		Elongation	Remarks

NO	(mm)	Area (mm²)	(kg /ML)	Strength fy (N/mm²)	(N/mm²)	fu / fy	%	Testing Lab	Source of Sample
1	12.15	115.9	0.910	440	703	1.60	19	U.of K	(3)
2	12.16	116.2	0.912	452	709	1.57	19		
3	12.07	114.4	0.898	424	690	1.63	21		

Sample Number (T12/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	12	113.1	0.888	416	603	1.54	25	U.of K	(3)
2	11.95	112.3	0.882	367	581	1.58	26		
3	11.96	112.4	0.882	380	580	1.53	27		

Tensile Test Result
Sample of Turkish 1-Steel R B

Sample Number(T16/1)

Specimen	Actual Size	X - Sectional	Weight	Yield	Tensile St		Elongation	Remarks

NO	(mm)	Area (mm²)	(kg /ML)	Strength fy (N/mm²)	(N/mm²)	fu / fy	%	Testing Lab	Source of Sample
1	15.97	200.5	1.574	431	695	1.61	23	U.of K	(3)
2	16.33	209.6	1.645	431	693	1.61	22		
3	15.80	196.2	1.540	430	705	1.64	24		

Sample Number (T16/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	15.85	197.3	1.549	452	687	1.52	24	U.of K	(3)
2	15.88	198.1	1.555	431	669	1.55	23		
3	15.87	198.0	1.554	436	669	1.53	25		

Sample Number (T16/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	15.77	195.5	1.535	422	682	1.62	23	U.of K	(3)
2	15.68	193.1	1.516	417	681	1.63	23		
3	15.77	195.3	1.533	412	678	1.65	23		

Tensile Test Result
Sample of Turkish 1-Steel R B

Sample Number (T32/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm^2)	Weight (kg /ML)	Yield Strength fy (N/mm^2)	Tensile St (N/mm^2)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	31.42	775.9	6.091	503	614	1.22	23	U.of K	(3)
2	31.46	777.7	6.105	396	624	1.58	16		
3	31.50	779.6	6.120	489	623	1.27	23		

Tensile Test Result

Sample of Egypt 1-Steel R B

Sample Number (E10/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	9.97	78.1	0.613	396	647	1.63	20	U.of K	(1)
2	9.95	77.8	0.611	403	649	1.61	20		
3	10.06	79.5	0.624	401	635	1.58	20		

Sample Number (E10/2)

Specimen	Actual Size	X - Sectional	Weight	Yield	Tensile St		Elongation	Remarks

NO	(mm)	Area (mm²)	(kg /ML)	Strength fy (N/mm²)	(N/mm²)	fu / fy	%	Testing Lab	Source of Sample
1	9.98	78.2	0.614	395	615	1.56	25	U.of K	(1)
2	10.00	78.5	0.616	400	612	1.53	23		
3	9.98	78.3	0.615	388	608	1.57	24		

Sample Number (E10/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	10.12	80.4	0.631	403	665	1.65	21	U.of K	(1)
2	10.23	82.2	0.645	388	650	1.68	23		
3	10.20	87.7	0.688	438	654	1.49	21		

Tensile Test Result
Sample of Egypt 1-Steel R B

Sample Number (E12/1)

Specimen	Actual Size	X - Sectional	Weight	Yield	Tensile St		Elongation	Remarks

NO	(mm)	Area (mm²)	(kg /ML)	Strength fy (N/mm²)	(N/mm²)	fu / fy	%	Testing Lab	Source of Sample
1	11.92	111.7	0.877	373	606	1.62	29	U.of K	(1)
2	11.94	112.1	0.880	372	608	1.63	25		
3	11.94	112.1	0.880	372	608	1.63	26		

Sample Number (E12/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	11.99	112.9	0.886	391	626	1.60	26	U.of K	(1)
2	12.00	113.2	0.889	412	624	1.51	24		
3	11.98	112.7	0.885	418	609	1.46	26		

Sample Number (E12/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	12.12	115.5	0.907	408	684	1.68	20	U.of K	(1)
2	11.85	110.4	0.867	427	720	1.69	21		
3	12.12	115.4	0.906	408	784	1.92	23		

Tensile Test Result
Sample of Egypt 1-Steel R B

Sample Number (E16/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	16.25	207.5	1.629	321	610	1.90	21	U.of K	(1)
2	16.12	204.1	1.602	327	596	1.82	22		
3	16.10	203.6	1.598	337	660	1.96	22		

Sample Number (E16/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	15.88	198.2	1.556	431	703	1.63	22	U.of K	(1)
2	15.91	199.0	1.562	429	700	1.63	23		
3	15.83	196.9	1.546	433	705	1.63	25		

Sample Number (E16/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	15.99	201.0	1.578	351	610	1.74	20	U.of K	(1)
2	15.94	199.7	1.568	329	589	1.79	21		
3	15.59	199.1	1.561	363	622	1.71	22		

Tensile Test Result
Sample of Egypt 1-Steel R B

Sample Number (E18/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	17.79	248.49	1.951	311	470	1.51	26.67	U.of K	(1)
2	17.79	247.6	1.944	319	469	1.47	25.00		
3	17.8	248.77	1.953	302	466	1.54	25.00		

Sample Number (E18/2)

Specimen	Actual Size	X - Sectional	Weight	Yield	Tensile St		Elongation	Remarks

NO	(mm)	Area (mm²)	(kg /ML)	Strength fy (N/mm²)	(N/mm²)	fu / fy	%	Testing Lab	Source of Sample
1	18.02	255.2	2.003	384	680	1.77	23	U.of K	(1)
2	17.93	252.6	1.983	353	668	1.89	25		
3	17.96	253.4	1.987	394	671	1.70	24		

Tensile Test Result

Sample of Egypt 1-Steel R B

Sample Number (E20/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	20	315.4	2.476	280	544	1.94	23		

2	20.08	316.9	2.488	350	619	1.77	25	U.of K	(1)
3	20.04	315.5	2.477	351	619	1.76	24		

Sample Number (E20/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	19.89	310.8	2.440	350	609	1.74	27	U.of K	(1)
2	19.92	311.8	2.448	330	610	1.85	26		
3	19.84	309.2	2.427	349	606	1.74	26		

Sample Number (E20/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tens Streng (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	20.14	318.7	2.502	382	656	1.72	24	U.of K	(1)
2	20.05	315.8	2.479	354	652	1.84	24		
3	19.95	312.7	2.455	358	646	1.80	24		

Tensile Test Result

Sample of Egypt 1-Steel R B

Sample Number(E25/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	24.99	490.57	3.851	416	673	1.62	12	U.of K	(1)
2	25.00	490.96	3.854	420	681	1.62	17		
3	25.95	488.98	3.839	419	677	1.62	20		

Sample Number (E25/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	24.89	486.8	3.821	359	649	1.81	24	U.of K	(1)
2	24.84	485.5	3.811	368	651	1.77	23		
3	24.86	485.4	3.810	374	651	1.74	25		

Sample Number (E25/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	24.95	489.3	3.841	383	638	1.67	19	U.of K	(1)
2	24.86	485.7	3.813	374	667	1.78	27		
3	24.83	484.4	3.803	372	635	1.71	21		

Tensile Test Result
Sample of Egypt 1-Steel R B

Sample Number (E32/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	31.66	787.5	6.182	409	691	1.69	22	U.of K	(4)
2	31.70	789.6	6.198	410	678	1.65	22		
3	31.79	794.1	6.234	403	689	1.71	22		

Tensile Test Result
Sample of Ukraine 1-Steel R B

Sample Number (U5.5/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	5.46	23.4	0.184	243	361	1.49	26%	U.of K	(5)
2	5.49	23.7	0.186	240	356	1.48	22%		
3	5.46	23.7	0.186	257	373	1.45	20%		

Sample Number(U5.5/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	5.54	24.1	0.189	244	366	1.50	28%	U.of K	(5)
2	5.55	24.2	0.190	251	397	1.58	29%		
3	5.60	24.6	0.193	247	367	1.49	24%		

Sample Number (U5.5/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	5.62	24.8	0.195	269	388	1.44	26%	U.of K	(5)
2	5.46	23.4	0.184	293	394	1.34	22%		
3	5.55	24.2	0.190	243	405	1.67	26%		

Tensile Test Result
Sample of Ukraine 1-Steel R B

Sample Number (U6/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	5.8	26.4	0.207	253	386	1.53	16%	U.of K	(5)
2	6.0	28.3	0.222	243	364	1.50	20%		
3	5.9	27.4	0.215	243	372	1.53	21%		

Sample Number (U6/2)

Specimen	Actual Size	X - Sectional	Weight	Yield	Tensile St		Elongation	Remarks

NO	(mm)	Area (mm²)	(kg /ML)	Strength fy (N/mm²)	(N/mm²)	fu / fy	%	Testing Lab	Source of Sample
1	5.96	27.9	0.219	485	626	1.29	18%	U.of K	(5)
2	5.96	27.9	0.219	563	633	1.12	15%		
3	5.95	27.8	0.218	487	621	1.28	16%		

Sample Number (U6/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	6.0	28.3	0.222	250	364	1.46	25%	U.of K	(5)
2	6.0	28.3	0.222	260	364	1.40	25%		
3	6.0	28.3	0.222	253	347	1.37	25%		

Tensile Test Result
Sample of Ukraine 1-Steel R B

Sample Number (U8/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	8.0	50.3	0.395	341	478	1.40	24%	U.of K	(5)
2	8.0	50.3	0.395	332	497	1.50	23%		
3	8.0	50.3	0.395	283	449	1.59	26%		

Sample Number (U8/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	7.5	44.2	0.347	231	368	1.59	25	U.of K	(5)
2	7.5	44.2	0.347	226	351	1.55	31		
3	7.5	44.2	0.347	200	364	1.82	20		

Sample Number (U8/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	8.0	50.3	0.395	293	400	1.37	26	U.of K	(5)
2	8.0	50.3	0.395	273	400	1.47	30		
3	8.0	50.3	0.395	254	390	1.54	30		

Tensile Test Result
Sample of Ukraine 1-Steel R B

Sample Number(U28/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	27.4	589.99	4.631	399	488	1.22	13.3	U.of K	(6)
2	27.1	589.57	4.628	375	427	1.14	10.00		
3	27.87	585.6	4.597	410	490	1.20	13.67		

Sample Number(U32/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm^2)	Weight (kg /ML)	Yield Strength fy (N/mm^2)	Tensile St (N/mm^2)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	31.35	772.0	6.060	589	661	1.12	14	U.of K	(6)
2	31.38	773.3	6.070	579	649	1.12	15		
3	31.46	778.98	6.115	570	666	1.17	15		

Tensile Test Result
Sample of Ukraine 1-Steel R B

Sample Number(U10/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	10.32	83.7	0.657	463	686	1.48	16	U.of K	(7)
2	10.29	83.2	0.653	472	696	1.47	17		
3	10.29	82.7	0.649	469	688	1.47	19		

Sample Number (U10/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	10.33	83.9	0.659	526	620	1.18	16	U.of K	(7)
2	10.33	83.9	0.659	526	626	1.19	15		
3	10.32	83.7	0.657	545	627	1.15	17		

Sample Number(U10/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	9.98	78.3	0.615	520	620	1.19	17	U.of K	(7)
2	10.32	83.7	0.657	527	639	1.21	14		
3	10.30	83.3	0.654	530	642	1.21	16		

Tensile Test Result
Sample of Ukraine 1-Steel R B

Sample Number(U12/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	12.03	113.67	0.892	507	624	1.23	17	U.of K	(7)
2	12.06	114.29	0.897	500	616	1.23	16		
3	11.91	111.47	0.875	531	722	1.36	15		

Sample Number (U12/2)

Specimen	Actual Size	X - Sectional	Weight	Yield	Tensile St		Elongation	Remarks

NO	(mm)	Area (mm²)	(kg /ML)	Strength fy (N/mm²)	(N/mm²)	fu / fy	%	Testing Lab	Source of Sample
1	12.20	116.9	0.918	587	692	1.63	14	U.of K	(7)
2	12.16	116.4	0.914	574	675	1.17	15		
3	12.19	116.7	0.916	605	694	1.14	13		

Sample Number (U12/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	11.95	112.2	0.881	538	647	1.20	16	U.of K	(7)
2	12.00	113.2	0.889	572	676	1.18	18		
3	11.98	112.7	0.885	566	662	1.16	20		

Tensile Test Result
Sample of Ukraine 1-Steel R B

Sample Number(U16/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	16.00	197.19	1.548	584	690	1.18	12.18	U.of K	(7)
2	16.00	197.19	1.548	596	706	1.18	10.18		
3	16.00	197.19	1.548	598	705	1.18	11.64		

Sample Number(U16/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	15.84	197.2	1.548	522	662	1.27	16	U.of K	(7)
2	15.80	196.2	1.540	556	660	1.19	19		
3	15.99	201.0	1.579	556	683	1.23	18		

Sample Number (U16/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tens Streng (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	15.99	200.9	1.577	586	693	1.18	17	U.of K	(7)
2	16.01	201.4	1.581	589	701	1.19	19		
3	16.00	204.0	1.601	575	685	1.19	19		

Tensile Test Result
Sample of Ukraine 1-Steel R B

Sample Number (U20/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	20.00	302.06	2.371	600	730	1.22	13.25	U.of K	(7)
2	20.00	301.44	2.366	634	740	1.17	13.75		
3	20.00	303.32	2.381	603	706	1.17	12.00		

Sample Number(U20/2)

Specimen	Actual Size	X - Sectional	Weight	Yield	Tensile St		Elongation	Remarks

NO	(mm)	Area (mm²)	(kg /ML)	Strength fy (N/mm²)	(N/mm²)	fu / fy	%	Testing Lab	Source of Sample
1	20.04	315.5	2.477	470	703	1.50	23	U.of K	(7)
2	20.03	315.3	2.475	470	688	1.46	22		
3	20.03	315.3	2.475	470	694	1.48	22		

Sample Number(U20/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	19.65	303.4	2.382	378	588	1.56	31	U. of K	(7)
2	19.57	301.0	2.363	385	593	1.54	29		
3	19.65	303.4	2.382	362	585	1.62	31		

Tensile Test Result
Sample of Ukraine 1-Steel R B

Sample Number(U25/1)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tens Streng (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	24.79	483.2	3.793	378	564	1.49	34	U.of K	(7)
2	24.93	488.3	3.833	374	556	1.49	32		
3	24.66	478.0	3.752	376	575	1.53	31		

Sample Number(U25/2)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	25.05	493.2	3.872	479	696	1.45	28	U.of K	(7)
2	24.99	490.7	3.852	482	698	1.45	27		
3	25.01	491.5	3.858	459	715	1.56	23		

Sample Number(U25/3)

Specimen NO	Actual Size (mm)	X - Sectional Area (mm²)	Weight (kg /ML)	Yield Strength fy (N/mm²)	Tensile St (N/mm²)	fu / fy	Elongation %	Remarks	
								Testing Lab	Source of Sample
1	24.66	478.0	3.752	376	575	1.53	31	U.of K	(7)
2	24.93	488.30	3.833	374	556	1.49	32		
3	24.79	483.20	3.793	378	564	1.49	34		

Chemical Composition Test Results

Samples of Giad Steels Reinforcing Bars

Sample No. (Gr60/1)

Specimen No.	C	Si	P	S	Mn	Cu	CE
1	0.281	0.100	0.011	0.040	0.5185	0.0000	0.417
2	0.389	0.321	0.017	0.019	1.1780	0.0235	0.671
3	0.385	0.073	0.018	0.022	0.9201	0.0046	0.610

Sample No. (Gr60/2)

Specimen No.	C	Si	P	S	Mn	Cu	CE
1	0.415	0.068	0.028	0.040	0.963	0.035	0.636

2	0.383	0.063	0.039	0.032	1.019	0.012	0.613
3	0.381	0.066	0.036	0.035	1.017	0.011	0.611

Sample No. (Gr60/3)

Specimen No.	C	Si	P	S	Mn	Cu	CE
1	0.367	1.059	0.086	0.058	0.244	0.013	0.468
2	0.390	0.970	0.038	0.023	0.230	0.006	0.489
3	0.410	1.017	0.041	0.230	0.180	0.004	0.501

Sample No. (Gr40/1)

Specimen No.	C	Si	P	S	Mn	Cu	CE
1	0.250	0.919	0.036	0.021	0.129	0.174	0.332
2	0.270	0.926	0.036	0.022	0.135	0.176	0.376
3	0.270	0.925	0.037	0.023	0.136	0.175	0.385

Chemical Composition Test Results
Samples of Ukraine Steel Reinforcing Bars

Sample No. (U 10/1)

Specimen No.	C	Si	P	S	Mn	CE
1	0.31	0.39	0.027	0.012	1.37	0.578
2	0.33	0.42	0.41	0.018	1.45	0.610
3	0.32	0.37	0.038	0.016	1.34	0.593

Sample No. (U 12/1)

Specimen No.	C	Si	P	S	Mn	CE
1	0.257	0.200	0.004	0.012	0.6340	0.403
2	0.203	0.079	0.010	0.018	0.0048	0.274
3	0.221	0.131	0.014	0.018	0.5783	0.377

Sample No. (U 16/3)

Specimen No.	C	Si	P	S	Mn	CE
1	0.246	0.214	0.010	0.016	0.6054	0.401
2	0.282	0.092	0.006	0.018	0.8307	0.420
3	0.302	0.174	0.011	0.029	0.8621	0.486

Sample No. (U 20/2)

Specimen No.	C	Si	P	S	Mn	CE
1	0.35	0.39	0.031	0.024	1.43	0.628
2	0.35	0.38	0.034	0.032	1.40	0.597
3	0.34	0.28	0.022	0.009	1.39	0.601

Chemical Composition Test Resutls
Samples of Egypt Steel Reinforcing Bars

Sample No. (E 12/3)

Specimen No.	C	Si	P	S	Mn	CE
1	0.34	0.47	0.031	0.013	1.43	0.598
2	0.36	0.43	0.031	0.024	1.40	0.623
3	0.34	0.40	0.033	0.021	1.38	0.610

Sample No. (E 16/2)

Specimen No.	C	Si	P	S	Mn	CE
1	0.34	0.40	0.043	0.018	1.46	0.623
2	0.34	0.39	0.035	0.025	1.48	0.637
3	0.33	0.42	0.036	0.021	1.43	0.618

Chemical Composition Test Results
Samples of Turkish Steel Reinforcing Bars

Sample No. (T 10/2)

Specimen No.	C	Si	P	S	Mn	CE
1	0.31	0.30	0.033	0.020	1.36	0.577
2	0.32	0.39	0.026	0.014	1.32	0.590
3	0.31	0.38	0.021	0.017	1.30	0.567

Sample No. (T 12/2)

Specimen No.	C	Si	P	S	Mn	CE
1	0.34	0.41	0.032	0.044	1.40	0.623
2	0.36	0.50	0.023	0.045	1.26	0.614
3	0.36	0.37	0.026	0.031	1.46	0.654

Sample No. (T 16/1)

Specimen No.	C	Si	P	S	Mn	CE
1	0.34	0.27	0.032	0.014	1.20	0.591
2	0.35	0.36	0.042	0.015	1.43	0.628
3	0.35	0.36	0.040	0.023	1.39	0.622

Tensilt Test Results
Samples of Giad Steel Reinforcing Bars

Sample Number (G10/1)

Specimen NO	Actual size (mm)	Cross-section Area (mm^2)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample
1	9.96	77.87	0.611	492	748	1.52	15	Giad	G
2	10.00	78.50	0.616	478	741	1.55	15		
3	9.90	76.94	0.604	486	744	1.53	13		

Sample Number (G10/2)

Specimen NO	Actual size (mm)	Cross-section Area (mm^2)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample
1	9.95	77.79	0.611	365	618	1.69	24	U. of K.	G
2	9.88	76.70	0.602	372	623	1.67	21		
3	0.87	76.54	0.601	361	608	1.68	22		

Sample Number (G10/3)

Specimen NO	Actual size (mm)	Cross-section Area (mm²)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample
1	10.01	78.7	0.618	399	598	1.50	23	U. of K.	(8)
2	10.00	78.5	0.616	400	600	1.50	22		
3	10.06	79.5	0.624	383	611	1.60	24		

Tensilt Test Results
Samples of Giad Steel Reinforcing Bars

Sample Number (G10/4)

Specimen NO	Actual size (mm)	Cross-section Area (mm²)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample

1	9.93	77.50	0.608	646	771	1.19	15	Giad	G
2	10.17	81.19	0.637	496	759	1.53	15		
3	10.17	81.19	0.637	412	656	1.59	16		

Sample Number (G10/5)

Specimen NO	Actual size (mm)	Cross-section Area (mm^2)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample
1	9.83	75.85	0.595	530	814	1.54	14	Giad	G
2	10.06	79.47	0.624	551	813	1.48	14		
3	9.96	77.95	0.612	510	778	1.52	15		

Tensilt Test Results
Samples of Giad Steel Reinforcing Bars

Sample Number (G12/1)

Specimen NO	Actual size (mm)	Cross-section Area (mm²)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample
1	11.95	112.1	0.880	479	749	1.56	15	Giad	G
2	11.75	108.38	0.851	465	733	1.58	15		
3	11.97	112.48	0.883	482	763	1.58	14		

Sample Number (G12/2)

Specimen NO	Actual size (mm)	Cross-section Area (mm²)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample
1	11.84	110.05	0.864	381	583	1.53	21	U. of K.	G
2	11.89	110.98	0.871	377	566	1.50	23		
3	11.74	112.66	0.884	350	546	1.56	22		

Sample Number (G12/3)

Specimen NO	Actual size (mm)	Cross-section Area (mm²)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample
1	12.47	122.2	0.959	425	650	1.53	22	U. of K.	(8)
2	12.50	122.8	0.964	407	639	1.57	22		
3	12.48	122.3	0.960	393	650	1.65	22		

Tensilt Test Results
Samples of Giad Steel Reinforcing Bars

Sample Number (G12/4)

Specimen NO	Actual size (mm)	Cross-section Area (mm²)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample
1	12.02	113.42	0.890	582	743	1.28	16	Giad	G
2	11.87	110.72	0.869	559	656	1.17	17		
3	11.92	111.57	0.876	570	770	1.35	16		

Sample Number (G12/5)

Specimen NO	Actual size (mm)	Cross-section Area (mm²)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample
1	11.97	112.62	0.884	503	789	1.57	19	Giad	G
2	12.03	113.61	0.892	545	780	1.43	18		
3	12.12	115.45	0.906	555	751	1.35	16		

Sample Number (G16/1)

Specimen NO	Actual size (mm)	Cross-section Area (mm²)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample
1	15.81	196.46	1.542	597	737	1.23	16	Giad	G
2	15.81	199.46	1.566	588	736	1.25	18		
3	15.83	196.96	1.546	618	736	1.19	19		

Tensilt Test Results

Samples of Giad Steel Reinforcing Bars

Sample Number (G16/2)

Specimen NO	Actual size (mm)	Cross-section Area (mm^2)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample
1	15.71	193.8	1.521	370	623	1.68	21	Giad	G
2	15.89	198.3	1.557	331	561	1.69	22		
3	15.78	195.7	1.536	396	682	1.72	21		

Sample Number (G16/3)

Specimen NO	Actual size (mm)	Cross-section Area (mm^2)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample
1	15.67	193.6	1.520	427	728	1.70	22	U. of K.	(8)
2	15.73	197.4	1.550	429	727	1.69	24		
3	15.73	197.4	1.550	414	651	1.57	25		

Sample Number (G16/4)

Specimen NO	Actual size	Cross-	Weight (Kg/ML)	Yield	Tensile	Fu/fy	Elongation	Remarks

	(mm)	section Area (mm²)		Strength fy (N/mm^2)	Strength fu (N/mm^2)		%	Testing Lab	Source Of Sample
1	15.71	193.99	1.523	443	692	1.56	17	Giad	G
2	15.71	193.82	1.521	419	628	1.50	21		
3	15.72	194.23	1.525	464	719	1.55	27		

Tensilt Test Results

Samples of Giad Steel Reinforcing Bars

Sample Number (G16/5)

Specimen NO	Actual size (mm)	Cross-section Area (mm²)	Weight (Kg/ML)	Yield Strength fy (N/mm^2)	Tensile Strength fu (N/mm^2)	Fu/fy	Elongation %	Remarks	
								Testing Lab	Source Of Sample
1	15.95	199.9	1.569	383	649	1.69	26	U. of K.	G
2	15.88	198.1	1.555	391	654	1.67	20		
3	15.83	196.8	1.545	379	638	1.68	22		

CHAPTER FIVE

ANALYSIS AND DISCUSSION OF RESULTS

5.1 General

The details of all Structural steel sections, considered in this study, are outlined in Chapter Two, and the relevant standard specifications are listed in Appendices (B&C) which are most used in the Sudan . In the following sections of this chapter, the properties of structural steel sections and reinforcing bars, available in the Sudan, are compared with the requirements of standard specifications.The parameters considered in the comparison are the dimensions, weight, mechanical properties and chemical composition.

5.2 Structural Steel Sections

5.2.1 Types of Sections Considered

(a) Square-shaped Pipes

According to BS 4848 Part II (1987), the minimum and maximum sizes of square pipes are (20x20) mm and (400 x400) mm, respectively, with thicknesses ranging between 2mm up to 12.5 mm. In the (mm) size of the square pipes produced locally, the minimum size is (16 x 16) mm with thickness 0.6 mm {see Appendices (A.1.2) which is significantly below the value specified.

The maximum size of local products does not exceed (25 x 25) mm, the larger sizes are not produced in the Sudan and they are not usually available in the market.

(b) Rectangular Pipes

According to BS 4848 Part II (1987), the minimum and maximum sizes of rectangular pipes are (30x50) mm and (250 x450)mm, respectively, the thickness ranges between 2.6mm up to 16 mm. For the locally produced square pipes, the minimum size is only (15x30)mm, the thickness ranges between 1.2 mm up to 1.5 mm {see Appendices (A.1.3). Similar to the case of square-shaped pipes, the dimensions of rectangular pipes are below the standard specification requirements.

(c) Circular Pipes

The minimum external diameter in BS 4848 part II (1987) is 21.3 mm and the maximum is 457mm.The thickness ranges between 3.2 and 40 mm. However, for the locally produced pipes, the external diameter varies between 12.7 and 101.6mm, while the thickness ranges between (1.5&2.0) mm (see Appendices A.1.4 , A.2.6, A.3.1). Hence, the dimensions, of the locally produced circular pipes, are below the standard specification requirement.

(d) Equal Angles

The minimum dimension in BS 4848 part4 (1987) is (25x25x3mm) and the maximum dimension is (200x200x24mm). For local products, the minimum

dimension is (20x20x2mm) and the maximum is to (75x75x6mm) (see Appendices A.1.1, A.2.1). Moreover, the thickness does not comply with the Specifications for the same nominal size.

(e) Unequal Angles

There are no unequal angles produced in the Sudan .The imported unequal angles comply with the dimensions specified in BS 4848 part 4(1987).

(f) Steel Sheets

There are only two types of corrugated Zinc produced in the Sudan, while Standard Specifications list eleven types.

5.2.2 Mechanical Properties

Sudanese Malaysian Factory (SM), United Triple Factory (3U), Metal Factory (M) are local manufactures. Polish (P) and Egyptian (E) refer to Imported structural steel from these countries .

Table (5.1) describes the comparison of the performance for yield strength of steel sections produced by (SM, 3U, M, P and E.) The products of (M, 3U, P and E) comply with the specifications, while for the tested samples from (SM) products,few failed to comply with specifications for hot rolled sections (HR) and many failed to comply in the case of cold rolled sections (CR) .

In Table (5.2) for tensile strength of steel sections, it is observed that, for imported sections, samples tested (P and E), complied with BS and EURONORM specifications but (E) products did not comply with the ASTM specifications. Also, all different types do not comply with ASTM specifications except for (P and M) for HR, (SM) for HR which meet the requirements, but (M) for CR does not comply with any standard specifications.

According to Table (5.3) for elongation of steel sections (M for CR, SM for CR and 3U) do not comply with the standard specifications, but (P and E) satisfy the requirements

Table (5.4) shows that all different types of steel sections do not comply with (ASTM) standards except for (P).

Tables (5.5) shows the chemical composition of the steel sections. It can be seen that the different types comply with the standard specifications except Egyptian steel, in which the carbon percentages do not comply the specifications.

Figures (5.1), (5.2)& (5.3) are comparison of results for minimum Yield Strength, Tensile Strength, Elongation of steel sections respectively. It can be seen that the Polish steel

sections have higher values than the Egyptian and (3U) makes, but (M) and (SM) products have variation in results.

Figures (5.4), (5.5) and (5.6) illustrate the variation of results for steel Sections. It is found that the imported sections have lower variation than the local ones.

5.3 Reinforcing Bars

5.3.1 Geometric Properties

According to the different standards , these reinforcing bars are produced in diameters ranging from 8mm to 40 mm (BS4449/97, ASTM 615) ,or 8mm to52mm (EURONORM 80 -85), or 8mm to 28mm (DIN 488/1986) or 10mm to 41mm (JIS.G3113/1995). It is observed that all their sizes comply with the requirements for nominal weight and allowable tolerances.

Reinforcing bars with diameters greater than 25mm are rarely used in the building construction in the Sudan.

a) Rib Dimensions of Imported Reinforcing Bars

Tables (5.6.1) to (5.6.6) show the compliance of dimensions of the imported reinforcing bars (height & width) of ribs with the standard specifications, while Tables (5.6.7) to (5.6.9) cover the compliance of dimensions of the locally produced reinforcing bars

(I) Ukranian

For longitudinal ribs, as shown in table (5.6.1). the

dimensions Ukrainian made reinforcing bars comply with the specifications of all standard except for (EURONORM 88-85), while for oblique ribs, all of the tested samples of the Ukrainian -made reinforcing bars matches the height requirements of the BS, and EURONORM standards and many of the tested samples comply with the ASTM Specifications.

On the other hand, the width of the oblique ribs of the Ukrainian made reinforcing bars don't comply with any of the standards since it is produced in bigger dimension than specified (see Table 5.6.2) .

(II) Turkish

All of the tested samples of the Turkish -made longitudinal ribs reinforcing bars comply with the standards for height while only some of the tested samples matches the specifications for width requirements (see Table 5.6.3).

Table (5.6.4) for oblique ribs many of the tested samples of Turkish-made reinforcing bars match the height requirements, while the width is comparatively bigger than the specified values.

(III) Egyptian

Table (5.6.5) for longtudanal ribs of the Egyptian-made

reinforcing bars show that their dimensions (height & width) comply with the BS & ASTM specifications , but fail to match EURONORM standards as they are bigger than the values specified there in .

The height of oblique ribs, for Egyptian –made reinforcing bars complies with the specifications as shown in Table (5.6.6) .But the width is again greater than values specified in standard.

b) Rib Dimensions of Local Reinforcing Bars

(I) Giad

In Many of the tested samples, for Giad – made the longitudinal and oblique ribs of reinforcing bars comply with the specifications for height as shown in Tables (5.6.7 & 5.6.8). While for width, all of the tested samples of longitudinal ribs matches the specifications, but the oblique ribs dimensions don't comply with the standards.

(II) Omdurman

The longitudinal ribs of Omdurman – made reinforcing bars are shown in Table (5.6.9). It can be seen that the dimensions (height & width) comply with the standard specifications. Many of the tested samples for oblique ribs matches the specification for height while width does not comply with the standard specifications (Table 5.6.10).

5.3.2 Mechanical Properties

Table (5.8) shows a comparison of yield strength of the reinforcing bars with specifications. It can be deduced that most of the Omdurman and Egyptian –made reinforcing bars do not comply with all required specifications. Many reinforcing bars produced by Giad don't comply with BS 4449, ASTM and DIN standards. On the other hand, most of the reinforcing bars produce by Giad, comply with JIS

and EURONORM specifications.

a) Yield Strength of Reinforcing Bars

Ukrainian –made reinforcing bars up to 16mm nominal size, comply with all standards except JIS , but bars having nominal size grater than 16 mm don't comply with the specifications.

It is also noticed that Turkish –made reinforcing bars don't comply with BS and DIN standards but they show compliance with JIS and EURONORM specifications .

As for yield strength, all types of reinforcing bars don't comply with the BS specifications except the Ukrainian-made ones .

The comparisons of results for the minimum yield strength are shown diagrammatically in Figures (5.7), (5.10) and (5.13) According to these Figures, it is observed that the Ukrainian-made reinforcing bars always possess higher values than the Turkish and the Egyptian-makes. For the Giad-made of reinforcing bars, yield strength values are less than the above mentioned, but there are variations in these values. Omdurman-made reinforcing bars generally have lower values of yield strength.

b) Tensile Strength of Reinforcing Bars

Table (5.8) shows a comparison of tensile strength of the reinforcing bars with the specifications. This comparison reveals that all types of reinforcing bars, with the exception of the Omdurman. And Egyption made bars, comply with BS ,EURONORM and DIN specifications .

Figures (5.8), (5.11) and (5.14) show comparisons of results for minimum tensile Strength. It can be seen that the Turkish and Ukrainian-made reinforcing bars have higher values than Giad and Egyptian-makes. In general, locally manufactured reinforcing bars have lower values of tensile strength with some variation in results.

c) Elongation of Reinforcing Bars

According to Table (5.9), in which a comparison of elongation of reinforcing bars with specifications is presented, Turkish- made reinforcing bars do not comply with all specifications.

Giad-made reinforcing bars comply with the standard specifications except for the JIS .

Most of the Egyptian– made reinforcing bars comply with the standard specifications for elongation.

Omdurman-made reinforcing bars comply with all specifications except JIS.

Figures (5.9) and (5.12) describe the comparison of results for minimum elongation. These Figures show that Egyptian-made reinforcing bars have higher values of minimum elongation than Giad, Turkish and Ukrainian makes respectively Omdurman-made reinforcing bars have variations in values of minimum elongation.

Figure (5.15) illustrate that Turkish-made reinforcing bars have higher values than the Egyptian, Ukrainian, Giad and Omdurman-makes in terms of elongation.

Figures (5.29) to (5.32) indicates that the yield strength of the Ukrainian-made reinforcing bars of 10mm diameter has higher values than the Turkish ,

Egyptian and Giad makes. It is also noted that Giad-made reinforcing bars have large variation in values.

According to Figures (5.35) Turkish-made reinforcing bars possess higher values of tensile strength than the Ukraine and Giad-makes. However, the Egyptian-made reinforcing bars have large variations in tensile strength values.

d) Variations of Results of Reinforcing Bars

Figures (5.16), (5.17) and (5.18) illustrate the variations in results of reinforcing bars of 10mm – diameter.

Also the set of Figures (5.19), (5.20) and (5.21) show the same variations for specimens with 12mm diameter, while Figures (5.22), (5.23) and (5.24) deal with specimens of 16mm diameter.

Figures (5.25), (5.26) and (5.27) illustrate the variations in yield Strength values for all samples. It is observed that results of the Omdurman-made reinforcing bars have larger variation than the others. Ukrainian, Egyptian and Turkish-made

reinforcing bars have lower variation than the Omdurman and Giad makes.

5.3.3 Chemical Composition

According to table (5.14.1) to (5.14.6), the chemical composition of the different types of reinforcing bars does not comply with the standard specifications.

Finally, it is necessary to describe general state of the types of reinforcing bars. It is noted that Ukrainian-made reinforcing bars sometimes, have rough appearance and are more exposed to risks of corrosion and abrasion. The Turkish and Egyptian makes have less corrosion. This rough appearance of imported bars is mainly due to the storage and other factors that do not concern manufactory the locally produced reinforcing bars Giad and Omdurman have good appearance.

Table (5.1)Comparison for Results of Yield Strength
of S.S* with Specifications

Sample No	**Test Result N/mm^2**	BS **Min 235**	**ASTM Min 220**	**EURO Min 235**
M/1	259	OK	OK	OK
M/2	321	OK	OK	OK
M/3	290	OK	OK	OK
Acceptance %		**100**	100	100
M/4	247	**OK**	OK	OK
M/5	205	NOT OK	NOT OK	NOT OK
M/6	194	NOT OK	NOT OK	NOT OK
Acceptance %		67	67	67
SM/1	274	OK	OK	OK
SM/2	232	NOT OK	OK	NOT OK
SM/3	298	OK	OK	OK
Acceptance %		67	100	67
SM/4	203	NOT OK	NOT OK	NOT OK
SM/5	321	OK	OK	OK
SM/6	212	NOT OK	NOT OK	NOT OK
Acceptance %		33	33	33
3U/1	236	**OK**	OK	OK
3U/2	252	OK	OK	OK
3U/3	244	OK	OK	OK
Acceptance %		100	100	100
P/1	291	OK	OK	OK
P/2	295	OK	OK	OK
P/3	314	OK	OK	OK
Acceptance %		100	100	100
E/1	248	OK	OK	OK
E/2	269	OK	OK	OK
E/3	271	OK	OK	OK
Acceptance %		100	100	100

*** S.S. - Structural Steel**

Table (5.2)Comparison for Results of Tensile Strength
of S.S with Specifications

Sample No	**Test Result N/mm^2**	BS **340 - 500**	**ASTM 400 - 550**	**EURO 340 - 470**
M/1	342	OK	NOT OK	OK
M/2	393	OK	NOT OK	OK
M/3	316	NOT OK	NOT OK	NOT OK
Acceptance %		67	0	67
M/4	280	NOT OK	NOT OK	NOT OK
M/5	243	NOT OK	NOT OK	NOT OK
M/6	269	NOT OK	NOT OK	NOT OK
Acceptance %		0	0	0
SM/1	349	OK	NOT OK	OK
SM/2	293	NOT OK	NOT OK	NOT OK
SM/3	365	OK	NOT OK	OK
Acceptance %		67	0	67
SM/4	250	NOT OK	NOT OK	NOT OK
SM/5	363	OK	NOT OK	OK
SM/6	260	NOT OK	NOT OK	NOT OK
Acceptance %		33	0	33
3U/1	280	NOT OK	NOT OK	NOT OK
3U/2	312	NOT OK	NOT OK	NOT OK
3U/3	304	NOT OK	NOT OK	NOT OK
Acceptance %		0	0	0
P/1	421	OK	OK	OK
P/2	426	OK	OK	OK
P/3	453	OK	OK	OK
Acceptance %		100	100	100
E/1	370	OK	NOT OK	OK
E/2	377	OK	NOT OK	OK
E/3	376	OK	NOT OK	OK
Acceptance %		100	0	100

Table (5.3)Comparison for Results of Elongation
of S.S with Specifications

Sample	**Test Result %**	BS **Min 19**	**ASTM Min 20**	**EURO Min 19**
M/1	15	-	NOT OK	NOT OK
M/2	20	-	OK	OK
M/3	20	-	OK	OK
Acceptance %		-	67	67
M/4	7	-	NOT OK	NOT OK
M/5	13	-	NOT OK	NOT OK
M/6	13	-	NOT OK	NOT OK
Acceptance %		-	0	0
SM/1	19	-	NOT OK	OK
SM/2	20	-	OK	OK
SM/3	13	-	NOT OK	NOT OK
Acceptance %		-	33	67
SM/4	8	-	NOT OK	NOT OK
SM/5	9	-	NOT OK	NOT OK
SM/6	13	-	NOT OK	NOT OK
Acceptance %		-	0	0
3U/1	18	-	NOT OK	NOT OK
3U/2	18	-	NOT OK	NOT OK
3U/3	18	-	NOT OK	NOT OK
Acceptance %		-	0	0
P/1	23	-	OK	OK
P/2	26	-	OK	OK
P/3	27	-	OK	OK
Acceptance %			100	100
E/1	20	-	NOT OK	OK
E/2	20	-	NOT OK	OK
E/3	21	-	NOT OK	OK
Acceptance %			100	100

Table (5.4) Comparison of General Mechanical Properties of S.S. with Specification

Sample No.	BS	ASTM	EURONORM
M/1	**OK**	**NOT OK**	**NOT OK**
M/2	**OK**	**NOT OK**	**OK**
M/3	**NOT OK**	**NOT OK**	**OK**
M/4	**NOT OK**	**NOT OK**	**NOT OK**
M/5	**NOT OK**	**NOT OK**	**NOT OK**
M/6	**NOT OK**	**NOT OK**	**NOT OK**
3U/1	**NOT OK**	**NOT OK**	**NOT OK**
3U/2	**NOT OK**	**NOT OK**	**NOT OK**
3U/3	**NOT OK**	**NOT OK**	**NOT OK**
SM/1	**OK**	**NOT OK**	**OK**
SM/2	**NOT OK**	**NOT OK**	**NOT OK**
SM/3	**OK**	**NOT OK**	**NOT OK**
SM/4	**NOT OK**	**NOT OK**	**NOT OK**
SM/5	**OK**	**NOT OK**	**NOT OK**
SM/6	**NOT OK**	**NOT OK**	**NOT OK**

E/1	**NOT OK**	**NOT OK**	**OK**
E/2	**NOT OK**	**NOT OK**	**OK**
E/3	**NOT OK**	**NOT OK**	**OK**
P/1	**OK**	**OK**	**OK**
P/2	**OK**	**OK**	**OK**
P/3	**OK**	**OK**	**OK**

Table (5.5.1) Compliance of Chemical Composition of Steel Sections with Specifications (Carbon)

Sample No.	Test Result %	BS Max. 0.22	ASTM Max. 0.25
M/1	0.093	OK	OK
M/2	0.174	OK	OK
M/3	0.092	OK	OK
M/4	0.083	OK	OK
M/5	0.174	OK	OK
M/6	0.092	OK	OK
3U/1	0.180	OK	OK
3U/2	0.169	OK	OK
3U/3	0.143	OK	OK
SM/1	0.188	OK	OK
SM/2	0.178	OK	OK
SM/3	0.129	OK	OK
SM/4	0.078	OK	OK
SM/5	0.082	OK	OK
SM/6	0.069	OK	OK
E/1	0.267	OK	NOT OK
E/2	0.233	NOT OK	OK
E/3	0.233	NOT OK	OK

Table (5.5.2) Compliance of chemical Composition of Steel Section with Specifications (Manganese)

Sample No.	Test Result %	BS Max. 1.6	ASTM
M/1	0.3333	OK	---
M/2	0.3204	OK	---
M/3	0.3038	OK	---
M/4	0.3397	OK	---
M/5	0.3211	OK	---
M/6	0.3290	OK	---
3U/1	0.3514	OK	---
3U/2	0.3645	OK	---
3U/3	0.3751	OK	---
SM/1	0.3953	OK	---
SM/2	0.3715	OK	---
SM/3	0.3942	OK	---
SM/4	0.0210	OK	---
SM/5	0.0180	OK	---
SM/6	0.0190	OK	---
E/1	0.4463	OK	---
E/2	0.4364	OK	----
E/3	0.4329	OK	---

Table (5.5.3) Compliance of Chemical Composition of Steel Sections with Specifications (Phosphorus)

Sample No.	Test Result %	BS Max. 0.05	ASTM Max 0.04
M/1	0.006	OK	OK
M/2	0.007	OK	OK
M/3	0.005	OK	OK
M/4	0.006	OK	OK
M/5	0.006	OK	OK
M/6	0.007	OK	OK
3U/1	0.015	OK	OK
3U/2	0.008	OK	OK
3U/3	0.006	OK	OK
SM/1	0.020	OK	OK
SM/2	0.019	OK	OK
SM/3	0.015	OK	OK
SM/4	0.006	OK	OK
SM/5	0.005	OK	OK
SM/6	0.006	OK	OK
E/1	0.006	OK	OK
E/2	0.008	OK	OK
E/3	0.008	OK	OK

Table (5.5.4) Compliance of Chemical Composition of Steel Sections with Specifications (Sulfur)

Sample No.	Test Result %	BS Max. 0.05	ASTM Max. 0.05
M/1	0.007	OK	OK
M/2	0.004	OK	OK
M/3	0.019	OK	OK
M/4	0.008	OK	OK
M/5	0.008	OK	OK
M/6	0.007	OK	OK
3U/1	0.015	OK	OK
3U/2	0.016	OK	OK
3U/3	0.008	OK	OK
SM/1	0.016	OK	OK
SM/2	0.015	OK	OK
SM/3	0.017	OK	OK
SM/4	0.021	OK	OK
SM/5	0.018	OK	OK
SM/6	0.019	OK	OK
E/1	0.025	OK	OK
E/2	0.030	OK	OK
E/3	0.024	OK	OK

Compliance of Rib Dimensions (Height & Width) with Specifications

Table (5.6.1) Longitudinal Ribs of Ukrainian Reinforcing Bars

Sample		Data		Compliance with Specifications Considered											
Dia mm (d)	ID	Dimensions Measured (as a fracture of sample Dia)		BS				ASTM				EUR			
				Requirement		Result With respect to		Requirement		Result With respect to		Requirement		Result With respect to	
		Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width
12	U12/1	0.075d	0.200d	≥ 0.05d ≤ 0.14d	≥ 0.08 ≤ 0.2d	Ok	Ok	≥ 0.05d ≤ 0.14d	≥0.08d ≤ 0.2d	Ok	Ok	≥ 0.05d ≤ 0.10	≥0.08d ≤ 0.12	Ok	Not Ok
	U12/2	0.058d	0.183d			Ok	Ok			Ok	Ok			Ok	Not Ok
	U12/3	0.083d	0.200d			Ok	Ok			Ok	Ok			Ok	Not Ok
16	U16/1	0.075d	0.194d			Ok	Ok			Ok	Ok			Ok	Not Ok
	U16/2	0.047d	0.150d			Not Ok	Ok			Not Ok	Ok			Ok	Not Ok
	U16/3	0.063d	0.150d			Ok	Ok			Ok	Ok			Ok	Not Ok

Table (5.6.2) Oblique Ribs of Ukrainian Reinforcing Bars

Sample		Data		Compliance with Specifications Considered											
Dia mm (d)	ID	Dimensions Measured (as a fracture of sample Dia)		BS				ASTM				EUR			
				Requirement		Result With respect to		Requirement		Result With respect to		Requirement		Result With respect to	
		Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width

12	U12/1	0.083d	0.183d	≥ 0.05d ≤ 0.10d	≥ 0.08 ≤ 0.12d	Ok	Not Ok	≥0.045d ≤ 0.09d	≥0.08d ≤0.12d	Ok	Not Ok	≥0.065d ≤ 0.10d	≥0.08d ≤ 0.12	Ok	Not Ok
	U12/2	0.100d	0.200d			Ok	Not Ok			Not Ok	Not Ok			Ok	Not Ok
	U12/3	0.071d	0.216d			Ok	Not Ok			Ok	Not Ok			Ok	Not Ok
16	U16/1	0.050d	0.193d			Ok	Not Ok			Ok	Not Ok			Ok	Not Ok
	U16/2	0.063d	0.188d			Ok	Not Ok			Ok	Not Ok			Ok	Not Ok
	U16/3	0.075d	0.138d			Ok	Not Ok			Ok	Not Ok			Ok	Not Ok

Compliance of Rib Dimensions (Height & Width) with Specifications

Table (5.6.3) Longitudinal Ribs of Turkish Reinforcing Bars

Sample		Data		Compliance with Specifications Considered											
Dia mm (d)	ID	Dimensions Measured (as a fracture of sample Dia)		BS				ASTM				EUR			
				Requirement		Result With respect to		Requirement		Result With respect to		Requirement		Result With respect to	
		Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width
12	T12/1	0.080d	0.134d	≥ 0.05d ≤ 0.14d	≥ 0.08 ≤ 0.2d	Ok	Ok	≥ 0.05d ≤ 0.14d	≥0.08d ≤ 0.2d	Ok	Ok	≥ 0.05d ≤ 0.10	≥0.08d ≤ 0.12	Ok	Not Ok
	T12/2	0.054d	0.183d			Not Ok	Ok			Not Ok	Ok			Not Ok	Ok
	T12/3	0.046d	0.117d			Ok	Ok			Ok	Ok			Ok	Not Ok
16	T16/1	0.084d	0.093d			Ok	Ok			Ok	Ok			Ok	Ok
	T16/2	0.081d	0.075d			Ok	Not Ok			Ok	Ok			Ok	Not Ok
	T16/3	0.063d	0.100d			Ok	Ok			Ok	Ok			Ok	Ok

Table (5.6.4) Oblique Ribs of Turkish Reinforcing Bars

Sample		Data		Compliance with Specifications Considered											
Dia mm (d)	ID	Dimensions Measured (as a fracture of sample Dia)		BS				ASTM				EUR			
				Requirement		Result With respect to		Requirement		Result With respect to		Requirement		Result With respect to	
		Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width
12	T12/1	0.088d	0.117d	≥ 0.05d ≤ 0.10d	≥ 0.08 ≤ 0.12d	Ok	Ok	≥0.045d ≤ 0.9d	≥0.08d ≤0.12d	Ok	Not Ok	≥0.065d ≤ 0.10d	≥0.08d ≤ 0.12	Ok	Ok
	T12/2	0.067d	0.191d			Ok	Not Ok			Ok	Not Ok			Ok	Not Ok
	T12/3	0.075d	0.183d			Ok	Not Ok			Ok	Not Ok			Ok	Not Ok
16	T16/1	0.037d	0.188d			Not Ok	Not Ok			Not Ok	Not Ok			Not Ok	Not Ok
	T16/2	0.071d	0.187d			Ok	Not Ok			Ok	Not Ok			Ok	Not Ok
	T16/3	0.037d	0.187d			Not Ok	Not Ok			Not Ok	Not Ok			Not Ok	Not Ok

Compliance of Rib Dimensions (Height & Width) with Specifications

Table (5.6.5) Longitudinal Ribs of Egyptian Reinforcing Bars

Sample		Data	Compliance with Specifications Considered		
Dia	ID	Dimensions	BS	ASTM	EUR

mm (d)		Measured (as a fracture of sample Dia)		Requirement		Result With respect to		Requirement		Result With respect to		Requirement		Result With respect to	
		Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width
20	E20/1	1.2	4	≥2.00 ≤ 1.00	≥ 2.4 ≤ 1.6	Ok	Not Ok	≥ 20 ≤ 1.00	≥ 2.4 ≤ 1.6	Ok	Not Ok	≥ 2.0 ≤ 1.3	≥ 2.4 ≤ 1.6	Ok	Not Ok
	E20/2	1.5	4			Ok	Not Ok			Ok	Not Ok			Ok	Not Ok
	E20/3	1.3	4.2			Ok	Not Ok			Ok	Not Ok			Ok	Not Ok

Table (5.6.6) Oblique Ribs of Egyptian Reinforcing Bars

Sample		Data		Compliance with Specifications Considered											
Dia mm (d)	ID	Dimensions Measured (as a fracture of sample Dia)		BS				ASTM				EUR			
				Requirement		Result With respect to		Requirement		Result With respect to		Requirement		Result With respect to	
		Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width
20	E20/1	2.7	3	≥ 0.8 ≤ 1	≥ 4 ≤ 1.6	Ok	Ok	≥ 2.8 ≤ 1.00	≥4.00 ≤ 1.6	Ok	Ok	≥2.0 ≤ 1	≥ 2.4 ≤ 1.6	Not Ok	Not Ok
	E20/2	2.5	3.1			Ok	Ok			Ok	Ok			Not Ok	Not Ok
	E20/3	2.7	3.2			Ok	Ok			Ok	Ok			Not Ok	Not Ok

Compliance of Rib Dimensions (Height & Width) with Specifications

Table (5.6.7) Longitudinal Ribs of Giad Reinforcing Bars

Sample		Data		Compliance with Specifications Considered											
				BS				ASTM				EUR			
Diam mm (d)	ID	Dimensions Measured (as a fracture of sample Dia)		Requirement		Result With respect to		Requirement		Result With respect to		Requirement		Result With respect to	
		Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width
10	G10/1	0.055d	0.170d	≥ 0.05d ≤ 0.14d	≥ 0.08 ≤ 0.2d	Ok	Ok	≥ 0.05d ≤ 0.14d	≥0.08d ≤ 0.2d	Not Ok	Ok	≥0.05d ≤ 0.10	≥0.08d ≤ 0.12	Not Ok	Ok
	G10/2	0.045d	0.130d			Not Ok	Ok			Ok	Ok			Ok	Ok
	G10/3	0.065d	0.130d			Ok	Ok			Not Ok	Ok			Not Ok	Ok
12	G12/1	0.038d	0.141d			Not Ok	Ok			Not Ok	Ok			Not Ok	Ok
	G12/2	0.083d	0.125d			Not Ok	Ok			Not Ok	Ok			Ok	Ok
	G12/3	0.012d	0.125d			Ok	Ok			Ok	Ok			Ok	Ok
16	G16/1	0.056d	0.125d			Ok	Ok			Ok	Ok			Ok	Ok
	G16/2	0.071d	0.131d			Ok	Ok			Ok	Ok			Ok	Ok
	G16/3	0.053d	0.138d			Ok	Ok			Ok	Ok			Ok	Ok

Table (5.6.8) Oblique Ribs of Giad Reinforcing Bars

Sample		Data	Compliance with Specifications Considered					
			BS		ASTM		EUR	
Dia mm (d)	ID	Dimensions Measured (as a fracture of sample Dia)	Requirement	Result With respect to	Requirement	Result With respect to	Requirement	Result With respect to

		Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width
10	G10/1	0.075d	0.170d			Ok	Not Ok			Ok	Not Ok			Ok	Ok
	G10/2	0.050d	0.150d			Ok	Not Ok			Ok	Not Ok			Not Ok	Ok
	G10/3	0.065d	0.140d			Ok	Not Ok			Ok	Not Ok			Ok	Ok
12	G12/1	0.046d	0.175d	≥ 0.05d ≤ 0.10d	≥ 0.08 ≤ 0.12d	Not Ok	Not Ok	≥0.045d ≤ 0.09d	≥0.08d ≤0.12d	Ok	Not Ok	≥0.065d ≤ 0.10d	≥0.08d ≤ 0.12	Not Ok	Ok
	G12/2	0.025d	0.191d			Not Ok	Not Ok			Not Ok	Not Ok			Not Ok	Ok
	G12/3	0.029d	0.183d			Not Ok	Not Ok			Not Ok	Not Ok			Ok	Ok
16	G16/1	0.065d	0.150d			Ok	Not Ok			Ok	Not Ok			Ok	Ok
	G16/2	0.050d	0.150d			Ok	Not Ok			Ok	Not Ok			Ok	Ok
	G16/3	0.081d	0.150d			Ok	Not Ok			Ok	Not Ok			Ok	Ok

Compliance of Rib Dimensions (Height & Width) with Specifications
Table (5.6.9) Longitudinal Ribs of Omdurman Reinforcing Bars

Sample		Data		Compliance with Specifications Considered											
Dia mm (d)	ID	Dimensions Measured (as a fracture of sample Dia)		BS				ASTM				EUR			
				Requirement		Result With respect to		Requirement		Result With respect to		Requirement		Result With respect to	
16		Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width
	S16/1	1.6	2	≥ 0.8 ≤ 2.24	≥ 1.2 ≤ 3.2	Ok	Ok	≥ 0.8 ≤ 2.24	≥1.28 ≤ 3.2	Ok	Ok	≥ 0.8 ≤ 1.6	≥ 1.28 ≤ 1.92	Ok	Ok
		1.7	2			Ok	Ok			Ok	Ok			Not Ok	Ok
		1.5	1.9			Ok	Ok			Ok	Ok			Ok	Ok

Table (5.6.10) Oblique Ribs of Omdurman Reinforcing Bars

Sample		Data		Compliance with Specifications Considered											
Dia mm (d)	ID	Dimensions Measured (as a fracture of sample Dia)		BS				ASTM				EUR			
				Requirement		Result With respect to		Requirement		Result With respect to		Requirement		Result With respect to	
		Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width	Height	Width
16	S16/1	1.2	2.3	≥ 0.8 ≤ 1.6	≥1.28 ≤ 1.92	Ok	Not Ok	≥ 0.8 ≤ 2.24	≥ 1.28 ≤ 1.92	Ok	Not Ok	≥1.04 ≤ 1.6	≥ 1.28 ≤ 1.92	Ok	Not Ok
	S16/2	1.3	2.4			Ok	Not Ok			Ok	Not Ok			Ok	Not Ok
	S16/3	0.7	2.8			Not Ok	Not Ok			Not Ok	Not Ok			Ok	Not Ok

Table (5-7) Comparison for Results of Yield Strength of R.B with Specifications

Size Mm	Sample ID	Test **R** N/mm²	BS 4449/97 GR 460 Min 460	ASTM 615 **GR 60** Min 414	JIS G3112/1993 SD 40 Min 390	**EURONO -RM 80.85** Fe B 400 Min 400	DIN 488/1986 Bst 420s Min 420
10	G10/1	478	OK	OK	OK	OK	OK
10	**G10/ 2**	361	NOT OK	NOT OK	NOT OK	OK	NOT OK
10	G10/3	383	NOT OK	NOT OK	NOT OK	OK	NOT OK
10	G10/4	412	NOT OK	NOT OK	OK	OK	NOT OK
10	G10/5	515	OK	OK	OK	OK	OK
12	G12/1	465	OK	OK	OK	OK	OK
12	G12/2	350	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
12	G12/3	393	NOT OK	NOT OK	OK	NOT OK	NOT OK
12	G12/4	559	OK	OK	NOT OK	OK	OK
12	G12/5	503	OK	OK	OK	OK	OK
16	G16/1	597	OK	OK	OK	OK	OK
16	G16/2	331	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
16	G16/3	414	NOT OK	NOT OK	OK	OK	NOT OK
16	G16/4	419	NOT OK	OK	OK	OK	NOT OK
16	G16/5	379	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
Acceptance %			40	47	60	73	40
12	S12/1	393	NOT OK	NOT OK	OK	NOT OK	NOT OK
12	S12/2	321	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
12	S12/3	660	OK	OK	NOT OK	OK	OK
16	S16/1	338	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
16	S16/2	314	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
16	S16/3	414	NOT OK	NOT OK	OK	OK	NOT OK
Acceptance %			17	17	33	33	17
10	U10/1	463	OK	OK	OK	OK	OK
10	U10/2	526	OK	OK	OK	OK	OK
10	U10/3	520	OK	OK	OK	OK	OK
12	U12/1	500	OK	OK	OK	OK	OK
12	U12/2	574	OK	OK	NOT OK	OK	OK
12	U12/3	538	OK	OK	NOT OK	OK	OK
16	U16/1	584	OK	OK	NOT OK	OK	OK
16	U16/2	522	OK	OK	NOT OK	OK	OK
16	U16/3	575	OK	OK	NOT OK	OK	OK
20	U20/1	600	OK	OK	NOT OK	OK	OK
20	U20/2	470	OK	OK	OK	OK	Ok

20	U20/3	362	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
25	U25/1	374	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
25	U25/2	459	NOT OK	OK	OK	OK	OK
25	U25/3	374	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
28	U28/1	376	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
28	U28/2	570	OK	OK	NOT OK	OK	OK
Acceptance %			100	100	44	100	100

Table (5-7) Comparison for Results of Yield Strength of R. B with Specifications

Size Mm	Sample ID	Test **R** N/mm²	BS 4449/97 GR 460 Min 460	ASTM 615 **GR 60** Min 414	JIS G3112/1993 SD 40 Min 390	EURONO- RM 80-85 Fe B 400 Min 400	DIN 488/1986 Bst 420s Min 420
10	T10/1	412	NOT OK	NOT OK	OK	OK	NOT OK
10	T10/2	428	NOT OK	NOT OK	OK	OK	OK
10	T10/3	401	NOT OK	NOT OK	OK	OK	NOT OK
12	T12/1	415	NOT OK	OK	OK	OK	NOT OK
12	T12/2	424	NOT OK	OK	OK	OK	OK
12	T12/3	367	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
16	T16/1	430	NOT OK	OK	OK	OK	OK
16	T16/2	431	NOT OK	OK	OK	OK	OK
16	T16/3	412	NOT OK	NOT OK	OK	OK	NOT OK
32	T32/1	396	NOT OK	OK	OK	NOT OK	NOT OK
Acceptance %			0	50	90	80	40
10	E10/1	396	NOT OK	NOT OK	OK	NOT OK	NOT OK
10	E10/2	388	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
10	E10/3	388	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
12	E12/1	372	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
12	E12/2	391	NOT OK	NOT OK	**O**	NOT OK	NOT OK
12	E12/3	408	NOT OK	*NOT OK*	OK	**O**	NOT OK
16	E16/1	321	NOT OK	NOT OK	OK	OK	OK
16	E16/2	429	NOT OK	OK	OK	OK	OK
16	E16/3	329	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
18	E18/1	302	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
18	E18/2	353	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
20	**E**	280	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
20	E20/2	330	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
20	E20/3	354	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
25	E25/1	416	NOT OK	OK	OK	OK	NOT OK
25	E25/2	359	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK

25	E25/3	372	NOT OK	***NOT OK***	NOT OK	NOT OK	NOT OK
32	E32/1	403	NOT OK	NOT OK	OK	OK	NOT OK
Acceptance %			0	11	39	22	11

Table (5-8) Comparison for Results of Tensile Strength of R. B with Specifications

Size mm	Sample ID	Test **R** N/mm²	BS 4449/97 **GR 460** Min Fyx1.05	ASTM 615 **GR 60** Min 621	JIS G3112/1993 **SD 40** **Min 560**	EURONO-RM 80-85 **Fe B 400** Min 460	DIN 488/1986 Bst 420s Min 500
10	**G**	741	Ok	OK	Ok	Ok	Ok
10	G 10/2	608	OK	NOT Ok	OK	**O**	Ok
10	G10/3	598	OK	NOT OK	Ok	Ok	Ok
10	G10/4	656	Ok	OK	Ok	Ok	Ok
10	G10/5	778	Ok	OK	Ok	Ok	Ok
12	G12/1	733	Ok	OK	Ok	Ok	**(**
12	G12/2	546	Ok	NOT OK	NOT OK	Ok	Ok
12	G12/3	639	Ok	OK	Ok	Ok	Ok
12	G12/4	656	Ok	OK	Ok	Ok	Ok
12	G12/5	751	Ok	OK	Ok	Ok	Ok
16	G16/1	736	Ok	OK	Ok	Ok	OK
16	G16/2	561	Ok	NOT OK	Ok	Ok	OK
16	G16/3	651	Ok	OK	Ok	Ok	OK
16	G16/4	628	Ok	OK	Ok	Ok	OK
16	G16/5	638	Ok	OK	Ok	Ok	OK
Acceptance %			100	73	93	100	100
12	S12/1	496	Ok	NOT OK	NOT OK	Ok	***NOT OK***
12	S12/2	473	Ok	NOT OK	NOT OK	Ok	***NOT OK***
12	S12/3	974	Ok	OK	Ok	Ok	Ok
16	S16/1	467	Ok	NOT OK	NOT OK	Ok	**NOT OK**
16	S16/2	471	Ok	NOT OK	NOT OK	Ok	NOT OK
16	S16/3	637	Ok	OK	OK	Ok	Ok
Acceptance %			100	33	33	100	33
10	U10/1	686	Ok	OK	Ok	Ok	Ok
10	U10/2	620	Ok	NOT OK	Ok	Ok	Ok
10	U10/3	620	Ok	NOT OK	Ok	Ok	Ok
12	U12/1	616	Ok	NOT OK	Ok	Ok	Ok
12	U12/2	675	Ok	OK	Ok	Ok	Ok
12	U12/3	647	Ok	OK	Ok	Ok	Ok
16	U16/1	690	OK	OK	OK	OK	OK
16	U16/2	660	OK	OK	OK	OK	OK

16	U16/3	685	OK	OK	OK	OK	OK
20	U20/1	705	OK	OK	OK	OK	OK
20	U20/2	688	OK	OK	OK	OK	OK
20	U20/3	585	OK	NOT OK	OK	OK	OK
25	U25/1	556	OK	NOT OK	NOT OK	OK	OK
25	U25/2	696	OK	OK	OK	OK	OK
25	U25/3	550	OK	NOT OK	NOT OK	OK	OK
28	U28/1	427	OK	NOT OK	NOT OK	OK	**NOT OK**
28	U28/2	649	OK	OK	OK	OK	OK
Acceptance %			100	65	82	100	94

Table (5-8) Comparison for Results of Tensile Strength of R. B with Specifications

Size Mm	Sample ID	Test **Re** N/mm²	BS 4449/97 GR 460 MinFyx1.05	ASTM 615 **GR 60** Min 621	JIS G3112/1993 SD 40 Min 560	EURONO -RM 80-85 Fe B 400 Min 460	DIN 488 /1986 Bst 420s Min 500
10	T10/1	652	**O**	OK	Ok	Ok	Ok
10	T10/2	694	Ok	OK	Ok	Ok	Ok
10	T10/3	662	Ok	OK	Ok	Ok	Ok
12	T12/1	634	Ok	OK	Ok	Ok	Ok
12	T12/2	690	Ok	OK	Ok	Ok	Ok
12	T12/3	580	Ok	NOT OK	Ok	Ok	Ok
16	T16/1	693	OK	OK	OK	OK	OK
16	T16/2	669	OK	OK	OK	OK	OK
16	T16/3	678	OK	OK	OK	OK	OK
32	T32/1	614	OK	NOT OK	OK	OK	OK
32	T32/2	678	OK	OK	OK	OK	OK
Acceptance %			100	80	100	100	100
10	E10/1	635	Ok	OK	Ok	Ok	Ok
10	E10/2	608	Ok	NOT OK	Ok	Ok	Ok
10	E10/3	650	Ok	OK	Ok	Ok	Ok
12	E12/1	606	Ok	NOT OK	Ok	Ok	OK
12	E12/2	609	Ok	NOT OK	Ok	Ok	OK
12	E12/3	684	Ok	OK	Ok	Ok	OK
16	E16/1	596	OK	NOT OK	OK	OK	OK
16	E16/2	700	OK	OK	OK	OK	OK
16	E16/3	589	OK	NOT OK	OK	OK	OK
18	E18/1	466	OK	NOT OK	OK	OK	OK
18	E18/2	680	OK	NOT OK	NOT OK	OK	OK

20	E20/1	544	OK	NOT OK	NOT OK	OK	OK
20	E20/2	606	OK	NOT OK	OK	OK	OK
20	E20/3	646	OK	OK	OK	OK	OK
25	E25/1	672	OK	OK	OK	OK	OK
25	E25/2	649	OK	OK	OK	OK	OK
25	E25/3	635	OK	OK	OK	OK	OK
Acceptance %			100	50	89	100	**100**

Table (5-9)Comparison for Results of Elongation of R.B with Specifications

Size mm	Sample ID	Test **R** %	BS 4449/97 GR 460 Min 12	ASTM 615 **GR 60** Min 9	JIS G3112/1993 SD 40 Min 16	EURONO-RM 80-85 Fe B 400 Min 12	DIN 488/1986 **Bst 420s** Min 10
10	G10/1	13	OK	OK	NOT OK	OK	OK
10	**G10/2**	21	OK	OK	OK	OK	OK
10	G10/3	22	OK	OK	OK	OK	OK
10	G10/4	15	OK	OK	NOT OK	OK	OK
10	G10/5	14	OK	OK	NOT OK	OK	OK
12	G12/1	14	OK	OK	NOT OK	OK	OK
12	G12/2	21	OK	OK	OK	OK	OK
12	G12/3	22	OK	OK	OK	OK	OK
12	**G12/4**	16	OK	OK	NOT OK	OK	OK
12	G12/5	16	OK	OK	NOT OK	OK	OK
16	**G16/1**	16	OK	OK	OK	OK	OK
16	G16/2	21	OK	OK	OK	OK	OK
16	G16/3	22	OK	OK	OK	OK	OK
16	G16/4	17	OK	OK	OK	OK	OK
16	G16/5	20	OK	OK	OK	OK	OK
Acceptance %			100	100	60	100	100
12	S12/1	14	OK	OK	NOT OK	OK	OK
12	S12/2	17	OK	OK	OK	OK	OK
12	S12/3	7	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
16	**S16/1**	13	OK	OK	NOT OK	OK	OK
16	S16/2	14	OK	OK	NOT OK	OK	OK
16	S16/3	7	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
Acceptance %			67	67	16	67	67
10	U10/1	16	OK	OK	OK	OK	OK
10	U10/2	15	OK	OK	NOT OK	OK	OK
10	U10/3	14	OK	OK	NOT OK	OK	OK
12	U12/1	15	OK	OK	NOT OK	OK	OK
12	U12/2	13	OK	OK	NOT OK	OK	OK
12	U12/3	16	OK	OK	OK	OK	OK
16	U16/1	10	NOT OK	OK	NOT OK	NOT OK	OK
16	U16/2	16	OK	OK	OK	OK	OK
16	U16/3	17	OK	OK	OK	OK	OK

20	U20/1	12	OK	OK	NOT OK	OK	OK
20	U20/2	22	OK	OK	OK	OK	OK
20	U20/3	29	OK	OK	OK	OK	OK
25	U25/1	31	OK	OK	OK	OK	OK
25	U25/2	23	OK	OK	OK	OK	OK
25	U25/3	31	OK	OK	OK	OK	OK

Table (5-9) Comparison for Results of Elongation of R. B with Specifications

Size Mm	Sample ID	Test **R** %	BS 4449/97 **GR 460** Min 12	ASTM 615 **GR 60** Min 9	JIS *G3112/1993* SD 40 Min 16	EURONO-RM 80-85 Fe B 400 Min 12	DIN 488/1986 Bst 420s Min 10
28	U28/1	10	NOT OK	OK	NOT OK	NOT OK	OK
28	U28/2	8	NOT OK	OK	NOT OK	NOT OK	NOT OK
Acceptance %			82	100	59	82	94
10	T10/1	17	OK	OK	OK	OK	OK
10	T10/2	16	OK	OK	OK	OK	OK
10	T10/3	20	OK	OK	OK	OK	OK
12	T12/1	21	OK	OK	OK	OK	OK
12	T12/2	19	OK	OK	OK	OK	OK
12	T12/3	25	OK	OK	OK	OK	OK
16	T16/1	22	OK	OK	OK	OK	OK
16	T16/2	23	OK	OK	OK	OK	OK
16	T16/3	23	OK	OK	OK	OK	OK
32	T32/1	16	OK	OK	OK	OK	OK
Acceptance %			100	100	100	100	100
10	E10/1	20	OK	OK	OK	OK	OK
10	E10/2	23	OK	OK	OK	OK	OK
10	E10/3	21	OK	OK	OK	OK	OK
12	E12/1	25	OK	OK	OK	OK	OK
12	E12/2	24	OK	OK	OK	OK	OK
12	E12/3	20	OK	OK	OK	OK	OK
16	E16/1	21	OK	OK	OK	OK	OK
16	E16/2	22	OK	OK	OK	OK	OK
16	E16/3	20	OK	OK	OK	OK	OK
18	E18/1	25	OK	OK	OK	OK	OK
18	E18/2	23	OK	OK	OK	OK	OK
20	E20/1	23	OK	OK	OK	OK	OK
20	E20/2	26	OK	OK	OK	OK	OK

20	E20/3	24	OK	OK	OK	OK	OK
25	E25/1	12	NOT OK	OK	NOT OK	NOT OK	**OK**
25	E25/2	23	OK	OK	OK	OK	OK
25	E25/3	19	OK	OK	OK	OK	OK
32	E32/1	22	OK	OK	OK	OK	OK
Acceptance %			94	100	94	94	100

Table (5-10)Comparison for Results of Yield Strength of R.B with Specifications

Size mm	Sample ID	Test **Resu** N/ mm²	BS 4449/97 GR 250 Min 250	ASTM 615 **GR 4(** **Min 27**	JIS G3112/1993 **SD 30** Min 294
5.5	U 5.5/1	240	**NOT OK**	**NOT OK**	**NOT OK**
5.5	U5.5/2	244	**NOT OK**	**NOT OK**	**NOT OK**
5.5	U5.5/3	243	**NOT OK**	**NOT OK**	**NOT OK**
5.5	T5.5/1	260	OK	**NOT OK**	**NOT OK**
5.5	T5.5/2	264	OK	**NOT OK**	**NOT OK**
5.5	T5.5/3	257	OK	**NOT OK**	**NOT OK**
6	U6/1	243	**NOT OK**	**NOT OK**	**NOT OK**
6	U6/2	485	OK	OK	OK
6	U6/3	250	OK	**NOT OK**	**NOT OK**
6	T6/1	277	OK	OK	**NOT OK**
6	T6/2	541	OK	OK	OK
8	U8/1	283	OK	OK	**NOT OK**
8	U8/2	200	**NOT OK**	**NOT OK**	**NOT OK**
8	U8/3	254	OK	**NOT OK**	**NOT OK**
8	T8/1	464	OK	**OK**	**OK**
8	T8/2	230	**NOT OK**	**NOT OK**	**NOT OK**

Table (5-11)Comparison for Results of Tensile Strength of R.B with Specifications

Size mm	Sample ID	Test **Resu** N/mm²	BS 4449/97 GR 250 Min Fy x 1.15	ASTM 615 **GR 40** **Min 483**	*JIS G3112/1993* SD 30

					Min 441
5.5	U 5.5/1	356	**OK**	**NOT O**	**NOT O**
5.5	U5.5/2	366	**OK**	**NOT O**	**NOT O**
5.5	U5.5/3	388	**OK**	**NOT O**	**NOT O**
5.5	T5.5/1	383	OK	**NOT O**	**NOT O**
5.5	T5.5/2	412	OK	**NOT O**	**NOT O**
5.5	T5.5/3	361	OK	**NOT O**	**NOT O**
6	U6/1	364	**OK**	**NOT O**	**NOT O**
6	U6/2	621	OK	OK	OK
6	U6/3	347	OK	**NOT O**	**NOT O**
6	T6/1	395	OK	**NOT O**	**NOT O**
6	T6/2	735	OK	**OK**	**OK**
8	U8/1	449	OK	**NOT O**	**OK**
8	U8/2	351	**OK**	**NOT O**	**NOT O**
8	U8/3	390	OK	**NOT O**	**NOT O**
8	T8/1	701	OK	**OK**	**OK**
8	T8/2	374	**OK**	**NOT O**	**NOT O**

Table (5-12)Comparison for Results of Elongation of R.B with Specifications

Size mm	Sample ID	Test **Result** %	BS 4449/97 GR 250 Min 22	ASTM 615 **GR 40**	JIS G3112/1993 SD 30
5.5	U 5.5/1	20	**NOT OK**	-	-
5.5	U5.5/2	24	**OK**	-	-
5.5	U5.5/3	22	**OK**	-	-
5.5	T5.5/1	22	OK	-	-
5.5	T5.5/2	20	NOT OK	-	-
5.5	T5.5/3	13	NOT OK	-	-
6	U6/1	16	**NOT OK**	-	-
6	U6/2	15	NOT OK	-	-
6	U6/3	25	OK	-	-
6	T6/1	17	NOT OK	-	-
6	T6/2	14	NOT OK	-	-
8	U8/1	23	OK	-	-
8	U8/2	20	**NOT OK**	-	-
8	U8/3	26	OK	-	-
8	T8/1	19	NOT OK	-	-
8	T8/2	28	**OK**	-	-

Table (5.13.1)Comparison for Results of R.B (Carbon %) with Specifications

SAMPLE NO	Result Test	BS Max 0.25	ASTM 0.37-0.41	JIS Max 0.29	EURO Max 0.22	DIN Max 0.22
Gr 60/1	0.281	NOT OK	OK	OK	NOT OK	NOT OK
Gr 60/2	0.381	NOT OK	OK	NOT OK	NOT OK	NOT OK
Gr 60/3	0.367	NOT OK	OK	NOT OK	NOT OK	NOT OK
Gr 40/1	0.250	OK	OK	OK	NOT OK	NOT OK
U10/1	0.310	NOT OK	OK	NOT OK	NOT OK	NOT OK
U12/1	0.203	OK	OK	OK	OK	OK
U16/3	0.246	OK	OK	OK	NOT OK	NOT OK
U20/2	0.340	NOT OK	OK	NOT OK	NOT OK	NOT OK
E12/3	0.340	NOT OK	OK	NOT OK	NOT OK	NOT OK
E16/2	0.330	NOT OK	OK	NOT OK	NOT OK	NOT OK
T10/2	0.310	NOT OK	OK	NOT OK	NOT OK	NOT OK
T12/2	0.340	NOT OK	OK	NOT OK	NOT OK	NOT OK
T16/1	0.340	NOT OK	OK	NOT OK	NOT OK	NOT OK

Table (5.13.2)Comparison for Results of R..B (Silicon %) with Specifications

SAMPLE NO	Result Test	BS Max 0.35	ASTM Max 0.35	JIS Max 0.40	EURO Max 0.35	DIN Max 0.35
Gr 60/1	0.073	OK	OK	OK	OK	OK
Gr 60/2	0.063	OK	OK	OK	OK	OK
Gr 60/3	0.970	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
Gr 40/1	0.925	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
U10/1	0.370	NOT OK	NOT OK	OK	NOT OK	NOT OK
U12/1	0.079	OK	OK	OK	OK	OK
U16/3	0.092	OK	OK	OK	OK	OK
U20/2	0.280	OK	OK	OK	OK	OK

E12/3	0.400	NOT OK	NOT OK	OK	NOT OK	NOT OK
E16/2	0.400	NOT OK	NOT OK	OK	NOT OK	NOT OK
T10/2	0.300	OK	OK	OK	OK	OK
T12/2	0.370	NOT OK	NOT OK	OK	NOT OK	NOT OK
T16/1	0.270	OK	OK	OK	OK	OK

Table (5.13.3)Comparison for Results of R.B (Sulfur %) with Specifications

SAMPLE NO	Result Test	BS Max 0.05	ASTM Max 0.06	JIS Max 0.04	EURO Max 0.05	DIN Max 0.05
Gr 60/1	0.019	OK	OK	OK	OK	OK
Gr 60/2	0.032	OK	OK	OK	OK	OK
Gr 60/3	0.023	OK	OK	OK	OK	OK
Gr 40/1	0.021	OK	OK	OK	OK	OK
U10/1	0.012	OK	OK	OK	OK	OK
U12/1	0.012	OK	OK	OK	OK	OK
U16/3	0.016	OK	OK	OK	OK	OK
U20/2	0.009	OK	OK	OK	OK	OK
E12/3	0.013	OK	OK	OK	OK	OK
E16/2	0.018	OK	OK	OK	OK	OK
T10/2	0.014	OK	OK	OK	OK	OK
T12/2	0.031	OK	OK	OK	OK	OK
T16/1	0.014	OK	OK	OK	OK	OK

Table (5.13.4)Comparison for Results of R . B (Phosphorus %) with Specifications

SAMPLE NO	Result Test	BS Max 0.05	ASTM Max 0.06	JIS Max 0.04	EURO Max 0.05	DIN Max 0.05
Gr 60/1	0.011	OK	OK	OK	OK	OK
Gr 60/2	0.028	OK	OK	OK	OK	OK
Gr 60/3	0.038	OK	OK	OK	OK	OK
Gr 40/1	0.036	OK	OK	OK	OK	OK
U10/1	0.027	OK	OK	OK	OK	OK
U12/1	0.004	OK	OK	OK	OK	OK
U16/3	0.006	OK	OK	OK	OK	OK
U20/2	0.022	OK	OK	OK	OK	OK
E12/3	0.031	OK	OK	OK	OK	OK
E16/2	0.035	OK	OK	OK	OK	OK
T10/2	0.021	OK	OK	OK	OK	OK
T12/2	0.023	OK	OK	OK	OK	OK
T16/1	0.032	OK	OK	OK	OK	OK

Table (5.13.5)Comparison for Results of R.B (Manganese %) with Specifications

SAMPLE NO	Result Test	BS 0.6 – 1.10	ASTM 0.95 – 1.2	JIS Max 0.30	EURO 0.7 – 0.9	DIN 0.6 – 0.95
Gr 60/1	0.519	NOT OK	NOT OK	OK	NOT OK	NOT OK
Gr 60/2	0.963	OK	OK	OK	NOT OK	NOT OK
Gr 60/3	0.180	NOT OK	NOT OK	OK	NOT OK	NOT OK
Gr 40/1	0.129	NOT OK	NOT OK	OK	NOT OK	NOT OK
U10/1	1.340	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
U12/1	0.005	NOT OK	NOT OK	OK	NOT OK	NOT OK
U16/3	0.605	NOT OK	NOT OK	OK	NOT OK	NOT OK
U20/2	1.390	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
E12/3	1.380	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
E16/2	1.430	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK

T10/2	1.300	NOT OK	NOT OK	OK	NOT OK	NOT OK
T12/2	1.260	NOT OK	NOT OK	OK	NOT OK	NOT OK
T16/1	1.200	NOT OK	OK	OK	NOT OK	NOT OK

Table (5.13.6) Comparison of Chemical Composition of R.B with Specification

SAMPLE NO	**BS**	ASTM	JIS	EURO	DIN
G 60/1	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
G 60/2	**NOT OK**	OK	NOT OK	NOT OK	NOT OK
G 60/3	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
G 40/1	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
U 10/1	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
U 12/1	NOT OK	NOT OK	OK	NOT OK	NOT OK
U 16/3	OK	NOT OK	OK	NOT OK	NOT OK
U 20/2	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
E 12/3	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
E 16/2	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
T 10/2	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
T 12/2	NOT OK	NOT OK	NOT OK	NOT OK	NOT OK
T 16/1	NOT OK	***OK***	NOT OK	NOT OK	NOT OK

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. Some structural steel products (local and imported), such as angles, I-sections and pipes (square, rectangular, and circular) have smaller dimensions than those covered by the specifications. Moreover, products at the higher end of the range (i.e. large size) are not normally available in the Sudan.

2. Some types of steel products are not imported, while other types are available only in small quantities and varieties. For example corrugated iron (roofing) sheets are present in two shapes only, whereas specifications cite eleven different shapes of such sheets. The other shapes are nowhere to be found on the local market.

3. In most cases, chemical composition test is not usually carried out on imported structural steel.

4. The shapes and dimensions of locally produced angles and iron rods do not comply with specifications.

5. Sample prepared for the tensile-strength tests of structural steel for this study were all strip sections, as local steel products fall short of the 8mm thickness required for bolts and, therefore, it was not possible to prepare bolt sample for testing.

6. It was not possible to prepare samples for impact tests from locally-made structural steel, as local steel sections are smaller than the required dimensions of 10mm × 10mm (according to both BS & ASTM).

7. All tested samples of structural steel are classified as 40A or 50A since at temperature greater than 20 ºC, no need for the impact test as stated in British Standards.

8. There are two types of reinforcing bars made by Giad (G40 and G60) . However, both types are sold in the market as if they were of the same type, labeling them as deformed reinforcing bars – regardless of Grade.

9. Measurements of samples tested indicated that the dimensions of ribs of most reinforcing bars comply with specifications. However, the rib widths of Turkish and Ukrainian bars exceed the specified values. Also the width and height of ribs of Giad bars do not meet the values required by the specifications.

10. All reinforcing bars meet the minimum weight requirements (as per various specification standards) except those produced by the Omdurman factory.

11. Tests show that the reinforcing steel bars produced by Omdurman Factory does not comply with most of the specifications, in terms of both mechanical properties as well as chemical composition.

12. Tests of samples of reinforcing bars produced by Giad (carried out within the study period) show that some of them meet requirements while not complying with specifications in other instances.

13. Tests also revealed that Ukrainian reinforcing steel bars are the best among all imported bars, and that the one produced at Omdurman Factory is the worst among those produced locally.

14. All the results of bending tests for reinforcing bars (locally- made and imported) comply with specifications and no transverse rupture was observed on the surface of the samples tested.

15. It was found that the chemical compositions of most of the reinforcing bars and structural steel elements , produced in the Sudan, do not comply with specifications. Furthermore, chemical analysis tests are not usually conducted on such products.

6.2 Recommendations

1. Prices of structural steel to the public should be based on both dimensions and weight rather than number of bars, especially regarding reinforcing bars, e.g. a ton of 16-mm diameter bars is sold as consisting of only 101 bars (length 6m), whereas, according to the specified weight, such a ton should contain 105 bars. Conversion to numbers should be controlled by the Specification Authority and the correct equivalent numbers should be clearly written in a permanent way and placed in front each steel shop.

2. Most Design Codes of practice recommend 8-mm diameter bars as the minimum bar size to be used in structural design. Hence imports of large quantities of 5.5mm and 6mm diameter reinforcing bars ought be stopped, in order to prevent their use in the construction of buildings. So specific diameters hare to be set for approval of imports or local manufacturing of rods.

3. As there are two types of reinforcing bars produced locally and sold as deformed reinforcing bars ; It is recommend that high tensile bars be clearly marked, along the length of the bars, for Grade identification .

4. Measures are to be taken, for quality control purposes to ensure compliance with specifications , regarding locally produced steel products. Imports are also to be subjected to controls and checks for compliance with specifications.

5. A study has to be conducted to find out the cause behind such fluctuations in quality control of Giad reinforcing bars especially as most bars available on the local market are Giad – made.

6. Some local manufactures have accumulated partial expertise in the production of reinforcing bars and structural steel. Elements development can be carried out to provide a wider range of steel products to meet needs of the structural steel market.

7. Some testing equipment (in steel – testing laboratories) need calibration and steel-testing laboratories in the country have to be developed and increased in number – especially the steel chemical analysis – labs as there are only a few. Various factories have to be required to set up laboratories for tests and quality control .There must be certain laboratories credited by the specifications authority, with calibration and inspection being periodically carried out on equipment and instruments of such labs .

8. Limited information is available on structural steel specifications in Sudan. Reference books and different specifications for structural steel have to be availed for engineers and researchers.

9. Internationally recognized specifications (e.g. British, American, Japanese) are different, therefore, it is imperative that specific standards be adopted in the Sudan and made Sudanese specifications are to be made.

10. This study is limited to steel products used in building construction. It is hoped that further work will be conducted on structural steel utilized in other fields (e.g bridges).

References

Standards

1. **American Society for Testing and Materials (ASTM) , "Specification for Structural Steel, Concrete Reinforcing steel". ASTM part 4**
2. **"Specification for Metals - physical, Mechanical, Nondestructive Tests," ASTM part 31.**
   - **2.1 A 370 – 68 Mechanical Testing of Steel Products.**
   - **2.2 E 8 – 69 Tension Testing of Metallic Materials.**
   - **2.3 E 10– 66 Test for Brinell Hardness of Metallic Materials.**
   - **2.4 E 23 – 66 Notched Bar Impact Testing of Metallic Materials.**
   - **2.5 E 83–67 Verification and Classification of a Metal Crystal.**
3. **American Standard / ASTM 615 for reinforcing bars**

British Standards

All British Standards which equivalent International (ISO) and European (Euronorm) standards are given in parentheses where appropriate.

General

4. **BS 6562:1986 Terms used in the iron and steel industry (Euronorm 79).**

Structural steels

5. **BS 4: 1980 Hot-rolled sections**
6. **BS 2994: 1987 Cold- rolled steel sections**
7. **BS 4360: 1986 Weldable structural steels**
8. **BS 4848: Hot-rolled structural steels sections**

8.1 Part 2: 1975 Hollow section (ISO R657/14)

8.2 Part 4: 1986 Equal and unequal angles (ISO 657; Euronorms 56,57)

8.3 Part 5: 1980 Bulb flats (Euronorms 67)

9. BS 5950 Structural use of steelwork in building

9.1 Part 1: 1985 Code of practice for design in simple and continuous Construction : hot rolled sections.

9.2 Part 2: 1985 Materials, fabrication and erection: hot-rolled sections.

Reinforcing bars

10. BS 4449 Carbon steel bars for the reinforcement of concrete. (1988)

Testing

11. BS 18: 1987 Methods for tensile testing of metals (ISO 6892).

12. BS 131: Parts 1-5: 1972-1989 Methods for notched bar tests (ISO R148, R83, R442; (Euronorms 7)

13. BS 240: 1986 Method for Brinell hardness test (ISO 156, 6506; Euronorms 3, 125, 128)

14. BS 427: 1981 Method for Vickers hardness test (ISO 6507, R146; (Euronorms 5, 124, 127)

15. BS 891: 1989 Method for Rockwell hardness test (ISO6508,716)

16. BS 1639: 1989 Methods for bend testing of metals (ISO 7438,8491; Euronorms 6, 12 , 13)

17. Euronorm Standard 80 (1985) for reinforcing bars

18. German Standard DIN 488/1986 for reinforcing bars

19. Japan Standard / JIS G 3112 for reinforcing bars

For Further Reading

20. **Brockenbrough . R.L & Merritt . F.S, Structural Steel Designer's Handbook, Me Graw- Hill, USA, 1994.**
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Appendix B

Table : The maximum permissible carbon equivalent (CE) value for different steel grades

Grade	Maximum CE (%)
40	**0.39-0.41**
43	**0.39-0.41**
50	**0.43-047**
55	**0.41-053**

Table: Properties of structural steels according to BS 4360: 1986

(Plates and wide flats)

Grade	Tensile strength ($N\ mm^{-2}$)	Minimum yield strength at 16mm ($N\ mm^{-2}$)	Charp V-notch impacts 27 J at °C
40A	340/500	235	-
40B	340/500	235	20+
40C	340/500	235	0
40D	340/500	235	-20
40EE	340/500	260	-50
43A	430/580	275	-
43B	430/580	275	20+
43C	430/580	275	0
43D	430/580	275	-20
43EE	430/580	275	-50
50A	490/640	355	-
50B	490/640	355	20+
50C	490/640	355	0
50D	490/640	355	-20
50DD	490/640	355	-30
50EE	490/640	355	-50
50F	490/640	390	-60
55C	550/700	450	0
55EE	550/700	450	-50
55F	550/700	450	-60

Equivalent Standards

Equivalences between the 1986 version of BS 4360 and the two replacements of 1990 are given in Table below:

Table : Equivalences between the two standards published in 1990 and the 1986 version of BS 4360.

BS 4360: 1986	BS EN 10 025: 1990
40B	Fe 360 B
40C	Fe 360 C
40D	Fe 360 D1, Fe 360 D2
43B	Fe 430 B
43C	Fe 430 C
43D	Fe 430 D1, Fe 430 D2
50B	Fe 510 B
50C	Fe 510 C
50D	Fe 510 D1, Fe 510 D2
50DD	Fe 510 DD1, Fe 510 DD2

BS 4360	
1986	1990
40E	40EE
43E	43EE
50E	50EE
50F	50F
55C	55C
55E	55EE

APPENDIX (D)
Statistical Variation of Results

Sample Number	Properties	X	Sd	COV
G10/1	Yield Strength (fy N/mm^2)	485.33	5.73	1.18
	Tensile Strength (fu N/mm^2)	744.33	2.87	0.39
	Elongation %	14.33	0.94	6.58
G10/2	Yield Strength (fy N/mm^2)	366.00	4.55	1.24
	Tensile Strength (fu N/mm^2)	616.33	6.24	1.01
	Elongation %	22.33	1.25	5.58
G10/3	Yield Strength (fy N/mm^2)	394.00	7.79	1.98
	Tensile Strength (fu N/mm^2)	603.00	5.72	0.95
	Elongation %	23.00	0.82	3.55

Sample Number	Properties	X	Sd	COV
G12/1	Yield Strength (fy N/mm^2)	475.33	7.41	1.56
	Tensile Strength (fu N/mm^2)	748.33	12.26	1.64
	Elongation %	14.67	0.47	3.21
G12/2	Yield Strength (fy N/mm^2)	369.33	13.77	3.73
	Tensile Strength (fu N/mm^2)	565.00	15.12	2.68
	Elongation %	22.00	0.82	3.71
G12/3	Yield Strength (fy N/mm^2)	408.33	13.10	3.21
	Tensile Strength (fu N/mm^2)	646.33	5.19	0.80
	Elongation %	22.00	0.00	0.00

Sample Number	Properties	X	Sd	COV
G16/1	Yield Strength (fy N/mm^2)	601.00	12.57	2.09
	Tensile Strength (fu N/mm^2)	736.33	0.47	0.06
	Elongation %	17.67	1.25	7.06

G16/2	Yield Strength (fy N/mm^2)	365.67	26.71	7.31
	Ultimate Strength (fu N/mm^2)	622.00	49.40	7.94
	Elongation %	21.33	0.47	2.21
G16/3	Yield Strength (fy N/mm^2)	423.33	6.65	1.57
	Tensile Strength (fu N/mm^2)	702.00	36.06	5.14
	Elongation %	23.67	1.25	5.27

Sample Number	Properties	X	Sd	COV
S12/1	Yield Strength (fy N/mm^2)	406.33	10.27	2.53
	Tensile Strength (fu N/mm^2)	551.00	40.90	7.42
	Elongation %	17.00	2.45	14.41
S12/2	Yield Strength (fy N/mm^2)	365.00	34.77	9.52
	Tensile Strength (fu N/mm^2)	534.33	46.94	8.79
	Elongation %	19.00	1.41	7.44
S12/3	Yield Strength (fy N/mm^2)	698.33	27.18	3.89
	Tensile Strength (fu N/mm^2)	1036.00	43.85	4.23
	Elongation %	6.67	0.00	0.00

Sample Number	Properties	X	Sd	COV
S16/1	Yield Strength (fy N/mm^2)	383.33	32.07	8.37
	Tensile Strength (fu N/mm^2)	558.67	66.20	11.85
	Elongation %	17.00	3.27	19.21
S16/2	Yield Strength (fy N/mm^2)	334.00	22.23	6.65
	Tensile Strength (fu N/mm^2)	499.67	37.75	7.55
	Elongation %	17.33	4.71	27.20
S16/3	Yield Strength (fy N/mm^2)	508.33	90.53	17.81

	Tensile Strength (fu N/mm^2)	766.33	134.03	17.49
	Elongation %	7.00	0.00	0.00

Sample Number	Properties	X	Sd	COV
T10/1	Yield Strength (fy N/mm^2)	436.00	23.55	5.40
	Tensile Strength (fu N/mm^2)	681.33	30.87	4.53
	Elongation %	18.00	0.82	4.54
T10/2	Yield Strength (fy N/mm^2)	428.67	0.94	0.22
	Tensile Strength (fu N/mm^2)	659.00	1.41	0.20
	Elongation %	17.00	0.82	4.80
T10/3	Yield Strength (fy N/mm^2)	422.33	15.43	3.65
	Tensile Strength (fu N/mm^2)	681.00	22.76	3.34
	Elongation %	21.33	0.94	4.42

Sample Number	Properties	X	Sd	COV
T12/1	Yield Strength (fy N/mm^2)	433.33	15.54	3.59
	Tensile Strength (fu N/mm^2)	66.67	24.78	3.72
	Elongation %	23.00	1.41	6.15
T12/2	Yield Strength (fy N/mm^2)	438.67	11.47	2.61
	Tensile Strength (fu N/mm^2)	700.67	7.93	1.13
	Elongation %	19.67	0.94	4.79
T12/3	Yield Strength (fy N/mm^2)	387.67	20.73	5.35
	Tensile Strength (fu N/mm^2)	588.00	10.61	1.81
	Elongation %	26.00	0.82	3.14

Sample Number	Properties	X	Sd	COV
T16/1	Yield Strength (fy N/mm^2)	430.67	0.47	0.11

	Tensile Strength (fu N/mm^2)	787.00	124.49	15.82
	Elongation %	23.00	0.82	3.55
T16/2	Yield Strength (fy N/mm^2)	439.67	8.96	2.04
	Tensile Strength (fu N/mm^2)	675.00	9.49	1.26
	Elongation %	24.00	0.82	3.40
T16/3	Yield Strength (fy N/mm^2)	417.00	4.08	0.98
	Tensile Strength (fu N/mm^2)	680.33	1.70	0.25
	Elongation %	23.00	0.00	0.00

Sample Number	Properties	X	Sd	COV
U10/1	Yield Strength (fy N/mm^2)	468.00	3.74	0.80
	Tensile Strength (fu N/mm^2)	690.00	4.32	0.63
	Elongation %	17.33	1.25	7.20
U10/2	Yield Strength (fy N/mm^2)	532.33	8.96	1.68
	Tensile Strength (fu N/mm^2)	624.33	3.09	0.50
	Elongation %	16.00	0.82	5.10
U10/3	Yield Strength (fy N/mm^2)	526.67	4.19	0.80
	Tensile Strength (fu N/mm^2)	633.67	9.74	1.54
	Elongation %	15.67	1.25	7.96

Sample Number	Properties	X	Sd	COV
U12/1	Yield Strength (fy N/mm^2)	512.73	13.35	2.60
	Tensile Strength (fu N/mm^2)	654.43	48.25	7.37
	Elongation %	15.95	0.70	4.41
U12/2	Yield Strength (fy N/mm^2)	588.67	12.71	2.16
	Tensile Strength (fu N/mm^2)	687.00	8.52	1.24
	Elongation %	14.00	0.82	5.83
U12/3	Yield Strength (fy N/mm^2)	558.67	14.82	2.65
	Tensile Strength (fu N/mm^2)	661.67	11.84	1.79
	Elongation %	17.67	2.05	11.63

Sample Number	Properties	X	Sd	COV
U16/1	Yield Strength (fy N/mm^2)	593.00	6.38	1.08
	Tensile Strength (fu N/mm^2)	700.33	7.32	1.04
	Elongation %	11.33	0.84	7.45
U16/2	Yield Strength (fy N/mm^2)	544.67	16.03	2.94
	Tensile Strength (fu N/mm^2)	668.33	10.40	1.56
	Elongation %	17.67	1.25	7.06
U16/3	Yield Strength (fy N/mm^2)	583.33	6.02	1.03
	Tensile Strength (fu N/mm^2)	693.00	6.53	0.94
	Elongation %	18.33	0.94	5.14

Sample Number	Properties	X	Sd	COV
E10/1	Yield Strength (fy N/mm^2)	400.00	2.94	0.74
	Tensile Strength (fu N/mm^2)	643.67	6.18	0.96
	Elongation %	20.00	0.00	0.00

E10/2	Yield Strength (fy N/mm^2)	394.33	4.92	1.25
	Ultimate Strength (fu N/mm^2)	611.67	2.87	0.47
	Elongation %	24.00	0.82	3.40
E10/3	Yield Strength (fy N/mm^2)	409.67	20.95	5.11
	Tensile Strength (fu N/mm^2)	656.33	6.34	0.97
	Elongation %	21.67	0.94	4.35

Sample Number	Properties	X	Sd	COV
E12/1	Yield Strength (fy N/mm^2)	372.33	0.47	0.13
	Tensile Strength (fu N/mm^2)	607.33	0.94	0.16
	Elongation %	26.67	1.70	6.37
E12/2	Yield Strength (fy N/mm^2)	407.00	11.58	2.84
	Tensile Strength (fu N/mm^2)	619.67	7.59	1.22
	Elongation %	25.33	0.94	3.72
E12/3	Yield Strength (fy N/mm^2)	414.33	8.96	2.16
	Tensile Strength (fu N/mm^2)	729.33	41.35	5.67
	Elongation %	21.33	1.25	5.85

Sample Number	Properties	X	Sd	COV
E16/1	Yield Strength (fy N/mm^2)	328.33	6.60	2.01
	Tensile Strength (fu N/mm^2)	622.00	27.47	4.42
	Elongation %	21.67	0.47	2.18
E16/2	Yield Strength (fy N/mm^2)	431.00	1.63	0.38
	Tensile Strength (fu N/mm^2)	702.67	2.05	0.29
	Elongation %	23.33	1.25	5.35
E16/3	Yield Strength (fy N/mm^2)	364.33	35.57	9.76

	Tensile Strength (fu N/mm^2)	640.33	58.38	9.12
	Elongation %	21.00	0.82	3.89

Sample Number	Properties	X	Sd	COV
G10	Yield Strength (fy N/mm^2)	415.11	51.33	12.36
	Tensile Strength (fu N/mm^2)	654.56	63.92	9.77
	Elongation %	19.89	4.07	20.45
G12	Yield Strength (fy N/mm^2)	417.67	45.33	10.85
	Tensile Strength (fu N/mm^2)	653.22	75.90	11.62
	Elongation %	19.56	3.50	17.90
G16	Yield Strength (fy N/mm^2)	463.33	101.66	21.94
	Tensile Strength (fu N/mm^2)	686.78	59.51	8.67
	Elongation %	20.89	2.69	12.85

Sample Number	Properties	X	Sd	COV
S12	Yield Strength (fy N/mm^2)	489.89	150.64	30.75
	Tensile Strength (fu N/mm^2)	707.11	236.78	33.49
	Elongation %	14.22	5.64	39.68
S16	Yield Strength (fy N/mm^2)	408.56	92.86	22.73
	Tensile Strength (fu N/mm^2)	608.22	144.93	23.83
	Elongation %	13.78	5.83	42.29

Sample Number	Properties	X	Sd	COV
U10	Yield Strength (fy N/mm^2)	508.67	29.52	5.80
	Tensile Strength (fu N/mm^2)	649.33	29.71	4.57
	Elongation %	16.33	1.33	8.16
U12	Yield Strength (fy N/mm^2)	553.36	34.08	6.16
	Tensile Strength (fu N/mm^2)	667.70	32.28	4.83
	Elongation %	15.87	2.01	12.66
U16	Yield Strength (fy N/mm^2)	573.67	23.40	4.08
	Tensile Strength (fu N/mm^2)	667.22	15.98	2.33
	Elongation %	15.78	3.32	21.02

Sample Number	Properties	X	Sd	COV
T10	Yield Strength (fy N/mm^2)	429.00	17.20	4.01
	Tensile Strength (fu N/mm^2)	685.78	23.10	3.37
	Elongation %	18.78	2.04	10.88
T12	Yield Strength (fy N/mm^2)	419.89	28.13	6.70
	Tensile Strength (fu N/mm^2)	651.78	49.90	7.66
	Elongation %	22.89	2.81	12.26

T16	Yield Strength (fy N/mm^2)	429.11	10.92	2.54
	Tensile Strength (fu N/mm^2)	714.11	88.61	12.41
	Elongation %	23.33	0.82	3.50

Sample Number	Properties	$\bar{X}$	Sd	COV
E10	Yield Strength (fy N/mm^2)	401.33	14.05	3.50
	Tensile Strength (fu N/mm^2)	637.22	19.55	3.07
	Elongation %	21.89	1.79	8.19
E12	Yield Strength (fy N/mm^2)	397.89	20.17	5.07
	Tensile Strength (fu N/mm^2)	652.11	59.97	9.20
	Elongation %	24.44	2.63	10.76
E16	Yield Strength (fy N/mm^2)	374.56	47.39	12.65
	Tensile Strength (fu N/mm^2)	655.00	50.80	7.76
	Elongation %	22.00	1.33	6.06

Sample Number	Properties	$\bar{X}$	Sd	COV
M	Yield Strength (fy N/mm^2)	306.67	27.01	8.81
	Tensile Strength (fu N/mm^2)	370.22	31.20	8.43
	Elongation %	21.44	3.89	18.14
SM	Yield Strength (fy N/mm^2)	280.22	34.36	12.26
	Tensile Strength (fu N/mm^2)	348.33	28.11	8.07
	Elongation %	19.33	3.50	18.08
3U	Yield Strength (fy N/mm^2)	264.56	19.58	7.40
	Tensile Strength (fu N/mm^2)	318.89	27.33	8.57
	Elongation %	19.11	1.29	6.73
P	Yield Strength (fy N/mm^2)	312.11	17.62	5.64
	Tensile Strength (fu N/mm^2)	447.11	19.81	4.43
	Elongation %	28.44	3.86	13.58

E	Yield Strength (fy N/mm^2)	281.78	19.72	7.00
	Tensile Strength (fu N/mm^2)	386.67	12.17	3.15
	Elongation %	21.44	1.07	4.97