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Engineering Properties of Bolts and Nuts in Lagos State, Nigeria *(pp. 173-185)*

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Abstract

In steel construction, the importance of connection cannot be overemphasized. Steel connection can be made of bolts, rivets and welding. The quality of bolts, rivets and welds in structural steel connection affects the connection and hence the capacity of the whole steel structure. This paper examined the quality of bolts and nuts available in the Nigeria market. Samples of bolts of diameters 10mm, 12mm, 16mm and 20mm were sourced from five providers in Lagos State. After testing the samples for both tensile and shear strengths, it was established that only 10mm and 12mm diameter bolts meet the grade 4.6 requirements of 195N/mm^2 and 160N/mm^2 for tensile and shear strengths respectively. For 20mm diameter bolts, only specimens from providers B, C and D meet the code requirements for both tensile and shear strengths for grade 4.6 bolts.

Keywords: Shear, Bearing y, Tensile, Capacity, Connections, Bolts, Rivets, Welds.

Introduction

Structural steel is used in construction in form of rolled stock procured from iron and steel works with various sections to meet construction requirements. A steel structure consists of structural elements such as the rolled section e.g universal beam, universal column, etc. The elements are joined together to form structural steel members with the aid of bolts, welds and rivets. The whole steel structure is developed from these by connecting the members together (Morris, 1998).

Steel structure can widely be classified into two main groups (The Steel Construction Institute, 2001). These are:

(a) Framework or skeleton systems having as their main members beams, girders, trusses, columns etc; such as industrial halls, large span bridges, civil multistory buildings, exhibition pavilions, hangers, tower, masts etc.

(b) Shell systems, largely made up of plates or sheets, which includes among others, gasholder and tanks etc.

For the two groups above, the function of connections cannot be overestimated. Connection could be defined as component parts used to join together elements or members in a structure. The function of connection is to transmit co-existent forces and moments between members and the joints "node" points (Owens and Cheal, 1989).

Connection could be categorized as pinned or fixed depending on their ability to transmit moment. Practically a pure or fully fixed connection is not achievable but these terms describe the prime functions in structural design (The Steel Construction Institute, 1995). Connections can be formed by bolts, rivets and welding. There are three modes of failures for connection; shear failure, tension failure and bearing failure (Owens and Knowles, 1992).

The capacity P_s of a shearing bolt in shear depends on the strength p_s of the bolt, the number of shear planes n, and the area A_{sn} of the bolt in each plane (either the gross area A_n or tensile stress area A_t ,

through the threads, as appropriate) it can be expressed in the form (Nethercot, 2001).

$$P_s = p_s \sum K_r A_{sn} \quad (1)$$

In which k_r is a factor, which allows for the overloading of end bolts that occurs in long connections.

BS5950 (1990) requires the factored shear force F_s to be limited by

$$F_S < P_s \quad (2)$$

With the shear strength p_s of the bolt material being approximated by the lesser of

$$p_s = 0.48U_b \quad (3) \text{ and}$$

$$p_s = 0.697Y_b \quad (4)$$

where U_b and Y_b are the ultimate tensile strength and the yield stress of the bolt material respectively.

The capacity of a bolt in tension depends on the tensile strength of the minimum cross sectional area of the threaded length of the bolt. The design force F_t is limited by BS5950(1990).

$$F_{t <} P_t \quad (5)$$

If any of the connecting plates is sufficiently flexible, then additional prying forces may be induced in the bolts. According to Kulak (1987), when any prying actions can be calculated and are included in F_t, then

$$P_t = p_t A_t \quad (6)$$

In which A_t is the tensile stress area of the bolt, while the tensile strength of the bolt p_t is generally approximated by the lesser of $0.7U_b$ and Y_b. For a bolt with $U_b/Y_b = 1.0/0.7 = 1.43$, these correspond to the use of a conservative factor of 0.7 to ensure a higher level of safety than for members.

Under some circumstances, according to Kulak (1987), the prying forces need not be calculated, provided p_t is reduced to

$$p_{tr} = 0.8\ p_t = 0.8 \text{ x } 0.7\ U_b = 0.581\ U_b \qquad (7)$$

The value of $p_{tr} = 0.581\ U_b$ is approximately equal to the value of p_t given in BS5950 (1990) as $P_t = 0.58\ U_b$ (8)

Test result by Kulak (1987) for bolts in bearing, shear and tension suggest a circular interaction relationship for the strength limit state, which can be expressed in the form of equations (2), (5), and

$$F_s/P_s + F_t/P_t < 1.4 \qquad (9)$$

Where P_s is the nominal shear capacity when there is no tension, and P_t, the nominal tension capacity when there is no shear.

Objectives of the Study

Design of steel structures in Nigeria is to BS5950 (1990). Hence, the objectives of the study is to determine whether the bolts and nuts available in Nigeria meet the grade 4.6 requirements of 195N/mm^2 and 160N/mm^2 for tensile and shear strength respectively.

In order to achieve the said objectives, the following are set:

(a) Identify the various providers and, sourcing of bolts and nuts from some of them.

(b) Determination of the strength characteristics.

(c) Comparison of the strength characteristics with that available in the BS5950 (1990).

Materials and Methods

The specimens used in this research work were sourced from five different providers and these were labeled specimens A to E. The diameters of bolts used are 10mm, 12mm, 16mm and 20mm. From each provider, five bolts for each diameter were purchased. Hence from each provider 20 bolts were purchased. The total numbers of bolts used in this study is thus 100. The tests were carried out at the laboratory of the civil engineering department of university of Lagos, Nigeria.

Tensile Strength Test
The specimen, which included the bolt and nut attached together, was fitted into the 7113 DCJ Universal Testing Machine, using the specimen holder. The dial gauge was reset back to zero, after the machine was put on; making sure that the unloading valve was closed as well as the loaded valve.

The setting control lever was selected, after which the load was applied. At a particular point in time the specimen failed and the maximum load pointer reading on the dial was recorded.

Shear Strength Test
The test was carried out by placing the specimen and it's holder in between the adjustable crosshead and the table. After keeping it balance longitudinally, the load was applied with the aid of the load valve. When the load pointer stopped, maximum load was recorded.

Result
The result of the tensile and shear strength tests are presented in tables 1 to 5

Discussion of Result
The results of tensile test for the bolts from provider A (Table 1), shows that, for the 10mm diameter bolt, the average ultimate tensile strength U_{ba} is 418.3N/mm^2, while the yield stress Y_b ranges between 289.3N/mm^2 and 293.8N/mm^2 and the average strength of the bolt p_t is 242.4N/mm^2,. For the 12mm diameter bolts, the average ultimate tensile strength U_{ba} is 338.2N/mm^2, the average yields stress Y_{ba} and average strength of the bolts are 236.5N/mm and 196.4N/mm^2 respectively. For the 16mm diameters bars, the average ultimate tensile stress U_{ba}, average yield stress and average strength of bolts are 267.4N/mm^2, 187.1N/mm^2 and 155N/mm^2 respectively. For bolt 20mm diameter the average ultimate tensile stress, U_{ba}, average yield stress, Y_{ba}, and average strength of bolts are respectively 317.1N/mm^2,221.4N/mm^2 and 184N/mm^2. From the above, as far as

tensile strength P_t is concerned, only 10mm and 12mm bolts meet the grade 4.6 requirement, of 195N/mm^2 tensile strength (BS 5950, 1990). For 16 mm and 20 diameter bolts, their strength values are 155N/mm^2 and 184N/mm^2 respectively which are both less that the 195N/mm^2 stipulated by the code.

Also, results of the shear tests for the bolts from provider A (Table 2), shows that, for the 10mm diameter bolts, the average shear stress Y_{ua} and shear strength P_s are 246.3N/mm^2 and 201N/mm^2 respectively. For the 12m diameter bolt, the average shear stress Y_{ua} and shear strength P_s are 240.4N/mm^2 and 162N/mm^2. Also for 16mm diameter bolts, these values are 201.3N/mm^2 and 128N/mm^2, while for 20mm diameter bolts, they are 228.2N/mm^2 and 152N/mm^2 respectively. Form the foregoing, it is clear that only 10mm and 12mm diameter bolts with shear strength P_s values of 201N/mm^2 and 162N/mm^2 respectively meet the grade 4.6 requirement (BS5950, 1990). The 16mm and 20mm bolts with shear strengths values of 128N/mm^2 and 152N/mm^2 fall short of 160N/mm as stipulated by the code. Results of tensile tests for bolts from provider B, (Table 3), shows that only 10mm, 12mm and 20mm diameter bolts with average tensile strength P_t values of 241.7N/mm^2, 231.7N/mm^2 and 264.6N/mm^2 respectively meet the grade 4.6 requirements for tensile strength. Equally, it is only these bolt diameters that meet the grade 4.6 requirement for shear strength with values 200.0N/mm^2, 191.8N/mm^2 and 219N/mm^2 respectively (Table 4).

The results of the tests for bolts from providers C and D (tables 5 to 8), shows that, 10mm, 12mm and 20mm diameter bolts, satisfy the requirement for grade 4.6 bolts in terms of both tensile and shear strength. Also results of tests for provider E (tables 9 and 10), shows that only 10mm and 12mm bars meet requirements for grade 4.6 bolts.

Conclusion

The results of this work shows that for all the bolts tested, those of diameter 10mm and 12mm meet the requirements for 4.6 bolts, for

20mm diameter bolts, only the ones from providers B, C and D meets the requirement for grade 4.6 bolts, while 16mm diameter bolt does not satisfy the requirement of the code for all the providers.

Recommendation

It is recommended here that the Nigerian Standard Organisation (NSO) should ensure that importers of bolts and nuts registered with them. Also, NSO should compile list of reputable manufacturers of these products so that the registered importers will know where to get the product. NSO should from time to time carry out random test on the bolts and nuts from the importers so as ensure that they are of good standard.

Table 1: Results of tests for tension and shear, from provider A

Spe	Dia mm	Area mm^2	Ultima tensile force KN	Ultima tensile tress, U_b N/mm^2	Average ultimate tensile stress U_{ba} N/mm^2	Yield stress Y_b N/mm^2	Streng of bolts P_t N/mm^2	Average strength of bolts N/mm^2	Ultim shear force KN	Ultim shear stress, Y_{Ub} N/mm^2	Avera ultim shear stress Y_{ua} N/mm^2	Shear streng P_s N/mm^2	Ultimate
1	10	78.55	32.5	413.7		289.3	240.0		248.2	248.2			19.5
2	10	78.55	33.0	420.1		293.8	244.0		245.9	245.9			19.3
3	10	78.55	32.9	418.8	418.3	292.9	242.0	242.4	242.0	242.0	246.3	201	19.0
4	10	78.55	32.9	418.8		292.9	242.0		247.1	247.1			19.4
5	10	78.55	33.0	420.1		293.8	244.0		248.2	248.2			19.5
1	12	113	37.6	332.7		232.7	193.0		240.1	240.1			27.1
2	12	113	38.3	338.9		237.0	197.0		239.3	239.3			27.0
3	12	113	38.3	338.9	338.2	237.0	197.0	196.4	239.3	239.3	240.4	162	27.0
4	12	113	38.4	339.8		237.6	197.0		241.6	241.6			27.3
5	12	113	38.5	340.7		238.3	198.0		241.6	241.6			27.3
1	16	201	53.8	267.7		187.2	155.0		200.6	200.6			40.3
2	16	201	53.5	266.2		186.2	154.0		200.6	200.6			40.3
3	16	201	54.0	268.7	267.4	187.9	156.0	155	203.3	203.3	201.3	128	40.9
4	16	201	53.8	267.7		187.2	155.0		199.6	199.6			40.1
5	16	201	53.6	266.7		187.2	155.0		202.3	202.3			40.7
1	20	314	99.5	316.9		221.6	184.0		228.3	228.3			71.7
2	20	314	99.5	316.9		221.6	184.0		228.0	228.0			71.6
3	20	314	100.0	318.5	317.1	222.7	185.0	184	227.4	227.4	228.2	152	71.4
4	20	314	99.2	315.9		220.9	183.0		228.0	228.0			71.6
5	20	314	99.7	317.5		220.0	184.0		229.1	229.1			71.9

Table 2: Results of tests for tension and shear, from provider B

Sp	Dia mm	Area mm^2	Ultima tensile force KN	Ultima tensile tress, U_b N/mm^2	Averag ultimate tensile stress U_{ba} N/mm^2	Yield stress Y_b N/mm^2	Streng of bolts P_t N/mm^2	Average strength of bolts N/mm^2	Ultim shear force KN	Ultim shear stress, Y_{ub} $(N/mm^2$	Avera shear stress Y_{ua} N/mm^2	Shear streng P_s N/mm^2
1	10	78.5	32.8	417.8		290.1	242.3		20.3	258.6		
2	10	78.5	32.5	414.0		287.5	240.1		20.3	258.6		
3	10	78.5	32.6	415.3	416.8	288.4	240.9	241.7	20.6	262.4	259.4	
4	10	78.5	32.9	419.1		291.0	243.1		20.8	265.0		200.0
5	10	78.5	32.8	417.8		290.1	242.3		19.8	252.2		
1	12	113	45.0	398.2		276.5	231.0		32.5	287.6		
2	12	113	45.0	398.2		276.5	231.0		32.4	286.7		
3	12	113	45.3	400.9	399.5	278.4	232.5	231.7	32.4	286.7	287.4	
4	12	113	45.3	400.9		278.4	232.5		32.5	287.6		191.8
5	12	113	45.1	399.1		277.2	231.5		32.6	288.5		
1	16	201	53.2	264.7		183.8	153.5		41.2	205.0		
2	16	201	53.4	265.7		184.5	154.1		40.8	203.0		
3	16	201	53.0	263.7	264.7	183.1	152.9	153.5	40.8	203.0	203.9	
4	16	201	53.0	263.7		183.1	152.9		41.0	204.0		127
5	16	201	53.4	265.7		184.5	154.1		41.1	204.5		
1	20	314	143.4	456.7		317.2	264.9		74.5	237.3		
2	20	314	143.0	456.4		316.3	264.1		74.3	236.6		
3	20	314	143.4	456.7	456.2	317.2	264.9	264.6	74.5	237.3	237.3	219
4	20	314	143.2	456.1		316.7	264.5		74.7	237.9		
5	20	314	143.2	456.1		316.7	264.5		74.6	237.6		

Table 3: Results of tests for tension and shear, from provider C

Sp	Dia mm	Area mm^2	Ultima tensile force KN	Ultima tensile tress, U_b N/mm^2	Averag ultimate tensile stress U_{ba} N/mm^2	Yield stress Y_b N/mm^2	Strenof bolts P_t N/mm^2	Averag strengt of bolts N/mm^2	Ultim shear force KN	Ultim shear stress, Y_{Ub} N/mm^2	Averag shear stress Yua N/mm^2	Shear streng Ps N/mm^2
1	10	78.5	32.8	417.8		290.1	242.3		18.9	241.3		
2	10	78.5	32.8	417.8		290.1	242.3		19.5	248.1		
3	10	78.5	32.5	414.0	416.0	287.5	240.1	241.3	19.2	244.5	243.9	199.7
4	10	78.5	32.5	414.0		287.5	240.1		18.9	241.3		
5	10	78.5	32.7	416.6		289.3	241.6		19.2	244.5		
1	12	113	42.5	376.1		261.2	218.1		30.0	265.6		
2	12	113	42.8	378.8		263.1	219.7		29.8	264.1		
3	12	113	42.8	378.8	376.1	263.1	219.7	218.1	29.7	262.5	263.3	180.5
4	12	113	42.2	373.5		259.4	216.6		29.7	262.5		
5	12	113	42.2	373.5		259.4	216.6		29.6	261.8		
1	16	201	50.4	250.7		174.1	145.4		40.0	199.2		
2	16	201	50.4	250.7		174.1	145.4		39.9	198.5		
3	16	201	50.6	251.7	251.1	174.8	146.0	145.6	40.0	199.2	199.2	127.1
4	16	201	50.5	251.2		174.4	145.7		40.1	199.7		
5	16	201	50.5	251.2		174.4	145.7		40.1	199.7		
1	20	314	110.6	352.2		244.6	204.3		74.9	238.5		
2	20	314	110.4	351.6		244.2	203.9		74.9	238.5		
3	20	314	110.6	352.2	351.9	244.6	204.3	204.1	75.0	239.0	238.8	168.9
4	20	314	110.4	351.6		244.2	203.9		75.1	239.0		
5	20	314	110.5	351.9		244.4	204.1		74.9	238.6		

Table 4: Results of tests for tension and shear, from provider D

Sp	Dia mm	Area mm^2	Ultima tensile force KN	Ultima tensile stress U_b N/mm^2	Averag ultimate tensile stress U_{ba} N/mm^2	Yield stress Y_b N/mm^2	Stren of bolts P_t N/mm^2	Averag strengt of bolts N/mm^2	Ultim shear force KN	Ultim shear stress, Y_{Ub} N/mm^2	Averag shear stress Y_{ua} N/mm^2	Shear streng P_s N/mm^2
1	10	78.5	32.9	419.1		297.2	243.1		18.2	231.5		
2	10	78.5	32.9	419.1		297.2	243.1		18.7	236.5		
3	10	78.5	33.0	420.4	419.4	298.2	243.8	243.2	18.7	236.5	232.6	
4	10	78.5	33.0	420.4		298.2	243.8		18.1	230.7		201.3
5	10	78.5	32.8	417.8		296.3	242.3		17.9	227.8		
1	12	113	40.4	357.5		253.5	207.4		31.2	276.8		
2	12	113	40.3	356.6		252.9	206.8		31.4	278.0		
3	12	113	40.3	356.6	357.3	252.9	206.8	207.3	31.4	278.0	278.1	
4	12	113	40.4	357.5		253.5	207.4		31.5	278.6		171.5
5	12	113	40.5	358.4		254.2	207.9		31.6	279.4		
1	16	201	63.7	316.9		224.7	183.8		48.5	241.2		
2	16	201	63.8	317.4		225.1	184.1		48.5	241.2		
3	16	201	63.6	316.4	316.8	224.4	183.5	183.7	48.3	240.4	240.8	
4	16	201	63.7	316.9		224.8	183.8		48.4	240.6		152.1
5	16	201	63.6	316.4		224.4	183.5		48.3	240.4		
1	20	314	105.6	336.3		238.5	195.1		79.4	252.8		
2	20	314	105.6	336.3		238.5	195.1		79.3	252.4		
3	20	314	105.4	335.7	336.1	238.1	194.7	194.9	79.0	251.6	252.1	
4	20	314	105.5	336.0		238.3	194.9		79.1	251.9		161.3
5	20	314	105.5	336.0		238.3	194.9		79.1	252.9		

Table 5: Results of tests for tension and shear, from provider E

Sp	Dia (mm)	Area mm^2	Ultima tensile force KN	Ultima tensile stress U_b N/mm^2	Averag Ultimate tensile stress U_{ba} N/mm^2	Yield stress Y_b N/mm^2	Stren of bolts P_t N/mm^2	Averag Strength of bolts N/mm^2	Ultim shear force KN	Ultim shear stress, Y_{Ub} N/mm^2	Averag shear stress Y_{ua} N/mm^2	Shear Strength P_s N/mm^2	Shear Strength P_s N/mm^2
1	10	78.5	32.7	416.6	415.3	291.3	241.6	240.9	17.9	227.8			
2	10	78.5	32.7	416.6		291.3	241.6		17.9	227.8			
3	10	78.5	32.5	414.0		289.5	240.1		18.2	231.5	229.9	199.3	199.3
4	10	78.5	32.5	414.0		289.5	240.1		18.2	231.5			
5	10	78.5	32.6	415.3		290.4	240.9		18.1	230.7			
1	12	113	41.0	362.8		253.7	210.4		31.2	276.4			
2	12	113	40.9	361.9		253.1	209.9		31.0	274.7			
3	12	113	41.9	361.9	363.2	253.1	209.9	210.6	31.0	274.7	275.9	174.3	174.3
4	12	113	41.0	362.8		253.7	210.4		31.2	276.4			
5	12	113	41.4	366.4		256.2	212.5		31.3	277.2			
1	16	201	61.4	305.5		213.6	177.2		48.7	242.3			
2	16	201	61.4	305.5		213.6	177.2		48.6	241.6			
3	16	201	61.5	306.0	305.6	214.0	177.5	177.3	48.6	241.6	241.8	146.7	146.7
4	16	201	61.3	305.5		213.6	177.2		48.5	241.2			
5	16	201	61.5	306.0		214.0	177.5		48.7	242.5			
1	20	314	102.5	326.4		228.3	189.3		79.0	251.7			
2	20	314	103.0	328.0		229.4	190.2		79.0	251.7			
3	20	314	102.4	326.1	326.4	228.0	189.1	189.3	78.9	251.4		156.7	156.7
4	20	314	102.1	325.2		227.4	188.6		78.9	251.4	251.7		
5	20	314	102.5	326.4		228.3	189.3		79.2	251.3			

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