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Evaluation of existing steel structure building through safety of bolts at connections

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ABSTRACT

The main aim of this paper is to evaluate existing steel structure building through the safety of bolts at connections, the steel structure is checked by designer through safety of elements due to structure analysis, and safety of foundations but not through safety of bolts, so that this study becomes important to check the safety through bolts at connections, specially it's noted that there is corrosion at bolts and some bolts are not tightened well. A total of 70 samples have taken, from beam to column connections for each floor, and from beam to beam connections for each floor too, and from different size of bolts (16 mm, 20 mm, and 24 mm) all bolts taken were from Grade 5.6. All samples were tested under tensile at Istanbul Technical University. Results show that all bolts in good strength, it is higher than specifications of **Grade 5.6** in yield stress with **81 %** and in tensile strength with **27 %** , the results show that bolts are from **Grade 6.8** according to bolts standard, so it is recommended that bolts do not need to replace in this existing building, and they only need tightening wherever needed, and results may interpreted that during the construction period of the building (1980s) manufacture used written lesser Grade on bolts as safety factor.

تقييم سلامة مبني قائم من هيكل فولاذي من خلال سلامة البراغي عند الوصلات

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الكلمات المفتاحية:
إجهاد الخضوع
أقصي إجهاد
تقييم البراغي
صنف البراغي
وصلات الهيكل الفولاذي

الملخص

إن الهدف الرئيسي من هذا البحث هو تقييم سلامة مبنى قائم من هيكل فولاذي من خلال سلامة البراغي عند الوصلات , تم تدقيق سلامة الهيكل الفولاذي من قبل المصمم من نتائج التحليل الإنشائي للتأكد من أمان العناصر الفولاذية القائمة و القواعد الخرسانية, و لكن لم يتم التأكد من سلامة البراغي عند الوصلات, و بالتالي أصبح من المهم تدقيق سلامة الوصلات من خلال سلامة البراغي و خاصة أنه قد لوحظ أن بعض البراغي بها إرتخاء وبعضها به تأكل , فقد تم أخذ 70 عينة من البراغي من صلات تقاطع الكمرات مع الأعمدة في كل طابق , و عينات من وصلات تلاقي الكمرات مع الكمرات في كل طابق إيضاً , و بمقاسات مختلفة من البراغي (16 مم , 20 مم و 24 مم) , كل البراغي التي تم أخذها كعينات وجدت من معيار (**5.6**) وفقاً لمعايير البراغي, كل العينات تم إختبارها تحت الشد المباشر في جامعة إسطنبول التقنية, و النتائج توضح بأن كل البراغي في حالة مقاومة جيدة, و هي تزيد عن ما نصت عليه المواصفات لهذا المعيار من البراغي (5.6) بـ **81** % لإجهاد الخضوع و بـ **27** % لمقاومة الشد , و النتائج توضح بأن البراغي هي في الحقيقة من صنف (**6.8**) وفقاً لمعايير البراغي , و لذلك تمت التوصية بأن هذه البراغي لا تحتاج لتغيير في هذا المبنى القائم , بل تحتاج لإعادة إحكام قفلها إينما يلزم ذلك , و يمكن تفسير هذه النتائج بأن خلال فترة تصميم و تنفيذ المبني (فترة الثمانينيات) أن المصنع إستخدم الكتابة على البراغي بصنف أقل مما هي عليه كمعامل أمان.

1. INTRODUCTION

Through the importance of safety of existing steel structure of building which to be used as management building, the building is located in Tripoli, near university of Tripoli, opposite of Tripoli medical centre, about 6.7 km from the coast, the steel structure of building has checked by designer through safety of elements due to structure analysis, and safety of foundations but not through safety of

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bolts, so check of connection safety through bolts test became very important, specially some bolts noted with corrosion at edges of building and near hinges where some humidity spread on steel structure and connections, some bolts are not tightened well.

A decision of replace bolts with an extra cost for project or re-tightening of some bolts may take a place due to bolts tensile test results, and the test of bolts should be done before starting of finishing activities in the building.

Figure (1) : Existing steel structure building (5TH and 6th floor constructed recently based on designer decision).

A number of 6 samples of bolts have been taken from connections of **beam to column** for each floor of building which consist 6 floors (from basement to 4th floor), and 6 samples of bolts have been taken too from connection of **beam to beam** for each floor, so a total of 70 samples have been taken based on visual inspection, a different size of bolts have considered during collection of samples (16 mm, 20mm, 24 mm). All bolts which have been taken as samples were founded from **Grade 5.6**.

The location of samples in the building at connection and at exact axes is shown in table (1).

Table (1): Location of samples in the building

Floor	Connection	Location in the building at axes
Basement	Beam to beam	(B-C/4)
	Beam to column	(D/9), (E/9)
Ground	Beam to beam	(K/9), (I/10)
	Beam to column	(I/8),(H-I/7), (H-I/8)
1st	Beam to beam	(B/8), (C/7)
	Beam to column	(B/6), (B-C/7), (B/4)
2nd	Beam to beam	(E-F/9), (F/9)
	Beam to column	(H/2), (G/8), (G/10), (H/10), (E/10)
3rd	Beam to beam	(C-D/7), (C/8), (C-D/9)
	Beam to column	(D/7), (E/9)
4th	Beam to beam	(C-D/9), (E-D/9-8), (E-D/8)
	Beam to column	(H/2),(D/2), (G/2), (G/8), (H/8)
5th & 6th	New floor so no samples taken	

There weren't samples taken from floors (5th and 6th floors) which constructed in building recently due to designer's calculation, because bolts are new and from Grade 10.9, and building were using as shopping Mall in 1980s, and now will be used as office building, the live load according to ASCE [1] is diffident 400 % between these two uses. Especially it's indicated in architectural drawings that light weights will be used (water and fire resistance dry walls as shown in figure 1, foam concrete, and rise up floor) all as super structure. The samples have been tested under tensile to compare their Mechanical results to mechanical properties of bolts standards of Grade 5.6 according to ISO 898-1:2013 [E] specification based on maximum tensile strength and yield stress.

The specifications indicated above of bolts standards of Grade5.6 [2] are as following:

Table (2): Mechanical properties of bolts standard of Grade 5.6

mechanical properties	**Grade 5.6**
Tensile strength Rm in MPa (N/mm2)	500
Yield stress Re in MPa (N/mm2)	300
Percentage elongation after fracture %	20

The Grade 5.6 refers to 5 is 500 MPa as nominal tensile strength, and 6 refers to 60 % of maximum stress which is 300 MPa as yield stress. A 70 bolts were tested under tensile and their mechanical properties compared to mechanical properties indicated in Table (2), and based on this decision a replacing or tightening of bolts at the existing building was taken.

According to Swamy, R.N [3] who considered that RC beams strengthened with steel plates exposed to weather condition for a period of 11 years (which is long – term exposure) as durable beams. So corrosive bolts (see fig 2D below) can be also accepted as durable bolts, and corrosion can be solved with sandblasting.

2. EXPERIMENTAL PROGRAMME

The results reported in this paper were obtained from 70 bolts which were tested in laboratory under tensile up to failure. After testing in Libratory results compared to mechanical properties of bolts standard based on maximum tensile strength and yield stress to decide whether bolts have to be changed or not, and have to be tightened before architectural finishing of existing steel structure building.

Detail of tested bolts

A total of 70 bolts with different length and diameter were collected from the existing steel structure building. A different size of bolts have considered during collection of samples (16 mm, 20mm, 24 mm). All bolts which have been taken were founded from **Grade 5.6**.

Table (3) shows detail of collected samples of bolts based on visual inspection because there were some corroded bolts which were near the edge of the building or near to construction hinges.

Table (3) shows detail of collected bolts

Size	Length mm	Total samples
D16	65	10
D20	65	45
D24	80	15
Total	**-**	**70**

The collection of samples is shown in figure (2a and b) the non corrosive and corrosive bolts are also shown in figure (2 c and d) respectively below:

Figure 2(A): Samples from beam to column connection

Figure 2(B): Samples from beam to beam connection

Figure 2(C): Non Corrosive bolts

Figure 2(D): Corrosive bolts.

Testing Program:

Due to length of bolts which considered so short for local laboratories, all bolts were transported to Turkey, exactly at Istanbul Technical University (**ITU**), and due to experience at dealing with shorts samples the bolts taken to Materials Testing and Innovation Laboratories (**MATIL**). Then the Bolts were tested, they were loaded under tensile force gradually up to complete failure.

Figure (3) : Tensile testing machine with an extension parts to test short samples.

3. RESULTS AND DISCUSSION:

Tensile test has been done for all bolts according to ASTM F606M-14a [4] they were loaded until complete failure to get yield stress and maximum tensile strength, then results compared with bolts standard of Grade 5.6 , and decision has taken for non replace of bolts based of comparison between results and standards. The mode of failure has also recognized for each individual bolt test. The results of all bolts were so good and satisfied bolts standard according to ISO 898-1:2013[E] [2].

Yield stress

ISO 898-1:2013 [E] [2] shows that yield stress of bolts of Grade 5.6 should be minimum 300 MPa as indicated in table (2), results showed that the minimum yield stress value is above 400 MPa, and the maximum yield stress value is above 700 MPa. These results are so good that these bolts do not need to be replaced in the building.

Figure (4) shows yield stress average in MPa for each bolt size compared with bolts standard for Grade 5.6

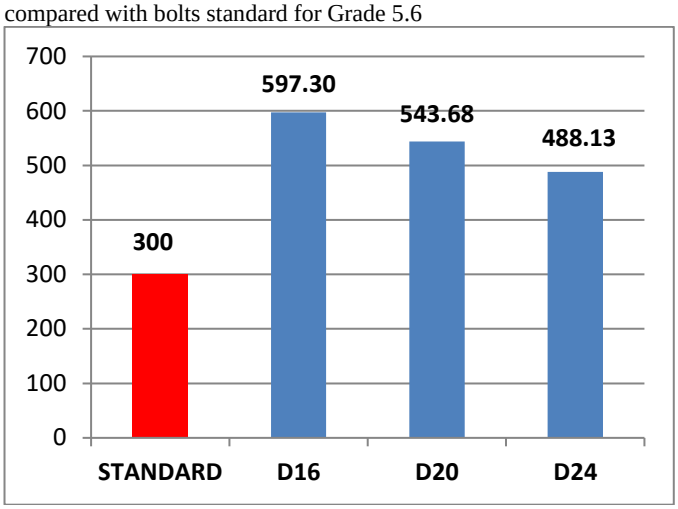

Figure (4): shows yield stress in MPa of all bolts compared with Bolts standard

From the figure shown above it can be shown as percentage from the standard value as shown in figure (5) bellow.

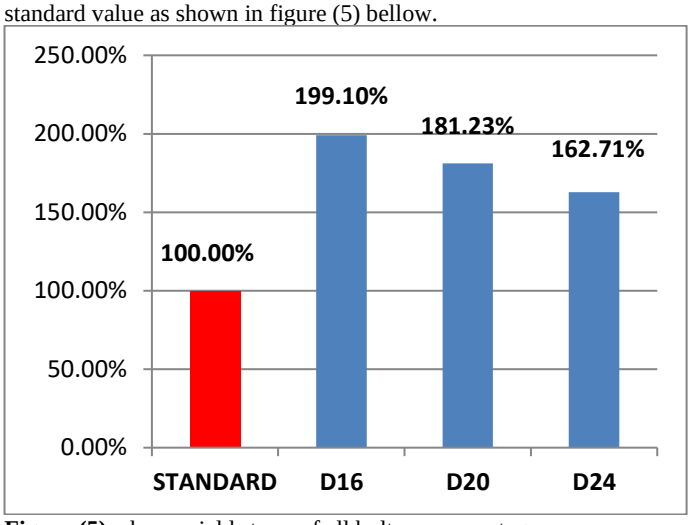

Figure (5): shows yield stress of all bolts as percentage From bolts standard

Tensile strength

ISO 898-1:2013[E] [2] shows that maximum tensile strength of bolts of Grade 5.6 should be minimum 500 MPa as indicated in table (2), results showed that the minimum strength value is above 500 MPa, and the maximum strength value is above 760 MPa. These results are so good that these bolts do not need to be replaced in the building.

Figure (6) shows tensile strength average in MPa for each bolt size compared with bolts standard for Grade 5.6

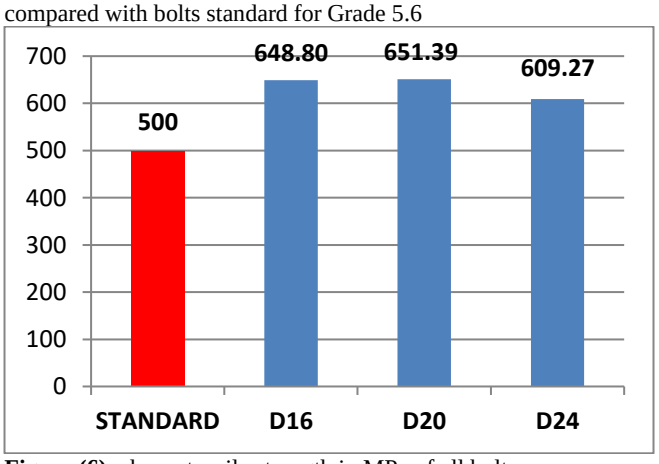

Figure (6): shows tensile strength in MPa of all bolts Compared with bolts standard

From the figure shown above it can be shown as percentage from the standard value as shown in figure (7) bellow.

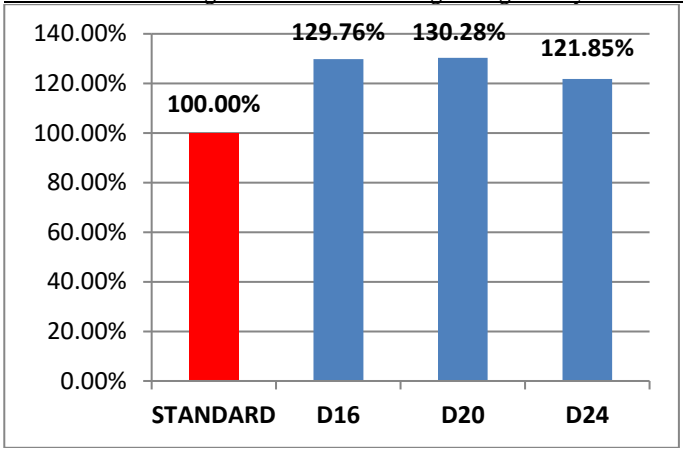

Figure (7): shows tensile strengths of all bolts as percentage from bolts standard

Figure (8) shows stress- strain relation for such a bolt, and it shows that yield stress compared to standards is higher than 300 MPa and maximum strength is also above 500 MPa, from the figure it is noted that elongation is 22 %.

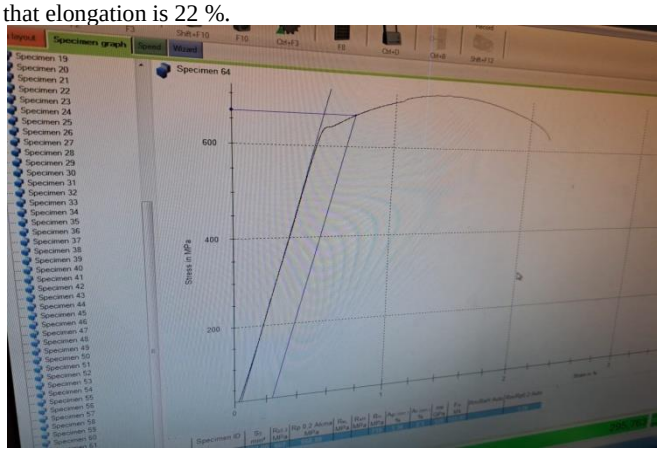

Figure (8): Stress- strain relation for a bolt.

From figures (5 and 7) shown above all bolts yield stress is higher than yield stress according to standard with minimum 63 %, and tensile strength is higher than tensile strength according to standard with minimum 22 %, in all tested bolts the average of elongation is above 20 % which also satisfied specification of bolts, this gives indication that bolts still in good condition that do not need to be replaced during maintenance of building, and based on results bolts grade can be named as **Grade 6.8**. This can be interpreted that during the period of building construction (1980s) the writing on bolts during manufacturing them used less Grade which is 5.6 as factor of safety, because the method of design at that time which was commonly used was working stress design which based on reducing the strength of material for about 50 % .

Mode of failure

The mode of failure recognized for all tested bolts, most of them were failed in straight zone as shown in figure (9), and some failed in thread zone but not by slipping off threads as shown in figure (10), there weren't any bolt failed by stripping off the head of the bolt. All cases of failure happen after the bolt has reached the value of tensile strength which indicated in bolts standard as shown in table (2), and this can be interpreted that all bolts are in good condition and can be accepted as safe bolts.

Figure (9): shows failure of bolts in straight zone

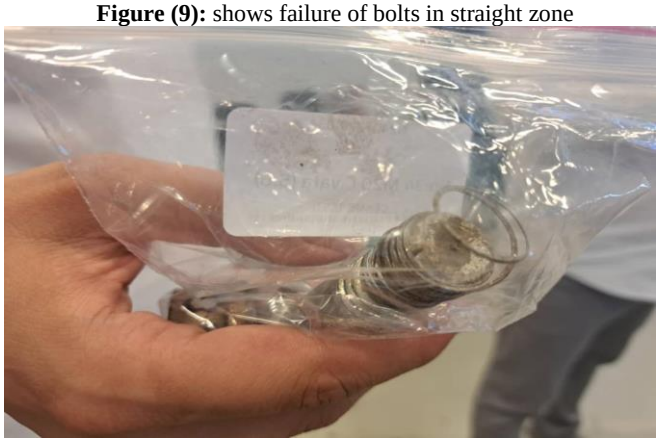

Figure (10): shows failure of bolts in thread zone

4. CONCLUSION

Based on the experimental results and discussion above it can be said clearly that bolts in this steel structure building are in good condition, durable , safe and do not need to be changed with new bolts with higher Grade, and architectural finish can be started without delay, tightening of bolts can be done as needed.

Based on the ratio of ultimate failure stress and yield stress of tested bolts to tensile strength and yield stress of bolts as Grade 5.6 as shown in figures (5) and (7) it can be said that bolts made from **Grade 6.4** but during manufacturing it's written 5.6 on the bolt as safety factor.

5. NOTATIONS:

D = Bolt size in (mm).

Re = Yield stress of a bolt in (MPa).

Rm = Specified tensile strength of a bolt in (MPa).

6. ACKNOWLEDGEMENTS:

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7. REFERENCES

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