MSc Thesis Abdisamed Ahmed ABDILAHI Department Of Civil Engineering 2015

T. R.
ERCİYES UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCE
DEPARTMENT OF CIVIL ENGINEERING

MEASURMENT AND DETERMINATION OF KERBSTONE BENDING STRENGTH

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MSc Thesis

January 2015
KAYSERİ

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Signature

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Chairman of the Department of Civil Engineering

Prof. Dr. Mehmet ARDIÇLIOĞLU

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ACCEPTANCE AND APPROVAL PAGE

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This study entitled "**MEASURMENT AND DETERMINATION OF KERBSTONE BENDING STRENGTH"** prepared by **Abdisamed Ahmed ABDILAHI** under the supervision of **Prof. Dr. Cengiz Duran ATIŞ** was accepted by the jury as MSc thesis in Civil Engineering department.

20 /01 / 2015

(thesis defense exam date)

JURY:

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Juror : **Assoc. Prof. Dr. A. Alper ÖNER**

Juror : **Assist. Prof. Dr. Zülküf KAYA**

APPROVAL

That the acceptance of this thesis has been approved by the decision of the Institute's Board of Directors with the 03/02/2015 date and 2015/05-12 numbered decision.

03 / 02 / 2015

Prof. Dr. Kâzım KEŞLİOĞLU

Director of the Institute

Director of the Institute

ACKNOWLEDGEMENTS

First and foremost I offer my sincerest gratitude to my supervisor, Prof.Cengiz Duran ATIŞ, who has supported me though out my thesis with his patience and knowledge.

You have been a tremendous mentor for me. I attribute the level of my Masters degree to his encouragement and effort and without him this thesis, would not have been completed or written. One simply could not wish for a better or friendlier supervisor.

Besides my advisor, I would like to thank the rest of my motivational lecturereres: Prof. Dr. Mehmet ARDICLIOGLU, Prof. Dr. Tafaruk HAKTANIR, Prof. Dr. Kamil AYDIN and Assoc. Prof. Bekir AKTAS, for their encouragement and insightful comments.

In the laboratory experiment I have been aided for a months in running the equipment by Res. Assist. Serhan ILKENTAPAR, a good Research Assistant who kept me in sample.

The somooth running of the Erciyes University concrete laboratory is much more statement to his effort then my own.

Serhan helped, tutor me in the more esoteric methods necessary from to make durable concrete and how to make the samples from them.

Res.Assist.Furkan BIRDAL has also inadvertently, and without fail, provided something much greater in all the years I've known him: a friendly smile and a hello every time we met.

A special thanks to my family. Words cannot express how grateful I am specially to my great grand mother, my father and mother for all of the sacrifices that you’ve made on my behalf. Your prayer for me was what sustained me thus far.

I would also like to thank all of my friends who supported me in writing, and incented me to strive towards my goal.

At the end I would like express appreciation to my sister Sundus Ahmed ABDILAHI who spent much for her positive psychological motivation support in the moments when there was no one to answer my queries.

MEASURMENT AND DETERMINATION OF KERBSTONE BENDING STRENGTH

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Msc Thesis, January 2015
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ABSTRACT

In the study, the determination of flexural tensile strength of concrete kerb stone is shown. Currently, flexural tensile strength of concrete kerb stone is determined using simple bending formula. However, due to un symmetric cross section of kerb stone the bending take place on the section of kerb stone is not simple bending but bi-axial bending. Study shows how the flexural tensile strength of un symmetric section is determined. Additionally, flexural strength results obtained using simple bending formula and bi-axial bending formula was compared. It was found that bi-axial bending formula gave higher value than that of simple bending formula.

Keywords: Kerbstone, biaxial bending, moment of inertia

BORDÜR TAŞI EĞİLME DAYANIMI ÖLÇÜMÜ VE HESABI

Abdisamed Ahmed ABDILAHI

Erciyes Üniversitesi Fen Bilimleri Enstitüsü

Yüksek Lisans Tezi, Ocak 2015

Tez Danışmanları: Prof. Dr. Cengiz Duran ATIŞ

ÖZET

Bu çalışmada bordür taşı eğilme dayanımı tespiti ve eğilme dayanımının nasıl hesaplanacağı gösterilmektedir. Mevcutta bordür eğilme dayanımının hesabı, basit eğilme formülleriyle yapılmaktadır. Ancak, bordür taşı kesitinin simetrik olmaması nedeniyle bordür taşı kesitinde oluşan eğilmenin basit eğilme değil, eğik eğilme olmasına neden olur. Çalışmada eğik eğilme formülleri yardımıyla bordür eğilme dayanımının nasıl hesaplanacağı gösterilmektedir. İlaveten, basit eğilme yardımıyla hesaplanan dayanım değerleri ile çalışmada elde edilen dayanım değerleri karşılaştırılmaktadır. Çalışmada kullanılan teorik yöntemle elde edilen dayanımın, mevcutta kullanılan yöntemle elde edilen değerden daha yüksek olduğu anlaşılmıştır.

Anahtar kelimeler: Bordür taşı, eğik eğilme, atalet momenti

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INTRODUCTION

There are three different approaches in the measurement of tensile strength of concrete materials. These are direct tensile strength testing, splitting tensile strength testing and bending tensile strength testing measurement (Erdoğan, 2003). The information on direct tensile strength testing and splitting tensile strength testing measurement are available in the relevant literature (Erdoğan, 2003; Neville, 2004). In this work, bending tensile strength testing and determination would be under consideration.

In general, bending tensile strength of concrete can be found by simply supported beam bending testing using a concrete prism sample with square or rectangular section. In the testing, three point or four point loading testing apparatus are used.

Kerbstone or border stone is generally used in the border of road to separate pedestrian walking way and motorised vehicle way, also it is used to make traffic island, or to separate double roads properly, or in construction of parking lots.

It is expected that kerbstone, used in border of access way or road in urban, to have specified dimensions with appropriate tensile strength. Turkish Standard that specifies the dimensions and strength of kerbstone made with concrete is TS 436 EN 1340 (2005). Apart from describing dimensions, standard specification specifies the lower limit of flexural strength of kerb stone. This study is focused on measurement and determination of flexural strength of concrete kerb stone.

CHAPTER 1
LITERATURE REVIEW

1.1- Theory And Methadologies Used For The Thesis

Kerb stone bending test is carried out according to relevant standard TS 436 EN 1340 (2005), using three point load testing by simply supported beam simulation.
Modelling of three point load by simply supported beam simulation can be seen in Fig.1, and application of testing can be seen in Fig.2.
Bending strength is determined using the equation given by relevant standard, in the equation, kerbstone working dimensions and section parameters, breaking load obtained from laboratory testing, distance between supports and position of point load are used.

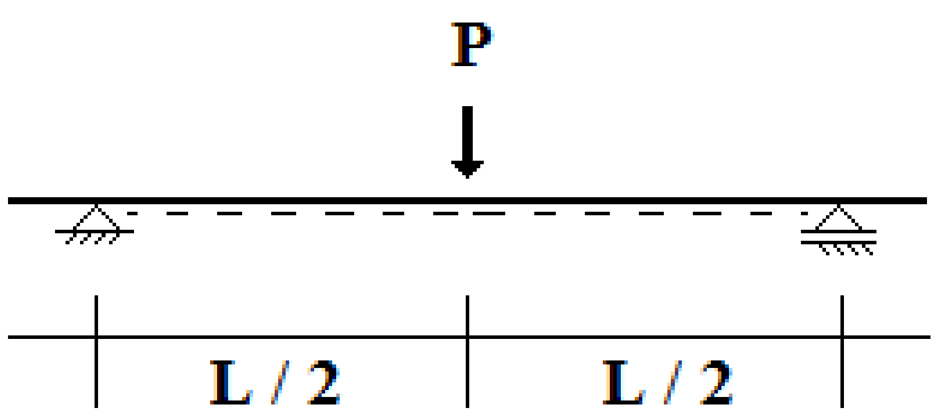


Figure 1. Kerbstone bending testing by simply supported beam simulation

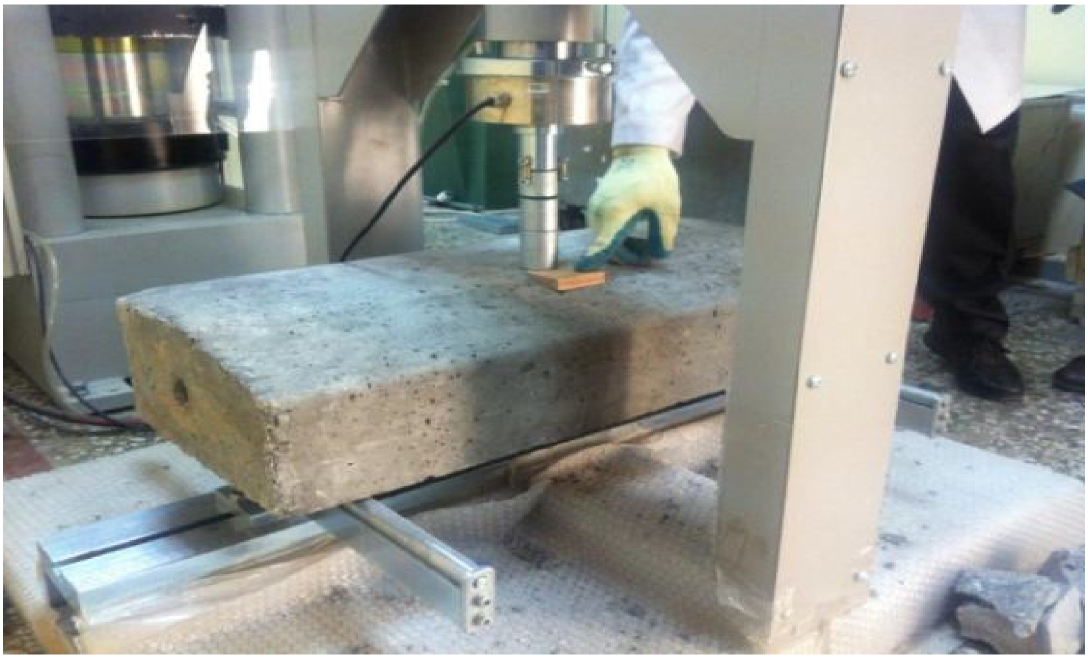


Figure 2. Kerbstone bending application picture

Bending strength determination formula specified by Standard (TS 436, EN 1340, 2005) is presented in the following equation 1.

$$\boldsymbol{T = \frac{P\,L}{4\,I}\,y} \quad \textbf{(1)}$$

Where,

P: Breaking load (Newton),

L: Span length of beam or distance between support (mm),

I: Moment of inertia for working or breaking section of kerbstone, (mm^4),

y: Distance between centroid of working section and outer fibre of beam (mm),

T: Bending tensile strength of kerbstone, MPa dır.

It is known that above given formula by equation 1 is valid for symmetrical section under simple bending. However, in general, the cross section of kerb stone is not a symmetrical, thus, given formula is under question. Therefore, this case should be analysed and the situation has to be clarified. This clarification is taken as the main of this thesis. To achieve this goal a theoretical and experimental program were planned and carried out.

CHAPTER 2

DETERMINATION OF FLEXURAL STRENGTH

2.1. Methods Used For Determination Of Flextural Strength

As it was stated that the given formula by equation 1, is valid for simple bending with symmetrical section, it is not valid for simple bending of unsymmetrical section.

In equation 1, there appear a "**y**" term, the definition of y value by standard is that "distance between centroid of working section and outer fibre of beam". This definition of y value is also thought to be inappropriate. The realistic definition of y should be that "distance of outer fibre in tension zone to neutral axis".

Strength determination can be carried out for a general section regardless if the section is either symmetrical or unsymmetrical, using the formula (equation 2) presented below (Omurtag, 2007).

$$\sigma_z = \frac{\mathbf{M_x(Iy.Y - Ixy.X) + My.(Ixy.Y - Ix.X)}}{\mathbf{Ix.Iy - (Ixy)2}} \qquad \textbf{(2)}$$

Where,

M_x is bending moment about x axis of section,

M_y is bending moment about y axis of section,

I_x is inertial moment of section about x axis,

I_y	is inertial moment of section about y axis,
I_{xy}	is product inertial moment of section,
X	is apsis of a point, according to the axis its origins located at centroid, where stress is calculated,
Y	is ordinate of a point, according to the axis its origins located at centroid, where stress is calculated,
σ_z	stress at any point.

In addition, the equation of neutral axis is given in equation 3 that is presented below [Omurtag4]. The definition of neutral axis is that the stress distribution of a crossection becomes zero on a linethat passes through centroid, such line is called neutral axis and it can be found by equating the stress values given in equation 2 to zero, then equation of neutral axis is found as presented in equation 3.

$$Y = \frac{X\,(Ixy.Mx - Ix.My)}{Iy.Mx - Ixy.My} \qquad \textbf{(3)}$$

In the case of symmetrical kerb stone section, the formula (equation 1) suggested by relevant standard to be used in the determination of the strength of kerb stone section, can be used. However, if either the section is unsymmetrical or regardless of the section that subjected to a moment which have two components about two axis meaning biaxial, the general formula (equation 2) can be used.

In case of kerbstone flexural tensile strength, the value of maximum moment about x axis can be determined using the three point testing and formula (equation 4) described and suggested by the relevant Standard.

$$M_x = \frac{P.L}{\mathbf{4}} \qquad \textbf{(4)}$$

The general dimension and shape of the kerb stone used in this study is presented in Figure 3. It can be clearly seen from the figure that kerbstone section is not symmetrical. The bending moment that breaks the section would be about x axis, there would not be no moment about y axis. Therefore, moment about x axis would be determined after bending testing that could be determined using equation 4, and moment about y axis My would be zero.

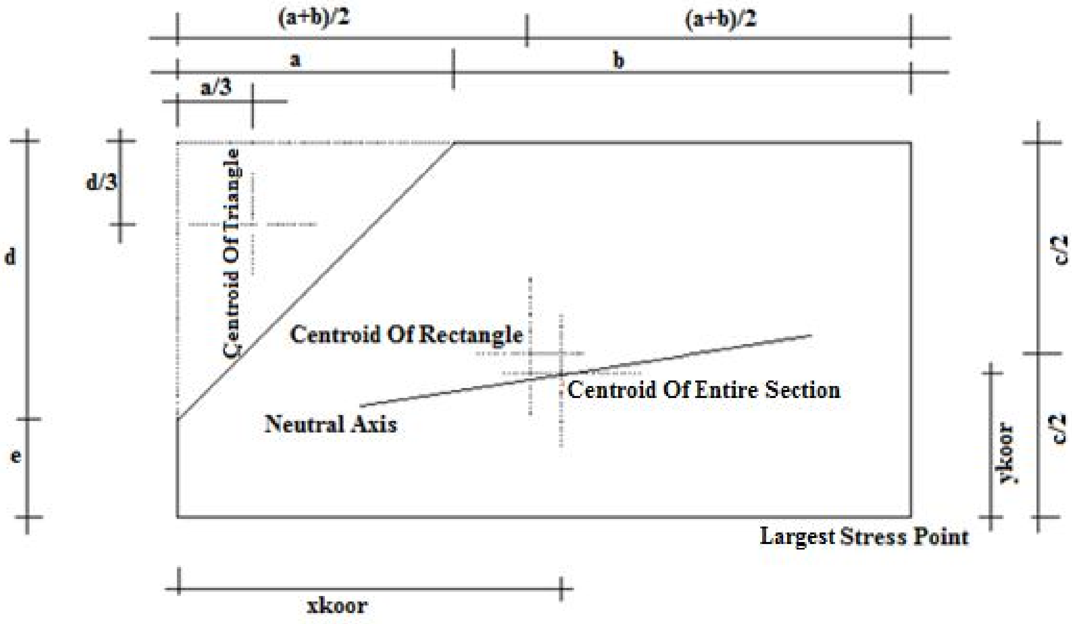


Figure 3 Typical kerb stone section, dimension and axis used in the study

While strength calculation carried out for kerb stone section, equation 2 have to be used since the section is unsymmetrical and the formula is general. Therefore, the parameters that used in equation 2, i.e. Ix, Iy, Ixy, X ve Y are to be determined. Determinations of those parameters are shown in the following.

Section of kerb stone is made of a total of a two geometrical shape, rectangle and triangle. If section of triangle reduced from rectangle, then kerb stone section exists. Accordingly, strength determination is based on this assumption. First, centroid of kerb stone section is determined. Inertial moments of kerb stone section (Ix, Iy, Ixy) are determined with respect to the axis whose origins located at centroid of the entire section. For each shape (rectangle and triangle) two moment of inertia are determined, one of which are moment of inertia with respect to the local axis that located at centroid of each section separately. Another part of moment of inertia caused by transformation of moment of inertia from local axis of each section to the axis that located at centroid of entire section. This additional moment of inertia is determined using ***steiner*** theorem. In the following, formulation is given by stepwise. First, the areas of rectangle and triangle are determined for calculation of centroid of entire section.

$$Fd = (a + b).c \quad \textbf{(5)}$$

$$Fu = \frac{a.d}{2} \quad \textbf{(6)}$$

Where,

a, b, c d, e are side length of cross section as defined in Fig.3,

Fd is area of rectangle,

Fu is area of triangle.

Static moment of those area about the x and y axis, that is located at left corner of kerb stone, are determined.

$$Sxd = \frac{Fd.c}{2} \quad \textbf{(7)}$$

$$Sxu = Fu.(e + \frac{2.d}{3}) \quad \textbf{(8)}$$

$$Syd = \frac{Fd.(a+b)}{2} \quad \textbf{(9)}$$

$$Syu = \frac{Fu.a}{3} \quad \textbf{(10)}$$

Where,

Sxd is static moment of rectangle about x axis,

Sxu is static moment of triangle about x axis,

Syd is static moment of rectangle about y axis,

Syu is static moment of triangle about y axis.

Coordinates of centroid of entire section are determined based on static moment of each section according to the axis located at left corner of kerb stone section. Static moment of triangle is reduced from static moment of rectangle and, then the resultant static moment that belongs to entire section is divided by the area of entire section that is determined by reducing the area of triangle from rectangle. The formulae are presented below.

$$xkoor = \frac{(Syd - Syu)}{(Fd - Fu)} \tag{11}$$

$$ykoor = \frac{(Sxd - Sxu)}{(Fd - Fu)} \tag{12}$$

where,

xkoor is abscissa of centroid of entire section wrt axis located at left corner of section,

ykooris ordinate of centroid of entire section wrt axis located at left corner of section,

Moment of inertia for each section, rectangle and triangle, with respect to local axis located at their centroid are determined using the formula presented below.
These formula can be found in any strength of materials textbook or lecture notes.

$$Ixd = \frac{(a+b).c^3}{12} \tag{13}$$

$$Ixu = \frac{a.d^3}{36} \tag{14}$$

$$Iyd = \frac{c.(a+b)^3}{12} \tag{15}$$

$$Iyu = \frac{d.ad^3}{36} \quad \textbf{(16)}$$

$$Ixyd = 0 \quad \textbf{(17)}$$

$$Ixyu = \frac{a^2d^2}{72} \quad \textbf{(18)}$$

Where,

Ixd is moment of inertia about local x axis of rectangle,

Ixu is moment of inertia about local x axis of triangle,

Iyd is moment of inertia about local y axis of rectangle,

Iyu is moment of inertia about local y axis of triangle,

Ixyd is product moment of inertia for local axis of rectangle,

Ixyu is product moment of inertia for local axis of triangle.

Product moment of inertia and moment of inertia about x and y axis that its origins located at centroid of entire section can be determined using the formula presented below, in the formula **steiner** theorem was also implemented. In the summation of all those of inertial moments, the sign for rectangular part was considered positive and it was negative for triangle part. These are presented in equation 19, 20, 21.

$$Ix = Ixd + Fd.(\frac{c}{2} - ykoor)^2 - Ixu - Fu.(e + \frac{2d}{3} - ykoor)^2 \quad \textbf{(19)}$$

$$Iy = Iyd + Fd.(\frac{(a+b)}{2} - xkoor)^2 - Iyu - Fu.(\frac{a}{3} - xkoor)^2 \quad \textbf{(20)}$$

$$Ixy = Ixyd + Fd.\left(\frac{c}{2} - ykoor\right).\left(\frac{a+b}{2} - xkoor\right) - Ixyu - Fu.\left(e + \frac{2d}{3} - ykoor\right).\left(\frac{a}{3} - xkoor\right) \quad \textbf{(21)}$$

Therefore, stress value at any point on the entire section can be calculated using those moment of inertia and other parameters. It is known that compressive strength of concrete is much higher than flexural tensile strength of concrete. Thus, the breaking occurs due to tensile stress on the section. Highest breaking stress should be calculated, since it causes the breaking of section.

The highest breaking stress is also called flexural tensile strength of material. In the section presented in figure 3, neutral axis is also plotted. It is known that the highest stress is existed on the fibre, which is the farthest from the neutral axis. In our case, farthest fibre is located at a point on entire section that is farthest from neutral axis also, that point is located at right corner of kerbstone section. That point is also marked on the entire section in figure 3. Coordinates of the above mention points, with respect to the axis of whose origins located at centroid of entire section, can be stated as given below. These coordinates are used in determination of flexural strength of entire section of kerb stone.

$$X = a + b - xkoor \quad \textbf{(22)}$$

$$Y = -ykoor \quad \textbf{(23)}$$

Above, it was stated that value of bending moments existed about Y axis was zero.
If that is replaced in stress formula given in equation 2. Then below statement can be obtained.

$$\sigma_z = \frac{\mathbf{M_x(Iy*Y-Ixy*X)}}{\mathbf{Ix*Iy-Ixy^2}} \quad \textbf{(24)}$$

For clarification or easing the process, if the statement next to Mx moment is considered as coefficient of Mx, then inverse of that coefficient can be described as W (section modulus). Thus equation 25 is obtained. If W is replaced in Equation 24, then, equation 26 is obtained.

$$W = \frac{\mathbf{Ix * Iy - Ixy^2}}{\mathbf{Iy * Y - Ixy * X}} \quad \textbf{(25)}$$

$$\sigma_z = \frac{M_x}{W} \quad \textbf{(26)}$$

When those moments of inertia i.e. Ix, Iy, Ixy, and X and Y value are determined as described above, and substituted in section modulus (Equation 25), then W section modulus is obtained. The value of W can be substituted in equation 26, thus, the highest stress value existed on entire kerbstone section namely σz is obtained. The resultant value is also called flexural strength of kerbstone.

When the neutral axis is considered, bending moment about y axis was zero, this can be substituted in neutral axis equation 3, then, simplified form of neutral axis can be obtained as presented below (equation 27).

$$Y = \frac{X.\mathbf{Ixy}}{\mathbf{Iy}} \quad \textbf{(27)}$$

It can be seen from equation 27 that slope of the neutral axis is ratio of product moment of inertia to moment of inertia about y axis for entire section namely Ixy/Iy. Definition of slope is that tangent of the angle between neutral axis and x axis, thus, that angle ϕ can be determined using equation 28.

$$\phi = ArcTan(\frac{Ixy}{\mathrm{Iy}}) \quad \textbf{(28)}$$

By using equation 26 and 28, flexural strength of kerbstone and angle between neutral axis and x axis can be determined.

CHAPTER 3
MATERIALS

3.1- Materials Used and Experimental Study

In real application and production, kerbstone dimensions are about 100 cm in length, and 30 and 40 cm in width and height. Thus, weight of a kerb stone becomes heavy to handle it, i.e. weight of a kerb stone heavier than 100 or more. In this study, producing small samples for laboratory were considered. Prismatic mortar samples with square section were produced. Unsymmetrical section was obtained by cutting a triangle from the corner of a square section. Mortar samples regardless of its cross section were tested under tree point bending test. Then, bending strength were calculated using breaking load, span between supports and section properties. In calculation equation 1 and equation 2 were employed. It is known that strength of unsymmetrical section and symmetrical section has to be equal or near equal. Therefore, it is expected that equation 1 would be failed, and equation 2 would satisfy the results. Mortar sample would be prepared with 4x4cm section and with 16cm length. In preparation of mortar sample a standard mixture was used. In the mixture, 450 gr cement, 1350 gr standard rilem sand, and 225 water used to prepare three 4x4x16 cm^3 sized prismatic specimen. In total 18 prismatic specimens were prepared, 9 of them were subjected to saw cutting to obtain unsymmetrical section that looks like kerb stone section. For each sample testing was carried, picture of mortar samples with symmetrical and unsymmetrical section were taken with their dimensions written on section were taken, and presented in the following figures. Breaking load of each sample was given.

In addition a computer program was coded in mathematica computer medium to evaluate all equation starting from equation 1 to equation 28.

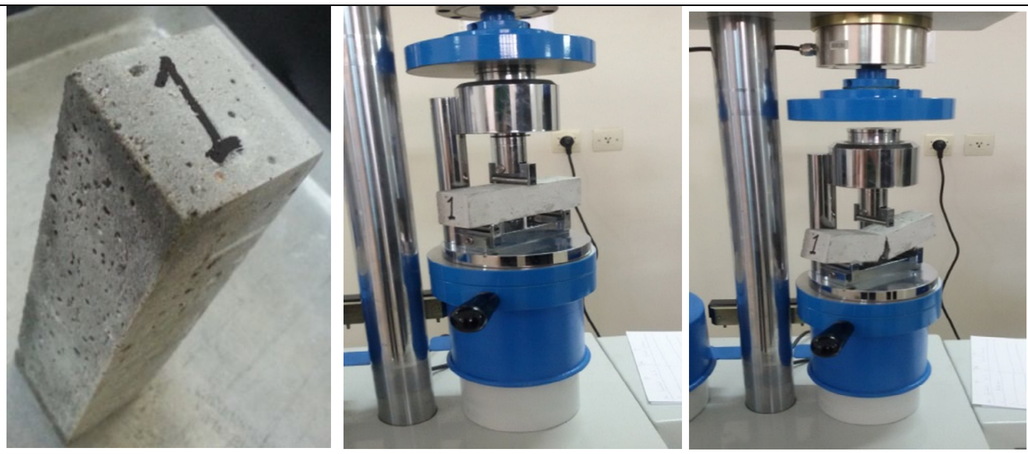
All the parameters to be used in determination of strength of kerb stone were calculated, then, finally strength of kerb stone section were determined and presented in the following testing. Computer program were presented below. Given program was used for each testing to calculate strength of kerb stone

```
Print["The lenthgs in mm, force is in Newton: to be entered"]
Print["This code is written in accordance with the data given in the thesis."]
P=1000
L=100
Mx=P*L/4.;
a=20.; d=20;
c=40;

b=40-a;
e=40-d;
Fd=(a+b)*c;
Fu=a*d/2;
Sxd=Fd*c/2;
Sxu=Fu*(e+2*d/3);
Syd=Fd*(a+b)/2;
Syu=Fu*a/3;
xkoor=(Syd-Syu)/(Fd-Fu);
ykoor=(Sxd-Sxu)/(Fd-Fu);
Ixd=(a+b)*c^3/12;
Ixu=a*d^3/36;
Iyd=c*(a+b)^3/12;
Iyu=d*a^3/36;
Ixyd=0;
Ixyu=d^2*a^2/72;
(*Ix, Iy, Ixy are calulated according to axis located at centroid of entire section.*)
Ix=Ixd+Fd*(c/2-ykoor)^2-Ixu-Fu*(e+2d/3-ykoor)^2;
Iy=Iyd+Fd*((a+b)/2-xkoor)^2-Iyu-Fu*(a/3-xkoor)^2;
Ixy=Ixyd+Fd*(c/2-ykoor)*((a+b)/2-xkoor)-Ixyu-Fu*(e+2d/3-ykoor)*(a/3-xkoor);
Print["Inertial moment about x axis Ix=",Ix,"  mm4"] ;
Print["Inertial moment about y axis Iy=",Iy,"  mm4"];
```

```
Print["Product inertial moment     Ixy=",Ixy,"  mm4"];

tnfi=Ixy/Iy;  fi=ArcTan[tnfi];

Print["Angle between x and neutral axis, using rigth hand side, by turning from x axis
to y axis; = ",fi*180/Pi," degree."]

xx=a+b-xkoor;  yy=-ykoor;

(*Formula is presenten in Omurtags Book (strength of matriasl)*)

Wx=-FullSimplify[(Ix*Iy-Ixy^2)/(Iy*yy-Ixy*xx)];

Print["section modulus=",Wx," mm3"]

strength=Mx/Wx;

Print["Strength calculated in this study =",strength," MPa"]

Print["Strength calculated by TS 436     =",Mx*ykoor/Ix," MPa"]

Print["Ratio of this study to TS 436 =",strength/(Mx*ykoor/Ix)]

trex=tnfi*(x-xkoor)+ykoor;

(*section is plotted*)

gr1=ListLinePlot[{{0,0},{a+b,0},{a+b,c},{a,c},{0,e},{0,0}},PlotStyle→{Black,Thick},Axes
→False];

gr2  =ListLinePlot[{{0,e},{a,c},{0,e+d},{0,e}},PlotStyle→{Black,Thin,Dashed}];

pnt1=Graphics[{PointSize[Medium],Black,Point[{(a+b)/2,c/2}]}];

pnt2=Graphics[{PointSize[Medium],Black,Point[{a/3,e+2d/3}]}];

pnt3=Graphics[{PointSize[Medium],Black,Point[{xkoor,ykoor}]}];

pnt4=Graphics[{PointSize[Large],Black,Point[{a+b,0}]}];

prm=6;

ax1=ListLinePlot[{{(a+b)/2-prm,c/2},{(a+b)/2+prm,c/2}},PlotStyle→{Black,Thin,Dashed}];

ax2=ListLinePlot[{{(a+b)/2,c/2-prm},{(a+b)/2,c/2+prm}},PlotStyle→{Black,Thin,Dashed}];

ax3=ListLinePlot[{{xkoor-prm,ykoor},{xkoor+prm,ykoor}},PlotStyle→{Black,Thin,Dashed}];

ax4=ListLinePlot[{{xkoor,ykoor-prm},{xkoor,ykoor+prm}},PlotStyle→{Black,Thin,Dashed}];

ax5=ListLinePlot[{{a/3-prm,e+2d/3},{a/3+prm,e+2d/3}},PlotStyle→{Black,Thin,Dashed}];

ax6=ListLinePlot[{{a/3,e+2d/3-prm},{a/3,e+2d/3+prm}},PlotStyle→{Black,Thin,Dashed}];

tre=Plot[trex,{x,a/2,a+3b/4},PlotStyle→{Black,Thin}];

Show[gr1,gr2,pnt1,pnt2,pnt3,pnt4,ax1,ax2,ax3,ax4,ax5,ax6,tre]
```

4.1 Experiment number 1 for square section

In the following, experiment number 2 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

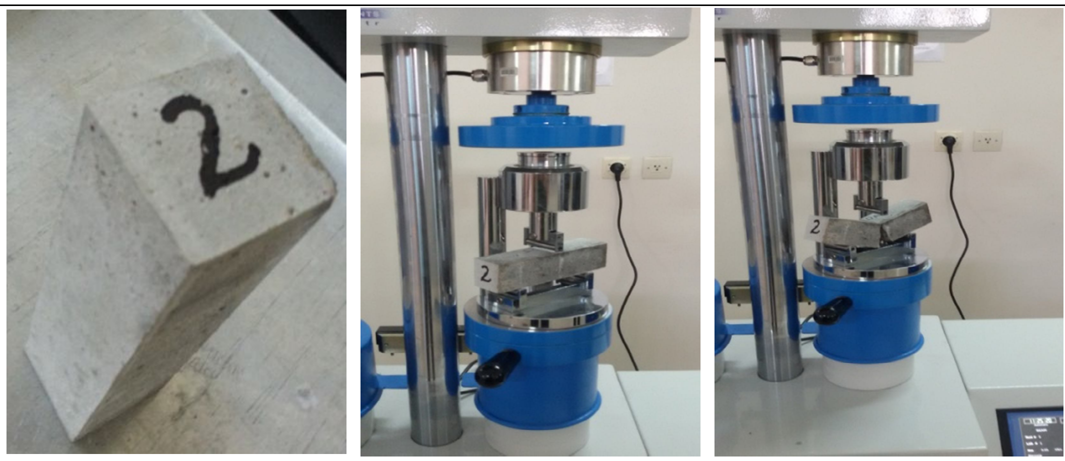


P1=3330 Newton

Figure 4 Experiment number 1 in laboratory for symmetrical section

4.2 Experiment number 2 for square section

In the following, experiment number 2 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

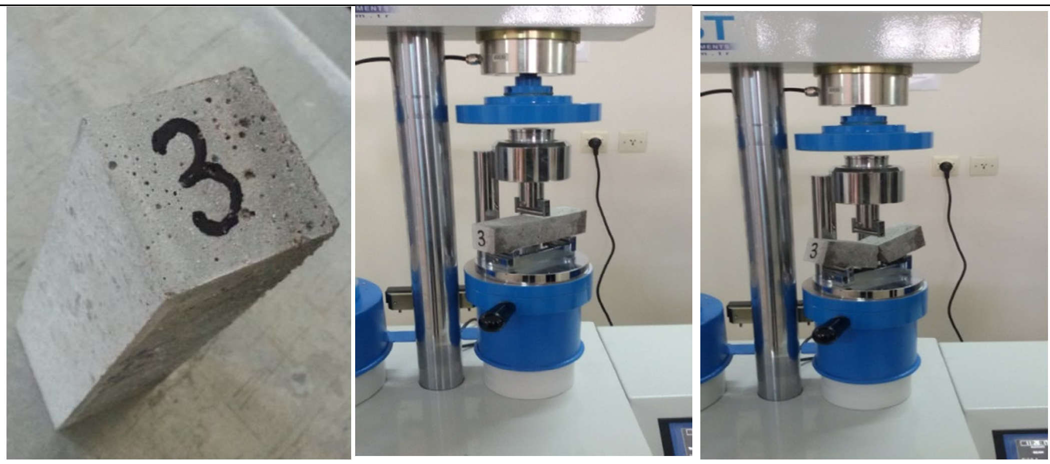


P1=3330 Newton

Figure 5 Experiment number 2 in laboratory for symmetrical section

4.3 Experiment number 3 for square section

In the following, experiment number 3 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

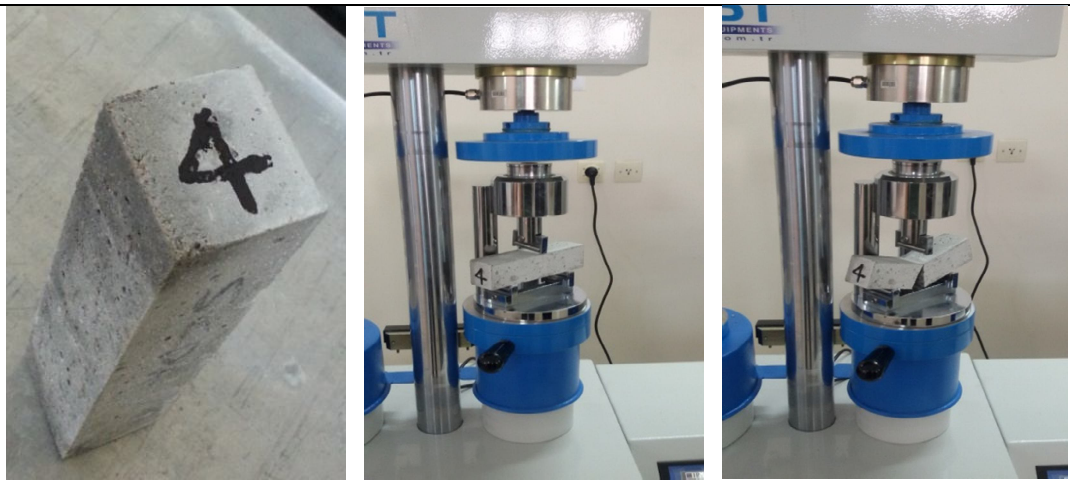


P3= 3460 Newton

Figure 6 Experiment number 3 in laboratory for symmetrical section

4.4 Experiment number 4 for square section

In the following, experiment number 4 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

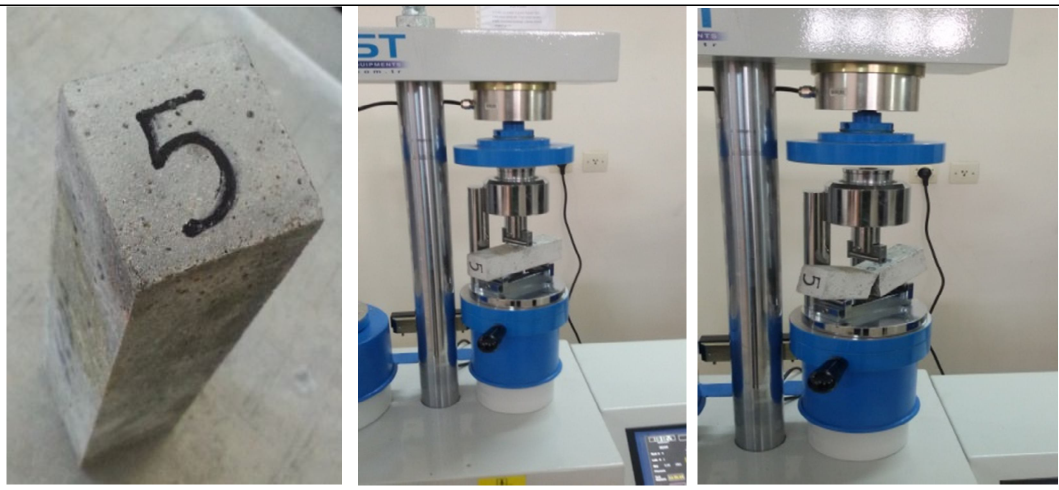


P4=3410 Newton

Figure 7 Experiment number 4 in laboratory for symmetrical section

4.5 Experiment number 5 for square section

In the following, experiment number 5 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

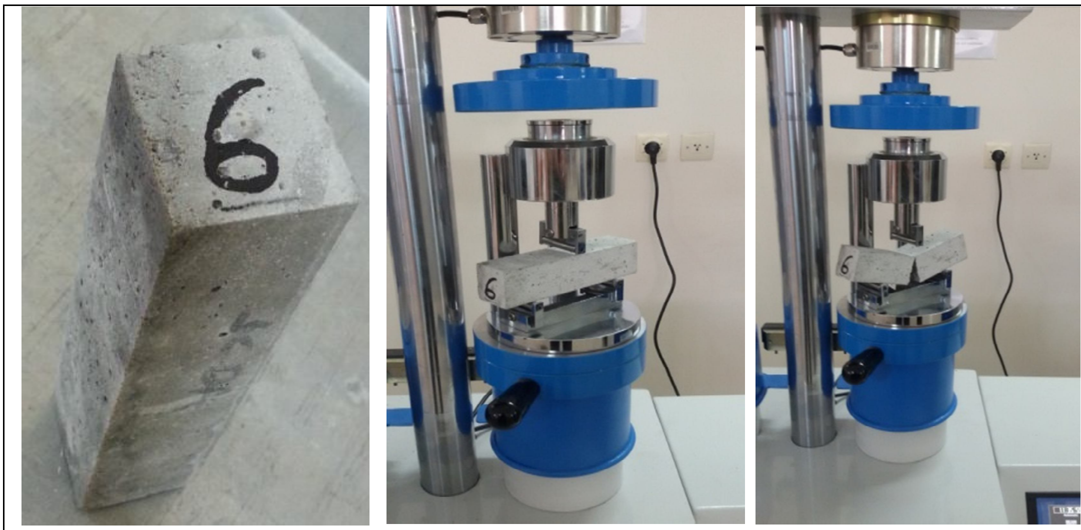


P5=3550 Newton

Figure 8 Experiment number 5 in laboratory for symmetrical section

4.6 Experiment number 6 for square section

In the following, experiment number 6 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.



P6=3360 Newton

Figure 9 Experiment number 6 in laboratory for symmetrical section

4.7 Experiment number 7 for square section

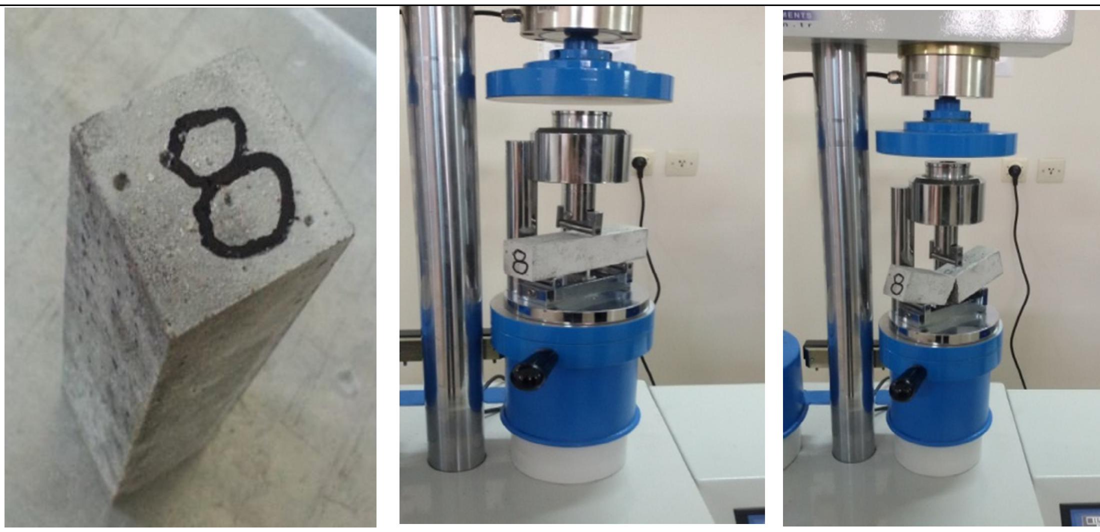
In the following, experiment number 7 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

P7=3290 Newton

Figure 10 Experiment number 7 in laboratory for symmetrical section

4.8 Experiment number 8 for square section

In the following, experiment number 8 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

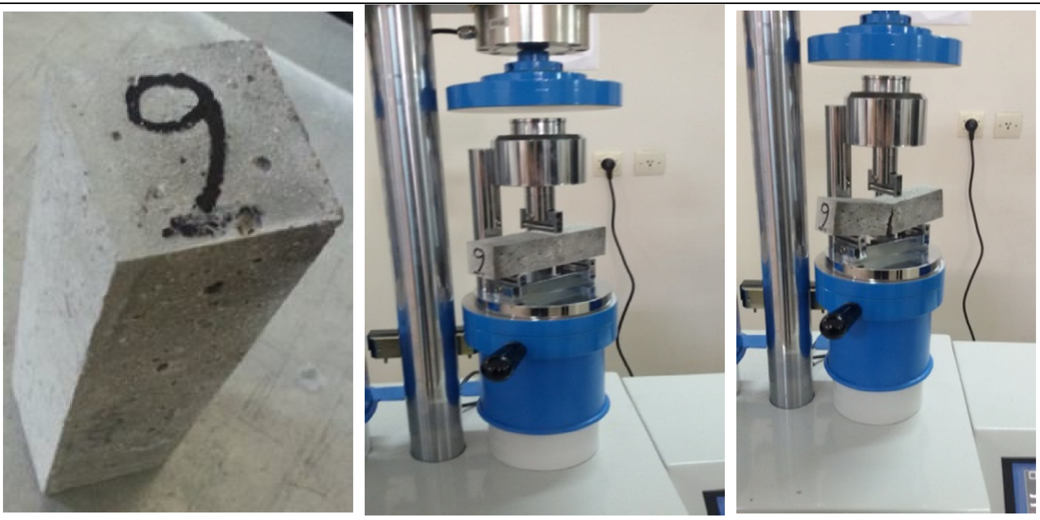


P8=3650 Newton

Figure 11 Experiment number 8 in laboratory for symmetrical section

4.9 Experiment number 9 for square section

In the following, experiment number 9 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.



P9=3220 Newton

Figure 12 Experiment number 9 in laboratory for symmetrical section

4.10 Summarizing the resulst obtained in laboratory for square sections

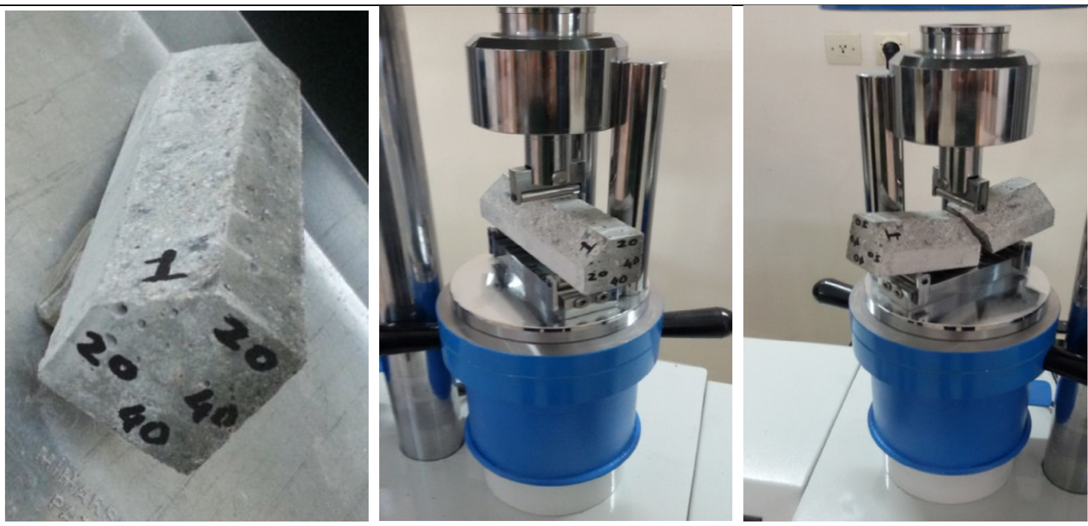
In the following Table 1, breaking load and dimensions of square section summarized.

Table1. Breaking load for each square section samples

Experiment Number	**a, mm**	**b, mm**	**c, mm**	**d, mm**	**e, mm**	**L, mm**	**P, Newton**
1	0	40	40	0	40	100	3520
2	0	40	40	0	40	100	3330
3	0	40	40	0	40	100	3460
4	0	40	40	0	40	100	3410
5	0	40	40	0	40	100	3550
6	0	40	40	0	40	100	3360
7	0	40	40	0	40	100	3290
8	0	40	40	0	40	100	3650
9	0	40	40	0	40	100	3220

4.11 Experiment number 1 for unsymmetrical section

In the following, experiment number 1 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

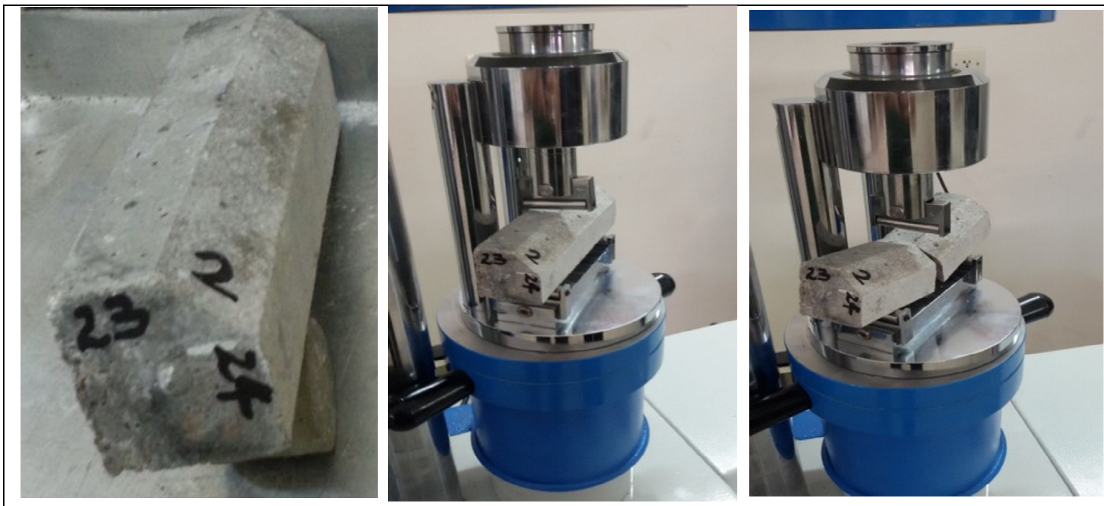


P1=2670 Newton

Figure 13 Experiment number 1 in laboratory for unsymmetrical section

4.12 Experiment number 2 for unsymmetrical section

In the following, experiment number 2 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

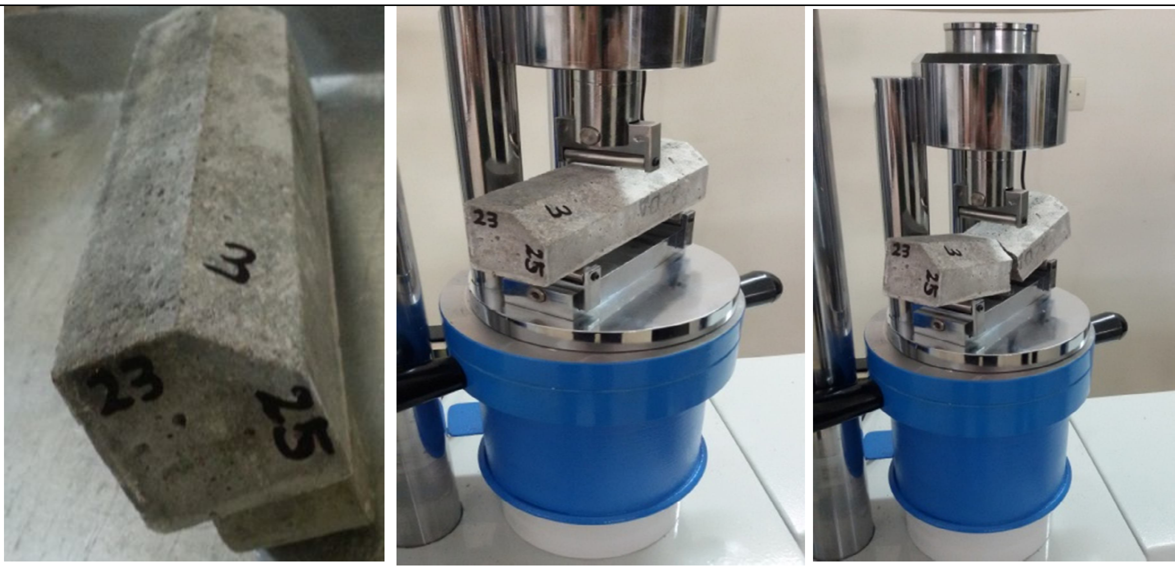


P2=2720 Newton

Figure 14 Experiment number 2 in laboratory for unsymmetrical section

4.13 Experiment number 3 for unsymmetrical section

In the following, experiment number 3 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

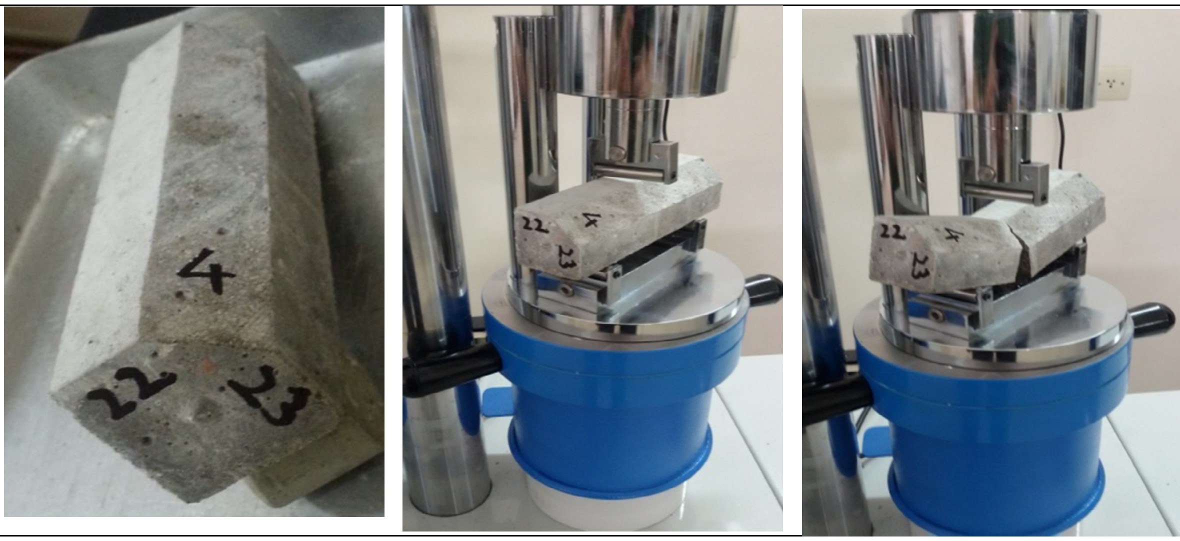


P3=2560 Newton

Figure 15 Experiment number 3 in laboratory for unsymmetrical section

4.14 Experiment number 4 for unsymmetrical section

In the following, experiment number 4 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

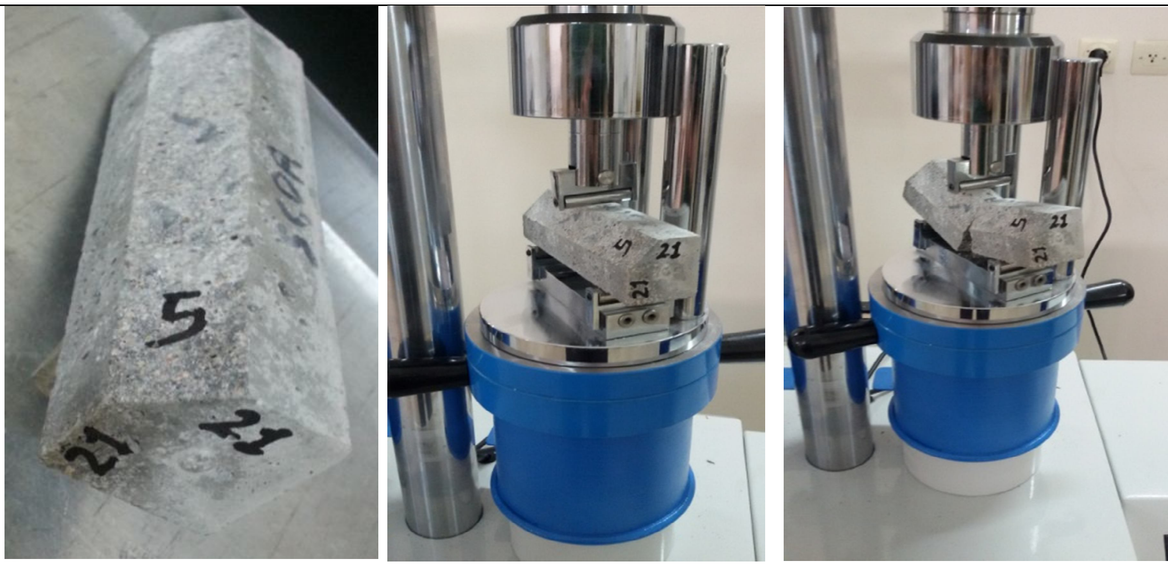


P4=2380 Newton

Figure 16 Experiment number 4 in laboratory for unsymmetrical section

4.15 Experiment number 5 for unsymmetrical section

In the following, experiment number 5 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

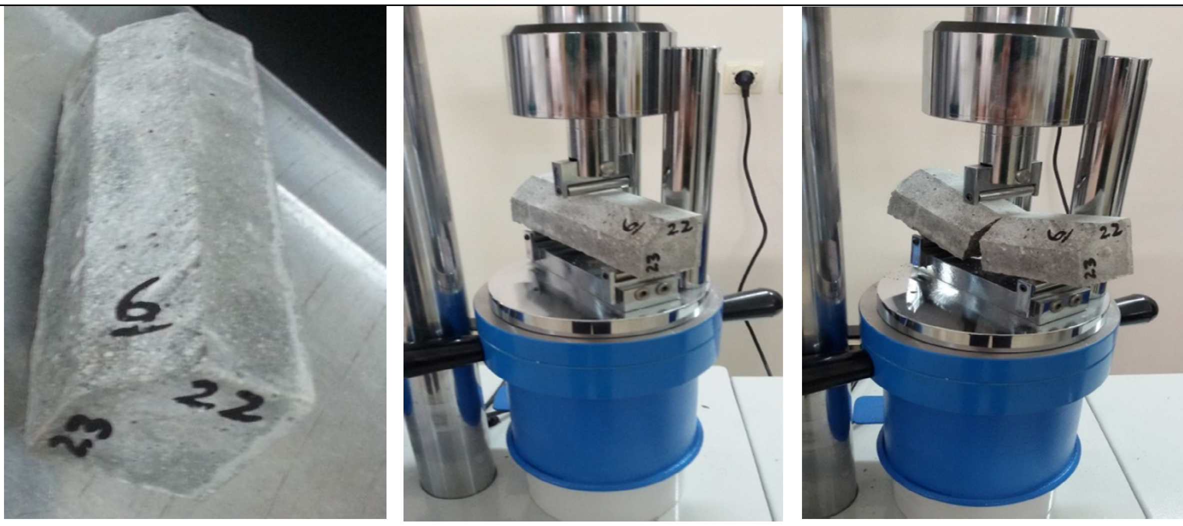


P5=2370 Newton

Figure 17 Experiment number 5 in laboratory for unsymmetrical section

4.16 Experiment number 6 for unsymmetrical section

In the following, experiment number 6 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

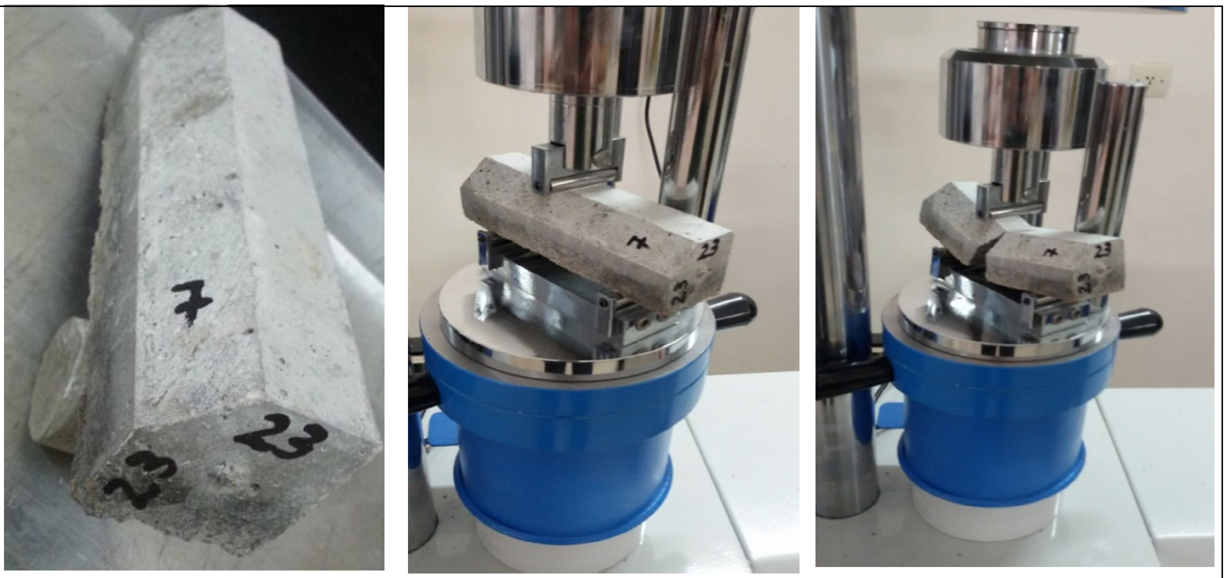


P4=2380 Newton

Figure 18 Experiment number 6 in laboratory for unsymmetrical section

4.17 Experiment number 7 for unsymmetrical section

In the following, experiment number 7 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

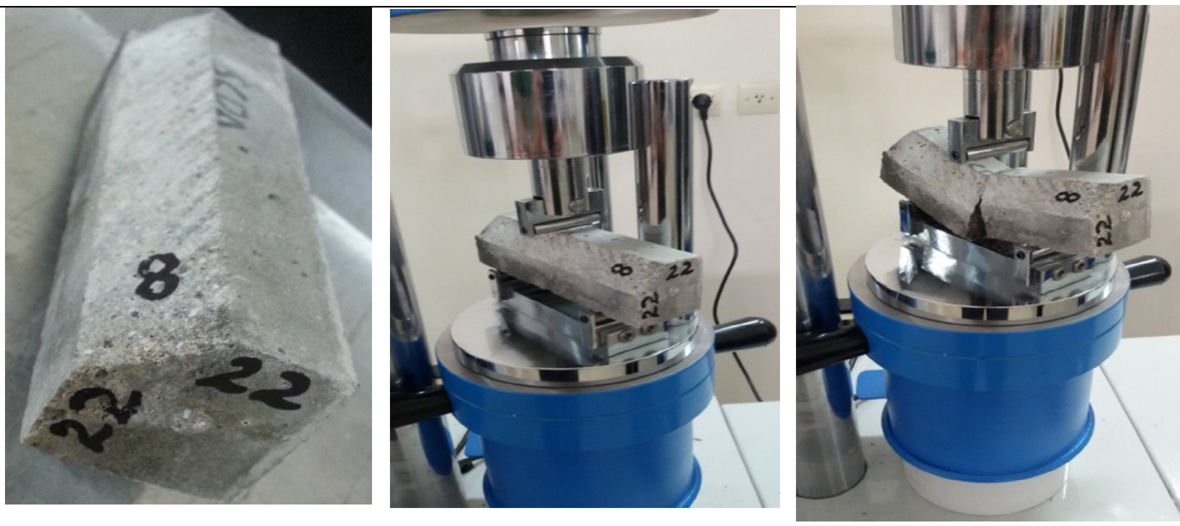


P7=2250 Newton

Figure 19 Experiment number 7 in laboratory for unsymmetrical section

4.18 Experiment number 8 for unsymmetrical section

In the following, experiment number 8 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.

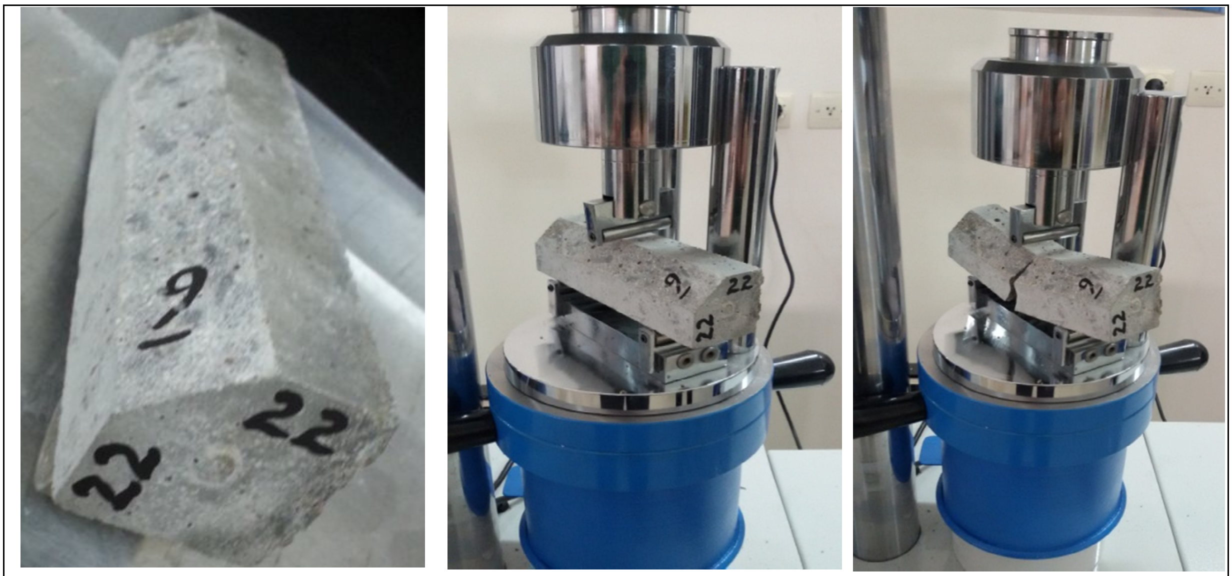


P=2400 Newton

Figure 20 Experiment number 8 in laboratory for unsymmetrical section

4.19 Experiment number 9 for unsymmetrical section

In the following, experiment number 9 is visualized. The result of breaking force of the section is also provided at the bottom of the picture.



P=2380 Newton

Figure 21 Experiment number 9 in laboratory for unsymmetrical section

4.20 Summarizing the results obtained in laboratory for unsymmetrical sections

In the following Table 2, breaking load and dimensions of section summarized.

Table2. Breaking load for unsymmetrical section samples

Experiment Number	a, mm	b, mm	c, mm	d, mm	e, mm	L, mm	P, Newton
1	20	20	40	20	20	100	2670
2	17	23	40	16	24	100	2720
3	17	23	40	15	25	100	2560
4	18	22	40	17	23	100	2380
5	19	21	40	19	21	100	2370
6	18	22	40	17	23	100	2380
7	17	23	40	17	23	100	2250
8	18	22	40	18	22	100	2400
9	18	22	40	18	22	100	2380

CHAPTER 4
RESULTS

4.1. Output Of The Experiments

The data presented in Table 1 and Table 2 was used to calculate the strength of the entire sections using both formulas suggested by TS 436 and this study. Strength obtained from both formulas is presented in Table 3 and Table 4, for symmetrical and unsymmetrical sections, respectively.

Table3. Strength of each square section samples calculated by both formulas

Experiment Number	$\sigma_{(TS\ 436)MPa}$	$\sigma_{(WorkMPa}$	ϕ^o	$\frac{\sigma_{(Work}}{\sigma_{(TS\ 436)}}$
1	8.25	8.25	0	1
2	7.80	7.80	0	1
3	8.11	8.11	0	1
4	7.99	7.99	0	1
5	8.32	8.32	0	1
6	7.88	7.88	0	1
7	7.11	7.11	0	1
8	8.55	8.55	0	1
9	8.55	8.55	0	1
Average	8.06	8.06		
Standard Deviation	0.45	0.45		

Table4. Strength of each unsymmetrical section samples calculated by both formulas

Experiment Number	$\sigma_{(TS\ 436)}$, MPa	$\sigma_{(Work)}$, MPa	ϕ^o	$\frac{\sigma_{(Work)}}{\sigma_{(TS\ 436)}}$
1	7.18	9.30	12.86	1.29
2	7.06	8.49	9.50	1.20
3	6.63	7.88	8.98	1.19
4	6.24	7.66	10.43	1.23
5	6.30	7.98	11.90	1.27
6	6.24	7.66	10.43	1.23
7	5.86	7.11	10.00	1.21
8	6.31	7.83	10.94	1.24
9	6.26	7.76	10.95	1.24
Average	6.45	7.96		
Standard Deviation	0.43	0.61		

Averages and standard deviations of the strength obtained are also calculated and presented in Table 3 and Table 4.

It can be seen from Table 3 that average strength of symmetrical section is 8.06 MPa. The average strength of unsymmetrical section calculated using standards formula is 6.45. While the average strength of unsymmetrical section calculated using formula suggested in this work is 7.96.

5.1. Discussion – Conclution And Recommendations

The output of this study has shown that, results of symmetrical section and results of formula suggested in this work are near to each other.

The results of standards formula deviates in the order of 20% from other results. Therefore this proves that formula suggested in this study is more appropriate comparing to standards formula.

In this study small numbers of samples were used, it is suggested that more experiment should be carried out to verify this results. Additionally, the dimensions of samples used in this study is small, it is suggested that testing should be carried out on real samples.

As a result of this study, it is found that standards formula is over safe in calculating kerb stone section strength.

Therefore, it is suggested that the formula used in this work could be used in calculating kerb stone strength. Another suggestion is that a symmetrical section can be prepared by cutting kerbstone section, and the strength of sample with symmetrical section should be calculated.

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11th April 2012 to 20th June 2012	SCET TUNISIE	Assistant For Construction Site Supervisor
4th December 2011 up to10th April 2011	Alliance Construction Company	Site engineer
1st October 2011 upto 1st December 2011	Al-Buruuj S.A.R.L	Site and office training about construction supervision.
26th march 2009 upto 14th July 2011	Horn engineering construction and consulting company (HECC)	Training
2009-2011	Ubaya schools	Lecturer
Feb 2008 upto 3th March 2010	SOHURA organization	Admin and finance

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4. Turkish: fair