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EXPERIMENTAL STUDY OF REINFORCED CONCRETE DAPPED ENDS BEAMS STRENGTHEN WITH TRANSVERSE SUBSEQUENT INSTALLED BARS

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Abstract: This study involves in taking seven reinforced concrete dapped end beams strengthened with transverse Subsequent installed bars under concentered loads. These specimens of dimension (length=1220 x height=240 x width=130mm) with two types of sections (i.e. without and with transverse opening) and studied to evaluate the response of test beams to compare the strength capacity of beams strengthened with transvers subsequent installed bars relative to beams with or without opening region in sections. All specimens are simply supports. The five of R.C. dapped ends beams are strengthened with transverses Subsequent installed bars with or without opening and designed to test up to failure. Three parameters were investigated: compressive strength, amount of transvers Subsequent installed bars, and effect of section (with and without opening). It is found that's increased in compressive strength by about 20% give increase in load carrying capacity by about 9%. Also, the reinforced concrete dapped ends beams contains transverse opening section compared to beams without opening results show decrease in strength capacity and gives more deflection by about in range (10-20%) and (18-26%) respectively. The transverse Subsequent installed bars are provided by steel bolts diameter of 10.5mm gives more enhancement in strength capacity and decrease deflection more than the others without transvers bars by about (8-27%) & (20-30%). Strengthened of beams by transvers bars can show to again in ultimate strength capacity by about (30%).

Keywords: *Dapped-end Beams, Opening, Transverse, Subsequent installed bars.*

دراسة عملية للعتبات الخرسانية المسلحة الغير مستمرة النهايات المقواة بالقضبان العرضية المثبتة المشدودة بعد الصب

الخلاصة: شمل هذا البحث دراسة سبعه عتبات خرسانيه مسلحة غير مستمره النهايات مقواة بقضبان عمودية عرضية مثبتة بعد الصب تحت حمل مركز.كانت ابعاد العتبات (الطول 1200 ملم والعرض 130 ملم والعمق 240 ملم) وبمقاطع مختلفه مع او بدون فتحات عرضية تم تحريها لتقييم سلوكها من الناحية العملية ومقارنه مقاومتها مع النماذج المقواة بقضبان العرضية نسبه لتلك العتبات مع او بدون فتحات. كل العتبات بسيطة الاسناد. خمسة من هذة العتبات صممت لتقويتها بواسطة القضبان العمودية العرضية المثبتة بعد الصب مع او بدون فتحات. وفحصت لغاية الفشل.تضمنت التحريات ثلاث متغيرات وهي مقاومة الانضغاط للخرسانه نسبه القضبان العرضيه للتقويه ونوع المقطع (مع او بدون فتحات). وجد ان زيادة مقاومة الانضغاط بنسبه 20% تعطي زيادة في قابليه التحمل للعتبة بمقدار 9%. وكذلك العتبات التي تحوي على الفتحات العرضية بالمقارنة مع العتبات بدون فتحات تعطي نقصان في قابليه التحمل وزيادة في الهطول المقابل بمقدار(10 الى 20 %) و(18 الى 26%) على التوالي.جهزت القضبان العرضية بواسطة استخدام براغي قطر 10.5 ملم وادى ذلك الى زيادة في قابليه التحمل ونقصان في الهطول المقابل بالمقارنه بالعتبات الغير مقواة عرضيا" بمقدار (8 الى 27%) و (20 الى 30%) على التوالي. كذلك شاركت تقوية العتبات بالقضبان العرضية المثبتة بعد الصب في زيادة مقاومة التحمل بمقدار 30%.اخيرا تم اجراء المقارنة بين كل العتبات بالاعتماد على قابليه التحمل والهطول و نمط التشقق وانماط الفشل.

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1. Introduction

Reinforced concrete (RC) beams with dapped ends are frequently found in bridge girders and precast concrete construction. The dapped-end beam provides an economical and efficient means of connecting precast to precast and precast to cast in place concrete members.

It enables reduction in the construction depth of a precast concrete floor or roof structure, by recessing the supporting corbels or ledge into the supported beams (Lu et al., 2003). Reinforced concrete dapped-end beams have many applications as drop-in beams between corbels or beam-to-beam connections (Yang et al., 2010). Previous investigations (Mattock and Chan, 1979; Lin et al., 2003; Lu et al., 2003; Wang and Hoogenboom, 2005 and Yang et al., 2010) have focused on dapped-end beams with a shear span-to-depth ratio (a /d) not greater than unity.

Typically, reinforcement for a dapped-end beam with a /d ≤ 1 is composed of the main bars, hanger bars and horizontal stirrups. According to Wang and Hoogenboom (2005), inclined stirrups and longitudinal bent reinforcement have greater shear capacity than vertical stirrups for dapped-end beams with a /d < 1. Vertical stirrups, however, may play a significant role in the shear-carrying capacity of dapped-end beams with a/d > 1 (Mattock and Chan, 1979).

Three failure modes have been found in dapped-end beams with a/d ≤ 1: flexure failure, diagonal compression failure and tensile failure initiated by the yielding of hanger bars (Mattock and Chan, 1979; Lin et al., 2003; Lu et al., 2012). The failure mode of dapped-end beams with a/d > 1 is dominated by flexure failure (Lu et al., 2012). However, in design practice, most engineers prefer the ductile failure mode to the brittle one. Further experimental works on dapped-end beams with a/d > 1 should be performed.

2. Objective of Study

The objective of the present research was to show the effect of strengthening provided by Subsequent installed bars. Variables included, concrete strength, opening region and transverse strengthen by post-tension bars arrangement and layout.

Also to get way to develop method of strengthen to get equivalents beams with opening strengthen with posttension transvers that give same load capacity of beam without opening sections.

3. Experimental program

This program consist of seven R.C. dapped ends beams was investigate to show the behavior of specimens when strengthened with transvers vertical Subsequent installed bars.

The experimental program described in this study incorporated seven beams with dapped ends; two without opening main defects were intentionally introduced compressive concrete strength as reference specimens, opening region (location and number of bars (bolts)) through cross section and five different strengthening techniques were applied.

3.1. *Materials*

In this study, the mixes of the concrete were consist of ordinary Portland cement, irregular gravel of (19 mm) maximum size, and sand.

The mix proportioning began with the selection of the unit weight (wet density) are given in Table 1 for all beams .

The mix was then proportioned by the method of absolute volumes of one cubic meter are obtained by series test of trial mixes. Table (1) shows final adopted mix of designs. The average compressive strength of concrete (standard cylinder (150 x 300mm)) fc` of these mixer of 28 days are 25 and 30 MPa.

Table (1) Mix proportions of Concrete (1 m^3)

Try mix.	Cement (kg/m^3)	Sand (kg/m^3)	Gravel (kg/m^3)	Water/Cement Ratio	Water (kg/m3)
A	420	630	1260	0.5	210
B	550	825	1650	0.5	275

3.2. *Dapped End R.C. Beams Details*

Seven reinforced concrete dapped end beams with details shown in Table (2) were designed, fabricated and tested up to failure. All beams are simple support, two without opening, three beams had a transvers recess of diameter (50 mm) in the bottom fiber and five beams had strengthen with transvers Subsequent installed bars with different number of subsequent installed bares as shown in Figs.(1,2 and 3).

The transvers vertical subsequent installed bars system used in this work to provide more strength capacity and strengthen the discontinuous edges of beams. Before casting specimens all components were thoroughly hand mixed for at least 3 min to get homogenous mixture.

After finish cast the concrete to the molds as shown in figures. When complete 28 days of curing the specimens ready to strengthen by transvers vertical bars. The properties of materials and strength are shown in Tables (2).

Table (2) Table (3) Properties of Steel Reinforcement

Nominal Diameter (mm)	Measured Diameter (mm)	A_s (mm^2)	Yield Tensile Strength f_y (MPa)	Ultimate Strength f_u (MPa)
8	7.88	48.76	420	504
10	9.88	76.67	421	520
12	12.2	116.89	480	576

*: According to ASTM A615/615M-08a

**: Average of three specimens (Bars of length 500mm)

Table (2): Details of R.C. Dapped end Beams Specimens

Beam Symbol	*As Bottom*	*As Top*	*Av*	*Ah*	*Hanger reinforcing*	*Opening Diameter (mm)*	*T.S.B*	f_c`** MPa
DENT 1	2Ø10	2Ø8	Ø8/100	2Ø10	3Ø10	---	---	25
DENT 2	2Ø10	2Ø8	Ø8/100	2Ø10	3Ø10	---	---	30
DET 3	2Ø10	2Ø8	Ø8/100	2Ø10	3Ø10	---	2Ø12	25
DET 4	2Ø10	2Ø8	Ø8/100	2Ø10	3Ø10	2Ø50	2Ø12	25
DET 5	2Ø10	2Ø8	Ø8/100	2Ø10	3Ø10	---	4Ø12	25
DET 6	2Ø10	2Ø8	Ø8/100	2Ø10	3Ø10	2Ø50	4Ø12	25
DET 7	2Ø10	2Ø8	Ø8/100	2Ø10	3Ø10	4Ø50	6Ø12	25

DENT: Dapped End Non Transverse (None Strengthen).
DENT: Dapped End Transverse (Strengthen).
* : According to ASTM C39-86 and take average of three specimens (cylinder).
Av : Vertical Stirrups Reinforcing ; Ah : Horizontal Stirrups Reinforcing
T.S.B: Transvers Subsequent Bars

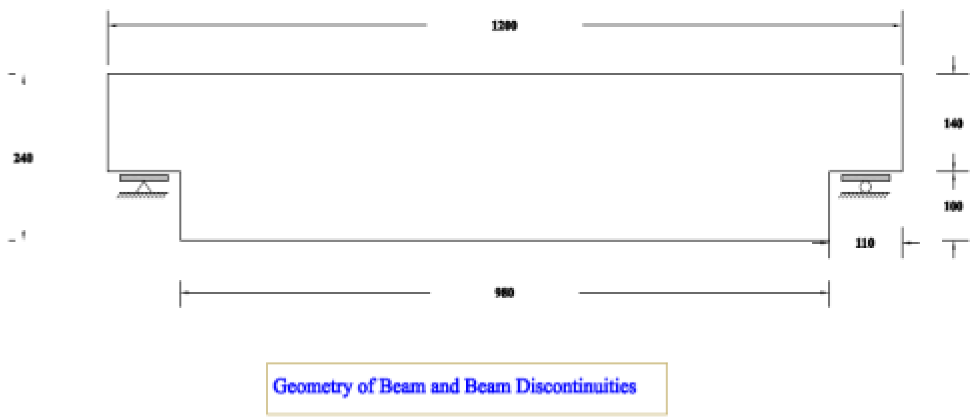

Fig.(1) R.C. Beam Dapped Ends Layout & Dimensions (mm).

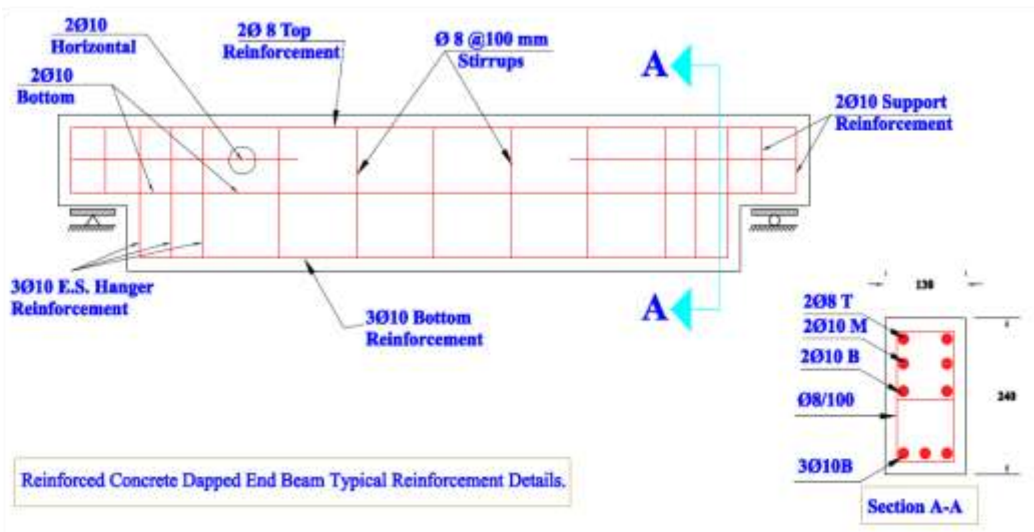

Fig.(2) Reinforcement Details of R.C. Beam Dapped Ends.

(A) Mold of R.C. Beam, (Dapped Ends).

(B) Molds and Reinforcement of R.C. Beam Dapped Ends, (DE1 & DE2)

(C) Mold and Reinforcement of R.C. Beam Dapped Ends, (DE3).

(D) Mold and Reinforcement of R.C. Beam Dapped Ends, (DE4).

(E). Mold and Reinforcement of R.C. Beam Dapped Ends, (DE5)

(F) Mold and Reinforcement of R.C. Beam Dapped Ends, (DE6).

(G) Mold and Reinforcement of R.C. Beam Dapped Ends, (DE7).

Fig.(3) Molds Details of R.C. Beam Dapped Ends.

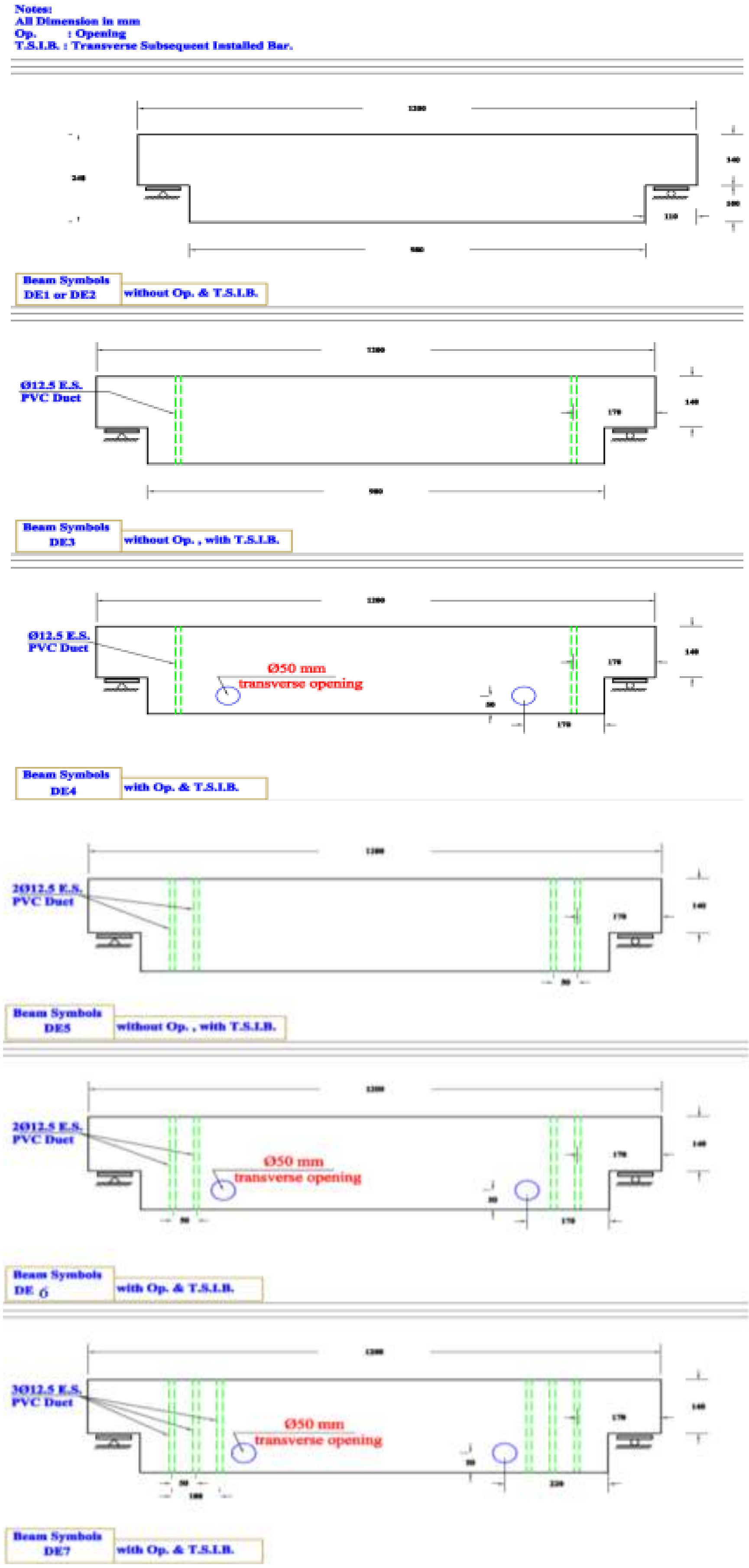

Fig.(4) Location of OP. or T.S.I.B. in Dapped Ends R.C. Beam Specimen.

4. Instrumentation and Testing Procedure

The specimens are painted with white colures after complete of curing duration. Then the beams are moved to position under two points of concentrated load.

During the testing stage we will recorded the deflection at mid span and near support at each of load increment (every 5 kN), the deflection measured using digital dial gauge of capacity 3 cm and accuracy of 0.01) the instrument and layout of specimens are shown in Fig.(5). The test is continue till failure

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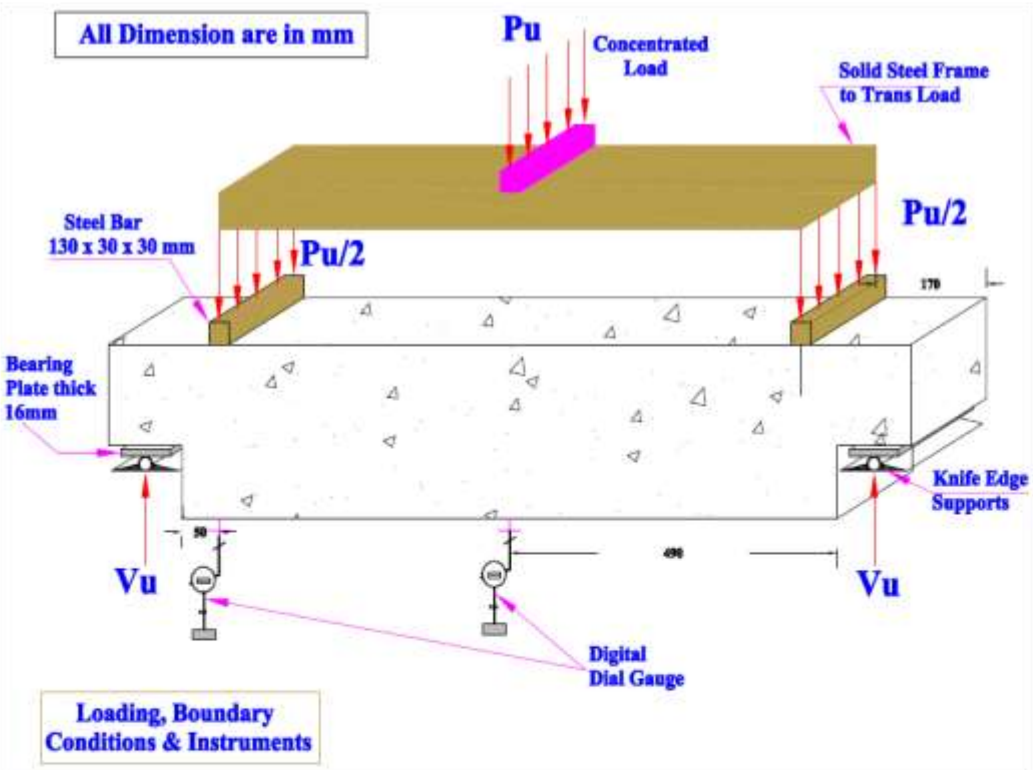
a. Testing Machine



b. Test Setup.

Fig.(5) Loading, Boundary Conditions and Instruments Layouts.

5. Experimental Results

5.1. *First Crack and Ultimate Load*

The comparison between different variables that will take in this study based on first crack, ultimate load and deflection are listed in Table (5 and 6).

Table (5) Fist Crack Loading, Ultimate Loading and deflection

Beam Symbol	First Crack Load kN	Ultimate Load, kN	Difference in Load %	*Deflection mm*	*Difference deflection %*	*Failure mode*
DENT1	29	95	---	15.8	---	Compound
DENT 2	34	103	8.5	13.43	-15.4	Compound
DET 3	40	106	11.6	12.64	-20	Compound
DET 4	38	102	7.4	13.20	-16.5	Compound
DET 5	45	114	15.8	11.12	-30	Compound
DET 6	43	108	10.53	11.51	-27.15	Compound
DET 7	50	120	26.31	11.81	-25.25	Compound

** : Reference beam (control). : Compound Failure = Flexure & Shear Failure

Table (6) Loads and Deflections Central and Near Dapped Ends.

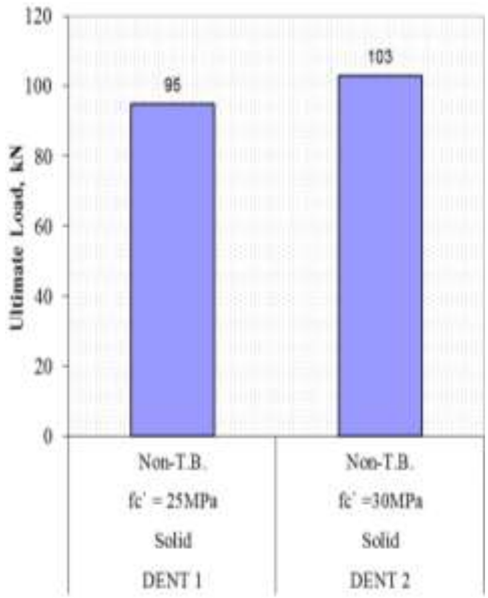
Beam Symbol	*Opening Diameter (mm)*	*Transvers subsequent bars*	f_c`** *MPa*	Ultimate Load, kN	*Near Dapped Deflection mm*	*Max. Central Deflection mm*
DENT1	---	---	25	95	5.56	15.8
DENT 2	---	---	30	103	4.56	13.43
DET 3	---	2Ø12	25	106	4.45	12.64
DET 4	2Ø50	2Ø12	25	102	4.89	13.20
DET 5	---	4Ø12	25	114	3.7	11.12
DET 6	2Ø50	4Ø12	25	108	3.84	11.51
DET 7	4Ø50	6Ø12	25	120	3.94	11.81

** : Reference beam (control). : Compound Failure = Flexure & Shear Failure

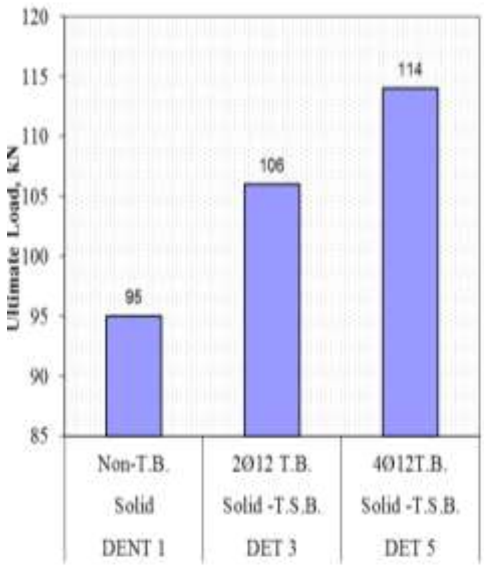
5.2. *Variables Effect and Ultimate Load*

The comparison between specimens based on variables are shown in Fig.(6).These were the compressive strength, transvers subsequent installed bars, opening region and section types.

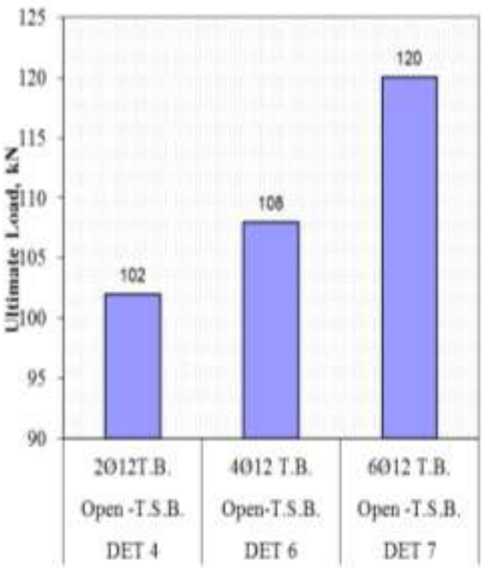
Note:
T.B. : Transvers Bars (Bolts).
T.S.B.: Transvers subsequent Installed Bars (Bolts).



a- Effect of Concrete Compressive Strength.



b- Effect of Transvers subsequent Installed bars



c- Effect of Opening and Transvers Subsequent Installed Bars.

d- Effect of Section Type (Opening and Transvers Subsequent Installed Bars).

Fig.(6) Effect of Adopted Parameter on Ultimate Load Capacity

Note:
T.B. : Transvers Bars (Bolts).
T.S.B.: Transvers subsequent Installed Bars (Bolts).

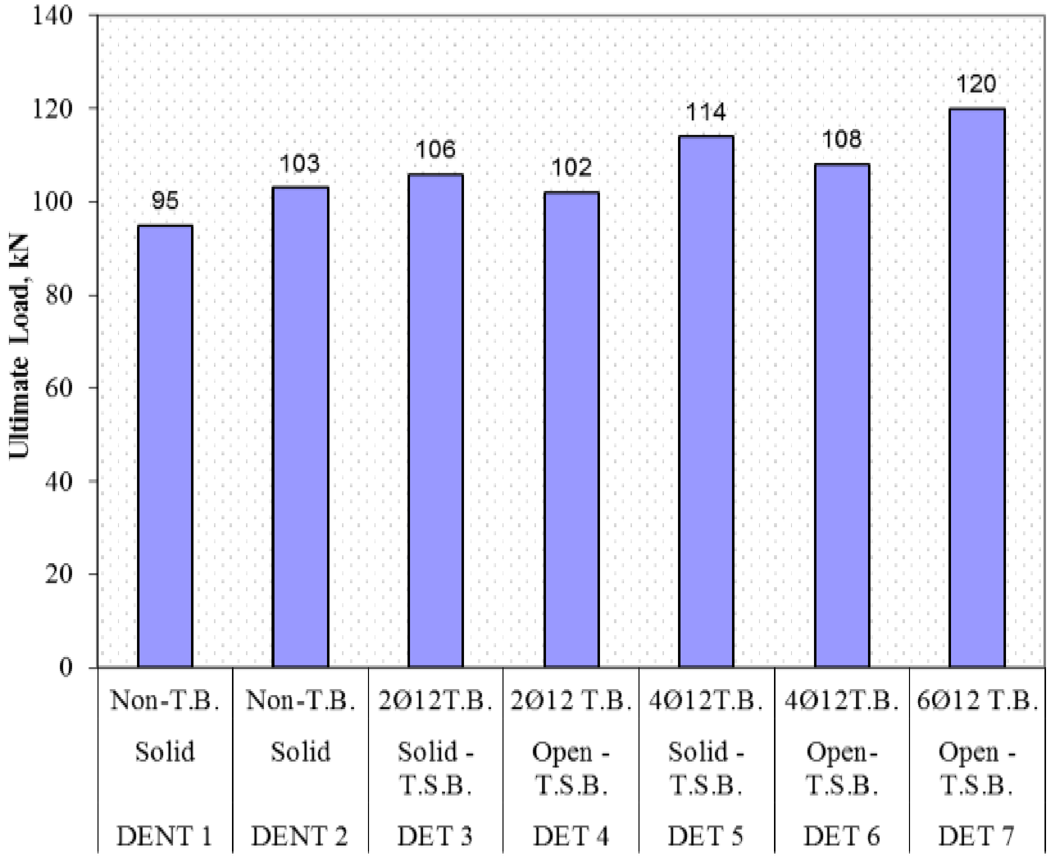


Fig.(7) Ultimate Load of All Tested R.C. Dapped Ends Beams

5.3. *Crack Patterns*

From tested all specimens that shows transverse subsequent installed bars has effect on crack propagation and numbers of crack.

The typical crack pattern and failure modes of tested beams reported in this paper are shown in Fig.(8).

In the tests, cracks always initiated at the reentrant corner of the tested beams at approximate 40o-60o to the axis of the beam, resulting in a redistribution of stresses causing increasing steel stresses, bond stresses and some bond slip [4].

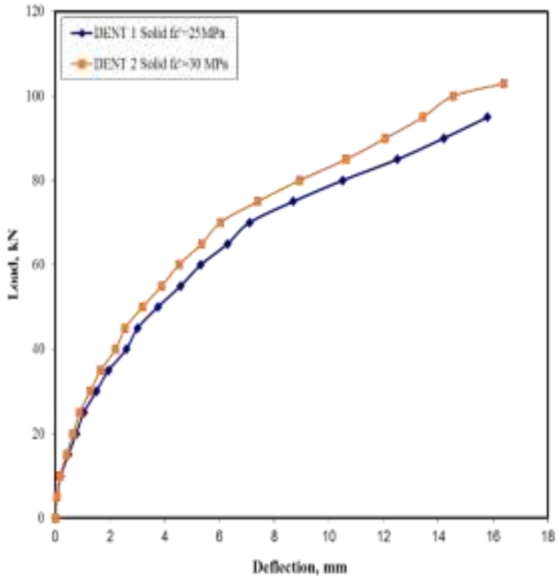
Under an additional load these cracks spread, increased in number and reduced the compression zone of the beam considerably. At one or a few load increments before failure, more inclined cracks, occurred at the reentrant corner of the majority of dapped end beams, and steeper (50^o-70^o) than the first inclined crack up to the vicinity of the load point.

In summary, the higher load carrying capacity led to appear more cracks, this gives larger difference in cracking loads due to conditions)) as shown in figures.

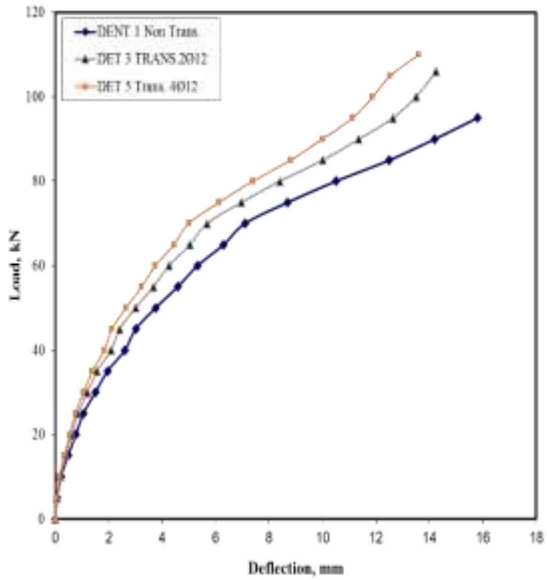
Fig. (8). Crack Pattern of Tested Beams.

5.3. *Load Deflection Behavior*

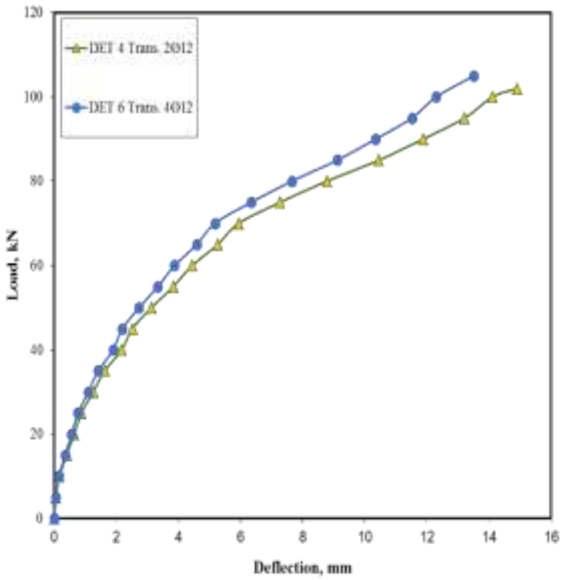
The load deflection curves of all reinforced concrete dapped ends beams at the center of tension face (bottom fiber) are shown in Fig.(9). ((The load deflection at point near dapped end that's give same behavior of central point. These Figures, show the same behavior of load –deflection curve because the same properties and strength of materials that used in construction of beams. When used transvers subsequent bars due to same reason the deflection decreased by about (15- 30%), (8-27%) respectively. The opening provide by transvers circle holes diameter of 50 mm that lies in tension fiber of beams has little effect on load carrying capacity or deflection by about 7 to 15%.



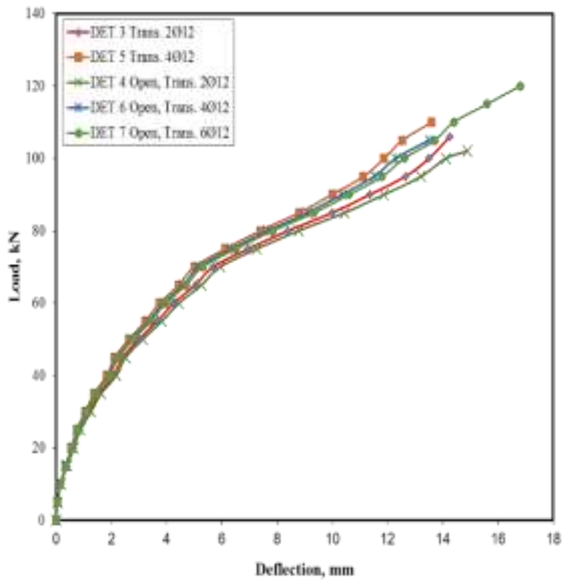
A- Effect of Compressive Strength of Concrete.



B- Effect of Transvers Subsequent Installed Bars.



C- Effect of No. of Transvers Subsequent Installed Bars.



D- Effect of Section Types (with or without opening).

Fig.(9) Load deflection Curves of Tested Beams.

6. Conclusions

It can be concluded that:

1. The transvers subsequent installed bars of diameter (Ø10.5 mm) is makes additional stirrups in R.C. dapped ends beams led to gain of load capacity and decrease in deflections by about (11% to 26%) and (20% to 30%) respectively compared with beams without transvers bars for same physical properties.
2. The increases in shear reinforcement provided by transvers bars led's to increases in load capacity by about (27%) and decrease in deflections by about (30%).
3. The increased ratio of transvers subsequent installed bars to double or triple lead to more load strength capacity and reduced in corresponding deflection by about (8 to 27 %) and (20 to 30%) respectively.
4. The strength capacity enhancements ratio by about (27%) due to used transvers subsequent installed bars. These bars gives resists against deformations due to the applied loading.
5. When the compressive strength of concrete increased f_c\` by about 20% led to enhancement strength capacity by about 9% and decreased in deflection by about 15%, With smaller a/d ratio of beams, there is greater stiffness and ultimate load of dapped-end beams.
6. The transvers opening provided by holes diameter of (Ø50 mm) at tension fiber have less effect on loading capacity, these holes led to decreased in strength capacity by about 3.7% & deflection increased by about 5% compare with beams without opening.
7. The modes failure of specimens are compound failure (flexure and shear).

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