Effect of opening on strength characteristics of reinforced concrete dapped ends beams

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Abstract. This study is devoted to investigate experimentally the ultimate strength capacity performance of seven dapped ends simply supported reinforced concrete beams with a (length, height, and width) dimension of (1200, 240, and 130) mm, either solid cross section or top/bottom hollow opening/s. One-point load test method results a different crack patterns of multi types of failure with varying intensity. It is found that the beams strength capacity values with openings less than the solid beams by 5-10%, while the deflection values of solid cross section beam contrary increased by 11-30%. Also, for the same location of opening the increase in hollow openings reduce the capacity load by 4.5-10%, but increase the deflection values by 6-12.5%. Finally, the beams with opening located at the compression zone decrease the load capacity and increase the deflection values by 5% than the beams with opening at tension zone. Therefore, this study handed to the civil engineering designer using the dapped ends beams in bridge construction structures under effect of static loads, “for the necessary purposes of installing power supply cable or water pipe, the authors recommended using beams with opening to be located at bottom fiber tension zone”.

1. Introduction
The dapped-end beam is a useful concept, are usually used for bridge girders construction units [1]. It allows to reduce the height of floor building of a concrete structure, by recessing the corbels that supporting it into the beams. Recently, the precast concrete become commonly used in the world than the poured in situ concrete [2]. A precast reinforced concrete structure dapped-end beams members used in construction, due to the higher lateral stability of an insulated dapped-ends beam compared with that supported at its bottom face. Despite the fairly expensive use made of this form of construction [3], [4]. But in 2011, Caltrans implemented a lower construction costs design of the dapped-end-beam connected integrally with a poured in situ inverted T-beam, in fact, this concept is more suitable for quick earth events than precast concrete design, ‘figure 1’.
According to Wang, et al., 2005 [6], if the nib section height is less than the un-dapped section by 0.45 then the beam reveals a very small shear strength capacity. The shear strength capacity developed by increasing the nib height, shear span, and steel reinforcement. The small shear strength capacity has been remedied by a new technic revealed by P.C. Huang and A. Nanni in 2006 [7], using the carbon fiber reinforced polymers CFRP to enhance the shear strength capacity [8].

2. Significant of the work
The main significant of research is to determine the performance of reinforced concrete dapped ends beams under concentrated load and to show the effect of variable parameters on this behaviour. These variables were the section type solid or hollow opening, number of opening, location of opening at tension or compression fiber of the beam. Also;

- Study the effect of section type with or without opening on strength capacity and structural behaviour of beams with a dapped end.
- Determine the presence of transverse opening in increasing or decreasing load capacity at different location.
- Study the impacts of numbers and location of opening (ratio) on the strength of specimens.
- To progress new recommendation method when construct the opening (location and ratio) without effect or reducing the load carrying capacity.
- For the necessary purposes of installing power supply cable or water pipe, and for this study case, the authors recommended using beams with opening to be located at bottom fiber tension zone.

3. Experimental aspect:
Seven dapped ends beam specimens were casted, cured, and tested till failure. The cross section of these beams either solid or have a hollow opening/s of 50 mm in diameter. The illustrated of these specimens are details (see table 1) and ‘figure 2’.

### Table 1. Specimens details of Reinforced concrete beams

| Beam Symbol | Reinforcing steel at bottom | Reinforcing steel at top | Stirrups Reinforcement of Vertical Stirrups of horizontal @ 100 mm c/c | Reinforcement Hanger | Reinforcement of Horizontal Stirrups | Opening Region casting bars | Open Size mm | Opens Number |
|-------------|-----------------------------|--------------------------|---------------------------------|---------------------|----------------------------------|-------------------------------|--------------|--------------|
| DENO        | 2Ø10                        | 3Ø10                     | Ø10/100                          | 2Ø10               | 3Ø10                             | ***                          | 0            | 0            |
| DÆO2        | 2Ø10                        | 3Ø10                     | Ø10/100                          | 2Ø10               | 3Ø10                             | Bottom Ø50                   | 1            |              |
| DEO3    | 2Ø10 | 3Ø10 | Ø10/100 | 2Ø10 | 3Ø10 | Bottom  | Ø50   | 2   |
|--------|------|------|---------|------|------|---------|-------|-----|
| DEO4   | 2Ø10 | 3Ø10 | Ø10/100 | 2Ø10 | 3Ø10 | Bottom  | Ø50   | 3   |
| DEO5   | 2Ø10 | 3Ø10 | Ø10/100 | 2Ø10 | 3Ø10 | Bottom  | Ø50   | 4   |
| DEO6   | 2Ø10 | 3Ø10 | Ø10/100 | 2Ø10 | 3Ø10 | Top     | Ø50   | 2   |
| DEO7   | 2Ø10 | 3Ø10 | Ø10/100 | 2Ø10 | 3Ø10 | Top     | Ø50   | 3   |

**Figure 2.** Molds & reinforcement of dapped ends beams
3.1. Materials

OPC cement type I, used in the concrete mix to casted the specimens with fine aggregate maximum size 4.75 mm and crushed gravel passing 14 mm, mixed with tap water in electrical concrete mixer. The tensile strength of Ukrainian 10 mm in diameter deformed steel bars tested by universal tensil testing machine according to ASTM A615/A615M-05a [9], test results are illustrated (see table 2).

Table 2. Deformed steel bars properties

| Type      | Nominal bars Diameter (mm) | Measured bars Diameter (mm) | Area of steel bars (mm²) | Tensile yield Strength f_y (MPa) | Ultimate Strength f_u (MPa) |
|-----------|----------------------------|-----------------------------|--------------------------|---------------------------------|----------------------------|
| Bars      | 10                         | 9.88                        | 76.67                    | 421                             | 520                        |

Trial concrete mixes tests specimens were performed, the average compressive strength of cylinder 150 x 300 mm obtained was 28 MPa at age 28 days, (see table 3).

Table 3. Mix proportions for one cubic meter of concrete.

| Try mix. | Cement kg.m⁻³ | Fine aggregate kg.m⁻³ | Course Aggregate kg.m⁻³ | W/C % | Water kg.m⁻³ |
|----------|----------------|-----------------------|-------------------------|-------|--------------|
| A        | 420            | 630                   | 1260                    | 0.5   | 210          |

4. Test set up

The duration of curing was 28 days, the samples were dried cleaned and painted with a light white coating then prepared for testing. The specimens were handled in the correct position on the universal testing machine (MFL) system under one-point static loading method and tested until failure, the load increment rate was 10 kN. The deflection values were measured at the mid span of the beams using dial gauge accuracy of 0.01. First crack, maximum load, crack patterns and mode of failure were recorded.

5. Results and discussion

The results obtained from the test specimens were discussed depending on the ultimate strength, cracks pattern, modes failure and deflection:

5.1. First crack load and ultimate capacity

The number of opening and location reducing strength capacity by about 5-10% and increased deflection by about 10-32%. While the location of opening at top fiber have more effect on reducing the strength capacity and increasing in corresponding deflection approximately 10%. The loads at first crack (see table 4), shown the ultimate load capacity and maximum central deflections ‘figure 3’.

Table 4. load deflection values

| Beam Character | Opening Character | Opening Number | Loads values at first Crack (kN) | Max. Load, kN | Max. Deflection at Center mm | Near Dapped Deflection mm |
|----------------|-------------------|----------------|----------------------------------|---------------|-------------------------------|--------------------------|
| DENO1          | ---               | ---            | 55                               | 240           | 5.1                           | 2.35                     |
| DEO1 Top       | 1                 | 53             | 233                              | 4.65          | 1.85                          |
| DEO3 Top       | 2                 | 48             | 218                              | 4.8           | 2.1                           |
5.2. Influence of parametric studied on ultimate load

Three parameters were taken to study the effect of the ultimate load capacity and deflection of the specimens. These parameters were type of cross section solid or hollow, the number of opening, and the location of opening at tension or compression zone.

|           | Type | Number | Region | Beam Symbols | Ultimate Load, kN |
|-----------|------|--------|--------|--------------|------------------|
| DEO4      | Top  | 3      | 45     | 198          | 4.47 1.95        |
| DEO5      | Top  | 4      | 37.5   | 182.5        | 4.3 1.73         |
| DEO6      | Bottom | 2    | 50     | 227          | 4.29 2.05        |
| DEO7      | Bottom | 3    | 48     | 222          | 4.58 2.3         |

**Figure 3.** Ultimate load vs different variables
Continue Figure 3. Ultimate load vs different variables
5.3. Crack pattern
For the solid beam the cracks initially appear at the bottom of the mid span to form a flexural type mode of failure, as long as the load gradually increased the cracks expanded with load applied in number, length, and width. Some of the cracks change the line direction from vertical to 40o-65o degrees horizontally towards the beam supports. While a new cracks created at the bottom middle of solid beam and hollow opening/s beams and adjacent to beam supports near the nib corner of the dapped ends and re-distributed according to the type of applied stress, the number of hollow openings, and the location of the openings to form a potential type mode of failure. It is clearly seen during the test; the cracks grow fast near the hollow openings from many directions to form an attractive point to the closing boundary of a circle circumference of the opening which is developed and grow very fast till failure. In general, all the cracks will not stop until the failure of the specimens ‘figure 4’.

![Figure 4. Crack Patterns](image)

5.4. Load-deflection pattern
Usually the test of simply supported beam with one-point load method, the deflection should be measured using dial gauge at the bottom of the lower face of the middle reinforced concrete beam. to study the deflection behavior due to the hollow openings located up or down the dapped ends beams ‘figure 5’.

![Figure 5. Load-deflection vs different variables.](image)
6. Conclusions
The subsequent conclusions may be obtained from tests results. It can be concluded that:

- The dapped ends beam specimens of a cross section have 50 mm diameter hollow opening reduce the ultimate load values by 5-24%, and increased deflection values by 10-32%, in compare with solid beams.
- Increasing the number of opening to double ratio whether up or down hollow openings, leads to reduces the maximum load values by 4.7-10%, and increased the deflection values by 5-12%.
- Beams with opening lies at tension fiber have given less effect on decreased strength capacity compare with others that lies at compression fibers by about (7.5%) in loading and (5%) in deflection. However, the concrete particles at tension zone has less strength in tension, in the sense the concrete at lower part of beams (tension area) less contribution on strength of beams as compare with upper part (compression area).
- The all specimens have same behaviour and good strength capacity and ductility ratio, this trend due to the location of opening that lies near zero shear or when reinforcing of hanger reinforcement location. The hanger's bars add to shear reinforcing in dapped beams to provide more deformation resists caused by the concentrated vertical load.
- For the same number of hollow openings, the strength capacity of specimens with openings at top fiber compression zone, have more effected than the openings lie at the tension zone.
Therefore, for necessary purposes the authors recommended using beams with opening to be located at bottom fiber tension zone.

- all the reinforced concrete dapped ends beams have different behaviour of cracks pattern and modes of failure. These cracks will propagate near nib and other parts of beam region with varying intensity
- the beams have a solid cross section are much safe than the beams with hollow openings, and the structural material bonds keep the load capacity far from fast crack growth.

7. References

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