# Improving The Voided Reinforced Concrete Beams Behavior by Strenthining The Compression Zone Concrete Using Polyvinyl Alcohol

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## Abstract

Determining dimensions of continuous RC beam depend on the critical span. Practically, changing the dimensions of others spans is difficult. So that, this work aimed to discuss the possibility of adding voids within the beams which its dimensions are more than required in order to reduce the cost and dead load. The selected percent of voids to volume of tested beams was 10%. The shape of voids was a first variable (spherical voids or conic voids). Also, the alteration in behavior when a (5cm) concrete layer thickness of compression zone was replaced with a concrete layer modified with adding polyvinyl alcohol (PVA) was investigated, as a second variable. After testing six samples, the result showed that the failure criteria of normal concrete voided beams is transformed from flexural behavior to shear behavior, while the failure criteria of control solid specimen was flexure behavior. Also, the modified beams failed in flexural behavior except the beam with conic voids failed in shear behavior. Corresponding to this transform, the ultimate load varied in the same manner. Where, the normal concrete voided beams failed with lesser ultimate load than control solid beam of about (6.4% and 18.3%) for spherical and conic voids, respectively. While, the ultimate load of modified concrete beams is increased of about (13.8%, 5.4% and 3.1%) for solid beam, spherical and conic voided beams respectively in comparing control specimen.
**Keywords**: Conic voids, RC beams, Spherical voided, Polyvinyl alcohol, Experimental work

## الخلاصة

تحديد أبعاد العتب الخرساني المسلح المستمر يعتمد على الفضاء الحرج. من الناحية ألعملية فإن تغيير أبعاد الاعتاب الأخرى أمر صعب. يهدف هذا العمل إلى التحقق من إمكانية إضافة فراغات في المناطق الداخلية من الاعتاب التي ابعادها أكثر من المطلوب من أجل تقليل التكلفة والحمل الميت. وعليه، كانت النسبة المئوية المختارة من حجم الفراغات لحجم النماذج المفحوصة هي 10٪. كان شكل الفراغات هو المتغير الأول في الدراسة (الفراغات الكروية أو الفراغات المخروطية). كذلك تم دراسة التغير في سلوك الاعتاب عندما تم استبدال 5 سم من خرسانة منطقة الضغط بطبقة خرسانية أخرى تم تعديلها باستخدام كحول بولي فينيل كمتغير ثان. بعد فحص ست نماذج اظهرت النتائج ان صيغة الفشل تتحول من الانثناء الى القص في الاعتاب الخرسانية المجوفة في حين ان صيغة فشل العتب غير الجوف المصدري كانت بالانثناء. كذلك، كانت صيغة فشل الاعتاب ذات الخرسانة المعدلة باستخدام كحول بولي فينيل بالانثناء باستثناء العتب ذو الفراغات المخروطية فشل بالقص. ورافق هذا ألتحول، تغير الحمل الاقصى بنفس الطريقة. حيث فشلت الاعتاب الخرسانية المجوفة بحمل اقصى أقل من العتب المصدري بنسبة (6.4٪ و 18.3٪) بالنسبة للفراغات الكروية والفراغات المخروطية على التوالي. أما للاعتاب ذات الخرسانة المعدلة ازداد الحمل الاقصى لها عن الحمل الاقصى للعتب المصدري بنسبة (13.8٪ و 5.4٪ و3.1٪) بالنسبة للعتب غير المجوف والعتب ذو الفراغات الكروية والعتب ذو الفراغات المخروطية على التوالي.

**الكلمات المفتاحية :-** الفراغات المخروطية، RC الحزم، كروية باطلة، الكحول البولي فينيل، العمل التجريبي .

## 1. Introduction

Reducing cost and dead load is a significant part of civil engineering. At the same time, loading capacity should not to be decreased noticeably. Plurality of researches deals with hollow beams in longitudinal or transverse directions. ( Saksena1 and Patel , 2013) studied the influence of diameter of circular opening and its location on behavior of beams by testing five beams. The important condition that was obtained for the same opening size of (0.55%) of depth and located at L/8 decrease the beam strength of about 60.11%. While at L/4 distance decrease the strength of about 48.14%. Also, for percent of (0.45) of depth the decreasing was about 32.19% and 24.21% compared with solid beam for opening at distance L/8 and L/4, respectively.

(Al-sheikh , 2014) published a research conducted to investigate the effect of opening with varying diameters at different locations on behavior of RC beam. For specimens with large opening at flexure zone, the decreasing in ultimate load was about (10% max.). While the decreasing in ultimate load for specimens with large opening at shear zone was about (64% max.).

**(** Al-Maliki and Alshimmeri , 2014) deal with the effect of longitudinal hollow core in beam on the load capacity and the deflection. Two ratios of hollow were investigated with two spacing of stirrups. The six tested beams indicated that the load capacity was decreased about (37.14% to 58.33%) for a hollow ratio (7.4% and14.8%), respectively.

( Vyas *et.al.,*2017) transacted with effect of opening on flexure and shear experimentally and theoretically by measuring maximum load and deflection. Two scales of openings were investigated (28 and 42mm), also beams dimensions was(65*126*700mm).Three beams of each diameter of opening were tested without any reinforcement with one, two and three opening, respectively. The openings increased the deformation in beam as compared with beam without openings.

It can be noticed from previous studies, that the behavior of beams with imbedded voids was not investigated. The purpose of this work is trying to understand some important information about this type of beams. Also, the change in behavior when the layer of modified concrete with PVA was added.

## 2. **Experimental Preparation**

Before testing, the beams were prepared and voids were placed at the intended locations then cast. The description of experimental details will be as follows:

### 2.1 Tested Beams Details

Beams dimensions were 1220mm total length (1000mm tested length) with (120x180mm) cross section as shown in Fig.(1). The longitudinal reinforcement was performed with two ф8mm top and bottom. The stirrups located at spacing of 70 mm c/c of Φ6mm diameter. The depiction names were specified for tested beams as shown in Table (1).

### 2.2 Voids Distribution

Voids were represented by spherical plastic balls (40mm diameter) and conic cork cups of 40mm top diameter, 70mm base diameter and 70mm effective height. Voids ratio was constant about 10% of effective volume of tested beam (1000*120*180mm) for all voided specimens. According to these dimensions, the number and arrangement of voids were determined. Thirteen conic voids located at (2cm) from the base of beam along one line at (80mm c/c) spacing as shown in Fig.(2a). Spherical voids distributed for three lines (two at 4cm from base of beam to the center of spherical ball and the third one at 6cm from base), as shown in Fig.(2b). Each line of balls constitutes of (21) balls at (50mm c/c) spacing and to gathering with two steel wire by filmy adhesive bandage.

### 2.3 Properties of Materials

#### 2.3.1 Steel Reinforcement

Two diameters of steel bars were utilized in beam reinforcement. The results of testing three specimens signified that the average yield stresses were 524.5 MPa for Φ8 mm and 520 MPa for ϕ6 mm diameter steel bar. Main reinforcement was Φ8 mm diameter and the stirrups was ϕ6 mm diameter.

### 2.3.2 Polyvinyl Alcohol (PVA)

Polymer concrete is one of new approaches in concrete technology. Adding PVA to concrete mix was one of the methods of producing polymer concrete. PVA influence on concrete with two manners. First one is provided internally curing for the concrete because that the PAV has water conservation capability. The other advantage is that PVA constitute gelatin connected concrete materials, so that behavior of concrete is enhanced. Physical properties of PVA were grainy fine particles, milk-white color and melt in the water as shown in Fig(3). Depending on Allahverdi *et.al.*,2010) research, the optimum percent of PVA was 0.16 of cement.

### 2.3.3 Compressive Strength ($f^{/}_{c}$)

To determine the compressive strength of normal and modified concrete with PVA, three (100*200mm) standard cylinders at 28 days were tested. Compressive strength that measured from these tests were 31.2 MPa and 43MPa for normal and modified concrete, respectively. The amount of materials are given in Table (2).

### 2.3.4 Test Arrangement and Measurements

Before testing the beams, the dial gauges were arranged (two near support and one in the middle) to determine net deflection at midspan by deducting value of middle deflection from the value of average deflection of that dial gages close to supports. All tests done using hydraulic machine of 150 kN maximum load as shown in Fig(4).

## 3. Testing Results

Main results that discussed were cracking load, ultimate load, deflection corresponding to the ultimate load and failure criteria as shown in Table (3). Discussion of results apportioned for two cases (normal concrete beams and modified concrete beams). Fig(5) shows all beams after testing

### 3.1 Normal Concrete Beams

Three beams were tested NS, NB and NC to investigate voids effect on normal concrete beams. The results shown in Figs.(6,7,8 and 9) indicated that voids changed the failure criteria from flexural to shear for both types of voids. As repercussion of this change, the ultimate load of voided beams and the related deflection were less than those of solid beam.

### 3.2 Modified Concrete Beams

Figs.(10,11,12 and 13) represented the effect of replacing (5cm) layer from compression face of beam with PVA modifying concrete. This effect was clearly observed by enhancing the behavior of all beams. For three modifying beams, solid beam and spherical voids beam undergo flexural failure but the conic voids beam failed by shear.

## 4. Conclusions

The important notes that can be inference from the results of the tested beams were:

1. Decreasing in cracking load was observed of about 14.3% and 28.6 (with respect to control normal concrete solid beam) for spherical voids beam and conic voids beam, respectively. Whilst for modified beams, the cracking load was increased of about 28.6% and 14.3% (with respect to control specimen) for solid beam and the two types of voided modified beams, respectively.

**2.** For normal concrete beams, decreasing in ultimate load was observed (with respect to control specimen) of about 6.4% and 18.3% for spherical and conic voids beams, respectively.

**3.** Comparison between all modified beams and control solid normal concrete beam concerning ultimate load, the ultimate load was increased of about 13.8% 5.4% and 2.9% for modified solid, spherical and conic voids beams, respectively.

**4.** From the results, it can be noticed that spherical voids beam is better than conic voids beam.

**5.** With reference to deflection at maximum load, each modified concrete beam is more ductile from the comparable normal concrete beam as shown in Fig.(14).

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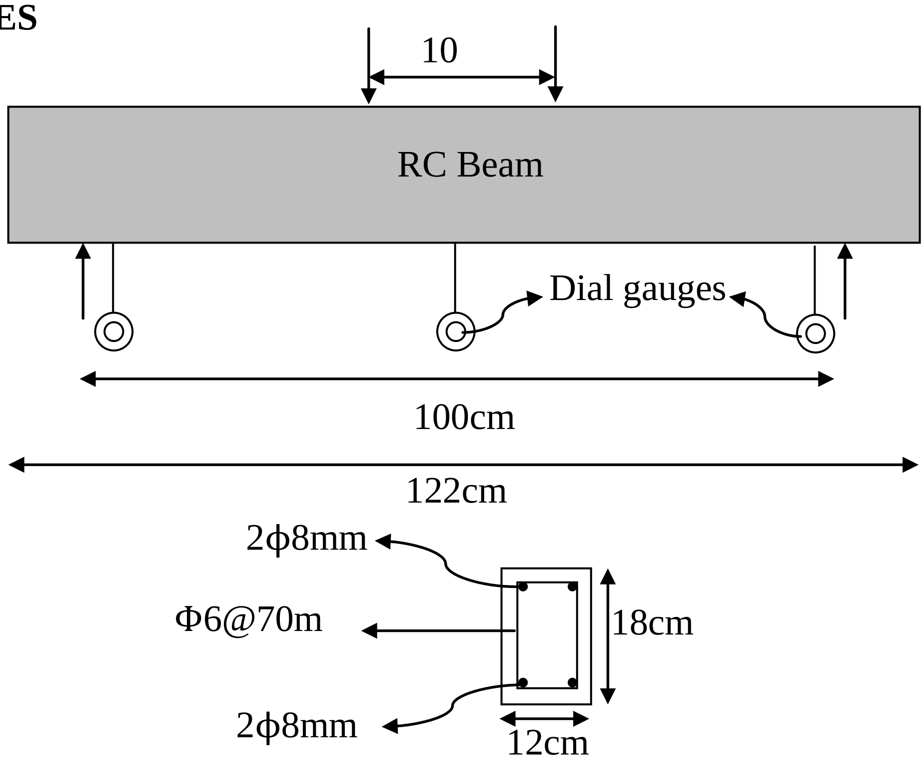
## FIGURES




Solid beam

**Fig.(1). Test specimen details**

a- Spherical voids　　　b- Conic voids

**Fig.(2). Voids distribution**

a- Powder　　　b- Solution

**Fig.(3). Polyvinyl Alcohol (PVA)**

**Fig.(4). Arrangement of beam prior testing**

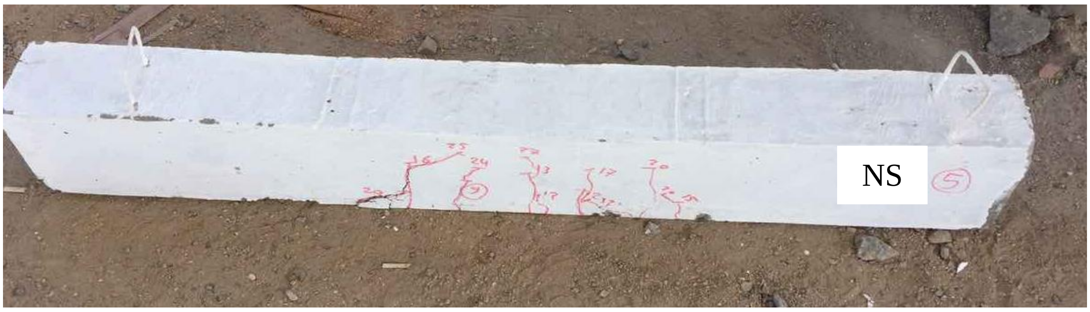
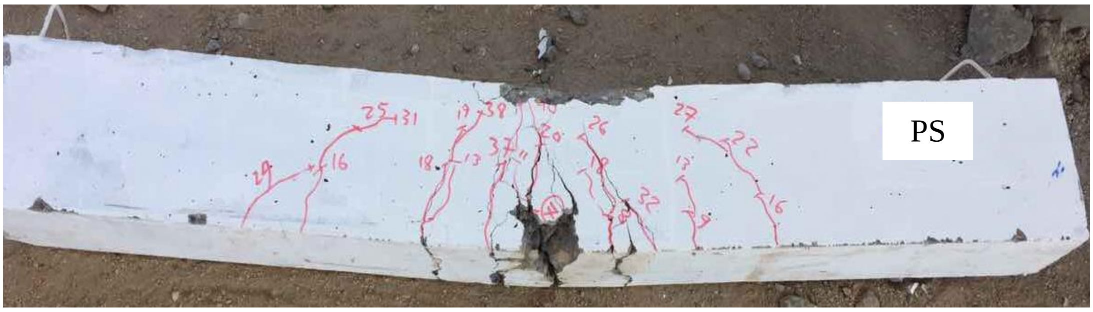
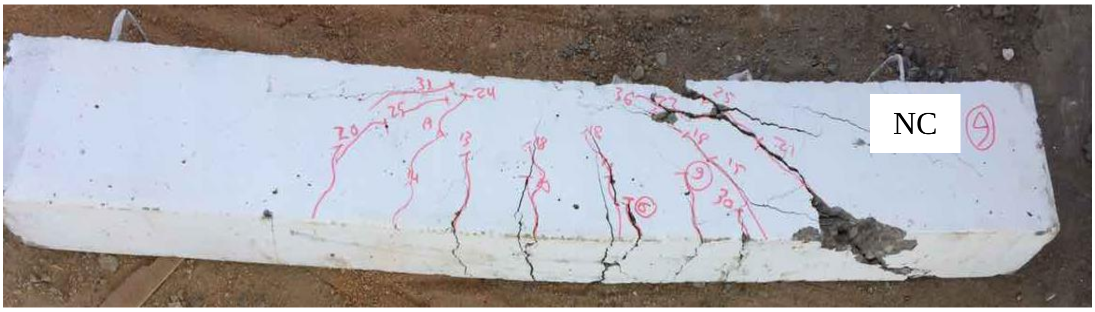



**Fig.(5). Tested RC beams**



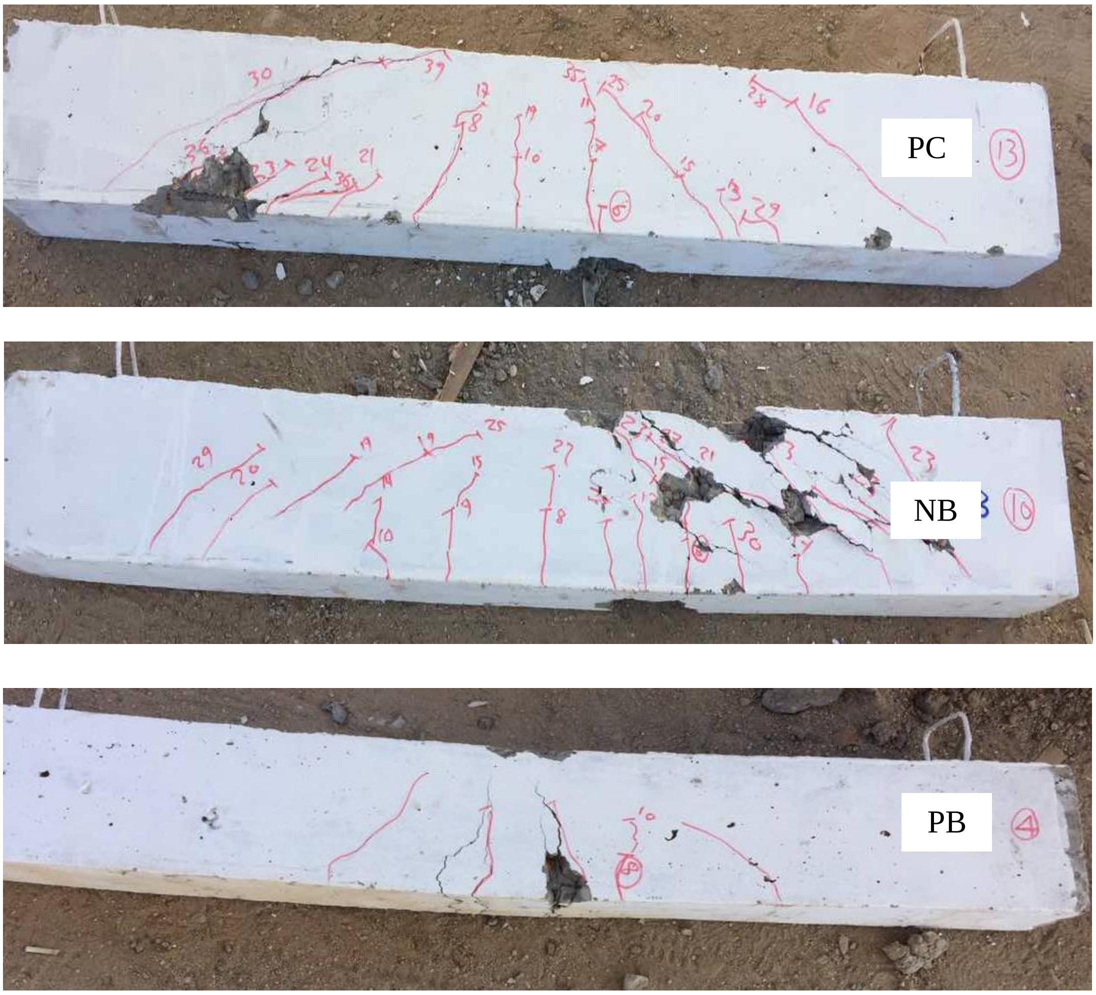



**Fig.(5). Continued**

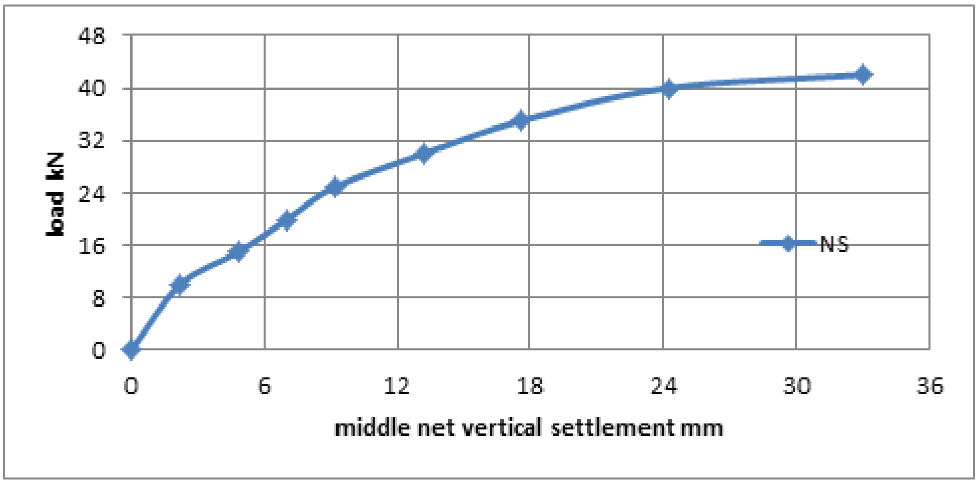



**Fig.(6). Load vs middle net vertical settlement of beam NS**

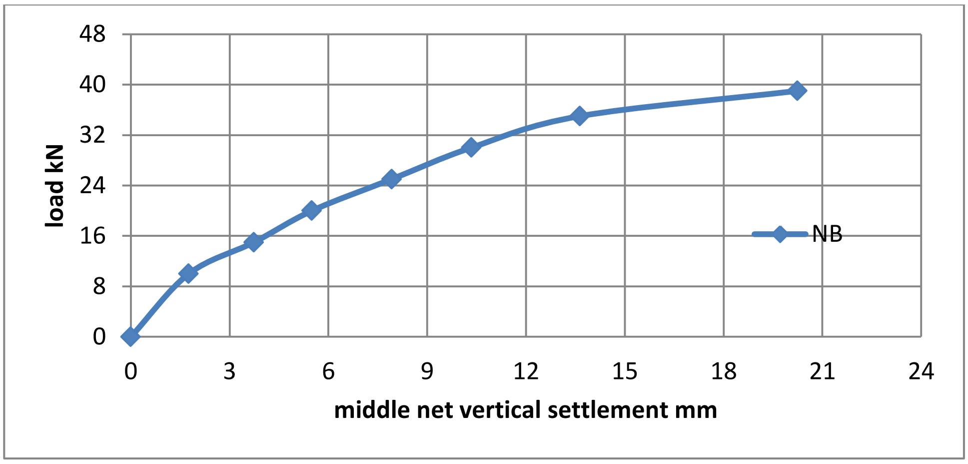



**Fig.(7). Load vs middle net vertical settlement of beam NB**

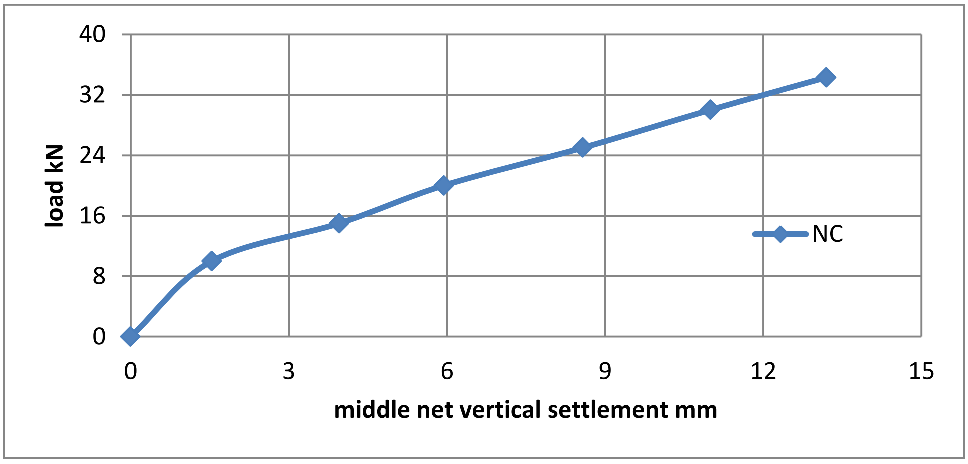



**Fig.(8). Load vs middle net vertical settlement of beam NC**

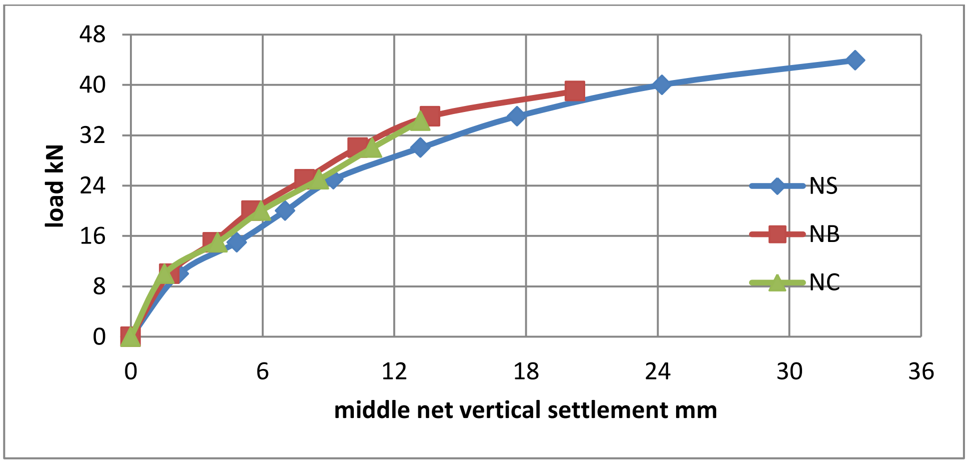



**Fig.(9). Load vs middle net vertical settlement of beams NS,NB and NC**

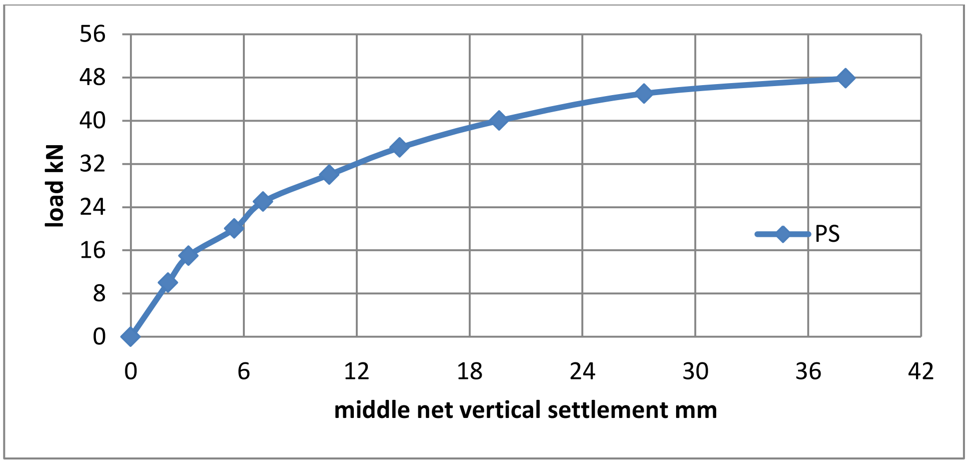



**Fig.(10). Load vs middle net vertical settlement of beam PS**

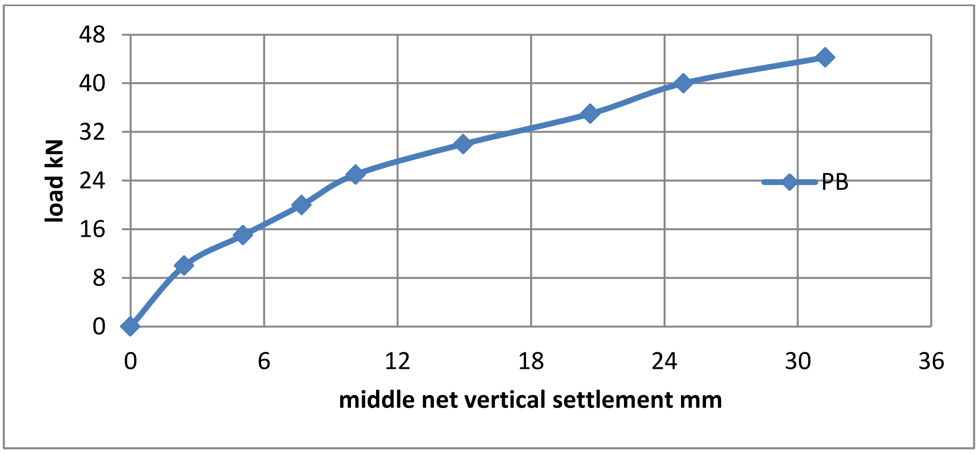



**Fig.(11). Load vs middle net vertical settlement of beam PB**

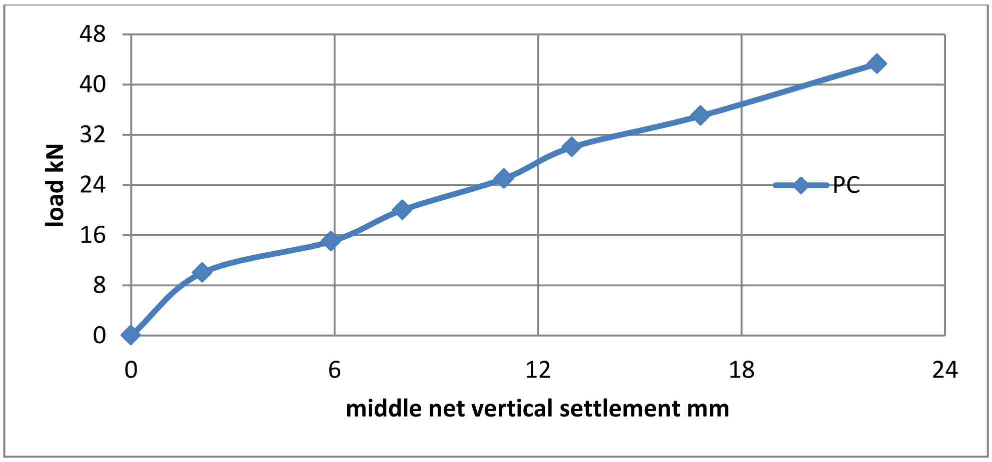



**Fig.(12). Load vs middle net vertical settlement of beam PC**

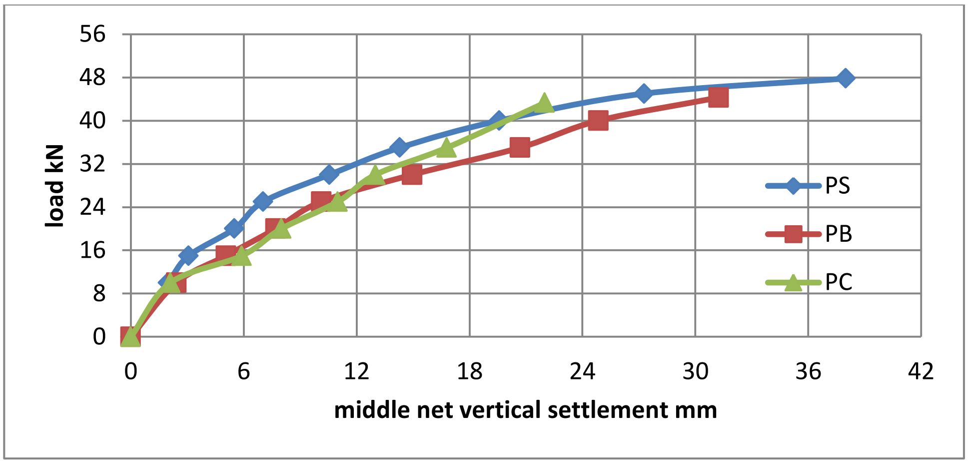



**Fig.(13). Load vs middle net vertical settlement of beams PS,PB and PC**

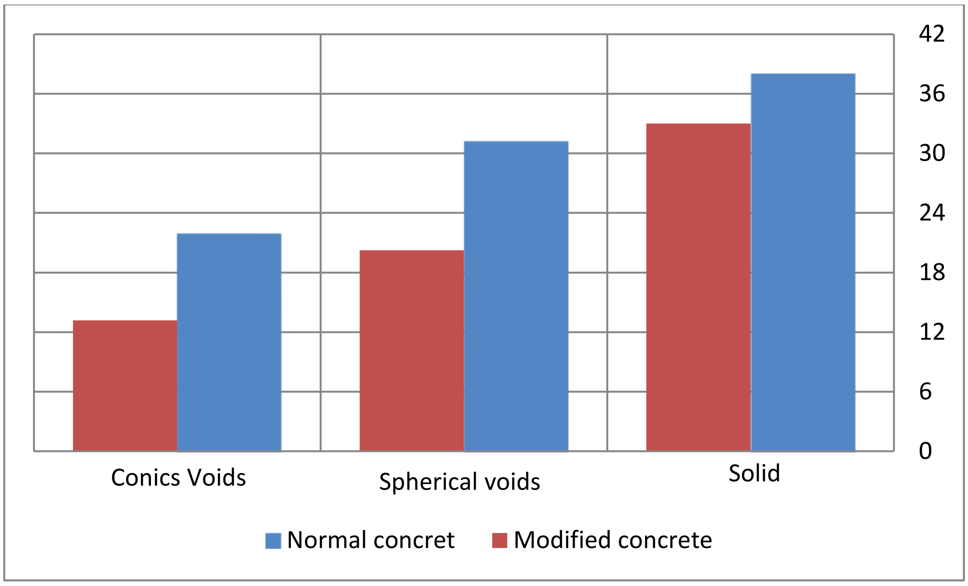



**Fig.(14). Comparison of deflections at maximum load**

## TABLES

**Table (1) Beams Characters**

| Normal Concrete | | Modified Concrete with PVA | |
|---|---|---|---|
| Beam Specific | Beam Denotation | Beam Specific | Beam Denotation |
| Solid beam | NS | Solid beam | PS |
| Spherical voids | NB | Spherical voids | PB |
| Conic voids | NC | Conic voids | PC |

**Table(2) . Concrete Mix Details.**

| Material | Amount |
|---|---|
| PVA/cement ratio | 0.16 |
| PVA (kg/m$^3$) | 39 |
| Water/cement ratio | 0.53 |
| Water (kg/m$^3$) | 242 |
| Cement (kg/m$^3$) | 456 |
| Fine aggregate (kg/m$^3$) | 675 |
| Coarse aggregate (kg/m$^3$) | 1090 |

**Table (3). Summarize of Results.**

| Sample code | First cracking load (kN) | Ultimate load (kN) | Deflection at ultimate load (mm) | Failure Criteria |
|---|---|---|---|---|
| NS | 7 | 42 | 33.1 | Flexural |
| NB | 6 | 39.3 | 20.4 | Shear |
| NC | 5 | 34.3 | 13.2 | Shear |
| PS | 9 | 47.8 | 38.1 | Flexural |
| PB | 8 | 44.27 | 31.24 | Flexural |
| PC | 8 | 43.29 | 22.2 | Shear |