A Proposed Model At Failure Stage To Assess The Bearing Stress Of Normal Weight Concrete

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ABSTRACT

Experimental investigations indicate that the bearing strength of concrete is increased by the confinement effect provided by the enveloping concrete. Various empirical formulas have been used in international codes relating the bearing strength of concrete to the compressive strength and the ratio of the total surface area to load bearing area (A/A_b) (known as bearing ratio). This study presents a new approach developed for the bearing strength of concrete loaded through rigid steel plate by way of analyzing the final failure pattern of concrete prism and cube specimen under axial compression considering slip planes direction, mechanical properties of normal weight concrete, relative element height and the effect of the bearing ratio. The main objective of the present paper is thus an attempt to put forward an analytical approach which conservatively predicts the bearing strength of normal weight concrete and accounts for all of the parameters mentioned above. The method depends on the final failure pattern mechanism of concrete prism and cube under axial compression load and considers the possible failure mode of diagonal shear failure, direction of shear failure planes, characteristic compressive strength of normal weight concrete, relative element height and the effect of the A/A_b ratio. The results of the proposed approach herein are compared with test data existing in the literature and the output values of standard design procedure available in some international codes.

Keywords-Bearing strength, diagonal shear failure, bearing ratio, and direction of failure planes

I. INTRODUCTION

In practice, the bearing strength of concrete elements is regularly encountered for the design of bridge bearing on concrete piers, anchorages in post-tensioned concrete beams and building columns on concrete pedestals. Experiments on concrete structural members under local pressure demonstrated that the concrete compressive strength at the bearing area is increased by the confinement effect provided by the surrounding concrete. Research works proved that the bearing stress is greatly influenced by the characteristics of mechanical properties of concrete, area of local load distribution, and the cross-section of the loaded member. The most important variables of experiments have been the ratio of the total surface area to load bearing area (A/A_b) (known as bearing ratio) and the relative element height.

The bearing strength was first investigated by Bauschinger (1876) and he was the first in proposing a cubic root formula as result of his experiments in sandstone. Meyerhof and Shelson (1957) suggested an expression for bearing strength that includes the cohesion and the angle of friction of the concrete material as a consequence of conducting several tests of footing-like blocks with large A/A_b ratios and observed the formation of the splitting wedge and the characteristic failure cone and pyramid at failure of concrete blocks. Au and Baird [1] also noticed a formation of an inverted pyramid under the loading bearing plate and developed a theory for concrete bearing strength on the assumption that the inverted pyramid would cause horizontal pressures prior to failure.

Niyogi [2] carried out tests on plain and reinforced concrete blocks and studied the effect of specimen size, geometry of the plates , strength of concrete , the nature of the supporting bed (rigid and elastic) and the mix concrete proportions on the bearing resistance of concrete. The mainly remarkable results were that the bearing strength was almost constant for specimens with aspect ratios (length / width) greater than 2 and the ratio $f_b/f_c^{'}$ decreases as $f_c^{'}$ increases, where f_b is the bearing stress and $f_c^{'}$ is the specified compressive cylindrical strength of concrete. Niyogi proposed the following equation for the bearing strength for blocks concentrically loaded through square plates:

$$\frac{f_b}{f_c^{'}} = 0.84\left(\frac{a}{a^{'}}\right) + 0.23 \qquad (1)$$

Where a is the block side dimension and a' is the plate side dimension as shown in Fig. 1.

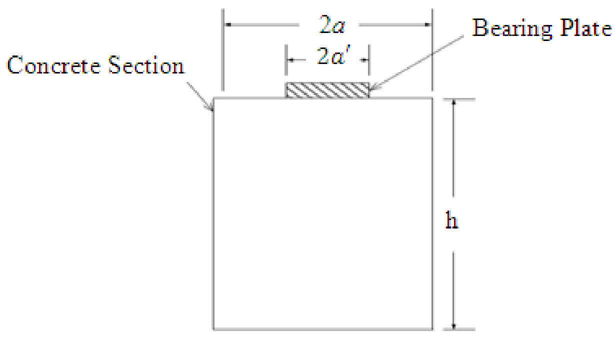


Fig. 1 . Niyogi's 2D Bearing Stress

Several design codes have used the square-root formula by Hawkins [3] .Hawkins' model predicts that the failure will occur due to sliding on planes that are inclined to the direction of principle stresses at angle α as shown in Fig. 2.

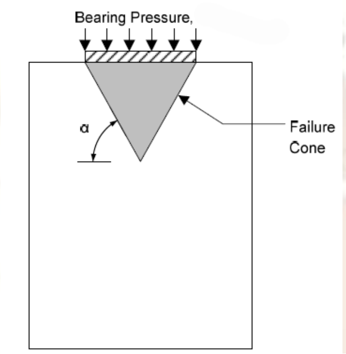


Fig. 2. Hawkins' Failure Model

Hawkins developed a general expression to estimate the bearing strength of concrete loaded concentrically through rigid plates as:

$$f_b = f_c' + K\sqrt{f_c'}(\sqrt{R} - 1) \qquad (2)$$

Where f_c' is the specified compressive cylindrical strength in psi., R is the A/A_b, ratio and K is a coefficient that depends on the concrete tensile strength and the angle of friction, both determined experimentally. Hawkins suggested a value of *K=50* for design purposes. The biggest problem associated with this model is the difficulty in determining the angle of internal friction of the concrete material.

R. Ince, E. Arid [4] in 2004 tested six series of concrete cube specimens under local pressure and the maximum loads obtained from the test results were analyzed by means of Bazant's size effect law. The experimental data and statistical investigations indicated that the bearing strength at failure decreases as the specimen size increases and with the increasing size of specimen, the height of pyramid beneath bearing plate decreases relatively.

Research performed by Bonetti [5] in 2005 at Virginia Tech investigated how the shape of the bearing plate, size of the bearing plate, concrete strength, and concrete density affects the ultimate strength of the concrete. The research showed that the shape of the bearing pad had no effect of the ultimate bearing strength of the concrete when the A/A_b ratio is between 2 and 16.

Axson, D. [6] in 2008 tested reinforced and unreinforced light weight concrete prisms and cylinders taking into consideration the effect of A/A_b ratio. The fractured cylinders and prisms have a shape of a cone below the bearing pad. Axson compared the bearing stress values obtained in tests with the equation of the ultimate strength of the local zone in normal weight concrete published by National Cooperative Highway Research Program Report 356.

Two important conclusions can be inferred from this review. The first one is that these studies suggest that failure of concrete subjected to a bearing load condition is due to sliding action along planes that are inclined to the direction of principal stresses. The second one is that the failure mechanism is constant through all the different investigations, namely the formation of inverted cone or pyramid at failure. These observations lead to the assumption that the failure mechanism of plain concrete under local pressure can be modeled by a failure criterion defined with the concepts sliding along failure planes.

II. RESEARCH SIGNIFICANCE

The state of stress in the bearing zone is of an outstandingly complex and is influenced by several parameters, such as the relation between the area over which the load is applied, the size and shape of the cross-section, the relative element height and the specified compressive strength. It is broadly accepted that the concrete element under concentrated load over a limited contact area fails to the formation of inverted cone or pyramid underneath the loaded surface, which moves downwards, bursting or splitting the block apart. A distinct theoretical explanation of that failure mechanism for the determination of bearing strength of concrete has not been executed. Therefore, so far several design codes have employed the empirical square-root formula by Hawkins.

Special attention in this paper is paid to the comparison of the suggested approach with the experimental research data and the existing in design codes calculation methods of the bearing strength

III. THE BEARING STRESS OF PLAIN CONCRETE IN DESIGN CODES SPECIFICATION

1-ACI318 and AASHTO Design Codes.

The American Concrete Institute's Building Code and Commentary (ACI 318-11) as well as the American

Association of State Highway and Transportation Officials (AASHTO 2010) address the bearing strength of concrete in very similar ways as proposed by Komendant (1952) but with some modifications. The ACI 318-11 [7] suggest the design bearing strength as a function of the characteristic compressive strength of concrete and a square root function between the bearing area and total surface area . The ACI 318-11 states that design bearing strength of concrete shall not exceed ϕ ($0.85f_c'A_1$), except when the supporting surface is wider on all sides than the loaded area, then the design bearing strength of the loaded area shall be permitted to be multiplied by $\sqrt{A_2/A_1}$ but by not more than 2 for unconfined concrete as shown by Equation 3.

$$f_b = \phi 0.85 f_c' \sqrt{\frac{A_2}{A_1}} \leq \phi 1.7 f_c' \qquad (3)$$

where f_b is design bearing stress of unconfined concrete, MPa; ϕ = 0.65 (strength reduction factor); f_c' is characteristic compressive cylinder strength of unconfined concrete at 28 days. MPa; A_1 is bearing load area, mm^2; and A_2 is area of the lower base of the largest frustum of a pyramid, cone, or tapered wedge, mm^2. It is assumed that load spreads out into the concrete block at a slope of 2 horizontal to 1 vertical to the level at which spreading first reaches the edge of the block. A_2 is calculated at this level, as clearly described in Fig. 3.

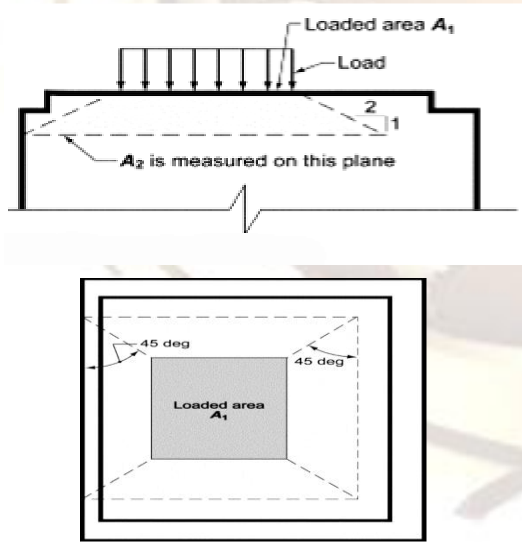


Fig. 3. Illustrates the application of the frustum to find A_2 in stepped or sloped supports (After Fig.R10.14 from ACI 318-11)

The AASHTO [8] bearing strength equation is very similar to the ACI 318-11equation but with an additional provision. The factor defines how the A/A_b ratio will affect the strength and under normal conditions the square root of the A/A_b ratio is limited to 2, but for the condition that the pressure distribution over the loaded area is non-uniform the square root of the A/A_b ratio multiplied by 0.75 is limited to 1.5 (AASHTO 2010).

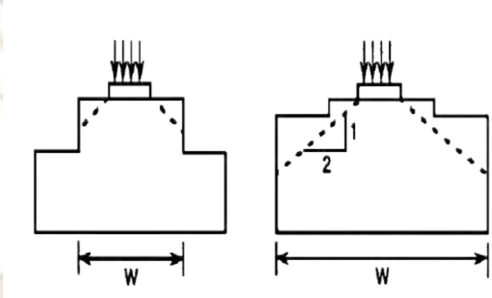
$$F_{ult} = \phi(0.85 f_c' A_1) m \quad where: m = \sqrt{\frac{A_2}{A_1}} \leq 2 \qquad (4)$$

For non-uniform distributed loads

$$m = 0.75\sqrt{\frac{A_2}{A_1}} \leq 1.5$$

Where the supporting surface is sloped or stepped, A_2 may be taken as the area of the lower base of the largest frustum of a right pyramid, cone, or tapered wedge contained wholly within the support and having for its upper base the loaded area, as well as side slopes of 1.0 vertical to 2.0 horizontal as shown in Fig. 4.

AASHTO also has different ϕ factors than ACI 318-11. For the condition of pure bearing ϕ is equal to 0.70. In anchorage zones in normal weight concrete and lightweight concrete ϕ is equal to 0.80 and 0.65 respectively.



W = width for computing A_2

Fig. 4. Determination of A_2 for a Stepped Support. (After Fig. C5.7.5-1 from AASHTO 2010)

Russian Design Code (SNiP 52-01-03). According to the Russian design code [9], the design of concrete elements for a local compression is performed with the increase of concrete compressive strength due to the triaxial state of stress developed underneath the loaded area and the bearing strength can be expressed by:

$$N \leq \psi R_{b,loc} A_{b,loc} \qquad (5)$$

Where N is the local normal compressive external force ; ψ =1 in case of a uniform local load distribution and ψ=0.75for non-uniform local load distribution on the rigid plate ;$A_{b,loc}$ is the external load bearing area and $R_{b,loc}$ is the local bearing stress under the rigid plate determined by the expression:

$$R_{b,loc} = \varphi_b R_b \qquad (6)$$

The coefficient φ_b should be determined by the formula:

$$\varphi_b = 0.8\sqrt{\frac{A_{b,max}}{A_{b,loc}}} \le 2.5 \qquad (7)$$

Where R_b is the characteristic compressive strength of concrete prism;$A_{b,max}$ is the maximum design area which is symmetric to the area $A_{b,loc}$ and should be determined by the scheme shown in Fig.5.

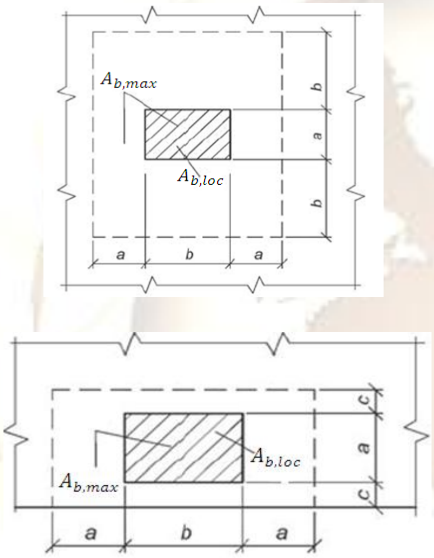


Fig.5. The scheme for determination of maximum design area $A_{b,max}$ (After Fig.6.11 from SNiP 52-01-03)

Obviously, the codes design specifications are conservative in the design for the bearing strength of concrete in comparison to published researches carried out by the previous researchers. This is evident in the limitation of the ratio of bearing strength to compressive strength to a limited value.

IV. PROPOSAL OF SIMPLIFIED MECHANICAL MODEL

It is well known that the most common of all tests on hardened concrete is the compressive strength test and almost the other characteristics of concrete are related to its compressive strength. Three types of compression test specimens are used nowadays, especially in researches, cubes, cylinders, and prisms. Under compression, concrete specimens expand in the lateral direction. Thereby, a frictional force between the loading plates and specimens occurs. This frictional force generates ,namely for low and normal strength concrete, a lateral compressive force responsible for the formation of a general appearance of a quadrangular pyramid or frustum of a pyramid shape at the ends of the specimens at failure of prisms and cubes as illustrated in Fig. 6 and 7.

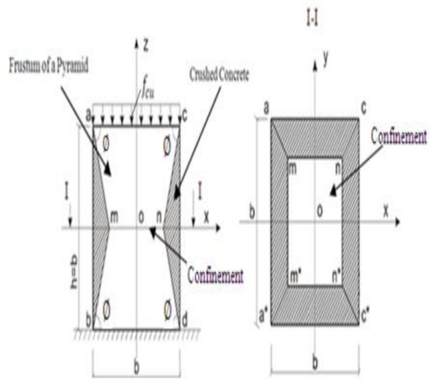


Fig.6.Typical cube compressive failure pattern with a general appearance of a truncated pyramidal shape with confinement zone.

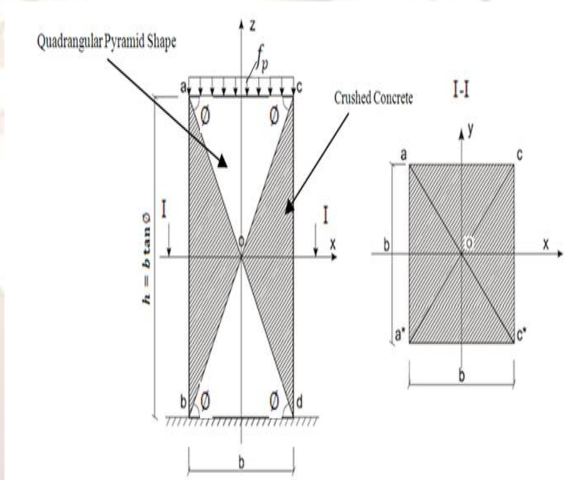


Fig.7. Typical prism compressive failure pattern with a general appearance of a pyramidal shape without confinement zone.

Experimental data indicate that for the same specimen geometry, the compressive strength of concrete specimens decrease with increasing specimen size before a compressive strength limit is approached. If the height of specimen smaller than $b \tan \emptyset$, such as for cube specimen, as shown in Fig.6, the confinement effect zone extends through the specimen resulting in increase in the compressive strength of the material. In this study the magnitude of the direction failure plane $\emptyset$ shown in Fig.6 and 7 was approximately selected as a function of characteristic concrete compressive strength, *b* is the side dimension of specimen with height *h*, f_p is the characteristic prismatic strength and f_{cu} is characteristic cube strength The choice of the specimen slenderness ratio (height to diameter of cylinder or side of prism) of 2 or the height of specimen ≥ $b \tan \emptyset$,such as for prism specimen ,as shown in Fig.7, is not only because the confinement effect zone is vanished but a slight increase from this ratio does not seriously affect the measured value of compressive strength.

Based on the aforementioned interpretations and from the findings of the experimental and statistical investigations of bearing strength of concrete, the following conclusions may be drawn:

1-For a concrete element with constant cross sectional area subjected to axial load applied through a constant bearing rigid plate area and shape, the bearing compressive strength at failure decreases as the specimen height increases.

2-For a concrete element with a constant height subjected to axial load applied through a constant bearing rigid plate area and shape, the bearing compressive strength at failure increases as the cross sectional area of specimen increases.

3- It was observed that the apex angles of the pyramidal failure values under the rigid plate at vary from 38° to 56° approximately.

It may be concluded that the concrete element under axial local pressure revealed typical type of failure mode and identical response to size effect. Therefore, on the apparently reasonable justifications, a simplified mechanical model is directly related to the final failure mode of concrete prism and cube specimen has been worked out to assess the bearing strength of normal weight concrete. This approach is based on the concept of quasi-plastic failure mode of brittle material along the sliding failure surface, principally the invariant direction of slip planes with respect to the direction of applied stress when maintaining the physical and geometrical similarity of slip planes system.

A graphical description of the above assumptions and variables involved is presented in Fig. 8. In the Fig., f_b is bearing stress, *b* is the width of the rigid square plate, *B* is the side dimension of the prismatic concrete block ,Ø is angle of sliding plane and *h* is the height of the prismatic concrete block.

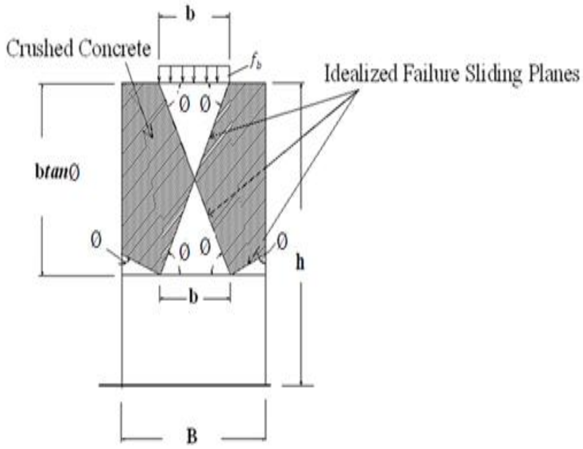


Fig.8. Proposed approximate final failure pattern of concrete block under local bearing pressure.

Considering the proposed mechanical model, the concrete bearing ratio is suggested to be evaluated by the formula:

$$\frac{f_b}{f_p} = \frac{\mu \sum A_{b,loc}}{\mu A_b} = \frac{\sum A_{b,loc}}{A_b} \qquad (8)$$

Where μ is specific bond stress aroused between sliding surface planes of concrete block under local pressure. $\sum A_{b,loc}$ is the integrated sliding surface of the concrete block ,with *h* height and *BxB* cross sectional area, due to the bearing compressive strength; A_b- integrated sliding surface of a concrete prism under axial compressive strength with a height equals $b \tan \emptyset$.as clearly shown in Fig.8.

For the realization of expression (8) it is initially necessary to know the angle of sliding planes Ø of normal weight concrete. Seminenko .I.P[10] suggested the angle of sliding plane Ø at failure of unconfined normal weight concrete specimen subjected to axial compression by to be evaluated by:

$$\emptyset = \tan^{-1}\left(\frac{1}{\rho}\left(1 + \sqrt{1-\rho}\right)\right)$$

(9)

Where ρ is the ratio of the characteristic prismatic strength f_p with a height to width ratio greater than 2 to characteristic cube strength f_{cu} of normal weight concrete specimen of the same material constituents and cross sectional dimensions.

For example, when ρ =0.800 then $\emptyset$ =61.07° and when ρ =0.645 then $\emptyset$ =67.99°

In conclusion, we consider necessary to give an analytical calculations that is applied to the Fig.8 for the evaluation of the integrated surface area to determine the bearing ratio within the theory limits of sliding

$A_b = 2b^2/\cos\emptyset$ (10)

$\sum A_{b,loc} = 2b^2/\cos\emptyset + (B^2 - b^2)/\sin\emptyset$ (11)

The formulae (10 and 11) apply to square blocks loaded through square plates and cylinders loaded through circular plates.

V. VERIFICATION ANALYSIS WITH DESIGN CODES AND TEST DATA

To investigate the accuracy and suitability of the proposed approach, a verification analysis of the performance of the proposed approach was evaluated against actual test data extracted from [5] and [11] as shown in Figs.9 and 10, where the values of $f_b/f_c^{'}$ obtained are plotted against the A/A_b ratios .In the research [11], the diameter of the concrete cylinders varied from 152 mm up to 610 mm, while the diameter of the circular bearing plate was always 152 mm. The height of the specimens varied from 230 mm up to 914 mm. The specimens had a cylinder compressive strength of 30 MPa and 20 MPa. The test data of square prism loaded with square plate (SS) and square prism loaded through circular plate (RS) with the geometric and material properties extracted from the research [5] are reported in Table 1. In Table 2, consequently, are illustrated the procedures followed to calculate the $\sum A_p/A_p$ ratio. Table 3 presents a comparison of the prediction results of the proposed method for the bearing stress data gathered from Table 1 along with data induced from using the equations by Niyogi (1973) ,Hawkins (1968) the ACI318-11 and AASHTO 2010 , SNiP 52-01-03. The reported cylindrical strength for normal weight ($f_c^{'}$) values in Table 1 were converted to cubic concrete strength (f_{cu}) the according to the Neville's expression [13] as follow:

$$f_{cu} = \left[0.76 + 0.2\log\left(\frac{f_c^{'}}{19.58}\right)\right]/f_c^{'}$$

(SI un its) (12)

On the basis of statistical handling of data, the cubic concrete strength were converted to the prismatic concrete strengths for normal weight by the expression:

$$f_{pr} = \frac{1}{3} f_{cu}\left(\frac{288 + f_{cu}}{116 + f_{cu}}\right)$$

(SI units) (13)

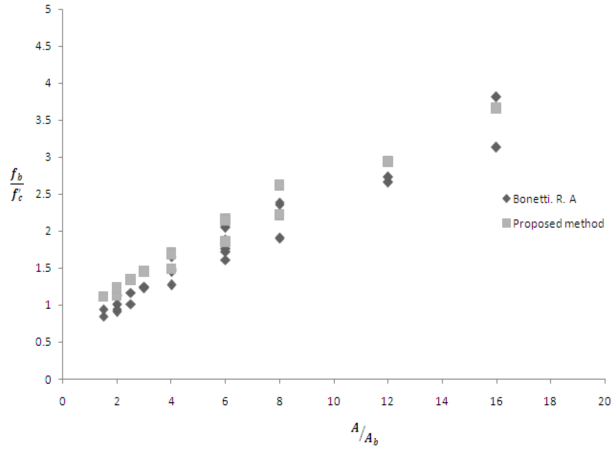


Fig. 9. Comparison of experimental data versus suggested proposed method.

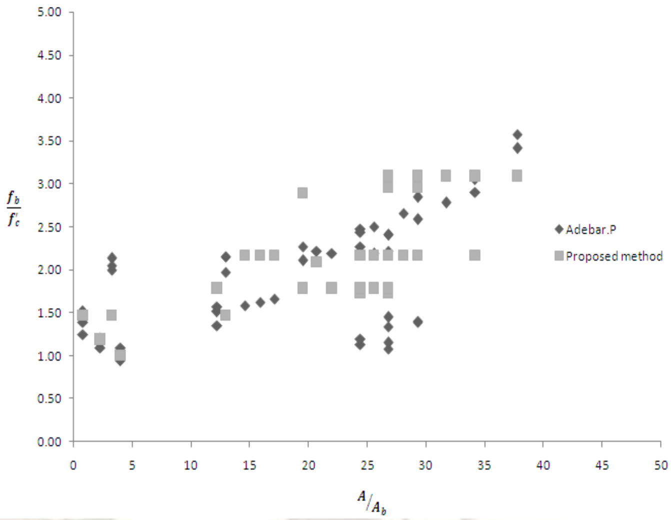


Fig. 10. Comparison of experimental data versus suggested proposed method.

TABLE 1: Geometrical and material properties of the specimens with the bearing stress of experimental results.

Specimen	h mm	A mm^2	A_b mm^2	A/A_b	f_c' Mpa	f_b Mpa	f_b/f_c'
SS4-2A. B	406.40	41290.24	20645.12	2.00	27.92	31.65	1.13
SS44A. B	406.40	41290.24	10322.56	4.00	27.92	41.43	1.48
SS4-6A. B	406.40	41290.24	6877.41	6.00	27.92	49.18	1.76
SS4-8A. B	406.40	41290.24	5161.28	8.00	30.06	57.76	1.92
SS4-12A. B	406.40	41290.24	3438.70	12.00	30.06	74.68	2.48
SS4-16A.B	406.40	41290.24	2580.64	16.00	30.06	87.97	2.93
RS4-2A. B	406.40	41290.24	20645.12	2.00	30.06	30.27	1.01
RS44A. B	406.40	41290.24	10322.56	4.00	30.06	44.98	1.50
RS4-6A. B	406.40	41290.24	6877.41	6.00	30.06	51.68	1.72
RS4-8A. B	406.40	41290.24	5161.28	8.00	30.06	57.09	1.90
RS-4-12A, B	406.40	41290.24	3438.70	12.00	30.06	80.02	2.66
RS4-16A,B	406.40	41290.24	2580.64	16.00	30.06	94.19	3.13

TABLE 2: Predictions of the $\sum A_P/A_p$ ratio to determine the bearing stress utilizing equation 8.

Specimen	f_{cu} Mpa	f_p Mpa	f_{cu}/f_{pr}	$\tan Ø$	Ø degree	b mm	A_p mm^2	B mm	$\sum A_P$ mm^2	$\sum A_P/A_p$
SS4-2A. B	35.25	25.11	1.40	2.16	65.12	143.68	98028.45	203.20	120791.30	1.23
SS4-4A. B	35.25	25.11	1.40	2.16	65.12	101.60	49014.23	203.20	83158.53	1.70
SS4-6A. B	35.25	25.11	1.40	2.16	65.12	82.93	32655.73	203.20	70598.59	2.16
SS4-8A. B	37.64	26.59	1.42	2.18	65.38	71.84	24748.00	203.20	64500.07	2.61
SS4-12A. B	37.64	26.59	1.42	2.18	65.38	58.64	16488.36	203.20	58135.74	3.53
SS4-16A.B	37.64	26.59	1.42	2.18	65.38	50.80	12374.00	203.20	54965.50	4.44
RS4-2A. B	37.64	26.59	1.42	2.18	65.38	162.17	126104.50	203.20	142598.50	1.13
RS44A. B	37.64	26.59	1.42	2.18	65.38	114.67	63052.23	203.20	94014.72	1.49
RS4-6A. B	37.64	26.59	1.42	2.18	65.38	93.60	42008.55	203.20	77799.88	1.85
RS4-8A. B	37.64	26.59	1.42	2.18	65.38	81.09	31526.12	203.20	69722.82	2.21
RS4-12A, B	37.64	26.59	1.42	2.18	65.38	66.19	21004.28	203.20	61615.40	2.93

RS4-16A,B	37.64	26.59	1.42	2.18	65.38	57.34	15763.06	203.20	57576.88	3.65

TABLE 3: A comparison of the bearing stress of experimental results with the analytical results of the equations by Niyogi (1973) ,Hawkins (1968) the ACI318-11 and AASHTO 2010 , SNiP 52-01-03 and the Proposed method

Normal Weight Concrete		Predicted Bearing Stress, f_b (MPa)					$f_{b(test)}/f_{b(pred)}$				
Specimen	Test Bearing stress, f_b (MPa)	Niyogi Eq. 1	Hawkins Eq. 2	ACI318-11 and AASHTO 2010 Eq. 3and4	SNiP 52-01-03 Eq. 5	Proposed method Eq. 11	Niyogi	Hawkins	ACI318-11 and AASHTO 2010	SNiP 52-01-03	Proposed method
SS4-2A	31.24	26.94	37.00	33.84	29.58	30.94	1.16	0.84	0.92	1.06	1.01
SS4-2B	30.16	26.94	37.00	33.84	29.58	30.94	1.12	0.81	0.89	1.02	0.97
SS4-4A	41.58	40.82	50.00	47.85	41.83	42.60	1.02	0.83	0.87	0.99	0.98
SS-4-4B	38.78	41.00	50.00	48.00	44.28	42.60	0.95	0.77	0.81	0.88	0.91
SS4-6A	50.12	51.37	60.09	58.63	54.23	54.28	0.98	0.83	0.85	0.92	0.92
SS4-6B	45.27	51.37	60.09	58.63	54.23	54.28	0.88	0.75	0.77	0.83	0.83
SS4-8A	56.02	64.40	71.63	72.20	62.62	69.31	0.87	0.78	0.78	0.89	0.81
SS4-8B	56.02	64.40	71.63	72.20	62.62	69.31	0.87	0.78	0.78	0.89	0.81
SS4-12A	73.73	80.51	86.15	88.48	76.69	93.76	0.92	0.86	0.83	0.96	0.79
SS4-12B	71.14	80.51	86.15	88.48	76.69	93.76	0.88	0.83	0.80	0.93	0.76
SS4-16A	82.73	94.00	98.29	102.11	88.56	118.13	0.88	0.84	0.81	0.93	0.70
SS4-16B	87.90	94.00	98.29	102.11	88.56	118.13	0.94	0.89	0.86	0.99	0.74
RS4-2A	29.62	28.77	39.45	36.10	30.48	30.07	1.03	0.75	0.82	0.97	0.99
RS4-2B	29.08	28.77	39.45	36.10	30.48	30.07	1.01	0.74	0.81	0.95	0.97
RS4-4A	45.24	43.54	53.00	51.05	43.10	39.65	1.04	0.86	0.89	1.05	1.14
RS4-4B	42.01	43.54	53.00	51.05	43.10	39.65	0.96	0.80	0.82	0.97	1.06
RS4-6A	47.86	54.90	63.03	62.55	52.79	49.25	0.87	0.76	0.77	0.91	0.97
RS4-6B	52.39	54.90	63.03	62.55	52.79	49.25	0.95	0.83	0.84	0.99	1.06
RS4-8A	52.57	64.44	71.63	72.20	60.96	58.81	0.82	0.73	0.73	0.86	0.89
RS4-8B	58.17	64.44	71.63	72.20	60.96	58.81	0.90	0.81	0.81	0.95	0.99
RS4-12A	76.32	80.53	86.15	88.48	74.66	78.01	0.95	0.89	0.86	1.02	0.98
RS4-12B	78.90	80.535	86.15	88.48	74.66	78.01	0.98	0.92	0.89	1.06	1.01

RS4-16B	84.46	94.00	98.29	102.00	86.21	97.14	0.90	0.86	0.83	0.98	0.87
RS4-16B	98.25	94.00	98.29	102.11	90.73	97.14	1.05	1.00	0.96	1.08	1.01

Average	0.95	0.82	0.83	0.96	0.92
Standard deviation	0.08	0.06	0.05	0.07	0.11
Coefficient of variation	0.09	0.08	0.06	0.07	0.12

VI. CONCLUSIONS

The proposed failure model shows a reasonable agreement with available tests results. The analysis of the numerical results yields a satisfactory correspondence between the theoretical predictions of the established model for bearing stress of normal weight concrete and the experimental data. Applications of the new model to a number of actual failure data sets have shown that the model can fit the failure data much better compared to Hawkins ,the ACI318-11 and AASHTO 2010 models. The values from the proposed model given in Table3 for $f_{b(test)}/f_{b(pred)}$ have an average equals to 0.92 with a standard deviation 0.11 for a coefficient of variation of 0.12. A very slight difference is observed in the results obtained with the use of proposed approach, therefore an extensive research is still required
to improve the reliability of suggested failure mechanisms under local pressure

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