*International Journal of Engineering and Science Applications*

ISSN: 2406-9833 @2016 PPs-UNHAS

**IJEScA**

# Comparative Theoretical Study of Response of R.C Slab for Hard Missiles Impact

Faiza[1,2], H. Parung[3] , M.W.Tjaronge[3], R. Jamaluddin[3]

[1]Student of Doctoral Program in Civil Engineering Faculty, Hasanuddin University, Makassar Indonesia
[2]Lecturer of Civil Engineering Dept. University of Jazeera Sudan
[3]Professor in Civil Engineering Faculty, Hasanuddin University, Makassar Indonesia

Email: auja597@gmail.com

## ABSTRACT

Nuclear facilities as well as other important government, military and security premises are usually protected against missile impacts from missiles and flying objects using reinforced concrete panels. The current study attempts to conduct a comparative theoretical study of the response of R/C slabs under hard missiles impact. More than 26 formulae were developed previously by many researchers to facilitate the design of R/C slabs against the impact of hard missiles. Different empirical and semi-empirical formulae available in the literature were collected, studied, classified and evaluated with respect to the main performance indicators (penetration, scabbing and perforation). A computer program was developed using the most important formulae. The effect of each selected independent variable on the slab performance was studied and evaluated comparatively between the different formulae .In the comparison of penetration formulae the ACE formula, Petry and Amman formula over-estimate the penetration depth compare to the other formulae. The Chang, Adli and Bechtel formulae gave the minimum of scabbing thickness compare to the other formulae. The ACE, Adli, CEA-EDF perforation formulae under-estimate the perforation thickness.

*Keywords: penetration, scabbing, perforation, hard missiles*

Article history: Received 12 April 2016, last received in revised 1 May 2016

## 1. INTRODUCTION

Nuclear power plants and many other structures need protection against impact from sources such as missiles and aircraft. A missile impact results in both local wall damage and overall dynamic response of the target wall and supporting structure. The response of the structure depends on the mechanical and physical properties of both the impacting object and the structure. The characteristics of the impacted loads which control the overall response of the target are governed by the absorption of kinetic energy from the missile at acceptable target deflections. These loads are limited, however, by the yield, buckling, crushing or local destruction of the impacting objects. The overall dynamic response of the target consists of shear and flexural deformations. A potential flexural or shear failure of the target will occur if the strain energy capacity of the wall and the supports is smaller than that part of the kinetic energy which has been transmitted from the zone of penetration or perforation into the wall. The barriers were reinforcement with 0% - 1.5%

each way, front face bending reinforcement and 0.3% - 1.7% each way back face-bending reinforcement with no shear reinforcement.

These effects include the following physical phenomena:

a. Penetration: it is the depth to which a projectile enters a massive concrete target without passing through it. The concrete is assumed not to yield (scab) on the back face. Thus, penetration is independent of the thickness of the target.
b. Scabbing: It is the ejection of pieces of concrete from the back of the slab opposite to the impact area thus leaving a back crater after the impact.
c. Spalling: it is the ejection of pieces of concrete from the front face region surrounding the area of impact thus leaving a front crater.
d. Perforation: it is the depth to which projectile just passes completely through the slab causing the exit velocity of the projectile after it passes through the slab to be zero. Fig. 1 refers to these local effects depend largely on the relative properties of the missile and the impacted object. For concrete barriers, local damage in the form of scabbing, penetration or perforation of the barrier is generally termed the response indicators of the slab or wall panel. Soft missile impact rarely produces penetration or perforation except at extremely high unlikely velocities. They may, however, cause back cracking and scabbing. The effects of impact of a flexible missile such as an aircraft are intermediate between those caused by hard and soft missiles.

These response indicators will be used through this study to evaluate comparatively the response of reinforced concrete (R/C) panels to hard missile impact. In recognition of the complex nature of hard missile impact upon reinforced concrete, empirical formulae have been developed to determine the local effects of missiles on target or barriers. In general the local impact effects of hard missiles on concrete structures were studied in three research methodological bases.

1. Empirical studies to predict formulae based on experimental data.
2. Analytical studies to create formulae based on physical laws.
3. Numerical simulations based upon computer based material models.

### *A. The problem statement*

This study attempt to analyze twenty-six different formulae which were previously developed to predict the depths of local effect resulting from the impact of missiles hitting reinforced concrete panels at different velocities and having different weights of the missiles. The formulae under analysis were based on different theoretical and empirical bases according to the author’s methodologies and assumptions and to the nature of local effect. There are eight formulae dealing with penetration, eleven dealing with scabbing and seven dealing with perforation.

***B. Objective of the study***

The main objective of this study is to perform a comparative theoretical evaluation of different formulae developed in the last ten years to predict the response of r/c slabs and walls to the impact of hard missiles. Another objective of the study is to evaluate the effect of some important parameters on the response of r/c slabs.

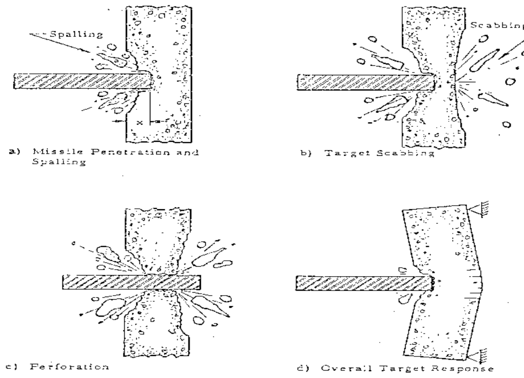


Fig. 1. Missile impact phenomena

## 2. LITERATURE REVIEW

Analytical and rational mathematical prediction of the effects of local impact of hard missiles on reinforced structures was extremely difficult due to the complex nature of the transient loads. Various papers were published in recent years describing new ideas and methods for analyzing and designing against impacts on concrete structures connected with nuclear plant facilities. Owing to complexities in evaluating structural damage due to impact loading, design criteria so far developed had been mainly dependent on experimental tests and empirical formulae. There are various empirical formulae that used to be employed in connection with missile impact problems on nuclear plant structures, but many of them had been discarded because over the years new, more relevant test data was made available. However, there are some older and newer formulae which are still very much applicable.

## 3. METHODOLOGY

Different formulae developed in various studies by different researchers were obtained and analyzed using excel computer program to predict the effects of varying missile parameters on the performance indicators variable of the resulting impact effects e.g. penetration, scabbing and perforation, the tested varying missile and target parameters, missile velocity, missile weight and concrete strength each of these applied to determine the three impact local effects e.g. penetration, scabbing and perforation. The parameters other than the above there are kept constant. The parameters of the missile such as Weight of missile w (in pounds), Size of missile e.g. diameter if it is cylindrical d (in inches), Velocity of the missile V (in ft per second ft/s), Nose shape of the missile k (flat, blunt, sharp) and Inclinations of missile with respect to the target surface, With the exception of missile weight and missile velocity the other parameters are kept constant while generating the required data.

The parameters of the target (reinforced concrete slab) such as Target thickness, concrete strength (compressiveness), size of aggregate and amount of reinforced concrete.

It was assumed that the target (slab) is totally fixed and that the overall performance of the structure is not affected by the impact of the missile (projectile).

## 4. RESULT AND DISCUSSION

The several empirical formulae had their range of applicability when used to determine their impact effects penetration, scabbing and perforation. The data showing these effects also indicate the range of applicability of each parameter. The generated data was used in regression analysis to test the objectives of the study. The data generated for the different parameter were grouped according to their specific effects such that they can easily be compared. Each of the parameters is tested for each of the three impacts effect such that when testing the missile weight the other two parameters e.g missile velocity and concrete strength are kept constant at their maximum range. The same process is repeated for missile velocity that is varied throughout its range while keeping the missile weight and concrete strength at their maximum range, and so on with respect to concrete strength. The range of each parameter is indicated in the relevant table for the specific impact effects as the relevant parameter changes in its range. Hence the different formulae have different impact effects from each other according to each specific equation. Finally the results of all formulae for each different impact effect are plotted together for easy comparison.

### *A. Effect of missile velocity on penetration depth.*

Fig (2) shows the impact effect of missile velocity on penetration depth It is

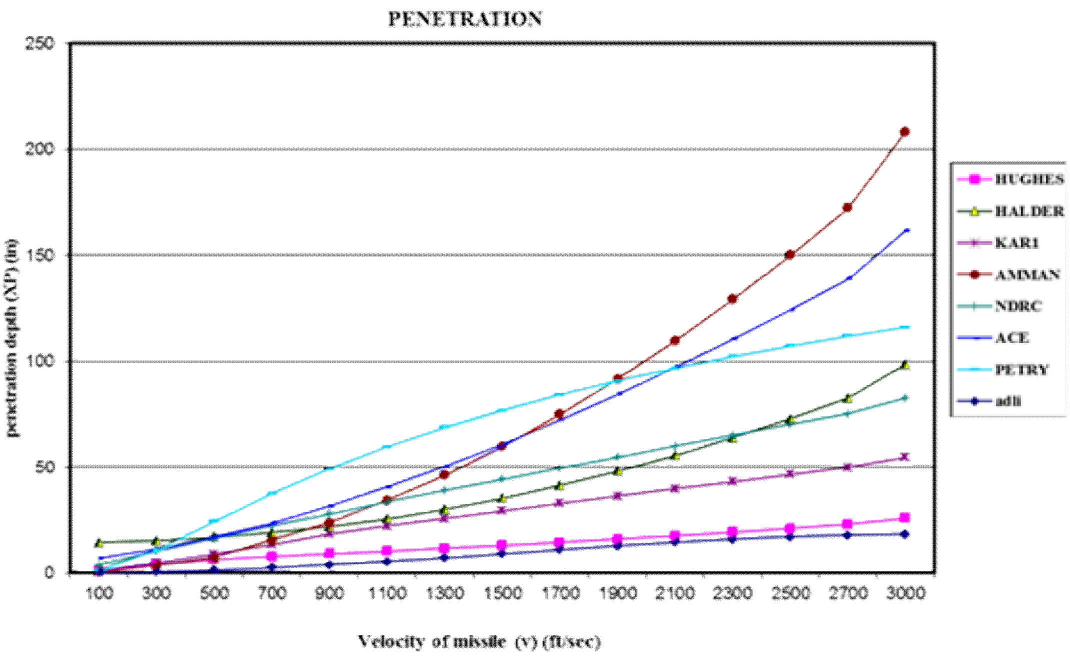


Fig. 2 Relationship between missile's velocity and penetration depth

worth noting that the maximum limit of any velocity should not exceed 24 inches. This limited achieved by most formulae but at different velocity ranges in each formulae.

### *B. Effect of missile weight on penetration depth.*

Fig (3) shows the impact of missile weight on penetration depth When the missile weight is 400 pounds all formulae attained a penetration of less than 24 inches. When comparing the different formulae among themselves it was found that Adlie formula was the best.

### *C. Effect of strength of concrete on penetration depth.*

Fig (4) refers to the relation between concrete strength and the penetration depth. The relation is descending as the strength increases. The reinforced strength varies between 3200 psi and 7130 psi. The lowest depth was attained by Adlie formula. Similar discussions and analysis are followed to examine the impact of effects on of missile velocity, missile weight and reinforced concrete strength of slab on scabbing and perforation. These results in six figures compos of three figures for each parameter. Figures (6-8) refer to scabbing, and figures (9-11) refer to perforation.

## 5. CONCLUSION

The following paragraph presents the conclusions obtained from the discussion and analysis of data regarding the relationship between the performance indicators of local impact effects on reinforced concrete slabs and walls structures inflicted by the missile parameters.

A. In The comparison of penetration formulae the ACE formula, Petry and Amman formula over-estimate the penetration depth compare to the other formulae. Adlie, Hughes, Halder and Miller provided the minimum of penetration depth compare to the other formulae.

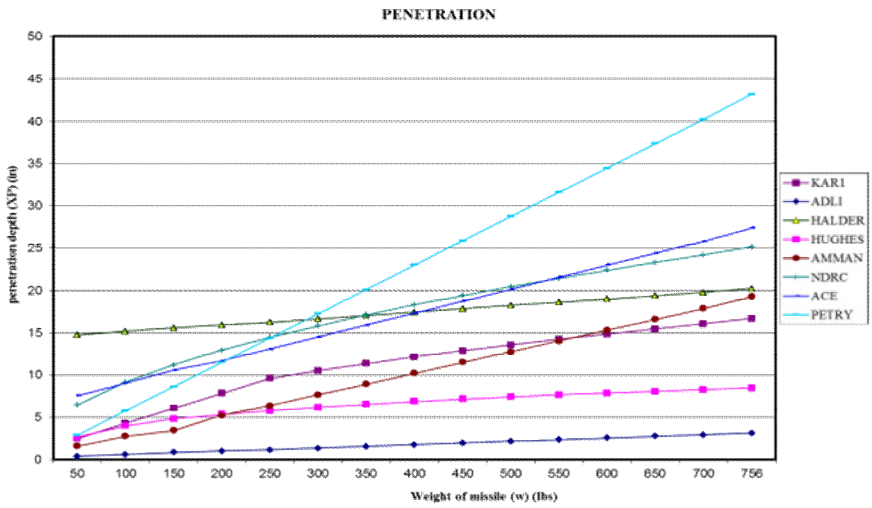


Fig. 3. Relationship between missile's weight and penetration depth

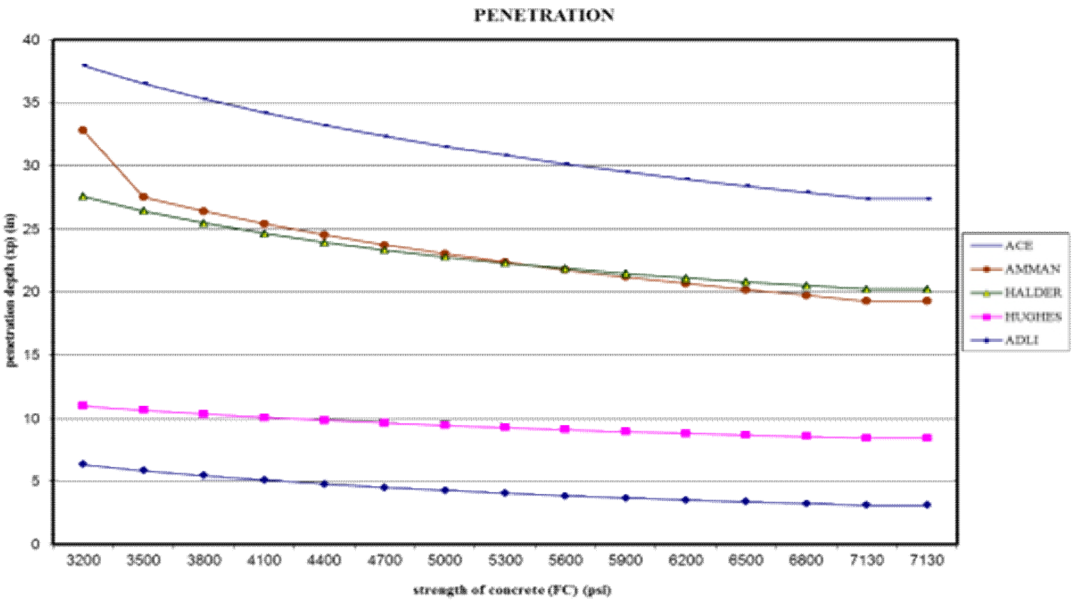


Fig. 4 Relationship between strength's concrete and penetration depth

B. The following observations can be made regarding the calculation of scabbing thickness: The Chang, Adlie and Bechtel formulae gave the minimum of scabbing thickness compare to the other formulae. They are, in general, the least conservative.

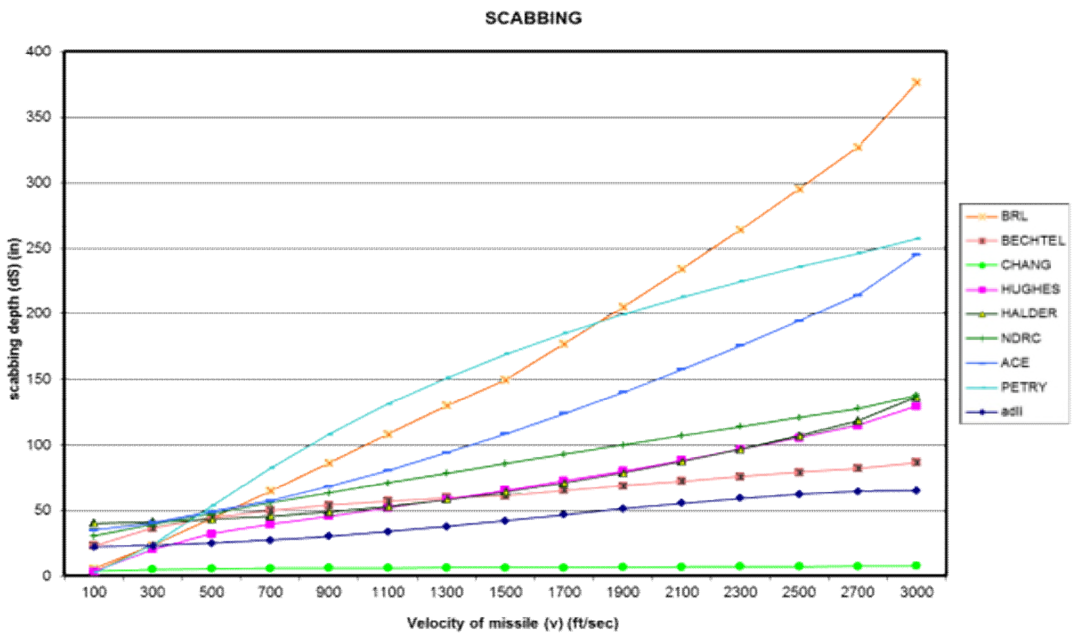


Fig. 5 Relationship between missile's velocity and scabbing depth

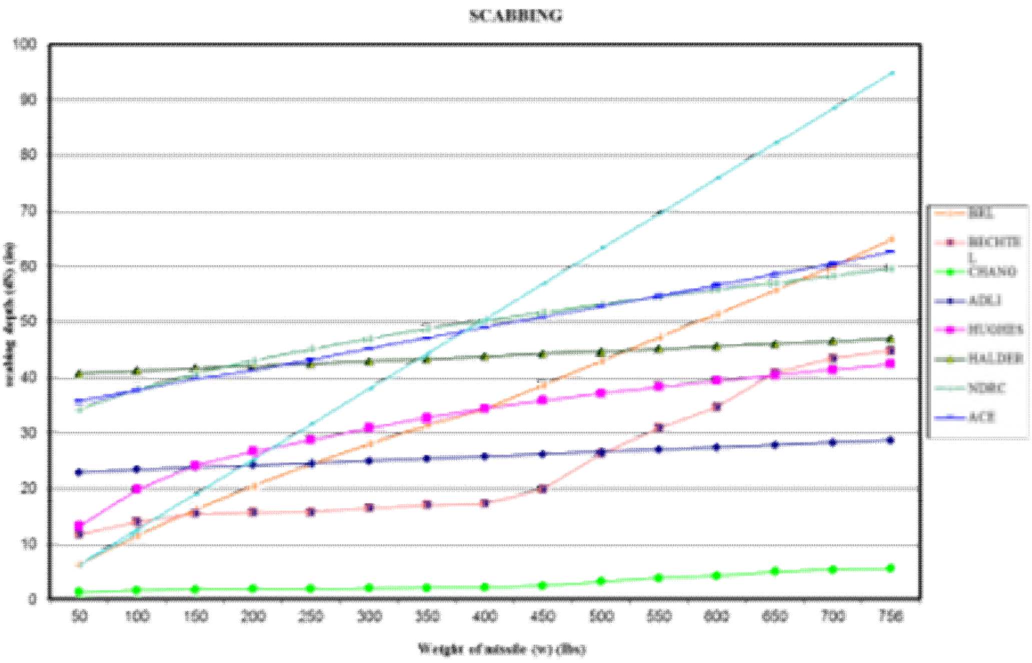


Fig. 6 Relationship between missile's weight and scabbing depth

The NDRC and ACE formulae compare favorable with the experimental data, but they are somewhat more conservative than the Chang and Bechtel formula. The Hughes formula is the most conservative in predicting the scabbing thickness. The modified petry and BRL formulae in predicting the scabbing thickness greater than the other formulae.

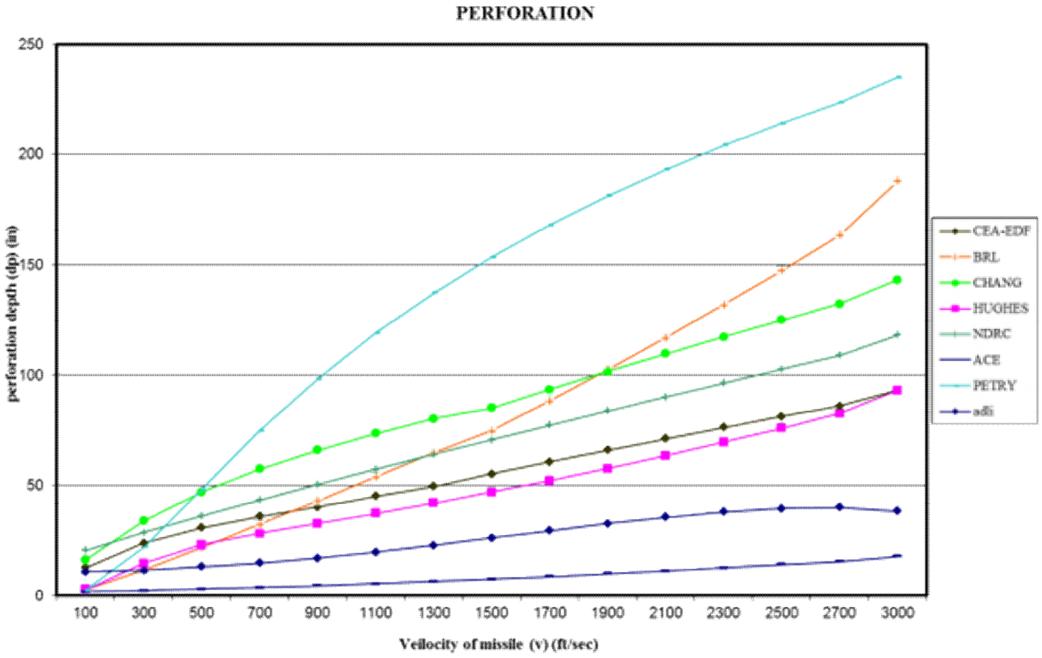


Fig. 8 Relationship between missile’s velocitiy and perforation depth

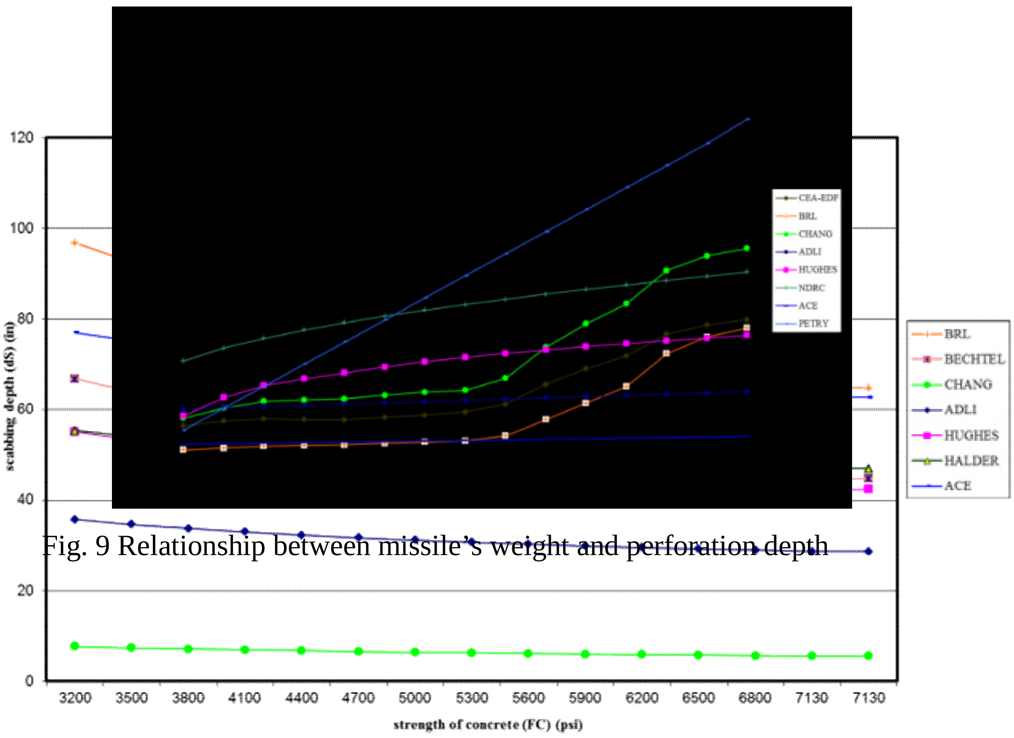


Fig. 9 Relationship between missile’s weight and perforation depth

Fig. 7 Relationship between missile’s strength and scabbing depth

C. The ACE, Adlie, CEA-EDF perforation formulae under-estimate the perforation thickness.16 A general observation of the conclude results show that the formulae which are based on statistical base gave better results followed by the experimental and the empirical base, respectively.

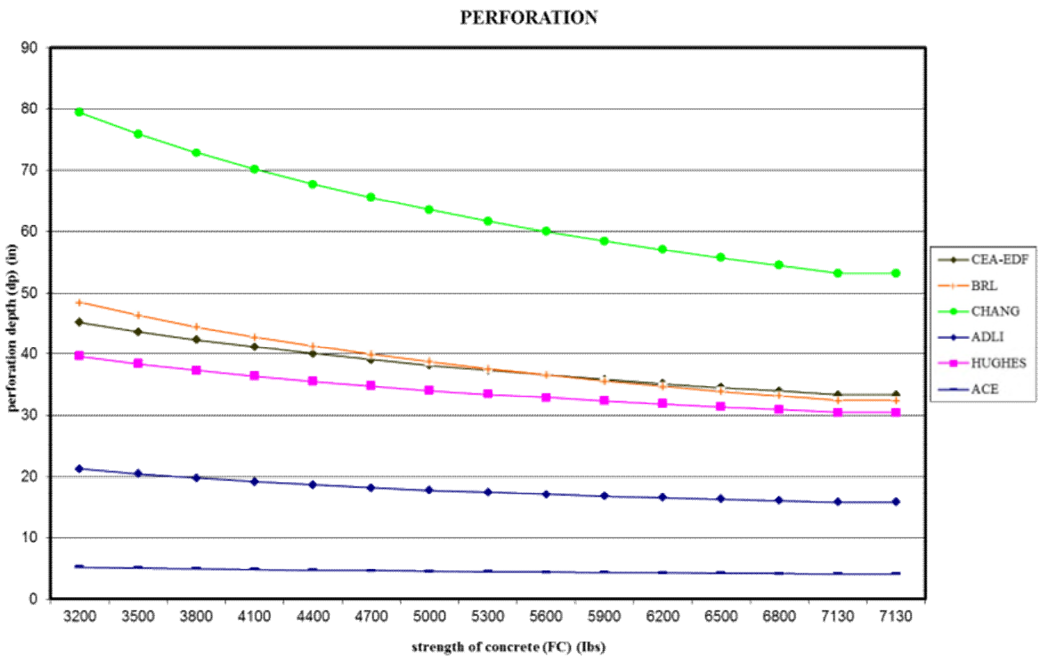


Fig. 10 Relationship between strength of concreat and perforation depth

## 6. REFERENCES

[1] Aircraft and Missile Impact-Data and Analysis, M.Y.H Bangash –T.Bangash, Explosion-Resistant''.

[2] Halder, A. and Miller, F.J, (1982). Penetration depth in concrete for non-deformable missile, Nuclear Engineering and Design, 71, 79–88,

[3] Halder, A., Hatami, M, and Miller, F.J., (1983). Concrete structures penetration depth estimation, ASCE, Structural Division, 109(1), January, 245– 250,

[4] Kennedy, R.P., (1976). A review of procedures for analysis and design of concrete structures to resist missile impact effects, Nuclear Engineering and Design, 37, 183 – 203,

[5] Adli, H. and Amin, A. M., (1985). Local effects of impactors on concrete structures, Nuclear Engineering and Design, 88, 301 – 317,

[6] Slitter, G. E., (1980). Assessment of Empirical Concrete Impact Formulas, ASCE structural division, 106(ST5), May, 333 – 364,

[7] Raymond M.L., Ting, A.M., (1970). Penetration Modes and Philosophical Boundaries, ASCE. Mgr. Struct.Tech., H.H. Robertson co., Pittsburgh, pa. February,

[8] Gueraud, R., Sokolovsky, A., Kavyrchine, M., and Asrtuc, M., (1970). Study of the perforation of reinforced concrete slab by

ISSN: 2406-9833 @2016 PPs-UNHAS

rigid missiles", part1, Nuclear Engineering and Design, 41, 91–102,

[9] Fiquet, G., and Dacquet, S., (1977). Study of the perforation of reinforced concrete slabs by rigid missiles, part2. Nuclear Engineering and Design, 41, 103 – 120,

[10] Goidstein, S., and Berriaud, C., (1972). Study of the perforation of reinforced concrete slabs by rigid missiles, part3. Nuclear Engineering and Design, 4, 121–128,

[11] Al-Azawi, Z.M., (1990). The response of reinforced concrete slabs to hard missile impact, (U.K) January, (18),

[12] Kar, A.K., (1978). Local effects of tornado- generated missiles, ASCE, Structural division, 104(ST5), May, 809 – 816,

[13] Kar, A.K., (1978). Impact load for tornado-generated missiles, Nuclear Engineering and Division, 47, 107 – 114,

[14] Kar, A.K., (1979). Impactive effects of tornado missiles and aircraft, ASCE, Structural Division, 105(ST5-ST11), November, 2243 – 2260,

[15] Kar, A. K., (1979). Loading time history for tornado-generated missiles, Nuclear engineering and division, 51, 487 – 493,

[16] Kar, A.K., (1978). Projectile penetration into buried structures, ASCE, Structural Division, 104(ST1), January, 125 – 139,

[17] Burdette, E.G., (1979). Projectile penetration into buried structures, ASCE, Structural Division, 105(ST2), February, 254 – 457,

[18] Beter P.D., (1980). Perforation of Reinforced Concrete Slabs by Rigid Missiles, 106(ST7), July, 1623 – 1642,

[19] Chang, W.S., (1981). Impact of solid missiles on concrete barriers, ASCE, Structural Division, 107(ST2), February, 257 – 271,

[20] Halder, A., (1981). Impact of solid missiles on concrete barriers, ASCE, Structural Division, 107(ST11), November, 2307 – 2309,

[21] Halder, A, and Hamieh, H.A. (1984), Local effect of solid missiles on concrete structures, ASCE, Structural Division, 110(ST5), May, 948 – 960,

[22] Sridharan, A., Prakash, K. (2000), Classification Procedures for Expansive Soils. Proceeding Institution of Civil Engineers. London.

[23] Chen, F.H., (1975). Foundations on Expansive Soils. Elsevier Scientific Publishing Company. Amsterdam.

[24] Jones, D.E, dan Holtz, W.G., (1973). Expansive Soils – the Hidden Disaster. Civil Engineering. ASCE; 43, November 8. New York.

[25] Fredlund, D.G. dan Rahardjo, H.. (1993). Soil Mechanics for Unsaturated Soils. John Wiley & Sons Inc. Canada.

[26] Charles, W.W.Ng., dan Bruce Menzies. (2007). Advanced Unsaturated Soil Mechanics and Engineering. 1st Published. Taylor & Francis Group. New York, USA.