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A Statistical Approach for Modelling of Lightweight Palm Oil Clinker Reinforced Concrete Beams with Openings

Sadaam Hadee Hussein, Mohammed Alzaidi, Qusay Othman Hasan
Al-Maaref University College, Iraq

Abstract -**This paper proposes two models for ultimate load and first crack of lightweight Palm Oil Clinker (POC) reinforced concrete (RC) beams with web openings using the Response Surface Methodology (RSM). The suggested models are developed to predict the ultimate load and first crack for a comparison with the experimental measurements and design accordingly. The ultimate load and first crack have been investigated against three parameters, namely depth of beams, location of openings and length of openings. The results of this work show that the developed models have good adaptability and high accuracy.**

Keywords: **POC; RC beams with web openings; RSM**

I. Introduction

In the modern buildings, a lot of pipes and ducts are needed to accommodate essential services like air-conditioning, water supply, computer network, telephone, and electricity. Usually, these pipes and ducts are placed under the soffit of the RC beam and, for aesthetic reasons, are covered via a suspended ceiling, thus creating a dead space 1-3 . The dead space height that adds to overall building height depends on the number and pipes or depth of ducts. Various ranges from a couple of centimetres to as much as half a meter 4. An alternative arrangement is to pass these pipes or ducts through transverse openings in the floor beams. This arrangement of building service leads to a significant reduction in the headroom and data in a more compact design. For small buildings the saving thus achieved may not be significant compared to the overall cost. But for multi-storey buildings, any savings in the overall height, length of air-conditioning, electrical ducts, risers, plumbing, walls and partitions surface will reduce the overall load on the foundation and will lead to substantial reduction in costs. The classification of opening web opening in beams may be of different shapes and sizes 3 . Many types of research for RC beam with openings using Normal Weight Concrete. In the past, a lot of research had been carried out to study the behaviour of RC beams with transverse openings. The investigations dealt with the behaviour of RC beams with a transverse opening under flexure, shear, torsion and the combined effect of (flexure and shear) or (flexure and torsion) 5-7 . Newly, the construction materials technologies and building practice have developed. The construction industry is the biggest energy consuming part. With growing urbanization, natural resources are being used in the construction. Environmental conscious buildings design has become significant. The concept of green building is the construction of energy efficient construction buildings which result in reduced water and air pollution, less water consumption, and increased user productivity. The consciousness of green building has begun and with building industry poised for a big growth, green building industry would be a mantra of the construction building industry in future. Going green is a prospective building technology for the environmentally harmonious cities. Moreover, the primary advantage of using waste in nature and converting them to useful material such as Lightweight concrete (LWC) will lead to environmental conservation and decrease pollution. Lightweight concrete serves to decrease a dead load of concrete structures without any loss in strength. LWC can reduce the dead load (D.L) as much as 35% and still provide structural strength 8. Reduction of structure D.L can reduce the cost of construction. This is the key motivation for the use of lightweight concrete in the construction industry. Lightweight concrete has been used since 2000 years ago, an early example being a 44-meter dome for a Roman building. Clinker concrete, a form of lightweight concrete, was in use in the United Kingdom and in the USA in the late nineteenth century. It was also used for the extension of a British museum in 1907. Moreover, there was a problem that needed to be resolved, which the experimenter faced at the starting when the researcher or experimenter wanted to do the Experiments Design, especially in the field of structural engineering. In Design of Experiments (DOE), there is occasionally more than one variable that cannot be determined precisely, or there may be a variable which is more effective than the other, and a suitable number of samples have to be specified. Moreover, the results that obtained from experimental work are compared with predicted data obtained from RSM using Minitab Software. In addition, in this research will develop three statistical models using RSM.

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II. Design of Experiments

A. Box- Behnken Design

The Box-Behnken Design (BBD) 9 is an independent quadratic design in that it does not contain an embedded factorial or fractional factorial design. In this design, the treatment combinations are at the midpoints of the edges of the process space and at the centre. These designs are rotatable (or nearly rotatable) and require 3 levels of each factor. The number of experiments (N) required for the development of BBD is defined as N=2k (k−1) +C0, (where k is the number of factors and C0 is the number of central points). Figure 1 shows the required number of experiments for the three levels. Building a design means carefully choosing a small number of experiments that are to be performed under controlled conditions. There are some interrelated steps in building a design 10.

- Defining an objective to the investigation, e.g. better understanding or sorting out important variables or finding an optimum.
- Defining the variables that will be controlled during the experiment (design variables), and their levels or ranges of variation.
- Defining the variables that will be measured to describe the outcome of the experimental runs (response variables) and examining their precision.

B. Concrete Materials and Mix Proportion

POC lightweight aggregate has been selected as fine and course aggregate (100%) rather than NWC in LWC mix without any admixture for producing lightweight reinforced concrete beams with web openings. The clinker, which was produced from local sources, is an unprocessed by- product material from palm oil clinker industrial. Initially clinkers were taken in a form of hard porous lumps. The clinker was from the bottom part of the boiler after the finishing of oil extraction process and the clinker needs to be crushed to a smaller size. The sieve analysis of the POC was found according to the requirement of (ASTM C136) 11 which stated that any

C. Lightweight POC RC beams with web openings: Instruments and Testing

12 Fifteen specimens of full scale lightweight palm oil clinker beams with web openings were fabricated and tested. All the beams were simply supported and they were subjected to a two point load. All beams tested had a rectangular cross section with a total length of 2400 mm. The width of beams, depth of openings and shear span of beams were kept constant. The selected beams differed in their depths (D), location of openings (L) and length of openings (W). The bottom reinforcement provided for all beams consist of three 16 mm diameter bars, and the top

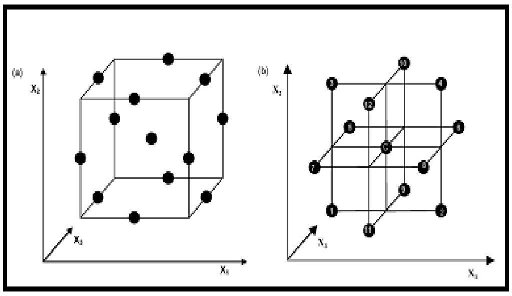

FIGURE 1: BOX- BEHNKEN DESIGNS FOR THREE LEVELS

Typically, each design variable is scaled such that it has a range of [–1, +1] in the standard design of experiments software to avoid a numerical error in the calculations. In conjunction with the corresponding BBD levels, the value matches are shown in Table 1.

TABLE 1: SUGGESTED VALUES OF CORRESPONDING LEVELS

Level / Coding	Low	Medium	High
	-1	0	1
D	350	400	450
L	275	325	375
W	250	325	400

Aggregates passing the 5 mm sieve size are classified as fine aggregates. Also, the coarse aggregate fractions are obtained by taking particles passing a particular maximum size (14 mm) but retained on a 5 mm sieve size 12. A coarse lightweight aggregate of structural coarse class has particle gradation in the range 14 mm to 5 mm. Three cylindrical (150 mm diameter and 300 mm height) compressive strength tests at an age of 28 days produced compressive strengths of 25.4 MPa, which is higher than the minimum required strength of 17 MPa, for structural concrete recommended by ASTM C330. The results of the tests were then checked with appropriate standards to ensure the suitability of clinker aggregates to be used in lightweight concrete mixture 13.

Reinforcement consists of two bars of 12 mm diameter. All tested beams were having vertical stirrups of 8 mm diameter. The rectangular openings had vertical closely spaced stirrups of diameter 8 mm around its openings as corner reinforcement. LWPOCRC beams with web openings have been tested with different boundary conditions to investigate all the various parameters mentioned above. The fifteen beam specimens were obtained based on an analysis using RSM. All the specimens were prepared for experimental tests to evaluate the effect of the ultimate load and first crack on beams dept, openings location and openings length 12.

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III. RESULTS AND DISCUSSION

The process considered three input variables [depth of the beam (D), location of openings (L), and length of opening (W)] to develop models from the experimental results using RSM. The polynomial model has been used as defined by equation (1) for ultimate load and equation (2) for first crack.

$$\textit{Ultimate load} = -135 + 0.823\ D + 0.262\ L + 0.165\ W - 0.000570\ D{*}L - 0.000440\ D{*}W - 0.000367\ L{*}W \quad (1)$$

$$\textit{First crack} = -368 + 1.41\ D + 0.279\ L + 0.279\ W - 0.00133\ D^2 - 0.00109\ L{*}W \quad (2)$$

The models generate an equation to describe the statistical relationship between one or more predictors and the response variable and to predict new observations. The predicted data by the models for ultimate load and first crack versus experimental data is shown in Table 4. The predicted data for ultimate load and first crack by using the model versus experimental data is shown in Figure 5 and Figure 6 respectively. Similarly, the relationship between the ultimate load and first crack are shown in Figure 7.

TABLE 4: PREDICTED ULTIMATE LOAD DATA VS. EXPERIMENTAL ULTIMATE LOAD

Run order	D (mm)	L (mm)	W (mm)	(Experimental) Ultimate Load (kN)	(Predicted) Ultimate load (kN)	(Experimental) 1st Crack load (kN)	(Predicted) 1st Crack load (kN)
1	400	275	400	158.2	158.5	49.3	50.3
2	450	375	325	180.5	181.7	57.5	58.0
3	400	325	325	162.9	162.6	49.9	48.0
4	400	375	250	169.8	169.5	52.2	54.0
5	450	275	325	192.7	193.0	64.9	65.7
6	400	375	400	147.8	147.2	30.8	34.4
7	450	325	250	199.4	198.8	68.9	67.5
8	400	275	250	174.7	175.2	54.3	53.5
9	450	325	400	176.3	175.9	56.0	56.1
10	400	325	325	162.9	162.6	49.9	48.0
11	350	375	325	135.4	135.0	26.1	23.8
12	400	325	325	162.9	162.6	49.9	48.0
13	350	275	325	141.9	140.6	28.8	31.4
14	350	325	250	145.1	146.0	30.9	33.3
15	350	325	400	128.6	129.8	24.6	21.9

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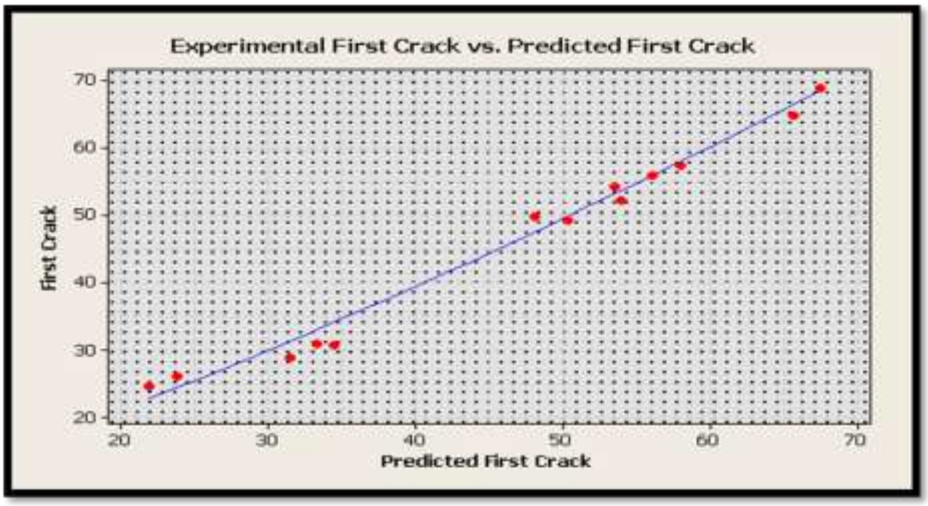

FIGURE 5: THE PREDICTED DATA USING THE MODEL VS. EXPERIMENTAL DATA

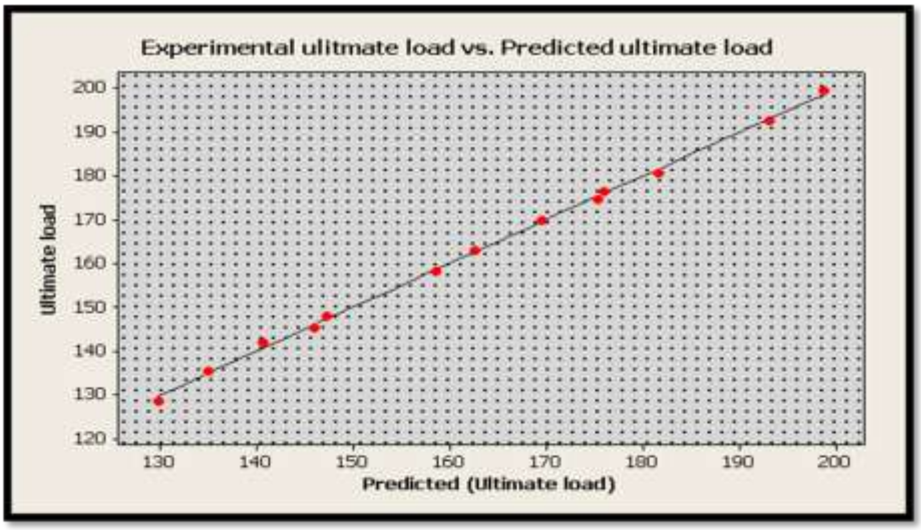

FIGURE 6: THE PREDICTED DATA BY THE MODEL VS. EXPERIMENTAL DATA

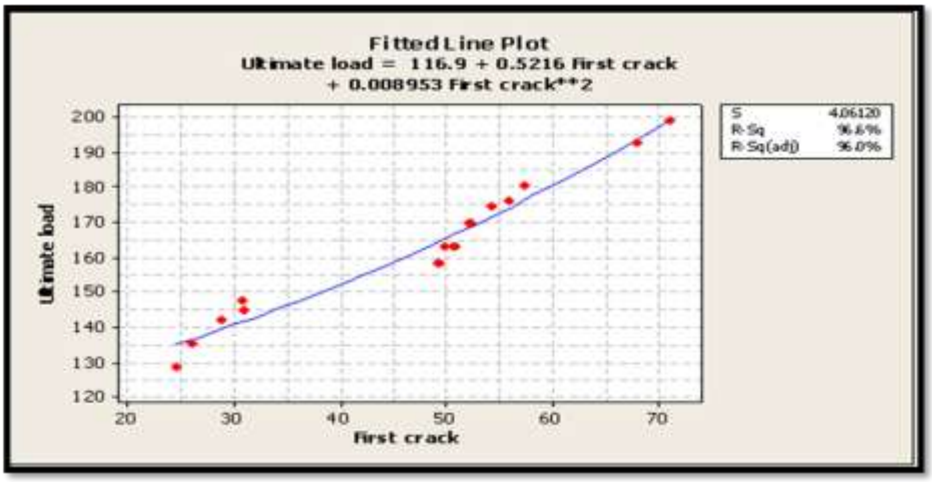

FIGURE 7: THE RELATIONSHIP BETWEEN TWO RESPONSES

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From Tables 5 and 6, it can be seen that the p-values for the test on individual regression coefficient are all less than 0.05 and the standard error deviation (S) is quite low with a value of 0.920043 for ultimate load and 2.50407 for first crack. The R2 and adjusted R2 are very high with values of 99.8 % and 99.7% respectively 14-15 . Similarly, the R2 and adjusted R2 for first crack model are high with values of 96.96% and 98.4% respectively. Therefore, the parameters chosen in this study are very significant.

Where,
S: Standard error of the regression.
R2: Percentage of response variable variation.
Adjust R2: Adjust Percentage of response variable variation.
Coef: The numbers by which the variables in an equation are multiplied.
SE Coef: Standard error of coefficient.

Table 5: Regression output for full quadratic model (Ultimate load)

Term	Coef	SE Coef	T	P
Constant	-135.393	31.7445	-4.265	0.003
Depth of beams	0.823	0.0722	11.404	0.000
Location of openings	0.262	0.0840	3.123	0.014
Length of openings	0.165	0.0634	2.604	0.031
Depth of beams*Location of openings	-0.001	0.0002	-3.098	0.015
Depth of beams*Length of openings	-0.000	0.0001	-3.587	0.007
Location of openings* Length of openings	-0.000	0.0001	-2.989	0.017

S = 0.920043 PRESS = 34.9847 R-Sq = 99.8% R-Sq(adj) = 99.7%

The analysis of variance (ANOVA) for the model ultimate load and first crack are shown in Table 5 to Table 8. The analysis of variance (ANOVA) is the total sum of squares and helps express the total variation that can be attributed to various factors. For example, you run an experiment to test the effectiveness of three factors.

Table 6: Analysis-of-variance for full quadratic model (Ultimate Load)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	6	5829.08	5829.078	971.5129	1147.71	0.000
Linear	3	5802.50	163.839	54.6131	64.52	0.000
Interaction	3	26.58	26.575	8.8583	10.46	0.004
Residual Error	8	6.77	6.772	0.8465		
Lack-of-Fit	6	6.77	6.772	1.1286		
Pure Error	2	0.00	0.000	0.0000		
Total	14	5835.85				

Table 7: Regression output for full quadratic model (First Crack)

Term	Coef	SE Coef	T	P
Constant	-367.840	90.0411	-4.085	0.003
Depth of beams	1.408	0.4151	3.392	0.008
Location of openings	0.279	0.1099	2.534	0.032
Length of openings	0.279	0.1091	2.559	0.031
Depth of beams*Depth of beams	-0.001	0.0005	-2.570	0.030
Location of openings* Length of openings	-0.001	0.0003	-3.275	0.010

S = 2.50407 PRESS = 226.528 R-Sq = 98.04% R-Sq(adj) = 96.96%

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The ANOVA for the model (First crack) is shown in Table 8.

Table 8: Analysis-of-variance for full quadratic model (First Crack)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	5	2829.08	2829.080	565.8160	90.24	0.000
Linear	3	2720.43	113.297	37.7657	6.02	0.016
Square	1	41.41	41.407	41.4074	6.60	0.030
Interaction	1	67.24	67.240	67.2400	10.72	0.010
Residual Error	9	56.43	56.433	6.2704		
Lack-of-Fit	7	56.43	56.433	8.0619		
Pure Error	2	0.00	0.000	0.0000		
Total	14	2885.51				

Where,
DF: Degrees of freedom
SS: Sum of squares between groups (factor) and the sum of squares within groups (error).
F: Calculated by dividing the factor MS by the error MS;

In order to judge the accuracy of the prediction model, the percentage deviation ($\emptyset i_i$) and the average percentage deviation ($\overline{\emptyset}$) were used as defined below:

$$\emptyset_i = \frac{|Ra_{exp} - Ra_{pre}|}{Ra_{exp}} x100\%$$

Where $\emptyset_i$= Percentage deviation of a single experiment data.

Ra_{exp}= actual Ra by Experimental work.

Ra_{pre}= predicted Ra generated by a multiple regression equation.

$$\overline{\emptyset} = \frac{\sum_{i=1}^{n} \emptyset_i}{n}$$

Where $\overline{\emptyset}$**:** average percentage deviation of all experiments,

n: the size of sample data

This method tests the average percentage deviation of actual Ra (measured by an off-line stylus type handheld method) and predicted Ra (produced by the regression model) as well as its ability to evaluate the prediction of this model. The regression model could predict the ultimate load and first crack from experimental data sets with average percentage deviation of an accuracy of 99.27% and an accuracy of 95%, respectively. Hence, the analysis can start with main effect plots as shown in Figure 8 and Figure 9.

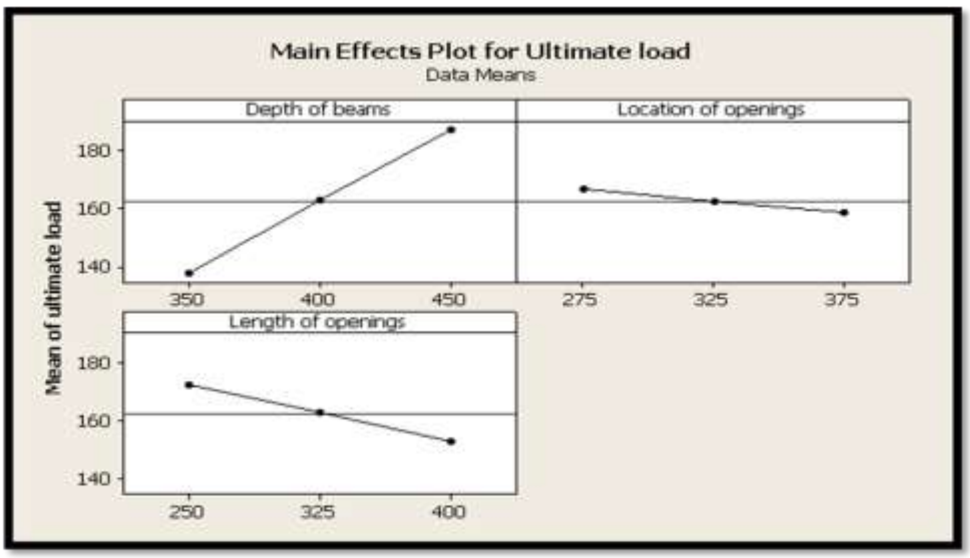

FIGURE 8: MAIN EFFECT PLOT FOR ULTIMATE LOAD

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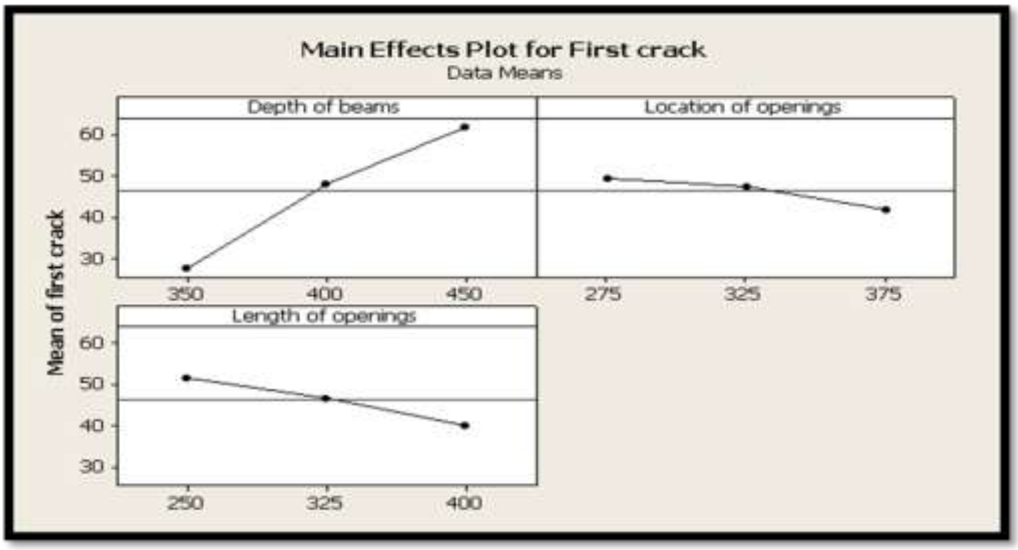

FIGURE 9: MAIN EFFECT PLOT FOR FIRST CRACK

IV. CONCLUSION

The important conclusions drawn from the present research are summarized as follows:

- Through experimentation, the system proved the capability of predicting the ultimate load and first crack of LWPOCRC beams with web openings with a 99.27% and 95% accuracy, respectively.
- The RSM test suggests that the full quadratic models are capable of explaining the data and the factors used in this study are very significant, which leads to an increase in the values of R^2 and adjusted R^2 for two models.
- The RSM proved to be a good way to design the experiment and to determine the appropriate number of samples which are used in the experimental test of LWPOCRC beams with web openings and achieve accurate results. In addition, this method saves time and cost.
- The ultimate load and first crack were affected by the depth of beams, location of openings and length of openings and their interactions into the regression model.
- The depth of beams, length of openings and location of an opening are very significant parameters which were used to predict the ultimate load and first crack in the regression model.

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REFERENCES

1) Mansur M.A., "Design of Reinforced Concrete Beams With Web Openings" the 6th Asia-Pacific Structural Engineering and Construction Conference, APSEC 2006.

2) Mansur M.A., and Hasnat A. "Concrete Beams with Small Openings under Torsion" Journal of the Structural Division, ASCE, Vol. 105, No. ST11, November 1979, pp. 2433-2447.

3) Mansur M.A., Tan K.H., and Lee, S.L., "Collapse Load of Reinforced Concrete Beams with Large Opening" Journal of the Structural Division, ASCE, Vol. 110, No. ST11, November 1984, pp. 2602-2618.

4) Mansur M.A., and Alwis W.A.M., "Reinforced Fiber Concrete Deep Beams with Web Opening" The International Journal of Cement Composites and Lightweight Concrete, Vol. 6, No. 4, November 1984, pp. 263-271.

5) Mansur M.A., Tan K.H., and Lee, S.L., "Collapse Load of Reinforced Concrete Beams with Large Opening" Journal of the Structural Division, ASCE, Vol. 110, No. ST11, November 1984, pp. 2602-2618.

6) Mansur M.A., and Paramasivam P., "Reinforced Concrete Beams with Small Opening in Bending and Torsion" ACI Structural Journal, Vol. 81, No. 2, March-April 1984, pp.180-185.

7) Mansur M.A., Tan K.H., and Lee S.L., "Design Method for Reinforced Concrete Beams with Large Openings" ACI Structural Journal, Vol. 82, No. 4, July-August 1985, pp. 517-524.

8) Wahid Omar and Mohamed Roslli (2002). The Performance of Pretensioned Prestressed Concrete Beams Made With Lightweight Concrete (Journal of Civil Engineering). Vol.14 No. 1.

9) G.E.P. Box and K.P. Wilson, (1951). On the experimental attainment of optimum condition. J. Roy. Stat. Soc. 13: p. 1-45.

10) Montgomery C. D (2001). Design and analysis of experiments. 7th ed. Singapore: John Wiley and Sons, Pte. Ltd.

11) ASTM C136. Test method for sieve analysis of fine and coarse aggregates. Annual Book of ASTM Standards, American Society for Testing and Material.

12) Sadaam Hadee Hussein, Kamal Nasharuddin Bin Mustapha, Zakaria Che Muda,Salmia Budde (2011), Modeling of Ultimate Load for Lightweight Palm OilClinker Reinforced Concrete Beams with Web Openings Using Response Surface Methodology" International Journal of Civil Engineering and Technology(IJCIET), Volume 3, Issue 1.

13) M. Abdullahi, H. M. A. Al-Mattarneh (2008), A. H. Abu Hassan. Trial Mix Design Methodology for Palm Oil Clinker (POC) Concrete. ICCBT -A-(45)pp507-516, Malaysia.

14) M. Abdullahi, H. M. A. Al-Mattarneh, B.S. Mohammed (2009). Statistical modeling of lightweight concrete mixtures. European Journal of Scientific Research ISSN 1450-216X Vol.31 No.1, pp. 124-131.

15) Nuran Bradley, (2007). The response surface methodology, Indiana University South Bend in partial fulfilment of requirements for the degree of Master of Science.

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