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Nonlinear analysis of RHA concrete beam using ANSYS

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ABSTRACT

So rice husk can be used as supplemental cement material due to its pozzolanic effect. Rice husk as agricultural waste if used properly not only reduces environmental problems but also reduces carbon dioxide emissions into the atmosphere by reducing cement production. Current experimental work using ash of rice husk (RHA) being material of supplementation has shown good enhancement in the properties of the RC beams. This paper presents results obtained from the analytical model of the RHA concrete beams. The study included developing an analytical model using finite element method ANSYS R15.0 software. For validation the results, the analytical model was compared with the experimental work using similar properties. By using four point loading flexural test, ten simply supported RC beams were tested containing various rice husk ash percentages. Results showed that all RHA concrete beams of the analytical model failed by flexural similarly to the experimental work.
The average of FEM to experimental ratio (for the ten models) for ultimate load was 91.173%, while for maximum deflection was 93.055 %. This indicates that the agreement between finite element results and experimental results are excellent. Also, the crack pattern, failure mode and the load-deflection curve from the analytical model related to the experimental works show good agreement.

Keywords: Concrete Beam, RHA, ANSYS, Ultimate load, Maximum Deflection

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1. Introduction

Concrete considered as mostly common material for building utilized by humans. Where global consumption is estimated annually about ten billion tons [1]. Cement is material which is a constituent for concrete making. As time progresses, obtaining raw materials from land resources will be rare, and cement demanding is elevating as a result of population and economic growth, so more efforts must be made to detect materials as alternative that should be cheap compared to the cost of cement and also require very little energy to produce them. Thus, waste or by-products using to replace partially cement being dominant trend for such purpose of concrete making.
When cement is used in concrete, it will be emit gases that lead to greenhouse occurs, and which causes many problems effect on the environment [2]. The Portland cement manufacturing process is responsible for 5-8% CO2 emissions into the atmosphere [3-6]. Therefore, concrete technologists are looking for solutions to reduce carbon dioxide emissions, by using alternative cement supplement materials to replace cement [7].
To get rid of materials large quantities of that might produce pollution to water, land, and air, it is preferable to use by-products, as it is an environmentally friendly method [8]. Recycling of waste is essential to create a clean and healthy environment.
RHA utilization being an alternative to cement is a concrete new path technology. Besides, it will also help in solving problems that you are supposed to face in waste disposal. For environmental reasons, throwing out rice husks is a big problem and burning them in an open space is unacceptable. Therefore, most of the husks currently go to landfill. As a result of the environmental problem caused by the disposal of rice husks, the idea of replacing RHA, which has a high content of silica [8- 10], arose in the cement industry. The ash contains about of 92- 97 % silica [11, 12]. So rice husk can be used as supplemental cement material due to its pozzolanic effect [13, 14]. Rice husk as agricultural waste if used properly not only reduces environmental problems but also reduces carbon dioxide emissions into the atmosphere by reducing cement production [15].

For RHA obtaining, rice husk is burned at heat in rang of (500 -800 °C) [12, 16, 17], then the rice husk may forms as a cellular micro structure is produced [12].
Below is a literature review of some of the research that used some cementitious materials and their influence on the concrete properties.
Abdul Aleem and Arumairaj [18] in 2016 used the waste material as the binding material and is called fly ash. This material can form a gel that binds coarse and fine aggregates if it is chemically reacted with an alkaline solution such as Na2SiO3 and NaOH. 100 x 150 x 1000 mm concrete beams were prepared, cured under steam treatment for 24 hours and then cured up to 28 days at room temperature. By two point load methods, the beams were tested and measuring of deflections. ANSYS models were formed and the results were obtained close between the experimental results and those of ANSYS models.
Ogbologugo et al. [19] in 2018 presented a numerical analysis study on flexural new cementations' performance being GEM-TECH materials utilizing FEM. To design a steel reinforced model of GEM-TECH beam, a nonlinear element finite model was utilized by employing Ansys (a commercial software. The results of the experimental works for five reinforced GEM-TECH beams were compared to those obtained from FEA results and crack plots. The load deflection diagrams and the failure mode crack diagrams that resulted from model of FE gave agreement being good along results of experimentation.
Kalyan et al. [6] in 2017 focused on numerical fly ash (FA) and Ground Granulated Blast Furnace Slag (GGBS) investigation blended reinforced beams of geo-polymer concrete. Via utilizing Ansys R15.0, the beams were analyzed. The proportions of materials for geopolymer concrete used were (FA) 50, (GGBS) 50 and FA0-GGBS100. The parameters such as maximum normal stress, stress of Von-Misses, stress of maximum shear, maximum elastic normal strain, maximum strain shear and deflection as maximum were calculated.
Patil et al. [20] in they used in concrete Metakaolin and RHA as substitute being partial for standard Portland cement, and they introduced a new formula for determining the flexural strength of standard concrete. By using these mineral admixtures, Ordinary Portland cement was utilized instead at 5, 10, 15 and 20% by weight. Control Mix used cement only. After curing 28 days in water of concrete beam (150x150x700 mm), the flexural test was conducted on it. By ANSYS Workbench, the beam was simulated to calculate the flexural strength numerically.
Mohammed and Sajjad [2] in 2020 studied the rice husk as a waste material. It is then eliminated by incineration at a temperature of 500 to 600°C to get on the rice husk ash. RHA was obtained containing 86.76% of silica, meaning that the properties of material is pozzolanic. The weight ratios of RHA that substituted in place of cement were (5,10,15,20) % when designing of the mix (1: 1.89: 2.64) for ratio of water/ binder (w/b) equal 0.53 and (1: 1.43: 2.19) for (w/b) equal 0.44. To determine the compressive strength, sixty cube were casted and tested. Also thirty cylinder were tested to calculate the strength of split and 30 prism to compute the flexural strength. Ten beams were casted for testing the strength as flexural. Adding of RHA on the mix constituents was improved the concrete properties especially for the flexural strength and generally in the behavior of beams.
There are many experimental studies that dealt with studying the effect of replacing a cement proportion with rice husks on physical and mechanical concrete properties. But there is a paucity of theoretical studies to represent concrete that contain rice husks, so this was the current study.
In this research, ten beams having the same design are tested to fail by flexural as illustrated in Figure (1) by Mohammed and Sajjad [2].

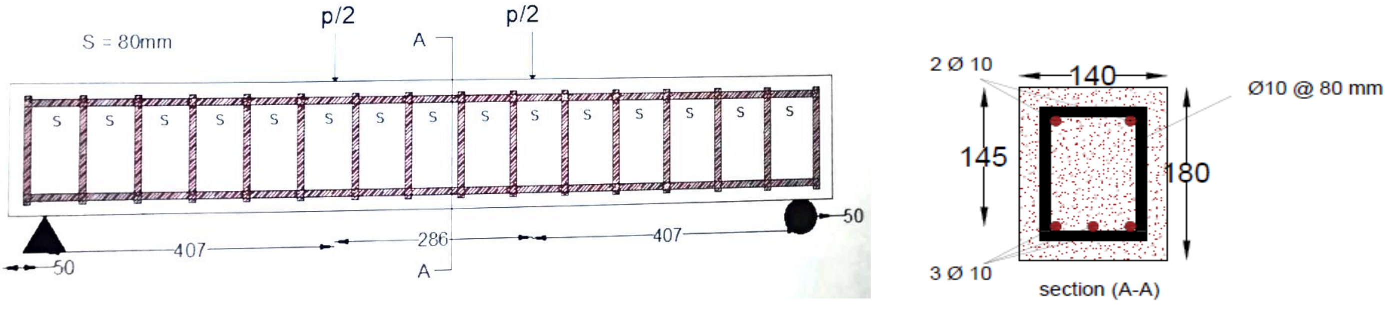


Figure 1. Details of beams for Flexural Strength

All beams mix proportions are illustrated in Table 1.

Table 1. Concrete Mix Proportions

Symbol	Mix proportion	RHA (%)	w/b ratio
A1	**(1: 1.89: 2.64)**	**0**	**0.53**
A2	**(1: 1.89: 2.64)**	**5**	**0.53**
A3	**(1: 1.89: 2.64)**	**10**	**0.53**
A4	**(1: 1.89: 2.64)**	**15**	**0.53**
A5	**(1: 1.89: 2.64)**	**20**	**0.53**
B1	**(1: 1.43: 2.19)**	**0**	**0.44**
B2	**(1: 1.43: 2.19)**	**5**	**0.44**
B3	**(1: 1.43: 2.19)**	**10**	**0.44**
B4	**(1: 1.43: 2.19)**	**15**	**0.44**
B5	**(1: 1.43: 2.19)**	**20**	**0.44**

Some of the parameters are presented and discussed in this research such as ultimate load, maximum deflection, load-deflection relationship. RHA effect on the flexural and modes of failure. All results, were get from finite element analysis by using ANSYS (R15.0), are compared with the experimental results conducted by Mohammed and Sajjad [2].

The lack of performance regarding delays of time, quality, and increase in cost is usually in a construction project [9]. [10] proposed that time delays and increases in cost are mainly due to problems in payment, lack of management by the contractor, issues with material procurement, lack of technical ability, and material price escalation. On the other hand, several researchers have studied the leading causes of defects of quality. For example, [11] recognized as an effort of human and another of which [12] is labeled as poor workmanship. These studies also participated in identifying quality, time, and cost as the three most significant signs to evaluate the performance of the construction project.

The development segment wasteful aspects start from, among various things, developing the expenses of development, battles, and customer dismay, the split idea of the business, little rivalry, and cost increment and postponements [13-17]. Expenses of Swedish lodging development have expanded more than the swelling rate through the most recent decade (1994-2004). In [15] reported to the British Department for Transport, he recognized that transport ventures are on a fundamental level which is dangerous because the long arranging skyline and composite task interface, that regularly instigates varieties related to dithering at the underlying undertaking stages, specialized norms, and states of the geotechnical aspects. Additionally, the nature that considers the split and present moment of development ventures joined with numerous partners with changed purposes makes it challenging to achieve the elevated levels and dependable quality [16].

[18] examined the change orders cost on 22 government development extends and builds up that change orders on these activities that are around 5.5% of the agreement's estimation.[19] set up in his examination that varieties in development undertaking can cost among 10-15% of the estimate of the agreement. [19] likewise settled Framework that has objectives to offer to undertaking change the board with an instrument that will permit development experts to consider and inspect the progressions that occur on ventures from motivation to result. To discover whether a change is conceivable and to decide an outcome that is good for all gatherings.

From the above, it can be concluded that several factors affect the performance of the project, which we can order them as follows, time overruns, cost overruns considered as the main contribution to the degradation in the project performance, therefore, this paper attempted to evaluate the construction project under different circumstances and different periods.

2. Finite element modeling

In this research, a three-dimensional nonlinear finite element analysis (FEA) was performed by using ANSYS (R15.0) as shown in Figure. (2). The analysis and validation of the finite element analysis results were performed by depending on the dimensions and properties of the experimental work carried out by Mohammed and Sajjad, (2020). Figure. (2) shows the details of RHA concrete beam, plate loadings and supports.

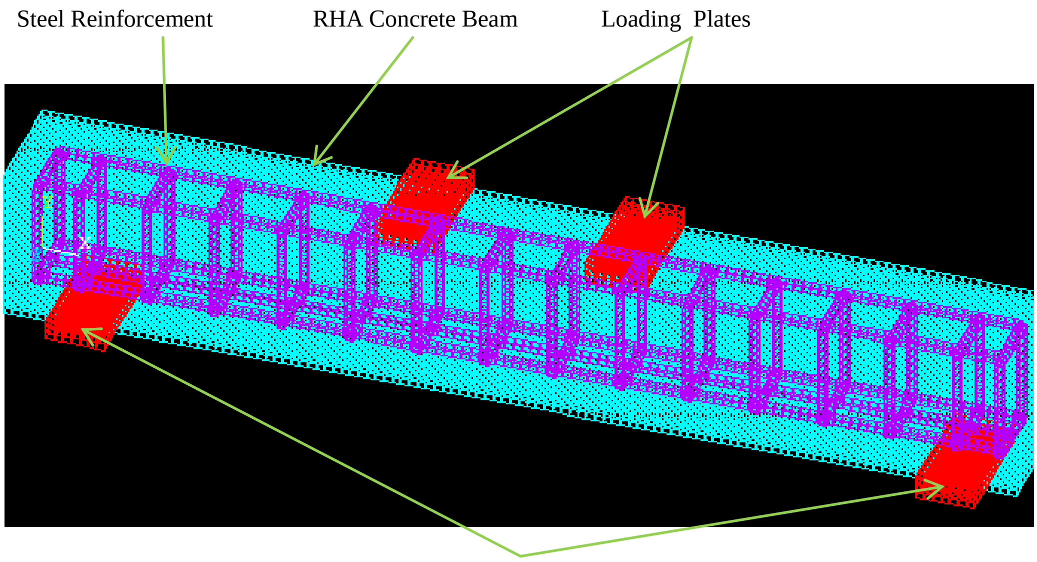


Figure 2. Details of RHA Concrete beam in Ansys

2.1. The RHA concrete beam

Elements as solid 65 were utilized for modeling husk ash of rice as beam of concrete.
In the present research the coming formulas to calculate the multi-linear isotropic concrete stress-strain curve can be used [21]:

$$f = \frac{E_c \varepsilon}{1 + \left(\frac{\varepsilon}{\varepsilon_o}\right)^2} \quad (1)$$

$$\varepsilon_o = \frac{2 f'_c}{E_c} \quad (2)$$

$$E_c = \frac{f}{\varepsilon} \quad (3)$$

Since:

f = stress, kPa

ε= strain

ε_o= ultimate compressive strength strain, f_c'

Point (1), illustrated as (0.3 f_c'), was computed from the linear formula (3). The remain points except last point were computed from equation (1) with (εo) get from formula (2). Strains were elected and the stress was computed for every strain, the last point is illustrated at (f_c').

2.2. **Reinforcing steel**

The type of reinforcing steel used is in the form of round bars. The two main The numerical properties that calculate the reinforcement character are its yield point, generally identical in compression and tension, and it's the modulus of elasticity, Es, the latter is particularly the same for all the steel reinforcement [22]. A bilinear stress-strain curve is adopted for this type of steel. In this stress-strain curve, equal yield stress, σy, in tension and compression is taken; Figure. (3).

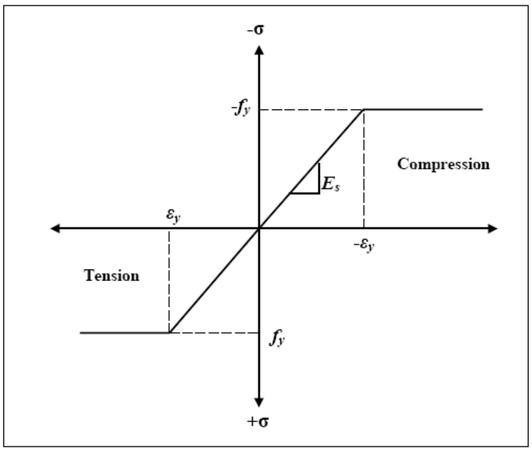


Figure 3. Stress-strain for steel reinforcement

All reinforcements were modeled using Link 8-3D spar element as shown in Figure. (4).

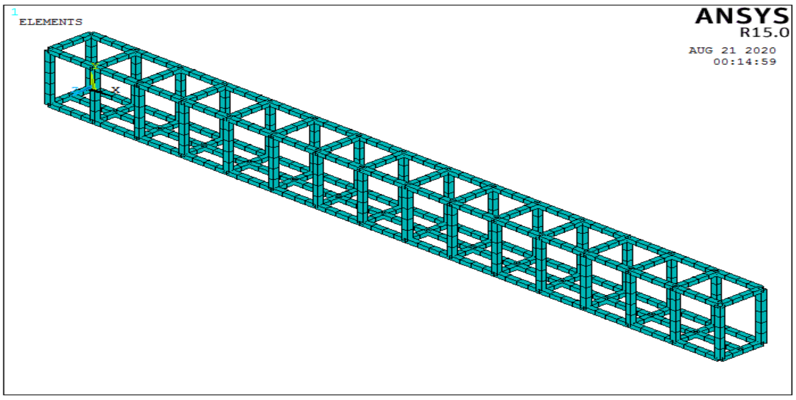


Figure 4. All steel reinforcement in the RHA concrete beam

2.3. **The plates supports and loading**

Plate as steel was utilized as the foundation for loading supports and concrete in order not to be subjected to excessive concentrated local stress, which leads to the stopping of ANSYS operation. These elements contain eight nodes, and every node with 3 freedom degrees at x, y, and z [23]. Using SOLID 185 element, the steel plates had been modeled.

2.4. **Meshing**

The RHA concrete beam and the steel plates were meshed using a size sweep command as shown in Figure (5). This correctly adjusts the length and width of the elements in the concrete parts to be consistent with the nodes and elements in the plates of the model. In order for the rebar to be represented correctly within the program, the rebar and concrete elements must be shared in the same node, and this is done through meshing the model of reinforcement using the elements of line in order to the nodes of elements of the line come exactly above the node of elements of the solid that are subsequently combined.

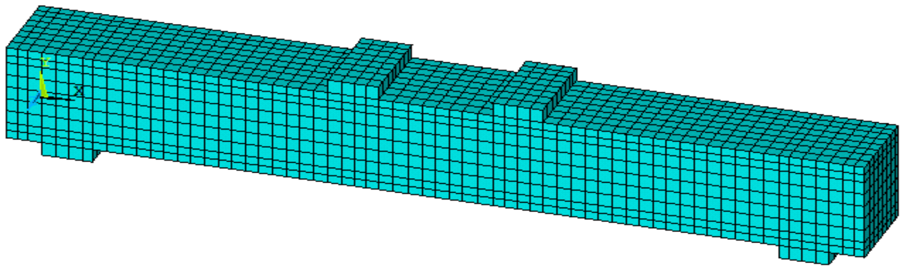


Figure 5. RHA concrete beam meshing

2.5. **Loads and boundary conditions**

For purpose of obtaining a unique solution, the conditions of displacement boundary are required in order to constraining the model. The terms for the boundaries of symmetry were established first. Constraints in UY given at one support and at another support are in UX, UY and YZ, because the beam is simply supported. Figure (6) illustrates boundary and loads conditions are utilized at model.

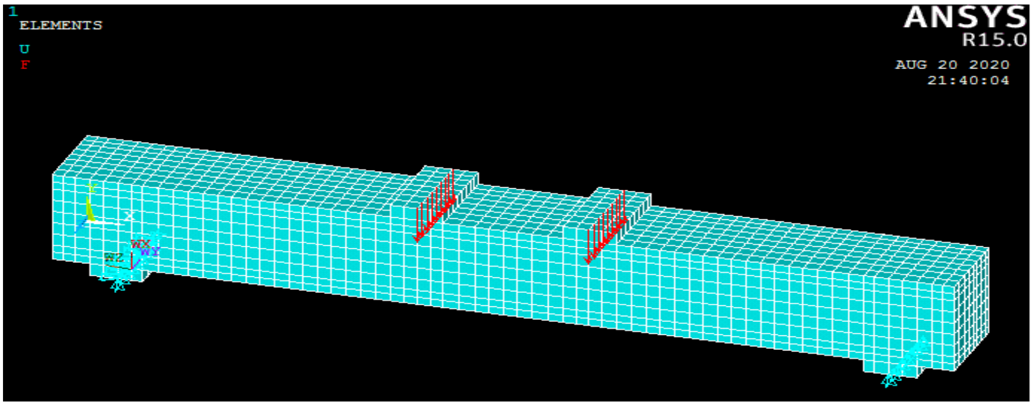


Figure 6. Loads and boundary conditions

3. Analysis results and discussion

3.1. Deformation diagrams

The deformation diagrams of RHA concrete beam at failure load are shown in Figure. (7).

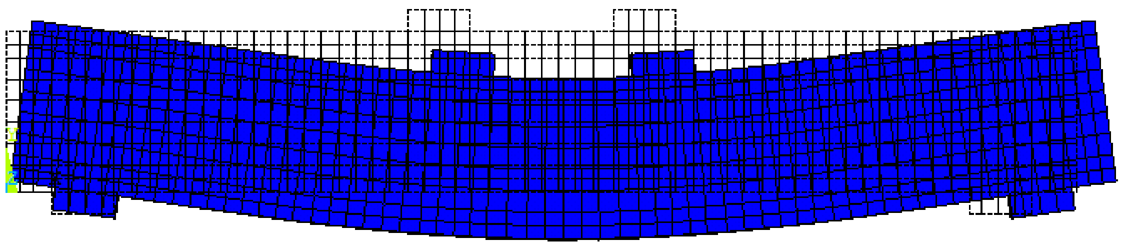


Figure 7. RHA concrete beam deformations

3.2. **Crack pattern**

Figure. (8) shows the crack pattern in the RHA concrete beams that have been analyzed and which also gave good compatibility with the experimental model shown in Figure. (9).

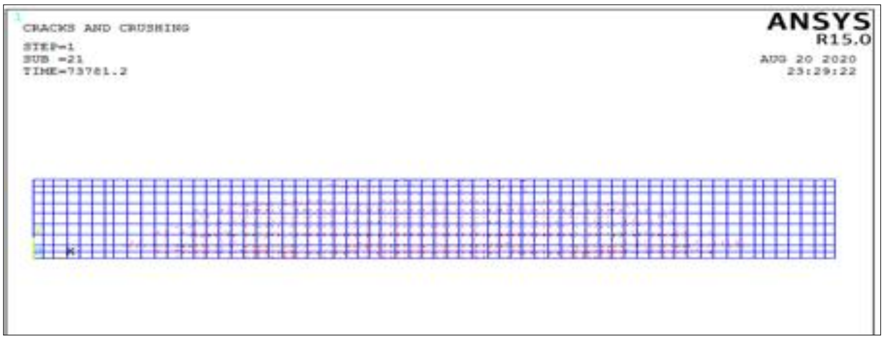


Figure 8. Analytical work crack pattern

Figure 9. Experimental work Crack pattern [2]

3.3. Failure load

The comparison of ultimate load and maximum deflection between finite element and experimental results (by reference 2) are shown in Table (2). From this table, From Table 2 it can be seen that the average of FEM to experimental ratio (for the ten models) for ultimate load was 91.173%, while for maximum deflection was 93.055 %. This indicates that the agreement between finite element results and experimental results are excellent.

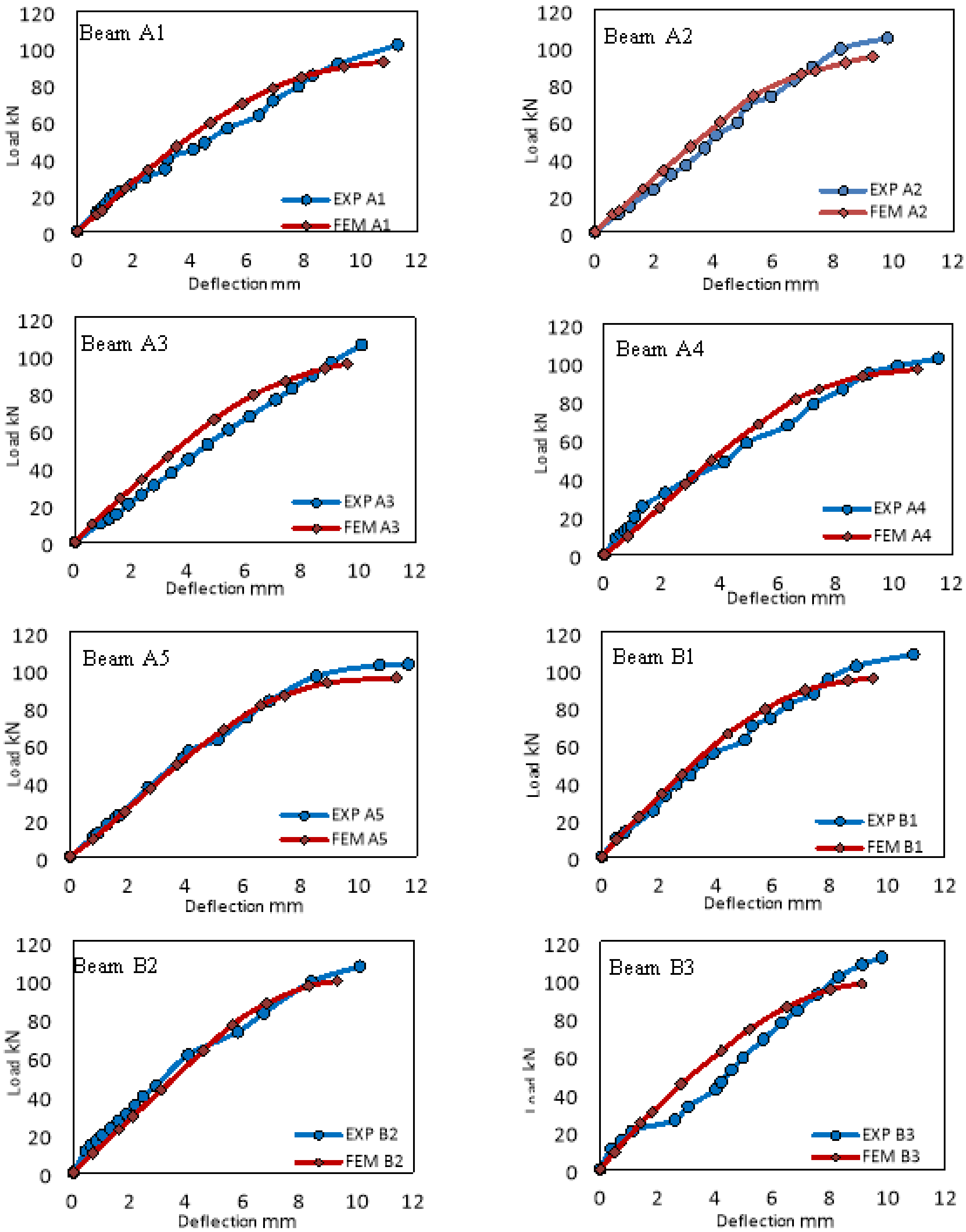
Table 2. Ultimate load and deflection results

Name of Beam	Ultimate Load (kN)			Maximum Deflection (mm)		
	EXP.	FEM	FEM/EXP.	EXP.	FEM	FEM/EXP.
A1	101.3	92.3	0.911155	11.3	10.8	0.955752
A2	104.5	94.6	0.905263	9.8	9.3	0.94898
A3	105.4	95.3	0.904175	10.1	9.6	0.950495
A4	102	96.3	0.944118	11.51	10.8	0.938315
A5	102.7	95.6	0.930867	11.7	11.3	0.965812
B1	108	95.3	0.882407	10.9	9.5	0.87156
B2	107	99.4	0.928972	10.1	9.3	0.920792

B3	111.6	97.8	0.876344	9.8	9.1	0.928571
B4	108.2	98.7	0.9122	9.9	9.1	0.919192
B5	111.3	102.6	0.921833	11.7	10.6	0.905983
Average			0.911733			0.930545

3.4. Load–deflection relationship

The load-deflection curve of analyzed RHA concrete beams is illustrated in Figure. (10). This Figure shows the load-deflection relationship resulted from the analysis of finite element related to the experimental works.



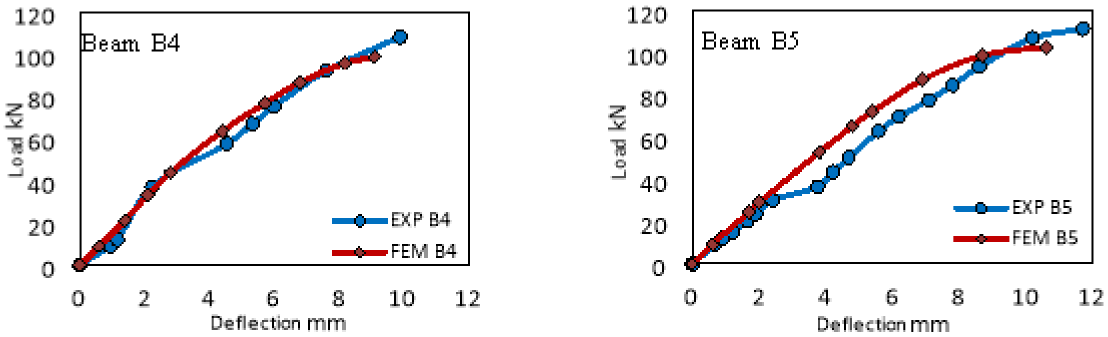


Figure 10. Ultimate load – deflection comparison relationship between experimental and simulation of RHA concrete beams.

4. Conclusions

Results from the FE model and experimental work were compared. The observation from the study can be concluded as follows:

- RHA concrete beams can be modeled by using three dimensional modified analytical modeling.
- Load being ultimate from the element as finite results to the experimental results shows excellent agreement. The average percentage was 91.173%.
- Maximum deflection from the element as finite results to the experimental results shows excellent agreement. The average percentage was 93.055%.
- The crack pattern , failure mode and the load-deflection curve from the analytical model related to the experimental works show good agreement.
- It was observed that all RHA concrete beams of the analytical model failed by flexural similarly to the experimental work.

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