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Behaviour of Optimized Honey Comb Beam Under Monotonic Loading

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ABSTRACT

Honey comb beam is a steel beam which has opening on its web. The advantage of this beam is to increase the bending capacity of the beam due to increasing of inertia moment and plastic moment of steel beam section. There are three important variables which determining the capacity of the honey comb beam, i.e. opening space, opening angle, and opening ratio of the honey comb beam. This paper presents the behavior of honey comb beam which has firstly been optimized and has been done by using fast multi swarm optimization (FMSO). In the previous research, there are two cases of optimization considered. First case is optimization of opening space and opening angle with certain opening ratio, while the second case is optimization of opening space, opening angle, and opening ratio. Based on FMSO, the result showed that the second case of optimization has a better result than first case of optimization. Therefore, in order to validate the result of FMSO, the finite element analysis was conducted to obtain the behavior of optimized section of honey comb beam using monotonic loading.

Keywords: *Honey comb beam; finite element analysis; monotonic loading*.

1. INTRODUCTION

Nowadays, there are several types of steel section properties especially as a beam structure. One type of the beam section which lately popular in building construction is honey comb beam or also known as castellated beam. The main idea of honey comb beam is to increase the bending capacity of “parent” beam due to the increasing of the inertia moment and plastic moment of the steel beam, therefore the performance of honey comb beam is better than that of normal I hot-rolled shape [1].

The bending capacity of the honey comb beam is based on three important variables, i.e. opening space, opening angle, and opening ratio. In the previous research, FMSO has been used to obtain the optimized section of the honey comb beam [2]. To ensure the result of FMSO, finite element analysis was conducted using finite element package, ABAQUS.

Honey comb beams are beam which has opening on its web. Honey comb beams are fabricated by cutting the web of hot rolled steel (HRS) I section into zig-zag pattern and thereafter rejoining it over one another [3]. Fig.1 shows the honey comb beam geometry section, where, Do is opening depth, D is total depth of beam after castellation, tw is web thickness, tf is flange thickness, b is flange width, S is gross opening space, e is clearing opening space, e is opening angle.

2. METHODOLOGY

Generally, there are 4 steps for solving the finite element with computational calculation [4]

a. Build a geometry model
b. Discretization (element meshing)
c. Material properties
d. Determining the boundary condition, initial condition, and loading condition.

ABAQUS is one of many finite element software that has good ability to predict the behavior of structure. There are several types of element in ABAQUS [5].

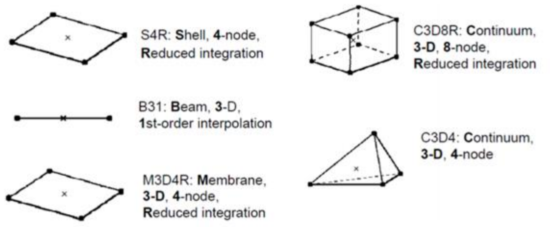

Fig. 1. Element types of ABAQUS [6]

Fig. 1. Shows the element adopted by ABAQUS

This paper used S4R (shell 4 nodes with reduced integration and hourglass control) element for modelling the honey comb beam. This shell element fits for assuming a thin plate element and this shell element has been used and has been validated with the experimental test by many previous research [7], [8].

A. Optimized Honey Comb Beam

Honey comb beam which considered in this paper is the optimized honey comb beam that has been done in the previous research [2] using FMSO. FMSO is the modified optimization technique from particle swarm optimization (PSO) which first proposed by Kennedy and Eberhart [9] and be modified become FMSO by Zhang [10]. Fig. 3. shows the beam structure used for optimization purpose while Table 1 shows the section properties and material properties of parent beam. Previously, there are two cases of optimization considered. The first case is to optimize only the opening space (e) and the opening angle (α) with constant depth ratio (Do/H=0.6) and the second case did the optimization for three variables simultaneously (the optimum opening space, opening angle, and depth ratio).

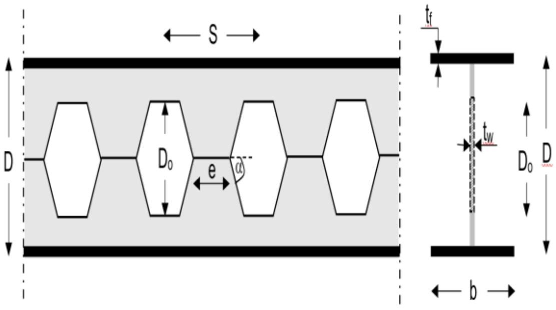

Fig. 2. Honey comb beam geometry

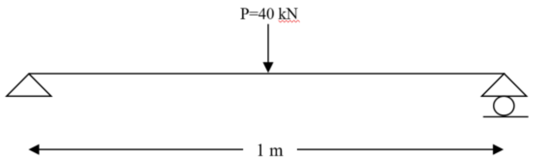

Fig. 3. Simple supported beam with point load at mid span

Table 1. Section properties and material properties for parent beam

Overall depth (H)	200 mm
Flange width (b)	100 mm
Web thickness (t_w)	5.5 mm
Flange thickness (t_f)	8 mm
Yield stress (F_y)	240 MPa
Elastic modulus material (E)	200000 MPa

Table 2 shows the optimization result for first case and second case [2]. In first case, optimum clearing space opening was 74.9938 mm and optimum opening angle was 58.5839°. The fitness value for the first case is 2.6429x1011. Then, for the second case, optimum clearing opening space, optimum opening angle, and optimum Do/H ratio which obtained were 56.4083 mm, 56.1477°, and 0.4587 respectively with Do/D ratio was 0.6289 and the fitness value was 2.4187x1011. It can be clearly seen that the second case (with Do/H ratio optimization) showed better result than the first case (without Do/H ratio optimization).

Table 2. Optimization result for both cases

Optimization parameters	First Case (e, α optimization)	Second Case (e, α, D_o/H ratio optimization)
e (clearing opening space)	74.9938	56.4083 mm
α (opening angle)	56.5839°	56.1477°
D_o/H ratio	-	0.4587
Fitness value	2.6429x10^{11}	2.4187x10^{11}

Based on Table 2, it can be seen that based on the FMSO, second case shows a better result compared by first case which according to the fitness value. The fitness value of second case is lower than the fitness value of first case (2.4187x1011 < 2.6429x1011).

3. RESULT AND DISCUSSION

Fig. 4. shows the beam structure with loading condition and boundary condition. Monotonic loading was applied at the middle of the beam. The beam was loaded until the maximum capacity of the beam was reached and in order to obtain the behavior of optimized castellated beam for the first and second case.

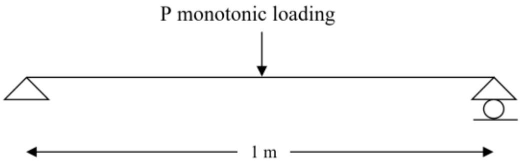

Fig. 4. Simple supported beam with point load at mid span

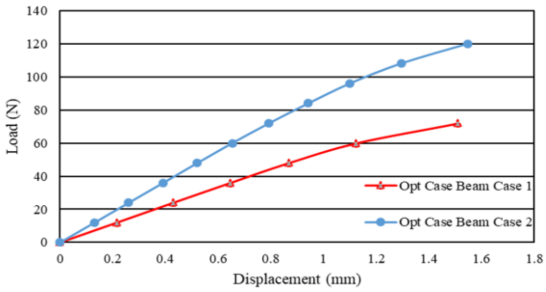

Fig. 5. Load-displacement relationship for optimized beam.

Table 3 shows the result of first case and second case. It can be seen that, only the yield displacement for first case is higher than the second case, but others behavior variable of second case such as yield load, maximum displacement, maximum load, and ductility shows better behavior than first case. Yield load of the second case is 1.6 times from yield load of the first case. Maximum displacement of the second case is 1.026 times than the maximum displacement of the first case. Maximum load for the second case is 1.6667 times than the maximum load obtained of first case and ductility of second case is 1.0387 times than the ductility obtained of first case.

Table 3. Result comparison of first case and second case

	First Case	Second Case
Yield displacement (mm)	1.1237	1.11
Yield load (kN)	60	96
Maximum displacement (mm)	1.5093	1.5486
Maximum load (kN)	72	120
Ductility	1.3432	1.3951

Based on the Table 3, it can be seen that, displacement variable, e.g. yield displacement and maximum displacement is not significantly different between first case and second case. But a significant different for load variable such as yield load and maximum load. Load variable of the second case is higher than the first case.

Table 4. Elastic and post elastic stiffness

	First Case	Second Case
Elastic stiffness (kN/mm)	53.3950	86.4865
Post elastic stiffness (kN/mm)	31.1203	54.7196

Table 4 shows the elastic stiffness and post elastic stiffness for the first case and second case. The elastic stiffness of second case is 1.6197 times than the elastic stiffness of first case and for the post elastic stiffness, the second case is 1.7583 times than the elastic stiffness.

4. CONCLUSION

This paper considered two optimized honey comb beam subjected to monotonic loading. First case is honey comb beam with optimization of opening space and opening angle with certain opening ratio, while the second case is honey comb beam with optimization of opening space, opening angle, and opening ratio. Based on the previous result, the second case has a better result than the first case. This is according to the fitness value of second case is lower than the first case. Therefore, the aim of this paper is to validate the result using finite element method for obtaining the behavior of both cases. Based on the result, it can be concluded that the second case optimization of honey comb beam has a better behavior compared with the first case optimization.

REFERENCES

[1] Tonapa, S.R., Sandy, D., and Parung, H., 2015. "Behaviour of honey comb beam-columns subjected to monotonic and cylic loadings". International Journal of Engineering and Science Applications, pp 147-152.

[2] Frans, R., Parung, H., Muhiddin, A.B., and Irmawaty, R., 2016. "Optimization of Short-Span Hexagonal Castellated Beam Using Fast Multi Swarm Optimization". International Seminar on Infrastructure Development, Indonesia.

[3] Jamadar, A.M. and Kumbhar, P.D., 2015. "Parametric study of honey comb beam with circular and diamond shaped openings". International Research Journal of Engineering and Technology, India, 2015, Volume 2, pp 715-722.

[4] Utomo, J. 2017. "Pengembangan Pendisipasi Energi Dari Pipa Baja Untuk Proteksi Seismik Bangunan". Disertasi Program Doktor ITB.

[5] ABAQUS/Standard, ABAQUS Analysis User’s Guide, ABAQUS, 2016. Hibbit, Karlsson and Sorenson Inc., Providence, RI, 2016.

[6] ABAQUS/Standard, User’s Manual I-III, version 6.5, Hibbit, Karlsson and Sorenson Inc., Providence, RI, 2005.

[7] Gizejowski, M.A., and Salah, W.A. 2007. “Numerical Modelling of Composite Castellated Beams”.

[8] Prakash, A.N., Anandavalli, N.C.K., Madheswaran, C.K., Rajasankar, J., and Lakshmanan, N., 2011. “Three Dimensional FE Model of Stud Connected Steel-Concrete Composite Girders Subjected to Monotonical Loading”. International Journal of Mechanics and Applications. Volume 1(1), pp 1-11.

[9] Kennedy, J and Eberhart. R.C., 1995. “Particle Swarm Optimization. In Proceedings of the 1995 IEEE International Conference on Neural Networks”. IEEE Service Center, Piscataway, pp 1942-1948.

[10] Zhang,Q., Li, C., Liu, Y., and Kang, L., 2007. “Fast Multi-swarm Optimization with Cauchy Mutation and Crossover Operation”. Proceedings of Advances in Computation and Intelligence, Springer-Verlag, Berlin Heidelberg, pp 344-352.