Influence of Randomized Data Code in Harmony Search Method for Steel Structure Arrangement

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ABSTRACT

Harmony search (HS) method is widely used for solving engineering optimization problems and gives global solution of the problems. But the Pitch Adjustment strategy shows a little weakness inside HS. In this paper HS's performance for solving engineering problem will be discussed between in sorted and randomized candidate solution code. Three steel structure models are arranged with HS using sorted and randomized data code. HS needs 1.32 until 9.92 times iteration with randomized data code compared with sorted data code. HS solves the problems easier with Pitch Adjusting Rate (PAR) 0.2 than 0.8. It is concluded that HS is powerful for solving steel structure arrangement in sorted data code and in small PAR.

Keywords: Arrangement, harmony search, pitch adjusting rate, steel frame structure.

INTRODUCTION

Many meta-heuristic algorithms combining rules and randomness imitating natural phenomena have been developed to satisfy the computational drawbacks of numerical algorithms for solving engineering optimization problems. These algorithms include harmony search (HS) method in which is widely used for optimization problems and it gives global solution of the problems especially in steel structure optimization (Khalifa, 2011). The main parameters in HS are Pitch Adjusting Rate (PAR), Harmony Memory Consideration Rate (HMCR), Harmony Memory (HM) and Harmony Memory Size (HMS). The PAR indicates how the melody adjusted little up or down. But this pitch adjusting strategy can work whether the candidate solutions stand in sorted condition. Or in other word, HS has one impairment if candidate solutions placed in random position. Then it is so interesting if randomized data code can influence HS's performance. So in this paper HS's performance for solving one engineering problem will be discussed between in sorted and randomized placed candidate solutions.

THEORIES

Column and Beam Arrangement Concept

Building always has stronger elements than elements at lower storey. Stronger columns are placed below the column at upper story and also the beams (Budiati, 2013). Through this elements arrangement, the structure can serve "Strong Column Weak Beam" concept (Ghozi, 2011). Profile's width and depth are also considered to ensure the application in the construction phase. The colum in the lower storey must have profile's depth bigger than column in upper storey. The column's width must be bigger than beam's width (see Fig. 1). This consideration ensures beam can be connected to column (Safari, 2011).

Harmony Search

Harmony search (HS) meta-heuristic algorithm having the purpose to produce better solution than other existing algorithm in less number of iterations. In current international literature

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one can find variety of applications of HSA and number of publications on HSA can be found. The flowchart of HS method is shown in Figure 2 (Patil, 2013).

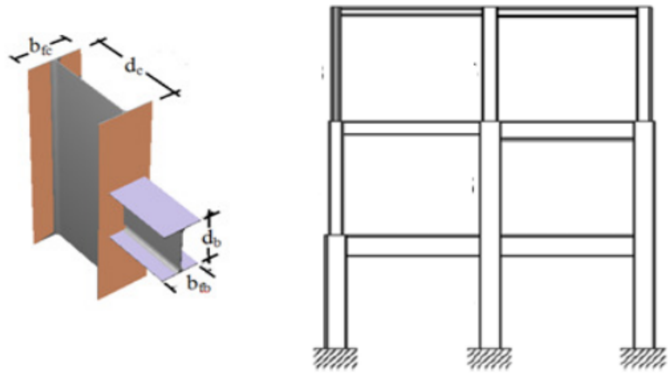

Figure 1. Notations and well arranged profile (Safari, 2011)

Analogy between the optimum design of steel frames and the music improvisation process which is used in HS can be established in the following way (Khalifa, 2011) :

1) The harmony denotes the design vector.
2) The different harmonies during improvisation represent the different design vectors throughout the optimum design process.
3) Each musical instrument denotes the design variables (steel sections) of objective function.
4) The pitches of the instruments represent the design variable's values (steel section code).
5) A better harmony represents local optimum and the best harmony is the global optimum.

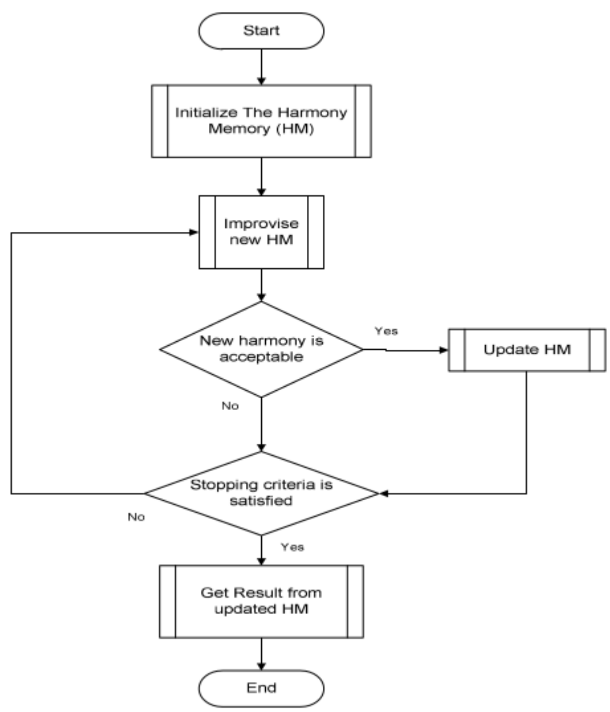

Figure 1. Flowchart of HS (Geem, 2001)

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MATERIAL AND METHOD

The objective function for solving the WF steel arrangement is:

$$objfunc = Weight * \left\{ 1 + \sum_{j=1}^{nstorey} K\_CD_j + \sum_{j=1}^{nstorey} K\_BD_j + \sum_{j=1}^{nstorey} K\_BC_j \right\}^2 \quad (1)$$

Where :

K_CD_j is Column's depth constraint at storey j.

K_BD_j is Beam's depth constraint at storey j.

K_BCo_j is Beam-Column flens ratio constraint at storey j.

And

$$K\_CD = 0 \ \ if \ \frac{d_c upper\ storey}{d_c lower\ storey} < 1 \qquad K\_CD = 1 \ \ if \ \frac{d_c upper\ storey}{d_c lower\ storey} \geq 1 \quad (2)$$

$$K\_BD = 0 \ \ if \ \frac{d_b upper\ storey}{d_b lower\ storey} < 1 \qquad K\_BD = 1 \ \ if \ \frac{d_b upper\ storey}{d_b lower\ storey} \geq 1 \quad (3)$$

$$K\_BC = 0 \ \ if \ \frac{b_{fb}}{b_{fc}} < 1 \qquad K\_BC = 1 \ \ if \ \frac{b_{fb}}{b_{fc}} \geq 1 \quad (4)$$

Where :

d_c is Column's depth .

d_b is Beam's depth.

b_{fb} is Beam's flens width.

b_{fc} is Column's flens width.

The group and decision variable of each structure model are shown in Table 1 below.

Table 1. Number of decision variable and stopping criteria

No	Structure Model	Number of Decision Variables	Weight for Stopping Criteria
1	3 storey	6	4800 kg
2	10 storey	9	26800 kg
3	15 storey	12	50000 kg

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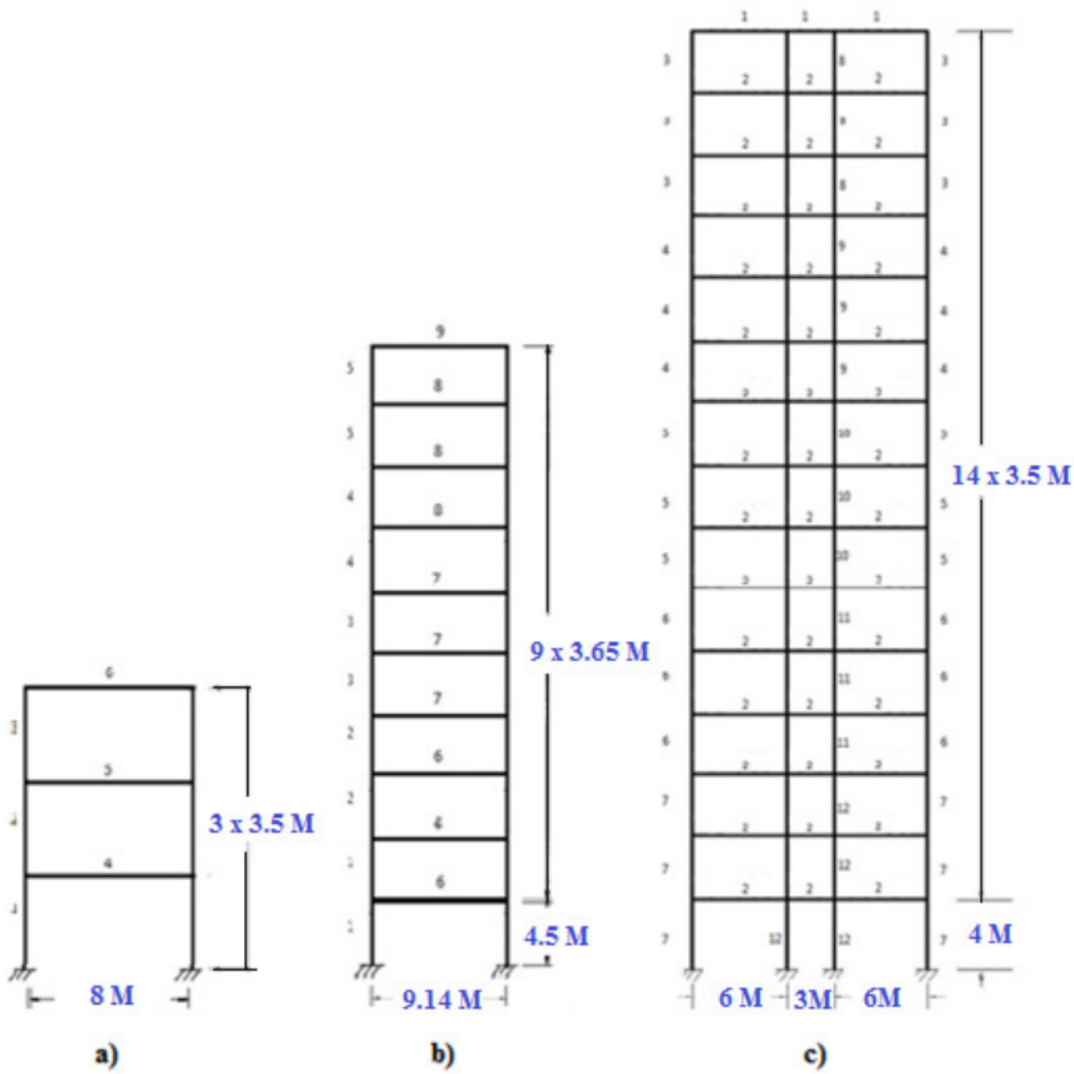

Figure 13. Structure model: a) The three storey, b) The ten Storey, c) The 15 Storey.

HS process is then deployed with the parameters: HMS=30, maximum iteration=10000, HMCR=0.9, PAR 0.2 until 0.8. The stopping criteria is "stop process if weight of structure is smaller than the determinated weight and no constraint is violated". Every test is run 100 times to get the average of iteration (see Fig 3).

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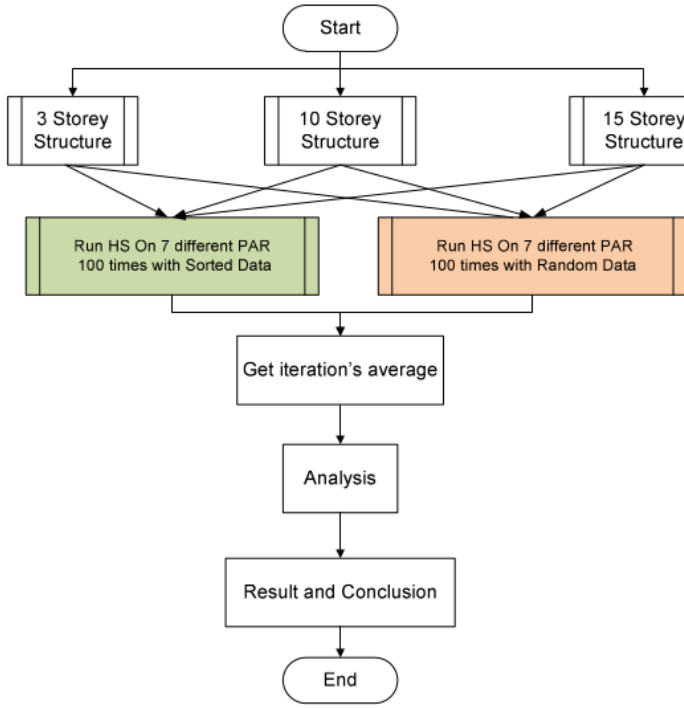

Figure 14. Research Method

The candidate solution will be placed in two types. In the first type, candidate solutions are placed in sorted condition based on WF's depth. And in the second type, candidate solutions are placed in randomized condition. The 267 WF profiles are taken from AISC profile list. The sample of sorted and randomized data code are shown in Table 1 below.

Table 2. Sorted and randomized Data code

Code	Sorted Section Name	depth (cm)	width (cm)	Area (cm^2)	Randomized Code	Section Name	depth (cm)	width (cm)	Area (cm^2)
1	W4X13	10.57	10.31	24.71	101	W4X13	10.57	10.31	24.71
2	W5X16	12.73	12.70	30.39	259	W5X16	12.73	12.70	30.39
3	W5X19	13.08	12.78	35.87	30	W5X19	13.08	12.78	35.87
4	W6X8.5	14.81	10.01	16.19	194	W6X8.5	14.81	10.01	16.19
5	W6X9	14.99	10.01	17.29	215	W6X9	14.99	10.01	17.29
6	W6X15	15.21	15.21	28.71	16	W6X15	15.21	15.21	28.71
7	W6X12	15.32	10.16	22.90	70	W6X12	15.32	10.16	22.90
…	…	…	…	…	…	…	…	…	…
267	W44X335	111.76	40.64	634.19	260	W44X335	111.76	40.64	634.19

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RESULT AND DISCUSSION

HS for solving three steel structure models arrangement have been deployed. HS is executed 100 times for every structure models, for every PAR and for every data code type. Iteration's average for every PAR is displayed in Tables 3 and Table 4 and $\frac{HS\ iteration\ of\ randomized\ data}{HS\ iteration\ of\ sorted\ data}$ ratio is shown in Figure 5 below.

Table 3. Iteration's average of HS with sorted data

Model	PAR						
	0.2	0.3	0.4	0.5	0.6	0.7	0.8
3 Storey	456.43	484.63	578.95	513.93	630.83	637.43	713.86
10 Storey	338.90	380.30	435.35	360.70	374.22	369.09	435.00
15 Storey	631.31	645.43	719.9	770.85	844.28	931.37	1063.6

Table 4. Iteration's average of HS with randomized data

Model	PAR						
	0.2	0.3	0.4	0.5	0.6	0.7	0.8
3 storey	626.60	853.76	942.80	1239.18	1701.19	2271.20	2821.40
10 Storey	931.04	1185.57	1661.19	2336.92	2890.98	3223.5	4316.32
15 Storey	891.70	1239.39	1579.20	2416.45	2937.75	4206.71	7031.77

The data in Table 2 and Table 3 are then displayed in graphic mode for making it easier to be understood.

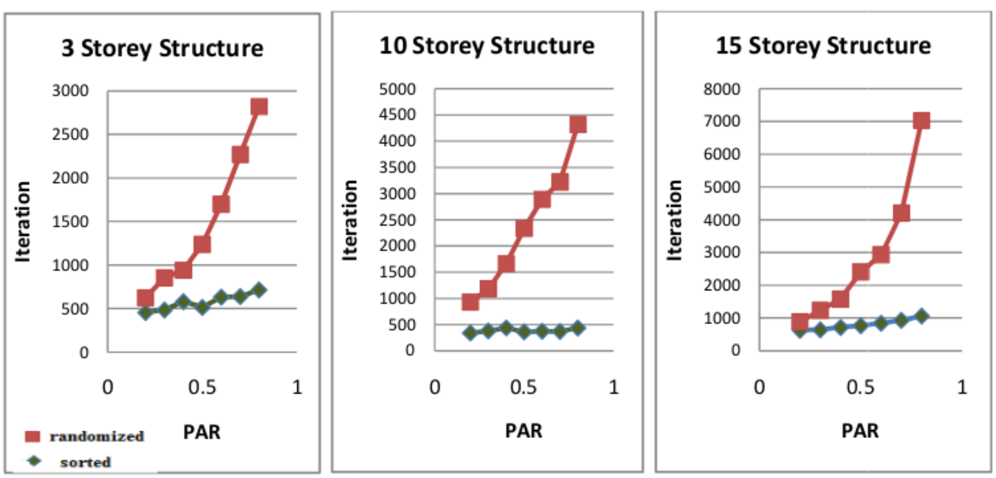

Figure 15. HS's average iteration on 7 different PAR

For the three storey structure model, HS needs 456, 484, 578, 513, 630, 637, 713 iterations on PAR 0.2 to 0.8, respectively, to satisfy the profile's configuration. When HS uses randomized data code, HS needs 626 until 2821 iteration to finish the process. HS needs 1.32 until 3.95 times iteration of sorted data code when using randomized data code (see Fig. 5).

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For the ten storey structure model, HS needs 338, 380, 435, 360, 374, 369, 435 iterations on PAR 0.2 to 0.8, respectively, to satisfy the WF profile's configuration. When HS uses randomized data code, HS needs 931 until 4316 iteration to finish the process. HS needs 1.41 until 6.61 times iteration of sorted data code when using randomized data code.

For the 15 storey structure model, HS needs 631, 645, 719, 770, 844, 931, 1063 iterations on PAR 0.2 to 0.8, respectively, to fulfill the WF profile's configuration. When HS uses randomized data code, HS needs 831 until 7031 iteration to finish the process. HS needs 2.75 until 9.92 times iteration of sorted data code when using randomized data code.

It can be seen that HS can solve WF profile arrangement with sorted and randomized data code. HS needs more iteration in PAR 0.8 than PAR 0.2 for both data code type for three steel structure model. The $\frac{iteration\ of\ randomized}{iteration\ of\ sorted}$ ratio is then displayed in Figure 5 below. So it is advised to solve WF profile arrangement problem using HS with little PAR value and sorted data code.

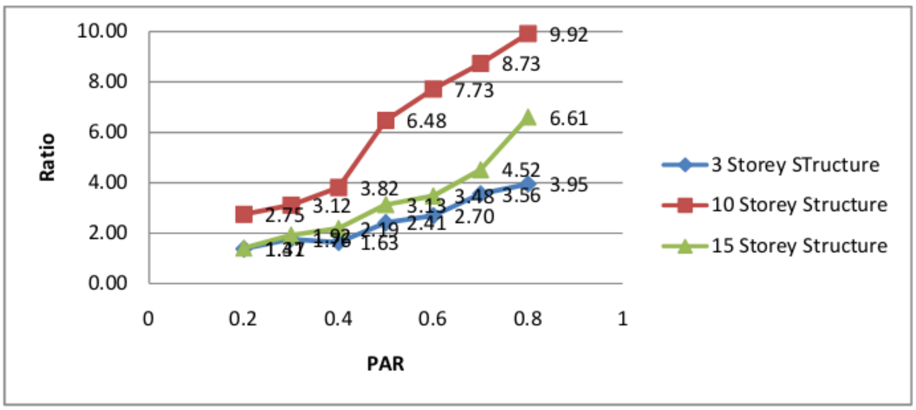

Figure 16. $\frac{HS\ iteration\ of\ randomized\ data}{HS\ iteration\ of\ sorted\ data}$ ratio.

CONCLUSION

Research of comparing HS performance using sorted and randomized data code is already carried out. HS can solve WF profile arrangement problem using sorted and randomized data code. HS solves problem with sorted data code easier than with randomized data code. HS needs more iterations in PAR 0.8 than PAR 0.2 for both data code type.

FUTURE WORK

Some research can be applied to continue this paper. It would be advisable such as combining Finite Element Analysis with HS for justification of this paper's conclusion.

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