Optimization System For Indonesian Steel Structure Using Genetic Algorithm And Sni 1726-2012

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Abstract
Optimization process have been the main problem for civil engineer and designer. The problem comes with how to accommodating specific ready stock WF Profile, SNI 1729-2015 Indonesian steel design code and SNI 1726-2012 Indonesian earthquake design code. In this paper, the problems is solved with combination of Chromosome Repairing (CR) - Genetic Algorithm (GA) – Finite Element Method (FEM) and then verified with commercial FEM program. The structure's weight model is 29050 Kg which remain not to violate all predefined Indonesian constraints. It is concluded that combined GACR-FEM successfully provide optimized Indonesian steel structure.

Keywords: Genetic algorithm, Optimization, Steel structure, SNI 1726- 2012 earthquake design code, SNI 1729- 2015 Steel Structure Design code

INTRODUCTION
Commercial Finite Element Method (FEM) program commonly is not designed for optimization process and has lack in iterative process. On the other hand, the application of genetic algorithms (GA) has been become the automated design of steel frame structures. One excellent method was combining commercial SAP2000 program with GA method in single PC and in parallel computing method (Ghozi, 2011) and combining the Chromosome repairing module (Budiati, 2013). But those methods still have lacks in the time required for completing the optimization process.
Since the advantage and lacks of commercial FEM program have already known for analyze and design structure and its combination with GA, it will be good for using combination of Chromosome Repairing (CR)–GA-FEM for research in optimizing Indonesian structure. For thisreason, itwillbediscussedthe combination of GA-FEM–SNI2015 for obtaining fittest WF profiles in 2D steel structure and then SAP2000 will be used to verivy the result.

THEORIES
THE 2015 INDONESIA STEEL STRUCTURE DESIGN CODE
Indonesia already had regulation for steel design. The regulation is written in SNI 1729-2015 code and requires all member shall pass H1-1 AISC-LRFD requirement. The Indonesia code also defined inter story drift of steel moment frame accommodated through a combination of elastic and inelastic frame deformations. Strong column and weak beam design philosophy also accommodated in this code (SNI, 2015). 2015 Indonesian steel design code regulate slenderness for predetermined values. The slenderness are restricted in form:

$$\frac{Lb}{ry} > 0.086\,\frac{E}{F_y} \qquad (1)$$

$$\frac{L}{r} > 60 \qquad (2)$$

$$\frac{K\,L}{r} > 5.87\,\sqrt{\frac{E}{F_y}} \qquad (3)$$

THE 2012 INDONESIAN EARTHQUAKE DESIGN CODE
The 2012 Indonesian earthquake design code devines response spectrum value Indonesia depend on location lattitude and longitude (see Fig. 1). For each location and soil type denotes specific response spectrum. Response Spectrum for Surabaya City are displayed as shown in Fig 2. The maximum spectrum responses are 0. 42, 0. 56, 0. 61, for hard soil, medium soil and soft soil, respectively (SNI, 212).

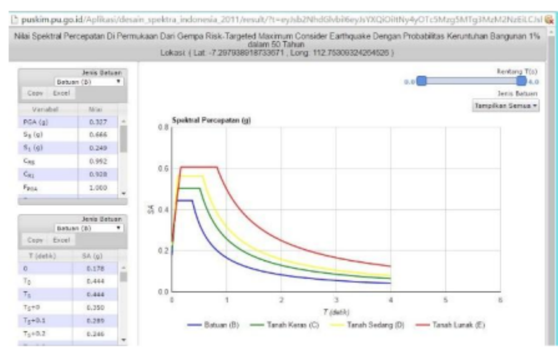

Figure 1: Surabaya peak ground acceleration.

FINITE ELEMENT METHOD
Finite element method came in several steps:

1. FEM model Preparation. The analyst shall
   a. Discretize the structure by dividing it into finite elements,
   b. Prescribe the structure's load.
   c. Prescribe the structure's supported.

2. The calculations. The software must:
   a. Generate local stiffness matrix k of each element,

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b. Assemble the element k matrices to obtain the structure or "global" matrix K,
c. Assemble loads into a global load vector R,
d. Impose support conditions, and
e. Solve the global equations KD = R for the vector D of displacement of the nodes.

3. Post processing information in D and it means compute strains and stresses.

Details of FEM can be found in the referenced book (Cook, 1995). All FEM script are written in MS Visual Basic 6. 0 programming language. The data of WF profile properties and the data during optimization process are saved in file with. MDB extension.

GENETIC ALGORITHM (GA) AND CHROMOSOME REPAIR (CR).

GA is a strategy inside group of Evolutionary Algorithm (EA). GA with population-based global search strategy run the evolution theory. Usually GA startedwithinitizalizationof population, andthenfollowedby evaluate population, selection, mating, crossover, mutation, stopping criteria and get results(Goldberg, 1989). These steps are displayed as seen in Fig. 3. For the FEM as "expensive" process so CR is deployed to fit the chromosome due to variables before FEM process. This combination is named Genetic Algorithm – Chromosome Repairing (GACR). These variables are fitted to dimension aspects (such as height of profiles, weight structures, etc.) and the data area obtained through ordinary program, not FEM. Individual ofpopulation are presentedbychromosomes in whichthecombinationofgenotypes (Budiati, 2013). In thispaper, genotypes are takenfrom WF profileprovidedandreaystock in marketplace in Indonesia. The codeofgenotypesandPhenotypes are thendisplayed in Table 1.

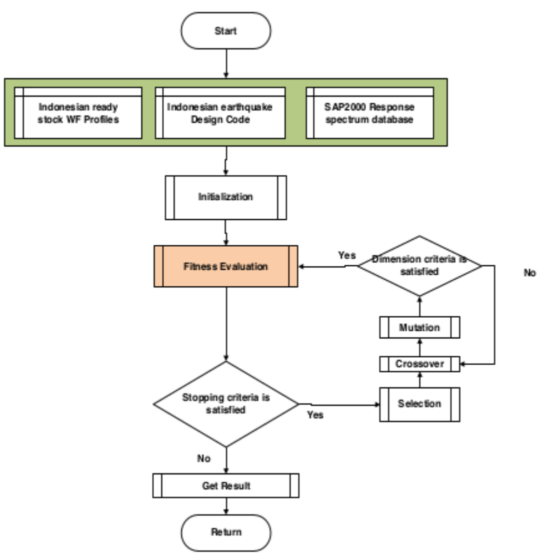

Figure 2: Flowchart of GACR (Budiati, 2013).

Table 1: GenotypeandPhenotypeofreadystock WF Profile in Indonesia.

Genotype	Phenotype	H	W	FlensThick	Web Thick
001	100x100	10	10	0, 8	0, 6
002	150x150	15	15	1	0, 7
003	150x75	15	7, 5	0, 7	0, 5
004	200x100	20	10	0, 8	0, 55
005	200x200	20	20	1, 2	0, 8
006	250x125	25	12, 5	0, 9	0, 6
007	300x150	30	15	0, 9	0, 65
008	300x300	30	30	1, 5	1
009	350x175	35	17, 5	1, 1	0, 7
010	350x350	35	35	1, 9	1, 2
011	400x200	40	20	1, 3	0, 8
012	450x200	45	20	1, 4	0, 9
013	500x200	50	20	1, 6	1
014	600x200	60	20	1, 7	1, 1
015	600x300	60	30	2	1, 2
016	700x300	70	30	2, 4	1, 3
017	800x300	80	30	2, 6	1, 4
018	900x300	90	30	2, 8	1, 4
019	900x303	90	30	3	1, 6
020	900x306	90	30	3, 4	2
021	900x350	90	35	3, 8	2, 2
022	900x400	90	40	4, 2	3, 4
023	999x400	100	40	5, 8	3, 4
024	999x300	105	31	6, 4	3, 6
025	999x420	109	42	8, 2	4, 5

MATERIAL AND METHOD

STEEL STRUCTURE MODEL.

The structure to be optimized is 2D 10 stories Original Moment Frame (OMF) steel structure. Each story has 9. 14 Meter height except the first floor has and each beam has 9. 14 Meter length. 6 different group types of columns are used in every floor and also 4 different froup types of beams are used in every floor (see Fig. 3).

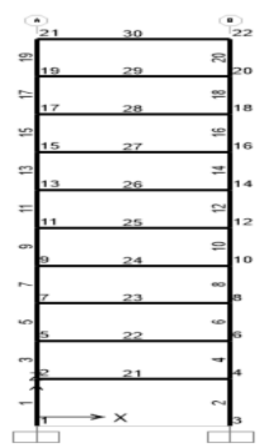

Figure 3: 2D steel structure model.

The structure has dead load in 89. 29 Kg/cm for each floor, 44. 64 Kg/cm for roof and the earthquake's parameters are OMF structure type, medium soil, location in Surabaya City. Earthquake force is defined by auto lateral load according to of Surabaya's response spectrum, SRSS directional combination, modal analysis case use 12 modes Eigen vector type mode. The unbraced length factor in out of plane direction for column defined to be 1 and for beam is set to 0. 2.

The objective function is to minimize weight subject to three constraints (stress constraint, displacement constraint, dimension constraint) and forms as:

$$Objfunc = \sum \rho_i A_i L_i \,(1 + \left(\sum \frac{D}{C} ratio_{el} + \sum Drift_{storey} + \sum Cc_{storey} + + \sum Cbc_{storey} + \sum slendernes_{el}\right) \quad (4)$$

Where Objfunc is objective function, ρ is unit weight, A is Area of cross sectional, L is length of element, $\frac{D}{C} ratio_{el}$ is Demand / capacity ratio due to element's stress, $Drift_{storey}$ is drift storey constraint, Cc_{storey} is Column's depth constraint, and Cbc_{storey} is beam's widt to colum's width ratio.

For displacement constraint, the interstory drift is limited to 2% times the story height for T>0. 7second. For stress constraints, the D/C ratio of each element is limited with equation:

$$\frac{D}{C} ratio = \frac{P_u}{\varphi P_n} + \frac{8}{9}\left\{\frac{M_{u33}}{\varphi b M_{n33}} + \frac{M_{u22}}{\varphi b M_{n22}}\right\} for \frac{P_u}{\varphi P_n} \geq 0.2 \quad (5)$$

$$\frac{D}{C} ratio = \frac{P_u}{2\varphi P_n} + \left\{\frac{M_{u33}}{\varphi b M_{n33}} + \frac{M_{u22}}{\varphi b M_{n22}}\right\} for \frac{P_u}{\varphi P_n} < 0.2 \quad (6)$$

Where Pu is the required compressive strength, Pn is the nominal compressive strength, Mu is the required flexural strength, Mn is the nominal flexural strength, φ = 0:85 and φ b = 0, 9. The D/C ratio is displayed by SAP2000 program after Run-Design process (CSI, 2000).

The dimension constraint maintains chosen WFprofiles to be available for construction. In this constraint the depth of lower column has to be bigger than upper column, the depth of lower beam has to be bigger than upper beam. Those ratio of dimension constraint at every floor must under 1, with form as:

$$C_c = \sum_{storey=1}^{storey} \frac{DC_{storey}}{DC_{storey-1}} < 1 \quad (7)$$

$$C_{bc} = \sum_{storey=1}^{storey} \frac{Wb_{storey}}{WC_{storey-1}} < 1 \quad (8)$$

Where R is dimension constraint ratio, $H_{lowercol}$ is Height of lower column profile. $H_{uppercol}$ is Height of upper column profile. $H_{lowerbeam}$ is Height of lower beam profile. $H_{upperbeam}$ is Height of lower column profile.

METHOD

This research is carried out by several phase. The first phase is reviewing (surveying) the ready stocked WF profiles in Indonesia, Literature study about 2015 Indonesia Steel structure design code and 2012 Indonesia earthquake design code. After Studying and surveying phase, then second phase is deployed. The second phase is inserting the response spectrum values of Surabaya into SAP2000 response spectrum function database. The values of response spectrum are preserved by Indonesian "*desain spectra Indonesia 2011*"in http://puskim. pu. go. id/Aplikasi web page through location of Surabaya city with Latitude -7. 27989 Longitude 112. 75. The third phase is the optimization process and deployed with Original Moment Frame, medium soil for obtaining the optimum structure weight. Analysis of the data is performed to get the relationship among structure weight in different soil type and earthquake zone. The flowchart of phases in this research is displayed as shown in Fig. 4.

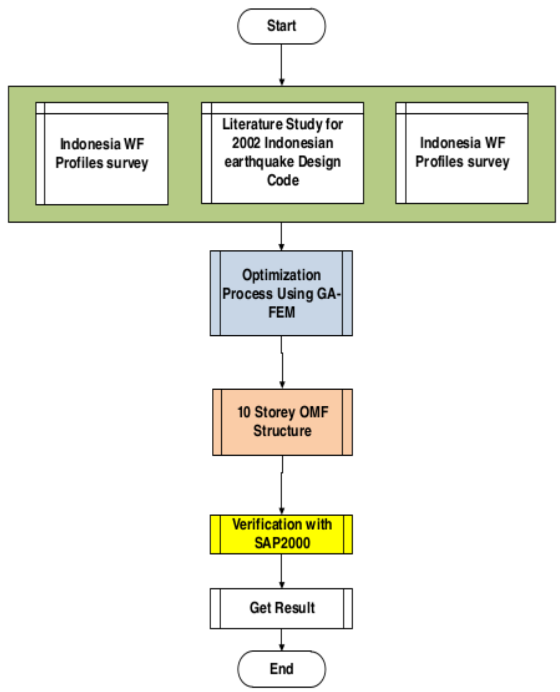

Figure 4: Research flow chart

The database is then to be inserted to Database table – Function – Response Spectrum – User. GA process are carried out with parameters: 50 individual, 200 generation, 0, 8 crossover, 0, 005 mutation, 1 cut point crossover, 20% elitism and 80% roulette wheel selection. The optimization process is then deployed in single PC with intel Core i-5 2400 CPU @ 3. 1 GHz processor DDR3-8GB memory and AMD Radeon R7-200 Series 2GB-DDR3 graphic chipset.

RESULTS AND DISCUSSION

Optimization process have been accomplished in this research for obtaining Indonesian steel structure. The first structure model optimization completed in about 8 minutes. The genotype code of optimized structure is "01801501301301301701501301 2" and has 29050 Kg in weight. The WF profile are 900x303; 700x300; 600x300; 600x300; 600x300for columns and 900x300; 700x300; 600x300; 500x200 for beams. The optimized structure found in 78th generation in about 23minutes. Total optimization process for 100 population and 100 generation took about 31 minutes. The optimized WF configuration and the D/C ratio values is then displayed as shown in Fig. 5.

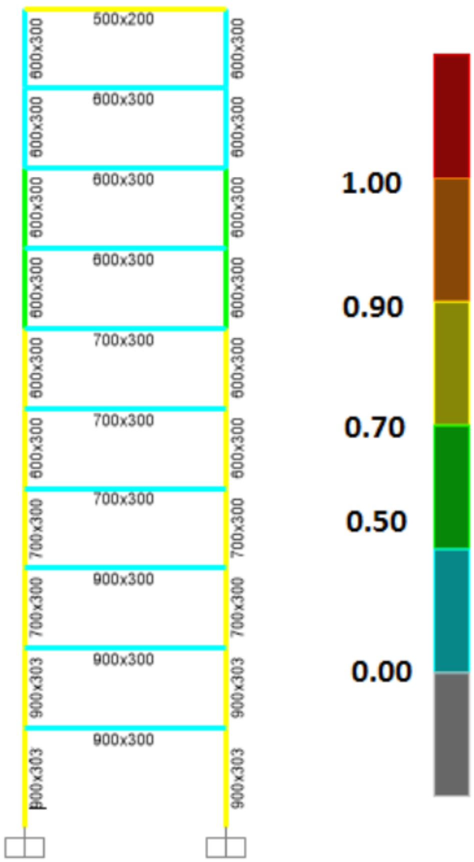

Figure 5: D/C ratio of optimized structure.

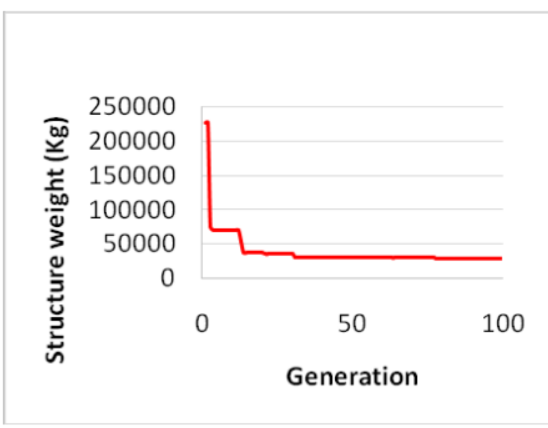

Figure 6: The minimum objective function plot (found in gen # 78).

CONCLUSION

Optimization process have been completed to define steel structure due to ready stock Indonesian WF Profile, 2015 Indonesian steel design code and 2012 Indonesian earthquake design code. The optimization process is carried out with Chromosome repairing (CR) - Genetic Algorithm (GA) – Finite Element Method (FEM) and then verified with commercial FEM program. The first model structure is 29050 Kg which remain not to violate all predefined constraints. It is concluded that combined CR-GA-FEM successfully provide Indonesian steel structure.

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Optimization System For Indonesian Steel Structure Using Genetic Algorithm And Sni 1726-2012

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