Effects Of Zoning In 2002 Indonesian Standard Earthquake Design For Steel Frame Weight

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Abstract - An approach is presented as usage of genetic algorithm (GA) concept for obtaining steel structure weight due to Indonesia's zoning earthquake design. The purpose of this paper is to comparing the weight of structures in 6 earthquake zones and 3 soil types based on 2002 Indonesian National Standard. The optimization processes are carried out through 6 storey 2D steel structure model using GA-SAP2000. This research results that the weight is gaining from 102% to 205% for hard soil. The gains are 22% to 228 % and 135% to 277% for intermediate soil and soft soil, respectively. The weight of structure forms Y=24.867 x + 76.689 linear equation as x refers to number of zone. It is concluded that SNI 2002 gives much bigger weight in soft soil than in hard soil and also zone 1 needs lighter structure weight than zone 6.

Keywords: Genetic algorithm, Optimization, Steel structure, Zone, SNI earthquake design code.

Introduction

The 1726 – 2002 Indonesia National Standard (SNI) for earth design code has arranged in 2002 and enforced to be based for design building in Indonesia [8]. In this code Indonesia has 6 earthquake zone and each zone has 3 type of soil. Zone 1 means the lowest earthquake force and zone 6 means the strongest earthquake force. Three soil types for each zone differs soil in hard type, medium type and soft soil type and the impacts in ground acceletration and notates the earthquake spectrum respons. For the uncommonly used optimization method, so the weight differences among Indonesian 6 zones are not obtained yet [8].
The application of genetic and evolutionary computation to the automated design of structures has followed several avenues. The first is topology and shape optimization, in which the applications have included elastic truss structures subjected to static loading [2]. There have also been research efforts devoted to developing algorithms for optimized structure topologies to satisfy user-determined natural frequencies. The following major area of automated design based on GA method are using linear elastic analysis with US. design specifications[6].
The final major application of genetic algorithms (GA) has been the automated design of steel frame structures. One excellent method was combining commercial finite element method (FEM) program with iteration method to find required area of steel reinforced concrete plate [6] and commercial FEM program with GA in parallel computing method [4][1].

Since we know the advantage of commercial FEM program for analyze and design structure and its combination with GA, it will be good for academics for using combination of commercial FEM-GA for research in optimization. For this reason, it will be discussed the optimum structure weight among different 6 zones and 3 soil types according to SNI 2002.

Theories

The 2000 Indonesia Steel Structure Design Code

The current design methodology in the SNI 03-1729-2000 Steel Structure Design Code (SNI, 2000) requires that all member sha ll pass the H1-1 AISC-LRFD 1999 requirement and also interstory drift of a steel moment frame be accommodated through a combination of elastic and inelastic frame deformations. The inelastic deformations are provided through development of plastic hinges at pre-determined locations within the frame. When moment connections are used, the plastic hinges are developed through inelastic flexural deformations in the connecting beams and in the column panel zone. This results in a strong column and weak beam design philosophy [7].
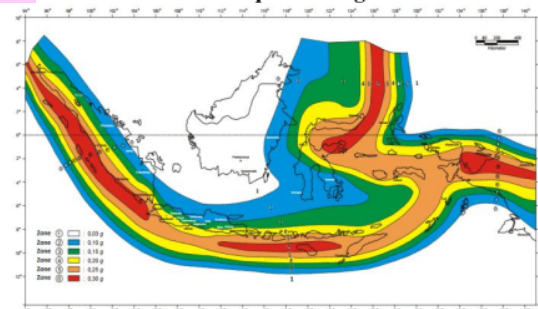
The 2002 Indonesia Earthquake Design Code

Fig 1. Indonesian peak ground acceleration zoning [8].

The 2002 Indonesian earthquake design code devides Indonesia into 6 zones (see Fig. 1). Each zone and soil type denotes specific spectrum response. Spectrum responses for each zone are displayed as shown in Fig 2. In the hard soil, the maximum spectrum responses are 0.1, 0.3, 0.45, 0.6, 0.7, 0.83, for zone 1 to zone 6, respectively. For medium soil, the maximum spectrum responses are 0.13, 0.38, 0.55, 0.7, 0.83, and 0.9, for zone 1 to zone 6, respectively. For soft soil the

maximum spectrum responses are 0.2, 0.5, 0.75, 0.85, 0.9. and 0.95 for zone 1 to zone 6, respectively [8](see Fig. 2).
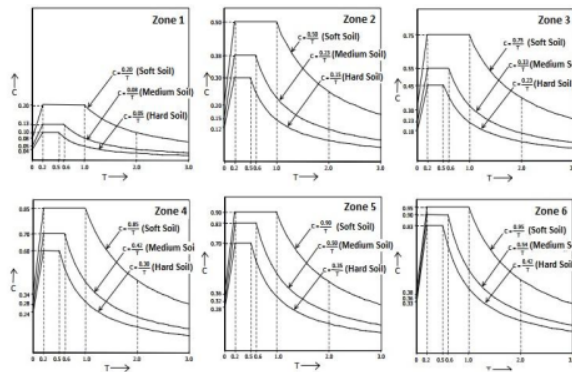

Fig 2. Spectrum response of earthquake design [8].

Genetic Algorithm (GA)

GA is a strategy inside group of Evolutionary Algorithm (EA). GA with population-based global search strategy run the darwinian theory [5]. Usually GA started with initizalization of population, and then followed by evaluate population, selection, mating, crossover, mutation, stopping criterion and get results [3] (see Fig. 3). Individuals of population are presented by chromosomes in which the combination of genotypes. in this paper, The genotypes are taken from WF profile provided and reay stock in marketplace in Indonesia. The code of genotypes and Phenotypes are then displayed in Table 1.
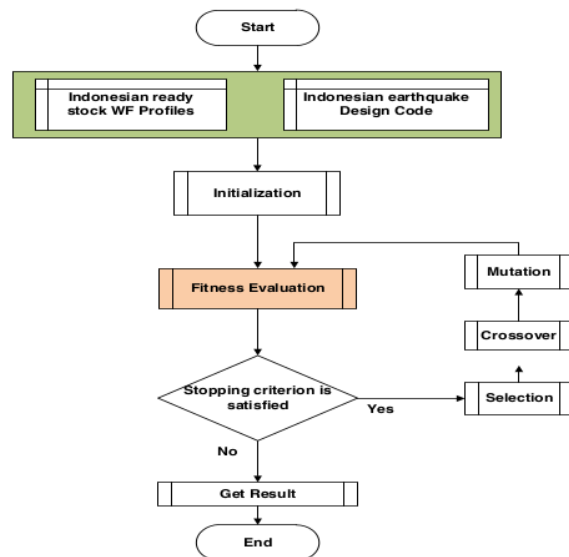

Fig.3. Flowchart of GA (modified of [3]).

TABLE.1. Genotype and Phenotype of readystock WF Profile in Indonesia

Geno-type	Pheno-type	Height (cm)	Width (cm)	Flens (cm)	Web (cm)
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 For Optimization

The structure to be optimimized is a 2D 6 stories braced steel structure. Each story has 4 Meter height and each beam has 5 Meter length. 6 different types of columns are used in every storey and also 6 different types of beams are used in every storey (see Fig. 4).
The objective function is to minimize weight subject to three constraints (stress constraint, displacement constraint, flexural strength constraint) and forms as :

$$Objfunc = \sum \rho_i A_i L_i + gen_g{}^2 \left(\sum re_i + \sum rj_j + \sum scwb_j \right)$$

(1)
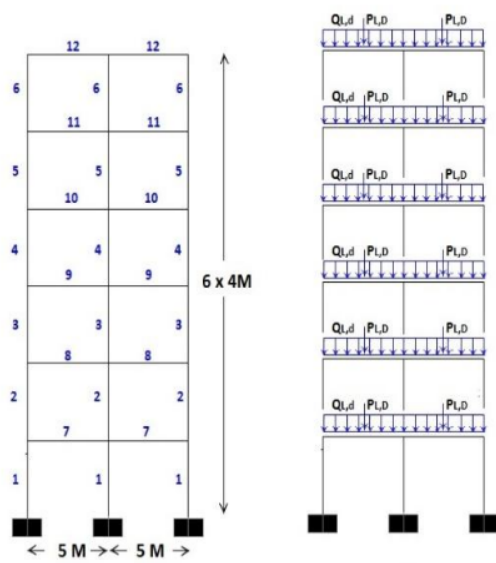
Fig.4. 2D steel structure a) The Frame b) Load

Where Objfunc is objective function, ρ is unit weight, A is Area of cross sectional, L is length of element, gen is generation, re is element constraint, and rj is displacement constraint. Rei = 0 if ratioi < 1 and rei = ratioi2 if ratioi > 1, rji = 0 if drifti < 0,04672 and rji = drifti2 if drifti > 0,04672, scwbj = 0 if Rj < 1 and scwbj = Rj 2 if scwbj > 1.

For displacement constraint, the interstory drift is limited to 004 times the story height. For stress constraints, the capacity ratio of each element is limited with equation [7] :

$$\text{ratio} = \frac{P_u}{\varphi P_n} + \frac{8}{9}\left\{\frac{M_{u33}}{\varphi b M_{n33}} + \frac{M_{u22}}{\varphi b M_{n22}}\right\} \text{ for } \frac{P_u}{\varphi P_n} \geq 0.2 \quad (2)$$

$$\text{ratio} = \frac{P_u}{2\varphi P_n} + \left\{\frac{M_{u33}}{\varphi b M_{n33}} + \frac{M_{u22}}{\varphi b M_{n22}}\right\} \text{ for } \frac{P_u}{\varphi P_n} < 0.2. \quad (3)$$

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, $\varphi = 0{:}85$ and $\varphi b = 0{,}9$.

For the flexural strength constraint, the ratio of beam to column stiffness at every joint must under 1, with form as [7]:

$$R = \frac{\sum_{n=1}^{nb} M_{pbn}}{\Sigma M_{pc}} < 1. \quad (4)$$

Where R is strong column weak beam ratio, Mpbn is plastic moment of beams, Mpc is plastic moment of columns above and below the joint.

The loading on the structure consists of a dead load of 800Kg/M' and live load of 400Kg/M'. The lateral loads due to wind are computed according to the SNI [7]. Lateral forces are determined by assuming a basic wind speed of 113 km/h (70 mil/h), exposure C, and an importance factor of 1. Earthquake force is defined by auto lateral load according to CQC modal combination of response spectrum of 6 zone and 3 soil type, SRSS directional combination, modal analysis case use 8 modes Eigen vector type mode. GA process are carried out with parameters: 40 individual, 200 generation, 0,8 crossover, 0,005 mutation, 1 cut point crossover, 25% elitism and 75% roulette wheel selection.

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 2000 Indonesia Steel structure design code and 2002 Indonesia earthquake design code. After Studying and surveying phase, then second phase is deployed. The second phase is optimization process and deployed through variables of 6 earthquake zones and 3 soil types 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. 5.
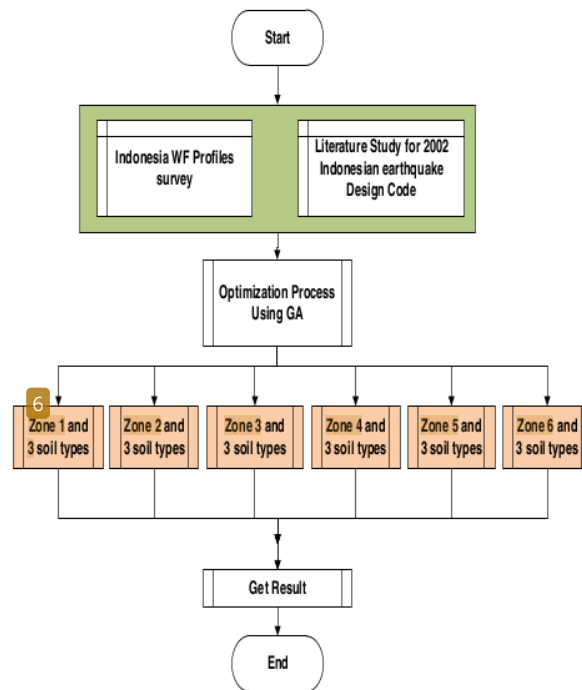

Fig.5. Phases in this research

In proposed system the delay to reach the energy information of sensor is lesser when compared to the hierarchical order of the nodes in the wireless sensor network, because in cluster there is no more no of intermediate nodes to receive and send the neighbor nodes energy message.
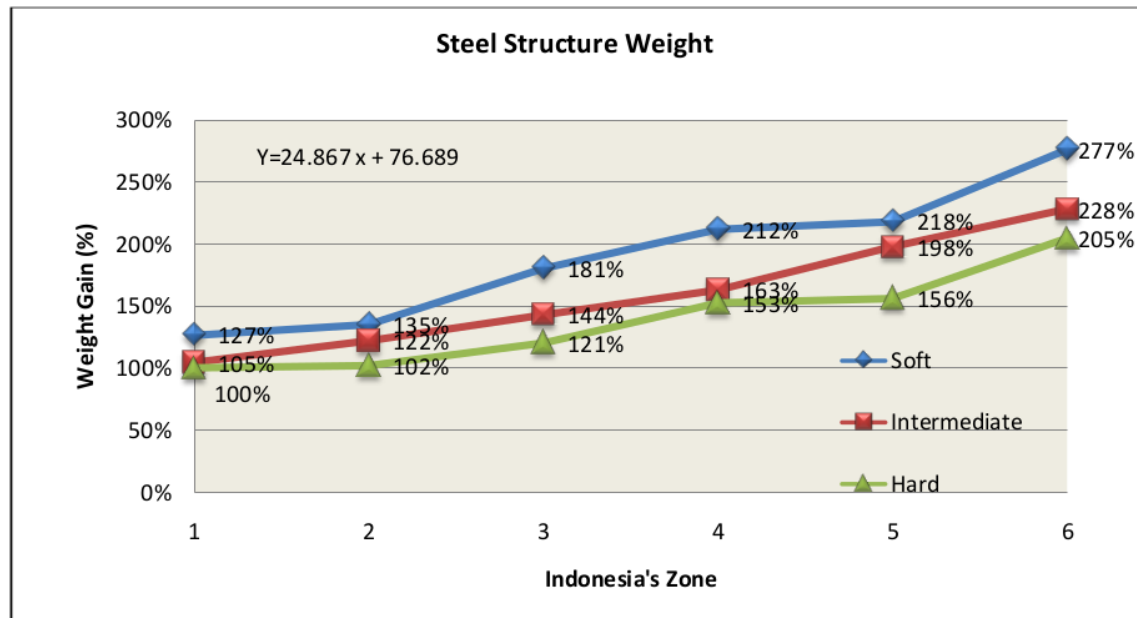
Fig.6. Optimum weight in different zoning in Indonesia

Conclusion

Eighteen optimization process have been completed to compare effect of earthquake zonings. This research results weight is gaining from 1025 to 205% for hard soil. The gains are 22% to 228 % and 135% to 277%, for intermediate soil and soft soil, respectively. The weight of structure forms $Y=24.867 x + 76.689$ linear equation as x refers to number of zone. It is concluded that more number zone so more bigger the structure.

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