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Investigation Of The Effect Of Earthquake On Concrete Minaret Under Static Loads Using Genetic programing

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Abstract
Minarets are special structures commonly used in Islamic architectures. The seismic behaviors of minarets is quite different from that the other well known structures because of their unique structural characteristics such as slenderness, distinctive geometrical shape and support system. Post earthquake observations indicate that there is a direct relationship between site selection and overall minaret behavior and damage. This study investigates the seismic response of cylindrical concrete minarets with circular cross section under static loads using genetic programing. Using SAP 2000 software, considered minarets were analyzed. At the first phase of study, according to regulation of designing of structures against earthquake (regulation No.2800), minarets dynamic responses were determined by a hand-operated analysis. Seismic analysis were carried out considering the design spectra defined by Iran structure design codes in Naqan, Shahr-e-kord. On the base of hand-operated and SAP2000 calculations the shear base and maximum lateral displacements were estimated.

Key words: Minaret, genetic programing, static loads, modeling, SAP2000 software.

1. Introduction.

A minaret is a slender tower built next to the mosque [12] which is used by Muezzin to call out the adhan in order to make people to come to prayers in Islam. Also it is used as a guide tower near the roads, mosques and caravanserai.

A minaret basically consist of three parts: a base, a shaft and a gallery. The base is foundation of a minaret. The shaft is the thin, slim body of the minaret and stairs are place cylindrically in the shaft to provide the necessary structural support for the elongated shaft. The gallery is a balcony that encircles upper section where the muezzins call out to prayers [1].
A large number of research studies investigating the seismic response of historical minarets and towers are available [3, 4,8,13], but the most important structural properties should be known prior to analysis of structure [2].
One of the main goal of this research is study of concrete minarets, the response of them to earthquake and providing a suitable analysis method on the base of this structure specifications. In analysis of minaret in different modes, equal static analysis method is used. But some of these methods and obtaining exact solution are difficult and time consuming [7]. Also, optimum dimensions of minarets in the field of diameter, thickness and height were studied on the base of base shear and moment in minaret shell using SAP2000 software.
Providing a program to answer to multivariate problem as input or output is hard or impossible because we cant consider all of variables and their effect on each other [14]. Therefore getting to know Genetic programing and use of software can help to answer this problem.
Since genetic programing was born, it has been seen by some researchers in and out of the field that GP is a potentially powerful method for automated synthesis of computer programs by evolutionary means [11]. Genetic programing is a research method, belong to evaluation computation family and is a powerful method for automatically generating computer programs via the process of natural selection [6]. Genetic programing is the application of genetic algorithms [5,9] to creation of program code. It uses a genetic algorithm to search though a space of possible computer programs for one which is nearly optimal in its ability to perform a particular task [10]. Compared with Genetic Algorithm, GP can optimize more complex structures, so it use in various problems. At the second phases, a set of programs were generated. The better programs were selected from this set. GP model is used for some of minaret parameters such as diameter, thickness and height. Using genetic operators such as generation, mutation and cross over, we will get final population which are base shear and maximum lateral displacement in concrete minaret. Then, produced minaret samples will analyze using GP to find the best models for simulation of minaret behavior. Using GP and considering different diameter, thickness and height values (100 samples) in SAP2000, special models were provide for each minaret. Then, they compared with other 100 analyzed samples by SAP2000 and error percent was determined for each model.

Static analysis of concrete minarets

To study of static behavior of concrete minaret, height, diameter and thickness parameters were used which are 20-70 m, 2-7 m and 0.2-0.45 m, respectively. Also, considering three modes, computer models were provided:

1- Minaret with fixed diameter and height, but variable thickness

2- Minaret with fixed diameter and thickness, but variable height

3- Minaret with fixed height and thickness, but variable diameter

Static analysis of these three modes with shear base and maximum lateral displacement output are shown in figures 3 to 8. Modeling hypothesis is as follow:

1- Minaret is build in Shahr-e-kord, Iran.

2- Minaret is made of armed concrete and $f'c = 210\ kg/cm^2$, $fy = 4000\ kg/cm^2$, $\nu = 0.2$, $E = 2.188 \times 10^9 kg/cm^2$ and $\gamma_c = 2400\ kg/cm^3$.

3- Minaret loading includes deed, seismic, thermal and earthquake loads in X and Y directions. For example, table 1 includes the results of hand-made and computer calculation in a cylinder minaret in which height, diameter and thickness are 30m, 2m and 20 cm, respectively. In hand-made method, code of Iranian structure No.2800 and in computer method, SAP2000 software is used. In this table, A,I,R,T,B, C, W, V, K and U are design baseline acceleration, importance coefficient, behavior coefficient, period time, reflection coefficient, ABI/R, weight, base shear, rigidity and top displacement, respectively.

Minaret specification	A	I	R	T(sec)	B	C	W(ton)	V(ton)	K(ton/m)	U(cm)
Hand- operated method	0.30	1.2	5	0.758	2.5	0.18	92.53	16.66	380	4.39
Computer method	0.30	1.2	5	0.870	2.5	0.18	94.3	17.33	347	5

Table 1: Static analysis results

Because of excessive calculations in hand- operated method, the details are not presented. Also, in SAP2000, modeling is presented on a cylindered minaret in height, diameter and thickness equal to 30m, 2m and 20 cm, respectively (fig.1).

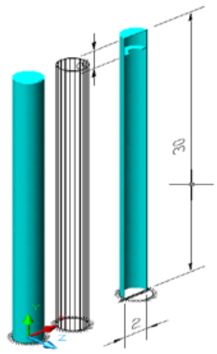

Fig.1: Geometric specification of supposed concrete minaret with fixed support

Data modeling using GP

150 samples of concrete minaret were modeled using SAP 2000 software in different length, diameter and thickness (inputs) and two parameters include minaret base shear and top lateral displacement (outputs), and transferred to Genetic programing to provide the best model for concrete minaret modeling.

Specifications of 150 concrete minaret samples were used in GP training. Minaret specification includes 7 parameters: length, diameter, thickness, elasticity modulus, poison's ratio, compressive strength and density. Length, diameter and thickness variability in concrete minaret is 20-70m, 2-7 m and 0.2- 0.45 m, respectively. General characteristics of used concrete minaret are provided in table 2.

Concrete specifications	poison's ratio (υ)	Elasticity modulus (E) $kg/m2$	Density (γ) $kg/m3$	Compressive strength ($f'c$) kg/cm^2
Concrete minaret	2	2188197889	2400	210

Table 2: General characteristics of used concrete minaret

In GP modeling, suitable GP figuration is needed which is primary setting and determination of mathematic operators.

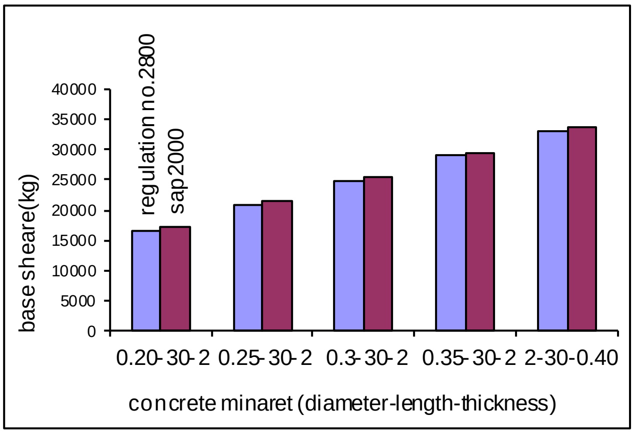

Fig.4: Base shearing on the base of fixed diameter and height but variable thickness

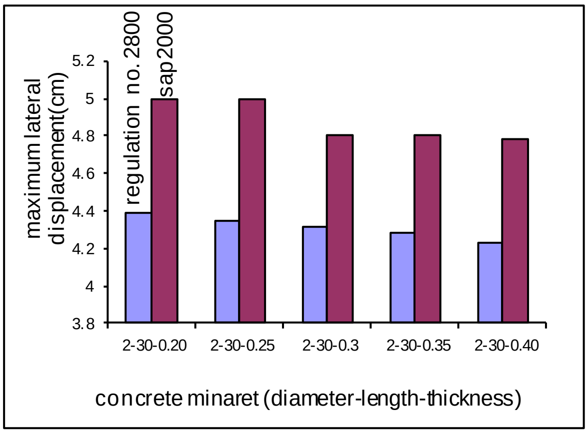

Fig.3: Maximum lateral displacement on the base of fixed diameter and height but variable thickness

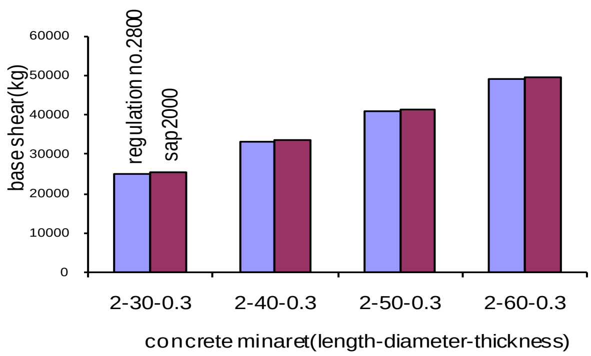

Fig.6: Base shearing on the base of fixed diameter and thickness but variable height thickness but

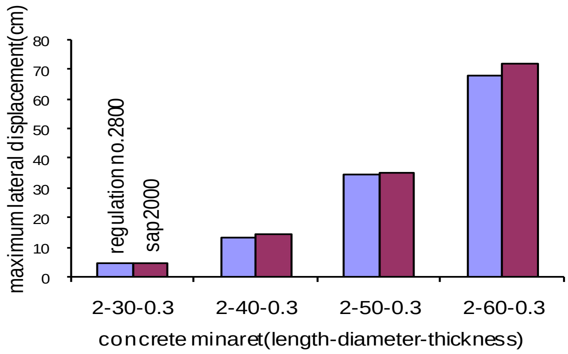

Fig.5: Maximum lateral displacement on the base of fixed diameter and height

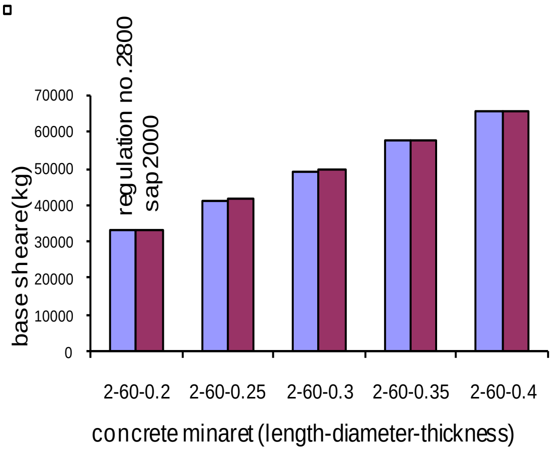

Fig.8: Base shearing on the base of fixed height and thickness but variable diameter

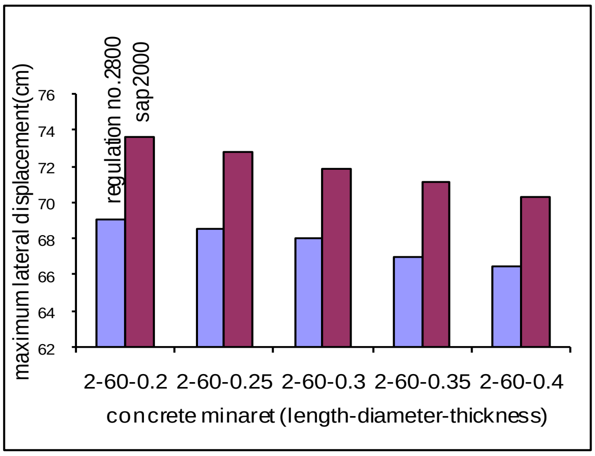

Fig.7: Maximum lateral displacement on the base of fixed height and thickness but variable diameter

Primary setting

In adjusting, the follow factors should be considered in genetic programing:

1. Data value and number of variables (table 3)
2. General settings include number of chromosomes and gens, size of head, tail , the place of division and gen linking function (table 4)
3. Fitness function (table 5)
4. Genetic operators (table 6)
5. Numerical constants (table 7)
6.

Data	
Independent Variables:	6
Training Samples:	100
Testing Samples:	

Table 3: data

Settings	
General	
Chromosomes:	30
Genes:	3
Head Size:	8
Tail Size:	25
Dc Size:	25
Gene Size:	58
Linking Function:	Addition

Table 4: General settings

Fitness Function	
Error Type:	RRSE
Precision:	--
Selection Range:	--

Table 5: fitness function

Genetic Operators	
Mutation Rate:	0.044
Inversion Rate:	0.1
IS Transposition Rate:	0.1
RIS Transposition Rate:	0.1
One-Point Recombination Rate:	0.3
Two-Point Recombination Rate:	0.3
Gene Recombination Rate:	0.1
Gene Transposition Rate:	0.1

Table 6: genetic operators

Numerical Constants	
Constants per Gene:	2
Data Type:	Floating-Point
Lower Bound:	-10
Upper Bound:	10
RNC Mutation:	0.01
Dc Mutation:	0.044
Dc Inversion:	0.1
Dc IS Transposition:	0.1

Table 7: numerical constant

Top displacement analysis

SAP 2000 analysis in minaret top displacement

The analysis of 50 samples of concrete minaret in diameter of 5.5m was performed and top displacement output is shown in table 8.

No.	Average diameter (m)	Length (m)	Thickness (m)	Weight (kg)	Top displacement determined using SAP 2000
1	5.5	21	0.21	199686.4267	0.001796962
2	5.5	21	0.26	243531.5863	0.001746532
3	5.5	21	0.31	287379.3848	0.001711733
4	5.5	21	0.36	331229.8223	0.001685949
5	5.5	21	0.41	375082.8987	0.001665793
6	5.5	26	0.21	243228.9001	0.004130076
7	5.5	26	0.26	297441.3153	0.004028043
8	5.5	26	0.31	351656.3694	0.00395743
9	5.5	26	0.36	405874.0625	0.003904905
10	5.5	26	0.41	460094.3945	0.003863639
11	5.5	31	0.21	286771.3736	0.008203811
12	5.5	31	0.26	351351.0443	0.008023087
13	5.5	31	0.31	415933.354	0.007897648
14	5.5	31	0.36	480518.3027	0.007803971
15	5.5	31	0.41	545105.8902	0.007730008
16	5.5	36	0.21	330313.847	0.014716984
17	5.5	36	0.26	405260.7734	0.014424578
18	5.5	36	0.31	480210.3386	0.014221025
19	5.5	36	0.36	555162.5429	0.014068412

20	5.5	36	0.41	630117.386	0.01394733
21	5.5	41	0.21	373856.3205	0.024485716
22	5.5	41	0.26	459170.5024	0.024042645
23	5.5	41	0.31	544487.3232	0.0237333
24	5.5	41	0.36	629806.783	0.023500468
25	5.5	41	0.41	715128.8818	0.023314856
26	5.5	46	0.21	417398.7939	0.038443435
27	5.5	46	0.26	513080.2314	0.037804627
28	5.5	46	0.31	608764.3078	0.037357318
29	5.5	46	0.36	704451.0232	0.037019351
30	5.5	46	0.41	800140.3775	0.036748666
31	5.5	51	0.21	460941.2673	0.057640868
32	5.5	51	0.26	566989.9604	0.056755076
33	5.5	51	0.31	673041.2924	0.056133025
34	5.5	51	0.36	779095.2634	0.055661249
35	5.5	51	0.41	885151.8733	0.055281663
36	5.5	56	0.21	504483.7408	0.083246049
37	5.5	56	0.26	620899.6894	0.082055759
38	5.5	56	0.31	737318.277	0.081217469
39	5.5	56	0.36	853739.5036	0.080579321
40	5.5	56	0.41	970163.369	0.080063578
41	5.5	61	0.21	548026.2142	0.116544315
42	5.5	61	0.26	674809.4184	0.114985653
43	5.5	61	0.31	801595.2616	0.113884802
44	5.5	61	0.36	928383.7437	0.1130437
45	5.5	61	0.41	1055174.865	0.112360965
46	5.5	66	0.21	591568.6876	0.158938305
47	5.5	66	0.26	728719.1475	0.15694095
48	5.5	66	0.31	865872.2462	0.155526278
49	5.5	66	0.36	1003027.984	0.154441494
50	5.5	66	0.41	1140186.361	0.153557206

Table 8: The results of concrete minaret analysis with top displacement output using SAP 2000

GP modeling in minaret top displacement: Using data in table 8 as primary population in genetic programing, some models were provided. Specifications the best model is shown in figure 9 and mathematical details are provided in figure 10.

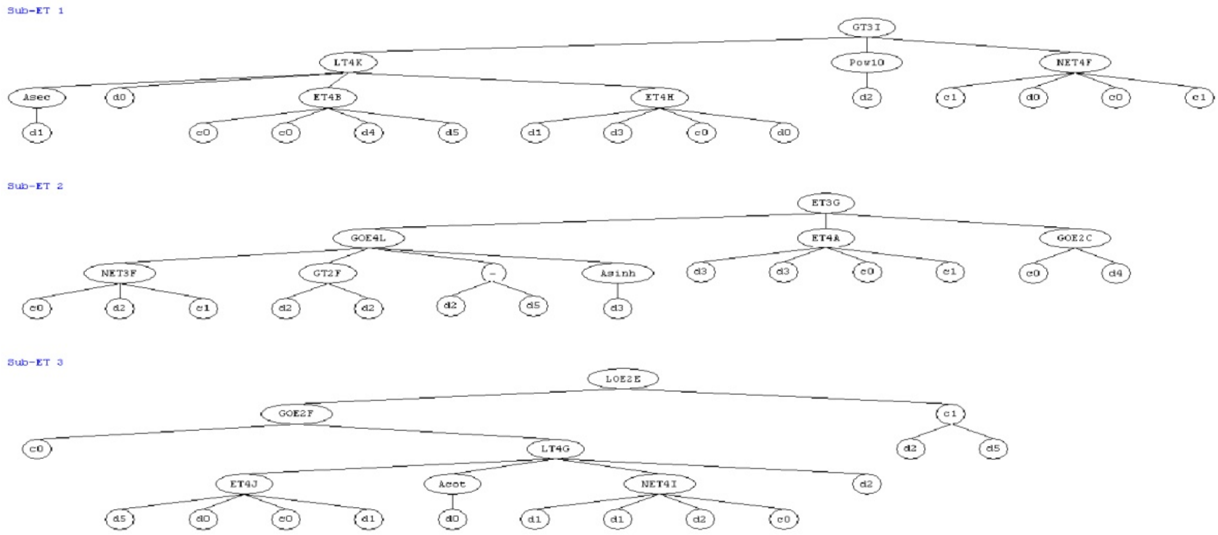

Fig.9: Genetic programing tree in modeling of base shear calculation in concrete minaret in diameter of 5.5m

Generation	Program Size	Literals	Used Variables	Training Fitness	Testing Fitness	Training R-square	Testing R-square
4505	62	26	ar(5), e(5), gama(7), nou(4), tol(2), zekhamat (3)	878.616357565559	--	0.982727992034072	--

GOE2F.c1.c0.LT4G.ET4J.Acot.NET4I.d2.d5.d0.c0.d1.d0.d3.d3.c0.c1.c0.d0.d0.d1.d5.c0.d4.d3.d1.d4.d4.d1.d3.c0.c1
+
ET3G.GOE4L.ET4A.GOE2C.NET3F.GT2F.-.Asinh.d1.d1.d2.c0.c0.d4.c0.d2.c1.d2.d2.d2.d5.d3.c1.d1.d2.d1.d1.c1.d3.c0.d4.d2.d5
+
LOE2E.GOE2F.c1.c0.LT4G.ET4J.Acot.NET4I.d2.d5.d0.c0.d1.d0.d3.d3.c0.c1.c0.d0.d0.d1.d5.c0.d4.d3.d1.d4.d4.d1.d3.c0.c1

Numerical Constants:

Gene 1
c0 = -4.651337
c1 = 1.226165

Gene 2
c0 = -3.435394
c1 = -8.430298

Gene 3
c0 = 6.808777
c1 = 4.538727

Figure 10. Mathematic formula details of the best genetic programming model in calculation of base shear in concrete minaret with diameter of 5.5m

Test of model

Comparing concrete minaret top displacement in SAP2000 and Genetic Programing

To test of models, secondary population is needed, so that non of them don't find in initial population. Then we compare the results of minaret top displacement and base shearing in SAP2000 and Genetic Programing. Once again, 50 minarets were chose to compare the results of SAP 2000 and GP analysis. The results are presented in table 10. Also, figure 11 implies comparison diagram of error percent. In this model, the average of error percent is 12.5%.

No.	Diameter (m)	Height (m)	Thickness (m)	Weight (kg)	Top displacement using SAP2000 (m)	Top displacement using GP (m)	Error percent
1	6	20	0.2	200843.8874	0.001276468	0.001222916	-4.19529263
2	6	20	0.25	246411.3686	0.001233724	0.001125334	-8.785572297
3	6	20	0.3	291981.4888	0.001204861	0.00120286	-0.166043496
4	6	20	0.35	337554.2478	0.001183866	0.001311585	10.78829956
5	6	20	0.4	383129.6458	0.001167736	0.001145231	-1.927194554
6	6	25	0.2	246082.8209	0.003036567	0.003064911	0.9334243
7	6	25	0.25	302960.0354	0.00294716	0.002891449	-1.890328889
8	6	25	0.3	359839.8889	0.002886659	0.003076267	6.568404466
9	6	25	0.35	416722.3814	0.002842524	0.002834937	-0.266906168
10	6	25	0.4	473607.5127	0.002808486	0.003059307	8.930841214
11	6	30	0.2	291321.7543	0.006170338	0.005724264	-7.229331397
12	6	30	0.25	359508.7022	0.006008597	0.006608136	9.978015297
13	6	30	0.3	427698.2891	0.005898913	0.005499492	-6.771104434
14	6	30	0.35	495890.5149	0.005818662	0.005508171	-5.336118473
15	6	30	0.4	564085.3796	0.005756534	0.005655093	-1.762185524
16	6	35	0.2	336560.6878	0.011248991	0.011582485	2.964660508
17	6	35	0.25	416057.369	0.010983494	0.010258071	-6.604661719
18	6	35	0.3	495556.6892	0.010803059	0.012239889	13.30022269
19	6	35	0.35	575058.6484	0.01067065	0.011166848	4.65012082
20	6	35	0.4	654563.2465	0.010567754	0.009968588	-5.669765782
21	6	40	0.2	381799.6212	0.018942335	0.021477294	13.38250381
22	6	40	0.25	472606.0358	0.018535847	0.019952082	7.640520487
23	6	40	0.3	563415.0894	0.018258996	0.020648842	13.08859269
24	6	40	0.35	654226.7819	0.018055236	0.01890349	4.698106833
25	6	40	0.4	745041.1134	0.017896297	0.018183567	1.605188477
26	6	45	0.2	427038.5546	0.030018783	0.031881031	6.203609183
27	6	45	0.25	529154.7026	0.029428195	0.031195212	6.004506335

28	6	45	0.3	631273.4896	0.029025093	0.029751944	2.504216615
29	6	45	0.35	733394.9154	0.028727542	0.030404063	5.835936688
30	6	45	0.4	835518.9802	0.028494586	0.026660707	-6.435884571
31	6	50	0.2	472277.4881	0.045345348	0.04881875	7.659887248
32	6	50	0.25	585703.3694	0.044521616	0.04616313	3.687002988
33	6	50	0.3	699131.8897	0.043958179	0.049028885	11.53529686
34	6	50	0.35	812563.049	0.043541069	0.048857337	12.20977993
35	6	50	0.4	925996.8471	0.043213319	0.049397223	14.31018177
36	6	55	0.2	517516.4215	0.065887646	0.060520557	-8.14581923
37	6	55	0.25	642252.0362	0.064775731	0.069369308	7.091510165
38	6	55	0.3	766990.2899	0.064013552	0.071880364	12.28929149
39	6	55	0.35	891731.1825	0.063447692	0.064646453	1.889367605
40	6	55	0.4	1016474.714	0.063001469	0.065728635	4.328733922
41	6	60	0.2	562755.355	0.092709894	0.101146595	9.100107854
42	6	60	0.25	698800.703	0.091248696	0.098811402	8.288015535
43	6	60	0.3	834848.69	0.090244973	0.086656375	-3.976507763
44	6	60	0.35	970899.316	0.089497667	0.09655449	7.88492467
45	6	60	0.4	1106952.581	0.088906284	0.091678905	3.118587661
46	6	65	0.2	607994.2884	0.126974913	0.121623575	-4.214484382
47	6	65	0.25	755349.3698	0.125097213	0.135000775	7.916693226
48	6	65	0.3	902707.0902	0.12380467	0.12891223	4.125498529
49	6	65	0.35	1050067.45	0.122839622	0.133149748	8.393160706
50	6	65	0.4	1197430.448	0.122073286	0.113633113	-6.914021778

Table 10:Comparing the best model of SAP2000 and GP for minaret top displacement in diameter of 6 m

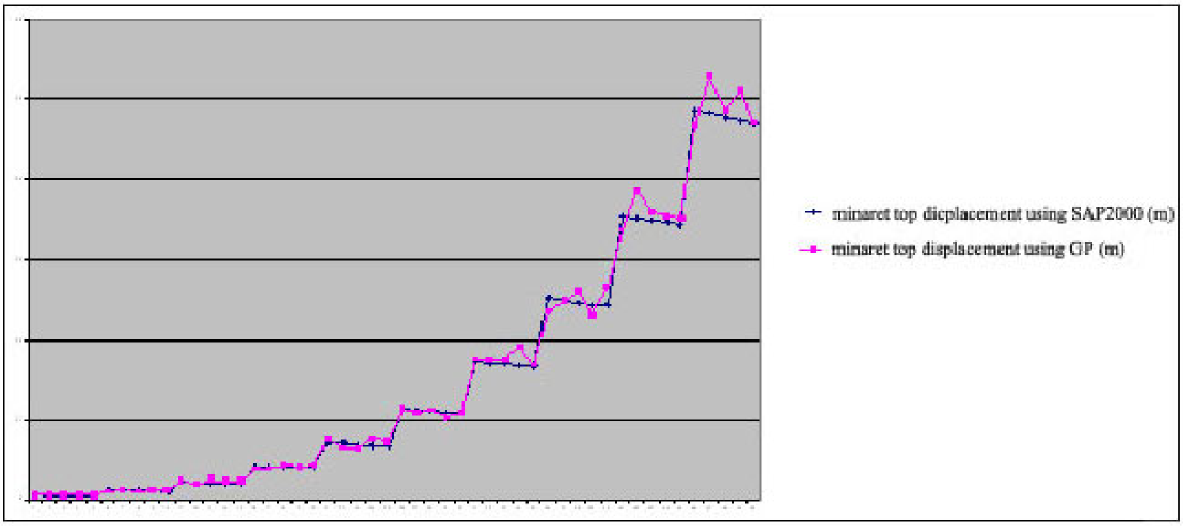

Fig.11: Comparing the best model of genetic programming and SAP2000 software in top displacement of concrete minaret with diameter of 6 m.

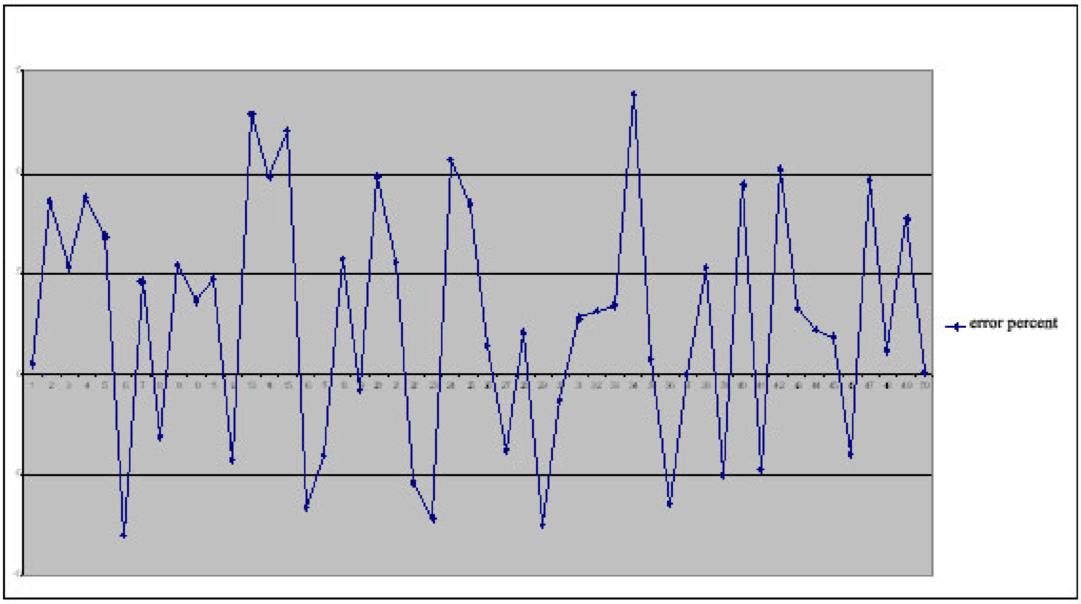

Figure 12. Comparing error percent of the best the best model of genetic programming and SAP2000 software in calculation of top displacement of concrete minaret with diameter of 6m

Comparing concrete minaret base shearing in SAP 2000 and Genetic Programing

Results of base shearing calculated in GP and SAP 2000 are provided in table 11. Also, the results and error percent in samples are depicted in figures 13 and 14, respectively. The average of error percent in this model is 12.5%.

No.	Diameter (m)	Height (m)	Thickness (m)	Weight (kg)	Base shear using SAP2000 (kg)	Base shear using GP (kg)	Error percent
1	6	20	0.2	200843.8874	36151.89974	35197.30821	-2.640501716
2	6	20	0.25	246411.3686	44354.04635	40878.21729	-7.836554606

3	6	20	0.3	291981.4888	52556.66798	61082.79476	16.22273084
4	6	20	0.35	337554.2478	60759.76461	67267.44603	10.71051123
5	6	20	0.4	383129.6458	68963.33625	75147.79082	8.967742719
6	6	25	0.2	246082.8209	44294.90776	42164.99611	-4.808479693
7	6	25	0.25	302960.0354	54532.80638	63750.34633	16.9027427
8	6	25	0.3	359839.8889	64771.18001	62275.96488	-3.852353978
9	6	25	0.35	416722.3814	75010.02864	72416.98333	-3.456931503
10	6	25	0.4	473607.5127	85249.35229	94436.57678	10.77688479
11	6	30	0.2	291321.7543	52437.91578	56177.97709	7.132360725
12	6	30	0.25	359508.7022	64711.5664	58264.59691	-9.962623144
13	6	30	0.3	427698.2891	76985.69204	68927.96338	-10.46652754
14	6	30	0.35	495890.5149	89260.29268	103302.7054	15.73198146
15	6	30	0.4	564085.3796	101535.3683	110985.8779	9.307603615
16	6	35	0.2	336560.6878	60580.9238	54757.70107	-9.612304275
17	6	35	0.25	416057.369	74890.32643	70773.1551	-5.497600991
18	6	35	0.3	495556.6892	89200.20406	87119.16129	-2.333002259
19	6	35	0.35	575058.6484	103510.5567	104177.4374	0.644263434
20	6	35	0.4	654563.2465	117821.3844	120217.4555	2.033647105
21	6	40	0.2	381799.6212	68723.93182	67498.67727	-1.782864447
22	6	40	0.25	472606.0358	85069.08645	77901.07093	-8.426110842
23	6	40	0.3	563415.0894	101414.7161	116699.9515	15.07200928
24	6	40	0.35	654226.7819	117760.8207	121055.9248	2.798132693
25	6	40	0.4	745041.1134	134107.4004	129853.8854	-3.171722823
26	6	45	0.2	427038.5546	76866.93984	75683.59205	-1.539475606
27	6	45	0.25	529154.7026	95247.84647	90393.90054	-5.096121451
28	6	45	0.3	631273.4896	113629.2281	129405.5961	13.88407563
29	6	45	0.35	733394.9154	132011.0848	128231.7611	-2.862883625
30	6	45	0.4	835518.9802	150393.4164	143658.2176	-4.478386734
31	6	50	0.2	472277.4881	85009.94786	82852.82084	-2.537499519
32	6	50	0.25	585703.3694	105426.6065	118505.044	12.40525319
33	6	50	0.3	699131.8897	125843.7402	127633.4051	1.422132683
34	6	50	0.35	812563.049	146261.3488	135141.7985	-7.602521385
35	6	50	0.4	925996.8471	166679.4325	190880.9408	14.51979282

36	6	55	0.2	517516.4215	93152.95587	93450.25128	0.319147584
37	6	55	0.25	642252.0362	115605.3665	126549.7946	9.467058857
38	6	55	0.3	766990.2899	138058.2522	155058.0241	12.3134776
39	6	55	0.35	891731.1825	160511.6128	185852.563	15.78761171
40	6	55	0.4	1016474.714	182965.4485	197055.804	7.701101805
41	6	60	0.2	562755.355	101295.9639	95710.52152	-5.513983143
42	6	60	0.25	698800.703	125784.1265	130895.9246	4.063945291
43	6	60	0.3	834848.69	150272.7642	165371.6176	10.04763136
44	6	60	0.35	970899.316	174761.8769	191058.185	9.324864426
45	6	60	0.4	1106952.581	199251.4646	221331.5167	11.08150054
46	6	65	0.2	607994.2884	109438.9719	124331.0477	13.60765326
47	6	65	0.25	755349.3698	135962.8866	127720.6701	-6.062107597
48	6	65	0.3	902707.0902	162487.2762	156432.4099	-3.726363349
49	6	65	0.35	1050067.45	189012.1409	184680.9267	-2.291500505
50	6	65	0.4	1197430.448	215537.4806	200367.6932	-7.038120425

Table 11: Comparing base shear calculated in SAP2000 and GP for minaret in diameter of 6 m

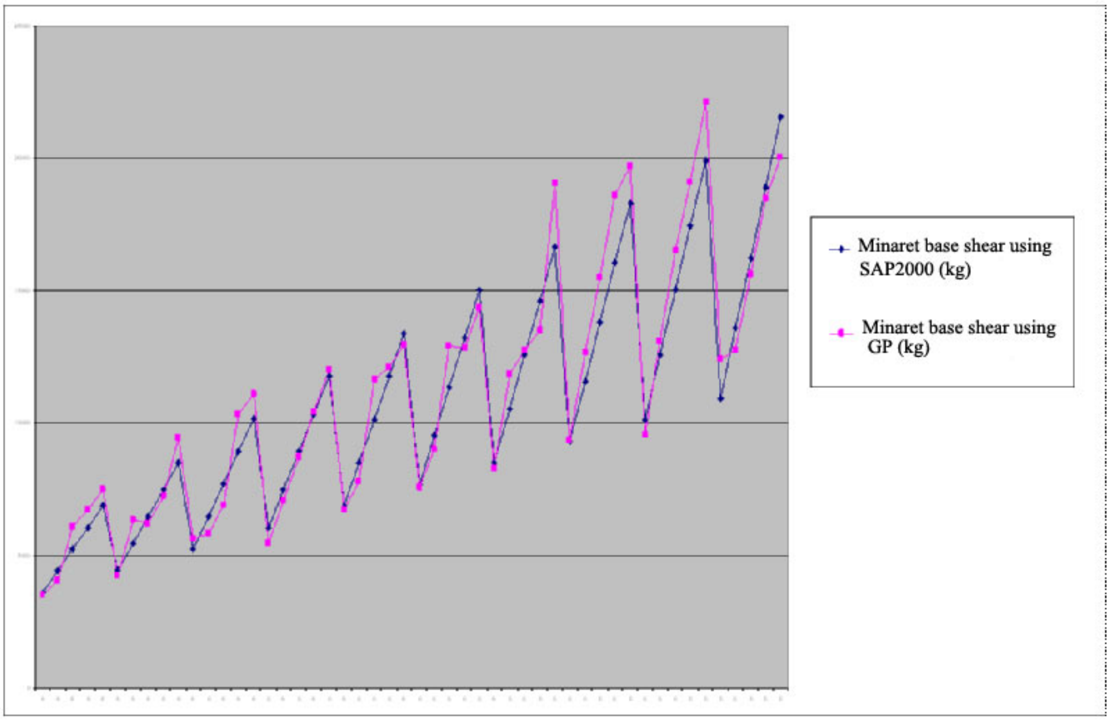

Fig.13: Comparing base shear in GP and SAP2000 for concrete minaret in diameter of 6m

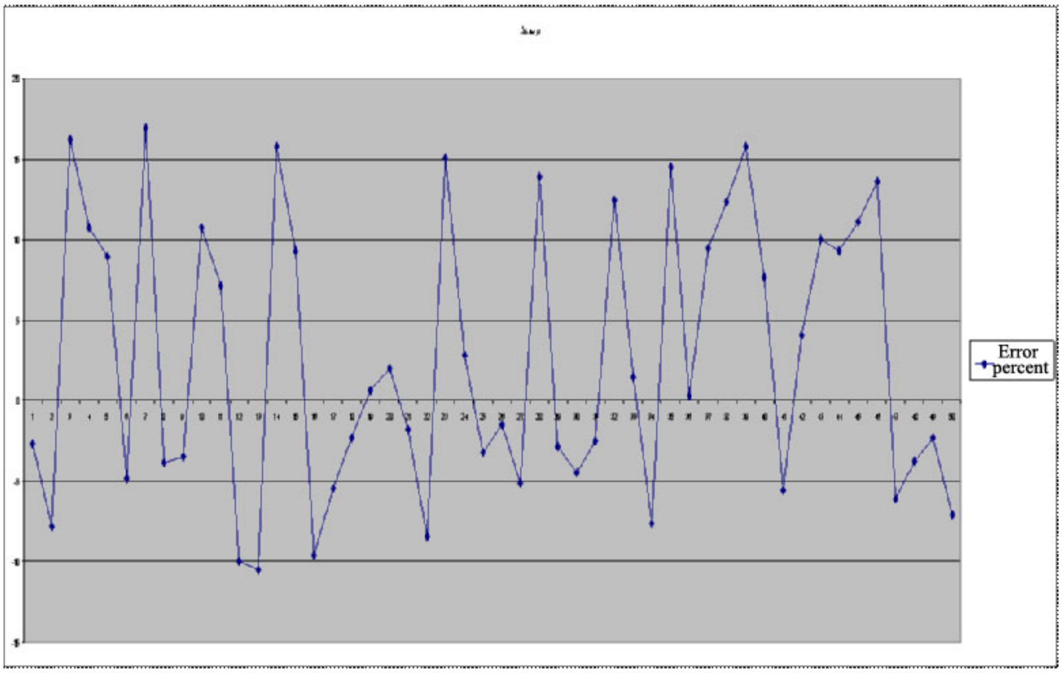

Fig.14: Comparing base shear error percent in GP and SAP2000 for concrete minaret in diameter of 6m

Conclusions

Regarding to hand- operated and computer analysis on concrete minarets, it is concluded that in concrete minarets, increase of height leads to increase of base shar and top displacement. Increase of the diameter has increased the base shear and has decreased minaret top displacement. It should be noted that increasing the diameter (above 5m) had no dramatic effect on top displacement decreasing, but base shear increases. Because of increase of structural mass, thickness increasing leads to increase of base shear in acceptable limit, but top displacement is not decrease considerably. According to hand- operated and computer analysis, the following are suggested in design of pendulum structures:

1. Decrease of concrete bulk decreases mass and inertia force.

2. Increase of minaret flexibility leads to increasing natural frequency and decreasing earthquake force,

3. To recognize of structure behavior, using dynamic analysis in pendulum structure is suggested.

Also, we can concluded that according to comparison between error percent in GP models and SAP2000, the results of genetic programing is more acceptable, so GP models can used in maximum lateral top displacement and base shear in concrete minarets.

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