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Computational Modelling Applications for the Optimal Design of Prefabricated Industrial Buildings According to the Harmonious Research Method

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Abstract : The study aimed to use of computer science programs to find innovative solutions for the design of prefabricated industrial buildings, often these buildings are only on the ground floor. The researcher used the (HS) algorithm, where the model was designed within the following measurements: {height 6 meters}, {extension 3 meters} taking into account the type of soil and taking into account the general rules for earthquake prevention, and international standards related to the relationship. After that, the researcher conducted preliminary and advanced tests for the purpose of checking the sensitivity of the model, and the researcher also performed some analyzes using five different parameter sets. The researcher concluded: The possibility of designing a prefabricated modular building, which is compatible with the code using the HS algorithm, taking into account all the relevant restrictions.

Keywords*: Precast buildings, Harmony search, Optimum design.*

1. Introduction

Prefabricated structures are a type of building widely used throughout the country, due to advantages such as allowing large openings to be passed, short construction period and not being affected by seasonal conditions. These structures, especially in industrial areas, are mostly built as single storey and their joints are articulated [1], after year 2000, a significant proportion of these structures were damaged or destroyed. Due to these disasters, the calculation principles of these structures, their behavior under the effects of earthquakes, etc. There have been many studies covering such topics as [2]-[4]. In 2007, the design of these structures and the provisions were finalized. All these studies point out the importance of the design of these structures, which contribute to the country's economy and employment.

Structural optimization is the process of finding the best configurations of elements for a structural system with consideration of design constraints and a fully developed objective function. In most cases, the total construction cost of the structure is considered objective functions in which the topology, size and shape of the structural systems have the main role in this purpose. Design constraints are the other aspect of the structural optimization process which demonstrate the structural behavior, including the deformation, force, fatigue, and damping of structural members. Structural optimization considers these objective functions and design constraints to provide a better configuration of elements for a structural system.

In this study, a solution approach based on harmony research optimization technique has been developed for the design of a typical prefabricated industrial building with 3 spans and 6 m height in the truss direction on good and bad soils. In all the solutions made within the scope of the related approach, the Regulation on Buildings to be Constructed in UK Standards [17-20], have been taken into account. The obtained results showed that the solution approach developed for the optimum design of prefabricated structures can be used effectively.

2. Problem Formulation

The view of the single-storey and hinged prefabricated structure used in the study is given schematically in Figure 1.

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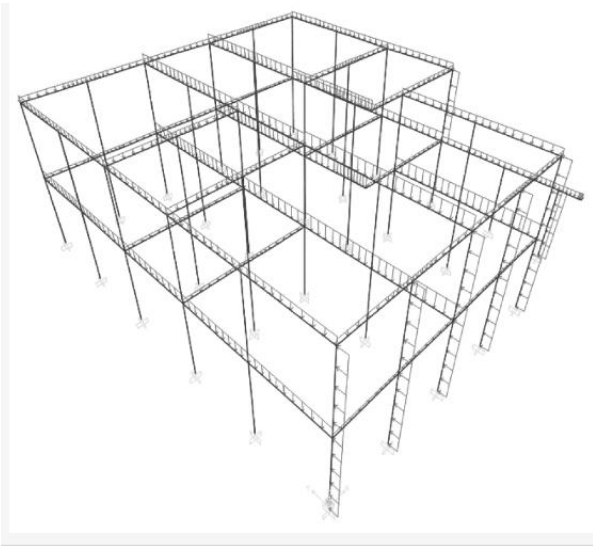

Fig. 1: Schematic diagram of the overall structure model under the action of loads.

In single-storey prefabricated industrial buildings, the frames move independently of each other because the connections on the roof plane are hinged. Therefore, plane frames are considered separately for the analysis of prefabricated industrial buildings. In this case, the prefabricated industrial structure can be represented by four frames: inner and outer frames in the X direction (X-inner and X-outer) and inner and outer frames in the Y direction (Y-inside and Y-outer). The X-inner frame consists of columns 3 and 4, and the X-outer frame consists of columns 1 and 2. Similarly, the Y-inner frame consists of columns 2 and 3, and the Y-outer frame consists of columns 1 and 4. While the structure given in Figure 1 has 2 outer frames in the X and Y directions, it has 5 inner frames in the X direction and 2 in the Y direction.

In the solutions made with the harmony research optimization technique, the properties of some structural elements are considered constant. For example, all truss and purlin lengths were taken as 20 m and 7.5 m, respectively, and it was assumed that 9 purlins were seated on each truss. In addition, the weight of one scissors (g_{scissors}) is 5.1 tons and the weight of a lover (g_{hook}) is 0.29 tons. The weight of the coating used on the roof of the building has been taken as 25 kg/m^2 and the snow load (movable load) as 75 kg/m^2. As a result, the vertical and horizontal loads acting on the building for the design are calculated for the X-inner frame and shown schematically in Figure 2. The calculations for the X-inner frame were made separately within the other frames and were taken into account during the solution with the algorithm. Equation (1) is used to calculate the horizontal ($V_{t,\text{ earthquake}}$) load given in the figure [16].

$$V_{t,\ earthquake} = \frac{A_0 I.S(T)}{R}.W \ldots\ldots..(1)$$

Since most of the prefabricated industrial buildings are built in first degree earthquake zones, the effective ground acceleration (A_0) is 0.4 and the building importance coefficient (I) is 1. The load-bearing system behavior coefficient (R) in Equation (1) has been taken as 3 according to the expression "single-storey buildings in which all the seismic loads are carried by the columns with hinged connections at the top" in the earthquake code. For the calculation of S(T) in the equation, the building period (T_{building}) must be calculated and the soil characteristic periods (T_A, T_B) must be determined. Soil classes in the earthquake code [16] were used to take into account different soil properties during the designs, and soil characteristic periods were used for good soils (S1) T_X=0.2r, T_Y=0.4r., for bad soils (S4) T_x=0.3r, T_y= 0.8r taken. Equation (2) is used for the calculation of the building period (T_{building}).

$$T_{\text{building}} = 2\pi\sqrt{\frac{m_{\text{building}}}{K_{\text{building}}}} \ldots\ldots\ldots(2)$$

In Equation (2), m_{building} the building mass and K_{building} the building rigidity. The weight of the building is calculated by Equation (3)-(5), taking into account the dead and live loads. In Equation (3), the unit volume weight of concrete (γ_{concrete}) is 2.5 t/m^3, while the expressions B, H and L represent the column dimensions and column height (building height). The n in Equation (5) has been taken as 0.3 considering the earthquake code [16].

$$G = \sum_{i=1}^{ks-1} (g_{i,scissors} + 9.g_{i,Asik}) + \sum_{i=1}^{ks} (\gamma_{concrete} B_i . H_i . L_i) + G_{covering} \quad (3)$$

$$Q = Q_{right} \quad (4)$$

$$W_{building} = G + n.Q \; \& \; m_{building} = W / g \quad (5)$$

For the calculation of $K_{building}$, another expression in Equation (2), the behavior of articulated prefabricated industrial structures is taken as a basis. Since the single-storey prefabricated industrial buildings are designed as hinged from the column ends, the columns in the building show cantilever behavior. Taking advantage of this feature, each column stiffness can be calculated using Equation (6). The elasticity module in Equation (6) was calculated by Equation (7) given in TS-500 [17]. The column moment of inertia can be calculated by Equation (8).

$$k_i = \frac{3EI_i}{L_i^3} \ldots\ldots\ldots . (6)$$

$$E = 3250 \sqrt{f_{ck}} + 14000 \left(\frac{N}{mm^2}\right) \ldots\ldots\ldots (7)$$

$$I_i = \frac{1}{12} B_i H_i^3 \ldots\ldots\ldots (8)$$

Finally, the building stiffness is obtained by adding the column stiffnesses (Equation (9)).

$$K_{building} = \sum_{i=1}^{ks} k_i \ldots\ldots\ldots\ldots (9)$$

2.1 Identifying Design Variables

The stiffness and period of prefabricated structures are directly related to the dimensions of the reinforced concrete columns used in the building. For this reason, in the developed approach, the dimensions of the arm were taken as the first decision variable of the optimization model. The column dimensions used in the study were taken as discrete (discrete) variables and the maximum and minimum dimensions are shown in Equation (10). As can be seen from the equation, square columns are used in the designs.

$$350 \leq B = H \leq 650 \; (mm) \ldots\ldots\ldots (10)$$

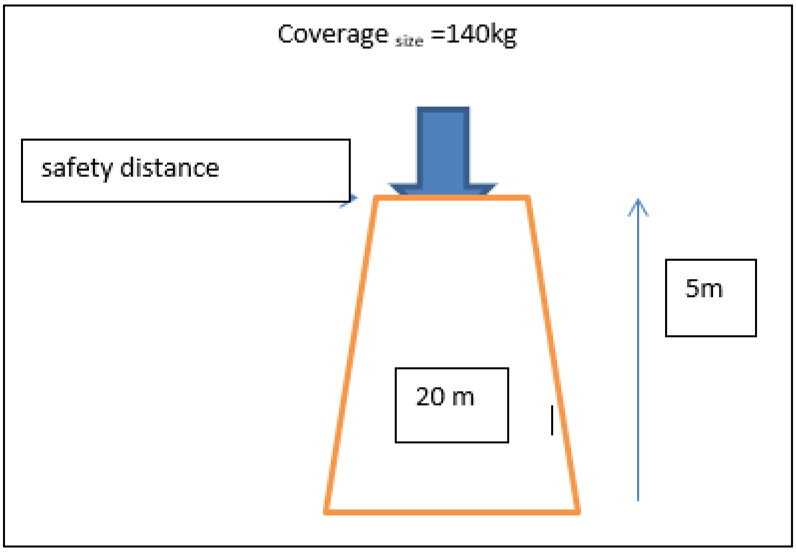

Fig. 2: Schematic representation of the S-inner frame dimensions and the vertical and horizontal loads acting on the frame.

Another issue to be considered after determining the column dimensions is the percentage of reinforcement in the columns. Due to the cantilever behavior of the columns in these structures and their high bending moments, they have high bending moments. Reinforcement ratios increase due to high moments. In 2007, [16], the minimum and maximum reinforcement rates to be used in reinforced concrete columns are given as 1% to 4%. Considering the situation in question, the longitudinal reinforcement ratio was taken as a discrete decision variable in the range of maximum and minimum. At this point, it should be reminded that the selected longitudinal reinforcement ratio was ensured to be equal in all columns while the designs were carried out with the case solution algorithm.

Another variable used during the designs is the concrete class. Due to the pre-production and quality control of prefabricated buildings, the quality of concrete used in these structures is high. However, in order to get a wider range of concrete grades in the study, the concrete grade was taken between 20-30 MPa as a discrete decision variable.

In the solution process with the algorithm, the longitudinal and transverse reinforcement material class S420 (f_{yk}=420 MPa) was taken. In the regulations and standards, a certain safety margin has been given for the concrete and reinforcement materials to be used in the designed buildings and it has been made mandatory to use the material properties divided by the safety coefficients in the designs. For this reason, the safety coefficients for concrete and reinforcement given in TS-500 [17] were taken as 1.5 and 1.15, respectively, during the designs.

As a result, load combinations brought by the regulations and standards for prefabricated systems were created and the columns were designed according to the material and section properties that were considered during the solution with the algorithm.

2.2 Identification of Design Constraints

One of the most important constraints encountered during the design of prefabricated structures is the displacement limit. The typical displacement view of a single storey prefabricated building is given in Figure 3.

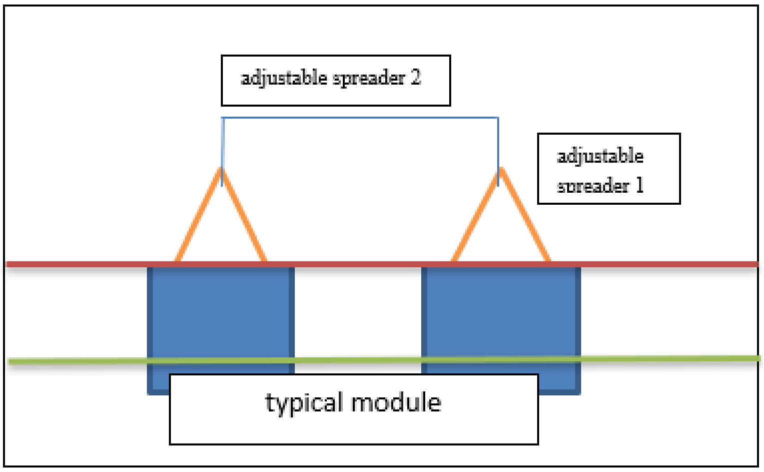

Fig. 3: Designing a Lift Operation Where the upper lift is designed with adjustable distribution (left) and mobile crane capacity through the use of lift angles, distances and offsets (right)..

In 2007, the effective relative story drift for each earthquake direction is calculated using Equation (11). This calculated value should be less than 0.02 if it is on any floor of the building.

$$\frac{R.\Delta}{L} \leq 0.0 \dots \dots (11)$$

As seen in equation 11, the (Δ) in the equation represents the displacement demand of the building in the related earthquake direction. "L" in the equation is the height of the building and it was taken as 6 m in the study. This situation was taken as a constraint during the designs and controlled in both directions.

One of the most important constraints in the design of buildings is that the bearing elements have to meet the stresses caused by earthquakes and static loads. The moment and shear force diagrams that can occur in a typical single-storey prefabricated building are shown in Figure 4.

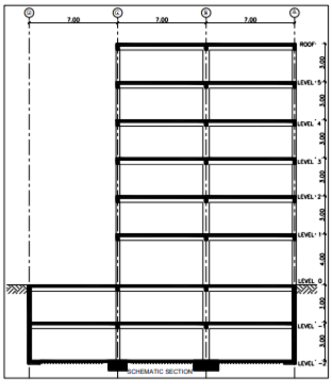

Fig. 4: Section in the Y direction showing the foundation elements

As seen in Figure 4, the load-bearing elements must have a capacity at least equal to or higher than these cross-sectional stresses (Equation (12)). Therefore, this design criterion has been taken into account and added as a constraint to the algorithm.

$$\forall M_{i,capacity} \geq M_{i,static} \ \& \ \ V_{i,capacity} \geq V_{i,static}$$

After the columns are designed under static and earthquake loads, the shear value that will arise due to the moment capacity of each column is calculated and compared with the shear capacity (Equation (13).

$$\forall V_{e,i} = \frac{M_{i,capacity}}{\mathrm{L}_{colon}} \ \& \ \forall \mathrm{V}_{\mathrm{r,i}} - V_{e,i} \geq 0 \qquad (13)$$

The shear capacity of the carrier elements is calculated using Equation (14). V_c and V_w in the related equation are the shear capacities of concrete and transverse reinforcement, respectively. As a result, the expression given in Equation (13) was also considered as a constraint in the solution approach developed.

$$\mathrm{V}_{\mathrm{r,i}} = \mathrm{V}_{\mathrm{c,i}} + \mathrm{V}_{\mathrm{w,i}} \qquad (14)$$

2.3 Identification of Purpose Function

After determining the decision variables and constraints related to the design of prefabricated structures, which is an engineering problem, the mathematical expression of the problem, namely the definition of the objective function, is made. In this study, optimum design of a prefabricated building that meets the regulations by using minimum cross-section and material (longitudinal reinforcement, concrete class) is aimed and the function is created as given in Equation (15). In order to prevent the function from being affected by the value differences between the decision variables (effective in the solution process), the decision variable selected during the research process was divided by the largest value of that decision variable and normalized. The limits of the decision variables are given in Equation (16)-(18).

$$AF = \sum_{i=1}^{ks} \left(\frac{B_i}{B_{max,i}} \right) + \frac{\rho_l}{\rho_{l,max}} + \frac{\mathrm{f_{ck}}}{\mathrm{f}_{\mathrm{ck},max}} + \alpha \left(g_1 + g_1 \right) \qquad (15)$$

constraints:

$$350 \leq B_i \leq 650 \ \ \forall i = 1, 2, 3, \ldots, ks \ (mm) \qquad (16)$$

$$\%1 \leq \rho_l \leq \%4 \qquad (17)$$

$$20 \leq f_{ck} \leq 30 \ (MPa) \qquad (18)$$

The g_1 and g_2 in Equation (15) are penalty values and are defined separately for each constraint. In addition, α=1 was taken in the equation, so that the objective function was enlarged as much as the penalty value in the research process with the optimization technique, and in cases where the criteria were not met, that is, it was tried to pass from the region outside the solution space back into the solution space.

$$g_1 \ (12) = \begin{cases} 1, \dfrac{\mathrm{R.\Delta}}{\mathrm{L}} > 0.02 & if \\ 0, \dfrac{\mathrm{R.\Delta}}{\mathrm{L}} \leq 0.02 & if \end{cases} \qquad (19)$$

Equation (19) is used for cases where the required displacement criteria for prefabricated buildings are not met and the penalty value is taken as 0 or 1 and added to the target function.

The second penalty function is given in Equation (20). Equation (20) is mainly used to check the conditions given in Equation (12) and Equation (13). In case the conditions sought in the design are not met, the objective function is subject to a penalty, that is, a penalty, by assigning a value of 1 to the relevant function.

$$g_2 = \begin{cases} 0, \forall \ \mathrm{i} = 1,2,\ldots, \mathrm{For\ ks} \quad M_{i,capacity} \geq M_{i,static} \quad V_{r,i} \geq V_{e,i} & if \\ 1, otherwise \end{cases} \qquad (20)$$

3. Harmony Research Optimization Technique

The harmonious search optimization technique has been used to find solutions to a number of engineering problems[7]. The advantages of this method are:

1)There is no need to define initial business solutions.

2) the ability to overlook local procedures as they continue the process of improvement with additional solutions;

3) It can be used for both continuous and discrete variables. The optimization problem is solved through the use of harmonious search technology, according to the following steps:

3.1 Identifying the Problem and Setting the Solution Parameters

In the first step, the optimization problem is defined, an example definition is given below.

$$min\{f(x)\} \ \mathrm{x_i} \ [\mathrm{x_{i,min}} \ \& \ \mathrm{x_{i,max}}] \ i = 1,2,3,\ldots, N \qquad (21)$$

Here, f(x) is the decision adjective that should be reduced, xi is the decision variable, xi, min is the lower bound, xi, max is the upper bound of the decision variable, and N is the number of decisions changed. In this step, dimensions such as (HMS), (HMCR), (PAR) and the maximum number of iterations are also transmitted.

3.2 Creating the Harmony Memory

In this step, The values of the objective function for the decision are calculated from randomly generated decisions variables from the given solution space and the harmony memory is filled as given in Equation (22).

$$\begin{bmatrix} x_1^1 & x_2^1 & \cdots & x_{N-1}^1 & x_N^1 \\ x_1^2 & x_2^2 & \cdots & x_{N-1}^2 & x_N^2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_1^{\mathrm{HMS}-1} & x_2^{\mathrm{HMS}-1} & \cdots & x_{N-1}^{\mathrm{HMS}-1} & x_N^{\mathrm{HMS}-1} \\ x_1^{\mathrm{HMS}} & x_2^{\mathrm{HMS}} & \cdots & x_{N-1}^{\mathrm{HMS}} & x_{N-1}^{\mathrm{HMS}} \end{bmatrix} \Rightarrow \begin{bmatrix} f(x^1) \\ f(x^2) \\ \vdots \\ f(x^{\mathrm{HMS}-1}) \\ f(x^{\mathrm{HMS}}) \end{bmatrix} \qquad (22)$$

3.3 Creating the New Harmony

In this step, the generation of each variable that will be included in the new harmony h'=(h'$_1$, h'$_2$, ,…, h'$_N$), is applied according to 3 rules: (1) using the harmony memory, (2) tone tuning, (3) random selection. Whether or not the variable will be choose from within the harmony knowledge is made according to the HMCR ratio, whose value is selected between 0 and 1. While HMCR shows the probability of being selected from the harmony memory for a decision variable, (1-HMCR) corresponds to the random selection of the new decision variable from the existing solution space. How the selection process is done is given in Equation (23).

$$h_i^{'} = \begin{cases} h_i^{'} \in \left[h_i^1 \dots x_i^{\mathrm{HMS}}\right] & With\ the\ possibility\ of\ HMCR \qquad \mathrm{i} = 1,2,3 \dots \mathrm{N} \\ h_i^{'} \in \left[h_{i,min} \dots h_{i,max}\right] & With\ the\ possibility\ of\ (1-HMCR) \end{cases} \qquad (23)$$

After this stage, it is decided whether the decision variables selected from the harmony memory will be subjected to tone adjustment or not. This process is controlled by the tonal adjustment rate (PAR). The tonal adjustment process is done as given in Equation (24).

$$h_i^{'} = \begin{cases} h_i^{'} \mp Rand\ (0,1) * \ bw & With\ the\ possibility\ of\ PAR \\ h_i^{'} & With\ the\ possibility\ of\ (1-PAR) \end{cases} \qquad (24)$$

Here, bw is the bandwidth selected for tone tuning, and rand(0,1) is a uniform random number whose value varies between 0 and 1. HMCR and PAR parameters in Equation (23) and (24) are used for the algorithm to obtain global and local optimum solutions, respectively. In the literature, it is recommended to choose values between 0.70-0.95 and 0.20-0.50 for HMCR and PAR parameters, and between 10-50 for harmony memory capacity (HMS) [13].

3.4 Improve memory of knowledge

In this step, the values of the objective functions between the newly created harmony and the worst harmony in the memory are compared, and if the new Harmony yields better results than many memory solutions, by which the worst harmony is removed from knowledge and a new harmony direction is set instead.

3.5 Checking Stop Condition

In this step, it is checking whether the given stopping condition is met. If the condition is not met, the steps between step three and step five are repeated while the desired condition have completed.

The solution of the problem handled within the scope of the study with the harmony research optimization technique is given below, step by step. This solution approach for design has been prepared using the Visual Basic [20] programming language running in the background of Microsoft Excel, one of the widely used spreadsheet programs.

Step 1. Get Started

Step 2. Define Problem Parameters (Title 3.1)

a) Decision variables and their number,

b) Determine the maximum and minimum values of the decision variables,

c) Objective function,

d) Constraints,

e) Define harmony parameters (HMS, HMCR, PAR).

Step 3. Randomly populate the Armani memory and calculate the value of the objective function for the HMS number of vectors (Title 3.2)

Step 4. Create the new harmony (Title 3.3)

Step 5. Compare the new harmony vector with the worst vector in memory. If the new harmony is better than the worst one, go to Step 6, if not, skip to Step 7.

Step 6. Replace the new solution vector with the worst solution vector (Title 3.4)

Step 7. Check the stopping condition, go to Step 8 if it is satisfied, return to Step 4 if not. (Title 3.5)

Step 8. STOP

4. Digital Application

Within the scope of the study, the design of the prefabricated building built on the good and bad ground (Z1 and Z4) groups in the first degree earthquake zone was made using the developed solution approach. In order to test the effect of the solution parameters of the optimization technique used on the results, 5 different parameter groups consisting of different HMS, HMCR and PAR values were randomly generated and given in Table 1. In addition, in order to test the stability of the results obtained with the algorithm used, each parameter group was run 30 times, including different initial solutions, and the results were summarized statistically. As a result, a total of 300 analyzes were performed for both soil groups.

The maximum number of iterations was chosen as 10,000 in all analyzes. Analyzes were performed on a 64bit operating system with a 2.30GHz Inteli5-2410M processor and 4GB (RM) memory.

Table 1: Harmony parameters used in the solution algorithm.

Parameter/Group	PG1	PG2	PG3	PG4	PG5
H.M.S	22	44	33	33	33
H.M.C.R.	1.1	1.1	1.10	1.10	1.90
P.A.R.	0.6	0.6	0.40	0.50	0.30

4.1 Design of Prefabricated Industrial Building on Good Ground (G1) Class

As a result of the analyzes made for the G1 floor class, it has been determined that the prefabricated building designed meets all the constraints in all parameter groups. In Table 2, the best, worst, average and standard deviation values of the objective function values obtained for each parameter group of the prefabricated industrial structure built on the G1 soil class are given.

Table 2: Results obtained for soil class G1 by parameter group.

Result/ Group	**GP1**	**GP2**	**GP3**	**GP4**	**GP5**
Worst	1.7325	1.8828	1.7424	1.7413	1.7314
Best	1.7149	1.8708	1.7149	1.7149	1.7149
Average	1.7226	1.8768	1.7248	1.7237	1.7237
Std. Handle. (%)	0.6413	0.6396	0.8074	0.7689	0.5104

As can be seen from Table 2, it is seen that the worst results obtained for each parameter group vary according to the parameter group, but are not relatively far from each other. The best objective function values given in Table 2 are the same in all parameter groups. In addition, the fact that the averages of the results obtained from the parameter groups are very close to each other is an indicator of the stability of the applied solution algorithm. Although the parameter group with the lowest standard deviation among the values of the objective functions is the GP5 group, it is seen that the standard deviation value is below 1% in all groups.

The values of the decision variables of the optimum design obtained in all parameter groups as a result of the analyzes are given in Table 3.

Table 3: Building design results corresponding to the best objective function obtained for soil class G1.

Decision variables	
Frost your neck. Ratio (ρl)	% 1.26
Column size 1 (B1)	350
Column size 2 (B2)	350
Column size 3 (B3)	450
Column size 4 (B4)	350
Concrete class (N/mm^2)	20

In Figure 5, the convergence graphs obtained in each parameter group are given. As can be seen from the figure, the values for the objective function are in close proximity to each other, especially after 1000 iterations.

As mentioned before, the fact that the prefabricated industrial structures are high and their joints are articulated causes the shear effects to be low, and the criteria for shearing are mostly determined by the minimum requirements in the regulation. Horizontal reinforcement spacing in all designs obtained as a result of the analyzes were designed using 100 mm and 8 mm diameter reinforcement.

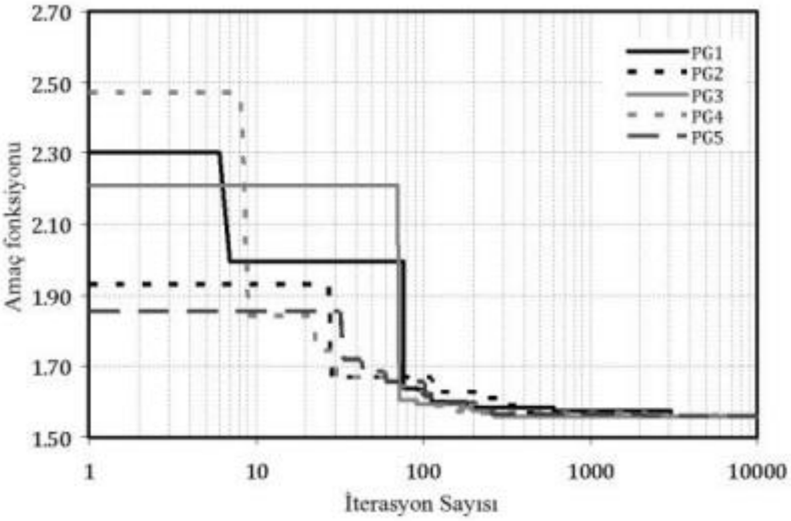

Fig. 5: Design convergence plot for soil class G1.

The analyzes on good ground showed that the stresses in the structure were especially effective in determining the column dimensions. In addition, it was determined that the critical sections in the designs were obtained from the inner frames.

4.2- Design of Prefabricated Industrial Building on Bad Ground (Z4) Class

In this part of the study, the building built on bad ground was designed with the developed solution approach. Thus, both the structural differences between the structures built on different soils were determined and the effect of different solution parameters of the harmony research technique on any soil class was investigated.

The best, worst, average and standard deviation of the objective function values obtained for each parameter group of the prefabricated industrial structure examined in the analyzes are given in Table 4. As a result of the analysis, it was determined that all constraints were met in all groups and structural designs were carried out.

Table 4: Global results obtained for soil class Z4 by parameter group.

Result/ Group	PG1	PG2	PG3	PG4	PG5
Worst	2.0493	2.0416	2.0757	2.0581	2.0471
Best	1.9778	1.9778	1.9778	1.9778	1.9778
Average	2.0196	2.0075	2.013	2.0108	2.0053
Std. Handle. (%)	2.8127	2.2	2.3485	2.5542	1.969

When Table 4 is examined, it is seen that the best objective *f* value is the same in all groups. The results obtained show that the standard deviation is between 1.7-2.6% and the mean objective function values obtained from each parameter group are close to each other. As in the G1 soil class, the PG5 group is the parameter group with the lowest standard deviation among the objective functions in the G4 soil class, followed by the PG2, PG3, PG4 and PG1 groups. The values of the decision variables for the optimum design obtained as a result of the analyzes are given in Table 5.

Table 5: Building design results corresponding to the best objective function obtained for soil class G4.

Decision variables	
Frost your neck. Ratio (ρl)	% 1.45
Column size 1 (B1)	350
Column size 2 (B2)	600
Column size 3 (B3)	550
Column size 4 (B4)	500
Concrete class (N/mm^2)	20

In Figure 6, convergence graphs for each parameter group are given. When Figure 6 is examined, it is seen that the objective function initial values of each parameter group are different from each other. This situation shows that, as mentioned before, memory is randomly created and started randomly during the research process with harmony. Although the objective function values are different from each other at the beginning, it is seen that the function values approach each other during the iteration process. This is an indication that the memory is updating itself.

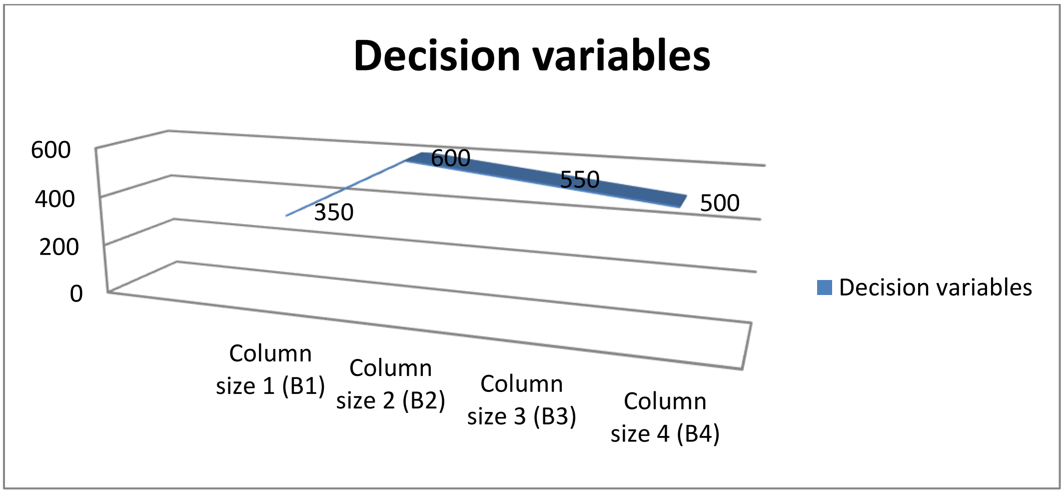

Fig. 6: Design convergence plot for ground class G4.

It is seen that the cross-sections obtained for the bad soil class are higher than the good soil class. Due to the higher spectrum corner period in bad ground, the building elastic periods remain in the constant velocity region. In this case, the earthquake forces acting on the structure and the horizontal displacement demands increase. Column sections are starting to grow due to increasing demands. As a result, it has been determined that the column sections in the structure in bad soil are affected by the stresses occurring in the structure and the relative storey drift limit, which has become critical. In addition, it has been determined that the critical sections in the designs occur in the interior frames of the building.

5- Results and Recommendations

In this study, a solution approach has been developed for the optimum design of prefabricated structures, most of which are single-storey and their joints are articulated, especially in industrial zones in Turkey, using the intuitive harmony research technique.

For the design, a typical prefabricated industrial structure with a height of 6 meters and a span of 3x20m in the X direction and 6x7.5m in the Y direction, which is thought to be built on the building importance coefficient I=1 and G1 and G4 soil classes, located in the first degree seismic zone, was considered.

In the study, the iteration number was taken as 10,000 as the stopping condition of the algorithm and 5 different parameter groups were created to show the effect of the parameters in the harmony research technique used on the global minimum and local minimum solutions. In addition, each parameter group was run 30 times considering different initial solutions, and the sensitivity of the parameters of the algorithm used on the solution and the stability of the results were investigated.

It has been determined that all the designs obtained in the solutions made with the algorithm meet all the constraints and the best objective function values are the same in all parameter groups used. The average objective function values calculated in the comparisons between the parameter groups are quite close to each other in both soil groups. This is an important indication that the algorithm used is stable. In the analyzes made for the good ground (G1) class, the standard deviation values are GP5, GP2, GP1, GP4 and GP3 from smallest to largest, while in the bad ground (G4) class, GP5, GP2, GP3, GP4 and GP1 groups follow this order. The group with the lowest standard deviation in both soil classes is the GP5 parameter group. Therefore, it may be a good choice to use this parameter group in the design of prefabricated structures.

As a result of the evaluations, it has been determined that with the solution algorithm used, it is possible to realize designs within different regulations, constraints and/or different soil classes, and even perform performance-based designs including non-linear analysis of these structures.

The results show that the harmony research optimization technique, which is used in the solution of many engineering problems, can also be used effectively in the design of prefabricated industrial structures.

Among the different analysis methods (e.g. linear static, nonlinear static, linear dynamic and nonlinear dynamic analysis methods) used to determine seismic design actions in building components, the equivalent static analysis procedure, in which a lateral force is calculated and then applied to the structure as a set of equivalent static forces, is widely accepted in seismic codes of most earthquake prone countries. In this approach, the lateral design seismic force is calculated as a product of the building weight and a seismic design coefficient.

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