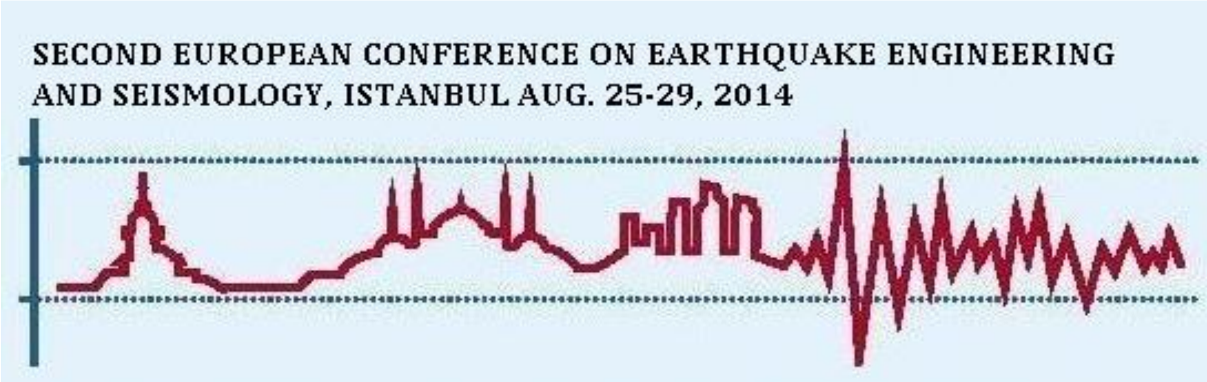

DIRECTION BASED ELASTIC PERIOD EXPRESSIONS FOR REINFORCED CONCRETE SHEAR WALL DOMINANT STRUCTURES USING GENETIC ALGORITHMS

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ABSTRACT

Empirical formulas for estimating the fundamental period provided by building codes are generally expressed as a function of building height, material (steel, reinforced concrete (RC)) and building type (frame or shear wall (SW)). Although these empirical equations are widely used in practice, it has been indicated that they can be improved.

In order to evaluate the dynamic properties of RC SW buildings, a parametric study on 230 different RC building models with shear walls was carried out by varying the following parameters: building height, number of bays and the ratio of shear walls area to floor area. The periods obtained from eigenvalue analysis were compared with the period obtained using building codes. Direction based expressions are proposed for predicting the elastic period of regular RC SW structures and are obtained by performing non-linear regression analysis on the database using genetic algorithms.

1 INTRODUCTION

The determination of the natural period of vibration of a reinforced concrete (RC) structure is an essential procedure in earthquake design and assessment since it is the main property of the structure that determines the elastic demand and, indirectly, the required inelastic performance in static procedures. For new buildings, the period can be evaluated using simplified empirical relationships found in codes, with a simple relation between the periods of buildings and their geometry (height or number of storeys of the structure). Expressions for estimating the fundamental period provided by seismic code provisions, generally given as a function of building height, building type (frame or shear wall (SW)), has been the subject of a significant deal of research of both experimental and analytical studies.

In reinforced concrete shear-wall (RC SW) buildings the lateral load resistance is mainly provided by shear walls, which represent, when properly designed, economical and effective lateral stiffening elements that can be used to reduce potentially damaging inter-storey drifts in multi-storey structures under earthquake excitations. Shear walls are commonly put into multi-storey buildings because of their good performance under lateral loads, such as earthquake forces, because they provide lateral stability and they act as vertical cantilevers in resisting the horizontal forces. Stiffness, strength and ductility are the basic criteria that the structure should satisfy and shear walls provide a nearly

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optimum means of achieving those objectives. Buildings having shear walls are stiffer than framed structures resulting in reduced deformations under earthquake load. The mass of these buildings is greater than the mass of RC moment resistant frames (MRF) and the period of oscillation is shorter than the period of RC MRF structures. Since they are stiffer their period is shorter.

Period-height relationships obtained for different building typologies from the measured periods of vibration during earthquake ground shaking are generally used because they are useful for the first design iteration since the actual period cannot be accurately calculated until a first trial design is performed. The most reliable estimate of periods are from structures which have experienced strong earthquakes and shaken strongly but not deformed into the inelastic range. However, this is often difficult to achieve since such data of periods are slow to accumulate. There are three reasons for this: first, relatively few buildings are installed with accelerographs and second, earthquakes causing strong motions of these instrumented buildings are infrequent (Goel and Chopra, 1998). The third reason is that this database is further reduced by analysing distinguishing materials (steel, concrete etc.), structural systems (RC frames, shear walls etc.) and amplitude of shaking (Michel et al., 2010). In order to obtain a realistic estimate of seismic demand, many authors propose to evaluate the period of vibration based on empirical data from existing buildings subjected to earthquakes. Seismic codes often adopt formulas obtained in this way. Different simple expressions are used by various seismic codes to calculate the fundamental periods of structures. However, it has long been realized that significant errors occur when the code-given formulas such as those in the UBC (1997) or other codes are utilized for shear-wall dominant systems or tunnel form building (Lee et al., 2000, Balkaya and Kalkan, 2003, Tavafoghi and Eshghi, 2008).

2 GENETIC ALGORITHM

Genetic algorithms (GA) have proven themselves as reliable computational search and optimization procedures for complex objectives involving large number of variables. In structural and earthquake engineering, genetic algorithms have been used in various problems (Naeim et al., 2004). Some examples include design optimization of nonlinear structures (Pezeshk, Camp and Chen, 1999), active structural control (Alimoradi, 2001) and performance-based design (Foley, Pezeshk and Alimoradi, 2003).

GAs are optimization techniques based on the concepts of natural selection, genetics and evolution. The variables are represented as genes on a chromosome. Each chromosome represents a possible solution in the search space. Like nature, GAs solve the problem of finding good chromosomes by manipulating the material in the chromosomes blindly without any knowledge about the type of problem they are solving. The only information they are given is an evaluation (or fitness) of each chromosome they produce.

GAs feature a group of candidate solutions (population) in the search space. The initial population is usually produced randomly. Chromosomes with better fitness are found through natural selection and the genetic operators, mutation and recombination. Natural selection ensures that chromosomes with the best fitness will propagate in future populations. Using the recombination operator (also referred to as the crossover operator), the GA combines genes from two parent chromosomes to form two new chromosomes (children) that have a high probability of having better fitness than their parents. Mutation is a necessary mechanism to ensure diversity in the population, thus mutation allows new areas of the response surface to be explored. Given a problem, one must determine a way or method of encoding the solutions of the problem into the form of chromosomes and, secondly, define an evaluation function that returns a measurement of the cost value (fitness) of any chromosome in the context of the problem. Details of GA can be found in (Lin and Lee, 1996).

The advantages to using GAs are many: they require no knowledge or gradient information about the response surface, discontinuities present on the response surface have little effect on overall optimization performance, they are resistant to becoming trapped in local optima, they perform very well for large-scale optimization problems and can be employed for a wide variety of optimization problems. GA can be used in nonlinear regression. Even though certain nonlinear problems can be transformed to linear regression problems, there are several advantages to performing nonlinear regression directly:

- Caution is needed in transforming nonlinear problems to linear problems since the influence of the data values on the dependent variable changes.
- The minimization of the sum of the squared residual values is based on the true nonlinear value rather than the linearized form.

Determining the parameters of the new empirical expressions for the fundamental period is considered a parameter identification problem. Let the mathematical model of the fundamental period be defined as a function f

$$T = f(\boldsymbol{x},\boldsymbol{p}), \tag{1}$$

where $\boldsymbol{x} = (x_1, \ldots x_k)^T$ is the vector of k independent variables and $\boldsymbol{p} = (p_1, \ldots p_m)^T$ the vector of m unknown real parameters. Let the provided experimental data be represented by $(\boldsymbol{x}_i, T'_i)$, $i = 1,\ldots n$ where $\boldsymbol{x}_i$ represents the values of the independent variables and, T'_i, the measured values of the fundamental period. Usually $k << n$ and $m << n$. With the given measured values, one needs to estimate the optimal parameter vector, $\boldsymbol{p}^*$ for Eq. (1) such that

$$F(\mathbf{p}^*) = \min_{\mathbf{p}\in \mathbb{R}^m} F(\mathbf{p}), \quad F(\mathbf{p}) = \frac{1}{n}\sum_{i=1}^{n}[f(\mathbf{x}_i,\mathbf{p}) - T_i']^2 . \tag{2}$$

In this paper, the parameters which need to be determined and optimized are encoded into chromosomes using the floating point implementation. In the GA, after each iteration, the new values $f(\boldsymbol{x}_i, \boldsymbol{p})$ for each possible solution of $\boldsymbol{p}$ are determined. The fitness of each chromosome is then determined using Eq. (2) The GA then consists of the following steps (Lin and Lee, 1996)

1. Initialize a population of chromosomes (possible solutions of $\boldsymbol{p}$).
2. Find the values $f(\boldsymbol{x}_i, \boldsymbol{p})$ for each chromosome, $\boldsymbol{p}$, in the population.
3. Evaluate the fitness of each chromosome, $\boldsymbol{p}$, in the population using Eq. (2).
4. Create new chromosomes by using GA operators.
5. Delete unsuitable chromosomes of the population to make room for the new members.
6. Find the new values $f(\boldsymbol{x}_i, \boldsymbol{p})$ for each new chromosome, $\boldsymbol{p}$, in the population.
7. Evaluate the fitness of each new chromosome, $\boldsymbol{p}$, in the population using Eq. (2) and insert them into the population.
8. If the stopping criterion is satisfied, then stop and return the best chromosome, otherwise, go to step 4.

3 EMPIRICAL EXPRESSIONS FOR THE FUNDAMENTAL PERIOD OF RC SW BUILDINGS

In current seismic code provisions, seismic forces estimation using design spectra requires either implicitly the use of empirical equations for the fundamental period determination or more specifically detailed dynamic analysis.

Since the predicted fundamental period is used to obtain the expected seismic load affecting the structure, a precise estimation of it is important for the safety of the applied procedure in the design steps and consequently in the future performance of the structure after it is constructed.

In the majority of cases, the assessment of the period is considered as function of the structural system classification and number of storeys or height and/or wall area. Several different expressions for evaluating the period of vibration of RC SW buildings are given further in the text.

The formulation of period-height relationships is typically of the type:

$$T = \alpha \cdot H^{\beta}, \tag{3}$$

where H represents the height of the system and α and β are constants. Since it first appeared in U.S. building code ATC3-06 (ATC, 1978) with β equal to 0.75, the first empirical formula was of the form:

$$T = C_t \cdot H^{0.75}, \qquad (4)$$

where: H – height of the structure [m] and C_t – constant depending on the structure type. The coefficient C_t is calibrated in order to achieve the best fit to experimental data. The value of C_t is given in the Table 1, as well as A_c – the total effective area of the shear walls in the first storey of the building (m^2), A_i – the effective cross-sectional area of shear wall „i" in the direction considered in the first storey of the building (m^2), D_i – length of the shear wall „i" in the first storey in the direction parallel to the applied (m), with the restriction $D_i/H \leq 0.9$; A_e – equivalent shear area assuming that the stiffness properties of each wall are uniform over its height and $\overline{A_e}$ – the equivalent shear area expressed as a percentage of A_B, which represent the building area.

This particular form of Eq. (3) was theoretically derived using Rayleigh's method with the assumptions that the equivalent static lateral forces are distributed linearly over the height of the structure, the seismic base shear is proportional to $1/T^{2/3}$ and the distribution of the stiffness with height produces a uniform interstory drift under the linearly distributed horizontal forces.

Empirical expressions given in building codes are presented in Table 1. The Turkish Seismic Code (TSC) concerning construction in seismic areas has been recently modified in 1998 and the equations for predicting fundamental periods of structures were taken directly from the UBC (1997) with small modifications (Balkaya and Kalkan, 2003).

Table 1. Expressions for periods of RC SW buildings given in building codes and by researchers

Building Code	Formula	Equation	Units
NEHRP-94	$T = C_t H^{\frac{3}{4}}; \quad C_t = 0.02$	(5)	(meters; square meters)
ATC3-06	$T = \dfrac{0.05H}{\sqrt{D}}$	(6)	(feet)
UBC-97 and SEAOC96	$T = C_t \cdot H^{0.75};\ C_t = \dfrac{0.1}{\sqrt{A_c}}; \quad A_c = \sum_{i=1}^{NW} A_i \left[0.2 + \left(\dfrac{D_i}{H}\right)^2\right]; \quad \dfrac{D_i}{H} \leq 0.9$	(7)	(feet; square feet)
TSC	$T = C_t \cdot H^{0.75};\ C_t = \dfrac{0.075}{\sqrt{A_c}}; \quad A_c = \sum_{i=1}^{NW} A_i \left[0.2 + \left(\dfrac{D_i}{H}\right)^2\right]; \quad \dfrac{D_i}{H} \leq 0.9$	(8)	(meters; square meters)
Goel and Chopra	$T_L = 0.0019 \dfrac{1}{\sqrt{\overline{A_e}}} H; \quad A_e = \sum_{i=1}^{NW} \left(\dfrac{H}{H_i}\right)^2 \dfrac{A_i}{\left[1 + 0.83\left(\dfrac{H_i}{D_i}\right)^2\right]}; \quad \overline{A_e} = 100 \dfrac{A_e}{A_B}$	(9)	(feet; square feet)
Goel and Chopra	$T_U = 0.0026 \dfrac{1}{\sqrt{\overline{A_e}}} H; \quad A_e = \sum_{i=1}^{NW} \left(\dfrac{H}{H_i}\right)^2 \dfrac{A_i}{\left[1 + 0.83\left(\dfrac{H_i}{D_i}\right)^2\right]}; \quad \overline{A_e} = 100 \dfrac{A_e}{A_B}$	(10)	(feet; square feet)
EC8 (CEN, 2004)	$T = C_t \cdot H^{0.75}; \quad C_t = \dfrac{0.075}{\sqrt{A_c}}; \quad A_c = \sum \left[A_i \left(0.2 + \dfrac{D_i}{H}\right)^2\right]; \quad \dfrac{D_i}{H} \leq 0.9$	(11)	(meters; square meters)

4 NUMERICAL ESTIMATE OF THE PERIOD OF RC SW BUILDINGS - STRUCTURAL MODELS USED IN ANALYSES

The numerical investigation of the period of vibration of RC SW buildings is carried out through a parametric study on a class of structure models. Each model is generated according to a series of geometrical parameters (number of storeys, plan dimensions, bay length) and percentage of shear walls (Figure 1.). The considered buildings are designed for gravity loads only.

The base unit had a span of 5 m in the direction of both axis and with a height of 3 m. RC walls were modelled with a thickness of 30 cm in accordance with the EN1998-1 (CEN, 2004) requirement for minimum shear wall thickness of 20 cm. The largest model was set to be nine base units in length, ten base units in height and three base units in width. In order to fulfil the EN1998-1 (CEN, 2004) requirement for structural uniformity in plan and in elevation, structures were modelled with an odd number of base units thus avoiding eccentricity between mass and stiffness. Figure 1 shows three dispositions of shear walls in the observed structures.

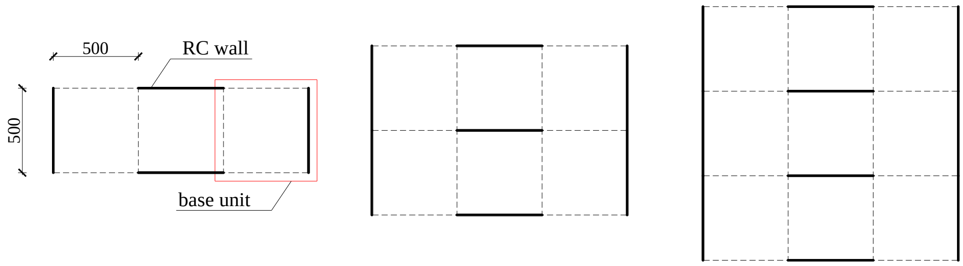

Figure 1. Layout of shear walls in models (cm)

A database was obtained constituting the analysis results of 230 different case studies and the calculations of their basic properties. The considered variable parameters of a given structure model were the longitudinal length (L_x), transversal length (L_y), the global height (H) excluding the foundation, the percentage of shear walls and their dispositions. The building dimensions considered were as follows:

- longitudinal length: L_x = (5.0, 15.0, 25.0, 35.0, 45.0) m;
- transversal length: L_y = (5.0, 10.0, 15.0) m;
- building height (H) was between (3.0 ÷ 30.0)m corresponding to 1–10 storeys.

Shear wall disposition was symmetrical with respect to both the horizontal axes, in order to avoid any additional eccentricity between the centre of mass and centre of stiffness. Therefore, when selecting the appropriate distribution of shear walls with respect to the action of horizontal forces, the walls need to be placed as much as possible on the edges of the building in order to improve torsional resistance. Disposition of walls remained the same per floor.

There were two groups of models, with each model having a different percentage of shear walls, as can be seen in Table 2. The percentage of the amount of built walls, in order to obtain a symmetrical layout structure, ranges from 2.5% to 5.5%. The second group had a slightly lower percentage of the walls. Varying the number stories (from 1 to 10), the number of bays in one direction (from 1 to 3) and in the other direction (from 1 to 10), each group consisted of 120 models.

Table 2. Percentage of built-in walls

Models	L_x	L_y	$\%_u$ 1-x	$\%_u$ 1-y	L_y	$\%_u$ 2-x	$\%_u$ 2-y	L_y	$\%_u$ 3-x	$\%_u$ 3-y
	m	**m**			**m**			**m**		
Group 1	15	5	4.00	4.00	10	3.00	4.00	15	2.67	4.00
	25	5	4.80	4.80	10	3.60	4.80	15	3.20	4.80
	35	5	5.14	3.43	10	3.86	3.43	15	3.43	3.43
	45	5	5.33	4.00	10	4.00	4.00	15	3.56	4.00
Group 2	15	5	4.00	4.00	10	4.00	4.00	15	2.67	2.67
	25	5	2.40	2.40	10	2.40	2.40	15	1.60	1.60
	35	5	1.71	1.71	10	1.71	1.71	15	1.71	1.71
	45	5	2.67	2.67	10	2.00	2.67	15	1.78	1.78

Numerical modal analysis was performed using SAP2000v10.0.1. software in order to determine the vibration modes of observed structures. There are two types of modal analysis in the applied software: eigenvector and Ritz-vector analysis. Eigenvector analysis determines the undamped free-vibration mode shapes and frequencies of the system. These natural modes provide an excellent insight into the behaviour of the structure. Ritz-vector analysis seeks to find modes that are excited by a particular loading. Ritz vectors can provide a better basis than eigenvectors when used for response-spectrum or time-history analyses that are based on modal superposition (CSI Analysis Reference Manual for SAP2000, 2007). Eigenvector analysis involves the solution of the generalized eigenvalue problem. Modal analysis is always linear and can be based on the stiffness of the unstressed structure (before applying any load) or after the nonlinear analysis. In the first case stiffness remains unchanged but after the nonlinear analysis stiffness is reduced by cracking (in concrete elements) or plastic hinge formation (in steel elements). Stiffness was taken as unchanged in this analysis what is in accordance with the recommendation given in EN 1998-1-2 which states that the calculation can be performed with the assumption of uncracked bearing walls. Bearing walls were modelled as shell elements. The shell element is a three- or four- node formulation that combines membrane and plate-bending behaviour. A four-point numerical integration formulation is used for the shell stiffness. Stresses, internal forces and moments, in the element local coordinate system, are evaluated at the 2-by-2 Gauss integration points and extrapolated to the joints of the element (Figure 2).

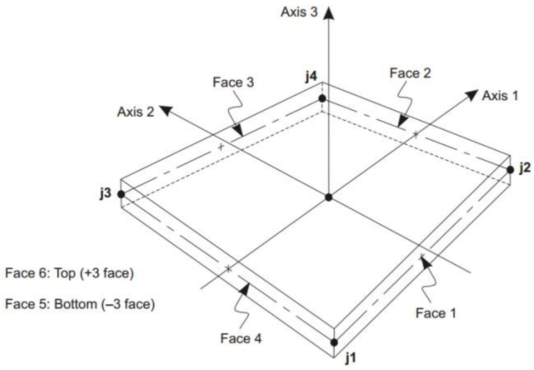

Figure 2. Four-node Quadrilateral Shell Element (CSI Analysis Reference Manual for SAP2000)

Edge constraints are assigned to elements in order to automatically connect all joints that are on the edge of the element to the adjacent corner joints of the element. In that way wall continuity throughout the structure height was achieved (Figure 3).

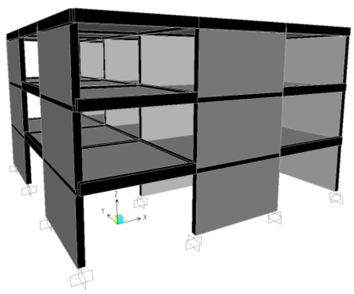

Figure 3. Three-dimensional numerical model of the building

5 COMPARISON OF PERIODS OF RC SW MODEL STRUCTURES WITH PERIOD OBTAINED USING BUILDING CODES

The obtained periods in both directions for two groups RC SW models are compared to those obtained using the empirical expressions described in Section 3. Since the periods depend on percentage of RC walls and their plan dispositions, a comparison with empirical expressions will be displayed for chosen models from the database.

The curves of results obtained for the periods in both directions for the chosen model structures with different ratio of the percentage of walls are compared to those obtained using the empirical expressions for the longitudinal and transversal direction of the structure and are displayed in Figs. 4, 5, 6 and 7.

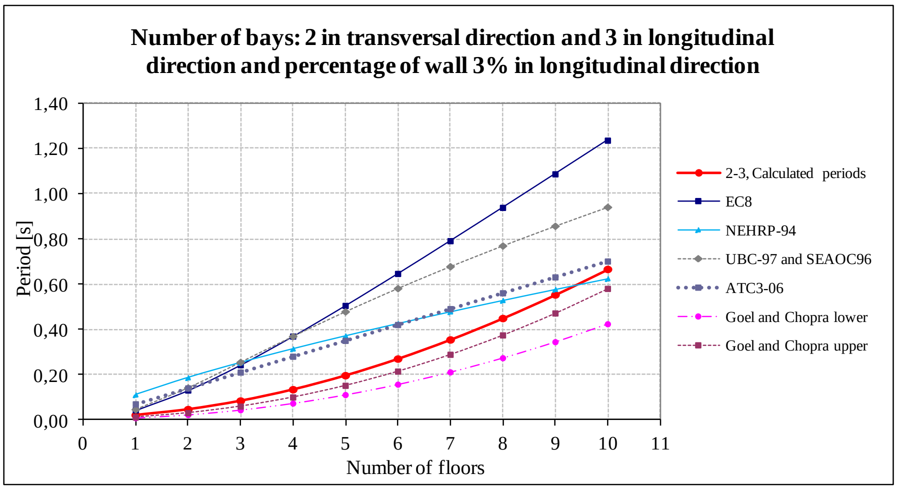

Figure 4. Comparison of period for 3% of walls in longitudinal direction

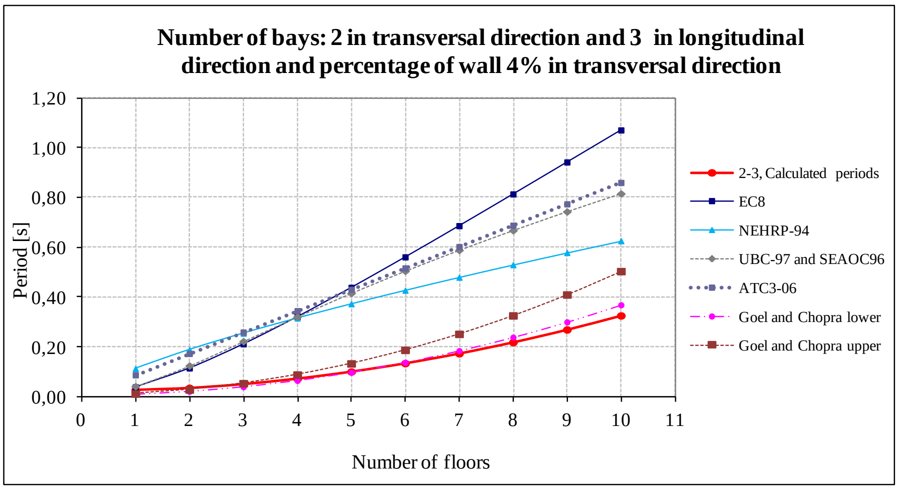

Figure 5. Comparison of period for 4% of walls in transversal direction

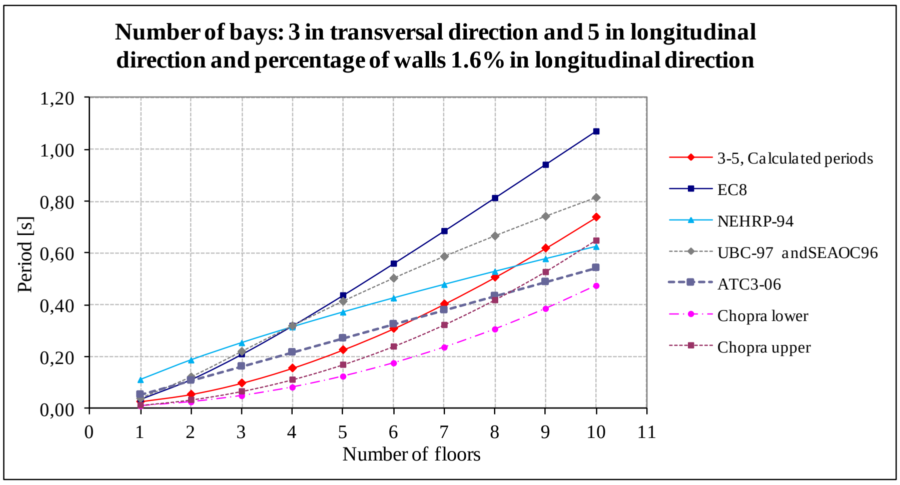

Figure 6. Comparison of period for 1.6% of walls in longitudinal direction

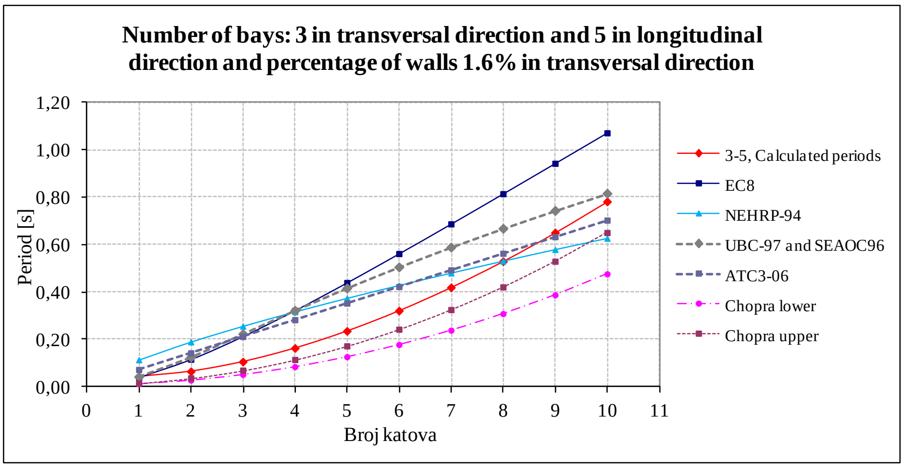

Figure 7. Comparison of period for 1.6% of walls in transversal direction

Figs. 4 to 7 show that for all 10 models, the code formulas (ATC3-06 (Eq. (6), NEHRP-94 (Eq. (5)) and EC8 (Eq. (11)) give a period longer than the value obtained by modal analysis. The longer period from the code formula leads to seismic coefficients smaller than the value obtained by modal analysis if the period falls outside the flat portion of the seismic coefficient spectrum.

Values of obtained periods in transversal direction, which are greater than those in the longitudinal direction and thus represent the fundamental periods of the observed structure, are closer to the values obtained by expressions from Goel and Chopra upper curve (Eq. (10)) and for nine and ten storeys are close to the values of NEHRP-94 (Eq. (5)) and ATC-06 (Eq. (6)).

7 NEW EXPRESSIONS FOR THE PERIOD OF RC SW BUILDINGS USING GENETIC ALGORITHM

Studies have shown that very often the impact of earthquakes on the wall is expressed by the ratio of the sum of surface cross-sections of all walls that are activated in one of the main directions and total the layout surfaces.

The calculation of the periods of models of RC structures with walls described in Section 4 were made using SAP2000v10.0.1. A database was created using the calculated values of periods in both directions. Regression analysis using genetic algorithm was applied and the parameters of period expression for both directions were calculated.

Several expressions for the period of RC shear wall dominant structures are proposed. The first expression took into account the percentage of the amount of built walls, the height, i.e. number of floors and the ratio between the number of bays in the longitudinal (x) and transversal (y) direction. Using genetic algorithms for nonlinear regression analysis the following expression was obtained:

$$T_{x(y)} = 0.00084 \cdot \left(\frac{m_{x(y)}}{m_{y(x)}} \right)^{0.0682} \cdot u_{x(y)}^{-0.7165} \cdot N^{1.6718}, \tag{12}$$

where T_x is the period of the RC shear wall dominant structure in x direction; m_x is number of bays in x direction; m_y is number of bays in y direction and u_x is percentage of area of walls in x direction in relation to the total plan area of the structure and N is the number of storeys.

The second expression did not take into account the ratio of the bays, but the height, i.e. number of floors and the amount and percentage of wall area in the observed direction in relation to the area of the entire layout of the building. The following expression for the calculation of the period was obtained:

$$T_{x(y)} = 0.0008 \cdot u_{x(y)}^{-0.7323} \cdot N^{1.666}, \tag{13}$$

A period expression period depending only on the height and length of the building was considered as well. The following expression for the period was obtained:

$$T_{x(y)} = 0.0013 \cdot H^{1.6671} \cdot D_{x(y)}{}^{0.0957}, \tag{14}$$

where H is the total height of building (m) and D_x is the total length of building in x direction (m).

The corresponding periods in the transversal direction can be calculated using the same above three expressions (Eqs. (12), (13) and (14)). However, the longitudinal parameters are substituted by the corresponding transversal parameters: (m_y / m_x) and u_y in Eq. (12); D_y in Eq. (13) and u_y in Eq. (14).

These expressions, given by equations (12)-(14) are compared in Table 3, which shows the error of the expressions given above: the mean squared error, minimum absolute error and maximum absolute error.

Looking at Table 3., it can be noticed that the period of RC SW dominant structures is best approximated by Eq. (12) since it has the least mean squared error. However, since its value is comparable to that obtained by Eq. (13) it can be noticed that the bay ratio is not a dominant factor. Both these equations take into account the percentage of wall area in relation to the area of the entire layout of the building compared to Eq. (14). Thus, it can be concluded that for the RC SW structures the most important parameters in calculating the period are the building height and the percentage of wall area w.r.t. the area of the entire layout of the building.

Table 3. Mean squared error, minimum and maximum error for proposed equations (12)-(14)

Equation	Expression	Direction	Mean squared error	Minimum absolute error	Maximum absolute error
(12)	$T_{x(y)} = 0.00084 \cdot \left(\frac{m_{x(y)}}{m_{y(x)}}\right)^{0.0682} \cdot u_{x(y)}{}^{-0.7165} \cdot N^{1.6718}$	*Longitudinal (transversal)*	0.0043	0.0001	0.2762
(13)	$T_{x(y)} = 0.0008 \cdot u_{x(y)}{}^{-0.7323} \cdot N^{1.666}$	*Longitudinal (transversal)*	0.0048	0.00005	0.3008
(14)	$T_{x(y)} = 0.0013 \cdot H^{1.6671} \cdot D_{x(y)}{}^{0.0957}$	*Longitudinal (transversal)*	0.0102	0.000002	0.4044

8 RESULTS AND DISCUSSION

Results of regression analysis performed by genetic algorithm given by Eq. (12) for the calculation of the periods of RC SW structures are shown in Figs. 8, 9, 10 and 11 for randomly selected models. The values of periods obtained for period using Eq. (12) (presented by the black line), are compared with the values obtained analytically (red line). The values of calculated periods using code formulas and obtained by researchers Chopra and Goel (Eq. (10)) are also presented in the same figures.

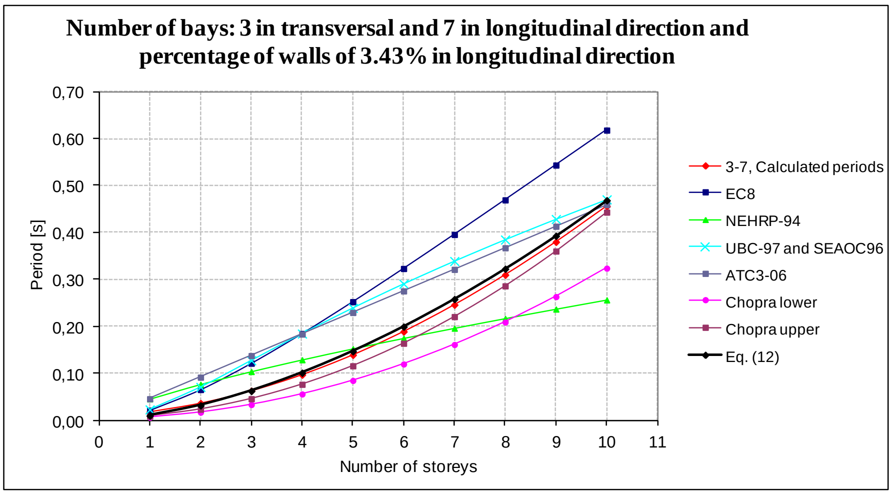

Figure 8. Comparison of periods for 3.43% of walls in longitudinal direction

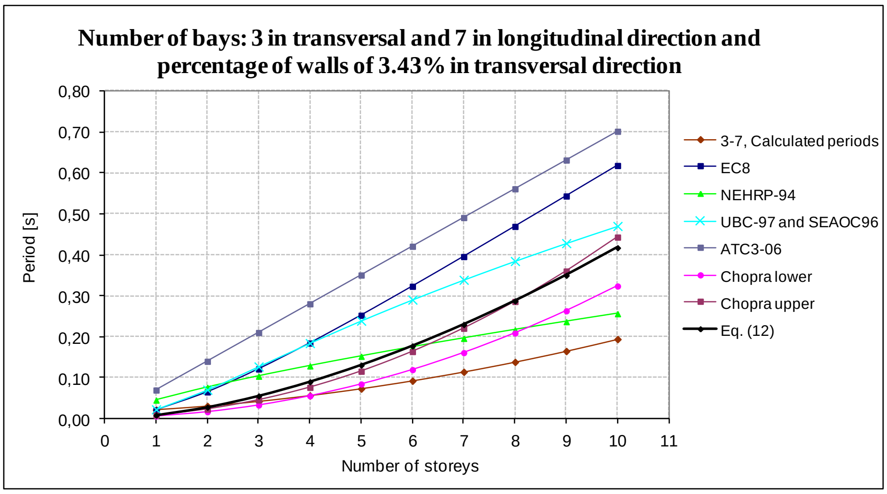

Figure 9. Comparison of periods for 4% of walls in transversal direction

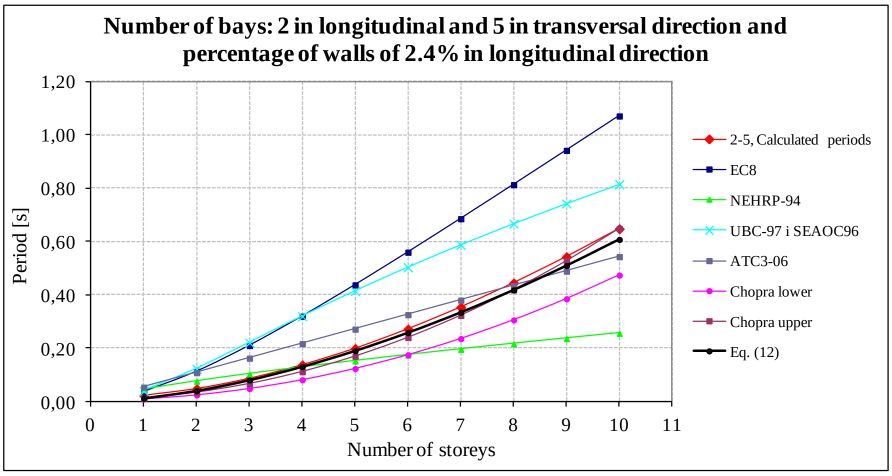

Figure 10. Comparison of periods for 2.4% of walls in longitudinal direction

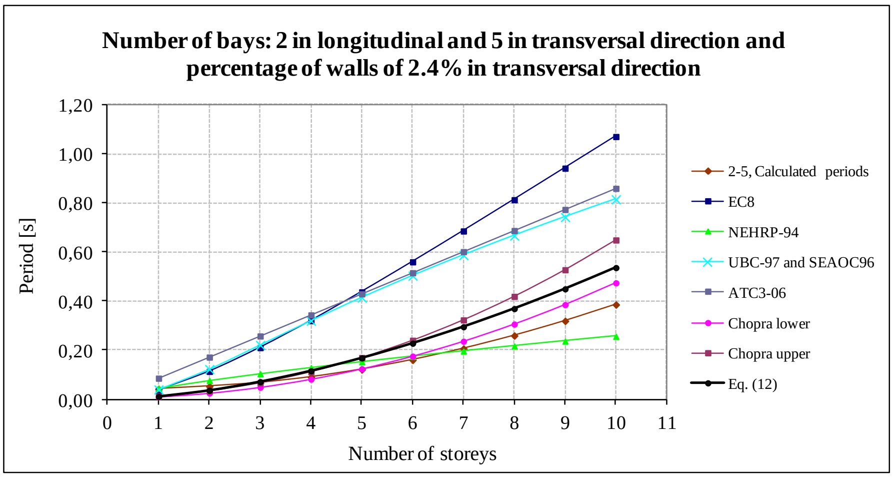

Figure 11. Comparison of periods for 2.4% of walls in transversal direction

The values of periods for models with layout of 2 and 5 bays and with the percentage of walls of 3.43% in longitudinal and transversal direction presented in Figs. 8 and 9 show that Eq. (12), that takes into account only the percentage of the walls in the observed direction, is very close to the obtained periods. The next expression with lowest error is that from Goel and Chopra (Eq. (10)).
The values of periods for models with layout of 3 and 7 bays and with the percentage of walls of 2.4% in longitudinal and transversal direction presented in Figs. 10 and 11 show that Eqs. (12), and Eq. (10) give the smallest errors.

Looking at Figs. 8-11, it can be noticed that the periods obtained by Eq. (12) are close to the *actual* periods of the models obtained analytically as is to be expected since Eq. (12) was obtained by nonlinear regression. The largest errors in periods are obtained using EC8, especially with an increase in the number of storeys. It can also be concluded that the expressions given by Goel and Chopra are the most appropriate among all expressions given in building codes.

9 CONCLUSION

The fundamental period of vibration plays a major role in predicting the expected behavior of structures under dynamic excitations and it has also been traditionally used to estimate the equivalent lateral seismic design force according to building design codes and recommendations. The empirical formulas for the fundamental period in most building design codes depend on all or some parameters of the material, type of construction, and global dimensions, and, in the case of RC SW structure, on the areas of the walls. In this study, a numerical investigation of the elastic period of vibration of RC SW structures was carried out by means of modal analyses on a set of RC SW models of buildings, which were defined by means of varying geometrical building parameters and arrangement and percentage of shear walls. Only regular buildings, rectangular in the plan, were considered, with symetrically arrangement of shear walls so as not to cause additional torsional effects. Numerical results were analyzed and compared with the results of several expressions for the evaluation of period given by building design codes and by researchers. The significant deviation between current code given formulas and modal analysis leads to intolerable errors for the dynamic parameters and corresponding design loads.

Using a created database of 230 RC SW building models, the differences between the periods of the models obtained from eigenvalue analysis and the corresponding periods obtained using building codes indicate that the expressions in building codes can be improved.

Direction based expressions are proposed for predicting the elastic period of regular RC SW structures and are obtained by performing non-linear regression analysis on the database using genetic algorithms. The proposed expressions take into account the direction of the structure considered, the number of floors (or height), the percentage of walls and the relationship between the bays in the longitudinal and transversal direction. Preliminary results indicate better estimation of the elastic period compared to those obtained using existing building codes with the most important parameters in calculating the period being the building height and the percentage of wall area w.r.t. the area of the entire layout of the building.

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