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The Ultimate Anti-Seismic Design Method

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Abstract

The design mechanisms and methods of the invention are intended to minimize problems related to the safety of structures in the event of natural phenomena such as earthquakes, tornadoes, and strong winds. It is achieved by controlling the deformations of the structure. Damage and deformation are closely related concepts since the control of deformations also controls the damage. The design method of applying artificial compression to the ends of all longitudinal reinforced concrete walls and, at the same time, connecting the ends of the walls to the ground using ground anchors placed at the depths of the boreholes, transfers the inertial stresses of the structure in the ground, which reacts as an external force in the structure's response to seismic displacements. The wall with the artificial compression acquires dynamic, larger active cross-section and high axial and torsional stiffness, preventing all failures caused by inelastic deformation. By connecting the ends of all walls to the ground, we control the eigenfrequency of the structure and the ground during each seismic loading cycle, preventing inelastic displacements. At the same time, we ensure the strong bearing capacity of the foundation soil and the structure. By designing the walls correctly and placing them in proper locations, we prevent the torsional flexural buckling that occurs in asymmetrical floor plans, and metal and tall structures. Compression of the wall sections at the ends and their anchoring to the ground mitigates the transfer of deformations to the connection nodes, strengthens the wall section in terms of base shear force and shear stress of the sections, and increases the strength of the cross-sections to the tensile at the ends of the walls by introducing counteractive forces. The use of tendons within the ducts prevents longitudinal shear in the overlay concrete, while anchoring the walls to the foundation not only dissipates inertial forces to the ground but also prevents rotation of the walls, thus maintaining the structural integrity of the beams. The prestressing at the bilateral ends of the walls restores the structure to its original position even inelastic displacements by closing the opening of the developing cracks.

Keywords

Ultimate, Control-System, Anti-Seismic, Earthquakes, Construction, Method, Design

1. Introduction

Modern seismic construction technology has been able to significantly increase the response of structures to seismic displacements. However, structures cannot withstand just any large earthquake. There are too many unpredictable factors that can bring about the destruction of even the most modern seismic structures. Basically, the factors that determine the seismic behaviour of structures are numerous and partly probabilistic in nature (The direction of the earthquake is unknown, the exact content of the seismic excitation frequencies is unknown, its duration is unknown). Even the maximum possible accelerations given by seismologists, which determine the seismic design factor, have a probability of being exceeded of more than 10%.

The correlation of quantities such as "inertia stresses, damping forces, elastic forces, dynamic characteristics of the structure, soil-structure interaction, imposed ground motion" is non-linear, and they interact with each other. According to modern regulations, the seismic design of buildings is based on the requirements of satisfactory design and ductility. The inevitable inelastic behaviour under strong seismic excitation is directed to selected elements and failure mechanisms.

In particular, the lack of satisfactory design of the nodes and the clearly limited ductility of the elements lead to failure.

The aim of modern seismic codes is to construct buildings that: 1) In small earthquakes with a high probability of occurrence, nothing will happen; 2) In earthquakes with a medium probability of occurrence, minor, repairable damage will occur; and 3) In very strong earthquakes with a low probability of occurrence, no loss of life will occur. So we should not use the term "absolute" in seismic structures. We should use the term "quality" structure which means applying at least the requirements of all modern regulations. The quality of construction and its safety is also a function of the economic situation of countries, among other factors. It is understandable that poor countries cannot be compared with countries where they have expensive modern seismic regulations. Conclusion… there is no absolute seismic planning today, and we should not refer to absolute seismic planning. So there is a great need today to invent a more modern seismic design that corresponds to absolute seismic design, with lower construction costs.

The new design method aims to increase the response of structures to seismic displacements by reducing construction costs. By imposing artificial compression on the ends of the wall sections using tendons and prestressing mechanisms, it succeeds in increasing the dynamic of the walls, making them more stiff and reducing the damage caused by deformation. By anchoring the ends of the walls to the ground, it achieves the deflection of inertia forces into the ground, removing tensions over the structure.

It is commonly accepted and has been shown that prestressing creates stiffness by imposing compensating compression stress to the tensile stresses. Wall stiffness means little deformation by controlling the deformation and eccentricity of the walls, diverting inertial stresses to the ground, control all failures.

This extensive research, spanning the disciplines of civil engineering, geological engineering and mechanical, represents an innovative and interdisciplinary approach to the critical issue of the response of structures to seismic displacements. Since this investigation there has been a significant shift in thinking in the field of earthquake resistant structures. Instead of simply adding more mass and reinforcement, which paradoxically increases seismic loads and costs, new innovative solutions are coming to the fore which, on the one hand, exploit external forces derived from the ground, to improve the dynamic response of structures, combining the prestressed ends of longitudinal reinforced concrete walls, which acquire fully active, rigid and dynamic cross-sections, without adding additional mass, which increases inertia and costs.

The bilateral clamped wall with the ground deflects the compressive and tensile upright forces into the ground, and allows the ground to participate in receiving of the tension, by enhancing the response of the structure to seismic displacements, preventing the generation of large moments at the nodes due to the fact that it stops the turning of the walls and increases the stiffness of their trunk thereby maintaining the vertical position of the walls during the rocking of the earthquake preventing the deformation of the beams, pre compacts the ground in all directions, transfers the loads of the structure deep into the soil where there are stronger areas, reduces foundation costs.

The incorporation of this seismic design technology, which is based on mechanisms for compressing the edges of the longitudinal walls and simultaneously anchoring them to the foundation soil, promises to significantly increase the load-bearing capacity of the structure under the influence of strong seismic excitation. The thorough analysis of preliminary simulation and mathematical investigation results, which methodically determines the deviations, the determination of the orthogonal axial forces and their tabulation, which determines the loads to be absorbed by the ground, the comparable seismic experiments under scale up on a seismic base and the geological experimental investigation of both the ground and the anchoring mechanism, underline the paramount importance of precision and methodological rigour in research and analysis.

The ability of the methodology to mitigate deformations, eliminate tensile forces and moments and increase the active cross-section of the walls, preventing shear failure of the concrete coating along the steel bars, developed at the concrete-steel interface due to the steel's superior tensile strength and the concrete's low shear strength, presents a highly encouraging method of designing cheap and durable earthquake-resistant structures. Furthermore, the problem in the mismatch between the super tensile strength of steel and the small shear strength of concrete which was solved by the design methodology I develop, highlights the often overlooked complexities of material behavior during seismic events. My sustained efforts to address these complexities are intended to significantly shape the development of cost-effective and robust seismic building methodologies.

While the economic and scientific recognition challenges are undoubtedly formidable, this pivotal research underscores its potential to revolutionize the field, ultimately promoting safer and cheaper urban environments against seismic hazards.

Finding the optimal balance between elasticity, ductility, dynamics and cost efficiency remains a constant challenge. While elastic columns and rigid walls each have their advantages and disadvantages, a possible solution by placing elongated walls with prestressed and ground-fixed ends emerges as a promising but underutilized approach. These elongated walls with embedded and prestressed ends offer the potential to enhance the seismic resilience of structures and soils by redirecting seismic forces both by deflecting stress into the ground and by the active participation of the ground in the response of the structure to seismic displacements, increasing the load-bearing capacity of the structure. We now control the structural soil coordination since we have the possibility, through the dynamic participation of the soil, to mitigate the displacement in each seismic loading cycle. With dynamic ground participation and stiff walls we control the rocking of the structure so that it shifts within the elastic displacement range, eliminating inelastic displacements regardless of the acceleration magnitude and duration of the seismic event. The foundation soil enhances with the use of anchors because it is compacted in every direction before the construction of the building and the soil samples collected from the drilling of boreholes reveal the quality of the foundation soil before the construction is erected. This innovative concept promises not only to enhance structural performance but also to address cost concerns by substantially reducing the need for reinforcing materials, potentially revolutionizing seismic design practices in the construction industry. Furthermore, the method when applied to prefabricated houses made of reinforced concrete which have longitudinal double-lever walls, (height and width) increase the design efficiency, increase the height of the floors, reducing the cost compared to conventional housing, since industrialized production products are 30% to 50% cheaper.

The earthquake imposes on the structure a horizontal displacement and some vertical components, which contain an unknown number of frequencies, unknown acceleration level, factors that contribute to the elastic or inelastic deformation of the structures.

If the deformation is small enough to keep all members of the structure within the elastic region, the energy generated is energy stored in the structure and then dissipated to return the structure to its original position. As long as the deformation resulting from the rocking of the structure in the earthquake keeps any part of any member within the elastic region, some of the energy will be converted to frictional heat, while the energy stored in the structure will be released at the end of the cycle in the opposite direction. This displacement region is called the elastic region, in which no failures are observed. If the seismic energy (measured by ground acceleration) is too great, it will produce excessively large displacements, causing a very high curvature in the vertical and horizontal elements. If the curvature is too high, it means that the rotation of the column and beam sections will be well above the elastic range (concrete compressive strain above 0.35% and reinforcement fibre stresses above 0.2%) beyond the yield strength. When the rotation goes beyond this elastic limit, the structure starts to dissipate energy storage through plastic displacement, which means that the sections will have a residual displacement that will not be able to be recovered.

The strength design of a current building is limited to the limits of the elastic design range, and then it passes to inelastic displacements, exhibiting leakage and plastic deformations. If the load-bearing elements of the structure experiencing plastic deformations exceed the breaking point limit, and there are too many on the structure, the structure will collapse. By the design method of connecting the ends of the top level of the longitudinal walls to the ground and by imposing artificial compression on their cross sections, I hope to stop their rotation, deflect the lateral inertia stresses into the ground, and increase the stiffness of the structure, stopping the inelastic deformation that causes earthquake failures.

In an earthquake, the columns lose their eccentricity and their bases are lifted, creating torques at all the nodes of the structure. There is a limit to the eccentricity of the base of which part of one edge is lifted by the rollover moment. To minimize the twisting of the bases, we place strong foot girders in the columns. In the large longitudinal walls, due to the large moments which occur during an earthquake, it is practically impossible to prevent rotation with the classical way of construction of the foot girders.

If we want stronger structures we must prevent the causes of failure and the causes of inelastic deformation in general. The overturning moment of the structure and walls, base shear, shear failure, inadequate bearing capacity of the foundation soil, and shear failure of the concrete overlay that develops along the bars over the concrete and steel interface due to the over tensile strength of the steel and the low shear capacity of the concrete, are some of the destructive factors of structures that deserve more research. The inevitable inelastic behaviour of structures needs to be controlled. The wall sections must be made stronger, capable of absorbing all the forces. The overturning moment of the structure and the walls must be prevented so that it does not create the fishy moments around the nodes. We need to increase the bearing capacity of the soil. We need to eliminate the tension at the wall faces that causes the shear failure in the overlay concrete.

We need to increase the stiffness of the vertical elements of concrete, we need to stop the increasing deformation from the duration and ground construction coordination but the main thing to do is to divert the inertia of the structure into the ground.

Compression of the walls by means of the prestressing mechanism increases the active cross-section, corrects the arrows of the oblique tensile, increases the capacity towards base shear and shear failure of the cross-sections, increases the bearing capacity of the structure, reduces deformation by increasing the stiffness of the wall frames, reduces or even eliminates tensile stress at the ends, reduces deformation and preventing the generation of large moments at the nodes.

2. Applied Research

2.1. Methods of Anti Seismic Building Design

There are two options for seismic design using the proposed method.

1) Absolute dynamic design.

2) Dynamic design combined with seismic damping mechanisms.

1) Absolute dynamic design methods using longitudinal walls prestressed and *anchored* at their ends to the foundation soil by expanding piles [1] [2].

The longitudinal walls are large rigid lever arms at height which multiply to the maximum the downward moments at the base, compared to the elastic columns. However, in addition to the height lever arm, the walls also have a width lever arm which reduces the overturning moments, and the columns do not have this width lever arm, nor do they have a large dynamics. The width lever is a major advantage of the walls because it greatly reduces the overturning forces that the method's mechanisms have to absorb, as well as the cost of application, since it reduces the anchoring operations on the ground.

As the simulation showed, the prestressing of the vertical support elements increases the load bearing capacity of the structure and their capacity to shear reaction to the base.

2) Dynamic design combined with seismic damping mechanisms.

The main dilemma facing a structural engineer tasked with ensuring superior seismic resistance of a building is how to minimize the acceleration of the floors. Large displacements between floors cause damage to non-structural elements and to the structural elements that connect floors together. Deformations can be minimized by stiffening the structure, achieved through the use of walls, but this leads to an amplification of ground motion, which leads to high floor accelerations that can damage sensitive interior equipment and the structure. The installation of many strong walls results, due to their high stiffness, in a significant reduction of the fundamental eigenmodes of the structure. This, combined with the q = 1 consideration, leads to a correspondingly large increase in the seismic loads of the structure. In this respect, it should not be overlooked that it is precisely because of the many strong walls that the strength of the section increases in seismic loads. High accelerations contribute to damage to sensitive internal equipment and structure.

The acceleration of floors can be reduced by making the system more flexible, but this leads to large movements between floors. The only practical way to reduce the mentioned problems is discussed below.

There are five factors that increase the earthquake loads on a structure.

1) Ground acceleration;
2) Mass weight;
3) Mass height;
4) Ground—structural coordination;
5) Duration.

These factors increase the earthquake loads on a structure. The structure must counter these forces with proportional compensating forces and the materials must have the necessary strength to receive them.

Still, various other techniques dampen the displacements by reducing the deformation that causes inelastic failures and deflecting the inertia forces into the ground.

These seismic design techniques will be discussed in my next proposal.

This design method [3] includes a flexible structure with columns and within or outside this flexible structure we place one or more independent rigid wall structures with appropriately shaped plan cross-sections and with prestressed ends connected to the ground.

We place horizontal seismic isolation at the base to prevent high accelerations.

We place strong damping tyres for the smooth absorption of the impact between the diaphragms of the slabs and the walls which occurs due to the difference in the displacement phase of the two independent structures.

In this method, the displacements of the two independent structures cancel each other out reason of impact, and the inelastic deformation of the elastic structure with columns it is prevented.

At their upper ends, the walls have hydraulic jacks connected to the prestressing tendons. When the wall tends to deform due to displacement, the fluids in the hydraulic jacks are heated because they prevent deformation by converting the kinetic force of displacement into heat, creating a smooth elastic seismic damping.

The diversion of seismic forces to the ground and the high stiffness of the walls and the bearing capacity of the foundation soil is given and is due to the pre-stressing and the connection of the edges of the walls to the ground.

2.2. Mechanical Anchoring (Connection) of the Ground and the Construction

There are two different anchoring mechanisms, the anchor mechanism for rock [4] and the anchor mechanism for soft soils (**Figure 1**).

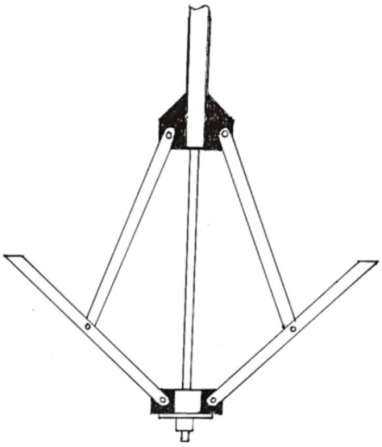

Figure 1. Shows the soft ground anchoring mechanism.

The size of the mechanisms, depends on the quality of the steel, the depth of the boreholes where they are installed, the number of pressure radii of the mechanism, the quality of the soil and the axial compressive and tensile calculation loads that they have to take along with the safety factor.

2.3. Method of Activating Expansion and Compression of the Anchoring Mechanism at the Depth of the Borehole and Connection between the Structure and the Ground

Rock and soft soil anchoring mechanism how it works. It works much like the mechanical jack of a car (see Figure 2).

The mechanism consists of the green tube (13) at the lower end of the tube (13) a smaller diameter tube (14) of red colour penetrates into it. Both tubes are penetrated by the prestressing tendon (3) which is threaded along its entire length in order to be able to screw in the nuts (16), (2), (10) as well as the fasteners (1) extension of tendon (3). The large tube (13) is welded at its upper end with a metal plate (5) the dimensions of which are greater than the diameter of the borehole in order to retain the mechanism suspended in the borehole. On the metal plate (5) two or four hydraulic tract jacks are mounted (8) which, when expanded, lifts the metal plate (4) which is connected through the nut (2) with the tendon of the prestretching (3) which lifts and creates the pulling force of the tendon. The tendon (3) is connected at its lower end to the nut (16). As the tendon rises, the nut displaces the tube (14) upwards, which penetrates the tube (13). During this upward movement of the tube (14) are activated the opening—rotating spokes (19) which push the bars (18) towards the slopes of the borehole and compact the soil condense before creating adhesion through the friction they create. To remove the hydraulic jacks (8) and at the same time maintain tension of the mechanism towards the drilling slopes (17) turn the screw (10) until it ends on the metal base (5). Before screwing the screw (10) fill with concrete grout the borehole from the hole (9). After ensuring that the mechanism is firmly fixed to the ground, gradually extend through transit pipes the

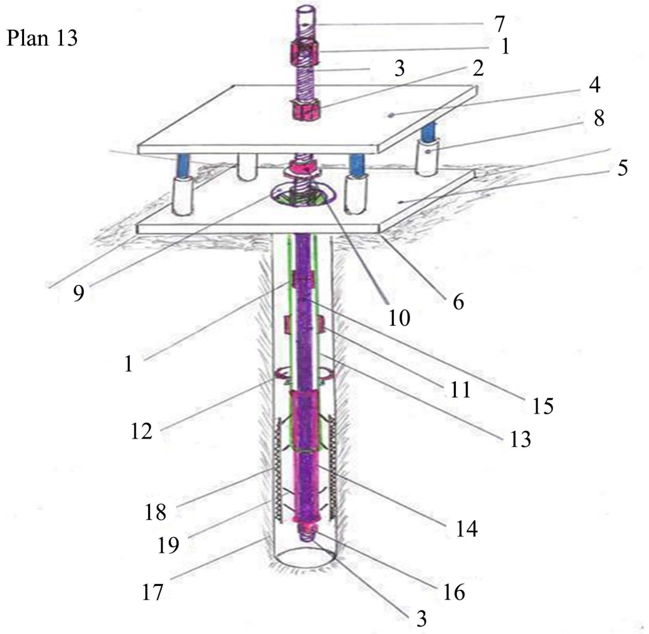

Figure 2. Shows the mechanism placed in the depths of a borehole.

pre-tensioning tendons through the walls using the tendon connection nuts (1) until the tendons gradually reach the top level of the roof. On top of the roof and after the concrete of the slab has fallen, we apply the next day a second pre-extension smaller than the initial one that we had initially applied on the surface of the ground. In order to apply the second pre-stretch, we need to ensure the free passage of the tendon through plastic passageway tubes. The first preload on the ground surface shall be twice the intensity of the axial calculation loads. The size of the expansion radials of the mechanism determines the size of the expansion (opening) of the mechanism. The maximum pressure towards the slopes of the borehole is exerted when the radials of the anchoring mechanism, is fully open. The number of radials as well as the size of their cross-section depends on the quality of the steel, their length and the calculation forces.

2.4. Measurement of Forces Exerted on the Slopes of the Drilling by the Rock Anchoring Mechanism

The compression bars located at the bottom of the mechanism deflect the vertical pull of the prestressing tendon towards the slopes of the drilling. However, the deflected force towards the drilling slope is not always of the same magnitude and the magnitude of the deflection force depends on the position of the inclination of the bars. As **Figure 3** shows, when the bars are inclined at 45 degrees, only 12.5 tonnes of the 25 tonnes of tendon pull is deflected towards the borehole slopes. When the inclination of the rods is 67 degrees, of the 25 tonnes of tendon pull, 17.7 tonnes are deflected towards the drilling slope. If the inclination of the bars is 85 degrees from the 25 tonnes of pull of the tendon, 23.5 tonnes shall be deflected towards the drilling slope.

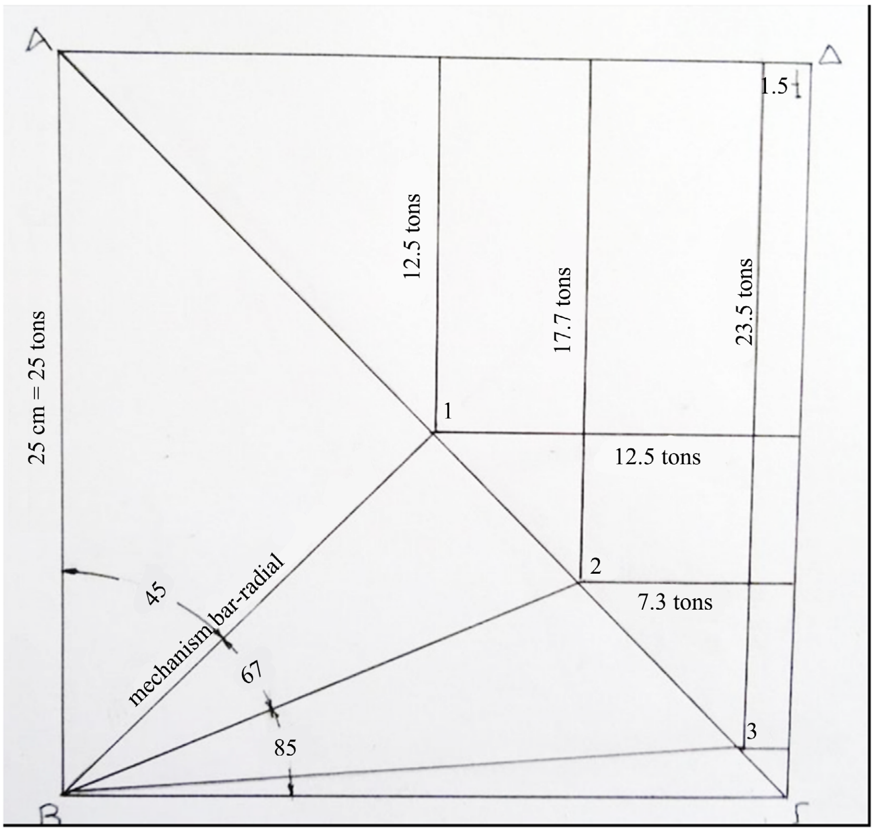

Figure 3. It shows the component force measurement diagram of the anchor bars.

Conclusion

The greater the inclination of the bars, the greater the deflection of the tendon pulling forces towards the drilling slope.

2.5. Experiments on Rock Mounted Mechanisms

Anchorage method in practice:

1) The first video shows the mechanism, the prestressing components, and the 2.10 m deep and 40 cm wide borehole [4].

2) The second video shows the anchoring mechanism's clamped the two hydraulic preload jacks with a pulling capacity of 50 tons each, are placed on the drill cap to open the clamped mechanism to ensure the clamped structure the pull of 100 tons is twice the calculation of the loads that the anchorage has to take. When the footing is achieved, before removing the jacks to maintain the strong footing, we need to screw the nut on the hole cap [5].

3) The third video shows the clamped structure of the mechanism inside the concrete hole [6].

4) In the fourth video we remove the jacks above the cap and place them away from the hole, up the flat concrete to test the anchor's resistance to traction.

Under the pull of 100 tons, the steel beams did not hold and buckled. So we don't know its ability of the anchorage in tension [7].

2.6. High Acceleration Seismic Testing Experiments on Similar Structural Specimens under Scale on a Seismic Base, with and without the Proposed Method, in Order to Carry out Useful Comparative Conclusions

Results of Seismic Simulation Experiments with and without the Seismic Design Method

I built an earthquake simulator that creates a convex displacement inside steel beams Earthquake simulator video [8].

The convex oscillation of the earthquake simulator has a displacement of 30 cm in one direction and a return of 30 cm. In total it goes and comes 60 cm.

Within a second at full load, it makes two full runs of 60 cm each, so its frequency is 2 Hz or 3 Hz without load.

When reciprocating, at the edges of the paths, it creates an impact up and down 7 cm.

The earthquake simulator machine has 12 Hp;

The maximum acceleration without load is 3.1 g;

The maximum acceleration with a load of 1500 kg is 2.1 g;

The maximum acceleration with a load of 1000 kg is 2.41 g.

Up on the earthquake simulator I constructed a two-story specimen on a scale 1/7 with the rules of the micro-scale.

Area per floor: 60 sq·m. The weight of the specimen is 1500 kg.

It has a large inverted beam on the roof, a middle slab without beams and its base is full-length.

The dimensions of the test specimen of the experiment are given in **Figure 4**.

The concrete consists of sand with grains with a diameter of 1 and 2 mm with the addition of cement 1 part of cement to 6 parts of sand.

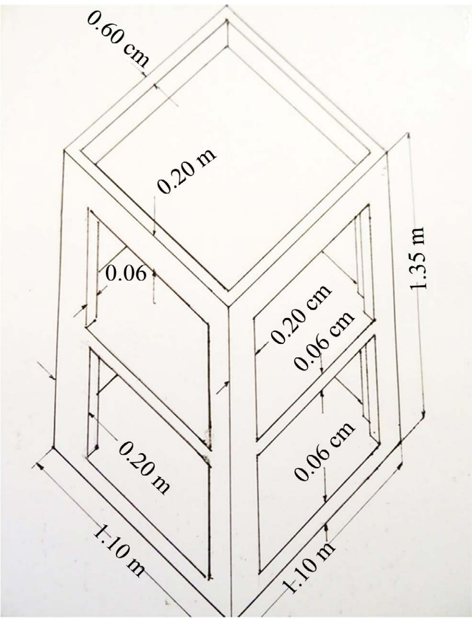

Figure 4. Shows the dimensions of the experiment being tested.

The reinforcement is of stainless steel, double mesh with a 5 × 5 cm canvas with and diameter 1.5 mm.

16 tendons of prestretching with a diameter of 6.5 mm were placed, externally covered with 6 layers of elastic tape to avoid adhesion to the concrete.

Prestressing tendons were placed on the edges of doors and windows as well as in every corner.

Video construction formwork includes tendons [9].

Presentation Experiment [10].

Multiple experiments were performed with the same construction in the numerical order below.

1) The first experiment consists of a specimen made of reinforced concrete under a scale, 1/7, is rigid, It is tested, with the new antiseismic design method. Weight 1500 kg Acceleration 1.5 g Frequency 1.25 Hz Oscillation width 30 cm Failures none. Duration 1.4 min [11].

2) The second experiment, consisting of a specimen made of reinforced concrete under a scale, is rigid, it is tested, with the new antiseismic design method. Weight 1500 kg Acceleration 2 g Frequency 1.67 Hz Oscillation with 30 cm No failures. Duration: 25 sec. [12].

3) Third experiment without the new seismic design method. I removed the anchor bolts from the bottom of the seismic base, so there is no clamped structure. Carrier weight: 1500 kg Oscillation with 30 cm. The experiment could not be done with high acceleration over 0.5 g because there was a risk of a complete reversal of the construction [13].

4) Fourth experiment. Wanting to see where the carrier fails, I removed part of the walls with a cutting wheel and basically made a carrier with four angular elongated walls. Its weight was reduced from 1500 kg to 1000 kg. Oscillation at the top of the carrier is greater than 30 cm because the base oscillates on a convex surface.

Acceleration was applied gradually before reaching 2.41 g towards the end of the experiment. Duration of experiment: 3.45 min. Acceleration measurement values are in one direction on the horizontal axis.

The convex displacement of the seismic base, as well as the up and down displacement beats 7 cm that appear at the end of the regression paths have not been measured in acceleration.

The experiment results in no failure. The tendons are simply tense with the traction force of the small screws so they cannot be considered fully pre-stretched.

Width of oscillation 0.15 m Shift 0.30 m Full oscillation 0.60 m Frequency 2 Hz Acceleration in (g) a = (−(2 * π * 2)^2 * 0.15)/9.81 a = 3.14 × 2 = 6.28 × 2 = 12.56 × 12.56 = 157.754 × 0.15 = 23.6631/9.81 = 2.41 g of natural earthquake.

Inertia power (F) ground floor F.a 450 × 23.663 = 10,648 Newton or 1065 kN.

First floor 450 × 23.663 = 10,648 Newton or 1065 kN.

Total force F (Inertia) 10.65 × 10.65 = 21.3 kN.

Moment of inertia Strength × Height^2 Ground floor 10.65 × 0.67 × 0.67 =

4.8 kN First floor 10.65 × 1.35 × 1.35 = 19.4 kN Total Moment of Inertia 4.8 × 19.4 = 24.2 kN [14].

5) Fifth experiment. I removed the anchorage of the tendons, and with 4 screws I connected the full body base of the structure, along with the base of the seismic simulator and did the experiment. Result failure of the base [15].

6) Sixth experiment in this experiment I completely disconnected the carrier from the base of the earthquake simulator. I had a hard time holding the player on the simulator, but with effort I managed, before it completely failed [16].

7) The construction, without having the antiseismic design method, completely failed in the cross sections around the nodes Failure check [17].

2.7. Preliminary Simulation and Numerical Investigation with and without the Application of Compression

One of the methods of mounting the anchorage and compression mechanism are given in Figure 5.

Project methodology

The behavior of buildings with and without the proposed system is investigated, in order to compare the useful conclusions for its effectiveness. The purpose is the preliminary investigation, at the level of preliminary design, of the behavior of the seismic system and the drawing of conclusions for further more detailed investigation. The numerical simulation will be done using appropriate construction analysis software based on the finite element method. Specifically, for the analysis, various finite element software packages were used in the first phase and finally seismostruct v5.2.2 software is selected by the company Seismosoft General description of the examined models. Finite elements A three-storey building with a reinforced concrete load-bearing structure is being examined. The building has a standard layout of load-bearing elements (columns, beams) and shows regularity, in top view and in height. The following paragraphs give the details of the models used for the analysis.

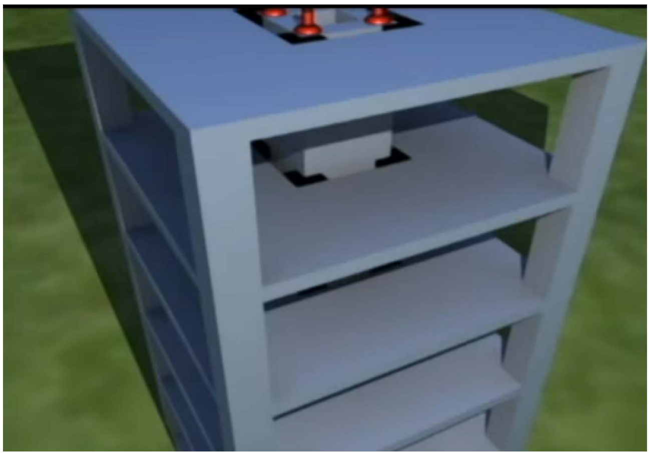

Figure 5. Shows one of the methods of mounting the anchorage and compression mechanism.

Materials

The materials used in the finite element models are as follows:

1) Compacted concrete (conf);

2) Non compacted concrete (unc);

3) Steel (rain).

Compacted concrete (conf)

The compacted concrete used in the models has the following characteristics.

Characteristics of compacted concrete (conf) are given in **Table 1**.

Concrete element reinforcement details. The positions of compacted concrete can be seen in **Figure 6**.

Stress-strain diagram (sample) for the compacted concrete used in finite element models are given in **Figure 7**.

Characteristics of non-compacted concrete (unc) are given in **Table 2**.

Stress-strain diagram (sample) for the non-compacted concrete used in finite element models are given in **Figure 8**.

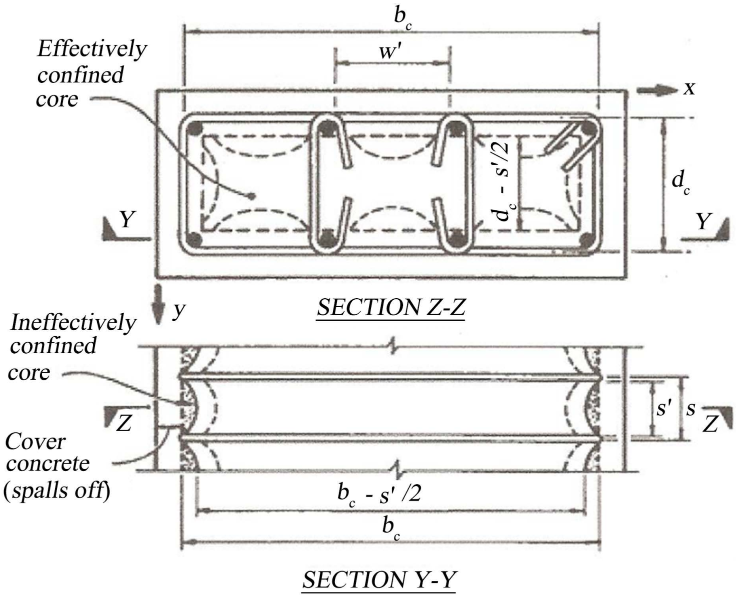

Figure 6. Concrete element reinforcement details. The positions of compacted concrete can be seen.

Table 1. Shows the characteristics of compacted concrete (conf).

Feature	Symbol	Rate	Units
Compressive strength	fc	30	MPa
Tensile strength	ft	0	MPa
Deformation in σmax	εc	0.002	
Tightening parameter	kc	1.2	
Specific weight	γconc	24	kN/m^3

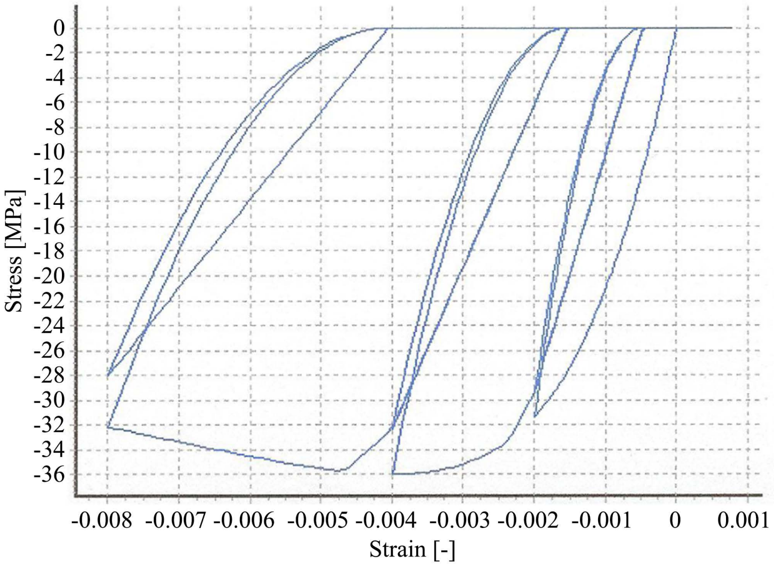

Figure 7. Stress-strain diagram (sample) for the compacted concrete used in finite element models.

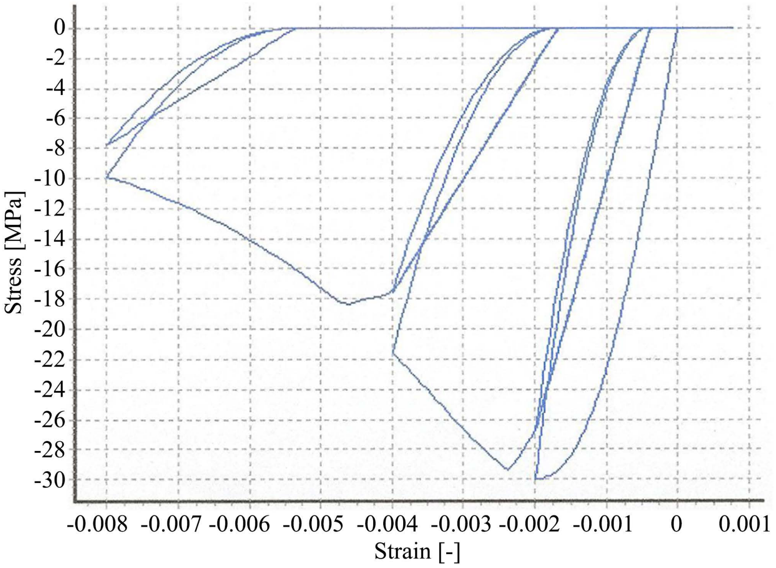

Figure 8. Stress-strain diagram (sample) for the non-compacted concrete used in finite element models.

Table 2. Shows the characteristics of non-compacted concrete (unc).

Feature	Symbol	Rate	Units
Compressive strength	fc	30	MPa
Tensile strength	ft	0	MPa
Deformation in σmax	εc	0.002	
Tightening parameter	kc	1	
Specific weight	γconc	24	kN/m^3

Steel (rein)

The steel used in the models has the following characteristics.

Characteristics of steel (rein) are given in Table 3.

Stress-strain diagrams (sample) of steel used in finite element models are given in Figure 9.

Cross sections

The cross sections used in finite element models are as follows.

1) Column cross section;

2) Beam cross section.

Column cross section

The column cross section used in the models consists of compacted concrete (conf) non compacted concrete (unc) and steel reinforcement (rein) as shown in detail in Table 4 below, and has the following characteristics.

Column cross section

Three different materials are distinguished are given in Figure 10.

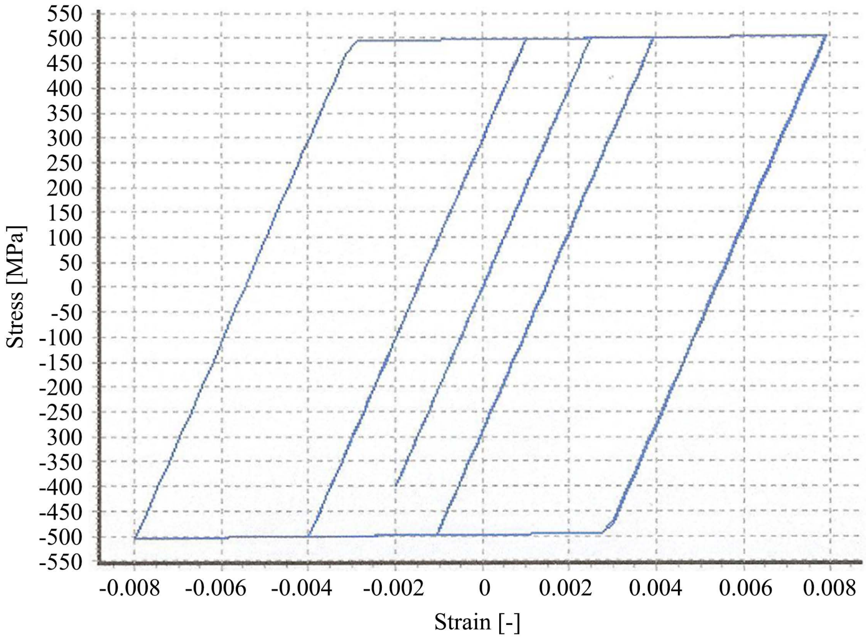

Figure 9. Stress-strain diagram (sample) of steel used in finite element models.

Table 3. Shows the characteristics of steel (rein).

Feature	Symbol	Rate	Units
Measure of elasticity	Es	200	GPa
Leakage strain	Fy	500	MPa
Shortening parameter	μ	0.005	
Fracture deformation	εult	0.1	
Specific weight	γsteel	78	kN/m^3

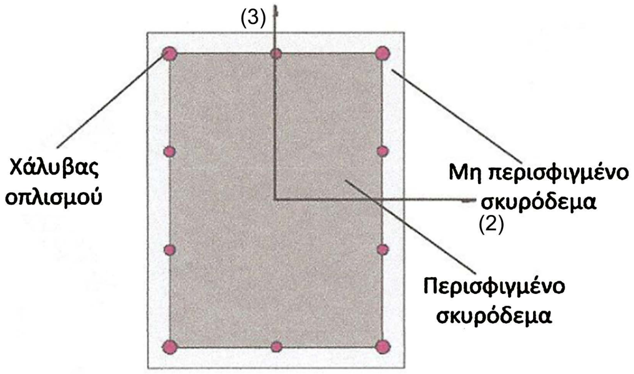

Figure 10. Column cross section. Three different materials are distinguished.

Table 4. Shows the column cross section used in the models consists of compacted concrete (conf) non compacted concrete (unc) and steel reinforcement (rein) and has the following characteristics.

Feature	Rate
Cross section shape	Rectangular
Width	30 cm
Height	40 cm
Reinforcement in the corners	4Φ16
Upper and lower side reinforcement	Φ12/side
Lateral side reinforcement	2Φ12/side
Total reinforcement	4Φ16 + 6Φ12

Beam cross section

The beam cross section used in the models consists of compacted concrete (conf) non compacted concrete (unc) and steel reinforcement (rein) as shown in detail in Table 5 below, and has the following characteristics.

Beam cross section.

Three different materials are distinguished and are given in Figure 11.

Finite elements

The finite element used in building models is a three-dimensional non-linear ribbed finite element based on forces (3D, inelastic force-based element) with 4 integration points along it, with fibers. The number of fibers in each section is 200 This element is used both for the simulation of the columns and for the beams of the buildings.

Finite elements in space for the simulation of columns and beams are given in Figure 12.

Analyzes—methodology

Non-linear analyzes were performed for each building using the finite element method, taking into account non-linearity phenomena of the material and geometry. The analyzes are non-linear, static (pushover) while the load has a triangular

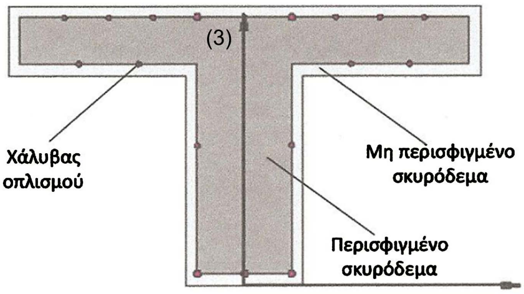

Figure 11. Beam cross section. Three different materials are distinguished reinforcing steel, non-reinforced concrete, reinforced concrete.

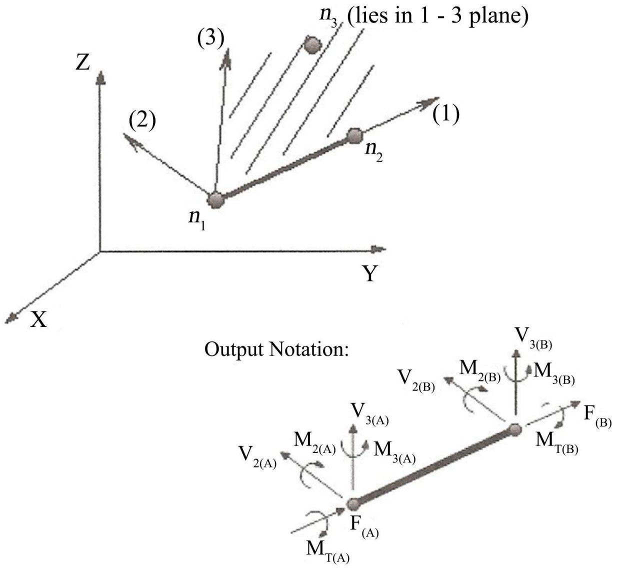

Figure 12. Finite elements in space for the simulation of columns and beams.

Table 5. Shows the beam cross section characteristics used in the models consists of compacted concrete (conf) non compacted concrete (unc) and steel reinforcement (rein) and has the following characteristics.

Feature	Rate
Cross section shape	T-shaped slab and beam
Collaborating width	100 cm
Slab thickness	15 cm
Beam height	60 cm
Beam width	25 cm
Beam reinforcement below	3Φ14
Upper beam reinforcement	2Φ14
Side beam reinforcement	Φ10/side
Upper plate reinforcement	6Φ/10
Lower slab reinforcement	4Φ/10
Total steel reinforcement	5Φ14 + 12Φ10

distribution in height which corresponds approximately to the 1st peculiarity of the examined construction. The total of the applied horizontal loads has a value of 1 kN, so that the shear force of the base during this loading has a value of 1 kN and therefore the load factor λ is equal to the intersecting base ($1 * \lambda$) for the various phases of the analysis.

The target price of the movement is set at 0.18 m, while the load is exercised in 50 steps, for both models. The control node is defined as the node with the highest level of construction (z = max) to which it applies $x = 0$ and $y = 0$, as shown in more detail in the figures below.

The proposed system applies compression to the cross-sections of the columns and at the same time the anchoring of the construction to the foundation ground. This simulation examines the imposition of a compressive force on the concrete elements to which the system is considered to be applied.

Three-storey reinforced concrete building

General characteristics of the building

The building under consideration shows regularity in the floor plan and in height.

The general characteristics of the building are described below.

Floor height:	3 m;
Aperture length x	5 m;
Aperture length y	5 m;
Diaphragm	YES, on every floor;
Supports	Anchors at all nodes with z = 0 (ground).

Top view of the three-storey building is given in **Figure 13**.

Front view of the three-storey building is given in **Figure 14**.

Side view of the three-storey building is given in **Figure 15**.

Perspective depiction of the three-storey building (a). *The construction control node can be seen* in **Figure 16**.

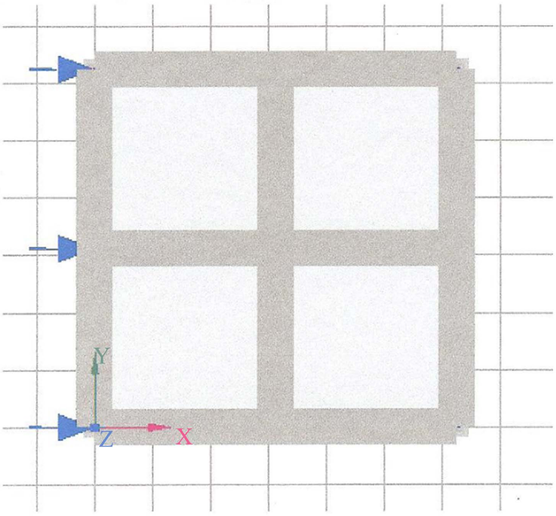

Figure 13. Top view of the three-storey building.

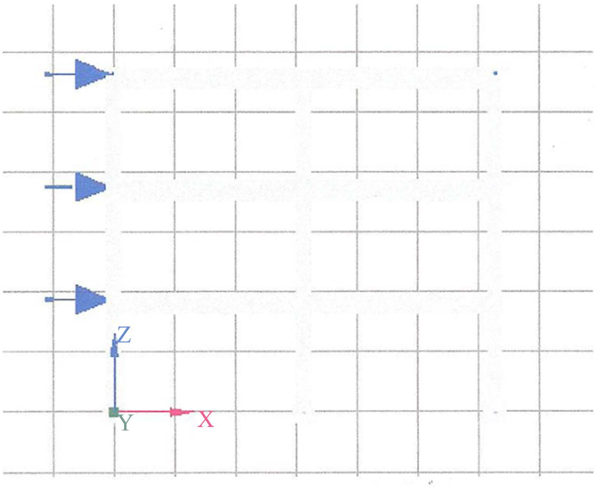

Figure 14. Front view of the three-storey building.

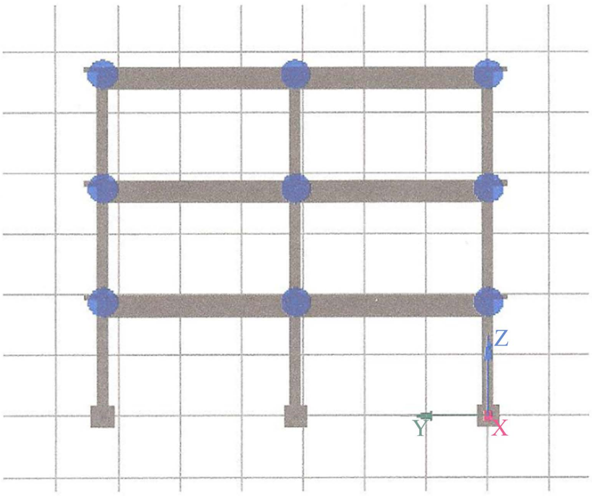

Figure 15. Side view of the three-storey building.

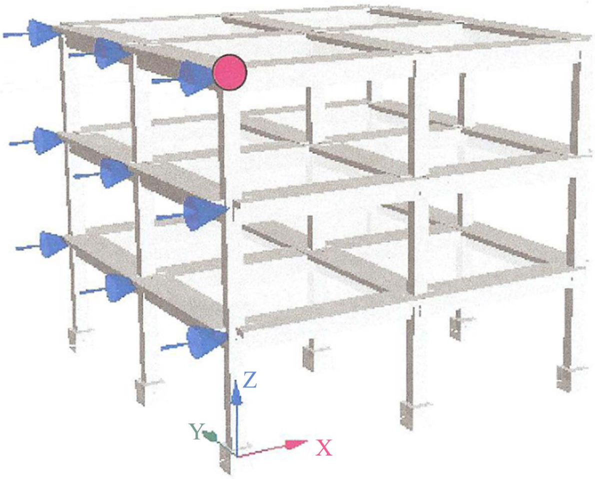

Figure 16. Perspective depiction of the three-storey building (a). The construction control node can be seen.

Perspective illustration of the three-storey building (b). The construction control node can be seen in **Figure 17**.

Results of the analyzes

Without the pre-tensioning application.

The image below shows a diagram of the shear force of the base—displacement for the control node.

Force curve (KN)—Displacement (m) without the application of prestressing force given in **Figure 18**.

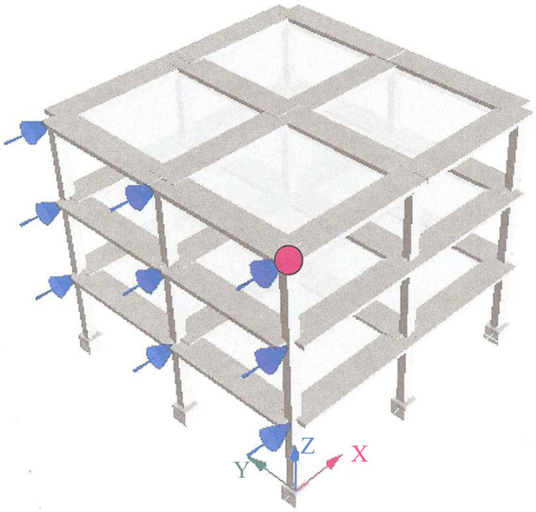

Figure 17. Perspective illustration of the three-storey building (b). The construction control node can be seen.

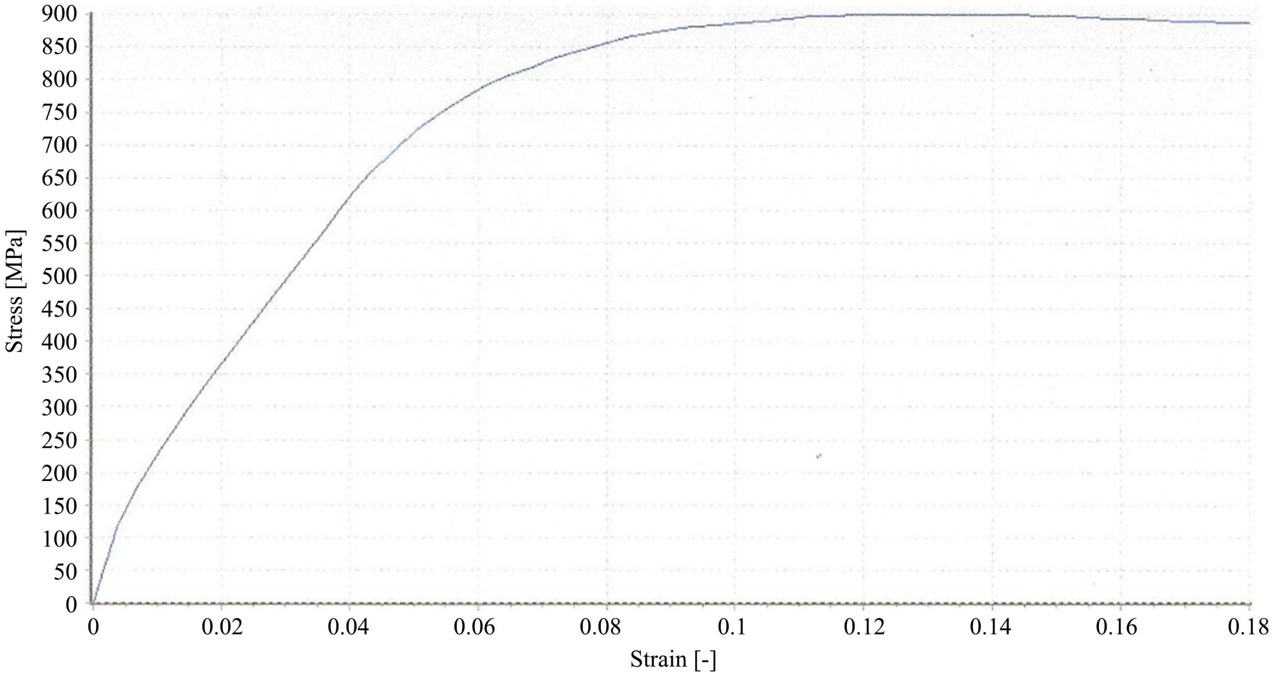

Figure 18. Force curve (KN)—Displacement (m) without the application of prestressing force.

The maximum value of the diagram is 900.62 kN, which is presented for displacement of the control node 0.1296 m.

Compressive load 600 kN at nodes at the highest level

A compressive load of 600 kN is applied to nodes of the maximum level due to the prestressing force. Initially (A) only the central column is charged with the prestressing force. Then (B) the compressive load is extended to the four corner columns of the floor plan. Finally (C) all 9 pillars of the building are charged.

The imposed tension on each pillar is 600 kN/(0.30 m * 0.40 m) = 5000 kN/m^2 = 5 NM/m^2 = 5 MPa.

In the compressive failure condition (taking into account the safety factor of 1.5 for concrete) the breaking tendency for concrete C30 is 30 MPa/1.5 = 20 MPa.

Therefore, the imposed stress on the columns corresponds to 5/20 = 25% of the breaking intensity in the marginal failure state.

Compressive load 600 kN at the central node of the top level.

The image below shows the diagram shear force of base—movement for the control node

Strength curve (kN)—Displacement (m) with application of a compressive load of 600 kN at the central node of the top level are given in **Figure 19**.

The maximum value of the diagram without the prestressing force was 900.62 kN for a displacement of 0.1296 m.

The maximum value of the diagram with the imposition of a compressive load of 600 kN at the central node of the upper level is 929.82 kN for displacement 0.1116 m.

The improvement in bearing capacity is 978.77 − 929.82 = 48.95 kN.

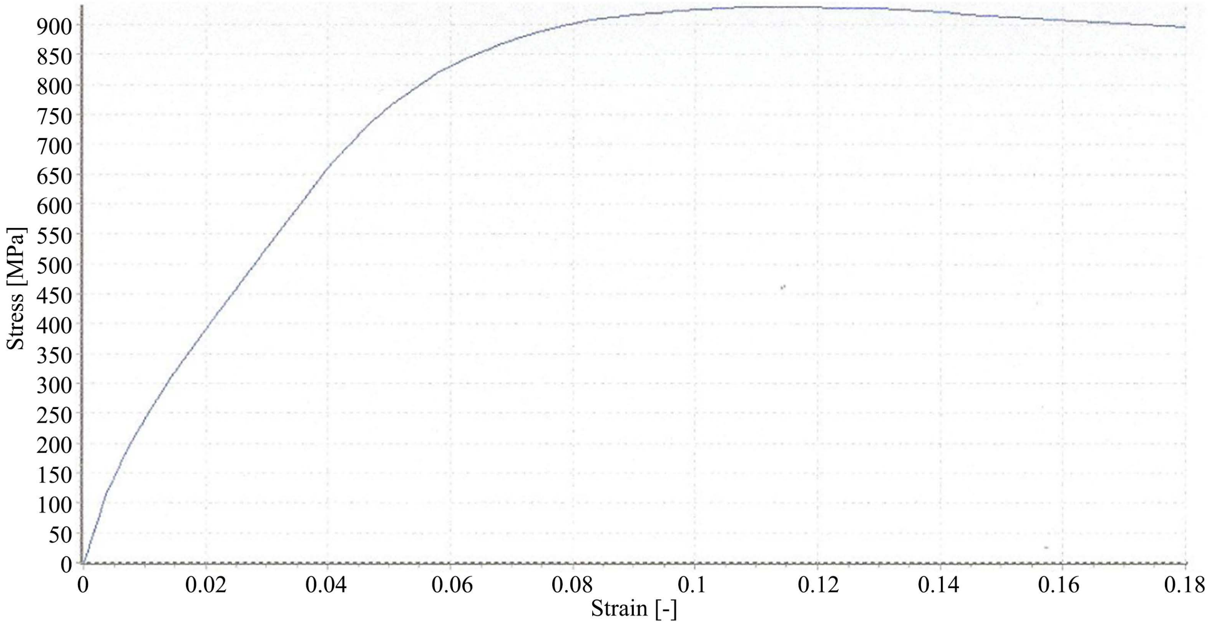

Figure 19. Strength curve (kN)—Displacement (m) with application of a compressive load of 600 kN at the central node of the top level.

The percentage improvement in the maximum shear force of the base is 48.95/900.62 = 5.4%.

There is a slight improvement in the load-bearing capacity of the building, due to the application of the compressive load on the central pillar of the building.

1) Compressive load 600 kN at the 4 corner nodes at the maximum level

The image below shows the diagram shear force of base—movement for the control node.

Strength curve (kN)—Displacement (m) with application of compressive load 600 kN at the 4 corner nodes of the highest level are given in **Figure 20**.

The maximum value of the diagram without the prestressing force was 900.62 kN for a displacement of 0.1296 m.

The maximum value of the diagram with the imposition of a compressive load of 600 kN at the 4 corners nodes of the highest level is 978.77 kN for displacement 0.1044 m.

The improvement in bearing capacity is 978.77 − 900.62 = 78.15 kN.

The percentage improvement in the maximum shear force of the base is 218.39/900.62 = 8.7%.

There is a slight improvement in the load-bearing capacity of the building, due to the application of the compressive load on the 4 corner pillars of the building.

2) Compressive load 600 kN at all nodes at the maximum level

The image below shows the diagram shear force of base—movement for the control node.

Strength curve (kN)—Displacement (m) with application of compressive load 600 kN at all nodes at the maximum level are given in **Figure 21**.

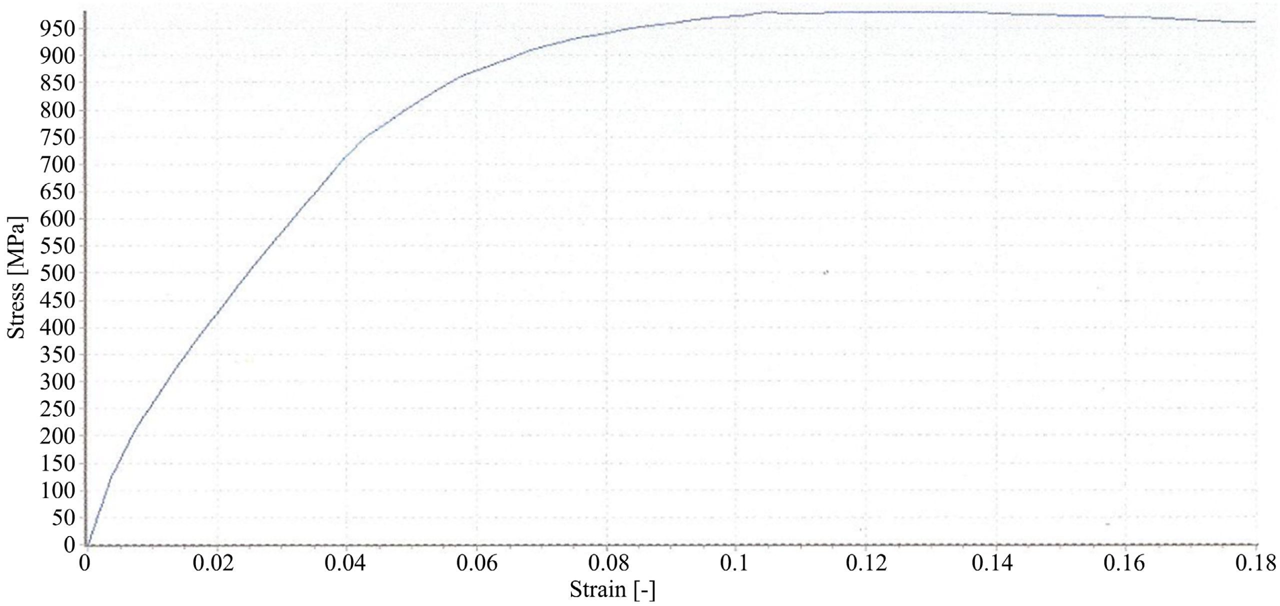

Figure 20. Compressive load 600 kN at the 4 corner nodes of the highest level.

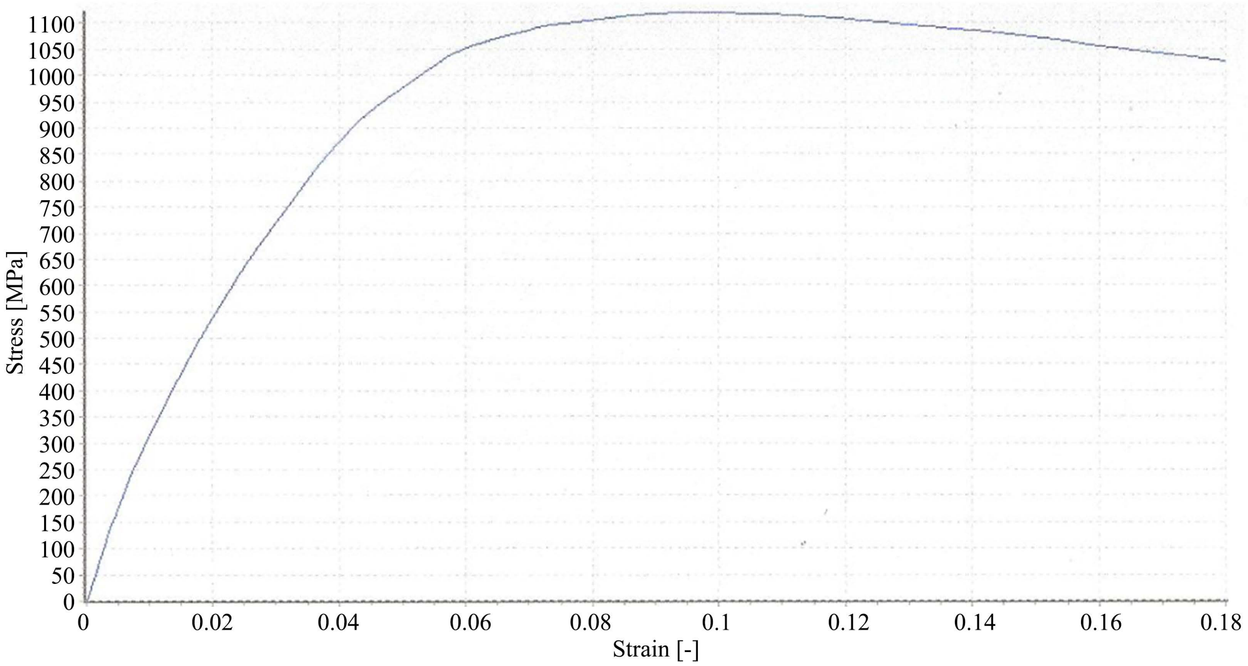

Figure 21. Strength curve (kN)—Displacement (m) with application of compressive load 600 kN at all nodes at the maximum level.

The maximum value of the diagram without the prestressing force was 900.62 kN for a displacement of 0.1296 m.

The maximum value of the diagram with the imposition of a compressive load of 600 kN at all nodes at the maximum level is 1119.01 kN for displacement 0.1008 m.

The improvement in bearing capacity is 1119.01 − 900.62 = 218.39 kN.

The percentage improvement in the maximum shear force of the base is 218.39/900.62 = 24.2%.

There is a significant improvement in the load-bearing capacity of the building due to the application of compressive forces in all (9) pillars of the building.

Compressive load of 1200 kN at nodes at the highest level

A compressive load of 1200 kN is applied to nodes of the maximum level, due to the prestressing force.

Initially (A) the (4) angular columns of the floor plan are loaded with compressive force, while then (C) all (9) columns of the building are loaded.

The imposed force on each pillar is 1200 kN/(0.30 m * 0.40 m) = 10,000 kN/m^2 = 10 MN/m^2 = 10 MPa.

In the column margin failure condition due to compression (taking into account the safety factor of 1.5 for concrete), the breaking tendency for concrete C30 is 30 MPa/1.5 = 20 MPa.

Therefore, the applied force on the columns corresponds to 10/20 = 50% of the breaking force.

3) Compressive load of 1200 kN at the (4) angular nodes of the maximum

level.

Figure 22 below shows the diagram shear force of base—movement for the control node.

Strength curve (kN)—Displacement (m) with application of compressive load 1200 kN at the (4) angular nodes of the maximum leve.

The maximum value of the diagram without the prestressing force was 900.62 kN for a displacement of 0.1296 m.

The maximum value of the diagram with the application of a compressive load of 1200 kN at the 4 angular nodes of the highest level is 995.46 kN for displacement 0.1188 m.

The improvement in bearing capacity is 995.46 − 900.62 = 94.84 kN.

The percentage improvement in the maximum shear force of the base is 218.39/900.62 = 10.5%.

There is a slight improvement in the load-bearing capacity of the building, due to the application of the compressive load on the 4 corner pillars of the building.

Compressive load of 1200 kN in all nodes at the highest level.

The image below shows the diagram shear force of base—movement for the control node.

Strength curve (kN)—Displacement (m) with application of compressive load 1200 kN at all nodes of the maximum level are given in Figure 23.

The maximum value of the diagram without the prestressing force was 900.62 kN for a displacement of 0.1296 m.

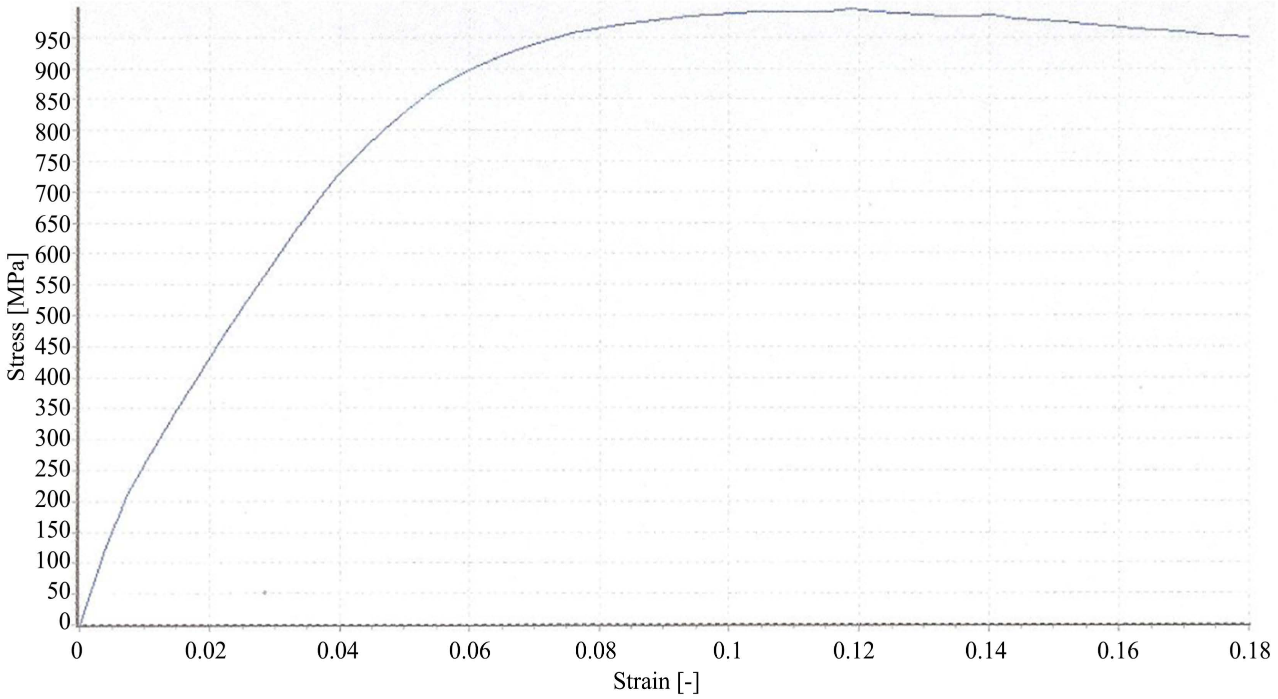

Figure 22. Shows the diagram shear force of base-movement for the control node.

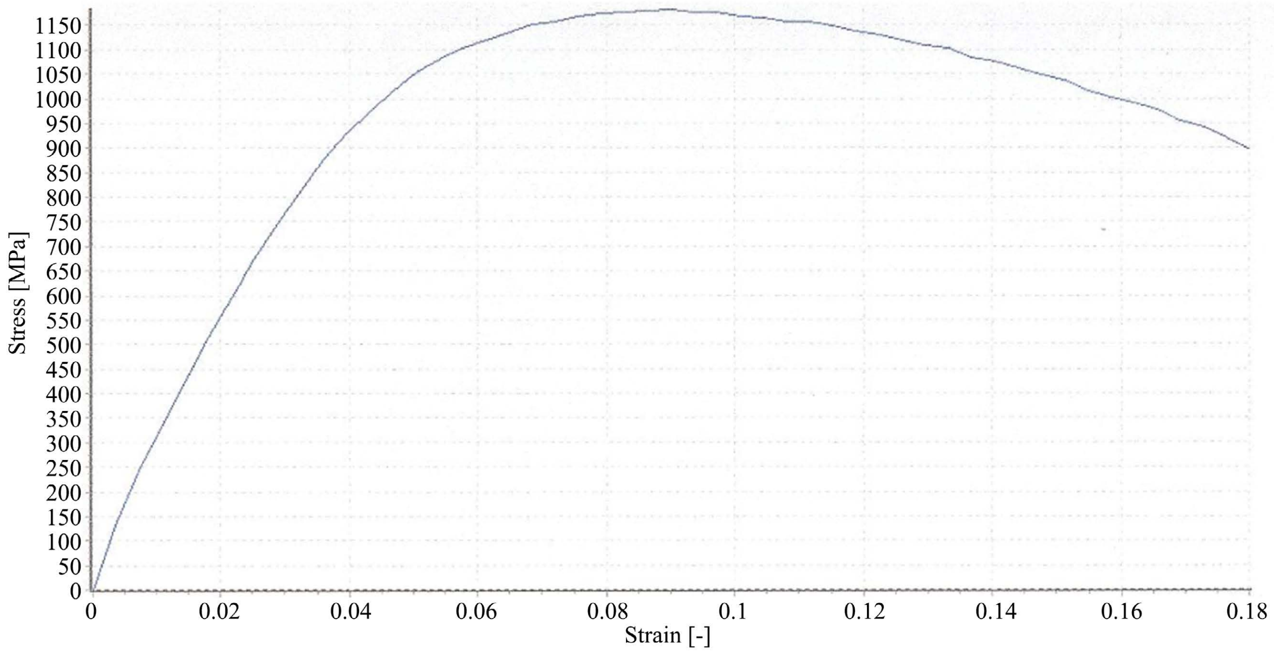

Figure 23. Strength curve (kN)—Displacement (m) with application of compressive load 1200 kN at all nodes of the maximum level.

The maximum value of the diagram with the application of Compressive load 1200 kN at all nodes of the maximum level is 1179.33 kN for displacement 0.0864 m.

The improvement in bearing capacity is 1179.33 − 900.62 = 278.71 kN.

The percentage improvement in the maximum shear force of base s is 278.71/900.62 = 30.9%.

There is a significant improvement in the load-bearing capacity of the building, due to the application of compressive forces to all (9) pillars of the building.

Conclusion of the Simulation

From the analyses made, the following conclusions are generally drawn:

- Nonlinear static analyses were performed (pushover) in order to draw the diagram of the shear force of base—displacement of the control node and to find the bearing capacity of the structure in lateral loads.
- It has been found that the application of the system generally has beneficial effects on the bearing capacity of the construction, as in each case it increases it.
- It is generally desirable to apply the compressive load evenly throughout the structure and not to individual vertical elements.
- When the system is applied only to the central pillar of the structure the benefit is very small.
- When the system is applied to only the four corner pillars of the structure, the benefit is relatively limited.
- When the system is applied to all columns, then it achieves significantly increased load-bearing capacity values.

- Here we observe that by increasing the cross section of the vertical elements and the number of these columns and walls that support the system, the bearing capacity of the structure increases, we have better control of the displacements, and the ability of the structure to the shear force of base increases.
- It is considered that the results of the investigation are very encouraging and that further detailed investigation of the system in two phases is required. First at the level of more detailed simulation where more construction models will be examined (with walls instead of columns) and with higher loads, since it was found that by increasing the compressive forces at the cross section, the bearing capacity of the structure increases, we have better control of the displacements, and the ability of the structure to the shear force of base increases. Second, at the level of an experiment on a seismic basis where a series of structures on a scale must be examined.
- The application of the seismic system on the columns and the walls of the construction, has as a result, the application of compressive force in their cross sections, as well as the anchoring of the construction with the foundation ground.
- In this simulation, the analyses performed were based on the application of compressive forces to the concrete elements in which the seismic system in question was installed, and did not include any benefits arising from the clamped structure of the edges of the elongated walls.

This simulation of the three-storey building has only columns which, due to elasticity and low dynamics, fail even at low accelerations before downloading moments to the base. In the case of columns, the connecting beams are statically sufficient to take up any small moment downloaded to the base.

So although this simulation includes clamping of the column to the ground, the clamped structure with the foundation does not offer too many benefits in structures with columns.

The highly elongated walls react differently from the way columns react. Due to the high stiffness and dynamics of prestressed walls, the moments that are transmitted to the base are impossible to be absorbed by the connecting beams and will fail without the help of ground anchors.

If instead of connecting beams we connect the longitudinal walls with the underground walls, this would certainly increase the strength more.

But the moment loads that the longitudinal walls in the high rise buildings download to in a large earthquake are three and even four times larger than the weight of the whole building. These torque loads downloaded to the base contrast with the loads of the horizontal arm of the basement walls, which also multiply the static loads by the length of the horizontal arm.

The cross-sections of the two huge lever arms of the walls are subjected to such enormous moments that it is impossible for the lever arms of the vertical longitudinal wall to withstand them without failing. If the cross-section of the vertical longitudinal wall can withstand these moments, (which is impossible with linear reinforcement because the overlay concrete will fail first due to shear failure) then we will have total overturning of the basement and the structure.

If we do not have total overturning of the basement and the structure, we will have a recall of the basement footprint and the now unstable loads of the structure will break the horizontal sections. With the design method I propose in these super dynamic structures we will not have total overturning of the structure, we will not have wall rotation or recall, we will not have shear failure of the concrete overlay, we will not have shear failure of the base, we will ensure strong foundation soil and small moments at the nodes.

And let's not forget that building strong cross-sections is expensive and generates inertial loads, while diverting inertial forces to the ground allows us to design smaller cross-sections since they are not heavily stressed, which makes them cheaper. The same applies to the volume of the foundations, which becomes cheaper since the method reinforces the soil. It strengthens the cross-sections without increasing the volume and reinforcement and without additional enhancers and this reduces costs.

Furthermore, due to the fact that the installation of the proposed method is easily applied to existing structures this is a comparatively prominent advantage of the method for their reinforcement. Their easy installation of prefabricated heavy-duty double walls and 3D printed houses make it the only solution if these structures want to offer high rise and cheap housing

The existing design method is only for short duration and short accelerated earthquakes.

For long duration and big accelerating earthquakes and for rigid high rise buildings only the design method I propose can stand up.

If we want the ultimate in seismic design, we build rigid dynamic structures, using reinforced concrete walls, with their ends prestressed and anchored to the ground

It is not enough to lower the moments to the base we have to transfer them into the ground by preventing their transfer to the base connecting beams and girders and this can only be done by anchoring to the ground.

Dynamically prestressed walls help us get the moments down to the base, and anchors help us to send them into the ground. Linear reinforcement is subject to shear while the proposed method takes a moment from the roof by compressing the concrete and sending it directly into the ground, preventing shear failure in the concrete overlay.

2.8. To Find the Axial Compressive and Tensile Forces in a Large Earthquake Which the Footing Mechanisms Must Be Able to Receive in Cooperation with the Cross-Sections of the Load-Bearing Structure

AXIAL LOADS

Table 6, shows the axial Forces N (KN) from one to six floors of a building with dimensions of the floor plan 10 × 10 m. that develop in a very strong earthquake.

Table 7, shows the axial Forces N (KN) from one to six floors of a building with dimensions of the floor plan 20 × 20 m. that develop in a very strong earthquake.

A.1 Ground floor height 3.50 m;
A.2 Two-storey, total height 7.00 m;
A.3 Three-storey, total height 10.50 m;
A.4 Four floors, total height 14.00 m;
A.5 Five-storey, total height 17.50 m;
A.6 Six floors, total height 21.00 m.

There are other paper publications that mention the method. These are as follows:

Ioannis, N. (2015) The Ultimate Anti-Seismic System [18]; SSRN Keys to Successful Design of Earthquake-Resistant Buildings [19]; Research Gate Ioannis Lymperis Inventor International Patent Independent Research Principal Investigator at The Ultimate Anti-Seismic System [20]; There are two patents for mechanisms and methods [21] [22].

Table 6. Axial Rights Forces N (KN) from one to six floors are given in **Table 6**, that develop in a very strong earthquake.

Building	Axial power N (kN)
A.1	140
A.2	420
A.3	840
A.4	1400
A.5	2100
A.6	2940

Table 7. Axial Rights Forces N (KN) from one to six floors are given in **Table 6**, that develop in a very strong earthquake.

Building	Axial power N (kN)	
	Perimeter	First Row of Interiors
A.1	140	70
A.2	400	200
A.3	810	405
A.4	1350	675
A.5	2020	1010
A.6	2830	1415

3. Conclusions

The stiffness and increased dynamics due to the imposition of artificial compression of the walls, as well as the deflection of the forces of inertia into the ground and the tightening of the foundation ground in all directions due to ground compaction, make the method a promising approach to the response of structures to seismic shifts. The usefulness of the anchoring mechanism for many other uses such as anchoring wind turbines to the ground, anchoring dams and bridge pillars, their use in 3D printed house constructions, as well as in existing structures, highlights the seriousness for further research of the system.

It is understandable that the union of the base of the structure with the foundation soil deflects the normal forces into the soil. If we combine the joint with prestressing at the ends of the walls we have increased the stiffness and therefore the deformation that causes cracking. This is well known from the literature [23].

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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