

TILTING PREVENTION OF A FOUR FLOOR RESIDENTIAL BUILDING WITH THE ASSISTANCE OF MICRO-PILES BENEATH THE FOUNDATION

Assoc. Prof. **CHAVDAR KOLEV** PhD, University of Transport, 1574 Sofia, 158-Geo Milev Str, Tel: 359 885 256 905, e-mail: ch_kolev@abv.bg

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Introduction

- National standards for prefabricated panel structures from the early 60-s did not taken into consideration soil characteristics;
- Industrial approach to the construction of in Bulgaria between 1964 and 1990 (the technology of large-sized precast armored panels) affected in some unstable and unsafe residential buildings;
- There are about 15 buildings with such deformations as shown in the same quarter of living, city of Sofia;
- The problem became increasingly serious with the aging of panel buildings, especially after 2000.

Portrait of the Building

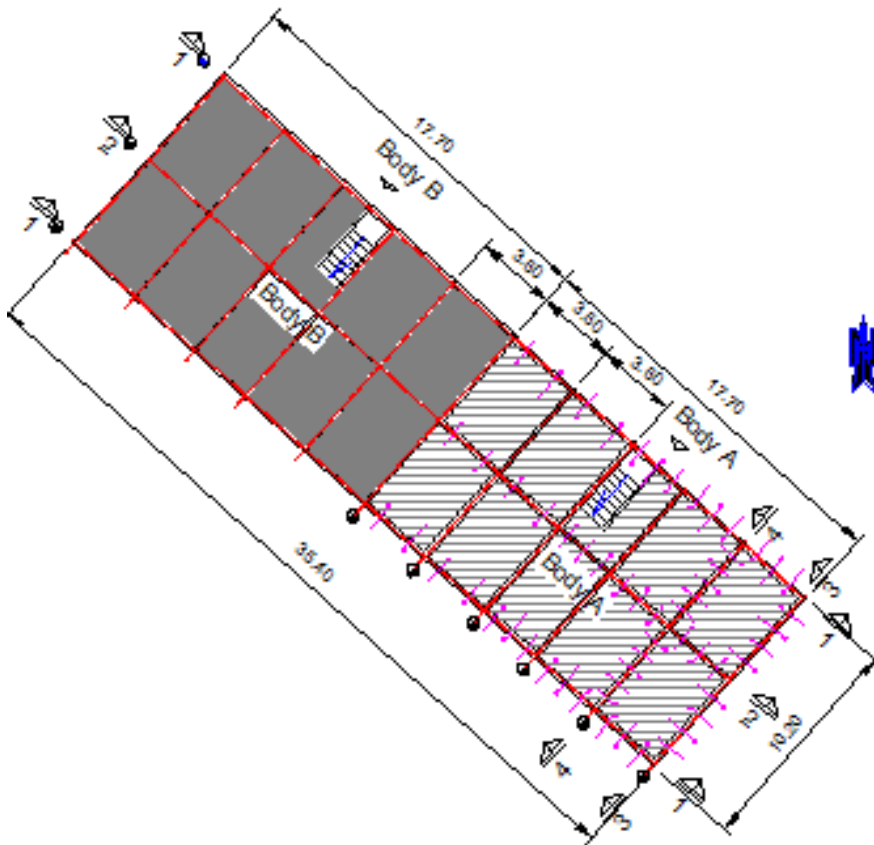


Fig. 1: Plan of the Building

- A building with 2 entrances (no deformation joints between them); 4 floors (walls -2.7m high); 3 apartments per floor; flat roof; basement walls - 2.20m high;
- Form of a rectangle 10.20 x 35.40 m with 11 frame axes in transverse direction and 3 axes in longitudinal direction;
- Framing of load-bearing transverse walls, scheme similar to herringbone;
- Basement of solid concrete (walls - 24cm tick);

Portrait of the Building (Cont'd)

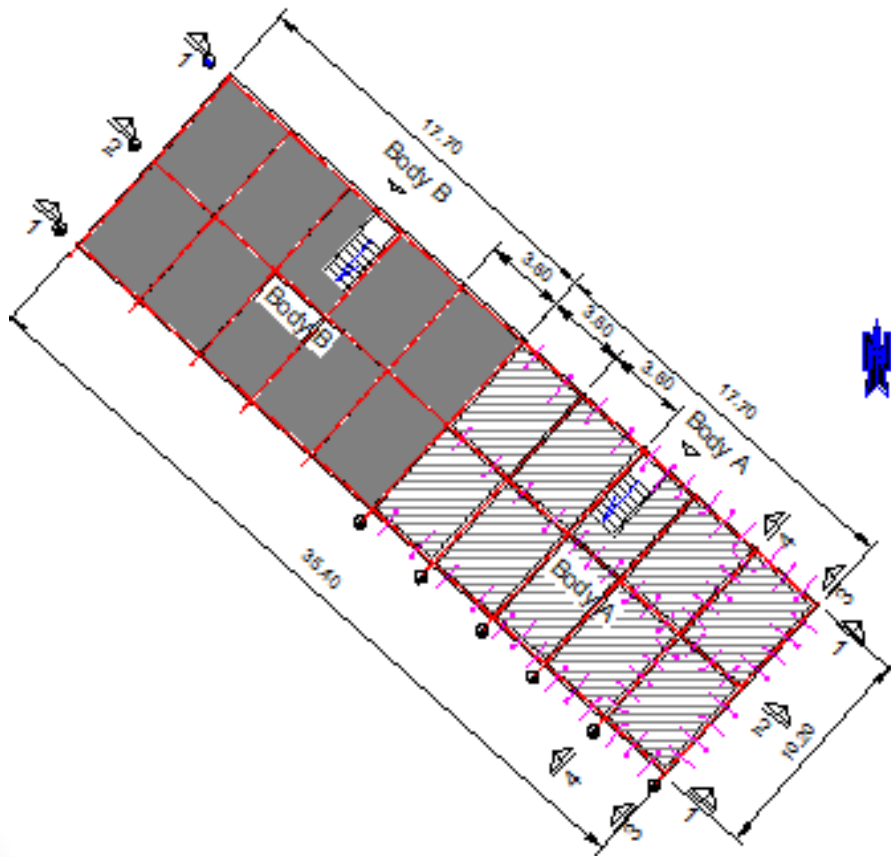


Fig. 1: Plan of the Building

- Foundations of strip concrete with width of:
 - 70 cm for the median foundation;
 - 74 cm for transverse foundations (excl. end ones);
 - 45 cm for the end foundations;
 - 45 cm for foundations beneath the facade.
- Foundations depth – up to 1.70m below ground level;
- 20cm concrete base under the foundation slab (1.90m trench beneath ground level).

Failure Description



Picture 1: Vertical joints opening between façade panels

- Vertical joints opening between façade panels (7mm wide at 1st floor to 40mm wide at roof level);
- Joints in compounds of internal longitudinal panels at axis No. 8;

Failure Description (Cont'd)



Picture 2: Vertical joints opening between façade panels

- Horizontal joints in the framing between staircase landings and interior panels (14mm wide at 2nd floor to 29mm wide at 4th floor);
- Almost proportionally linear increase in the longitudinal joint width with the height of the building;

Failure Description (Cont'd)



Picture 3: Cracks in the foundations

- Cracks in both section A and B;
- A drop in the south-eastern part of the housing block (35mm in the outer wall)
 - Subsidence depth was 10mm in axis No. 9 and almost no drop in axis 8).

Failure Description (Cont'd)



Picture 4: Broken sidewalk pavement around section A

Stress Analysis

- Foundation deep 1.90m was laid on silty sandy clay with average bearing capacity of 250 kPa;
- Stresses in the ground beneath strip foundations:
 - 163 kPa for foundations along the medium longitudinal wall
 - 217 kPa for foundations beneath the transverse walls
 - 254 kPa for foundations beneath the end transverse walls
- Edge stress of 507 kPa for the basement wall, which was not located centrally at the foundation (at permitted 178 kPa for secondary stress and 356 kPa for edge stress);
- Stress exceeded the average load-bearing capacity of the ground (250 kPa).
- **Conclusion:** High stress was a prerequisite, but cannot cause such a big deformation by itself.

Engineering-geological Conditions

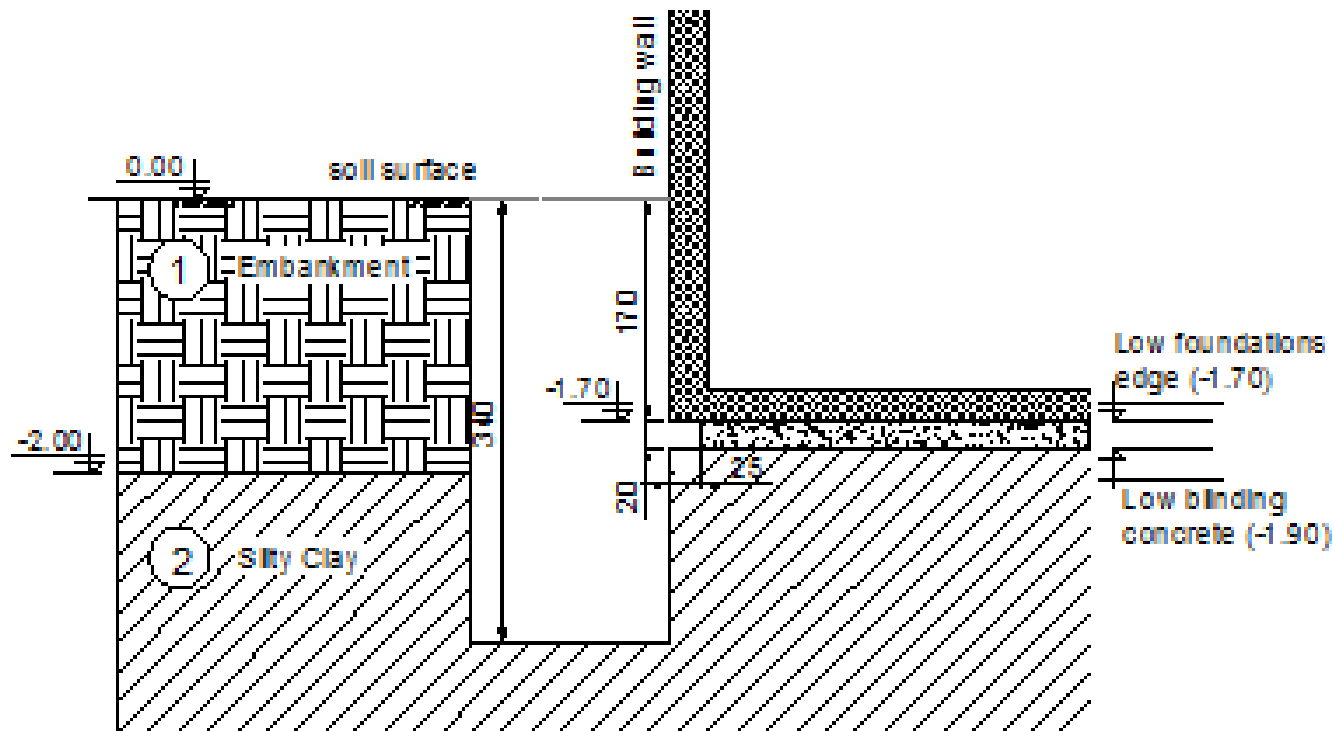


Fig. 2: Profile of the investigating trench at the base of the building

Engineering-geological Conditions (Cont'd)

- Physical and mechanical characteristics of the brown silty clay:

- Bulk Density $\rho_n = 1.87 \text{ g/cm}^3$
- Dry Bulk Density $\rho_d = 1.53 \text{ g/cm}^3$
- Void ratio $e = 0.756$
- Degree of water saturation $S_r = 0.78$
- Natural Water Content $w_n = 21.94 \%$
- Plasticity index $I_p = 30.80 \%$
- Consistence Index $I_c = 1.04$
- Angel of Internal Friction $\varphi = 23,8^\circ$
- Cohesion $c = 40 \text{ kPa}$
- Deformation Modulus $E_0 = 17,5 \text{ MPa}$

Engineering-geological Conditions (Cont'd)

- Physical and mechanical characteristics of the lowest 3rd layer:

- Bulk Density

$$\rho_n = 2.00 \text{ g/cm}^3$$

- Deformation Modulus

$$M = 16 \text{ MPa}$$

- Poison's ratio

$$\nu = 0.31$$

- Angel of internal Fraction

$$\varphi = 36,6^\circ$$

Triggers and Causes of Accident

- A breakdown in the water supply tubes along the street and extreme water flow to the building in 1994;
- Water collection around the **south-eastern part of the building** and retention for a long period of time;
- Part of the water has evaporated, but the larger portion permeates into the soil;
- Values of deformation modules decreased additionally due to the extreme soil moisture;
- Stress concentrated beneath the short walls of the building rectangular contour and stayed there for a very long time.

Source of information: Residents' interviews

Recovery & Rehabilitation

- 1st phase of rehabilitation
 - Strengthen the basement walls and further eliminate the effects of shrinkage and swelling of the soil;
 - Prevent a further deformation of the structure
 - **HOW? *By micro-pile injections drilled deep under the strip foundation, coating and anchoring the soil by injecting grout under high pressure to displace moisture from the pores and improve deformation properties of the soil .***
- 2nd phase of rehabilitation
 - Reconnecting panels, flooring and plastering;
 - Strengthening and recovery of outer construction;
 - Painting the façade.

1st Phase: Micro-Pile Injection

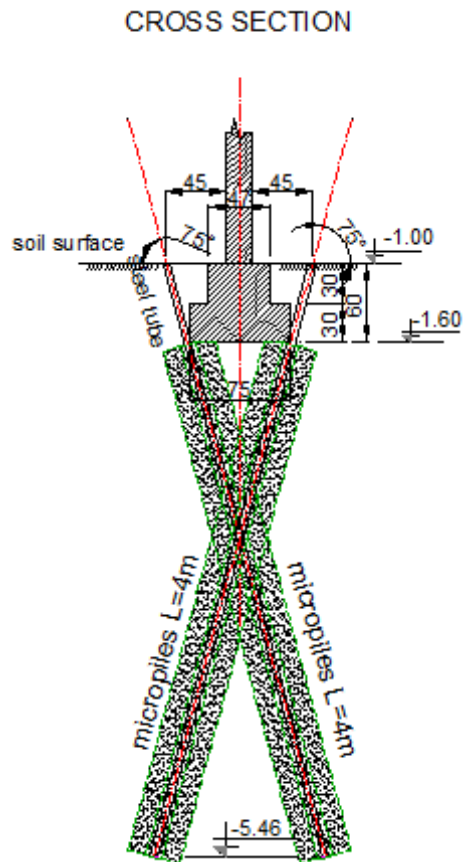
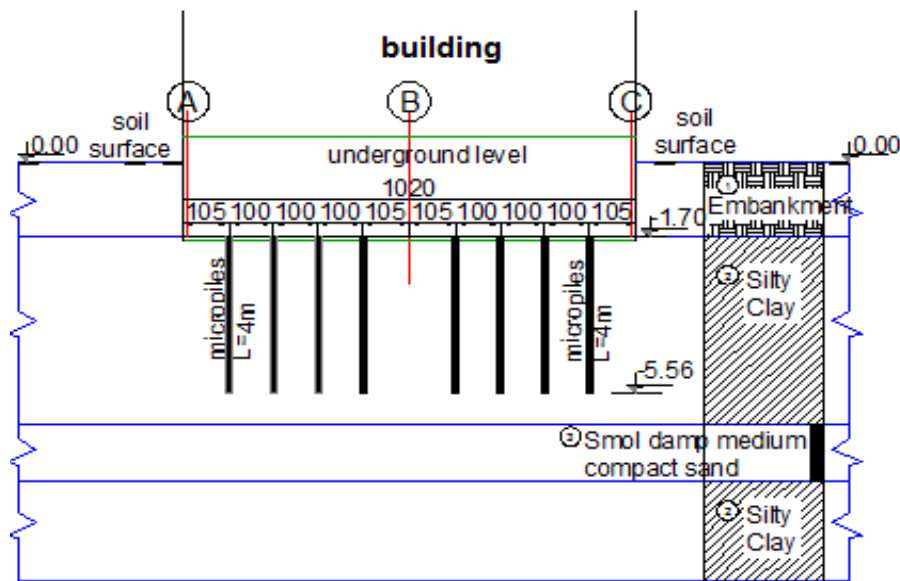


Fig. 3: Micro-piles under the foundations – Cross section

Technological Peculiarities of the 1st Phase



- 57 piles long 4m each was placed at different distances, 83-90 to 180 cm from each other;
- Injections inclination at 75° to the horizontal line;
- X-shaped reinforced earth base in the transverse profile.

Fig.4: Micro-piles under the foundations – longitudinal section

Technological Peculiarities – Summary (Cont'd)

- 5 profiles of micro-pile injections:
 - 3 piles longitudinal to the building (along axes A, B and C)
 - 2 piles transverse to the building (along axes 5 and 6)
- Higher density of micro-piles along axis 5 and 6;
- Micro-piles along axes A, C and 6 injected from outside and inside the building;
- Micro-piles along axes C and 5 injected only from the basement with a small portable drill 50 to 70mm in diameter:
 - A thick, closed-ended steel tube, fitted with a nozzle and packer, was inserted in the apparatus mouthing. The grout was fed through the packer; pressure monitoring for possible deformation
 - A “collar” of grout formed around the borehole and entered the ground in a radius of about 40 - 45cm
 - The steel tube remained concreted in the pile and became an additional reinforcement
- Finally, the total length of the micro-piles was 228m, and the total length of steel tube was 279.60 m.

Technological Peculiarities of the 1st Phase (Cont'd)

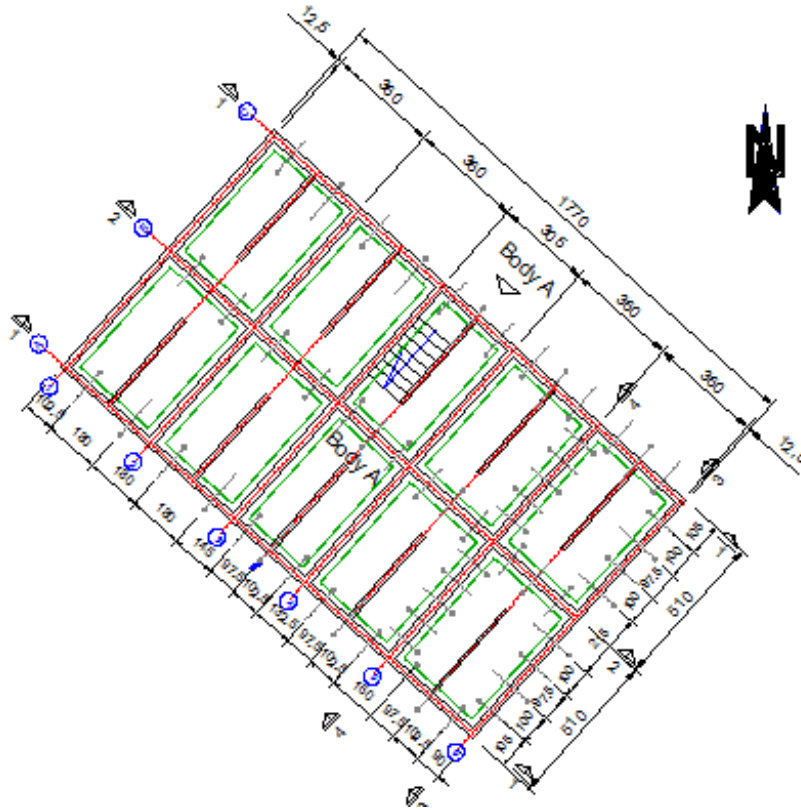


Fig.5: Plan of the foundations and micro-piles

2nd Phase of Rehabilitation

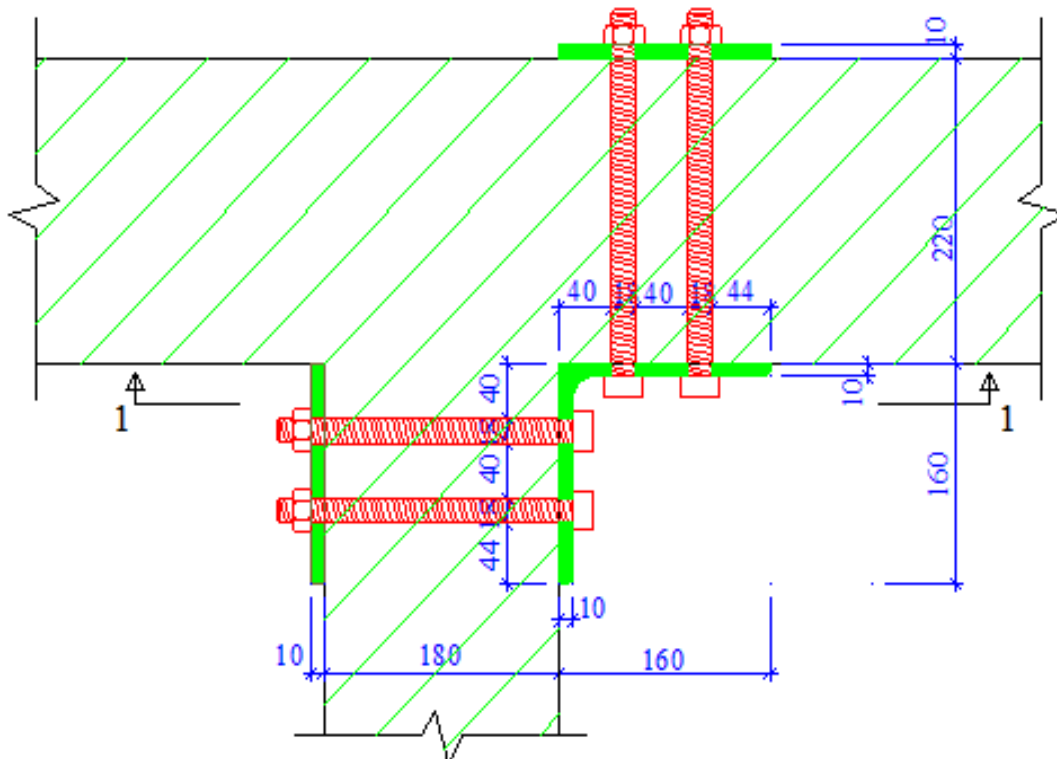


Fig. 6: Embedded panels with steel bars and bolts

- Panels embedding with steel bars and bolts;
- Cracks and joints retainage;
- Façade plastering and painting.

Results

- House building became a normal place for living for its inhabitants:
 - All deformations were removed
 - People feel safe to live there
- Restoration of the building became a best practice for the community;
- Case study was presented to municipality administration for further usage.

Conclusions

- Micro-piling technology is very effective and efficient in repairing buildings damaged by-swelling soils;
- Injection eliminates the effects of swelling and increased dramatically the load-bearing capacity of the ground;
- Fine stress control while injection works are done can strengthen the ground without causing additional pressure and deformations to the top sections of buildings;
- Micro-pile injection can be applied to pre- wound swelling soils, and before construction of any kind of buildings and premises.

**Thank you
for your attention!**