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Seismically stable buildings on hillsides

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ABSTRACT: Complex of seismically stable buildings on hillsides (from 10°-12° up to 40°-45°), hollows and ravines has been designed. It is characteristic that when constructing such buildings there is no need to terrace the ground, landsliding processes are not active, landslides are kept by the building; buildings are not multistoreyed ones, they are in good keeping with relief. The constructions are granted patent in the USSR and some other countries (USA, FRG). The first types of such buildings have been designed and built in the Crimea.

Buildings for construction on hillsides and hills have foundation in the form of grating of cross tapes put on the sloping surface of hillside and which takes a firm stand in foot of a hillside (it can be as underground room). Another type of buildings - building-breast-walls. Experiments have shown high seismic stability of developed constructions. They allowed to reveal that such buildings successfully combine both high seismic stability and capability to hold landslides.

1 INTRODUCTION

The Southern coast of the Crimea is the most valuable recreation zone and at the same time construction of buildings is difficult due to complex relief (steep hillsides, hollows), a great number of landsides (about 600), seismic zone (maximum magnitude M=7,0, the highest intensiveness - force 8), seashore abrasion (up to 0,5 m per year on some plots). All this special constructive decisions of buildings adapted to these conditions. Constructions of buildings had to meet such requirement as to be seismically stable, to hold landslides, to have possibility to be built on hillsides with slope up to 45° without terracing to be harmonious keeping with relief, to hold slope. Polyfunctional principle was the basis of designing, i.e. building should be seismically stable and simultaneously to hold landslide or slope.

2 CONSTRUCTION OF BUILDINGS ON HILLSIDES

Two complexes of constructive decisions of buildings have been designed: buildings located on natural hillsides without terracing and buildings - breast-walls (Fig.1). The first complex presents terraced or pointed type of buildings, which rest upon foundation in the form of cross beams (grating), located on natural hillside and at a depth of bearing layer of ground (about 0.5...0.7 m). Inclined foundation transfers load to rest construction, located in the foot of a hillside and is made in two variations. In terraced buildings discs of floors are fixed to tapes of foundations and play the part of hard diaphragms, that are placed vertically in traditional buildings. Holding construction takes from building not only horizontal load but landslide pressure of ground; this pressure should become less because grating of foundation transfers force to ground which presses landslide to surface of sliding. Measures are taken in order to avoid transfer of inclined load from grating of foundation to ground of hillside and avoid activization of

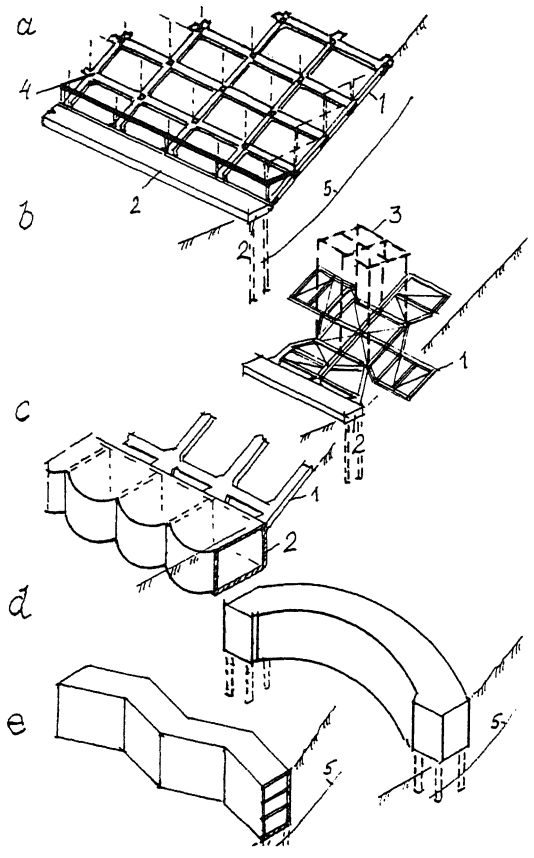

Fig.1. Constructions of buildings:
a - building of terraced type;
b - isolated buildings;
c - building with rest construction in the form of used space;
d - building-breast-wall (arched);
e - building-breast-wall (folded);
1 - foundation; 2 - rest construction; 3 - vertical diaphragms;
4 - horizontal diaphragms; 5 - landslide (surface of sliding).

landslide. The main junction of this construction is joint of inclined grating of foundation and rest construction where action of moments is eliminated and friction is brought down owing to installed washer of some layers of plastics. In order to avoid transfer of inclined load from foundation to hillside ground installation of flat jacks between rest construction and foundation grating is provided; as building load and horizontal shift of rest construction in flat jacks increases, additional pressure is made and it doesn't allow building to slip down the hillside.

Combination of flat foundation grating put on hillside with horizontal hard diaphragms resting upon grating and columns creates hard space system of triangle type. Foundation grating can follow uneveness of hillside, in such a case it has a space form. Point 3-5 storeyed buildings, placed on common grating of foundations considered to be further development of that construction. In point buildings vertical cross-shaped diaphragms are fixed to foundations, up to 9 buildings being placed on one grating and the number of rest constructions can be up to 3. This new constructive scheme stable and it doesn't make landslide active because of the lack of ground terracing. Underground operated structure to which pressure from foundation grating is transferred can be used as rest construction. One of the variants provides construction of underground structure from ferro-concrete covers, convex to ground.

The second complex, i.e. buildings-breast-walls are designed for 3-4 storey buildings, in plan they are of rectangular or curvilinear (arched, folded) forms. They hold slope with height up to 12 metres, hold landslide and at the same time fulfil the functions of recreation buildings. These constructions being new ones it demanded to make experiments to determine real operation of buildings when influenced seismically. Tasks of experiments were to reveal possibilities of new types of buildings in complex ground conditions under seismic load; interaction of a building with ground, holding of landslide, operation of new types of horizontal diaphragms under seismic load, mutual influence of some buildings located on one foundation grating.

3 METHODS OF TESTS

Ferro-concrete models made in 1:15 scale to real objects were equivalent to natural constructions geometrically and physically. Composition, concrete and stell frame deformation were modelled. Ground of foundation modeled natural ground (loamy soil with gravel), addition of steel small balls increased the weight of gound model and sliding surface was modelled by polyethylene film. For buildings-breast-walls additional weight on p prism surface was made with the help of cast-iron prisms. Ground model with building model placed on it was put into ground chute with vibration

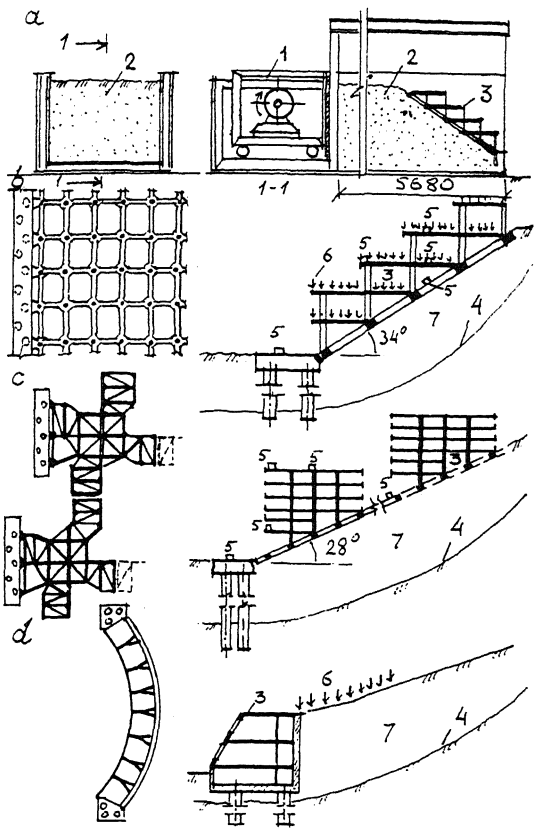

Fig. 2. Test plant: ground chute (a), models of: terraced building (b), isolated buildings (c), buildings-breast-walls (d):
1 - vibration machine; 2 - ground; 3 - models; 4 - sliding surface; 5 - places where vibration transducers were put; 6 - weight; 7 - landslide.

machine (Fig. 2).

Influence of seismic type was made by vibration machine with engine power of 100 kilowatt and by regulated cams and it was transferred to foundation ground through side of ground chute, connected with chute and fixed to vibration machine. Rotation frequency of vibration machine engine was regulated on control panel, intensiveness of seismic influence was up to force 9. Amplitudes and acceleration of oscillation of ground and floors, concrete and steel frame deformations in calculated sections were measured for each building. In buildings-breast-walls distribution of active ground pressure with seismic influence was determined with the help of force cells. Force cells on rest constructions served for determination of intensiveness of landslide pressure of ground. Additional weight on floors of buildings was made by small steel balls and leaden small shot in packets.

4 RESULTS

For terrace type buildings it is fixed that hard discs of floors jamed one side in foundation and from the other side resting upon columns provide with large space hardness of buildings and columns are not seismically influenced by action of curving moments. Building shifts as hard unit (Fig. 3), experiencing oscillations of basic tone. However, for providing of such a favourable stressed condition it is necessary that length of sides of floor to be in ratio B/L 2.

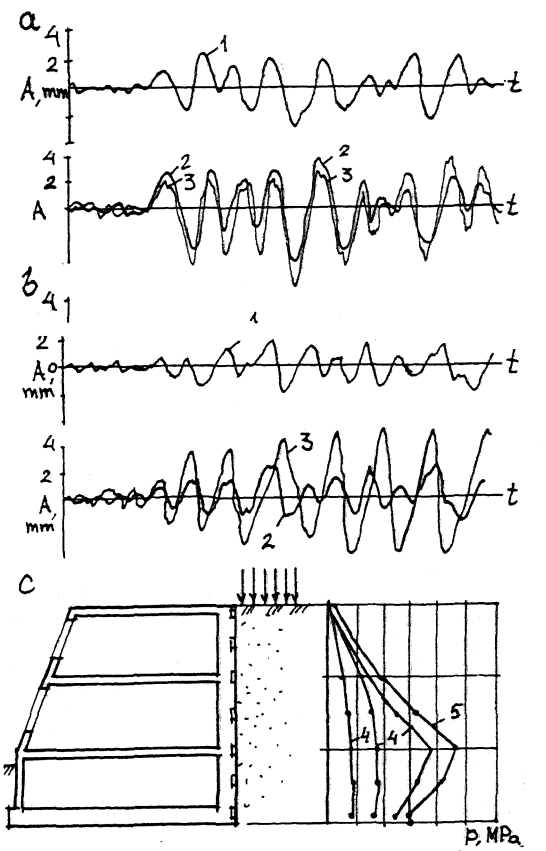

Fig. 3. Rezults of tests: a - for terraced building; b - for point buildings; a - for building-breast-wall; 1 - record of oscillation amplitude of groun; 2 - record of oscillation amplitude of foundation; 3 - record of oscillation amplitude of floor;

4 - orthographic epure of active pressure of ground when having statistical load; 5 - orthographic epure of active pressure of ground when having seismic load.

When testing point buildings, it was revealed that cross-shaped diaphragms of hardness and cross-shaped form of buildings gives more hardness to building in plan and owing to this building vibrates as hard unit. Symmetric form of building in plan leads to absence of its torsion. Placing of some point buildings on one foundation grating causes additional bending moments in foundation beams which joins foundations of separate buildings.

Both types of buildings render action of stability to landslide and reduce landslide pressure up to 50-70 per cent. The most important junction of buildings on grating foundation is the place where grating rests upon rest construction, where with high accelerations of ground vibration and low height of joint it is possible to have derangement of grating from rest construction. In order to avoid this joint height should be not less than 10-15 sm (in real buildings it was 50 sm).

Buildings-breast-walls under seismic influence experiences influence of active pressure of ground increased by 15-25 per cent as compared with static pressure. Holding construction kind is the most economical decision, however, taking into considerations the influence of considerable forces it is recommended to make rest wall of curvilinear elements.

5 CONCLUSIONS

Experimental tests revealed that constructions of buildings mentioned possess considerable seismic stability and have holding influence upon landslide. At present first buildings of described above types have been built in the Crimea (Yalta, Alushta) after designs of the Crimean scientific research project institute. New types of buildings can be recommended for construction on hillsides under seismic load up to force 8-9.

REFERENCE

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