ANALYSIS OF INSTRUMENTAL AND MACROSEISMIC OBSERVATIONS OF BUILDING BEHAVIOUR IN ZHALANASH-TIUP EARTHQUAKE, MARCH 25, 1978

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SUMMARY

On the 25th of March, 1978, 140km to the south-east of Alma-Ata a strong earthquake occurred (of magnitude M=6.5, intensity I=8-9, source depth 25-30km) that was felt in the territories of the Kazakh and Kirghiz republics.

This paper describes an engineering analysis of macroseismic observations behaviour of cob-brick, masonry, timber and reinforced frame buildings excited by ground motions in the earthquake of intensity 7-8. Considerable attention is given to vibrations of modern differently storeyed and designed buildings on different soils recorded by seismometric engineering stations in Alma-Ata.

Instrumental data show the effect of soil conditions and constructional features of buildings on the seismic force.

MACROSEISMIC OBSERVATIONS OF BUILDINGS LOCATED NEAR EPICENTRAL ZONE

To evaluate the earthquake intensity, statistical processing of the macroseismic damage observation data on different-type buildings was carried out on the basis of the MSK-64 scale [1]. The earthquake intensity depended on the area relief. In Toghuz-Bulak dwellings on hills were maximally damaged, and numerous ground cracks opened up to 15cm in width (Fig.1). The widths of crack openings in some building foundations were the same of those in the ground.

Cob-brick buildings. The foundations of the most cob-brick buildings are constructed of rubble concrete, and, in individual cases, of concrete. Main supporting constructions, i. e. walls, are made of cob-brick. The magority of buildings have timber roofings and inclined state roofs.

The earthquake caused major damages to all cob-brick buildings, that corresponded to degree IV(seismic scale MSK-64). Characteristic damages due to decoupling of some parts of buildings were as follows: large differently-oriented through cracks in walls; mutual breakage of walls up to 150-200mm in width; breakage and collapse of building corners (Fig.2). Stoves in all the buildings were destroyed.

All buildings with cob-brick constructive walls were severely damaged and displayed extremely low seismic resistance. Any repair and reconstruction of the cob-brick buildings were considered to be irrational and they were recommended to be pulled down as unfit for service.

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Buildings with constructive masonry walls. This group of buildings can be separated into two subgroups: buildings that were constructed with seismic provisions and without ones.

Buildings of the second subgroup had timber or reinforced-concrete floors. Most of them got series damages corresponding to degree III and in individual cases to degree IV. For instance, the obstatrical dispensary building got damages of degree IV (Fig.3): numerous widely-open through cracks formed in the walls; the building corner bulged from the wall plane; some longitudinal walls were broken away from cross-walls; floor slabs displaced 5cm relative to the walls. The building was considered to be unfit for service.

The obstetrical dispensary boiler house was also constructed of supporting masonry walls with a prefabricated reinforced-concrete roof covering. In one end wall of the building diagonal cracks formed that continued on the longitudinal wall of the yard façade as a horizontal up to 6-cm long crack in the upper third portion of the wall and on the face longitudinal wall as an oblique crack in the lower third portion of the wall (on the length of 1.2 m to the door aperture). The tambour walls were broken away from the longitudinal wall of the main house by vertical through cracks. The masonry of the boiler was completely destroyed.

The school boiler house erected in 1977 can be considered as a building of the first subgroup. This building has masonry walls, monolithic reinforced-concrete framings of apertures, its floors are made of precast ribbed reinforced-concrete slabs. No evident damages were seen in the building.

The Kazakh secondary school building in Zhalanash is H-shape in plan and consists of two- and three-storey school houses that communicate through a two-storey gallery. A single-storey gymnasium adjoins the two-storey school house. All these structures are devided into rectangular-in-plan compartments by aseismic joints. Aseismic girdles are made around floor slabs. Wall elements sizes do not exceed standards. No serious damages were evident in the building but plaster splitting-off, oblique cracks in partitions and so on.

Similar damages were observed in other buildings but the dwelling where horizontal and diagonal cracks were seen in internal and external walls, which had been caused by bad construction workmanship.

As a whole, the least damages were observed in buildings with aseismic provisions, in which the reinforced-concrete floor served as a rigid disk and ensured the combined behaviour of all the structures. At the same time buildings with timber and prefabricated non-monolithic floors were severely damaged.

Buildings with reinforced-concrete frames and masonry walls. The school building under construction in Toghuz-Bulak represents this kind of buildings. It consists of six independent pavillions separated by aseismic joints. The school design was developed with consideration of construction site seismicity 9 on the scale MM. The construction (but the finishing) of the school hall, gymnasium and dining-room had been completed by the moment of the earthquake. The three-storey school pavillions had been erected partially, one or two storeys in height.

Because of bad construction workmanship all buildings had been seriously damaged and found to be in catastrofic

condition (they got damages of degree III on the scale MSK). Concrete cut-offs and column reinforcement swelling were observed (Fig.4), appreciable cracks in walls, displacement of some portions of the constructive walls from their planes, breakage of longitudinal walls from crosswalls, collapse of some masonry partitions were seen. It should be noted that in one of the portions of the auditorium longitudinal wall a monolithic reinforced-concrete collar beam had been missed and here appreciable cracks formed in the masonry wall. The masonry in the zones of the resting og six precast reinforced-concrete lintels was destroyed.

Timber houses are, in the main, single-storey buildings. Two-storey timber buildings are erected only in single cases for public purposes.

Timber framed buildings are constructed of squared timbers with board and slab filling between columns. A characteristic defect of such buildings is the absence of safe coupling of the columns with the binding (the joining was provided by nails without joggles and dovetails). Besides, the slant lathes on the walls were nailed only to the filling boards and were not joined with the frame. Therefore they did not take part in the behaviour of the frame and did not contribute to increasing its stability but served only for fastening the plaster layer. The building floors were made of two types:

- floors fastened to the lathes of 40x40mm cross-section supported by bars nailed to the truss beams (type I);
- floors made of boards laid on timber beams of 80x80 (100x x100) cross-section, supported by the upper binding of the frame (type II).

The above described defects to a considerable extent determined the damage degree of the framed buildings. Characteristic damages were: collapse of large portions of plaster from walls and seilings, thruogh cracks in the corners of intersection of longitudinal walls, crosswalls, and partitions. The construction defects caused the deterioration of the stability of the most buildings in the earthquake (they swing when pushed by hand).

In buildings with the 1-st type floors considerable distortions of floors from the plane in some cases caused collapse.

The framed buildings with floors over beams (2-nd type) got slightly less damages corresponding to degrees II and III. After the reinforcing of the supporting structures, these buildings may be used for dwelling.

Block houses made of squared timbers and individual logs behaved best of all in the earthquake. Their characteristic damages were cracks in plaster wall and ceiling plaster falling out, destruction of stoves. The block-house damages can be qualified as degree I or II. Stoves were destroyed in all timber buildings.

Reconstruction of buildings damaged in earthquake. The observation of buildings in the area of the earthquake showed that their damages were of different character that determined reconstruction approaches. A part of the buildings was considered to be pulled down as reconstruction of them was irrational. They were cob-brick houses, a number of framed and masonry buildings that had damages of degrees III and IV. Individual timber block-houses constructed without consideration of any construction standards and that were in catastrofic condition

after the earthquake were recommended to be reconstructed in conformity with the aseismic construction requirements. Some buildings needed the restoring of the supporting capacity of some elements or simple repair.

The choice of reconstruction techniques for the damaged buildings was determined, first of all, by the design requirements for a concrete object and by its state. However, the reinforcing technique choice considerably depended upon the limited potentialities of the local construction institutions in the region of the earthquake. Therefore, from a large number of techniques for restoring the building supporting capacity some simple techniques were chosen that had proved to be good in reconstruction of buildings after the Zhambul earthquake [2].

The buildings to be reconstructed or repaired were built of masonry, timber block-walls or framed walls.

Buildings with supporting masonry walls were considerably damaged in the earthquake. The main cause of this was a low masonry quality. Damages occured in a wide range: from insignificant cracks in the constructive walls to widely-open through cracks, breakage of longitudinal walls from crosswalls, displacement of the floor from the walls.

The low quality of the masonry in the most buildings to be reconstructed and considerable damages of the supporting structures made it impossible to develope reinforcing designs with account of the supporting capacity of the available brick elements.

In connection with the above said to restore the support porting capacity of the masonry buildings, it was decided to transfer all the design seismic loads onto the reinforcement elements specified by the design. The elements were either reinforced-concrete shear walls or reinforcing fabrics in the layer of air-placed concrete. The thickness of the air-placed concrete, and the cross-section and size of the reinforcing fabric cells were determined from the lateral seismic force design. The reinforcing fabrics installed on both planes of the wall were coupled by Z-shape anchors 6mm in diameter, passed through predrilled 20-mm dia holes in the wall. Lintel girdles and individual lintels were additionally reinforced by reinforcing their air-placed concrete plaster, the measure being a part of the general wall reinforcing system. When making the air-placed concrete plaster, the cracks in the masonry were filled with cement mortar by injection.

With considerable damages of the supporting walls and excessive spaces between the wall axes, monolithic reinforced-concrete shear-walls were added that unloaded the walls of the given direction and decreased the free length of the perpendicular walls.

II. ANALYSIS OF INSTRUMENTAL DATA ON VIBRATIONS OF BUILDINGS IN ALMA-ATA

By the moment of the earthquake occurrence the seismometric engineering service system (SES) on Alma-Ata buildings inclined 17 stations equipped with standard and specially-designed apparatus. As distinct from seismologic stations, this service system has a first-hand aim to obtain objective data on earthquake excitation of buildings and structures

erected in different seismic areas and on different soils. For the first time in Alma-Ata, Zhalanash-Tiup earthquake, one of the strongest earthquakes of the last years, was recorded simultaneously by a large number of SES stations. They obtained material characterizing vibrations of differently-designed and differently-storeyed buildings (4 to 11-storey large-panel and framed dwellings and public buildings, single-storey industrial buildings), as well as vibrations of different-type soils (stratified pebbles, boulder pebbles, and plastic clays).

The SES stations are equipped with three-component accelerometers ОСП and seismometers ВБП and СБС. Each station carries out the recording of two kinematic parameters of vibrations: accelerations and velocities (or displacements). The recording is performed by wide-screen oscillographs Н010М (30 cm). Some stations use narrow-screen oscillographs Н700. Besides the galvanometer apparatus the Alma-Ata SES stations use direct-optical recording accelerofraphs of the ССР3 type, mechanical recording seismoscopes СБМ (single-pendulum) and АМС (multi-pendulum). They are also equipped with apparatus designed and constructed by the SES laboratory of the Kazakh Research and Designing Institute of Industrial Construction, as, for example, a quick-operating starting device characterized by operation stability, power-supply economy, and including a unit for monitoring the operational capability of the whole starting channel; apparatus recording simultaneously absolute and relative displacements (velocities) of vibrations of different building points; tensometric apparatus for recording supporting structure deformations, etc. The SES stations operate automatically in the continuous recording mode and are started from the first shock of earthquake.

Fig.5 illustrates a scheme of the SES stations arrangement in the territory of Alma-Ata and in the adjoining regions. The stations cover a one-hundred kilometer zone in the meridional direction. The diagram indicates the earthquake intensities recorded by seismoscopes СБМ, АМС at each station and intensities calculated using accelerograms of ground motion and building basement vibrations. It should be noted that the earthquake intensities determined from the macroseismic observation data agreed with those from the instrumental data records.

The instrumental recording data show that almost all the surveyed territory was subjected to earthquake of intensity 6 (except one small area of the city-center where soils are represented by firm boulder-pebbles and so the shock intensity did not exceed 5).

The analysis of the earthquake character was carried out using accelerograms, seismograms, and velocigrams recorded on the ground, in basements, and on building foundations, and the quantitative estimate of the building excitation and response was made using values of maximum vibration amplitudes and respective vibration periods calculated using records on upper floors. Records of the ground motion and building basement vibrations show high-frequency (8-15 Hz) longitudinal waves of small amplitude (3-8 cm/s^2; 0.1-0.5 cm/s; 0.1-0.3 mm). The longitudinal wave interval was 14 to 19 s. Then rather abruptly appear transversal waves with periods of 0.2-0.3 s (T=0.4 and 0.6 s at some stations) that are

complicated with high-frequency vibrations with T=0.1-0.25 s. Just the transversal waves are characterized by maximum vibration amplitudes. Accelerations on boulder-pebbles were equal to 14-23 cm/s^2 (vertical accelerations 5-7 cm/s^2), velocities -1.5 cm/s, displacements - 1.1-1.7 mm. On pebbles with layers of plastic clays and sands the parameters increased a little: accelerations were equal to 27-37 cm/s^2, velocities - 2-5 cm/s; on plastic clays accelerations reached 29-32 cm/s^2, and displacements - 1.8 mm.

Transversal waves are followed by Rayleigh surface waves with T=0.6-0.8 s and more, that are complicated with short-period vibrations. Surface wave amplitudes were 1.5-2 times less than transversal ones. The interval of the greatest ground vibrations (transversal and surface waves) is 10-15 s with the total duration of the earthquake about 2 min. The vibration accelerograms for different-type soils differ not only in amplitude but also in spectrum composition. The accelerograms on boulder-pebbles are rather high-frequency ones (3-10 Hz) and vibrations of plastic clays and pebbles with layers of plastic clays and sands are characterized by longer-period waves with the presence of short- period components.

The gross spectral character of the earthquake observed in different local-geology conditions of the region is illustrated by response spectra according to records of seismoscopes АИС (Fig.6).

The spectra have two peaks almost equal in amplitude, on periods 0.25 s and 0.6 s, with a small decrease of amplitudes in the zone of periods from 0.3 s to 0.5 s and from 0.8 s to 1.0 s.

The building vibration records are different in amplitude and spectrum composition, depending on building construction scheme and local soil conditions. Vibration periods of four-storey large-panel buildings on firm pebble-soils were equal to 0.15-0.18 s, and vibration periods of similar buildings on plastic clays were 0.2-0.25 s. A large-panel dwelling of the serie 147 and a nine-storey large-panel building with flexible first storey had periods of 0.38-0.45 s. Four- and nine-storey framed administrative and dwelling buildings, as well as single-storey industrial buildings vibrated with periods of 0.5-0.6 s. The most flexible of all the surveyed buildings was an 11-storey steel-framed building which vibration period was 1.2-1.3 s.

The given above values of the building vibration periods recorded during the earthquake of intensity 5-6 were about 15-20% higher than in weak earthquakes, and slightly lower than the design period values.

REFERENCES

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2. Zhunusov T.Zh., Aubakirov A.T., Ashimbayev M.U., Budanov V.I., Boochatskiy E.G. Damages of Buildings and Structures in Jambul Earthquake, May 10, 1971. Publishing House "Kazakhstan", Alma-Ata, 1974.

Figure 1

Figure 2

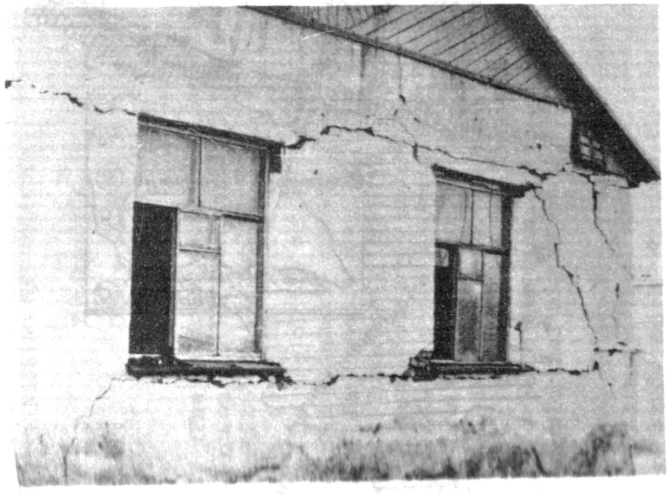

Figure 3

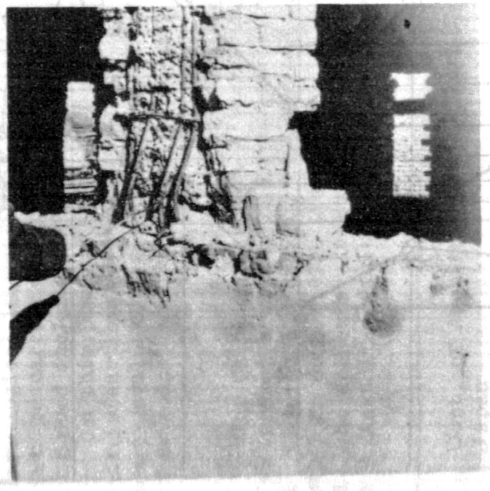

Figure 4

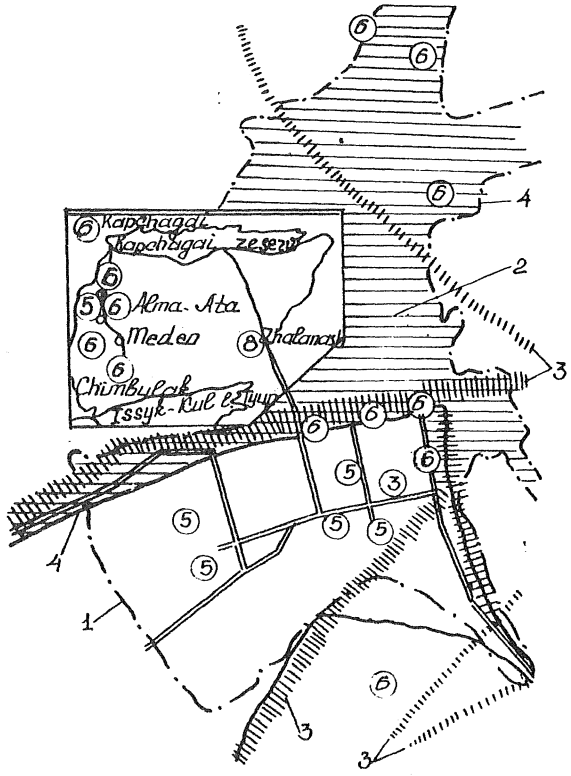

Fig.5 Alma-Ata ESS stations dislocation scheme.

1,2 - regions of seismisity 9 and 10;
3 - failt zones; 4 - town boundary
(5) - ESS stations location and earthquake intensity.

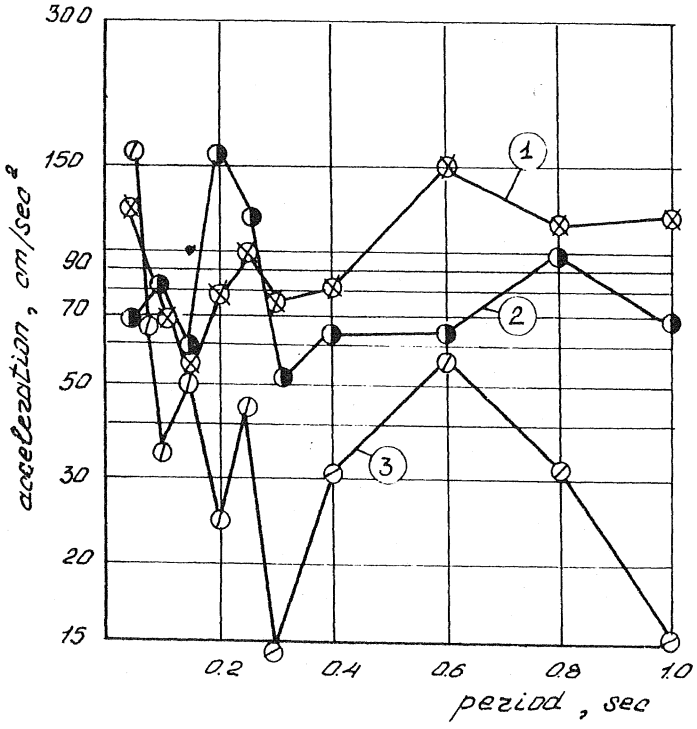

Fig. 6. Seismoscope pendulums response spectra.
1 - on plastic clays; 2 - on stratified pebbles; 3 - on boulder pebbles.