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FELT EFFECTS IN RELATION TO THE DEVELOPMENT OF THE INTRAFAULT SPACE

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ABSTRACT

Being large discontinuities, faults may act as stress cincentratirs in the Earth's crust, intensifying the eartuquake effect under certain conditions. On the other hand, in a different environment the same large discontinuities may absorb and dampen seismic waves, reducing the effect of earthquakes. Main role here is played by the structure of intrafault space (the fault dynamic impact zone). This zone include the main fault and a series of concomitant ruptures. A detailed analysis of faults shows that distribution of earthquakes within particular fault zones by their frequency, magnitude and depth depends on the structural element within which earthquake energy is released. An analysis of the macroseismic effect in the researched territory confirms the interrelationship between tectonic deformations and the extent of damage done to buildings. In tectonic deformation zones the mechanism of structure destruction is marked by a specific dynamic effect.

KEYWORDS

Fault dynamic impact zone-FDIZ, main fault, series of concomitant ruptures, active fault, destructive fields, macroseismic effect.

The provoking role of faults in the development of seismic events is well known. Apart from seismogenous faults within any seismic region, however, there exists a network of faults that are passive as regards the formation of earthquake focus. Their role in macroseismic effects of earthquakes cannot is not yet absolutely clear. There are both objective and subjective reasons for this. On the one hand, being large discontinuities, faults may act as stress concentrators in the Earth's crust, intensifying the earthquake effect under certain conditions. On the other hand, in a different environment the same large discontinuities may absorb and dampen seismic waves, reducing the effect of earthquakes and mitigating their consequences. When, how and in which particular environment does either of these scenarios come into play? There is not a straightforward answer to this question as no one has ever conducted research on a regular basis devoted specifically to the subject; as for the available statistics on experimental data and relevant natural effects, these are fragmentary. Even so, the available (far from complete) information on the influence of faults on the macroseismic effects of earthquakes shows that the main part here is played by the structure of intrafault space (the fault dynamic impact zone, FDIZ) and the pattern of its structural elements activation. FDIZ structural elements include the main fault, coming first in the hierarchy of fault space organisation, and a series of concomitant ruptures, which bring strong influence to bear on the dynamic and kinematics features of this space and unite into second-type structures in fault zones' internal organisation, i.e. into destructive fields.

Research into active faults of a number of large seismic regions of the world suggests some preliminary conclusions regarding the dependence of macroseismic effects on the pattern of fault activation in connection with their internal structural organisation and specific features of its evolution. A detailed analysis of such faults as San Andreas, Talaso-Fergansky, Glavny Kopetdagsky, Gerirudsky and Surkhob-Ilyaksky, among many others, shows that distribution of earthquakes within particular fault zones by their frequency, magnitude and depth depends on the structural element within which earthquake energy is released.

Thus, destructive fields occupy first place with regard to earthquake frequency: they account for 65-75 percent of the total number of earthquakes in a given zone. Main faults, on the other hand, account for no more than 25-30 percent of recorded earthquakes. With respect to magnitude, earthquake foci are distributed as follows, depending on the zone's structural elements. In destructive fields, foci with M = 4.1-5.0 account for 70-75 percent, those with M = 5.1-6.0, for 20-25 percent, and those with M = 6.1-7.0 occur as exceptions only. Earthquakes with magnitudes exceeding 7.1 have not occurred in destructive fields altogether.

The picture in main fault zones is different. Foci with M = 4.1-5.0 account for 10-15 percent, and those with M = 5.1-6.0, for 15-20 percent; foci with M = 6.1-7.0 and over 7.1 are generally connected with main faults only.

With regard to their depth, earthquake foci are distributed as follows. In destructive fields, shallow-focus earthquakes with the depth (H) up to 10 km account for 75-80 percent; foci 11-20 km deep account for 10-15 percent, and those 21-40 km deep, for 5-10 percent. On the contrary, in main fault zones foci 21-40 km deep account for 55-60 percent, those 11-20 km deep, for 25-30 percent, and foci whose depth is less than 10 km account for a mere 10-20 percent.

An analysis of earthquake frequency within one and the same intrafault structure suggests a period of stress relaxation on the planes of concomitant ruptures in destructive fields that does not exceed 3-10 years, and a period of not less than 20-30 years in main fault sections. Ample statistics on the internal structural organisation of faults and its evolution show that the main fault "migrates" across the strike of intrafault space, and a new intrafault plane activates (or breaks up) as the main one in the course of each new tectonic cycle. This circumstance largely determines both the nature of stress redistribution and the general pattern of the stressed and strained state of the intrafault volume of the Earth's crust, and hence realisation of the seismic process reflected in the nature and extent of damage done to buildings and structures.

The most striking example of dependence in question can be seen in the nature of destruction and fracturing in the village of Goryachiye Klyuchi on the island of Iturup during two Kurile earthquakes, which occurred on 7 November 1958 and 5 October 1994. The first one had intensity 8-9, and the second one, intensity 7-8 (according to the MSK-64 scale). In both cases the maximum destruction and concentration of faults breaking up on the surface were recorded in the large fault zone of the north-eastern strike traced on the terrain by a series of tectonic ledges and the river Blagodatnaya valley. Individual structural elements forming the intrafault volume of this zone also perform a distinct relief-shaping function and are traced both by small ledges on the terrain and by local sharp bends of the valleys of the river Blagodatnaya and stream Yaroslavna. Comparison of macroseismic effects of these earthquakes shows that in 1958 the bulk of opening fissures and destruction were recorded in the south-eastern limb and the axial part of the fault zone, while in 1994, on the contrary, these concentrated in the north-western limb. In the village of Goryachiye Klyuchi, all buildings are more or less of the same type, with seismic resistance of 8 grades. All of them were built by one contractor within four or five years. Building constructions, units and individual details were made according to single design principles.

A comparative analysis of the extent of damage done to buildings and structures within tectonic deformation zones and outside of them makes it possible to assess the impact of tectonic deformations on the level of macroseismic effect.

1. Damage done to buildings outside tectonic deformation zones.

Buildings with reinforced concrete frames and self-bearing walls sustained a medium degree damage (d = 2.1 according to the MSK scale), which is acceptable by the Russian standards. Typical damage done is as follows: exposed joints between floor slabs, cracks in partitions, exposed joints between partitions and bearing structures, line oblique cracks in columns in sections adjacent to frame assemblies, line cracks in supporting sections of cross-bars, disintegration of mortar in joints between wall panels, and line cracks in partition wall panels.

Buildings with masonry bearing walls with monolith reinforced concrete inclusions and earthquake-proof belts sustained a medium degree damage (d = 2.6 according to the MSK scale), which is acceptable by the current Russian standards. Typical damage done is as follows: exposed joints between floor slabs, cracks in partitions, exposed joints between partitions and bearing structures, line oblique and X-type cracks in exterior and interior walls, flaking of plaster, and cracks in monolith reinforced concrete inclusions in walls in the technological joints layer.

Virtually all buildings were declared suitable for occupation following repair of some elements and redecoration.

2. Damage done to buildings within tectonic deformation zones.

The surface of the earth was marked with fissures up to 30 cm wide, local landslides, and road slabs displacements (up to 40 cm).

Buildings with reinforced concrete frames and self-bearing walls sustained a medium degree damage (d = 4.2 according to the MSK scale), which by far exceeds the level permissible by the Russian standards. Some of the buildings collapsed. Typical damage done is as follows: through-the-thickness oblique cracks in columns and cross-bars in sections adjacent to frame assemblies, breaking of transverse reinforcement, loss of stability of longitudinal reinforcement, brittle failure of concrete in the body of columns, collapse of some columns and cross-bars, displacement of floor slabs off supporting sections, falling of some slabs, through-the-thickness cracks in partitions, collapse of a considerable number of partitions, through-the-thickness cracks in wall panels, and collapse of some panels and wall sections.

Buildings with masonry bearing walls with monolith reinforced concrete inclusions and earthquake-proof belts sustained a medium degree damage (d = 4.1 according to the MSK scale), which substantially exceeds the level permissible by the existing Russian standards. Typical damage done is as follows: through-the-thickness X-type cracks in exterior and interior walls, mutual displacements of masonry sections, through-the-thickness cracks in wall junctions, cracks in lintels, displacement of some reinforced concrete lintels off support platforms, displacement of floor slabs off supporting sections, through-the-thickness cracks in partitions, and collapse of a considerable number of partitions.

Most of the buildings were declared dilapidated and unfit for restoration.

An analysis of the macroseismic effect in the village of Goryachiye Klyuchi confirms the interrelationship between tectonic deformations and the extent of damage done to buildings. The results of research show that 92 percent of buildings which sustained damage exceeding permissible norms are located in tectonic deformation areas. Seismic effects in such areas are complex and multidimensional, substantially exceeding the average level in the region. In tectonic deformation zones, the mechanism of structure destruction is marked by a specific dynamic effect and definitely calls for further investigation.

In earthquake-prone regions, information on tectonic deformations is a most important indicator of seismic hazard. For the purpose of abating earthquake risks, it seems expedient to bar construction of buildings and facilities in tectonic deformation zones or provide for a considerably bigger bearing capacity of their structures. Identification of tectonic deformations in areas with existing buildings and facilities will make it possible to carry out, with good reason, precautionary prophylactic measures to prevent or reduce possible damage from earthquakes.