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РЕЗУЛЬТАТЫ ПРИМЕНЕНИЯ ГИС ДЛЯ ОЦЕНКИ СЕЙСМИЧЕСКОЙ УГРОЗЫ И МНОЖЕСТВЕННОГО (МУЛЬТИ) РИСКА ГОРНОЙ ТЕРРИТОРИИ КЫРГЫЗСТАНА

RESULTS OF GIS APPLICATION FOR SEISMIC HAZARD AND MULTI RISK ASSESSMENT IN MOUNTAIN AREA OF KYRGYZSTAN

Бул изилдөөдө табигый коркунучтардын ар түрдүү типтерин, тобокелчилик астында болгон элементти жана кооптуулук ченөөлөрдү эске алуу менен мульти тобокелчиликти баалоо усулдарын өнүктүрүүгө багыт алганбыз. Кыргызстан сыяктуу жогорку сейсмикалык аймактарда мульти тобокелчиликти баалоону эффективдүү жүргүзүү, көп (мульти) коркунучтарды баалоонун сапатын жакшыртуу үчүн микро-сейсмикалык усулдарды колдонуу маанилүү. Микро-сейсмикалык баалоону жүргүзүү максатында АКШнын Геологиялык кызматынын (USGS) туура толкундардын ылдамдыгы (Vs) боюнча маалыматтары жана үстүңкү толкундарды көп каналдуу талдоо усулу менен (MASW) жүргүзүлгөн жекече ченөөлөрүбүздүн маалыматтары колдонулду. Ошентип, биз Кыргыз Республикасынын Ош областына караштуу Чоң-Алай районунда жайгашкан билим берүү мекемелеринин мульти тобокелчилигин баалоо үчүн географиялык маалымат системасын (ГИС) колдонуу жана дисперсиондук толкундарды ченөө боюнча айрым илимий изилдөө жыйынтыктарын көрсөтүүгө максат койгонбуз.

Ачкыч сөздөр: *кырсык тобокелчилигин төмөндөтүү, мульти тобокелчиликти баалоо, сейсмикалык коркунучту баалоо, MASW, USGS, ГИС, Кыргыз Республикасы, Чоң-Алай району.*

В данном исследовании мы были нацелены на развитие подхода Оценки Мульти Риска с учетом различных типов природных угроз, измерений уязвимости и элемента находящиеся под риском. Для эффективного проведения Оценки Мульти Риска в таких высоко сейсмичных регионах как Кыргызстан, важно применять микро-сейсмические методы оценки для улучшения качества оценки множественных (мульти) угроз, а значит и результатов Оценки Мульти Риска. Для проведения микро-сейсмической оценки были применены данные скоростей поперечных волн (Vs) Геологической Службы США (USGS) и собственные измерения проведенные способом Многоканального Анализа Поверхностных Волн (MASW). Таким образом мы нацелены продемонстрировать некоторые исследовательские результаты в использовании ГИС и измерений дисперсионных волн, проведенных для Оценки Мульти Риска образовательных учреждений расположенных в Чон-Алайском районе, Ошской Области, Кыргызской Республики.

Ключевые слова: *Снижение риска бедствий, оценка мульти риска, оценка сейсмической угрозы, MASW, USGS, ГИС, Кыргызская Республика, Чон-Алайский район*

Within this research we aim to develop Multi Risk Assessment approach with consideration of various types of natural hazards, vulnerability dimensions and elements at risk. For effective implementation of Multi Risk Assessment in such seismic regions as Kyrgyzstan, is essential to incorporate the micro seismic evaluation methods towards an improvement of definition of the multi hazard and therefore the Multi Risk Assessment outcomes. For conducting of micro seismic assessment was adapted shear wave velocity (Vs) data received from USGS and the measurements *conducted by the Multichannel Analysis of Surface Waves (MASW) method. Thus we aim to show some case study results of applying GIS, dispersive wave data and tests with the objective of contributing towards a Multi Risk Assessment of education facilities (institutions) located in Chong-Alay district of Osh oblast, Kyrgyz Republic.*

Keywords: *Disaster risk reduction, multi risk assessment, seismic hazard assessment, MASW, USGS, GIS, Kyrgyz Republic, Chong-Alay district.*

1. Geographic setting

The target area is located in the south-western part of Kyrgyzstan, Chong-Alay district which occupies the western part of Alay valley (Figure 2). The northern boundary of the district is located in the Alay Mountains and the southern in the Trans-Alay Range, between the Tian Shan and the Pamir mountain systems. The hydrology is dominated by Kyzyl-Suu, to the west, and its tributaries .and flows from Irkestam to Kashgar, flowing westward on the northern side, through the Karamyk pass and into Tajikistan, where, under the name of the Vakhsh River it flows southwestwardly into the Amu Darya. The Alay valley is inclined from east to west, with the lowest point at 1560 meters above sea level. Villages and evaluated education institutions (schools, kindergartens, school based kindergartens and home based kindergartens) are located at altitude ranging from 2298 m. (Karamyk village) to 3028 m. (Achyk-Suu village).

2. Multi risk assessment paradigm.

The Multi Risk Assessment was based on main paradigm of Risk, where Risk considered as function of the hazard and the conditions of vulnerability and element at risk (Formula 1).

$$R = H \times V \times A \qquad \text{(Formula 1)}$$

Where: H
– hazard;
V – vulnerability; A
– elements at risk.

Final values (index) of Multi Hazard and Multiple Vulnerability were calculated within the adapted formula of Multi Risk (Formula 2) as a quasi-probabilistic level and was based on preliminarily fixed indexes and rates of each type of hazard, vulnerability and element at risk.

$$R = \sum(H_{n1p1}+H_{n2p2}) \times \sum(V_{n1p1}+V_{n2p2}) \times A \qquad \text{(Formula 2)}$$

Where: H
– hazard;
V – vulnerability; A
– elements at risk;
n – number (type) of hazards and vulnerability;
p – coefficient of priority.

Within research was considered 3 types of hazard (geotechnical, natural, seismic), 4 types of vulnerability (fire safety, disaster education, structural mitigation and retrofitting, structural) and 1 type of element of risk (number of students and teachers).

Within our work, we are united and analyzed data from different types of risk factors in one multi factor system. For this purpose we used relative system of normalization of numerical information and mapping the results through the application of GIS software. In general, the outline of this process was based on the adapted national standards of risk factor assessments used in Kyrgyzstan [7,9,10,11] and methodologies of Multi Risk analysis of European Community [3] and United Nations [20,21].

The priority coefficient for hazard and vulnerability were fixed according priorities revealed and evaluated within the regional risk assessment of the target area [23]. Integration of the priority coefficient makes it possible to increase the meaningfulness of the calculation of the final risk indexes, which was calculated according to differentiation of quasi-probabilistic level of impact from each specific risk factor.

The purpose and objectives of research were reached through the production of outcomes presented as information which clarifies the preliminary evaluated levels of all types of hazards, vulnerability and element of risk and final values of multi risk for each of the evaluated educational institutions.

The preliminarily methodology approaches and results of Multi Risk Assessment were reviewed and approved by the decision of the Scientific and Technical Council under the Inter-Ministerial Commission for Civil Protection of the Kyrgyz Republic and were recommended to be adapted to the local and national system of disaster management [12,13].

3. Seismic hazard assessment methodologies

The whole of the studied area is a highly seismically prone area, with 89% of it exhibiting Grade I – seismic hazard sub-area, with a seismic intensity of 9 and higher in the Medvedev–Sponheuer–Karnik macro seismic intensity scale (MSK) and the remaining 11% with a seismic intensity of 8 on the MSK scale [1]. Among all other types of disasters in the target area, earthquakes are the most hazardous types of natural disasters [23]. Regarding this, within multi risk calculation, the seismic hazard was considered with higher priority or higher coefficient of priority (within hazards block).

Methods and results of the macro seismic zonation was inappropriate for purpose of our research because we were needed to develop comparison of seismic parameters for separate points – objects of assessment (education institutions), which were located within similar macro seismic areas.

Within our research as micro seismic data we adopt shear wave velocity (Vs) data. Several methodologies exist for extending the utility of spatially limited Vs30 observations and estimations to larger areas. The measurement of shear wave velocity (Vs) is an established approach in contributing to earthquake site response [4,5].

The reason for adopting this type seismic data for hazard analysis is justified because building structures respond to dynamic forces exerted by earthquakes as well as being influenced by the soil response on which they are founded on. This can be achieved by identifying the dynamic properties of the soil and hence by determining the shear wave velocity profile, Vs in depth.

4. Masw method

4.1. Methodology.

The local seismic classification of a site essentially consists of determining the category to which the site belongs on the basis of the main parameters which influence the site response to earthquakes or more generally to external dynamic forces. Currently there are several international codes, which classify the sites on the basis of their nature and their geotechnical characteristics, especially based on the vertical shear wave velocity profile.

The NEHRP [6] and Eurocode 8 [2] regulations help to determine the seismic design force on the basis of the seismic zone to which the site belongs. The seismic motion at the bedrock is generally different from the seismic motion at the free surface, depending on the intensity and the frequency content of the seismic energy. In general terms the classification is defined by means of the equivalent average vertical shear wave velocity designated as Vs30 (Formula 3):

$$V^{s^{30}} = \frac{30}{d} \qquad \text{(Formula 3)}$$

$$\sum_{i=1}^{N}\left(\frac{\ i}{v_i}\right)$$

The MASW method is a non-invasive investigation technique, through which the vertical profile of Vs30 can be obtained by measuring the propagation of the surface waves at several geophones placed at the free surface of the site.

Generally, the main contribution to the surface waves is given by the Rayleigh waves, which travel through the upper part of the site at a speed, which is correlated to the stiffness of the ground. The dispersive wave methods can be applied as an active method, generally known as MASW, or as a passive method, generally known as passive MASW, ReMi or ESAC, or even as a combination of both active and passive methods. In the active method the surface wave is generated by a source located at a point on the free surface and then the wave motion is measured along a linear array of sensors.

The MASW data in the present work was carried solely resorting to active data, since there was not a sufficiently high level of noise to carry out passive data, and using a consistent geometry for the proposed objectives.

4.2.Field testing and settings.

The MASW data was carried out on twenty-six (26) different sites which represented all (48) educational institutions of target area. Within each site a consistent geometry for the proposed objectives was used. Each site generally consisted of two shots on each end of the linear array. Thus each site had two tests, using RAS-24 seismograph, to confirm it's representative result.

The results of the MASW data was carried out taking into account multi-modal interpretation and some a priori known geological knowledge. After the shear wave velocity profile has been determined, then the equivalent Vs30 value (Formula 3) can be calculated and hence the seismic class of the soil can be established.

The data of all of the tested sites was interpreted using the sequence described in the previous section. Since the obtained range of Vs30 velocities does not cover the full range of any of the Vs30 classification tables (EC8 or NEHRP) a local relative scale, that would permit a regional ranking and adequate distinction amongst the different classes of soils, was established. This scale consists of five rates that extend from the minimum Vs30 velocity (254 m/s) to the maximum (776 m/s).

Upon observing the results (Figures 1 and 3) the villages of Karamyk (school #15, kindergarten #7; school based kindergarten #5) and Jekendi (kindergarten #8) (western part of target area) exhibit the highest seismic hazard amongst the tested sites. The lowest seismic hazard values exhibited are from villages located in Central and Eastern part of the target area. This situation is confirmed by the regional seismic hazard characterization [1].

5. USGS seismic site Vs30 estimation.

As additional methodology for assessment of seismic hazard we used - USGS Active Tectonic mapping tool [22] available online, to produce a map of Vs30 for the studied region.

It seems that Vs30 map of USGS was solely based on the topographic slope and a very simple geology cartography, since there was not any available information about any geophysical Vs30 having been done in target area before. At first glance the obtained map seemed to be correct however when we zoomed in and observed the details of each interpolated element, overlaid with our measured values, it stood out that most estimates fell relatively far from the measured values. This fact can be confirmed and geographically visualized on the map depicted in Figure 2 and 3 when we compare the color code of the circles (MASW, Vs30 measurements) with the respective pixel of USGS Vs30 estimates of the map.

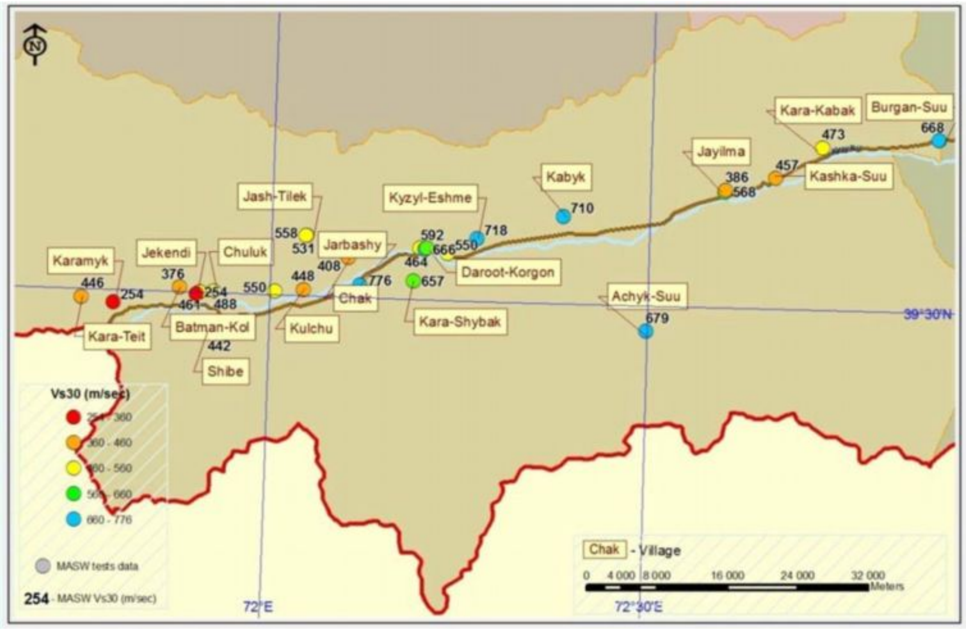

Figure 6. Mapped results of the detailed MASW Vs30av seismic site response within the target area *(The circles indicate tone according to the velocity and the precise velocity is indicated next each one)***.**

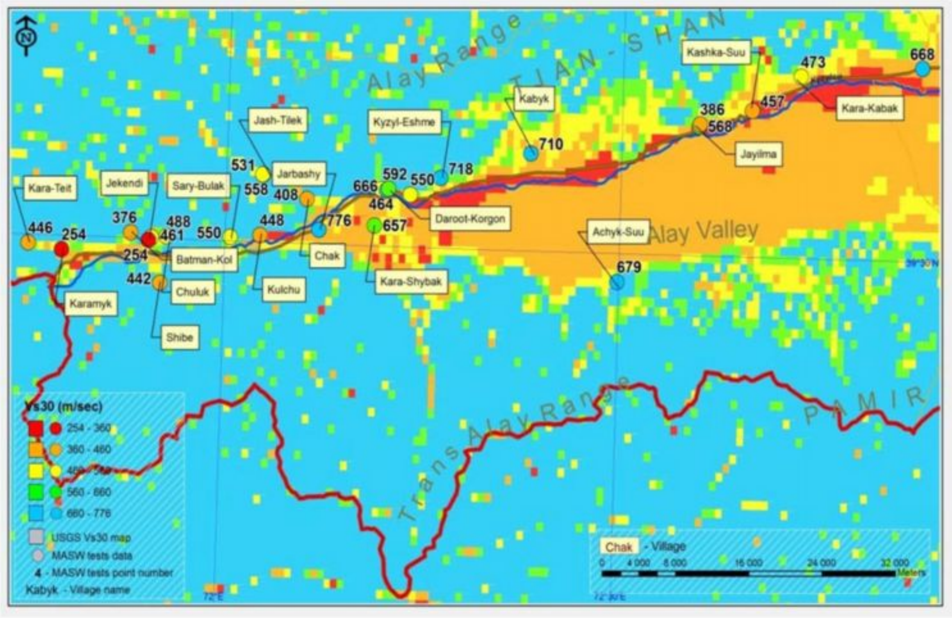

Figure 2. Figure 3.9: MASW Vs30 values and USGS Vs30 estimation map

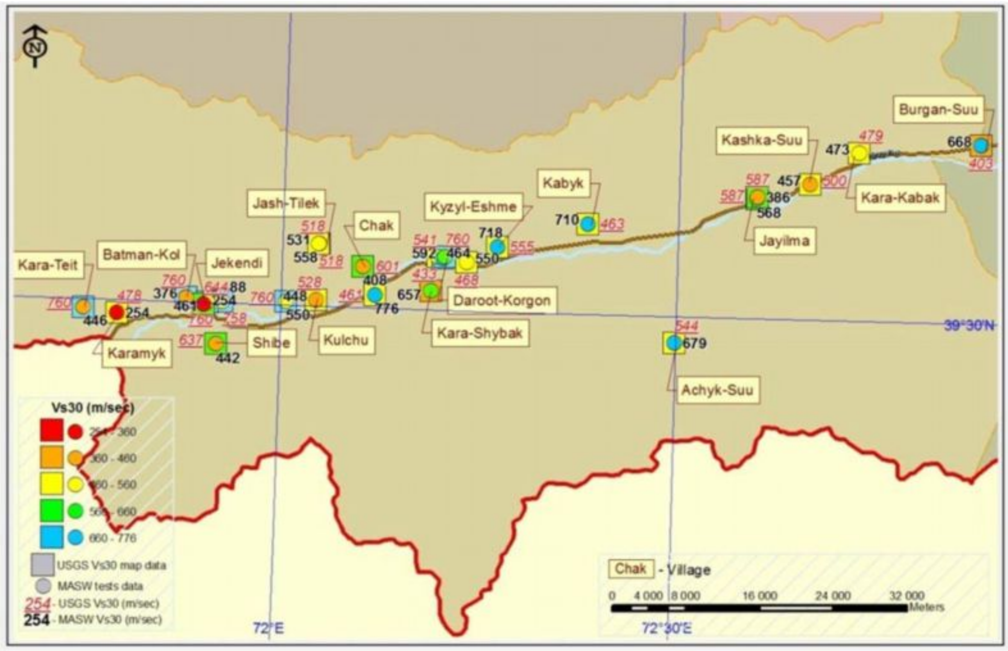

Figure 3. Map of comparison MASW Vs30 and USGS Vs30 values

In Figure 3 we present the values of MASW Vs30 (circles) and USGS Vs30 (squares). Thus it is possible to conclude that a Vs30 estimation solution for this region is still not adequate since it requires some type of calibration with in situ testing such as the MASW that was performed.

Appropriate methods of adaptation of USGS Vs30 data for Multi hazard or Multi Risk assessment and among others works in current region can be finding in additional consultations.

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