

## SEISMIC RESPONSE OF A 22-STOREY MONOLITHIC BUILDING BASED ON INSTRUMENTAL ACCELERATION RECORDS

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**Abstract.** *This study addresses the growing need for reliable seismic verification of high-rise monolithic reinforced concrete buildings in Almaty, Kazakhstan, where intensive vertical development is taking place in a high-hazard seismic environment. To improve the realism of structural response prediction, the building performance is evaluated using instrumental earthquake acceleration records and compared with the conventional response spectrum approach commonly applied in design practice. A 22-storey monolithic building is analyzed in the LIRA-SAPR environment by two independent procedures: (i) response spectrum analysis under the design spectrum and (ii) time-history analysis using selected three-component accelerograms representing strong ground motions (including recorded and artificial events). The comparison is performed for a representative structural element at the upper levels (a reinforced concrete wall along Axis 1/B at elevation 74.25 m), where higher-mode effects may be significant. The results indicate that peak lateral displacements are strongly record-dependent. For the El Centro (1940) input, time-history displacements are practically consistent with the spectrum-based estimates, whereas for the Kern County (1952), Baysorun (1990), and the artificial record, time-history responses are noticeably lower than those obtained by the response spectrum method, confirming the conservative nature of spectrum-based design. The observed discrepancies are primarily attributed to differences in frequency content and duration of ground motion. The findings support the combined use of response spectrum analysis for routine design and time-history analysis for enhanced verification of high-rise buildings, especially in regions with pronounced regional ground-motion features. The study also substantiates the value of engineering seismometric monitoring for refining local seismic inputs and improving assessment reliability.*

**Keywords:** *high-rise building; seismic response; maximum design earthquake; accelerogram; time-history analysis; structural displacements.*

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## ҮДЕУЛЕРДІҢ АСПАПТЫҚ ЖАЗБАЛАРЫ НЕГІЗІНДЕ 22 ҚАБАТТЫ МОНОЛИТТІ ҒИМАРАТТЫҢ СЕЙСМИКАЛЫҚ РЕАКЦИЯСЫ

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**Андатпа.** Бұл зерттеу Алматы қаласында сейсмикалық қауіптілігі жоғары аймақта қарқынды дамып жатқан биік монолитті темірбетон ғимараттардың сейсмикалық орнықтылығын бағалау дәлдігін арттыруға арналған. Қалалық аумақта бос жердің шектеулі болуы және соңғы жылдары көпқабатты құрылыстың көбеюі нақты жер сілкінісі әсері кезінде ғимараттардың жауап реакциясын сенімді болжауды талап етеді. Осы мақсатта дәстүрлі жобалау тәжірибесінде кең қолданылатын спектрлік әдіс нәтижелері жер сілкіністерінің аспаптық үдеу жазбаларына (акселерограммаларға) негізделген уақыттық талдау нәтижелерімен салыстырылды. Зерттеу нысаны ретінде 22 қабатты монолитті темірбетон ғимарат қарастырылып, ЛИРА-САПР бағдарламалық ортасында екі тәуелсіз тәсілмен есеп жүргізілді: (1) жобалық жауап спектрі бойынша есеп және (2) үшкомпонентті акселерограммалар жиынтығын пайдалана отырып тікелей динамикалық уақыттық есеп (нақты және жасанды жазбалар). Салыстыру биік жүйелерде жоғары тербеліс формаларының әсері күшеюі мүмкін болатын деңгейде орналасқан сипаттамалы көтергіш элемент үшін орындалды — I/B осі бойындағы 74,25 м белгісіндегі темірбетон қабырға. Нәтижелер максималды көлденең орын ауыстырулардың қолданылған жазбаға айқын тәуелді екенін көрсетті. El Centro (1940) әсері кезінде уақыттық талдау нәтижелері спектрлік есеппен іс жүзінде сәйкес келеді, ал Kern County (1952), Байсорун (1990) және жасанды жазба үшін уақыттық есеп орын ауыстыруларды төменірек береді, бұл спектрлік әдістің консервативті сипатын растайды. Айырмашылықтар негізінен жер тербелісінің жиіліктік құрамы мен ұзақтығындағы ерекшеліктермен түсіндіріледі. Алынған қорытындылар биік ғимараттарды жобалауда спектрлік әдісті негізгі құрал ретінде, ал уақыттық талдауды нақтыланған тексеру ретінде бірге қолданудың орынды екенін дәлелдейді. Сонымен қатар инженерлік-сейсмометриялық мониторинг жергілікті әсерлерді нақтылау және бағалау сенімділігін арттыру үшін маңызды екені көрсетілді.

**Түйін сөздер:** биік ғимарат; сейсмикалық реакция; максималды есептік жер сілкінісі; акселерограмма; уақыттық талдау; орын ауыстырулар.

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## СЕЙСМИЧЕСКАЯ РЕАКЦИЯ 22-ЭТАЖНОГО МОНОЛИТНОГО ЗДАНИЯ НА ОСНОВЕ ИНСТРУМЕНТАЛЬНЫХ ЗАПИСЕЙ УСКОРЕНИЙ

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**Аннотация.** Настоящее исследование посвящено актуальной задаче повышения достоверности оценки сейсмической устойчивости высотных монолитных железобетонных зданий в г. Алматы, где на фоне дефицита территорий активно развивается высотная застройка в условиях значительной сейсмической опасности. Для уточнения прогноза отклика сооружений выполнено сопоставление расчетов по спектральному методу, широко применяемому в проектной практике, с расчетами во временной области на основе инструментальных записей ускорений землетрясений (акселерограмм). Объектом исследования является 22-этажное монолитное здание, расчет которого выполнен в программной среде ЛИРА-САПР двумя независимыми подходами: (1) расчет по проектному спектру отклика и (2) прямой динамический расчет с использованием набора трехкомпонентных акселерограмм, характеризующих сильные сейсмические воздействия (включая реальные и искусственные записи). Сравнительный анализ выполнен для характерного несущего элемента верхней части здания — железобетонной стены по оси 1/Б на отметке 74,25 м, где вклад высших форм колебаний может быть существенным. Показано, что максимальные горизонтальные перемещения зависят от конкретной записи землетрясения. Для воздействия El Centro (1940) результаты временного анализа практически совпадают со спектральными оценками, тогда как для Kern County (1952), Байсорунского (1990) и искусственной акселерограммы временной анализ дает меньшие перемещения, что подтверждает консервативность спектрального метода. Выявленные различия объясняются различиями в частотном составе и длительности колебаний грунта. Полученные результаты обосновывают целесообразность совместного применения спектрального метода для рутинного проектирования и временного анализа для уточняющей проверки высотных зданий в регионах с выраженными региональными особенностями сейсмического воздействия. Дополнительно подтверждена практическая значимость инженерно-сейсмометрического мониторинга для накопления данных и совершенствования исходных воздействий.

**Ключевые слова:** высотное здание; сейсмическая реакция; максимальное расчетное землетрясение; акселерограмма; динамический расчет; перемещения.

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### **CONFLICT OF INTEREST**

The authors state that there is no conflict of interest.

During the preparation of this manuscript, the authors used artificial intelligence tools (ChatGPT) solely for editorial assistance, such as improving phrasing and checking grammar, spelling, and punctuation. All ideas, interpretations, and conclusions are the responsibility of the authors, who take full accountability for the content of the article.

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### **АЛҒЫС / ҚАРЖЫЛАНДЫРУ КӨЗІ**

Зерттеу жеке қаржыландыру көздерін пайдалана отырып жүргізілді.

### **МҮДДЕЛЕР ҚАҚТЫҒЫСЫ**

Авторлар мүдделер қақтығысы жоқ деп мәлімдейді.

Мақаланы дайындау барысында авторлар жасанды интеллект құралдарын (ChatGPT) тек редакциялық көмек мақсатында пайдаланды: тұжырымдарды жетілдіру, грамматикалық, орфографиялық және тыныс белгілеріндегі қателерді тексеру үшін. Барлық идеялар, интерпретациялар мен қорытындылар авторларға тиесілі, және олар мақаланың мазмұнына толық жауапты.

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### **БЛАГОДАРНОСТИ/ИСТОЧНИК ФИНАНСИРОВАНИЯ**

Исследование проводилось с использованием частных источников финансирования.

### **КОНФЛИКТ ИНТЕРЕСОВ**

Авторы заявляют, что конфликта интересов нет.

При подготовке рукописи авторы использовали инструменты искусственного интеллекта (ChatGPT) исключительно для редакторской поддержки: корректировки формулировок, проверки грамматических, орфографических и пунктуационных ошибок. Все идеи, интерпретации и выводы принадлежат авторам, которые несут полную ответственность за содержание статьи

## 1 INTRODUCTION

In recent decades, Almaty has experienced a significant increase in the number and height of high-rise buildings constructed in a seismically active region. This trend is driven by contemporary urban development requirements and the limited availability of free land in large metropolitan areas. Similar tendencies are observed in many major cities worldwide, where vertical expansion has become a strategic solution to urban densification.

The seismic safety of high-rise monolithic reinforced concrete buildings is therefore a critical engineering problem. The primary objective of earthquake-resistant design is to ensure acceptable levels of structural displacements, accelerations, and internal forces under maximum design earthquake (MDE) conditions. Reliable prediction of structural response is especially important for buildings exceeding 20 storeys, where higher-mode effects and dynamic interaction with ground motion become more pronounced.

In the former Soviet Union, one of the tallest buildings located in a 9-point seismic zone was the 25-storey “Kazakhstan” Hotel in Almaty. Instrumental monitoring of its dynamic behavior has been conducted for over 40 years. Observations indicate that the fundamental vibration period of the structure has changed by approximately 30% due to structural modifications and functional alterations over time. This example highlights the importance of long-term dynamic assessment and the need for accurate analytical tools.

Since 2005, both national and international construction companies have erected dozens of 20–35-storey monolithic buildings in Almaty. The evaluation of their seismic performance requires advanced analytical approaches capable of accounting for real ground motion characteristics.

Two principal methods are commonly applied in engineering practice to assess seismic response: the response spectrum method and time-history analysis based on instrumental accelerograms. While the response spectrum approach provides conservative and computationally efficient estimates of peak structural response, it does not fully capture phase relationships and frequency content variations of actual earthquakes. Conversely, time-history analysis enables detailed evaluation of structural behavior under recorded or synthetic accelerograms, including nonlinear effects and temporal characteristics of ground motion.

The present study investigates the seismic response of a 22-storey monolithic building in Almaty using instrumental acceleration records and compares the results with those obtained by the response spectrum method, aiming to assess their consistency and applicability for high-rise design in seismic regions.

## 2 LITERATURE REVIEW

Extensive research has been devoted to the modeling of seismic impacts and the assessment of structural reliability under earthquake loading. Probabilistic approaches and stochastic representations of seismic processes form the theoretical basis of modern seismic engineering (**V. Lapin, Yerzhanov, Kassenov, et al., 2022**).

A non-canonical spectral representation of random processes for simulating seismic impacts in structural calculations was proposed (**V. Lapin, Shokhbarov, et al., 2024**). The method enables efficient generation of artificial accelerograms with minimal computational effort. Further developments of this approach have been applied to reliability assessment of buildings (**V. Lapin, Yerzhanov, & Makish, 2022**) and to the evaluation of seismic risk based on passportization data (**Hare, 2019**). The probabilistic framework for seismic risk evaluation has also been discussed in earlier works (**V. Lapin, Kim, et al., 2024**).

The reliability-based perspective in seismic design has been further developed, including formulations that account for both random and bounded uncertainties in reinforced concrete structures (**Fathi-Fazl et al., 2018**). Rapid assessment methodologies for existing buildings in seismic regions have been proposed. International studies also emphasize the importance of regional seismic characteristics in risk assessment (**Liu & Wang, 2018**).

In the context of Kazakhstan, particular attention has been given to seismic performance of high-rise buildings in Almaty. The influence of the number of storeys on the seismic resistance of monolithic buildings has been investigated (Tuleyev et al., 2023). A macro-seismic assessment of residential buildings constructed during the Soviet era in Almaty has been performed, highlighting regional vulnerability patterns (Rashid et al., 2023).

Advances in ground motion modeling have contributed significantly to improving seismic input representation. The updated ground motion prediction model incorporates magnitude, source-to-site distance, fault mechanism, and local soil conditions, enabling more accurate estimation of expected ground motions (Chiou & Youngs, 2014). Regional modeling approaches and artificial accelerogram generation techniques have also been proposed (Devdas & Sengupta, 2007; Rashid et al., 2023).

Recent studies emphasize the necessity of time-history analysis when evaluating innovative seismic isolation systems (Hadjian, 1993), as realistic ground motion records are essential for assessing dynamic performance. Spectral characteristics of local earthquakes in Almaty demonstrate that distant events are typically dominated by low-frequency components, whereas near-field earthquakes exhibit high-frequency content (Huang et al., 2022). Such distinctions are crucial because flexible buildings are more vulnerable to low-frequency excitations, while stiff structures are sensitive to high-frequency ground motions (Chonratana & Chatpattananan, 2023).

Despite the significant body of research on seismic modeling and reliability assessment, comparative studies examining the response of high-rise monolithic buildings using both instrumental accelerograms and the conventional response spectrum method remain limited for the Almaty region. This gap justifies the need for the present investigation (Wang et al., 2024).

### 3 MATERIALS AND METHODS

The rapid growth of high-rise construction in large urban agglomerations makes the reliable evaluation of seismic performance of tall buildings a priority in structural engineering. In this study, instrumental earthquake acceleration records (accelerograms) are used to compute the maximum lateral displacements of a 22-storey monolithic reinforced concrete building in Almaty, Kazakhstan, and to compare these results with those obtained using the conventional response spectrum method. The comparison is intended to assess the consistency and practical applicability of both approaches for high-rise design in a high-hazard seismic region (Dzhinchvelashvili et al., 2018).

Although each earthquake is characterized by unique amplitude-frequency content and duration, the use of recorded or scenario-based accelerograms for structural analysis is widely adopted in international practice. Modern research emphasizes that time-history analysis based on instrumental records can capture essential features of ground motion (phase relations, frequency content, and nonstationary behavior) that may not be fully represented by spectrum-based procedures (V. A. Lapin et al., 2020). Probabilistic and stochastic approaches to seismic input representation are also increasingly applied in risk and reliability frameworks (Dostanova et al., 2025).

Design accelerograms should reflect the seismic features that are most critical for the investigated structural system, including the expected intensity, frequency content, and duration of ground motion. In practice, several approaches are commonly used to define input accelerograms:

1. selection of real records from global databases based on magnitude, source distance, focal depth, fault mechanism, and site conditions;
2. generation of synthetic accelerograms from generalized parameters of the source and site response;
3. transformation (re-targeting) of a real strong-motion record from the recording site to the construction site;
4. stochastic nonstationary random-process representations;
5. stationary process representations;
6. delta-correlated and Markov process models;
7. series of uncorrelated impulses.

Efficient methods for artificial accelerogram generation and seismic input modeling, including non-canonical representations of random processes, have been proposed and validated for engineering applications (Yerzhanov & Lapin, 2021). Such approaches have been further used in reliability calculations and seismic risk assessment based on building passportization results (Zhamek et al., 2025).

For the present study, the chosen strategy corresponds to the use of instrumental records applicable to Almaty conditions, supported by the availability of a broad set of strong-motion records (including local events). This choice is also consistent with the importance of regional ground-motion features: near-field earthquakes tend to contain higher-frequency components, while distant events are often dominated by lower-frequency content, which can differently affect stiff versus flexible structures (Tsiavos et al., 2020).

The dataset includes three-component accelerograms with magnitudes approximately  $M = 6.3$ – $7.4$  and hypocentral distances  $R = 19$ – $89$  km. Accelerograms are applied without preliminary normalization, since such procedures can distort the frequency spectrum of motion and may bias the response comparison, especially for high-rise systems sensitive to spectral content (Lapin et al., 2024). The mean amplitude of the horizontal components is  $432.24 \text{ cm/s}^2$  with a standard deviation of  $247.08 \text{ cm/s}^2$ , corresponding to high seismic intensity (approximately 9 points by local intensity scales). The selected three-component accelerograms used in the numerical analyses are summarized in Table 1.

**Table 1**  
Selected Three-Component Earthquake Accelerograms Used in the Analysis

Record Group	Record ID	Earthquake (Date, Source Parameters)	PGA (cm/s <sup>2</sup> )	Component	Units	Time Step (s)	Scale Factor
1	Aks.24	Kern County, 21.07.1952; R = 41 km; M = 7.2	152.7	X	mm/s <sup>2</sup>	0.02	1.0
	Aks.25	Kern County, 21.07.1952; R = 41 km; M = 7.2	175.9	Y	mm/s <sup>2</sup>	0.02	1.0
	Aks.26	Kern County, 21.07.1952; R = 41 km; M = 7.2	102.9	Z	mm/s <sup>2</sup>	0.02	1.0
2	Aks.7	El Centro, 18.05.1940; R = 31 km; M = 6.5	341.7	S00E	mm/s <sup>2</sup>	0.02	1.0
	Aks.8	El Centro, 18.05.1940; R = 31 km; M = 6.5	210.1	S90W	mm/s <sup>2</sup>	0.02	1.0
	Aks.9	El Centro, 18.05.1940; R = 31 km; M = 6.5	206.3	Z	mm/s <sup>2</sup>	0.02	1.0
3	Aks.190	Baysorun, 12.11.1990; D = 35 km; H = 20 km; M = 6.3	699.2	N–S	cm/s <sup>2</sup>	0.008	1.0
	Aks.191	Baysorun, 12.11.1990; D = 35 km; H = 20 km; M = 6.3	437.0	E–W	cm/s <sup>2</sup>	0.008	1.0
	Aks.200	Baysorun, 12.11.1990; D = 35 km; H = 20 km; M = 6.3	665.98	Z	cm/s <sup>2</sup>	0.008	1.0
4	Aks.201	Artificial record; M = 7.4	460.15	OX	cm/s <sup>2</sup>	0.0064	1.0
	Aks.202	Artificial record; M = 7.4	674.91	OY	cm/s <sup>2</sup>	0.0064	1.0
	Aks.203	Artificial record; M = 7.4	438.21	Z	cm/s <sup>2</sup>	0.0064	1.0

Seismic analyses were performed using the LIRA-SAPR 2024 structural analysis software package, utilizing the implemented Module 29 for time-history analysis with accelerogram input. The structural model was developed using standard modeling rules adopted in LIRA-SAPR, consistent with dynamic analysis practice.

For time-history computations, the following key parameters were specified:

- Damping ratio ( $\xi$ ): 0.05 (5% of critical), adopted for reinforced concrete structures;
- Scale factor for the accelerogram (used to convert input units to  $m/s^2$  and, when required, to scale the acceleration amplitudes);
- Time step and duration were taken directly from each record based on its digitization parameters;
- Direction cosines were not applied; horizontal components were assigned along the principal structural axes.

If the digitized record is provided in units other than  $m/s^2$  (e.g.,  $mm/s^2$  or  $a/g$ ), the scale factor is applied to ensure consistent units. The same scaling option may be used when a record is provided in normalized form.

The studied building is located on a site with seismicity intensity of 9 points. The site soil category according to local seismic properties corresponds to Category I. No site conditions complicating seismic or engineering-geological behavior were identified (Moldamuratov et al., 2025).

The building has three underground storeys, one semi-basement level, 21 above-ground residential storeys, and a top technical storey. The plan has a Y-shaped configuration and is separated from adjacent structures by seismic gaps. The design height from the top of the foundation slab to the top of the monolithic roof structure is approximately 85.7 m. Structurally, the building represents a spatial frame-wall (dual) system, typical for monolithic reinforced concrete high-rise construction.

General views and plan fragments of the building are presented in Figures 1–2.

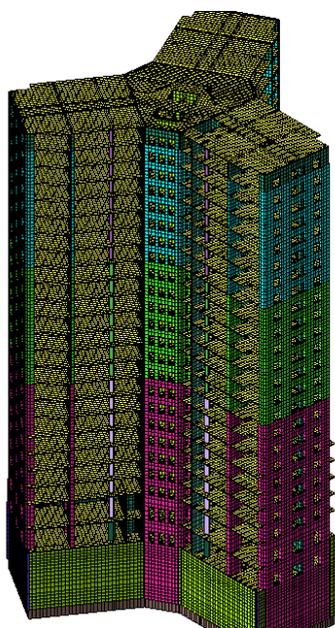


Figure 1 – General view of the building (author’s material)

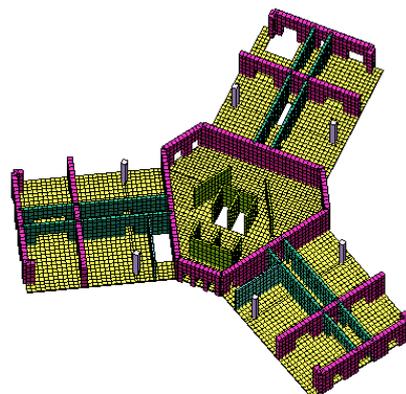


Figure 2 – Fragment of the building plan (author’s material)

Time-history analyses employed three-component (North–South, East–West, and vertical Z) accelerograms corresponding to the selected set of earthquakes (including historical and local records, as well as an artificial/synthetic record). The study uses representative records such as Kern County (1952), El Centro (1940), Baysorun (1990) and an artificial record (Table 1). Sample plots of selected horizontal components (e.g., Aks.7, Aks.24, Aks.190) are shown in Figures 3–5.

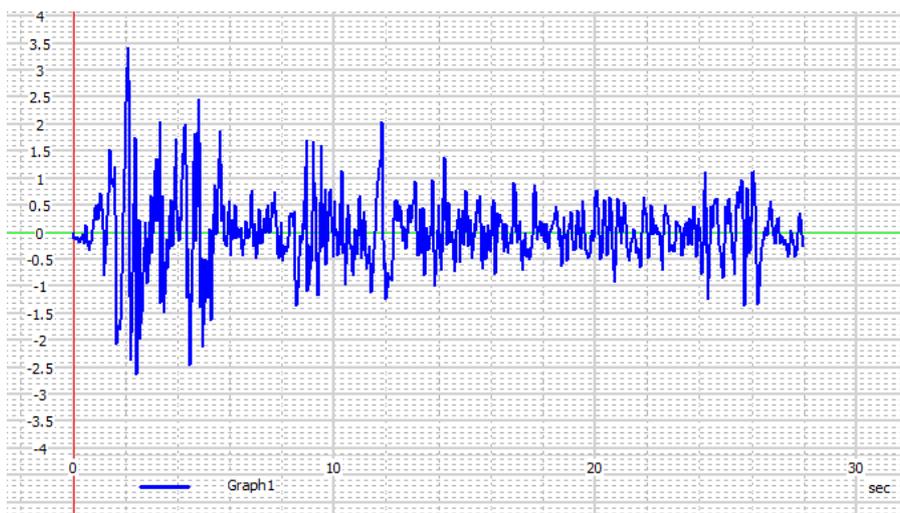


Figure 3 - Horizontal component (X-direction) of the El Centro earthquake accelerogram (18 May 1940;  $M = 6.5$ ;  $R = 31$  km), record Aks.7 (author's material)

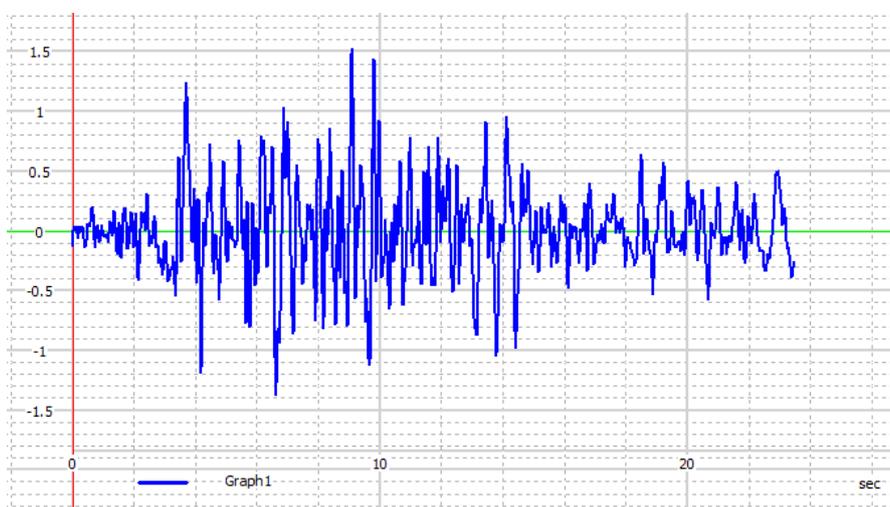


Figure 4 – Horizontal acceleration time history (X-component) of the Kern County earthquake (21 July 1952;  $M = 7.2$ ;  $R = 41$  km), accelerogram Aks.24 (author's material)

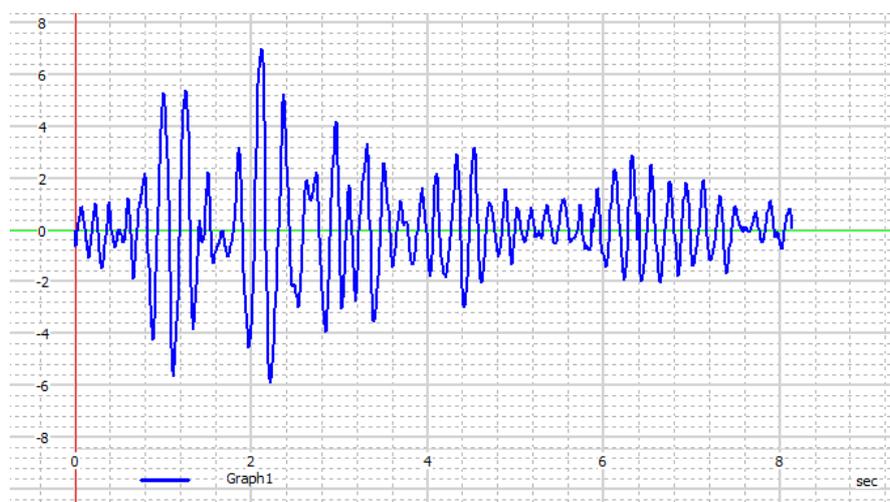
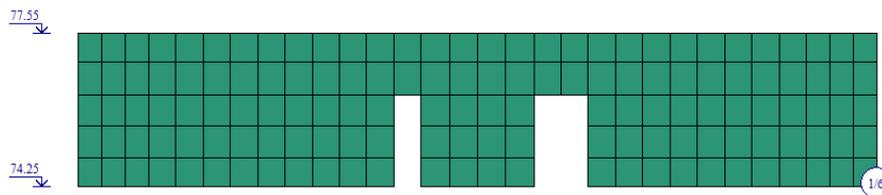


Figure 5 - Horizontal acceleration time history (X-component) of the Baysorun earthquake (12 November 1990;  $M = 6.3$ ;  $D = 35$  km;  $H = 20$  km), accelerogram Aks.190 (author's material)

#### 4 RESULTS AND DISCUSSION

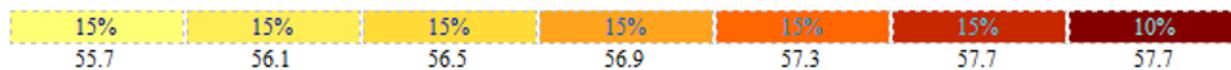
For the comparative assessment of structural response, a reinforced concrete wall located along axis 1/B at elevation 74.25 m was selected as a representative structural element (**Figure 6**). This level corresponds to the upper part of the building, where dynamic effects and higher-mode contributions become significant in high-rise systems.



**Figure 6** – Reinforced concrete wall along Axis 1/B at elevation 74.25 m (author’s material)

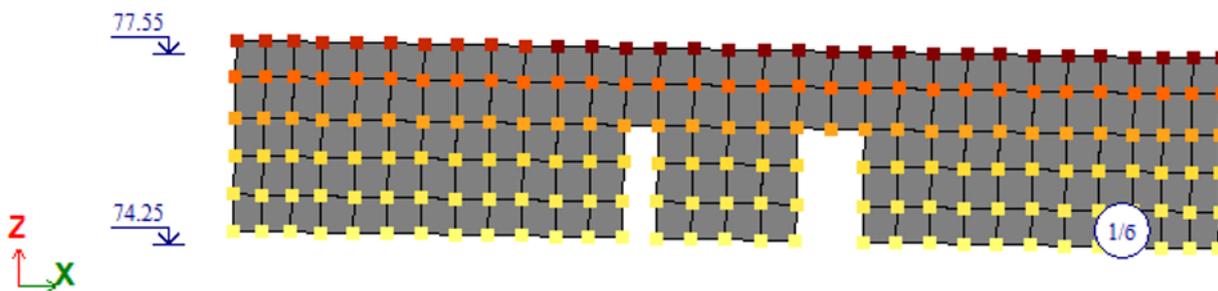
Two independent analyses were performed using the LIRA-SAPR software package (Module 29 for time-history analysis and the standard dynamic module for response spectrum analysis). The response spectrum analysis was carried out in accordance with national seismic design provisions (SNIIP), while the time-history analysis employed the selected sets of instrumental accelerograms with a scale factor equal to 1.0.

Maximum horizontal displacements of the wall along the X and Y directions obtained using the response spectrum method are shown in **Figures 7 and 8**. Corresponding displacement contour plot obtained using instrumental accelerograms (e.g., Aks.7 and Aks.8) are presented in **Figures 9 and 10**.



7 Seismic Case 1  
 Component 3  
 Displacement Contours in X(G)  
 Units: mm

Masses collected from load cases: 1, 2, 3, 4, 5, 6



**Figure 7** – Displacement contour plot in the X-direction obtained using the response spectrum method (author’s material)

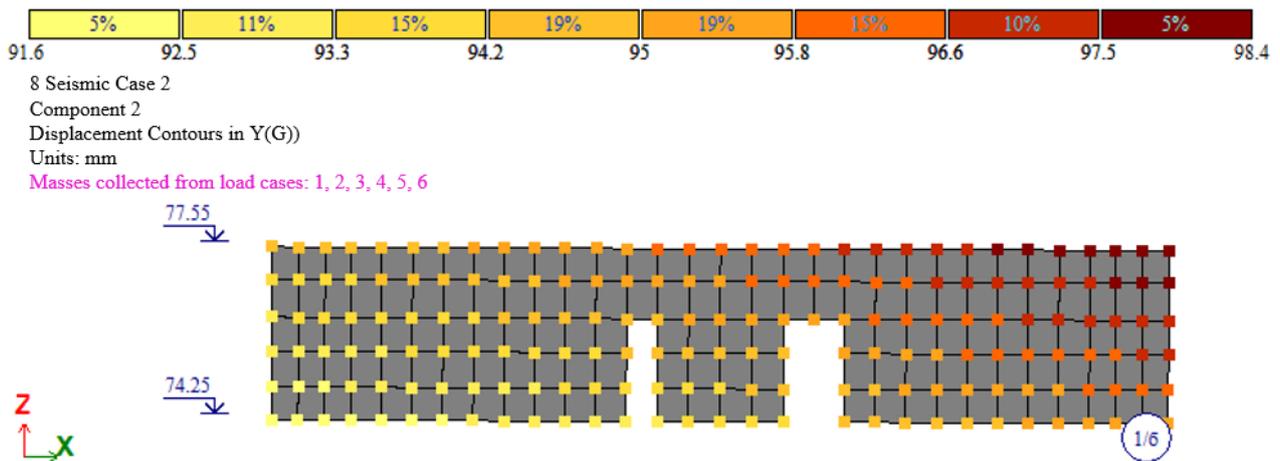


Figure 8 – Displacement contour plot in the Y-direction obtained using the response spectrum method (author’s material)

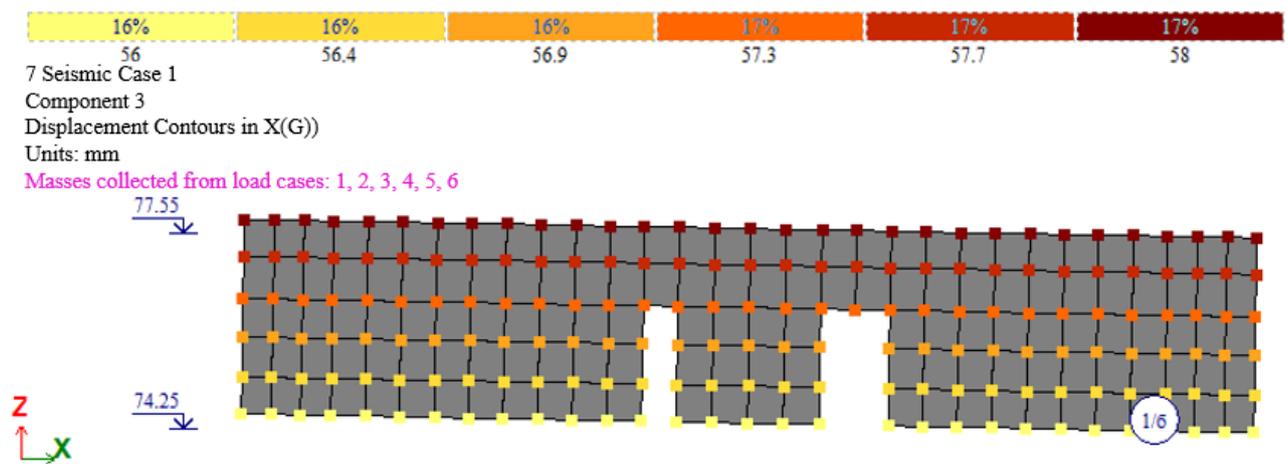


Figure 9 – Displacement contour plot in the X-direction obtained using instrumental accelerogram Aks.7 (time-history analysis) (author’s material)

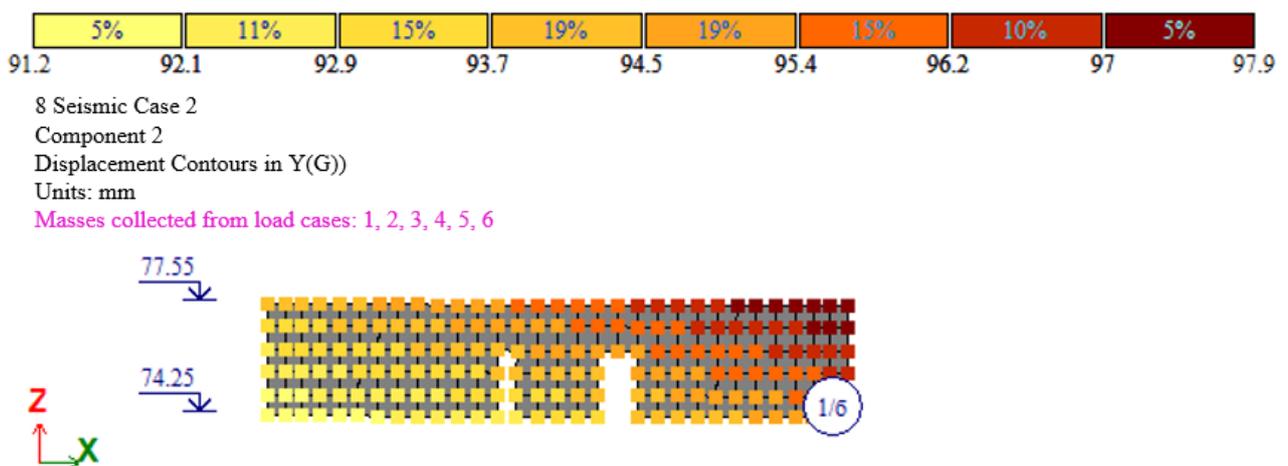


Figure 10 – Displacement contour plot in the Y-direction obtained using instrumental accelerogram Aks.8 (time-history analysis) (author’s material)

**Table 2** summarizes the maximum nodal displacements of the selected wall for both calculation approaches.

**Table 2**  
Comparative analysis of wall displacements (Axis 1/B, elevation 74.25 m)

Earthquake / Record	Node ID	Response Spectrum (mm)		Time-History (Module 29) (mm)	
		X	Y	X	Y
Kern County (1952), M = 7.2 (Aks.24–26)	184573	57.71	98.30	11.43	19.15
	179756	56.89	97.29	11.27	18.95
	178057	55.69	95.75	11.03	18.65
El Centro (1940), M = 6.5 (Aks.7–9)	184573	57.71	98.30	58.08	97.84
	179756	56.89	97.29	57.25	96.83
	178057	55.69	95.75	56.04	95.29
Baysorun (1990), M = 6.3 (Aks.190–200)	184573	57.71	98.30	20.46	33.42
	179756	56.89	97.29	20.17	33.08
	178057	55.69	95.75	19.74	32.55
Artificial record, M = 7.4 (Aks.201–203)	184573	57.71	98.30	18.11	34.78
	179756	56.89	97.29	17.85	34.42
	178057	55.69	95.75	17.48	33.88

**Note:** Vertical (Z-direction) displacements are not included, since the primary seismic analysis for the 22-storey building considered horizontal seismic actions along the X and Y axes.

The results demonstrate a substantial variation in maximum displacements depending on the applied calculation method and the specific accelerogram used.

For the Kern County, Baysorun, and artificial records, the displacements obtained from time-history analysis are significantly lower than those predicted by the response spectrum method. This indicates the conservative nature of the spectrum-based approach, which is consistent with established reliability-oriented design philosophy.

In contrast, the El Centro record produces displacement values that are nearly identical to those obtained using the response spectrum method. This suggests that the frequency content and amplitude characteristics of the El Centro accelerogram are well aligned with the design spectrum adopted in the normative method.

These observations confirm that the structural response of high-rise monolithic systems is highly sensitive to the spectral composition and duration of ground motion. As shown in previous studies, near-field events with specific frequency characteristics may lead to amplification effects not fully captured by simplified spectral representations.

From an engineering perspective, these findings emphasize that reliance on a single calculation approach may not fully reflect the possible range of structural response under different seismic scenarios. While the response spectrum method ensures normative safety margins, it may not always represent record-specific dynamic effects associated with real ground motions. Conversely, time-history analysis provides a more detailed insight into structural behavior, especially for upper-storey elements where higher-mode contributions become significant. Therefore, integrated application of both methods improves the robustness and reliability of seismic performance assessment for high-rise monolithic buildings.

The comparison highlights two important conclusions:

1. The response spectrum method provides stable and conservative displacement estimates suitable for routine design practice.

2. Time-history analysis using instrumental accelerograms enables more realistic assessment of structural behavior and allows identification of record-dependent effects.

For high-rise buildings located in seismically active regions such as Almaty, the combined use of both approaches is recommended, especially for structures of increased responsibility or when advanced seismic protection systems are implemented.

## **5 CONCLUSIONS**

Based on the performed comparative analysis of the horizontal displacements of the load-bearing reinforced concrete wall (Axis 1/B, elevation 74.25 m) of the 22-storey monolithic building, the following conclusions were drawn:

1. A high level of agreement was identified between the response spectrum method and the time-history analysis based on instrumental accelerograms in predicting maximum horizontal displacements.
2. The El Centro earthquake record (18 May 1940;  $M = 6.5$ ) produced displacement values that were practically identical to those obtained using the response spectrum method, indicating consistency between the spectral characteristics of this record and the adopted design spectrum.
3. For the Kern County (1952), Baysorun (1990), and artificial accelerograms, the maximum displacements obtained from time-history analysis were lower than those predicted by the response spectrum method, confirming the conservative nature of the spectral approach commonly used in engineering practice.
4. The observed differences between the two calculation methods are primarily attributed to variations in the frequency content of ground motion during different earthquakes, demonstrating the sensitivity of high-rise monolithic structures to spectral characteristics of seismic excitation.
5. The absence of displacement exceedances relative to the design spectral values indicates that the investigated building satisfies seismic performance requirements under the considered ground-motion scenarios.
6. Direct dynamic analysis using carefully selected instrumental accelerograms is a valuable tool for predicting structural behavior under realistic earthquake conditions and enhances the reliability of seismic performance assessment for high-rise buildings located in high-hazard regions.
7. The installation of engineering seismometric monitoring stations on high-rise buildings is recommended to accumulate real structural response data, refine regional ground-motion models, and use basement-level instrumental records as representative input for future structural analyses.

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