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RESEARCH, INNOVATION, RESULTS



**TOSHKENT DAVLAT  
TRANSPORT UNIVERSITETI**

Tashkent state  
transport university



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## Dynamic analysis of three-layer pendulum-type fluoroplastic seismic insulated buildings

Kh.L. Alimov<sup>1</sup>, A.Sh. Martazaev<sup>1</sup>, F.I. Azizova<sup>1</sup>, M.G. Umarov<sup>1</sup>

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Abstract:

This article studies the dynamic properties of reinforced concrete buildings with three-layer pendulum-type fluoroplastic seismic isolators. As part of the study, a 6-story frame building model was modeled in the ETABS program, and a comparative analysis was performed for the cases of single-base and seismic isolation. The real Santa Monica accelerogram was used as the seismic load. According to the modeling results, when isolation was used, the first-order vibration period of the building increased from 0.63 s to 1.20 s. It was found that the shear forces in the foundation decreased from 17564 kN to 4328 kN in the X direction (approximately 75%), and significantly decreased in the Y direction. It was also observed that inter-storey displacements decreased, and the main deformations were concentrated at the foundation level. Acceleration values also decreased significantly, confirming the increase in the dynamic stability of the building structure. The results obtained show that three-layer pendulum-type seismic isolators are highly effective in effectively absorbing earthquake energy and increasing the seismic safety of buildings. This article analyzes the theoretical load-bearing capacity of fiber-reinforced concrete beams by dispersing reinforcement with 40 mm long glass fibers into the concrete composition. Theoretical calculations have shown that the maximum load-bearing capacity of the beam increases significantly when the fiber content is in the range of 0.1÷0.5%. The highest efficiency was observed in fiber-reinforced concrete beams with 0.2% glass fibers. The results obtained are consistent with the existing scientific literature and theoretically confirm the effectiveness of dispersed reinforcement. This work serves to increase structural efficiency, determine the optimal fiber content, and analyze the load-bearing properties of fiber-reinforced concrete beams with glass fibers. By comparing theoretical results with experimental tests, the effectiveness of future research can be increased.

Keywords:

fluoroplastic, seismic action, dynamic analysis, shear force, acceleration, interlayer displacement, vibration period

## Uch qatlamli mayatnik turidagi ftoroplastik seysmik izolyatsiyali binolarning dinamik tahlili

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Annotatsiya:

Ushbu maqolada uch qatlamli mayatnik turidagi ftoroplastik seysmik izolyatorlar qo'llanilgan temir-beton binolarning dinamik xususiyatlari o'rganildi. Tadqiqot doirasida 6 qavatli karkasli bino modeli ETABS dasturida modellashtirilib, birk asosli va seysmik izolyatsiyalangan holatlar uchun qiyosiy tahlil amalga oshirildi. Seysmik yuklama sifatida real Santa Monica akselerogrammasi qo'llanildi. Modellashtirish natijalariga ko'ra, izolyatsiya qo'llanilganda binoning birinchi tartibli tebranish davri 0.63 s dan 1.20 s gacha oshdi. Asosdagi qirquvchi kuchlar X yo'nalishida 17564 kN dan 4328 kN gacha (taxminan 75%), Y yo'nalishida esa sezilarli darajada kamaygani aniqlandi. Shuningdek, qavatlararo siljishlar kamayib, asosiy deformatsiyalar poydevor sathida jamlanganligi kuzatildi. Tezlanish qiymatlari ham sezilarli darajada pasayib, bino konstruksiyasining dinamik barqarorligi oshgani tasdiqlandi. Olingan natijalar uch qatlamli mayatnik tipidagi seysmik izolyatorlarning zilzila energiyasini samarali so'ndirish va binoning seysmik xavfsizligini oshirishda yuqori samaradorlikka ega ekanligini ko'rsatadi. Ushbu maqolada uzunligi 40 mm bo'lgan shisha tolalarni bilan beton tarkibiga dispers armaturalash orqali fibrotmirbeton to'sinlarning nazariy yuk ko'tarish qobiliyati tahlil qilindi. Nazariy hisob ishlari shuni ko'rsatdiki, tolalar miqdori 0.1÷0.5% oralig'ida bo'lganda to'sinning maksimal yuk ko'tarish qobiliyati sezilarli darajada oshadi. Eng yuqori samaradorlik 0.2% shisha tolali fibrotmirbeton to'sinlarda kuzatildi. Olingan natijalar mavjud ilmiy adabiyotlar bilan mos kelib, dispers armaturalashning samaradorligini nazariy jihatdan tasdiqlaydi. Ushbu ish konstruktiv samaradorlikni oshirish, optimal tolalar miqdorini aniqlash va shisha tolali fibrobeton to'sinlarning yuk ko'tarish xususiyatlarini tahlil qilishga xizmat qiladi. Nazariy natijalarni eksperimental sinovlar bilan taqqoslash orqali kelgusidagi tadqiqotlar samaradorligini oshirish mumkin.

Kalit so'zlar:

ftoroplast, seysmik ta'sir, dinamik tahlil, qirquvchi kuch, tezlanish, qavatlararo ko'chish, tebranish davri

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## 1. Kirish

So'nggi yillarda seysmik faol hududlarda joylashgan binolarning zilzilabardoshligini oshirish dolzarb ilmiy-amaliy muammolardan biri bo'lib qolmoqda. Kuchli seysmik ta'sirlar natijasida yuzaga keladigan dinamik yuklamalar bino konstruksiyalarida katta siljishlar, ortiqcha ichki kuchlar va hatto konstruktiv buzilishlarga olib kelishi mumkin. Shu sababli zamonaviy qurilish amaliyotida an'anaviy "Bikrlikni oshirish orqali qarshilik ko'rsatish" yondashuvidan voz kechib, energiyani so'ndirish tamoyiliga asoslangan seysmik himoya tizimlariga o'tish tendensiyasi kuchaymoqda [1].

Seysmik izolyatsiya tizimlari bino va poydevor orasida elastik yoki ishqalanishli qatlam hosil qilib, zilzila energiyasining yuqori qismga uzatilishini kamaytiradi. Natijada konstruksiyaning asosiy tebranish davri uzayadi, rezonans xavfi pasayadi va inersiya kuchlari sezilarli darajada kamayadi. Bu esa bino elementlarining ekspluatatsion holatini saqlab qolishga xizmat qiladi. Hozirgi kunda turli turdagi seysmik izolyatorlar, jumladan elastomer tayanchlar, qo'rg'oshin rezinali podshipniklar va ishqalanishli mayatnik tizimlari keng qo'llanilmoqda. Xususan, ishqalanishli mayatnik tipidagi izolyatorlar o'zining energiya so'ndirish qobiliyati va qayta markazlashuv xususiyati bilan alohida ahamiyat kasb etadi. Bu yo'nalishda James M. Kelly [2] tomonidan elastomer asosidagi izolyatsiya tizimlari, Roberto Villaverde [3] tomonidan esa izolyatsiyalangan binolarning dinamik javobi chuqur o'rganilgan. Shuningdek, Anil K. Chopra [4] binolar dinamikasi va seysmik hisoblash usullarini rivojlantirishga katta hissa qo'shgan.

So'nggi yillarda uch qatlamli mayatnik tipidagi ftoroplastik seysmik izolyatorlar (Triple Friction Pendulum System) murakkab seysmik sharoitlarda yuqori samaradorlik ko'rsatishi bilan ilmiy tadqiqotlarning diqqat markaziga aylangan [5]. Ushbu tizimlar turli intensivlikdagi zilzilalarda o'z ish rejimini o'zgartirib, energiyani bosqichma-bosqich so'ndirish imkoniyatiga ega [6].

Shu nuqtai nazardan, mazkur tadqiqotning asosiy maqsadi uch qatlamli mayatnik turidagi ftoroplastik seysmik izolyatorlar qo'llanilgan temir-beton binolarning dinamik xatti-harakatini modellashtirish va ularning seysmik samaradorligini bikr asosli model bilan qiyosiy tahlil qilishdan iboratdir [7]. Tadqiqot jarayonida ETABS dasturidan foydalanilib, real seysmik akselerogramma asosida vaqt bo'yicha dinamik tahlil amalga oshirildi. Olingan natijalar seysmik izolyatsiya tizimlarining binoning asosiy dinamik parametrlariga, jumladan tebranish davri, qirquvchi kuchlar, tezlanishlar va qavatlararo siljishlarga sezilarli ijobiy ta'sir ko'rsatishini tasdiqlaydi.

## 2. Tadqiqot metodologiyasi

Tadqiqot doirasida 6 qavatli temir-beton karkasli turar-joy binosining fazoviy hisobiy modeli ishlab chiqildi. Modelni yaratish va uning dinamik xususiyatlarini tahlil qilish ishlari zamonaviy muhandislik hisoblashlariga mo'ljallangan ETABS dasturiy majmuasida amalga oshirildi. Loyihalash jarayonida bino 9 balli seysmik hudud sharoitlariga (MSK-64 shkalasi bo'yicha) mos ravishda qabul qilinib, amaldagi me'yoriy talablar asosida konstruktiv yechimlar shakllantirildi. Binoning yuk ko'taruvchi konstruksiyasi temir-beton karkas sifatida qabul qilinib, u ustunlar, to'sinlar va qavatlararo plitalardan iborat

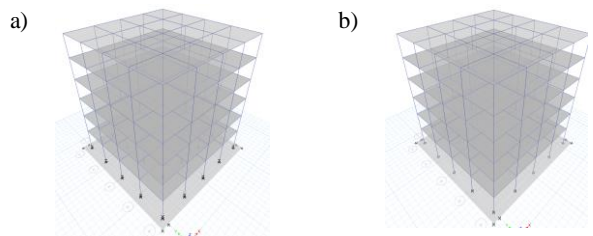
fazoviy rama ko'rinishida modellashtirildi. Ustunlar va to'sinlar chiziqli elastik xususiyatlariga ega elementlar sifatida qabul qilindi, qavatlararo plitalar esa gorizontaal yuklarni taqsimlashni ta'minlovchi bikr diafragma (rigid diaphragm) sifatida hisobga olindi. Konstruksiyada B25 sinfli beton va AIII sinfli armatura qo'llanildi, bu esa bino mustahkamligi va ekspluatatsion ishonchligini ta'minlashga xizmat qildi.

Seysmik himoya tizimi sifatida bino poydevori darajasida uch qatlamli mayatnik turidagi ftoroplastik ishqalanishli seysmik izolyatorlar o'rnatildi. Ushbu izolyatorlar nolinear xususiyatlariga ega bo'lgan bog'lovchi (link) elementlar sifatida modellashtirilib, zilzila vaqtida energiyani so'ndirish hamda bino va poydevor orasida nazorat qilinadigan nisbiy siljishni ta'minlash vazifasini bajaradi. Tadqiqotda seysmik yuklama sifatida real Santa Monica zilzilasi akselerogrammasi qo'llanildi. Ushbu seysmik hodisa yuqori intensivlikka ega bo'lib, MSK-64 shkalasi bo'yicha IX ballga teng deb baholangan. Dinamik tahlil vaqt bo'yicha o'zgaruvchi yuklama (time-history analysis) usulida bajarildi, bu esa binoni real seysmik ta'sir ostida baholash imkonini berdi.

Hisoblash jarayonida modal tahlil orqali binoning xususiy tebranish shakllari va davrlari aniqlandi, shuningdek, nolinear vaqt bo'yicha dinamik tahlil asosiy natijaviy bosqich sifatida amalga oshirildi. Energiya so'nishi Rayleigh damping modeli orqali hisobga olindi, umumiy so'nish nisbati 5% etib qabul qilindi. Vaqt integratsiyasi Newmark usuli asosida bajarildi.

Tadqiqot ikki xil konstruktiv holatda amalga oshirildi: birinchisi - bikr asosli (fixed base) model, ikkinchisi - seysmik izolyatsiya qo'llanilgan model. Har ikkala holatda ham binoning dinamik javobi, jumladan qirquvchi kuchlar, siljishlar, tezlanishlar va tebranish davrlari solishtirma tahlil asosida baholandi.

Seysmik izolyatsiya qo'llanilgan hamda izolyatsiya qo'llanilmagan binolarning hisobiy modellarining umumiy ko'rinishi 1-rasmda keltirilgan.



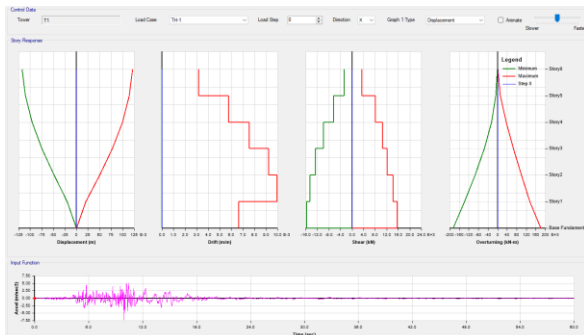
**1-rasm. Binoning hisobiy modellarining umumiy ko'rinishi: (a) seysmik izolyatsiya qo'llanilgan model; (b) izolyatsiya qo'llanilmagan (bikr mahkamlangan) model.**

## 3. Natija va muhokamalar

O'tkazilgan modal tahlil natijalariga ko'ra, seysmik izolyatsiya qo'llanilishi binoning dinamik xususiyatlariga sezilarli ta'sir ko'rsatdi. Bikr asosli modelda birinchi tartibli xususiy tebranish davri 0.63 s ni tashkil etgan bo'lsa, seysmik izolyatsiya qo'llanilgan holatda ushbu qiymat 1.20 s gacha oshdi. Bu holat tebranish davrining deyarli 90% ga uzayganini ko'rsatadi. Tebranish davrining ortishi binoning past chastotali tizimga aylanishiga olib keladi, natijada

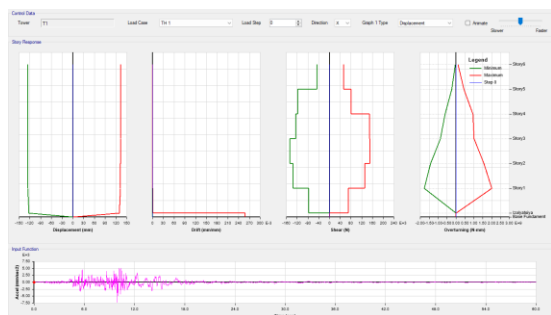


zilzila spektri bilan rezonans ehtimoli kamayadi va inersiya kuchlari sezilarli darajada pasayadi. Bu esa seysmik izolyatsiya tizimining asosiy funksional samaradorligini tasdiqlaydi. Santa Monica akselerogrammasi ta'sirida biki mahkamlangan (2-rasm) va seysmik himoya qilingan (3-rasm) binolar uchun ko'chish, qavatlararo nisbiy siljish (drift), qirquvchi kuch va ag'daruvchi momentning vaqt bo'yicha o'zgarish qonuniyatlarini tahlil qilindi.



**2-rasm. Santa Monica akselerogrammasi ta'sirida biki mahkamlangan bino uchun ko'chish, qavatlararo nisbiy siljish (drift), qirquvchi kuch va ag'daruvchi momentning vaqt bo'yicha o'zgarish qonuniyatlarini ko'rinishi**

Biki asosli va izolyatsiyalangan modellar o'rtasida qirquvchi kuchlar sezilarli farq bo'yicha aniqlandi. X yo'nalishi bo'yicha biki asosli modelda asosdagi maksimal qirquvchi kuch 17564 kN ni tashkil etgan bo'lsa, izolyatsiya qo'llanilgandan so'ng bu qiymat 4328 kN gacha kamaydi, ya'ni taxminan 75% pasayish kuzatildi. Y yo'nalishi bo'yicha esa qirquvchi kuch 29691 kN dan 13469 kN gacha kamaydi, bu esa 50% dan ortiq pasayishni anglatadi. Ushbu natijalar seysmik izolyatsiya tizimi zilzila energiyasining katta qismini poydevor sathida so'ndirishini ko'rsatadi.



**3-rasm. Santa Monica akselerogrammasi ta'sirida seysmik izolyatsiya qo'llanilgan bino uchun ko'chish, qavatlararo nisbiy siljish (drift), qirquvchi kuch va ag'daruvchi momentning vaqt bo'yicha o'zgarish qonuniyatlarini ko'rinishi**

Qavatlararo siljishlar tahlili shuni ko'rsatdiki, biki asosli modelda siljishlar bino balandligi bo'yablab ortib boradi va eng yuqori qiymat yuqori qavatlarida kuzatiladi. Maksimal siljish 121.13 mm ga yetgan. Seysmik izolyatsiya qo'llanilgan modelda esa siljishlar qavatlar bo'yicha deyarli bir xil taqsimlangan bo'lib, asosiy deformatsiya izolyatsiya qatlamida jamlangan. Bu holat bino karkasining nisbatan "biki jism" sifatida harakatlanishini ta'minlaydi va ustki konstruksiyalarda ortiqcha deformatsiyalarni kamaytiradi.

Dinamik tahlil natijalari seysmik izolyatsiya qo'llanilishi binoning tezlanish javobini sezilarli darajada

kamaytirishini ko'rsatdi. X yo'nalishda biki asosli modelda maksimal tezlanish  $+22.40 \text{ m/s}^2$ , minimal esa  $-12.55 \text{ m/s}^2$  ni tashkil etgan bo'lsa, izolyatsiyalangan modelda bu ko'rsatkichlar mos ravishda  $+7.27 \text{ m/s}^2$  va  $-5.26 \text{ m/s}^2$  gacha kamaydi. Y yo'nalishda esa maksimal tezlanish  $+29.48 \text{ m/s}^2$  dan  $+17.66 \text{ m/s}^2$  gacha, minimal qiymat esa  $-37.40 \text{ m/s}^2$  dan  $-14.76 \text{ m/s}^2$  gacha pasaydi. Bu natijalar inersiya kuchlarining sezilarli kamayishini va konstruksiya ichki zo'riqlarining pasayishini tasdiqlaydi.

## 4. Xulosa

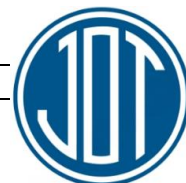
1. Olingan natijalar shuni ko'rsatdiki, uch qatlamli mayatnik turidagi ftoroplastik seysmik izolyatorlar bino dinamik reaksiyasini sezilarli darajada yaxshilaydi. Tebranish davrining uzayishi, qirquvchi kuchlarning kamayishi hamda tezlanishlarning pasayishi seysmik energiyaning asosiy qismining poydevor darajasida so'ndirilishini tasdiqlaydi.

2. Natijalar James M. Kelly va Anil K. Chopra tomonidan ilgari surilgan seysmik izolyatsiya nazariyalari bilan mos keladi. Xususan, energiyani ajratish va tebranish davrini uzaytirish orqali konstruktiv xavfsizlikni oshirish konsepsiyasi ushbu tadqiqot natijalari bilan tasdiqlandi.

3. Uch qatlamli mayatnik tizimining afzalligi shundaki, u turli intensivlikdagi zilzilalarda bosqichma-bosqich ishlash xususiyatiga ega bo'lib, bu uning chiziqsiz dinamik sharoitlarda ham samaradorligini saqlab qolishini ta'minlaydi.

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