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Kandilli Observatory and Earthquake Research Institute
Earthquake Engineering Department

DYNAMIC SEISMIC PERFORMANCE TESTS FOR THE GLASS CLADDING SYSTEM OF OKMEYDANI AND GOZTEPE TRAINING AND RESEARCH HOSPITALS in ISTANBUL

for

NUR Aluminum
Istanbul -TURKEY

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SUMMARY

This report presents the results of the shake table tests that were performed to investigate the dynamic seismic performance of the glass cladding system for **the Okmeydani and Goztepe Training and Research Hospitals in Istanbul.**

The tests were done at the Shake Table Laboratory of the Earthquake Engineering Department of Kandilli Observatory and Earthquake Research Institute (KOERI) of Boğaziçi University in Istanbul, Turkey.

The tests were carried out in accordance with the American Architectural Manufacturers Association Standard AAMA 501.6-01 – *Recommended dynamic test method for determining the seismic drift causing glass fallout from a wall system.* The testing procedure of AAMA 501.6-01 is known as the "Crescendo Tests" and involves subjecting the specimen to displacements composed of concatenated sinusoids at different frequencies, where each sinusoid includes a ramp-up and a constant-amplitude region. The boundary conditions of the test specimen were designed to represent those of the actual cladding system, which allows rigid body rotations and rocking motions in the plane of the test specimen. Based on the drift limit given in seismic design codes for multi-story buildings, the performance criteria for the cladding modules were set as no damage or glass fallout for a relative deformation of 75mm between the top and the bottom of the panel (i.e. 1% drift).

Three 2.43 m x 6.50 m glass cladding specimens with partial upper panel attached to check the panel connections were tested. The tests were stopped when the input displacement amplitudes reached to 100 mm. Although this value is much larger than the specified drift limit, no damage to the panels was observed. In all the tests, the panels were able to rock and rotate as a rigid body in the vertical plane as envisioned by the design.

Based on the specified displacement and performance criteria, all three specimens for **the Okmeydani and Goztepe Training and Research Hospitals in Istanbul** have successfully "passed" the tests.

ÖZET

Bu rapor, İstanbul'da inşa edilen "Okmeydani ve Göztepe Eğitim ve Araştırma Hastaneleri Projesi" dış cephe kaplama sisteminin dinamik sismik performansını belirlemek amacıyla yapılan sarsma masası deneylerinin sonuçlarını içermektedir. Sarsma masası deneyleri, Boğaziçi Üniversitesi, Kandilli Rasathanesi ve Deprem Araştırma Enstitüsü, Deprem Mühendisliği Anabilim Dalı'nda bulunan Sarsma Masası Laboratuarı'nda gerçekleştirilmiştir.

Sismik performans testleri, Amerikan Mimari Üretim Birliği (American Architectural Manufacturers Association) tarafından oluşturulan AAMA 501.6-01- *Recommended dynamic test method for determining the seismic drift causing glass fallout from a wall system)* Standartı'nda öngörülen kriterlere göre gerçekleştirilmiştir.

AAMA501.6-01 Standartında, "Crescendo" Deneyleri olarak bilinen deneylerde belirtilen test prosedürü kullanılmıştır. Bu deneylerde düşük frekanslı (0.4-0.8 Hertz) ve artarak yükselen yükleme şekli esas alınmıştır. Deney numunesine ait ankraj ve bağlantı detayları, numunenin deforme olmadan rijit olarak dönebilmesine müsade edecek şekilde tasarlanmıştır. Performans kriteri için dikkate alınacak olan hedef öteleme oranı panel yüksekliğinin 0.01 katı olup, bu orana karşılık gelen öteleme miktarı 75mm olarak belirlenmiştir. Numune ve bağlantılarda bu öteleme miktarına ulaşılana kadar hiç bir hasarın olmaması gerekmektedir (%1 öteleme oranı).

Panel elemanları bağlantılarını kontrol edebilmek için kısmi üst panel ilave edilerek 2.43m x 6.50m boyutlarındaki üç adet cam dış cephe kaplama numunesi test edilmiştir. Sarsma masası testi, +/-100mm öteleme değerine ulaşılınca durdurulmuştur. Bu değer test şartnamesinde belirlenen göreceli deplasman (drift limit) değerinin üstünde olmasına rağmen test sırasında sistemde herhangi bir hasar saptanmamıştır.

Tanımlanan yerdeğiştirme ve performans kriterlerine göre, **"Okmeydani ve Göztepe Eğitim ve Araştırma Hastaneleri (İstanbul) Projesi"** için test edilen cam kaplama alüminyum test numuneleri dinamik sismik performans testlerinden başarı ile geçmiştir.

INTRODUCTION

This report presents the results of dynamic seismic peformance tests on the glass cladding system that will be used on the Okmeydani and Goztepe Training and Research Hospitals in Istanbul.

For in-plane loads, the standards for such panels use the maximum drift (i.e., the relative displacement between the top and the bottom of the panel) as the performance criterion, not the maximum load. Therefore, for the in-plane behavior and the performance the weight is not critical, as long as the drift criterion is matched.

The shake table tests were done at the Shake Table Test Laboratory (STL) of the Earthquake Engineering Department of Kandilli Observatory and Earthquake Research Institute (KOERI), Bogazici University, Istanbul, Turkey. A test set up for a representative specimen was designed and built on top of the KOERI-STL's large uniaxial shake table with appropriate boundary conditions.

In accordance with the American Architectural Manufacturers Association Standard AAMA 501.6-01 dynamic seismic performance tests were performed. In accordance with the American Architectural Manufacturers Association Standard AAMA 501.6-01– *Recommended dynamic test method for determining the seismic drift causing glass fallout from a wall system,* a cascade of sinusoidal base motions were applied to the specimen.

The following paragraphs describe the test set-up, input excitations, performance criteria, the test procedure, and the test results.

TEST FACILITY AND SETUP

The shaking table test was performed on the STL's 3 x 3 m. uni-axial shake table, which is driven by a servo-hydraulic actuator with a stroke capacity of ±12 cm. The shake table can simulate any given earthquake, as well as sinusoidal motions, within the frequency range of 0-50 Hz. and can handle test specimens up to 10 tons.

The planned cladding system involves 2.43m x 6.50m double glazed glass modules encased in an aluminum frame. The test panels are mounted on a specially designed steel frame system as shown in Figure 1. The cladding panels are free to rotate as a rigid body due to the hinges at the top and the bottom. The middle beam is also pinned at both ends so that it shows no resistance to lateral deformations. The top of the frame is held by a rigid frame fixed to the laboratory wall as shown in Figure 1. The base of the frame is fixed on the shake table which moves as specified by the AAMA Code 501.6.-01. Since the frame is two-floor high, the shake table movements are higher than the drifts specified in the code.

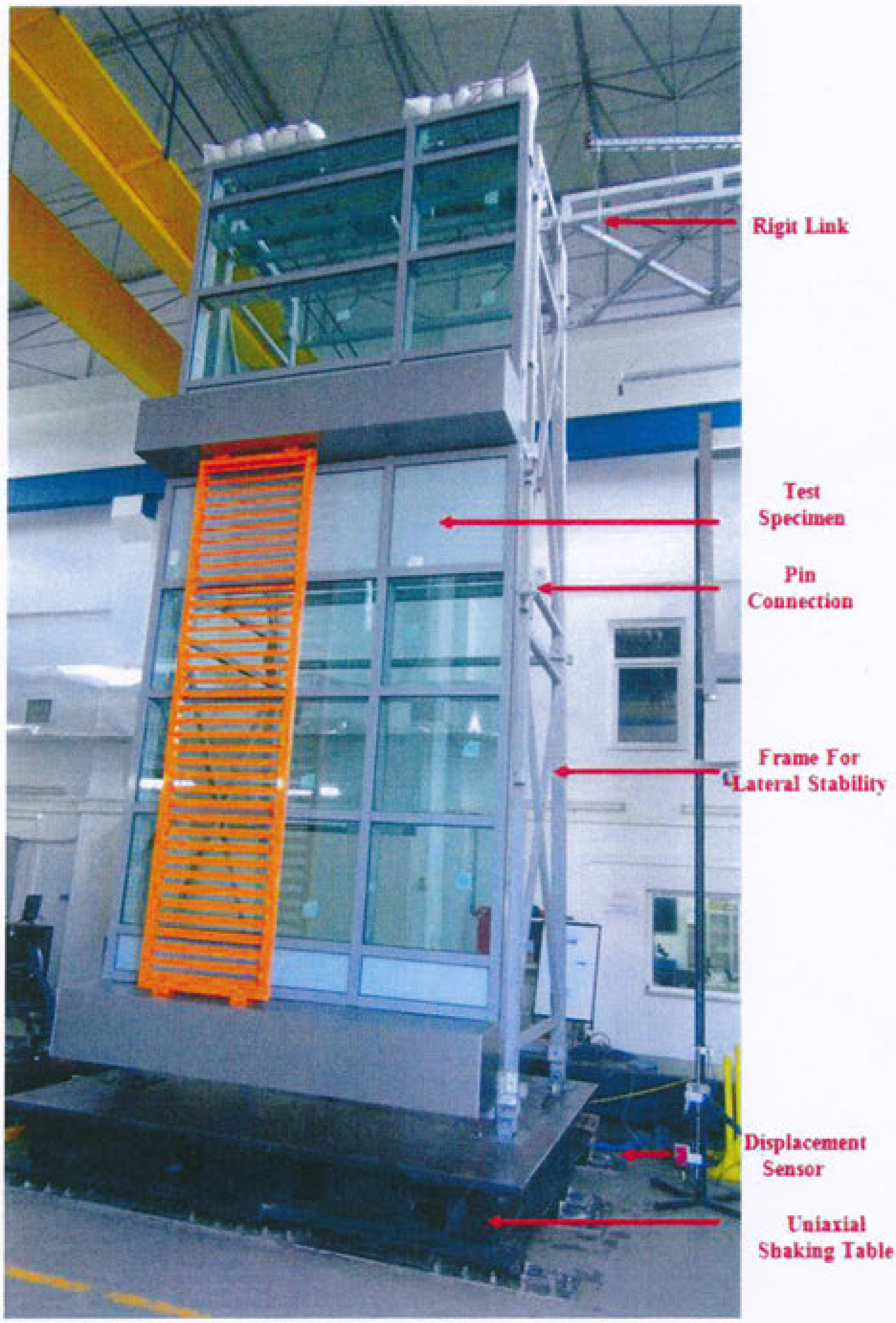


Figure 1. Picture of the test set up showing the shake table, test specimen, rigid frame, and sliding beam system.

Three 2.43 m. x 6.50 m. glass cladding specimens with partial upper panel attached to check the panel connections were tested. Additional weights were added to the top of upper panel to simulate the effect of panel weight and inertia forces. The pictures below (Figure 2 and Figure 3) show the details of the top and the bottom connections of the specimen to the structure, as simulated on the test table. The details can be found in the technical drawings for the cladding system in Appendix A. A schematic representation of the boundary conditions assumed for the specimen, showing the freedom for rigid body rotations and rocking motions, is presented in Figure 4.

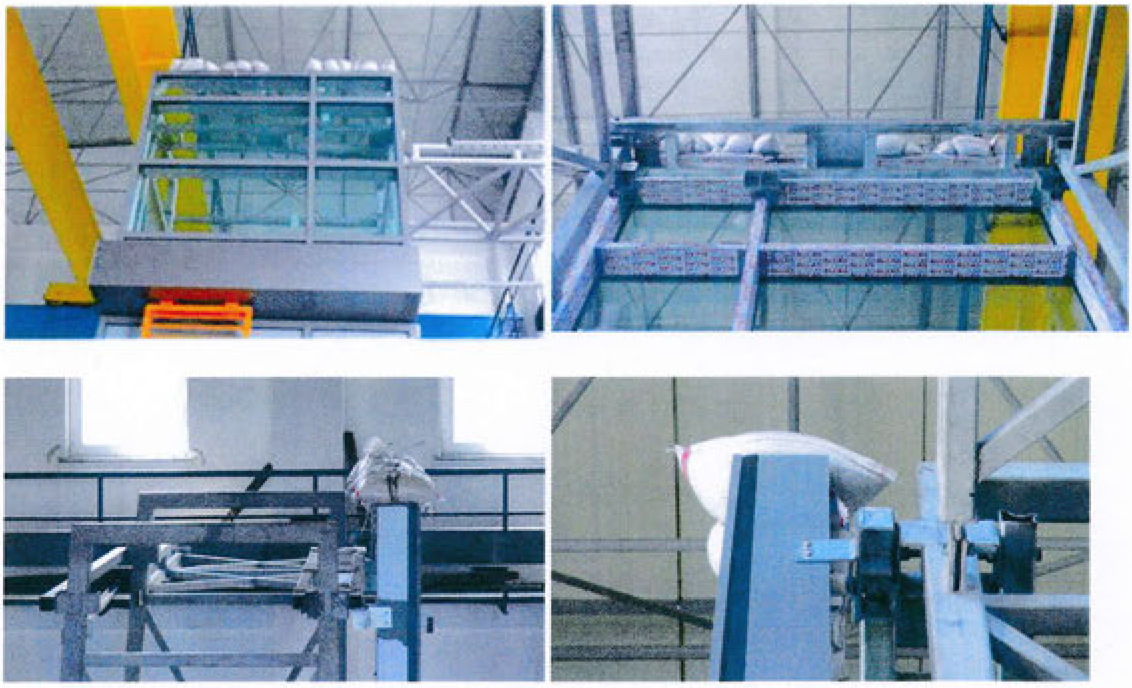


Figure 2. Connection details at the top.

Figure 3. Connection details at the bottom.

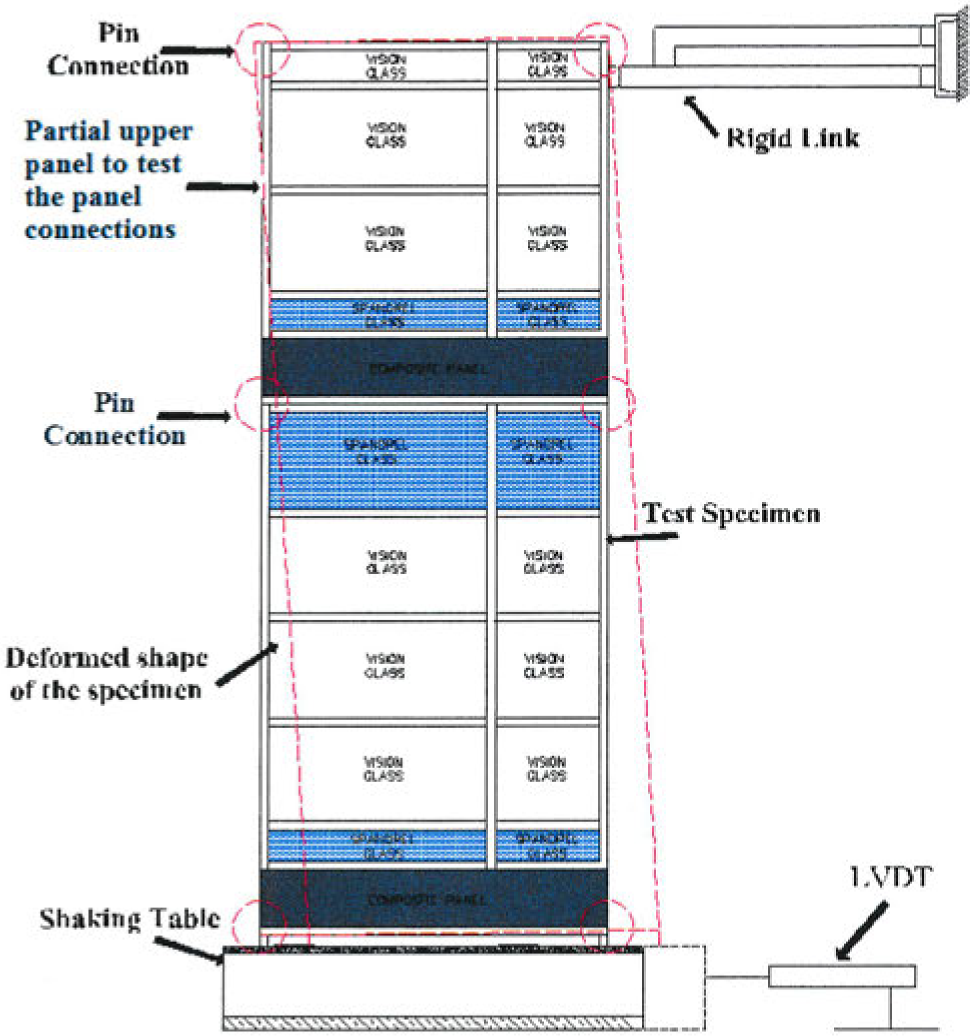


Figure 4. Schematic representation of the boundary conditions assumed for the test specimen, showing the freedom for rigid body rotations and rocking motions.

PERFORMANCE CRITERIA

The tests were carried out in accordance with the American Architectural Manufacturers Association Standard AAMA 501.6-01 – "*Recommended dynamic test method for determining the seismic drift causing glass fallout from a wall system*" and the international seismic design codes.

Seismic design codes specify the allowable inter-story drift limits for architectural components in multi-story buildings. Inter-story drift is defined as the relative horizontal displacement between the top and the bottom of a story divided by the story height. In most seismic design codes (e.g., International Building Code, SEAOC Code, EU Code, Turkish Code) the maximum allowable inter-story drift is 1%, which makes the allowable relative displacement between the top and the bottom of the specimen of 75 mm (0.01 x 7500 mm (*height of the panel)*.

The AAMA Standard 501.6-01 – *Recommended dynamic test method for determining the seismic drift causing glass fallout from a wall system* - specifies the testing procedure and the failure criteria. The testing procedure recommended in the AAMA Standard is generally known as the "Crescendo Tests" and involves subjecting the specimen to dynamic displacements composed of concatenated sinusoids at different frequencies. Each sinusoid involves a rump-up and a constant-amplitude segments. The input displacement time history that is used in the tests is composed of two concatenated sinusoids, the first with a frequency of 0.8 Hz for amplitudes up to 75 mm, and the second with a frequency of 0.4 Hz for amplitudes above 75mm. The tests are run until one of the following occurs:

1. A glass fallout
2. Inter-story drift exceeds 10%
3. Inter-story exceeds 150 mm.

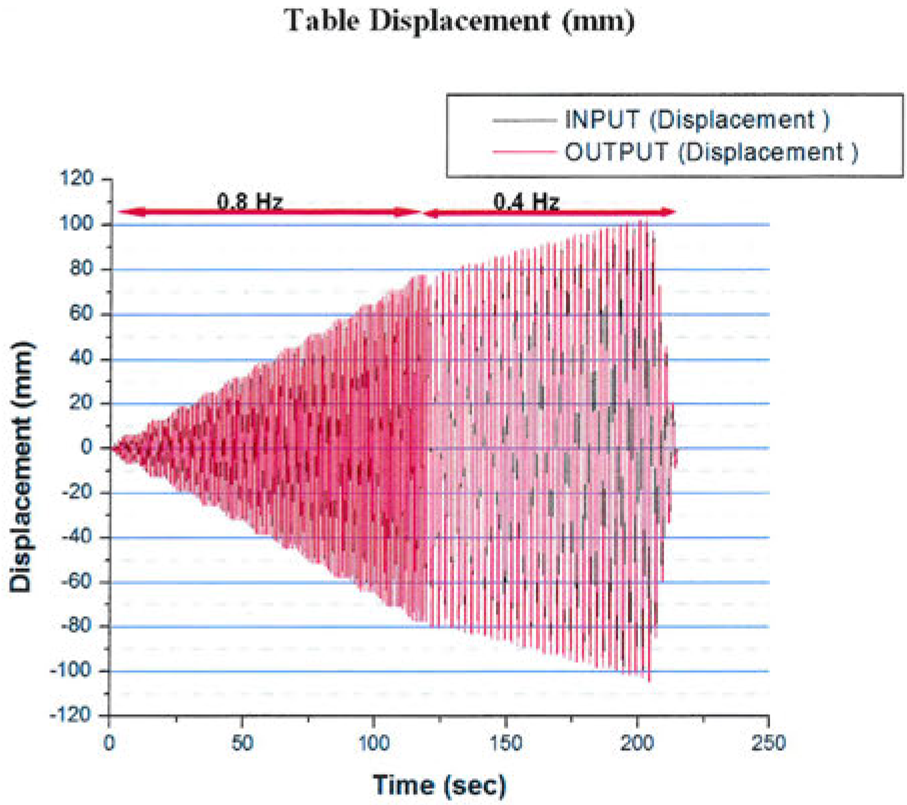
The performance criterion was set at 1% drift (i.e., 75mm), which is the allowable inter-story drift limit specified in seismic design codes for multi-story buildings. At the conclusion of the tests, technicians and witnesses visually inspect the specimen for any evidence of failure. All areas of distress, such as disengagement, metal distortions, sealant or glazing failure, or permanent deformation are reported.

TEST PROCEDURE and RESULTS

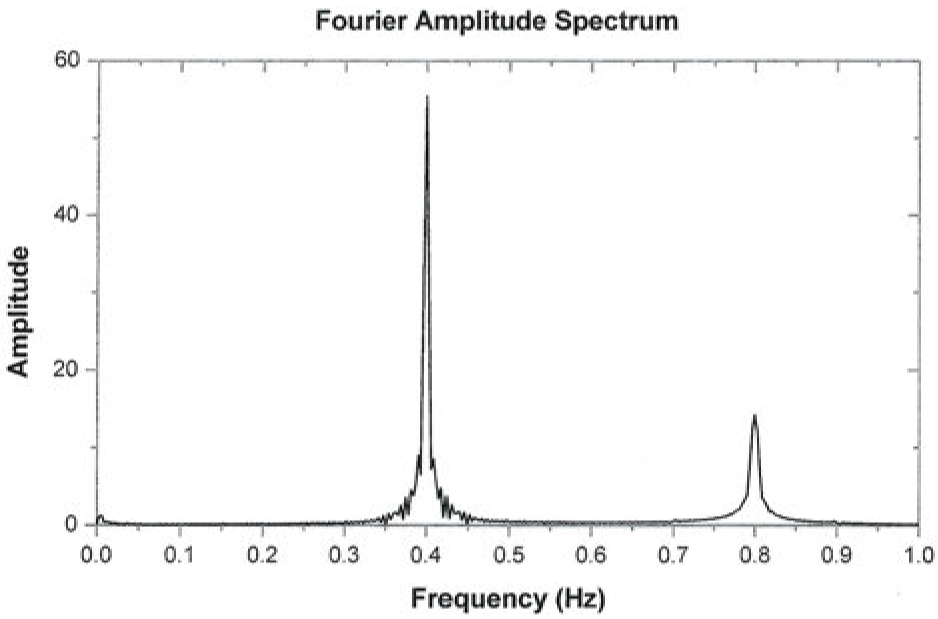
Three 2.43 m. x 6.50 m. glass cladding specimens with partial upper panel attached to check the panel connections were tested under the specified loading described above. The test procedure required that the test be stopped if there were any glass breakage, support failure, or visible frame damage, and the corresponding displacements and rotations be recorded.

Shake table tests were performed under the sinusoidal input defined above. Due to the request of the client, the performance criterion was set as 100 mm, which is almost two times of the allowable inter-story drift limit specified in seismic design codes for multi-story buildings. In the test, the specimen was able to rock and rotate as a rigid body in the vertical plane as envisioned by the design. The measured displacement of the shake table and its Fourier Amplitude Spectrum are shown in Figure 5.

During and after the tests, the specimens were visually observed by the test center personel and the client's representatives, and recorded on video for future reference.



a) Displacement – time History



b) Fourier Amplitude Spectrum of the Shake Table Motion

Figure 5. Two concatenated sinusoidal displacements at 0.8 and 0.4 Hz applied to the base of the cladding panel.

CONCLUSIONS

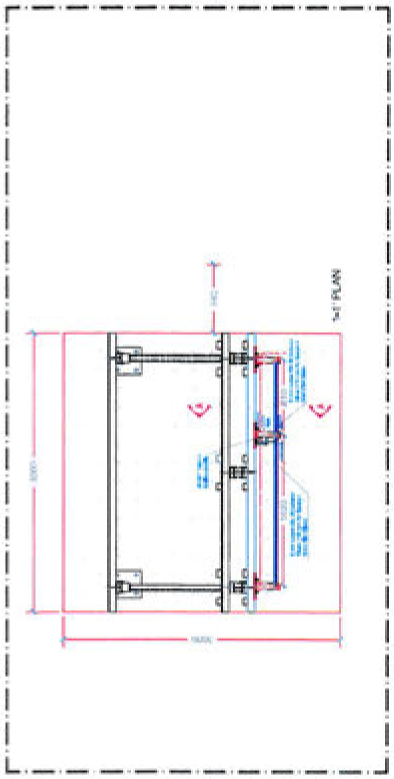
Based on the specified input motions and the performance criteria, the test specimens of the **Okmeydani and Goztepe Training and Research Hospitals (Istanbul) Project** have successfully "**passed**" the dynamic seismic qualification tests.

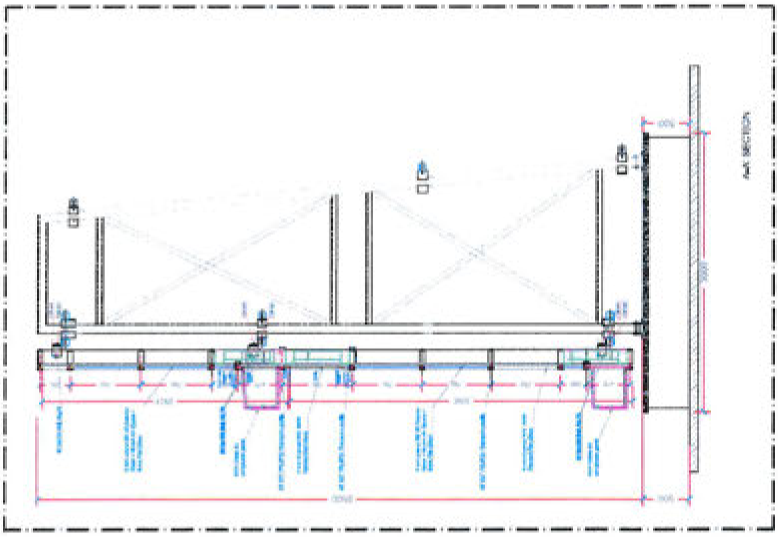
SONUÇLAR

"Okmeydanı ve Göztepe Eğitim ve Araştırme Hastaneleri (İstanbul)" Projesi'nde kullanılan cam dış cephe kaplama sistemine ait test numuneleri, ilgili şartnamelerde belirtilen performans kriterleri esas alinarak gerçekleştirilen dinamik sismik testlerden başarı ile geçmiştir.

APPENDIX A
Details of Test Setup and Connections


FRONT ELEVATION
VISION GLASS





T.C. BOĞAZİÇİ ÜNİVERSİTESİ
KANDİLLİ RASATHANESİ ve
DEPREM ARAŞTIRMA ENSTİTÜSÜ
Deprem Mühendisliği Anabilim Dalı

12 Ekim 2016

Nur Alüminyum
İstanbul-Türkiye.

Sayın Şafak YAMAN

Firmanız tarafından talep edilen "Okmeydani ve Göztepe Eğitim ve Araştırma Hastaneleri Projesi"ne ait dış cephe kaplama sisteminin AAMA 501.6-01 Standartı'nda belirtilen kriterlere göre gerçekleştirilen Sismik Performans Testlerinin Sonuçlarını içeren "Test Raporu" Ek'te verilmektedir. Gereğini bilgilerinize sunarım.

Saygılarımla.

Prof. Dr. Erdal Şafak
Deprem Mühendisliği ABD Başkanı

Ek: Nur Alüminyum için Test Raporu.

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