# Seismic Retrofit of Allstate Building

## Consolidation parasismique de l'immeuble Allstate

## Seismische Ertüchtigung des Allstate-Gebäudes

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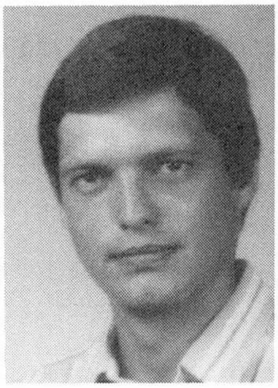

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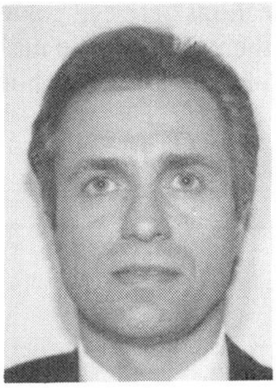

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## SUMMARY

The seismic retrofit of the Allstate Building in Seattle is presented. The retrofit used a new structural system concept called the hysteretic device system. This system concept can limit story shear and drift to levels only known from very ductile or very stiff systems, respectively, thus combining the advantages of both conventional approaches. In the case of the Allstate Building, this rendered upgrading of the existing brittle reinforced concrete frames unnecessary, resulting in substantial cost-savings and improved performance when compared to conventional systems.

## RÉSUMÉ

Cet article présente une nouvelle conception appelée "hysteretic device system", utilisée avec succès dans la consolidation parasismique de l'immeuble Allstate, à Seattle. Ce système permet de limiter les efforts et les déformations au cisaillement par étage successif, ceci à des ordres de grandeur atteints uniquement par des systèmes très ductiles ou très rigides. Dans le cas présent, il a été possible de renoncer à consolider les cadres en béton armé existants et relativement fragiles, entraînant une économie sensible des coûts de consolidation et une amélioration du comportement.

## ZUSAMMENFASSUNG

Es wird die seismische Ertüchtigung des Allstate-Gebäudes in Seattle gezeigt, bei der ein neues Tragwerkskonzept genannt "hysteretic device system" erfolgreich angewendet wurde. Dieses Konzept ermöglicht die Begrenzung der geschossweisen Schubkräfte und -deformationen auf Grössenordnungen, die nur von sehr duktilen Systemen einerseits bzw. sehr steifen Systemen andererseits erreicht werden. Es konnte dadurch die Ertüchtigung der vorhandenen spröden Stahlbetonrahmen entfallen, was erhebliche Kosteneinsparungen zur Folge hatte und zu einem verbesserten Verhalten führte.

## 1. INTRODUCTION

Built in 1959/60, the Allstate Building in Seattle is a three-story administration building that went through remodeling in 1991/92. FIG. 1 shows the plan and section of the building showing two new stairs and a new elevator shaft as well as a new glass-roofed atrium for the 1st and 2nd floor. The previous (and still existing) horizontal load resisting structure varies severely from floor to floor: The first floor has a stiff exterior concrete wall on the two short sides and one long side of the building which is needed as earth retaining wall. The second floor has a rc-frame formed by the columns and the slab and the 3rd floor has a light steel frame at the building's perimeter formed by steel columns and light steel trusses. The structural assessment of this system revealed several possible brittle failure modes. Built according to the relevant codes of that time, the rc-frame lacks ties in the columns and has weak connections between columns and slabs (FIG. 2) regardless of the solid concrete capitals. Although there is very little mass in the roof, the light steel perimeter frame is too soft and prone to connection failure as well as buckling of diagonals.

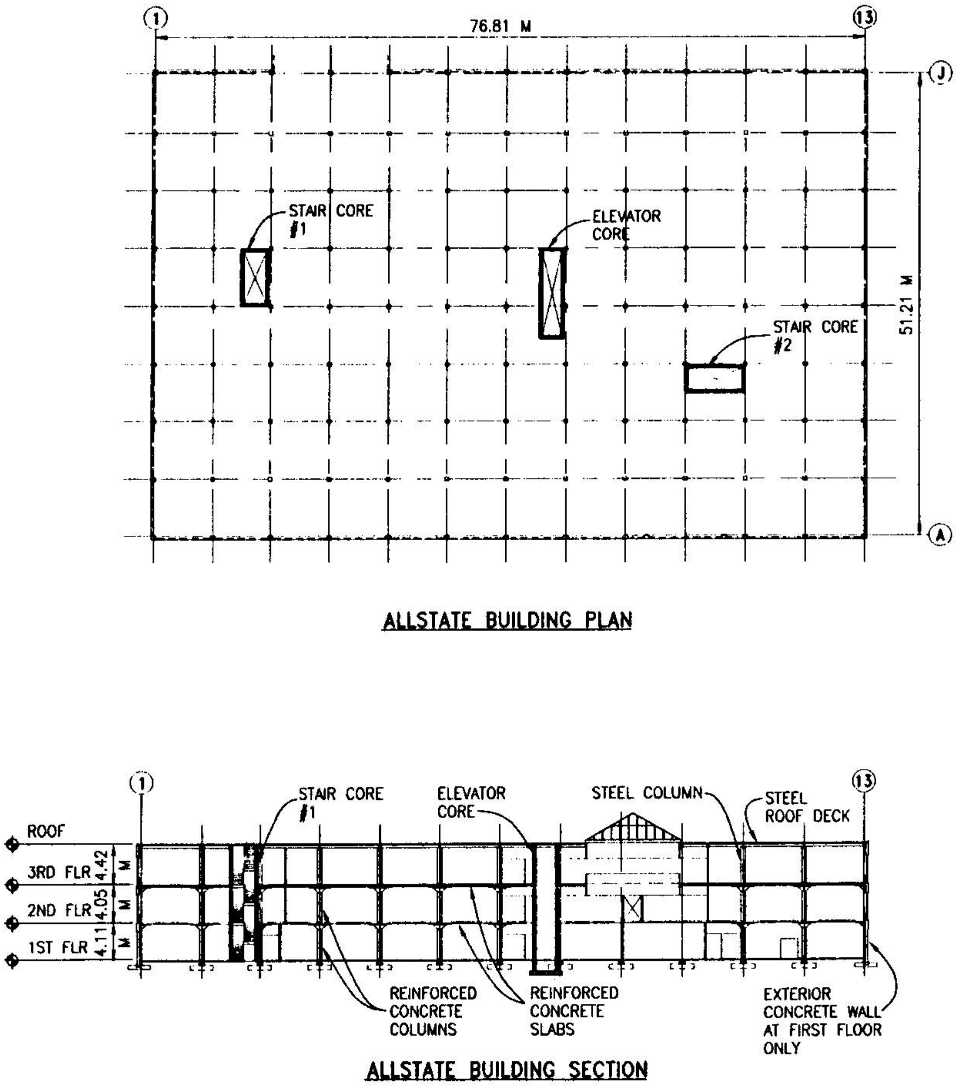


Fig. 1 Allstate Building floor plan and section with new rc-cores containing seismic links with shear panel dampers just below the 2nd floor ceiling.

Except for the stiff first floor system which will not exhibit any considerable story drift during an earthquake, the 2nd and 3rd story horizontal systems lacked the ductility required by modern codes. Therefore, a seismic retrofit became necessary.

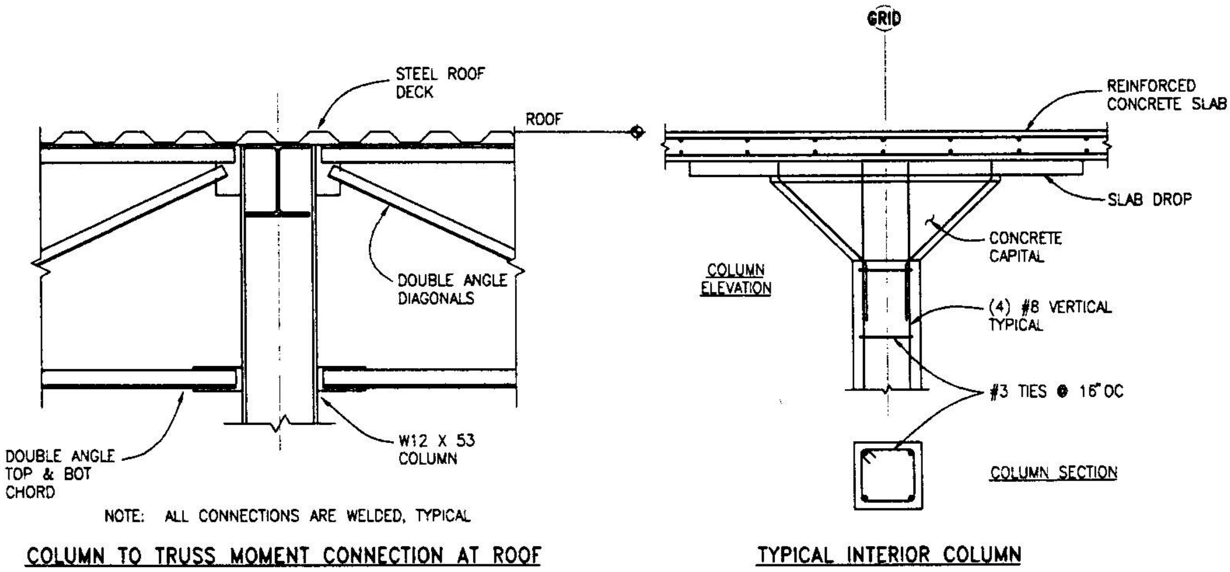


Fig.2 Details of existing framing system.

## 2. A NEW RETROFITTING SCHEME: THE HYSTERETIC DEVICE SYSTEM

Conventional retrofitting called for an upgrade of the rc-columns (confinement with an external layer of reinforcement) and joints in the existing frames and the implementation of new shear walls or truss systems. The new stair and elevator shafts provided only limited space for new conventional stiffening systems making the detailing of such systems very difficult and costly. In this situation, a Hysteretic Device - or Hyde-system (1) brought the solution.

Hyde-systems consist of a stiff primary horizontal system (PH-system), horizontal seismic links within the PH-system where hysteretic devices (Hydes) such as yielding or friction devices are placed and a soft secondary horizontal system (SH-system), where the masses are located.

Because of the stiffness of the PH-system, horizontal displacements of this system are concentrated in the seismic links where they activate the Hydes. These limit the maximum forces possible in the PH-system to their respective yield or friction force and dissipate most of the input energy. Both characteristics are very important for the structure: The physical force limit allows a static design approach and the use of very efficient structures for the PH-system and the large dissipation in combination with a large stiffness reduces story drifts. Studies (2) have shown that Hyde-systems are able to reduce story shears to very ductile system levels and story drifts to very stiff system levels, thus combining the benefits of both conventional approaches without many of their drawbacks. In addition, the seismic links can be designed such that, the Hydes are accessible and easily replaceable without major repair on the main structure. The performance of the structure is enhanced further, if well engineered yielding or friction devices are used (1), many of which were not available at the time of the Allstate Building's retrofit.

The SH-system has the important task to stabilize the P-Δ effect. Since during a major event, the Hydes are active most of the time, the PH-system provides little (if any) stabilization because its overall stiffness is near zero most of the time. Without an adequate SH-system, unpredictable and localized failure modes are possible (2).

In retrofitting, the existing system is often sufficient to act as SH-system. This is the case in the Allstate Building. Here, the new stair and elevator rc-cores provide the PH-system. The seismic links in each core are placed just below the 2nd floor ceiling (FIG. 3).

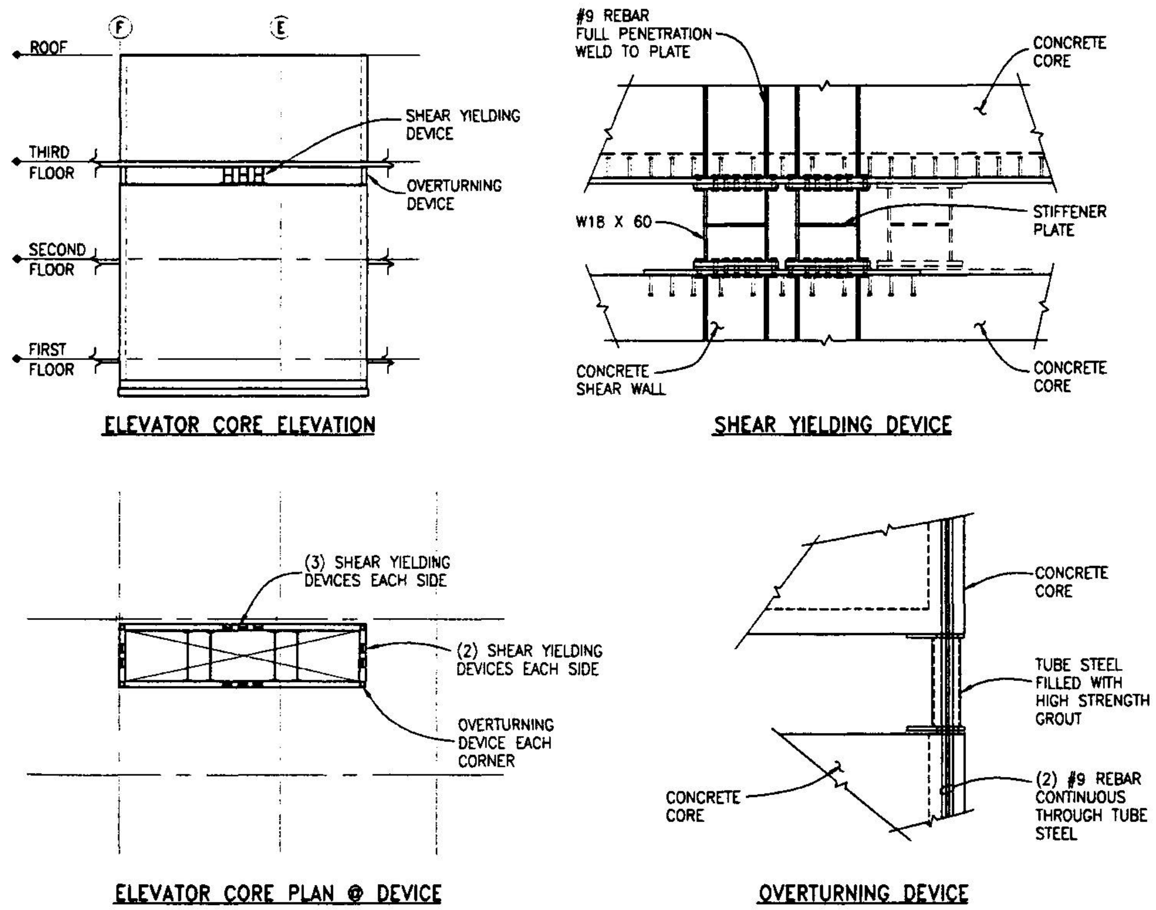


Fig.3 Elevator core as part of the primary horizontal system (PH-system) with seismic link below the 2nd floor ceiling. Shear panel dampers as hysteretic devices and grouted steel tubes in corners as overturning devices.

Only one link is necessary because the small roof mass can be coupled directly to the 3rd floor mass by the rc-cores and no story drift is expected in the 1st floor because of the stiff rc-perimeter walls there. As Hydes, shear panels cut from W18x60 were used. To prevent overturning, concrete filled steel tubes were placed in the corners of each link. These "overturning devices" yield during cyclic deformation of the seismic link without loosing their vertical load carrying capacity (tension and compression). Thus, the maximum horizontal yield force in each link is provided by the shear panels together with the overturning devices.

Because of its importance for the building's performance, the seismic links must be well detailed. Here, aspects like ease of inspection and replacement of devices are important. The links should be easily accessible and connections between devices and structure designed with additional capacity which depends on the possible variations in the devices' limit forces. Therefore, devices with well-known limit forces of small variation are preferable in Hyde-systems allowing for a more economical design not only of the connections but also of the complete PH-system. In the Allstate Building, the shear panels are bolted to the structure for easy replacement after a major event.

## 3. VERIFICATION

To verify the new PH-system, the UBC (3) provisions for excentrically braced frames (EBFs) were used because of the similarity of both systems: EBFs are also stiff-ductile systems with shear panels as hysteretic devices. The shear panels in the Allstate Building were designed to yield at the calculated story shear using the static force procedure.

In addition to this, non-linear three-dimensional analysis was performed on a system model using linear beam elements to model the frames (SH-system), lumped prismatic masses for each floor and a bi-linear two-dimensional hysteresis model for the shear action in each seismic link. A reliability study using 500 earthquake records generated from a modified Kanai-Tajimi spectrum scaled to the local properties of the site was performed and a comparison made to the performance of the previous system and a system with conventional rc-cores assuming linear behavior. Since this study is reported in (4), only the results in terms of standard deviations of the story drifts are given here (Table 1).

| System type | dim. | x-direction | y-direction |
|---|---|---|---|
| **previous** | mm | 24.48 | 30.13 |
| **stiff (linear) cores** | mm | 2.00 | 1.90 |
| **Hyde-system** | mm | 2.80 | 2.90 |

Table 1 Standard deviations of 2nd story drift.

The standard deviation of the story drift is a direct measure of the reliability index as it is defined in modern codes. The comparison shows clearly the effect of the new Hyde-system in the Allstate Building: It limits the standard deviation of the story drifts to stiff-(linear)system values without the large forces. The study also confirmed clearly the inadequacy of the previous system. Given a story failure drift of about 20 mm (elastic drift limit of existing rc-frames), the new Hyde-system provides adequate reliability against this limit state. Thus, extra ductility is not required in the frames of the SH-system and upgrading became obsolete.

## 4. SUMMARY AND CONCLUSIONS

The seismic retrofit of the Allstate Building in Seattle is presented where a new structural system concept called the hysteretic device - or Hyde-system was used successfully. This new system concept can limit story shear and drift to levels only known from very ductile or very stiff systems respectively thus combining the advantages of both conventional approaches. In the case of the Allstate Building, this rendered upgrading of the existing brittle rc-frames unnecessary resulting in substantial cost-savings and improved performance when compared to conventional systems.

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