Development of Guidelines and Effective Retrofit Strategies for Public Schools and Hospitals in Istanbul, Turkey

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ABSTRACT

A task committee comprised of local structural engineers and earthquake engineering experts from abroad was formed to assess the seismic performance of public schools in under auspices of this group; a guideline has been developed better assess the existing conditions and develop retrofit options for school and hospital buildings in Istanbul. The project is financed by a World Bank (WB) loan and is implemented through the Istanbul Special Provincial Administration (ISPA). The ISMEP project started on 1 February 1, 2006, and is expected to be completed by the end of 2010. The Istanbul Project Coordination Unit (IPCU), established under ISPA, is responsible for implementing the ISMEP. The Guideline is based on provisions of the ASCE 41 and Turkish earthquake code and is purposed to address the seismic design requirements for hospital and school facilities in Istanbul and recommends effective retrofit measures. Many such buildings were constructed prior to adoption of seismic codes and use non-ductile concrete moment frames and unreinforced masonry walls to resist earthquake loading. Recent earthquakes in Indonesia (2007) and China (2008) have shown that this type of construction is particularly sensitive to earthquake damage and even complete collapse due to the inadequate design and construction practices. Such vulnerability caused loss of life of thousands of students in China. The provisions of the guidelines are written to be easy to follow and implement. The engineer is charged with condition assessment, followed by analysis and determination of deficiencies. Both conventional and state-of-the-art retrofit measures are discussed in detail. The document also provides suggested retrofit measures for different building groups. It is hoped that the implementation of this guideline will drastically reduce the level of damage and loss of life in the public buildings during the next earthquake.

INTRODUCTION

The government of Turkey and the International Bank for Reconstruction and Development (IBRD) has entered into a loan agreement implementing the Istanbul Seismic Risk Mitigation and Emergency Preparedness Project (ISMEP). The goal is to improve the city of Istanbul's preparedness for a future earthquake. Seismic retrofit of school and hospital buildings vulnerable to earthquake damage is of great political and social importance in Turkey. The last two major earthquakes in the region have shown the vulnerability of these buildings in particular and of the built environment in general.

As part of this effort Guidelines for seismic retrofit of schools and hospital facilities in Istanbul, (hereafter referred to as the Guidelines [1]) has been developed. The aim of the proposed is to implement a procedure that leads to safeguarding Istanbul school and hospital buildings against a future earthquake in the area. The project scope is intended to protect as many buildings as possible, use cost-effective methodologies, produce on-schedule and high-quality construction, and ensure that the buildings meet their performance objectives. Fully implemented, the Guidelines describe retrofit methods that would significantly improve the seismic performance of school and hospital buildings in Istanbul. To remain cost-effective, a certain level of building damage is considered acceptable for school buildings, but Immediate Occupancy and Life Safety performance is highly likely. In this Guideline, supplements to Turkish Earthquake Code (herein referred to as TEC2007 [3]) are proposed for use specifically under the scope of ISMEP. These supplements are intended to increase confidence that collapse is prevented and damage is limited. The overall objectives are to minimize the retrofit cost, achieve acceptable earthquake performance, and to allow more buildings to be evaluated.

BASIS OF GUIDELINES

These Guidelines are primarily based on the TEC2007 and its appendix, with supplementary material referenced from ASCE 41 [2]. This Guideline is intended to supplement TEC2007, while retain the core provisions of the code. Performance-based engineering (PBE) is used extensively in this document. The acceptance criteria have been developed using data from applying the current codes, supplemented by the engineering judgment and experience of the development team.

The Guidelines relies heavily on performance based engineering (PBE). In PBE, realistic seismic hazard, condition assessment, and mathematical models of buildings are generated. In PBE, nonlinear procedures are used to more accurately predict the behavior of a building and its components, and to identify vulnerable elements.

KEY DIFFERENCES BETWEEN THE GUIDELINES AND TEC2007

The Guidelines has been developed to assist structural engineers in seismic retrofit of vulnerable school and hospital buildings in Istanbul, Turkey. TEC2007 primarily addresses new construction. Similar to other building codes worldwide, TEC2007 is prescriptive and is intended to provide life safety. By contrast, the Guidelines heavily rely on performance-based engineering. The Guidelines include eight (8) major modifications to TEC2007. These items are elucidated below.

- In the Guidelines, the latest database of geotechnical knowledge is used to prepare seismic hazard.
- TEC2007 requires that the computation of seismic mass include 60% of the live load acting on the structure. In the Guidelines, the inertial mass from live load is reduced to 30%.
- The Guidelines only addresses concrete structures. Hence only concrete infill walls are considered with their corresponding r factor from Table 7.4 of TEC2207.
- The Guidelines provides a comprehensive detailing package for seismic retrofit in its appendix. The Guidelines also requires that the new interior walls be placed with an offset with respect to the existing building frames to avoid brittle and premature failures.
- Compared to TEC2007, the Guidelines allows a 10% higher limit for the percentage of primary beams and columns in a damage zone and meeting the performance target.

- The Guidelines defines an ***rs*** factor of 3.0 for foundations. TEC2007 does not specify a factor
- The Guidelines retains the drift requirements of TEC2007 and in addition, requires that the existing concrete columns be checked for deformation compatibility.
- The Guidelines provides a detailed discussion on the *rs* values of TEC2007, but instead uses *m* factors. For demand to capacity ratio computations.

SAMPLE SECTIONS FROM THE GUIDELINES

The following sections present a summary of some of the most relevant material contained in the Guidelines.

Assessment of Existing Conditions

Data to be gathered include the as-built condition of the structure, components, site, and adjacent buildings and shall be collected in sufficient detail. This information will then be used to identify structural and nonstructural components that participate in resisting lateral loads, and potential seismic deficiencies in load-resisting components, such as discontinuities in the load path, weak members and connections, building irregularities, and inadequate strength and deformation capacities. As-built condition evaluation should utilize the following resources:

- Construction plans and specifications, engineering analyses, and maintenance records.
- Field observation of exposed conditions.
- Destructive and nondestructive testing of selected building materials and components
- Data available from previous seismic evaluations and/or seismic retrofits.
- For historic and unique structures, the locations of historically significant features.

The extent of data collected shall be consistent with the minimum or comprehensive levels of knowledge. The minimum level of the knowledge is required for the buildings for which seismic evaluation had previously been conducted and retrofitting projects are prepared by other ministries or agencies. The comprehensive data collection level is required in other cases.

Properties for both concrete and reinforcing steel can be established from combined core and reinforcement coupons taken at similar locations. Reinforcement continuity between existing connecting elements (for example, beams and columns, and diaphragms and shear walls) needs to be confirmed.

Core samples should be taken from components providing resistance to lateral and vertical (when necessary) loading. Samples shall be distributed uniformly in each story. Additional cores should be taken from damaged or deteriorated components, if such elements exist. Concrete cores shall be laboratory-tested to establish the compressive strength (f'c) of the samples. Tensile strength and modulus of elasticity shall be determined from the Code (TEC2007). Concrete testing should comply with the requirements of Section 7.2 of TEC2007 and additional requirements of this Guideline. The mean value of the compressive stresses obtained from the testing for each class of concrete shall be used in analysis and evaluation.

During the on-site surveys, reinforcement steel classes (for example, S220 and S420) should be determined, or if not determined class S220 should be assumed. If the nominal design strength of the reinforcing steel is known, additional testing is not required. The reinforcement shall be checked for evidence of degradation and corrosion. It is anticipated that most reinforcement corrosion would occur in either the basement or the ground floor due to water intrusion. When testing is required, the reinforcement coupons are to be tested to determine their yield and ultimate strengths and elongation. Coupon samples from both main (flexural) and transverse (shear) reinforcement are to be taken and tested.

The material properties of existing URM shall be determined by in-place testing of the masonry components. The location of the tests shall be distributed throughout the building.
The existing foundation data can be determined from the original design sheets specifying foundation capacity, and previous geotechnical reports for the site or for other sites in the immediate vicinity. In particular, it is important to establish the type and size of foundation. Such data is used in the retrofit phase. For example, when a shear wall retrofit is selected, an additional foundation would be required for the base of the wall if there is none present or if the existing foundation has inadequate capacity. Available data is supplemented by field investigations used to establish in situ conditions.

The scope of the geotechnical investigation is to determine the soil conditions at the site to estimate the local amplification due to ground shaking; assess whether there are additional hazards (such as liquefaction, swelling potential, differential settlement, and slope instability); and determine structural properties of the existing soil for use in the design of retrofit foundations. Data from construction plans and previous investigations, general geotechnical data, and field investigation and laboratory testing should also be used.

Earthquake Hazard and Design Spectra and Motions

This Guideline requires that the seismic demands to be expressed in terms of design response spectra or suites of acceleration histories. The hazards due to earthquake shaking is defined on either a probabilistic or deterministic basis. Probabilistic hazards are defined in terms of the probability that more severe demands would be experienced (probability of exceedance) in a 50-year period. Deterministic demands are defined within a level of confidence in terms of a specific magnitude event on a particular major active fault. However, the performance criteria of school and hospital buildings in Istanbul should not only be related to a generic ground motion probabilistically, but to the site-specific ground motion that would arise from the controlling scenario earthquake. The seismic hazard for any earthquake hazard level should be based on 5%-damped response and should be based on spectral values for short-period (0.2 second) and long-period (1 second) response.:

In the design process three levels of earthquake ground motion shall be considered;

- E1: with 50% probability of exceedance in 50 years
- E2: with 10% probability of exceedance in 50 years.
- E3:
    - With 2% probability of exceedance in 50 years
    - The Mw 7.5 deterministic event

The site-specific design spectra are presented as smooth curves and straight lines by following the procedure described in ASCE 41; see Figure 1.

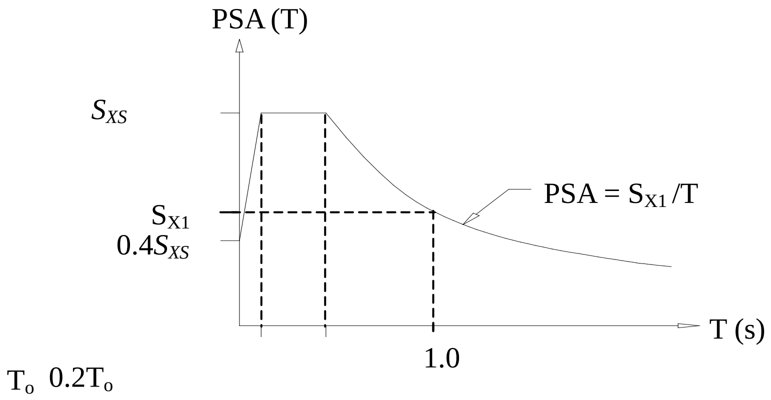


Figure 1. SMOOTHED DESIGN SPECTRUM

The analysis and design procedures of this guideline are primarily concerned with hazard resulting from ground shaking induced by earthquakes. However, other seismic hazards could exist at the building site that could damage the building regardless of its ability to resist ground shaking. These hazards include fault rupture, liquefaction or other shaking-induced soil failures, landslides, and inundation from offsite effects such as dam failure or tsunami.

Mathematical Modeling

A building should be modeled, analyzed, and evaluated as a three-dimensional assembly of elements and components. When a two-dimensional model of the building is judged to provide an adequate representation of the building (for example for a regular structure with no torsional irregularity), the use of two-dimensional models (one in each principal direction) is permitted. In such cases, the accidental torsional effect (when required) should be included by amplifying the response of the two-dimensional models.

The mathematical model of the structure shall adequately represent the structure's spatial distribution of mass and stiffness so as to allow accurate calculation of the significant features of its dynamic response. All concrete and masonry elements expected to affect the seismic response of the building shall be included in the analytical model. Concrete or masonry partitions that are adequately isolated from the concrete-frame members and the floor above do not need to be considered in the model.

Cast-in-place reinforced-concrete floors with span-to-width ratios less than 3:1 shall be assumed as rigid diaphragms. Other floors shall be analyzed to determine whether they must be considered as flexible diaphragms in accordance with [TEC2007] requirements and provisions of these Guidelines. The effective in-plane stiffness of the diaphragm, including effects of cracking and discontinuity between elements, shall be considered. If the building contains out-of-plane offsets in vertical lateral-force-resisting elements, the model should explicitly account for such offsets in determining diaphragm demands. The effect of any openings in diaphragms shall be considered and modeled appropriately.

Stiffness of structural components should be based on the requirements of TEC2007 and component stiffness is generally taken as the effective stiffness based on the secant stiffness to yield level forces. The cracked sections and tables should be taken into consideration.

Models should be analyzed for seismic motion in any horizontal direction. Multidirectional seismic effects should be considered to act concurrently. For regular buildings, seismic motions are considered acting non-concurrently in the direction of each principal axis of the building. The evaluation should then be based on the 100%+30% combination.

P-Δ effects are the second-order bending moments acting on structural elements and result from the application of their gravity loads at the displaced location due to seismic effects. In the evaluation of the overall structural stability, the buildings should be evaluated for P-Δ effects.

The effects of horizontal torsion should be considered for buildings with rigid diaphragms; it need not be considered in buildings with flexible diaphragms. Horizontal torsion consists of equilibrium and accidental components. When torsional effects are significant, three-dimensional models must be used. Increased forces and displacements due to equilibrium torsion should be calculated for all buildings if the ratio maximum displacement at any point on the floor diaphragm to the average displacement exceeds 1.2.

Many foundation systems in school and hospital buildings constructed in Turkey are relatively stiff and strong in the horizontal direction, due to passive resistance against the face of footings or basement walls, and friction beneath footings and floor slabs. Comparisons of horizontal stiffness of the foundation and the structure can provide guidance on the need to include horizontal foundation stiffness in analysis. When the foundation lateral stiffness is significantly greater than that of the superstructure, foundation flexibility can be ignored. However, when foundation stiffness is comparable or smaller than that of the supported building, the foundation lateral flexibility should be included in the model and it will alter the modal properties and seismic response of the building significantly.

In typical applications, only the seismic demands from the horizontal components of earthquakes need to be considered in design. However, for retrofit design, vertical seismic forces could be important and should be considered. In practice, for simple two to three story school buildings with standard construction, vertical seismic effects can be neglected, whereas for complex school and hospital buildings, they should be considered.

Self-weight of structural members should be calculated automatically by the computer software or spreadsheets and included in the analysis. Additional gravity loads for slabs should be calculated according to TS 498, based on material properties and thicknesses of slabs, and should be uniformly distributed on the slabs. The live load contributing to the seismic mass (n) should be taken as 0.3 for both school and hospital buildings.

Structural Performance Levels

Three structural performance levels are considered: Immediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP). These performance levels relate to damage states for elements of lateral-force-resisting systems and have specific drift limits (see Figure 2).

The IO limit state implies that only limited structural damage has occurred. The basic vertical- and lateral-force-resisting systems of the building retain nearly all their pre-earthquake strength and stiffness. The LS damage state implies that significant damage to the structure has occurred, but some margin against either partial or total structural collapse remains. Some structural elements and components are severely damaged, but this has not resulted in large falling debris hazards, either within or outside the building. The CP performance level implies that the post-earthquake damage state of the building is on the verge of partial or total collapse. Substantial damage to the structure has occurred, potentially including significant degradation of the stiffness and strength of the lateral-force-resisting system. There is permanent offset due to the large permanent lateral deformation of the vertical components, and there is limited degradation in the vertical-load-carrying capacity. However, all significant components of the gravity-load-resisting system continue to carry their load.

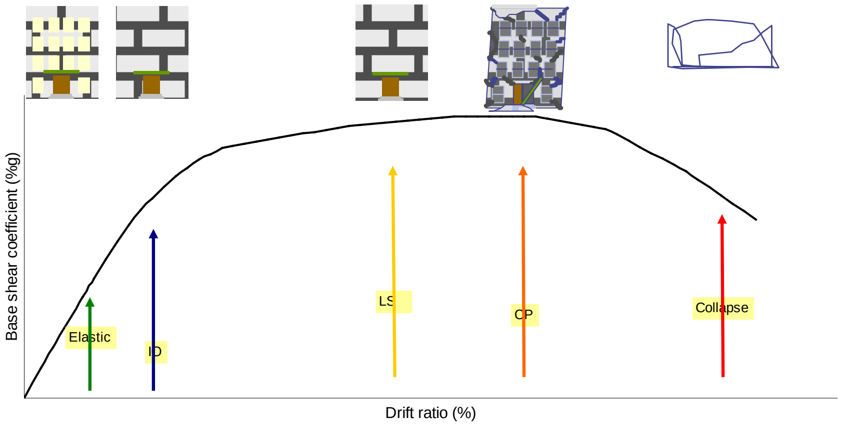


Figure 2. PERFORMANCE LEVELS

Retrofitted buildings would satisfy the LS performance level if both of the following conditions were met.

- Not greater than 40 % of the primary beams should be in the "Severe Damage Zone" for any direction of earthquake loading. If at least 75% of the total base shear force for any direction of loading can be carried by shear walls, the performance of the beams can be ignored.
- The ratio of the sum shear force carried by the columns and shear walls in the "Severe Damage Zone" to the total shear force at any storey for any direction of loading should be less than or equal to 0.4 for the top storey, and 0.2 elsewhere.

Retrofitted buildings would satisfy the IO performance level if both of the following conditions were met.

- Not greater than 20 % of the primary beams should be in the "Severe Damage Zone" for any direction of earthquake loading. If at least 75% of the total base shear force for any direction of loading can be carried by shear walls, the performance of the beams can be ignored.
- All the columns and shear walls should be in "minimal damage zone" for any direction of earthquake loading.

Structural Analysis and Evaluation Procedures

The Guidelines allows the use of the following methods. The simplified static procedure (SSP), linear static procedure (LSP), linear dynamic procedure (LDP) and the nonlinear static procedure (NSP), assuming that certain conditions are met. The nonlinear dynamic procedure (NDP) should be used with innovative retrofit devices such as dampers and isolators.

The linear procedures maintain the traditional use of a linear stress-strain relationship, but incorporate adjustments to overall building deformations and material acceptance criteria to consider the probable nonlinear characteristics of seismic response. NSP is used to compute the global building and member nonlinear demands expected during an earthquake. NDP is based on subjecting the building model to a series of acceleration records and determining the nonlinear response of the building and its components.

For buildings that have one or more of the irregularities (such as complex hospital buildings), linear procedures should not be used unless the earthquake demand-to-capacity ratio (DCR) complies with the requirements of TEC2007. For buildings with irregular distributions of mass or stiffness, with irregular geometries, or with nonorthogonal lateral-force-resisting systems, the distribution of demands predicted by an LDP or NSP would be more accurate than LSP. Either the response spectrum method or response history method may be used for LDP. Member capacities should be computed based on the nominal material strength. The calculated capacities should be reduced by the knowledge-level coefficient (κ). Material strengths of retrofitting members should be decreased with the strength reduction factors (ϕ). In the capacity calculations, the shear demand should be computed based on the value required to initiate flexural yielding. The ductile flexural yielding should precede shear failure in frame elements.

For linear analyses, the demand-capacity ratios (DCRs) should be computed and compared with the allowable (***m*** or ***rs***) factors. The NSP is used to obtain the plastic hinge rotation demands and the internal force demands expected at the intensity of seismic event under investigation. These demands are then compared with member capacities for both ductile and brittle members to assess the global and local performance of the building.

Seismic Deficiencies and Selected Retrofit

Concrete moment-frame components that do not meet the target performance levels should be rehabilitated. The primary concerns are listed below.

- The structural configuration is not conducive to good earthquake performance.
- Reinforcement details of members are not adequate to provide strength and ductility.
- The concrete compressive strength is lower than expected.
- The URM partition walls might respond in an abrupt and brittle manner.

The main objective of conventional retrofit is to use a cost-effective solution that upgrades the building response to meet its performance targets. An effective retrofit would reduce or eliminate the possibility of nonductile failure modes by upgrading lap splices and confinement. It would ensure that a continuous load path is present by providing continuity between diaphragms and the foundation and vertical lateral-load-resisting members. Retrofit would also attempt to reduce or eliminate features that serve as weak points or that lead to stress concentration. For example, asymmetrical distribution of the resisting members, abrupt changes of stiffness between floors, concentration of large masses, long rooms without cross-walls or buttresses, and large openings in the walls without trim or a proper peripheral reinforcement are mitigated.

Retrofitting options should also account for the performance of nonstructural components. They must maintain the existing functional, occupancy, energy-design, and spatial characteristics of the buildings. Retrofitting solutions must take into account physical constraints such as neighboring properties and the location of plant rooms and existing services routes. One of the objectives is to minimize the renovation cost related to architectural and building services. In most cases, this necessitates an external retrofit.

Conventional Retrofit

Conventional seismic retrofit methods reduce the demand-capacity-ratio (DCR) by either increasing capacity or reducing demand on a building and its members. The following are a number of retrofit measures.

Building capacity can be increased by the following measures.

- Walls or braced frames are added to the building to increase its lateral stiffness and strength.
- The existing beams, columns, or joints can be jacketed.
- The nonductile reinforcement details can be upgraded.

Seismic demand can be reduced by the following techniques.

- Removing heavy nonstructural components that produce large inertial forces.
- Weakening the beams to induce yielding in them and protecting columns
- Removing asymmetric members that exaggerate plan irregularity

The addition of shear walls and bracings is the most widespread retrofitting method because of its effectiveness, relative ease, and overall project cost. Although the braced frames have the highest ductility, post-cast concrete shear walls are the most commonly used alternative because of their low cost and ease of construction.

Additional shear walls are designed to resist a large portion of the lateral seismic loads, which significantly reduces the demand on the existing frame members. The walls must be designed and detailed to have adequate ductility. The walls can be placed on the exterior or interior of the building. Connections between new and existing materials should be properly designed to transfer the seismic forces. Where the existing concrete-frame columns and beams act as boundary components and collectors for the new shear walls or braced frame, they should be analyzed to ensure they could resist the loads imposed on them by the new walls. Diaphragms, collectors, and diaphragm anchorage to the new walls should be evaluated to ensure that a continuous load path exists. Connections between existing and new concrete components shall be subject to the quality assurance inspections. Pull-out tests shall be conducted to determine the shear and tensile strength of the dowels.

The design of new shear walls is based on limiting the drift of the existing concrete frame elements. This can be accomplished by modeling both the shear walls the concrete frame and checking the computed drifts of the concrete frame. The addition of shear walls to a building will always affect the architectural character and functional uses of the building. Selection of preferred wall locations must be made considering these issues, such as space layout, corridor locations, doorways, windows, main M/E/P distribution runs, as well as the structural or construction considerations. The new walls may be placed on the exterior or interior of the building.

Exterior walls are easier to construct and are less expensive. However, they are visible, exposed to the environment, and might affect exterior building finishes. Interior walls are better placed with an offset to existing column-frame lines to minimize direct impact on existing structural or architectural components or to simplify the wall-diaphragm connections.

URM partition walls should be retrofitted to reduce the risk of wall collapse. The existing walls can be removed, retrofitted, or replaced by lighter panels.

There are several standard methods to retrofit deficient shallow foundations. New isolated or spread footings might be added to support new structural members such as shear walls or frames. Existing isolated or spread footings could be enlarged to increase bearing or uplift capacity. Existing isolated or spread footings may be underpinned to increase their bearing or uplift capacity.

Improving existing soil material is effective in upgrading foundations. Soil improvement can increase the bearing capacity, lateral resistance, and passive resistance of the soils adjacent to foundations or grade beams. Soil grouting can be used to increase the bearing capacity and the lateral resistance of the foundation. Compaction grouting can achieve densification and strengthening of a variety of soil types and can be used to extend foundation support to deeper and stronger soil layers.

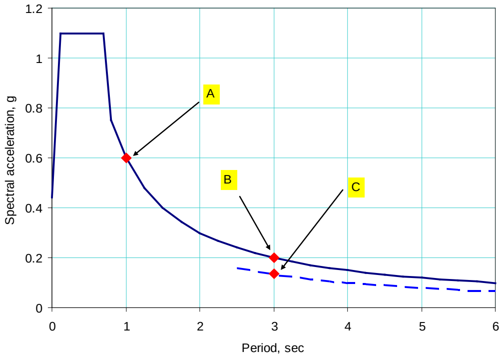
Innovative Retrofit Methods with Isolators and Dampers

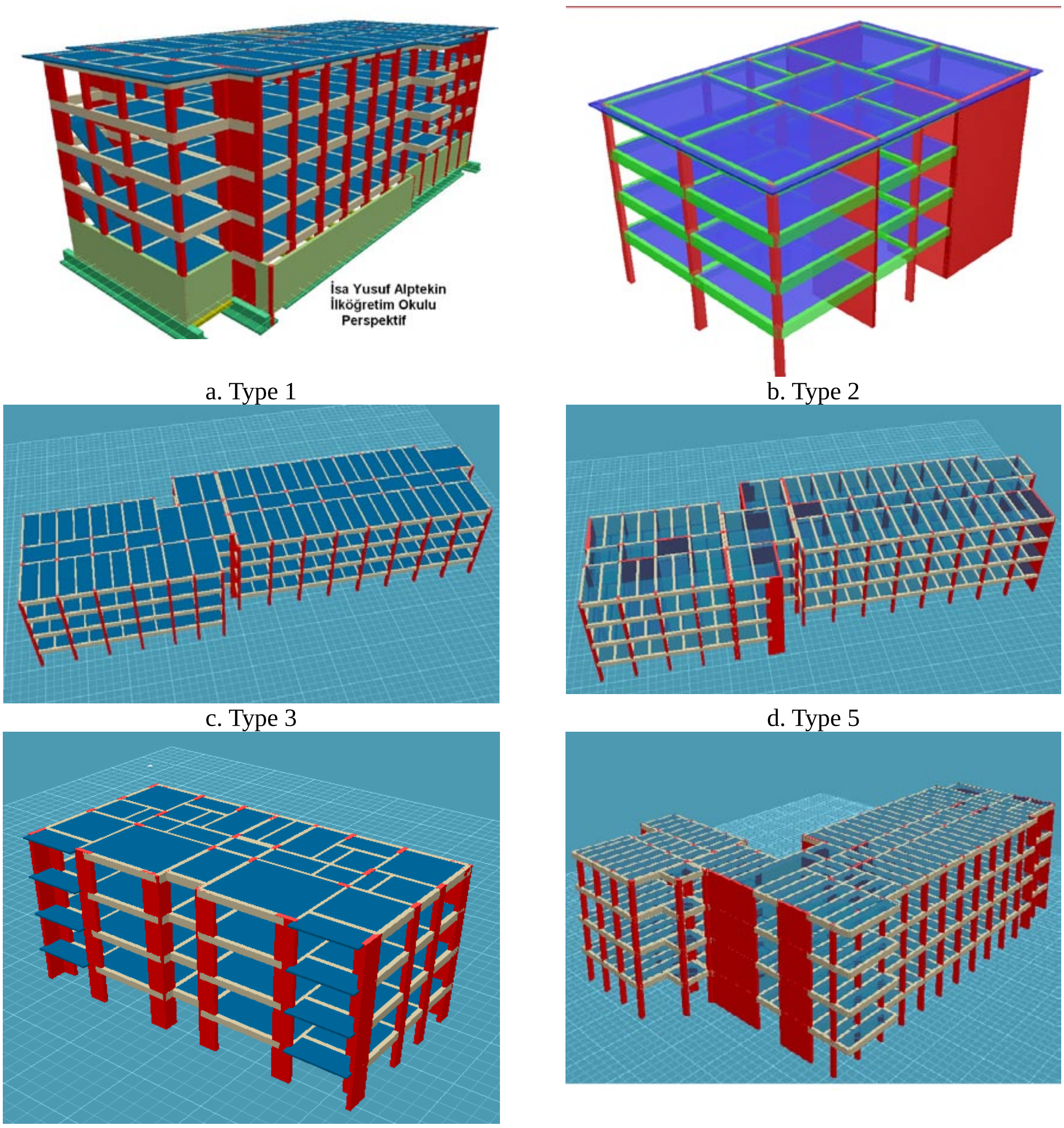
The main advantages of the devices are reliability, cost-effectiveness, maintaining building occupancy and functionality during retrofit, and preserving the existing vintage architecture and construction of the building.

Seismic isolation is an attractive retrofit for stiff, low- to mid-rise reinforced concrete buildings located on competent soil. This type of structure has a low period of vibration. When a fixed-base structure is subjected to design earthquakes, it would experience large input accelerations (point A on Figure 3a) resulting in high seismic demand on the structural and non-structural members. When the same structure is placed on relatively flexible isolators, the period of the structure shifts to the right (point B of Figure 3a). To limit seismic displacements, seismic isolators also have damping characteristics that further reduces the response (point C of Figure 3a). Thus, both the force (acceleration) and displacement demands are reduced. Since the lateral stiffness of the isolators is significantly smaller than that of the structure above, the predominant mode of vibration would correspond to the nearly rigid motion of the building over the isolators; this is referred to the isolator mode. In other words, most of the displacement takes place at the isolator level, resulting in very small story drifts in the building.

Seismic isolation is a relatively new technology in Turkey. However, it has been used for seismic design and upgrade of several major structures. For example, LRBs have been used in construction of Sabiha Gökçen Airport hangers and Sarnıç Hotel. FPSs have been used in seismic retrofit of the Atatürk airport terminal and Bolu viaduct; both damaged during the 1999 Düzce earthquake.

Supplementary damping is an attractive retrofit option for the non ductile reinforced concrete frame structures. The devices increase structural damping and hence reduce seismic demand (as shown in Figure 3b). For the un-damped structure, the seismic demand is denoted by point A. When additional damping is incorporated into structure, the entire demand spectrum is lowered. As such, story drifts, and member forces are significantly reduced. Dampers provide an ideal retrofit for structures having insufficient ductility, torsional irregularity, and soft story response. They are most effective for concrete frame buildings, since they depend on relative motion between the adjacent floors to become activated. For very stiff shearwall buildings, they can be used to reduce forces carried by the walls and thus prevent large ductility demand on these members. Dampers can be placed along the frame members using a number of configurations, such as diagonal, Chevron (inverted V), V-shaped, and double-story. In most cases, additional collector elements might be necessary to transfer damper forces at the floor diaphragms.





a. Type 1 b. Type 2

c. Type 3 d. Type 5

e. Type 7 f. Type 10

Figure 4. SCHEMATICS OF COMMON BUILDING TYPES

Key deficiencies and retrofit procedure for these structures and their main components are summarized in Table 1.

Table 1. SEISMIC DEFICIENCIES AND RETROFITS FOR RC BUILDINGS

Seismic deficiency	Retrofit options
Inadequate lateral strength	Add new RC walls
	Add new braced frames
	Shotcrete members
	Reduce seismic mass
	Seismic isolation
	Supplementary damping
Inadequate lateral stiffness	Add new RC walls
	Add new braced frames
	Increase size of beams and columns
	Supplementary friction damping
Soft or weak story	Add strength or stiffness to story
Torsional irregularity	Add balancing walls, braced frames, or moment frames
Inadequate collector	Add steel or concrete beams
Weak beam-column joints	Jacket or prestress joints
weak column- strong beam	Jacket columns, reduce beam strength
Inadequate shear strength	Fiber composite wrap
Lack Confinement or short splices	Fiber composite wrap Concrete/steel jacket
Inadequate shear capacity of floor diaphragms	R/C topping slab overlay
	RP overlays

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The proposed Guidelines developed under the auspices of the World Bank and ISMEP is intended to be used to mitigate earthquake hazard for schools and hospitals in Istanbul

- The Guidelines is primarily based on TEC2007. However, recent research data and knowledge from ASCE 41 is also implemented.
- The Guidelines can be used as an effective tool in assessing existing conditions, identifying vulnerable components, and devising cost-effective retrofits.
- The Guidelines used performance based engineering and hence can lead to a more realistic assessment.
- It is expected that when the Guidelines is fully implemented, it will significantly reduce damage from seismic hazard for the Istanbul schools and hospitals.

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