Safety Prioritization of School Buildings for Seismic Retrofit using Performance-Based Risk Assessment in the Kyrgyz Republic

Applied Technology Council

WORLD BANK GROUP
Social, Urban, Rural & Resilience

GFDRR
Global Facility for Disaster Reduction and Recovery

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Preface

This report summarizes the findings of a project supporting Component 2 of World Bank financed Enhancing Resilience in Kyrgyzstan (ERIK) project, "Improving the Safety of School Infrastructure (US$ 12-13M)," aimed to improve the safety and functional conditions of schools in areas of highest seismic hazard in Kyrgyz Republic. The ERIK project is a lending operation to support the Government of the Kyrgyz Republic in strengthening capacity to respond to disasters, providing safer and quality learning environments for children, and managing the cost of disasters and climate shocks. This work is to facilitate project preparation and provide analytical support to the Government in the preparation of a long-term national risk reduction strategy for school infrastructure, through a World Bank Global Facility for Disaster Reduction and Recovery (GFDRR) technical assistance grant (TA).

This objective of this project, entitled "Seismic Performance-Based Assessment of School Infrastructure in the Kyrgyz Republic" (also named the ATC-142 project), is to provide technical support for the process to establish a prioritization framework for eligible schools that have been shortlisted following selection criteria established by the Ministry of Emergency Situations, Ministry of Education and State Agency for Architecture, Construction and Communal Services of the Kyrgyz Republic. During the conduct of the ATC-142 project, field inspections of selected schools were completed to inform the analytical work that provided the technical basis for the prioritization process.

This project was conducted with the support of the World Bank Global Program for Safer Schools (GPSS). The GPSS aims to boost and facilitate large-scale investments for the safety and resilience of new and existing school infrastructure at risk from natural hazards and contribute to quality learning environments. For the conduct of this project and development of this report, the Program partnered with the Applied Technology Council (ATC). Since 1973, ATC has been at the forefront of developing and promoting user-friendly engineering resources and applications for use in mitigating the effects of natural and other hazards on the built environment. Over its history of operation, ATC has developed more than 150 major reports and engineering guidelines that have served to define seismic engineering design practice in the United States, including seismic design of new buildings, seismic evaluation and retrofit of existing buildings, and evaluation and repair of earthquake-damaged buildings; many have become de facto international standards.

Acknowledgements

This report is the result of World Bank work started in 2018 in contract with the Applied Technology Council (ATC). Numerous professionals participated in the development of this report.

Project Coordinators

This project was developed under the leadership of Fernando Ramirez Cortes (Task Team Leader). The World Bank team included: Carina Fonseca Ferreira, Diana Katharina Mayrhofer, and Jingzhe Wu.

Leading Authors and Team

The World Bank gratefully acknowledges the ATC-142 Project Team as the leading author of this report. The Project Technical Committee, consisting David Mar (Chair), Keith Porter, and Ilya Shleykov, researched and assembled the information contained herein and participated in in-country missions. Engineering design and cost estimation services were supported by Sandesh Aher and Sergei Utischev. ATC staff, consisting of Jon Heintz (Project Executive), Veronica Cedillos (Project Manager), Ayse Hortacsu (Project Manager), and Carrie Perna, provided project management and report production services.

Reviewers

The Project Advisory Panel, consisting of Svetlana Brzev, Stephanie King, and Jose Restrepo, provided technical review, advice, and consultation at key developmental stages of the work. In addition, Ulugbek Begaliev and Aidarbek Stamov, serving as local consultants to the World Bank, provided information and an independent technical review of the recommendations contained herein.

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The World Bank gratefully acknowledges the Global Facility for Disaster Reduction and Recovery (GFDRR) for funding the conduct of this project.

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Chapter 1
Introduction

1.1 Objective

The objective of this work is to provide technical support to Component 2 of World Bank financed Enhancing Resilience in Kyrgyzstan (ERIK) project, "Improving the safety of school infrastructure (US$ 12-13M)," aimed to improve the safety and functional conditions of schools in areas of highest seismic hazard in Kyrgyz Republic. More specifically, a risk-based framework is developed to assist in establishing a prioritized list among eligible schools that have been shortlisted following selection criteria established by the Ministry of Emergency Situations, Ministry of Education and State Agency for Architecture, Construction and Communal Services of the Kyrgyz Republic. This report describes the development of the framework and its results based on available information. The principles of the framework are intended to be transparent to stakeholders and government officials to facilitate informed policy decisions.

1.2 Approach

"Do the Most Good for the Most Kids" is the motto for the project. It captures the guiding objective to maximize benefit in terms of reducing seismic risk for students, predicated on the condition of limited funds. There are various approaches to select schools to improve given limited funds—a few schools can be made very safe, more schools could be made safe, or a lot of schools could be made much better than they are now. The risk-based framework developed in this project addresses the complex problem of how to most efficiently invest in seismic safety.

Determining the efficiency of a retrofit for a particular building at a particular site is complex. The efficiency is influenced by several factors: the specific vulnerabilities and capacity of the building, the costs of construction, and the seismic hazard. In the Kyrgyz Republic, as with many seismically active areas, smaller earthquakes are expected to occur at a much greater frequency than larger earthquakes. This characteristic of the hazard in a risk-based context suggests that retrofitting more buildings to resist smaller earthquakes may save more lives than retrofitting fewer buildings to resist larger earthquakes. Moreover, many institutions, governing bodies, and practicing engineers in the United States have frequently found that the levels of safety and damage resistance expected for new construction are very expensive to achieve in retrofits. These two trends suggest the safety vs. cost curve shown in Figure 1-1. This curve demonstrates that designing to very high levels of safety may be cost inefficient. Within the limits of the study, the framework presented in this report validates this assumption, and offers the means to efficiently improve safety for the candidate schools.

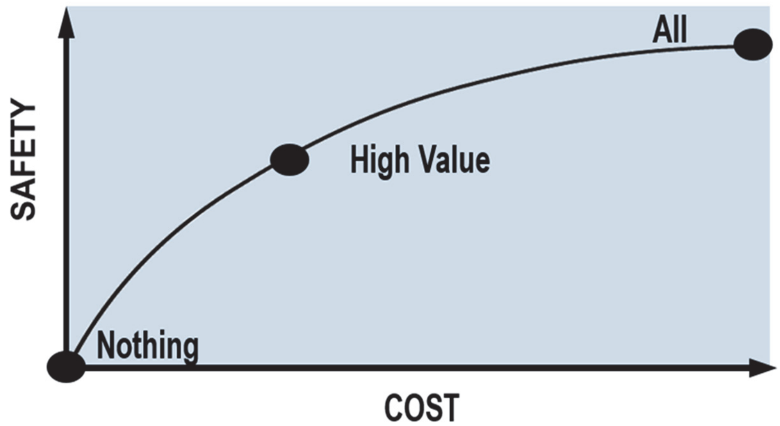


Figure 1-1 Illustration depicting concept of identifying high value risk reduction strategies to maximize benefit efficiently.

1.3 Context and Perspective

The performance-based seismic design concept was developed by the engineering community over several decades. In addition, there has been a gradual shift away from the black and white perspective of code compliance, to an understanding of behavior, consequence, and risk. This change was both technical and cultural, and driven by the complex necessities involved in mitigating existing structures. The global engineering community's journey to develop better understanding, tools, and techniques for seismic mitigation is ongoing.

The Kyrgyz engineering community appears to be at earlier stages of a similar process, with their embrace of performance-based seismic design. An additional objective of this project is to build trust through the technical exchange with the Kyrgyz engineering community and help accelerate their journey.

The risk-based framework presented in this report can be expanded with additional information for implementation at scale.

1.4 Intended Audience

The intended audience for this report includes:

- Decision makers who seek information regarding the priority order of schools that were considered in the project
- Program managers who seek to implement the methodology described at scale in Kyrgyz Republic or adapt it to other countries with similar circumstances
- Engineers who seek information regarding intervention options and underlying performance objectives for building types prevalent among schools in Kyrgyz Republic

1.5 Methodology Overview

The overall process to identify final list of "selected" schools to be financed under Component 2 of the ERIK project is shown in Figure 1-2.

Figure 1-2 Overall process to identify final list of "selected" schools to be financed under Component 2 of the ERIK project.

The methodology developed and implemented in this project comprises "prioritization criteria" in Figure 1-2.

The prioritization criteria rely on determining school seismic retrofit strategies that are most beneficial in terms of lives saved per unit of funds, under the presumption that funds are limited. The results are expressed in terms of benefit-cost ratio (BCR), which is a measure of efficiency.

The benefits are the statistical lives saved for a given retrofit. Use of performance-based seismic design allows design of various levels of retrofit for the prevalent typologies in the Kyrgyz Republic. Up to four retrofits with increasing capacity were developed for each selected representative index building. Each of these levels of retrofit are analyzed to determine a quantifiable benefit of seismic risk reduction, and the cost of each retrofit is determined. In addition, required energy efficiency (EE) and water, sanitation, and hygiene (WASH) costs were estimated for each school.

The utility of the BCR relies on the *relative* accuracy of the results. This is much more important than the precision of any given analysis or cost estimate. Consequently, it is important to be consistent with all the assumptions for all the retrofit increments and building types. This applies both for the analyses and the cost estimates.

It is noted that whereas the performance-based assessment calculations and the risk-based prioritization were applied at the "block level," the resulting priority list is indicated at the "school level." In this report, "block" refers to a rectangular whole building or rectangular portion of building with two or more seismically separated rectangular elements. The term "school" refers to a group of buildings at a common address.

The following steps are depicted in Figures 1-3 and 1-4 and documented in detail in corresponding chapters:

- Identify available data from provided database and inspection results (Chapters 2 and 3).
- Based on information from the eligible schools database and inspections, identify characteristics of the three most common structural typologies for blocks (Chapter 4).
- Determine vulnerabilities of index buildings selected to represent structural configurations, characteristics, and attributes (Chapter 5).
- Design interventions in terms of retrofit increments (Chapter 5).
- Estimate costs for each of the retrofit increments (Chapter 5).

- Develop vulnerability function for each index building at each retrofit increment, as well as the unretrofitted condition, informed by available information in the literature (Chapter 6).
- Calculate safety and cost efficiency index values for each increment; check code-conformance of each retrofit increment (Chapter 6).
- Develop prioritized list of schools utilizing combination of different policy options (Chapter 7).

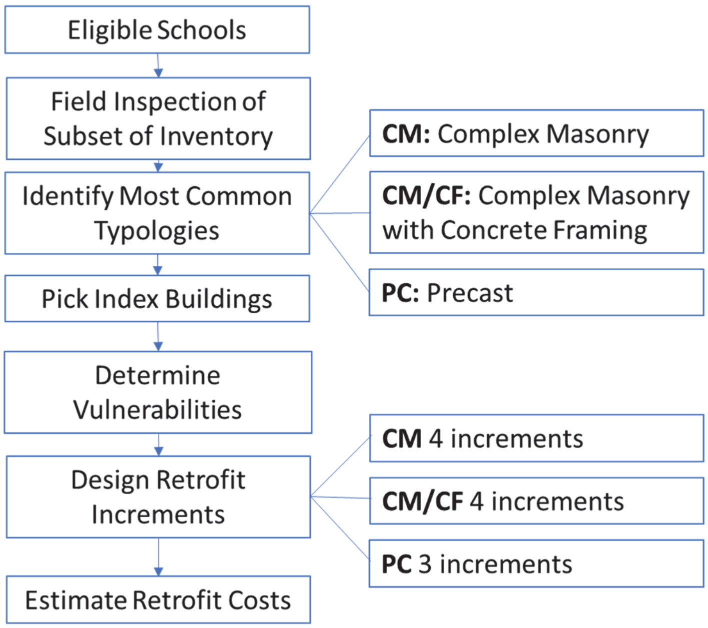


Figure 1-3 Flowchart depicting the steps of the methodology towards developing retrofit increments.

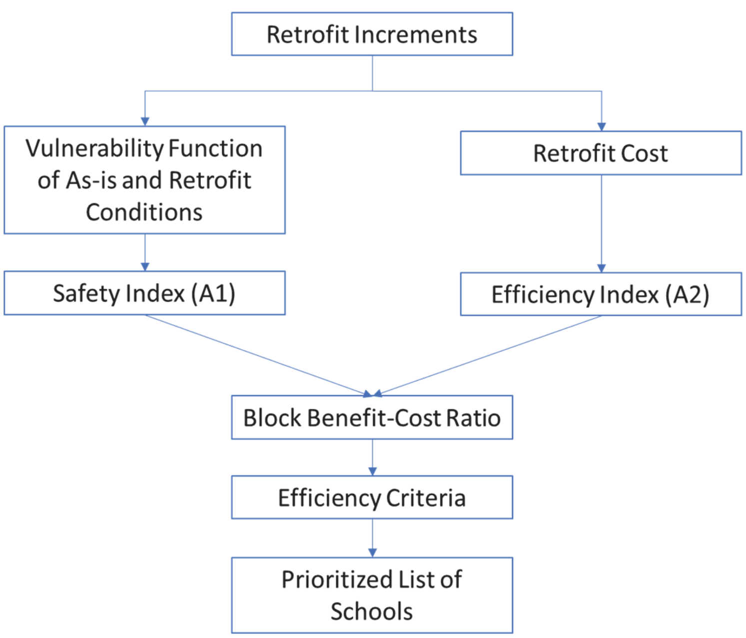


Figure 1-4 Flowchart depicting the development of prioritization criteria.

The risk-based framework was applied to all eligible schools for which necessary information was available. The framework allows the list of schools to be prioritized with the application of several options. The first is using only seismic safety efficiency, i.e., prioritizing schools by benefit-cost ratio. In this case, the schools listed highest on the list are schools where the most lives would be saved per dollar invested. The framework can also be constrained for additional policy options. For example, during the mobilization of a seismic retrofit, it may be relatively efficient to invest in improvements to energy efficiency (EE) and water, sanitation, and hygiene (WASH). These benefits (EE and WASH) cannot be directly compared to the safety benefit. However, because they draw from the same pool of funds, the policy decisions for EE and WASH investments impact safety. This report does not comment on policy options. Rather, the impacts of various policy options as they alter the framework results are presented in a transparent way to inform decision making.

1.6 Report Organization

This report describes the process and results from the field inspections, seismic retrofits, and prioritization framework in the following chapters:

- Chapter 2 summarizes the eligible schools database.
- Chapter 3 summarizes the conduct and results of the field inspections.
- Chapter 4 summarizes the characteristics of the most common typologies.
- Chapter 5 summarizes seismic retrofit using performance-based assessment of representative index buildings.
- Chapter 6 summarizes the risk-based prioritization framework.
- Chapter 7 presents the implementation of the framework to the eligible schools database.
- Appendix A presents the material used for field inspection training.
- Appendix B presents the list of inspected schools.
- Appendix C presents findings of a literature review for fraction of occupants killed in a collapse or partial collapse.
- Appendix D presents a review of building code information relevant for the project.
- Appendices E, F, and G present drawings developed for the conceptual retrofit increments described in Chapter 5 for confined masonry, reinforced concrete frame with masonry infill, and precast concrete frame and wall typologies, respectively.
- Appendix H presents vulnerability functions that were developed using the methodology described in Chapter 6.

Lists of references and project participants are provided at the end of this report.

Chapter 2

Eligible Schools

This chapter provides an overview of the eligible schools database provided by the World Bank.

2.1 Development of Educational Infrastructure Baseline

Since 2011, there have been several efforts to develop a dataset of educational institutions in the Kyrgyz Republic. The most comprehensive dataset was compiled by United Nations Children's Fund (UNICEF) in 2013 and included information about physical attributes (structural and nonstructural data) and functionality of 3,028 facilities.

In 2015, Resolution of the Government #551 indicated that the national portfolio was composed of 3,455 institutions, highlighting missing facilities from the dataset.

2.2 Selection of Eligible Schools

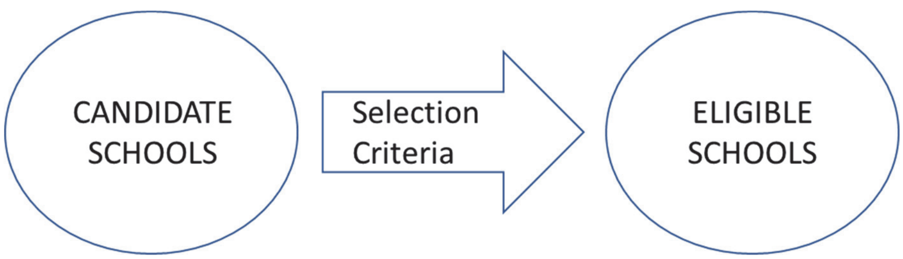


Figure 2-1 Process to identify "eligible" schools.

For Component 2 of ERIK, the Government of the Kyrgyz Republic established the following selection criteria to shortlist the national school portfolio ("candidate schools") to "eligible schools":

- **State schools.** Only state schools were considered eligible for ERIK funding.
- **Year of construction.** In an effort to select schools that are not yet nearing the end of their useful life, schools built before 1970 were not included in the list of eligible schools.
- **Number of students.** In order to maximize the social benefits, schools with a large number of students were selected for the list of eligible schools. The cutoff was defined as greater than 500 students for school buildings in large cities (specifically, Bishkek and Osh) and greater than 100 students for school buildings in rural areas.
- **Percent occupied.** In order to maximize the social benefits, schools that are fully occupied or near fully occupied were selected for the list of eligible schools. The cutoff was defined as occupancy of 70% or more of the school capacity.

- **Areas of high seismic risk.** Schools in oblasttars and cities with high seismic risk were selected for the list of eligible schools. High risk oblasttars and cities were identified as areas where the largest number of fatalities are expected in case of earthquakes per the most recent probabilistic seismic assessment conducted under the World Bank-funded project "Measuring Seismic Risk in Kyrgyz Republic." These included the following rayons: Alamedinsky, Aravansky, Bazar-Korgonsky, Bishkek City (which includes: Leninsky, Okyabrsky, Pervomaisky, and Sverdlovsky rayons), Kadamjaisky, Kara-Suisky, Kochkorsky, Nookensky, Osh City, Sokulusky, Suzaksky, and Uzgensky.
- **Engineered school buildings.** In selecting eligible schools, it was assumed that non-engineered buildings would likely not be cost-effective to retrofit and thus it was decided that at least 70% of school buildings in the eligible schools list should be engineered.
- **Eligible for funding.** Bishkek schools that were already approved for other school retrofit funding were not included in the list of eligible schools for ERIK funding.

Application of these selection criteria to the UNICEF dataset, coupled with the required data fields described in the next section, such as need for confirmed location (latitude/longitude), occupancy size, and structure type designation, resulted in an eligible school database with approximately 300 schools.

2.3 Required Data Fields

Data collected for each school facility was provided in terms of blocks. The term "block" refers to a rectangular whole building or a rectangular portion of building with two or more seismically separated rectangular elements. That is, school buildings that are not rectangular, but that are shaped in plan like an L, C, E, or I, tend to have structural joints that allow rectangular blocks to move independently, at least up to the point where they pound into each other. The term "school" refers to a group of buildings at a common address. See Figure 2-2 for an illustration of these terms. The approximately 300 schools in the eligible database comprise approximately 1,100 blocks.

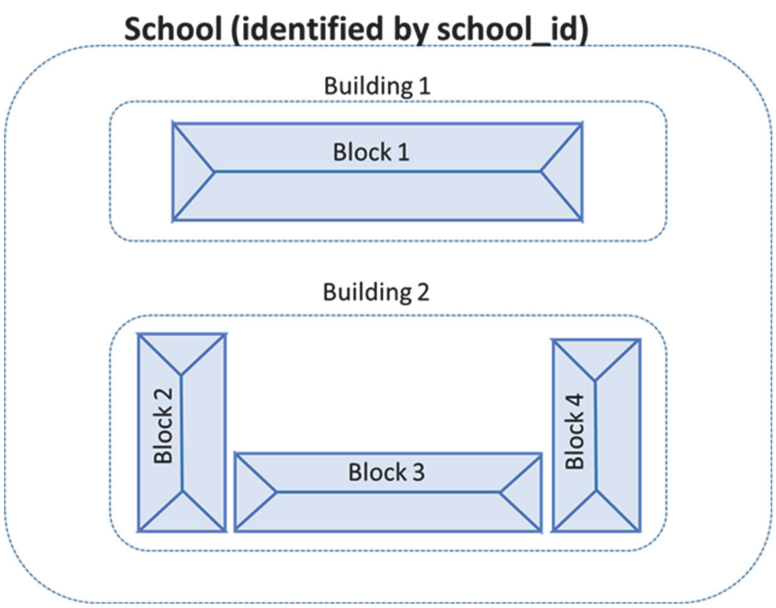


Figure 2-2 Illustration of school, building, and block terms.

The following data fields of the database are utilized in the prioritization framework:

- School and block identifying information, e.g., school code, oblast, rayon, school name, block number
- School location in latitude and longitude
- School total number of occupants
- Block dimensions
- Block typology in accordance with UNICEF taxonomy, described in the next section
- Year built by block
- Number of stories by block

Schools that lacked information in the required data fields were removed from the eligible schools list if no additional information sources, such as inspection reports, were available.

2.4 UNICEF Taxonomy

The United Nations Children's Fund (UNICEF) and the International Strategy for Disaster Reduction (UNISDR) developed a qualitative methodology to assess school safety (United Nations Children's Fund, 2013). Where possible, the eligible schools database identifies block typology using the taxonomy based on UNICEF that groups buildings in 13 categories. The categories, and their prevalence in the eligible schools database in presented in Table 2-1.

Table 2-1 UNICEF Taxonomy Definitions and Fraction in Eligible Schools Database

No.	*Description*	*% eligible schools*
1	Large-panel, flat-wall buildings from cast reinforced concrete.	2%
2	Frame-panel building with hinged plates; frame building with brick infill; metal frames.	32%
3	Structural system with incomplete frame where outer walls are brick and inner structures are frame.	7%
4	Brick building of composite structures (also called "in composite structures").	20%
5	Brick (stone) building of up to 5 floors.	21%
6	Building of traditional construction with wooden double frame for 9-point earthquake intensity and single frame for 7-8-point seismicity with the filling of soil materials and light-weight roofing. Their seismic resistance can be considered as existing under the following conditions: The foundation and the basement are made of solid waterproof materials (concrete, brick, stone, etc.); the distance between walls (in the clear) does not exceed 5 m; wooden parts are not rotten in the lower and upper parts of the support and stands of the frame; there are metal clamps and patch plates in the intersection nodes of vertical and horizontal elements of the frame assembled with a coak or jointing.	~0%
7	Same buildings with wooden frame which fail to meet requirements of item 6.	0%

Table 2-1 UNICEF Taxonomy Definitions and Fraction in Eligible Schools Database (continued)

No.	*Description*	*% eligible schools*
8	Buildings from puddle clay (pahsa) and raw brick, adobe (saman) blocks in the areas with 7-8 earthquake intensity can be considered seismically secure if the aggregate cross section of the party walls of structures in each direction (longitudinal, transverse) at the mid-level of a storey makes at least 4% of the building area calculated on the basis of outer faces of walls. The following elements should be in place as well: foundation and the basement made of solid waterproof materials (concrete, brick, stone and etc.); framing of outer walls; diagonal flooring from boards on the beams; and attic roof with asbestos cement or metal roofing on wooden beams.	1%
9	Same buildings from puddle clay and raw brick failing to comply with the requirements of item 8.	7%
10	Same buildings as per item 8 in the regions with seismic resistance of 9+ without reinforcement of walls may be used for various purposes except for permanent staying of people.	2%
11	Frameless buildings with walls of dried clay (gualyak) are seismically non-resistant for all seismic regions, and it is not recommended for people to stay in them.	0%
12	Buildings with walls from burnt brick built without any design and aseismic activities of 1-2 storeys high having no damages above 2 level according to MSK-64 or IMS-98 [sic].	2%
13	Wooden-board buildings in case of 7-8 seismic intensity in the area.	2%
	Unknown	4%

Chapter 3
Inspected Schools

This chapter provides an overview of the conduct of the field inspections and a summary of the findings from the inspections. A total of 78 schools comprising 421 blocks were inspected.

3.1 Objectives

In order to develop preliminary intervention options for risk reduction at scale, it is necessary to characterize and analyze the school portfolio in a manner that generalizes and categorizes school buildings, as it is not feasible to study the seismic vulnerability of each individual school building in the country. Accordingly, the eligible schools database described in Chapter 2 was reviewed for the presence of distinct categories that group together buildings with similar structural systems (such as masonry or reinforced concrete of various configurations called lateral-force-resisting systems), height range, seismic design level, and other parameters. During field inspections, information on more-detailed attributes that affect seismic performance were collected for the purpose of characterizing representative buildings for each structural typology. In addition, available structural drawings were documented for assistance in developing designs for performance-based assessment and retrofit increments.

3.2 Training and Staffing

A two-day, in-country training was conducted by the project team for 12 local surveyors. Training materials are presented in Appendix A. The scope of the training was to cover guidance and instructions for identifying each of the various entries on the inspection form. Training included both in-classroom instruction and discussion, as well as field exercises in applying the inspection form on a school building.

A total of 78 schools from the eligible schools list were inspected in June through August 2018 by local surveyors who attended the training. Inspection teams were from the International University of Innovation Technologies (IntUIT) and from the State Agency of Earthquake Engineering and Design Engineering (KNIIPS). Inspections were conducted under the direction of a Local Data Collection Manager, who provided guidance and direction and was available to answer questions for the field inspectors. Inspections focused on classroom and gymnasium buildings, as opposed to support or utility buildings.

The selection of schools to inspect from the pool of eligible schools considered various criteria such as:

- Diversity of structural typologies
- Distribution of schools to inspect weighted by the number of students per rayon

Appendix B provides the full list of schools that were inspected.

3.3 Data Collection and Quality Assurance

The focus of the field inspections was to gather data on parameters that affect a building's seismic response, such as: structural system, building height range, structural irregularities, floor/roof diaphragm flexibility, presence of weak columns, sensitive nonstructural elements, foundation flexibility, seismic design level, seismic pounding risk, prior seismic retrofitting, and building condition.

The data were gathered in a form that is in line with Global Library of School Infrastructure (GLoSI) data collection tools in order to be consistent with global school taxonomy efforts by the World Bank's Global Program for Safer Schools (GPSS). Other additional information was documented during field inspections, including school name and address, time of inspection, dimensions by block, education level, number of students, and year built. Figure 3-1 illustrates the inspection form in English.

The "seismic design level" entry on the form was defined per relevant historic building code changes in Kyrgyz Republic, as follows:

- Pre-code seismic design level: construction before 1970
- Low seismic design level: construction between 1970 to 1986
- Moderate seismic design level: 1987 to 2009
- High seismic design level: construction after 2010

Selection of corresponding cut-off dates corresponds to the major revisions of the local codes and technical regulations in seismic design (SNiP II.A-12-69, SNiP II-7-81 and SNiP II-7-81*, SNiP KR 20-02:2004, SNiP KR 20-02:2009), as well as consultation with the local engineering community. Additional time was allowed for construction of the projects designed after each major code revision. It is noted that the designation of "high" seismic design level is intended to communicate the use of recent local codes.

The "quality/condition" entry was completed by inspectors documenting evidence of rust coming out of cracks, spalled concrete cover, very low reinforcement ratio (steel area/concrete area), honeycombed concrete, or other issues that reduce strength relative to new construction. Accordingly, low, medium, and high quality conditions were defined as a lot, some, and no evidence of any of these issues, respectively.

A master spreadsheet with all the compiled data was developed and quality, completeness, and accuracy of the data were verified by the Local Data Collection Manager and spot-checked by the project team.

Seismic Performance-based Assessment of School Infrastructure in the Kyrgyz Republic

Inspector ______________________ Date __________ Start time __________

School ID ______________________ Building name ______________________

Address ____

Education level ________ Number of students __________ Year built ______________

Lateral system

Basic type, long axis	RC1 frame	RC2 infill walls	RC3 short columns	RC4 dual system	RC5 non-engineered	RC6 precast
	A adobe	UCM/URM unconfined, unreinforced	CM confined masonry	RM reinforced masonry		
Basic type, short axis	RC1 frame	RC2 infill walls	RC3 short columns	RC4 dual system	RC5 non-engineered	RC6 precast
	A adobe	UCM/URM unconfined, unreinforced	CM confined masonry	RM reinforced masonry		
Stories	1	2-3	4-7			
Irregularity	Horizontal & vertical	Horizontal only	Vertical only	No		
Seismic design level	Pre-code	1970 Low	1987 Moderate	2010 High		
Diaphragms	Flexible roof	Rigid roof	Flexible floor	Rigid floor		
Weak column	Yes long axis	No long axis	Yes short axis	No short axis		
Sensitive nonstructural elements	Chimneys	Parapets	Other falling hazards	No		
Mat foundation	Yes	No				
Pounding risk	Yes	No				
Seismic retrofit	Yes	No				
Quality, condition	Low	Medium	High	Structural system		

Blank means unknown

Comments: ____

____

Photograph the evacuation plan, the building passport, the cover page of any drawings, and provide a photo to support each assignment. Photograph the form and upload the photo of the form and all the other photographs to the Google Drive folder for that school and that building. Focus on classroom buildings, gymnasia, and perhaps connecting corridors if they are critical for evacuation.

Figure 3-1 Field inspection form in English.

3.4 GLoSI Taxonomy

The following GLoSI structural types were selected for use in the data collection forms:

- Reinforced concrete systems (based on Yamin et al. (2017)):
  - RC1, Moment frame
  - RC2, Moment frame with masonry infill (SNiP Subtype 2.3). Structural systems of concrete frame with masonry infill (RC2) in Kyrgyzstan are typically composed of interior concrete frames with exterior masonry bearing walls with concrete inclusions.
  - RC3, Moment frame with short columns
  - RC4, Dual wall-frame system
  - RC5, Non-engineered system
  - RC6, Precast concrete frame with exterior precast concrete panels (SNiP Subtype 2.6)
- Load-bearing masonry systems (based on Adhikari and D'Ayala (2017):
  - A, Adobe
  - UCM/URM, Unconfined/unreinforced masonry (SNiP Subtype 1.4, 1.5, 1.6)
  - CM, Confined masonry (SNiP Subtype 1.1, 1.2)
  - RM, Reinforced masonry

3.5 Data Collected

The data collected by field inspections were observed in different ways to inform the risk-based framework.

3.5.1 Distribution by GLoSI Typology

Table 3-1 provides the breakdown the data by typology. Percentages of the same typology in both directions are indicated by the lower percentage of the two axes.

Accordingly, the following three typologies were identified as most common in the field inspections:

- RC6, Precast concrete frame and walls
- CM, Confined masonry
- RC2, Concrete frame with masonry infill

The characteristics of each typology as typically observed in the field inspections are described in Chapter 4.

Table 3-1 Breakdown of Building Blocks Inspected by GLoSI Typology

Typology	*Symbol*	*Total (long axis)*	*Percent (long axis)*	*Total (short axis)*	*Percent (short axis)*
Moment frame	RC1	0	0%	1	0%
Concrete frame with masonry infill	RC2	73	17%	94	22%
Short columns	RC3	0	0%	0	0%
Dual system	RC4	2	0%	1	0%
Non-engineered	RC5	19	5%	19	5%
Precast concrete frame and walls	RC6	146	35%	124	30%
Adobe	A	1	0%	1	0%
Unreinforced masonry	UCM/URM	39	9%	38	9%
Confined masonry	CM	130	31%	131	31%
Reinforced masonry	RM	3	1%	3	1%
Other	N/A	8	2%	8	2%

3.5.2 Distribution by Construction Year

Figure 3-2 shows the distribution of inspected building blocks in accordance with seismic design level, assigned by the construction year report. Data are presented for long-axis GLoSI typologies for the prevalent building types. As can be seen in Figure 3-2, the majority of schools (approximately 78%) were constructed before the 1990s. The following is the breakdown of seismic design level per code changes in the country:

- 2% of the building blocks were constructed prior to 1970, which is considered pre-code (although it was the intention of the study to only inspect buildings built on or after 1970);
- 76% of the building blocks were constructed between 1970-1986, which is considered low seismic design;
- 18% of the building blocks were constructed between 1987-2009, which is considered moderate seismic design; and
- 4% of the building blocks were constructed after 2010, which is considered high seismic design.

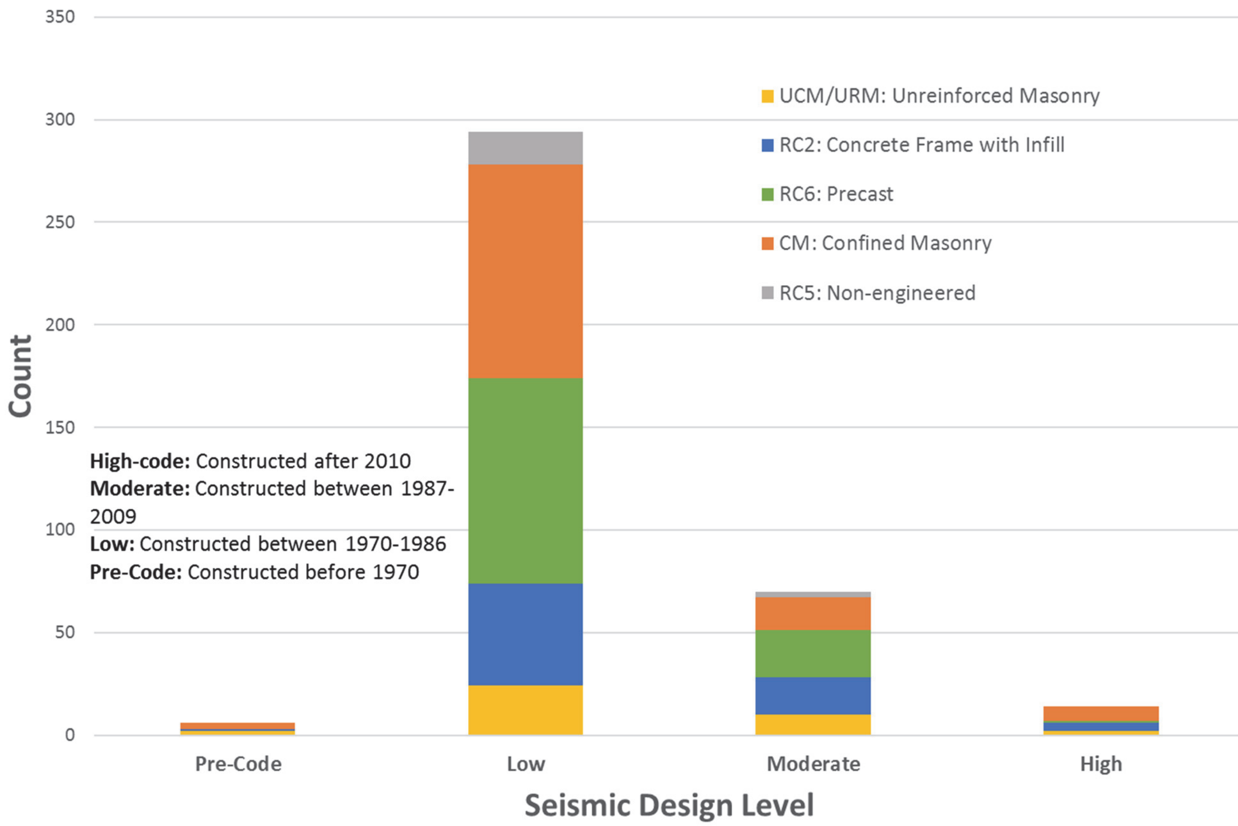


Figure 3-2 Distribution of seismic design level by school block.

3.5.3 Distribution of Attributes by Common Typology

The breakdown of attributes for each of the three most common typologies are summarized in Table 3-2, Table 3-3, and Table 3-4.

3.5.4 Presence of Drawings Onsite

Of the 78 school campuses that were inspected, 20 were indicated as having drawings, however, 8 of those had insufficient drawings, bad quality drawings, missing information, or no structural drawings. Of the 12 complexes that had good quality drawings, 8 school complexes were of the three prevalent typologies with the following breakdown: one confined masonry school campus, six reinforced frame with infill school campuses, and one precast school campus. In addition, structural drawings for one additional confined masonry school complex were also documented by the project team during the field visit.

Table 3-2 Breakdown of Attributes in Inspected CM: Confined Masonry Buildings

Category	*Attribute*	*Percentage*
Stories	1	31%
	2-3	69%
	4-7	0%
Seismic Design Level	Pre	0%
	Low	58%
	Moderate	32%
	High	5%
Irregularity	Horizontal & vertical	2%
	Horizontal only	19%
	Vertical only	5%
	No	74%
Roof Diaphragm	Flexible	2%
	Rigid	98%
Floor Diaphragms	Flexible	1%
	Rigid	92%
Weak Column	Yes (long axis)	1%
	No (long axis)	99%
	Yes (short axis)	1%
	No (short axis)	99%
Chimneys	Yes	3%
	No	97%
Parapets	Yes	2%
	No	98%
Other Falling Hazards	Yes	32%
	No	68%
Pounding Risk	Yes	32%
	No	67%
Seismic Retrofit	Yes	2%
	No	98%
Quality, Condition	Low	7%
	Medium	63%
	High	30%

Table 3-3 Breakdown of Attributes in Inspected RC2: Reinforced Concrete with Masonry Infill Buildings

Category	*Attribute*	*Percentage*
Stories	1	36%
	2-3	64%
	4-7	0%
Seismic Design Level	Pre	0%
	Low	53%
	Moderate	36%
	High	4%
Irregularity	Horizontal & vertical	14%
	Horizontal only	0%
	Vertical only	22%
	No	60%
Roof Diaphragm	Flexible	0%
	Rigid	100%
Floor Diaphragms	Flexible	0%
	Rigid	100%
Weak Column	Yes (long axis)	19%
	No (long axis)	81%
	Yes (short axis)	14%
	No (short axis)	85%
Chimneys	Yes	1%
	No	99%
Parapets	Yes	8%
	No	92%
Other Falling Hazards	Yes	32%
	No	68%
Pounding Risk	Yes	25%
	No	74%
Seismic Retrofit	Yes	1%
	No	99%
Quality, Condition	Low	5%
	Medium	55%
	High	40%

Table 3-4 Breakdown of Attributes in Inspected RC6: Precast Buildings

Category	*Attribute*	*Percentage*
Stories	1	27%
	2-3	73%
	4-7	0%
Seismic Design Level	Pre	0%
	Low	52%
	Moderate	48%
	High	0%
Irregularity	Horizontal & vertical	19%
	Horizontal only	24%
	Vertical only	0%
	No	56%
Roof Diaphragm	Flexible	1%
	Rigid	99%
Floor Diaphragms	Flexible	1%
	Rigid	91%
Weak Column	Yes (long axis)	10%
	No (long axis)	90%
	Yes (short axis)	10%
	No (short axis)	90%
Chimneys	Yes	0%
	No	100%
Parapets	Yes	9%
	No	91%
Other Falling Hazards	Yes	30%
	No	70%
Pounding Risk	Yes	46%
	No	54%
Seismic Retrofit	Yes	3%
	No	97%
Quality, Condition	Low	6%
	Medium	84%
	High	10%

Chapter 4
Characteristics of Structural Typologies

This chapter describes the typical characteristics of structural typologies observed most commonly in field inspections and used in seismic performance-based assessment and retrofit designs. Representative index buildings studied in Chapter 5 display the characteristics described herein.

4.1 Complex Masonry

One of the commonly identified GLoSI typologies in the field inspections is confined masonry where the definition includes load bearing masonry walls with horizontal seismic belts, regularly spaced vertical concrete or steel inclusions that assist in stabilizing (i.e., confining) the masonry walls in resisting in-plane and out-of-plane seismic forces, and hollow core precast concrete floor planks. Data from field inspections and available drawings indicate that confined masonry school buildings in Krygyz Republic occasionally have vertical reinforced concrete inclusions. Where they occur, the confining elements assist in stabilizing the masonry wall in resisting in-plane and out-of-plane forces. Accordingly, this typology could be more accurately described as complex masonry (CM). The typology has attributes of unreinforced masonry, confined masonry, and reinforced concrete frame construction, and thus it cannot be neatly categorized in the taxonomies used in the data collection efforts described in Chapters 2 and 3.

As summarized from inspection results in Table 3-2, CM school buildings in Krygyz Republic are generally rectangular in plan, one to three stories tall, have rigid diaphragms, are structurally separated from adjacent blocks, and generally do not include the presence of structural irregularities or weak columns. Most buildings of this type do not have appurtenances, such as chimneys, parapets, or other elements that represent falling hazards, and the buildings are generally in medium to good condition. Example buildings are shown in Figures 4-1 and 4-2. The following are typical characteristics for representative CM buildings:

- Buildings are one to two stories tall and rectangular in plan.
- Buildings are smaller and newer than the buildings in the CMCF typology.
- Gravity loads are carried by load bearing walls and headers at openings. No freestanding columns or long span beams were observed.
- The density of walls is greater than that found in the CMCF typology. The walls are also more regular in the configuration.
- The walls usually have vertical reinforced concrete inclusions at the boundaries, but this was not always observed. These boundary inclusions are lightly tied trim elements, rather than distinct

columns. They are rectangular in plan, with two long bars. The walls occasionally have inclusions that are configured as distinct square columns.

- Rigid floor and roof diaphragms are formed with hollow core precast concrete planks tied to perimeter belt beams integrated in the load bearing walls. Available drawings for both the CM and CMCF buildings referred to a common Series catalogue of assembly details for this condition. The diaphragms are untopped and work through clamping action from the belt beams.
- Nonstructural partitions occur. These are made with unreinforced masonry elements and poorly connected to the structure.
- The roof shape is formed with light timber framing.
- Light entry structures are present.
- Irregularities, weak columns, chimneys, parapets, other falling hazards, pounding, or seismic retrofit were not observed.

Information is based on structural drawings collected during the field inspections. The availability of drawings was limited. Accordingly, characteristics described are primarily qualitative, and the findings are informed by the drawing review.

Figure 4-1 Two-story CM school building in Osh that was selected as a representative index building.

Figure 4-2 Typical one-story (top) and two-story (bottom) CM school buildings in Kyrgyz Republic.

4.2 Complex Masonry with Concrete Framing

A second commonly identified GLoSI typology in the field inspections was concrete frame with masonry infill (RC2). Data from field inspections and available drawings indicate that these type of school buildings in Krygyz Republic include some column and beam elements but lack the regular spacing of horizontal and vertical elements comprising a complete monolithic frame. Accordingly, this typology could be more accurately described as complex masonry with concrete framing (CMCF). The CMCF typology is typically composed of a mix of interior concrete frames and masonry bearing walls, the latter of which occur in both interior and exterior conditions, and occasional interior concrete framing of beams and columns. Masonry bearing walls have concrete inclusions, both in the form of distinct square columns and rectangular trim elements. The typology has hollow core precast concrete floor planks connected to horizontal concrete seismic belts within the masonry walls. While similar to the CM typology described above, the CMCF typology has occasional concrete beams and columns and is defined to be larger and more complex than its CM counterpart. It is observed that CMCF school buildings in Krygyz Republic have similarities to the commonly accepted definitions for both confined masonry and reinforced concrete frames with masonry infill buildings.

As summarized in Table 3-3, CMCF school buildings in Krygyz Republic are generally rectangular in plan, one to three stories tall, have rigid diaphragms, are structurally separated from adjacent blocks, and generally do not include the presence of structural irregularities or weak columns (although horizontal and vertical irregularities and weak columns do exist in some cases). Most buildings of this type do not have appurtenances such as chimneys, parapets, or other elements that represent falling hazards, and the buildings are generally in medium to good condition. Example buildings are shown in Figures 4-3 through 4-6. The following are typical characteristics for representative CMCF buildings:

- Buildings are typically three stories tall and comprise rectangular blocks. The blocks are arranged to form complex buildings. The blocks are separated by seismic joints that could pound during an earthquake.
- Buildings are larger and older than the buildings in the CM typology. The blocks and plans are also more irregular.
- Buildings may have partial basements.
- At the perimeter along the longitudinal elevations, gravity loads are carried by load bearing walls and headers at openings. The three-story load-bearing walls for CMCF are thicker than those observed in the two-story CM typology.
- At interior lines of support, gravity loads are carried by load bearing walls, beams, and columns. Freestanding columns and long span beams occur.
- The density of walls is less than that found in the CM typology.
- The walls typically have vertical reinforced concrete inclusions at the boundaries, but this was not always observed. These boundary inclusions are lightly tied trim elements, rather than distinct columns. They are rectangular in plan, with two long bars. The walls occasionally have inclusions that are configured as distinct square columns.
- Rigid floor and roof diaphragms are formed with hollow core precast concrete planks tied to perimeter belt beams integrated in the load bearing walls. Available drawings for both the CM and CMCF buildings referred to a common Series catalogue of assembly details for this condition. The specific details are larger for the CMCF conditions. The diaphragms are untopped and work through clamping action from the belt beams.
- Nonstructural partitions were present. These are made with unreinforced masonry elements and are poorly connected to the structure.
- The roof shape is formed with light timber framing.
- Gymnasiums are present in these schools. Pounding at misaligned levels is a vulnerability.
- Other irregularities, weak columns, chimneys, parapets, other falling hazards, or seismic retrofit were not observed.

Information is based on structural drawings collected during the field inspections. The availability of drawings was limited. Accordingly, characteristics described are primarily qualitative, and the findings are informed by the drawing review.

Figure 4-3 Exterior of CMCF school building in Osh that was selected as a representative index building.

Figure 4-4 Interior of CMCF school building in Osh, Kyrgyz Republic. Structural drawings for this school building were used as a sample to analyze the CMCF typology.

Figure 4-5 Typical exterior of CMCF school buildings in Kyrgyz Republic.

Figure 4-6 Typical interior of CMCF school buildings in Kyrgyz Republic.

4.3 Precast Concrete Frames and Walls

The commonly accepted definition for a precast concrete frame and wall building (PC) includes a complete precast concrete frame system with both large panel precast wall panels (in which panels extend the full story height between floor levels) and small panel precast wall panels (in which panels span horizontally between column elements, and multiple panels are required to enclose a story level). Based on data from field inspections and available drawings, the PC typology for school buildings in Krygyz Republic includes precast concrete frames and small precast wall panels.

As summarized in Table 3-4, PC school buildings in Krygyz Republic are generally rectangular in plan, one to three stories tall, have rigid diaphragms, are structurally separated from adjacent blocks (but in many cases the provided separation is not sufficient to prevent pounding), and generally do not include the presence of structural irregularities or weak columns (although horizontal and vertical irregularities and weak columns do exist in some cases). Most buildings do not have appurtenances, such as chimneys, parapets, or other elements that represent falling hazards, and the buildings are generally in medium to good condition. An example building is shown in Figure 4-7. The following are typical characteristics for representative PC buildings:

- The framing system consists of precast columns, precast beams, precast hollow core planks and precast wall panels.
- The wall panels are detailed to not participate in carrying either vertical or lateral loads.
- Rigid floor and roof diaphragms are formed with hollow core precast concrete planks. These are tied to perimeter precast beams. The diaphragms are untopped and work through clamping action from the precast beams.
- Nonstructural partitions are present. They are made with unreinforced masonry elements and are poorly connected to the structure.
- Gymnasiums are present in these schools. Pounding at misaligned levels is a vulnerability.
- Irregularities, weak columns, chimneys, parapets, other falling hazards, or seismic retrofit are not present.

Information is based on limited structural drawings collected during the field inspections. Only incomplete sets of structural drawings for buildings of this typology were available during the field inspections and follow-up inquiries. Various relevant catalogues for precast concrete school buildings in Kyrgyz Republic (IIS-04 series) were collected and reviewed to identify details of construction that could be considered typical. However, due to missing critical information, assumptions were made.

Figure 4-7 Typical RC6 classroom block in Kyrgyz Republic.

Chapter 5
Seismic Retrofit Design using Performance-Based Assessment

This chapter describes the conduct of performance-based assessments and design of seismic retrofits for three school blocks in Kyrgyz Republic. The blocks serve as representative index buildings for the three structural typologies described in Chapter 4. The index buildings are evaluated in as-is and retrofit conditions using static nonlinear pushover analyses; a graphical display of the pushover analyses is especially useful for comparing the relative capacities of the various increments for the index buildings. This chapter also presents the cost estimates developed for the index buildings.

5.1 Approach

To prioritize among an inventory of school buildings, determine benefit-cost ratios, and identify the most beneficial retrofit solutions at scale, retrofit schemes were developed to incrementally address seismic deficiencies and incrementally reduce the associated risk. In such an approach, the absolute performance is less important, and the relative improvement associated with each retrofit increment is a key consideration in identifying practical solutions that have the greatest benefit in lives saved versus cost. Trade-offs between acceptable levels of performance and practical (i.e., cost-effective) retrofit solutions is a strategy that is regularly used in the United States and internationally.

Conceptual retrofit designs were prepared for multiple retrofit increments for each index building. Representative index buildings were selected based on availability of structural drawing information and consistency with typical characteristics described in Chapter 4. The objective of a seismic retrofit is to increase the seismic capacity of a building, increasing the building's ability to resist seismic demands. The general seismic retrofit approach in each increment involves providing additional strength to resist earthquake forces, additional stiffness to limit building movement (drift), or the addition of supplemental elements to allow additional displacement and maintain integrity in an earthquake.

The retrofits are described as retrofit increments, from 1 to 4. Increment 1 provides the lowest increase in capacity for the lowest cost whereas Increment 4 achieves the highest level of capacity for the highest cost. The increments build upon each other within each index building. For example, Increment 3 includes all the improvements of Increment 2, which includes all the improvements of Increment 1. An intermediary level, Increment 3.5 was developed for two of the typologies. Each increment was created with specific design goals and performance objectives. The benefit from each level of retrofit is calculated in accordance with the methodology described in Chapter 6 in terms of a safety benefit.

The configurations, details, and material properties were determined from construction drawings collected during the inspection process. Complete drawings were not available for all index buildings.

Accordingly, assumptions were made when there was missing information in the available drawings. Material properties used for evaluation are based on the specified nominal values from drawings, adjusted for expected strength, per general recommendations of ASCE/SEI 41-17, *Seismic Evaluation and Retrofit of Existing Buildings* (ASCE, 2017b).

5.1.1 Performance Objectives

The index buildings in their as-is conditions were evaluated for two performance objectives, life safety (LS) and collapse prevention (CP). Life safety is a state that poses a danger for either for injury and loss of life that could occur with a partial collapse within the building resulting from accelerations experienced by components of the building or from drifts within the building. Collapse Prevention (CP) is a state that poses a danger for either for injury and loss of life that could occur with a side-sway collapse of a major portion of the building. The fatality rates due to reaching these limit states are described in Chapter 6.

Each retrofit increment has different design objectives. All retrofit increments improve capacity, but not all meet the CP or LS performance objectives. Figure 5-1 is an illustration of how each retrofit increment differs in the strategy for adding displacement capacity, strength, resistance to collapse, and resistance to falling hazards.

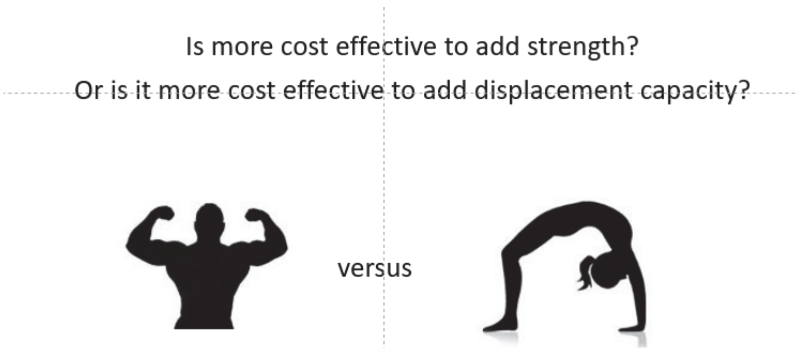


Figure 5-1 Graphic illustration depicting design for strength vs. flexibility.

Relative capacities of the increments are a progression starting from the as-is condition of the building. A series of partial collapse failures are expected in the as-is condition of each typology due to increased accelerations acting on components of the building even at relatively low levels of shaking from relatively frequent earthquakes. Examples include the out-of-plane failure of heavy nonstructural wall partitions, out-of-plane failures of non-load-bearing structural walls, and other similar events. In the retrofit approach, these initial series of failures are lumped into a single event because they occur at similar accelerations and deformations. Early failures do not occur due to drift in masonry buildings because they are stiff and brittle. These types of failures occur prior to a side-sway collapse of the overall building.

Increment 1 is designed to mitigate these initial failures and allows the existing building to reach its full capacity in terms of peak strength, but does not improve the displacement capacity. Once the retrofit of Increment 1 is in place, the next event is the global collapse of the buildings due to a side-sway mechanism.

Increment 2 is designed to increase seismic resistance of the building, primarily by increasing the displacement capacity prior to collapse. This is accomplished by a variety of means which differs for each typology. It is intended to add benefit primarily by forestalling the CP limit state.

Increment 3 is designed to further increase seismic resistance of the building by adding significant strength in addition to displacement capacity.

Increment 4 is designed to further increase seismic resistance of the building. It is aligned to satisfy the strength requirements expected in the upcoming Krygyz code for retrofits (see Appendix D for more information). Increment 4 is the only retrofit with significant foundation strengthening. It is intended to improve both the LS and CP limit states.

5.1.2 Structural Analysis

Index buildings were analyzed using pushover analysis techniques based on nonlinear static analysis procedures in ASCE/SEI 41-17. Two different analysis techniques were used to create the pushover curves for the index buildings and their retrofits:

- The CM and CMCF index buildings are dominated by the response the brick masonry wall elements. Both buildings are relatively stiff, and the behavior is more influenced by the strength and the nonlinear response of the elements, as compared to the elastic stiffness. The piers and walls vary greatly throughout the structure due to variation in size, the presence of inclusions, and variation of axial loads. The response tends to be controlled by brittle behavior. For these reasons, the overall capacities were determined by summing the backbone curves of the individual elements. The curves are per ASCE/SEI 41-17.
- The precast index building (PC) has a flexible frame and a relatively regular configuration. The response is dominated by the stiffness of the frame. An inelastic model was created using fiber elements to capture the flexibility and the nonlinear response.

Capacities were determined using nominal strengths per the drawings and modified for expected strength properties and material strength equations of ASCE/SEI 41-17. The masonry strengths and the expected strength were selected per the Krygyz Code. Material strength information was assumed when specific information was not available.

Performance was evaluated using limit state criteria contained in ASCE/SEI 41-17, and overall structural system capacities were compared to demands using a capacity spectrum approach, which modifies demand spectra to account for energy dissipation, associated with nonlinear response. The capacity spectrum method per Fajfar (1999) and as outlined in ATC-40, *Seismic Evaluation and Retrofit of Concrete Buildings* (ATC, 1996), was used for the following reasons:

- Pushover analysis is referenced in the new Kyrgyz code for retrofit. However, as of this writing, the performance states and acceptance criteria have not been defined.
- The method allows efficient processing of results under several hazards, integrating over multiple levels of shaking from multiple sites across the country.

- The method allows efficient processing of multiple retrofit increments.
- The method allows evaluation at specific performance points, such as LS and CP.
- The method provides a clear graphical display of a building's strength capacity.
- The method allows a clear comparison among all the increments of an index building. The relative capacity of the increments is important to determine the efficiency of increments.

Per Fajfar, the demand spectra are expressed in terms of ductility rather than damping.

5.1.3 Cost Estimates

Cost estimates were developed for each of the conceptual retrofit increments based on 2018 Kyrgyz rates and construction norms. Structural costs were calculated by directly accounting for labor and materials shown for each retrofit. The cost needed for the removal and restoration of finishes in kind was determined as a factor applied to the structural cost of each increment. The factor was determined by performing a detailed take-off and estimate of finish costs for Increment 4 of the precast typology and calculating the ratio of architectural cost to structural cost. Based on the case study the architectural finish costs are on the order of 16.7% of the structural costs. This factor was also applied to all the increments of other typologies. In addition, a contingency for unaccounted general expenses was taken as 5% of the structural cost, and value added taxes (VAT) as 12%. Costs for improving energy efficiency (EE) and water, sanitation, and hygiene (WASH) components were provided as 98.2 USD per square meter.

The retrofit levels compare as follows:

- The ratio of structural costs for Increment 1 to Increment 4 ranges from 5% to 24%.
- The ratio of structural costs for Increment 2 to Increment 4 is approximately 50%.
- The ratio of structural costs for Increment 3 to Increment 4 is approximately 85%.

5.2 Complex Masonry Index Building

The complex masonry (CM) index building is based on School Number 37 named after Aitiev in Osh, shown in Figure 5-2. It comprises two stories with a single loaded corridor the feeds classrooms. The floors and roof are anchored to a reinforced concrete belt beam that is integrated in the walls at the floor and roof levels. The planks have grouted shear keys that work with the belt beam to create the diaphragm. The diaphragm is untopped and has limited capacity to transfer seismic loads.

The lateral-load-resisting system consists of unreinforced walls of masonry (Figure 5-3). However, the reinforced concrete vertical inclusions can interact with the masonry to create ties within the wall piers. Exterior wall piers are regular in appearance but vary with regards to axial loads and the type, or lack of, reinforced concrete vertical inclusions.

Figure 5-2 A photo of School Number 37 in Osh. It is the basis for the CM index building.

Figure 5-3 Partially fired masonry units from Kyrgyzstan (S. Brzev).

5.2.1 Seismic Deficiencies

Unreinforced and lightly reinforced masonry buildings have demonstrated poor performance in past earthquakes. Masonry walls have limited capacity to resist in-plane and out-of-plane forces and deformations associated with earthquakes, resulting in the possibility for brittle response and subsequent loss of vertical and lateral load-carrying ability. Often, weak or inadequate diaphragms provide limited ability to develop wall anchorage forces into the building and to distribute loads to other elements of the lateral-force-resisting system. However, presence of reinforced concrete belt beams and positive ties to precast hollow core floor and roof planks found in this typology provides more wall tie capacity than many other types of brick construction.

The following seismic deficiencies are present in confined masonry buildings:

- Inadequate strength and brittleness of masonry walls

- Lack of positive connection between masonry walls and floor or roof diaphragms parallel to floor and roof planks
- Inadequate lateral capacity for nonstructural masonry partitions
- Inadequate lateral anchorage for the entry structure

5.2.2 In-Plane Analysis

The weight of the index building was calculated based on available information and subjected to two types of actions:

- Increasing lateral forces were applied in each primary direction using loads proportional to a triangular distribution of accelerations (pushover analysis) to determine the in-plane response of walls and piers.
- Internal accelerations were applied to the out-of-plane and anchorage capacity of elements at each level that correspond to the base shear resulting from the pushover. (Buildings made stronger through retrofit generate higher internal accelerations.)

For shear, the masonry piers were evaluated individually for the following mechanisms: bed joint shear (Figure 5-4a), diagonal shear (Figure 5-4b), and diagonal compression of the strut (Figure 5-5). The strut was only checked as part of a strut-and-tie mechanism when the pier was bounded by concrete inclusions that could form a tie. Piers were also evaluated for the following flexural mechanisms: flexure with toe crushing, and rocking, as shown in Figure 5-6.

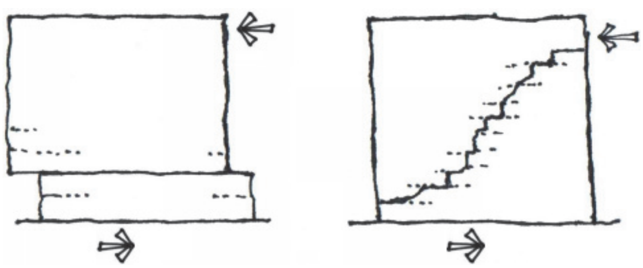


Figure 5-4 Bed joint shear and diagonal shear mechanisms.

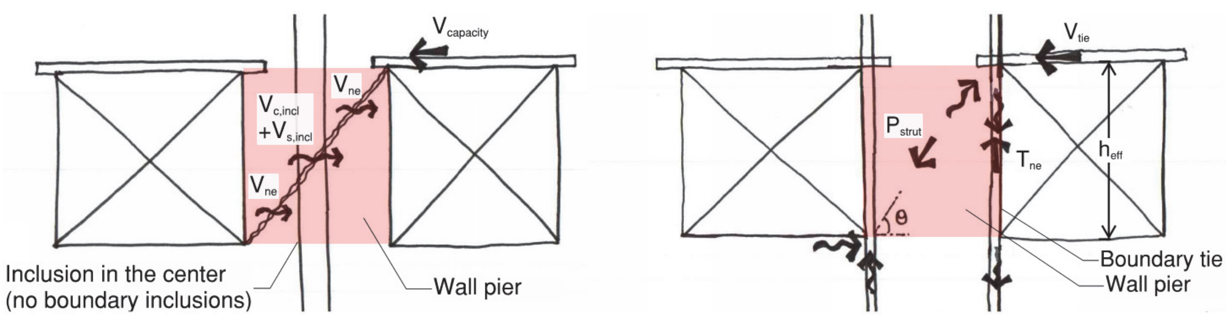


Figure 5-5 Diagonal shear mechanism with inclusions and strut-and-tie mechanism with ties from inclusions.

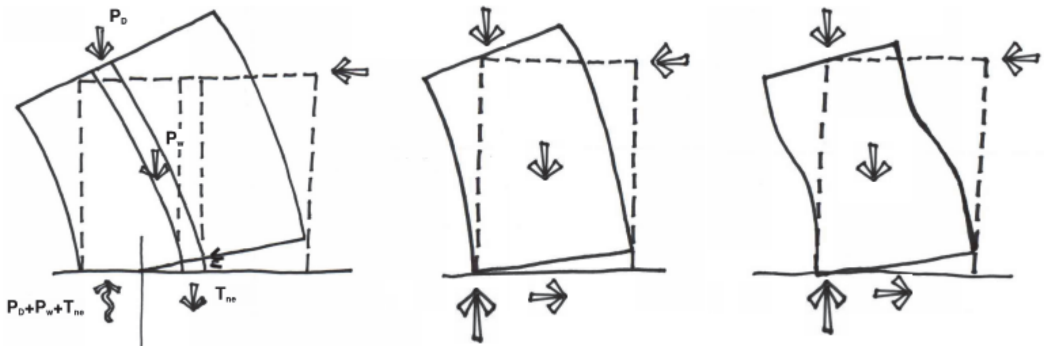


Figure 5-6 Flexure with toe crushing and flexure with rocking mechanisms.

The pier and wall capacities were tabulated for each mechanism. Figures 5-7 through 5-11 show the layout of the walls and piers and the presence of inclusions. The inputs are the geometry, the reinforcement from inclusions where applicable, and the axial load on the element due to self-weight plus the floor and roof framing. The controlling mechanism for each pier and wall was used to select backbone curve and the corresponding limit states per ASCE/SEI 41-17. Backbone curves were aggregated for each controlling direction to create the nonlinear pushover curves for the building. The initial stiffness was determined by flexibility of the piers and walls adjusted to account for the added flexibility from the diaphragm and the foundation.

For interior longitudinal and transverse walls, both one- and two-story mechanisms were evaluated, and two-story flexure with toe-crushing and rocking were found possible in the unretrofitted and retrofitted cases, respectively. In the longitudinal direction, the diaphragm is judged to be capable of distorting, in order to accommodate a two-story mechanism for the interior walls and a one story-mechanism for the exterior walls. This is because the diaphragm does not have a topping slab. It is comprised of individual planks spanning the transverse direction with shear keys between members and clamped together by the surrounding belt beam.

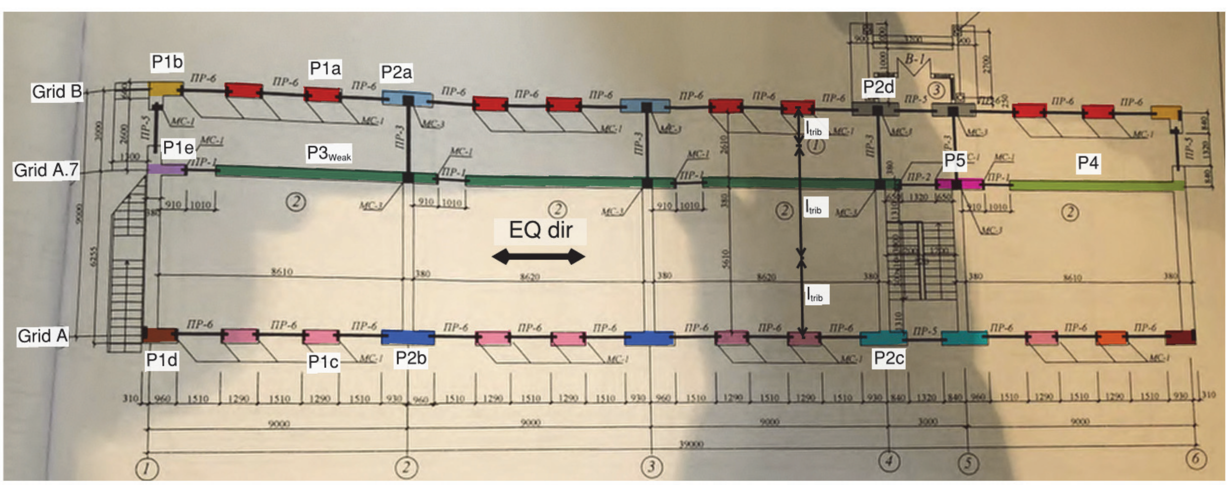


Figure 5-7 Map of participating piers and walls contributing to the longitudinal pushover.

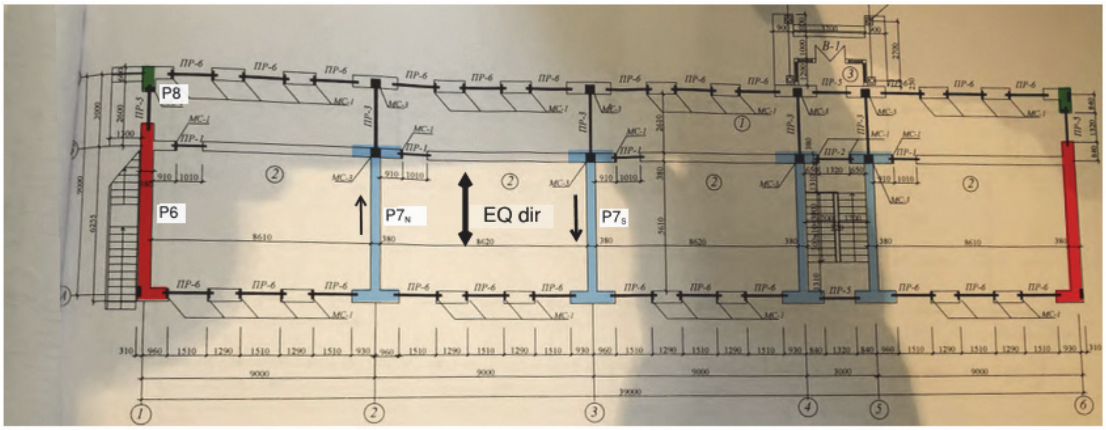


Figure 5-8 Map of participating piers and walls contributing to the transverse pushover.

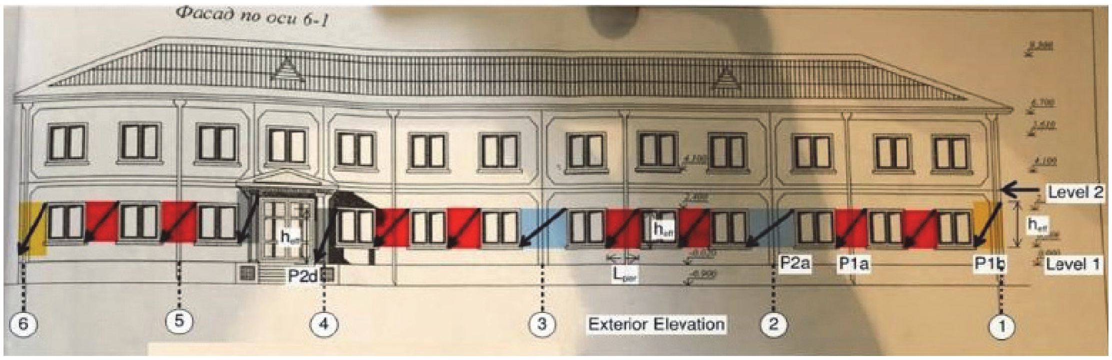


Figure 5-9 Map of exterior piers.

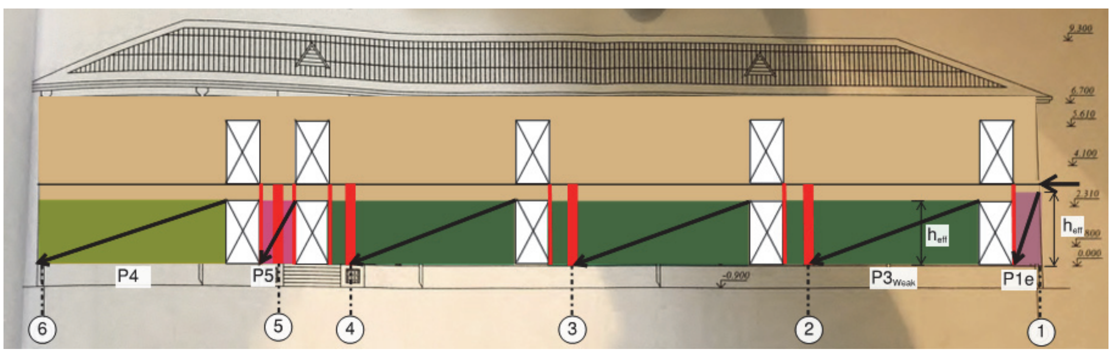


Figure 5-10 Map of interior walls.

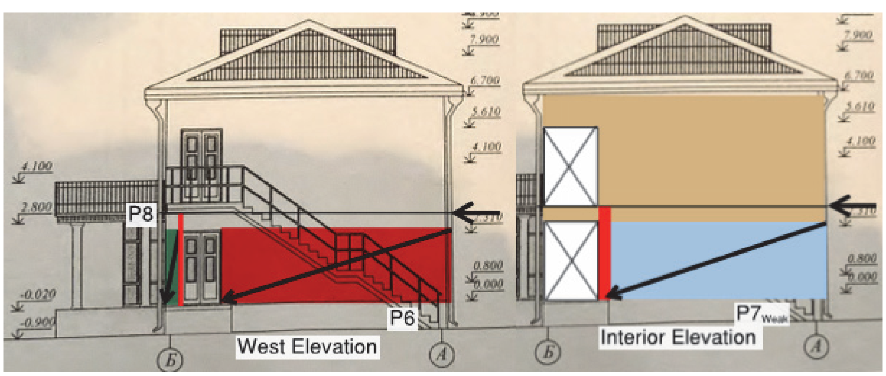


Figure 5-11 Transverse walls.

5.2.3 *Out-of-Plane Analysis*

Selected components of the building were subjected to accelerations that would be expected at the point of a side-sway collapse of the unretrofitted building. These include out-of-plane actions on walls, partitions, the entry structure, and the timber roof above the hollow-core concrete plank diaphragm. Failure of these items constitutes a partial collapse. The expectation is that these components would be retrofitted as part of any retrofit increment. Increment 1 eliminates these initial failure mechanisms and the ensuing capacity would be that of the overall building under the controlling side-sway collapse mechanism.

The following items are checked as part of the out-of-plane evaluation:

- Unreinforced structural walls subjected to out-of-plane forces. The walls were found to be adequate based on the height to thickness ratios per ASCE/SEI 41-17.
- Anchorage of the structural walls below the belt beams (as shown in Figure 5-12 and Figure 5-13). The resistance comes from friction due to normal forces. Upper-story transverse walls were found to fail because they are not load bearing, and there are low friction forces. This mechanism is mitigated in Increment 1.
- Anchorage and out-of-plane capacity of nonstructural masonry partitions. Partition walls were found to fail because they are very slender and do not have positive connection to the diaphragms. They are retrofitted or replaced with light gage gypsum sheathed walls in Increment 1.
- Anchorage of the entry structure. This was found to be inadequate. This is retrofitted as part of Increment 1.

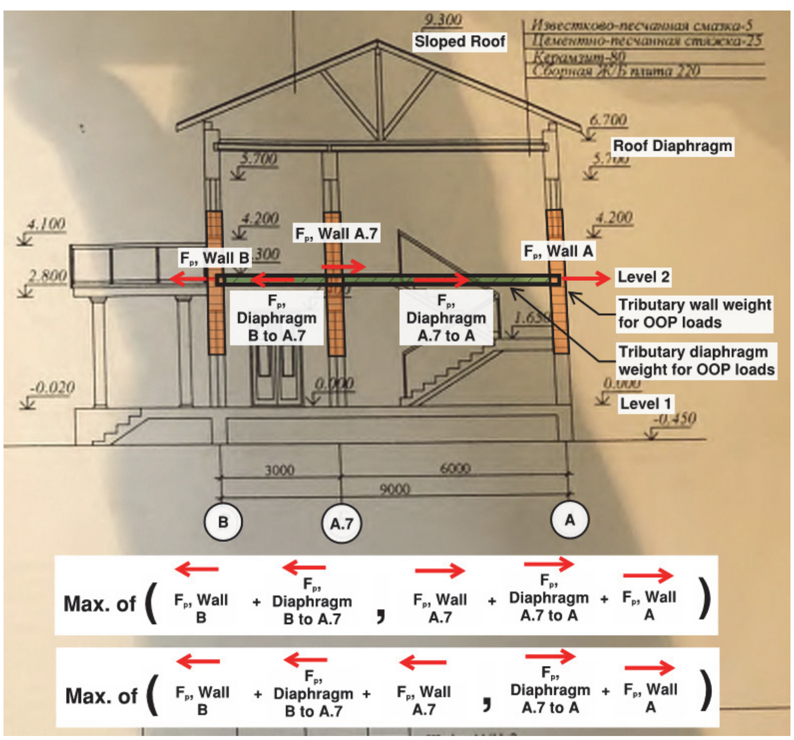


Figure 5-12 Anchorage demands for out-of-plane wall evaluations.

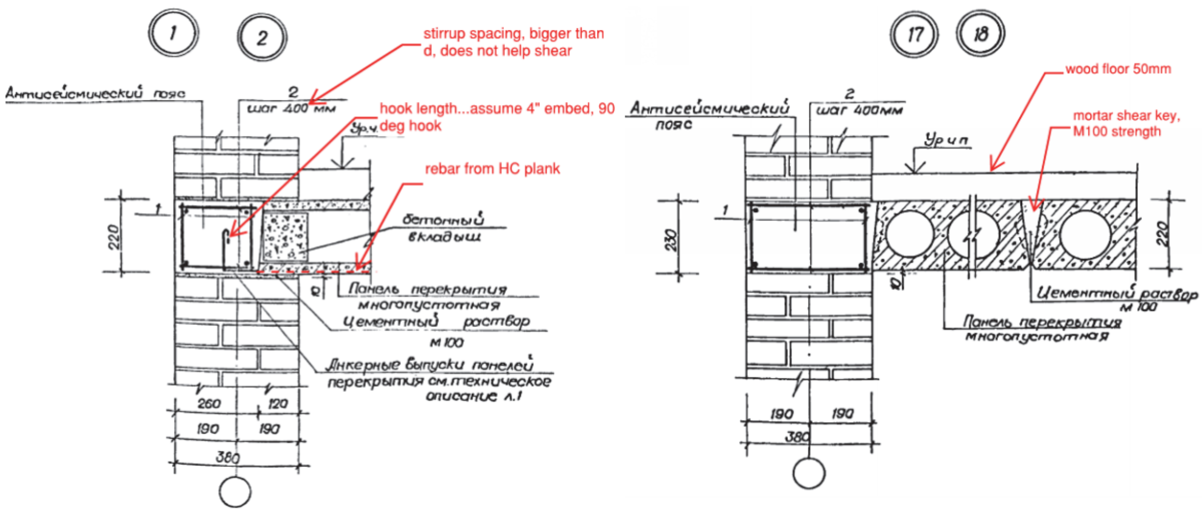
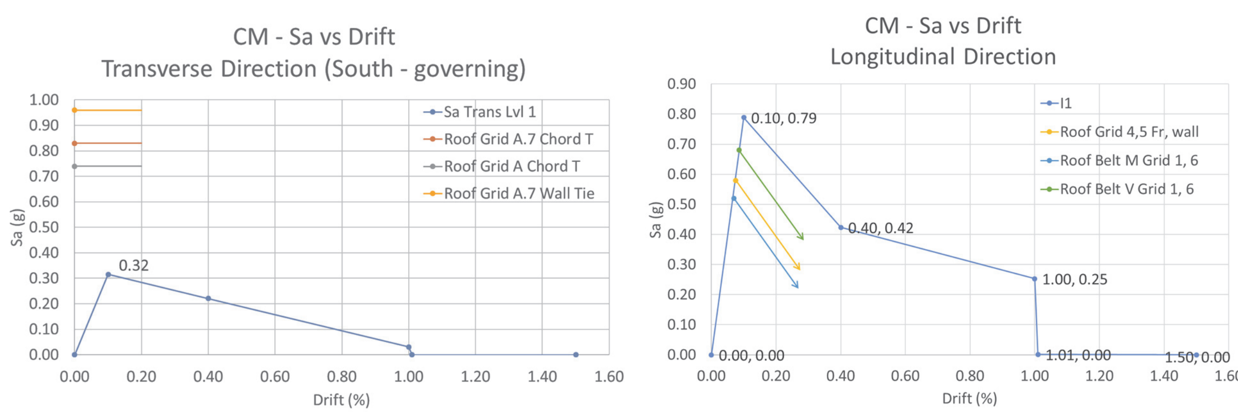


Figure 5-13 Plank to wall details. Note the positive anchorage in the load bearing direction and lack of anchorage in the non-load bearing direction.

5.2.4 *Existing Capacity*

Partial collapse failure of the nonstructural partitions and entry structure is expected for the CM index building prior to reaching the controlling sidesway collapse in the transverse direction. As shown in Figure 5-14, the strength limit in the transverse direction is 0.32W, where W is the building's weight. The governing failure mechanisms in the transverse direction are flexure with toe-crushing. Other partial collapse mechanisms would be expected to occur prior to reaching the controlling sidesway collapse in the longitudinal direction. The strength limit in the longitudinal direction is 0.79W. The failure modes in the longitudinal direction are a mix of flexural toe-crushing and sliding shear. The backbone curves are constructed for each direction by adding individual backbone curves for the piers. Each pier is evaluated to determine its controlling mechanism. The individual pier backbone curves and limits are from ASCE/SEI 41-17. This assumes that the partial collapse modes have been retrofitted in Increment 1. Consequently, the curves eliminate detail between events.



(a) (b)

Figure 5-14 CM pushover curves in the as-is condition, assuming partial collapse mechanisms have been retrofitted per Increment 1: (a) transverse direction; and (b) longitudinal direction. The curves for each direction are the summation of the backbone curves for the individual piers.

5.2.5 Conceptual Retrofits

In order to eliminate seismic deficiencies in the CM index building, the following conceptual retrofit measures are recommended. Each retrofit has two performance points for the controlling direction: CP when the building reaches a sideways collapse and LS when there are safety risks from falling bricks. The limits generally follow ASCE/SEI 41-17. Most of the increments are designed primarily to improve the response for the CP limit state, except for Increment 4 that is explicitly designed to improve the response for LS.

The following sections discuss improvements implemented with each retrofit increment. Conceptual plans and typical details are provided in Appendix E.

Increment 1

Increment 1 for CM eliminates the partial collapse mechanisms that would be expected prior to the building reaching a complete sidesway collapse in both directions. The efficiency for this retrofit increment cannot be known without the complete processing of the risk framework. There are several influencing factors including the specific hazard at the particular sites and the cost of the work. Moreover, although the work is relatively inexpensive, the partial collapse mechanisms are assigned a much lower fatality rate, compared to the collapse mechanisms (1.5% vs. 30%, as explained in Chapter 6). The elements that are improved in this increment are as follows:

- Nonstructural masonry partitions are braced using a light reinforced concrete skin anchored to the diaphragms (Figure 5-15). An alternative solution is to replace the partitions with light gage steel framing with gypsum board sheathing.

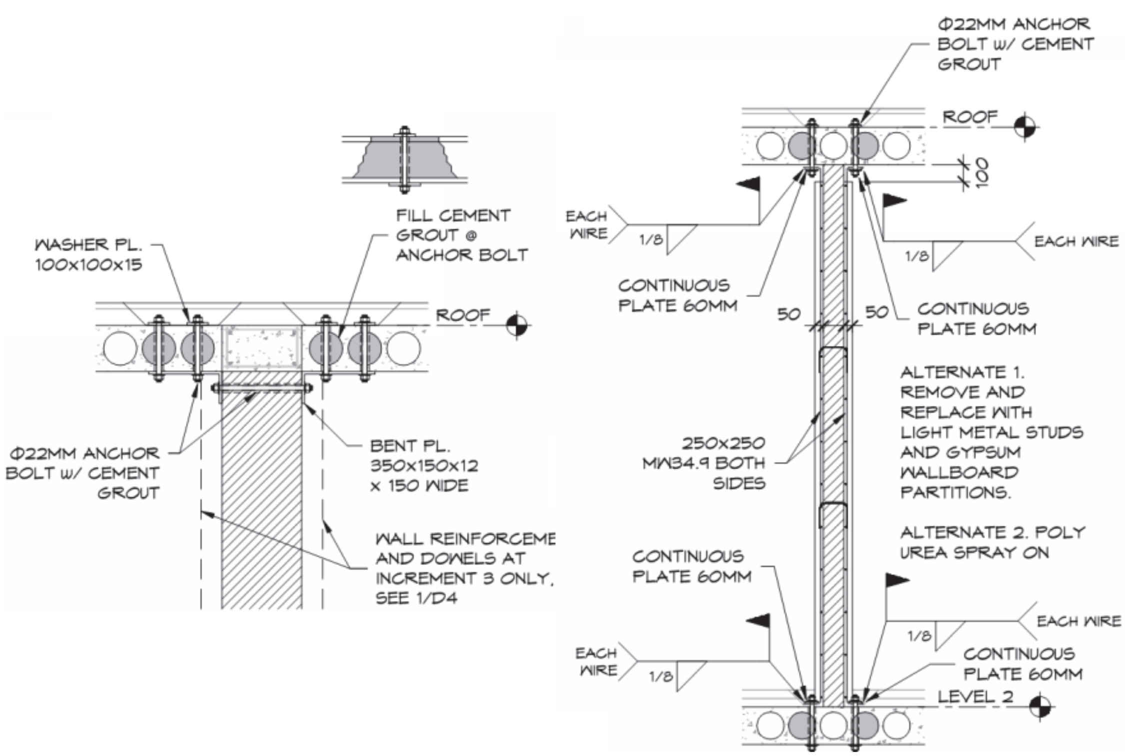


Figure 5-15 Details of CM Increment 1 showing bracing of nonstructural masonry walls.

- The steel framed entry is secured to structural walls with through bolts welded to the entry.
- Connection of transverse walls to the belt beams is strengthened at the roof level against shear failures from out-of-plane accelerations.
- Exterior belt beams are strengthened at the roof level against out-of-plane accelerations.

Increment 2

Increment 2 for CM builds on Increment 1 and adds displacement capacity to the controlling mechanisms. For the controlling transverse direction, the flexural toe-crushing mechanism is eliminated by adding reinforced shotcrete jackets applied to ground floor walls to induce stable rocking. The strong but brittle response of the longitudinal walls are also eliminated. No foundation work is performed with this increment.

The following elements that are improved in this increment are as follows:

- Reinforced concrete jackets are added to ground floor transverse walls (Figure 5-16) create a rocking mode. The jackets are grouted with epoxy dowels into tops of the unreinforced concrete footings to prevent sliding for higher displacements.
- Reinforced concrete jackets are added to ground floor internal longitudinal walls to eliminate brittle response and create a rocking mode.
- Two-story "finger" piers connected to a common base are added to exterior longitudinal walls (Figure 5-17). The fingers occur at every fourth brick pier and form flexural hinges at their base and induce a tilting mechanism more compatible with interior rocking walls (Figure 5-18).
- Roof and floor diaphragms are improved by adding perimeter belt beams to supplement the existing belt beam.
- Floor and roof planks are better secured to the reinforced perimeter belt beam. This connection along with the supplemental belt beam create a safety tether to secure floor and roof planks as load bearing exterior piers lose gravity capacity.

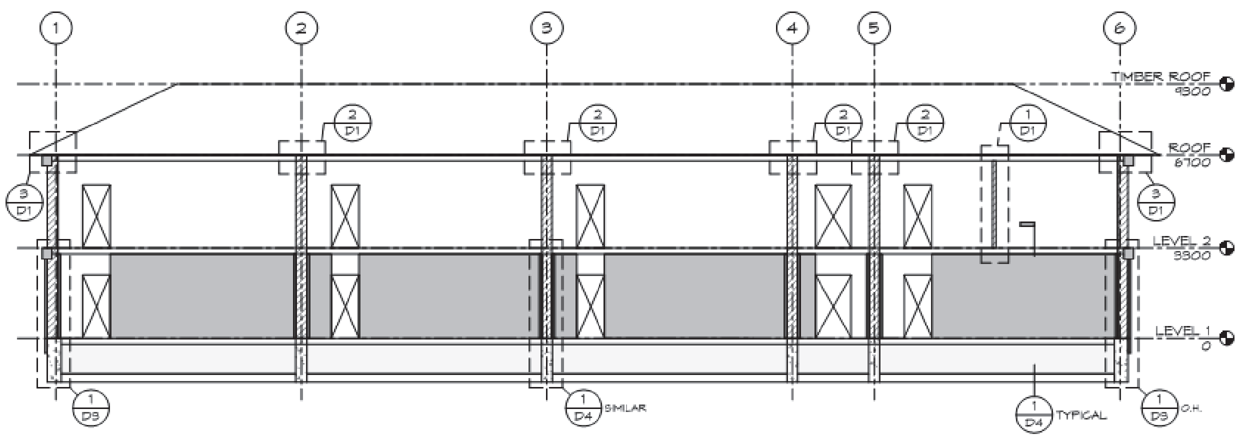


Figure 5-16 Reinforced concrete jackets added in CM Increment 2.

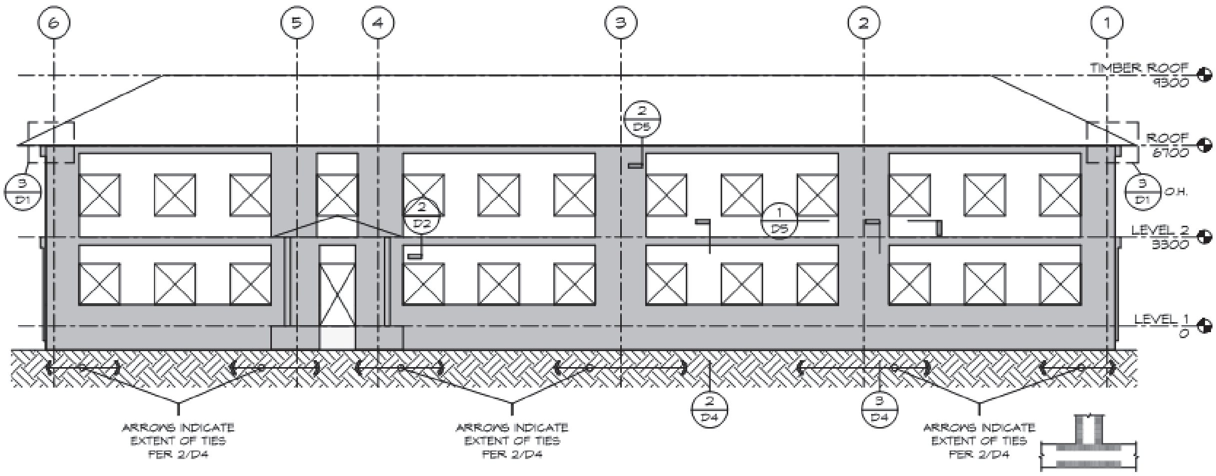


Figure 5-17 Reinforced concrete finger piers added in CM Increment 2.

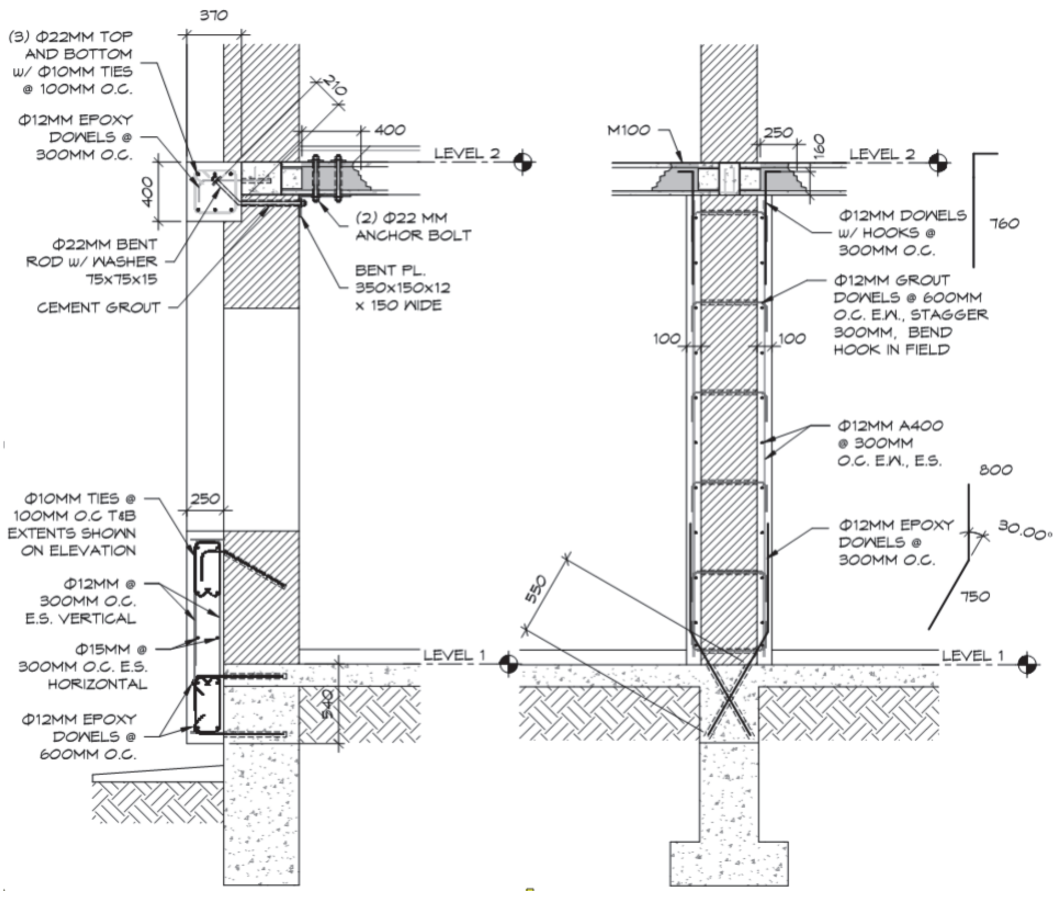


Figure 5-18 Detail of finger piers in CM Increment 2.

Increment 3

Increment 3 is similar to Increment 2 but the jackets for the interior walls extend two levels in both transverse and longitudinal directions. The two-level jackets eliminate uncertainty in the response of the walls by eliminating unprotected bricks. This allows higher rocking displacements at the collapse limit.

Increment 3.5

Increment 3.5 adds strength to Increment 3 in the controlling transverse direction in order to meet the minimum strength requirements expected for the forthcoming Kyrgyz retrofit code.

Transverse grade beams are added to interior walls (Figures 5-19 and 5-20). The grade beams work with the rocking mechanism. Ductile plastic hinges form during the response.

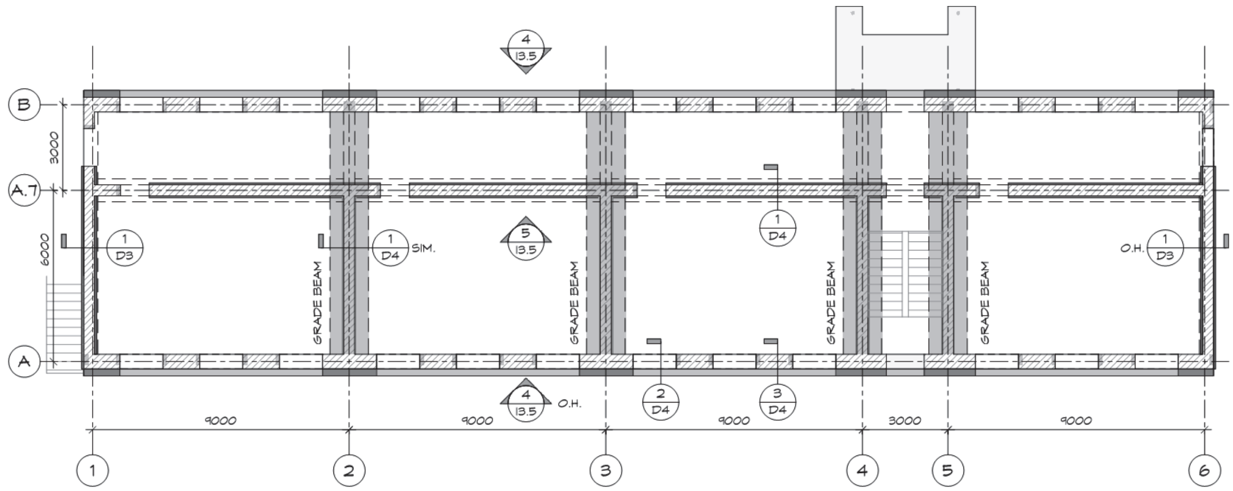


Figure 5-19 Transverse grade beams added in CM Increment 3.

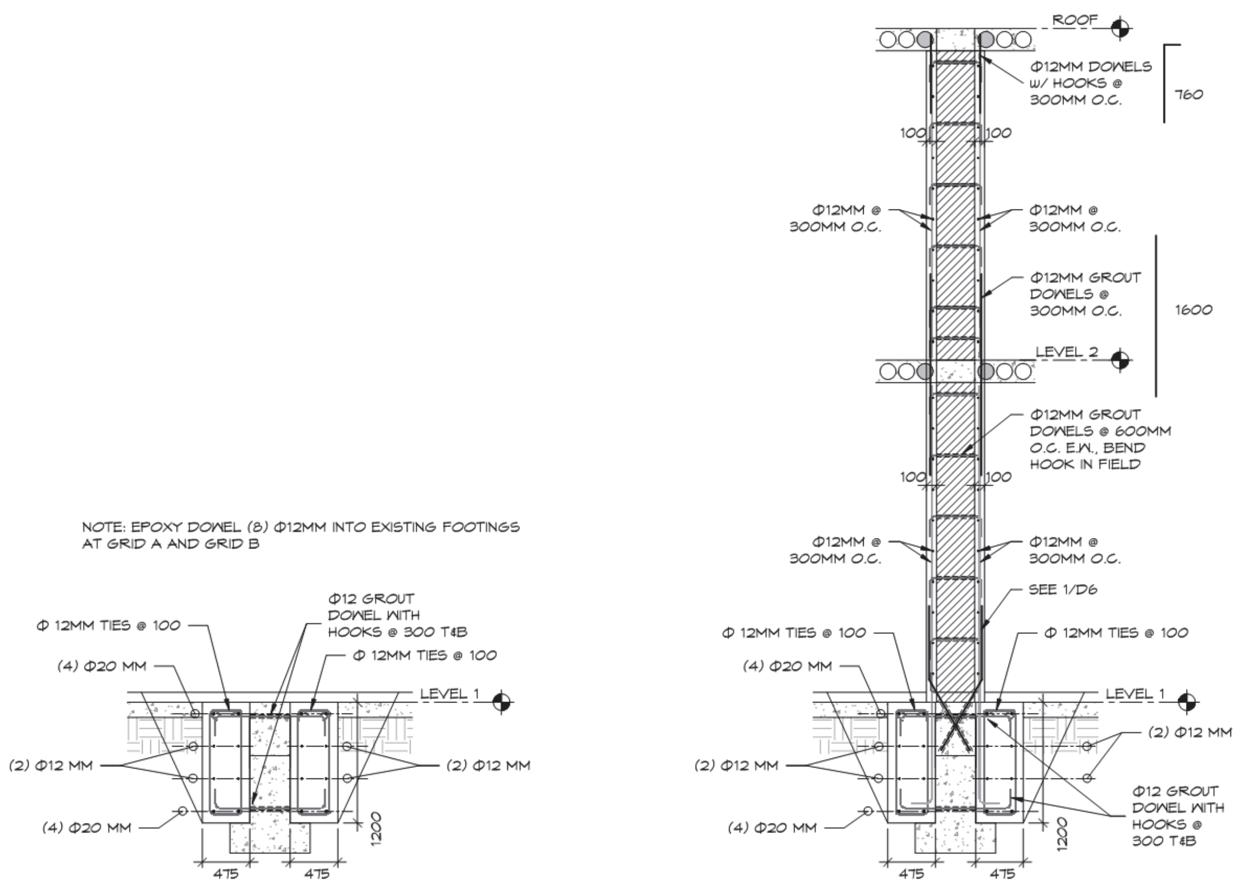


Figure 5-20 Detail of transverse grade beam in CM Increment 3.

Increment 4

Increment 4 is designed eliminate all unsecured brick to achieve the LS limit state. A complete exterior jacket of reinforced concrete is applied to the exterior longitudinal elevation (Figure 5-21).

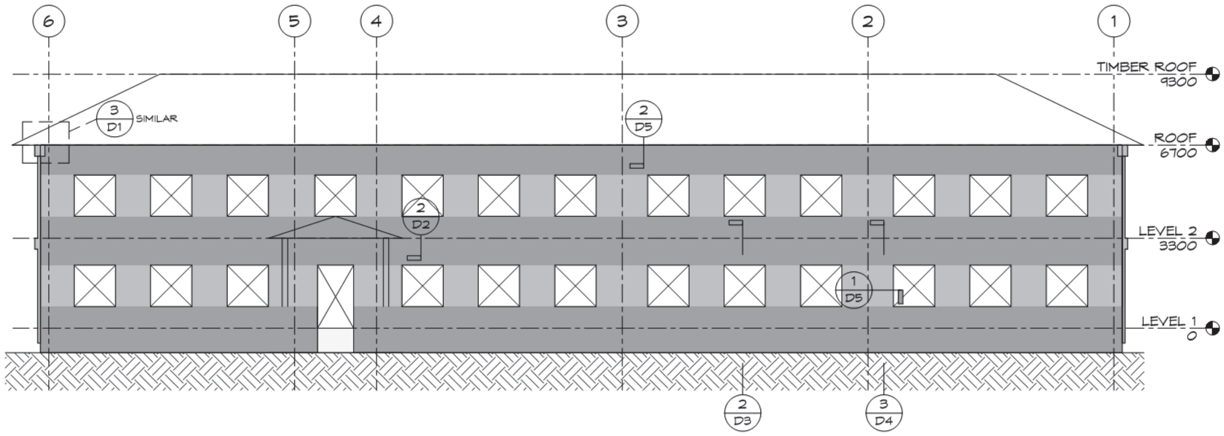


Figure 5-21 Exterior jacket of reinforced concrete in CM Increment 4.

5.2.6 Retrofitted Capacity

This section presents the retrofitted capacity of the index building. Figure 5-22 shows simplified backbone curves for all increments. Increments 2 and 3 add displacement capacity, Increments 3.5 and 4 add strength and displacement capacity.

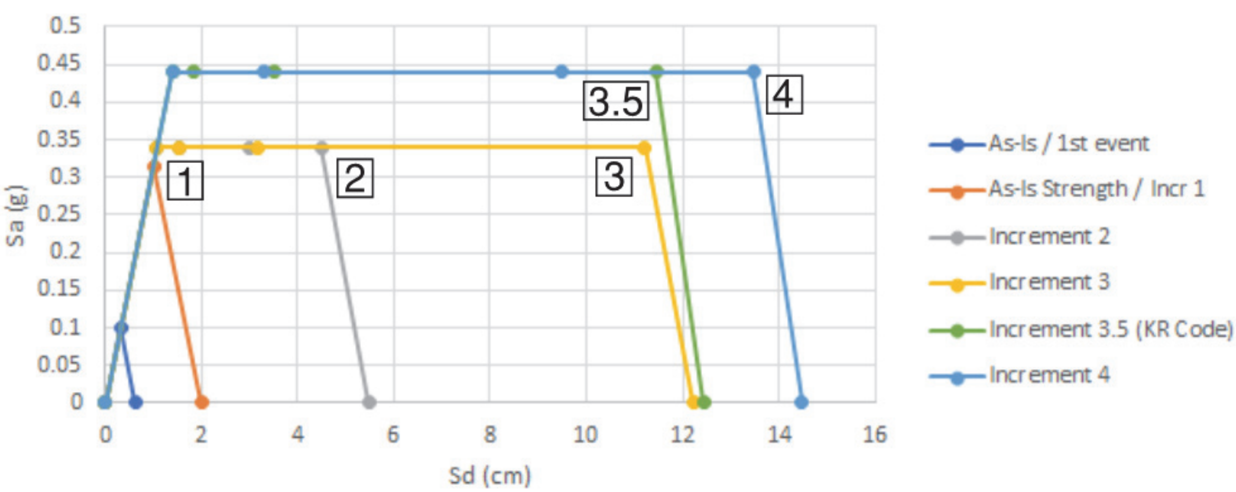


Figure 5-22 Pushover curves (spectral acceleration versus spectral displacement) for Increments 1 through 4 for CM index building, transverse direction.

5.2.7 Estimated Retrofit Costs

Table 5-1 below summarizes cost estimates per square meter for each increment level for the CM index building.

Table 5-1 Summary of Estimated Costs (USD) per Square Meter for Retrofit Increments of CM Index Building

Retrofit Increment	*Structural*[(1)]	*Contingency and VAT*[(1)]	*Architectural Finishes*[(1)]	*WASH and EE*[(1), (2)]	*Total*[(1)]
Increment 1	5.16	0.88	0.86	98.2	105.1
Increment 2	54.31	9.23	9.07	98.2	170.8
Increment 3	88.72	15.08	14.82	98.2	216.8
Increment 3.5	99.86	16.97	16.68	98.2	231.7
Increment 4	107.46	18.27	17.95	98.2	241.9

(1) All costs are given in USD per square meter.
(2) Energy efficiency (EE) and water, sanitation, and hygiene (WASH) costs.

5.3 Complex Masonry with Concrete Framing

The confined masonry with concrete framing (CMCF) index building is based on Pushkina School No. 21 in Osh (photos are provided in Chapter 4). It has three stories with various configurations of classrooms. There are multiple blocks separated by seismic joints that are expected to pound during a major earthquake. The floors and roofs align for the classrooms. Similar to the CM index building, the floors and roof are anchored to a reinforced concrete belt beam, that is integrated in the walls at the floor and roof level. The planks have grouted shear keys that work with the belt beam to create the diaphragm. The diaphragm is untopped, and it has limited capacity to transfer seismic loads.

Like the CM typology, the lateral-load-resisting system consists of unreinforced masonry walls and the presence of reinforced concrete vertical inclusions can interact with the masonry to create ties within the wall piers.

5.3.1 Seismic Deficiencies

The list of seismic deficiencies in the CMCF index building is essentially the same as that of the CM index building. Both typologies are susceptible to brittle behavior of the walls under in-plane loading. Both have floor and roof planks well tied to the belt beams in the load-bearing conditions. Both have poorly connected brittle partitions, and both are subject to out-of-plane wall failures at the non-load bearing floor conditions.

The following seismic deficiencies are present in the CMCF index building:

- Inadequate strength and brittleness of masonry walls
- Lack of positive connection between masonry walls and floor or roof diaphragms parallel to floor and roof planks
- Inadequate lateral capacity for nonstructural masonry partitions

5.3.2 In-Plane Analysis

The in-plane analysis for the CMCF index building follows similar steps to those for the CM index building. Pushover analyses were applied in each direction proportional to the seismic weight and the triangular distribution of accelerations (Figure 5-23).

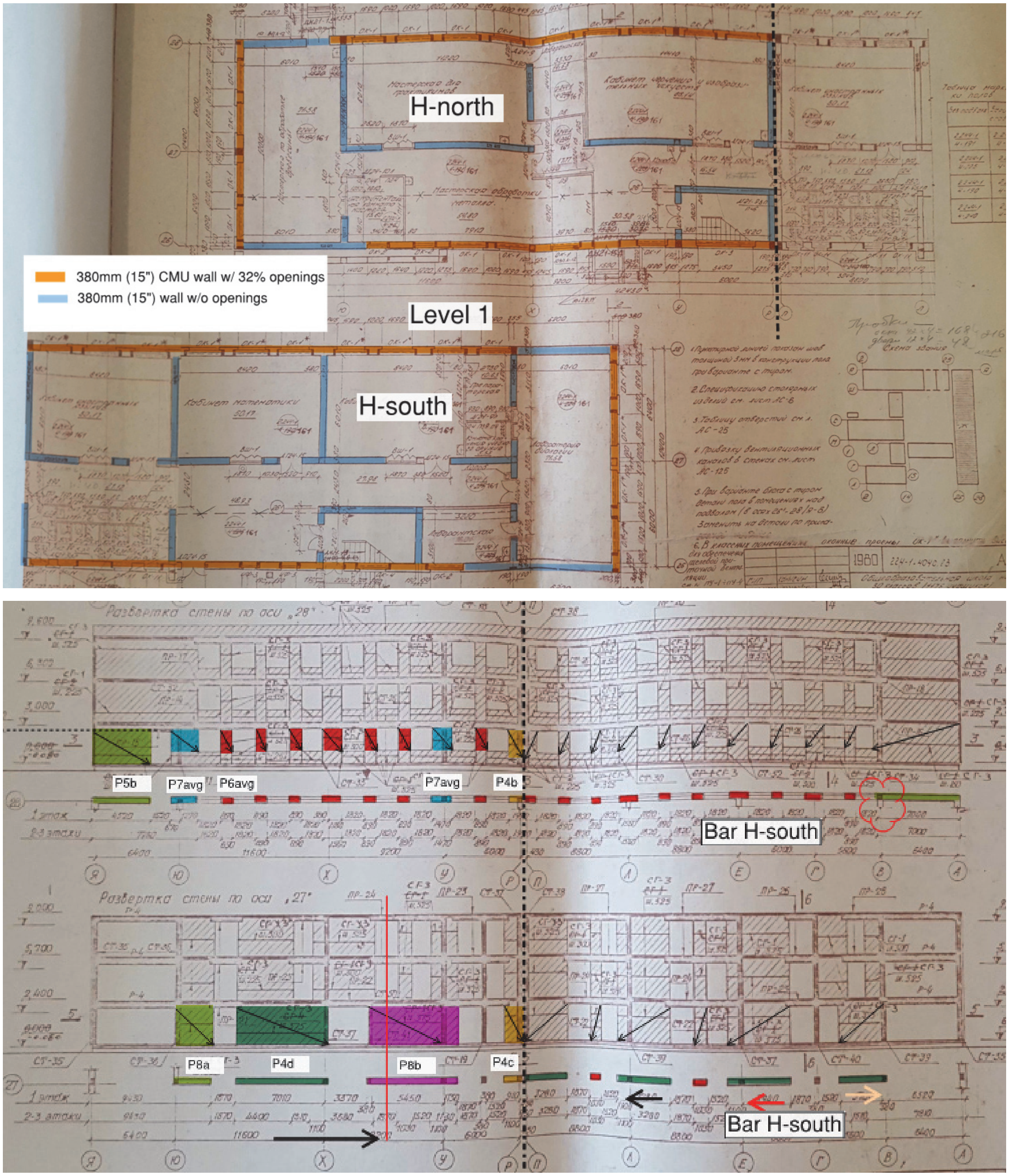


Figure 5-23 Map of structural piers and walls of CMCF index building that are assessed to determine the overall pushovers.

Each masonry pier was evaluated for the various shear and flexural mechanisms. These consist of bed joint shear (Figure 5-4a), diagonal shear (Figure 5-4b), diagonal compression of the strut (Figure 5-5 when inclusions exist that could form a tie), flexure with toe crushing, and rocking, as shown in Figure 5-6.

5.3.3 Out-of-Plane Analysis

Selected structural walls and nonstructural partitions were subjected to accelerations that would be expected at the point of a sidesway collapse of the unretrofitted building. Failure of these items constitutes a partial collapse and they would be retrofitted as needed. As with the CM index building, Increment 1 eliminates the partial mechanisms and the ensuing capacity would be that of the overall building under the controlling sidesway collapse mechanism. The following items were checked:

- Unreinforced structural walls subjected to out-of-plane forces. The walls were found to be adequate based on the height to thickness ratios per ASCE/SEI 41-17.
- Anchorage of the structural walls below the belt beams (as shown in Figure 5-24). The resistance comes from friction due to normal forces. Upper-story transverse walls were found to fail because they are not load bearing, and there are low friction forces. This mechanism is mitigated in retrofit Increment 1.
- Anchorage and out-of-plane capacity of nonstructural masonry partitions. Partition walls were found to fail because they are very slender and do not have positive connection to the diaphragms. They are retrofitted or replaced with light gage gypsum sheathed walls in retrofit Increment 1.

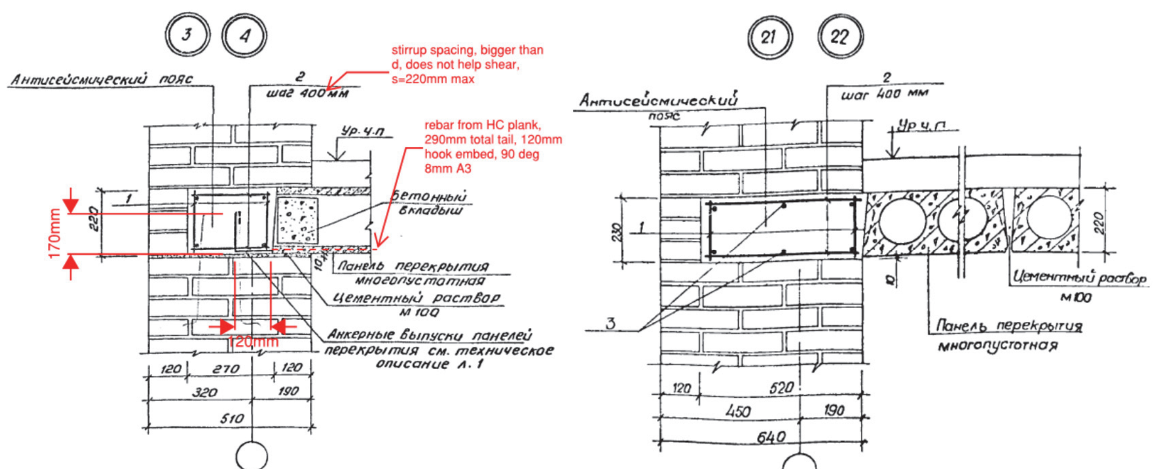
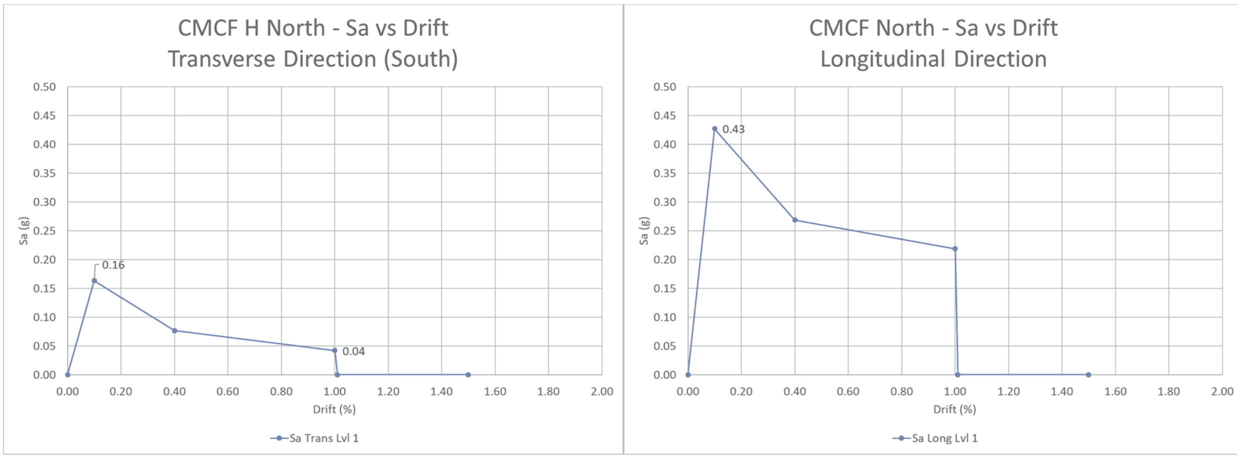


Figure 5-24 Anchorage of the structural walls.

5.3.4 Existing Capacity

Partial collapse failure of the nonstructural partitions is expected for the CMCF index building prior to reaching the controlling sidesway collapse in the transverse direction. The strength limit is $0.16W$ in the transverse direction. The strength limit is $0.43W$ in the longitudinal direction. The out-of-plane connections to the transverse walls to the roof planks would be expected to fail (non-load bearing direction parallel to the planks) prior to reaching the longitudinal sidesway mechanism. The governing transverse mode is flexure with toe-crushing. The modes in the longitudinal direction are a mix of flexural toe-crushing and sliding shear. The backbone curves are constructed by adding discrete controlling events following the curves and limits from ASCE/SEI 41-17, assuming that the partial collapse modes have been retrofitted in Increment 1. Although the CMCF typology and failure modes are similar to CM, CMCF is much weaker. This can be attributed to the greater weight with the additional story and fewer walls.



(a) (b)

Figure 5-25 CMCF pushover curves in the as-is condition, assuming partial collapse mechanisms have been retrofitted per Increment 1: (a) transverse direction; and (b) longitudinal direction.

5.3.5 Conceptual Retrofits

In order to eliminate seismic deficiencies in CMCF buildings, the following conceptual retrofit measures similar to those for the CM index building are recommended. Each retrofit has two performance points for the controlling direction: CP when the building reaches a sideways collapse and LS when there are safety risks from falling bricks. The limits generally follow ASCE/SEI 41-17. Most of the increments are designed primarily to improve the response for the CP limit state, except for Increment 4 that is explicitly designed to improve the response for LS.

The following sections discuss improvements implemented with each retrofit increment. Conceptual plans and typical details are provided in Appendix F.

Increment 1

Increment 1 for CMCF eliminates the partial collapse mechanisms that would be expected prior to the building reaching a complete sidesway collapse in both directions. The elements that are improved in this increment are as follows:

- Nonstructural masonry partitions are braced using a light reinforced concrete skin anchored to the diaphragms. An alternative solution is to replace the partitions with light gage steel framing with gypsum board sheathing.
- Connection of the transverse walls to the belt beams at the roof level are strengthened against shear failures from out-of-plane accelerations (Figures 5-26 and 5-27).

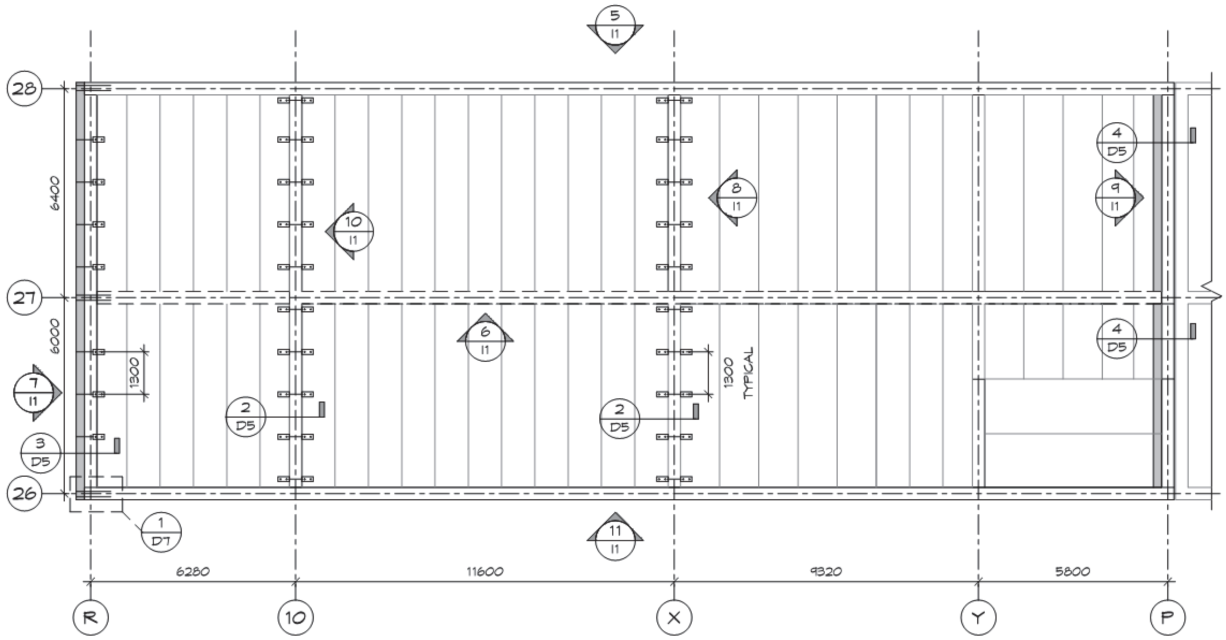


Figure 5-26 Plan showing location of transverse wall connections in CMCF Increment 1.

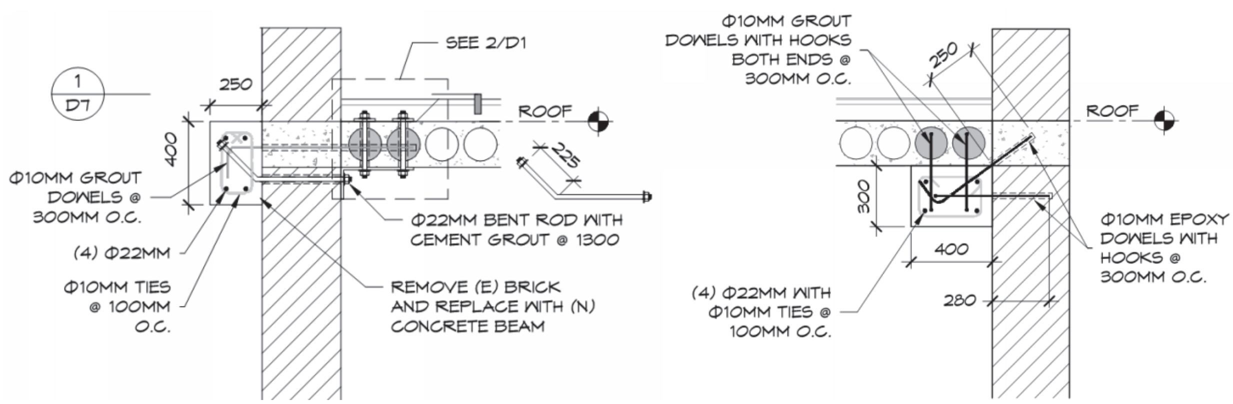


Figure 5-27 Detail of transverse wall to belt beam connection in CMCF Increment 1.

Increment 2

Increment 2 for CMCF builds on Increment 1 and adds displacement capacity to the controlling mechanisms. The strategies are the same as those used for CM. For the controlling transverse direction, the flexural toe-crushing mechanism is eliminated by adding reinforced shotcrete jackets applied to ground floor walls to induce stable rocking. The strong but brittle response of the longitudinal walls are also eliminated. No foundation work is performed with this increment. The following elements are improved in this increment:

- Reinforced concrete jackets are added to ground floor transverse walls (Figure 5-28) to create a rocking mode. The jackets are grouted with epoxy dowels into tops of the unreinforced concrete footings to prevent sliding for higher displacements.
- Reinforced concrete jackets are added to ground floor internal longitudinal walls (Figure 5-28) to eliminate a brittle response and create a rocking mode.

- Three level "finger" piers connected to a common base are added to the exterior longitudinal walls (Figure 5-29). The fingers occur at every third brick pier. They form flexural hinges at their base and induce a tilting mechanism more compatible with the interior rocking walls.
- Where existing walls occur on the longitudinal elevation, a shotcrete wall is added. The new composite wall is intended to rock and have compatible deformations with the fingers.
- Roof and floor diaphragms are improved by adding perimeter belt beams to supplement the existing belt beam.
- Floor and roof planks are better secured to the reinforced perimeter belt beam. This connection, along with the supplemental belt beam, creates a safety tether to secure the floor and roof planks if the load bearing exterior piers lose gravity capacity.

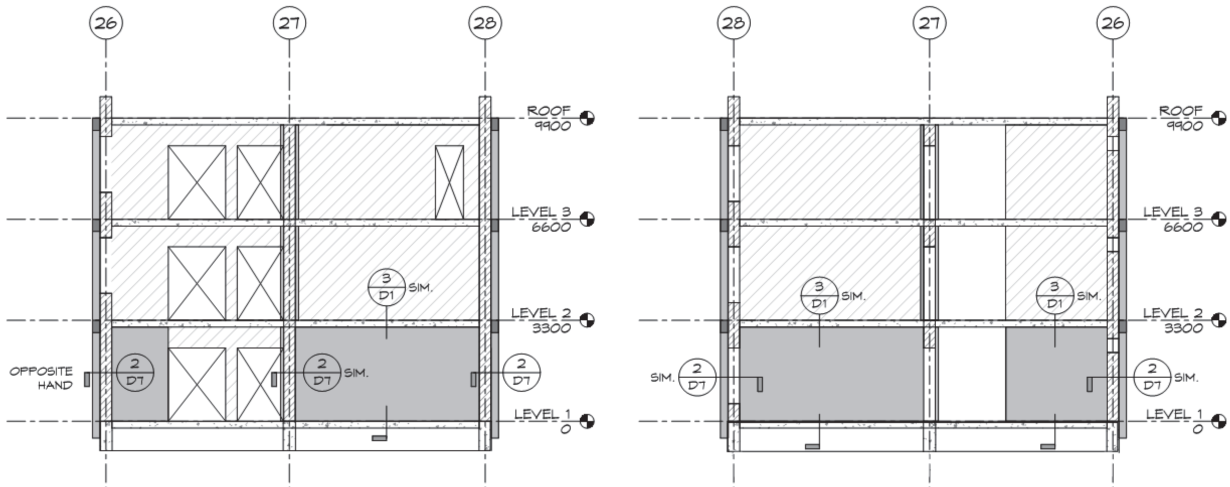


Figure 5-28 Reinforced concrete jackets added in CMCF Increment 2.

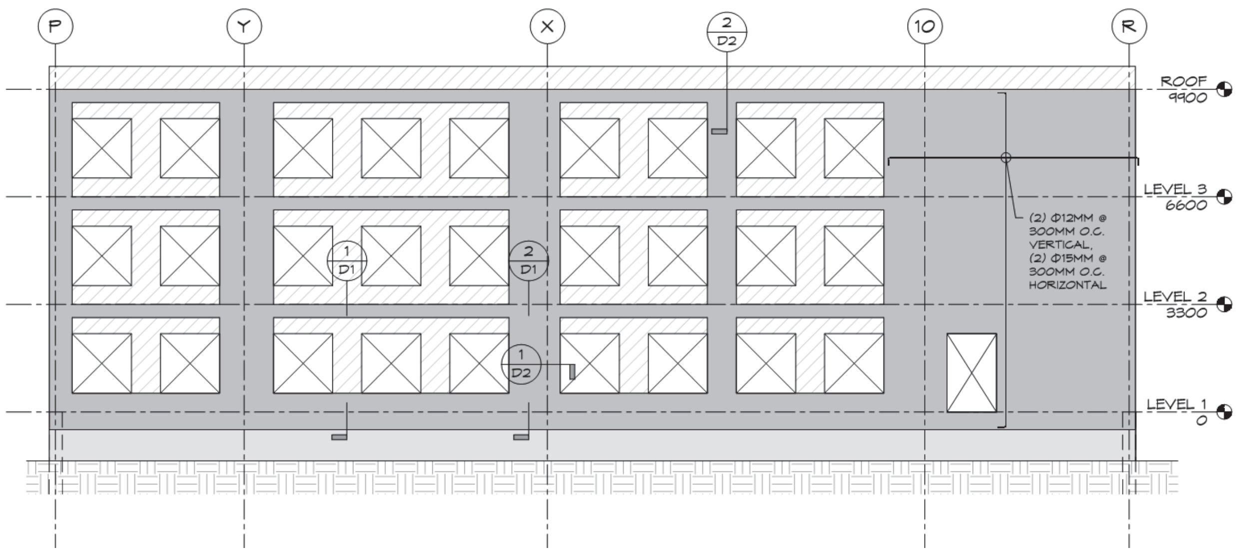


Figure 5-29 Finger piers added in CMCF Increment 2.

Increment 3

Increment 3 is similar to Increment 2 but the jackets for the interior walls extend two levels in both transverse and longitudinal directions. The two-level jackets eliminate uncertainty in the response of the walls by eliminating unprotected bricks. This allows higher rocking displacements at the collapse limit.

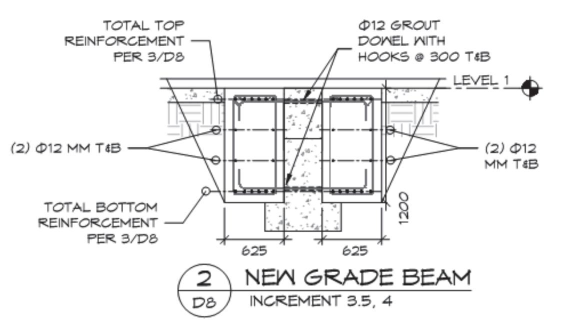
Increment 3.5

Increment 3.5 adds strength to Increment 3 in the controlling transverse direction in order to meet the minimum strength requirements expected for the forthcoming Kyrgyz retrofit code.

Transverse grade beams are added to interior walls (Figures 5-30 and 5-31). The grade beams work with the rocking mechanism. Ductile plastic hinges form during the response.

MARK	LONG. REINF.		TIES	
	TOP	BOTTOM	SIZE	SPACING
GB1	(12) Φ22	(12) Φ22	(2) Φ12	100
GB2	(12) Φ22	(12) Φ22	(2) Φ12	100
GB3	(6) Φ22	(6) Φ22	(1) Φ12	100

3 GRADE BEAM SCHEDULE
D8 INCREMENT 3.5, 4



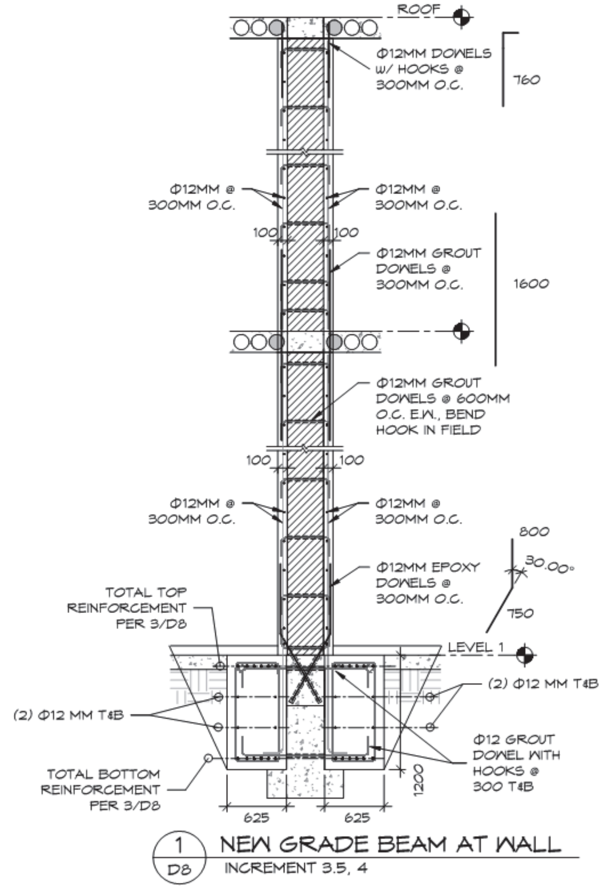


Figure 5-30 Detail of transverse grade beams in CMCF Increment 3.5.

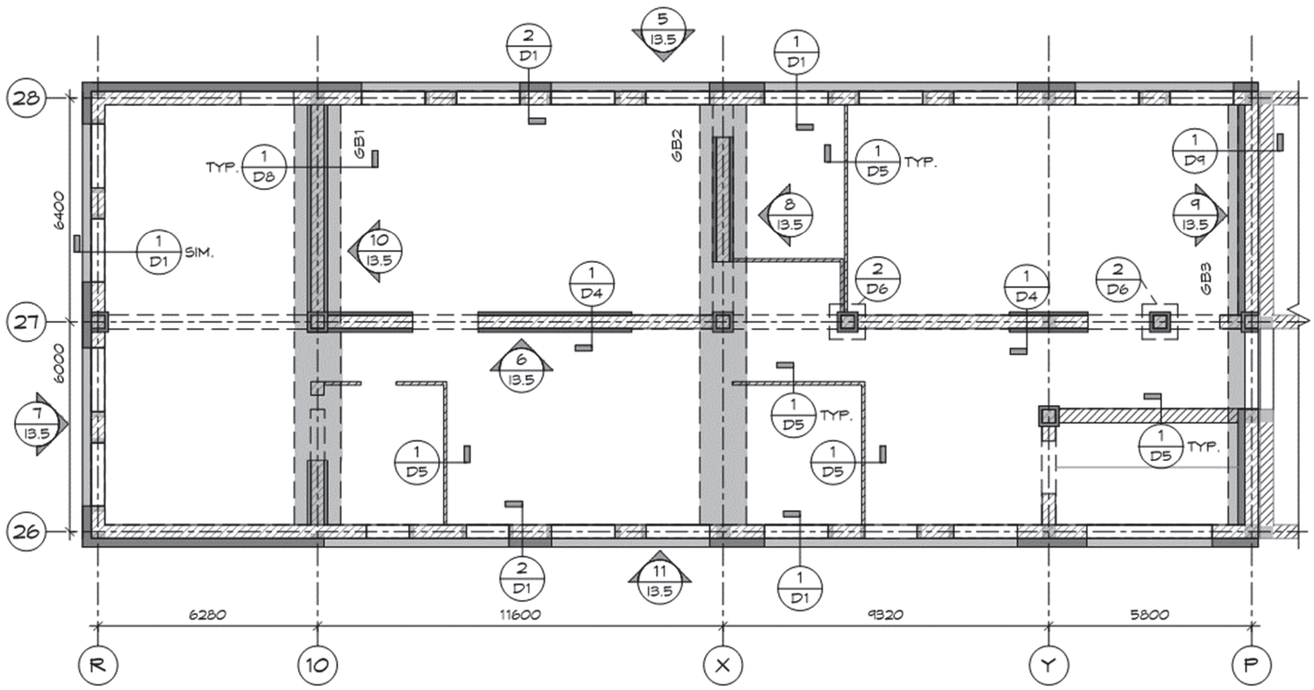


Figure 5-31 Plan showing transverse grade beams in CMCF Increment 3.5.

Increment 4

Increment 4 is designed to eliminate all unsecured brick to achieve the LS limit state. Similar to the CM index building, a complete exterior jacket of reinforced concrete is applied to the exterior elevation (Figure 5-32).

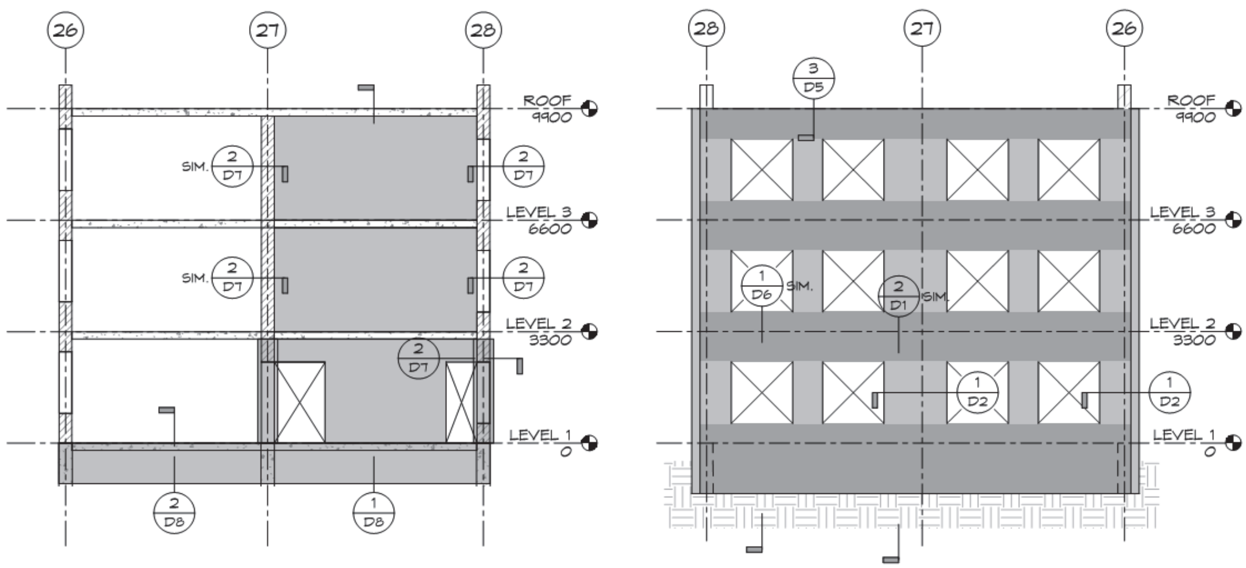


Figure 5-32 Exterior jacket of reinforced concrete in CMCF Increment 4.

5.3.6 Retrofitted Capacity

This section presents the retrofitted capacity of the index building. Figure 5-33 shows the backbone curve for the increment 4 retrofit. The curve shows a jagged loss of strength, primarily due to degradation of the grade beams as they undergo strength loss, following the curves of ASCE 41. The simplified curve is used for the prioritization framework. Figure 5-34 shows simplified backbone curves for all increments.

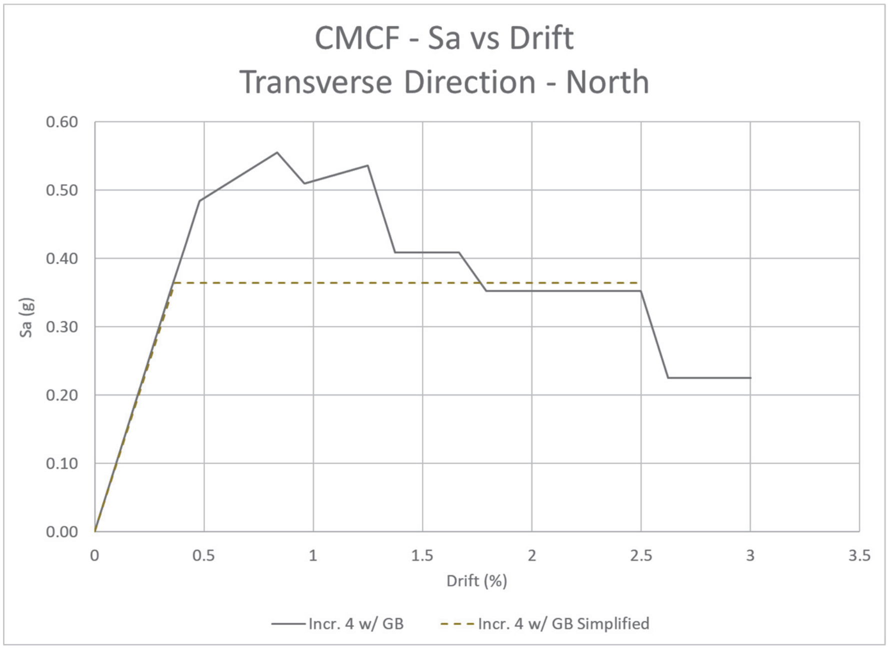


Figure 5-33 Pushover curves (spectral acceleration vs. spectral displacement) for CMCF Increment 4, transverse direction. The irregular shape is due to the degrading response of the grade beams, per the backbone curves of ASCE/SEI 41-17. The dashed line shows the simplified version that was used for the benefit cost analysis.

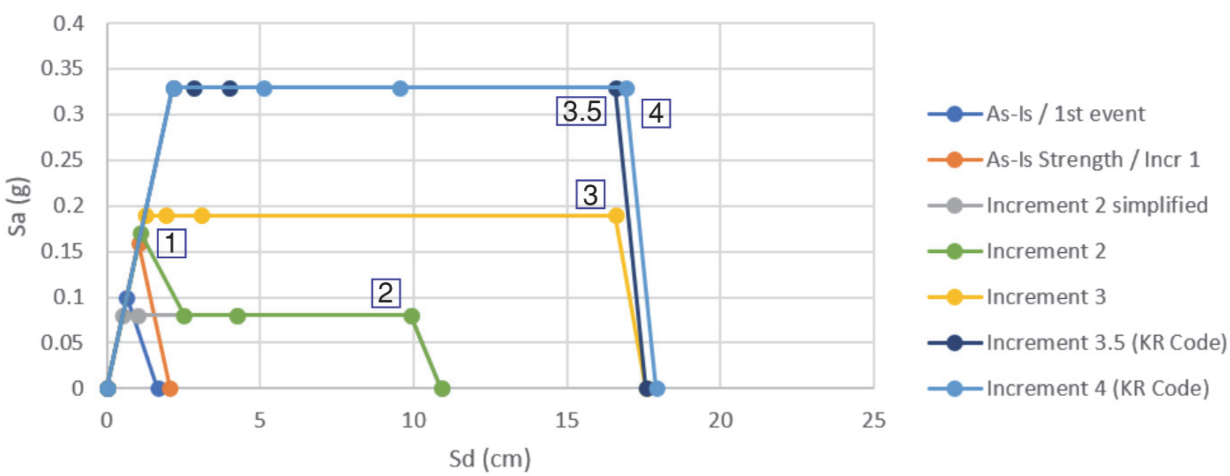


Figure 5-34 Pushover curves (spectral acceleration versus spectral displacement) for Increments 1 through 4 for CMCF index building, transverse direction.

5.3.7 Estimated Retrofit Costs

Table 5-2 below summarizes estimated costs per square meter for each increment level for the CMCF building.

Table 5-2 Summary of Estimated Costs for Retrofit Increments of the CMCF Index Building

Retrofit Increment	*Structural Costs* [(1)]	*Contingency and VAT* [(1)]	*Architectural Finishes*[(1)]	*WASH and EE*[(1), (2)]	*Total Cost*[(1)]
Increment 1	19.50	3.32	3.26	98.2	124,28
Increment 2	54.46	9.26	9.10	98.2	171.02
Increment 3	57.74	9.82	9.64	98.2	175.39
Increment 3.5	80.09	13.62	13.37	98.2	205.28
Increment 4	82.36	14.00	13.75	98.2	208.32

(1) All costs are given in USD per square meter.
(2) Energy efficiency (EE) and water, sanitation, and hygiene (WASH) costs.

5.4 Precast Concrete Frames and Walls

The index building for the precast (PC) typology is a concrete frame structure comprised of precast columns, beams, and hollow core precast concrete floor and roof planks. The index building has three stories, with a single loaded corridor the feeds classrooms. The index building is based on a block of Fedchenco High School No. 1 in Osh, shown in Figure 5-35, designed based on Series IIS-04. Similar blocks are arranged around a court, a seismically separated. There are also flanking structures of a different precast framing configuration. The available drawings are only partially complete, necessitating some assumptions for the analysis (Figure 5-36).

The columns are supported on deep precast spread footings. The ground floor is a concrete slab on grade, supported by backfilled soil. The floor and roof planks are anchored precast beams, which in turn connect to columns. The planks have grouted shear keys between the elements that work to create the diaphragm, as long as the boundary tension capacity is maintained by the frame. The diaphragm is untopped, and it has limited capacity to transfer seismic loads. Unlike the CM and CMCF index buildings, there is no belt beam. The exterior panels have an insulated core and lightweight concrete.

Figure 5-35 Fedchenco High School No. 1 view from front.

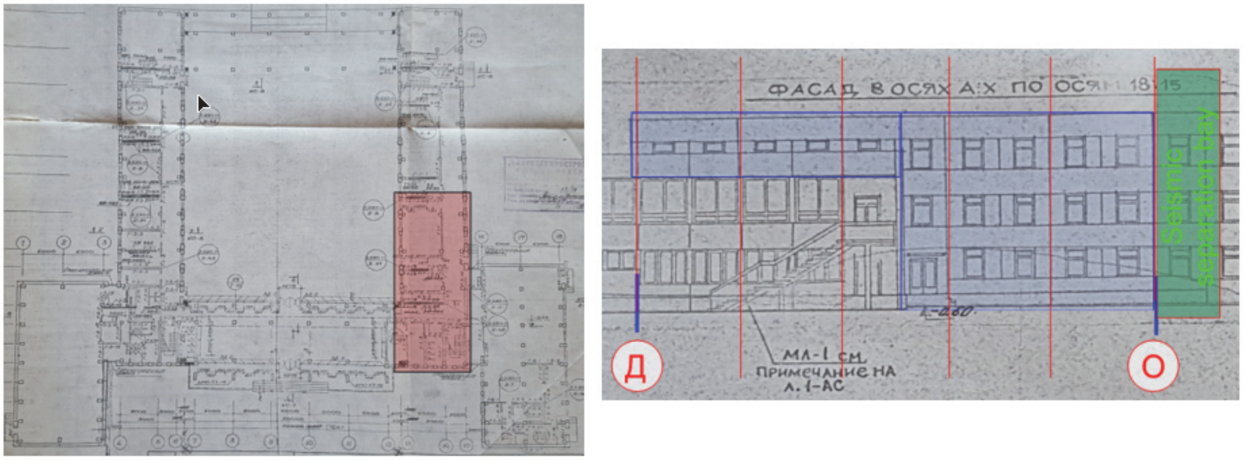


Figure 5-36 Available drawings on site.

The lateral-load-resisting system consists of frame action between the columns and the beams. The columns are three-stories tall and consist of a single piece. The beams are welded to the columns via steel embed elements and embedded rebar (Figure 5-37).

Figure 5-37 Beam-column connection in typical precast lateral-load-resisting system.

5.4.1 Seismic Deficiencies

Precast concrete buildings have demonstrated very poor performance in past earthquakes. Numerous collapses of precast buildings with high casualties were recorded in the 1988 Spitak earthquake in Armenia. The PC index building is observed to be flexible, weak, and brittle. The columns are especially vulnerable to a catastrophic loss of vertical and lateral load-carrying ability because they are shear critical and poorly detailed. Exacerbating this are the poorly detailed connections that may lack adequate strength and ductility to resist earthquake forces. The untopped diaphragms are also concerning and the ability to distribute loads to the elements of the lateral-force-resisting system is limited. The interior unreinforced masonry partition walls have little capacity to resist in-plane and out-of-plane forces and deformations associated with earthquakes, resulting in the potential for collapse of the walls and risk to the school population from falling hazards. The exterior panels are detailed to not participate in lateral loads. However, the interlocked segments appear vulnerable.

The following seismic deficiencies are present in precast concrete frame and wall buildings:

- Inadequate strength, stiffness, and displacement capacity of the columns. The columns are weak and brittle. They are shear critical as well as being poorly confined and inadequately detailed for flexure (Figure 5-38).
- The frame will likely exhibit a story mechanism at the first level. The lightly reinforced columns are 300 mm square. The beams are 480 mm deep. Assumptions were made for the beam reinforcement.
- Similar to the CM and CMCF index buildings, inadequate lateral capacity was observed for nonstructural masonry partitions. The partitions appear to be weak, brittle, and poorly connected.
- The roof and floor diaphragms are without topping slabs. The diaphragms rely on clamping between grouted keys between planks. The clamping action may deteriorate from dilation of the beams that occur under from yielding of the frame.
- The beam to column connections rely on field welding of rebar. The possibility of embrittlement of the heat-effected zone is a concern.
- Inadequately anchored exterior precast wall panels. The panels are segmented with head and sill members that span between columns. These are detailed to not participate in the lateral system. Between the head and sill panels are panels between windows. These are interlocked above and below, with a cementitious key. The displacement capacity appears to be limited, and the interlocking connections appear brittle.

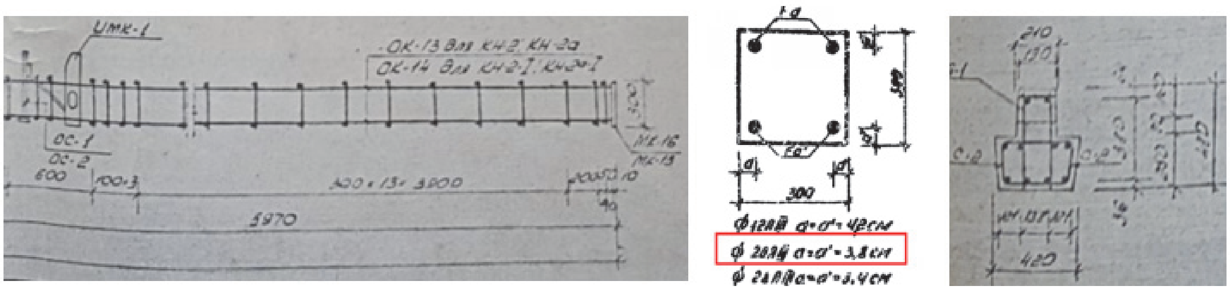


Figure 5-38 The lightly reinforced columns of the PC index building have stirrup spacing equal to the member depth. The column is essentially unreinforced for shear. The beams are significantly deeper and hinges due to lateral loads are expected to form in the columns and not in the beams.

5.4.2 *Analysis Results*

A nonlinear pushover analysis was performed using a 3-D fiber model using ETABS (CSI, 2018). The nominal material properties were determined from the drawings and modified for expected strengths per ASCE/SEI 41-17. Available drawings were incomplete and assumptions were made, such as rebar assumptions for the beams. However, because of the significant difference in depths and apparent reinforcement between the beams and the columns, there is good confidence in the results and conclusions. The shear capacities and rotational limits of the columns were calculated directly per ASCE/SEI 41-17 and used for inputs for the pushover analysis. Diaphragms were modeled as rigid and the precast panels were assumed to not participate in the evaluation of the as-is condition. This assumption is reasonable for the unretrofitted frame, because the frame fails prior to the panel drift limits. It is also a reasonable and conservative assumption for the retrofitted cases. This is because the panels add a small amount of strength and stiffness to the strengthened building.

In the unretrofitted state, the structure was found to be weak and flexible. The columns formed shear hinges at drifts of 0.03m and corresponding to a total shear of $0.08W$ in the controlling direction (Figures 5-39 through 5-41). This behavior is significantly worse than that of other typologies. Shear hinges in poorly confined columns can lead to catastrophic loss of gravity support and collapse. Because the building is so weak and brittle, Increment 1 was not developed for this typology. If the shear failures were forestalled or retrofitted, then a sidesway mechanism would form at the first story.

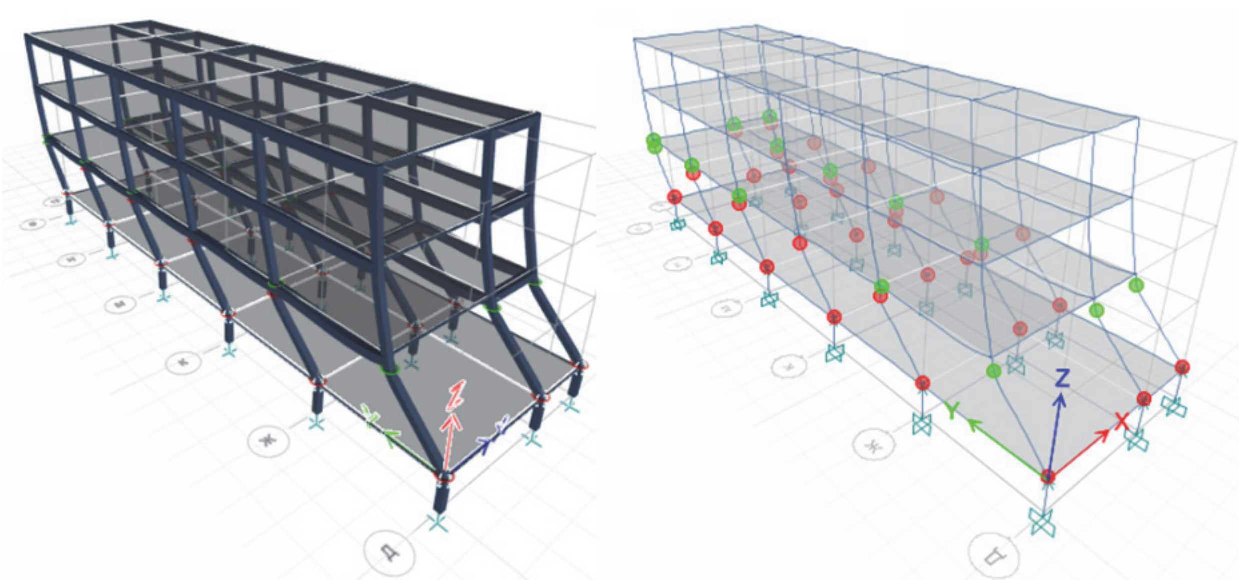


Figure 5-39 Deflected shapes of the precast frame. Shear failure was monitored and found to occur prior to flexural hinges. The model on the right forestalled shear failures to induce a side-sway mechanism at the first story. The columns are essentially fixed at the ground, due to a lock-off interaction with the slab-on-grade, and the deep footings.

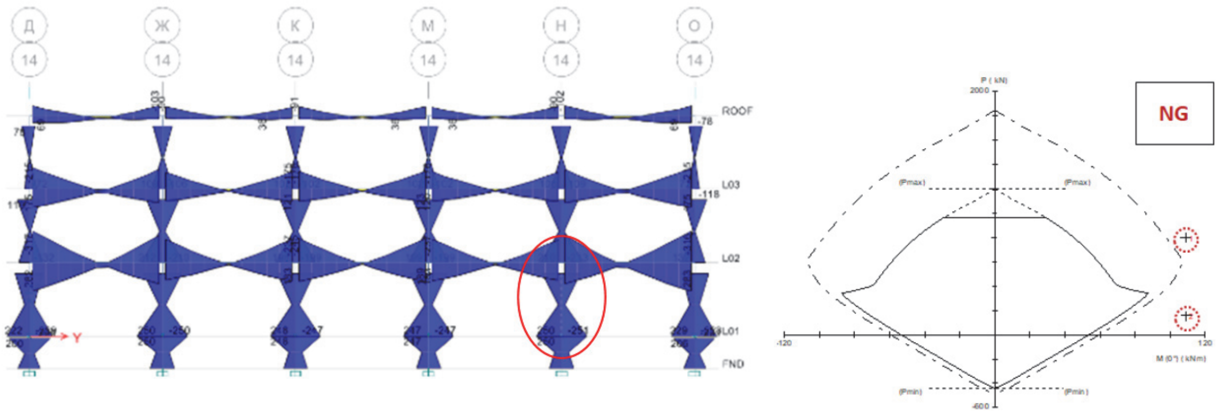


Figure 5-40 The model on the right forestalled shear failures to induce a moment demands shown. Plastic hinges form at the ground floor because the frame does not satisfy the strong column weak story criteria.

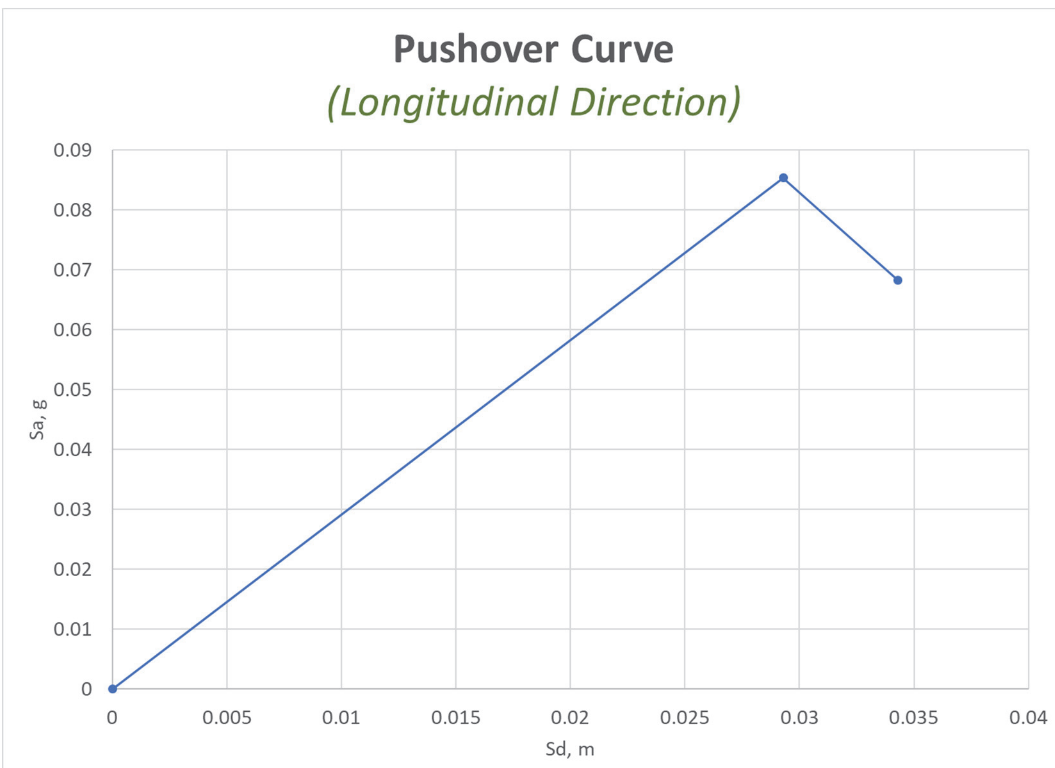


Figure 5-41 Shear failures occur in the ground floor columns at 0.08*W*.

5.4.3 Conceptual Retrofits

To eliminate seismic deficiencies in precast concrete frame and wall buildings, the following conceptual retrofit measures are recommended. Conceptual plans and typical details are provided in Appendix G.

Increment 1

Increment 1 was not developed because the structure is too weak and brittle.

Increment 2

Increment 2 addresses weak columns by retrofitting them with reinforced concrete jackets. The diaphragms are also strengthened. Nonstructural partitions are secured or replaced, as with the CM and CMCF retrofits. The following elements are improved in this increment:

- Reinforced concrete jackets are added to all brittle columns (Figures 5-42 through 5-44). The jackets extend down to the top of the footing (Figure 5-45) in order to eliminate the high shears induced by the backstay effect due lock-off interactions with the slab-on-grade, and the deep footings.
- Supplemental belt reinforcement is provided to diaphragms at all levels. This maintains the clamping forces between the grouted hollow core planks.
- Nonstructural masonry partitions are braced using a light reinforced concrete skin (Figure 5-45), anchored to the diaphragms. An alternative solution is to replace the partitions with light gage steel partitions and gypsum wall sheathing.

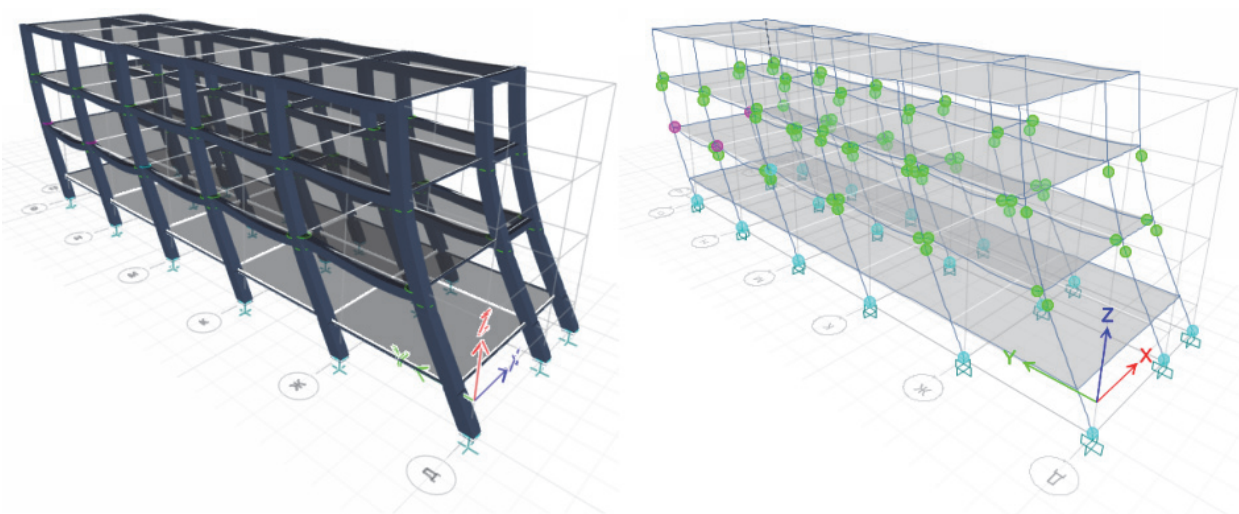


Figure 5-42 Deflected shapes of the precast frame retrofitted with reinforced column jackets. The structure is many times stronger than the as-is condition. The columns eliminate the first story mechanism.

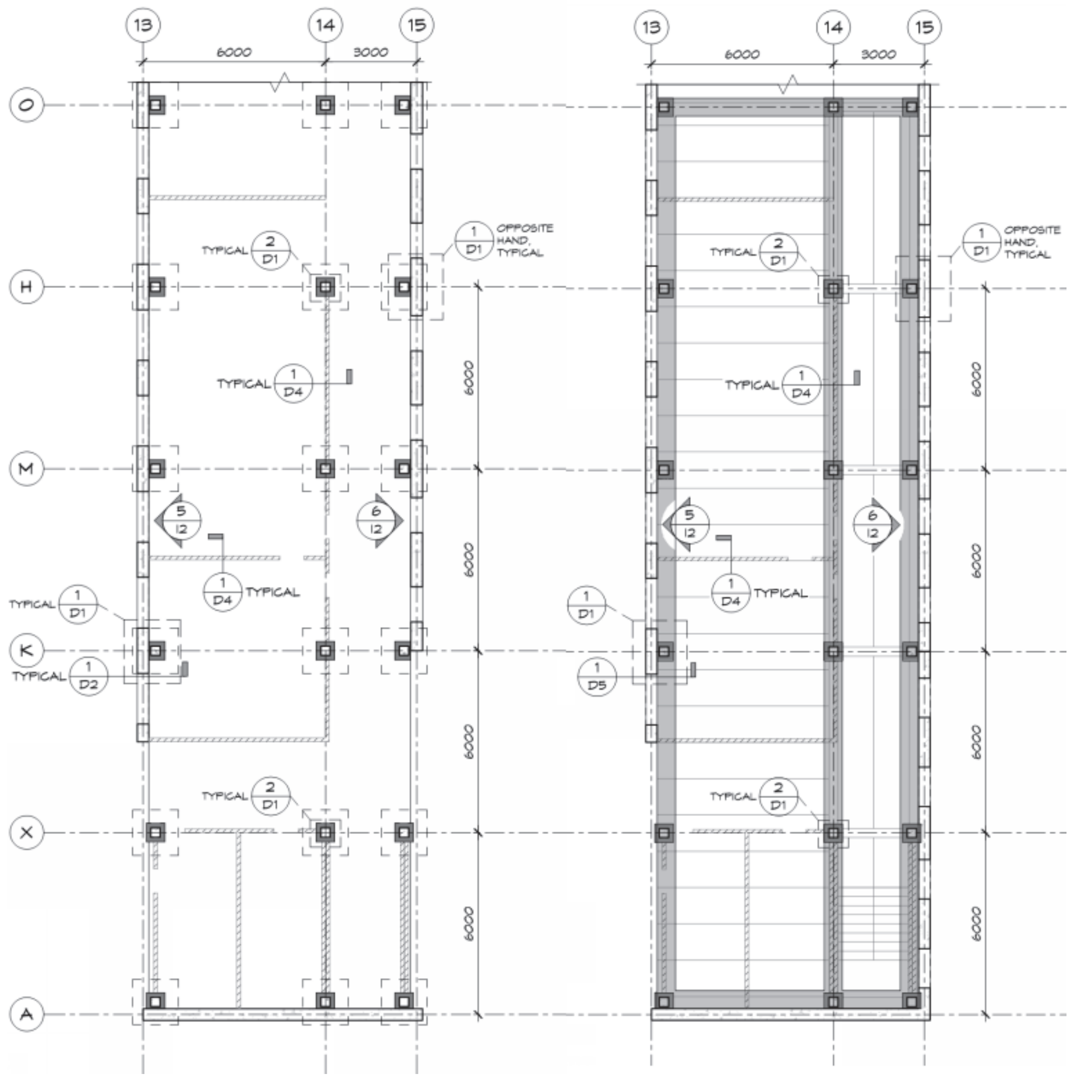


Figure 5-43 Plan showing columns and nonstructural walls with jacketing in PC Increment 2.

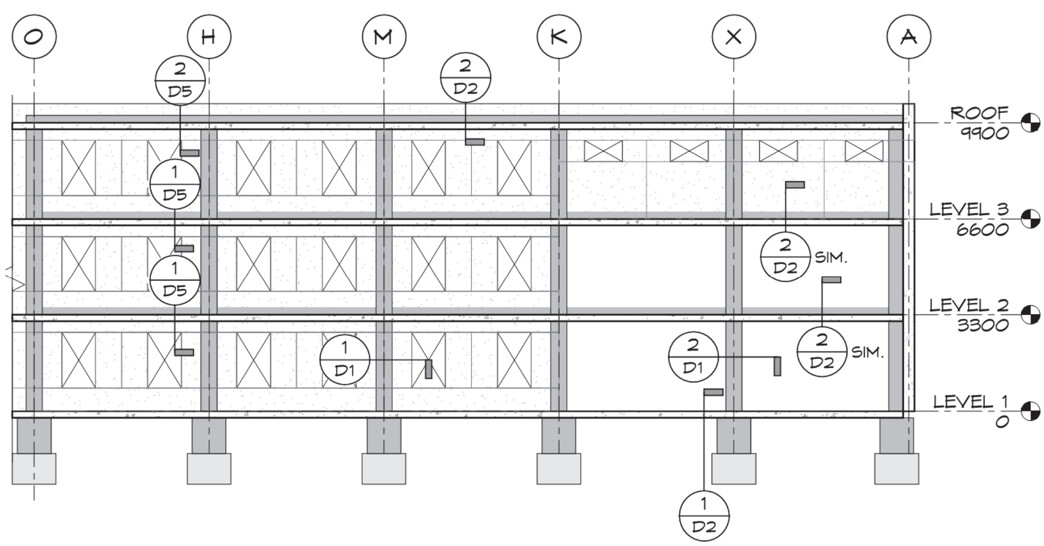


Figure 5-44 Elevation showing jacketed columns in PC Increment 2.

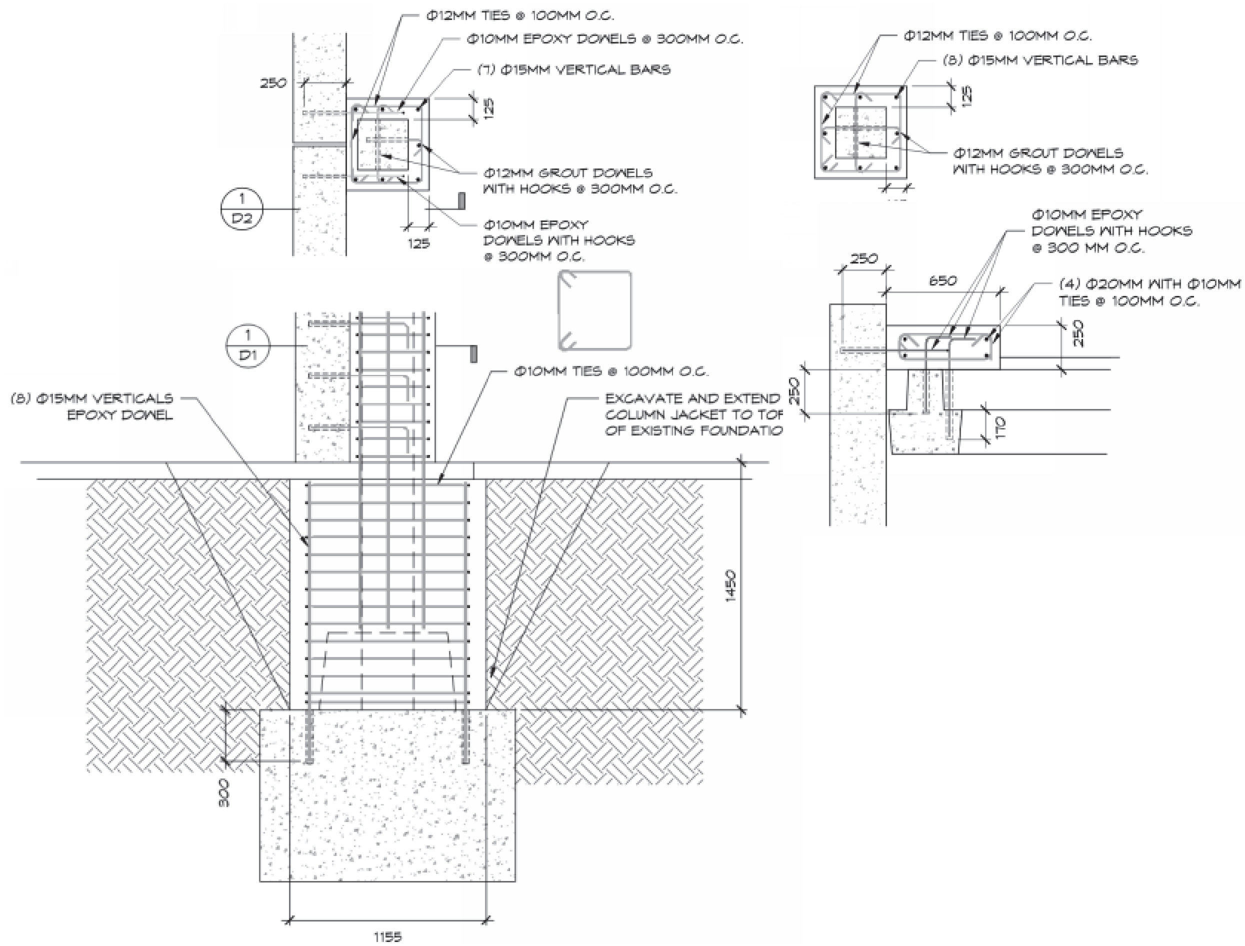


Figure 5-45 Column jackets extending to footing in PC Increment 2.

Increment 3

Increment 3 adds capacity to meet the expected strength demands of the forthcoming Kyrgyz retrofit code, with analysis results shown in Figure 5-46. The retrofit also targets improved collapse prevention (CP) as its primary objective. It adds new transverse shear walls and exterior wall "fingers" to the longitudinal direction. Because the original frame was very flexible, walls are the only practical means to meet the expected code stiffness criteria. The following elements are improved in this increment:

- Transverse walls were required. Deep "H" shaped foundations are added to connect to nearby columns in order to provide adequate uplift resistance (Figure 5-47).
- Longitudinal wall "fingers" are added to the available exterior elevations (Figure 5-48). The walls occur on a grid at every other window pier.
- The walls and the diaphragm are engaged to the exterior precast panels to help secure them against becoming dislodged and falling (Figure 5-49).

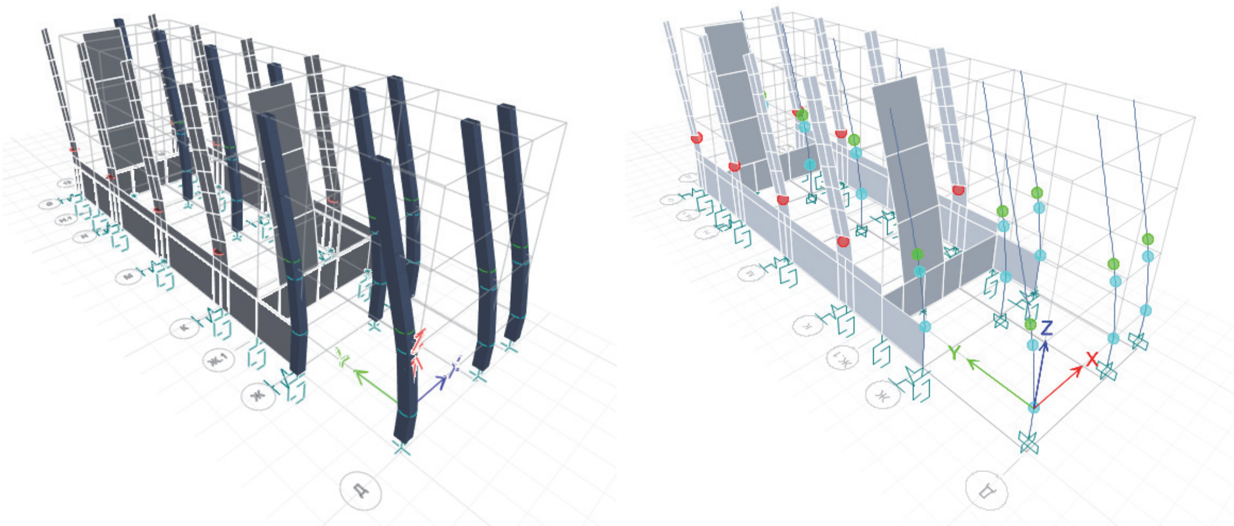


Figure 5-46 Deflected shapes of the precast frame retrofitted with Increment 3.

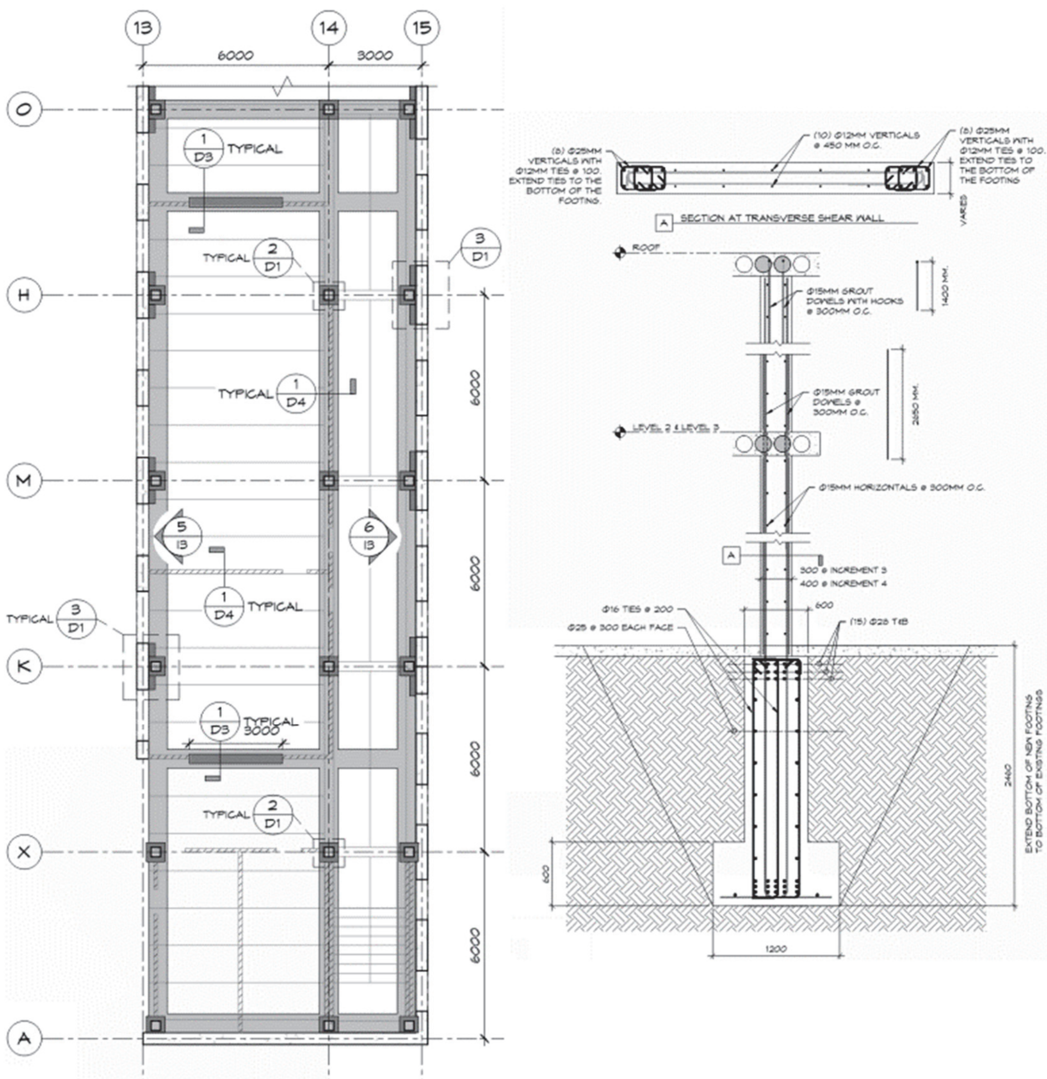


Figure 5-47 Transverse walls and foundation added for PC Increment 3.

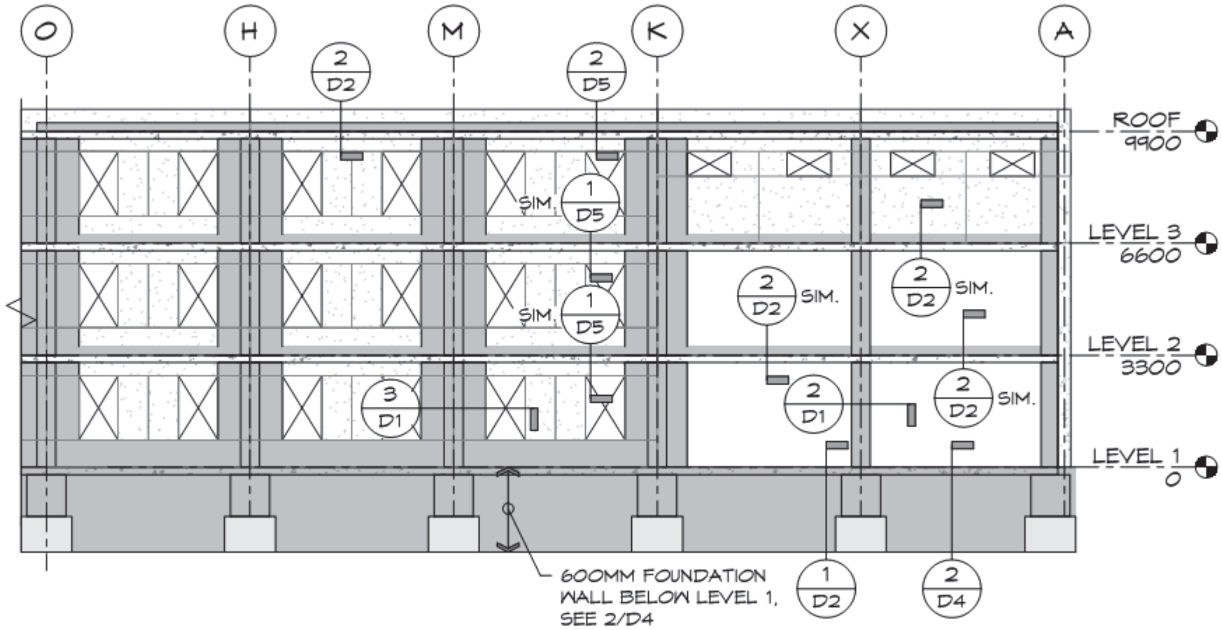


Figure 5-48 Longitudinal wall fingers added in PC Increment 3.

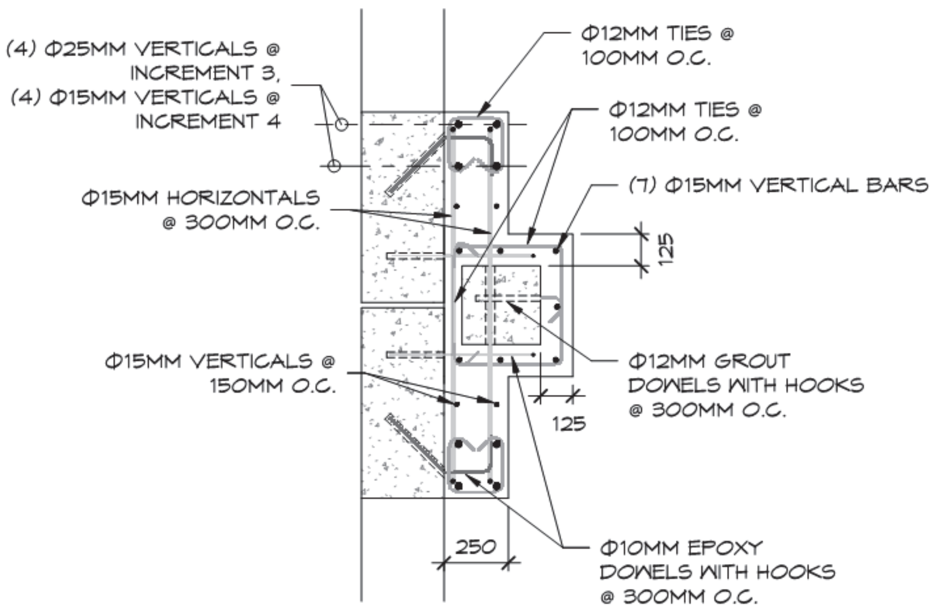


Figure 5-49 Engagement of precast panels from diaphragm in PC Increment 3.

Increment 4

In Increment 4, exterior wall "fingers" are added to cover every precast panel in the longitudinal direction (Figure 5-50). By doing so, the life safety (LS) performance was improved. Analysis results are shown in Figure 5-51.

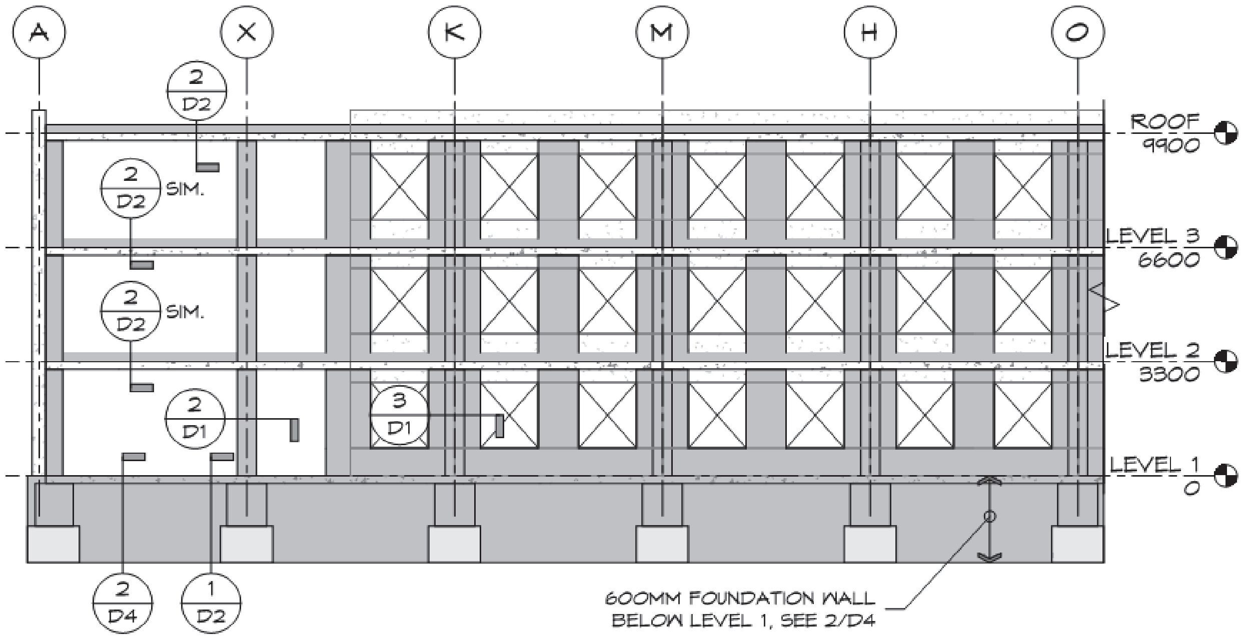


Figure 5-50 Reinforced concrete fingers covering every precast panel in PC Increment 4.

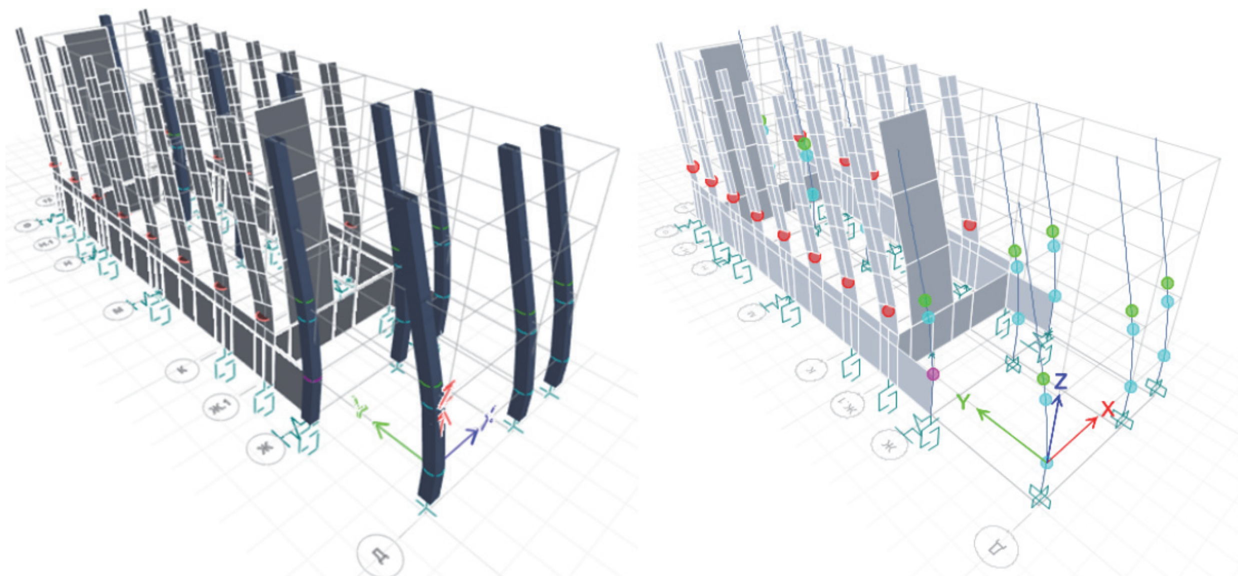


Figure 5-51 Analysis results for PC Increment 4.

5.4.4 *Retrofitted Capacity*

This section presents the retrofitted capacity of the PC index building at each different increment level. Figure 5-52 shows simplified backbone curves for all increments.

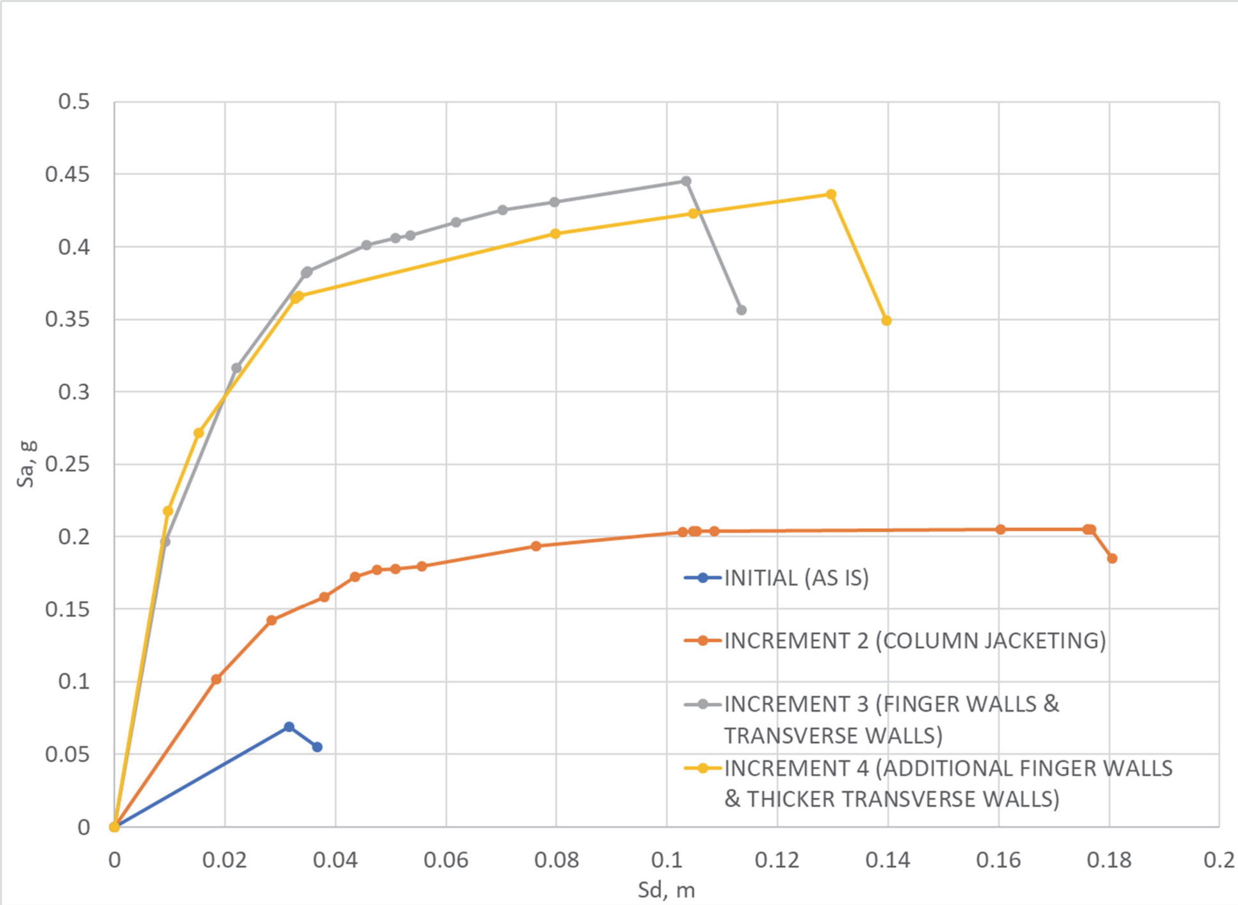


Figure 5-52 Pushover curves (spectral acceleration versus spectral displacement) for Increments 1 through 4 for PC index building, longitudinal direction.

5.4.5 *Estimated Retrofit Costs*

Table 5-3 below summarizes cost estimates per square meter for retrofit of the PC index building.

Table 5-3 Summary of Estimated Costs for Retrofit of PC Index Building

Retrofit Increment	*Structural Costs* [(1)]	*Contingency and VAT* [(1)]	*Architectural Finishes*[(1)]	*WASH and EE*[(1), (2)]	*Total Cost*[(1)]
Increment 2	105.96	18.01	17.70	98.2	239.87
Increment 3	172.89	29.39	28.87	98.2	329.36
Increment 4	187.68	31.91	31.34	98.2	349.13

[(1)] All costs are given in USD per square meter.
[(2)] Energy efficiency (EE) and water, sanitation, and hygiene (WASH) costs.

Chapter 6

Risk-Based Prioritization Framework

This chapter describes the analytical framework develop to prioritize the list of eligible Kyrgyz schools for seismic retrofit.

6.1 Overview

The prioritization framework relies on the calculation of two indices that can be combined into a benefit-cost ratio, in which benefit is measured in terms of lives saved and cost is measured in terms of retrofit cost. The framework has the following approach:

- Seismic hazard is characterized on a school-by-school basis (as described in Section 6.2).
- Seismic vulnerability of a building, in the form of a function giving the mean fraction of building occupants killed given a ground motion level, is estimated:
  - For a small subset of schools for which performance-based assessments are directly implemented, seismic vulnerability is estimated assuming one or more retrofit measures using idealized pushover curves based on available structural and architectural drawings (as described in Section 6.4).
  - A methodology found in literature is implemented to develop vulnerability functions for buildings with limited levels of information on seismically important attributes of the building (as described in Section 6.5).
  - Vulnerability functions for buildings with limited information are adjusted to be consistent with vulnerability functions for similar buildings with higher resolution data, where available (as described in Section 6.6).
- Prioritization indices and benefit-cost ratio are calculated (as described in Sections 6.7 and 6.8).
- Prescriptive performance levels are checked for compliance (as described in Section 6.9).

Results of application of the framework to the eligible schools list is presented in Chapter 7.

6.2 Determine Seismic Hazard

For each school site identified by a latitude and longitude, the seismic hazard is characterized by obtaining maps of the 5% damped short-period spectral acceleration response ground motion associated with two probability levels: 10% exceedance probability in 50 years, and 5% exceedance probability in 50 years. The geographic layers for two hazard levels are taken from the Kyrgyzstan Disaster Risk Data

Platform at http://geonode.mes.kg/, generally referred to here as Geonode. Figures 6-1 and 6-2 show the content of the two layers at the national scale. The two hazard levels equate with mean recurrence rates of 0.00211 events per year (a mean recurrence interval of 475 years) and 0.00103 events per year (a mean recurrence interval of 975 years), respectively.

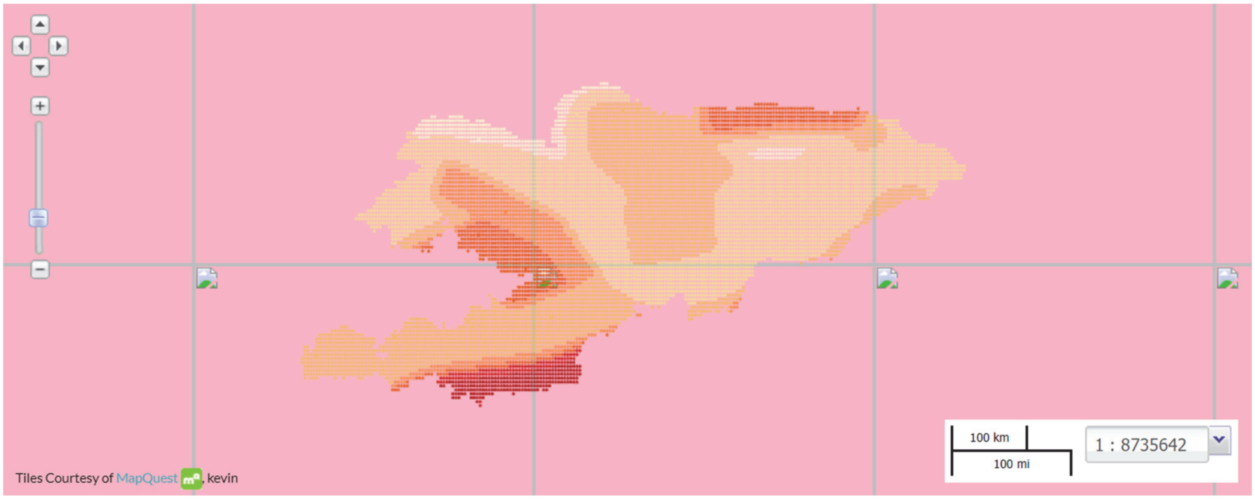


Figure 6-1 Probabilistic seismic hazard assessment map of the Kyrgyz Republic in terms of spectral acceleration expressed as fractions of g (gravit. acceleration) for a probability of exceedance of 10% over 50 years for bedrock conditions (V_s^{30} = 760 m/s) (from http://geonode.mes.kg/, last accessed February 20, 2019).

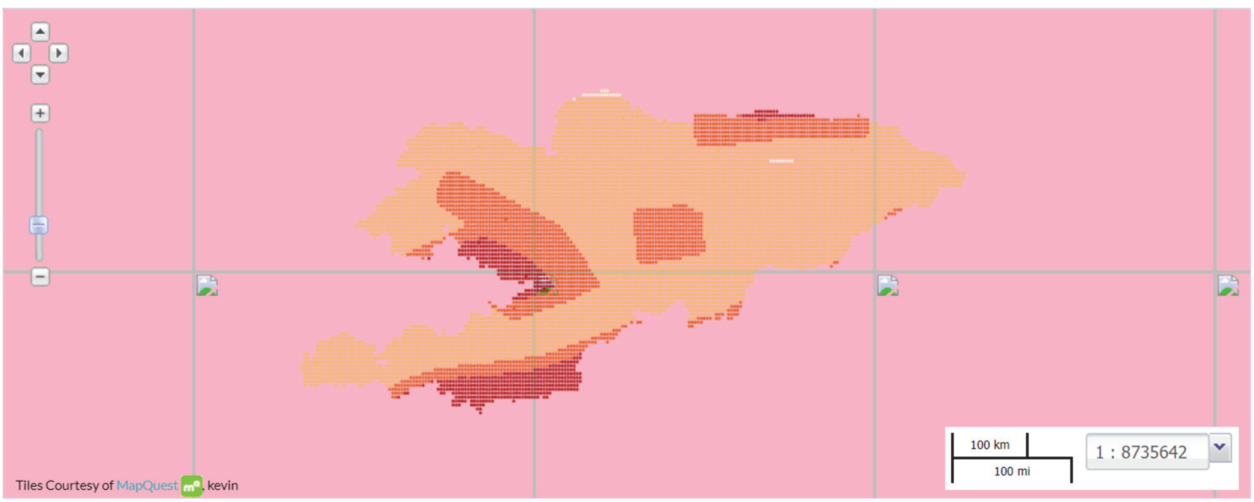


Figure 6-2 Probabilistic seismic hazard assessment map of the Kyrgyz Republic in terms of spectral acceleration expressed as fractions of g (gravit. acceleration) for a probability of exceedance of 5% over 50 years for bedrock conditions (V_s^{30} = 760 m/s) (from http://geonode.mes.kg/ last accessed February 20, 2019).

Next, to account for site amplification, the spectral acceleration values obtained are modified using U.S. Geological Survey's estimates of V_s^{30} (the mean shearwave velocity in the upper 30 meters of soil according to the 2007 global dataset by Wald and Allen) and the amplification factors from ASCE/SEI 7-16, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures, Provisions*

(ASCE, 2017a). It is necessary in the present project to interpolate between these two points and to extrapolate beyond them to all levels of ground motion. The relationship between exceedance frequency and ground motion tends to be loglinear, that is, the relationship is linear in the space of the ground motion on the x-axis and the logarithm of exceedance frequency on the y-axis. See for example Bommer and Abrahamson (2006). A line fit in the space of the natural logarithm of exceedance rates versus ground motion results in the seismic hazard curve for the given school site.

In this work, the hazard curve is denoted by $G(x)$, where x measures ground motion (here, 5% damped short-period spectral acceleration response in units of gravity) and $G(x)$ denotes the mean exceedance frequency of x, that is, the average rate at which a particular location experiences ground motion of intensity equal to or greater than x, in units of events per year. Figure 6-3 illustrates $G(x)$ for a building at latitude and longitude geographic coordinates (40.4958N, 72.8376E), where N denotes decimal degrees north latitude and E denotes decimal degrees east longitude. It is noted that Geonode provides spectral acceleration response for 5% damped, 0.1-second period (denoted here by SA01, short-period spectral acceleration response), but not 0.2-second period (SA02), which is the value typically used in U.S. practice.

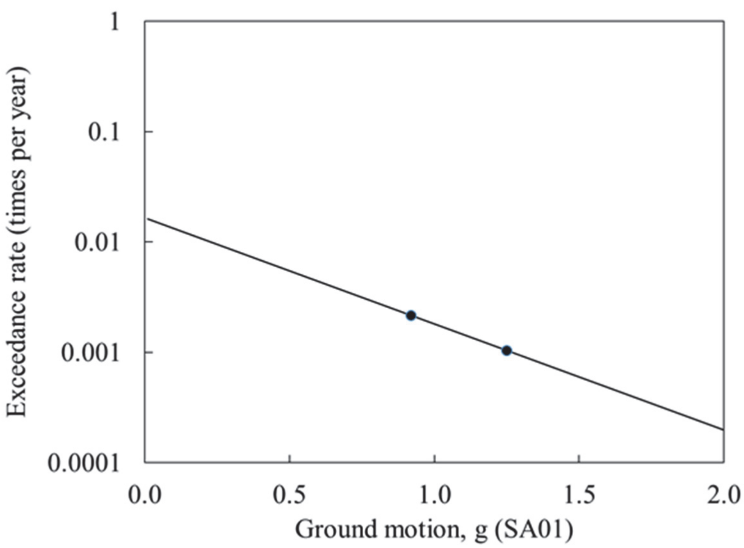


Figure 6-3 Seismic hazard curve developed from two spectral acceleration values acquired from Geonode for a given school site.

6.3 Available Building Data

Building data about eligible Kyrgyz schools were provided at three levels of resolution. The more seismically important attributes of the building are known, the better the building-to-building differences can be captured, leading to better vulnerability functions. The three levels of data are described as follows:

- **Low-resolution building data.** These are based on the information available in the eligible schools database compiled by the World Bank and provided to the project team in December 2018. This database identifies buildings in accordance with the UNICEF taxonomy, as described in Chapter 2, as well as indicating the building location in latitude/longitude, number of occupants by school, estimated year of construction, and number of stories by block.

- **Medium-resolution building data.** These are based on information collected during field inspections of 78 schools (approximately 25% of eligible schools list) by local engineers who were trained by the project team using the forms described in Chapter 3. This database identifies buildings in accordance with the GLoSI taxonomy.
- **High-resolution building data.** High-resolution data include structural and architectural design documents, especially structural and architectural drawings, that were collected by inspectors during site visits. This level of data resolution was only available for 3 blocks (0.3% of the eligible schools list).

6.4 Develop Vulnerability Function for Buildings with High-Resolution Data

Chapter 5 presents the estimation of seismic excitation (5% damped short-period spectral acceleration response) at which each of four limit states from the detailed performance-based assessments of representative index buildings, which are considered high-resolution data.

The results include the 1st limit state reflecting as-is conditions, and the 2nd, 3rd, and 4th limit states reflecting 1st, 2nd, and 3rd incremental retrofit, respectively. Each limit state is associated with a point on an idealized pushover curve. The pushover curve measures the earthquake force and deformation of the building in terms of spectral acceleration response (a normalized measure of force, denoted by S_a) and spectral displacement response (a normalized measure of displacement, denoted by S_d). When an earthquake causes the building to experience the pair (S_d, S_a), that pair is referred to as the performance point. Pushover curves developed as a result of performance-based assessments for each of the limit states for each of the representative index buildings are presented in Chapter 5. Figure 6-4 illustrates four pushover curves in the transverse direction for the precast concrete index building: one for the as-is condition, and one for each of three mitigation increments, labeled increments 2, 3, and 4. Each curve is labeled with at least one limit state. "LS" denotes a performance point at which life safety is threatened, generally by falling structural or nonstructural elements. "CP" denotes a performance point at which the building exceeds the collapse-prevention limit state, that is, where global collapse becomes more likely than not. In some cases (as in the as-is case illustrated here), the life-safety limit state coincides with the collapse-prevention limit state, in which the more deadly limit state, collapse prevention, governs the analysis, and one can ignore the life-safety limit state.

At levels of excitation beyond very modest ones, the performance point exceeds a value at which the building would not return to its initial pre-earthquake state—in engineering terms, it has exceeded its yield point. Beyond the yield point, energy is dissipated through structural damage, and damping (which measures energy dissipation) rises above the nominal value of 5%. Furthermore, as damage increases, the building stiffness decreases, so the building period lengthens, and SA is no longer the same as SA01 (0.1-second 5% damped elastic spectral acceleration response). One can relate the performance point back to SA01 using a methodology proposed by Fajfar (1999).

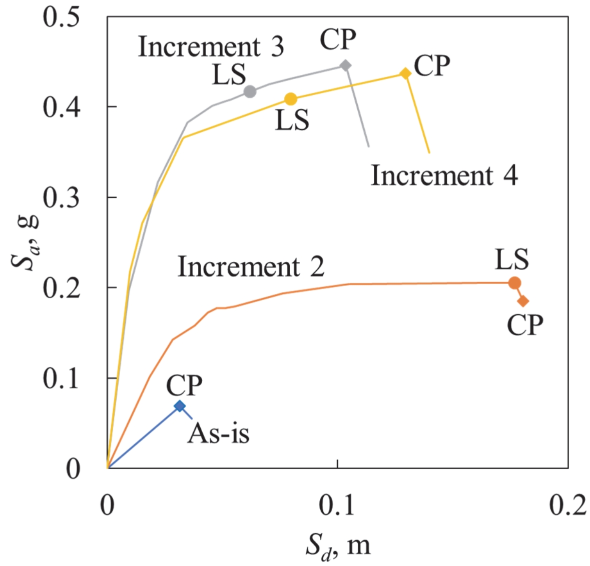


Figure 6-4 Pushover curves in the transverse direction for the precast concrete index building: one for the as-is condition, and one for each of three mitigation increments, labeled increments 2, 3, and 4. "LS" denotes a performance point at which life safety is threatened, generally by falling structural or nonstructural elements; "CP" denotes a performance point at which the building exceeds the collapse-prevention limit state.

Each block has two pushover curves: one for longitudinal motion (an earthquake acting along the long axis of the block) and one for transverse motion (an earthquake acting along the short axis of the block). Thus, for each block, the seismic excitation associated with 8 limit states (4 in each direction) is calculated and then related back to SA01 using the Fajfar (1999) methodology. The smaller of the two values of SA01 for any limit state—that is, the smaller of SA01 values associated with the limit state occurring in the longitudinal and transverse directions—is taken as the median value of SA01 associated with that limit state. The uncertainty around the median SA01 value is identified with a probability distribution that the present work, like other similar works (e.g., FEMA P-58 (FEMA, 2018)), treats as lognormal. A lognormal distribution has a second parameter that measures uncertainty, denoted here by β and referred to as the logarithmic standard deviation of capacity (more precisely, the standard deviation of the natural logarithm of the value of SA01 at which the limit state occurs). A typical value of $\beta = 0.8$ is used here regardless of building type, limit state, or direction, as is common.

The application of the methodology is illustrated below.

First, the period at which the constant-acceleration portion of the idealized response spectrum intersects the constant-velocity portion, a period to which Fajfar refers as the characteristic period, and denotes by T_c, is calculated using Equation (6-1) with the ground motion values having 10% exceedance probability in 50 years, and its average for all eligible schools tends to be approximately 0.2 sec:

$$T_c = \text{SA10/SA01} \qquad (6\text{-}1)$$

Because spectral acceleration response is approximately constant at periods less than T_c, and since SA01 measures spectral acceleration response at a period less than 0.2 sec, SA01 represents a good estimate of the spectral acceleration response along the entire constant-acceleration portion of the response spectrum. Given any performance point (S_d, S_a), the ductility demand μ and period T are calculated using Equations 6-2 and 6-3:

$$\mu = S_d/S_{dy} \tag{6-2}$$

$$T = 2\pi(S_d/(\mu\, S_a))^{0.5} \tag{6-3}$$

Equation 6-3 accounts for units by expressing S_d in meters and S_a in meters per sec^2. Equation 6-2 can be limited by some reasonable upper bound, such as 6, to control for unrealistically low yield displacement S_{dy}. Equation 6-4 gives the transition period, T_0, which separates two domains of the reduction factor due to ductility, R_μ, which is taken as a function of μ and T:

$$T_0 = 0.65\mu^{0.3} \quad T_c \leq T_c \tag{6-4}$$

$$R_\mu = (\mu - 1)(T/T_0) + 1 \quad T \leq T_0 \tag{6-5}$$

$$R_\mu = \mu \quad T > T_0 \tag{6-6}$$

The 5%-damped elastic spectral acceleration response associated with the same period T is given by Equation 6-7, and SA01 and SA10 calculated according to Equations 6-8 through 6-11:

$$S_{ae} = S_a R_\mu \tag{6-7}$$

If $T \leq T_c$:

$$\text{SA01} = S_{ae} \tag{6-8}$$

$$\text{SA10} = S_{ae} T_c \tag{6-9}$$

Otherwise, if $T > T_c$

$$\text{SA10} = S_{ae} T \tag{6-10}$$

$$\text{SA01} = \text{SA10}/T_c \tag{6-11}$$

Let d denote the limit state (1 through 5) and θ_d is the value of SA01 associated with 50% probability that limit state d will be exceeded. As shown in Equation 6-12, θ_d is the median capacity of the building to resist damage state d is taken as the smaller of the longitudinal and transverse values of SA01 associated with damage state d. Letting i and j denote motions in the longitudinal and transverse directions, respectively, then let:

$\text{SA01}_{d,i}$ = value of SA01 associated with limit state d, longitudinal direction

$\text{SA01}_{d,j}$ = value of SA01 associated with limit state d, transverse direction

$$\theta_d = \min\,(\text{SA01}_{d,i}, \text{SA01}_{d,j}) \tag{6-12}$$

The probability will be greater than 50% at SA01 values greater than θ_d, and it will be less than 50% at SA01 values that are less than θ_d. The probability is given by Equation 6-13:

$$P\left[D \geq d \mid X = x\right] = \Phi\left(\frac{\ln\left(x/\theta_d\right)}{\beta}\right) \tag{6-13}$$

The probability that a building is in damage state d but not a higher damage state (e.g., the life-safety limit state but not the collapse-prevention limit state, at which a few bricks fall but the building does not experience sidesway collapse) is given by Equation 6-14:

$$P\left[D=d \mid X=x\right]=P\left[D\geq d \mid X=x\right]-P\left[D\geq d+1 \mid X=x\right] \tag{6-14}$$

Equation 6-14 applies when a higher damage state $d + 1$ exists. If no higher damage state $d + 1$ exists, then Equation 6-13 also gives $P[D = d|X = x]$.

The seismic vulnerability function, $y(x)$, defined here as the expected fraction of occupants killed, given that earthquake ground motion x occurs, is estimated using Equation 6-15 using the theorem of total probability. In Equation 6-15, L_d denotes the expected value of loss given damage state d, such as the expected value of the fraction of occupants killed when a particular limit state (here, either the life safety or collapse prevention limit state) is exceeded:

$$y\left(x\right)=\sum_{d} L_d \times P\left[D=d \mid X=x\right] \tag{6-15}$$

The value of L_d is estimated as shown in Table 6-1. Appendix C presents a discussion on the determination of L_d. In this work, the life-safety limit state is denoted by $d = 4$, and the collapse-prevention limit state is denoted by $d = 5$, consistent with partial collapse and collapse damage states of the *European Macroseismic Scale 1998* (EMS-98; European Seismological Commission, 1998) damage scale and other works used here. Lower damage states 1 through 3 are not used here.

Table 6-1 Fatality Rates Given Collapse

Damage state d	L_d
Partial collapse (d = 4)	0.015
Collapse (d = 5)	0.30

6.5 Develop Vulnerability Function for Buildings with Low- and Medium-Resolution Data

This section describes the methodology used to estimate the seismic vulnerability of eligible school buildings with low- and medium-resolution data under as-is conditions.

6.5.1 SYNER-G Methodology

This project utilizes the SYNER-G methodology documented in Milutinovic and Trendafilovski (2003). The SYNER-G methodology associates each building type and structural attribute with existing motion-damage relationships, those of Milutinovic and Trendafilovski (2003). This is different than the approach used by the UNICEF and GLoSI taxonomies that were used to collect information on eligible buildings. It is therefore necessary to map from UNICEF building types in the low-resolution database to SYNER-G, and to map from GLoSI building types in the medium-resolution database to SYNER-G. Table 6-2 lists the SYNER-G building types.

Table 6-2 SYNER-G Building Types

ID	*Abbrev*	*Description*
1	M1.1	Masonry, rubble stone/fieldstone
2	M1.2	Masonry, simple stone
3	M1.3	Masonry, massive stone
4	M2.0	Masonry, adobe/earth brick
5	M3.1	Masonry, brick, wooden slabs
6	M3.2	Masonry, brick, masonry vaults
7	M3.3	Masonry, brick, composite steel and masonry slabs
8	M3.4	Masonry, brick, RC slabs
9	M4.0	Reinforced masonry, confined masonry
10	M5.0	Masonry, strengthened
11	RC1.0	Concrete moment frames
12	RC2.0	Concrete shear walls
13	RC3.1	Concrete frames with regularly in-filled walls
14	RC3.2	Concrete, irregular frames
15	RC4	Concrete, cast-in-situ dual systems
16	RC5	Precast concrete, tilt-up walls
17	RC6	Precast concrete, dual systems
18	S0.0	Steel structures
19	S1.0	Steel moment frames
20	S2.0	Steel braced frames
21	S3.0	Steel frames and unreinforced masonry infill walls
22	S4.0	Steel frames and cast-in-place shear walls
23	S5.0	Steel and RC composite systems
24	W0.0	Wood structures

Table 6-3 presents the project team's best estimate of the most similar SYNER-G type for each UNICEF type. Similarly, Table 6-4 presents the project team's best estimate of the most-similar SYNER-G type for each GLoSI type. For details about GLoSI reinforced concrete building types IDs 1 through 5 in the table, see Yamin et al. (2017). For details about masonry types, 6 through 10 in the table, see Adhikari and D'Ayala (2017).

Table 6-3 Mapping of UNICEF Taxonomy to Closest SYNER-G Building Type

UNICEF (2013) Taxonomy		*Closest SYNER-G Building Type*		
ID	*Description*	*ID*	*Abbrev*	*Description*
1	Large-panel, flat-wall buildings from cast reinforced concrete.	12	RC5	Precast concrete tilt-up walls
2	Frame-panel building with hinged plates; frame building with brick infill; metal frames.	17	RC6	Precast concrete, dual systems
3	Structural system with incomplete frame where outer walls are brick and inner structures are frame.	9	M4.0	Reinforced masonry, confined masonry
4	Brick building of composite structures (another table in UNICEF 2013 says "in composite structures").	7	M3.4	Masonry, brick, RC slabs
5	Brick (stone) building of up to 5 floors.	9	M4.0	Reinforced masonry, confined masonry
6	Building of traditional construction with wooden double frame for 9-point earthquake intensity and single frame for 7-8-point seismicity with the filling of soil materials and light-weight roofing. Their seismic resistance can be considered as existing under the following conditions: The foundation and the basement are made of solid waterproof materials (concrete, brick, stone, etc.); The distance between walls (in the clear) does not exceed 5 m; Wooden parts are not rotten in the lower and upper parts of the support and stands of the frame; There are metal clamps and patch plates in the intersection nodes of vertical and horizontal elements of the frame assembled with a coak or jointing.	24	W0.0	Wood structures
7	Same buildings with wooden frame which fail to meet requirements of item 6.	24	W0.0	Wood structures
8	Buildings from puddle clay (pahsa) and raw brick, adobe (saman) blocks in the areas with 7-8 earthquake intensity can be considered seismically secure if the aggregate cross section of the party walls of structures in each direction (longitudinal, transverse) at the mid-level of a storey makes at least 4% of the building area calculated on the basis of outer faces of walls. The following elements should be in place as well: foundation and the basement made of solid waterproof materials (concrete, brick, stone and etc.) framing of outer walls; diagonal flooring from boards on the beams; attic roof with asbestos cement or metal roofing on wooden beams.	4	M2.0	Masonry, adobe/earth brick
9	Same buildings from puddle clay and raw brick failing to comply with the requirements of item 8.	4	M2.0	Masonry, adobe/earth brick
10	Same buildings as per item 8 in the regions with seismic resistance of 9+ without reinforcement of walls may be used for various purposes except for permanent staying of people.	4	M2.0	Masonry, adobe/earth brick
11	Frameless buildings with walls of dried clay (gualyak) are seismically non-resistant for all seismic regions, and it is not recommended for people to stay in them.	4	M2.0	Masonry, adobe/earth brick
12	Buildings with walls from burnt brick built without any design and aseismic activities of 1-2 storeys high having no damages above 2 level according to MSK-64 or IMS-98 [sic].	5	M3.1	Masonry, brick, wooden slabs
13	Wooden-board buildings in case of 7-8 seismic intensity in the area.	24	W0.0	Wood structures

Table 6-4 Mapping of GLoSI Taxonomy to Closest SYNER-G Building Type

GLoSI Taxonomy				*Closest SNYER-G Building TYpe*		
ID	*Abbrev*	*Description*	*Comment*	*ID*	*Abbrev*	*Description*
1	RC1	Reinforced concrete frame	Infill walls if any have a seismic gap to allow beams and columns to deform	11	RC1.0	Concrete moment frames
2	RC2	Reinforced concrete frame with unreinforced masonry infill walls	Infill walls made of brick or stone. Openings do not produce short-column effect	13	RC3.1	Concrete frames with regularly in-filled walls
3	RC3	Reinforced concrete frame with short columns	Column behavior is unintentionally shear critical rather than governed by flexure	11	RC1.0	Concrete moment frames
4	RC4	Reinforced concrete combined or dual system	Reinforced concrete frames plus any kind of bracing or shear walls	15	RC4.0	Concrete, cast-in-situ dual systems
5	RC5	Non-engineered reinforced concrete	May contain long cantilever beams, weaker first story than upper stories, poorly cast members, non-straight members	14	RC3.2	Concrete, irregular frames
	RC6	Precast		17	RC6.0	Precast concrete, dual systems
6	A	Adobe		4	M2.0	Masonry, adobe/earth brick
7	UCM/URM	Unconfined unreinforced masonry	6 subtypes omitted	7	M3.3	Masonry, brick, composite steel and masonry slabs
8	CM	Confined masonry		9	M4.0	Reinforced masonry, confined masonry
9	RM	Reinforced masonry		9	M4.0	Reinforced masonry, confined masonry
10	SFM	Steel framed buildings with masonry walls	4 subtypes omitted; SFM not used in ATC-142, none in Kyrgyz schools	21	S3.0	Steel frames and unreinforced masonry infill walls

As discussed in Chapter 4, there are no bright lines between Kyrgyz school building types—some buildings have some attributes of complex masonry and other attributes of reinforced concrete frames, for example. These three types can be thought of as anchor points in a spectrum of real buildings.

Similar to the vulnerability function derived in Section 6.4 for buildings with high-resolution data, the vulnerability function indicates the expected fraction of occupants killed, given that earthquake ground motion x occurs. The ground motion, x, is parameterized in terms of 5% damped, short-period spectral acceleration response. In contrast, SYNER-G methodology uses EMS-98 macroseismic intensity, denoted here by I, as its measure of seismic excitation. Thus, a ground motion to intensity conversion equation, sometimes called a GMICE, is used here to relate the two. Equation 6-16 presents the estimation of I at each value of x using Worden et al. (2012), whose functional form is given by:

$$\begin{aligned} I &= c_1 + c_2 \times \log_{10}(x) \qquad \log_{10}(x) \leq t_1 \\ &= c_3 + c_4 \times \log_{10}(x) \qquad \log_{10}(x) > t_1 \end{aligned} \tag{6-16}$$

where x denotes 5%-damped short-period spectral acceleration response in units of cm/s^2, and parameters c_1, c_2, c_3, c_4, and t_1 are given by Table 6-5.

Table 6-5 GMICE Parameter Values (Worden et al., 2012)

x	c_1	c_2	c_3	c_4	t_1
SA03	1.26	1.69	–4.15	4.14	2.21

In the table, SA03 denotes the 5% damped spectral acceleration response at 0.3-second period, which Worden et al. (2012) use to measure the short-period spectral acceleration response, and is therefore interchangeable here with SA01. The probabilistic damage state of a building is calculated using the SYNER-G methodology, as follows: The vulnerability index, V_i, of a building is a function of the building type (which determines its median baseline index $V^*_{i.m}$), the presence of modifiers, V_m, and a regional factor, V_r, as shown Equation 6-17:

$$V_i = V_i^* + \sum V_m + V_r \tag{6-17}$$

where:

V_i^* is taken as median value of $V^*_{i.m}$ as indicated for each SYNER-G building type in Table 6-6

V_m is taken from Table 6-7

V_r denotes a regional factor, which World Bank (2016) takes as zero

Table 6-6 Baseline Vulnerability Index, $V^*_{i.m}$, per SYNER-G Building Type

SYNER-G Building Type	*Description*	$V^*_{i.m}$
M1.1	Masonry, rubble stone/fieldstone	0.873
M1.2	Masonry, simple stone	0.740
M1.3	Masonry, massive stone	0.616
M2.0	Masonry, adobe/earth brick	0.840
M3.1	Masonry, brick, wooden slabs	0.740
M3.2	Masonry, brick, masonry vaults	0.776
M3.3	Masonry, brick, composite steel and masonry slabs	0.704
M3.4	Masonry, brick, RC slabs	0.616
M4.0	Reinforced masonry, confined masonry	0.451
M5.0	Masonry, strengthened	0.694

Table 6-6 Baseline Vulnerability Index, $V^*_{i.m}$, per *SYNER-G* Building Type (continued)

SYNER-G Building Type	*Description*	$V^*_{i.m}$
RC1.0	Concrete moment frames	0.442
RC2.0	Concrete shear walls	0.386
RC3.1	Concrete frames with regularly in-filled walls	0.402
RC3.2	Concrete, irregular frames	0.522
RC4.0	Concrete, cast-in-situ dual systems	0.386
RC5.0	Precast concrete, tilt-up walls	0.384
RC6.0	Precast concrete, dual systems	0.544
S0.0	Steel structures	0.324
S1.0	Steel moment frames	0.363
S2.0	Steel braced frames	0.287
S3.0	Steel frames and unreinforced masonry infill walls	0.484
S4.0	Steel frames and cast-in-place shear walls	0.224
S5.0	Steel and RC composite systems	0.402
W0.0	Wood structures	0.447

Table 6-7 Vulnerability Modifier, V_m

		Pre/low code	*Medium code*	*High code*
Earthquake resistant design (ERD) level		0.16	0	-0.16
Number of floors	$n \leq 2$	-0.04	-0.04	-0.04
	$3 \leq n \leq 5$	0	0	0
	$n \geq 6$	0.08	0.06	0.04
Plan irregularity	Regular	0	0	0
	Shape	0.04	0.02	0
	Torsion	0.02	0.01	0
Elevation regularity	Regular	0	0	0
	Irregular	0.04	0.02	0
Short column		0.02	0.01	0
Bow windows		0.04	0.02	0
Soft story		0.04	0.04	0
Foundation system	Beams/mat	-0.04	0	0
	Connected Beams	0	0	0
	Isolated	0.04	0	0
Foundation level	Similar	0	0	0
	Different	0.04	0.04	0

Table 6-7	Vulnerability Modifier, V_m (continued)			
		Pre/low code	*Medium code*	*High code*
Soil morphology	No slope	0	0	0
	Slope	0.02	0.02	0.02
	Cliff	0.04	0.04	0.04
Maintenance	Good	0	0	0
	Poor	0.04	0.02	0

V_i is used to estimate the probability mass function of EMS-98 damage state (denoted here by *D*, an uncertain index that can take on one of five values 1, 2, 3, 4, or 5, each corresponding to a damage state) conditioned on macroseismic intensity, *I*. The expected value of damage state, denoted by μ_D, given macroseismic intensity, *I*, is calculated in accordance with Equation 6-18:

$$\mu_D = 2.5\left(1+\tanh\left(\frac{I+6.25V_i-13.1}{2.3}\right)\right) \tag{6-18}$$

The probability mass function of *D* is taken as having the following form, in which *d* is a particular value of *D*. The values *d* = 4 and *d* = 5 correspond to partial collapse and collapse, respectively, and are the only damage states used here.

$$P\left[D=d \mid X=x\right]=\int_{z=d}^{d+1}\frac{(z)^{q-1}(6-z)^{8-q-1}}{B(q,8-q)(6)^7} \tag{6-19}$$

$$q = 0.056\mu_D^3 - 0.416\mu_D^2 + 2.296\mu_D \tag{6-20}$$

Finally, the expected value of fatality rate, *y*, is calculated as follows:

$$y(x)=\sum_{d=4}^{5}L_d \times P\left[D=d \mid X=x\right] \tag{6-21}$$

where L_d denotes the expected value of the fraction of building occupants killed given the occurrence of the damage state *d*.

6.5.2 Vulnerability Function for Building with Low-Resolution Building Data

For low-resolution data, the following limited information is available to inform the determination of the vulnerability index:

- Structural typology is provided in accordance with UNICEF taxonomy by block. This information is mapped to SYNER-G building types using Table 6-3, and informs to the selection of the baseline vulnerability index $V_{i.m}^*$ in Table 6-6.
- Year built by block. This information relates to the selection of vulnerability modifier, V_m, in Table 6-7 as follows: Pre-code (meaning before seismic design requirements became common in Kyrgyz schools around 1970), low code (meaning 1971 to 1987), moderate code (1988 to 2009), and high code (2010 and later).

- Number of stories by block. This information relates to the selection of vulnerability modifier, V_m, in Table 6-7.

All other modifiers will be assigned a value of zero.

When implementing SYNER-G, let $y_{A,i}(x)$ denote the vulnerability function for building i in the population, given knowledge A, where i is an index to buildings in the population of eligible school buildings. Here low-resolution data are indicated by "A" and y refers to the mean fraction of building occupants killed—the mean fatality rate—given data A, when the building is shaking at ground motion x. (Note that, to calculate the expected value of fatalities, one must use the mean fraction of building occupants killed, not the median fraction.)

6.5.3 Vulnerability Function for Buildings with Medium-Resolution Building Data

Additional building data were collected during the field inspections (see Chapter 3 for details) for a subset of all eligible schools. The data collection forms were developed based on the information necessary for the implementing the SYNER-G methodology. Collected data include the following metadata and building attributes, plus photographs supporting each assignment of building attributes (item 12 through item 23).

1. School ID, a unique identifier.
2. Block ID, a unique integer identifier within a school campus.
3. Inspector name.
4. Inspection date.
5. Inspection start time.
6. School name.
7. Building name.
8. Address.
9. Education level.
10. Number of students.
11. Year built.
12. Basic type, long axis. Basic types in medium-resolution data are categories using the GLoSI taxonomy: six reinforced concrete types and four masonry types. "Long axis" refers to the structural system that resists lateral forces parallel to the axis of the longer dimension of the block.
13. Basic type, short axis. Same types as long axis.
14. Stories. Data are grouped in three bins: 1 story, 2 or 3 stories, and 4 to 7 stories. Taller buildings do not exist within the school inventory. Story grouping aligns with the GLoSI taxonomy.
15. Seismic design level.

16. Irregularity: horizontal, vertical, both, or neither. For definitions, see Table B-4 and Table B-5 in FEMA P-154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards* (FEMA, 2016). Generally however, vertical irregularities include a sloping site with at least 1 story difference within the footprint of a block, in-plane setback of the lateral system, out-of-plane setback of the lateral system, soft or weak story, short columns or piers, and split level. Plan irregularities include torsion, non-orthogonal systems, reentrant corners with at least 7-meter projections, diaphragm openings at least half the width of the diaphragm in each direction, and beam centerlines that do not align with column centerlines in plan.
17. Diaphragm flexibility (flexible or rigid roof, flexible or rigid floors). For this work, it is assumed that a rigid diaphragm indicates reinforced concrete.
18. Weak columns, long axis and short axis (yes or no). Weak columns have apparent moment capacity less than that of the beam, as evidenced for example by either column dimension being less than the beam depth.
19. Sensitive nonstructural elements, presence or absence of fragile chimneys, fragile parapets, and other falling hazards. Other falling hazards refers to many heavy elements that are not isolated from the structure, are inadequately reinforced or interconnected, and lack bracing or anchorage. Examples include hanging light fixtures, infill non-load-bearing walls, and heavy weak fences.
20. Mat foundation (yes or no). This feature was included because it appears in the SYNER-G methodology, although it is doubtful that the foundation type would ever be observable during field investigations.
21. Pounding risk (yes or no). If the block is separated by less than 25 mm per story from an adjacent block and the floors of the two blocks do not align, pounding risk is assumed.
22. Seismic retrofit (yes or no). This is indicated by evidence that a new lateral system, new structural connections, or both were added to the structure after initial construction.
23. Quality or condition (low, medium, or good). Low quality or condition is indicated by a lot of rust coming out of cracks, spalled concrete cover, very low reinforcement ratio (defined as steel area divided by concrete area, which can be seen from structural drawings available in some schools), honeycombed concrete, or other issues that reduce strength relative to a new building. Medium quality or condition is indicated by the presence of few of these features. Good quality is indicated by the absence of these features.

When implementing SYNER-G, let $y_{B,i}(x)$ denote the vulnerability function for building i in the population, given knowledge B, where i is an index to buildings in the population of eligible school buildings. Here medium-resolution data are indicated by "B" and y refers to the mean fraction of building occupants killed—the mean fatality rate—given data B, when the building is shaking at ground motion x.

6.6 Adjust Vulnerability Functions

Figure 6-5 shows the vulnerability functions for complex masonry typology with low-, medium-, and high-resolution data. It is noted that while the "high resolution" curve is a single line, as it represents the results for a specific index building, the low- and medium-resolution curves reflect the equally weighted average of all buildings in the group. Appendix H presents the vulnerability functions for the three typologies studied.

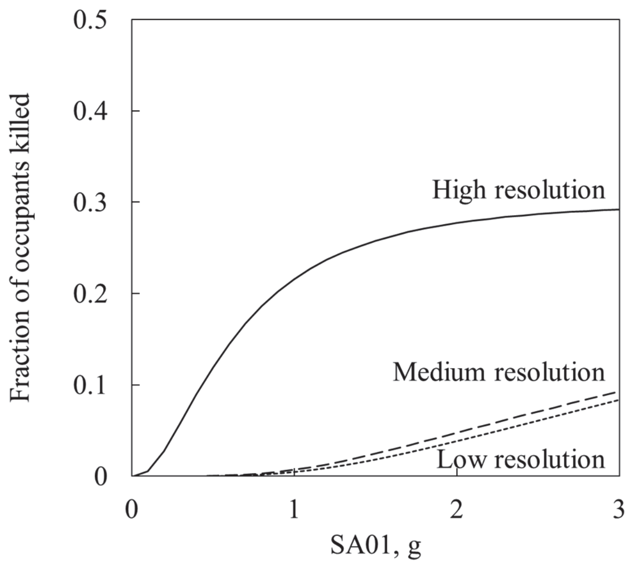


Figure 6-5 Vulnerability functions for complex masonry typology, low-, medium-, and high-resolution data.

This section describes adjustments made to vulnerability functions derived for buildings with low- and medium-resolution data in as-is conditions. The functions are adjusted to be consistent with vulnerability functions for similar buildings with higher resolution data, where available.

6.6.1 From Low-Resolution to Medium-Resolution

The mean seismic vulnerability function of a building that is in the population of eligible school buildings but not in the sample of buildings with medium-resolution data can be calculated by accounting for additional information (knowledge) available, using Equations 6-22 and 6-23:

$$F_{AB}\left(x\right)=\frac{\frac{1}{n}\sum_{i=1}^{n}y_{B,j}\left(x\right)}{\frac{1}{m}\sum_{i=1}^{m}y_{A,i}\left(x\right)} \tag{6-22}$$

In Equation 6-22, $F_{AB}(x)$ denotes an adjustment factor to adjust vulnerability functions $y_A(x)$ account for knowledge B; i and j are indices to buildings in the low-resolution population and medium-resolution sample of field inspected buildings, respectively; $y_{A,i}(x)$ denotes the vulnerability function for building i in the low-resolution population; $y_{B,j}(x)$ denotes the vulnerability function for building j in the medium-resolution sample; m denotes the number of buildings in the low-resolution sample; and n denotes the number of buildings in the medium-resolution sample. Thus, an adjusted seismic vulnerability function for building i with low-resolution data can be calculated, as follows:

$$y_{AB,i}\left(x\right)=F_{AB}\left(x\right)\times y_{A,i}\left(x\right) \tag{6-23}$$

6.6.2 From As-Is Condition to Retrofitted Condition

The seismic vulnerability function of a retrofitted building with medium-resolution data is obtained by applying two adjustments: one for the ratio of post-retrofit to pre-retrofit vulnerability for similar buildings with higher resolution data (Equation 6-24) and one for additional information available for similar buildings with higher resolution data (Equations 6-25 and 6-26).

$$F_{k,r}\left(x\right)=\frac{y_{Q,k,r}\left(x\right)}{y_{Q,k}\left(x\right)} \tag{6-24}$$

In Equation 6-24, $y_{Q,k}(x)$ denotes the seismic vulnerability function for a particular building indexed by k, evaluated using high-resolution data; $y_{Q,r,k}(x)$ denotes a similar seismic vulnerability function for building k, but given that retrofit r has been applied; and $F_{k,r}(x)$ denotes the ratio of post-retrofit to pre-retrofit vulnerability for building k in the high-resolution sample, given that retrofit r has been applied.

Each building k represents a group of buildings of similar building type (that is, associated with the same index building) in the medium-resolution sample, with N_k denoting the number of buildings in that latter group. Let $F_{BQ}(x)$ denote a factor to adjust the seismic vulnerability functions in the medium-resolution sample to account for the knowledge gained using performance-based earthquake engineering and the high-resolution dataset. Let j index only the buildings in the medium-resolution sample that building k is supposed to resemble. The adjustment factor $F_{BQ}(x)$ is calculated, as follows:

$$F_{BQ}\left(x\right)=\frac{y_{Q,k}\left(x\right)}{\frac{1}{N_k}\sum_{j=1}^{N_k}y_{B,j}\left(x\right)} \tag{6-25}$$

Let $y_{BQ,j}(x)$ denote a vulnerability function for building j in the medium-resolution sample of screened buildings, adjusted to account for knowledge Q. It is calculated as follows:

$$y_{BQ,j}\left(x\right)=F_{BQ}\left(x\right)y_{B,j}\left(x\right) \tag{6-26}$$

Let $y_{BQ,j,r}(x)$ denote a vulnerability function for building j in the medium-resolution sample of screened buildings, adjusted to account for knowledge Q, assuming that it has been retrofitted with retrofit measure r. Building j must be among the N_k buildings that building k is supposed to represent. It is calculated as follows:

$$y_{BQ,j,r}\left(x\right)=F_{BQ}\left(x\right)F_{k,r}\left(x\right)y_{B,j}\left(x\right) \tag{6-27}$$

The seismic vulnerability function of a retrofitted building with low-resolution data is obtained by applying both the adjustment for additional knowledge (low- to medium- to high-resolution) and the retrofit.

Let $y_{ABQ,i}(x)$ denote the vulnerability functions for building i in the low-resolution population of eligible buildings, adjusted to account for knowledge B and Q. It is calculated as follows:

$$\begin{aligned} y_{ABQ,i}\left(x\right)&=y_{AB,i}\left(x\right)F_{BQ}\left(x\right)\\ &=y_{A,i}\left(x\right)F_{AB}\left(x\right)F_{BQ}\left(x\right) \end{aligned} \tag{6-28}$$

Let $y_{ABQ,i,r}(x)$ denote a similar vulnerability function, except given that retrofit r is applied. It is calculated as follows:

$$y_{ABQ,r,i}(x) = y_{AB,i}(x) F_{BQ}(x) F_r(x) \tag{6-29}$$

This adjustment is only available if the building type matches one of the representative index building types.

6.6.3 When the Representative Index Building is not a Close Match

The most common type of school building that did not resemble the typologies of the representative index buildings was adobe construction, which is known to exceed life-safety and collapse-prevention limit states at lower levels of ground motion than complex masonry, complex masonry with concrete framing, and precast concrete frames and walls. Other building types included small numbers of timber and steel sandwich panel buildings. The project team did not create index buildings to represent these poor or uncommon types, but instead estimated the life-safety and collapse-prevention median capacities for this group by judgment: approximately SA01 = 0.13g and 0.27g, respectively. These values were used in Equation 6-21 to create the $y_Q(x)$ vulnerability function for all other building types. None of these building types appeared in the medium-resolution database, so $F_{AB}(x)$ was taken as 1.0 for all x and $F_{BQ}(x)$ was calculated using Equation 6-25, substituting $y_{A,j}(x)$ for $y_{B,j}(x)$. The only retrofit measure considered for these buildings was replacement, in which effectively all fatalities estimated under as-is conditions were assumed to be avoided.

6.7 Calculate Prioritization Indices

Based on the vulnerability function developed for each building, two prioritization indices are calculated for each eligible school.

6.7.1 Safety/Benefits Index A_1

The safety/benefits index, A_1, represents the safety benefit per student per unit cost of the retrofit. It is calculated as follows:

$$A_1 = \frac{B_r}{V} = \left(\frac{EAL}{V} - \frac{EAL_r}{V} \right) \times t \tag{6-30}$$

where:

B_r = benefit of retrofit r, in terms of reduced number of fatalities during the life of the building

V = estimated time-averaged population of students at the building, i.e., accounting for nighttime and weekend hours during which the building is unoccupied

$= Occs \times h$ (6-31)

where:

$Occs$ = actual number of occupants during school hours

h = fraction of the week during which the school is occupied

$$= \frac{5 \frac{\text{school days}}{\text{week}} \times 7 \frac{\text{school hr}}{\text{day}}}{7 \frac{\text{calendar days}}{\text{week}} \times 24 \frac{\text{hr}}{\text{day}}} \tag{6-32}$$

$= 0.21$

$$\frac{EAL}{V} = \int_{x=0}^{\infty} y(x)\left|\frac{dG(x)}{dx}\right|dx \tag{6-33}$$

$$\frac{EAL_r}{V} = \int_{x=0}^{\infty} y_r(x)\left|\frac{dG(x)}{dx}\right|dx \tag{6-34}$$

where:

EAL = expected annual number of fatalities under as-is conditions

EAL_r = expected annual number of fatalities under retrofit r

$G(x)$ = mean exceedance frequency of ground motion x, events per year

$y(x)$ = $y_Q(x)$ if among the buildings examined with performance-based earthquake engineering
= $y_{BQ}(x)$ if among medium-resolution but not high resolution
= $y_{ABQ}(x)$ otherwise

$y_r(x)$ = seismic vulnerability function under retrofit r
= $y_{Q,r}(x)$ if among the buildings examined with performance-based earthquake engineering
= $y_{BQ,r}(x)$ if among medium-resolution but not high resolution
= $y_{ABQ,r}(x)$ otherwise

t = expected remaining useful life of the structure. Absent better information, t is taken as 75 years, in agreement with NIBS (2018).

6.7.2 Cost/Efficiency Index A_2

The cost/efficiency index, A_2, represents representing the number of students benefited by a retrofit per unit cost of the retrofit. A_2 is calculated as follows:

$$A_{2,r} = \frac{Occs}{C_r} \tag{6-35}$$

where:

$Occs$ = actual number of occupants during school hours

C_r = cost of retrofit r, presented in Chapter 5. The cost might be a square-meter value multiplied by the area of the building.

6.8 Calculate Benefit-Cost Ratio

The benefit-cost ratio is calculated as a combination of two prioritization indices described further in Sections 6.7.1 and 6.7.2.

The benefit-cost ratio of retrofit r is calculated as follows:

$$BCR_r = A_{1,r}A_{2,r}h = \frac{B_r}{C_r} \tag{6-36}$$

where:

BCR_r = benefit-cost ratio of retrofit r for the particular building

$A_{1,r}$ = safety/benefits index of retrofit r for the particular building in question

$A_{2,r}$ = cost/efficiency index of retrofit r for the particular building in question

h = fraction of the week during which the school is occupied

B_r = benefit of retrofit r, in terms of reduced number of fatalities during the life of the building

C_r = cost of retrofit r. The cost might be a square-meter value multiplied by the area of the building.

6.9 Checking Prescriptive Vulnerability Requirements

Two performance objectives are checked at hazard levels as given in Table 6-8. For retrofit measures that aim to ensure life safety, low probability at the life-safety hazard level is checked with Equation 6-37. For retrofit measures that aim to prevent collapse, low collapse probability at the collapse-prevention hazard level is checked with Equation 6-38. Table 6-8 also lists limit states and maximum probabilities applied here.

Life-safety mitigation $$P_{LS} \le \Phi\left(\frac{\ln\left(x_{LS}/\theta_d\right)}{\beta}\right) \tag{6-37}$$

Collapse-prevention mitigation $$P_{CP} \le \Phi\left(\frac{\ln\left(x_{CP}/\theta_d\right)}{\beta}\right) \tag{6-38}$$

where:

x_{LS} = SA01 associated with life-safety exceedance frequency G_{LS}

x_{CP} = SA01 associated with collapse-prevention exceedance frequency G_{CP}

Table 6-8 Performance Requirements

Requirement	*Hazard level*	*Limit state*	*Maximum probability*
Life safety	G_{LS} = 0.002 yr^{-1}	Local collapse, e.g., bricks fall	P_{LS} = 0.10
Collapse prevention	G_{CP} = 0.0004 yr^{-1}	Global collapse, e.g., sidesway collapse	P_{CP} = 0.10

Chapter 7
Results and Recommendations

This chapter demonstrates the results from the benefit and cost studies and the application of the risk-based prioritization framework for prioritizing schools in the Kyrgyz Republic. A discussion of prioritization options is also presented.

7.1 Cost Estimate Summary

This section summarizes the cost estimates for each of the retrofit increments for three typologies. Figure 7-1 shows the cost estimates per square meter for seismic retrofit and capital repair. Figure 7-2 includes the same costs in addition to costs related to energy efficiency (EE) and water, sanitation, and hygiene (WASH).

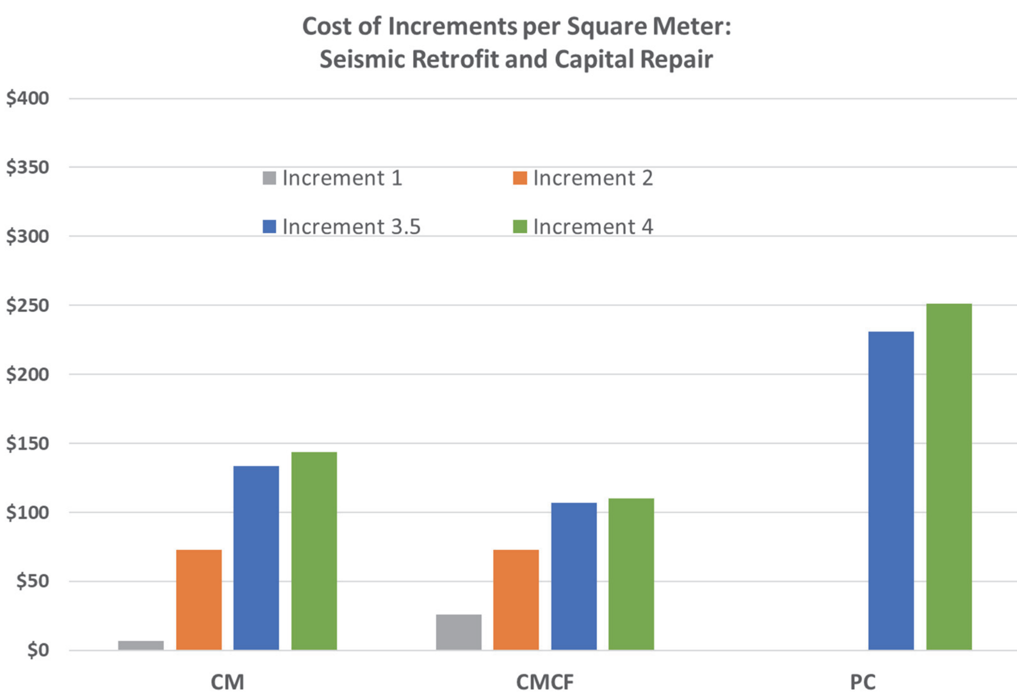


Figure 7-1 Seismic retrofit and capital repair cost estimate per square meter for three typologies at retrofit increment levels.

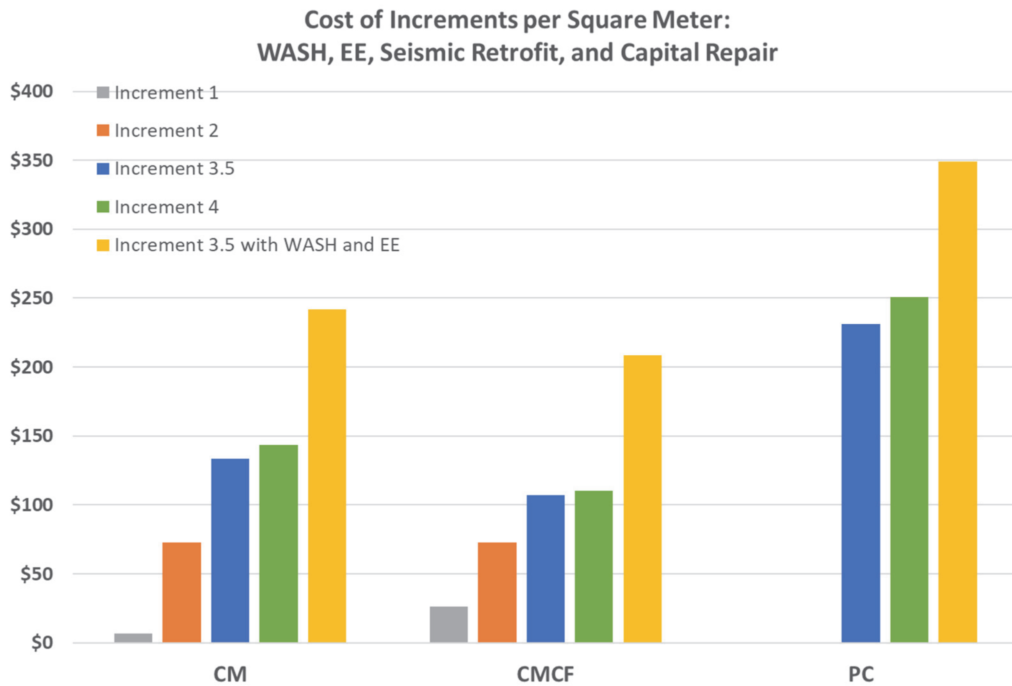


Figure 7-2 WASH, EE, seismic retrofit, and capital repair cost estimate per square meter for three typologies at retrofit increment levels.

7.2 Prioritization among Equals

The prioritization framework presented in Chapter 6 takes into account the seismic hazard at the school site location, the total area of the block, the number of students, as well as many other considerations. In order to compare typologies with each other and the benefit and cost ratio related to each of their increments, an additional study was conducted with three assumed buildings of identical size located at the same site, but with three different typologies.

Figure 7-3 shows the change in benefit-cost ratio for each typology and its increments. The figure suggests that implementing Increment 2 retrofit on Complex Masonry with Concrete Framing (CMCF) has the highest benefit-cost ratio. This is because the CMCF index building was found to be highly seismically deficient, and implementing any retrofit, even for a low increment at a low cost, provides a high level of benefit. The unretrofitted Precast Concrete Frames and Walls (PC) index building is also considered seismically deficient, but because the cost of retrofit is high, the benefit-cost ratio is not as advantageous as CMCF. The unretrofitted Complex Masonry (CM) index building is stronger in comparison and thus yields lower benefits at the same increment level.

Figure 7-4 is a presentation of the safety/benefits index, A_1, defined in Chapter 6, representing safety/efficiency benefit per student with respect to retrofit cost per square meter (WASH and EE costs are not considered). The curves fit to the increment points indicate that at a certain point, A_1 value does not increase, even if the more funds are spent. This can be interpreted to indicate that the points where the curves flatten out (Increment 2) is the most optimal point for achieving benefits. However, it is important to note that while one statistical occupant will be safe at an Increment 2, when this is applied to the whole population of occupants, the results will change, as this is captured by the cost/efficiency index, A_2, not considered in this plot.

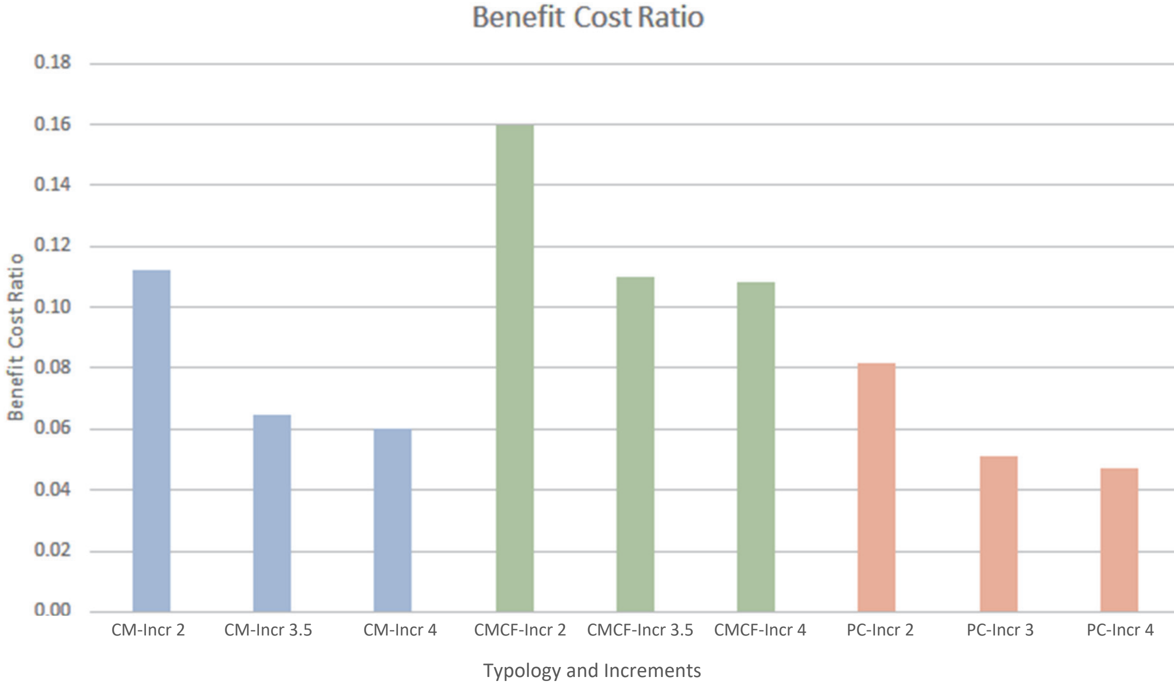


Figure 7-3 Comparison of benefit-cost ratio for retrofit increments of identical buildings constructed with different typologies.

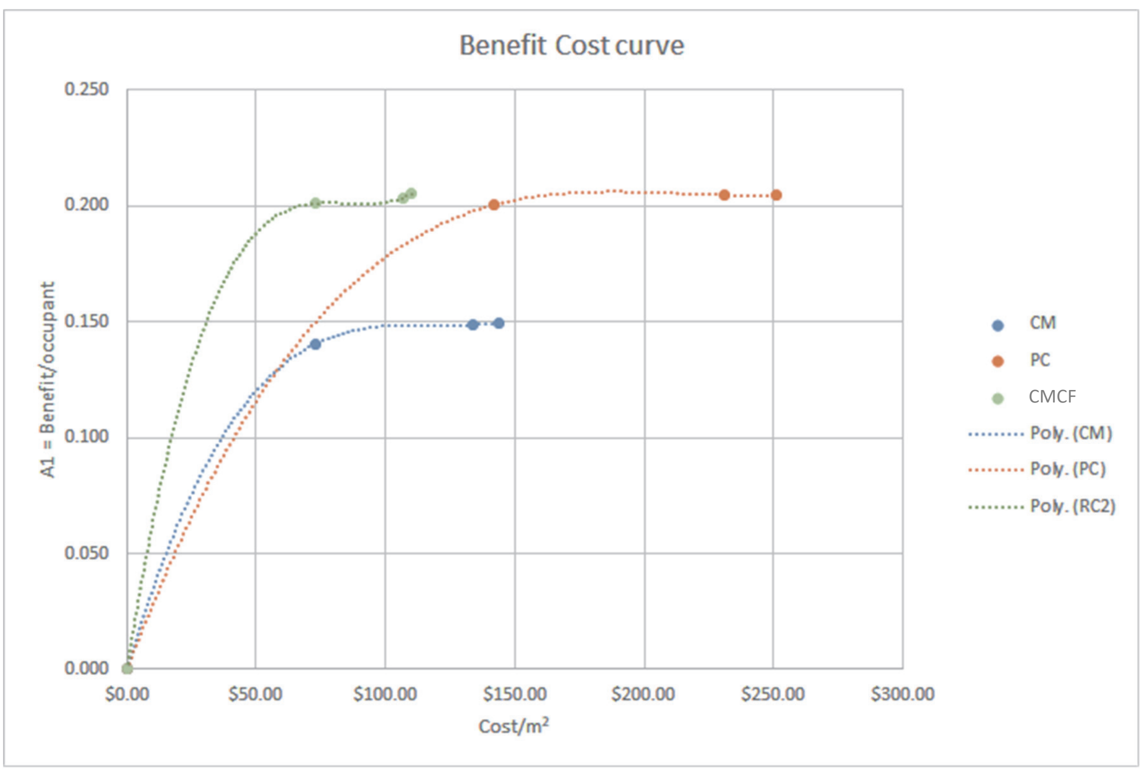


Figure 7-4 Fitted curves demonstrating the relationship between the safety/benefits index and cost for seismic retrofit.

7.3 Prioritization Options

The project team prioritized retrofits considering combinations of the following five factors:

1. Check life safety (LS) limit state. When this factor is considered, any intervention option (retrofit) is required to reduce the probability of exceeding the life-safety limit state to less than 10%, given the occurrence of shaking with 10% exceedance probability in 50 years, the life-safety level of ground motion. When this factor is ignored, mitigation factors are not required to achieve 10% or lower probability of exceeding the life-safety limit state given the life-safety level of ground motion.
2. Check collapse prevention (CP) limit state. When this factor is considered, any retrofit is required to reduce the probability of exceeding the collapse-prevention limit state to less than 10%, given the occurrence of shaking with 2% exceedance probability in 50 years, the collapse-prevention level of ground motion. When this factor is ignored, mitigation factors are not required to achieve 10% or lower probability of exceeding the collapse-prevention limit state given the collapse-prevention level of ground motion.
3. Include energy efficiency (EE) and water, sanitation, and hygiene (WASH) renovation costs. When this factor is considered, the estimated cost to retrofit electrical and plumbing components is included in addition to the seismic retrofit costs in prioritization index A_2. When this factor is ignored, the retrofit cost used in index A_2 only includes seismic retrofit costs.
4. 50% replacement cost trigger. When this factor is considered, any retrofit is required to cost less than 50% of the replacement cost of the building, with the exception of the factor to demolish and replace the building. When this factor is ignored, retrofit costs are allowed to exceed 50% of the replacement cost of the building.
5. Minimum Increment 3. When this factor is considered, only Increment 3 level retrofits or greater are considered. When this factor is ignored, all retrofit increments are considered.

The five factors produce 32 possible combinations ($2^5 = 32$), referred to here as prioritization options. That is, a prioritization option reflects a particular combination of whether or not to consider each of the five factors. Of the 32 options, 20 were examined. (Options where life-safety was checked but collapse-prevention were not examined because the combination seems to ignore the greater fatality risk. Moreover, only a few combinations with factor 5 were examined.) Table 7-1 lists the 20 options examined.

Each option, when considered, represents a constraint, because it generally reduces the number of mitigation increments that satisfy all the requirements. Fewer choices tend to produce higher costs and thereby reduce the benefit-cost ratio. That is, adding constraints tends to reduce retrofit efficiency, reducing the number of lives saved by the available budget. Viewed another way, adding constraints raises the average cost to save a life. With a fixed budget, this means that adding constraints to the framework costs human lives.

The prioritization indices A_1 and A_2 are defined at the level of individual blocks, retrofit increments, and prioritization options. However, one can quantify the outcomes and efficiency of a prioritization option at the level of an entire program, using the measures listed in Table 7-2. The table also shows the value of each outcome measure for three prioritization options: option 1, representing pure efficiency; option 7, which includes WASH and EE costs and requires fulfilling Life Safety and Collapse Prevention performance levels; and option 20, which includes all options except checking the life safety limit state.

Table 7-1 Prioritization Options

Option	*Check LS*	*Check CP*	*Include EE + WASH cost*	*50% cost trigger*	*Minimum increment 3*
1	FALSE	FALSE	FALSE	FALSE	FALSE
2	FALSE	TRUE	FALSE	FALSE	FALSE
3	TRUE	TRUE	FALSE	FALSE	FALSE
4	FALSE	FALSE	TRUE	FALSE	FALSE
6	FALSE	TRUE	TRUE	FALSE	FALSE
7	TRUE	TRUE	TRUE	FALSE	FALSE
8	FALSE	FALSE	FALSE	TRUE	FALSE
10	FALSE	TRUE	FALSE	TRUE	FALSE
11	TRUE	TRUE	FALSE	TRUE	FALSE
12	FALSE	FALSE	TRUE	TRUE	FALSE
14	FALSE	TRUE	TRUE	TRUE	FALSE
15	TRUE	TRUE	TRUE	TRUE	FALSE
16	FALSE	FALSE	FALSE	FALSE	TRUE
18	FALSE	TRUE	FALSE	FALSE	TRUE
19	TRUE	TRUE	FALSE	FALSE	TRUE
20	FALSE	TRUE	TRUE	TRUE	TRUE

Table 7-2 Effect of Prioritization Options

Outcome	*Range*	*Option 0*	*Option 7*	*Option 20*
Schools retrofitted	26 – 55	55	32	26
Lives saved	2,000 – 3,200	3,200	2,200	2,000
Occupants benefitted	23,000 – 49,000	49,000	28,000	25,000
Cost per life saved	$3,600 – $5,500	$3,600	$5,200	$5,500
Blocks retrofitted or replaced	82 – 200	200	95	82

7.4 Conclusions

A methodology was developed to prioritize the seismic retrofit of existing school buildings in Kyrgyz Republic to maximize the safety benefits, cost-efficiency, and benefit-cost ratio of available funds. The method uses performance-based earthquake engineering techniques combined with available data supplemented by field investigations to estimate the vulnerability of Kyrgyz schools. It proposes incremental retrofit techniques that can improve the earthquake life-safety and collapse resistance for common Kyrgyz school building types. It characterizes the probabilistic seismic hazard at each school building, and combines all these data to estimate the retrofit costs and life-safety benefits of each of several incremental retrofit techniques. The costs and benefits are calculated to demonstrate allocation of available retrofit funds to do the most good for the most school children.

The study produced several options for how best to allocate the retrofit money. One can allocate the funds based purely on efficiency: maximizing the number of lives saved for the available funds. With $12 million, using the pure-efficiency prioritization option, the Kyrgyz Republic can seismically retrofit 55 schools that together have 49,000 occupants. Considering how frequently events of various intensities occur, the pure-efficiency retrofit option would save 3,200 lives at a cost per life saved of $3,600.

Alternatively, one can allocate some of the funds to retrofit EE and WASH at the same time as the seismic retrofit. One can also constrain the retrofit so that the retrofitted schools meet the performance criteria that emerging Kyrgyz building codes demand for retrofit of schools. One can also require that, where the retrofit cost exceeds 50% of the replacement cost of the existing school, one should demolish and replace the school rather than retrofitting it. Because these constraints each add cost, the available funds do not go as far. Under such a prioritization scheme, the Kyrgyz Republic can use the available funds to retrofit 26 schools that together have 25,000 occupants, saving an estimated 2,000 lives at a cost per life saved of $5,500.

Each school is unique and will differ in important ways from the sample buildings considered here. Because of these differences, the ultimate cost and benefits of the retrofit will vary from the estimates presented here. However, the prioritization scheme should help the Kyrgyz Republic focus on the buildings that are most likely to save the most lives for the available funds.

Appendix A
Training on Field Inspections

This Appendix provides the slides that were used for the in-country training on collecting data for the field inspections. Guidance and instructions are indicated in the slides for identifying each of the various entries on the inspection form (Figure A-1). Instructions on compiling and checking the data are also provided.

Seismic Performance-based Assessment of School Infrastructure in the Kyrgyz Republic

Inspector ______________________ Date ____________ Start time ______________

School ID ______________________ Building name ______________________

Address ____

Education level __________ Number of students ____________ Year built ______________

Lateral system

Basic type, long axis	RC1 frame	RC2 infill walls	RC3 short columns	RC4 dual system	RC5 non-engineered	RC6 precast
	A adobe	UCM/URM unconfined, unreinforced	CM confined masonry	RM reinforced masonry		
Basic type, short axis	RC1 frame	RC2 infill walls	RC3 short columns	RC4 dual system	RC5 non-engineered	RC6 precast
	A adobe	UCM/URM unconfined, unreinforced	CM confined masonry	RM reinforced masonry		

Blank means unknown

Stories	1	2-3	4-7	
Irregularity	Horizontal & vertical	Horizontal only	Vertical only	No
Seismic design level	Pre-code	1970 Low	1987 Moderate	2010 High
Diaphragms	Flexible roof	Rigid roof	Flexible floor	Rigid floor
Weak column	Yes long axis	No long axis	Yes short axis	No short axis
Sensitive nonstructural elements	Chimneys	Parapets	Other falling hazards	No
Mat foundation	Yes	No		
Pounding risk	Yes	No		
Seismic retrofit	Yes	No		
Quality, condition	Low	Medium	High	Structural system

Comments: ____

____

Photograph the evacuation plan, the building passport, the cover page of any drawings, and provide a photo to support each assignment. Photograph the form and upload the photo of the form and all the other photographs to the Google Drive folder for that school and that building. Focus on classroom buildings, gymnasia, and perhaps connecting corridors if they are critical for evacuation.

Figure A-1 Field inspection form in English.

Seismic Performance-based Assessment of School Infrastructure in the Kyrgyz Republic

Inspection plan

School inspection work plan

- 2 days of training
- 10 additional days including:
  - Field inspections (50 schools, 2 schools per day)
  - Compiling data
  - Answering questions
  - Fixing errors
- Teams of 2 engineers
- Coordinate in advance with principal/municipality to get drawings
- Inspections March 2018

Data Collection Form

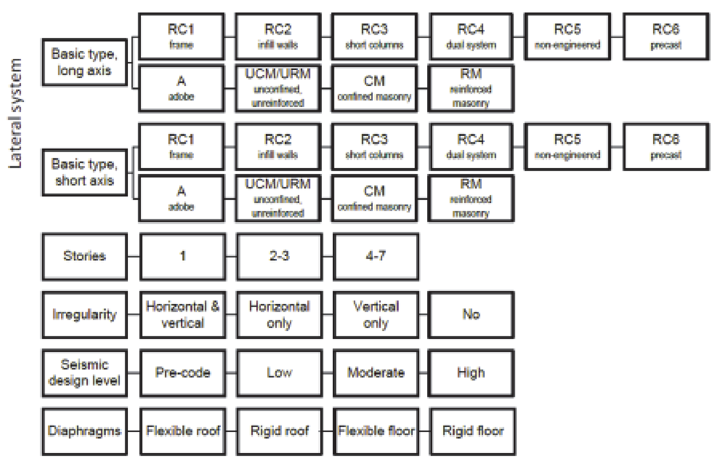
Data collection form

Inspector ______________________ Date __________ Start time ___________

School ID ______________________ Building name _____________________

Address ____

Education level ________ Number of students _________ Year built ______________



Data collection form

Blank means unknown

Weak column	Yes long axis	No long axis	Yes short axis	No short axis
Sensitive nonstructural elements	Chimneys	Parapets	Other falling hazards	No
Mat foundation	Yes	No		
Pounding risk	Yes	No		
Seismic retrofit	Yes	No		
Quality, condition	Low	Medium	High	Structural system

Comments: ____

____

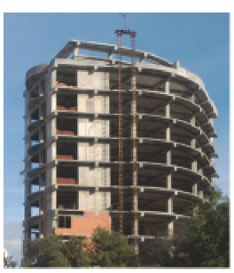
Please provide a photo to support each assignment. Photograph the form and upload the photo of the form and all the supporting photographs to the Google Drive folder for that school and that building.

Basic type: reinforced concrete

RC1: moment frame

RC2: frame with infill walls

RC3: frame with short columns



RC4: dual wall-frame system (Farsi)

RC5: non-engineered

RC6: Precast RC frame with exterior precast RC panels

Problems with reinforced concrete

RC1: moment frame, Haiti

RC2: frame with infill walls, Izmit

RC3: short columns, 1994 Northridge

RC4: dual system Izmit 1999

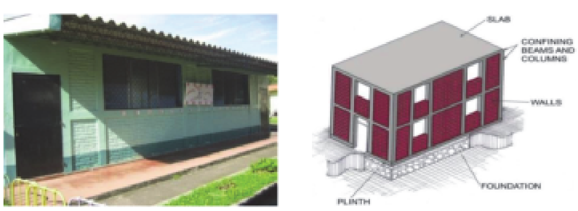
RC5: non-engineered

RC6: Precast RC frame with exterior precast RC panels

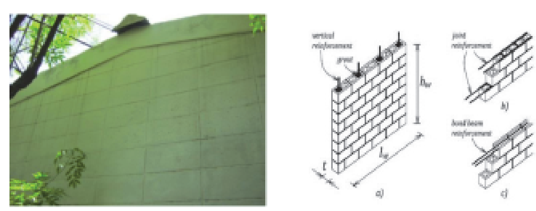
Basic type: load-bearing masonry

A: adobe

UCM/URM: unconfined unreinforced masonry



CM: confined masonry



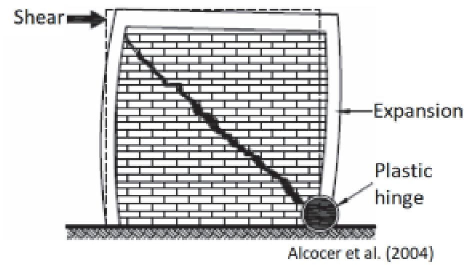
RM: reinforced masonry

Adhikari and D'Ayala (2017); Global Earthquake Model (ND)

Problems with load-bearing masonry

A: adobe (1985 Chile)

UCM/URM (1971 San Fernando)

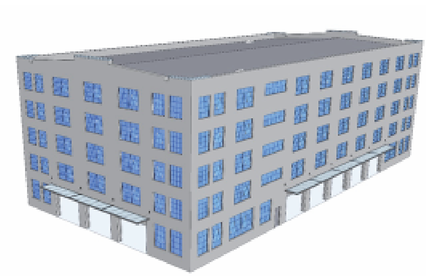


CM: confined masonry

RM: reinforced masonry

Vertical irregularities

Hillside

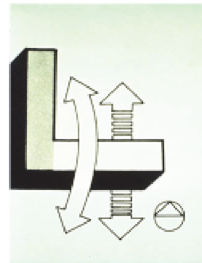


Soft story

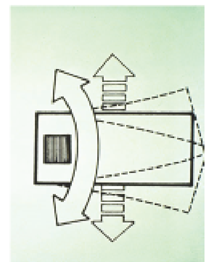
2003 Boumerdes, Algeria

Plan irregularities

Reentrant corners



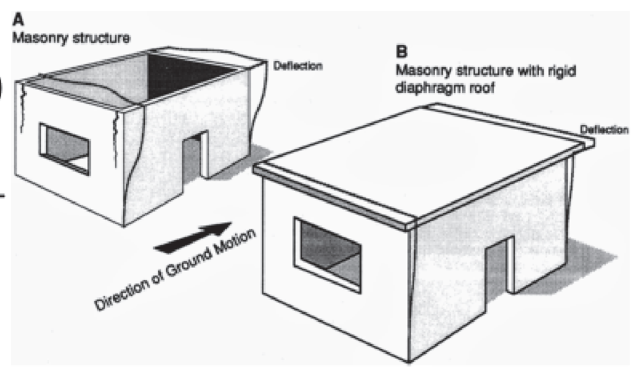
Eccentric stiffness



Roof diaphragm: rigid or flexible?

Rigid (concrete) or flexible (not concrete)

Rigid diaphragms support walls in out-of-plane motion & reduce damage at joints



Yamin et al. (2017)

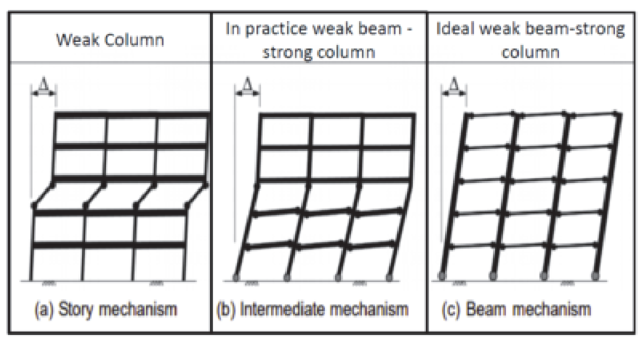
Floor diaphragm rigid or flexible?

Algeria (World Housing Encyclopedia)

Warehouse Culver City, California, 1994 (NISEE)

Weak column

- Is the moment capacity of the column obviously less than that of the beam?
- Is either column dimension less than the beam depth?
- If yes, then a story mechanism may occur, which can require less energy to collapse the building



National Institute of Standards and Technology (2008)

Chimneys or parapets

Forestry Building, Gediz, Turkey 1970 (NISEE)

Bicycle shop, Watsonville California 1989 (NISEE)

Other falling hazards

Yes if many elements are:

- Not isolated from the structure
- Inadequately reinforced or interconnected
- Not braced or anchored

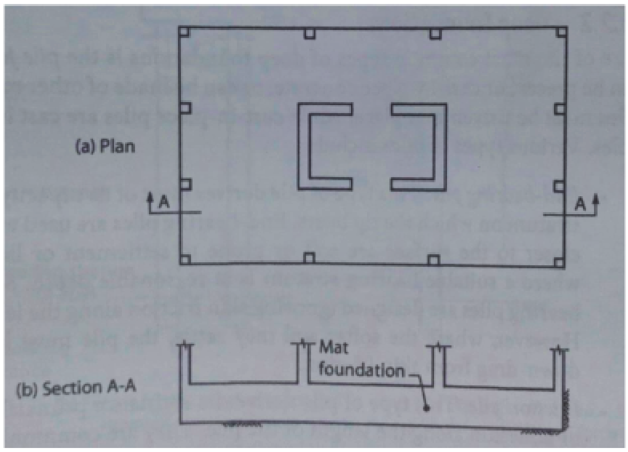
Examples:

- Hanging light fixtures
- Infill non-load-bearing walls
- Heavy weak fences

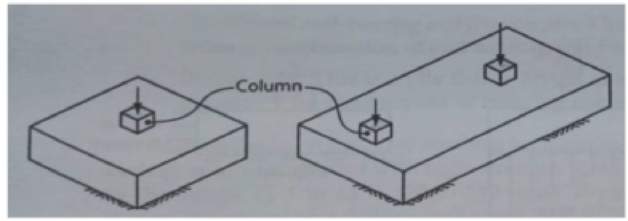
Yamin et al. (2017)

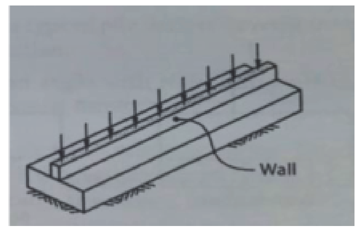
Mat foundation

Yes



No

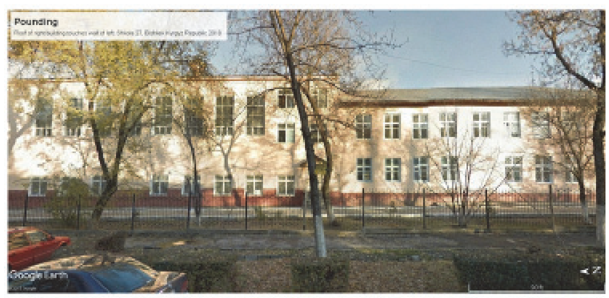




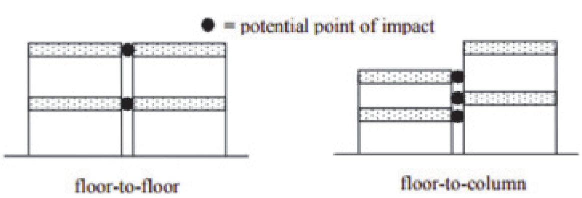
Moehle (2015)

Pounding risk

Yes if < 25 mm per story separation
AND floors do not align →



No otherwise →



No Yes

Cole et al. (ND)

Yamin et al. (2017)

Seismic retrofit

Yes if you see that someone added to the structure after initial construction:

- A new lateral system
- New connections

If not, no

Keith Porter

Keith Porter

NISEE

Quality, condition

Low if you see a lot of:

- Rust coming out of cracks
- Spalled concrete cover
- Very low reinforcement ratio (steel area ÷ concrete area)
- Honeycombed concrete
- Other issues that reduce strength relative to new

Medium if you see a few

Good if you see none

Yamin et al. (2017)

Comments, photos, upload

- Don’t know an answer? Best guess or leave blank, such as mat foundation
- Comments: key information of seismic strength, stiffness, ductility, or type, for example seria number

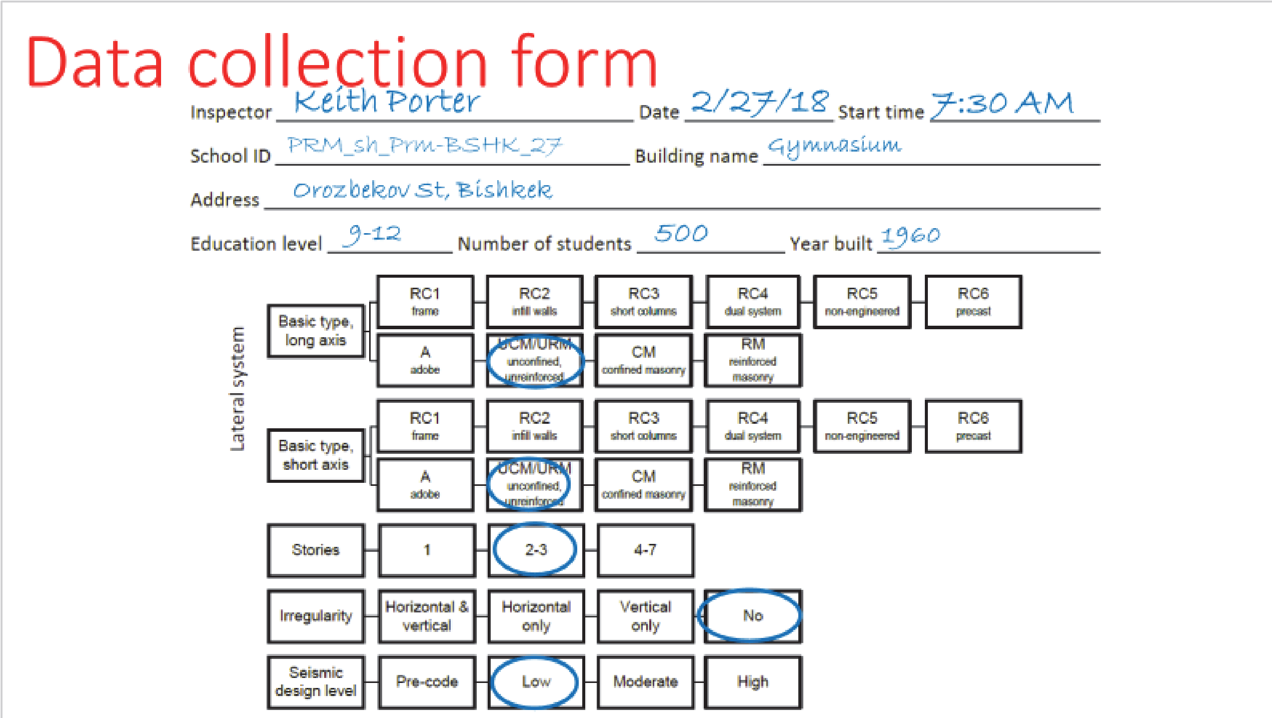
Comments: Seria 1-464c

- Photograph the form, each facade, and each feature such as pounding
- Upload all photos for one building to that building’s own Google Drive folder

Please provide a photo to support each assignment. Photograph the form and upload the photo of the form and all the supporting photographs to the Google Drive folder for that school and that building.

Manager gives assignments and Google Earth file

Unique identifier, also used to provide linkage with UNICEF database	Name of School	Name of the settlement where the school is located
PRM_sh_Prm-BSHK_27	HS No.27	Bishkek city
MAN_sh_Balasary_ÐįÑ˚.-Ð'Ð˚Ð»Ð˚-Ð	Bala-Saru HS	Bala-Saru village, Mar
JAC_sh_Kachkynchy_shkola-8	High School no 8	Dzhalal-Abad
JAC_sh_Kachkynchy_shkola-8	High School no 8	Dzhalal-Abad
NKT_sh_Dzhany-Nookat_Naymanbae	Naimanbaeva JHS	Jany Nookat village, J
KEM_sh_Ilichevskoe_Bakaeva	A.Bakaeva High school	Ilich, v., Kemin rayon
KEM_sh_Ilichevskoe_Bakaeva	A.Bakaeva High school	Ilich, v., Kemin rayon
NKN_sh_Byurgenduy_Moldalieva	M.Moldaliev High School no 18	Byurgenduy village
NKN_sh_Byurgenduy_Moldalieva	M.Moldaliev High School no 18	Byurgenduy village
NKN_sh_Byurgenduy_Moldalieva	M.Moldaliev High School no 18	Byurgenduy village
SOK_sh_Novopavlovka_Novopavlovk	Novopavlovka high school No1	Novopavlovka v.,



Data collection form

Inspector: Keith Porter Date: 2/27/18 Start time: 7:30 AM

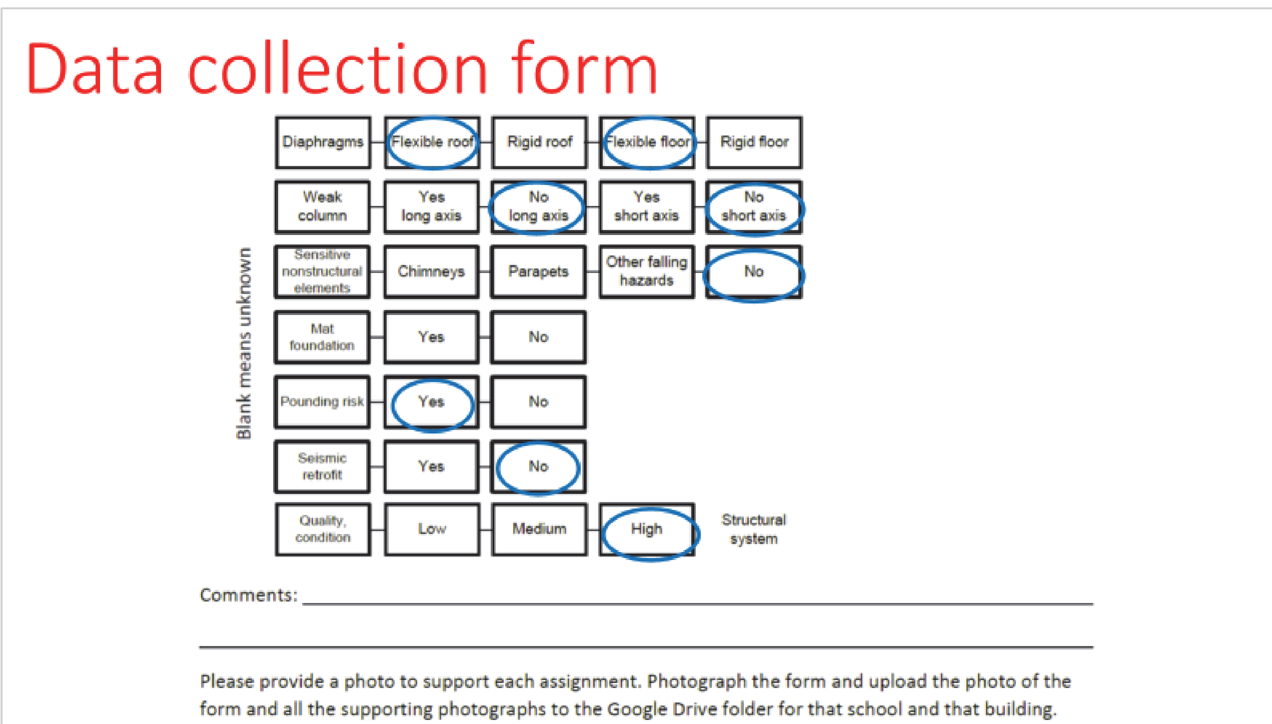
School ID: PRM_sh_Prm-BSHK_27 Building name: Gymnasium

Address: Orozbekov St, Bishkek

Education level: 9-12 Number of students: 500 Year built: 1960

Lateral system

Basic type, long axis	RC1 frame	RC2 infill walls	RC3 short columns	RC4 dual system	RC5 non-engineered	RC6 precast
	A adobe	UCM/URM unconfined, unreinforced	CM confined masonry	RM reinforced masonry		
Basic type, short axis	RC1 frame	RC2 infill walls	RC3 short columns	RC4 dual system	RC5 non-engineered	RC6 precast
	A adobe	UCM/URM unconfined, unreinforced	CM confined masonry	RM reinforced masonry		
Stories	1	2-3	4-7			
Irregularity	Horizontal & vertical	Horizontal only	Vertical only	No		
Seismic design level	Pre-code	Low	Moderate	High		



Data collection form

Blank means unknown

Diaphragms	Flexible roof	Rigid roof	Flexible floor	Rigid floor
Weak column	Yes long axis	No long axis	Yes short axis	No short axis
Sensitive nonstructural elements	Chimneys	Parapets	Other falling hazards	No
Mat foundation	Yes	No		
Pounding risk	Yes	No		
Seismic retrofit	Yes	No		
Quality, condition	Low	Medium	High	Structural system

Comments: ________________

Please provide a photo to support each assignment. Photograph the form and upload the photo of the form and all the supporting photographs to the Google Drive folder for that school and that building.

Compile & check data

Screener:

1. Photograph the form, each facade, and each feature such as pounding
2. Photograph the form
3. Upload photos to Google Drive > ERIK > Screening > [School name] > [Building name]

Local data collection manager:

1. Make preliminary Google Earth file of points and footprints, give to screeners
2. Assistant transcribes forms to Google Drive > ERIK > Screening > Screening data (Google sheet)
3. Spot-check all decisions for a few schools by each team
4. Correct errors or request clarifications from teams
5. Finalize Google Earth points and footprints & upload to Google Drive > ERIK > Screening

Appendix B
List of Schools Inspected

This Appendix provides basic information on the 78 inspected schools. Tables B-1 and B-2 present Oblast/Rayon and Education Level number designations, respectively. Table B-3 lists the 78 schools identified with School Codes, designated as [Oblast #]_[Rayon #]_[Education Level #]_[School #] and Additional School #, if code is duplicated. The schools were visited in June through August 2018 by inspectors trained by the project team. Names of inspectors are listed in the Project Participants.

Table B-1 School Code Oblast and Rayon Designations

Oblast #	*Rayon*	*District*	*Capital*
_01	Batken	_001. Batken-city	
		_002. Batkensky	Batken
		_003. Kadamjaisky	Pulgon
		_004. Kyzyl-Kiya-city	
		_005. Lyailyaksky	Isfana
		_006. Sulyukta-city	
_02	Bishkek city	_001. Leninsky	
		_002. Oktyabrsky	
		_003. Pervomaisky	
		_004. Sverdlovsky	
_03	Chui	_001. Alamedinsky	Lebedinovka
		_002. Chuisky	Tokmok
		_003. Issyk-Atinsky	Kant
		_004. Jaiylsky	Kara-Balta
		_005. Keminsky	Kemin
		_006. Moskovsky	Belovodskoe
		_007. Panfilovsky	Kaindy
		_008. Sokuluksky	Sokuluk
		_009. Tokmok city	
_04	Issyk-Kul	_001. Aksuisky	Ak-Suu [Teplokluchenka]
		_002. Bakai-Atinsky	Balykchi (city)
		_003. Issyk-Kulsky	Cholpon-Ata
		_004. Jety-Oguzsky	Kyzyl-Suu
		_005. Karakol-city	
		_006. Tonsky	Bokonbaevo
		_007. Tyupsky	Tyup

Table B-1 School Code Oblast and Rayon Designations (continued)

Oblast #	*Rayon*	*District*	*Capital*
_05	Jalal-Abad	_001. Aksyisky	Kerben
		_002. Ala-Bukinsky	Ala-Bulak
		_003. Bazar-Korgonsky	Bazar-Korgon
		_004. Chatkalsky	Kahysh-Kyya
		_005. Jelal-Abad-city	
		_006. Nookensky	Massy
		_007. Suzaksky	Suzak
		_008. Toguz-Torousky	Kazarman
		_009. Toktorgulsky	Toktogul
_06	Naryn	_001. Ak-Talinsky	Baetov
		_002. At-Bashinsky	At-Bashy
		_003. Jumgalsky	Chaek
		_004. Kochkorsky	Kochkor
		_005. Narynsky	Naryn
_07	Osh	_001. Alaisky	Gulcha
		_002. Aravansky	Aravan
		_003. Choh-Alaisky	Daroot-Korgon
		_004. Kara-Kuljinsky	Kara-Kulja
		_005. Kara-Suuisky	Kara-Suu
		_006. Nookatsky	Nookat
		_007. Osh-city	
		_008. Uzgensky	Uzgen
_08	Talas	_001. Bakai-Atinsky	Bakay-Ata
		_002. Kara-Burinksy	Kyzyl-Adyr
		_003. Manassky	Pokrovka
		_004. Talassky	Kok-Oi [Manas]

Table B-2 School Code Education Level Designations

Education Levels

Code	*Level*	*Grade*	*Age*	*ISCE*[1]
010	Primary General Education	1-4	7-10	1
21	Combination primary and basic general education	1-9	7-15	1, 2A
035	Combination Primary General Education, Basic General Education, Secondary General Education	1-11	7-17	1, 2A, 3A

[1] ISCE = International Standard Classification of Education

Table B-3 List of Schools Inspected by Building Block

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
06_004_035_010	KCH_sh_Don-Alysh_ Mambetalieva	A	Mambetaliev High School	Learning Campus	Naryn_Kochkor_Don-Alysh_Talaa-Bulak	1977
06_004_035_010	KCH_sh_Don-Alysh_ Mambetalieva	B	Mambetaliev High School	Learning Campus	Naryn_Kochkor_Don-Alysh_Talaa-Bulak	1977
06_004_035_010	KCH_sh_Don-Alysh_ Mambetalieva	C	Mambetaliev High School	Transition + Learning Campus	Naryn_Kochkor_Don-Alysh_Talaa-Bulak	1977
06_004_035_010	KCH_sh_Don-Alysh_ Mambetalieva	D	Mambetaliev High School	Canteen + Assembly Hall	Naryn_Kochkor_Don-Alysh_Talaa-Bulak	1977
06_004_035_010	KCH_sh_Don-Alysh_ Mambetalieva	E	Mambetaliev High School	Sports Hall	Naryn_Kochkor_Don-Alysh_Talaa-Bulak	1977
03_001_035_001 (2)	ALM_sh_Vasilievka_N1	A	Vasilievskaya high school No1	Learning Campus	Chui_Alamudun_Vasilievka_Frunze	1984
03_001_035_001 (2)	ALM_sh_Vasilievka_N1	B	Vasilievskaya high school No1	Sports Hall	Chui_Alamudun_Vasilievka_Frunze	1984
03_001_035_001 (2)	ALM_sh_Vasilievka_N1	C	Vasilievskaya high school No1	Dinning Room + Assembly Hall	Chui_Alamudun_Vasilievka_Frunze	1984
03_001_035_001 (2)	ALM_sh_Vasilievka_N1	D	Vasilievskaya high school No1	Learning Campus	Chui_Alamudun_Vasilievka_Frunze	1984
03_001_035_012	ALM_sh_Mramornoe_ Mramornaya	A	Mramornaya high school	Sports Hall	Chui_Alamudun_Mramornoe_ Severnoe	1972
03_001_035_012	ALM_sh_Mramornoe_ Mramornaya	B	Mramornaya high school	Dinning Room	Chui_Alamudun_Mramornoe_ Severnoe	1972
03_001_035_012	ALM_sh_Mramornoe_ Mramornaya	C	Mramornaya high school	Transinion + Learning Campus	Chui_Alamudun_Mramornoe_ Severnoe	1972
03_001_035_012	ALM_sh_Mramornoe_ Mramornaya	D	Mramornaya high school	Learning Campus	Chui_Alamudun_Mramornoe_ Severnoe	1972
03_001_035_012	ALM_sh_Mramornoe_ Mramornaya	E	Mramornaya high school	Learning Campus	Chui_Alamudun_Mramornoe_ Severnoe	1972
03_001_035_014	ALM_sh_Prigorodnoe_ Prigorodnaya	A	Prigordodnoe high school	Dinning room	Chui_Alamudun_Prigorodnoe_ Yubileinaya	1986

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
03_001_035_014	ALM_sh_Prigorodnoe_ Prigorodnaya	B	Prigordodnoe high school	Learning Campus	Chui_Alamudun_Prigorodnoe_ Yubileinaya	1986
03_001_035_014	ALM_sh_Prigorodnoe_ Prigorodnaya	C	Prigordodnoe high school	Learning Campus	Chui_Alamudun_Prigorodnoe_ Yubileinaya	1986
03_001_035_014	ALM_sh_Prigorodnoe_ Prigorodnaya	D	Prigordodnoe high school	Sports Hall	Chui_Alamudun_Prigorodnoe_ Yubileinaya	1986
03_001_035_014	ALM_sh_Prigorodnoe_ Prigorodnaya	E	Prigordodnoe high school	Learning Campus	Chui_Alamudun_Prigorodnoe_ Yubileinaya	1986
03_001_035_014	ALM_sh_Prigorodnoe_ Prigorodnaya	F	Prigordodnoe high school	Learning Campus	Chui_Alamudun_Prigorodnoe_ Yubileinaya	1986
03_001_035_005	ALM_sh_Besh-Kungei_ Taranchieva	A	I.Taranchieva High School	Learning Campus	Chui_Alamudun_Besh-Kungei_ Umetbaev	1979
03_001_035_005	ALM_sh_Besh-Kungei_ Taranchieva	B	I.Taranchieva High School	Learning Campus	Chui_Alamudun_Besh-Kungei_ Umetbaev	1979
03_001_035_005	ALM_sh_Besh-Kungei_ Taranchieva	C	I.Taranchieva High School	Transition + Learning Campus	Chui_Alamudun_Besh-Kungei_ Umetbaev	1979
03_001_035_005	ALM_sh_Besh-Kungei_ Taranchieva	D	I.Taranchieva High School	Sport Hall	Chui_Alamudun_Besh-Kungei_ Umetbaev	1979
03_001_035_005	ALM_sh_Besh-Kungei_ Taranchieva	E	I.Taranchieva High School	Dinning Room + Assembly Hall	Chui_Alamudun_Besh-Kungei_ Umetbaev	1979
06_004_035_007	KCH_sh_Kochkor_Arabaeva	A	Arabaev High School	Learning Campus	Naryn_Kochkor_Kochkor_Orozbekov	2008
06_004_035_007	KCH_sh_Kochkor_Arabaeva	B	Arabaev High School	Learning Campus	Naryn_Kochkor_Kochkor_Orozbekov	2008
06_004_035_007	KCH_sh_Kochkor_Arabaeva	C	Arabaev High School	Learning Campus	Naryn_Kochkor_Kochkor_Orozbekov	2008
06_004_035_007	KCH_sh_Kochkor_Arabaeva	D	Arabaev High School	Learning Campus + Canteen	Naryn_Kochkor_Kochkor_Orozbekov	2008
06_004_035_007	KCH_sh_Kochkor_Arabaeva	E	Arabaev High School	Sports Hall	Naryn_Kochkor_Kochkor_Orozbekov	2008
06_004_035_007	KCH_sh_Kochkor_Arabaeva	F	Arabaev High School	Learning Campus	Naryn_Kochkor_Kochkor_Orozbekov	2008
06_004_035_007	KCH_sh_Kochkor_Arabaeva	E	Arabaev High School	Sports Hall	Naryn_Kochkor_Kochkor_Orozbekov	2008
06_004_035_007	KCH_sh_Kochkor_Arabaeva	F	Arabaev High School	Learning Campus	Naryn_Kochkor_Kochkor_Orozbekov	2008
06_004_035_007	KCH_sh_Kochkor_Arabaeva	G	Arabaev High School	Assembly Hall	Naryn_Kochkor_Kochkor_Orozbekov	2008

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
06_004_035_012	KCH_sh_Kum-Dobo_ Mirzabekova	A	Myrzabaev Kum-Dobo HIgh School	Learning Campus	Naryn_Kochkor_Kum-Dobo	1982
06_004_035_012	KCH_sh_Kum-Dobo_ Mirzabekova	B	Myrzabaev Kum-Dobo HIgh School	Learning Campus	Naryn_Kochkor_Kum-Dobo	1982
06_004_035_012	KCH_sh_Kum-Dobo_ Mirzabekova	C	Myrzabaev Kum-Dobo HIgh School	Learning Campus + Transition	Naryn_Kochkor_Kum-Dobo	1982
06_004_035_012	KCH_sh_Kum-Dobo_ Mirzabekova	D	Myrzabaev Kum-Dobo HIgh School	Sports Hall	Naryn_Kochkor_Kum-Dobo	1982
06_004_035_012	KCH_sh_Kum-Dobo_ Mirzabekova	E	Myrzabaev Kum-Dobo HIgh School	Canteen + Assembly Hall	Naryn_Kochkor_Kum-Dobo	1982
06_004_035_006	KCH_sh_Tuz_Zhunushali	A	Zhunushaly kyzy Sainap High School	Learning Campus	Naryn_Kochkor_Tuz_S.Malibetaly	2007
06_004_035_006	KCH_sh_Tuz_Zhunushali	B	Zhunushaly kyzy Sainap High School	Assembly Hall + Learning Campus	Naryn_Kochkor_Tuz_S.Malibetaly	1985
06_004_035_006	KCH_sh_Tuz_Zhunushali	C	Zhunushaly kyzy Sainap High School	Dinning Room + Learning Campus	Naryn_Kochkor_Tuz_S.Malibetaly	1998
06_004_035_006	KCH_sh_Tuz_Zhunushali	D	Zhunushaly kyzy Sainap High School	Old Learning Campus	Naryn_Kochkor_Tuz_S.Malibetaly	1964
07_005_035_012	KSU_sh_Otuz-Adyr_ Otuz-Adyr	A [А]	Otuz Adyr HS No.12	Learning campus	Osh_Kara-Suu_Otuz-Adyr_ SherikbaevNo.5	1978
07_005_035_111	KSU_sh_Dzhany-Turmush_Osmonova	A [А]	Osmonova HS No.111	Learning campus	Osh_Kara-Suu_Dzhany-Turmush	1999
07_005_035_111	KSU_sh_Dzhany-Turmush_Osmonova	B [Б]	Osmonova HS No.111	Cabinet	Osh_Kara-Suu_Dzhany-Turmush	1999
07_005_035_111	KSU_sh_Dzhany-Turmush_Osmonova	C [В]	Osmonova HS No.111	Learning campus	Osh_Kara-Suu_Dzhany-Turmush	1999
07_005_035_033	KSU_sh_Asan-Chek-(was-Besh-Kepe)_Internacional	A [А]	Internatsional HS No.33	Learning campus	Osh_Kara-Suu_Asanchek	1977
07_005_035_033	KSU_sh_Asan-Chek-(was-Besh-Kepe)_Internacional	B [Б]	Internatsional HS No.33	Learning campus	Osh_Kara-Suu_Asanchek	1977

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_005_035_033	KSU_sh_Asan-Chek-(was-Besh-Kepe)_Internacional	C [В]	Internatsional HS No.33	1 floor - corridor, 2 floor - learning campus	Osh_Kara-Suu_Asanchek	1977
07_005_035_033	KSU_sh_Asan-Chek-(was-Besh-Kepe)_Internacional	D [Г]	Internatsional HS No.33	2 floor - canteen, 2 floor - assembly hall	Osh_Kara-Suu_Asanchek	1977
07_005_035_033	KSU_sh_Asan-Chek-(was-Besh-Kepe)_Internacional	E [Д]	Internatsional HS No.33	Sports hall	Osh_Kara-Suu_Asanchek	1977
07_008_035_057	UZG_sh_Ana-Kyzyl_OmurzakovN57	A [А]	Omurzakova HS No.57	Canteen	Osh_Uzgen_Ana-Kyzyl_Tort-Kol	1980
07_008_035_057	UZG_sh_Ana-Kyzyl_OmurzakovN57	B [Б]	Omurzakova HS No.57	Learning campus	Osh_Uzgen_Ana-Kyzyl_Tort-Kol	1980
07_008_035_057	UZG_sh_Ana-Kyzyl_OmurzakovN57	C [В]	Omurzakova HS No.57	Learning campus	Osh_Uzgen_Ana-Kyzyl_Tort-Kol	1998
07_005_035_104	KSU_sh_Talaa_Nyshanbaev	A [А]	Nyshanbaeva HS No.104	Learning campus	Osh_Kara-Suu_Talaa_st-Dolono	1985
07_005_035_104	KSU_sh_Talaa_Nyshanbaev	B [Б]	Nyshanbaeva HS No.104	Learning campus	Osh_Kara-Suu_Talaa_st-Dolono	1985
07_005_035_104	KSU_sh_Talaa_Nyshanbaev	C [В]	Nyshanbaeva HS No.104	Corridor	Osh_Kara-Suu_Talaa_st-Dolono	1985
07_005_035_104	KSU_sh_Talaa_Nyshanbaev	D [Г]	Nyshanbaeva HS No.104	Learning campus	Osh_Kara-Suu_Talaa_st-Dolono	1985
07_005_035_104	KSU_sh_Talaa_Nyshanbaev	E [Д]	Nyshanbaeva HS No.104	Kindergarden	Osh_Kara-Suu_Talaa_st-Dolono	1985
07_005_035_104	KSU_sh_Talaa_Nyshanbaev	G [Ж]	Nyshanbaeva HS No.104	Kitchen + Sports hall	Osh_Kara-Suu_Talaa_st-Dolono	1985
07_005_035_067	KSU_sh_Kara-Suu_Bobura	A [А]	Zakhiriddin Bobur HS	Learning campus	Osh_Kara-Suu_Kara-Suu_st-Lenina	1992
07_005_035_067	KSU_sh_Kara-Suu_Bobura	B [Б]	Zakhiriddin Bobur HS	Sports hall	Osh_Kara-Suu_Kara-Suu_st-Lenina	1992
07_005_035_067	KSU_sh_Kara-Suu_Bobura	C [В]	Zakhiriddin Bobur HS	Assembly hall + Learning campus	Osh_Kara-Suu_Kara-Suu_st-Lenina	1992
07_005_035_067	KSU_sh_Kara-Suu_Bobura	D [Г]	Zakhiriddin Bobur HS	Learning campus	Osh_Kara-Suu_Kara-Suu_st-Lenina	1992
07_005_035_105	KSU_sh_Zhilgeldi-(was-Lenin)_Alimbekova	A [А]	Alimbekov HS No. 105	Learning Campus	Osh_Kara-Suu_Zhilgeldi	2011
07_005_035_105	KSU_sh_Zhilgeldi-(was-Lenin)_Alimbekova	B [Б]	Alimbekov HS No. 105	Learning Campus	Osh_Kara-Suu_Zhilgeldi	2011

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_005_035_105	KSU_sh_Zhilgeldi-(was-Lenin)_Alimbekova	C [В]	Alimbekov HS No. 105	Transition to Block Б	Osh_Kara-Suu_Zhilgeldi	2011
07_005_035_105	KSU_sh_Zhilgeldi-(was-Lenin)_Alimbekova	D [Г]	Alimbekov HS No. 105	Sports hall	Osh_Kara-Suu_Zhilgeldi	2011
07_005_035_019	KSU_sh_Madaniyat_Musaeva	A [А]	Musaeva HS No.19	Learning Campus	Osh_Kara-Suu_Madaniyat_Begishov	1986
07_005_035_019	KSU_sh_Madaniyat_Musaeva	B [Б]	Musaeva HS No.19	Corridor	Osh_Kara-Suu_Madaniyat_Begishov	1986
07_005_035_019	KSU_sh_Madaniyat_Musaeva	C [В]	Musaeva HS No.19	Learning Campus	Osh_Kara-Suu_Madaniyat_Begishov	1986
07_005_035_019	KSU_sh_Madaniyat_Musaeva	D [Г]	Musaeva HS No.19	Corridor	Osh_Kara-Suu_Madaniyat_Begishov	1986
07_005_035_019	KSU_sh_Madaniyat_Musaeva	E [Д]	Musaeva HS No.19	Sports hall + Assembly hall	Osh_Kara-Suu_Madaniyat_Begishov	1986
07_005_035_019	KSU_sh_Madaniyat_Musaeva	F [Е]	Musaeva HS No.19	Corridor	Osh_Kara-Suu_Madaniyat_Begishov	1986
07_005_035_019	KSU_sh_Madaniyat_Musaeva	G [Ж]	Musaeva HS No.19	Learning Campus	Osh_Kara-Suu_Madaniyat_Begishov	1986
07_005_035_014	KSU_sh_Prisavai_Turusbekova	A [А]	Turusbekova HS No.14	Learning campus	Osh_Kara-Suu_Yntymak Savai	2014
07_005_035_014	KSU_sh_Prisavai_Turusbekova	B [Б]	Turusbekova HS No.14	Transition	Osh_Kara-Suu_Yntymak Savai	2014
07_005_035_014	KSU_sh_Prisavai_Turusbekova	C [В]	Turusbekova HS No.14	Sports hall	Osh_Kara-Suu_Yntymak Savai	2014
07_005_035_102	KSU_sh_Kysh-Abad_Teshebaeva	A [А]	Teshebaeva HS No.102	Assembly hall + Canteen	Osh_Kara-Suu_Kysh-Abad_M.Muratov No.20	1976
07_005_035_102	KSU_sh_Kysh-Abad_Teshebaeva	B [Б]	Teshebaeva HS No.102	Sports hall	Osh_Kara-Suu_Kysh-Abad_M.Muratov No.20	1976
07_005_035_102	KSU_sh_Kysh-Abad_Teshebaeva	C [В]	Teshebaeva HS No.102	Corridor	Osh_Kara-Suu_Kysh-Abad_M.Muratov No.20	1976
07_005_035_102	KSU_sh_Kysh-Abad_Teshebaeva	D [Г]	Teshebaeva HS No.102	Learning campus	Osh_Kara-Suu_Kysh-Abad_M.Muratov No.20	1976
07_005_035_102	KSU_sh_Kysh-Abad_Teshebaeva	E [Д]	Teshebaeva HS No.102	Learning campus	Osh_Kara-Suu_Kysh-Abad_M.Muratov No.20	1976

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_005_035_030	KSU_sh_Kyzyl-Sarai_Kyzyl-Sarai	A [A]	Kyzyl Sarai HS No.30	Learning campus	Osh_Kara-Suu_Kyzyl-Sarai_ T.Satkulov	2016
07_005_035_030	KSU_sh_Kyzyl-Sarai_Kyzyl-Sarai	B [Б]	Kyzyl Sarai HS No.30	Transition (wardrobe): 2 floor - Assembly hall	Osh_Kara-Suu_Kyzyl-Sarai_ T.Satkulov	2016
07_005_035_030	KSU_sh_Kyzyl-Sarai_Kyzyl-Sarai	C [B]	Kyzyl Sarai HS No.30	Sports hall	Osh_Kara-Suu_Kyzyl-Sarai_ T.Satkulov	2016
07_002_010_050	ARV_sh_Aravan_Saidahmatova	A [A]	Saidakmatova HS	Learning Campus	Osh_Aravan_Aravan_ Usupov VA	2002
07_002_010_050	ARV_sh_Aravan_Saidahmatova	B [Б]	Saidakmatova HS	Canteen	Osh_Aravan_Aravan_ Usupov VA	2007
07_002_010_050	ARV_sh_Aravan_Saidahmatova	C [B]	Saidakmatova HS	Sports hall	Osh_Aravan_Aravan_ Usupov VA	2005
07_002_035_005	ARV_sh_Kyzyr-Abad_Ismailov	A [A]	Tolon Ismailova HS No.5	Main entrance + Foye + Learning campus	Osh_Aravan_Jalachylyk_ Chek-Abad VA	1972
07_002_035_005	ARV_sh_Kyzyr-Abad_Ismailov	B [Б]	Tolon Ismailova HS No.5	Learning campus	Osh_Aravan_Jalachylyk_ Chek-Abad VA	1972
07_002_035_005	ARV_sh_Kyzyr-Abad_Ismailov	C [B]	Tolon Ismailova HS No.5	Learning campus	Osh_Aravan_Jalachylyk_ Chek-Abad VA	1972
07_002_035_005	ARV_sh_Kyzyr-Abad_Ismailov	D [Г]	Tolon Ismailova HS No.5	Canteen + Assembly hall	Osh_Aravan_Jalachylyk_ Chek-Abad VA	1972
07_002_035_005	ARV_sh_Kyzyr-Abad_Ismailov	E [Д]	Tolon Ismailova HS No.5	Staircase	Osh_Aravan_Jalachylyk_ Chek-Abad VA	1972
07_002_035_026	ARV_sh_Uigur-Abad_Kyrgyzstan	A [A]	Kyrgyzstan HS No.26	Main entrance + Foye	Osh_Aravan_Uigur-Abad_ Tepe-Korgon VA	1990
07_002_035_026	ARV_sh_Uigur-Abad_Kyrgyzstan	B [Б]	Kyrgyzstan HS No.26	Sports hall + Canteen	Osh_Aravan_Uigur-Abad_ Tepe-Korgon VA	1990
07_002_035_026	ARV_sh_Uigur-Abad_Kyrgyzstan	C [B]	Kyrgyzstan HS No.26	Learning campus	Osh_Aravan_Uigur-Abad_ Tepe-Korgon VA	1990

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_002_035_026	ARV_sh_Uigur-Abad_Kyrgyzstan	D [Г]	Kyrgyzstan HS No.26	Learning campus	Osh_Aravan_Uigur-Abad_ Tepe-Korgon VA	1990
07_002_035_026	ARV_sh_Uigur-Abad_Kyrgyzstan	E [Д]	Kyrgyzstan HS No.26	Learning campus	Osh_Aravan_Uigur-Abad_ Tepe-Korgon VA	1990
07_002_035_002	ARV_sh_Tepe-Kurgan_Saida	A [А]	Saida HS No.2	Learning Campus	Osh_Aravan_Tepe-Korgon_ Tepe-Korgon VA	1982
07_002_035_002	ARV_sh_Tepe-Kurgan_Saida	B [Б]	Saida HS No.2	Learning Campus	Osh_Aravan_Tepe-Korgon_ Tepe-Korgon VA	1982
07_002_035_002	ARV_sh_Tepe-Kurgan_Saida	C [В]	Saida HS No.2	Sports hall	Osh_Aravan_Tepe-Korgon_ Tepe-Korgon VA	2013
07_002_035_002	ARV_sh_Tepe-Kurgan_Saida	D [Г]	Saida HS No.2	Canteen	Osh_Aravan_Tepe-Korgon_ Tepe-Korgon VA	2016
07_007_035_014	OSH_sh_Osh_shkola-14-Altybaeva	A [А]	Altybaeva High School No.14	Main entrance + Foye + Learning campus	Osh city _ Kulatova (microdistrict)	1984
07_007_035_014	OSH_sh_Osh_shkola-14-Altybaeva	B [Б]	Altybaeva High School No.14	Learning Campus	Osh city _ Kulatova (microdistrict)	1984
07_007_035_014	OSH_sh_Osh_shkola-14-Altybaeva	C [В]	Altybaeva High School No.14	Canteen + Assembly hall	Osh city _ Kulatova (microdistrict)	1984
07_007_035_014	OSH_sh_Osh_shkola-14-Altybaeva	D [Г]	Altybaeva High School No.14	Learning Campus	Osh city _ Kulatova (microdistrict)	1984
07_007_035_014	OSH_sh_Osh_shkola-14-Altybaeva	E [Д]	Altybaeva High School No.14	Learning Campus	Osh city _ Kulatova (microdistrict)	1984
07_007_035_014	OSH_sh_Osh_shkola-14-Altybaeva	F [Е]	Altybaeva High School No.14	Learning Campus	Osh city _ Kulatova (microdistrict)	1984
07_007_035_014	OSH_sh_Osh_shkola-14-Altybaeva	G [Ж]	Altybaeva High School No.14	Learning Campus	Osh city _ Kulatova (microdistrict)	1984
07_007_035_014	OSH_sh_Osh_shkola-14-Altybaeva	H [З]	Altybaeva High School No.14	Sports hall	Osh city _ Kulatova (microdistrict)	1984
07_007_035_039	OSH_sh_Osh_shkola-39-October	A [А]	70 let okryabrya High School No.39	Main entrance + Foye	Osh city _ Madumarov (street)	1987

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_007_035_039	OSH_sh_Osh_shkola-39-October	B [Б]	70 let okryabrya High School No.39	Wardrobe	Osh city _ Madumarov (street)	1987
07_007_035_039	OSH_sh_Osh_shkola-39-October	C [В]	70 let okryabrya High School No.39	Sports hall	Osh city _ Madumarov (street)	1987
07_007_035_039	OSH_sh_Osh_shkola-39-October	D [Г]	70 let okryabrya High School No.39	Canteen + assembly hall	Osh city _ Madumarov (street)	1987
07_007_035_039	OSH_sh_Osh_shkola-39-October	D1 [Г1]	70 let okryabrya High School No.39	Staircase	Osh city _ Madumarov (street)	1987
07_007_035_039	OSH_sh_Osh_shkola-39-October	E [Д]	70 let okryabrya High School No.39	Learning campus	Osh city _ Madumarov (street)	1987
07_007_035_039	OSH_sh_Osh_shkola-39-October	F [E]	70 let okryabrya High School No.39	Learning campus	Osh city _ Madumarov (street)	1987
07_007_035_039	OSH_sh_Osh_shkola-39-October	G [Ж]	70 let okryabrya High School No.39	Learning campus	Osh city _ Madumarov (street)	1987
07_007_035_039	OSH_sh_Osh_shkola-39-October	G1 [Ж1]	70 let okryabrya High School No.39	Learning campus	Osh city _ Madumarov (street)	1987
07_007_035_001	OSH_sh_Osh_shkola-1-Fedchenco	A [A]	Fedchenko High School No.1	Main entrance + Foye + Learning campus	Osh city_Amir-Timur (district)	1985
07_007_035_001	OSH_sh_Osh_shkola-1-Fedchenco	B [Б]	Fedchenko High School No.1	Learning Campus	Osh city_Amir-Timur (district)	1985
07_007_035_001	OSH_sh_Osh_shkola-1-Fedchenco	C [В]	Fedchenko High School No.1	Canteen + Assembly hall	Osh city_Amir-Timur (district)	1985
07_007_035_001	OSH_sh_Osh_shkola-1-Fedchenco	D [Г]	Fedchenko High School No.1	Learning Campus	Osh city_Amir-Timur (district)	1985
07_007_035_001	OSH_sh_Osh_shkola-1-Fedchenco	E [Д]	Fedchenko High School No.1	Learning Campus	Osh city_Amir-Timur (district)	1985
07_007_035_001	OSH_sh_Osh_shkola-1-Fedchenco	F [E]	Fedchenko High School No.1	Learning Campus	Osh city_Amir-Timur (district)	1985
07_007_035_001	OSH_sh_Osh_shkola-1-Fedchenco	G [Ж]	Fedchenko High School No.1	Learning Campus	Osh city_Amir-Timur (district)	1985

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_007_035_001	OSH_sh_Osh_shkola-1-Fedchenco	H [З]	Fedchenko High School No.1	Sports hall	Osh city_Amir-Timur (district)	1985
07_007_035_021	OSH_sh_Osh_shkola-21-Pushkina	A [A]	Pushkina School Gymnasium No.21	Main entrance + Foye	Osh city _ Amir-Temir (street)	1986
07_007_035_021	OSH_sh_Osh_shkola-21-Pushkina	B [Б]	Pushkina School Gymnasium No.21	Wardrobe	Osh city _ Amir-Temir (street)	1986
07_007_035_021	OSH_sh_Osh_shkola-21-Pushkina	C [В]	Pushkina School Gymnasium No.21	Sports hall	Osh city _ Amir-Temir (street)	1986
07_007_035_021	OSH_sh_Osh_shkola-21-Pushkina	D [Г]	Pushkina School Gymnasium No.21	Canteen + Assembly hall	Osh city _ Amir-Temir (street)	1986
07_007_035_021	OSH_sh_Osh_shkola-21-Pushkina	D1 [Г1]	Pushkina School Gymnasium No.21	Staircase	Osh city _ Amir-Temir (street)	1986
07_007_035_021	OSH_sh_Osh_shkola-21-Pushkina	E [Д]	Pushkina School Gymnasium No.21	Learning campus	Osh city _ Amir-Temir (street)	1986
07_007_035_021	OSH_sh_Osh_shkola-21-Pushkina	F [E]	Pushkina School Gymnasium No.21	Learning campus	Osh city _ Amir-Temir (street)	1986
07_007_035_021	OSH_sh_Osh_shkola-21-Pushkina	G [Ж]	Pushkina School Gymnasium No.21	Learning campus	Osh city _ Amir-Temir (street)	1986
07_007_035_021	OSH_sh_Osh_shkola-21-Pushkina	G1 [Ж1]	Pushkina School Gymnasium No.21	Learning campus	Osh city _ Amir-Temir (street)	1986
07_007_035_050	OSH_sh_Osh_shkola-50-Nyshanova	I corpus_ A [A]	Nyshanova School Gymnasium No.50	Learning Campus	Osh city _ Osmonov (street)	2002
07_007_035_050	OSH_sh_Osh_shkola-50-Nyshanova	I corpus_ Б [B]	Nyshanova School Gymnasium No.50	Canteen	Osh city _ Osmonov (street)	2002
07_007_035_050	OSH_sh_Osh_shkola-50-Nyshanova	I corpus_ В [C]	Nyshanova School Gymnasium No.50	Learning Campus	Osh city _ Osmonov (street)	2002
07_007_035_050	OSH_sh_Osh_shkola-50-Nyshanova	II corpus_ Г [E]	Nyshanova School Gymnasium No.50	Sports hall	Osh city _ Osmonov (street)	2004
07_007_035_050	OSH_sh_Osh_shkola-50-Nyshanova	II corpus_ Д [F]	Nyshanova School Gymnasium No.50	Learning Campus	Osh city _ Osmonov (street)	2002

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_007_035_050	OSH_sh_Osh_shkola-50-Nyshanova	III corpus_ Е [G]	Nyshanova School Gymnasium No.50	Learning Campus	Osh city _ Osmonov (street)	2009
07_007_035_050	OSH_sh_Osh_shkola-50-Nyshanova	III corpus_ Ж [H]	Nyshanova School Gymnasium No.50	Learning Campus	Osh city _ Osmonov (street)	2009
02_004_035_011	SVD_sh_Bishkek_N11	А [A]	HS No. 11	Learning Campus	Bishkek city_Sverdlovsky	1977
02_004_035_011	SVD_sh_Bishkek_N11	Б [B]	HS No. 11	Learning Campus	Bishkek city_Sverdlovsky	1977
02_004_035_011	SVD_sh_Bishkek_N11	В [C]	HS No. 11	Learning Campus	Bishkek city_Sverdlovsky	1977
02_004_035_011	SVD_sh_Bishkek_N11	Г [D]	HS No. 11	Learning Campus	Bishkek city_Sverdlovsky	1977
02_004_035_011	SVD_sh_Bishkek_N11	Г1 [D1]	HS No. 11	Transition to learning campus	Bishkek city_Sverdlovsky	1977
02_004_035_011	SVD_sh_Bishkek_N11	Д [E]	HS No. 11	Learning Campus	Bishkek city_Sverdlovsky	1977
02_004_035_011	SVD_sh_Bishkek_N11	Д1 [E1]	HS No. 11	Transition to learning campus	Bishkek city_Sverdlovsky	1977
02_004_035_011	SVD_sh_Bishkek_N11	Ж [F]	HS No. 11	Administrative building	Bishkek city_Sverdlovsky	1977
02_004_035_011	SVD_sh_Bishkek_N11	И [G]	HS No. 11	Assembly Hall, Canteen	Bishkek city_Sverdlovsky	1977
02_004_035_011	SVD_sh_Bishkek_N11	И1 [H]	HS No. 11	Transition to learning campus	Bishkek city_Sverdlovsky	1977
02_004_035_011	SVD_sh_Bishkek_N11	К [I]	HS No. 11	Library	Bishkek city_Sverdlovsky	1977
02_004_035_011	SVD_sh_Bishkek_N11	Л [J]	HS No. 11	Sports Hall	Bishkek city_Sverdlovsky	1977
02_004_035_001	SVD_sh_Bishkek_N1	А [A]	HS No. 1	Transition to learning campus	Bishkek city_Sverdlovsky	1983
02_004_035_001	SVD_sh_Bishkek_N1	Б [B]	HS No. 1	Pool	Bishkek city_Sverdlovsky	1983
02_004_035_001	SVD_sh_Bishkek_N1	В [C]	HS No. 1	Sports Hall, Assembly Hall	Bishkek city_Sverdlovsky	1983
02_004_035_001	SVD_sh_Bishkek_N1	Г [D]	HS No. 1	Canteen	Bishkek city_Sverdlovsky	1983
02_004_035_001	SVD_sh_Bishkek_N1	Д [E]	HS No. 1	Learning Campus	Bishkek city_Sverdlovsky	1983
02_004_035_001	SVD_sh_Bishkek_N1	Ж [F]	HS No. 1	Learning Campus	Bishkek city_Sverdlovsky	1983

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
02_004_035_001	SVD_sh_Bishkek_N1	И [G]	HS No. 1	Learning Campus	Bishkek city_Sverdlovsky	1983
02_004_035_001	SVD_sh_Bishkek_N1	К [H]	HS No. 1	Learning Campus	Bishkek city_Sverdlovsky	1983
02_004_035_001	SVD_sh_Bishkek_N1	Л [I]	HS No. 1	Learning Campus	Bishkek city_Sverdlovsky	1983
02_004_035_001	SVD_sh_Bishkek_N1	Н [J]	HS No. 1	Learning Campus	Bishkek city_Sverdlovsky	1983
02_004_035_001	SVD_sh_Bishkek_N1	П [K]	HS No. 1	School of Music	Bishkek city_Sverdlovsky	1983
02_004_035_001	SVD_sh_Bishkek_N1	Р [L]	HS No. 1	Learning Campus	Bishkek city_Sverdlovsky	1983
06_004_035_013	KCH_sh_Kochkor_Zhundubaev	А [A]	Zhundubaeva High School	Learning Campus	Naryn_Kochkor_Kochkor	1985
06_004_035_013	KCH_sh_Kochkor_Zhundubaev	Б [B]	Zhundubaeva High School	Learning Campus	Naryn_Kochkor_Kochkor	1985
06_004_035_013	KCH_sh_Kochkor_Zhundubaev	В [C]	Zhundubaeva High School	Transition to learning campus	Naryn_Kochkor_Kochkor	1985
06_004_035_013	KCH_sh_Kochkor_Zhundubaev	Г [D]	Zhundubaeva High School	Learning Campus	Naryn_Kochkor_Kochkor	1985
06_004_035_013	KCH_sh_Kochkor_Zhundubaev	Д [E]	Zhundubaeva High School	Transition to learning campus	Naryn_Kochkor_Kochkor	1985
06_004_035_013	KCH_sh_Kochkor_Zhundubaev	Е [F]	Zhundubaeva High School	Assembly Hall	Naryn_Kochkor_Kochkor	1985
06_004_035_013	KCH_sh_Kochkor_Zhundubaev	Ж [G]	Zhundubaeva High School	Transition to learning campus	Naryn_Kochkor_Kochkor	1985
06_004_035_013	KCH_sh_Kochkor_Zhundubaev	З [H]	Zhundubaeva High School	Sports Hall	Naryn_Kochkor_Kochkor	1985
06_004_035_017	KCH_sh_Cholpon_Maltabarov	А [A]	Maltabarova High School	Learning Campus	Naryn_Kochkor_Moldo-Klych	2012
03_001_035_013	ALM_sh_Nizhnyaya-Ala-Archa_Nijne-Alarchinskaya	А [A]	N-Alarchincskaya high school	Learning Campus	Chui_Alamudun_Nijne-Alarchinskaya village	1975
03_001_035_013	ALM_sh_Nizhnyaya-Ala-Archa_Nijne-Alarchinskaya	Б [B]	N-Alarchincskaya high school	Learning Campus	Chui_Alamudun_Nijne-Alarchinskaya village	1975
03_001_035_013	ALM_sh_Nizhnyaya-Ala-Archa_Nijne-Alarchinskaya	В [C]	N-Alarchincskaya high school	Learning Campus and Transition to learning campus	Chui_Alamudun_Nijne-Alarchinskaya village	1975
03_001_035_013	ALM_sh_Nizhnyaya-Ala-Archa_Nijne-Alarchinskaya	Г [D]	N-Alarchincskaya high school	Learning Campus	Chui_Alamudun_Nijne-Alarchinskaya village	1975

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
03_001_035_013	ALM_sh_Nizhnyaya-Ala-Archa_Nijne-Alarchinskaya	Д [E]	N-Alarchincskaya high school	Learning Campus	Chui_Alamudun_Nijne-Alarchinskaya village	1975
03_001_035_013	ALM_sh_Nizhnyaya-Ala-Archa_Nijne-Alarchinskaya	Е [E]	N-Alarchincskaya high school	Learning Campus and Transition to learning campus	Chui_Alamudun_Nijne-Alarchinskaya village	1975
03_001_035_013	ALM_sh_Nizhnyaya-Ala-Archa_Nijne-Alarchinskaya	Ж [F]	N-Alarchincskaya high school	Assembly Hall	Chui_Alamudun_Nijne-Alarchinskaya village	1975
03_001_035_013	ALM_sh_Nizhnyaya-Ala-Archa_Nijne-Alarchinskaya	З [G]	N-Alarchincskaya high school	Sports Hall	Chui_Alamudun_Nijne-Alarchinskaya village	1975
03_001_035_001 (1)	ALM_sh_Alamudun_N1	А [A]	Alamudun high school No1	Learning Campus	Chui_Alamudun_Alamudun	1970
03_001_035_001 (1)	ALM_sh_Alamudun_N1	Б [B]	Alamudun high school No1	Transition to learning campus	Chui_Alamudun_Alamudun	1970
03_001_035_001 (1)	ALM_sh_Alamudun_N1	В [C]	Alamudun high school No1	Sports Hall and Canteen	Chui_Alamudun_Alamudun	1970
03_001_035_001 (1)	ALM_sh_Alamudun_N1	Г [D]	Alamudun high school No1	Assembly Hall	Chui_Alamudun_Alamudun	1970
03_001_035_001 (1)	ALM_sh_Alamudun_N1	Д [E]	Alamudun high school No1	Learning Campus	Chui_Alamudun_Alamudun	1970
03_001_035_001 (1)	ALM_sh_Alamudun_N1	Е [F]	Alamudun high school No1	Learning Campus	Chui_Alamudun_Alamudun	1970
03_001_035_011	ALM_sh_Leninskoe_Lenin	А [A]	Lenina high school	Learning Campus	Chui_Alamudun_Leninskoe	1973
03_001_035_011	ALM_sh_Leninskoe_Lenin	Б [B]	Lenina high school	Learning Campus	Chui_Alamudun_Leninskoe	1973
03_001_035_011	ALM_sh_Leninskoe_Lenin	В [C]	Lenina high school	Sports Hall	Chui_Alamudun_Leninskoe	1973
03_001_035_011	ALM_sh_Leninskoe_Lenin	Г [D]	Lenina high school	Canteen	Chui_Alamudun_Leninskoe	1973
02_001_035_077	LEN_sh_Bishkek_N77	А [A]	HS No.77	Learning Campus	Bishkek city_Leninsky	1995
02_001_035_077	LEN_sh_Bishkek_N77	Б [B]	HS No.77	Learning Campus	Bishkek city_Leninsky	1995
02_001_035_077	LEN_sh_Bishkek_N77	В [C]	HS No.77	Transition to learning campus	Bishkek city_Leninsky	1995
02_001_035_077	LEN_sh_Bishkek_N77	Г [D]	HS No.77	Sports Hall	Bishkek city_Leninsky	1995
02_001_035_077	LEN_sh_Bishkek_N77	Д [E]	HS No.77	Assembly Hall, Canteen	Bishkek city_Leninsky	1995

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
02_001_035_077	LEN_sh_Bishkek_N77	Е [F]	HS No.77	Transition to learning campus	Bishkek city_Leninsky	1995
02_001_035_077	LEN_sh_Bishkek_N77	Ж [G]	HS No.77	Learning Campus	Bishkek city_Leninsky	1995
02_001_035_077	LEN_sh_Bishkek_N77	З [H]	HS No.77	Wrestling hall	Bishkek city_Leninsky	1995
02_001_035_077	LEN_sh_Bishkek_N77	И [I]	HS No.77	Wrestling hall	Bishkek city_Leninsky	1995
02_001_035_072	LEN_sh_Bishkek_N72	А [A]	HS No.72	Learning Campus	Bishkek city_Leninsky	1991
02_001_035_072	LEN_sh_Bishkek_N72	Б [B]	HS No.72	Learning Campus	Bishkek city_Leninsky	1991
02_001_035_072	LEN_sh_Bishkek_N72	В [C]	HS No.72	Learning Campus	Bishkek city_Leninsky	1991
02_001_035_072	LEN_sh_Bishkek_N72	Г [D]	HS No.72	Transition to learning campus	Bishkek city_Leninsky	1991
02_001_035_072	LEN_sh_Bishkek_N72	Д [E]	HS No.72	Pool	Bishkek city_Leninsky	1991
02_001_035_072	LEN_sh_Bishkek_N72	Е [F]	HS No.72	Assembly Hall	Bishkek city_Leninsky	1991
02_001_035_072	LEN_sh_Bishkek_N72	Ж [G]	HS No.72	Sports Hall	Bishkek city_Leninsky	1991
07_005_035_086	KSU_sh_Mady_Kurmanzhan-Datka	А [A]	Kurmanjan Datka HS No.86	Foye	Osh_Kara-Suu_Mady_Madynsky VA	1986
07_005_035_086	KSU_sh_Mady_Kurmanzhan-Datka	Б [B]	Kurmanjan Datka HS No.86	Sports Hall	Osh_Kara-Suu_Mady_Madynsky VA	1986
07_005_035_086	KSU_sh_Mady_Kurmanzhan-Datka	В [C]	Kurmanjan Datka HS No.86	Locker room	Osh_Kara-Suu_Mady_Madynsky VA	1986
07_005_035_086	KSU_sh_Mady_Kurmanzhan-Datka	Г [D]	Kurmanjan Datka HS No.86	Assembly Hall	Osh_Kara-Suu_Mady_Madynsky VA	1986
07_005_035_086	KSU_sh_Mady_Kurmanzhan-Datka	Д [E]	Kurmanjan Datka HS No.86	Library	Osh_Kara-Suu_Mady_Madynsky VA	1986
07_005_035_086	KSU_sh_Mady_Kurmanzhan-Datka	Е [F]	Kurmanjan Datka HS No.86	Learning Campus	Osh_Kara-Suu_Mady_Madynsky VA	1986
07_005_035_086	KSU_sh_Mady_Kurmanzhan-Datka	Ж-1 [J1]	Kurmanjan Datka HS No.86	Learning Campus	Osh_Kara-Suu_Mady_Madynsky VA	1986
07_005_035_086	KSU_sh_Mady_Kurmanzhan-Datka	Ж-2 [J2]	Kurmanjan Datka HS No.86	Learning Campus	Osh_Kara-Suu_Mady_Madynsky VA	1986

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_005_035_088	KSU_sh_Papan_Zairov	А [A]	Zairova HS No.88	Learning Campus	Osh_Kara-Suu_Papan	1988
07_005_035_088	KSU_sh_Papan_Zairov	Б [B]	Zairova HS No.88	Learning Campus	Osh_Kara-Suu_Papan	1988
07_005_035_088	KSU_sh_Papan_Zairov	В [C]	Zairova HS No.88	Sports Hall	Osh_Kara-Suu_Papan	1988
07_005_035_088	KSU_sh_Papan_Zairov	Г [D]	Zairova HS No.88	Assembly Hall_ Dinning room	Osh_Kara-Suu_Papan	1988
07_005_035_053	KSU_sh_Kyzyl-Ordo_Orto-Mechit	А [A]	Orto Mechit HS No.53	Learning Campus	Osh_Kara-Suu_Kyzyl-Ordo_ Katta-Taldyksky VA	2009-2014
07_005_035_053	KSU_sh_Kyzyl-Ordo_Orto-Mechit	Б [B]	Orto Mechit HS No.53	Learning Campus	Osh_Kara-Suu_Kyzyl-Ordo_ Katta-Taldyksky VA	2009-2015
07_005_035_053	KSU_sh_Kyzyl-Ordo_Orto-Mechit	В [C]	Orto Mechit HS No.53	Assembly Hall library	Osh_Kara-Suu_Kyzyl-Ordo_ Katta-Taldyksky VA	2009-2016
07_005_035_053	KSU_sh_Kyzyl-Ordo_Orto-Mechit	Г [D]	Orto Mechit HS No.53	Sports Hall	Osh_Kara-Suu_Kyzyl-Ordo_ Katta-Taldyksky VA	2009-2017
07_005_035_089	KSU_sh_Pravda_Abdrahmanov	А-1 [A-1]	Abdrahmanova HS No.89	Assembly Hall Dinning room	Osh_Kara-Suu_Pravda_ Jany-Aryksky VA	1989
07_005_035_089	KSU_sh_Pravda_Abdrahmanov	А-2 [A-2]	Abdrahmanova HS No.89	Learning Campus	Osh_Kara-Suu_Pravda_ Jany-Aryksky VA	1989
07_005_035_089	KSU_sh_Pravda_Abdrahmanov	А-3 [A-3]	Abdrahmanova HS No.89	Learning Campus	Osh_Kara-Suu_Pravda_ Jany-Aryksky VA	1989
07_005_035_089	KSU_sh_Pravda_Abdrahmanov	Б-1 [B-3]	Abdrahmanova HS No.89	Learning Campus	Osh_Kara-Suu_Pravda_ Jany-Aryksky VA	1989
07_005_035_089	KSU_sh_Pravda_Abdrahmanov	Б-2 [B-2]	Abdrahmanova HS No.89	Learning Campus	Osh_Kara-Suu_Pravda_ Jany-Aryksky VA	1989
07_005_035_089	KSU_sh_Pravda_Abdrahmanov	Б-3 [B-3]	Abdrahmanova HS No.89	Sports Hall	Osh_Kara-Suu_Pravda_ Jany-Aryksky VA	1989
07_005_035_089	KSU_sh_Pravda_Abdrahmanov	В-1 [C-1]	Abdrahmanova HS No.89	Learning Campus	Osh_Kara-Suu_Pravda_ Jany-Aryksky VA	1989
07_005_035_089	KSU_sh_Pravda_Abdrahmanov	В-2 [C-2]	Abdrahmanova HS No.89	Learning Campus	Osh_Kara-Suu_Pravda_ Jany-Aryksky VA	1989

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_005_035_089	KSU_sh_Pravda_Abdrahmanov	В-3 [C-3]	Abdrahmanova HS No.89	Learning Campus	Osh_Kara-Suu_Pravda_ Jany-Aryksky VA	1989
07_005_035_089	KSU_sh_Pravda_Abdrahmanov	Г-1 [D-1]	Abdrahmanova HS No.89	Learning Campus	Osh_Kara-Suu_Pravda_ Jany-Aryksky VA	1989
07_005_035_089	KSU_sh_Pravda_Abdrahmanov	Г-2 [D-2]	Abdrahmanova HS No.89	Learning Campus	Osh_Kara-Suu_Pravda_ Jany-Aryksky VA	1989
07_005_035_089	KSU_sh_Pravda_Abdrahmanov	Г-3 [D-3]	Abdrahmanova HS No.89	Learning Campus	Osh_Kara-Suu_Pravda_ Jany-Aryksky VA	1989
07_005_035_074	KSU_sh_Ak-Tash_Sherkulov	А [A]	Sherkulov HS No.74	Learning Campus	Osh_Kara-Suu_Ak-Tash	1974
07_005_035_074	KSU_sh_Ak-Tash_Sherkulov	Б [B]	Sherkulov HS No.74	Learning Campus	Osh_Kara-Suu_Ak-Tash	1974
07_005_035_074	KSU_sh_Ak-Tash_Sherkulov	В [C]	Sherkulov HS No.74	Foye Assembly Hall	Osh_Kara-Suu_Ak-Tash	1974
07_005_035_074	KSU_sh_Ak-Tash_Sherkulov	Г [D]	Sherkulov HS No.74	Sports Hall, Dinning room	Osh_Kara-Suu_Ak-Tash	1974
07_005_035_072	KSU_sh_Konurat-(was-Socialism)_TashirovN72	А [A]	Tashirova HS No.72	Learning Campus	Osh_Kara-Suu_Kyzyl-Shark_Saraisky VA	1989
07_005_035_072	KSU_sh_Konurat-(was-Socialism)_TashirovN72	Б [B]	Tashirova HS No.72	Foye, Assembly Hall, Dinning room Спортивный зал	Osh_Kara-Suu_Kyzyl-Shark_Saraisky VA	1989
07_005_035_072	KSU_sh_Konurat-(was-Socialism)_TashirovN72	В [C]	Tashirova HS No.72	Learning Campus	Osh_Kara-Suu_Kyzyl-Shark_Saraisky VA	1989
07_005_035_072	KSU_sh_Konurat-(was-Socialism)_TashirovN72	Г [D]	Tashirova HS No.72	Assembly Hall	Osh_Kara-Suu_Kyzyl-Shark_Saraisky VA	1989
07_005_035_072	KSU_sh_Konurat-(was-Socialism)_TashirovN72	Д [E]	Tashirova HS No.72	Library	Osh_Kara-Suu_Kyzyl-Shark_Saraisky VA	1989
07_005_035_069	KSU_sh_Nariman_Zaribdar-Aitmatov	А [A]	Aitmatova HS No. 69	Learning Campus	Osh_Kara-Suu_Zadbor_ Nariman VA	1971
07_005_035_069	KSU_sh_Nariman_Zaribdar-Aitmatov	Б [B]	Aitmatova HS No. 69	Learning Campus	Osh_Kara-Suu_Zadbor_ Nariman VA	1971
07_005_035_069	KSU_sh_Nariman_Zaribdar-Aitmatov	В [C]	Aitmatova HS No. 69	Foye Assembly Hall	Osh_Kara-Suu_Zadbor_ Nariman VA	1971

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_005_035_069	KSU_sh_Nariman_Zaribdar-Aitmatov	Г [D]	Aitmatova HS No. 69	Sports Hall,	Osh_Kara-Suu_Zadbor_Nariman VA	1971
07_005_035_069	KSU_sh_Nariman_Zaribdar-Aitmatov	Д [E]	Aitmatova HS No. 69	Dinning room	Osh_Kara-Suu_Zadbor_Nariman VA	1971
07_005_035_065	KSU_sh_Kyzyl-Kyshtak_Sabirov	А [A]	Sabirova HS No.65	Learning Campus	Osh_Kara-Suu_Kyzyl-Kyshtak	1978
07_005_035_065	KSU_sh_Kyzyl-Kyshtak_Sabirov	Б [B]	Sabirova HS No.65	Learning Campus	Osh_Kara-Suu_Kyzyl-Kyshtak	1978
07_005_035_065	KSU_sh_Kyzyl-Kyshtak_Sabirov	В [C]	Sabirova HS No.65	Learning Campus	Osh_Kara-Suu_Kyzyl-Kyshtak	1978
07_005_035_065	KSU_sh_Kyzyl-Kyshtak_Sabirov	Г [D]	Sabirova HS No.65	Learning Campus	Osh_Kara-Suu_Kyzyl-Kyshtak	1978
07_005_035_065	KSU_sh_Kyzyl-Kyshtak_Sabirov	Г-1 [D1]	Sabirova HS No.65	Staircase	Osh_Kara-Suu_Kyzyl-Kyshtak	1978
07_005_035_065	KSU_sh_Kyzyl-Kyshtak_Sabirov	Д [E]	Sabirova HS No.65	Learning Campus	Osh_Kara-Suu_Kyzyl-Kyshtak	1978
07_005_035_065	KSU_sh_Kyzyl-Kyshtak_Sabirov	Д-1 [E1]	Sabirova HS No.65	Staircase	Osh_Kara-Suu_Kyzyl-Kyshtak	1978
07_005_035_065	KSU_sh_Kyzyl-Kyshtak_Sabirov	Ж [F]	Sabirova HS No.65	Foye, Dinning room,Assembly Hall	Osh_Kara-Suu_Kyzyl-Kyshtak	1978
07_005_035_065	KSU_sh_Kyzyl-Kyshtak_Sabirov	Ж-1 [F1]	Sabirova HS No.65	Staircase	Osh_Kara-Suu_Kyzyl-Kyshtak	1978
07_005_035_065	KSU_sh_Kyzyl-Kyshtak_Sabirov	Ж-2 [F2]	Sabirova HS No.65	Staircase	Osh_Kara-Suu_Kyzyl-Kyshtak	1978
07_005_035_065	KSU_sh_Kyzyl-Kyshtak_Sabirov	И [G]	Sabirova HS No.65	locker room, library	Osh_Kara-Suu_Kyzyl-Kyshtak	1978
07_005_035_065	KSU_sh_Kyzyl-Kyshtak_Sabirov	К [H]	Sabirova HS No.65	Sports Hall	Osh_Kara-Suu_Kyzyl-Kyshtak	1978
07_007_035_005	OSH_sh_Osh_N5-Bokonbaev	А [A]	School Gymnasium No.5	Learning Campus	Osh city	1972
07_007_035_005	OSH_sh_Osh_N5-Bokonbaev	Б [B]	School Gymnasium No.5	Learning Campus	Osh city	1972
07_007_035_005	OSH_sh_Osh_N5-Bokonbaev	В [C]	School Gymnasium No.5	Learning Campus	Osh city	1972
07_007_035_005	OSH_sh_Osh_N5-Bokonbaev	Г [D]	School Gymnasium No.5	Sports Hall	Osh city	1972
07_007_035_009	OSH_sh_Osh_N9-Rudaki	А (A)	Rudaki School Gymnasium No.9	Transition to learning campus	Osh city	1988
07_007_035_009	OSH_sh_Osh_N9-Rudaki	Б (B)	Rudaki School Gymnasium No.9	Transition to learning campus	Osh city	1988

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_007_035_009	OSH_sh_Osh_N9-Rudaki	В [C]	Rudaki School Gymnasium No.9	Sports Hall	Osh city	1988
07_007_035_009	OSH_sh_Osh_N9-Rudaki	Г (D)	Rudaki School Gymnasium No.9	Assembly Hall	Osh city	1988
07_007_035_009	OSH_sh_Osh_N9-Rudaki	Д [E]	Rudaki School Gymnasium No.9	Transition to learning campus	Osh city	1988
07_007_035_009	OSH_sh_Osh_N9-Rudaki	Е (F)	Rudaki School Gymnasium No.9	Learning Campus	Osh city	1988
07_007_035_009	OSH_sh_Osh_N9-Rudaki	Ж (G)	Rudaki School Gymnasium No.9	Learning Campus	Osh city	1988
07_007_035_009	OSH_sh_Osh_N9-Rudaki	И (H)	Rudaki School Gymnasium No.9	Learning Campus	Osh city	1988
07_007_035_026	OSH_sh_Osh_N26-Toktogul	А [A]	High School No.26	Learning Campus	Osh city	1969
07_007_035_026	OSH_sh_Osh_N26-Toktogul	Б [B]	High School No.26	Learning Campus	Osh city	1969
07_007_035_026	OSH_sh_Osh_N26-Toktogul	В [C]	High School No.26	Learning Campus	Osh city	1969
07_007_035_026	OSH_sh_Osh_N26-Toktogul	Г [D]	High School No.26	Sports Hall	Osh city	1969
07_007_035_029	OSH_sh_Osh_N29-Kalinin	B	Kalinina High School No.29	Learning Campus	Osh city, street Yubileinaya 2	1995
07_007_035_029	OSH_sh_Osh_N29-Kalinin	C	Kalinina High School No.29	Learning Campus	Osh city, street Yubileinaya 2	1995
07_007_035_029	OSH_sh_Osh_N29-Kalinin	C1	Kalinina High School No.29	Transition to learning campus	Osh city, street Yubileinaya 2	1975
07_007_035_029	OSH_sh_Osh_N29-Kalinin	C2	Kalinina High School No.29	Transition to learning campus	Osh city, street Yubileinaya 2	1975
07_007_035_029	OSH_sh_Osh_N29-Kalinin	D	Kalinina High School No.29	Learning Campus	Osh city, street Yubileinaya 2	1975
07_007_035_029	OSH_sh_Osh_N29-Kalinin	D1	Kalinina High School No.29	Transition to learning campus	Osh city, street Yubileinaya 2	1975
07_007_035_029	OSH_sh_Osh_N29-Kalinin	D2	Kalinina High School No.29	Transition to learning campus	Osh city, street Yubileinaya 2	1975
07_007_035_029	OSH_sh_Osh_N29-Kalinin	E	Kalinina High School No.29	Assembly Hall	Osh city, street Yubileinaya 2	1975
07_007_035_029	OSH_sh_Osh_N29-Kalinin	E1	Kalinina High School No.29	Transition to learning campus	Osh city, street Yubileinaya 2	1975

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_007_035_029	OSH_sh_Osh_N29-Kalinin	E2	Kalinina High School No.29	Transition to learning campus	Osh city, street Yubileinaya 2	1975
07_007_035_029	OSH_sh_Osh_N29-Kalinin	F	Kalinina High School No.29	Sports Hall	Osh city, street Yubileinaya 2	1975
07_002_035_070	ARV_sh_Achy_Aytmatov	А (A)	Aitmatova HS	Learning Campus	Osh_Aravan_Achy_Allya-Anarovsky VA	1990
07_002_035_070	ARV_sh_Achy_Aytmatov	Б (B)	Aitmatova HS	Transition to learning campus	Osh_Aravan_Achy_Allya-Anarovsky VA	1990
07_002_035_070	ARV_sh_Achy_Aytmatov	В [C]	Aitmatova HS	Learning Campus	Osh_Aravan_Achy_Allya-Anarovsky VA	1990
07_002_035_070	ARV_sh_Achy_Aytmatov	Г (D)	Aitmatova HS	Sports Hall	Osh_Aravan_Achy_Allya-Anarovsky VA	1990
07_002_035_027	ARV_sh_Kakyr-Piltan_Amir-Temur	А (A)	Amir-Temur HS No.27	Learning Campus	Osh_Aravan_Kakyr-Piltan_Nur-Abad VA	1982
07_002_035_027	ARV_sh_Kakyr-Piltan_Amir-Temur	Б (B)	Amir-Temur HS No.27	Transition to learning campus	Osh_Aravan_Kakyr-Piltan_Nur-Abad VA	1982
07_002_035_027	ARV_sh_Kakyr-Piltan_Amir-Temur	В [C]	Amir-Temur HS No.27	Kindergarten	Osh_Aravan_Kakyr-Piltan_Nur-Abad VA	1982
07_002_035_027	ARV_sh_Kakyr-Piltan_Amir-Temur	Г (D)	Amir-Temur HS No.27	Sports Hall	Osh_Aravan_Kakyr-Piltan_Nur-Abad VA	1982
07_002_035_027	ARV_sh_Kakyr-Piltan_Amir-Temur	Д [E]	Amir-Temur HS No.27	Additional building	Osh_Aravan_Kakyr-Piltan_Nur-Abad VA	2005
07_002_035_027	ARV_sh_Kakyr-Piltan_Amir-Temur	Е (F)	Amir-Temur HS No.27	Additional building	Osh_Aravan_Kakyr-Piltan_Nur-Abad VA	1982
07_002_035_068	ARV_sh_Sary-Tash_Sary-Tash	А [A]	Sary-Tash Elementary School	Learning Campus	Osh_Aravan_Sary-Tash_Too-Moyunsky VA	1989
07_002_035_068	ARV_sh_Sary-Tash_Sary-Tash	Б [B]	Sary-Tash Elementary School	Transition to learning campus	Osh_Aravan_Sary-Tash_Too-Moyunsky VA	1989
07_002_035_054	ARV_sh_Ak-Shar_Sydykov	А [A]	Sydykova HS	Learning Campus	Osh_Aravan_Ak-Shar_Too-Moyunsky VA	1986
07_002_035_054	ARV_sh_Ak-Shar_Sydykov	Б [B]	Sydykova HS	Learning Campus	Osh_Aravan_Ak-Shar_Too-Moyunsky VA	1986

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_002_035_054	ARV_sh_Ak-Shar_Sydykov	В [С]	Sydykova HS	Assembly Hall,Sports Hall	Osh_Aravan_Ak-Shar_Too-Moyunsky VA	1986
07_002_035_054	ARV_sh_Ak-Shar_Sydykov	Г [D]	Sydykova HS	Assembly Hall,Sports Hall	Osh_Aravan_Ak-Shar_Too-Moyunsky VA	1986
07_002_035_054	ARV_sh_Ak-Shar_Sydykov	Д [E]	Sydykova HS	Transition to learning campus	Osh_Aravan_Ak-Shar_Too-Moyunsky VA	1986
01_003_035_082	KDJ_sh_Adyr_Srednyaya-sh-Adyr	A [A]	HS Adyr	Learning Campus	Batken_Kadamjay_Alga	2004
01_003_035_017	KDJ_sh_Kadamjay_KadamjayN17	A [A]	HS No. 17 A.Masaliev	Learning Campus	Batken_Kadamjay_Kadamjay_Gagarin	1977
01_003_035_017	KDJ_sh_Kadamjay_KadamjayN17	B [Б]	HS No. 17 A.Masaliev	Learning Campus	Batken_Kadamjay_Kadamjay_Gagarin	1977
01_003_035_017	KDJ_sh_Kadamjay_KadamjayN17	C [В]	HS No. 17 A.Masaliev	Learning Campus	Batken_Kadamjay_Kadamjay_Gagarin	1977
01_003_035_017	KDJ_sh_Kadamjay_KadamjayN17	D [Г]	HS No. 17 A.Masaliev	Learning Campus	Batken_Kadamjay_Kadamjay_Gagarin	1977
01_003_035_017	KDJ_sh_Kadamjay_KadamjayN17	E [Д]	HS No. 17 A.Masaliev	Learning Campus	Batken_Kadamjay_Kadamjay_Gagarin	1977
01_003_035_017	KDJ_sh_Kadamjay_KadamjayN17	F [E]	HS No. 17 A.Masaliev	Learning Campus	Batken_Kadamjay_Kadamjay_Gagarin	1977
01_003_035_017	KDJ_sh_Kadamjay_KadamjayN17	I [И]	HS No. 17 A.Masaliev	Assembly Hall	Batken_Kadamjay_Kadamjay_Gagarin	1977
01_003_035_017	KDJ_sh_Kadamjay_KadamjayN17	J [K]	HS No. 17 A.Masaliev	Sports Hall	Batken_Kadamjay_Kadamjay_Gagarin	1977
01_003_035_017	KDJ_sh_Kadamjay_KadamjayN17	G [Ж]	HS No. 17 A.Masaliev	Faye - Dining Room	Batken_Kadamjay_Kadamjay_Gagarin	1977
01_003_035_017	KDJ_sh_Kadamjay_KadamjayN17	Y [Й]	HS No. 17 A.Masaliev	Transition to Sports Hall	Batken_Kadamjay_Kadamjay_Gagarin	1977
07_008_035_034	UZG_sh_Myrza-Ake_N34	A [A]	HS No. 34 T.Mashrapov	Learning Campus	Osh_Uzgen_Myrza-Ake_Polotova	1981
07_008_035_034	UZG_sh_Myrza-Ake_N34	B [Б]	HS No. 34 T.Mashrapov	Learning Campus	Osh_Uzgen_Myrza-Ake_Polotova	1981

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_008_035_034	UZG_sh_Myrza-Ake_N34	C [В]	HS No. 34 T.Mashrapov	Faye-Main entrance	Osh_Uzgen_Myrza-Ake_Polotova	1981
07_008_035_034	UZG_sh_Myrza-Ake_N34	D [Г]	HS No. 34 T.Mashrapov	Sports Hall	Osh_Uzgen_Myrza-Ake_Polotova	1981
07_008_035_034	UZG_sh_Myrza-Ake_N34	E [Д]	HS No. 34 T.Mashrapov	Assembly Hall	Osh_Uzgen_Myrza-Ake_Polotova	1981
07_008_035_039	UZG_sh_Changet1_Lenin	A [A]	HS No. 39 V.I. Lenin	Learning Campus	Osh_Uzgen_Osturuu_Kokonbaeva No.23	2008
07_008_035_039	UZG_sh_Changet1_Lenin	B [Б]	HS No. 39 V.I. Lenin	Library	Osh_Uzgen_Osturuu_Kokonbaeva No.23	1982
07_008_035_039	UZG_sh_Changet1_Lenin	C [В]	HS No. 39 V.I. Lenin	Learning Campus	Osh_Uzgen_Osturuu_Kokonbaeva No.23	1983
07_008_035_039	UZG_sh_Changet1_Lenin	D [Г]	HS No. 39 V.I. Lenin	Storage and dining room	Osh_Uzgen_Osturuu_Kokonbaeva No.23	1984
07_008_035_039	UZG_sh_Changet1_Lenin	E [Д]	HS No. 39 V.I. Lenin	Preparatory building before schools	Osh_Uzgen_Osturuu_Kokonbaeva No.23	2013
07_008_035_048	UZG_sh_Kochkor-Ata_ Omurzakov_N48	A [A]	HS No. 48 K.Omurzakov	Learning Campus	Osh_Uzgen_Kochkor-Ata_K.Borubaev	1988
07_008_035_048	UZG_sh_Kochkor-Ata_ Omurzakov_N48	B [Б]	HS No. 48 K.Omurzakov	Do not used at current time	Osh_Uzgen_Kochkor-Ata_K.Borubaev	1980
07_008_035_048	UZG_sh_Kochkor-Ata_ Omurzakov_N48	C [В]	HS No. 48 K.Omurzakov	Assembly Hall	Osh_Uzgen_Kochkor-Ata_K.Borubaev	1980
07_008_035_048	UZG_sh_Kochkor-Ata_ Omurzakov_N48	D [Г]	HS No. 48 K.Omurzakov	Dinning room	Osh_Uzgen_Kochkor-Ata_K.Borubaev	1980
07_008_035_049	UZG_sh_Kurshab_N49	A [A]	HS No. 49 Toktogul	Learning Campus	Osh_Uzgen_Kurshab_Sh_Ermekov	2003
07_008_035_049	UZG_sh_Kurshab_N49	B [Б]	HS No. 49 Toktogul	Sports Hall	Osh_Uzgen_Kurshab_Sh_Ermekov	2005
07_008_035_049	UZG_sh_Kurshab_N49	C [В]	HS No. 49 Toktogul	Transition to Sports Hall	Osh_Uzgen_Kurshab_Sh_Ermekov	2005
07_008_035_061	UZG_sh_Changet1_ Zhumabaeva	A [A]	HS No. 61 I.Jumabaev	Learning Campus	Osh_Uzgen_Changet_Kuron-Ata	2005
07_008_035_061	UZG_sh_Changet1_ Zhumabaeva	B [Б]	HS No. 61 I.Jumabaev	Library	Osh_Uzgen_Changet_Kuron-Ata	2007

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
07_008_035_091	UZG_sh_Myrza-Ake_ Raimbekova	A [A]	HS K.Raimbekov	Learning Campus	Osh_Uzgen-Myrza-Ake_K.Jumaliev No.18	1988
05_003_035_006	BZK_sh_Dzharake_ OsmonovN6	A	HS No.6 B.Osmonov	Learning Campus	Jalal Abad_Bazar Korgon_Djahy Akman	1995
05_003_035_006	BZK_sh_Dzharake_ OsmonovN6	B	HS No.6 B.Osmonov	Learning Campus	Jalal Abad_Bazar Korgon_Djahy Akman	1995
05_003_035_006	BZK_sh_Dzharake_ OsmonovN6	C	HS No.6 B.Osmonov	Transition to learning campus	Jalal Abad_Bazar Korgon_Djahy Akman	1995
05_003_035_006	BZK_sh_Dzharake_ OsmonovN6	D	HS No.6 B.Osmonov	Sports Hall	Jalal Abad_Bazar Korgon_Djahy Akman	1995
05_003_035_006	BZK_sh_Dzharake_ OsmonovN6	E	HS No.6 B.Osmonov	Assembly Hall	Jalal Abad_Bazar Korgon_Djahy Akman	1995
05_003_035_011	BZK_sh_Abdraimov-(was-Sovetskoe)_AlykulovN11	A	HS No.11 M.Alykulov	Learning Campus	Jalal-Abad_Bazar-Korgon_Abdyraimov	1976
05_003_035_011	BZK_sh_Abdraimov-(was-Sovetskoe)_AlykulovN11	B	HS No.11 M.Alykulov	Learning Campus	Jalal-Abad_Bazar-Korgon_Abdyraimov	1976
05_003_035_011	BZK_sh_Abdraimov-(was-Sovetskoe)_AlykulovN11	C	HS No.11 M.Alykulov	Learning Campus	Jalal-Abad_Bazar-Korgon_Abdyraimov	1976
05_003_035_011	BZK_sh_Abdraimov-(was-Sovetskoe)_AlykulovN11	D	HS No.11 M.Alykulov	Sports Hall	Jalal-Abad_Bazar-Korgon_Abdyraimov	1976
05_003_035_011	BZK_sh_Abdraimov-(was-Sovetskoe)_AlykulovN11	E	HS No.11 M.Alykulov	Dinning room + Assembly Hall	Jalal-Abad_Bazar-Korgon_Abdyraimov	1976
03_008_035_013	SOK_sh_Kamyshanovka_ Kamyshanovka	A	HS Kamyshanovskaya	Learning Campus	Chui_Sokuluk_Kamyshanovka	1988
03_008_035_013	SOK_sh_Kamyshanovka_ Kamyshanovka	B	HS Kamyshanovskaya	Sports Hall	Chui_Sokuluk_Kamyshanovka	1988
03_008_035_013	SOK_sh_Kamyshanovka_ Kamyshanovka	C	HS Kamyshanovskaya	Learning Campus	Chui_Sokuluk_Kamyshanovka	1988
03_008_035_013	SOK_sh_Kamyshanovka_ Kamyshanovka	D	HS Kamyshanovskaya	Dinning room	Chui_Sokuluk_Kamyshanovka	1988
03_008_035_002 (2)	SOK_sh_Novopavlovka_ Novopavlovka-gimnaziya	A	GS No.2 Novopavlovskaya	Learning Campus	Chui_Sokuluk_Novopavlovka	1978

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
03_008_035_002 (2)	SOK_sh_Novopavlovka_ Novopavlovka-gimnaziya	B	GS No.2 Novopavlovskaya	Learning Campus	Chui_Sokuluk_Novopavlovka	1978
03_008_035_002 (2)	SOK_sh_Novopavlovka_ Novopavlovka-gimnaziya	C	GS No.2 Novopavlovskaya	Assembly Hall + Learning Campus	Chui_Sokuluk_Novopavlovka	1978
03_008_035_002 (2)	SOK_sh_Novopavlovka_ Novopavlovka-gimnaziya	D	GS No.2 Novopavlovskaya	Entrance	Chui_Sokuluk_Novopavlovka	1978
03_008_035_002 (2)	SOK_sh_Novopavlovka_ Novopavlovka-gimnaziya	E	GS No.2 Novopavlovskaya	Learning Campus	Chui_Sokuluk_Novopavlovka	1978
03_008_035_002 (2)	SOK_sh_Novopavlovka_ Novopavlovka-gimnaziya	F	GS No.2 Novopavlovskaya	Sports Hall	Chui_Sokuluk_Novopavlovka	1978
05_006_035_004	NKN_sh_Alma_Jany-turmush	A	HS No.4 A.Satarov	Learning Campus	Jalal-Abad_Nooken_Alma	1976
05_006_035_004	NKN_sh_Alma_Jany-turmush	B	HS No.4 A.Satarov	Learning Campus	Jalal-Abad_Nooken_Alma	1976
05_006_035_004	NKN_sh_Alma_Jany-turmush	C	HS No.4 A.Satarov	Assembly Hall + Dinning room	Jalal-Abad_Nooken_Alma	1976
05_006_035_004	NKN_sh_Alma_Jany-turmush	D	HS No.4 A.Satarov	Sports Hall	Jalal-Abad_Nooken_Alma	1976
05_006_035_005	NKN_sh_Toskool1_Toktorbaev	A	HS No.5 N.Toktorbaev	Learning Campus	Jalal-Abad_Nooken_Toskool	1988
05_006_035_005	NKN_sh_Toskool1_Toktorbaev	B	HS No.5 N.Toktorbaev	Learning Campus	Jalal-Abad_Nooken_Toskool	1988
05_006_035_005	NKN_sh_Toskool1_Toktorbaev	C	HS No.5 N.Toktorbaev	Transition to Learning Campus	Jalal-Abad_Nooken_Toskool	1988
05_006_035_005	NKN_sh_Toskool1_Toktorbaev	D	HS No.5 N.Toktorbaev	Sports Hall + Dinning room	Jalal-Abad_Nooken_Toskool	1988
05_006_035_005	NKN_sh_Toskool1_Toktorbaev	E	HS No.5 N.Toktorbaev	Transition to Learning Campus	Jalal-Abad_Nooken_Toskool	1988
05_006_035_019	NKN_sh_Burgondu_Kazakov	A	HS No.19 A.Kazakov	Learning Campus	Jalal-Abad_Nooken_Byrgyndy	1990
05_006_035_019	NKN_sh_Burgondu_Kazakov	B	HS No.19 A.Kazakov	Entrance + Transition	Jalal-Abad_Nooken_Byrgyndy	1990
05_006_035_019	NKN_sh_Burgondu_Kazakov	C	HS No.19 A.Kazakov	Learning Campus	Jalal-Abad_Nooken_Byrgyndy	1990
05_006_035_019	NKN_sh_Burgondu_Kazakov	D	HS No.19 A.Kazakov	Transition	Jalal-Abad_Nooken_Byrgyndy	1990
05_006_035_019	NKN_sh_Burgondu_Kazakov	E	HS No.19 A.Kazakov	Dinning room+Sports Hall	Jalal-Abad_Nooken_Byrgyndy	1990

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
05_006_035_019	NKN_sh_Burgondu_Kazakov	F	HS No.19 A.Kazakov	Learning Campus	Jalal-Abad_Nooken_Byrgyndy	1990
05_006_035_032	NKN_sh_Burgondu_32Jenish	A	HS No.32 M.Duishenbiev	Learning Campus + Sports Hall	Jalal-Abad_Nooken_Jenish	1991
05_006_035_032	NKN_sh_Burgondu_32Jenish	B	HS No.32 M.Duishenbiev	Learning Campus	Jalal-Abad_Nooken_Jenish	1991
05_006_035_032	NKN_sh_Burgondu_32Jenish	C	HS No.32 M.Duishenbiev	Learning Campus	Jalal-Abad_Nooken_Jenish	1991
05_006_035_032	NKN_sh_Burgondu_32Jenish	D	HS No.32 M.Duishenbiev	Learning Campus+Garden	Jalal-Abad_Nooken_Jenish	1991
05_006_035_032	NKN_sh_Burgondu_32Jenish	E	HS No.32 M.Duishenbiev	Assembly Hall + Dinning room	Jalal-Abad_Nooken_Jenish	1991
05_003_035_034	BZK_sh_Arslanbob_IsmailovN34	A	HS No.34 U.Islamov	Learning Campus	Jalal Abad_Bazar-Korgon_ Arslanbob	1986
05_003_035_034	BZK_sh_Arslanbob_IsmailovN34	B	HS No.34 U.Islamov	Learning Campus	Jalal Abad_Bazar-Korgon_ Arslanbob	1986
05_003_035_034	BZK_sh_Arslanbob_IsmailovN34	C	HS No.34 U.Islamov	Learning Campus	Jalal Abad_Bazar-Korgon_ Arslanbob	1986
05_003_035_034	BZK_sh_Arslanbob_IsmailovN34	D	HS No.34 U.Islamov	Transition	Jalal Abad_Bazar-Korgon_ Arslanbob	1986
05_003_035_034	BZK_sh_Arslanbob_IsmailovN34	E	HS No.34 U.Islamov	Dinning room + Sports Hall + Assembly Hall	Jalal Abad_Bazar-Korgon_ Arslanbob	1986
05_003_035_034	BZK_sh_Arslanbob_IsmailovN34	F	HS No.34 U.Islamov	Stairs	Jalal Abad_Bazar-Korgon_ Arslanbob	1986
05_007_035_002	SUZ_sh_Suzak_N2-Hakimov	A [A]	HS No.2_ M.Hakimov, Doma-Ata	Learning Campus	Jalal-Abad_Suzak_Suzak_ Doma-Ata 34	1986
05_007_035_002	SUZ_sh_Suzak_N2-Hakimov	B [Б]	HS No.2_ M.Hakimov, Doma-Ata	Learning Campus	Jalal-Abad_Suzak_Suzak_ Doma-Ata 34	1986
05_007_035_002	SUZ_sh_Suzak_N2-Hakimov	C [B]	HS No.2_ M.Hakimov, Doma-Ata	Sports Hall	Jalal-Abad_Suzak_Suzak_ Doma-Ata 34	1986
05_007_035_002	SUZ_sh_Suzak_N2-Hakimov	D [Г]	HS No.2_ M.Hakimov, Doma-Ata	Assembly Hall + Dinning room	Jalal-Abad_Suzak_Suzak_ Doma-Ata 34	1986

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
05_007_035_005	SUZ_sh_Dzhar-Kyshtak_N5-Babur	A [A]	HS No.5 Z.Babur	Sports Hall + Dinning room + Assembly Hall	Jalal-Abad_Suzak_Jar-Kyshtak_ J.Kurashev 3	1980
05_007_035_005	SUZ_sh_Dzhar-Kyshtak_N5-Babur	A1 [A1]	HS No.5 Z.Babur	Stairs	Jalal-Abad_Suzak_Jar-Kyshtak_ J.Kurashev 3	1980
05_007_035_005	SUZ_sh_Dzhar-Kyshtak_N5-Babur	B [Б]	HS No.5 Z.Babur	Learning Campus	Jalal-Abad_Suzak_Jar-Kyshtak_ J.Kurashev 3	1980
05_007_035_005	SUZ_sh_Dzhar-Kyshtak_N5-Babur	B1 [Б1]	HS No.5 Z.Babur	Transition	Jalal-Abad_Suzak_Jar-Kyshtak_ J.Kurashev 3	1980
05_007_035_005	SUZ_sh_Dzhar-Kyshtak_N5-Babur	C [B]	HS No.5 Z.Babur	Learning Campus	Jalal-Abad_Suzak_Jar-Kyshtak_ J.Kurashev 3	1980
05_007_035_005	SUZ_sh_Dzhar-Kyshtak_N5-Babur	D [Г]	HS No.5 Z.Babur	Learning Campus	Jalal-Abad_Suzak_Jar-Kyshtak_ J.Kurashev 3	1980
05_007_035_005	SUZ_sh_Dzhar-Kyshtak_N5-Babur	D1 [Г1]	HS No.5 Z.Babur	Stairs	Jalal-Abad_Suzak_Jar-Kyshtak_ J.Kurashev 3	1980
05_007_035_005	SUZ_sh_Dzhar-Kyshtak_N5-Babur	E [Д]	HS No.5 Z.Babur	Learning Campus	Jalal-Abad_Suzak_Jar-Kyshtak_ J.Kurashev 3	2006
05_007_035_013	SUZ_sh_Ak-Bash-(was-Spasovka)_ Bazarov	A [A]	HS No.13 A.Bazarov	Sports Hall + Dinning room	Jalal-Abad_Suzak_Orto-Azia_ Suranbaeba	1987
05_007_035_013	SUZ_sh_Ak-Bash-(was-Spasovka)_ Bazarov	B [Б]	HS No.13 A.Bazarov	Transition gallery	Jalal-Abad_Suzak_Orto-Azia_ Suranbaeba	1987
05_007_035_013	SUZ_sh_Ak-Bash-(was-Spasovka)_ Bazarov	C [B]	HS No.13 A.Bazarov	Learning Campus	Jalal-Abad_Suzak_Orto-Azia_ Suranbaeba	1987
05_007_035_013	SUZ_sh_Ak-Bash-(was-Spasovka)_ Bazarov	B1 [B1]	HS No.13 A.Bazarov	Learning Campus	Jalal-Abad_Suzak_Orto-Azia_ Suranbaeba	1987
05_007_035_013	SUZ_sh_Ak-Bash-(was-Spasovka)_ Bazarov	D [Г]	HS No.13 A.Bazarov	Learning Campus	Jalal-Abad_Suzak_Orto-Azia_ Suranbaeba	1987
05_007_035_013	SUZ_sh_Ak-Bash-(was-Spasovka)_ Bazarov	E [Д]	HS No.13 A.Bazarov	Faye-Main entrance	Jalal-Abad_Suzak_Orto-Azia_ Suranbaeba	1987
05_007_035_013	SUZ_sh_Ak-Bash-(was-Spasovka)_ Bazarov	F [E]	HS No.13 A.Bazarov	Learning Campus	Jalal-Abad_Suzak_Orto-Azia_ Suranbaeba	1987

Table B-3 List of Schools Inspected by Building Block (continued)

School Code	*School ID (per UNICEF list of schools)*	*Block ID*	*School Name*	*Building Type*	*Address (Oblast_Rayon_Village_Street)*	*Year Built*
05_007_035_020	SUZ_sh_Aral_Matkerimov	A [A]	HS No.20 M.Matkarimov	Learning Campus	Jalal-Abad_Suzak_Aral_ J.Toroev	1970
05_007_035_020	SUZ_sh_Aral_Matkerimov	B [Б]	HS No.20 M.Matkarimov	Learning Campus	Jalal-Abad_Suzak_Aral_ J.Toroev	1970
05_007_035_020	SUZ_sh_Aral_Matkerimov	C [B]	HS No.20 M.Matkarimov	Transition Gallery	Jalal-Abad_Suzak_Aral_ J.Toroev	1970
05_007_035_020	SUZ_sh_Aral_Matkerimov	D [Г]	HS No.20 M.Matkarimov	Dinning room	Jalal-Abad_Suzak_Aral_ J.Toroev	1970
05_007_035_020	SUZ_sh_Aral_Matkerimov	E [Д]	HS No.20 M.Matkarimov	Sports Hall	Jalal-Abad_Suzak_Aral _J.Toroev	1970
05_007_035_078	SUZ_sh_Ladan-Kara_N78-Bakirov	A [A]	HS No.78 Z.Bakirov	Learning Campus	Jalal-Abad_Suzak_Suzak_ A.Madaminov 6	1982
05_007_035_078	SUZ_sh_Ladan-Kara_N78-Bakirov	A1 [A1]	HS No.78 Z.Bakirov	Learning Campus	Jalal-Abad_Suzak_Suzak_ A.Madaminov 6	1982
05_007_035_078	SUZ_sh_Ladan-Kara_N78-Bakirov	B [Б]	HS No.78 Z.Bakirov	Learning Campus	Jalal-Abad_Suzak_Suzak_ A.Madaminov 6	1982
05_007_035_078	SUZ_sh_Ladan-Kara_N78-Bakirov	C [B]	HS No.78 Z.Bakirov	Learning Campus	Jalal-Abad_Suzak_Suzak_ A.Madaminov 6	1982
05_007_035_078	SUZ_sh_Ladan-Kara_N78-Bakirov	D [Г]	HS No.78 Z.Bakirov	Dinning room	Jalal-Abad_Suzak_Suzak_ A.Madaminov 6	1982
05_007_035_080	SUZ_sh_Kara-Bulak_Toromamatov	A [A]	HS No.80 K.Toromamatov	Learning Campus	Jalal-Abad_Suzak_Talaa-Bulak_Y.Sairanbaev 52	2009
05_007_035_088	SUZ_sh_Bek-Abad_N88-Atabekov	Corpus 1	HS No.88 S. Atabekov	Learning Campus	Jalal-Abad_Suzak_Bek-Abad	2007
05_007_035_088	SUZ_sh_Bek-Abad_N88-Atabekov	Corpus 2	HS No.88 S. Atabekov	Learning Campus	Jalal-Abad_Suzak_Bek-Abad	2007
05_007_035_088	SUZ_sh_Bek-Abad_N88-Atabekov	Corpus 3	HS No.88 S. Atabekov	Learning Campus	Jalal-Abad_Suzak_Bek-Abad	1967
05_007_035_088	SUZ_sh_Bek-Abad_N88-Atabekov	Corpus 4	HS No.88 S. Atabekov	Learning Campus	Jalal-Abad_Suzak_Bek-Abad	1967
05_007_035_103	SUZ_sh_Sadda_N103-Sadda	A [A]	HS No.103 Sadda	Learning Campus	Jalal-Abad_Suzak_Sadda_ Abdulhamidov No.3	1973
05_007_035_103	SUZ_sh_Sadda_N103-Sadda	B [Б]	HS No.103 Sadda	Dinning room	Jalal-Abad_Suzak_Sadda_ Abdulhamidov No.3	1973

Appendix C

Fraction of Occupants Killed in Collapse

C.1 Summary of Literature Review

Researchers and governments commonly report total numbers of people killed and injured, but rarely, if ever, provide information about number of fatalities occurring in buildings, type of damage the earthquake caused to those buildings, or number of occupants in the damaged buildings at the time of the earthquake. In addition, simple statistics of deaths and injuries may lack a clear and defensible data collection methodology, and may be clouded by doubts about political influences that might tend to reduce reported deaths below the actual number. The statistics may also be ambiguously defined, such as whether they include self-treated injuries. Much research on fatality rates relies on reports by others, with information about definitions and methods being lost between primary source and the fatality-rate publication. A few disaster public health researchers have carried out rigorous, well-documented surveys of survivors, but acknowledge that such surveys ignore casualties among families without survivors. With these caveats, the following literature review of the limited available empirical data on fatality rates conditioned on collapse or partial collapse is offered.

The U.S. Geological Survey's HayWired scenario included a survey of every photograph in the University of California Berkeley NISEE eLibrary showing collapse or partial collapse of a building in California between 1965 and 2014. The photo survey was supplemented with photographs of other California collapses during the same time period that were known to have occurred but did not appear in the NISEE eLibrary (Porter, 2018). One result was an estimate of the fraction of building area that collapses, given that any collapse occurs, and the fraction of the collapsed area where it appears that people could be trapped and require extrication by urban search and rescue (USAR) professionals. Most relevant here are the estimates from nine collapsed concrete buildings other than tiltup, in which 50% of the building area collapsed, and 94% of the collapsed area appeared to require search and rescue extrication. In collapsed California unreinforced masonry buildings, 28% of the building area collapsed and 98% of that area appeared to require search and rescue extrication. The HayWired study does not include new evidence of the fraction of occupants in those collapsed areas that are killed, but rather relies on the Hazus methodology (FEMA, 2012), which suggests that 10% of occupants in the collapsed area of reinforced concrete or masonry buildings are killed. Trendafolski et al. (2011) recommend the use of Hazus casualty rates even for collapsed European and Asian buildings. The estimates for unreinforced masonry are possibly relevant in Kyrgyz Republic (because California unreinforced masonry structures tend to have wood diaphragms, whereas Kyrgyz unreinforced masonry structures tend to have heavier diaphragms).

Seligson (2008) reviewed the casualty consequence function for FEMA P-58 (FEMA, 2018), which took the form of an expected fatality rate (%) for all occupants, given collapse, for each of 13 structural systems, only some of which exist in Kyrgyz schools. Addressing casualty consequences of the collapse of nonductile concrete building, Seligson (2008) cites Petal (2009), who reports the results of a random-sample survey of 453 households (comprising 1,861 people) in Gölcük, Turkey, after the August 17, 1999 Kocaeli earthquake. The survey results show that among the households where at least one person survived to respond to the survey, approximately 1.5% of occupants of partially collapsed buildings and 11% of occupants of collapsed buildings died. In the survey, "the damage state of total collapse was assigned when the respondent identified the structure as 'Entire Building Destroyed,' along with any other reported damage. 'Partial Collapse' was assigned when the respondent reported 'Ceiling/roof collapsed' and/or 'Floors Collapsed.'" Seligson notes that "Sahin and Tari (2000) reported that 5,025 people died in Gölcük during the earthquake. In 1999, there were approximately 80,000 residents living in Gölcük. This translates to a mortality rate of about 6%. In contrast, the population survey produced an overall mortality rate of 2% of individuals. Since households where all of the members died could not be surveyed, models developed from these data can potentially underestimate mortality, and should be considered a lower bound."

Addressing fatality rates in unreinforced masonry buildings, Seligson (2008) considers anecdotal fatality data from California collapses, but finds them "inadequate to develop a reliable fatality model." Instead, she cites Shiono (1995), who analyzes fatality and collapse data reported by others from the 1976 Tangshan, China earthquake. In addition to the problem of the unclear connection between the actual evidence and the reports by others, a challenge of using Shiono's data is that he defined collapse as a damage status where a building is affected 'beyond repair,' which is not what is meant in the present project. Shiono suggests a fatality rate of 30% among collapsed unreinforced masonry buildings in Tangshan, which he points out agrees with another author's estimate from Eastern Turkey. Shiono also points out that still others suggest fatality rates as low as 10% in Italian and Chinese earthquakes.

Seligson recommends 19% fatality rate for the collapse of concrete frames with unreinforced masonry infill walls, based on data from upper floors of midrise reinforced concrete buildings with unreinforced masonry infill walls. Addressing fatality rates in other relevant building types, Seligson (2008) relies on Hazus, e.g., 10% fatality rate for complete damage with collapse for reinforced masonry bearing walls.

Armenian et al. (1997) reports results of a population-based survey of casualties among the families of Armenian Department of Health employees in the December 7, 1988 Spitak, Armenia earthquake. The survey reached 7,016 employees among 9,017 total employees, a high response rate. The authors report a 10.7% fatality rate among occupants of "panel" buildings—almost certainly meaning Soviet-style precast concrete panel buildings—but not the fatality rate conditioned on the collapse of those buildings, which would tend to be higher because not all panel buildings in the country collapsed. (It is noted that the survey reached most Department of Health employees, some of whom presumably lived outside the epicentral region).

C.2 Selected Approach

For concrete structures, figures from Petal's Gölcük survey (11% killed in collapses, 1.5% killed in partial collapses) are multiplied by 3 to account for households in which all occupants were killed and were therefore unrepresented in Petal's survey. (Recall the Sahin and Rati (2000) data showing 6% of Gölcük's population died, whereas Petal's fatality rate would imply 2%.)

For concrete frames with unreinforced masonry infill, a 33% fatality rate agrees with that of Shiono et al. (1995) wherein a 30% fatality-rate was estimated for unreinforced masonry in Tangshan.

For precast concrete panel buildings, there are little existing data about fatality rates and they speak only to a lower bound of 11%. (Recall the Armenian et al. (1997) data that are not normalized by the number of occupants in collapsed panel buildings, only by the number of occupants of panel buildings.)

Given the limited availability of consistent fatality-rate data, it is not possible to differentiate between fatality rates of different building types. Estimates of 30% fatality rate conditioned on collapse and 1.5% conditioned on partial collapse, are used.

Accordingly, the value of L_d, expected value of the fraction of building occupants killed given the occurrence of the damage state d is estimated as shown in Table C-1.

Table C-1 Fatality Rates Given Collapse

Damage State, d	L_d
Partial collapse	0.015
Collapse	0.30

Appendix D
Available Building Code Information

D.1 Kyrgyz Building Codes

Building construction in the region has been regulated by some form of building code since 1887. The following building codes applicable to seismic design and construction are currently in effect in the Kyrgyz Republic:

- SNIP KR 20-02:2009 (in Russian), *Building Code of the Kyrgyz Republic, Earthquake Engineering*. This is the current seismic design code in the Kyrgyz Republic and sets minimum requirements for design and construction of new buildings, reconstruction, and strengthening of existing buildings and structures located in areas with seismicity hazard levels 7, 8, 9 and greater than 9. Seismic hazard for a specific site is based on the area seismicity and local geotechnical conditions (consideration of soil amplification). Regulation of building performance for different occupancies is based on use of an importance factor (classification of different occupancy categories is provided in the document). Two analysis procedures are described: spectral analysis (elaborated requirements) and direct dynamic analysis procedures (generic requirements including mandatory participation of research institutes in interpretation of analytical results). The document provides specific design and detailing requirements for different building typologies, individual structural elements, and construction materials. Maximum interstory drift limitation is used for regulation of building global performance. The document outlines general procedures and requirements for buildings and structures that are not specifically addressed in the code. In general, the document outlines force-based analysis and design procedures that are widely used in multiple current model codes. The document also introduces the concept of nonlinear analysis and design procedures, but without specific guidelines and references.
- SNIP KR 22-01:1998 (in Russian), *Building Code of the Kyrgyz Republic, Seismic Evaluation of Existing Buildings*. This is the current code in the Kyrgyz Republic for seismic evaluation of existing buildings and structures and addresses the most common building typologies and sets an evaluation procedure based on compliance of structural systems with the current design codes and standards, structural survey of existing structure, analytical work, retrofit of existing structure and its influence on possible damage during seismic event. The evaluation procedure includes the following basic steps: preliminary survey, review of available construction documents and geotechnical information, building classification (typology), detailed survey (including material testing and testing of individual structural components or the entire structure), evaluation of compliance with the current building codes and standards, analytical work (verification analysis and design), preparation of a report and its review and discussion by a scientific-technical committee. Evaluation procedures are based on compliance with code requirements for new building structures.

- SNIP KR 31-02:2008 (in Russian), *Design and Development of Bishkek City Areas along the Ysykata Fault Line*. This is the current seismic design code in the Kyrgyz Republic and sets minimum requirements for design and construction of new buildings located in the Bishkek City Areas along the Ysykata Fault Line. The code provides subdivision of the area, seismic loading, limitations on building structures with different occupancies, requirements for building layouts and structural systems, and requirements for individual structural elements and building systems. The code allows two types of construction: buildings with cast-in-place concrete walls and frame buildings with light materials (exceptions are permitted with corresponding analytical support and further approval of the authorities).
- SNIP (Russia, in Russian). In addition to the local current and future building codes in the Kyrgyz Republic, several other codes were reviewed to track the code development for the region. It is important to mention that the current building codes in many countries in the region are direct descendants from the Soviet-era codes and standards, and have a lot of similarities. It was found to be very beneficial to review these additional documents and gain extra knowledge and understanding of the code intents, limitations at the time of construction, as well as future trends and developments of seismic design regulations in the region. The following codes were reviewed:
    - SNIP II-7-81* (1995). Construction in Seismic Regions.
    - SNIP II-7-81* (SP 14.13330.2014 – 2014). Construction in Seismic Regions.
    - SNIP II-7-81* (SP 14.13330.2014 – 2016). Construction in Seismic Regions.

  In general, new generation of the codes inherited Soviet-era code structure with additional considerations reflecting state of practice and scientific research in the field. In the latest revisions of the seismic design codes, seismic design objectives for a given level of earthquake are stated. New code revisions introduced second level of earthquake (Maximum Design Earthquake) in addition to Design Level Earthquake. Performance objective for Design Level Earthquake is to prevent partial or complete loss of the building functionality. Performance objective for Maximum Design Earthquake is to prevent a global collapse of the structure or its parts, threatening life of the occupants. Coefficients of allowed damage (similar to codes in the United States) are found to be similar for the reviewed codes, and typically correspond to low ductility systems.

Kyrgyz building codes are in the process of being updated. The following updated codes have been drafted, and are expected to be approved in 2019:

- SNIP KR 20-02:2018, *Building Code of the Kyrgyz Republic, Earthquake Engineering*. This code provides basic seismic design requirements for buildings in the Kyrgyz Republic, similar to ASCE/SEI 7-10, *Minimum Design Loads for Buildings and Other Structures*, (ASCE, 2010) in the United States. It includes calculation of seismic design forces based on a design response spectrum, consideration of regions with variable seismic hazard, site classification based on shear wave velocity, amplification for site factors, consideration of effective mass, amplification for building importance (by occupancy and number of stories), and reduction for “behavior factors” (i.e., *R*-factors). Requirements also include consideration of vertical earthquake forces, torsion, deformation compatibility, forces on parts and portions of structures, diaphragm deflections, and P-delta effects.

- SNIP KR 22-01:2018, *Building Code of the Kyrgyz Republic, Seismic Evaluation of Existing Buildings*. This code provides requirements for seismic evaluation of existing buildings in the Kyrgyz Republic. It refers to SNIP KR 20-02 for basic seismic design requirements, and incorporates provisions that are similar to requirements in ASCE/SEI 41-17, *Seismic Evaluation and Retrofit of Existing Buildings*, (ASCE, 2017b) in the United States, including: site investigation, review of drawings, sufficient knowledge, and establishment of material properties. It includes two approaches for evaluation: (1) the code approach; and (2) a pushover approach. The code approach requires existing buildings to have a lateral strength equal to a fraction of the capacity required for new buildings, ranging from 0.5 to 1.0, depending on the importance of the occupancy. The required capacity for existing school buildings is 0.8 times the capacity required for new buildings. The pushover approach utilizes a safety factor criterion evaluating the ratio between yield and the point at which a mechanism creates lateral instability. An appendix provides tables identifying component damage states that are good, satisfactory, unsatisfactory, or critical.
- SNIP KR 31-02:2018, *Design and Development of Bishkek City Areas along the Ysykata Fault Line*. This code provides seismic design requirements specific to the Bishkek City Areas. It includes performance statements identifying objectives to: protect lives, limit damage, safeguard function from earthquakes, and provides special seismic hazard values and factors for soil and terrain; but otherwise references SNIP KR 20-02:2018 for basic seismic design.

D.2 International Building Codes and Standards

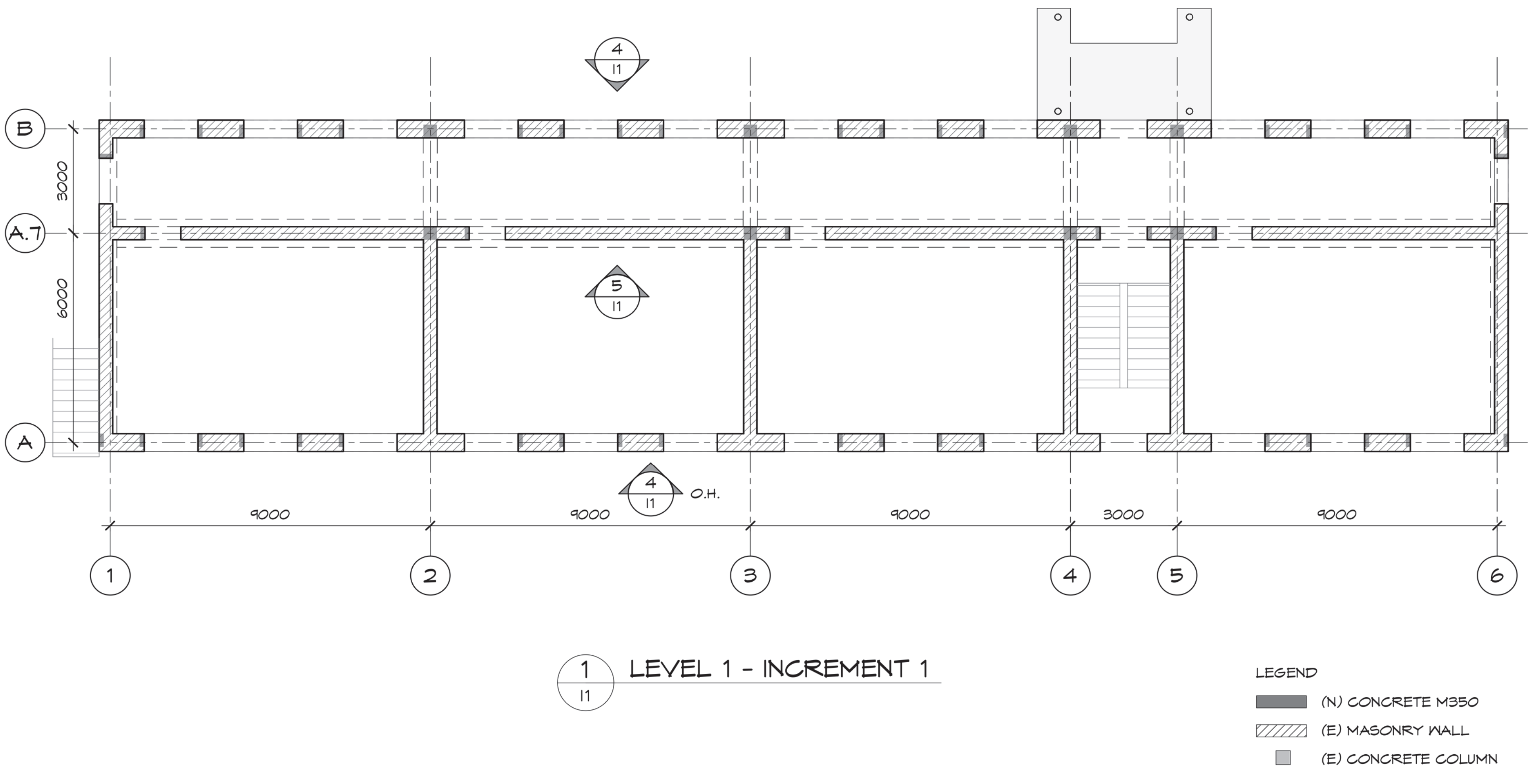
The following U.S. and Russian building codes and standards were considered in the performance-based assessment and design of retrofit increments for school buildings in Kyrgyz Republic:

- ACI 318-14, *Building Code Requirements for Structural Concrete*, (ACI, 2014). This code provides minimum requirements for materials, design, and detailing of structural reinforced concrete buildings in the United States.
- ASCE/SEI 7-16, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, (ASCE, 2017a). This standard specifies minimum load, load combinations, occupancy and risk categories, and design requirements for new buildings and other structures that are subject to U.S. building code requirements.
- ASCE/SEI 41-17, *Seismic Evaluation and Retrofit of Existing Buildings*, (ASCE, 2017b). This standard provides performance-based design and acceptance criteria for the seismic evaluation and retrofit of buildings in the United States.
- FEMA 547, *Techniques for the Seismic Rehabilitation of Existing Buildings*, (FEMA, 2006). This document provides a compilation of seismic rehabilitation techniques that are practical and effective. It includes guidance on mitigating specific seismic deficiencies in various model building types, along with detailing and constructability tips.

- TMS 402/602-16, *Building Code Requirements and Specification for Masonry Structures*, (TMS, 2016). This code provides minimum requirements for materials, design, and detailing of structural reinforced masonry buildings in the United States.
- NTC-M 2017, Normas Tecnicas Complementarias para Diseno y Construcccion de Estructuras de Mamposteria (in Spanish). This is the building code in Mexico confined masonry.

Appendix E
Conceptual Retrofit Drawings for CM Typology

This Appendix presents the conceptual retrofit drawings for the complex masonry (CM) typology developed for this project.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B
A.7
A
3000
6000
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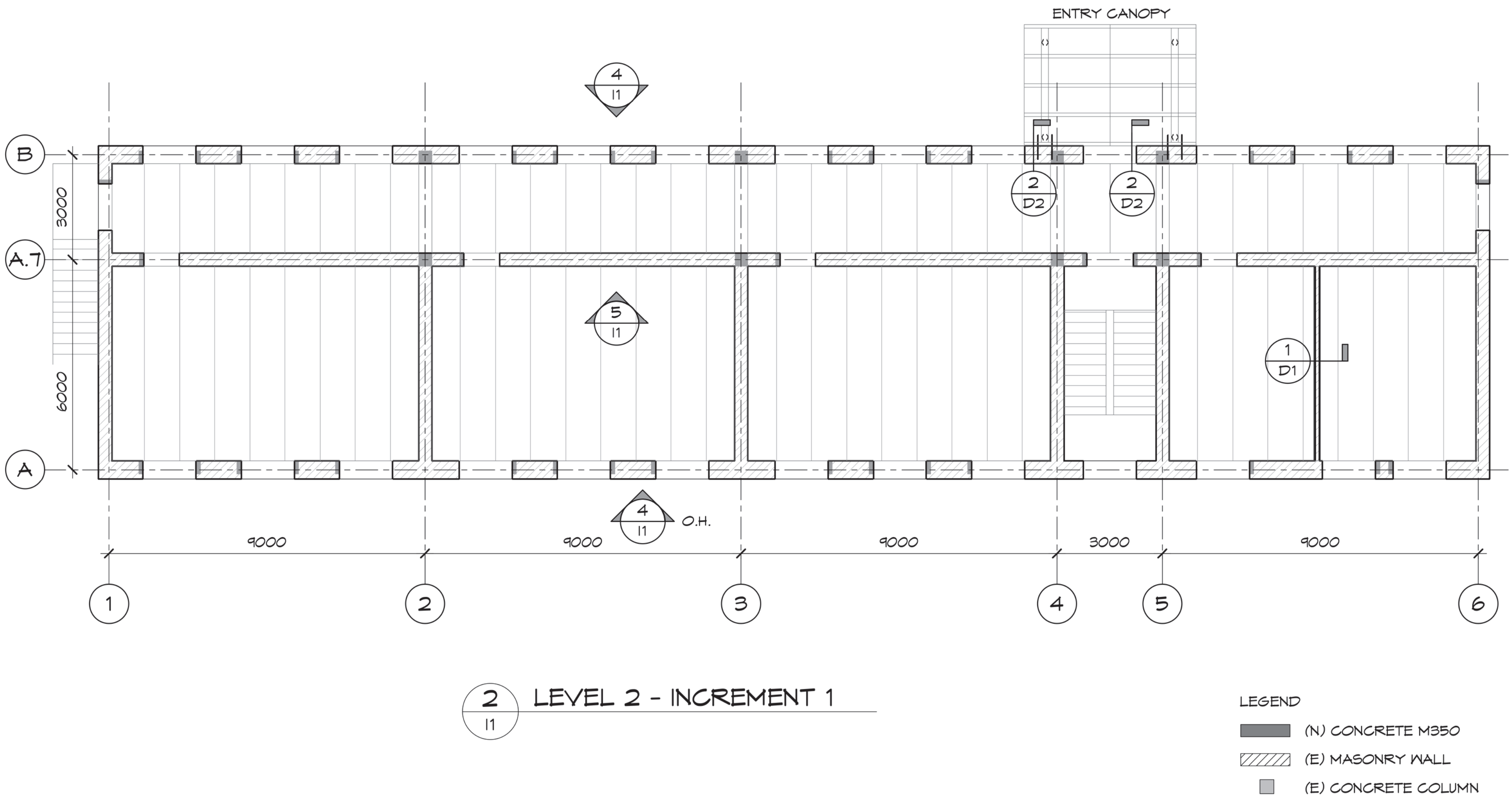
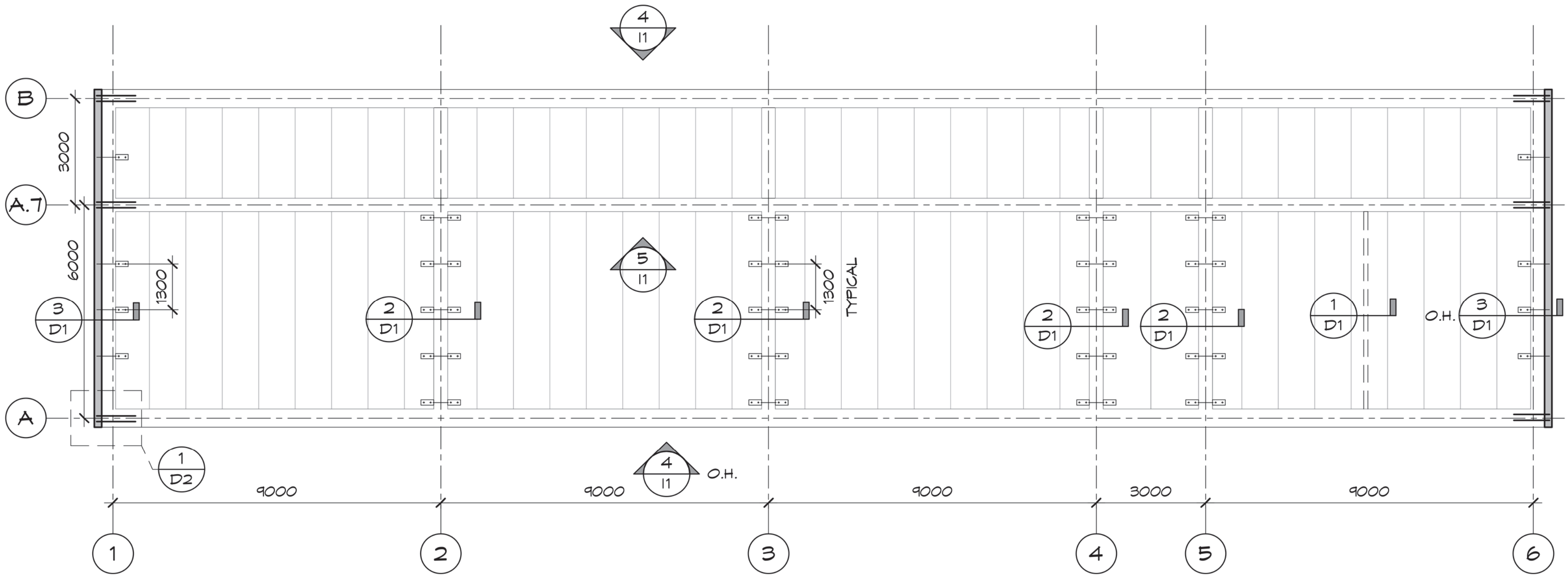
1
I1
LEVEL 1 - INCREMENT 1
LEGEND
(N) CONCRETE M350
(E) MASONRY WALL
(E) CONCRETE COLUMN



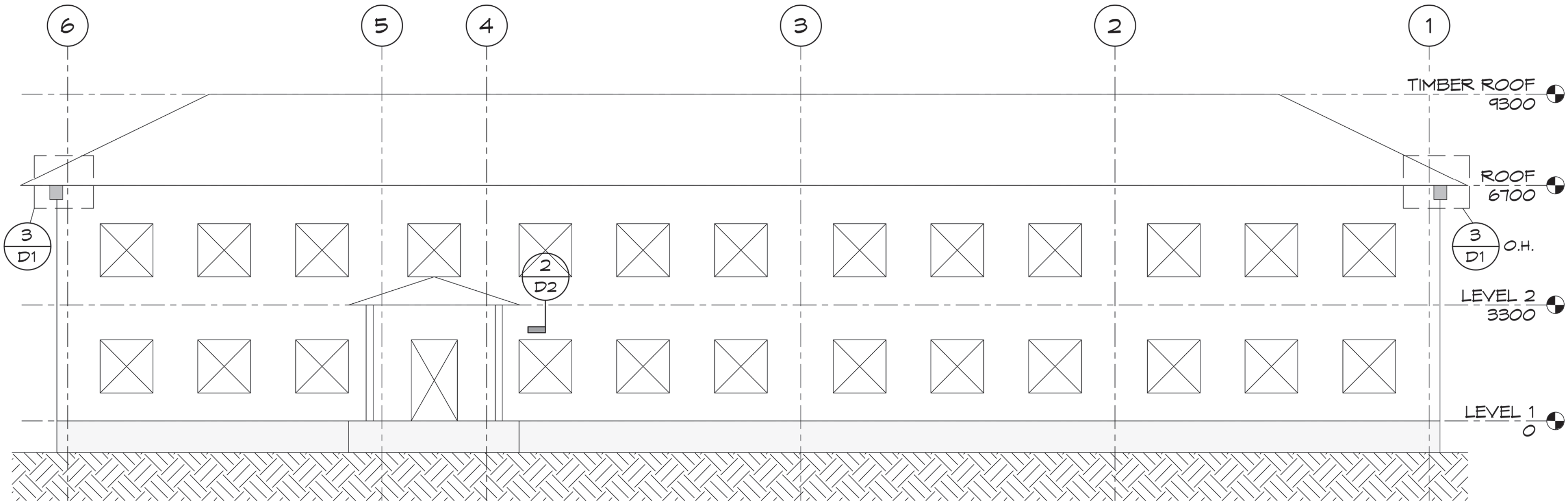
2 / I1 LEVEL 2 - INCREMENT 1



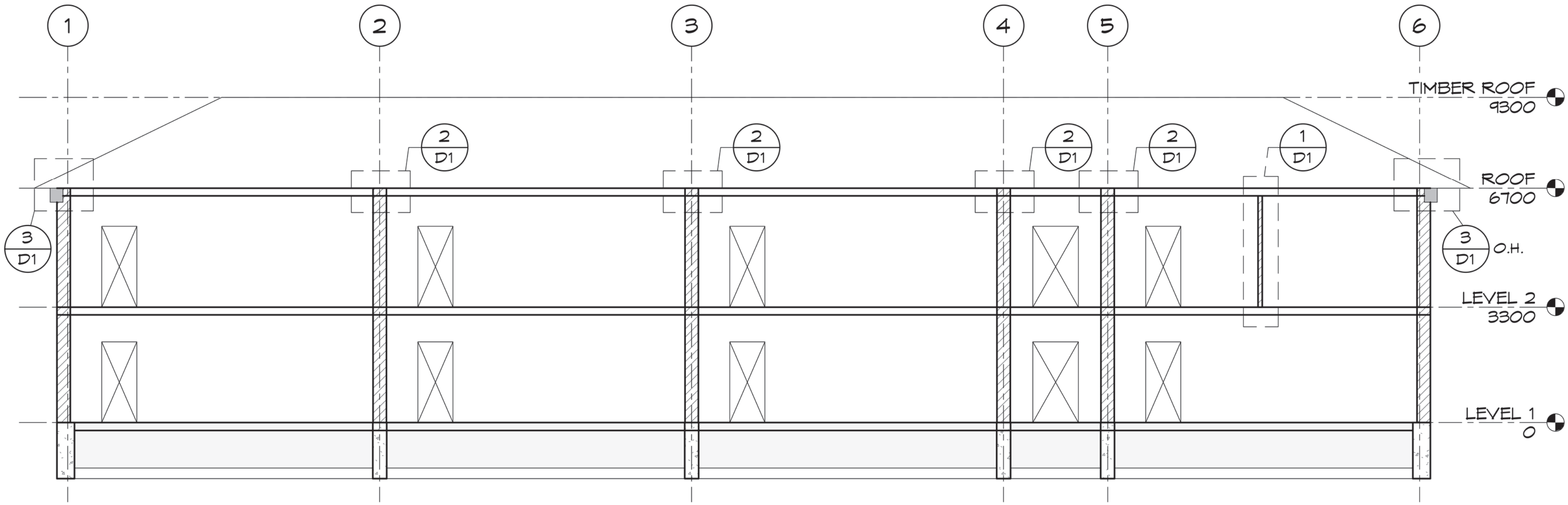
3 / I1 ROOF - INCREMENT 1

LEGEND

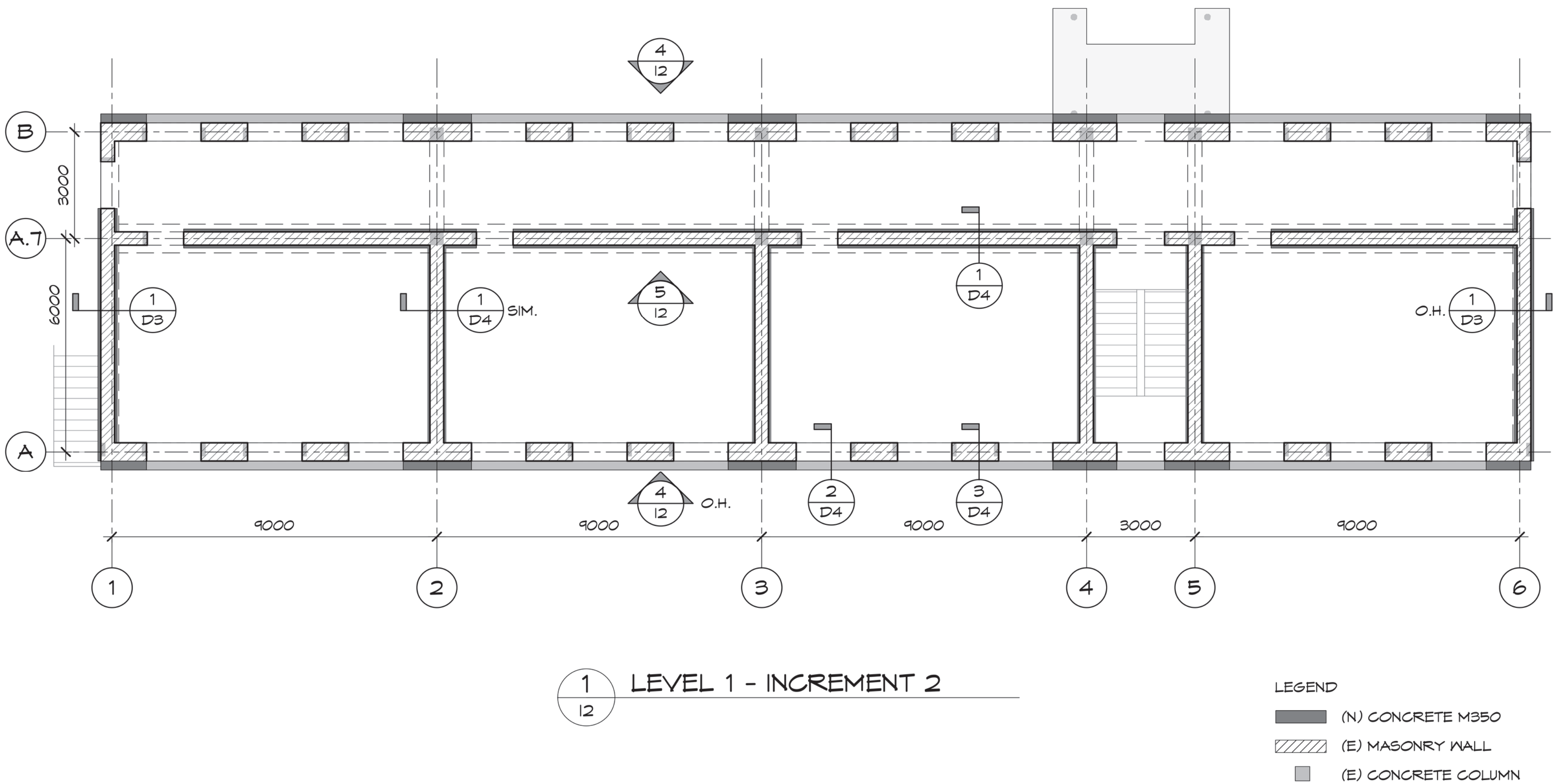
- (N) CONCRETE M350
- (E) MASONRY WALL
- (E) CONCRETE COLUMN

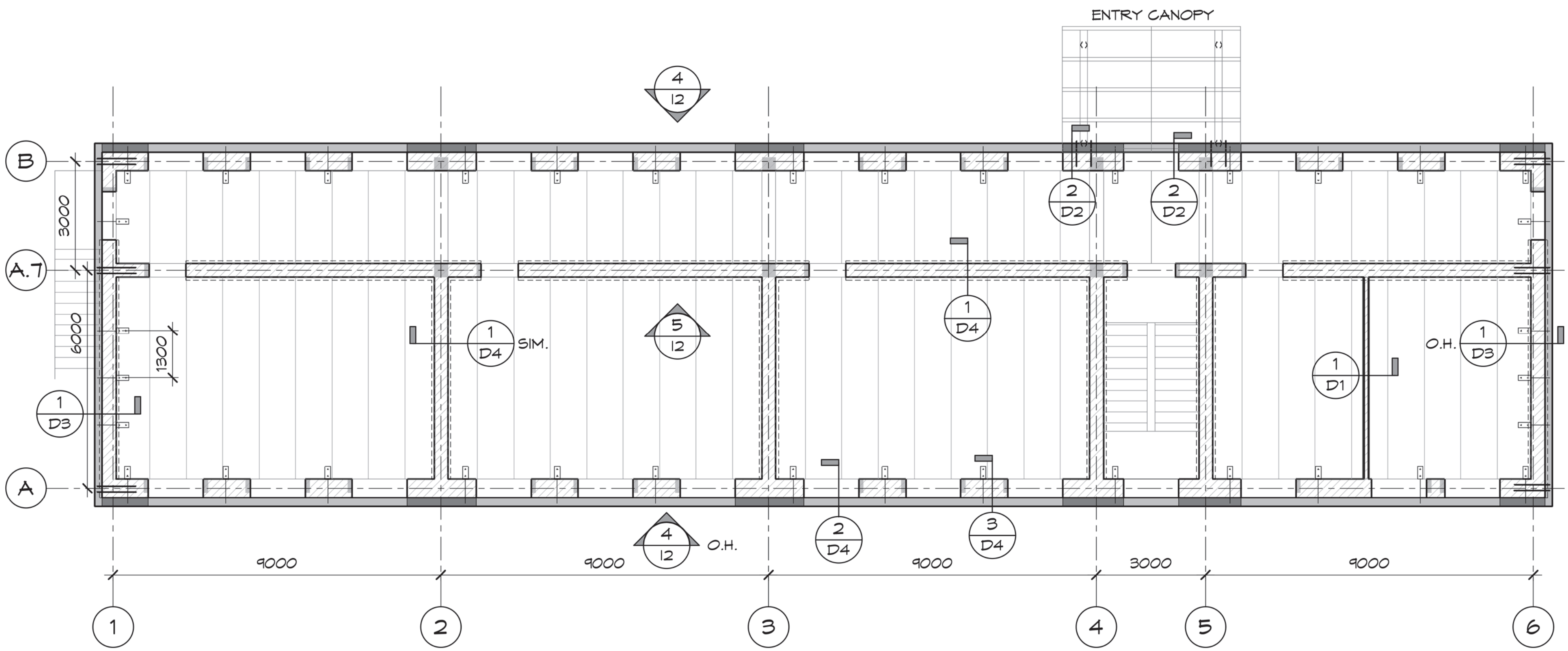


4
I1
EXTERIOR LONGITUDINAL WALL - INCREMENT 1



5
I1
INTERIOR LONGITUDINAL WALL - INCREMENT 1


B
A.7
A
3000
6000
4
I2
5
I2
4
I2
O.H.
1
D3
1
D4
SIM.
1
D4
2
D4
3
D4
O.H.
1
D3
9000
9000
9000
3000
9000
1
2
3
4
5
6
1
I2
LEVEL 1 - INCREMENT 2
LEGEND
(N) CONCRETE M350
(E) MASONRY WALL
(E) CONCRETE COLUMN



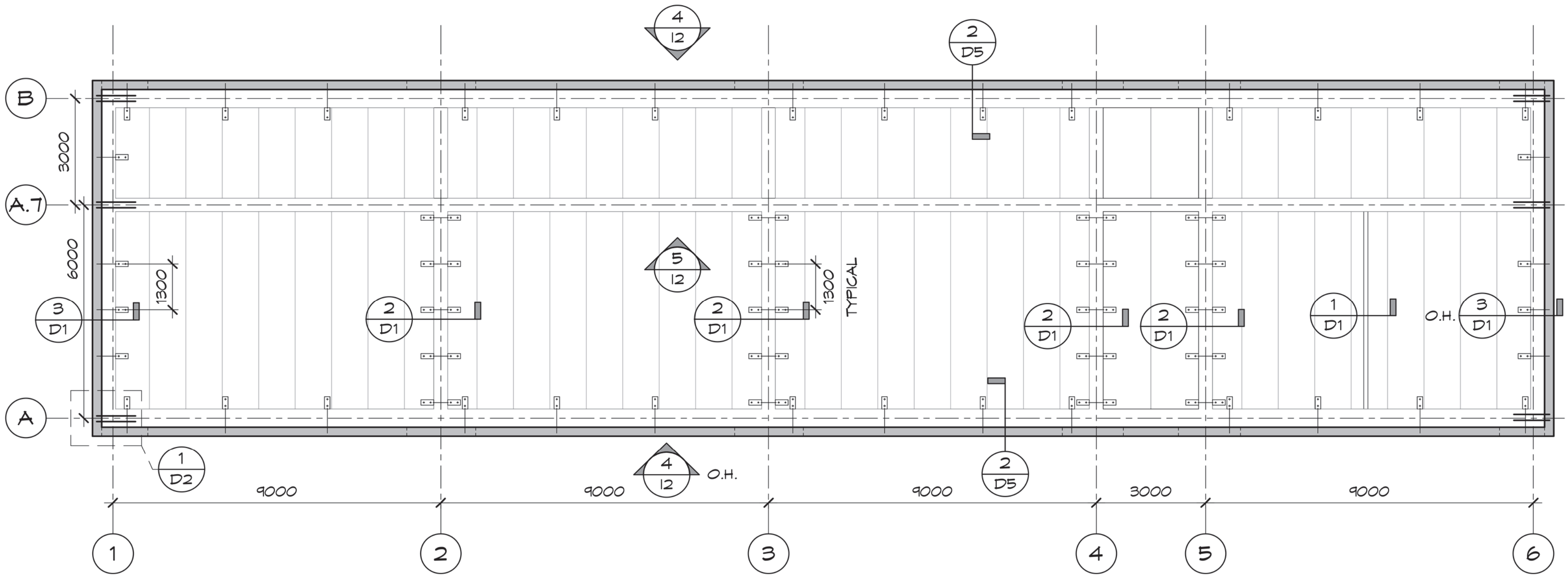
2 / I2 LEVEL 2 - INCREMENT 2

LEGEND

(N) CONCRETE M350

(E) MASONRY WALL

(E) CONCRETE COLUMN



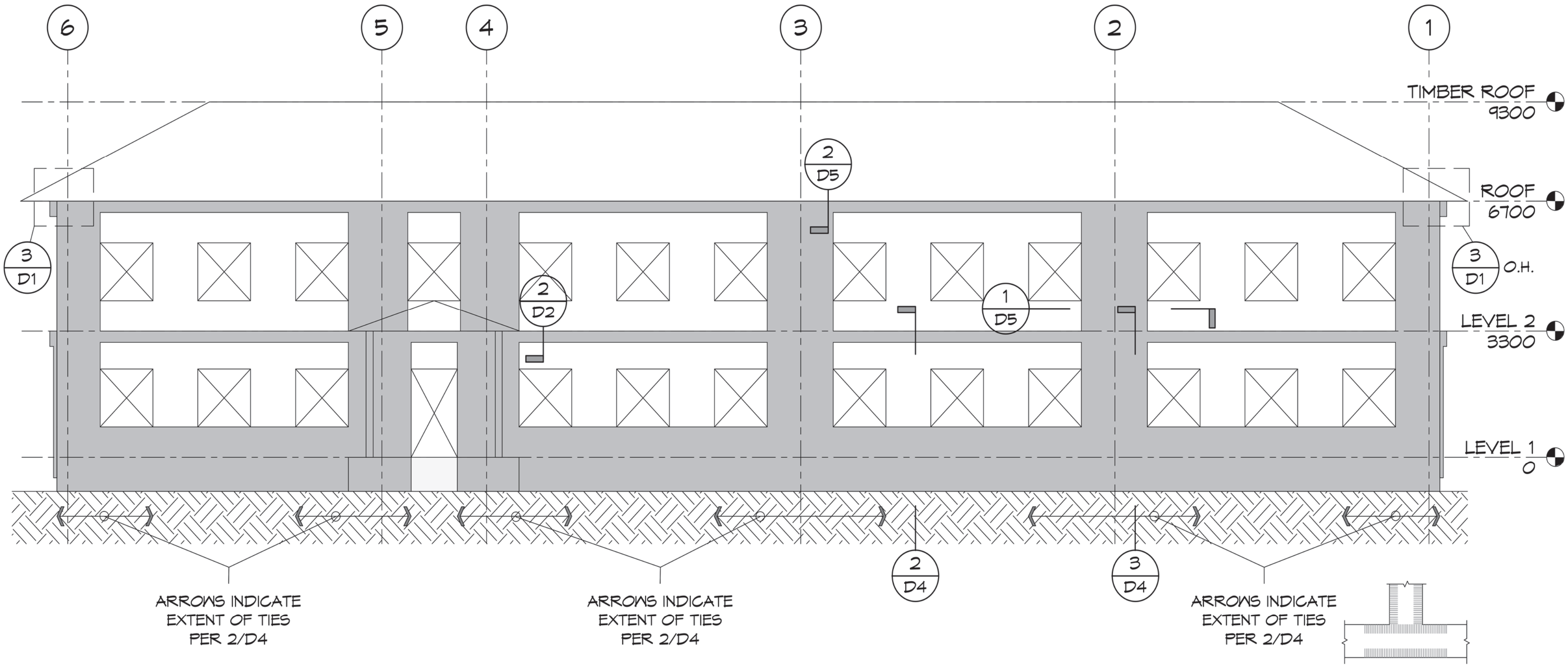
3/I2 ROOF - INCREMENT 2

LEGEND

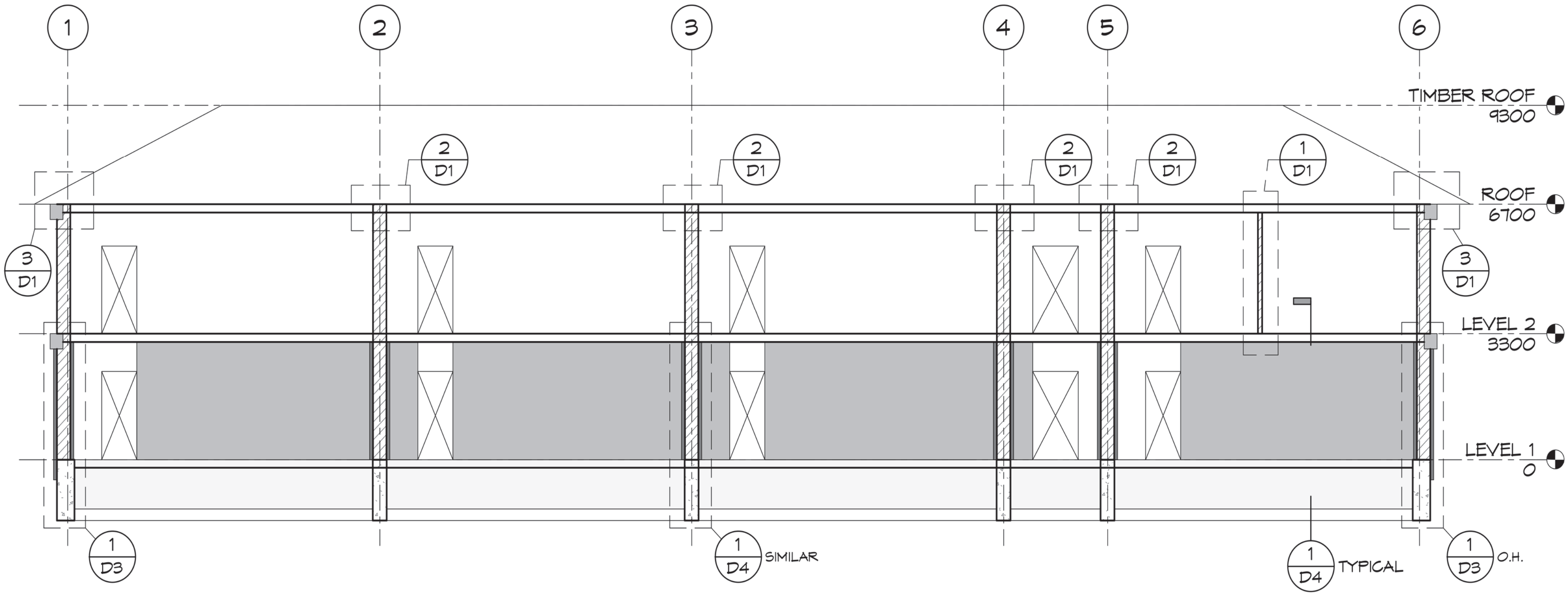
(N) CONCRETE M350

(E) MASONRY WALL

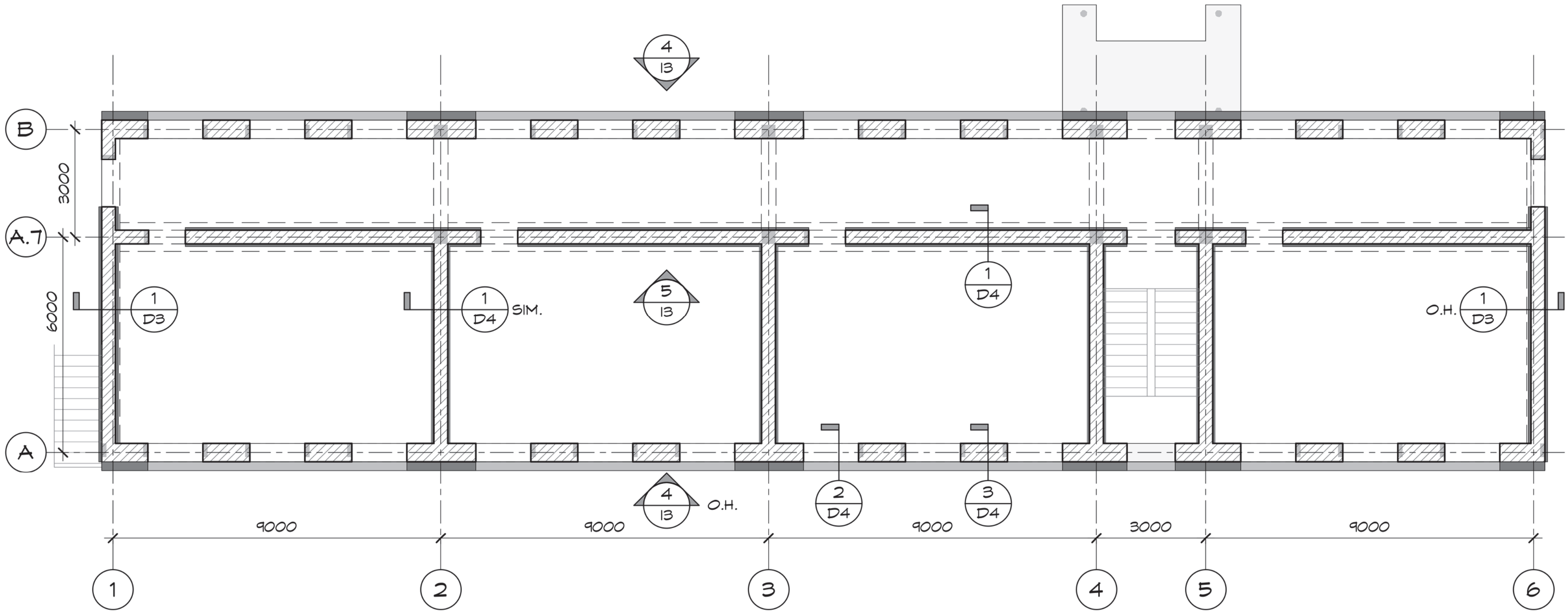
(E) CONCRETE COLUMN



4
12
EXTERIOR LONGITUDINAL WALL - INCREMENT 2



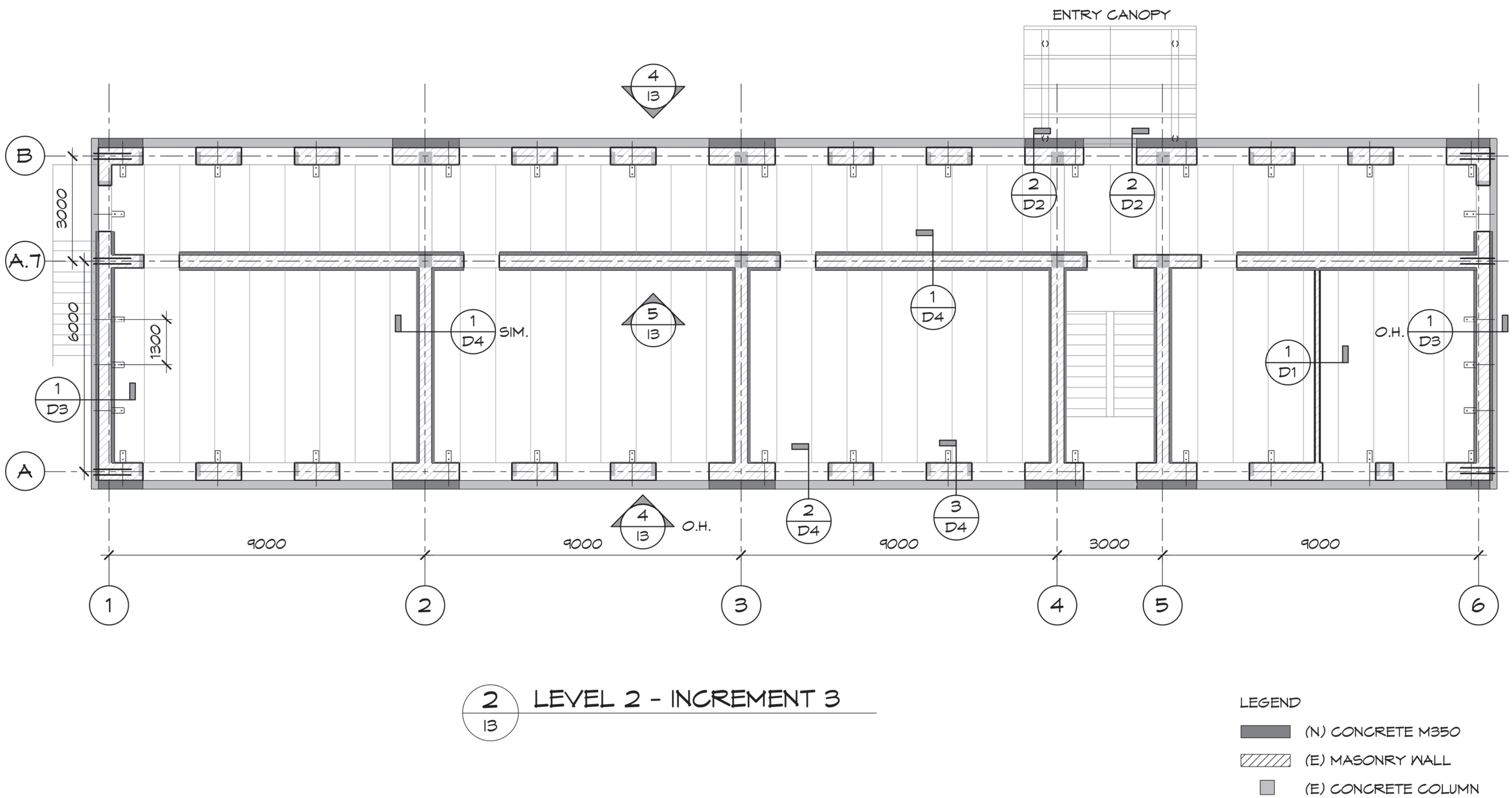
5/12 INTERIOR LONGITUDINAL WALL - INCREMENT 2



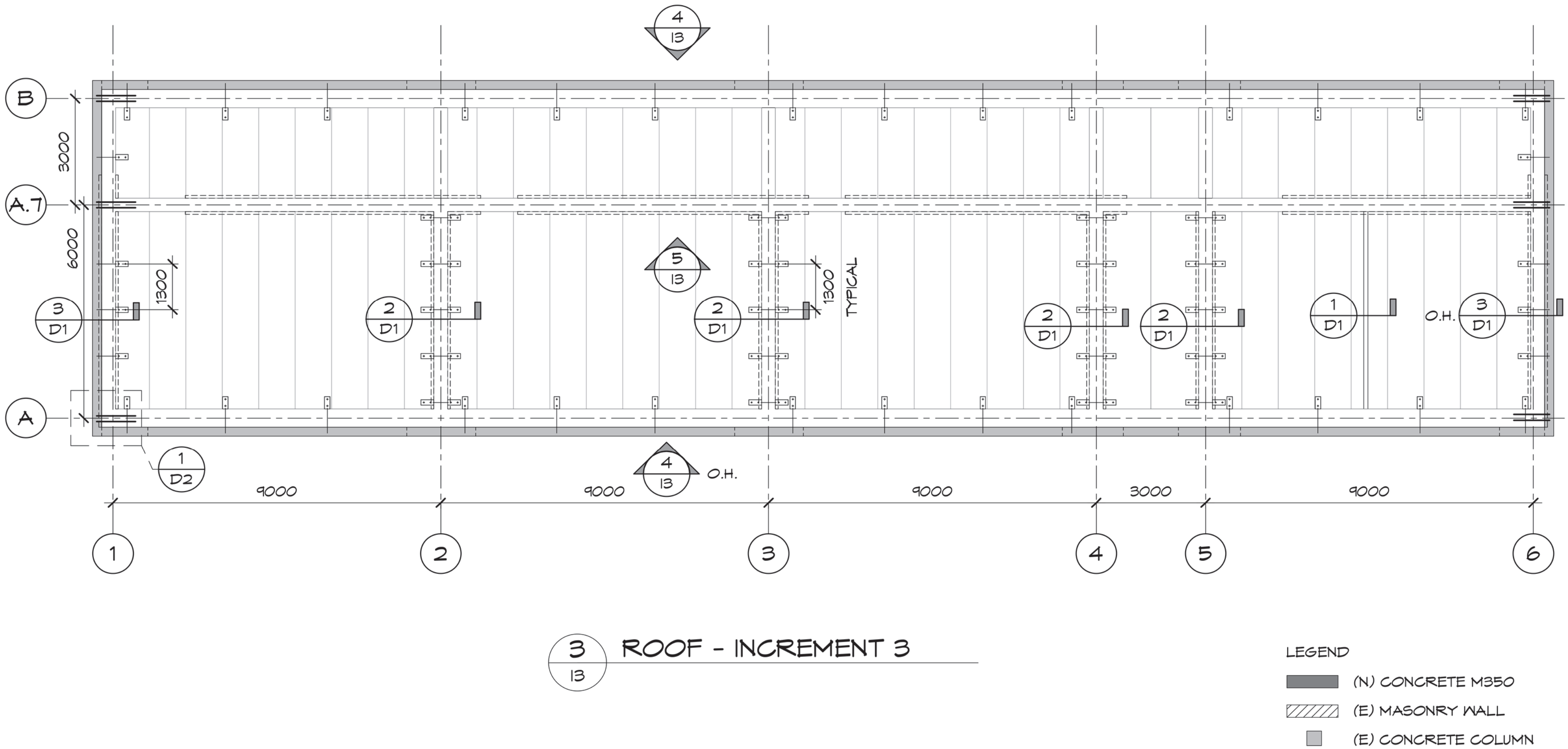
1/13 LEVEL 1 - INCREMENT 3

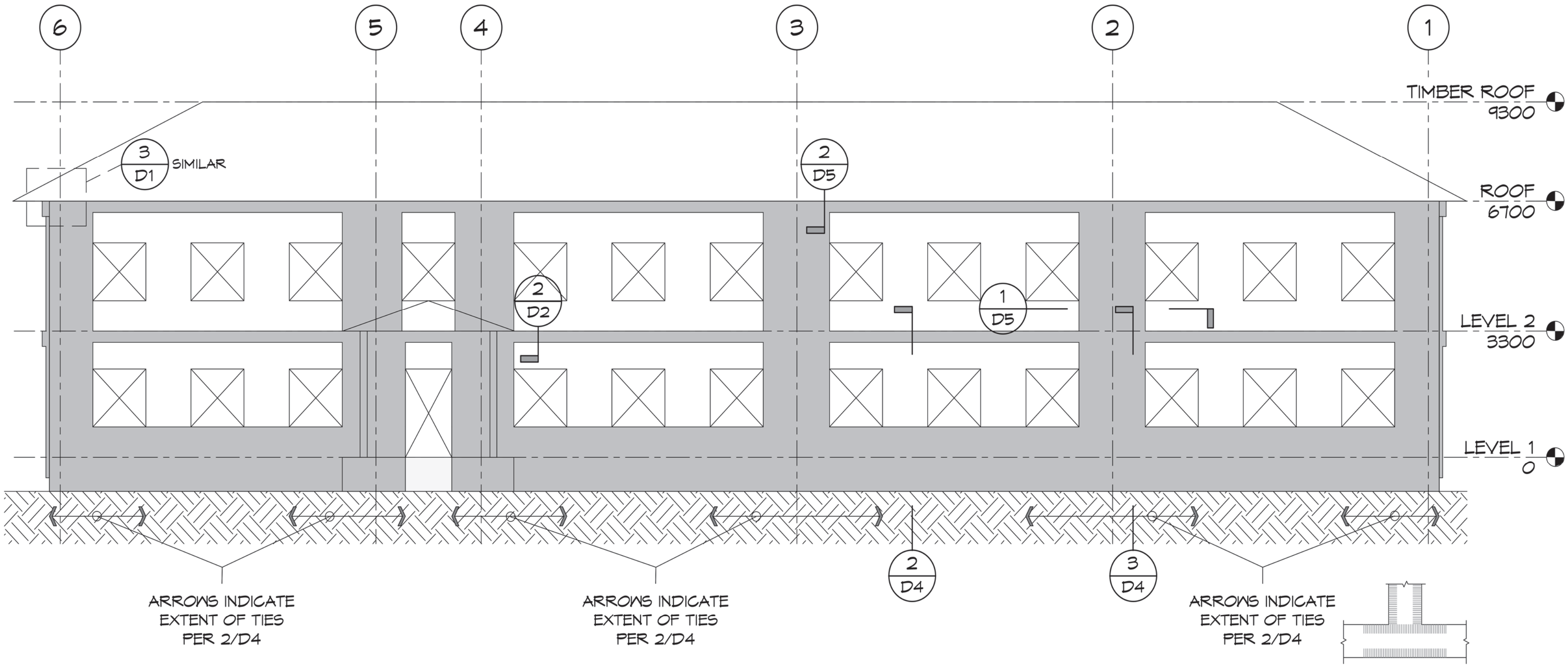
LEGEND

- (N) CONCRETE M350
- (E) MASONRY WALL
- (E) CONCRETE COLUMN

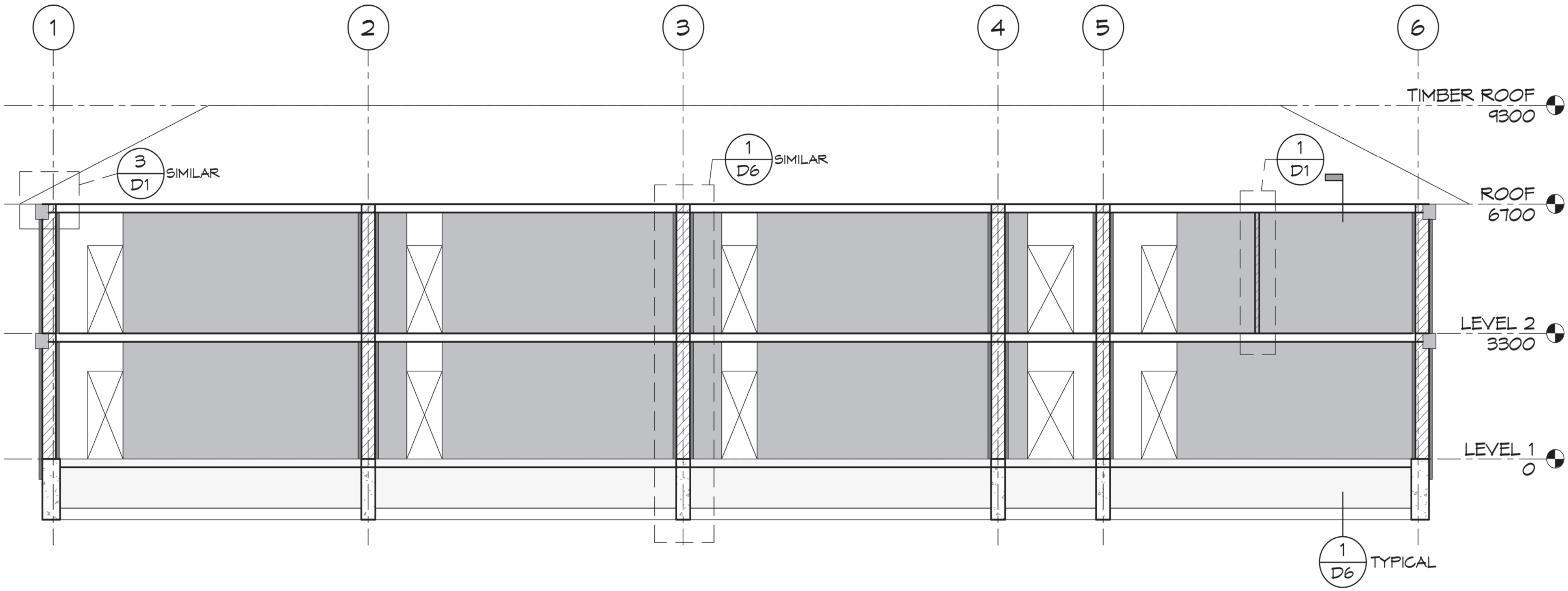


ENTRY CANOPY
4/I3
B
A.7
A
3000
6000
1300
1/D3
1/D4 SIM.
5/I3
1/D4
2/D2
2/D2
1/D1
O.H. 1/D3
4/I3 O.H.
2/D4
3/D4
9000
9000
9000
3000
9000
1
2
3
4
5
6
2/I3 LEVEL 2 - INCREMENT 3
LEGEND
(N) CONCRETE M350
(E) MASONRY WALL
(E) CONCRETE COLUMN

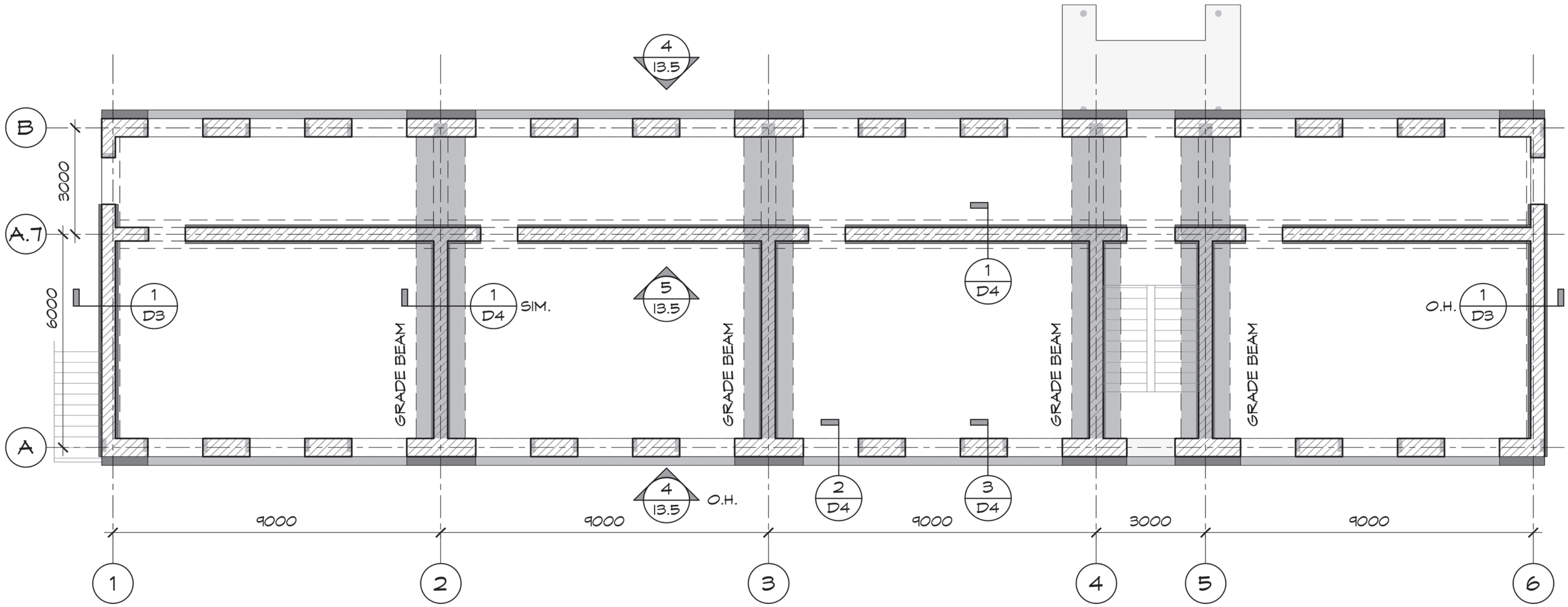

4
I3
B
A.7
A
3000
6000
1300
3
D1
2
D1
5
I3
1300
TYPICAL
2
D1
2
D1
1
D1
O.H.
3
D1
1
D2
4
I3
O.H.
9000
9000
9000
3000
9000
1
2
3
4
5
6
3
I3
ROOF - INCREMENT 3
LEGEND
(N) CONCRETE M350
(E) MASONRY WALL
(E) CONCRETE COLUMN



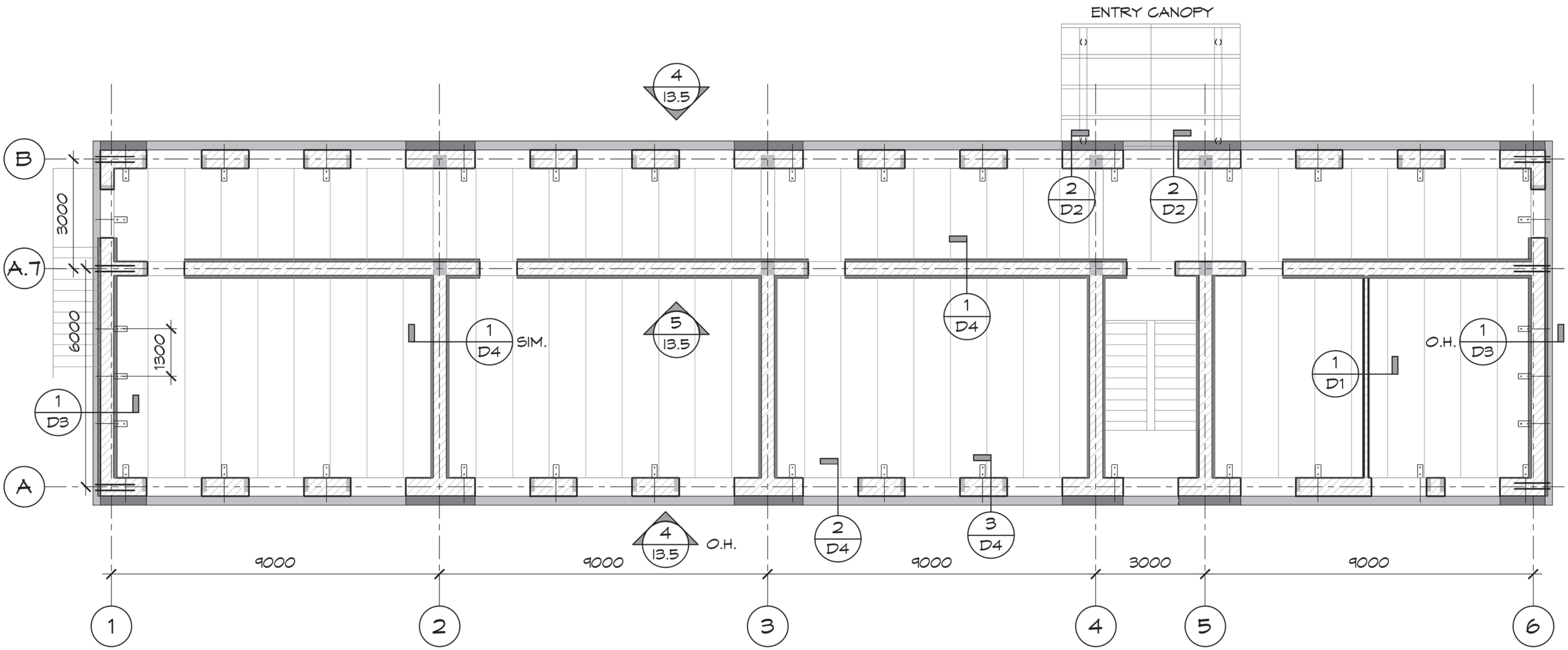
4
13
EXTERIOR LONGITUDINAL WALL - INCREMENT 3



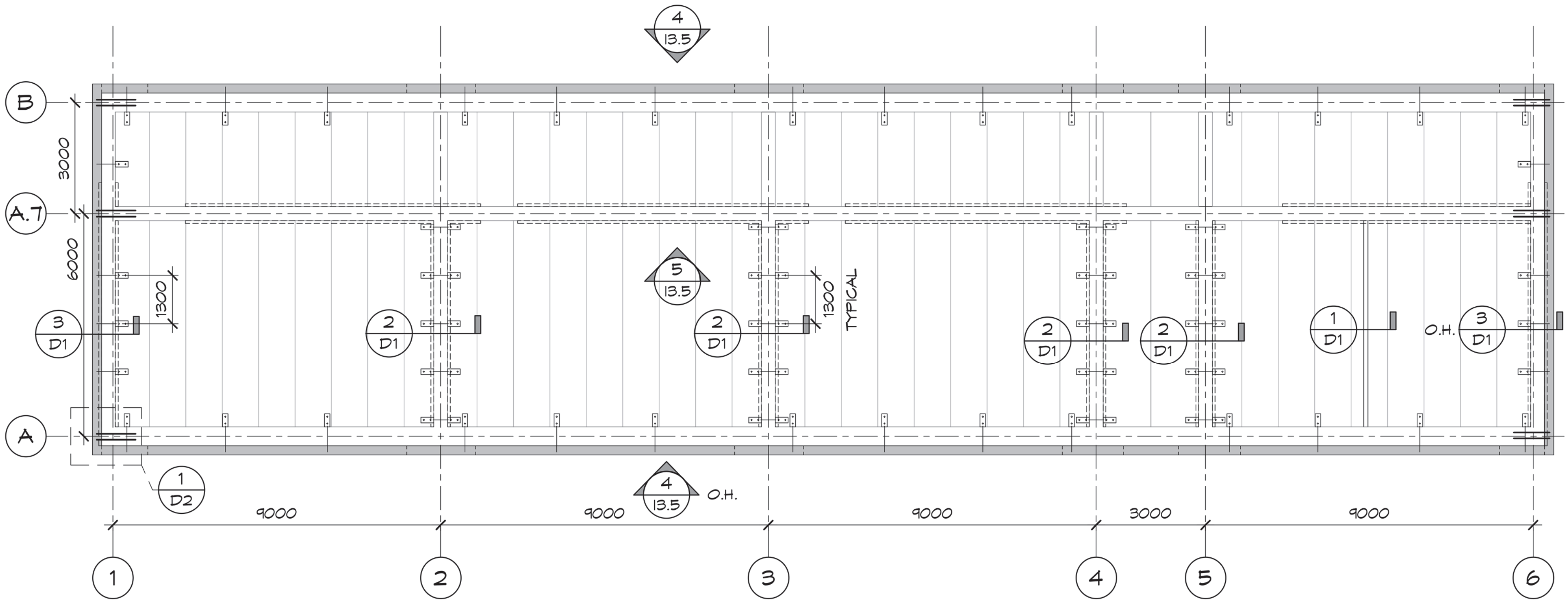
5/13 INTERIOR LONGITUDINAL WALL - INCREMENT 3



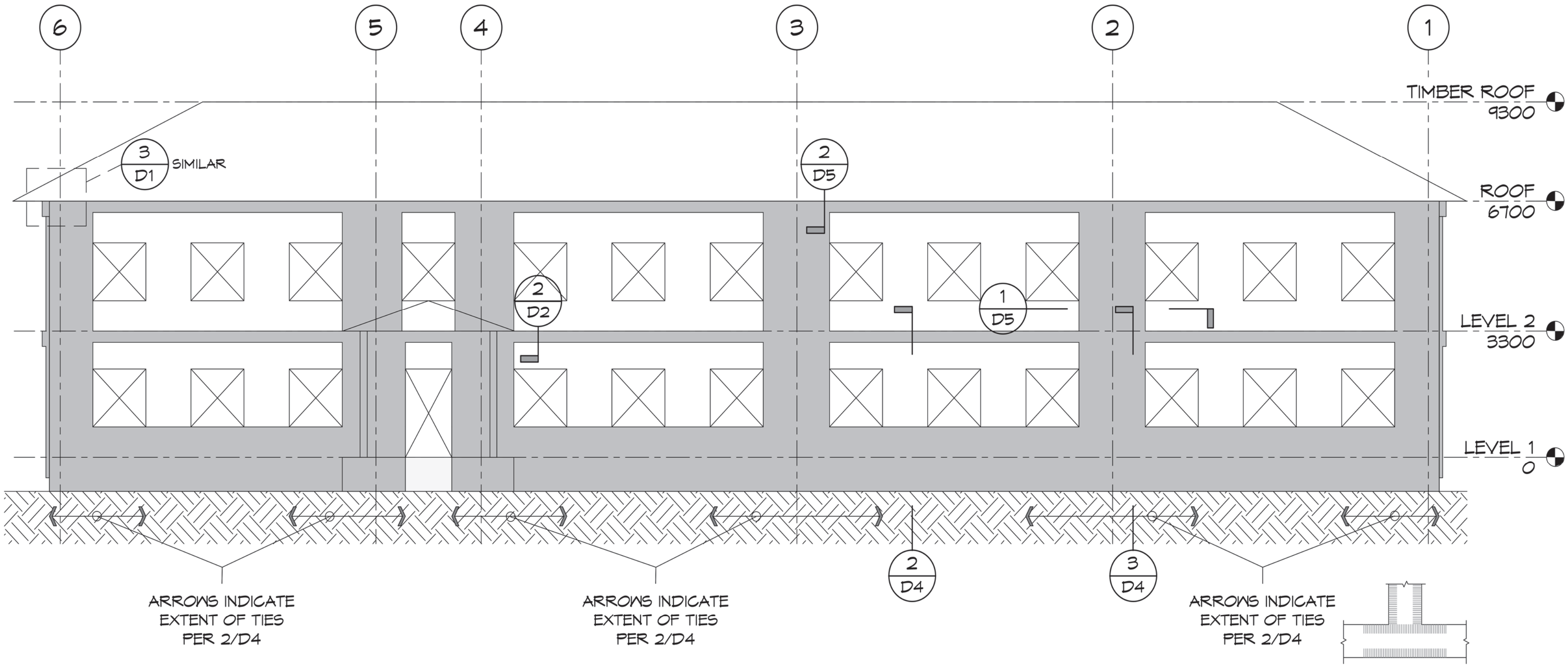
1 / 13.5 LEVEL 1 - INCREMENT 3.5



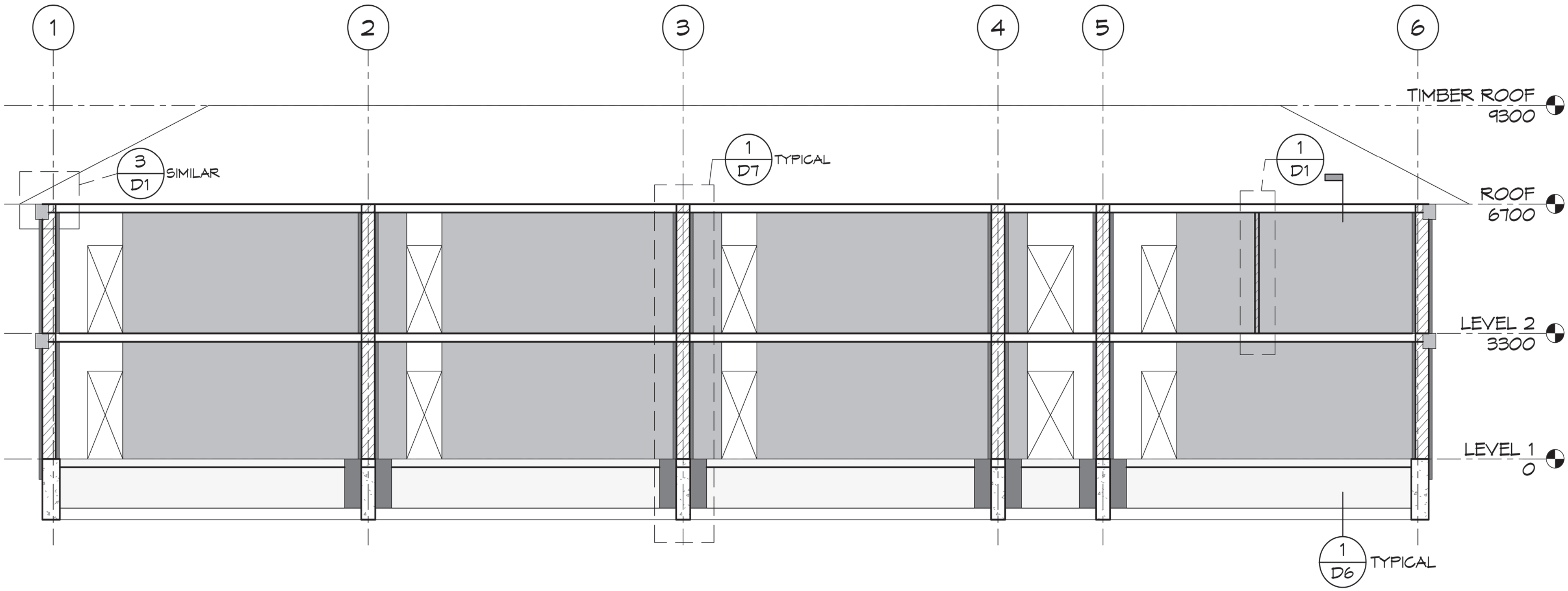
2/13.5 LEVEL 2 - INCREMENT 3.5



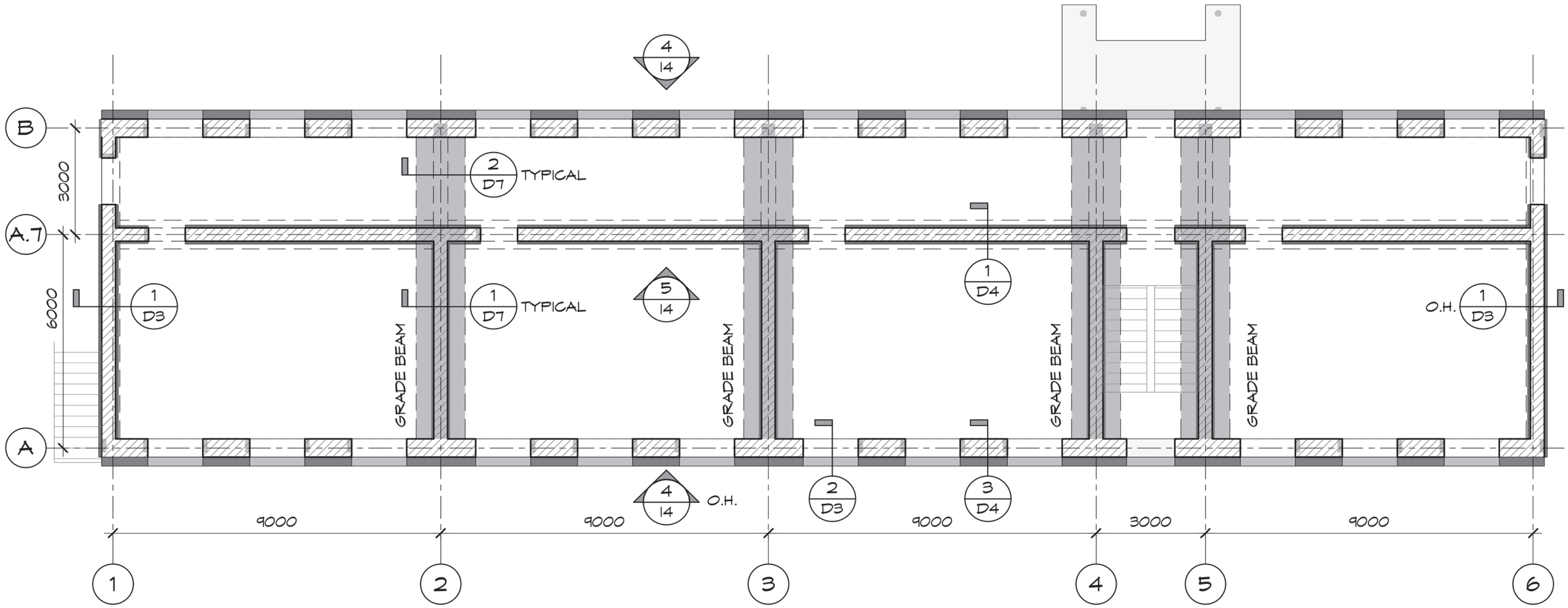
3 / 13.5 ROOF - INCREMENT 3.5



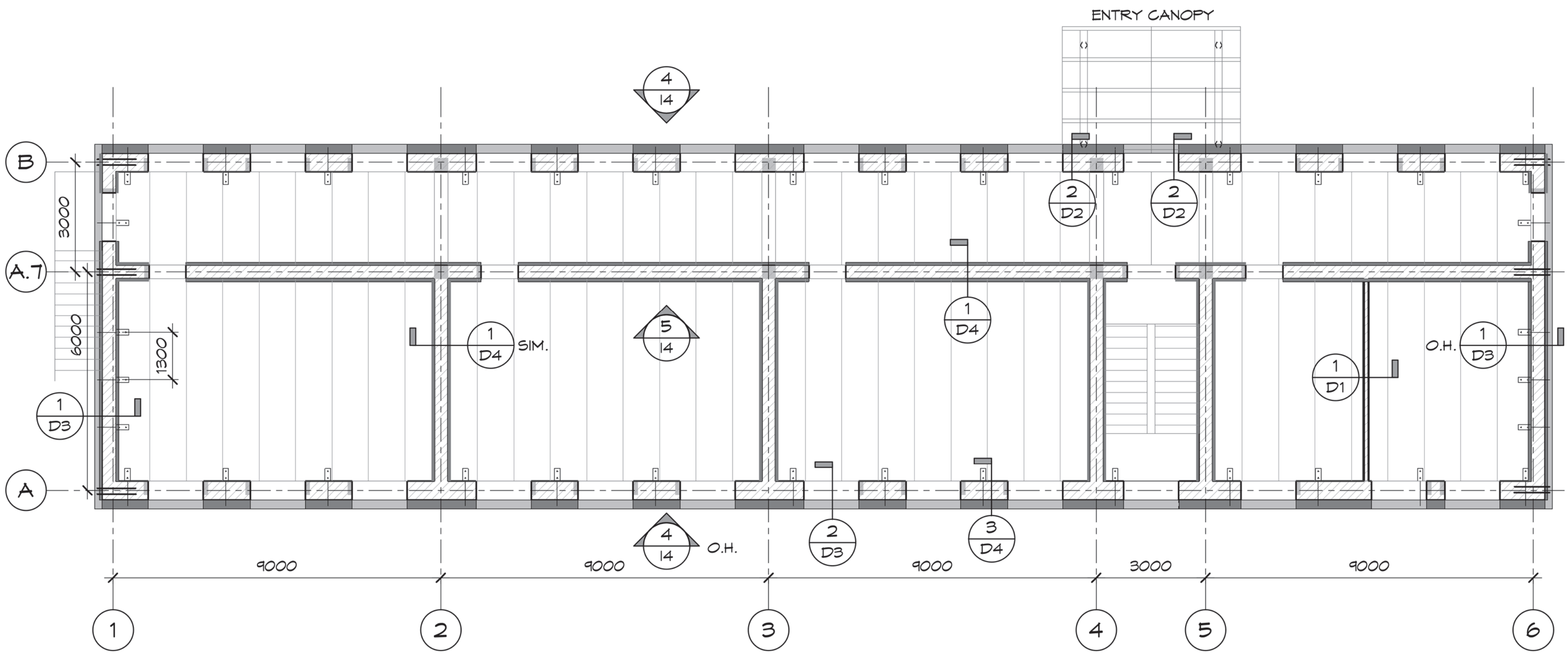
4
13.5
EXTERIOR LONGITUDINAL WALL - INCREMENT 3.5



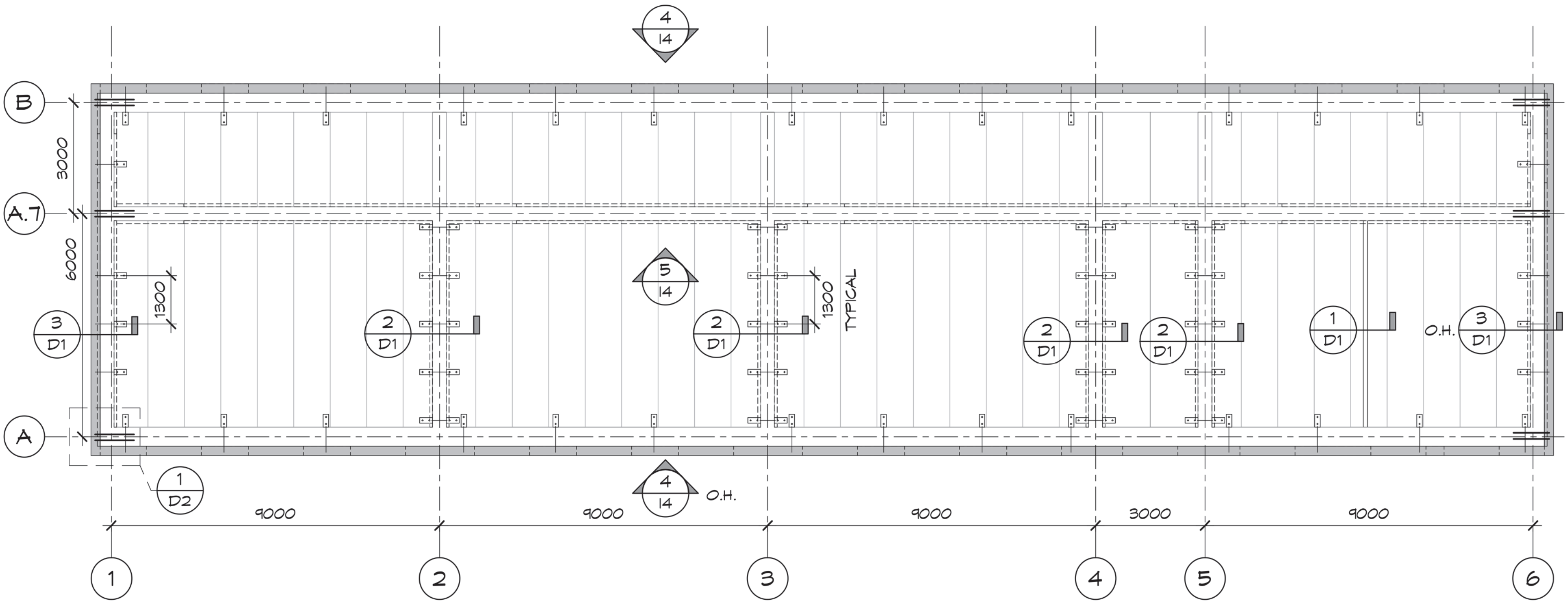
5
13.5
INTERIOR LONGITUDINAL WALL - INCREMENT 3.5



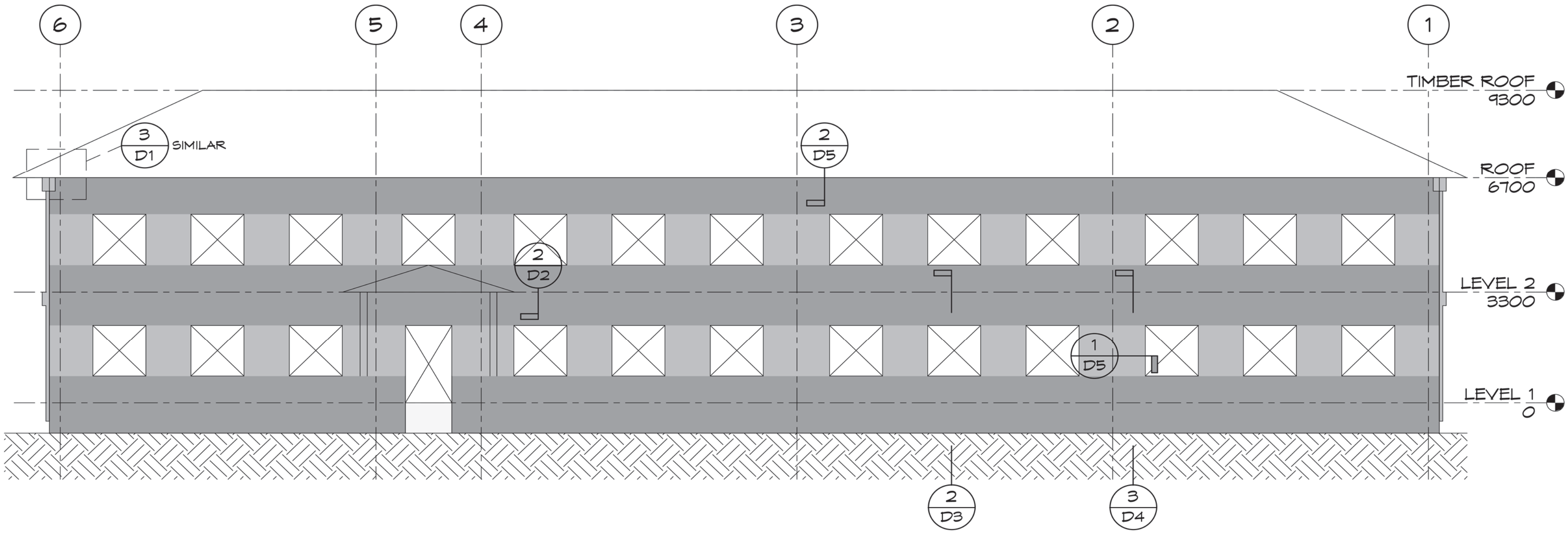
1 / I4 LEVEL 1 - INCREMENT 4



2 / I4 LEVEL 2 - INCREMENT 4

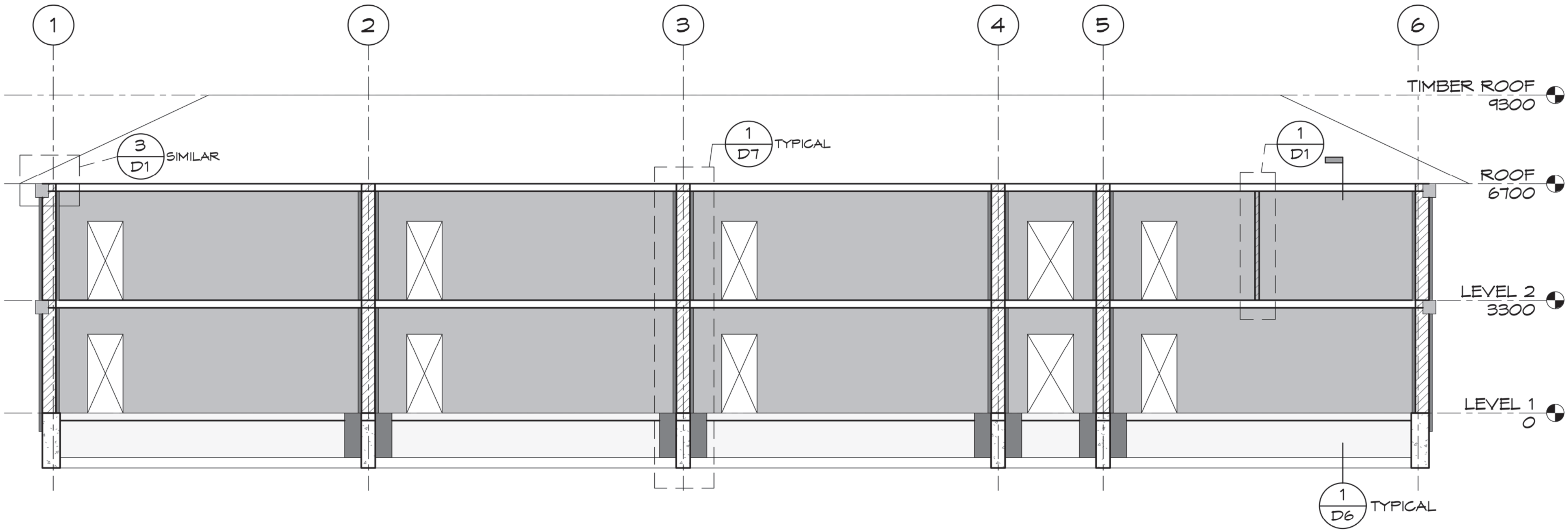


3 / I4 ROOF - INCREMENT 4

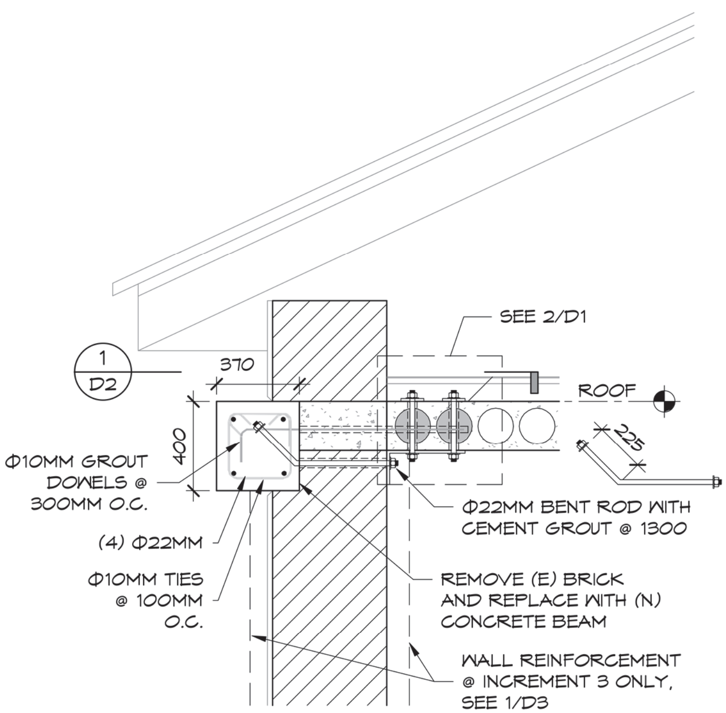


4
14

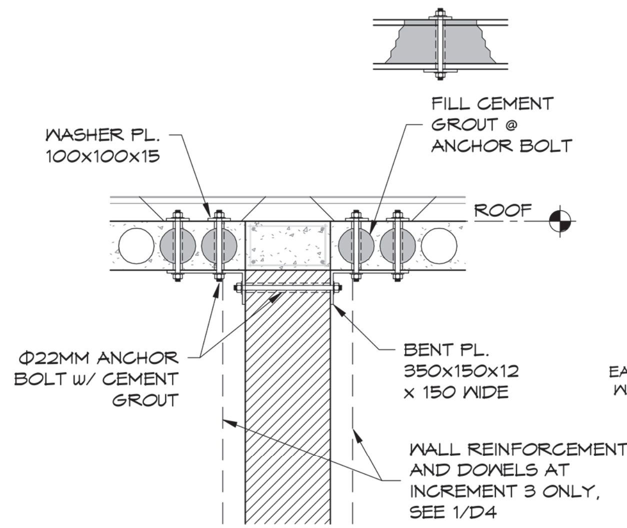
EXTERIOR LONGITUDINAL WALL - INCREMENT 4



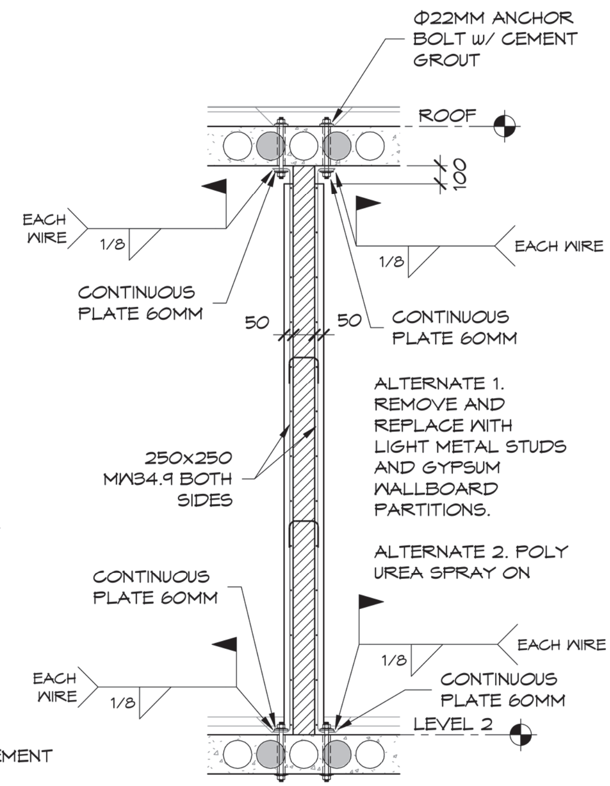
5
14
INTERIOR LONGITUDINAL WALL - INCREMENT 4



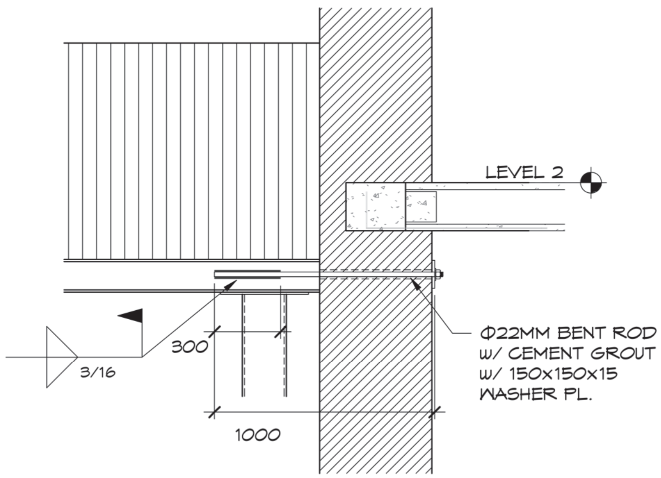
3 / D1 — EXT. ROOF BELT (LONG EQ.)
INCREMENT 1,2,3



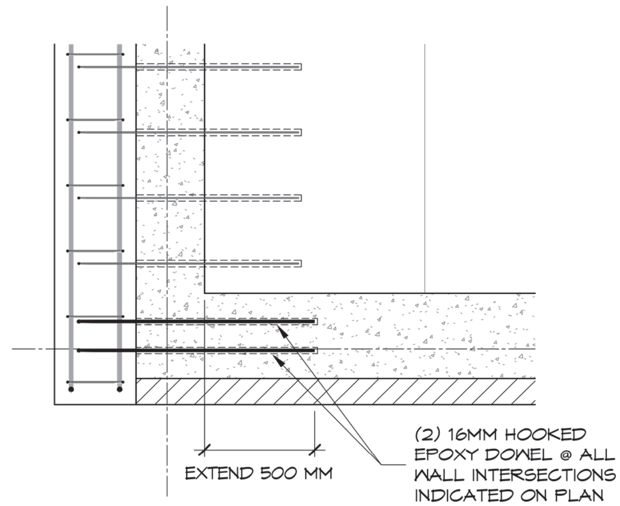
2 / D1 — INT. ROOF WALL TIE (LONG. EQ.)
INCREMENT 1,2,3



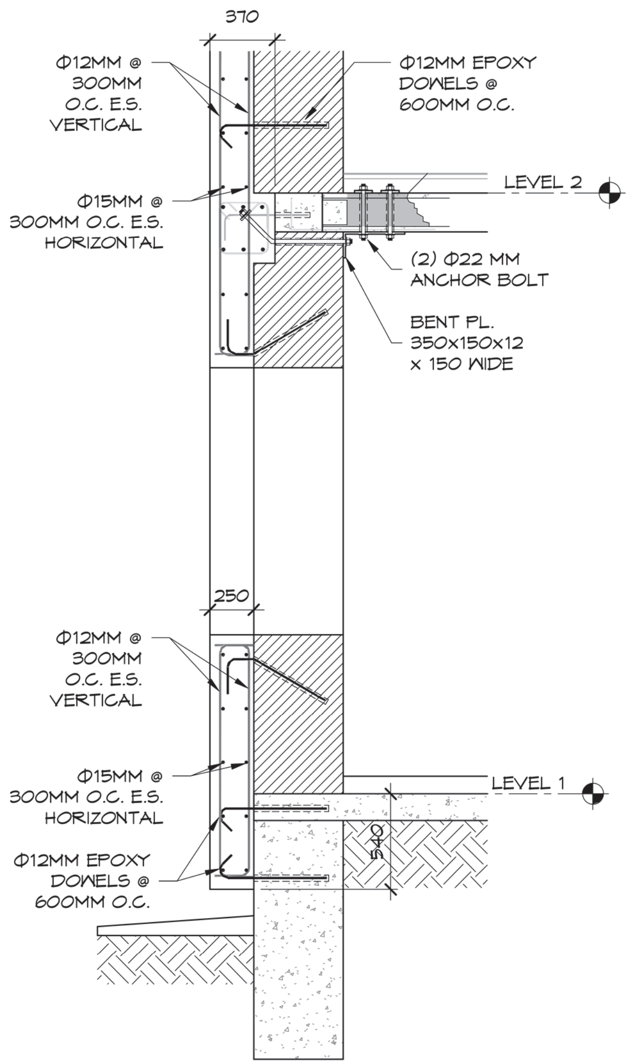
1 / D1 — INTERIOR PARTITION WALL
INCREMENT 1,2,3



2 D2 ENTRY ROOF TIE
INCREMENT 1,2,3

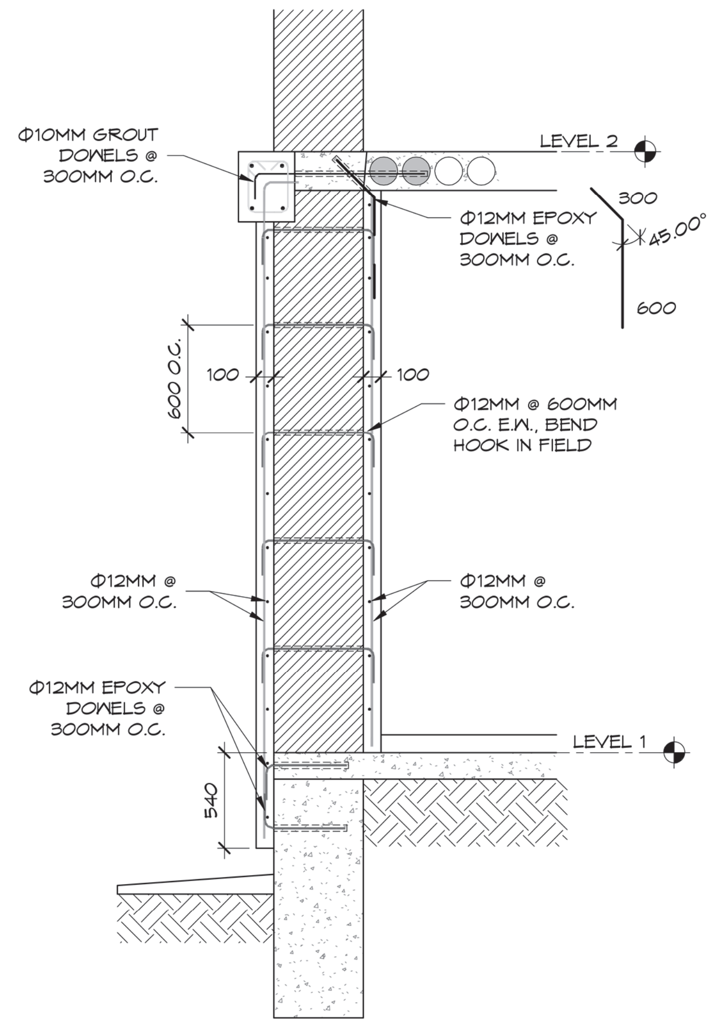


1 D2 EXTERIOR ROOF BELT (PLAN VIEW)
INCREMENT 1,2,3



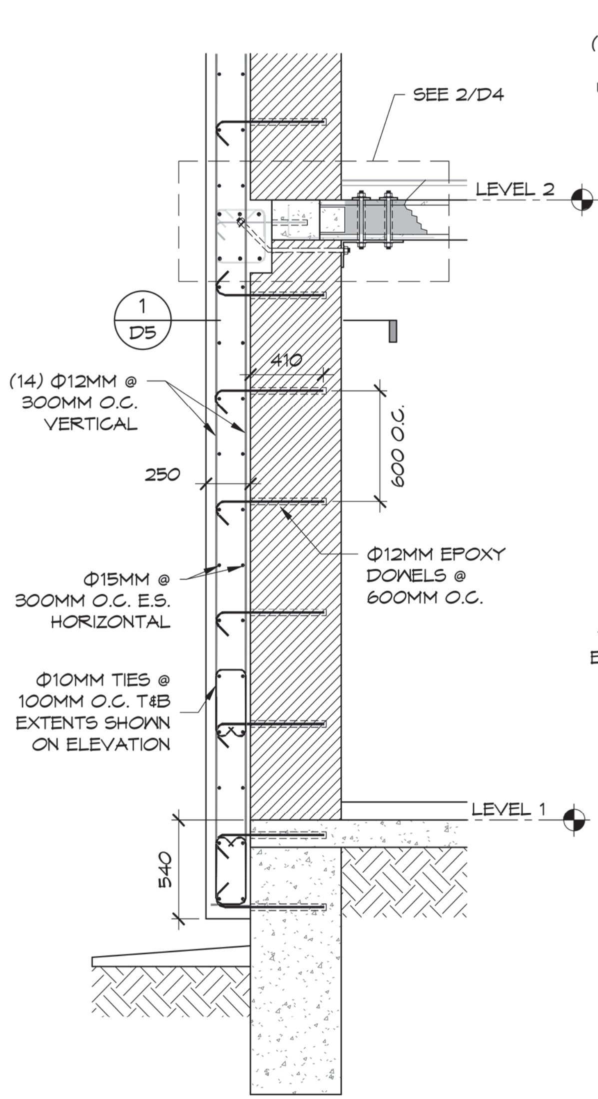
2 / D3 EXT. WALL (LONG. EQ.)

INCREMENT 4

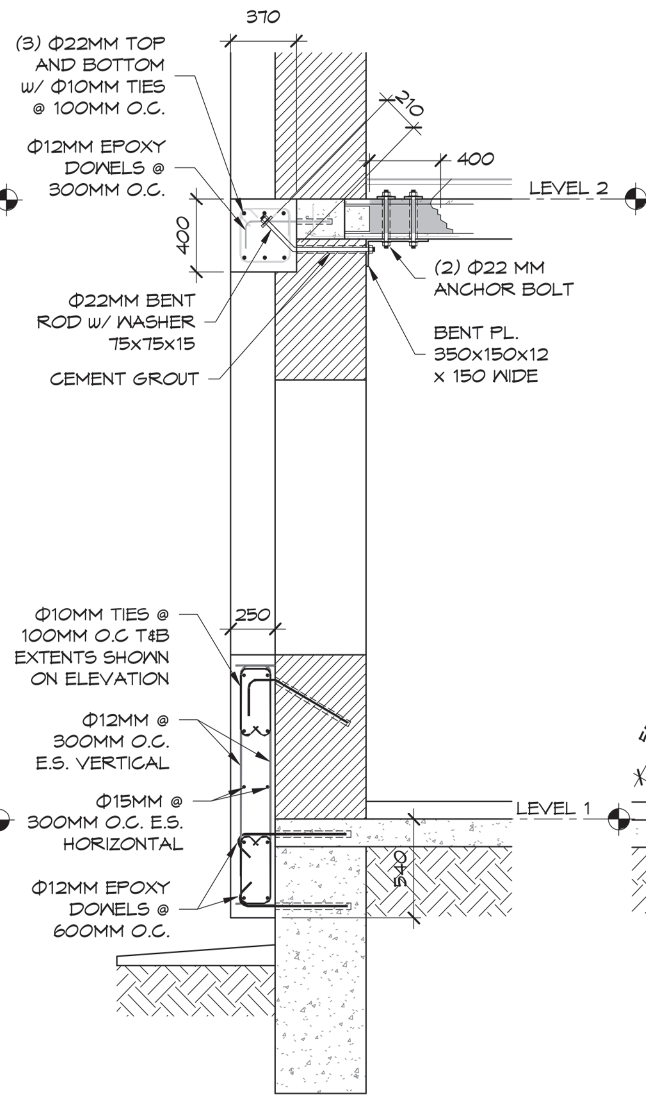


1 / D3 TRANS. WALL STRENGTHENING

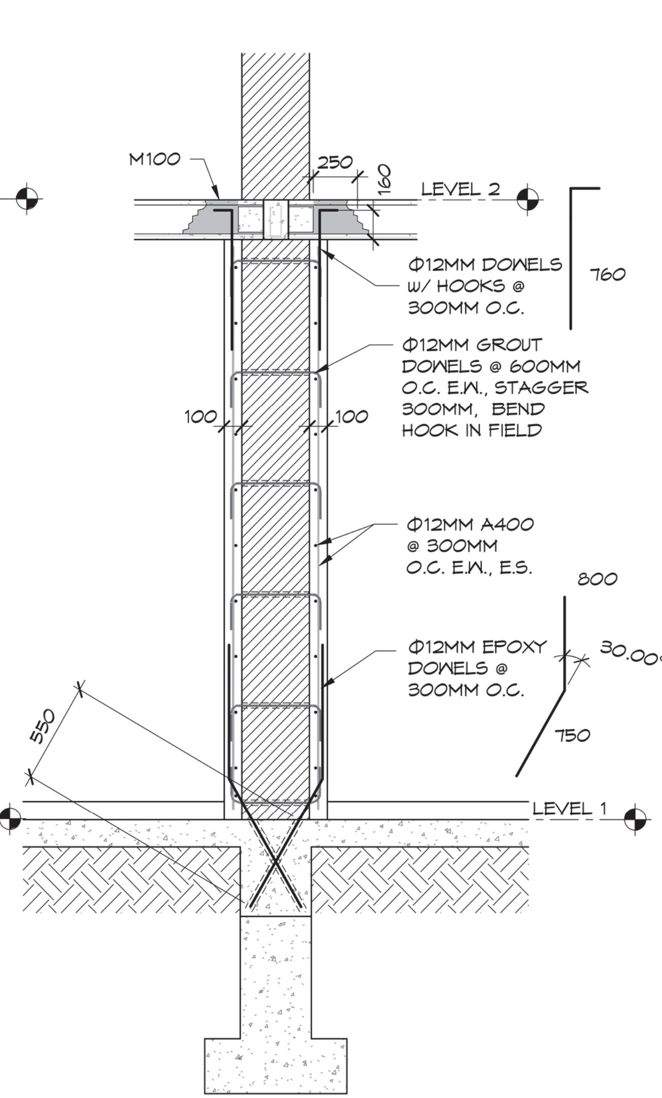
INCREMENT 2



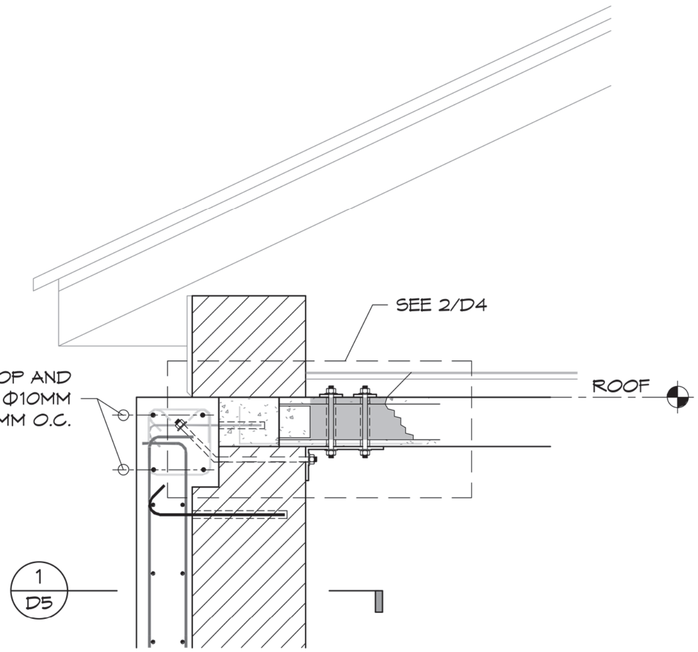
3 D4 EXTERIOR WALL
INCREMENT 2, 3, 3.5



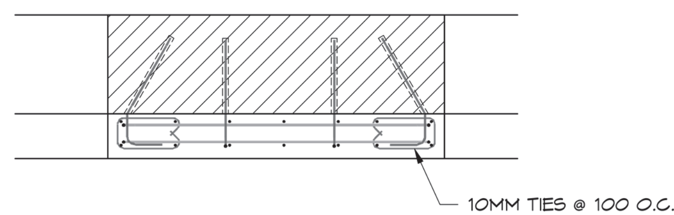
2 D4 EXT. WALL (LONG. EQ.)
INCREMENT 2, 3, 3.5



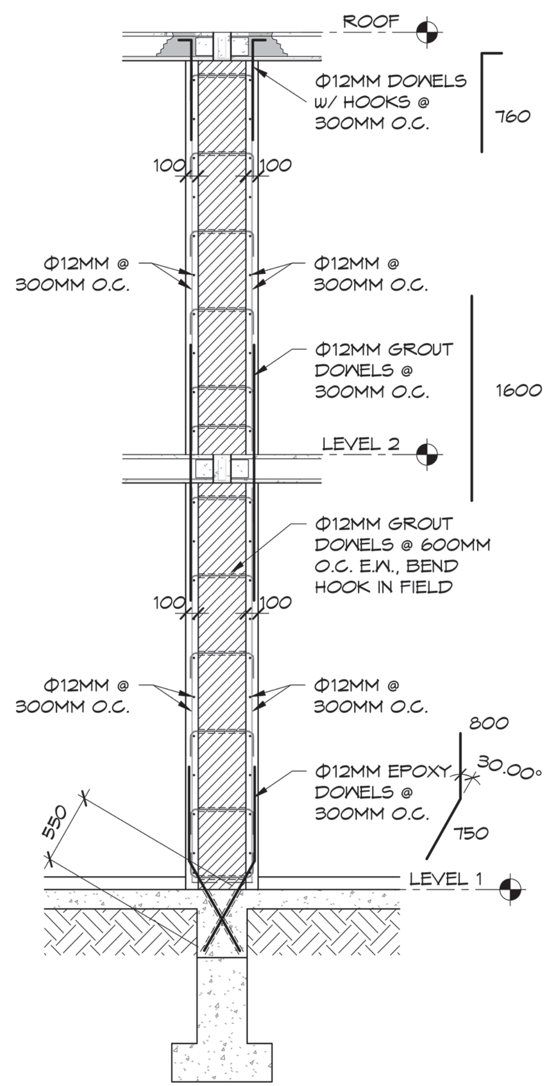
1 D4 INTERIOR LONGITUDINAL WALL
INCREMENT 2



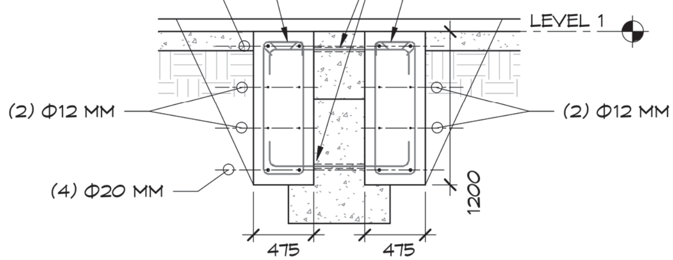
2 / D5 **EXT. ROOF TETHER**
INCREMENT 2,3



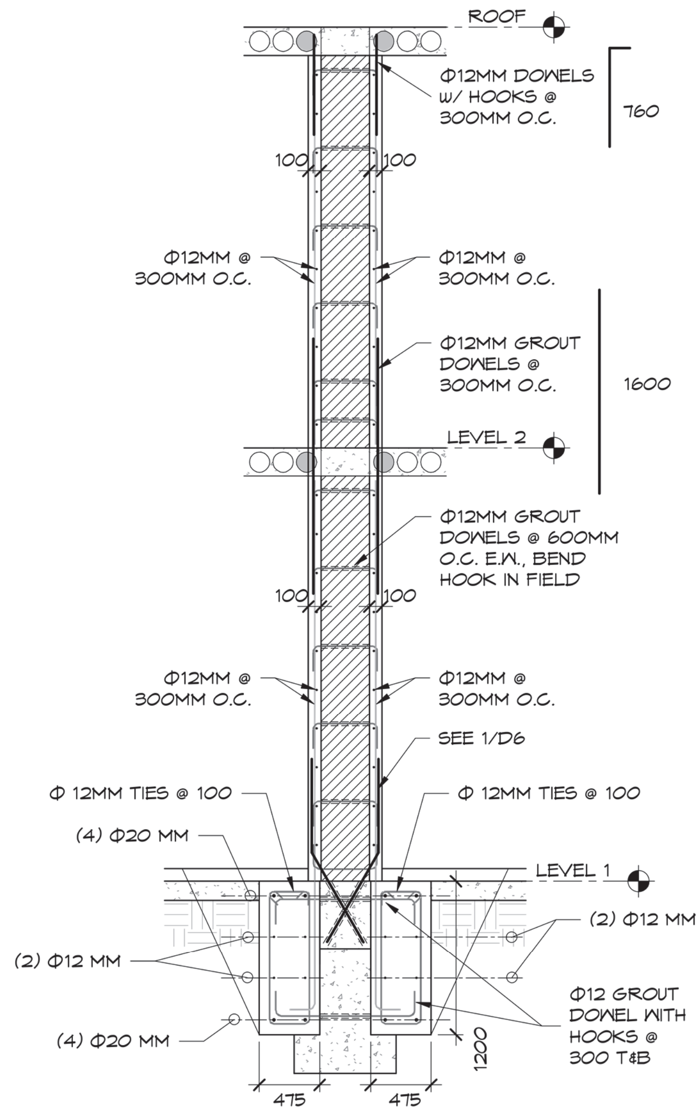
1 / D5 **EXT. PIER PARTIAL SECTION**
INCREMENT 2,3



1 / D6 INTERIOR WALL
INCREMENT 3



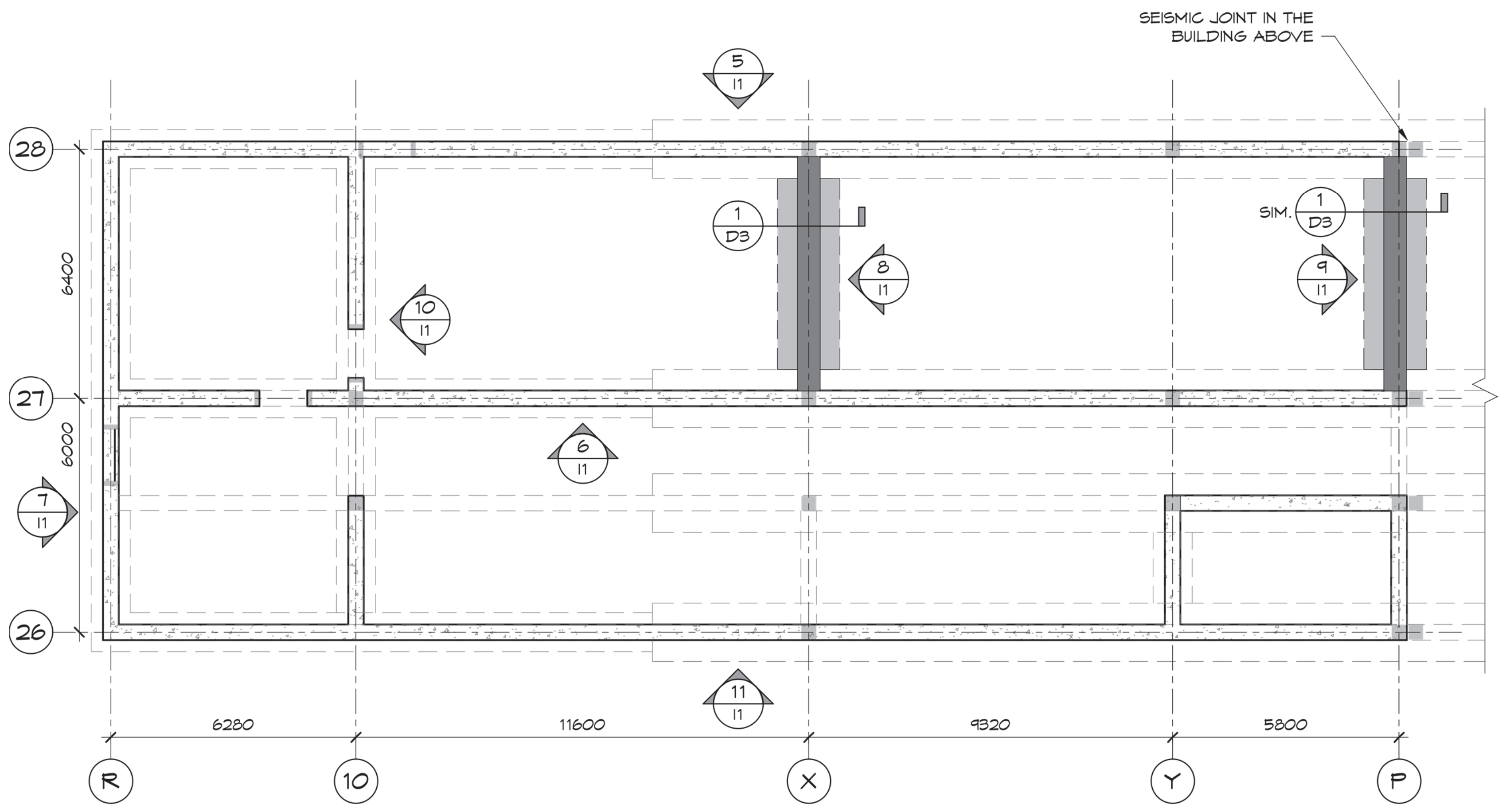
2 NEW GRADE BEAM
D7 INCREMENT 3.5, 4



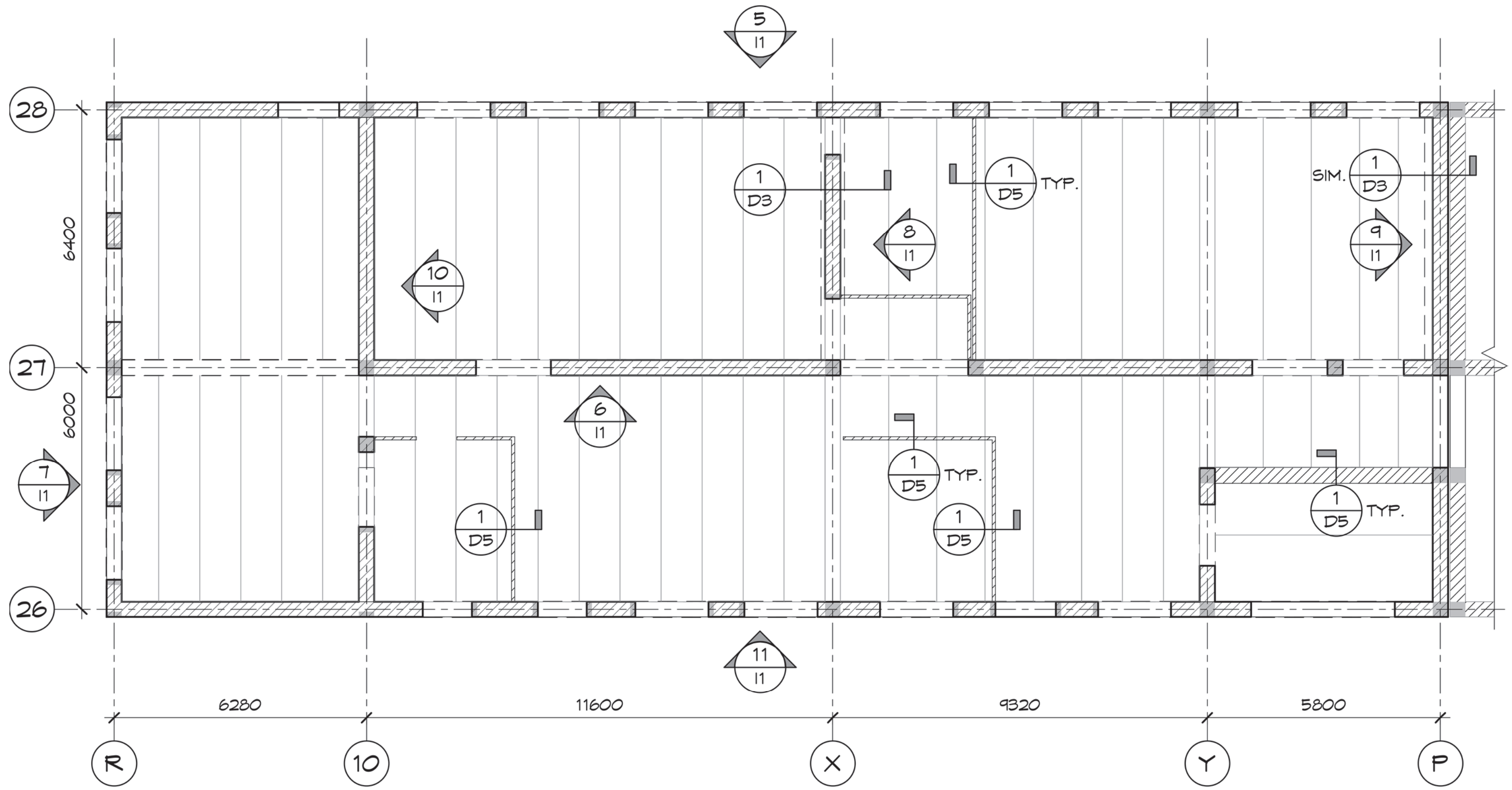
1 NEW GRADE BEAM AT WALL
D7 INCREMENT 3.5, 4

Appendix F
Conceptual Retrofit Drawings for CMCF Typology

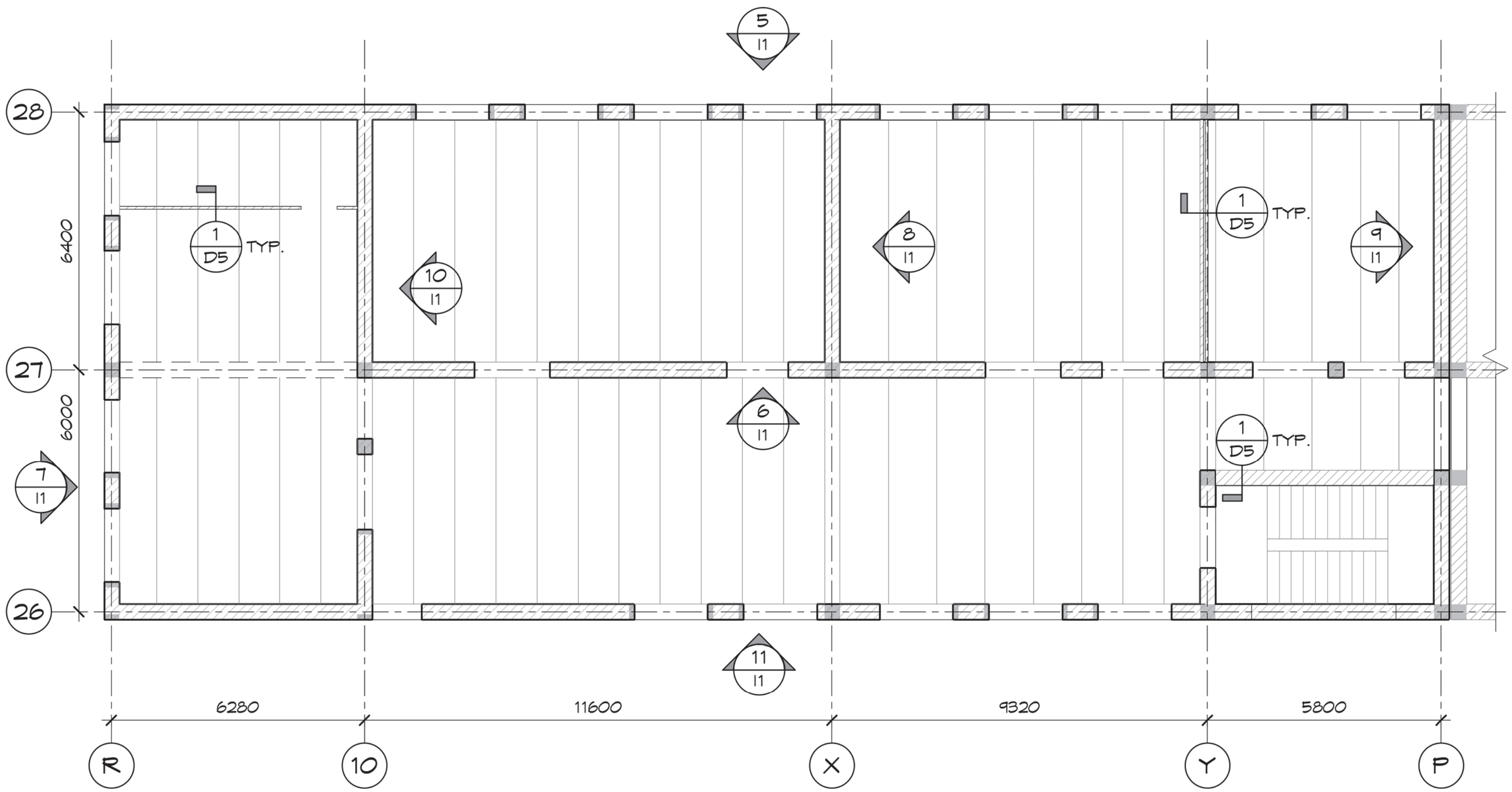
This Appendix presents the conceptual retrofit drawings for the complex masonry with concrete framing (CMCF) typology developed for this project.



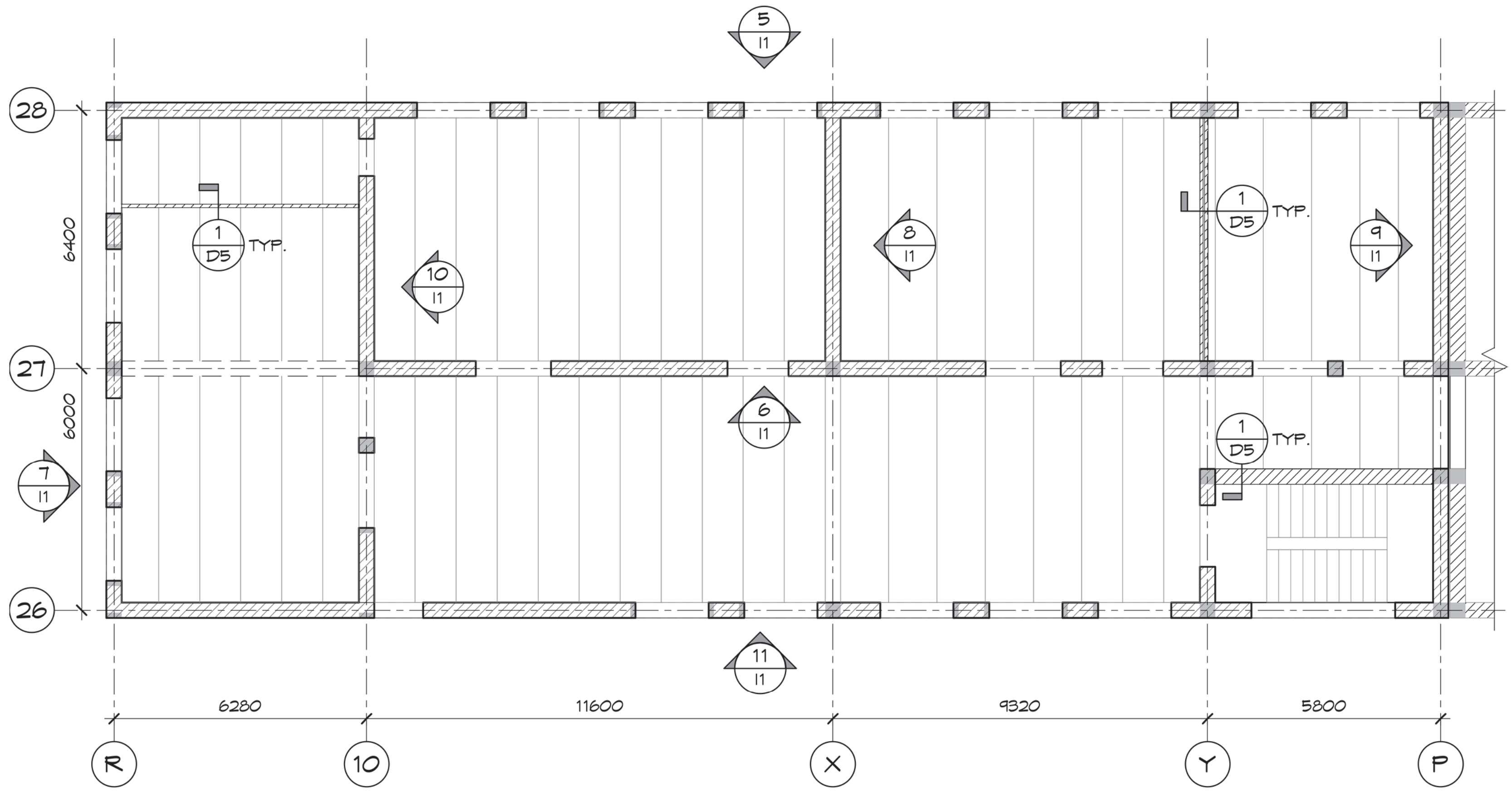
B
I1
BASEMENT - INCREMENT 1



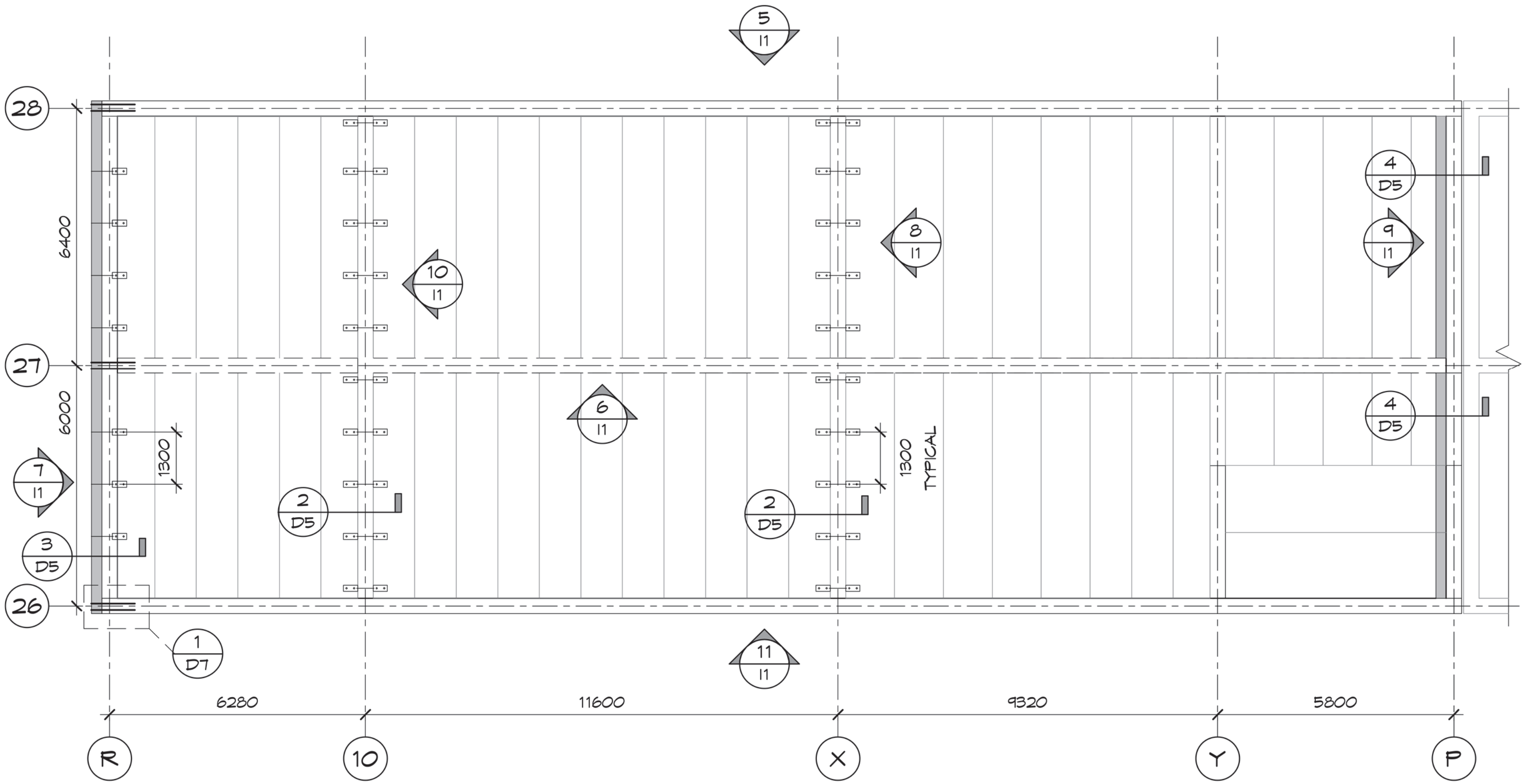
1
I1
LEVEL 1 - INCREMENT 1



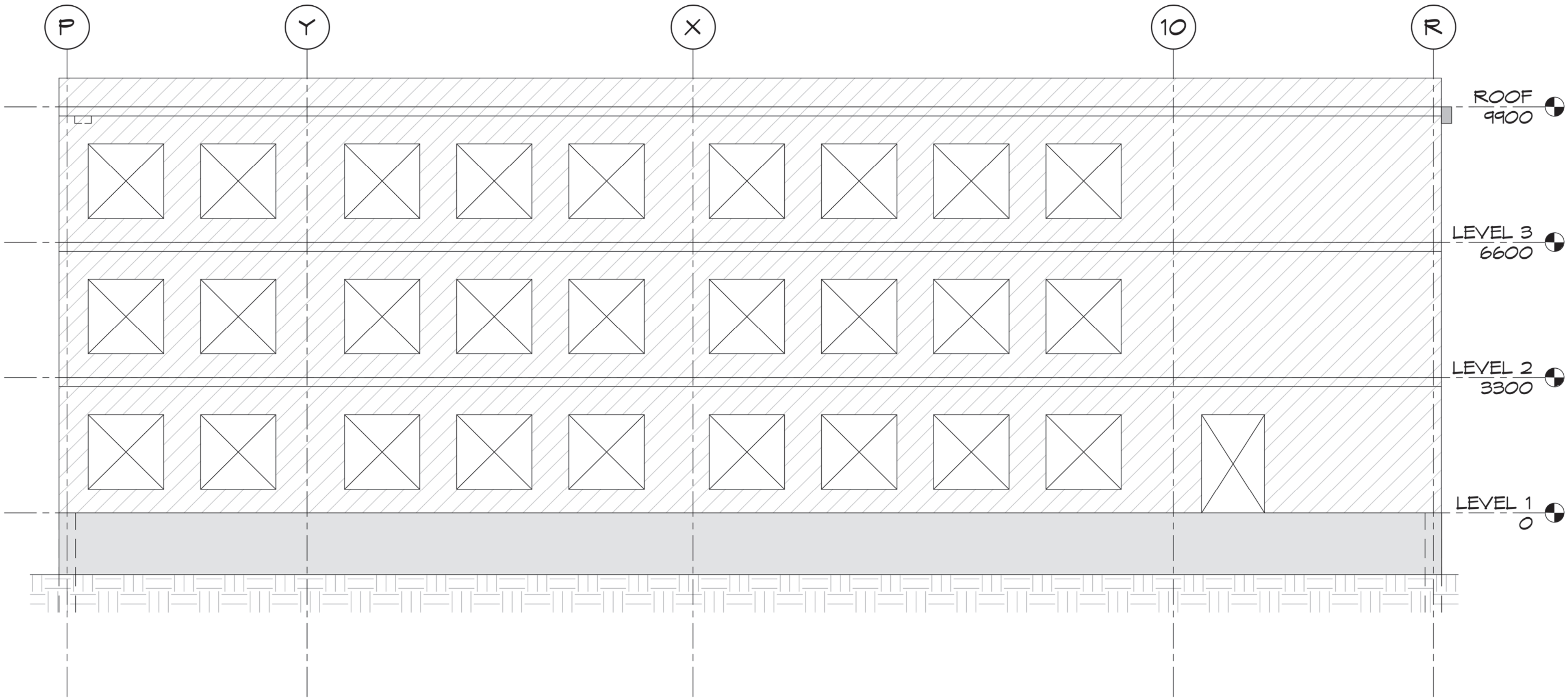
2/I1 LEVEL 2 - INCREMENT 1



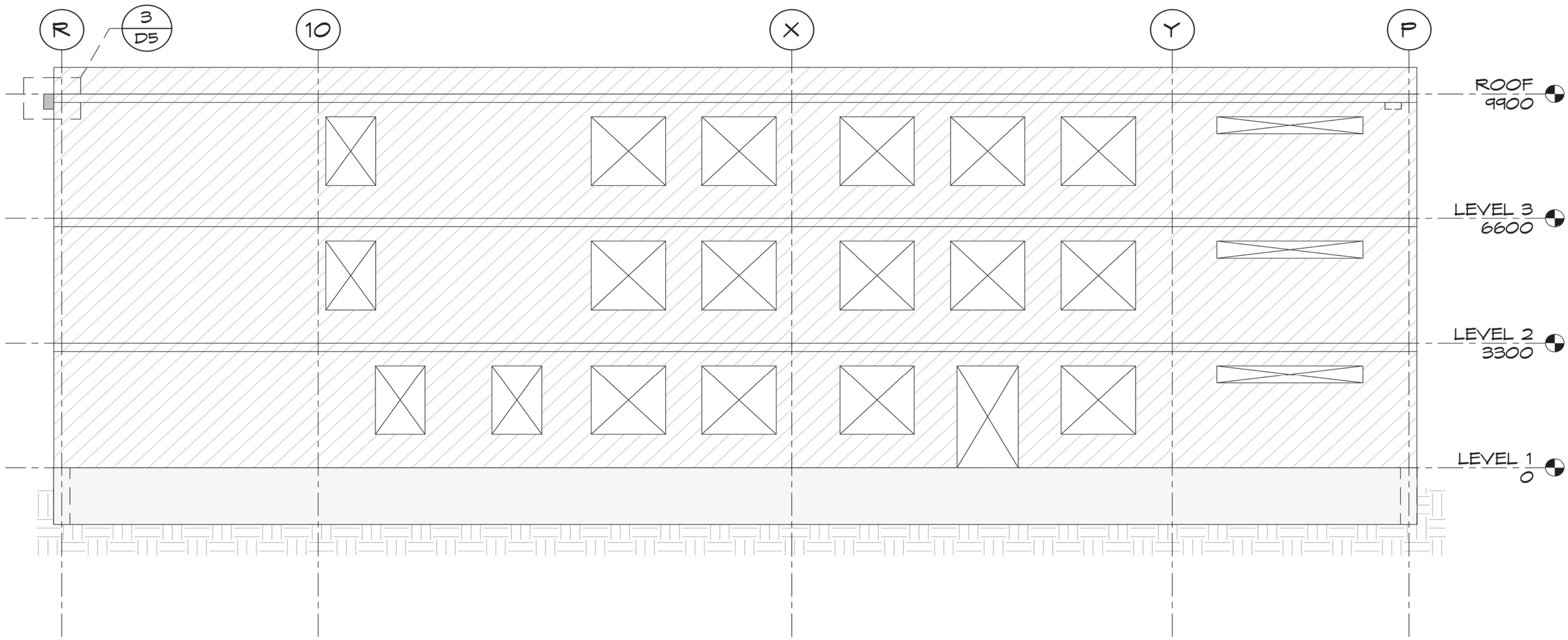
3
I1
LEVEL 3 - INCREMENT 1



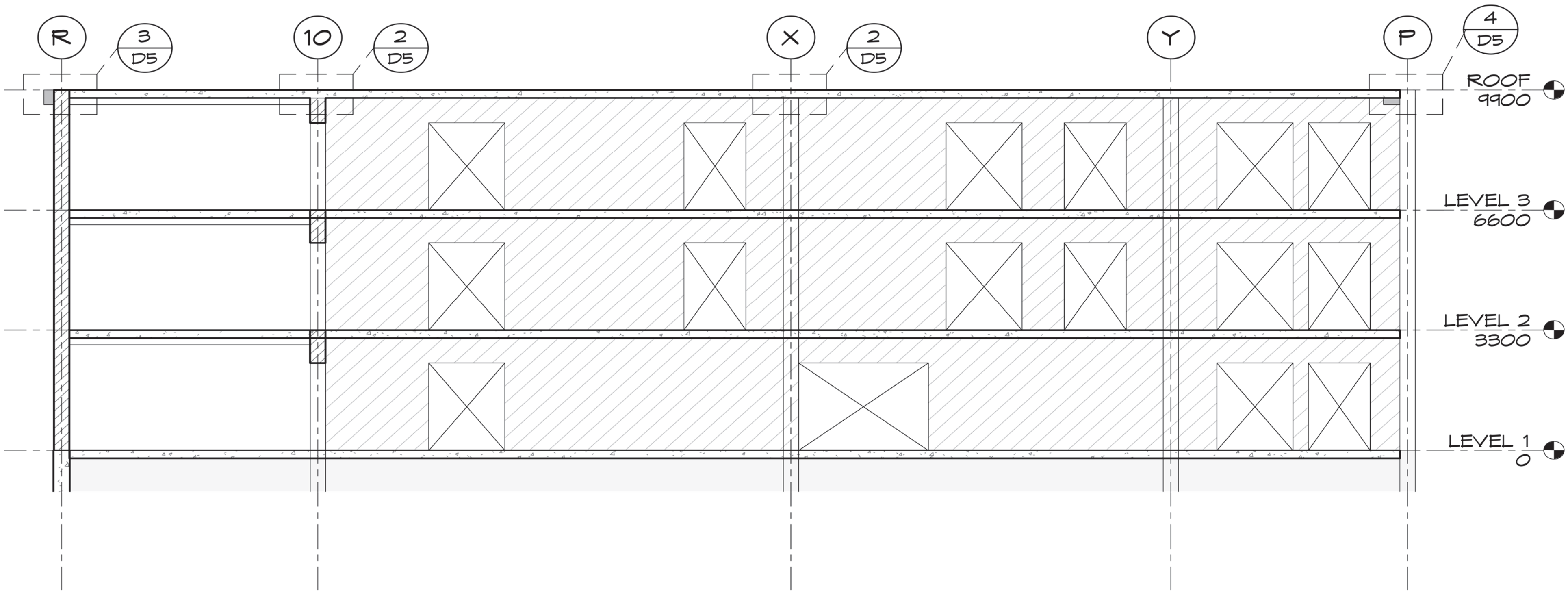
4
I1
ROOF - INCREMENT 1



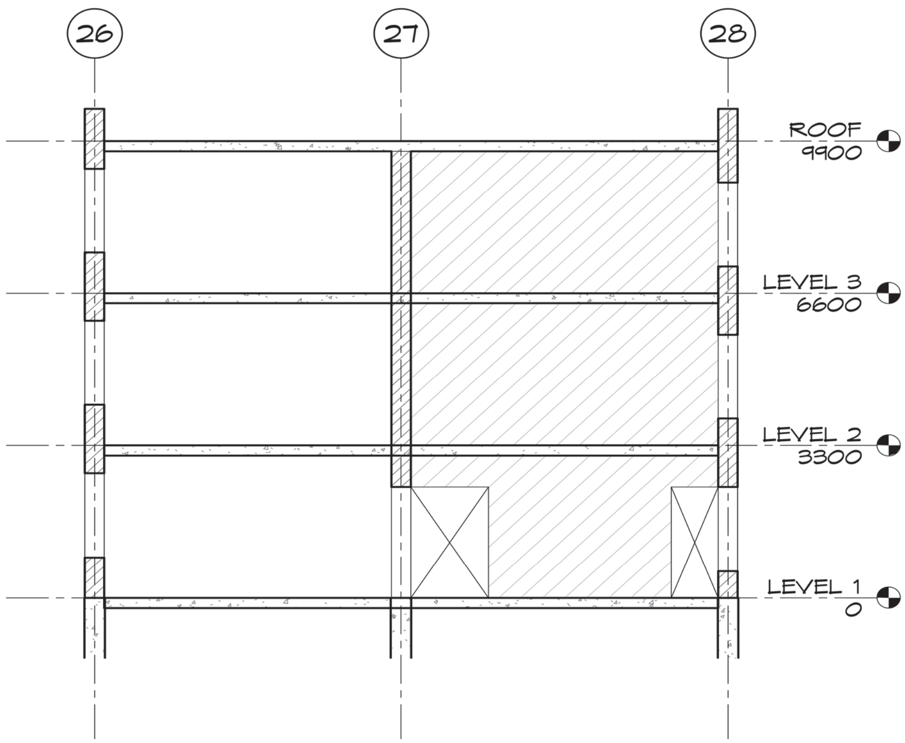
5
I1
EXTERIOR LONGITUDINAL WALL - INCREMENT 1



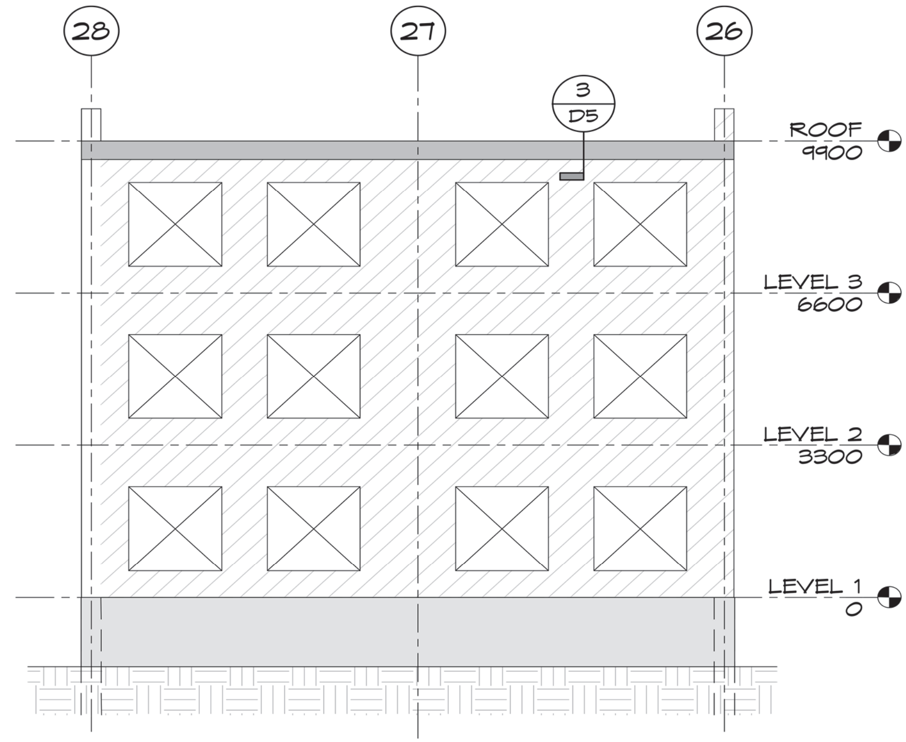
11
I1
EXTERIOR LONGITUDINAL WALL GRID 26 - INCREMENT 1



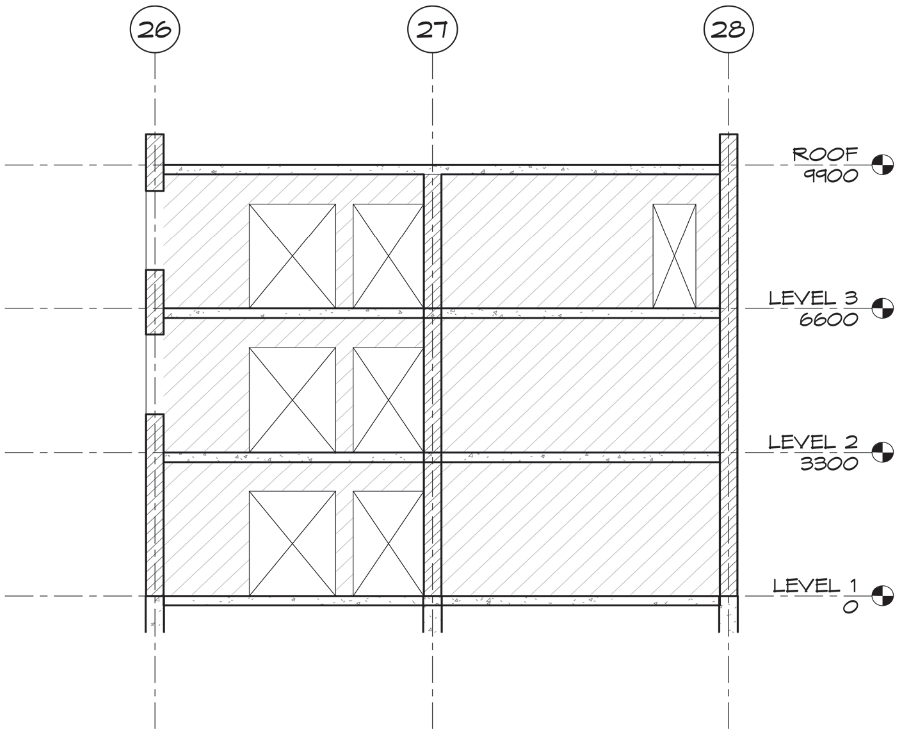
6
I1
INTERIOR LONGITUDINAL WALL - INCREMENT 1



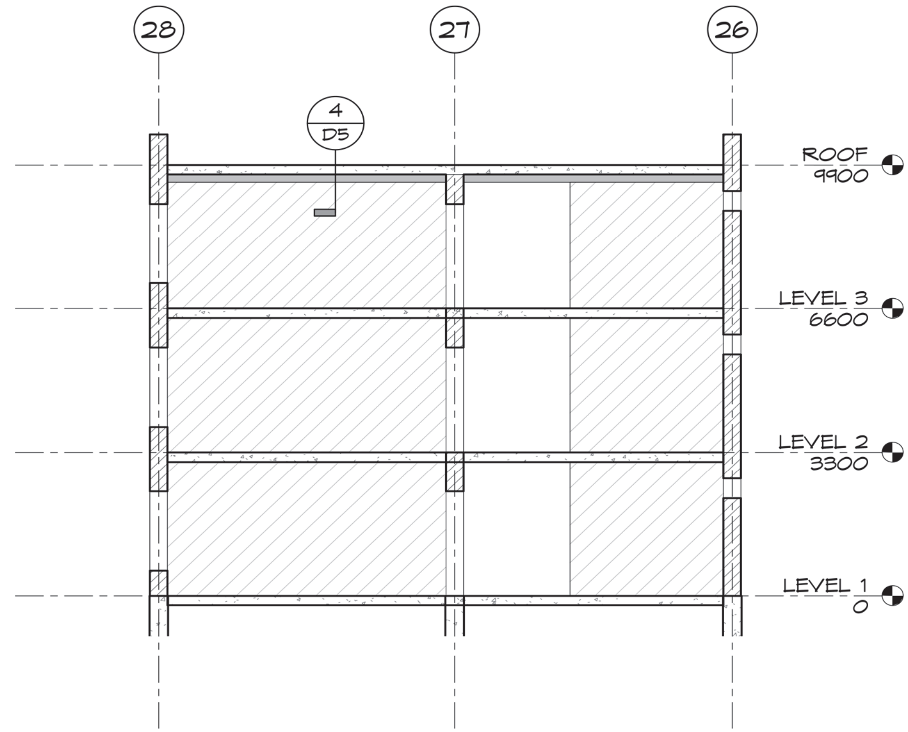
8
I1
TRANSVERSE WALL GRID X - INCREMENT 1



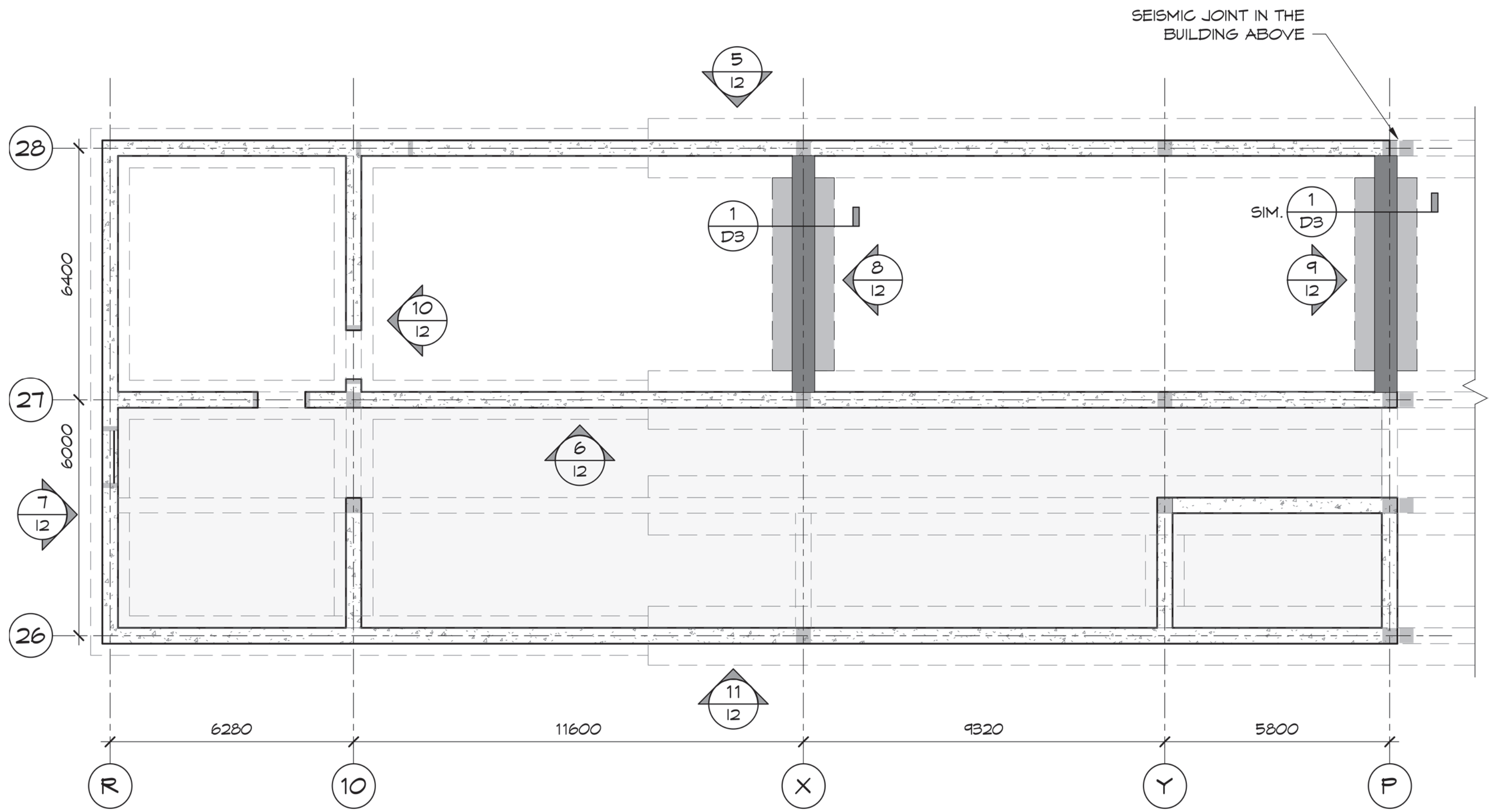
7
I1
TRANSVERSE WALL GRID R - INCREMENT 1



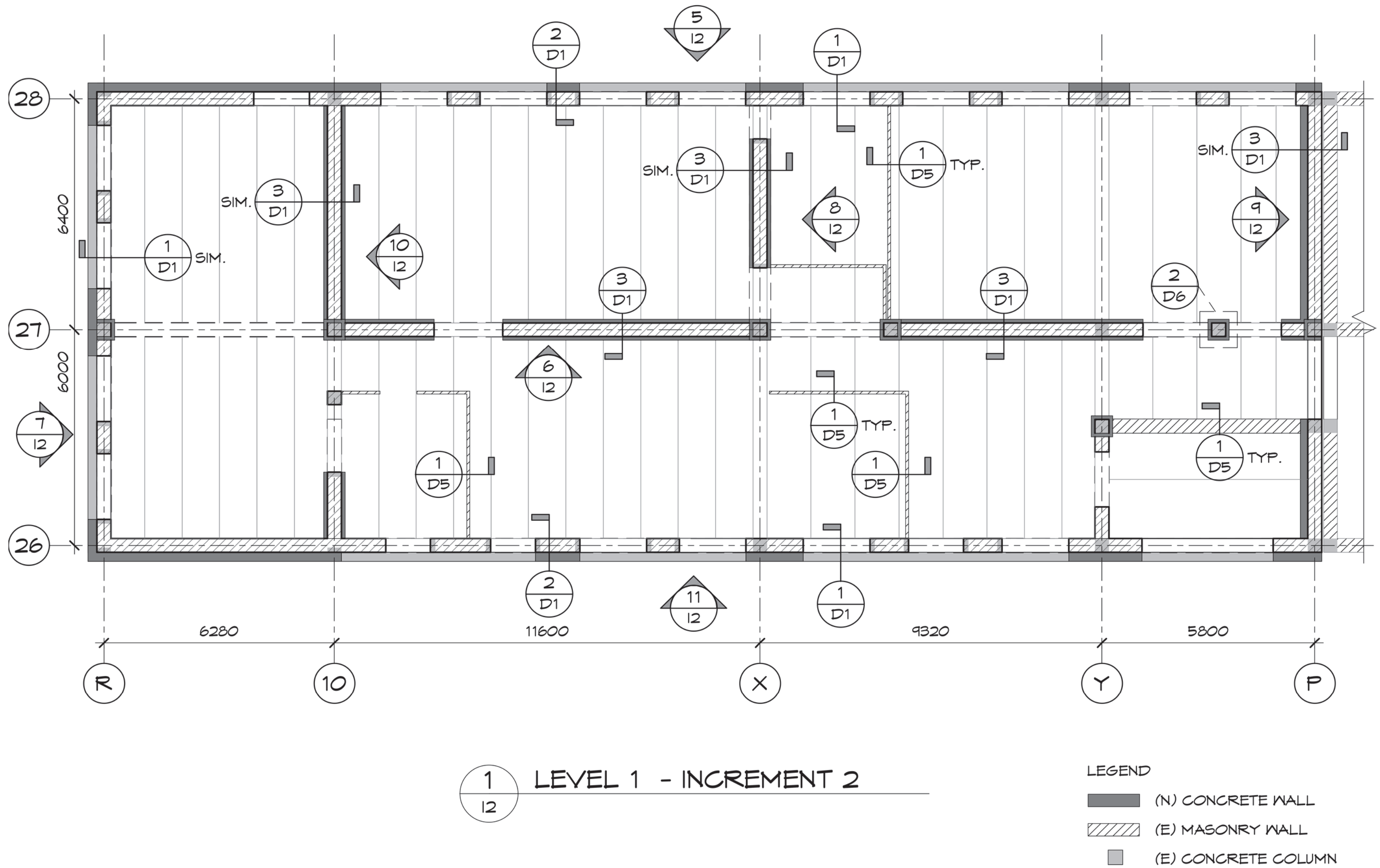
10
I1
TRANSVERSE WALL GRID 10 - INCREMENT 1



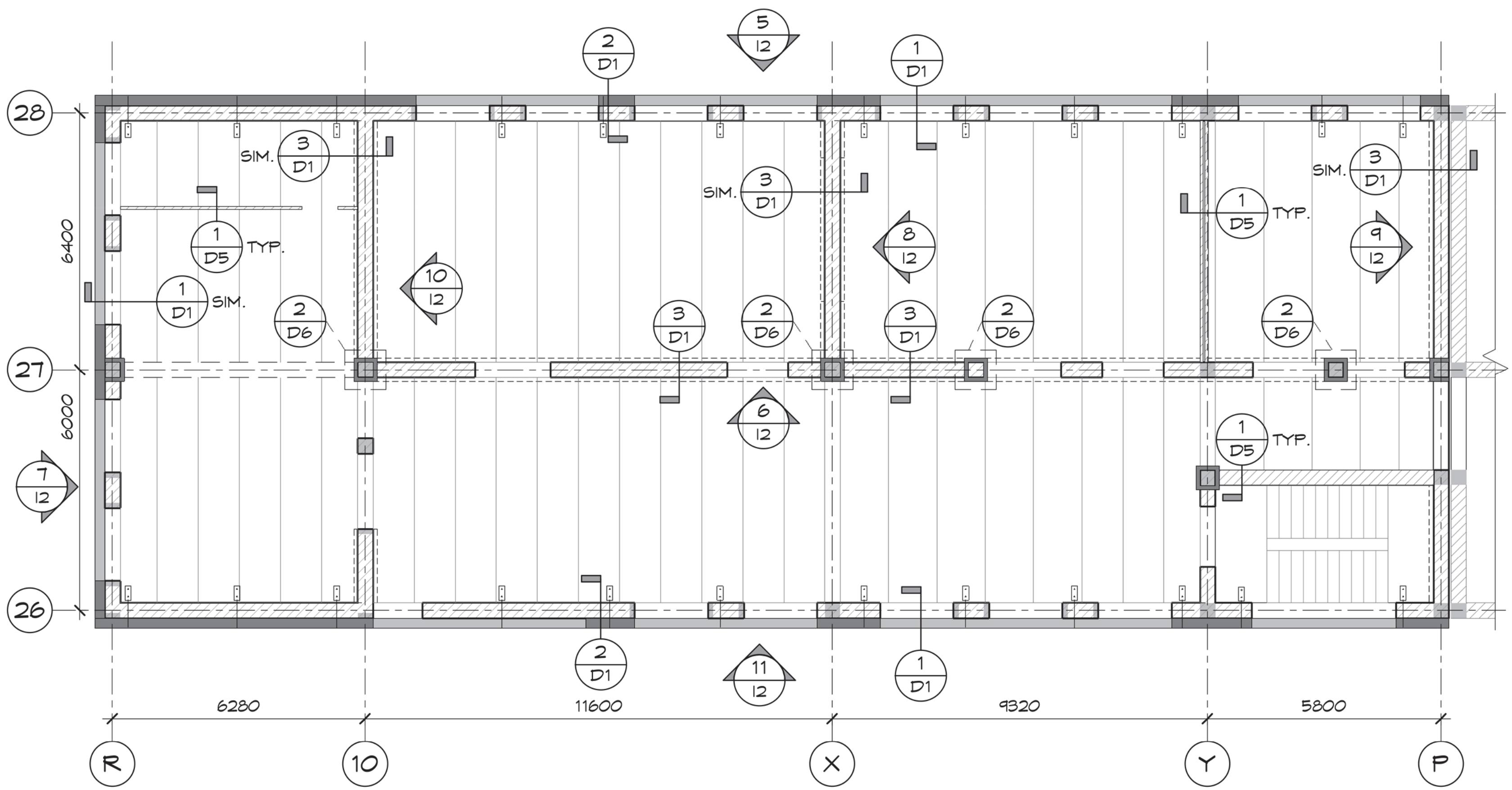
9
I1
TRANSVERSE WALL GRID P - INCREMENT 1



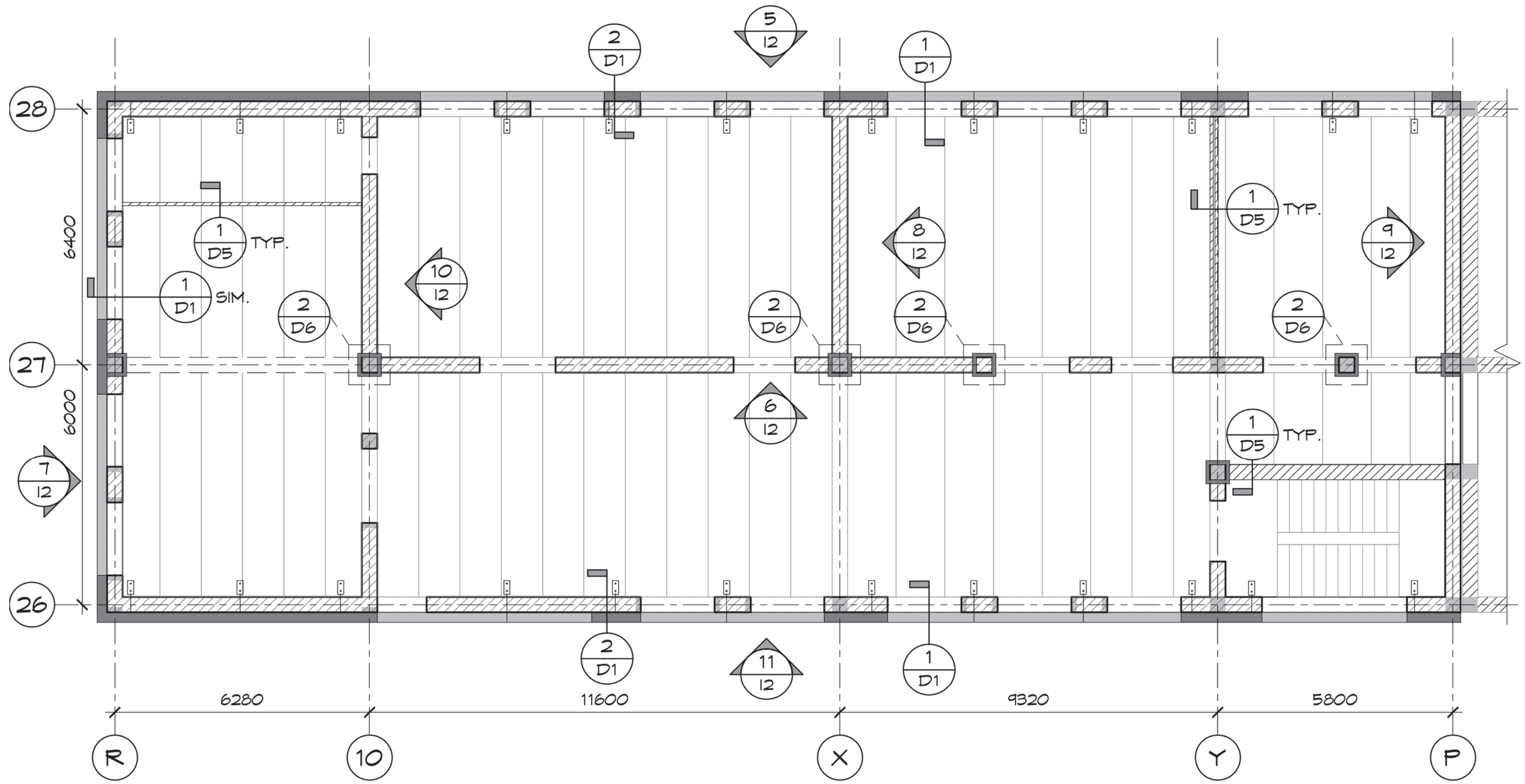
B / 12 BASEMENT - INCREMENT 2



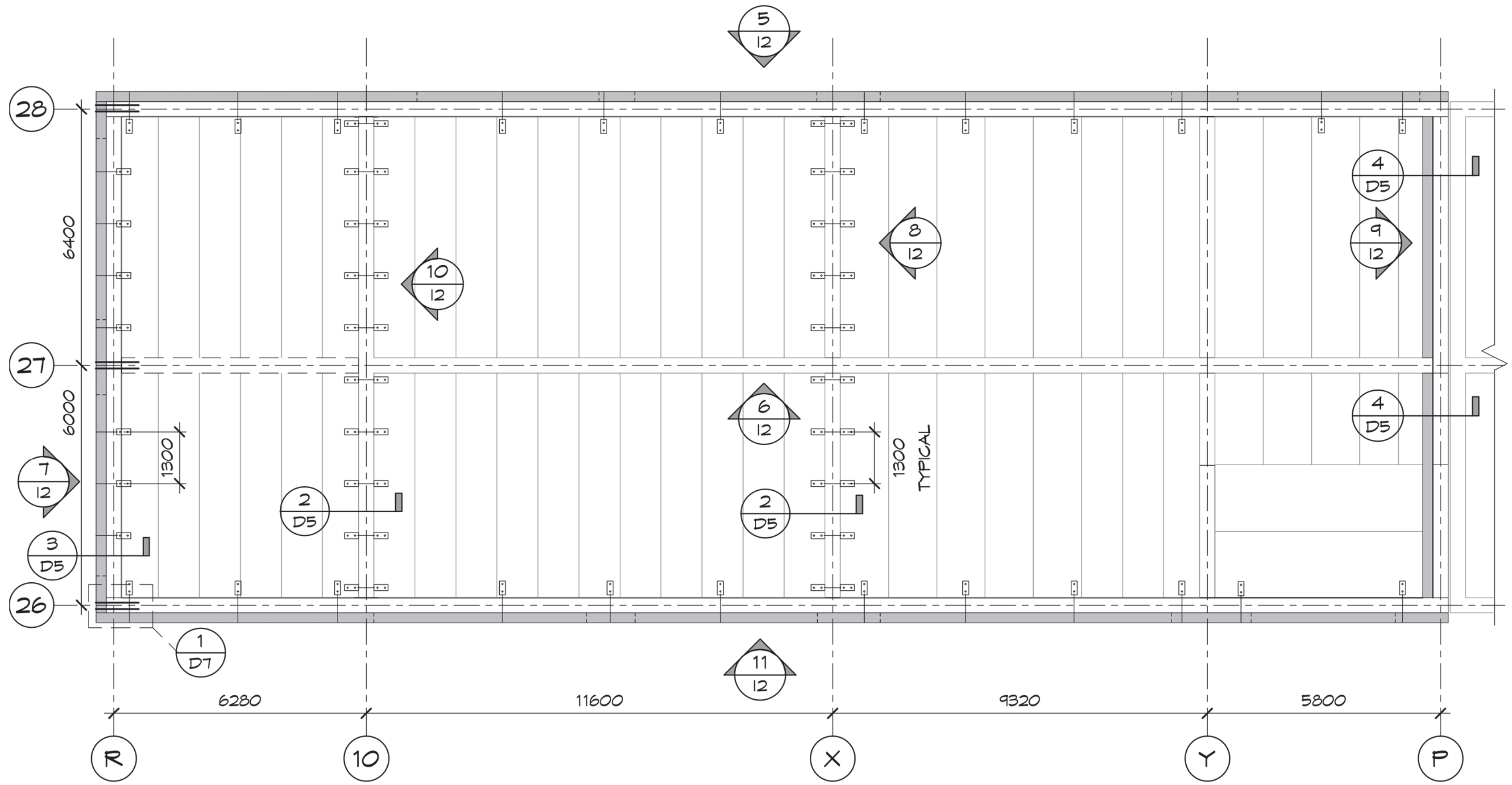
1/12 LEVEL 1 - INCREMENT 2



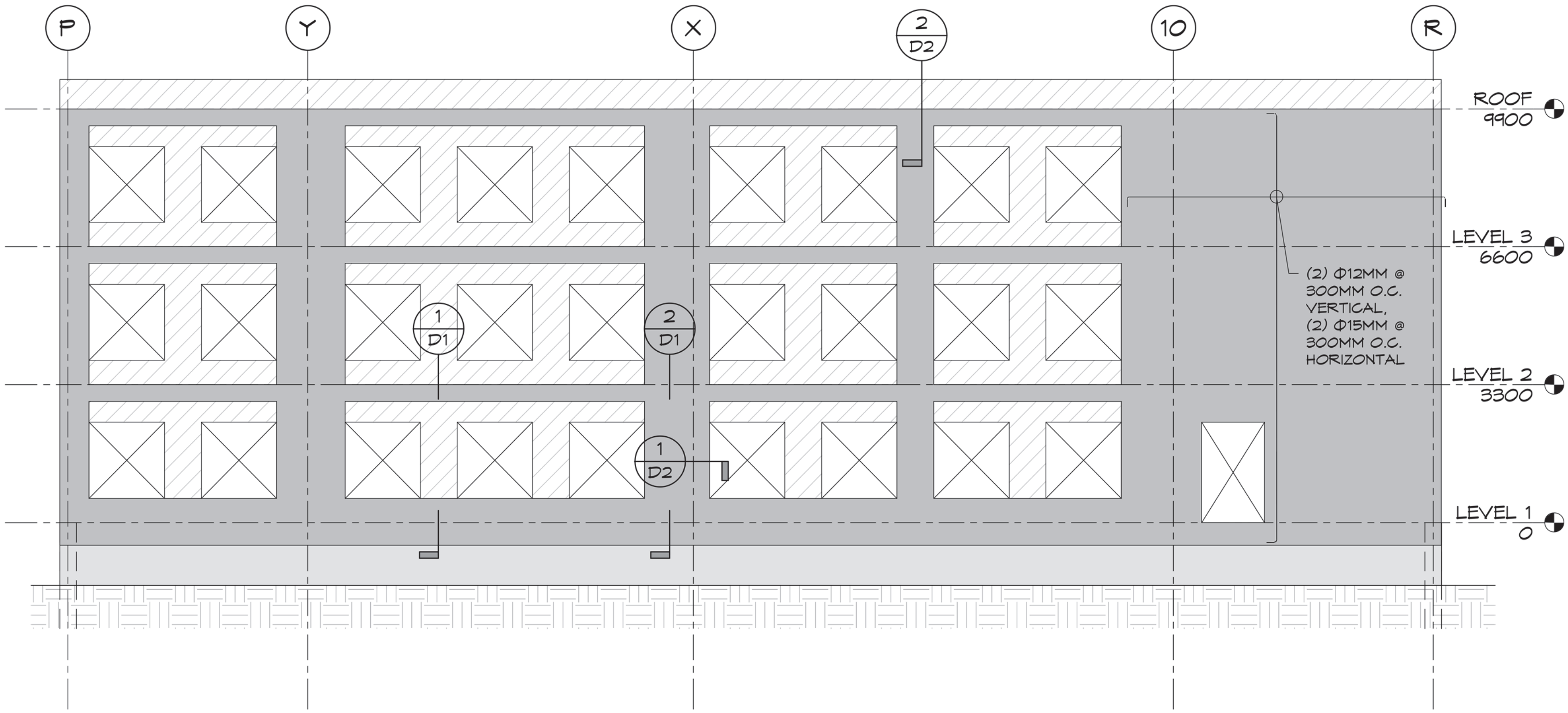
2/12 LEVEL 2 - INCREMENT 2



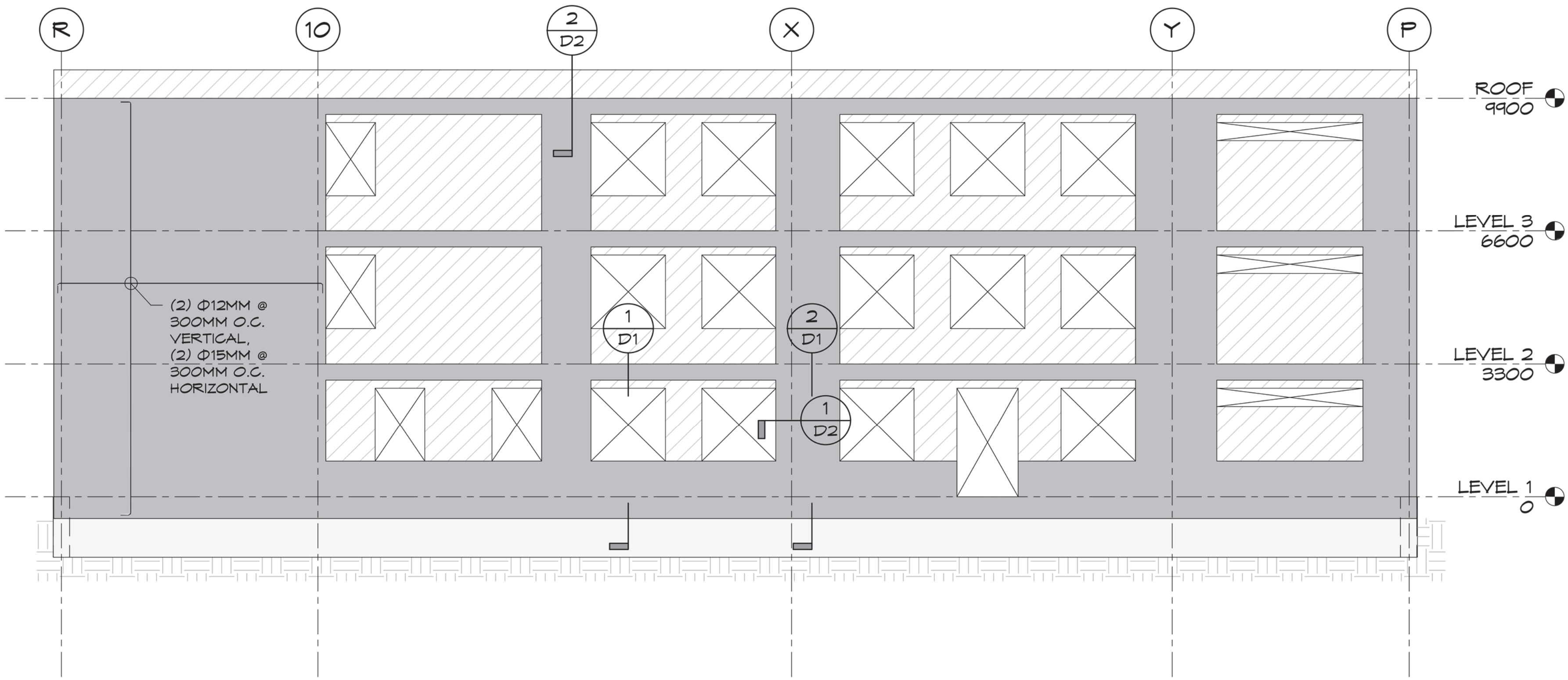
3/12 LEVEL 3 - INCREMENT 2



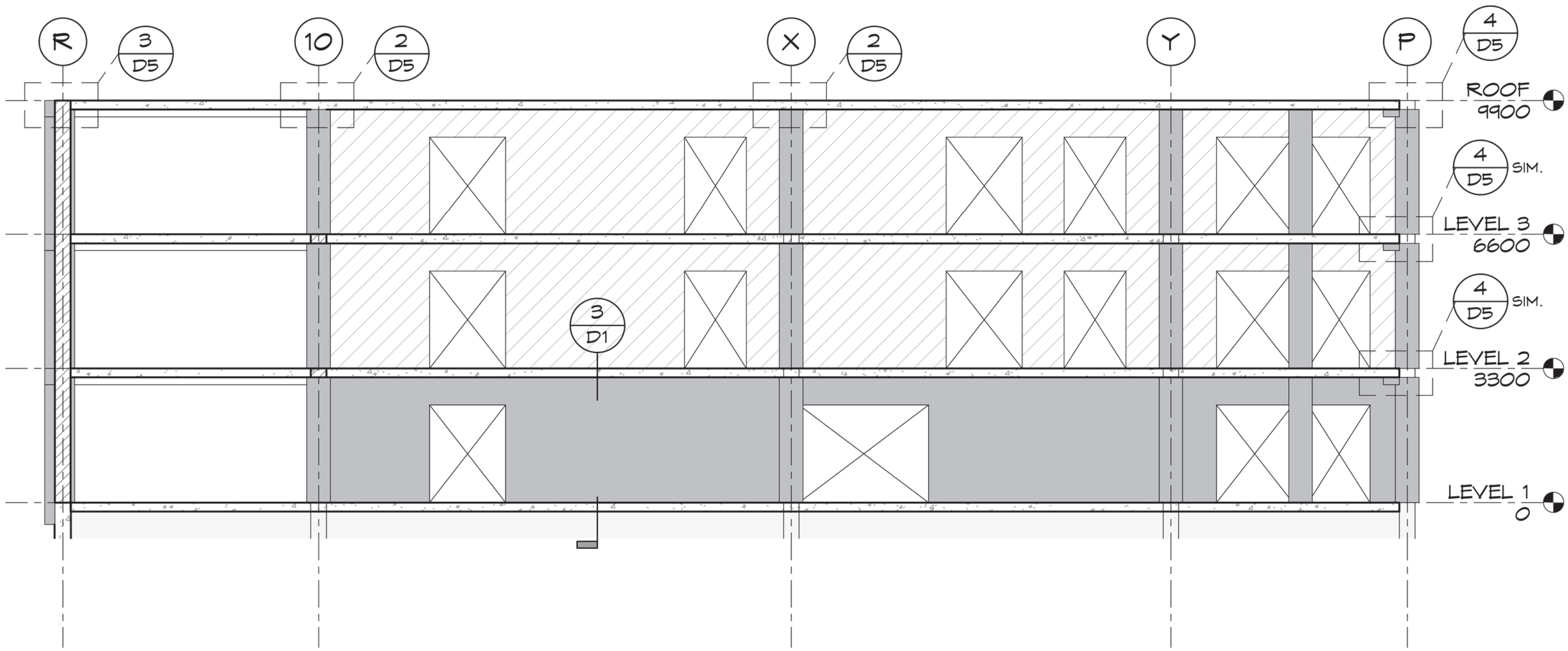
4/12 ROOF - INCREMENT 2



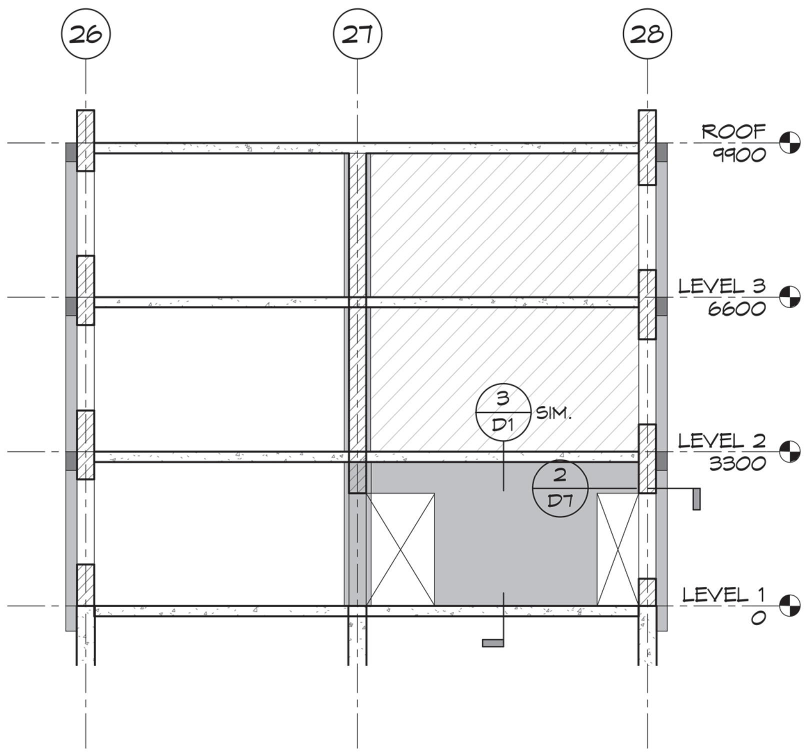
5
12
EXTERIOR LONGITUDINAL WALL - INCREMENT 2



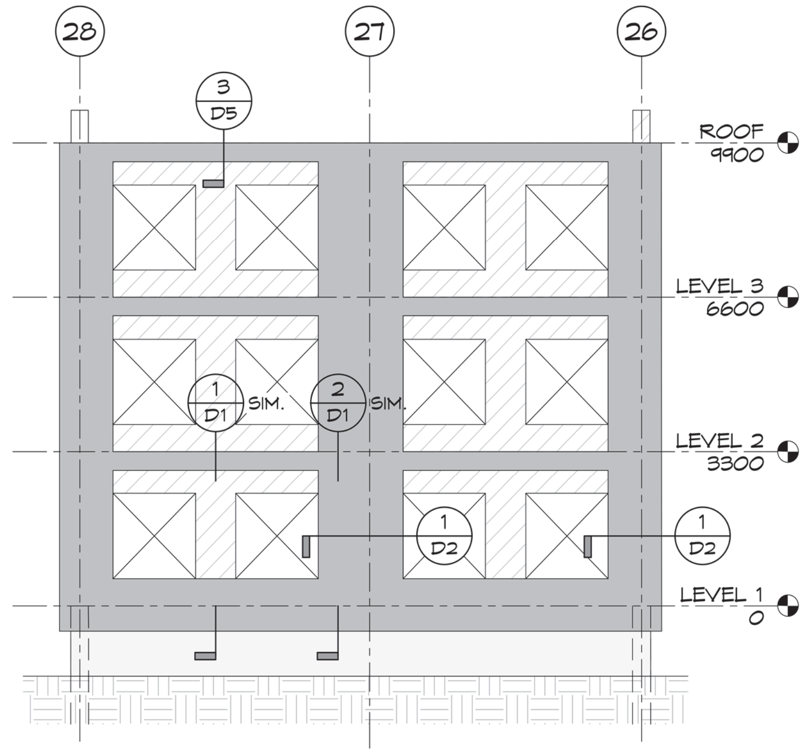
11
12
EXTERIOR LONGITUDINAL WALL GRID 26 - INCREMENT 2



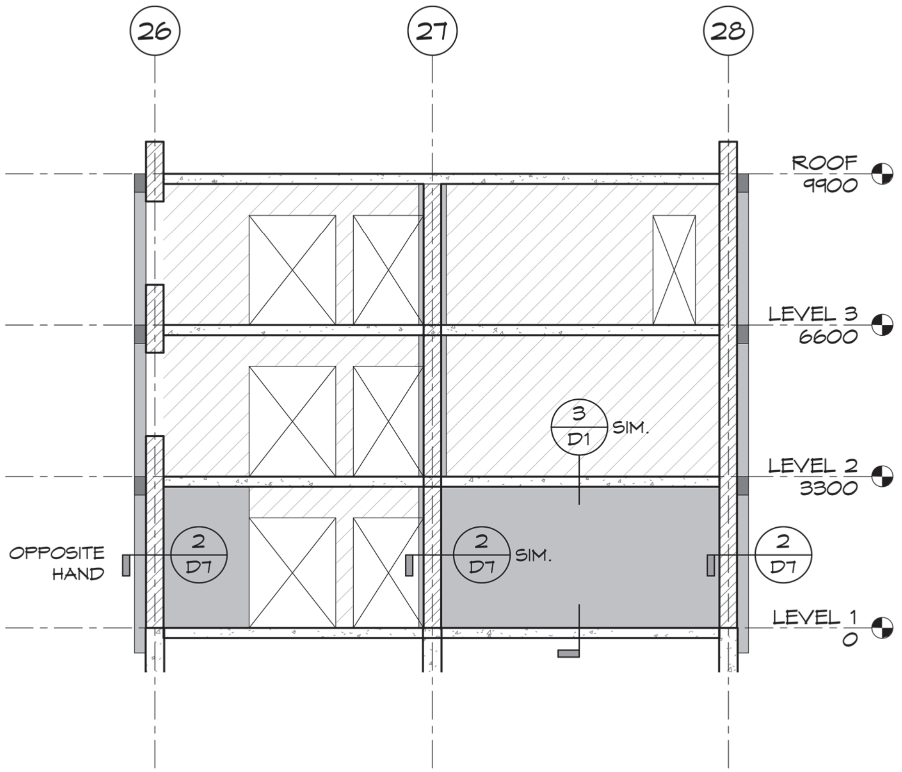
6 / 12 INTERIOR LONGITUDINAL WALL - INCREMENT 2



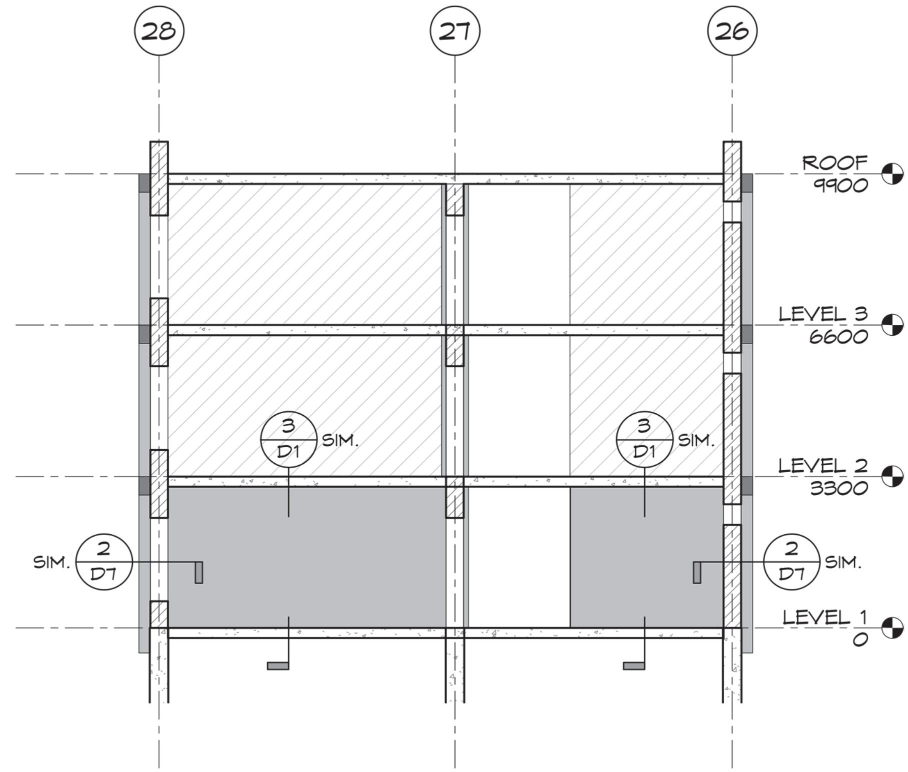
8
12
TRANSVERSE WALL GRID X - INCREMENT 2



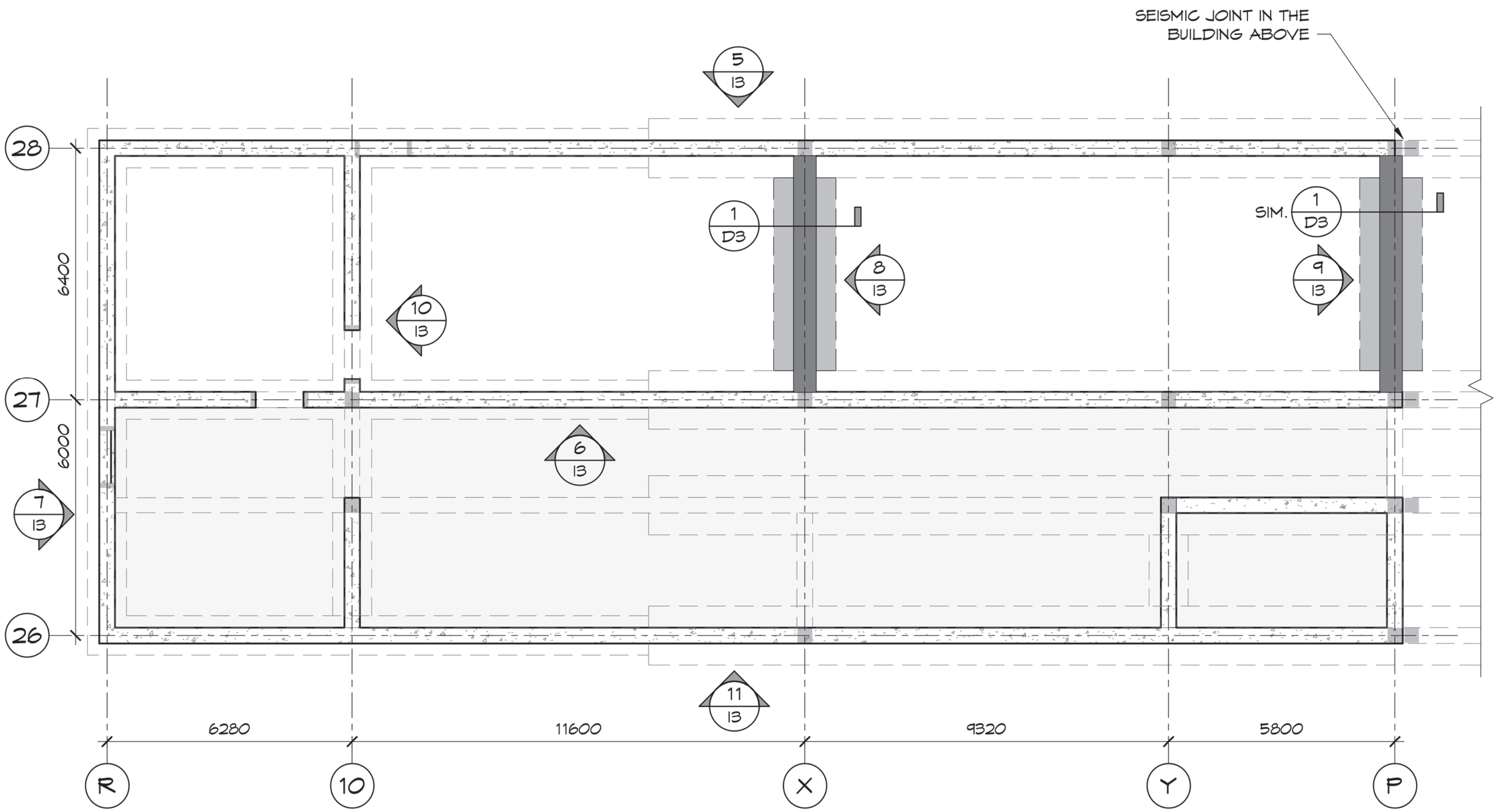
7
12
TRANSVERSE WALL GRID R - INCREMENT 2



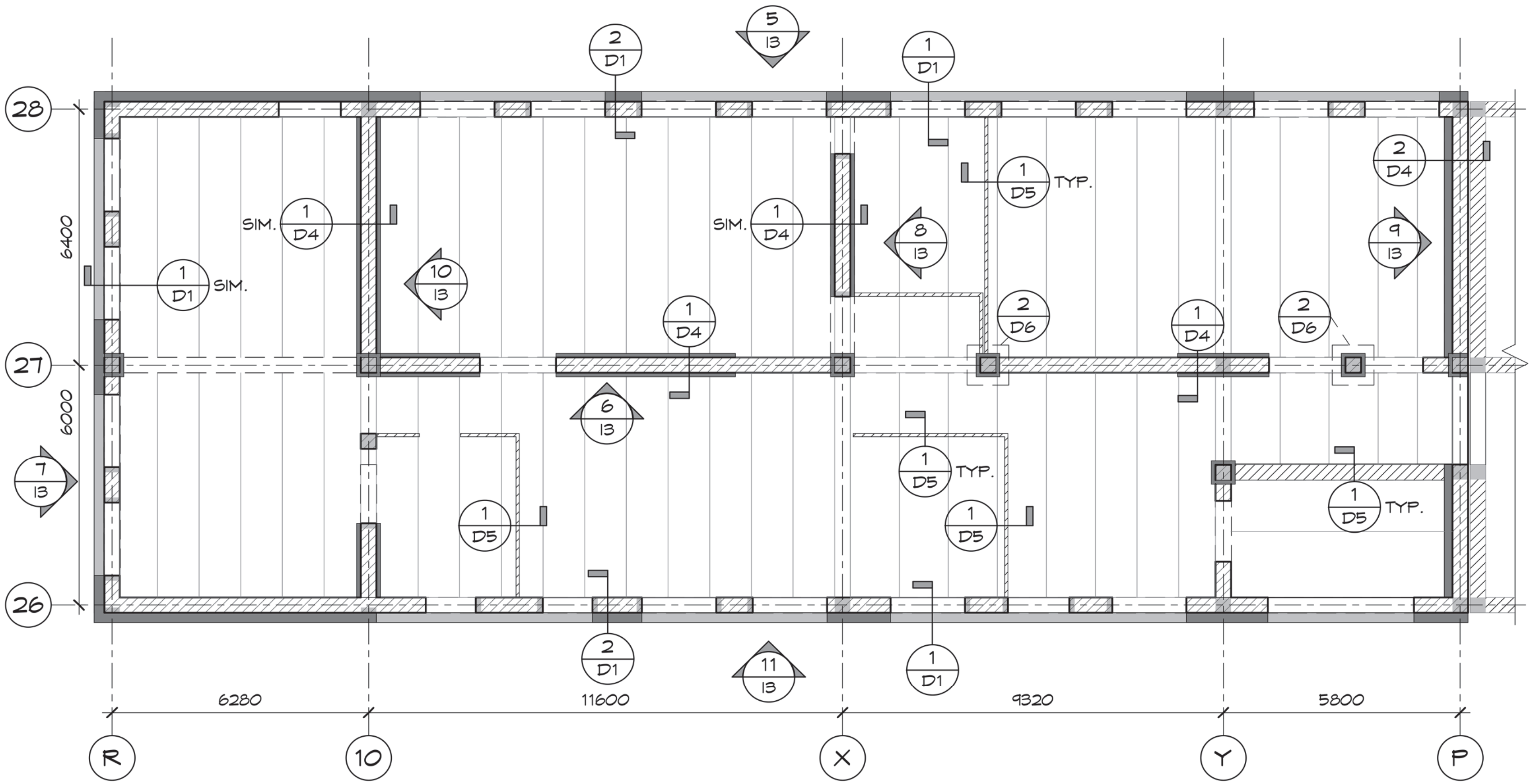
10/12 TRANSVERSE WALL GRID 10 - INCREMENT 2



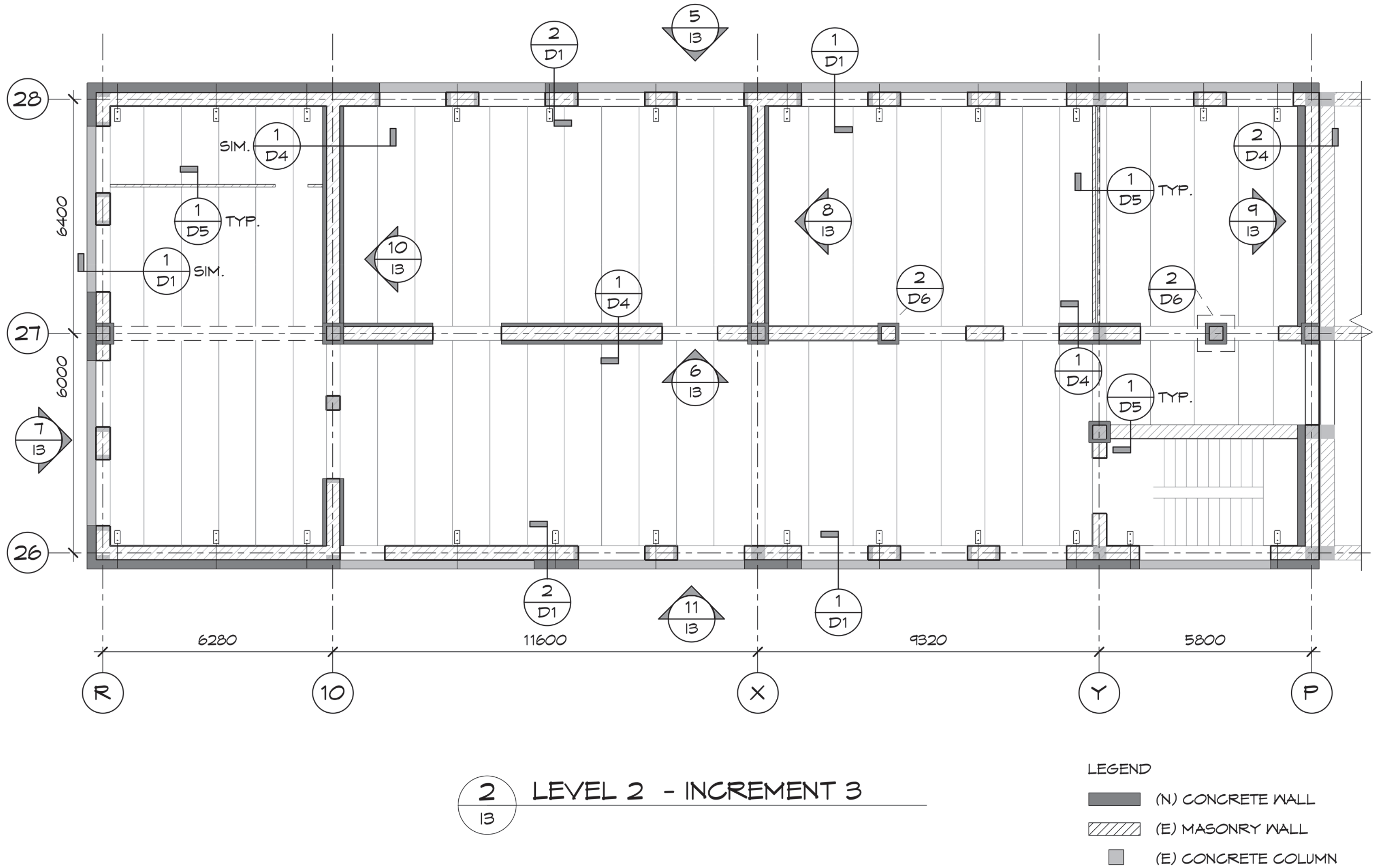
9/12 TRANSVERSE WALL GRID P - INCREMENT 2



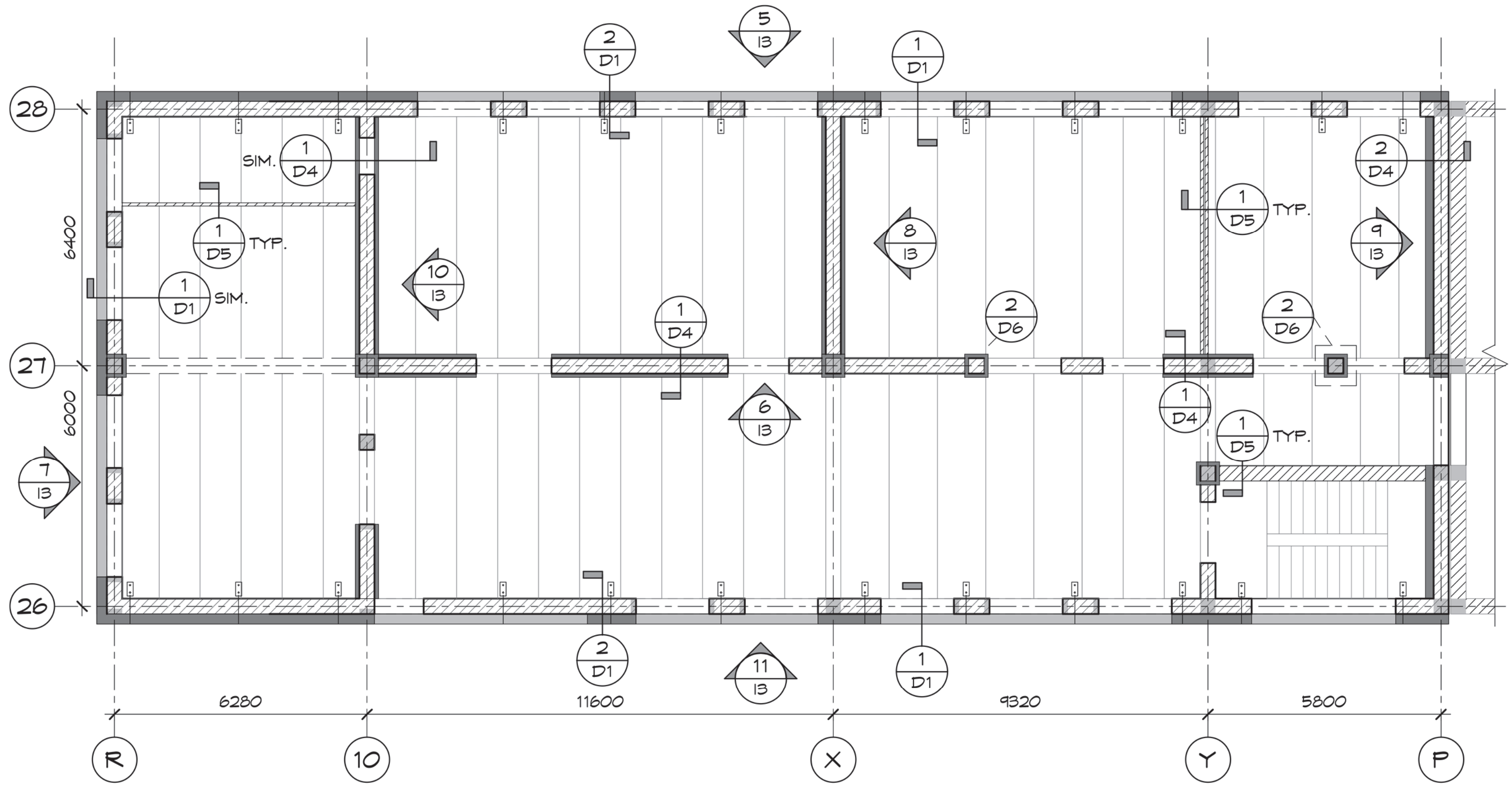
B
13
BASEMENT - INCREMENT 3



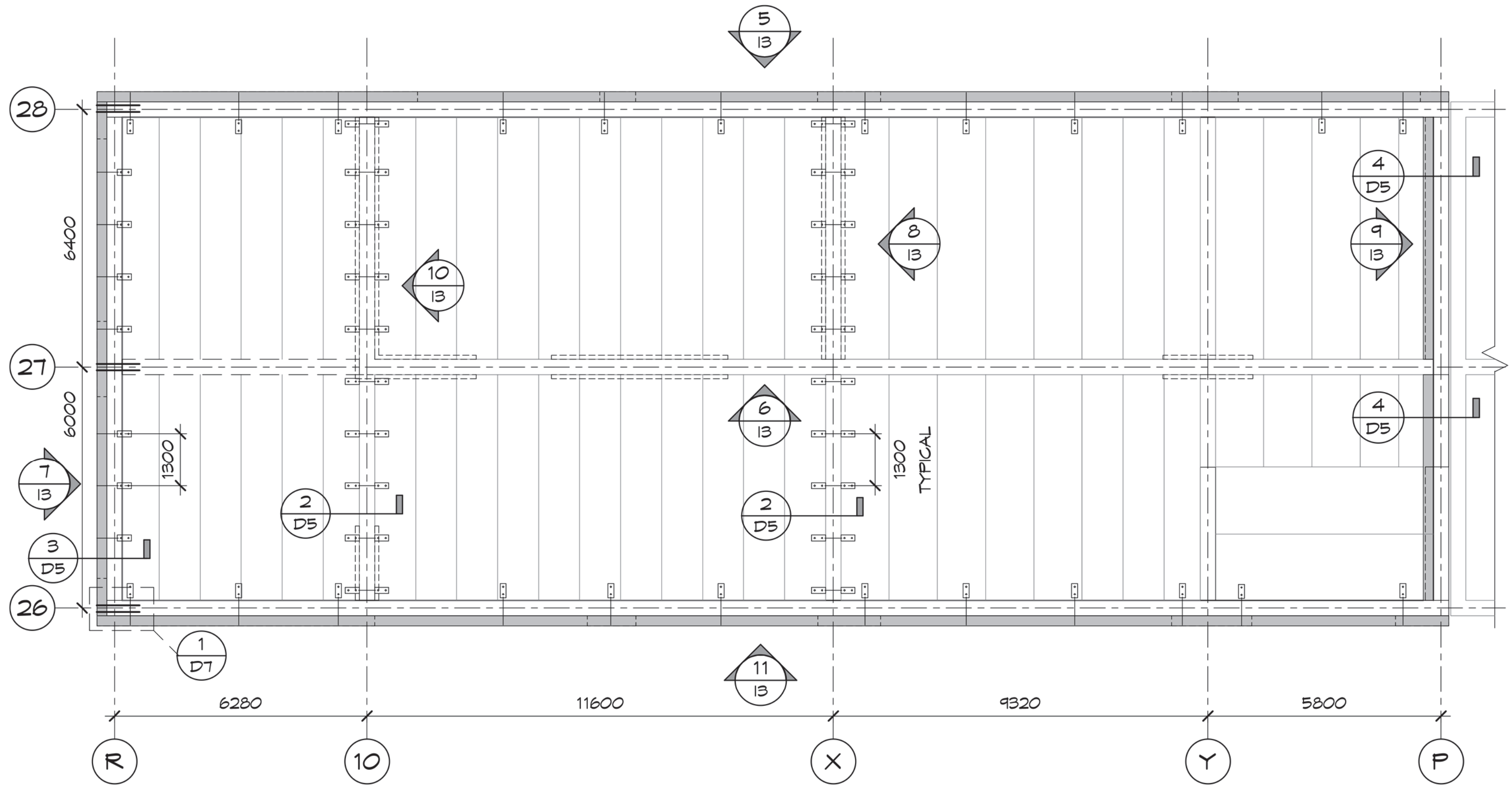
1/I3 LEVEL 1 - INCREMENT 3



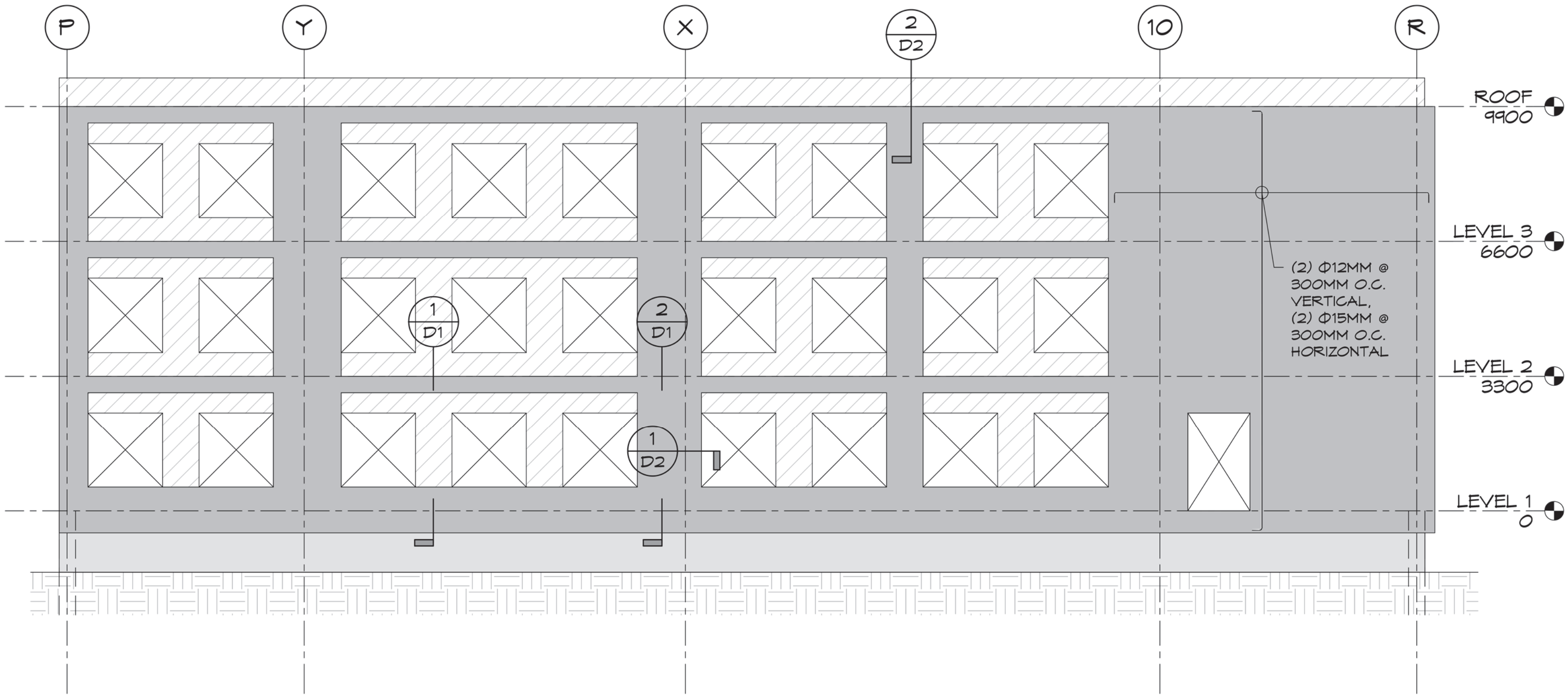
2 D1
5 13
1 D1
28
27
26
6400
6000
SIM.
1 D4
1 D5 TYP.
1 D1 SIM.
10 13
1 D4
8 13
2 D6
1 D5 TYP.
2 D4
9 13
2 D6
6 13
1 D4
1 D5 TYP.
7 13
2 D1
11 13
1 D1
6280
11600
9320
5800
R
10
X
Y
P
2 13 LEVEL 2 - INCREMENT 3
LEGEND
(N) CONCRETE WALL
(E) MASONRY WALL
(E) CONCRETE COLUMN



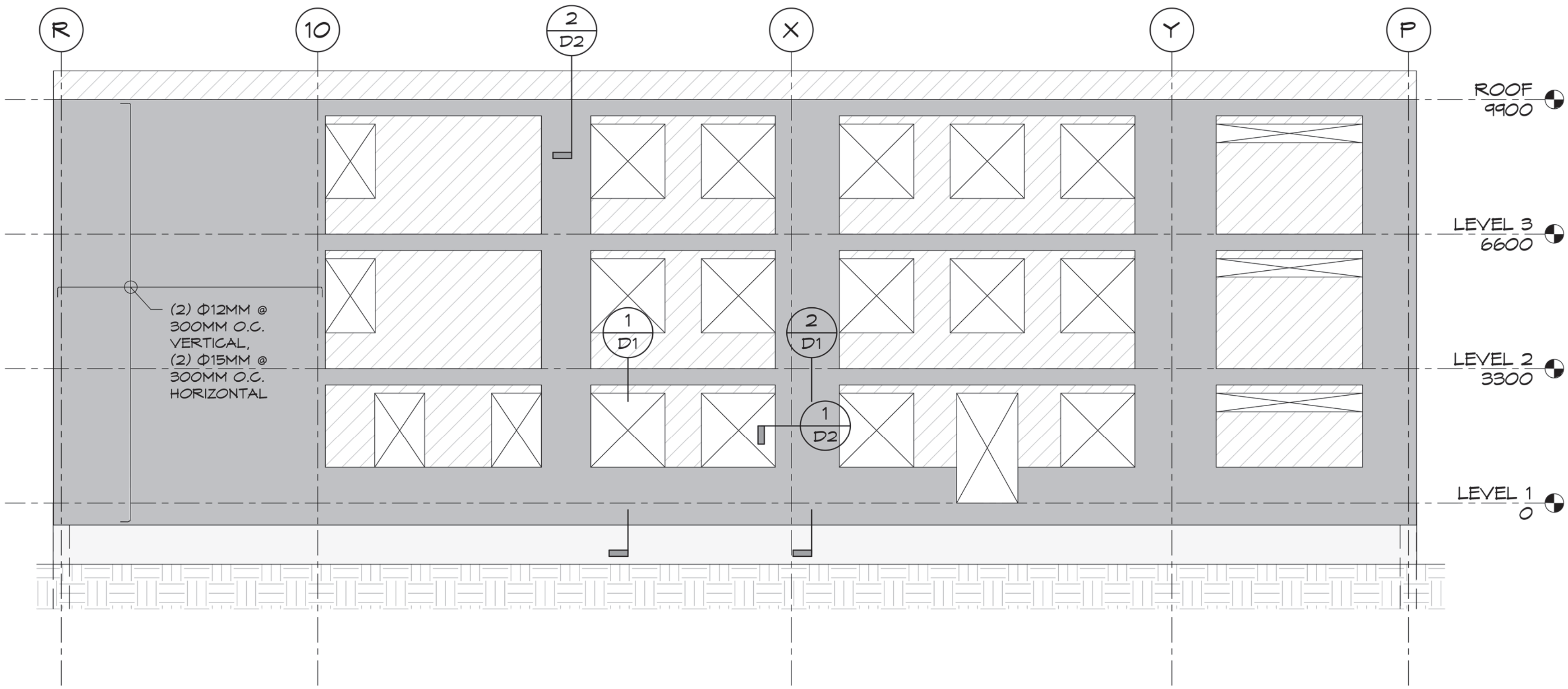
3 / I3 LEVEL 3 - INCREMENT 3



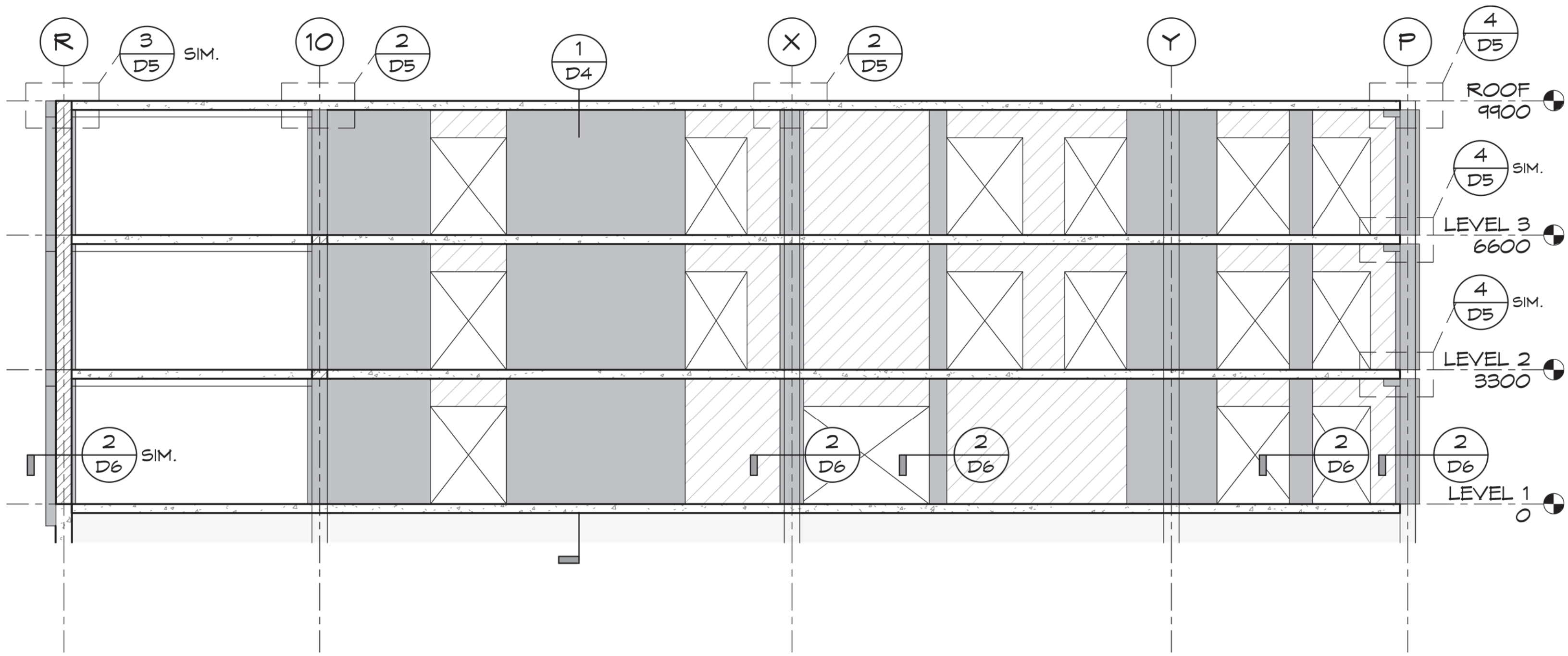
4 / 13 ROOF - INCREMENT 3



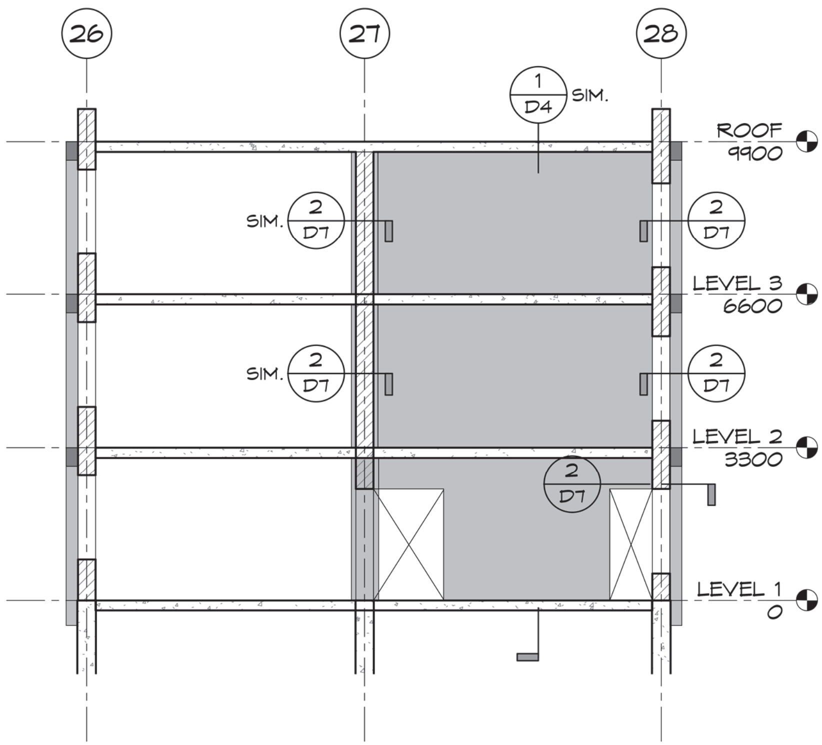
5
13
EXTERIOR LONGITUDINAL WALL - INCREMENT 3



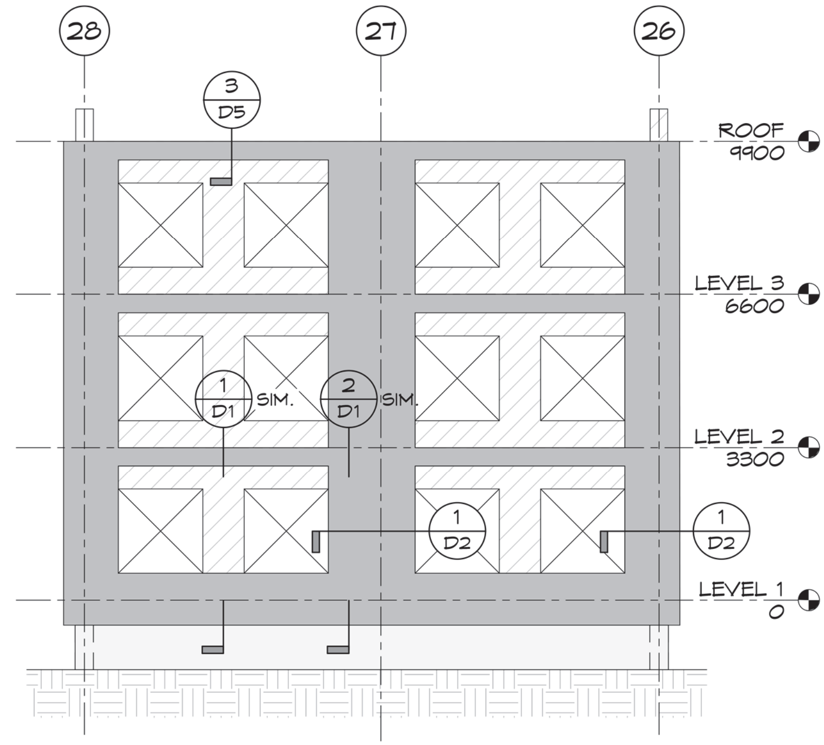
11/13 EXTERIOR LONGITUDINAL WALL GRID 26 - INCREMENT 3



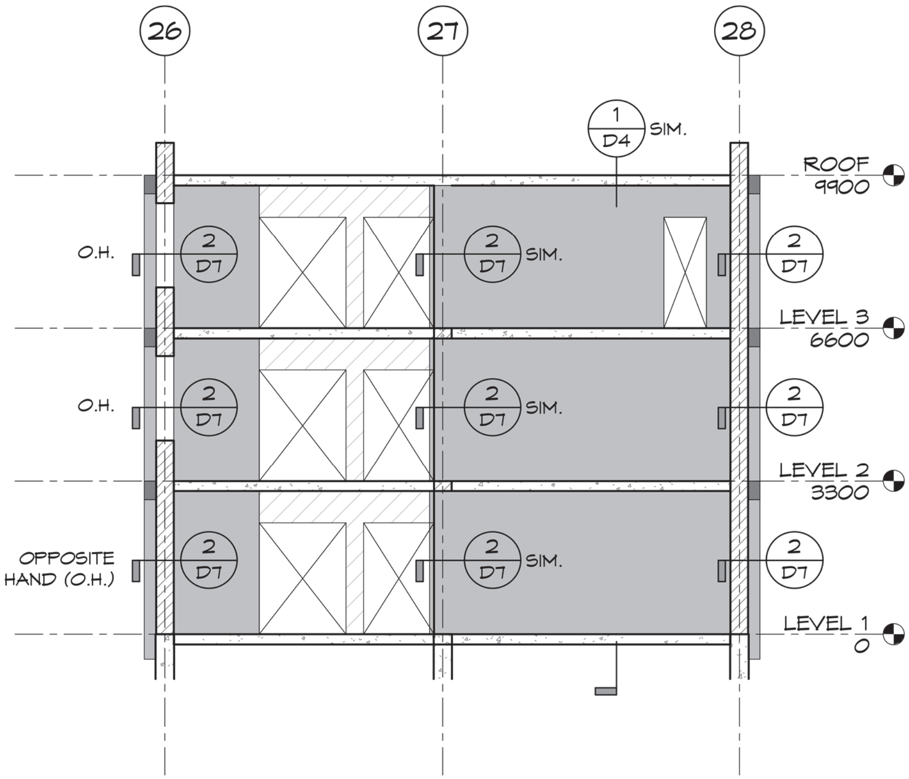
6/13 INTERIOR LONGITUDINAL WALL - INCREMENT 3



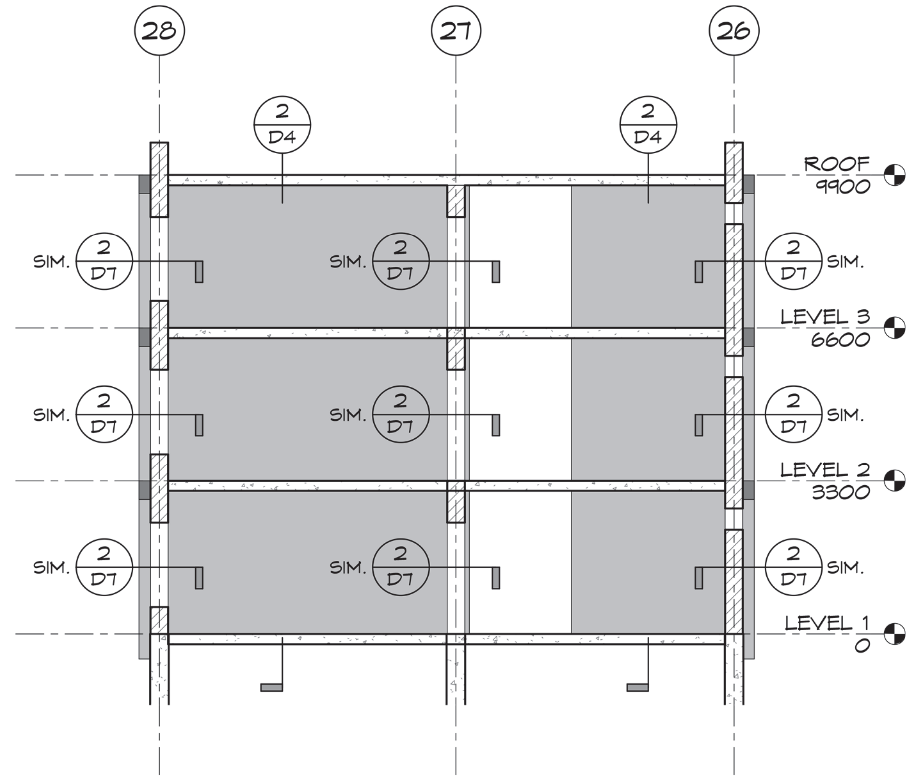
8/13 TRANSVERSE WALL GRID X - INCREMENT 3



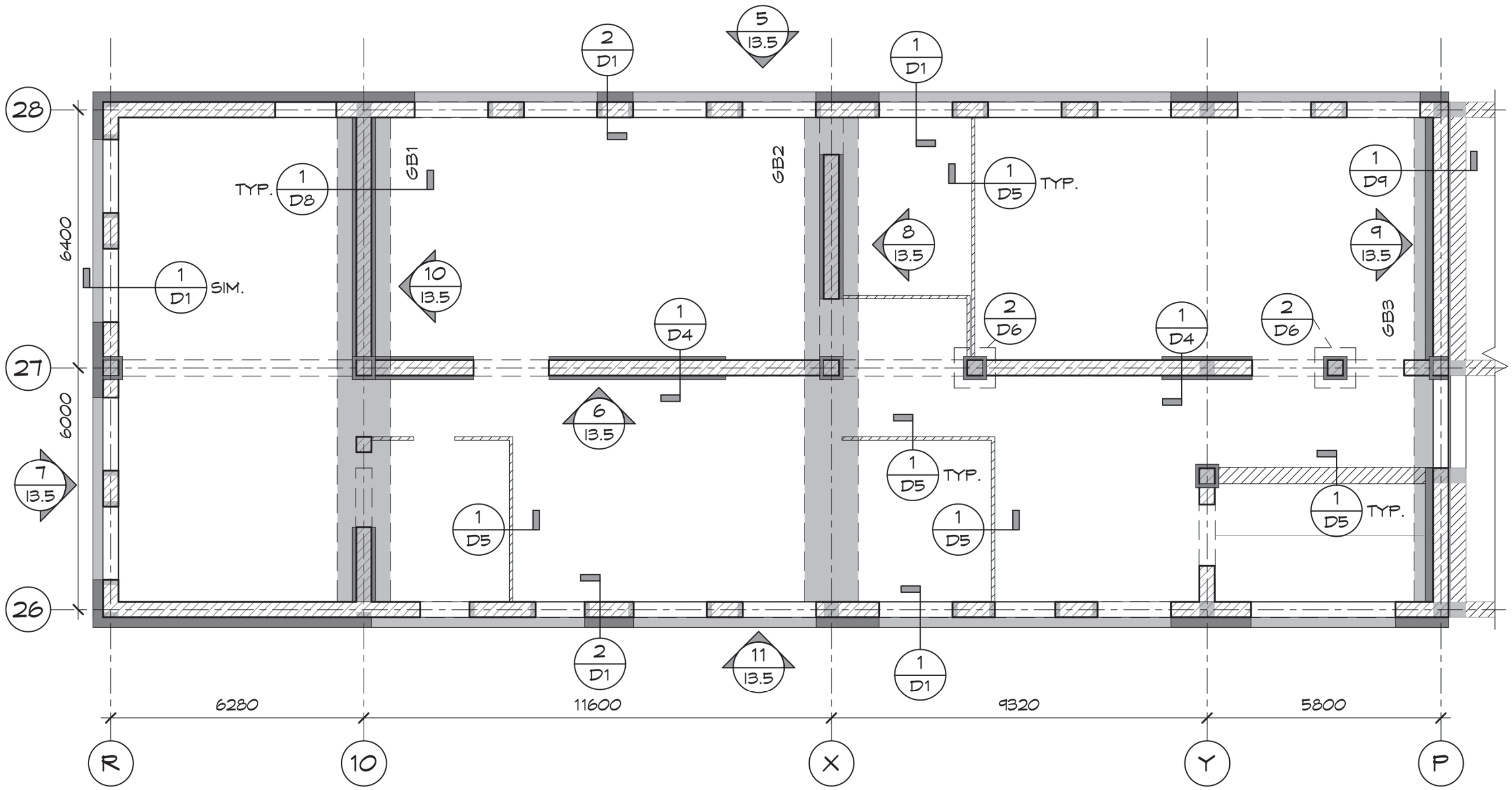
7/13 TRANSVERSE WALL GRID R - INCREMENT 3



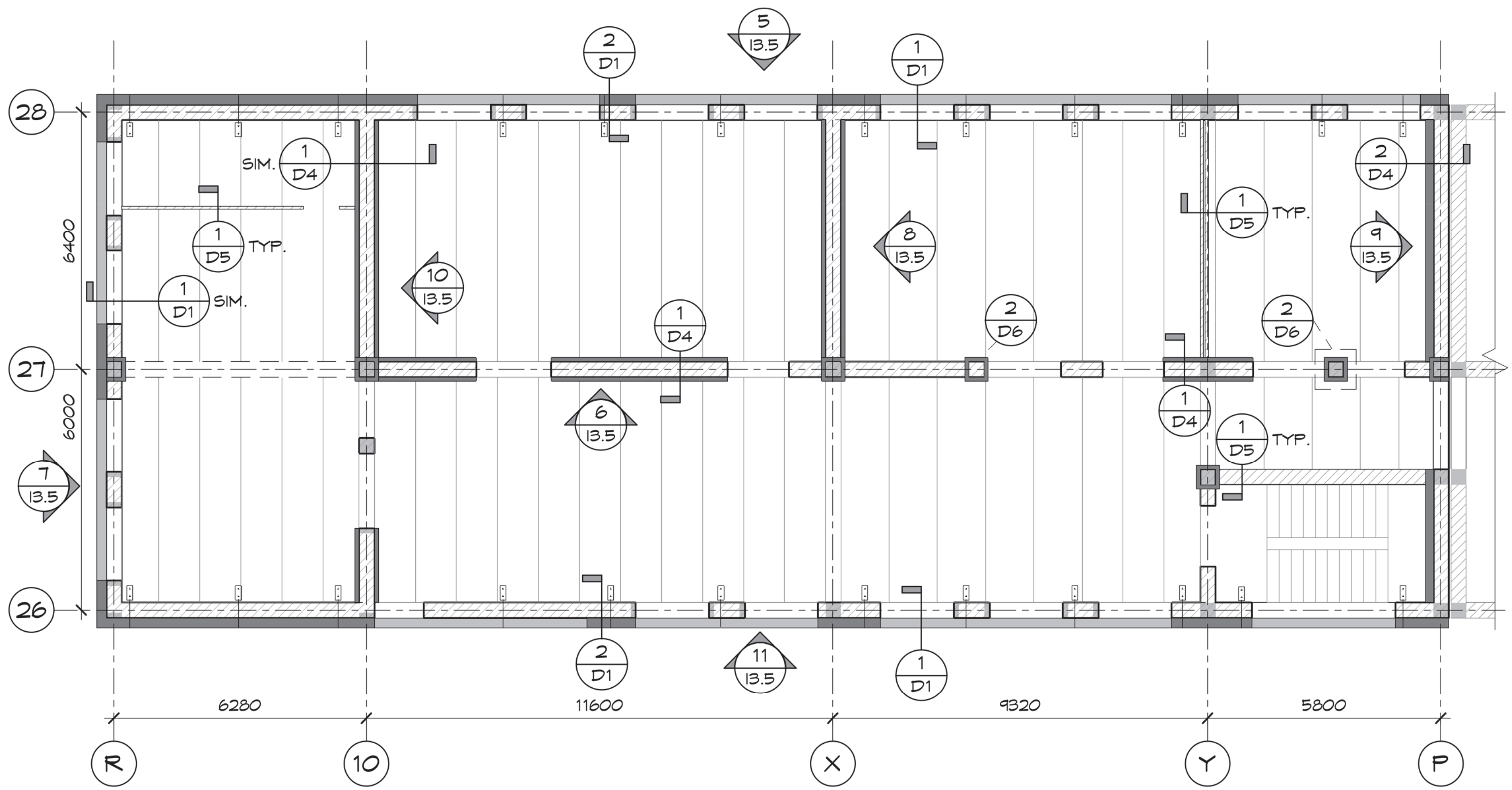
10 / 13 TRANSVERSE WALL GRID 10 - INCREMENT 3



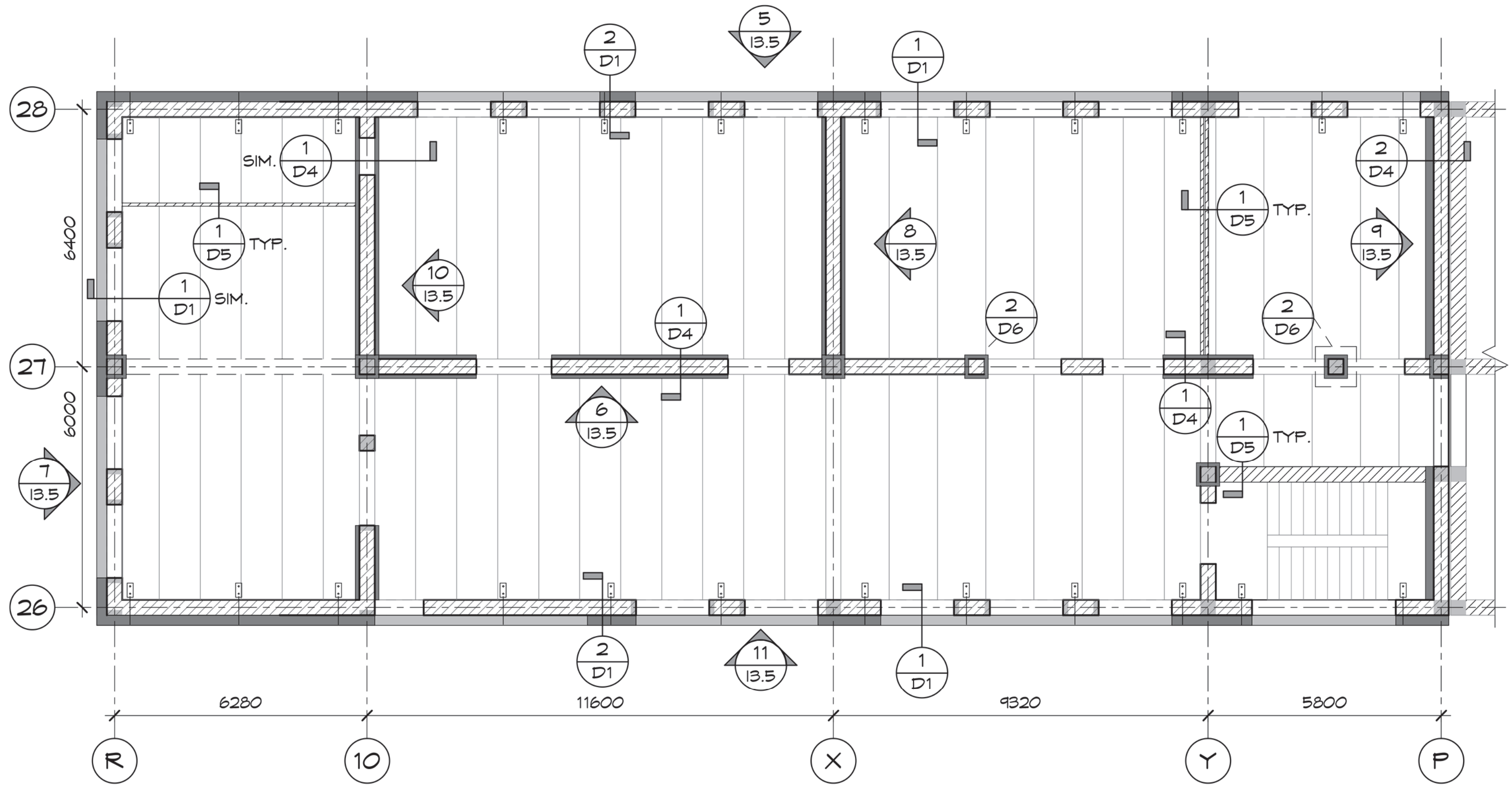
9 / 13 TRANSVERSE WALL GRID P - INCREMENT 3



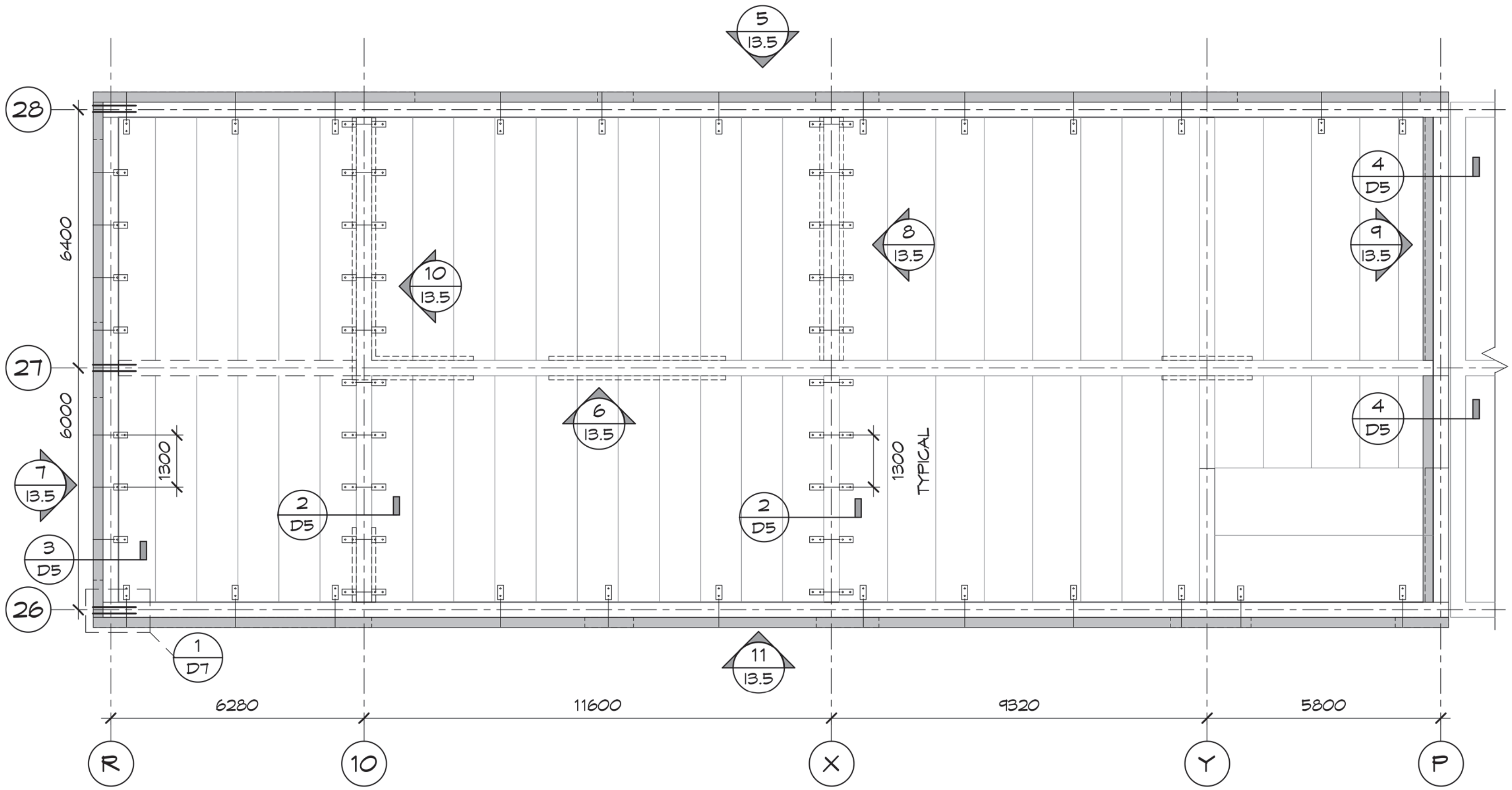
1 / 13.5 LEVEL 1 - INCREMENT 3.5



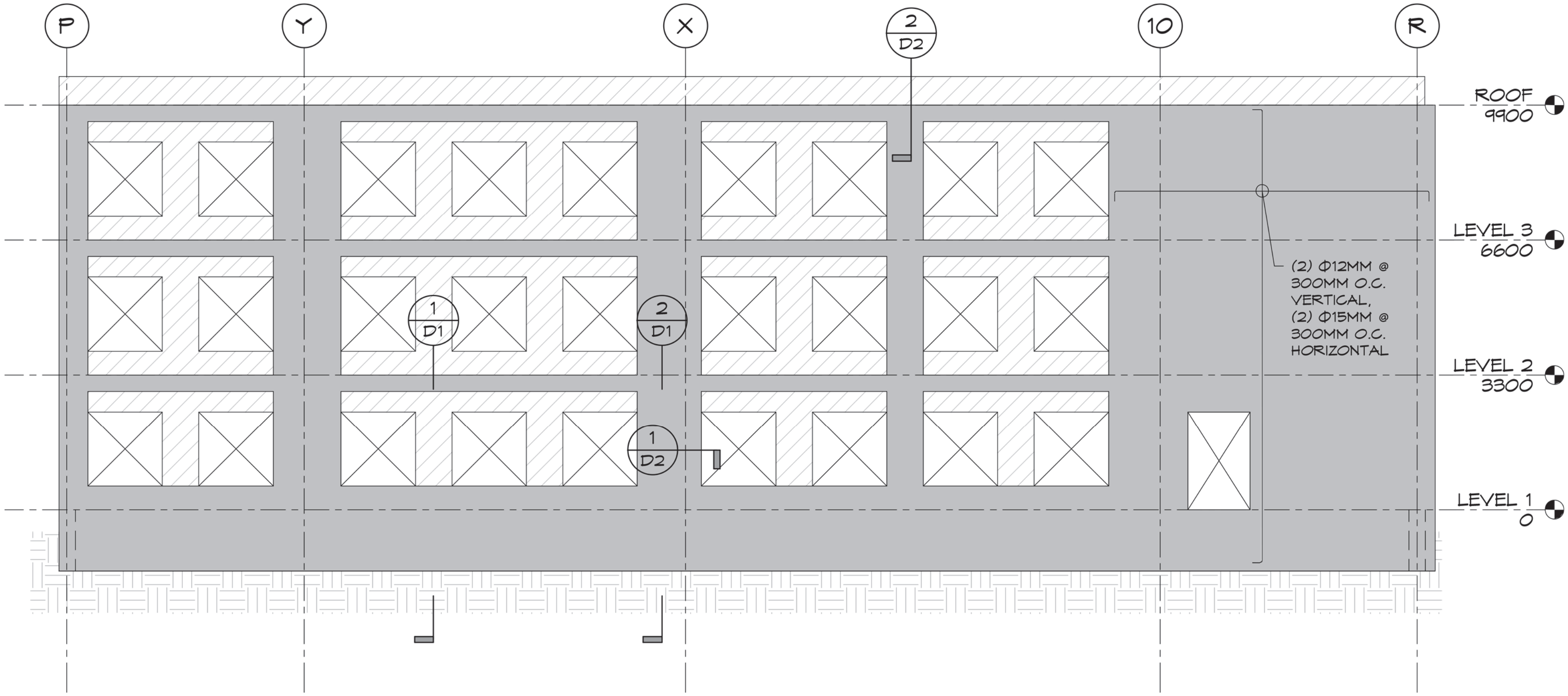
2/13.5 LEVEL 2 - INCREMENT 3.5



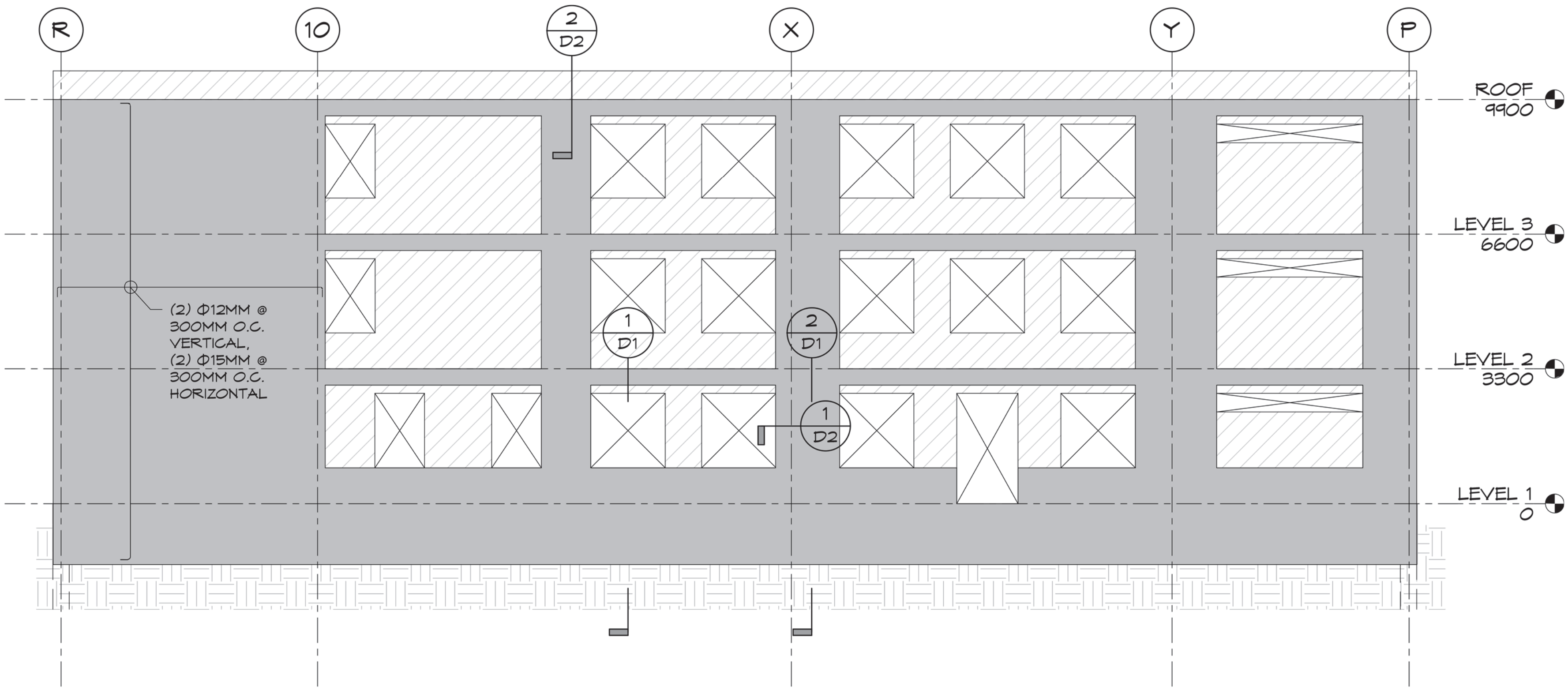
3 13.5 LEVEL 3 - INCREMENT 3.5



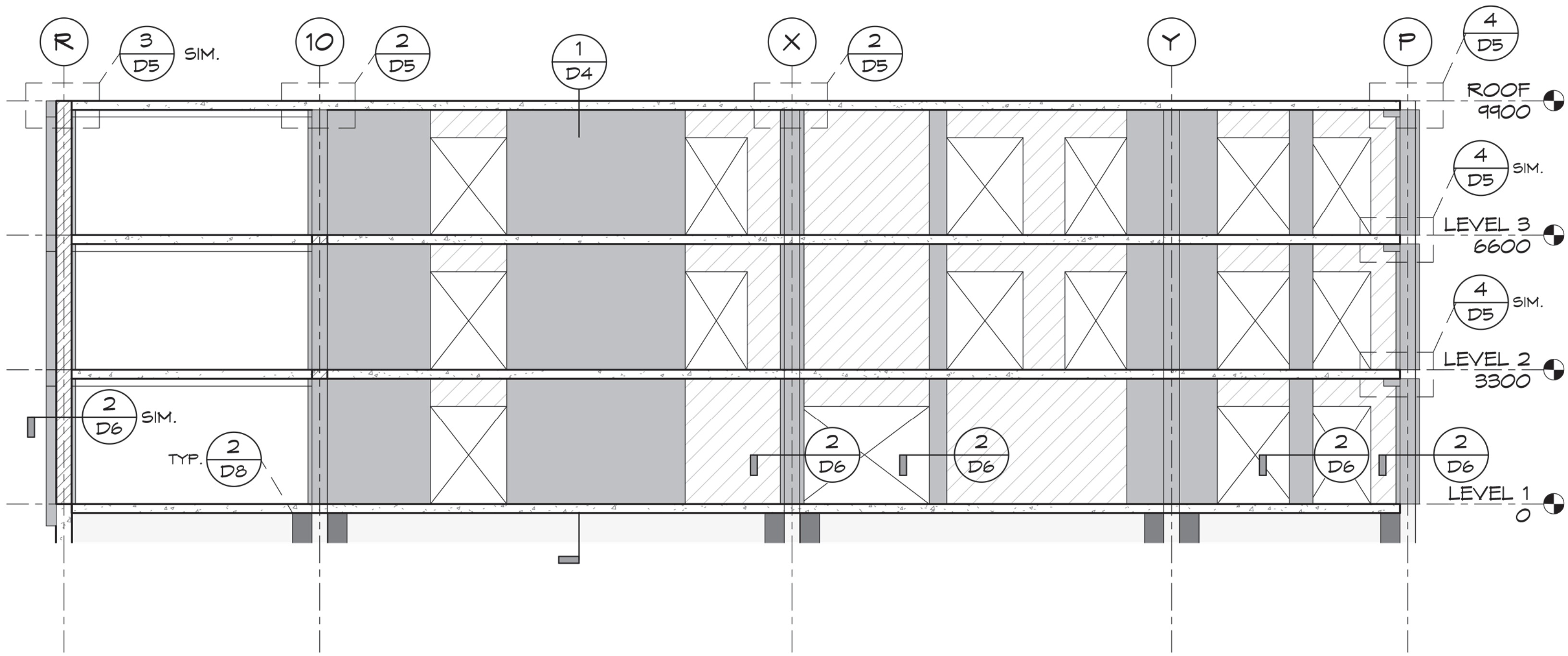
4 / 13.5 ROOF - INCREMENT 3.5



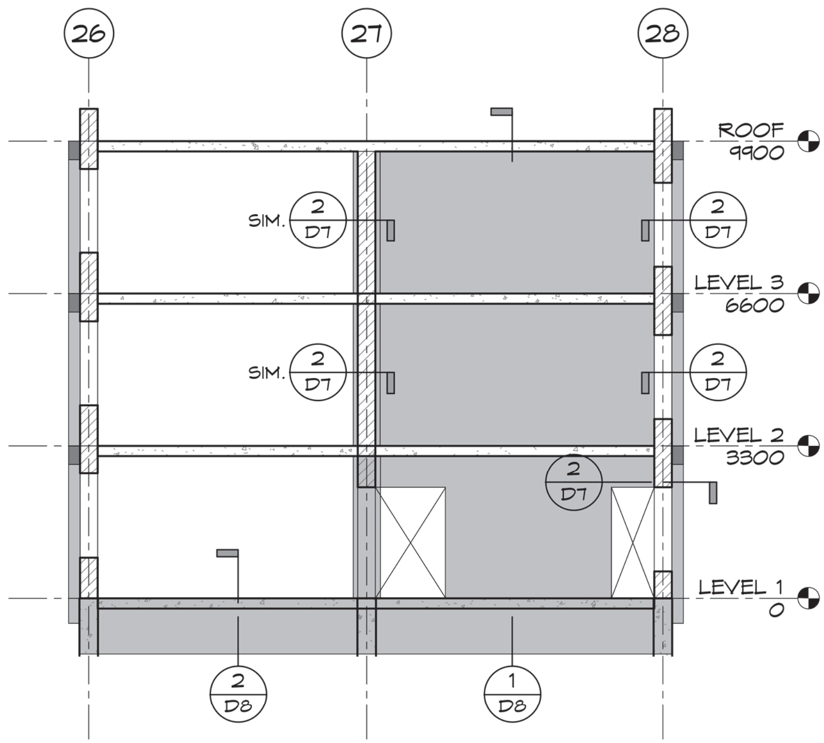
5
13.5
EXTERIOR LONGITUDINAL WALL - INCREMENT 3.5



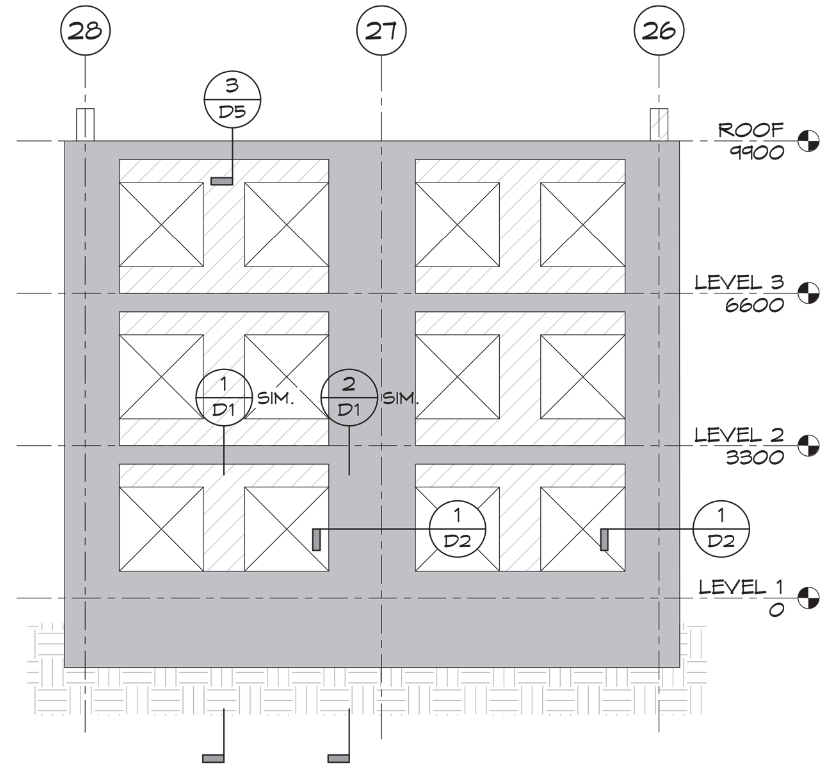
11
13.5
EXTERIOR LONGITUDINAL WALL GRID 26 - INCREMENT 3.5



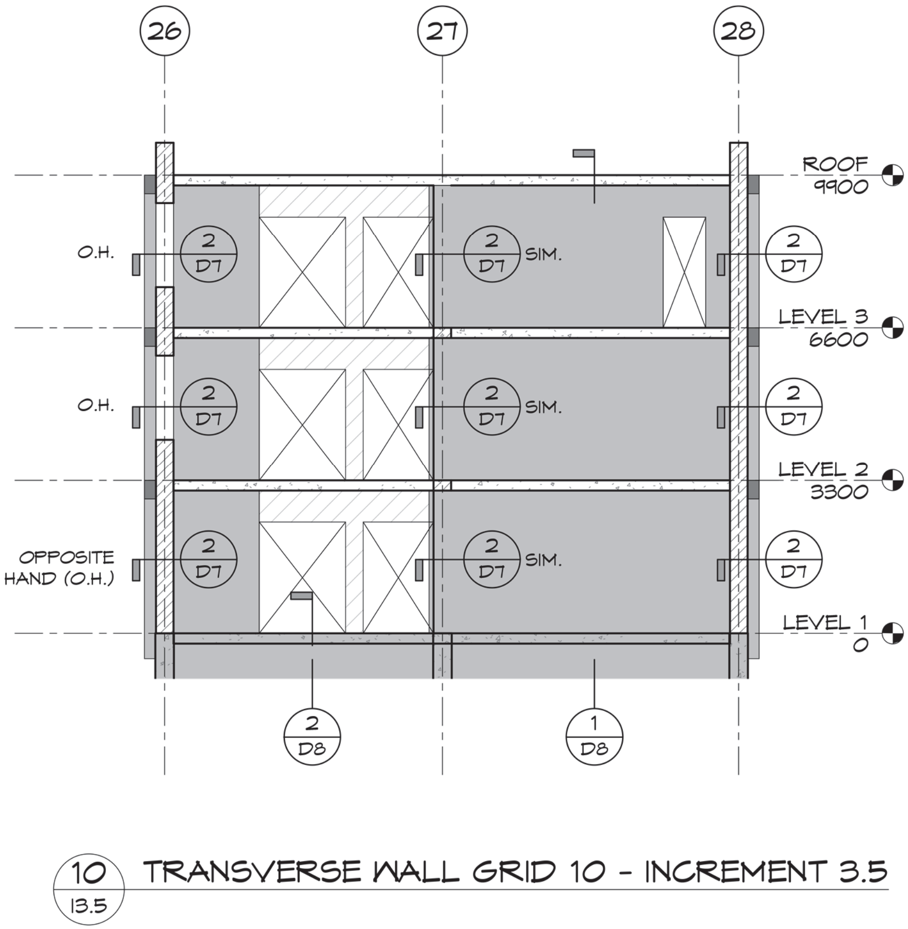
6
13.5
INTERIOR LONGITUDINAL WALL - INCREMENT 3.5

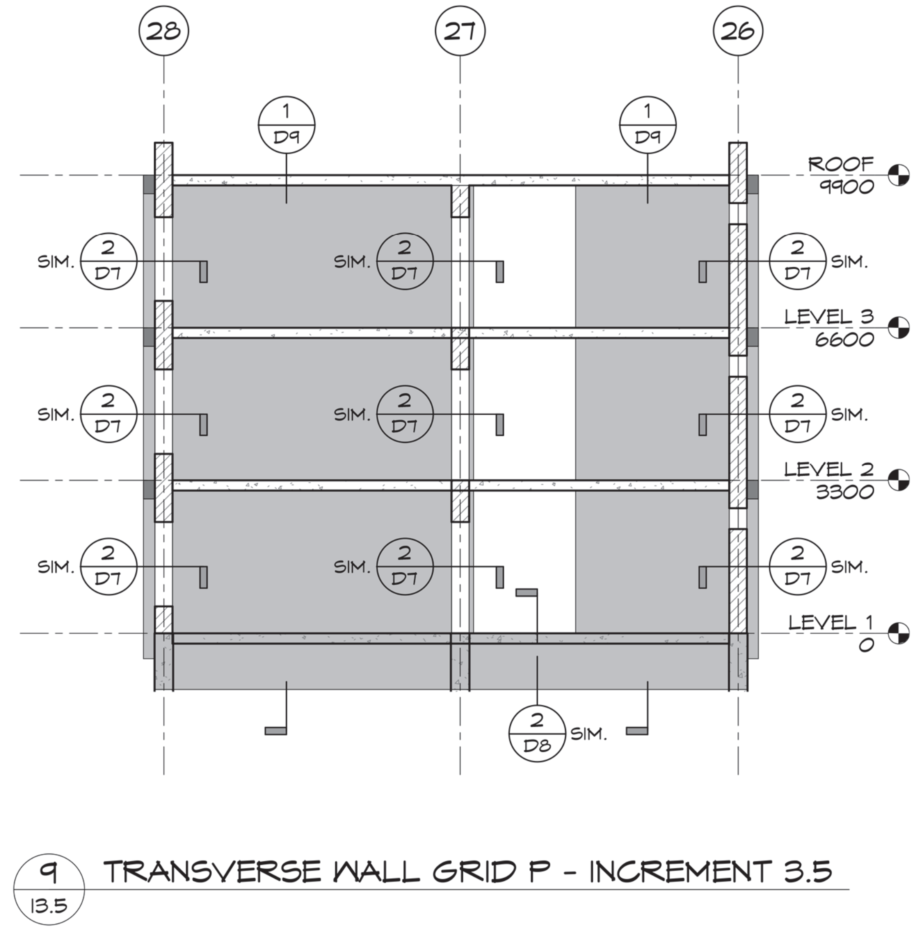


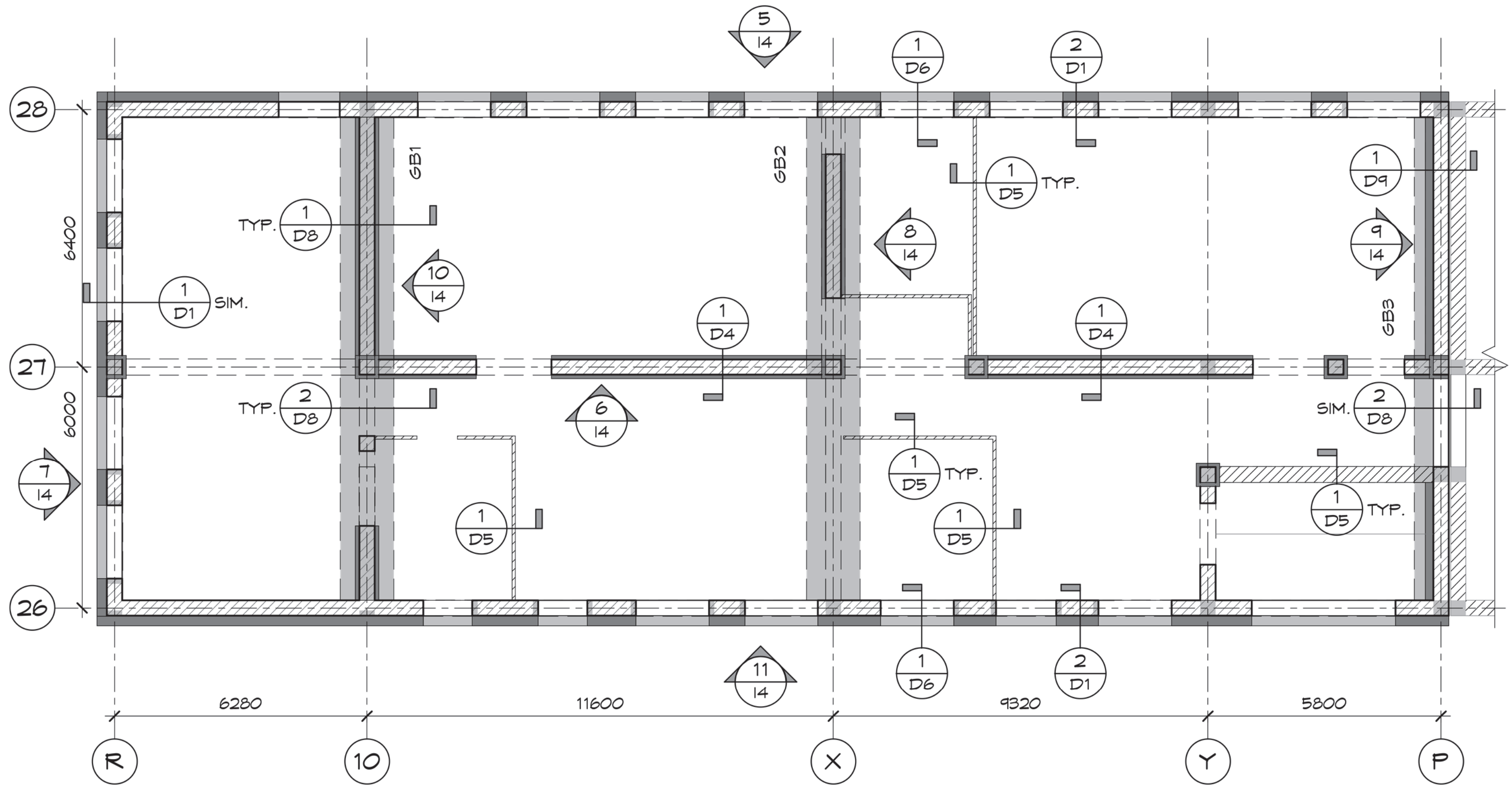
8/13.5 TRANSVERSE WALL GRID X - INCREMENT 3.5



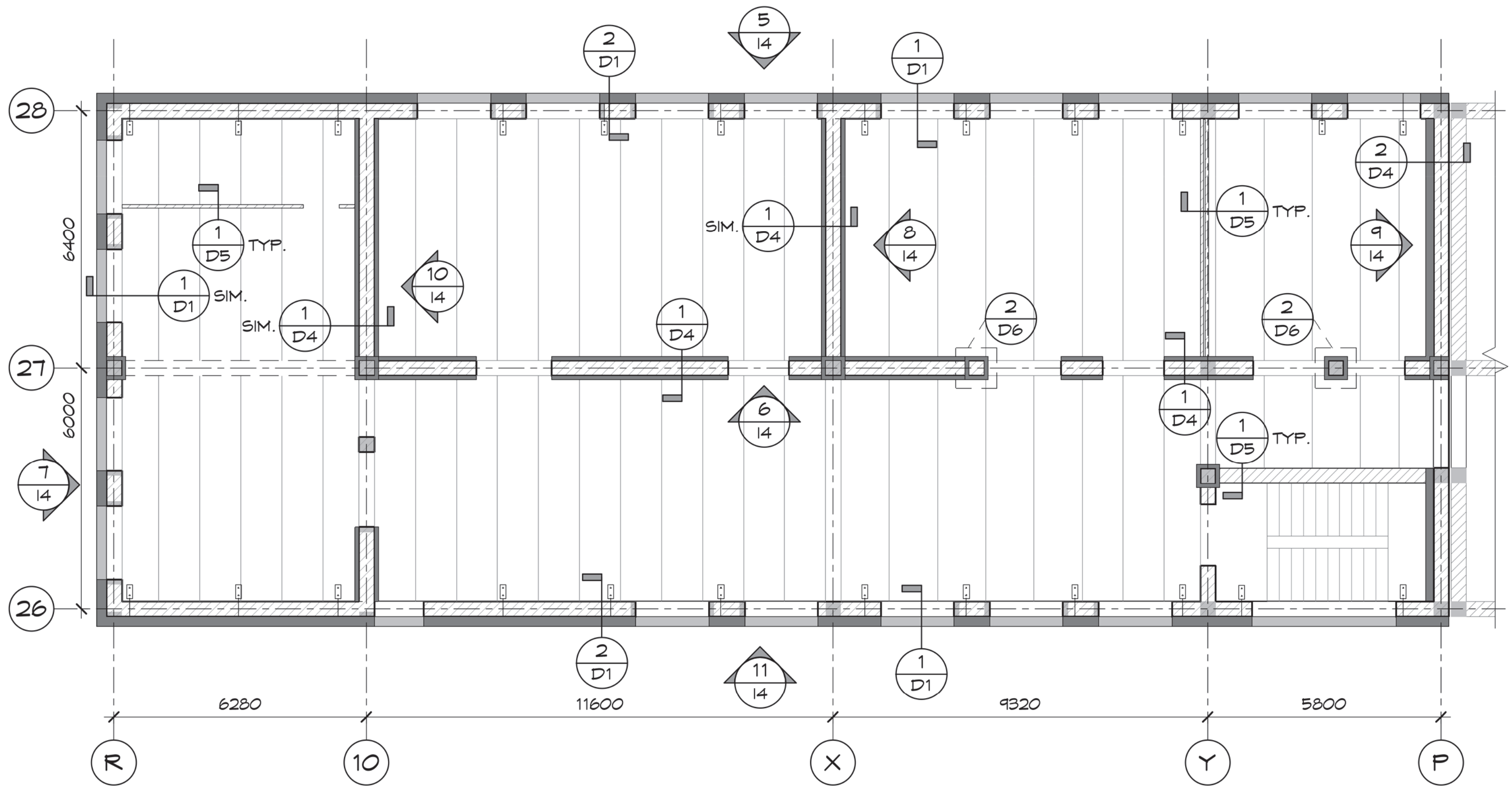
7/13.5 TRANSVERSE WALL GRID R - INCREMENT 3.5


26
27
28
ROOF
9900
LEVEL 3
6600
LEVEL 2
3300
LEVEL 1
0
O.H.
O.H.
OPPOSITE
HAND (O.H.)
2
D7
SIM.
2
D8
1
D8
10
13.5
TRANSVERSE WALL GRID 10 - INCREMENT 3.5

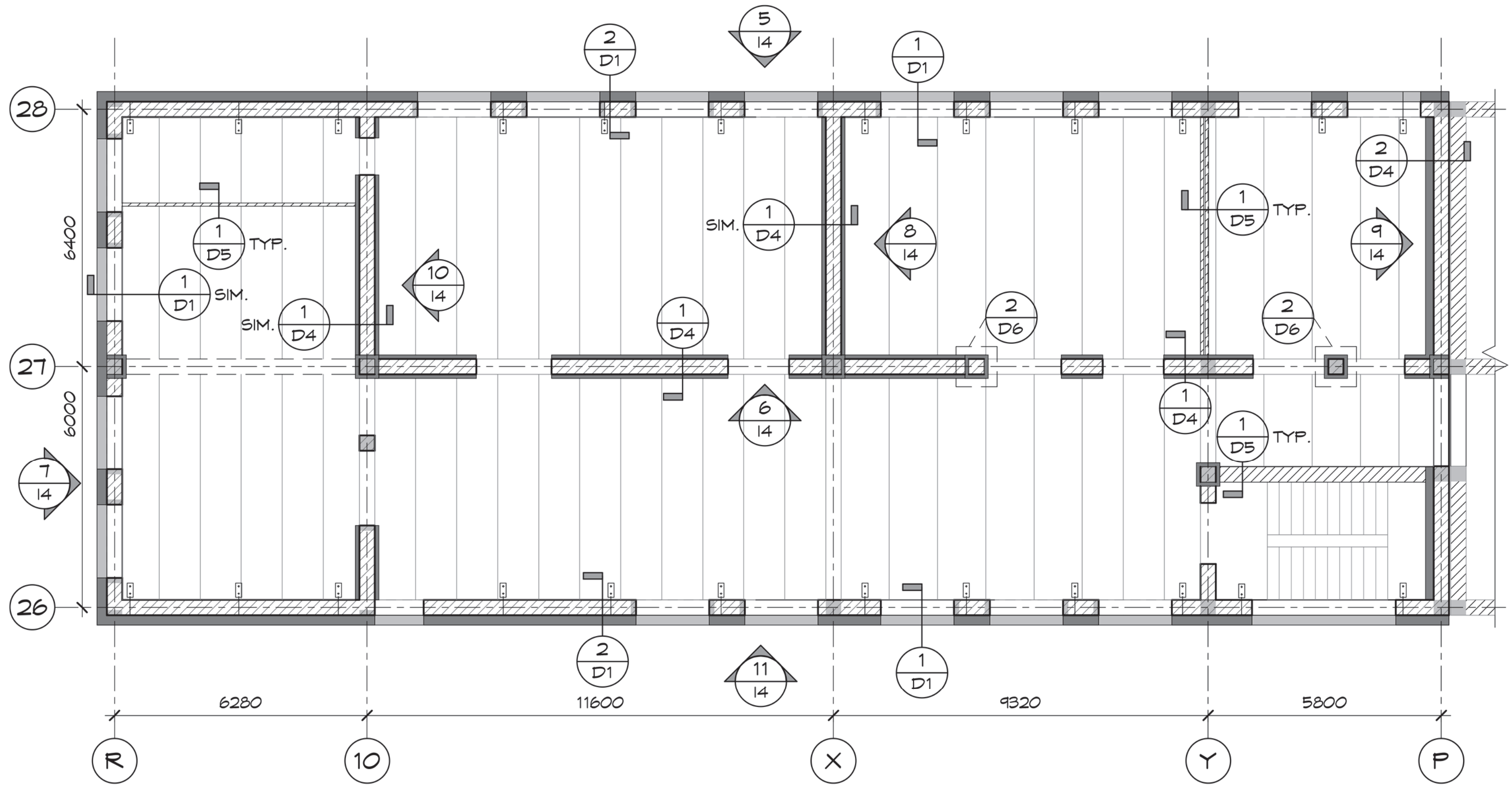

28
27
26
1
D9
ROOF
9900
LEVEL 3
6600
LEVEL 2
3300
LEVEL 1
0
2
D7
SIM.
2
D8
9
13.5
TRANSVERSE WALL GRID P - INCREMENT 3.5



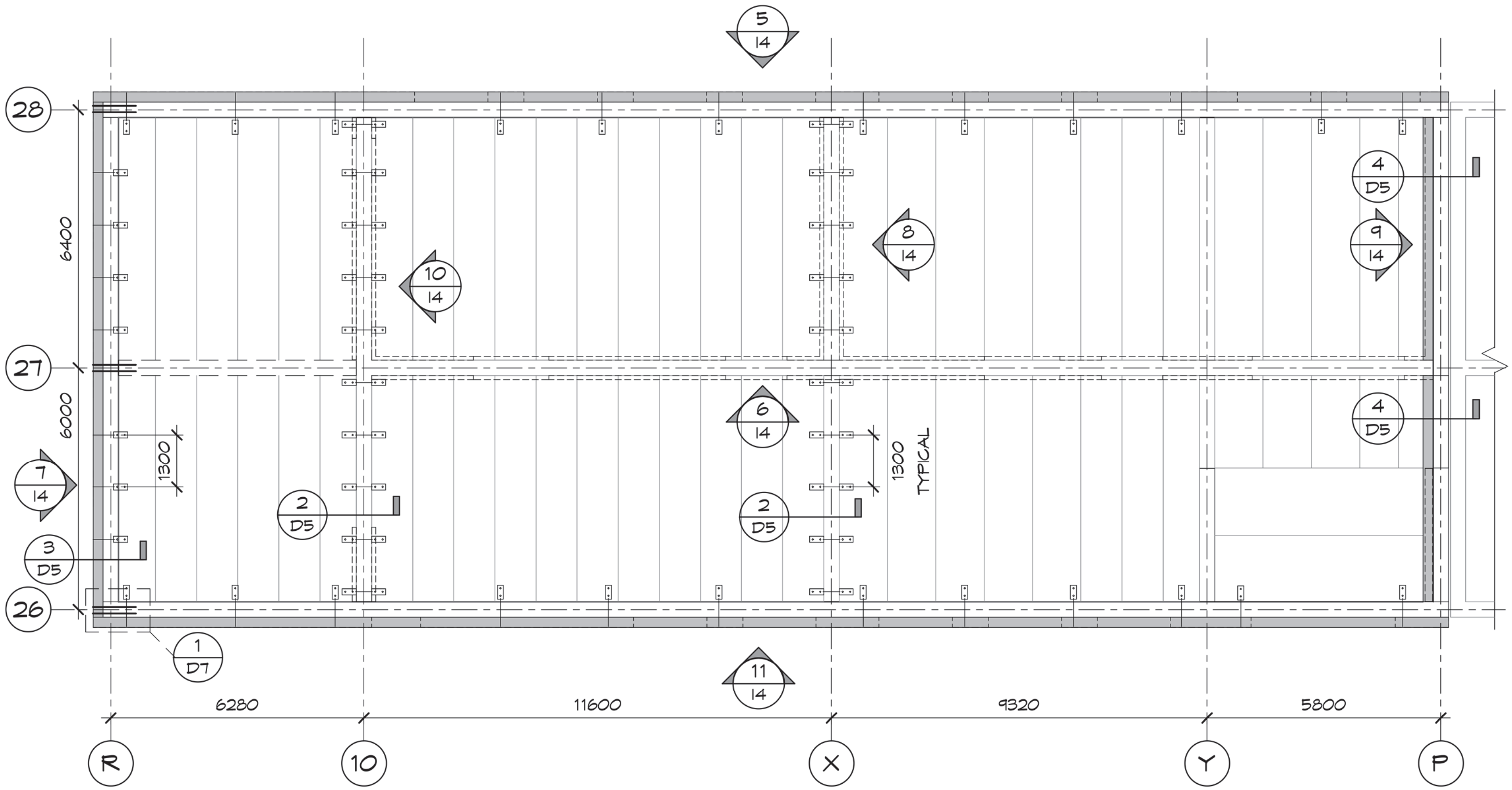
1 / I4 LEVEL 1 - INCREMENT 4



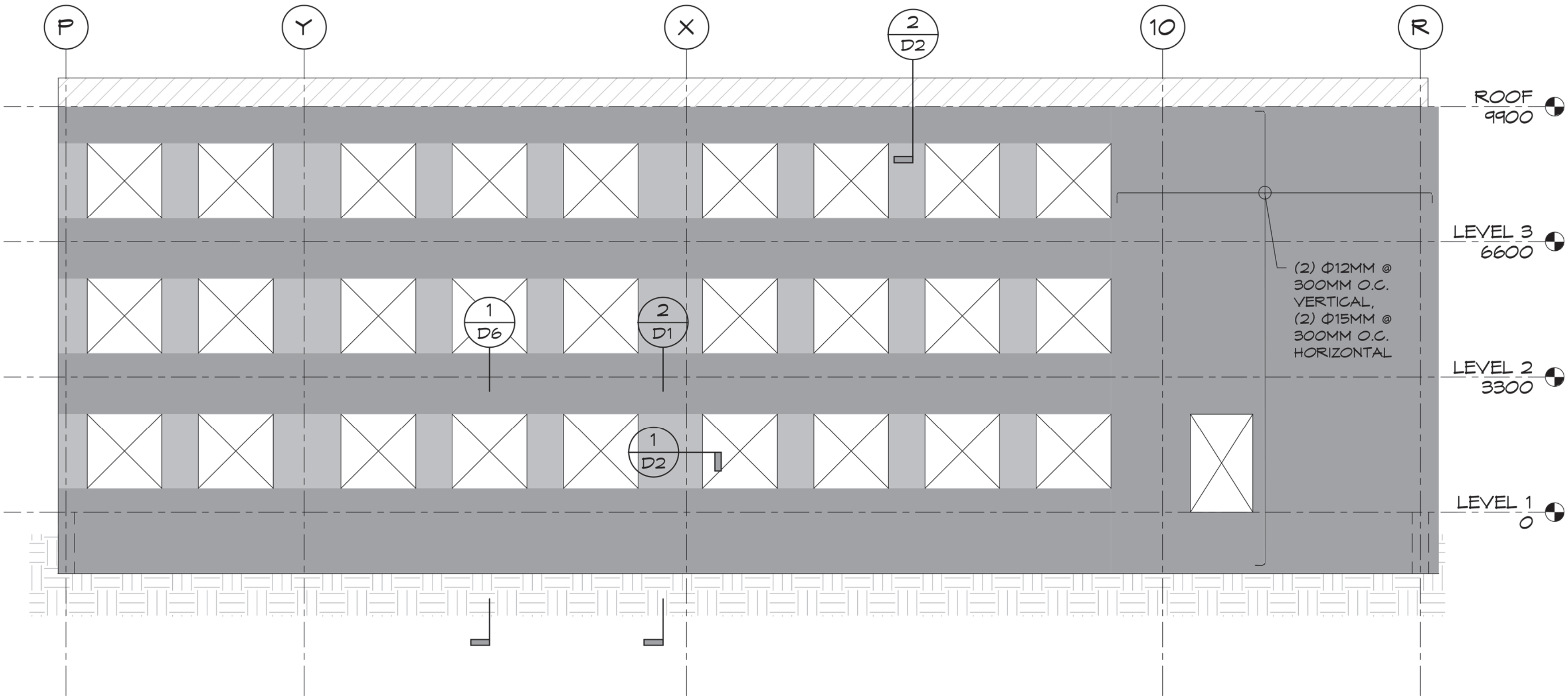
2/I4 LEVEL 2 - INCREMENT 4



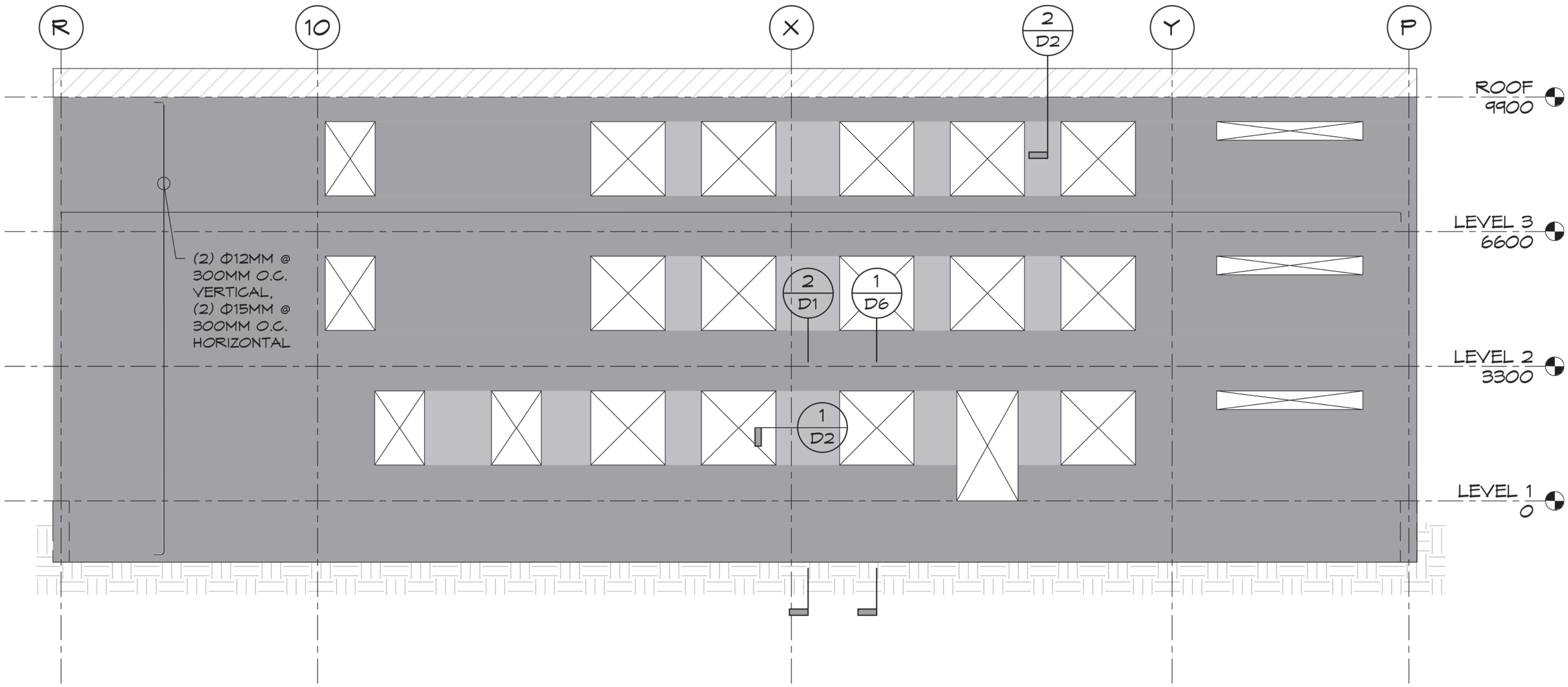
3/I4 LEVEL 3 - INCREMENT 4



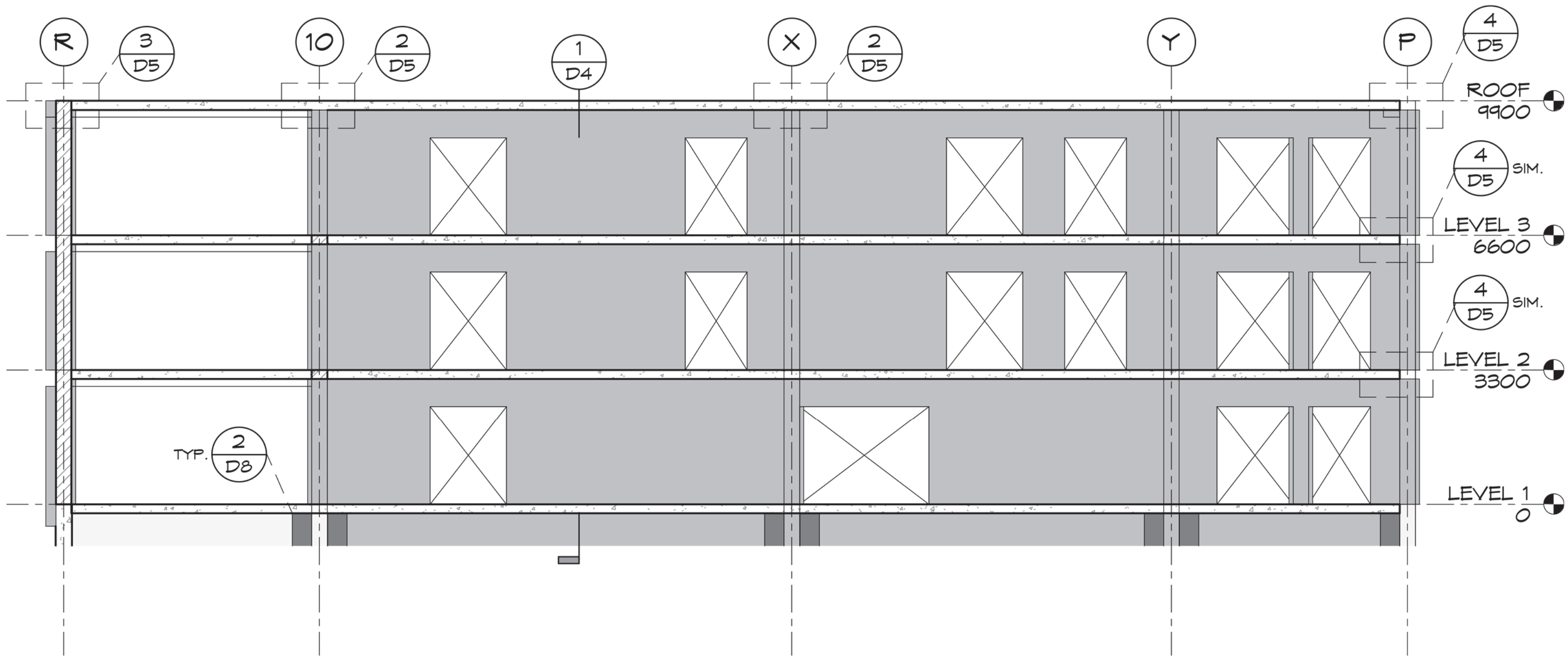
4/14 ROOF - INCREMENT 4



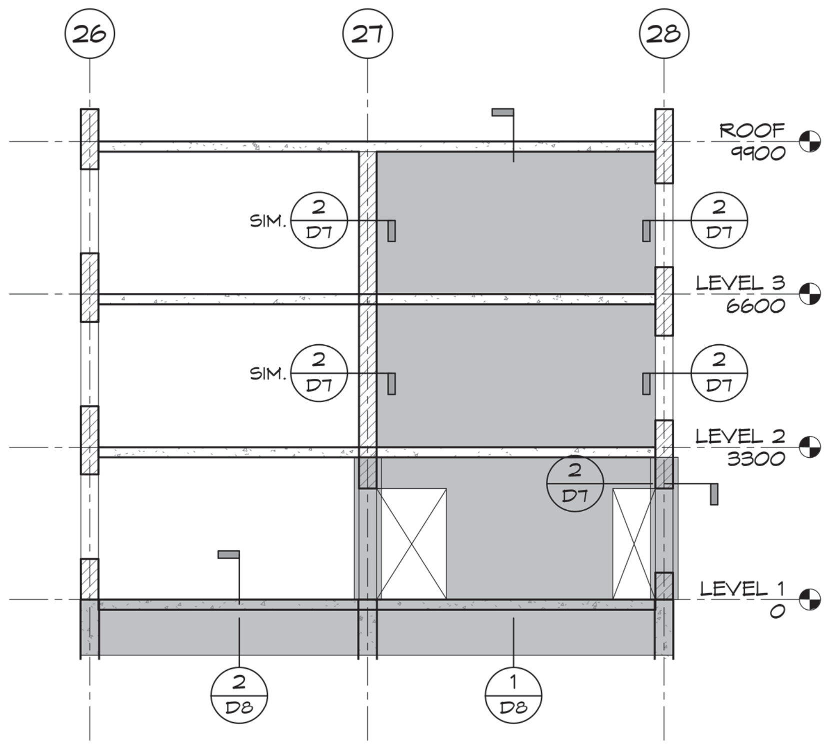
5
14
EXTERIOR LONGITUDINAL WALL - INCREMENT 4



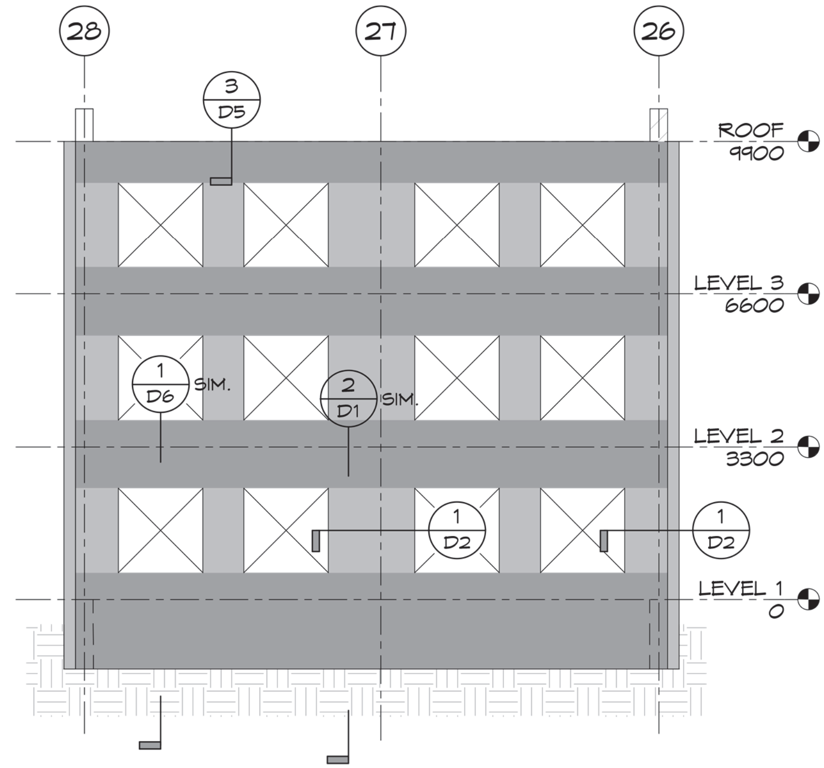
11/14 EXTERIOR LONGITUDINAL WALL GRID 26 - INCREMENT 4



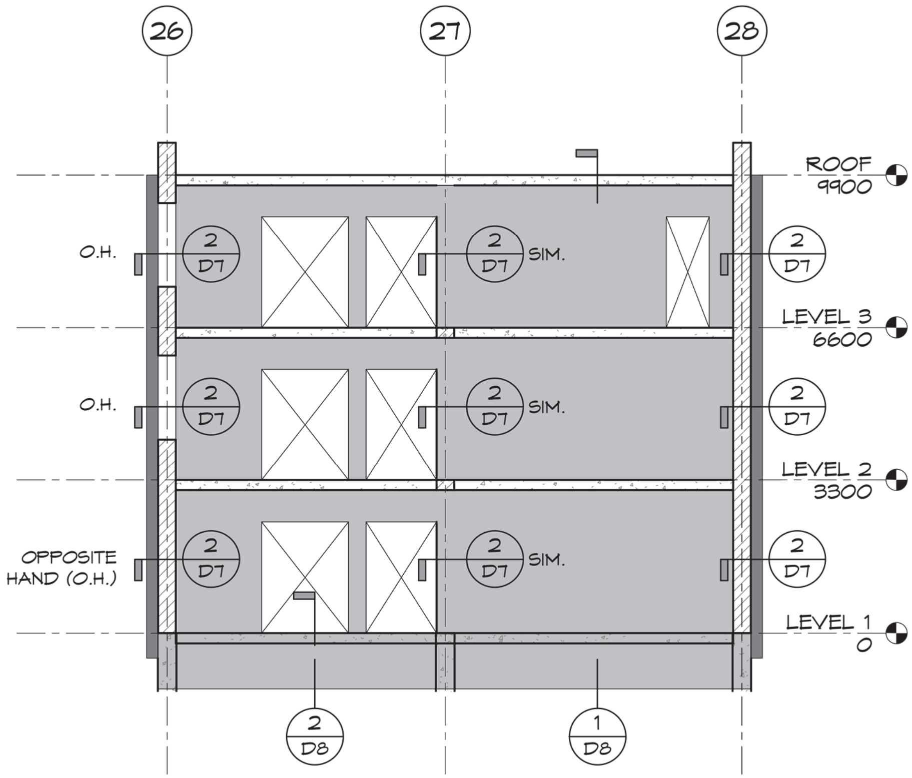
6 / 14 INTERIOR LONGITUDINAL WALL - INCREMENT 4



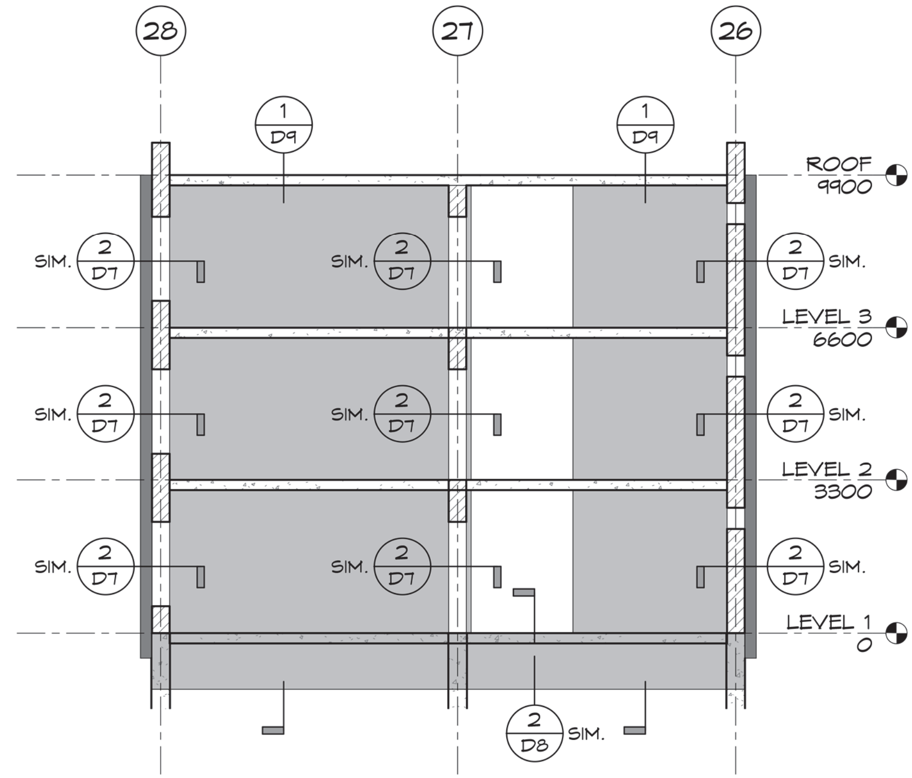
8
14
TRANSVERSE WALL GRID X - INCREMENT 4



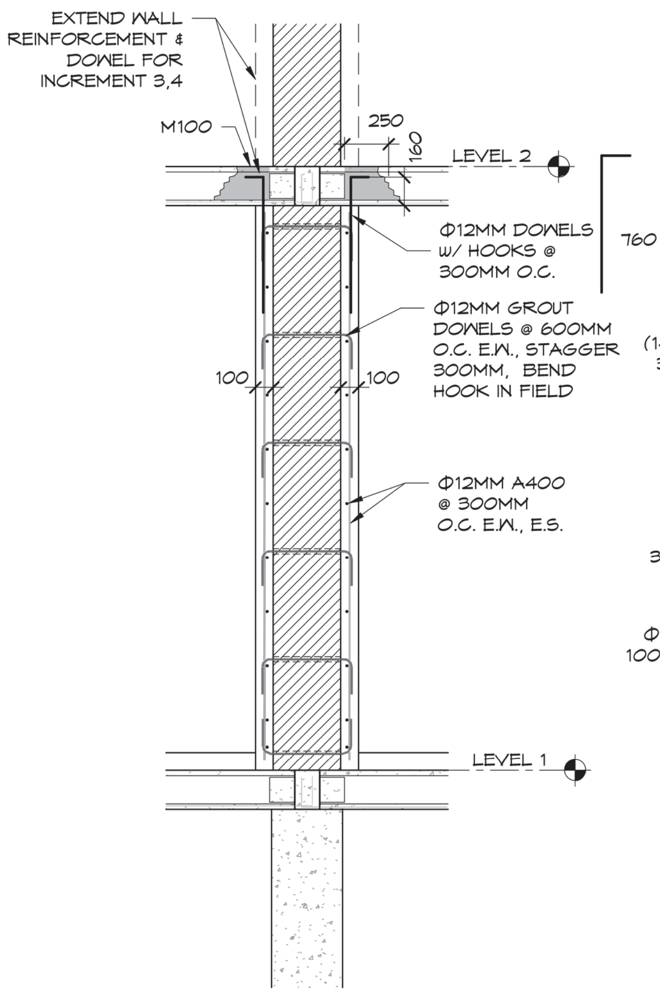
7
14
TRANSVERSE WALL GRID R - INCREMENT 4



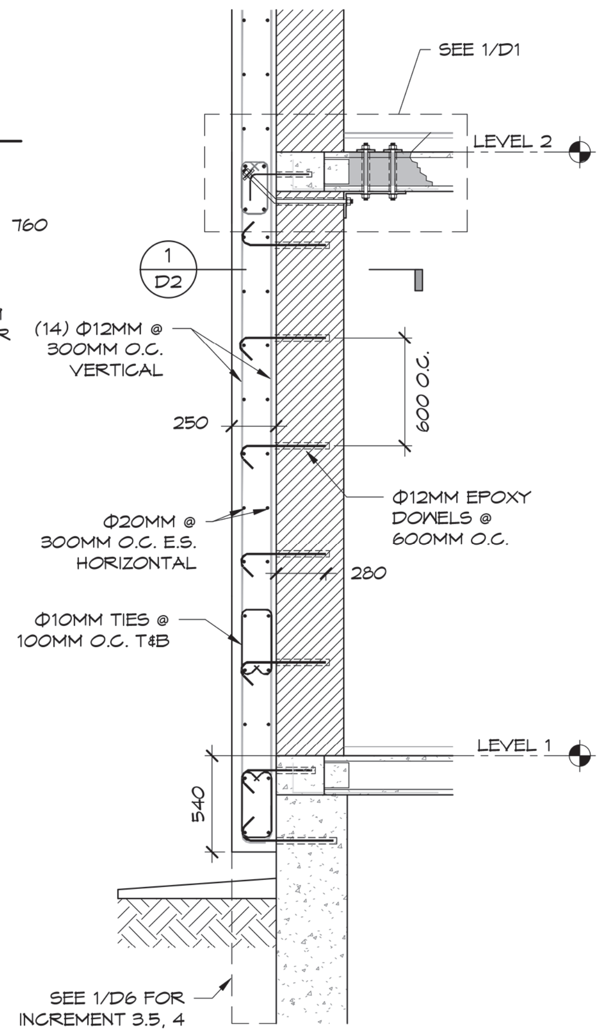
10 / 14 TRANSVERSE WALL GRID 10 - INCREMENT 4



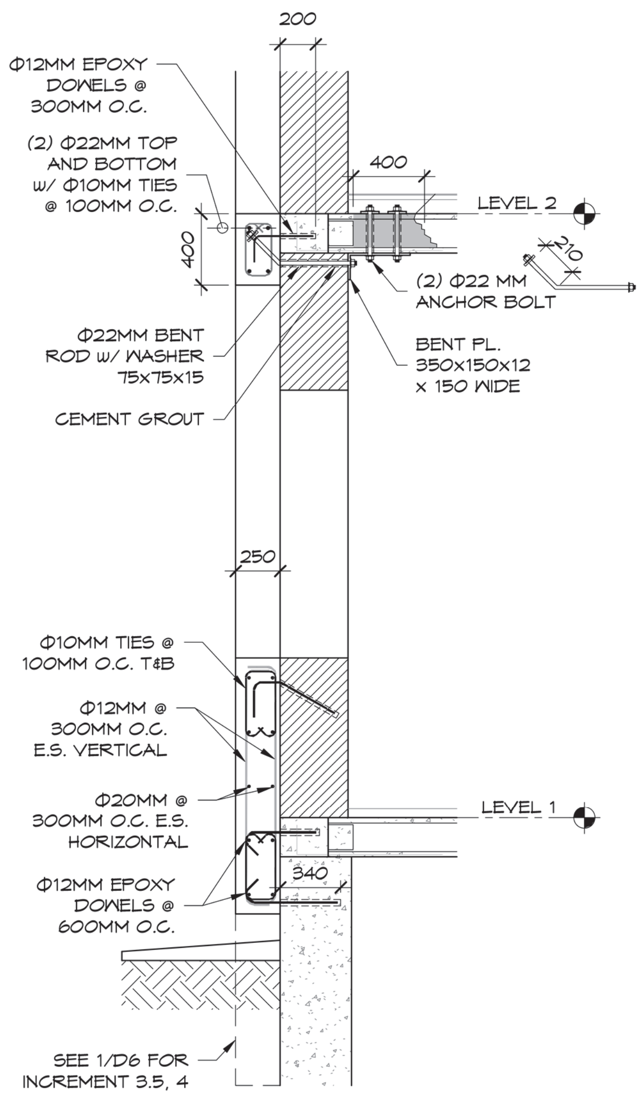
9 / 14 TRANSVERSE WALL GRID P - INCREMENT 4



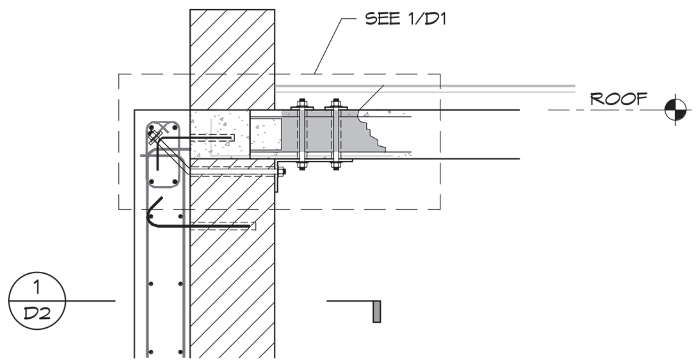
3 / D1 INTERIOR LONGITUDINAL WALL
INCREMENT 2



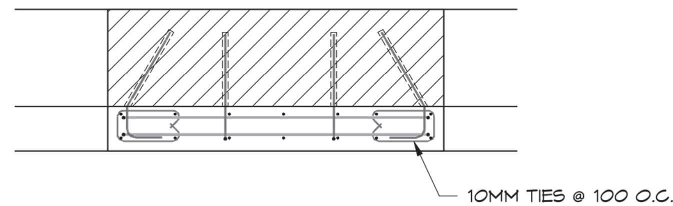
2 / D1 EXTERIOR WALL
INCREMENT 2,3



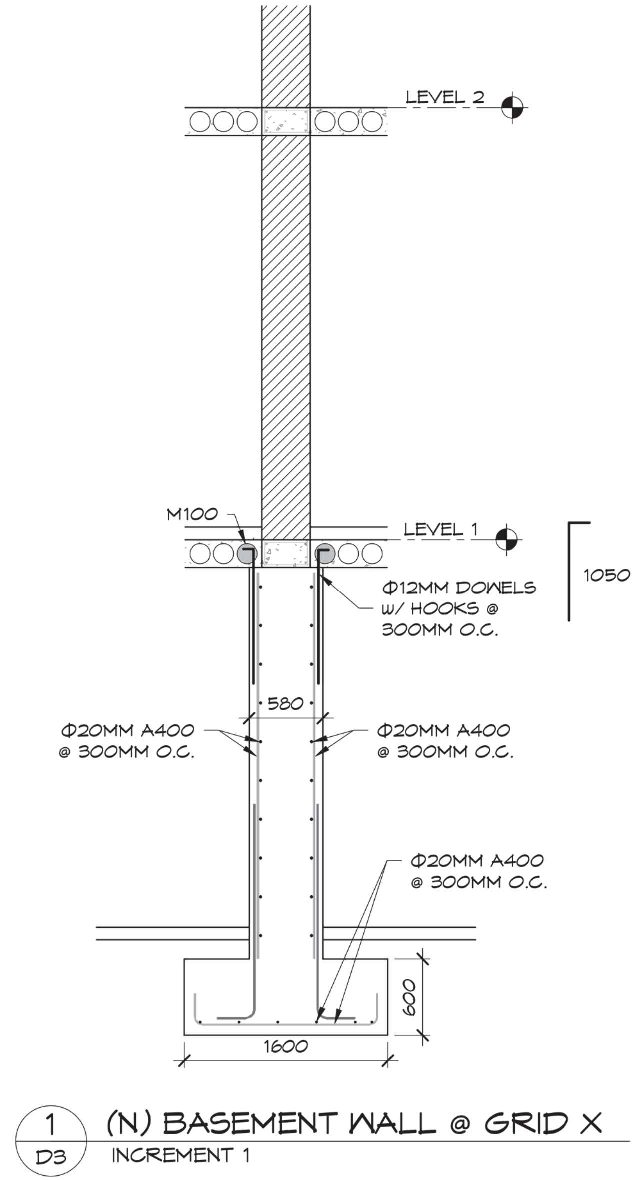
1 / D1 EXT. WALL (LONG. EQ.)
INCREMENT 2,3



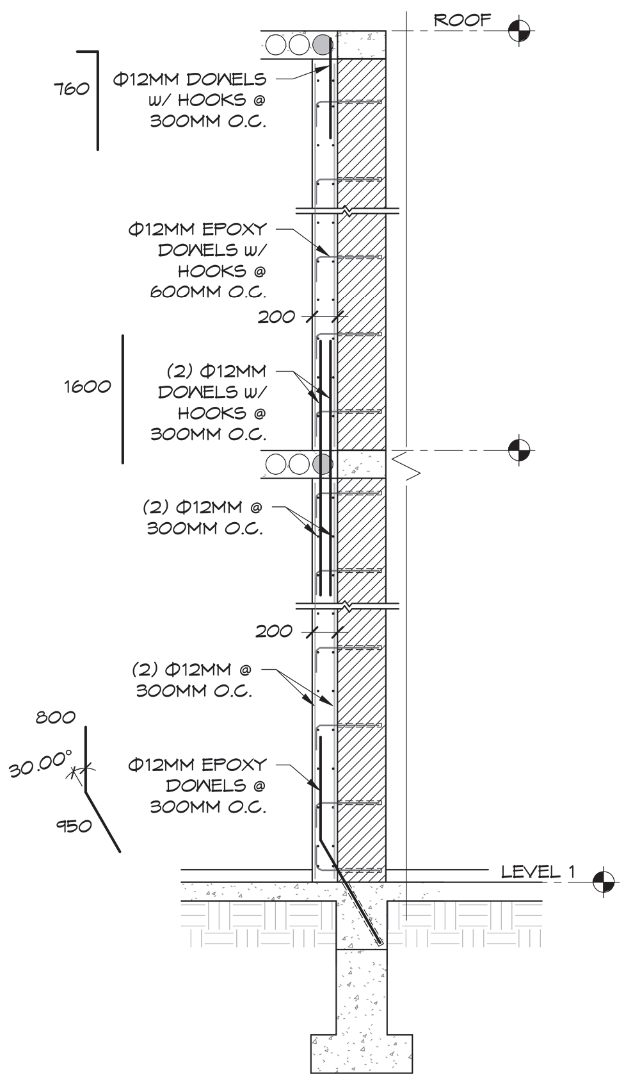
2 D2 EXT. ROOF TETHER
INCREMENT 2,3



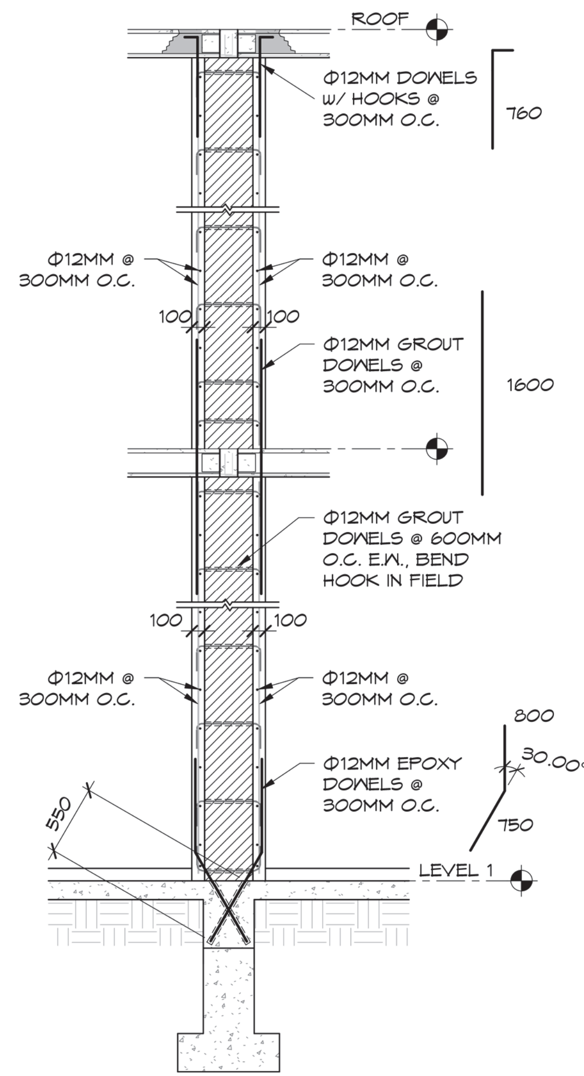
1 D2 EXT. PIER PARTIAL SECTION
INCREMENT 2,3



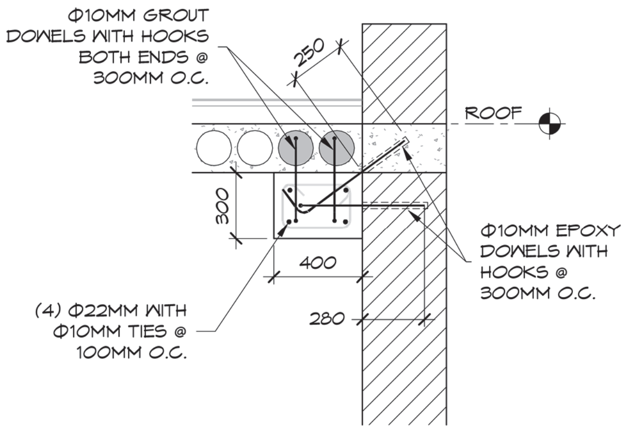
(N) BASEMENT WALL @ GRID X
INCREMENT 1



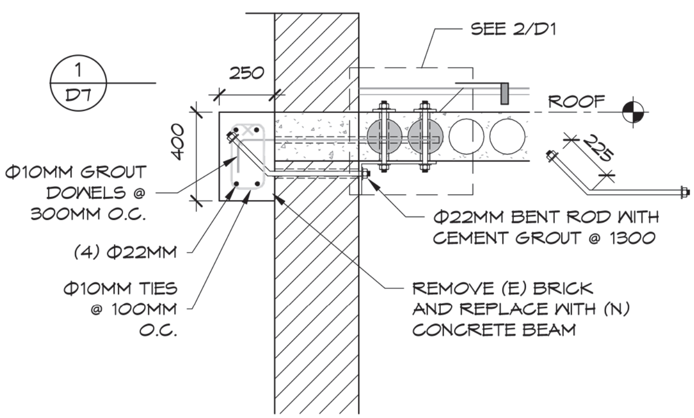
2 / D4 INTERIOR WALL @ GRID P
INCREMENT 3



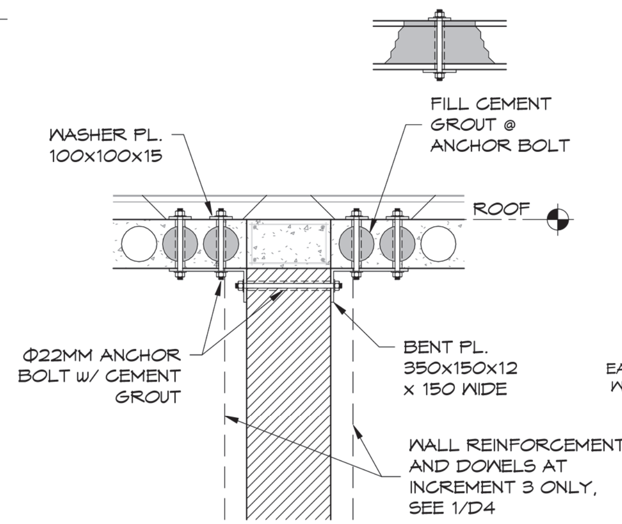
1 / D4 INTERIOR WALL
INCREMENT 3



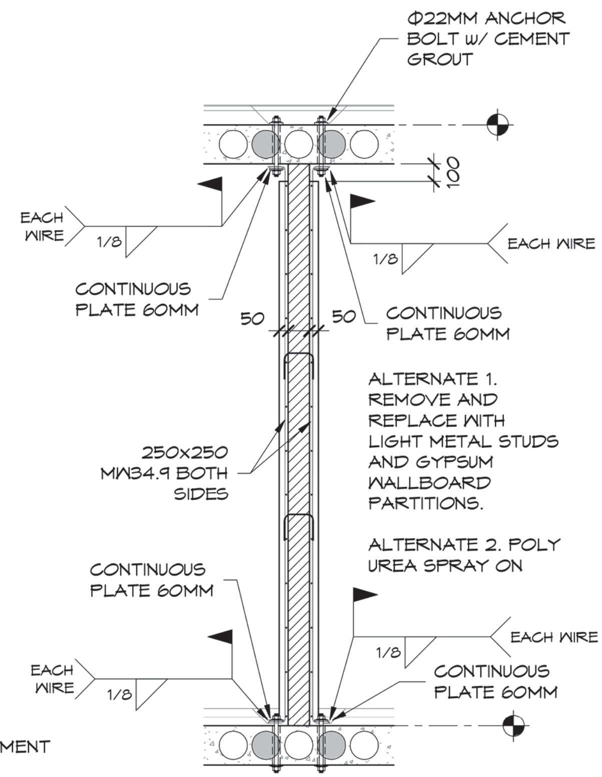
4 D5 INT. ROOF BELT
INCREMENT 1,2,3



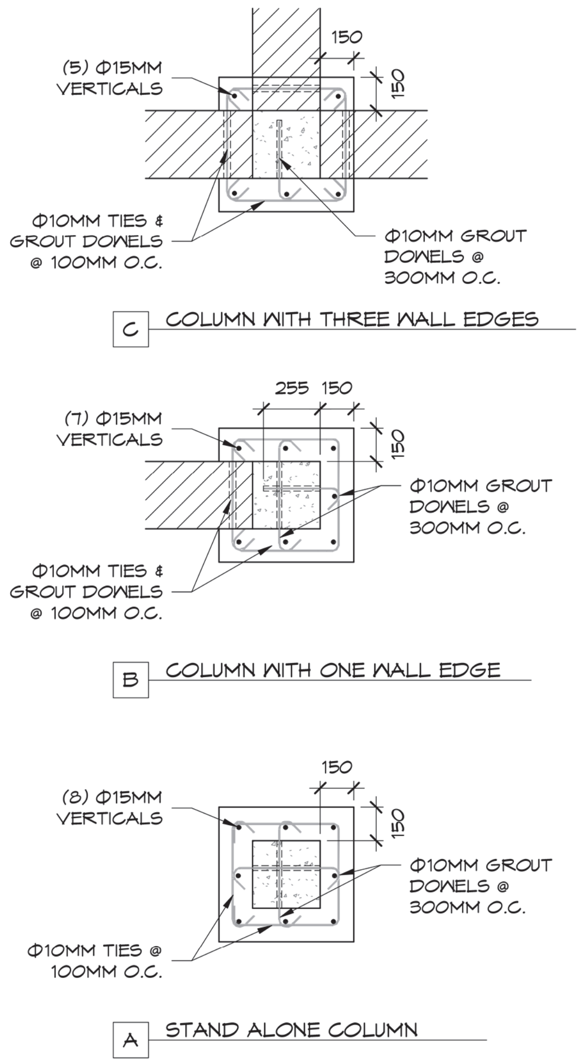
3 D5 EXT. ROOF BELT (LONG EQ.)
INCREMENT 1,2,3



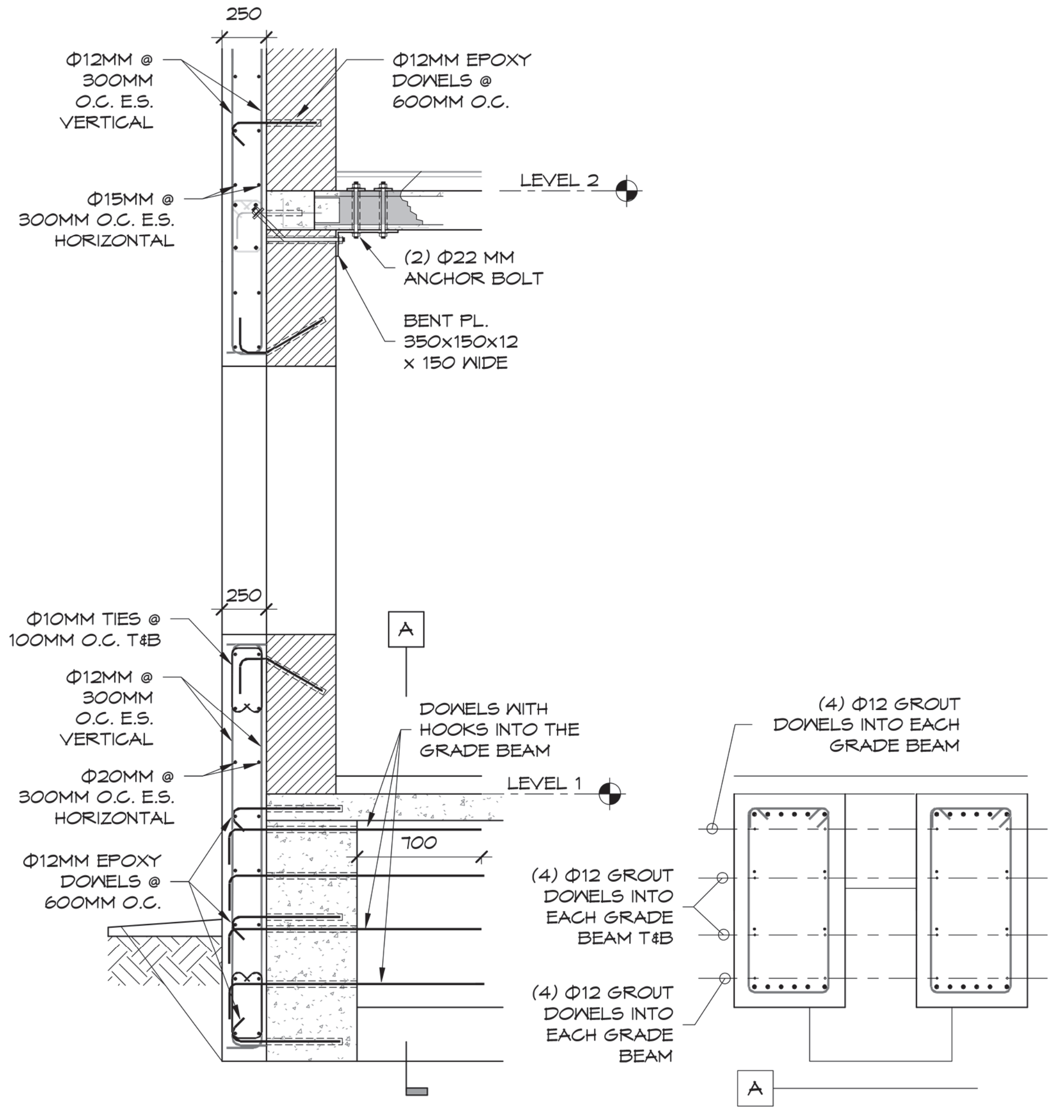
2 D5 INT. ROOF WALL TIE (LONG. EQ.)
INCREMENT 1,2,3



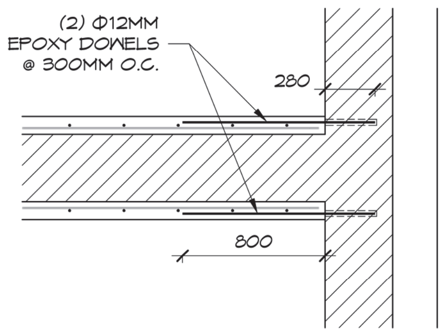
1 D5 INTERIOR PARTITION WALL
INCREMENT 1,2,3



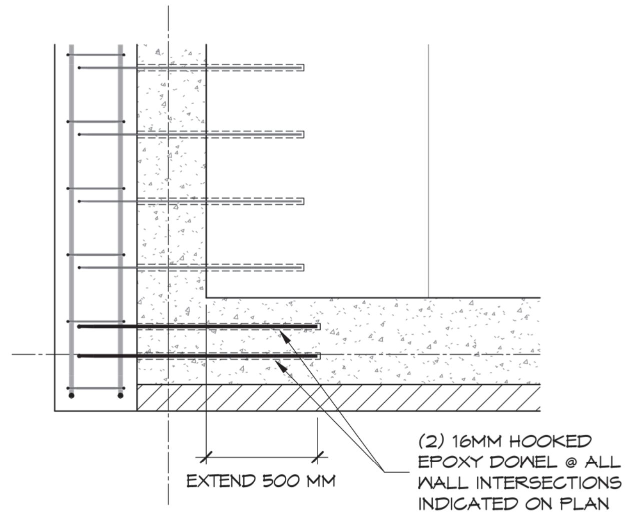
2 COLUMN WRAP
D6



1 EXT. WALL PIER
D6
INCREMENT 3.5, 4



2 D7 WALL INTERSECTION PLAN VIEW
INCREMENT 2,3,4

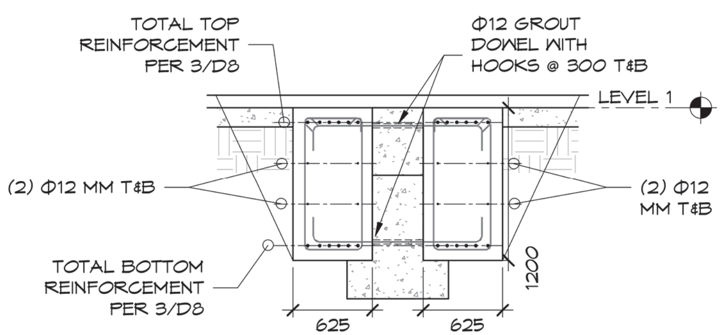


1 D7 EXTERIOR ROOF BELT (PLAN VIEW)
INCREMENT 1,2,3

MARK	LONG. REINF.		TIES	
	TOP	BOTTOM	SIZE	SPACING
GB1	(12) Φ22	(12) Φ22	(2) Φ12	100
GB2	(12) Φ22	(12) Φ22	(2) Φ12	100
GB3	(6) Φ22	(6) Φ22	(1) Φ12	100

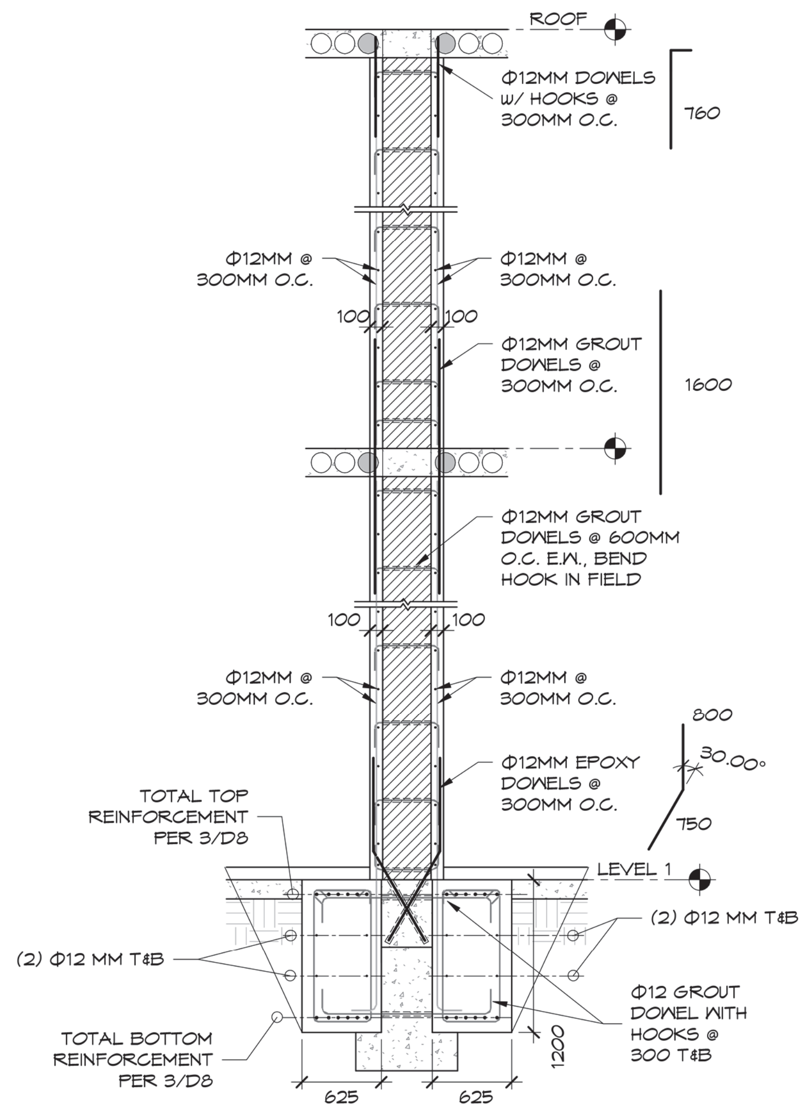
3 / D8 GRADE BEAM SCHEDULE

INCREMENT 3.5, 4



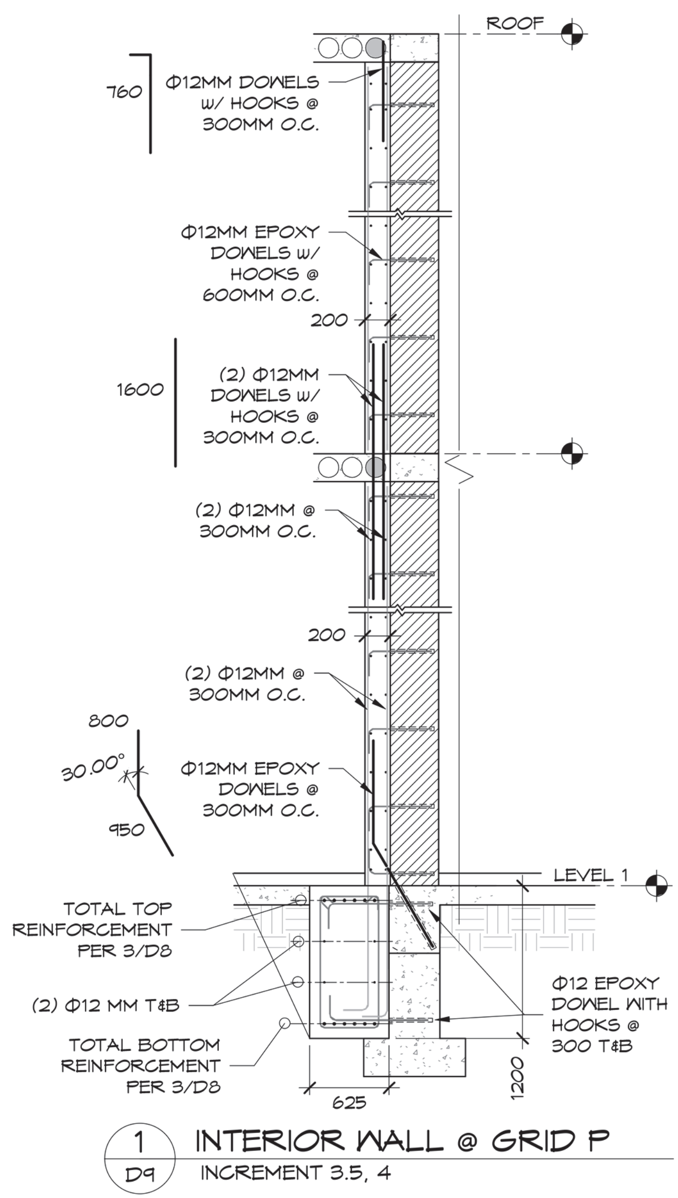
2 / D8 NEW GRADE BEAM

INCREMENT 3.5, 4



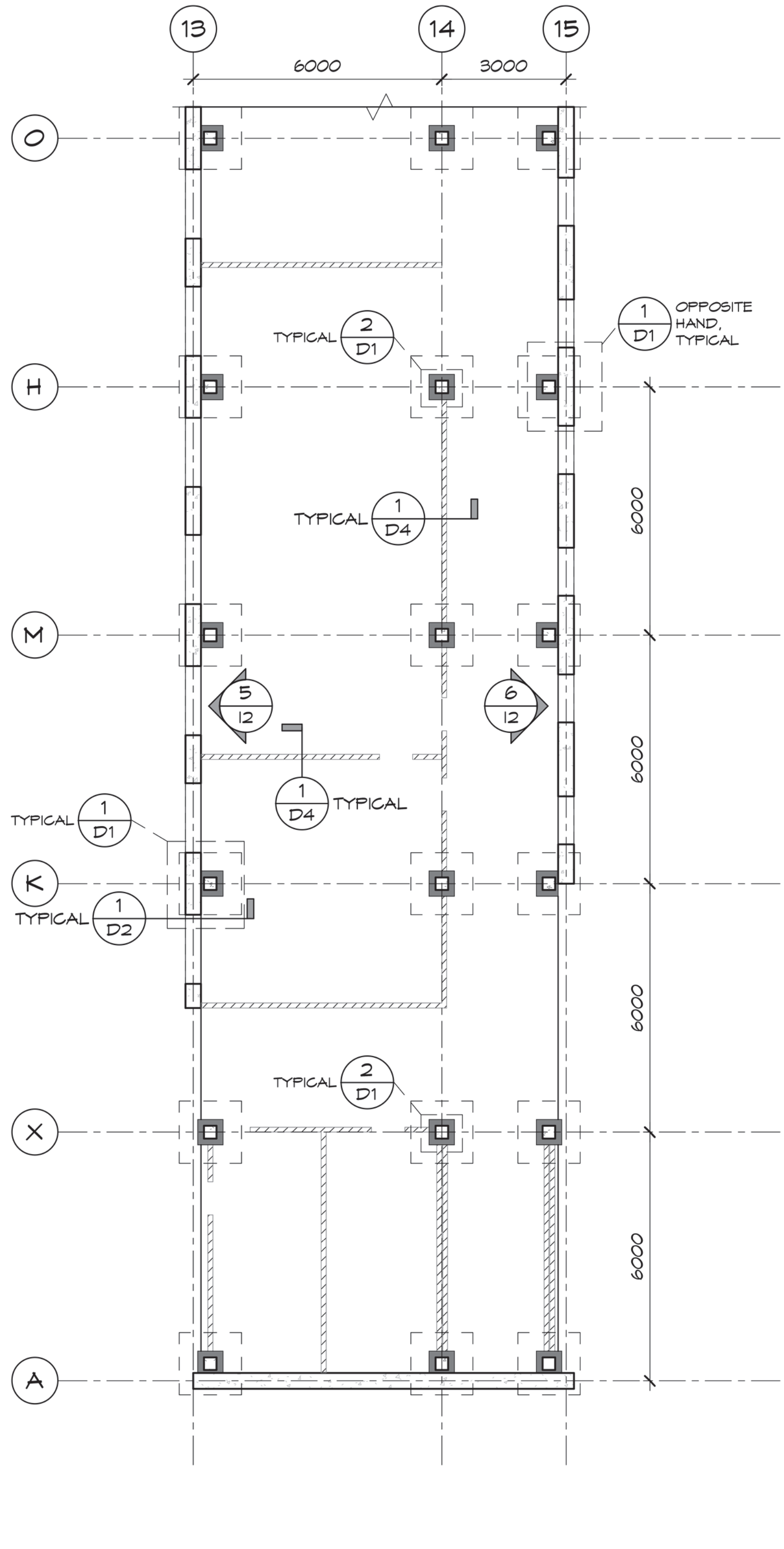
1 / D8 NEW GRADE BEAM AT WALL

INCREMENT 3.5, 4

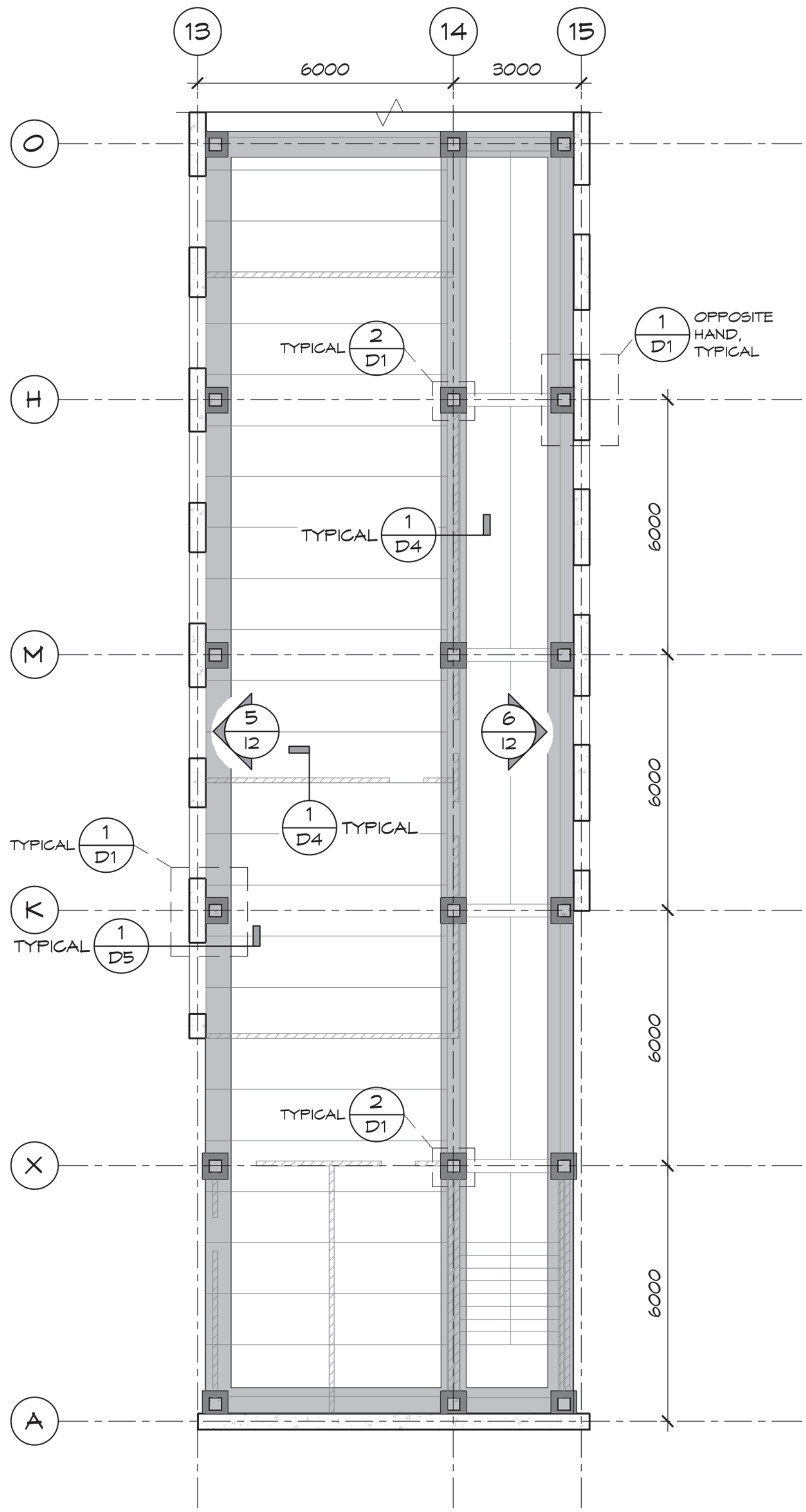

ROOF
Φ12MM DOWELS W/ HOOKS @ 300MM O.C.
760
Φ12MM EPOXY DOWELS W/ HOOKS @ 600MM O.C.
200
(2) Φ12MM DOWELS W/ HOOKS @ 300MM O.C.
1600
(2) Φ12MM @ 300MM O.C.
200
(2) Φ12MM @ 300MM O.C.
800
30.00°
950
Φ12MM EPOXY DOWELS @ 300MM O.C.
LEVEL 1
TOTAL TOP REINFORCEMENT PER 3/D8
(2) Φ12 MM T&B
TOTAL BOTTOM REINFORCEMENT PER 3/D8
Φ12 EPOXY DOWEL WITH HOOKS @ 300 T&B
625
1200
1
D9
INTERIOR WALL @ GRID P
INCREMENT 3.5, 4

Appendix G
Conceptual Retrofit Drawings for PC Typology

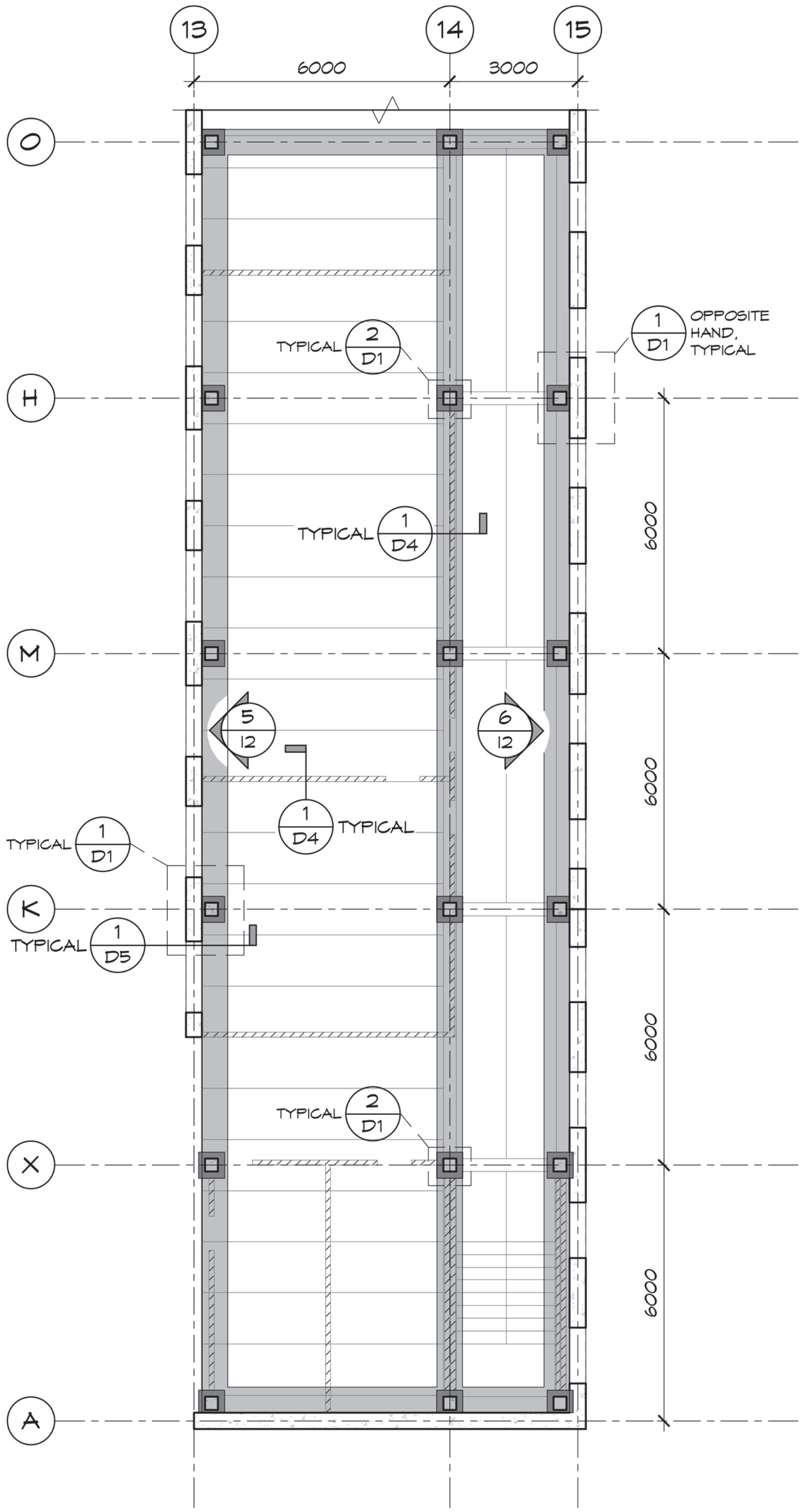
This Appendix presents the conceptual retrofit drawings for the precast concrete frames and walls (PC) typology developed for this project.



1
12
LEVEL 1 - INCREMENT 2



2/12 LEVEL 2 - INCREMENT 2



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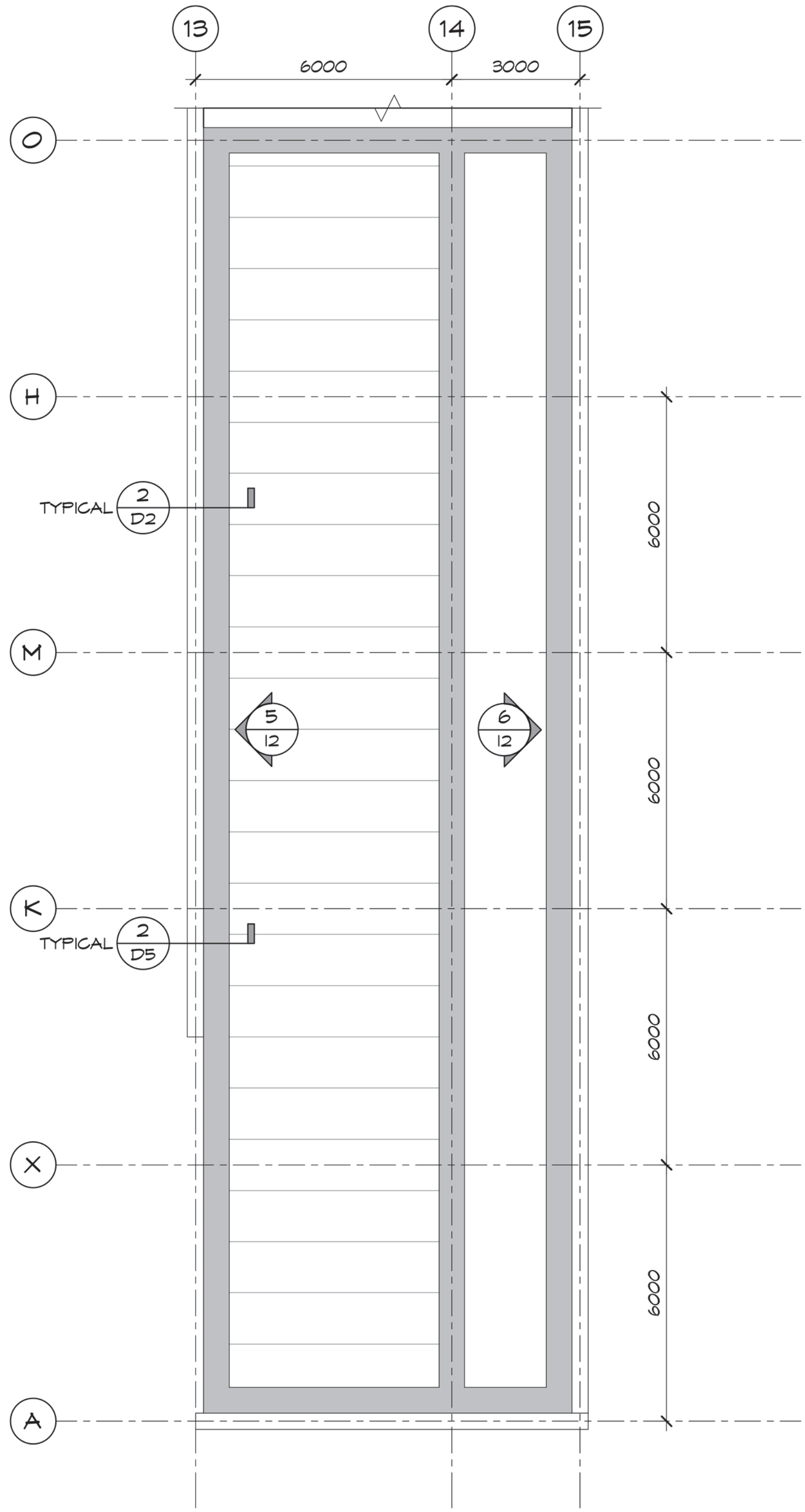
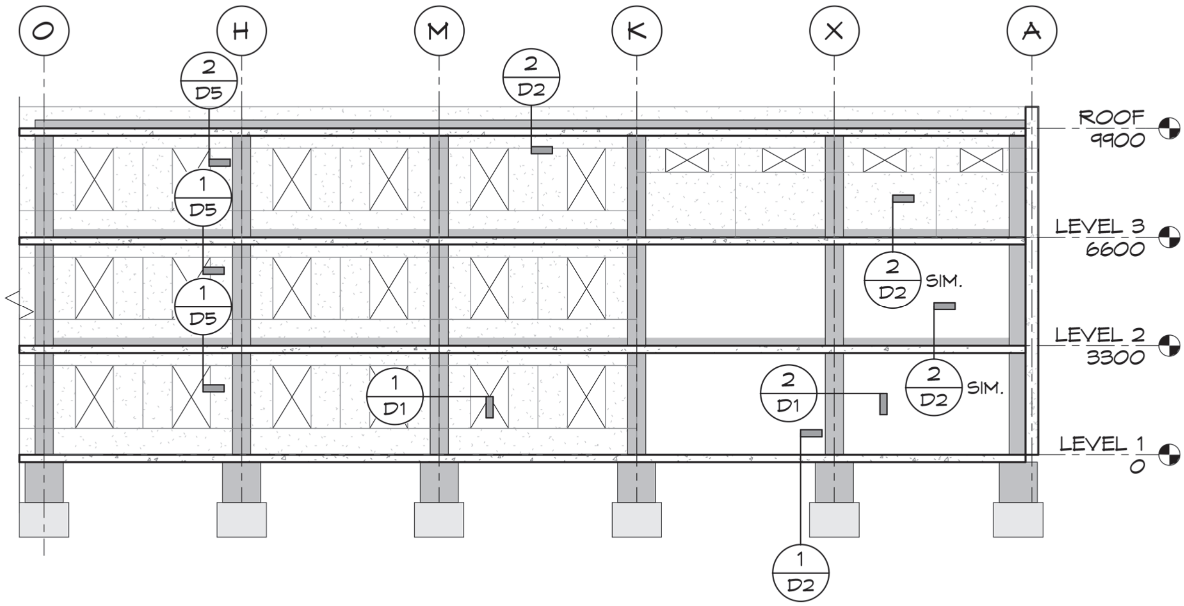


4/12 ROOF - INCREMENT 2



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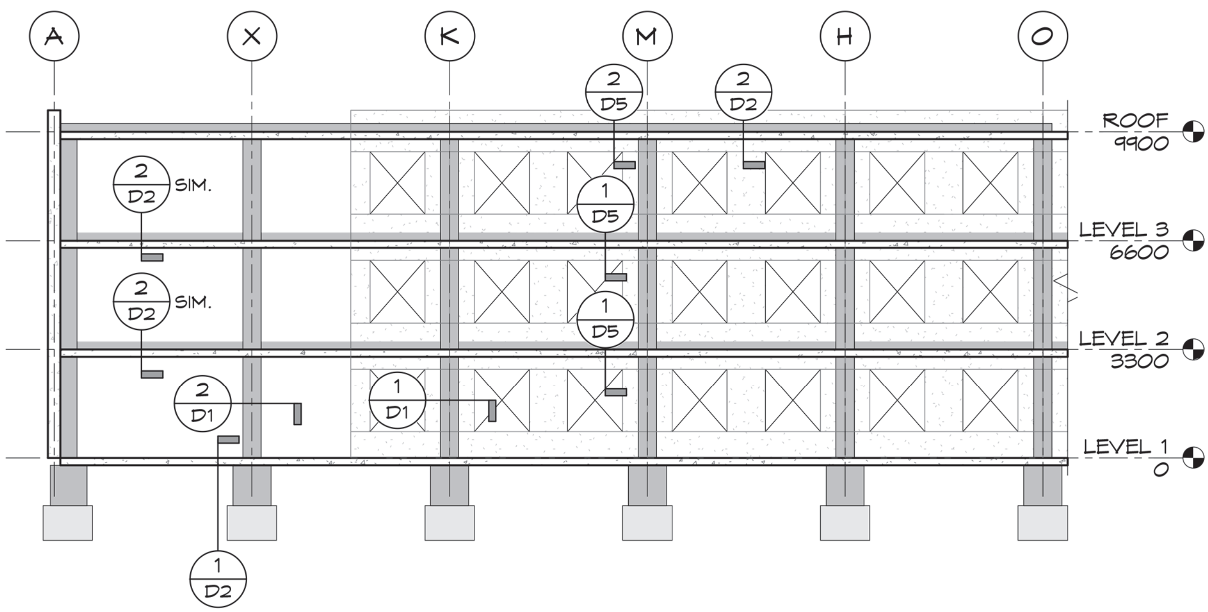
INTERIOR GRID 15 ELEVATION - INCREMENT 2



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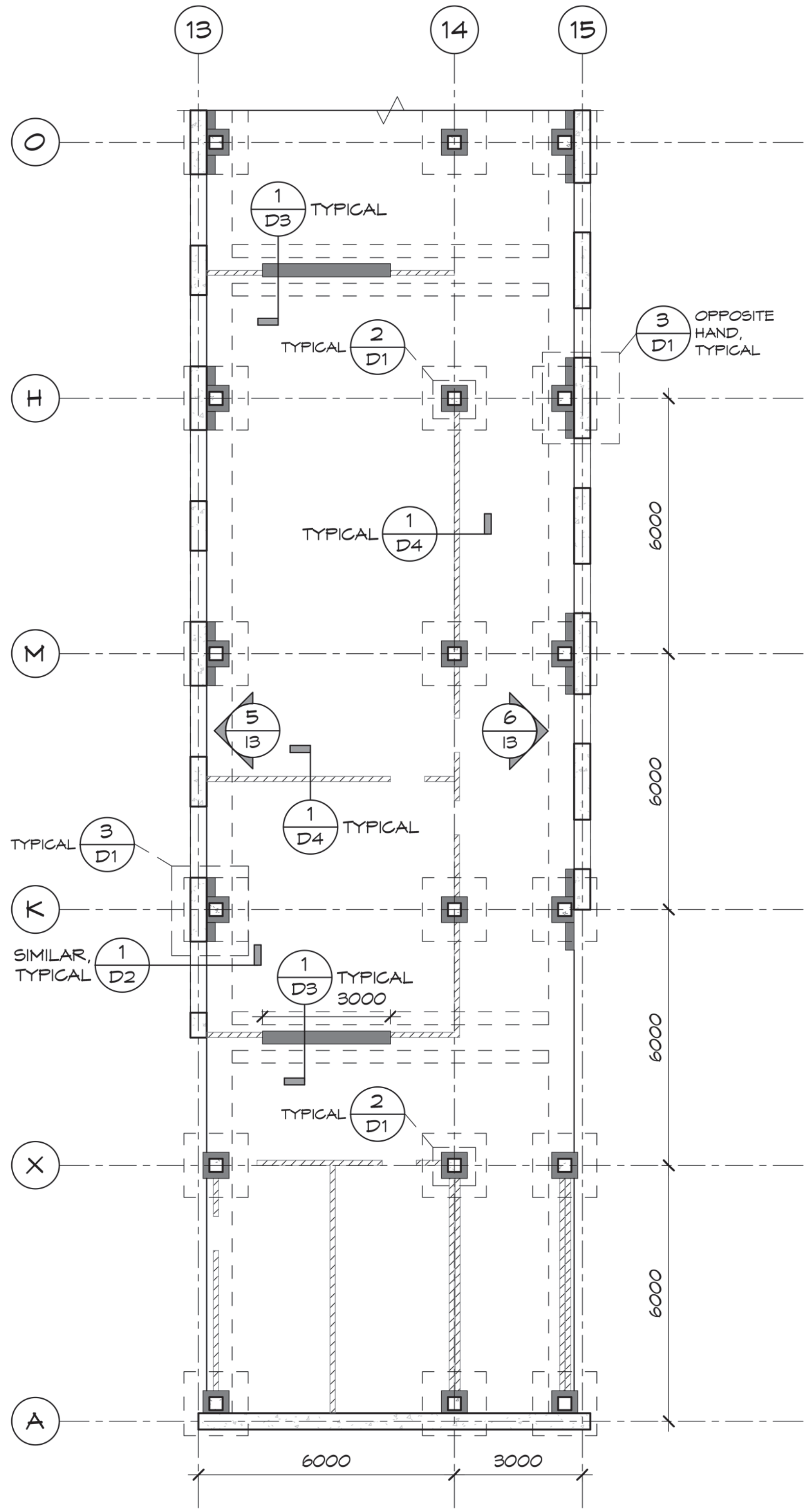
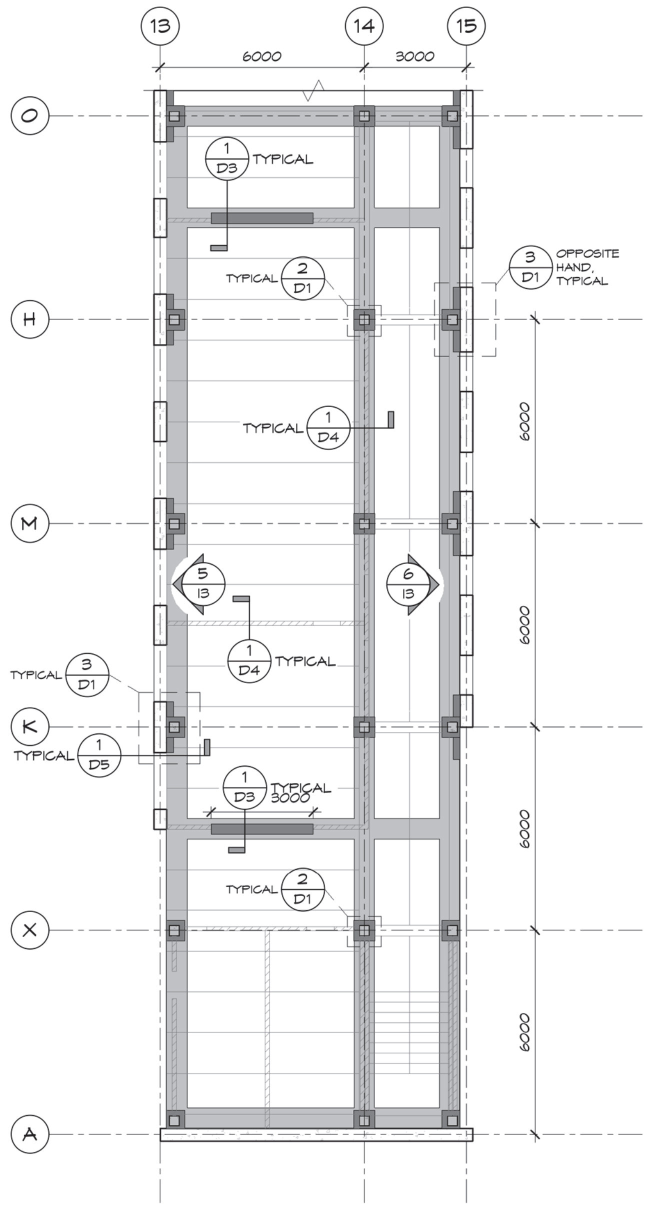
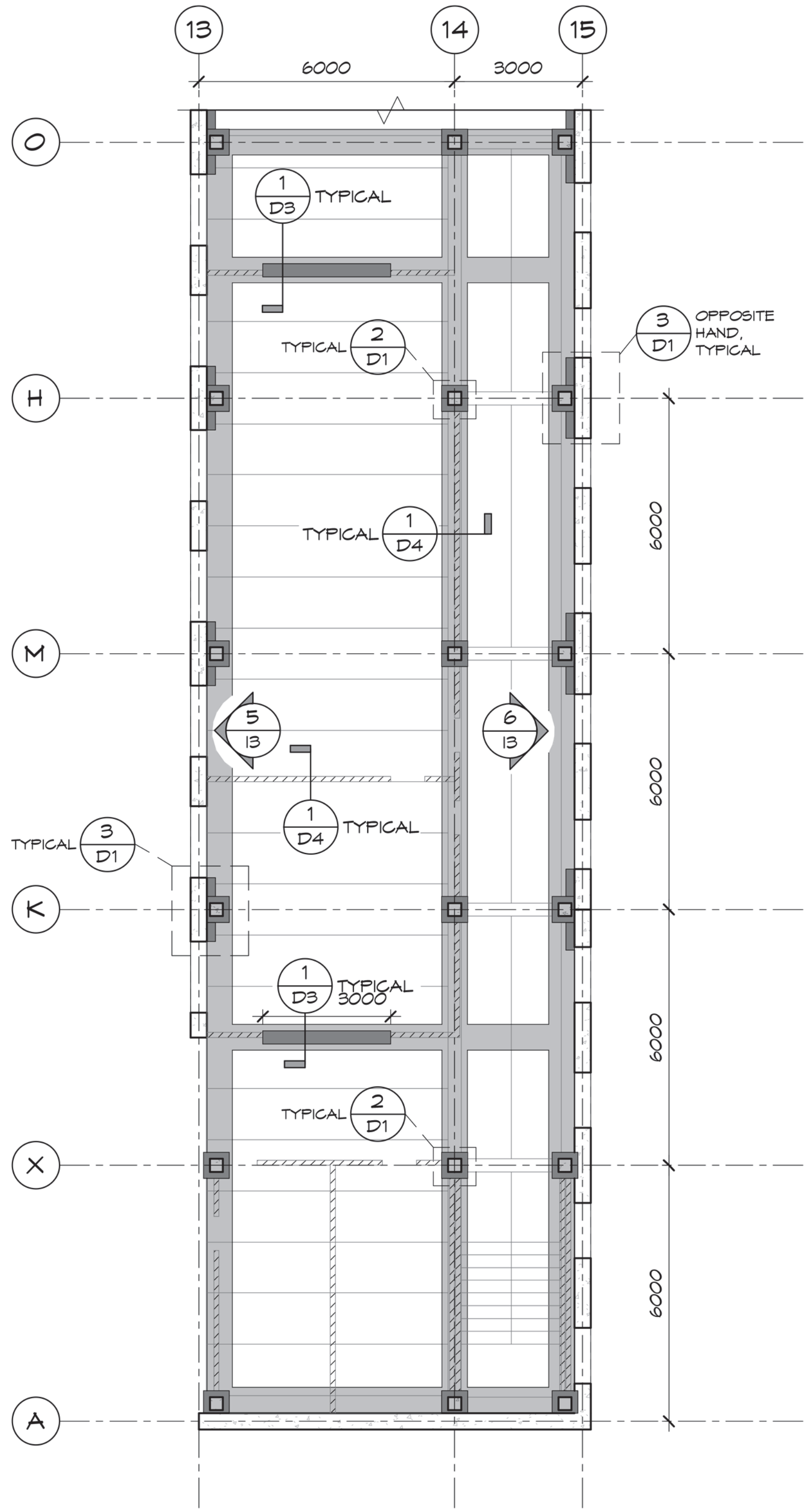


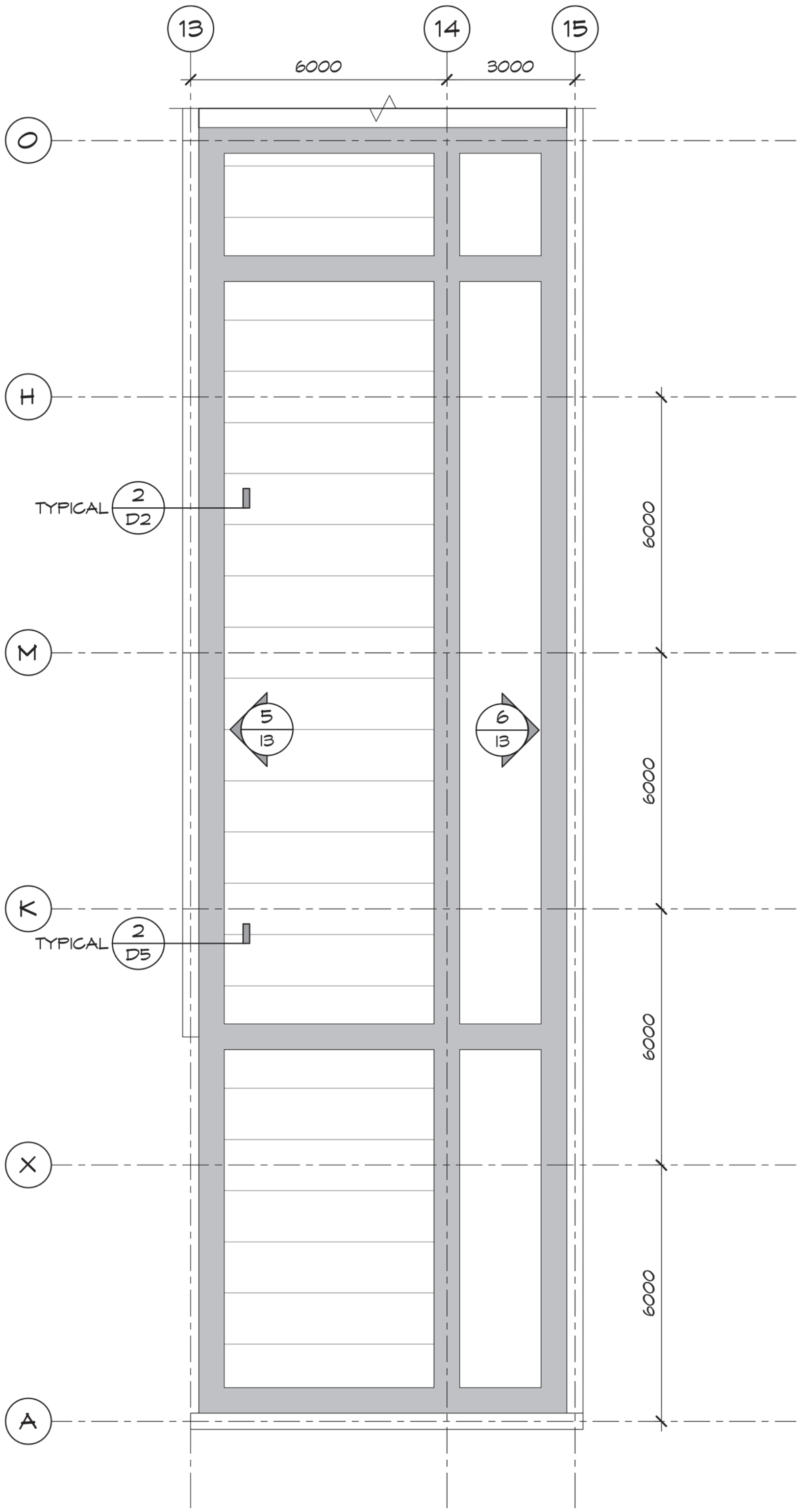
1/13 LEVEL 1 - INCREMENT 3



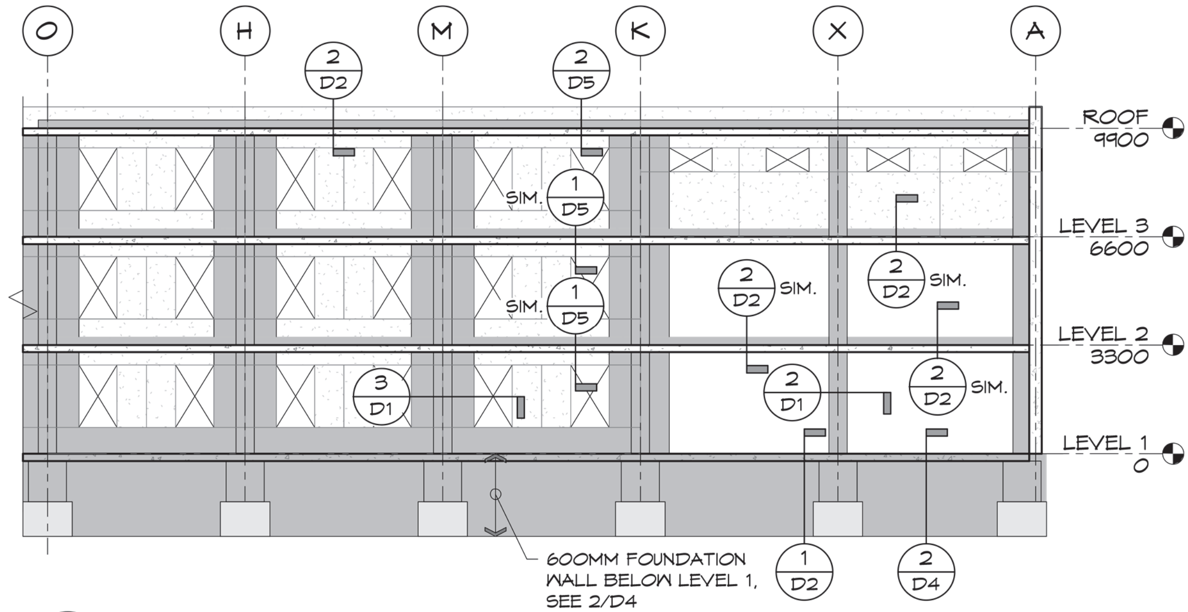
2 LEVEL 2 - INCREMENT 3
13



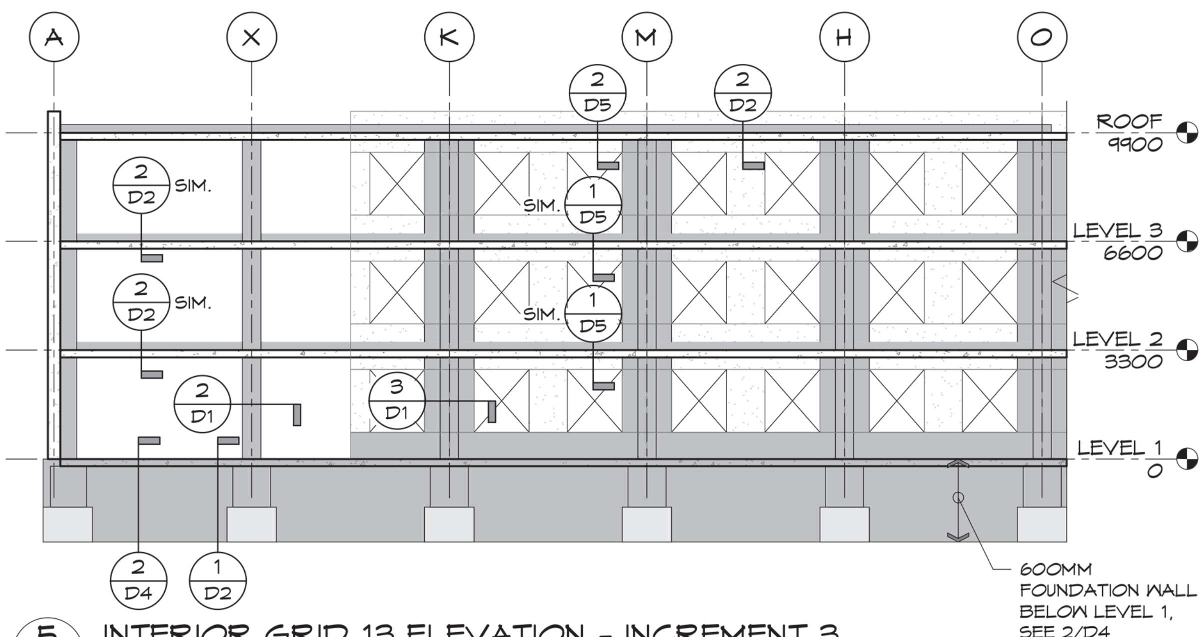
3/13 LEVEL 3 - INCREMENT 3



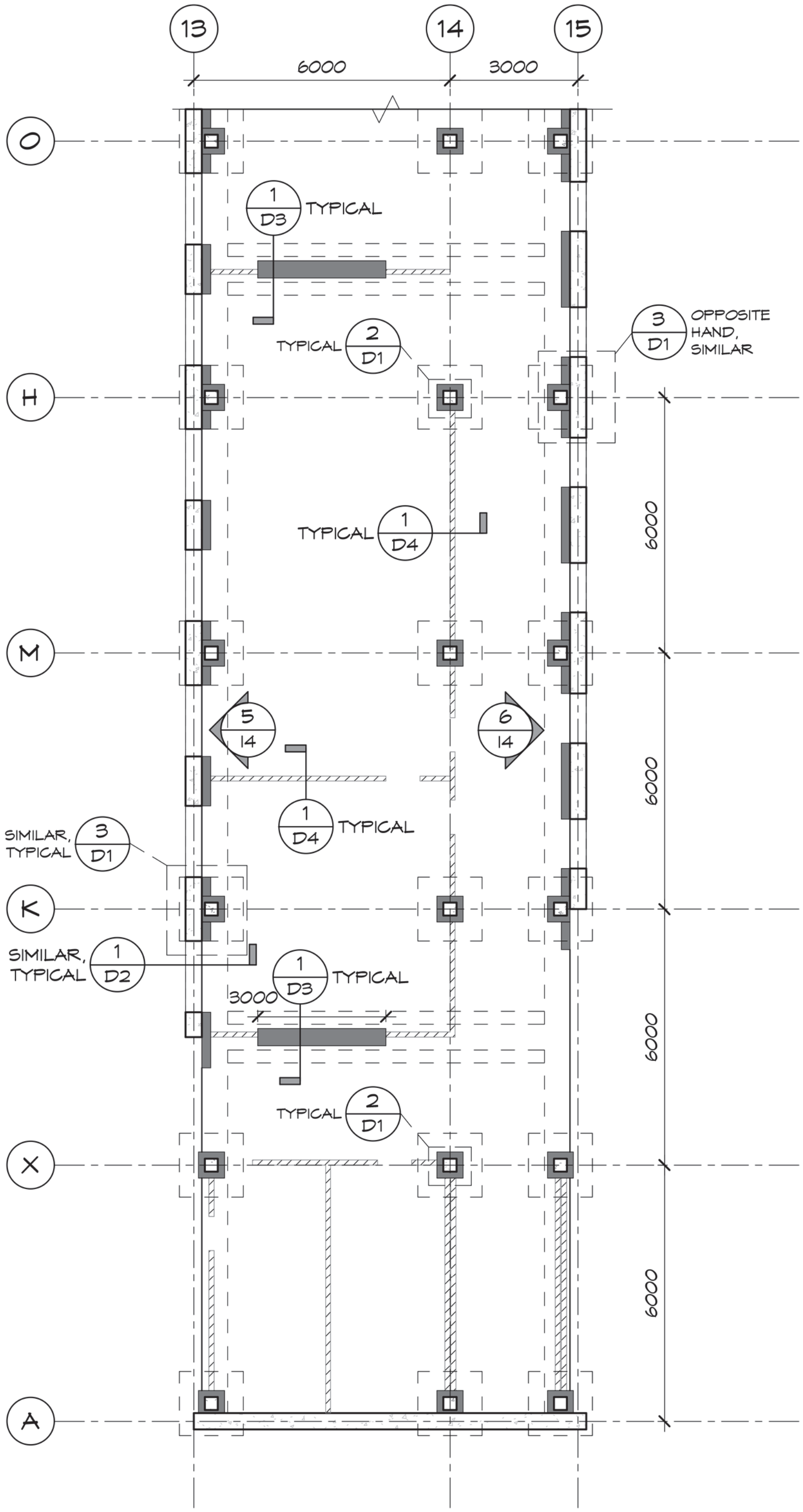
4/13 ROOF - INCREMENT 3



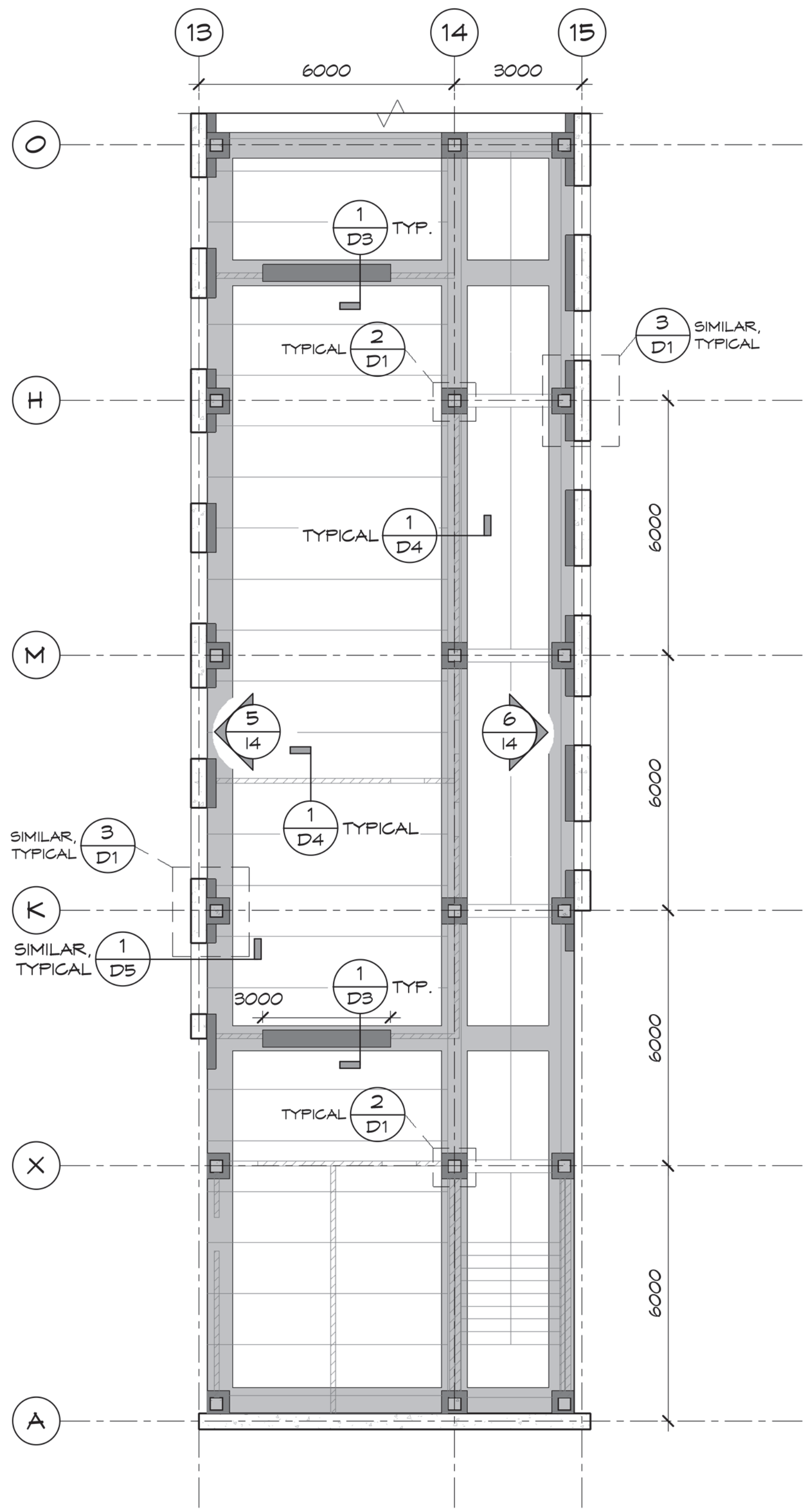
6 / 13 INTERIOR GRID 15 ELEVATION - INCREMENT 3



5 / 13 INTERIOR GRID 13 ELEVATION - INCREMENT 3



1/14 LEVEL 1 - INCREMENT 4



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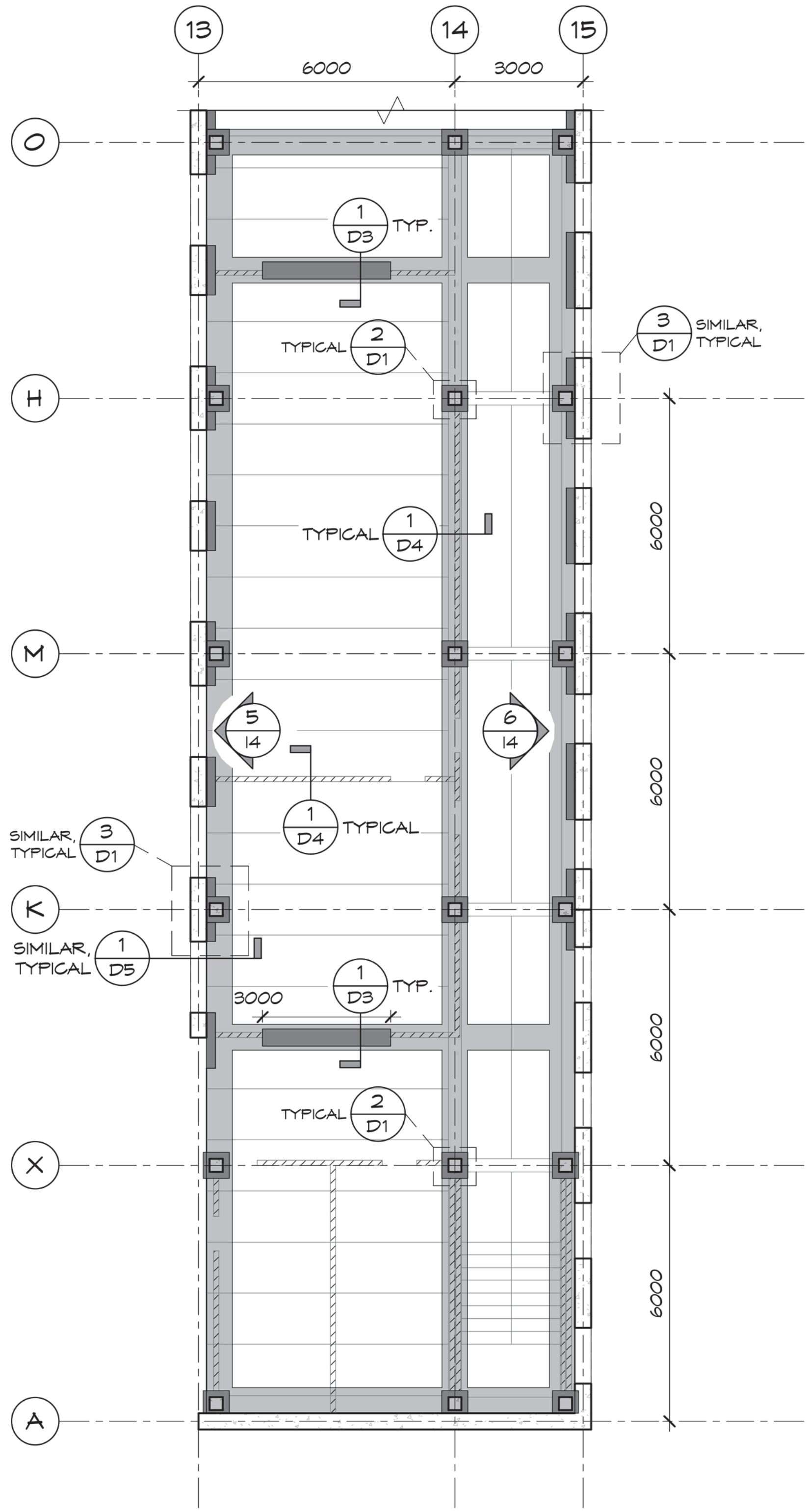

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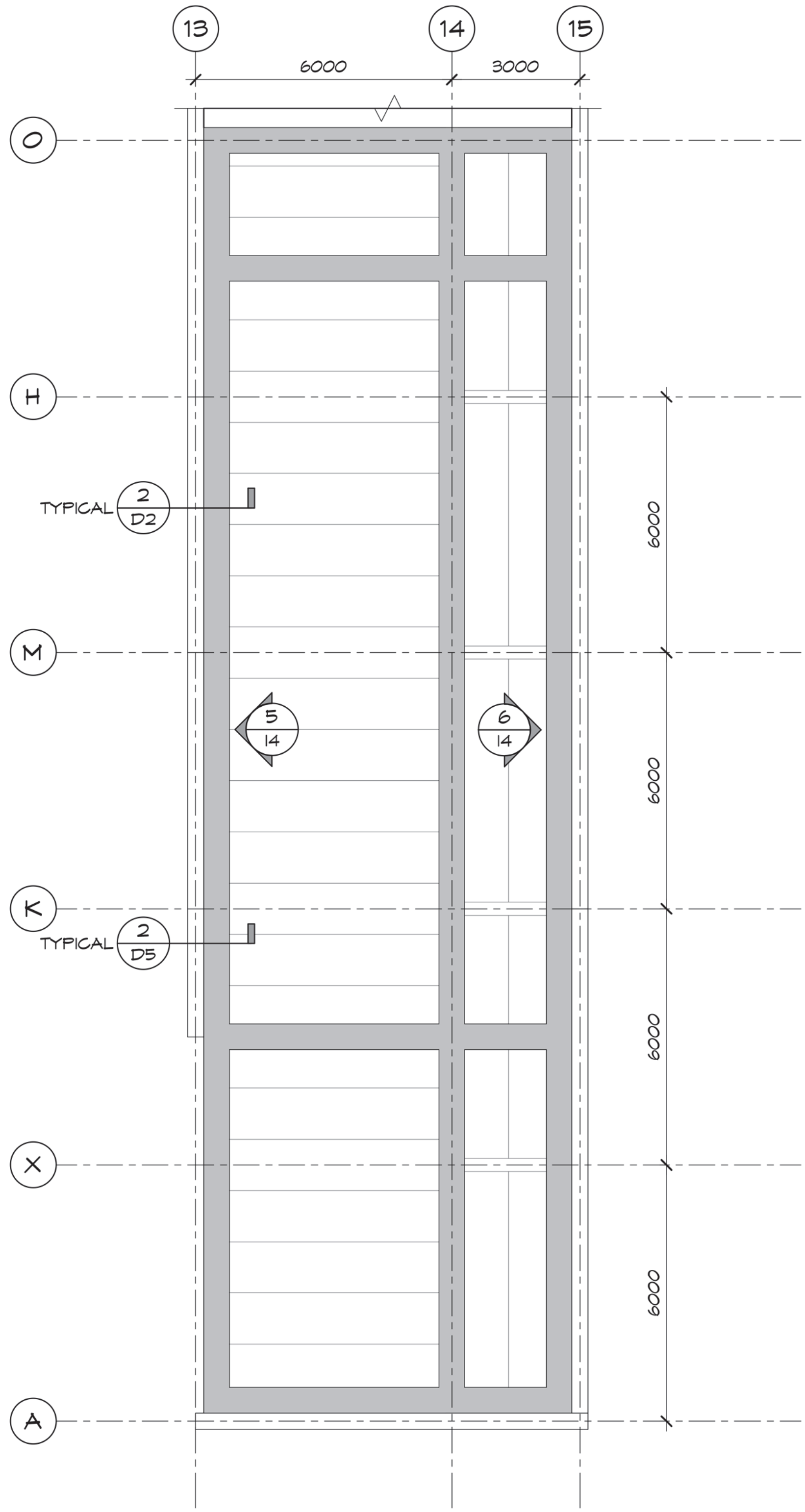
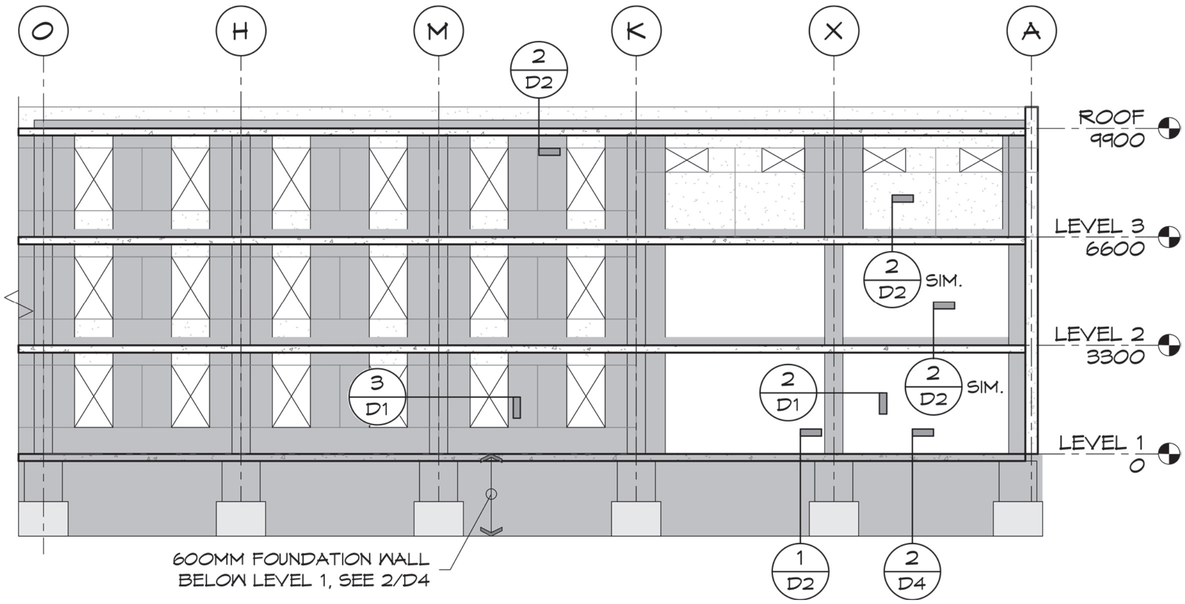


4
14
ROOF - INCREMENT 4



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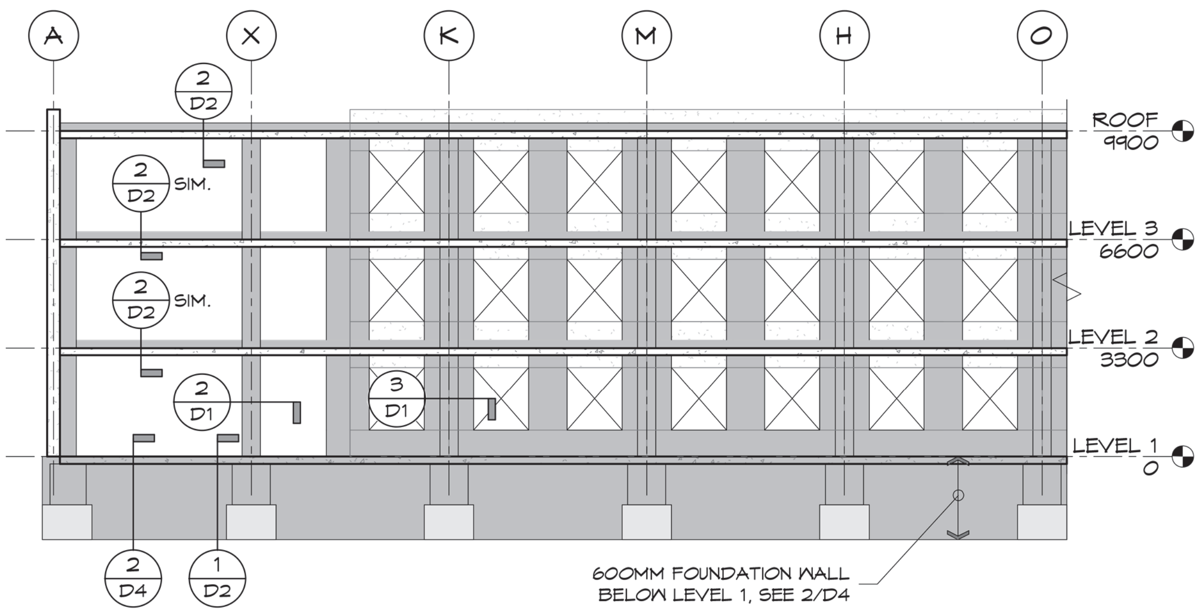
INTERIOR GRID 15 ELEVATION - INCREMENT 4



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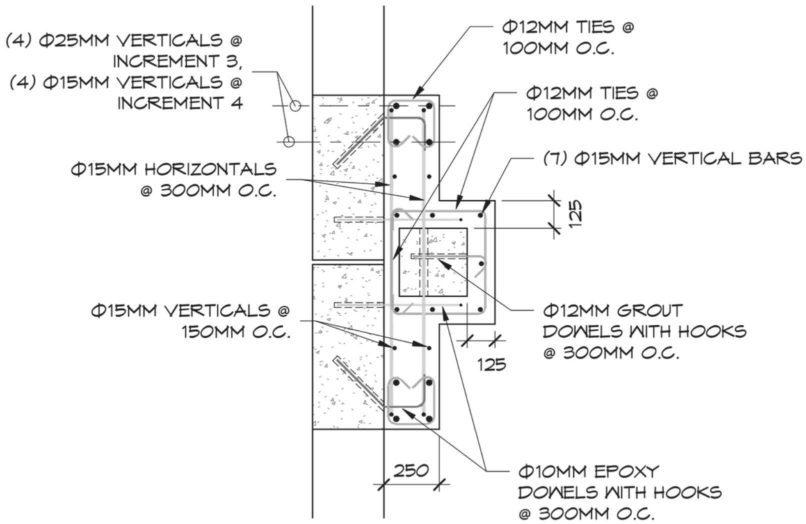
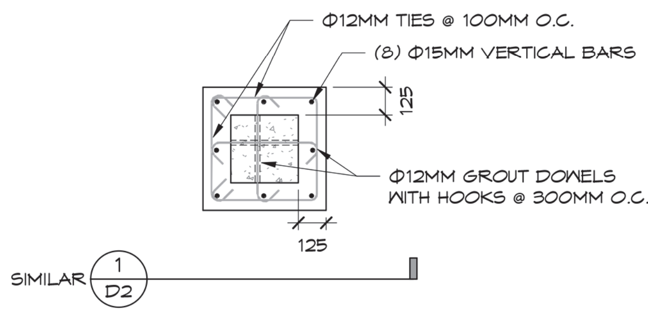
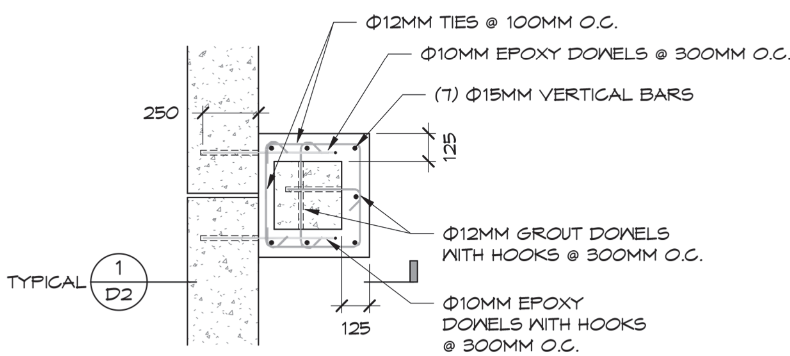
INTERIOR GRID 13 ELEVATION - INCREMENT 4



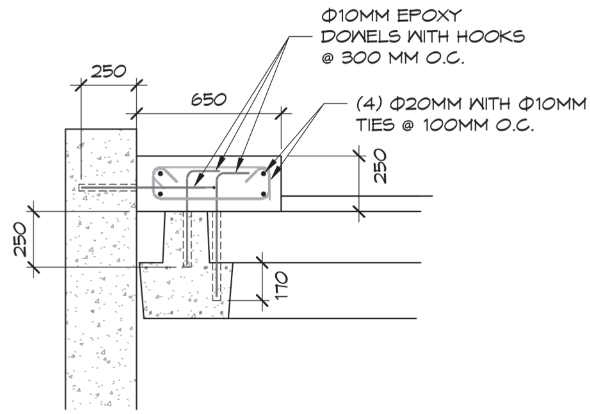
3 / **D1** INTERIOR WALL AT COLUMN
INCREMENT 3,4



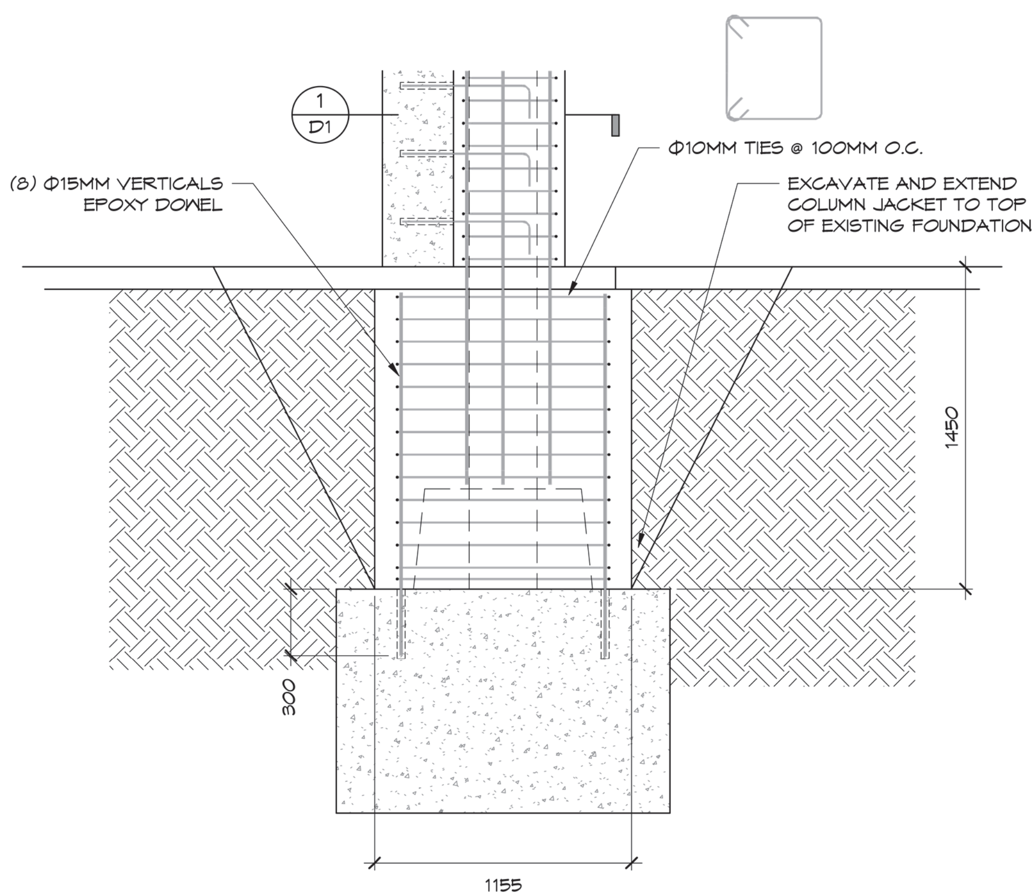
2 / **D1** STANDALONE COLUMN WRAP
INCREMENT 2,3,4



1 / **D1** COLUMN WRAP @ PRECAST WALL
INCREMENT 2,3,4

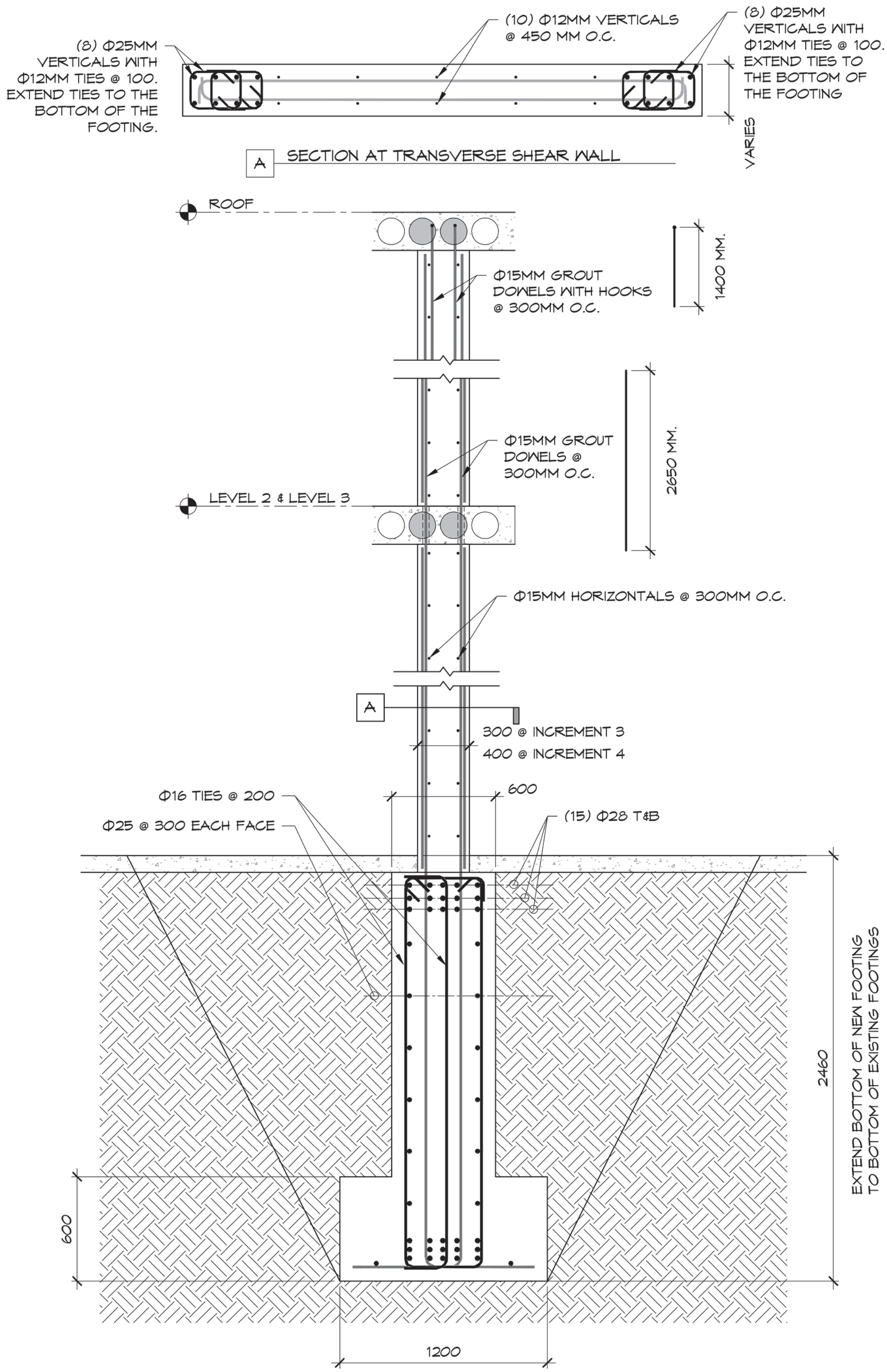


2 D2 ROOF CHORD

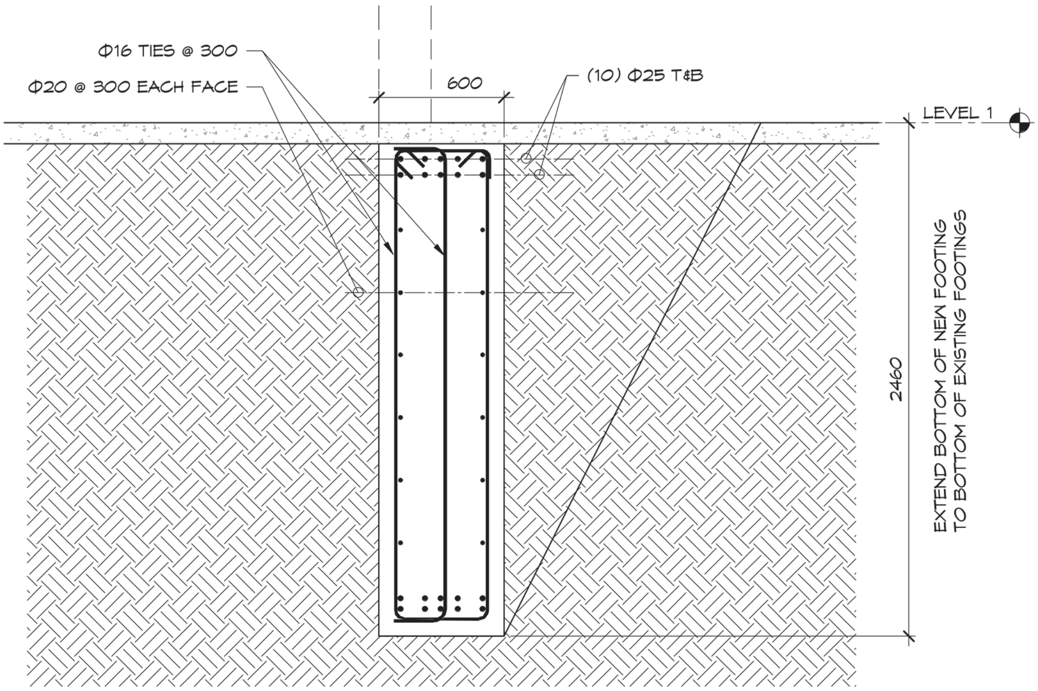


1 D2 COLUMN STRENGTHENING AT THE FOUNDATION

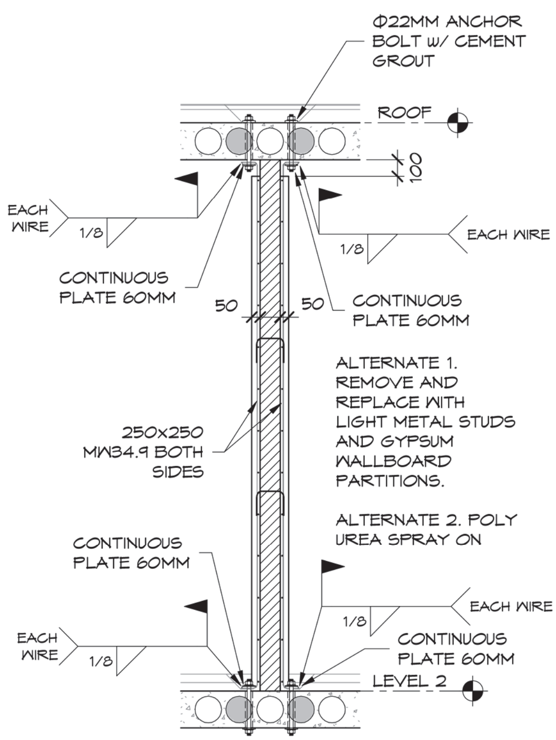
INCREMENT 2,3,4



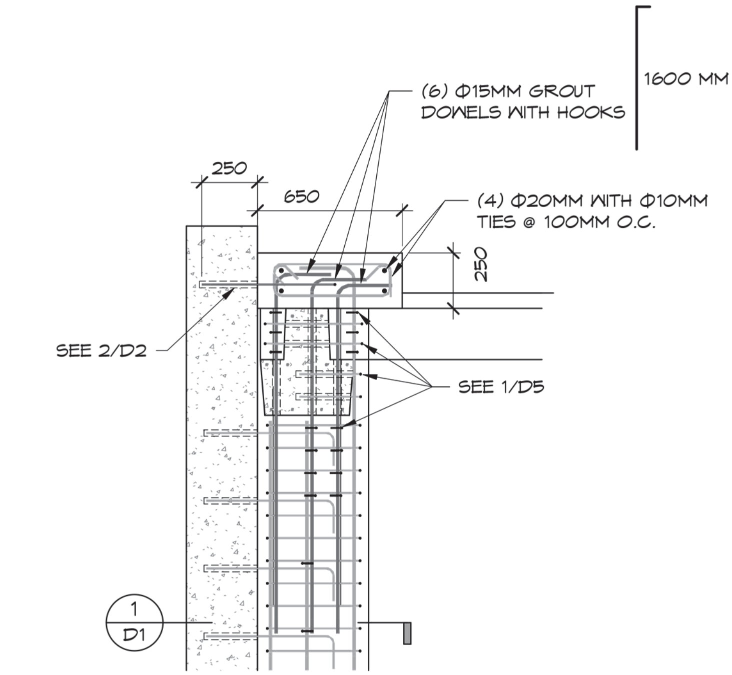
1
D3
NEW SHEAR WALL & FOUNDATION
INCREMENT 3,4



2 LONGITUDINAL FOUNDATION WALL
D4 INCREMENT 3,4

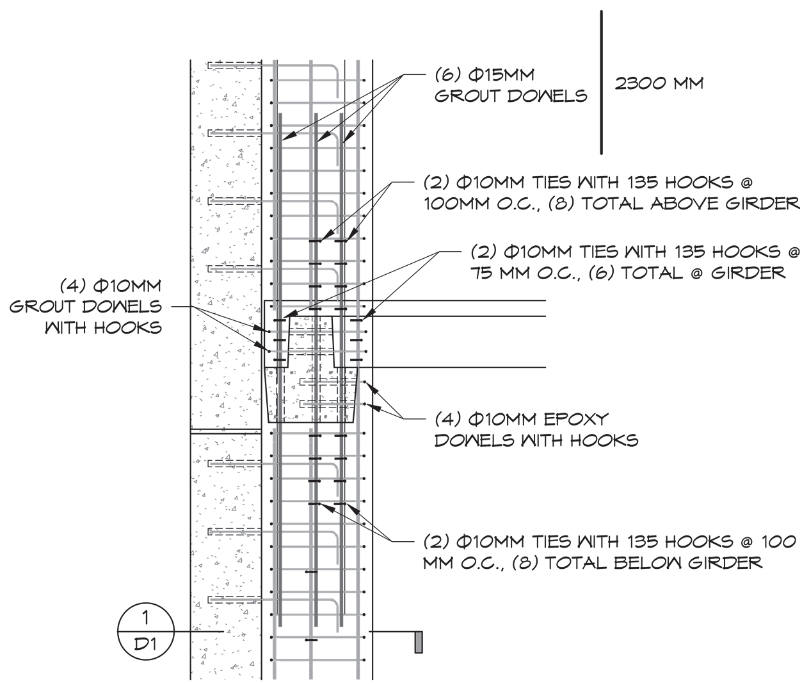


1 INTERIOR PARTITION WALL
D4 INCREMENT 2,3,4



2 D5 COLUMN WRAP AT GIRDER @ ROOF

INCREMENT 2,3,4



1 D5 COLUMN WRAP AT GIRDER @ FLOORS

INCREMENT 2,3,4

Appendix H
Vulnerability Functions

The section presents vulnerability functions that were developed using the methodology described in Chapter 6 for three structural typologies.

In accordance with Chapter 6, the following vulnerability functions have been developed:

- **High-resolution building data.** This function is based on pushover information developed for representative index buildings in Chapter 5.
- **Medium-resolution building data.** This function is based on the methodology presented in SYNER-G utilizing available building data from field inspections and adjusted using the methodology described in Section 6.5.4.
- **Low-resolution building data.** This function is based on the methodology presented in SYNER-G utilizing the minimum amount of data presented in the database provided by the World Bank, and adjusted using the methodology described in Section 6.5.4.

It is noted that the medium- and low-resolution cases are represented as data ranges because each building in the database is applied a unique adjustment factor.

H.1 Complex Masonry (CM)

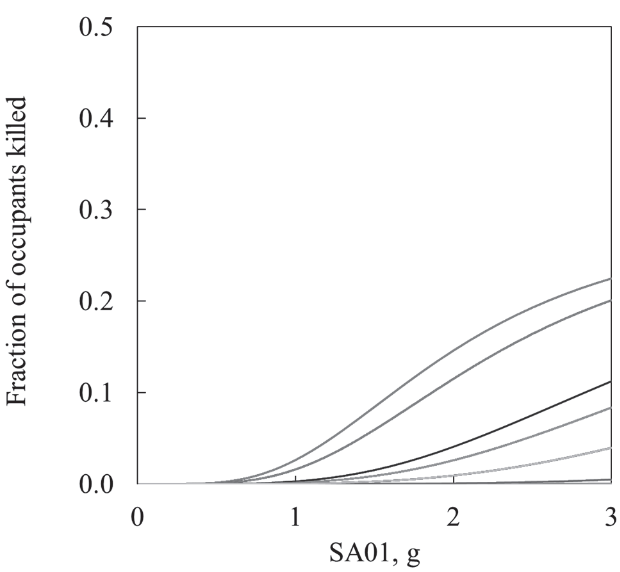


Figure H-1 Vulnerability functions for complex masonry typology, low-resolution data.

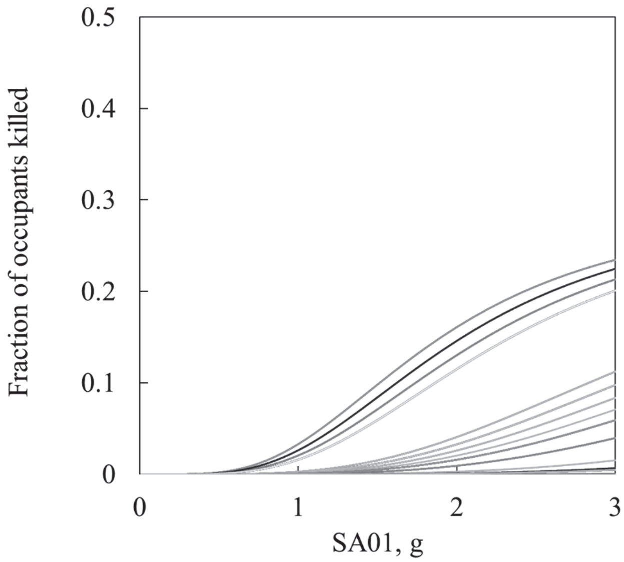


Figure H-2 Vulnerability functions for complex masonry typology, medium-resolution data.

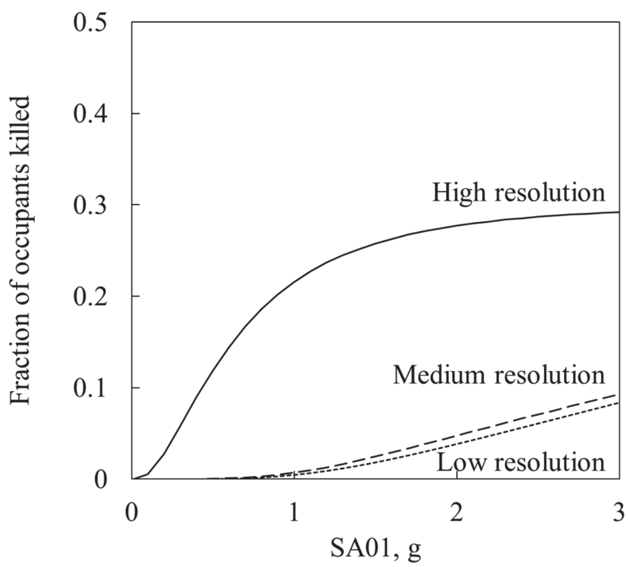


Figure H-3 Vulnerability functions for complex masonry typology, low-, medium-, and high-resolution data. Low- and medium-resolution curves reflect the equally weighted average of all buildings in the group.

H.2 Complex Masonry with Concrete Framing (CMCF)

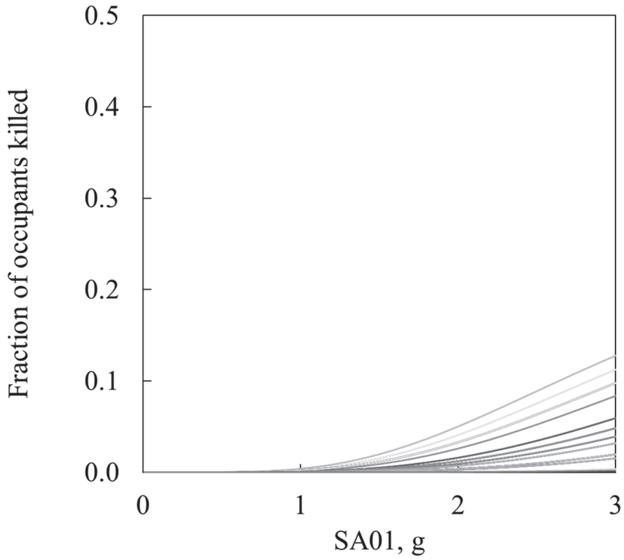


Figure H-4 Vulnerability functions for CMCF typology, medium-resolution data.

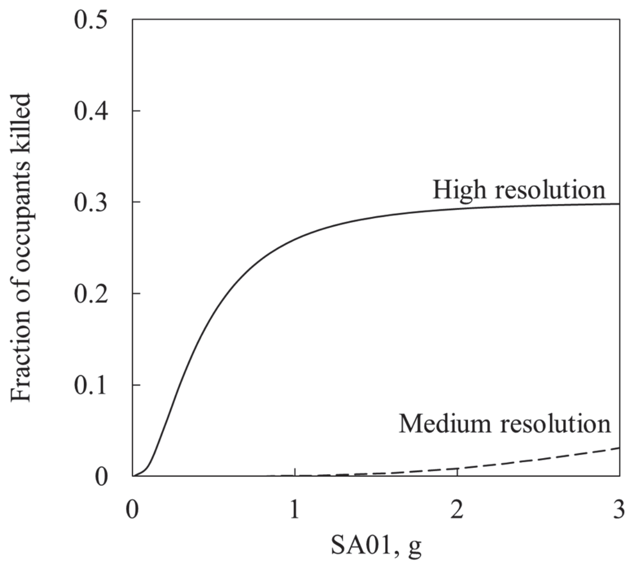


Figure H-5 Vulnerability functions for CMCF typology with medium- and high-resolution data. The medium-resolution curve represents the equally weighted average of all buildings in the group. (No buildings were mapped to CMCF from low-resolution data.)

H.3 Precast Concrete Frames and Walls (PC)

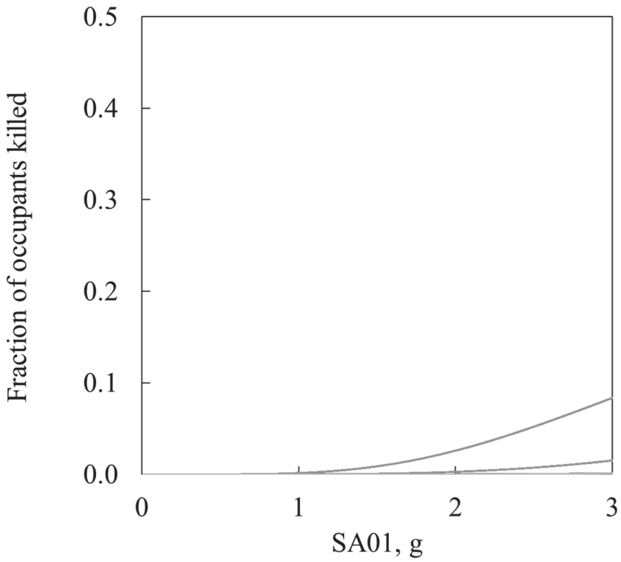


Figure H-6 Vulnerability functions for PC typology, low-resolution data.

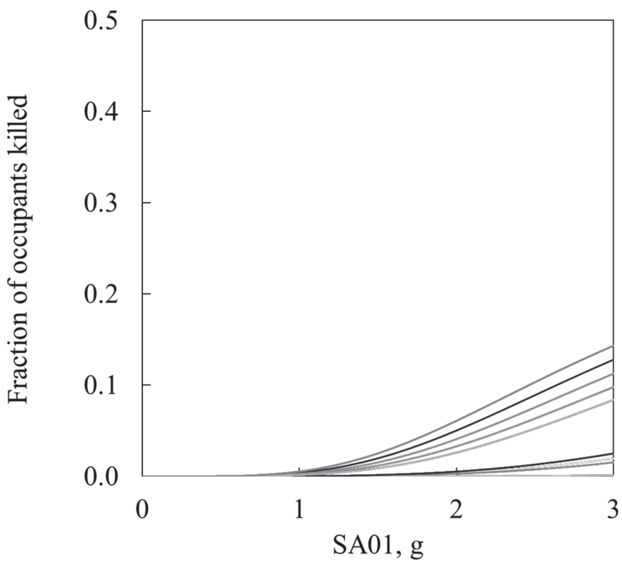


Figure H-7 Vulnerability functions for PC typology, medium-resolution data.

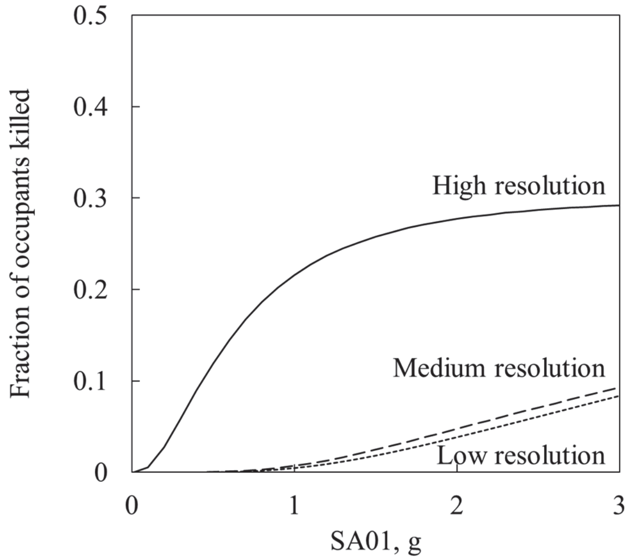


Figure H-8 Vulnerability functions for PC typology with low-, medium-, and high-resolution data. Low- and medium-resolution curves represent the equally weighted average of all buildings in the group.

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