Chapter 1
General

1.1 – Scope

This *Direct Design Handbook for Masonry Structures*, herein referred to as the *Handbook*, provides a direct procedure for the structural design of concrete masonry and clay masonry structures. The procedure shall be permitted to be used to design masonry subjected to factored combinations of dead, live, wind, seismic, soil, snow, and rain loads prescribed herein. The procedure outlined in this *Handbook* is based on the strength design provisions of the 2013 *Building Code Requirements for Masonry Structures* (TMS 402) and the 2010 ASCE 7 *Minimum Design Loads for Buildings and Other Structures* (ASCE 7).

Commentary Chapter 1
General

C1.1 – Scope

This *Handbook* is written in mandatory language to permit adoption by reference in standards and codes. The procedures in this *Handbook* were developed based on loading conditions as defined by ASCE 7 and procedures defined by the strength design method of TMS 402.

The direct design procedure is an analytical structural design method that permits the user, following a specific series of steps, to design and specify relatively simple, masonry buildings complying with TMS 402, TMS 602, and ASCE 7.

The motivation behind the creation of the direct design procedure was to provide a simple, quickly implemented alternative to conventional engineering analysis methods for the design of commonly encountered masonry structures. With this simplicity, however, comes some limitations as defined in Chapter 2 of this *Handbook*. These limitations include some types of structural irregularities, constraints on architectural layout, and restrictions on flood, fluid, impact loads as well as magnitudes of design loads. For the design of masonry structures outside of the scope of this *Handbook*, users are referred to TMS 402.

1.2 – Standards Cited

Standards of the American Concrete Institute, the Structural Engineering Institute of the American Society of Civil Engineers, ASTM International, and The Masonry Society cited in this document are listed below with their serial designations, including year of adoption or revision, and are declared to be part of this *Handbook* as if fully set forth in this document.

TMS 402-13/ACI 530-13/ASCE 5-13 – *Building Code Requirements for Masonry Structures*, referenced herein as TMS 402

TMS 602-13/ACI 530.1-13/ASCE 6-13 – *Specification for Masonry Structures*, referenced herein as TMS 602

C1.2 – Standards Cited

Because the procedures of this *Handbook* are based upon the combined requirements of ASCE 7 and TMS 402, users should verify that locally-adopted and enforced building code requirements are consistent with the methodologies incorporated into this *Handbook*. As changes in the referenced documents evolve, future editions of this *Handbook* are contemplated to correspond to each new edition of ASCE 7 and TMS 402.

ASCE 7-10 – *Minimum Design Loads for Buildings and Other Structures*, referenced herein as ASCE 7

ASTM A615/A615M-16 – *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement*

ASTM A706/A706M-16 – *Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement*

ASTM A996/A996M-16 – *Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement*

ASTM C90-16a – *Standard Specification for Loadbearing Concrete Masonry Units*

ASTM C270-14a – *Standard Specification for Mortar for Unit Masonry*

ASTM C476-16 – *Standard Specification for Grout for Masonry*

ASTM C652-17 – *Standard Specification for Hollow Brick (Hollow Masonry Units Made From Clay or Shale)*

ASTM C1314-16 – *Standard Test Method for Compressive Strength of Masonry Prisms*

ASTM C1714/C1714M-16 – *Standard Specification for Preblended Dry Mortar Mix for Unit Masonry*

1.3 – Definitions

Terms defined in TMS 402, TMS 602, and ASCE 7 shall apply to the design of masonry designed in accordance with this *Handbook*.

C1.3 – Definitions

For consistent application, terms that have particular meanings in the context of this *Handbook* are defined. The definitions given are for the unique application in this *Handbook* and may not correspond to ordinary usage. Glossaries of masonry terminology are available from several sources (NCMA TEK 1-4, 2004, BIA Technical Notes 2, 1999, ASTM C1180-10, ASTM C1232-15a).

1.4 – Notations

C_e = roof snow load exposure factor.

C_s = roof snow load slope factor.

C_t = roof snow load thermal factor.

D = dead load, lb/ft^2 (kN/m^2).

f_g = specified compressive strength of grout, psi (MPA).

f'_m = specified compressive strength of masonry, psi (MPa).

f_y = specified yield strength of reinforcement, psi (MPa).

g = acceleration due to gravity, ft/sec^2 (m/s^2).

K_{zt} = wind load topographic factor.

L = live load, lb/ft^2 (kN/m^2).

C1.4 – Notations

Notations used in this *Handbook* are summarized in this section. Each symbol is unique, and where possible, matches the notation used in other standards or reference documents.

L_r = roof live load, lb/ft^2 (kN/m^2).

p_g = ground snow load, determined in accordance with Figure 7-1 or Table 7-1 of ASCE 7, lb/ft^2 (kN/m^2).

S_S = mapped risk-targeted maximum considered earthquake ground motion response acceleration, 5 percent damped, spectral response acceleration parameter at short periods, determined in accordance with Section 11.4.1 of ASCE 7.

S_1 = mapped risk-targeted maximum considered earthquake ground motion response acceleration, 5 percent damped, spectral response acceleration parameter at a period of 1 second, determined in accordance with Section 11.4.1 of ASCE 7.

V = 3-second gust basic wind speed, determined in accordance with ASCE 7, miles per hour (kilometers per hour).

W = effective seismic weight resisted by each line of resistance, lb (kN).

References

ASTM C1180-10. "Standard Terminology of Mortar and Grout for Unit Masonry", ASTM International, West Conshohocken, PA, 2010, www.astm.org.

ASTM C1232-15a. "Standard Terminology of Masonry", ASTM International, West Conshohocken, PA, 2015, www.astm.org.

BIA Technical Notes 2, 1999. "Glossary of Terms Relating to Brick Masonry", Technical Notes 2, The Brick Industry Association, Reston, VA, 1999, www.gobrick.com.

NCMA TEK 1-4, 2004. "Glossary of Concrete Masonry Terms", NCMA TEK 1-4, National Concrete Masonry Association, Herndon, VA, 2004, www.ncma.org.

Chapter 2 Limitations

2.1 – General

If the limitations specified in Chapter 2 are satisfied, use of this *Handbook* to perform the structural design of masonry buildings shall be permitted.

Any segment, member, or portion of a masonry structure that does not meet the limitations of Chapter 2 shall be designed in accordance with

Commentary Chapter 2 Limitations

C2.1 – General

Some masonry design and construction conditions would not comply with the limitations established by this *Handbook*. To maximize the use and flexibility of this design approach, portions of a masonry structure may be designed using the engineering provisions presented in the legally adopted building code, of which TMS 402 forms a part, or for non-masonry the legally adopted building code provided each of the following conditions are met:

a) The strength and stiffness compatibility between the elements designed in accordance with the legally adopted building code and the masonry designed in accordance with this *Handbook* is verified;
b) The load path through the masonry designed in accordance with this *Handbook* is not interrupted; and
c) Loads are not transferred from the elements designed in accordance with the legally adopted building code into the masonry designed in accordance with this *Handbook*.

materials, designed in accordance with the legally adopted building code. This modification is permitted because the conditions require strength and stiffness compatibility, require a continuous load path, and prohibit the transfer of loads into masonry designed in accordance with this *Handbook*.

An example of a common design condition where engineering analysis could be considered is the bearing of a concentrated load from a transfer girder on a masonry wall. Under these conditions, the portion of masonry subjected to this concentrated load would be designed using the provisions of TMS 402 while the remainder of the masonry structure could be designed using the procedures of this *Handbook*, provided the conditions of this section are met.

2.2 – Site Conditions

2.2.1 *Ground Snow Load* – Ground snow loads, p_g, shall be determined in accordance with Figure 7-1 or Table 7-1 of ASCE 7.

2.2.2 *Wind Pressure* – Design wind pressure shall be determined in accordance with ASCE 7. The basic wind speed, V, shall not exceed 250 mph (112 m/s).

C2.2 – Site Conditions

C2.2.1 *Ground Snow Load* – Many jurisdictions require the use of local snow load design values based on experience or site-specific case studies. Such local criterion can be used with this *Handbook*. Section 2.3.5 includes additional limitations on roof configurations to limit complicated snow loading scenarios.

C2.2.2 *Wind Pressure* – Users are required to determine the required wind pressures, including main wind force and components and cladding pressures, as applicable to the project based upon the basic wind speed, site topography, building configuration exposure conditions, and related project variables that influence design wind pressures.

The upper limit of 250 mph (112 m/s) on the basic wind speed covers the U.S. States and its Territories, including tornado-prone regions. While this *Handbook* can be used to structurally design the masonry to be used as part of a tornado storm shelter, it does not consider all design criteria associated with such structures; such as debris impact resistance of the masonry. For additional information on the design of storm shelters, users are referred to ICC 500, 2014.

2.2.3 *Live Loads* – Live loads shall be determined in accordance with Chapter 4 of ASCE 7.	**C2.2.3** *Live Loads* – No commentary.
2.2.4 *Dead Loads* – Dead loads shall be determined in accordance with Chapter 3 of ASCE 7.	**C2.2.4** *Dead Loads* – No commentary.
2.2.5 *Spectral Response Acceleration* – The spectral response acceleration for short period structures, S_S, and the spectral response acceleration for 1-second period structures, S_1, shall be determined in accordance with Section 11.4.1 of ASCE 7.	**C2.2.5** In daily practice, mapped seismic acceleration parameters are often determined from databases that are searchable by zip code or latitude and longitude, particularly in regions where the mapped seismic acceleration parameters vary considerably over relatively short distances. The use of such resources may provide a more accurate determination of local site conditions for seismic design.
2.2.6 *Site Class* – The Site Class, determined in accordance with Chapter 20 of ASCE 7, shall be A, B, C, or D.	**C2.2.6** *Site Class* – Section 20.1 of ASCE 7 states that: “Where the soil properties are not known in sufficient detail to determine the site class, Site Class D shall be used unless the authority having jurisdiction or geotechnical data determine Site Class E or F soils are present at the site.” This *Handbook* does not address the design of masonry structures located on Site Class E or F soils.
2.3 – Architectural Conditions	**C2.3 – Architectural Conditions**
2.3.1 *Walls* – All participating elements shall be constructed of reinforced concrete masonry or reinforced clay masonry having a nominal thickness of 6 in. (152 mm) or greater and shall be continuous from foundation to top of wall. All nonparticipating elements shall be constructed of reinforced or unreinforced concrete masonry or reinforced or unreinforced clay masonry having a nominal thickness of 4 in. (102 mm) or greater. Walls shall be specified to be constructed vertically within the construction tolerances permitted by TMS 602.	**C2.3.1** *Walls* – TMS 402 defines masonry elements as either participating or nonparticipating. Participating elements form a part of the lateral force-resisting system; whereas nonparticipating elements are isolated from the lateral force-resisting system to prevent the inadvertent transfer of loads to these elements. While unreinforced masonry partitions walls are covered by the provisions of this *Handbook*, TMS 402 may require a minimum amount of prescriptive reinforcement for these elements based on the assigned seismic design category. The limitation on the use of 6 in. (152 mm) masonry units for the design of the participating system acknowledges the difficulty of reinforcing and grouting 4 in. (102 mm) masonry units.
2.3.2 *Height* – Tops of walls, parapets, and roof peaks shall not exceed 60 ft (18.2 m) above the finished grade elevation adjacent to the structure.	**C2.3.2** *Height* – The upper limit of 60 ft (18.2 m) on the total building height is driven by the wind analysis procedures used in developing this *Handbook*. Wall height and wall span are not necessarily the same value

for a given wall. Wall height is measured relative to finished grade and includes the parapet height, if present. Vertical wall span is measured from the point of lateral bracing at the base of the wall to the point of lateral bracing near or at the top of the wall, excluding the parapet height, if present.

This *Handbook* contains no explicit limit on the number of stories a masonry building can be designed to using the direct design procedure. Overall building height or number of stories may be limited structurally based on the user-defined inputs such as specified compressive strength of masonry, wall thickness, or size of openings in a wall.

2.3.3 *Openings* – Openings in masonry walls designed in accordance with this *Handbook* shall meet the requirements of Section 2.3.3.1 or 2.3.3.2.

C2.3.3 *Openings* – Openings in masonry walls can range in size depending upon their intended purpose. Section 2.3.3.1 addresses requirements for relatively large openings, such as windows and doors. Conversely, Section 2.3.3.2 provides options for smaller openings, or a grouping of smaller openings, to be located in masonry without the restrictions of Section 2.3.3.1. Walls with openings that do not comply with the requirements of Section 2.3.3.1 or Section 2.3.3.2 would need to be analyzed using the provisions of TMS 402 for their impact on the strength of the assembly in which they are located.

2.3.3.1 Openings in walls shall be rectangular. The sides of openings shall be oriented vertically. The distribution of loads and element stiffness shall account for the presence of openings, control joints, and similar discontinuities in the wall.

C2.3.3.1 The presence of openings and control joints impacts the strength and stiffness of masonry walls. For example, a continuous 60 ft (18.3 m) long masonry shear wall would be significantly stronger and stiffer than a 60 ft (18.3 m) line of resistance separated by control joints into three 20 ft (6.1 m) long segments.

When other than rectangular openings are desired, the provisions of Section 2.1 may be used.

2.3.3.2 Openings shall not interrupt reinforcement required by Chapter 3 and shall meet the following requirements:
a) Openings shall not exceed 6 in. (152 mm) in any dimension at the face of the wall;

C2.3.3.2 Relatively small openings, such as through-wall penetrations to accommodate electrical conduit or other utilities, are common in virtually all buildings. Some openings are relatively small and have negligible impact on the strength or performance of the element in

b) The cumulative area of openings shall not exceed 144 $in.^2$ (0.093 m^2) in any 10 ft^2 (0.93 m^2) of wall surface area; and

c) The cumulative area of openings shall not reduce the net cross-sectional area in a plane by more than 5%.

which they are located. Other, larger, openings can impact the strength of an assembly. The provisions of Section 2.3.3.2 permit relatively minor openings to be placed in masonry walls designed in accordance with this *Handbook* provided that the openings, regardless of their size, do not interrupt the reinforcement within the assembly as this could have significant impact on the strength of the masonry.

2.3.4 *Diaphragms* – The roof and floor systems shall consist of one or more rigid or flexible diaphragms and meet the following requirements:

- The maximum plan dimension of a single diaphragm shall not exceed 200 ft (61.0 m).
- Each diaphragm shall be rectangular in plan dimensions.
- Diaphragms of a single building shall not be offset in plan.
- The larger plan dimension of a diaphragm shall not exceed four times the shorter plan dimension of the diaphragm.
- Each diaphragm shall be connected to masonry walls on all four sides of the diaphragm. Anchorage design shall be in accordance with TMS 402 to transfer the required forces from the diaphragm into the walls and from the walls into the diaphragm.
- Diaphragms shall be anchored to masonry walls at a location that coincides with a reinforced masonry bond beam.
- The design of the diaphragms shall account for the transfer of loads from and to the masonry walls.
- A masonry shear wall shall be provided in each direction at each corner of the diaphragm.

C2.3.4 *Diaphragms* – Each rectangular diaphragm must be surrounded and supported along each edge by masonry walls because the procedure in this *Handbook* assigns chord forces to a bond beam in the masonry. Openings in the supporting masonry wall are permitted provided the conditions of this *Handbook* are met. Outside of stated limitations, this *Handbook* does not address diaphragm design or the design of collector elements such as drag struts. This *Handbook* does not address the design of connections. Transferring forces between horizontal diaphragms and vertical walls is critical to the performance of the structure. Anchors used to achieve this force transfer are designed in accordance with TMS 402.

To avoid potential vertical irregularities, this Handbook requires:

1) a designated shear wall segment in both principal directions at each corner of each diaphragm; and
2) Vertically continuous shear walls without changes in the diaphragm dimensions or location from one story to the next.

2.3.5 *Roof Slope* – The slope of the finished roof surface shall not be less than $^1/_4$ in./ft (20.8

C2.3.5 *Roof Slope* – The required minimum roof slope is to assure the roof will drain

mm/m) and shall not exceed 12 in./ft (1,000 mm/m). The roof shall not have a curved, multiple folded plate, sawtooth, barrel vault, or dome configuration.	water. Chapter 8 of ASCE 7 outlines minimum design criteria for roof drainage. The limitations on the permitted roof configurations are to simplify what could become complex loading scenarios resulting from snow accumulation on roofs. These limits were felt necessary to keep the design snow loads to a reasonable level for the broad range of ground snow loads considered. Some roof configurations are susceptible to the formation of ice dams along the eaves of the structure; depending on environmental conditions, distance of overhang, whether the roof is ventilated or not, and the extent to which the roof is insulated. The Commentary to ASCE 7 Section C7.4.5 states: "The intent is to consider heavy loads from ice that forms along eaves only for structures where such loads are likely to form. It is also not considered necessary to analyze the entire structure for such loads, just the eaves themselves." Users should consider where, and if, ice dam loading needs to be considered for their specific project and account for any additional load accordingly.
2.3.6 *Roof and Floor Framing* – The spacing of roof and floor framing elements shall not exceed 10 ft (3.0 m) and shall not support a tributary area greater than the span length multiplied by the joist spacing. Masonry shall not be used to support reactions from tributary areas greater than that supported by a single roof or floor framing element.	**C2.3.6** *Roof and Floor Framing* – Roof and floor framing elements typically include joists, beams, trusses, and similar systems used to construct a building's diaphragm(s). Other types of diaphragm systems include cast-in-place concrete slabs and precast concrete planks. The requirement that masonry elements are not permitted to support reactions from tributary areas greater than that supported by a single framing element is to preclude the application of loads from collector elements, such as joist girders, that would result in the application of a load on the masonry that is not considered in this *Handbook*. The analyses and modeling assumptions used in developing the provisions of this *Handbook* are based on an assumption that the framing elements and slabs transmit a uniform load along the plan length of the bearing walls. Considering the limitations of the direct design procedure, this design criterion can safely be applied to joists spaced up to 10 ft (3.0 m) on center. In cases

	where this spacing is exceeded, this *Handbook* can still be used to perform preliminary designs; however, the final solution will need to be checked using conventional structural analysis techniques.
2.3.7 *Isolation of Features* – Features that extend more than 6 in. (152 mm) from the face of the finished masonry surface shall be analyzed for the additional loading imparted to the masonry.	**C2.3.7** *Isolation of Features* – Features such as signs, small lights and similar nonstructural fixtures that are regularly attached to masonry walls. The projection of such features is limited to 6 in. (152 mm) to minimize the magnitude of increase in wind load acting on the structure due to the increased projected area.
2.3.8 *Cladding* – Wall finishes and similar cladding shall be permitted to be attached, anchored, or adhered to masonry designed in accordance with this *Handbook*. The weight of all installed finishes shall not exceed 50 lb/ft^2 (2.4 kPa) and shall be included in the effective seismic weight, *W*.	**C2.3.8** *Cladding* – The 50 lb/ft^2 (2.4 kPa) wall finish weight limit is considered a practical upper limit for most cladding systems and precludes the need for more complicated analyses resulting from specialized supports, cladding anchorage, or second order loading effects.
2.4 – Loading Conditions	**C2.4 – Loading Conditions**
2.4.1 *Load Types* – The provisions outlined in this *Handbook* shall not be applied to the design of structures that include design loads other than roof dead and live loads, floor dead and live loads, snow loads, wind loads, seismic loads, soil loads, and rain loads.	**C2.4.1** *Load Types* – The procedure in this *Handbook* is based on the assumption that the structure is not ice-sensitive, as defined in Section 10.2 of ASCE 7. No other load types are permitted on the masonry, including, but not limited to, hydrostatic pressures, unbalanced soil loads, flood loads, and crane loads.
2.4.2 *Eccentricity of Loads* – The maximum eccentricity of applied axial loads shall not exceed half the thickness of the masonry wall plus 3.0 in. (76 mm).	**C2.4.2** *Eccentricity of Loads* – The maximum axial load eccentricity was selected as a reasonable upper limit for ledger connections.
2.4.3 *Concentrated Loads* – Masonry designed in accordance with this *Handbook* shall not support concentrated loads not otherwise permitted by Section 2.3.6.	**C2.4.3** *Concentrated Loads* – See Commentary Section C2.3.6.
2.5 –Material and Construction Requirements	**C2.5 – Material and Construction Requirements**
2.5.1 *Units* – Concrete masonry units complying with ASTM C90 or clay masonry units complying with ASTM C652 shall be used. The units shall be laid in running bond construction.	**C2.5.1** *Units* – No commentary.

2.5.2 *Mortar* – Mortar complying with ASTM C270 or ASTM C1714/C1714M shall be used. Mortar cement type shall comply with Table 2.5-1. The specified mortar joint thickness shall be $^{3}/_{8}$ in. (9.5 mm).

Table 2.5-1 – Permitted Mortar Types by Seismic Design Category

SDC A, B, and C	SDC D, E, and F
Type N, S, or M masonry cement mortar	Type S or M mortar cement mortar
Type N, S, or M mortar cement mortar	Type S or M non-air-entrained portland cement-lime mortar
Type N, S, or M portland cement-lime mortar	Type S or M masonry cement mortar used in fully grouted masonry construction

C2.5.2 *Mortar* – While the specified thickness of mortar joints in masonry designed in accordance with this *Handbook* is $^{3}/_{8}$ in. (9.5 mm), TMS 602 does address permitted tolerances from specified dimensions for mortar joint construction. This includes permitting the mortar bed joint of the starting course of masonry to be up to ¾ in. (19.1 mm) for partially grouted construction and up to $1^{1}/_{4}$ in. (31.8 mm) for solid grouted construction.

2.5.3 *Reinforcement* – The size of reinforcement, including dowels but excluding bed joint reinforcement and lintel stirrups, shall be Grade 60 (420 MPa) with minimum size of No. 4 (M#13) and maximum size of No. 8 (M#25) reinforcement complying with ASTM A615/A615M, ASTM A706/A706M, or ASTM A996/A996M.

The spacing of vertical and horizontal reinforcement shall not exceed 10 ft (3.0 m). When the spacing of the vertical reinforcement exceeds the lessor of six multiplied by the nominal wall thickness or 72 in. (1829 mm), the minimum area of horizontal reinforcement shall be 0.0255 in.^{2}/ft (54.0 mm^2/m) of wall height. Reinforcement shall extend the full height or length of the masonry element in which it is required, less cover distances.

Shear stirrups used in the construction of lintels shall be No. 3 (M#10) or No. 4 (M#13), Grade 60 (420 MPa) reinforcement complying with ASTM A615/A615M, ASTM A706/A706M, or ASTM A996/A996M. Stirrups shall terminate with a 180-degree hook having a minimum extension of 2.5 in. (64 mm). The spacing of lintel stirrups shall not exceed 8 in. (203 mm).

C2.5.3 *Reinforcement* – TMS 402 limits the effective compressive width per reinforcing bar for simple-span elements. When the spacing of the vertical reinforcement exceeds the lessor of six multiplied by the nominal wall thickness or 72 in. (1829 mm), the direct design procedure requires a minimum amount of horizontal reinforcement to resist design loads permitted by this *Handbook* assuming two-way bending of the masonry wall. The minimum area of 0.0255 in.^{2}/ft for the horizontal reinforcement equates to 9 gage (MW11) bed joint reinforcement spaced at 16 in. (406 mm) on center.

Although TMS 402 allows for reinforcing bars and wires of different yield strength than permitted by Section 2.5.3, due to material availability and design simplicity, the direct design procedure has limited the permitted options for reinforcement yield strength.

A detailed analysis of the load distribution model is provided in the commentary of prior editions of TMS 403.

Masonry design shall be based on a specified yield strength, f_y, equal to 60,000 psi (413.7 MPa) for reinforcing bars and 70,000 psi (492.6) for reinforcing wire.	
2.5.4 *Grout* – Grout shall comply with ASTM C476 and shall have a specified compressive strength, f_g, that meets or exceeds the specified compressive strength of masonry, f'_m.	**C2.5.4** *Grout* – Either fine or coarse grout complying with the requirements of ASTM C476 is permitted.
2.5.5 *Specifications* – The construction documents shall contain specifications that meet or exceed the requirements of Chapter 4.	**C2.5.5** *Specifications* – Chapter 4 outlines the minimum material, testing, inspection, and construction requirements required by this *Handbook*.
	References **ICC 500, 2014.** "ICC/NSSA Standard for the Design and Construction of Storm Shelters", International Code Council, Washington, D.C., 2014, www.iccsafe.org.
Chapter 3 **Procedure**	**Commentary Chapter 3** **Procedure**
3.1 – General Design of masonry in accordance with this *Handbook* shall comply with the procedure given in Chapter 3. In each step, the design variables shall be determined by the user.	**C3.1 – General** The procedure in this *Handbook* is based on a comparison of factored design loads and design strengths in accordance with Part 1, Part 2, Chapter 9, and Chapter 14 of TMS 402. This *Handbook* covers only the design of masonry walls meeting the limitations of Chapter 2. The design of diaphragms, foundations, and other components critical to the performance of buildings is not covered by this *Handbook*. As required by this *Handbook* and TMS 402, structural continuity must be maintained between the application of load and the final point of resistance. For reinforcement, this is most commonly achieved through lap splicing of the reinforcement.
3.2 – Direct Design Procedure **3.2.1** *Step 1* – Verify that the site-specific limitations of Section 2.2 of this *Handbook* are met. If the conditions of Section 2.2 are satisfied, a building configuration that satisfies the architectural, loading, and construction conditions of Chapter 2 shall be developed.	**C3.2 – Direct Design Procedure** **C3.2.1** *Step 1* – The creation of preliminary plans will be more efficient when based on experience with the procedure in this *Handbook*, as the direct design procedure requires selection of options that affect architectural limitations. For example, a preliminary floor plan containing many small openings or a few large openings could result in a series of shear wall segments that are not

	long enough to accommodate the minimum spacing of vertical reinforcement required.
3.2.2 *Step 2* – Using ASCE 7, the following design variables shall be determined: 2A The Risk Category based on ASCE 7 Table 1.5-1. 2B The Ground Snow Load, p_g, using ASCE 7 Figure 7-1 or ASCE 7 Table 7-1. The Exposure Factor, C_e, using ASCE Table 7-2. The Thermal Factor, C_t, using ASCE 7 Table 7-3. The Roof Slope Factor, C_s, using ASCE 7 Figure 7-2. 2C The 3-Second Gust Basic Wind Speed, V, using ASCE 7 Figure 26.5-1. The Topographic Factor, K_{zt}, in accordance with ASCE 7 Section 26.8. 2D The Exposure Category, in accordance with Section 26.7 of ASCE 7. 2E The mapped spectral acceleration for short periods, S_S, in units of $\%g$, by dividing the values on ASCE 7 Figure 22-1, 22-3, 22-5, or 22-6 by 100. 2F The mapped spectral acceleration for a 1-second period, S_1 , in units of $\%g$, by dividing the values on ASCE 7 Figure 22-2, 22-4, 22-5, or 22-6 by 100. 2G The Live Load, L, and Roof Live Load, L_r, in accordance with Chapter 4 of ASCE 7. 2H The dead load, D, in accordance with Chapter 3 of ASCE 7.	**C3.2.2** *Step 2* – The information obtained in this step is required for design. Both wind and seismic design criteria are necessary because ASCE 7 requires that all buildings be designed for both wind and seismic loading conditions and meet all prescriptive seismic requirements even if seismic loads do not govern the design of any elements. Some ASCE 7 design parameters are not necessary as one or more of the limitations of Chapter 2 preclude their consideration for buildings designed using the direct design procedure.
3.2.3 *Step 3* – Based on S_S and S_1, the Seismic Design Category shall be determined in accordance with Table 3.2.3(1), 3.2.3(2), 3.2.3(3), or 3.2.3(4) based on the project's seismic site class.	**C3.2.3** *Step 3* – The Seismic Design Categories in Table 3.2.3 were determined in accordance with Sections 11.4 through 11.6 of ASCE 7 based upon the Site Class soil profile. The site soil is classified in accordance with Chapter 20 of ASCE 7 as Site Class A, B, C, or D, corresponding to hard rock, rock, very dense soil and soft rock, and stiff soil, respectively. The direct design procedure is not permitted for Site Class E (soft clay) or Site Class F (soils requiring site response analysis) soil profiles. Where applicable, accounting for the actual soil conditions at the project location may reduce the Seismic Design Category and therefore increase the economy of the

	structure. See Commentary Section C2.2.6 for additional discussion on seismic site class options.

Table 3.2.3(1): Seismic Design Category (SDC) for Site Class A

S_S	S_1	Seismic Design Category: Risk Categories I, II, III	Seismic Design Category: Risk Category IV
$S_S < 0.314$	$S_1 < 0.126$	A	A
	$0.126 \le S_1 < 0.250$	B	C
	$0.250 \le S_1 < 0.375$	C	D
	$0.375 \le S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F
$0.314 \le S_S < 0.619$	$S_1 < 0.250$	B	C
	$0.250 \le S_1 < 0.375$	C	D
	$0.375 \le S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F
$0.619 \le S_S < 0.938$	$S_1 < 0.375$	C	D
	$0.375 \le S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F
$0.938 \le S_S \le 3.00$	$S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F

Table 3.2.3(2): Seismic Design Category (SDC) for Site Class B

S_S	S_1	Seismic Design Category: Risk Categories I, II, III	Seismic Design Category: Risk Category IV
$S_S < 0.250$	$S_1 < 0.101$	A	A
	$0.101 \le S_1 < 0.200$	B	C
	$0.200 \le S_1 < 0.300$	C	D
	$0.300 \le S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F
$0.250 \le S_S < 0.495$	$S_1 < 0.200$	B	C
	$0.200 \le S_1 < 0.300$	C	D
	$0.300 \le S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F
$0.495 \le S_S < 0.750$	$S_1 < 0.300$	C	D
	$0.300 \le S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F
$0.750 \le S_S \le 3.00$	$S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F

Table 3.2.3(3): Seismic Design Category (SDC) for Site Class C

S_S	S_1	Seismic Design Category: Risk Categories I, II, III	Seismic Design Category: Risk Category IV
$S_S < 0.209$	$S_1 < 0.059$	A	A
	$0.059 \le S_1 < 0.119$	B	C
	$0.119 \le S_1 < 0.186$	C	D
	$0.186 \le S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F
$0.209 \le S_S < 0.413$	$S_1 < 0.119$	B	C
	$0.119 \le S_1 < 0.186$	C	D
	$0.186 \le S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F
$0.413 \le S_S < 0.661$	$S_1 < 0.186$	C	D
	$0.186 \le S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F
$0.661 \le S_1 \le 3.00$	$S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F

Table 3.2.3(4): Seismic Design Category (SDC) for Site Class D

S_S	S_1	Seismic Design Category: Risk Categories I, II, III	Seismic Design Category: Risk Category IV
$S_S < 0.156$	$S_1 < 0.041$	A	A
	$0.041 \le S_1 < 0.083$	B	C
	$0.083 \le S_1 < 0.132$	C	D
	$0.132 \le S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F
$0.156 \le S_S < 0.321$	$S_1 < 0.083$	B	C
	$0.083 \le S_1 < 0.132$	C	D
	$0.132 \le S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F
$0.321 \le S_S < 0.553$	$S_1 < 0.132$	C	D
	$0.132 \le S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F
$0.553 \le S_S \le 3.00$	$S_1 < 0.750$	D	D
	$0.75 \le S_1 \le 1.250$	E	F

3.2.4 *Step 4* – Determine the lateral force resisting system in accordance with Table 3.2.4. In each principal plan direction of each rectangular diaphragm of the building, a single lateral force-resisting option shall be selected.

C3.2.4 *Step 4* – The lateral force-resisting (shear wall) options per Table 3.2.4 satisfy the provisions of Chapter 7 of TMS 402. TMS 402 permits other types of shear wall systems; however, because the direct design procedure is based solely on the design of conventionally reinforced clay and concrete

Table 3.2.4: Lateral Force-Resisting Options

Seismic Design Category (SDC)	**Lateral Force Resisting System Options**
A, B or C	Ordinary Reinforced Masonry Shear Walls (ORMSW)
	Intermediate Reinforced Masonry Shear Walls (IRMSW)
	Special Reinforced Masonry Shear Walls (SRMSW)
D, E, or F	Special Reinforced Masonry Shear Walls (SRMSW)

masonry, only three shear wall types are permitted.

3.2.5 *Step 5* – For each diaphragm level, divide the building into rectangular diaphragms with masonry wall lines on each side. For multi-story buildings, the extents of the diaphragm boundaries shall be the same for each story. Walls inside the perimeter of a diaphragm shall be designed and detailed as nonparticipating walls.

C3.2.5 *Step 5* – Designation of rectangular diaphragms within the building plan dimensions defines the extent of the lateral force-resisting system. A single building may have more than one way to designate these diaphragms subject to the limitations of Section 2.3.5.

3.2.6 *Step 6* – Determine minimum design loads in accordance with ASCE 7.

C3.2.6 *Step 6* – The procedures of direct design permit most, but not all design loads covered in ASCE 7. See Section 2.2 for loading limitations.

3.2.7 *Step 7* – Masonry elements shall be designed in accordance with Section 9.3 of TMS 402 and the requirements of this *Handbook*. Unreinforced masonry partition walls shall be designed in accordance with Chapter 14 of TMS 402.

C3.2.7 *Step 7* – The direct design procedure is based on the strength design provisions for reinforced masonry as prescribed in TMS 402. Some TMS 402 design requirements are not necessary as one or more of the limitations of Chapter 2 preclude their consideration for buildings designed using the direct design procedure.

Chapter 14 of TMS 402 contains a prescriptive method for designing and detailing nonparticipating masonry partition walls subject to the constraints and limitations of those provisions.

3.2.8 *Step 8* – The following design assumptions shall be permitted for the design of masonry in accordance with this *Handbook*.

C3.2.8 *Step 8* – Due to the limitations and constraints placed on masonry designed in accordance with the direct design procedure, a number of simplifications can be applied that may only apply to a limited subset of conventionally design masonry.

3.2.8.1 *Coupling* – Unless specifically designed and detailed for the transfer of moment and shear forces, it shall be permitted to neglect the coupling effects between shear walls.

C3.2.8.1 *Coupling* – The direct design procedure does not address frame analysis of masonry structures. Although some degree of coupling may be present from spandrel beams, diaphragms, drag struts, and similar elements, unless there is a technical need to account for coupling effects between shear wall segments, it is a common and conservative practice to ignore these effects.

3.2.8.2 *Beam Deflection* – It shall be permitted to assume that deflections of masonry beams satisfy a deflection limit of *l*/360 when the beam span-to-depth (*l*/*d*) ratio is less than or equal to 12.

C3.2.8.2 *Beam Deflection* – Analysis shows that the deflection of reinforced masonry beams is limited to *l*/360 or less when constructed using a Type N masonry cement mortar. Deflections would be reduced if using a mortar with a larger modulus of rupture.

3.2.8.3 *Beam Shear* – In cantilever beams, the maximum shear shall be used. In non-cantilever beams, the maximum shear shall be used except that sections located within a distance *d*/2 from the face of support shall be designed for the same shear as that calculated at a distance *d*/2 from the face of support when the following conditions are met:
(a) support reaction, in direction of applied shear force, introduces compression into the end regions of the beam, and
(b) no concentrated load occurs between face of support and a distance *d*/2 from face.

C3.2.8.3 *Beam Shear* –The beam or wall loading within *d*/2 of the support is assumed to be transferred in direct compression or tension to the support without increasing the shear force, provided no concentrated load occurs within the *d*/2 distance.

3.2.8.4 *Diaphragm Classification* – Diaphragms shall be classified as either flexible or rigid in accordance with Table 3.2.8.4.

Table 3.2.8.4 – Diaphragm Classification

Diaphragm Construction	Diaphragm Classification
Wood structural panels	Flexible
Untopped steel decking	Flexible
Concrete slab	See Section 3.2.8.4.1
Concrete filled deck	See Section 3.2.8.4.1
Other – flexible diaphragm	Flexible
Other – rigid diaphragm	Rigid

C3.2.8.4 *Diaphragm Classification* – Whether a diaphragm is considered flexible or rigid is a function of the relative stiffness of the diaphragm construction and the supporting masonry walls. Based on the limitations of Chapter 2, diaphragms may be classified in accordance with Table 3.2.8.4 for simplification.

3.2.8.4.1 It shall be permitted to consider diaphragms rigid when either of the following conditions are met:

C3.2.8.4.1 No commentary.

a) The span-to-depth ratio of the diaphragm is less than or equal to 3 and there are not horizontal irregularities; or

b) The maximum diaphragm deflection is less than two multiplied by the average drift of the vertical elements of the lateral force-resisting system.

Where these conditions are not satisfied, the diaphragm stiffness shall be calculated.

3.2.8.5 *Stiffness Calculations* – Unless a more rigorous analysis procedure is used, it shall be permitted to use one-half of the gross moment of inertia as the cracked moment of inertia for the calculation of shear wall drift.

C3.2.8.5 *Stiffness Calculations* – The determination of cracked section properties is a complicated and often inaccurate exercise. Using one-half of the gross moment of inertia has been conservatively applied to the design of masonry for many years barring a more robust analysis.

Chapter 4 Specification

4.1 – General

Project specifications for masonry designed in accordance with this *Handbook* shall meet or exceed the requirements of TMS 602. Design decisions applicable to masonry designed in accordance with this Handbook shall include the requirements of Table 4.1.

Table 4.1 – Specification Requirements

TMS 602 Part/Article	Specification Requirement
Part 1 – General	
1.4A – Compressive strength	Specify f'_m.
1.4 B.2 – Unit strength method	Specify when strength of grout is to be determined by test.
1.5 - Submittals	Define the submittal reporting and review procedure.
1.6 A.1 – Testing Agency's services and duties	Specify which of TMS 602 Tables 4 or 5 applies to the project.
1.6 B.1 – Inspection Agency's services and duties	Specify which of TMS 602 Tables 4 or 5 applies to the project.

Commentary Chapter 4 Specification

C4.1 – General

Chapter 4 defines the design decisions in order to use the provisions of this *Handbook* and comply with the requirements of TMS 402 and TMS 602. The designer may choose to add additional or more stringent requirements to the project specification as permitted by TMS 602. Specifying the use of an integral water repellent or surface-applied coating is one example of an additional requirement that the designer might consider.

TMS 602 is a reference specification. The Mandatory Requirements Checklist of TMS 602 lists the choices that must be made by the designer and the Optional Requirements Checklist of TMS 602 lists the choices that are permitted to be made (but do not have to be made) if the designer wishes to invoke a requirement other than the default requirement where such a choice is permitted.

1.6 D – Sample panels	Specify requirements for sample panels.
Part 2 – Products	
2.1 – Mortar materials	Specify type, color, and cementitious materials to be used in mortar and mortar to be used for the various parts of the project and the type of mortar to be used with each type of masonry unit.
2.3 – Masonry unit materials	Specify masonry units complying with ASTM C90 or ASTM C652 to be used for the various parts of the project.
2.4 – Reinforcement and metal accessories	Specify Grade 60 reinforcing bars. Specify type and grade for connectors and accessories. For reinforcing bars, specify that the actual yield strength must not exceed the specified yield strength multiplied by 1.3.
2.4 C.1 – Joint reinforcement	Specify joint reinforcement wire size and number of longitudinal wires.
2.4 E – Stainless steel	Specify when stainless steel joint reinforcement, anchors, ties, and/or accessories are required.
2.4 F – Coating for corrosion protection	Specify the types of corrosion protection that are required for each portion of the masonry construction.
2.5 E – Joint fillers	Specify size and shape of joint fillers.
Part 2 – Products	
3.3 D.2-4 – Pipes and conduits	Specify sleeve sizes and spacing.

3.3 D.5 - Accessories	Specify accessories not indicated on the project drawings.
3.3 D.6 – Movement joints	Indicate type and location of movement joints on the project drawings.
3.3 B.11 – Placement tolerances	Indicate *d* distance for beams and drawings or as a schedule in the project specifications.
3.4 E – Veneer anchors	Specify type of anchor required.