

MANUAL OF CONSTRUCTION METHODS FOR BUILDING IN AFGHANISTAN

Compiled by the



*United States Agency for International Development
USAID/Afghanistan*

MANUAL OF CONSTRUCTION METHODS FOR BUILDING IN AFGHANISTAN

TABLE OF CONTENTS

I.	Introduction and Purpose	1
II.	Construction Material and Methods	1
	A. Earthwork and Soil Compaction	1
	B. Concrete Construction	3
	1. Structural Concrete	3
	2. Reinforcing Steel	5
	3. Forms and Formwork	7
	4. Finishing Concrete Surfaces	9
	5. Concrete Curing	10
	6. Hot/Cold Weather Concrete Operations	11
	7. Precast Concrete	12
	C. Masonry Construction	12
	1. Stone Masonry	13
	2. Brick Masonry	14
	3. Concrete Masonry Units	15
	4. Masonry Mortar	16
	5. Grout	17
	6. Scaffolding	17
	D. Steel Construction	18
	E. Wood Construction	19
III.	Components of Buildings	20
	A. Site Preparation and Housekeeping	20
	B. Building Foundations	21
	C. Structural Framing	23
	D. Wall Systems	25
	E. Slabs on Grade	27
	F. Elevated Floor and Roof Structures	28
	G. Concrete Columns and Walls	30
	H. Roof Systems	31
	I. Doors and Windows	34
	J. Masonry Wall Finishes (Stucco and Painting)	35
	K. Plumbing Systems	38
	1. Basic Plumbing Concepts and Terms	38
	2. Basic Water Supply Concepts and Terms	39
	3. Basic Waste Water Discharge Concepts and Terms	41
	4. Basic Liquid Fuel Concepts and Terms	43
	L. Mechanical Systems	47
	1. Electrical Generators	47
	2. Water Heaters	47
	3. Heating and Cooling Systems	48

M. Electrical Systems	49
1. On-Site Power Generation	49
2. Electrical System Interior Wiring	50

MANUAL OF BUILDING CONSTRUCTION FOR AFGHANISTAN

I. INTRODUCTION AND PURPOSE

Construction in Afghanistan is very different from U.S. construction and offers many challenges to maintaining good quality. The availability of materials and equipment (or lack thereof) dictates most construction methods. Outside of major cities, building designs seldom, if ever, have historically had any consideration for earthquake forces, but follow age-old methods without any modern building code influence. There are currently no building codes in place, nor are there any controls placed by the government on contractor or engineer licensing or certification. The Coalition Forces and international agencies have an opportunity with our current assistance effort to influence better building methods into the Afghan construction industry. The massive influx of dollars for infrastructure provides occasion to require Afghan contractors to adhere to near – if not entire – compliance with international building standards, if we will take opportunity to enforce those higher standards on projects that we fund. It will take a few years to spread, inculcate and reinforce these practices to the degree that they are generally accepted and even self-enforced by the Afghan construction industry itself. Therefore it is incumbent upon everyone who has an influence on construction to understand what minimum standards should apply to the construction methods that are – or should be – used in Afghanistan.

This manual is designed to be read and understood by non-building professionals who are taking on responsibilities for controlling, inspecting or in any other way influencing building construction in Afghanistan. It can also be used as a basis for minimum construction standards – and therefore a poor substitute for – project specifications, in the absence of such detailed specifications. It can also be used as a basic textbook for training Afghan contractors on construction methods.

II. CONSTRUCTION MATERIALS AND METHODS

A. EARTHWORK AND SOIL COMPACTION

Earthwork involves two general operations, cutting or filling. “Cutting,” or excavation, is the removal of the in-place soil or rock material. This could be the digging out of trenches or holes for installation of building foundations or to provide desired drainage across the ground surface, or it could involve excavation over a large area to bring the grade down to the level desired for a building pad or parking lot. “Fill” is the addition of soil or rock materials to bring up the level of the ground surface. Compaction of soils and types of materials used for fill are the two major concerns with earthwork operations.

Materials. Types of earth materials include organics, silt, clay, sand, and stone. Organics (e.g., plant roots, lumber, grasses, etc.) are bio-degradable and will therefore decompose over time. No organics should be allowed in the ground under a building or road. **Silts** are tiny rounded or angular particles that are generally smaller in diameter than 0.12 millimeters (or will pass the #200 sieve by American Society of Testing Materials standards). Because of their shape, silt particles will not stick together and are easily blown in the wind. Afghanistan air and surfaces are full of

silts. **Clays** are tiny flat particles that are smaller than 0.12 mm (will pass the #200 sieve). Because of their shape, clay particles tend to stick together and retain moisture in the space between them. (Imagine two sheets of window pane with a couple drops of water between them. They slide against each other easily, but are difficult to pull apart due to the tensile force imposed by the water filling the space between the panes.) Sand is angular or rounded in shape, larger than 0.12 millimeters and smaller than 0.6 centimeters in diameter. Like silt, sand does not stick together and is fairly easily blown by the wind. Stone includes any particles larger than 0.6 centimeters in diameter. When earth materials are all of about the same particle size, significant voids exist between the particles. When approximately equal amounts of varying particle sizes and types are mixed together, the smaller particles tend to fill the voids between the larger particles. Thus compaction is more readily achievable if the soil includes a mixture of particle sizes and types. High clay soils are particularly difficult to achieve dense compaction on, as the moisture cannot be easily removed from between the particles. If soils consist of all rounded particles, they more easily roll against each other under heavy loads and allow penetration of the loaded object. Angular particles provide a more stable bed due to the interlocking action of the particles when compacted. A material that has a good mixture of particle sizes is desirable for supporting foundation loads in construction projects.

Compaction. If the ground under buildings, roads, parking lots and other structures is not well compacted, the loads imposed from the weight of foundations or wheels can compact the soils after construction is completed, causing settlement of the structure. Since such settlement is usually uneven, it results in cracking of walls, rutting or potholes in roads, and other problems. Obviously, repair to correct those problems can cause far more effort and costs than care to achieve proper compaction would have taken in the first place. Soils undisturbed in place for millions of years have normally achieved a significant degree of natural compaction. With some exceptions, undisturbed soils in Afghanistan are hard and tightly compressed. This is due partly to a common mixture of sands, clays, silts, and rock found here, but more so to the low rainfall, resulting in little vegetation (thus few organics) and siltation brought down from erosion. One notable exception in some areas is a layer of wind-blown silt, several centimeters thick, that lies on the surface. Such loose silt or sand would not be well compacted and would require some compactive effort or removal.

Prior to construction, it is requisite that the soils where loads will be imposed are evaluated as to their existing state of compaction. One commonly accepted method is to run a heavily loaded truck over the area and watch to see if the ground deflects under the wheels. “**Pumping**” is the general deflection of the ground as the wheel passes over, followed by a rebounding to near its original level immediately behind the wheel. Often little actual evidence of tire tracks remains with pumping. This is because there are soft clays below the surface that have high moisture content. Moisture is temporarily forced out from between the granules under the pressure, but re-enter and re-expand the soil after the load is released. If “pumping” occurs, the only solution is to excavate the ground for about half a meter deep and replace with properly compacted layers of fill. If only surface **rutting** occurs without any pumping, only the top two to six centimeters of soil would likely need to be excavated and replaced with fill. In trenches or other confined spaces where the loaded truck method cannot be used, the compaction of the ground can be estimated by pushing a one centimeter diameter steel rod into the surface. If it penetrates the surface easily beyond one centimeter, the soil probably needs compaction prior to installation of the footing.

Typical compactive effort in confined spaces like trenches should include a pad tamper, a “jumping jack” tamper, or trench roller. For broad areas requiring compaction (e.g., parking lots, roads or large building pads), a large vibratory roller driven by an operator would save a lot of

time. The compactive effort should be wider than the future foundation on the ground surface or extend the full width of a trench. Some moisture in the soil is desirable to achieve proper compaction because it lubricates the soil grains, allowing them to slide into a compact space. Too much water in clays will displace air voids and cause the soil to swell, preventing proper compaction. In absence of a soils lab to determine optimum moisture content, common sense judgment and, possibly, some experimentation must be made in the field. Fill should be placed and compacted in no more than 15 cm lift thicknesses. On hard soils or rock, a minimum amount of aggregate may be spread and compacted over the surface and compacted in order to level the trench prior to placing the foundation.

Inspection items:

- Check clean cut lines, proper depth of cut, moisture content of soil, compaction of subgrade and stone fill, thickness of fill layers, and final elevations.

B. CONCRETE CONSTRUCTION

Concrete is one of the most common and readily available building materials in Afghanistan, and is arguably the least controlled and most abused in terms of quality. Concrete is commonly used for paving, foundations, floor and roof slabs, beams, columns, and retaining walls, among other structures. Concrete construction requires proper procedures, not only with the concrete itself, but also with steel reinforcing, forming and finishing.

1. STRUCTURAL CONCRETE

Concrete used in structures is composed of a mixture of large and small aggregate (stone and sand), Portland cement, and water. Concrete is relatively cheap and strong, and most of its ingredients are readily available in natural forms in nearly every area of the country. Portland cement is the only manufactured ingredient, although the aggregate may require some crushing in rock crushing machines to achieve the desired particle sizes and shapes. Concrete is normally about 1/10th as strong in tension (derived from the chemical bond formed between the cement and the aggregate) as it is in compression. Thus is the need for steel rebar to be used in the concrete, as the steel provides the tensile strength and the concrete the compressive strength.

To achieve minimal strength capacities of structural concrete, the typical mix should be a ratio of about 1:2:3 (cement, sand, stone) by weight. To achieve that ratio by volume is usually a close approximation of the ratio by weight. Ensure that no organic, clay or silt materials are allowed to be in the concrete mix. These materials will prevent proper consolidation and interlocking of the aggregate and bonding of the concrete to the rebar and aggregate surfaces. The small aggregate (smaller than 0.6 millimeters, but with very low percentage smaller than 0.12 millimeters) and large aggregate (between 0.6 and 2 to 3 centimeters) should be passed through a properly-sized screen to achieve the required size proportions. Without a proper mixture of large and small aggregate, cement will be required to fill the voids between particles, leaving insufficient cement to provide needed bonding between aggregate particles.

Water is required to precipitate the chemical reaction with the cement, which bonds all the aggregate together. Water must be clean, as contaminants will decrease the final strength. The percentage of water in the mix is critical. Water in excess of that involved in the actual chemical reaction with cement will eventually evaporate from the mix, leaving voids and causing internal

tensions that result in the cracking of concrete. However, some excess water must be provided in order to insure that every cement particle receives its minimal H₂O molecule and that the mix is fluid enough to settle into the forms.

Cements imported for use in Afghanistan vary greatly in their bonding capability. The bag should specify that the cement was manufactured for use in concrete, at a minimum. As we gain more experience here, we will learn and determine brands of cement to allow and to prohibit for use in structural concrete mixes. So far we've learned the "Elephant" brand cement produces less than acceptable strengths, and "Lucky" brand cement has produced good results. A good rule of thumb is a 1:2 water to cement ratio by weight (1:1½ ratio by volume) in order to achieve about 1,025 kg/cm² (3,000 pounds per square inch) compressive strength in the concrete. This is assuming that the cement, sand and stone are of good quality, angular in shape to provide good interlocking conditions, and properly mixed. If lesser conditions exist or greater strengths are desired, higher cement proportions should be provided.



(Above) Using a screen to sieve sand.



(Right) Hand mixing concrete using a shovel to measure volume. Note separate piles of large aggregate and sand. The water ratio measuring method should be better. Adequate mixing of materials is hard to achieve by hand, but is much easier with a rotating drum.



Separate piles of large and small aggregate, proportioning with measuring box.



Proportionate quantities of materials are placed into hopper, then fall into rotating mixing drum.



Ready for concrete columns in plane of wall to tie second floor ring beam to foundation.

Concrete materials should all be mixed together well, preferably in a rotating drum mixer for a minimum of 10 minutes per batch. The concrete should be placed in the forms with less than a 1-meter drop in order to prevent segregation of the aggregates. If placement conditions, such as in a wall, prevents placing the bucket within 1 meter of the form bottom, a tremie (flexible chute) should be used to guide the mix into position. A mechanical vibrator should be used to consolidate the concrete and cause air bubbles to float to the top. The vibrator should be placed into every area of the concrete for about 3 seconds. It should be dipped straight down and straight up, not used to “drag” the concrete sideways. Movement of concrete should be accomplished with tools, moving it in mass, not depending on the vibrator to make it “flow.” If a mechanical vibrator cannot be obtained, concrete consolidation can be somewhat achieved by a lot of prodding into the mix using a steel rod.

Concrete Inspection items

- Ensure the contractor is using proper gradations of large and small aggregate, that the large aggregate is angular in shape (not rounded), and that the aggregate is not soft (not easily crushed or broken).
- Ensure that proper proportions (1:2:3 or otherwise stated by engineering specifications) of cement and small and large aggregate are being mixed, and proper quantities of water (1:1½ water to cement by volume) are being added to the mix.
- Insure the ingredients are being adequately mixed, e.g., about 10 minutes per batch in a mechanical mixer; longer if by hand in a pit.
- No foreign objects should be in the mix; water should be clean.
- Insure proper placement procedures as described above.



Concrete in ring beam is poorly consolidated in form, leaving voids for moisture penetration.

2. REINFORCING STEEL (REBAR)

Concrete has high compressive but very little tensile strength; therefore rebar is required to provide the tensile strength. That is why concrete commonly cracks unless it is properly reinforced with steel. It is critical to place rebar in all concrete elements. It is also imperative to have rebar placed vertically in bearing walls in order to hold the walls together in earthquakes. Follow the structural engineering drawings which should show the desired placement of rebar. To help detect proper placement of reinforcing, be aware that the bottom of a slab or beam is usually in tension between its supporting members, and the top of the slab or beam is in tension directly over its supporting members. Thus rebar would be near the top of a beam or slab above the support and near the bottom midway between the supports. Rebar normally runs the length of beams and columns to carry the tensile forces in those members. Beams and columns also require steel ties wrapped around the main longitudinal steel. These ties provide strength against the shearing forces that

would break the member in two. Shear forces are maximum at the point where a beam meets its support, and are usually at a minimum near mid-span. Thus, if shear forces require ties, the spacing of ties should be closer as the beam approaches a support. In slabs, rebar usually runs in both directions, perpendicular and parallel to supporting beams or walls, in a crisscrossed pattern. Typical sizes of rebar are 6 to 8mm for ties and 10 to 16mm for floors, walls and foundations. Rebar must be adequately covered by concrete to prevent moisture from reaching it and rusting it out over time. This requires a minimum of 2 centimeters of space between the rebar and the form when the concrete is placed. Note that it is critical to inspect forms and rebar prior to placing the concrete. Once the concrete is placed, it is too late to check the rebar.



(Above) Rebar bent, spaced, placed and tied exactly as described on structural drawings for an elevated concrete floor or roof. Note overlap of rebar where splices occur.



(Top photo) Inadequate space between form and rebar plus inadequate vibration of concrete in form results in rebar exposed to weather. Extremely poor concrete finishing overall (rough surface).



(Right photo) Poor alignment of forms for ring beam and column, inadequate space between rebar and form.

Rebar Inspection items

- Always ensure that there is no rebar touching any part of a concrete form. There should be a minimum of the following spaces between the rebar and the form:

Face of concrete poured against earth	8 cm
Face to be exposed to weather	5 cm
Face to be protected from weather	2 cm
- Horizontal rebar in a flat slab should have 4 to 6 cm spacing between the rebar and the bottom of the form. Use brick or metal spacers to support or shim the rebar such as to provide appropriate spacing when the concrete is placed.
- When it is necessary to connect 2 pieces of rebar together, the two pieces shall be lapped (never welded) at their meeting ends. Lap lengths shall be a minimum of the following:

Columns and compression members	24 x bar diameter
Beams and tension members	36 x bar diameter
- Rebar must be placed to exact size, spacing and bending (if applicable) as shown on the engineering drawings.

3. FORMS AND FORMWORK

Since concrete is in a semi-fluid state when it is placed, forms must be used along the sides and bottoms of structural members to contain the concrete and provide the desired shape of the eventual structure. Forms may be plywood, strips of wood, or other materials that provide adequate containment and a smooth surface. Vertical side forms must be adequately strong to resist the lateral forces of the wet concrete. Wet concrete can exert lateral pressures of over 500 kilograms per square meter times the height of the wet placement in meters. Therefore, the form must be well braced from the outside. Concrete weighs about 2,400 kilograms per cubic meter; thus a 15-centimeter thick concrete slab will weigh about 360 kilograms per square meter. Shoring must be placed under horizontal forms (e.g., for slabs) sufficient to support the dead weight of the concrete, plus any live loads (e.g., workers) that may be imposed. It is much more advisable to over-design formwork (the entire forming system) than to chance a failure when the form is full of wet concrete.



(Left) Trash left in bottom of form, form does not provide uniform shape of beam, poor concrete consolidation in slab above. None of these problems would be visible after covered with plaster.
(Right) Debris left in form and rebar laid directly against bottom of form leaves it exposed after concrete placement. Very poor concrete consolidation, leaving voids. Beam will not be nearly as strong as required.



Roof slab has mud coating spread over forms, ready for placement of slab rebar. The mud, mixed with straw, is often spread thinly over the wood forms to fill in the cracks and provide a smoother bottom slab surface. Once the slab is placed, forms will be built each side of the beams, which will extend above the slab.



Forms are being stripped from underneath elevated slab after concrete has cured and gained enough strength to support its own weight. Forms and shoring are usually left in place a minimum of 14 days after concrete placement. If required, forms could be removed earlier and slab immediately reshored.

When concrete is placed against a form and hardens, it tends to hold onto the form, especially if the form's face is rough. If the form is pried away from the concrete, splinters often pull off and stick to the concrete. A light coating of oil on the form will help to loosen the form when it is removed. The more common method in Afghanistan is to spread a thin layer of mud over the surface of the form, allowing for easy form removal. The mud can then be washed off with a hose and water pressure. However, it is imperative to get all the mud off prior to application of plaster to the concrete surface. Otherwise, the plaster will not adhere for very long to the concrete.

Formwork Inspection Items:

- It is recommended that the form be oiled lightly or mud spread on the surface in order to facilitate their removal.
- For a concrete member placed on the ground, any soil that will come in direct contact with the placed concrete should be hosed down with water. (Do not create a mud bath). Ideally a plastic barrier should be placed between the soil and the concrete. If the soil absorbs too much water out of the fresh concrete, it will prevent uniform curing and cause surface cracking and spalling.
- The bottom of the form must be free of trash or other foreign objects.



(Above) Brick was used to form sides of lintel/ring beam, common due to high price of plywood. This is not good practice. Lintels should extend at least 20 centimeters onto the wall each side of opening to keep from overstressing the brick it sits on. Note exposed rebar at underside of beam; rebar was lying on the form when the concrete was placed.

4. FINISHING CONCRETE SURFACES

Concrete Surfaces After Stripping Forms. As discussed in the previous section, the surface of the concrete may be marred after the form is stripped away if proper care is not taken with vibrating during placement to remove air pockets or in oiling forms before placement. If the surface is to be exposed to public view, any scars should be filled with grout and smoothed over after the forms are stripped. If the defects are bad enough to affect the structural strength of the concrete member, it may be necessary to break out the entire concrete piece and have it replaced.

Floor Finishes. There are basically two methods that are acceptable for finishing the surface of floors, these are concrete or tile finish, described as follows.

Concrete Floor Surfaces: Concrete surfacing is the less expensive of the two methods, requiring less labor and good durability. There are two types of finished surfaces; smooth and broomed.

Smooth Finish

- Accomplished by swiping a flat-edged steel trowel repetitively across the surface, creating a flat and smooth surface, free of impressions.
- Advantages: Easy to clean and maintain. Surface is harder and more resistant to abrasions. Recommended where sanitation is of prime importance (e.g., medical or kitchen environment) or where surface will take industrial-level abuse (e.g., warehouses, factories).
- Disadvantages: Slippery when wet.

Broomed Finish:

- Accomplished by sweeping across the surface with a broom to create a flat surface with tiny ridges caused by the broom bristles.
- Advantages: Provides traction, is not slippery when wet. Recommended for all exterior and most interior applications.
- Disadvantages: Harder to clean and maintain because of the crevices created by the brooming, which tend to collect small particles.

Concrete Floor Surfacing Inspection Items:

- Finishing a concrete floor surface should be done just as the concrete is starting to harden, but while still workable. It must be timed so that the fresh concrete is not soft enough to allow imprints from workers' feet, and not too hard to prevent smoothing or brooming.
- The surface should be just hard enough to support the weight of the finisher. When it is ready to be steel troweled it must be done so as not to create depressions in the concrete.

Tile Floors: Tile floors are recommended in areas where aesthetics dictate a floor type that is more pleasing to the eye. They might also be used where floors require frequent or high levels of cleanliness, such as medical, kitchen, bathrooms and office areas. Tile can also be placed vertically on walls for back-splash and shower applications. The main disadvantage in using tile floors is the additional cost of materials and labor.

Tile Floor Inspection Items:

- The concrete slab surface on which the tile is to be placed should be flat (or sloped to drain, if required), roughened (broom finished at minimum), and clean.
- Look for proper alignment and spacing of the tiles.
- Once the tiles are glued in place, joints must be filled with grout (1 part cement to 6 parts sand).

5. CONCRETE CURING

After concrete has been placed, it undergoes a physical and chemical transformation, gradually gaining strength. The water and cement exchange atoms in their molecules and form crystals that interlock with the surfaces of the aggregate particles. These crystals bind them all together into a hard and strong common element. While concrete will harden within two to eight hours after placement, it continues to get harder and stronger at a decreasing rate for years if environmental conditions allow. The curing process is greatly slowed if temperatures are very high or low. (Refer to Hot/Cold Weather Concreting Operations.) For elevated slabs and beams, it usually takes about seven days before forms can safely be removed to ensure that the concrete can support its own weight. Forms on the sides of a concrete wall can usually be removed safely after about four days from placement.



(Above) Grade beam covered with burlap kept moist for 3 days minimum after concrete placement to prevent rapid evaporation of water from concrete surface. Future placement will extend grade beam at bottom of photo.

As important as insuring strength gain is the control of moisture loss in concrete during the first three to seven days of curing. Since there is some excess water in the mix, above that involved in the chemical bonding with cement, there will be evaporation from the concrete mass over time. This loss will be made worse in dry and windy conditions such as is common in Afghanistan. With rapid moisture loss near the surface, there is likelihood of adequate moisture not being available for the chemical reaction with cement. This often results in weak concrete at the surfaces, causing subsequent cracking, spalling or an otherwise marred surface. Sprinkling several times a day, covering with burlap and keeping it wet, flooding flat slab surfaces, and covering with plastic are all methods of preventing excess moisture loss from concrete surfaces.

Curing Inspection Items:

- Provide proper curing (cover with wet burlap and/or keep surfaces wet) for minimum of 3 days after the concrete placement to prevent drying at the surfaces and resultant cracking. Flat slabs may be dammed all around and flooded.
- Ensure an elapse of 7 days minimum for concrete to gain strength before allowing removal of forms and shoring supporting an elevated slab.

6. HOT/COLD WEATHER CONCRETE OPERATIONS

From the previous discussions on concrete operations, it should be obvious that extreme weather conditions would affect the placement and curing of concrete. Concrete curing generates internal heat due to the chemical reaction between the water and cement. This reaction normally elevates the temperature of the concrete between three degrees Fahrenheit for thin slabs to ten or more degrees for mass concrete structures. If the temperature is high, evaporation will be excessive and cracking and weak surfaces will occur. In extremely hot weather (above 38°C/100°F), measures should be taken to keep the temperature down and to insure appropriate curing. The temperature of the ingredients should be kept as low as possible prior to the mixing – techniques like shading the aggregate piles and using cooled water. Proper curing (keeping the surfaces wet and/or covered) is even more important in hot weather due to the increased evaporation rates.

In cold weather, concrete should never be placed when the air temperature is to be less than 5°C/40°F over the next five days, unless special cold weather protective measures are taken. Such measures include pre-heating of the ingredients prior to mixing, use of heaters in an enclosed space to keep the air temperature above the desired level, use of insulating blankets over the structure, or combinations of all the above. The reason for these precautions is that the chemical reaction is slowed considerably as the water/cement temperatures approach freezing. If the water in the mix freezes, it will totally prevent the curing and will cause internal weak points in the concrete, weakening the entire structure. Concrete can be placed in cold weather, but these protective measures are absolutely critical. Quality assurance measures must therefore be stepped up to ensure that the contractor follows adequate cold-weather concreting procedures.



(Photos above) Precast concrete beams used to span between bearing walls or ring beams and precast planks laid over beams.

7. PRECAST CONCRETE

“Precast” refers to concrete members that are placed and cured in a manufacturer’s yard and brought to the site to be emplaced in a structure. Typical precast members include beams, lintels over wall openings, slabs (flat solid, flat hollow-core, tee-shaped), walls, pipe, and culverts. The advantage of precasting is that the materials and curing conditions can be closely controlled in a manufacturing yard, in contrast to remote sites, and material stockpiles and formwork can be used for multiple castings. Duplication of effort allows workers to be better trained and greatly speeds the production rate. Because of the ease of controls, stronger and better-surfaced concrete members are produced. The major disadvantage is that heavy pieces have to be hauled from the casting yard to the project site. This can be nearly impossible in some locations with the poor road system in Afghanistan. Even so, precast concrete members are being used in buildings at an increasing rate.

C. MASONRY CONSTRUCTION

Masonry is one of the oldest building materials, and methods of masonry construction have changed little over the millennia. Masonry materials include dried mud, brick, stone, concrete block, glass block, and other materials. Masonry is inherently much higher in compressive strength than in tension. Therefore, with the exception of arched floors or roofs, masonry is normally used only for walls. Masonry walls are the major building system in Afghanistan, particularly with stone and brick. Because of the low tensile strength, masonry walls that are not reinforced with steel are subject to cracking and breaking apart from stresses imposed by earthquakes and differential settlement. This issue will be discussed further in Section III. Note that materials increase in size as temperatures rise and decrease as temperatures fall. Different materials shrink and expand at different rates. Because of this phenomena and the fact that they vary in temperature so greatly between summer days and winter nights, masonry walls are very subject to expansion and contraction. This commonly causes cracks in masonry walls, even when reinforced with steel. Therefore it is highly advisable to have a vertical joint in the wall at intervals not to exceed 25 to 30 feet on center. These joints should have a clear space about 2 to 3 centimeters wide between the masonry that is filled with an expandable material to allow expansion and contraction of the wall without allowing the weather through the crack. Ring beams and bond beams within the wall should be continuous through the control joint; the steel rebar in the beams will keep them from cracking.

1. STONE MASONRY

Preferred thickness of stone walls is 30 centimeters minimum for one-story walls and 50 centimeters minimum for walls supporting a second floor and roof. These thicknesses allow for proper stone placement and strength. Exterior and interior surfaces of stone walls are typically finished with plaster spread over the stone. Stone is also used typically for foundations in Afghanistan, forming a wide footing under a ring or “grade” beam. Stone is preferred to be angular in shape and tough to prevent crumbling under loads. Angular shaped stone interlocks better than rounded stone and thus produces stronger structures. Stone should not have visible seams, which are planes of weakness. They are susceptible to water retention in the seams, which will crack open the stone when the water freezes.



(Above) Stone walls, built well except for lack of adequate mortar. Mortar should be flush or slightly indented at the surface of the stone.



Almost no mortar between stones. The inspector found actual mud substituted for mortar.



Stone wall with mortar filling all voids. Note good interlocking of jagged-shaped stones.

Stone Masonry Inspection Items:

- Ensure a quality mortar mix is used and that it completely fills spaces between the stone. See section on mortar below. Also ensure that the wall is plumb (vertical) and level (horizontal at top and bottom).
- Elongated, jagged pieces of stone should be used instead of rounded rock. The odd-shaped pieces interlock better, providing greater strength, and, if properly laid, use less mortar than rounded, similarly-sized rocks.
- Ensure tough stone is used, not stone that is soft or seamed.

2. BRICK MASONRY

Clay bricks are also commonly used in wall construction in Afghanistan. The majority of these bricks are hand made and kiln dried. These bricks typically provide allowable compressive strengths of 14 to 21 kilograms per square cm (200 to 300 pounds per square inch). Clay kiln-dried brick should be used for all load-bearing walls, but a much weaker mud brick, dried in the sun and common in Afghanistan, may be allowed for interior partitions. Be sure that kiln-dried brick are used, as sun-dried brick are very commonly used also in Afghanistan. Sun-dried brick do not have nearly the strength of their kiln-dried counterparts. You can tell the difference by tapping a brick lightly against another brick; the sun-dried brick will easily split in two. Typical brick wall thickness is 20 centimeters for an interior non-load bearing partition (two brick wythes), 30 centimeters minimum for a load-bearing wall supporting a roof (3 brick wythes), and 50 centimeters minimum for walls supporting a floor and roof (5 brick wythes). Brick should be wetted prior to laying in order to prevent dry brick from absorbing moisture from the relatively thin mortar.



Good looking stone foundation and concrete grade beam. But where's the mortar in the brick?

Brick wall started on top of grade (ring) beam, which is on a stone foundation. Insufficient mortar and somewhat rounded stones in the foundation.

Brick Inspection Items:

- Ensure a quality clay kiln-dried brick and mortar mix is used. See section on mortar below.
- Ensure that the wall is plumb and level, and that brick is being placed on fresh mortar.
- Ensure that all joints are filled with mortar, including the vertical joints. Joints should all be uniform in thickness, preferably 9 mm.

- Typically no more than 4-6 courses (horizontal rows) are laid at a time. This is done so that there is not too much weight put on the bottom course causing the fresh mortar to settle, thereby creating an uneven wall and reducing its strength. After six to eight hours for curing of the mortar, additional courses may be laid.
- Check to ensure there are vertical expansion joints in walls every 30 feet maximum.



(Above) Good brick construction on left wall, joints in right wall not completely filled with mortar.

(Right) Very poor brickwork. Brick is not consistent in running bond (overlap of each brick halfway over brick below), and some joints not filled with mortar.



3. CONCRETE MASONRY UNITS (CMU)

Hollow core concrete block construction is not yet common in Afghanistan due to lack of block manufacturing facilities or those that can make quality blocks. If available, however, hollow core concrete block walls can provide a strong but lighter wall when cores are filled vertically with rebar and concrete. U-shaped blocks can be laid horizontally at 1 to 3 meters on center and filled with rebar and concrete, providing a bond beam with tensile strength to hold the wall together horizontally. Walls are normally one block thickness, which is usually 20 or 30 cm. Blocks are normally 20 cm high and 40 cm long, preferably laid in running bond (each block overlapping the ones below). Block can also be used with a one-wythe brick veneer thickness to improve the exterior wall appearance. The skills required to construct a block wall are basically the same as for stone and brick construction.

CMU Inspection Items

- Ensure a quality block is used, not easily broken, and all units made to the same dimensions. Defective CMU in terms of dimensions and concrete strength are common in Afghanistan.
- Ensure that the wall is plumb and level.
- Ensure a quality mortar mix is used, and that mortar fills the spaces between the exterior faces of the blocks in both the horizontal and the vertical joints.
- Typically no more than three to four courses should be laid at a time; allow eight hours for curing before laying more courses.

- A bond beam using U-blocks placed horizontally and containing rebar and concrete grout should be placed at the midpoint between floors, at second floors, and at the top of the wall (roof level) at a minimum.
- Rebar and concrete should be placed vertically in the aligned hollow cores at all wall corners and at a maximum spacing of 2 meters on center in low earthquake hazard areas and 1 meter on center in high earthquake hazard areas.
- Check to ensure there are vertical expansion joints in walls every 30 feet maximum.

Cross section of a CMU Bond Beam (U-Block)



“Dog-toothing” is not allowed. Intersecting wall must be placed and stepped along with main wall. How will mortar be placed in joints when rest of intersecting wall is laid?



Styrofoam Expansion Joint

Rebar used to tie exterior wall to interior wall

Electrical Rough-in



4. MASONRY MORTAR

Mortar is the “glue” that holds bricks, blocks, and stone together during construction. It consists of a mixture of sand, lime, Portland cement and water mixed in proper proportions. A 1:6 cement to sand mix is desirable (by weight or volume), with the cement consisting of about 3 parts Portland cement to 1 part powdered lime. The lime’s lower density provides some absorption of shock waves in an earthquake, helping prevent cracking in the wall. If lime is not available, the cement should be 100 percent Portland cement. It is important that sand used for mortar be screened and

only materials sized between 0.16 and 0.6 millimeters be used in the mix. Use 1:2 water to cement ratio by weight (1:1½ ratio by volume). The mortar should fill the entire joint between bricks and stone, both on top and on the ends. For CMU, mortar should fill the joint between the face flanges and the end flanges, but is not necessary between the interior flanges. It should also fill the joint between the end flanges at each face.

Joints should form a uniform and neat appearance from the exterior face if it is to be exposed to the public after construction is completed. Joints are “dressed” by “striking” (raking along the joint) with a shaped tool. The shape of the tool (rounded, squared or vee-shaped end) will determine the shape of the joint. Or the joint can be struck off flush with the face of the wall. Architectural preference will determine the joint shape. Whatever shape joint is used, all joints should look the same, with no loose remnants of mortar left hanging.

Masonry Mortar Inspection Items

- Ensure the contractor is using proper sizes of aggregate, and proper proportions of ingredients, as described above.
- Insure the ingredients are being adequately mixed, e.g., about 5 minutes per batch in a mechanical mixer, or longer if by hand in a pit.
- No foreign objects should be in the mix, and water should be clean.
- If the wall face is to be exposed, joints should be uniformly formed, and the face of the masonry left clean.

5. GROUT

Grout is similar to mortar, but is used as fill in the hollow cores of CMU, for filling large voids in concrete, and for filling the space under the base plate of a steel beam, as just some examples. Grout in spaces less than 1 centimeter wide should use a 1:6 cement to sand mix, with the aggregate sized up to about 2 millimeters in size. The cement should be 100% Portland cement (no lime), with water to cement at a 1:2 ratio by weight (1:1½ by volume). Grout in larger spaces can include slightly larger aggregate in the mixture, up to about 1 centimeter in size or ¼ the opening width, whichever is smaller. Because of the smaller aggregate, grout “flows” more easily than does concrete, and therefore fills these voids more easily without excessive vibration.

Grout Inspection Items

- Ensure the contractor is using proper sizes of aggregate, and proper proportions of ingredients, as described above.
- Ensure the ingredients are being adequately mixed, e.g., about 5 minutes per batch in a mechanical mixer, or longer if by hand in a pit.
- No foreign objects should be in the mix, and water should be clean.
- When filling openings such as the hollow cores of CMU, grout should be placed such that voids are eliminated, usually through rodding of the mix after it is placed.

6. SCAFFOLDING

Wall construction above a worker’s head requires a raised platform for him to work from and position his materials. Scaffolds are typically built in Afghanistan using vertical wood poles positioned about ½ to ¾ meter from the wall exterior, connected with a main horizontal pole

lashed between verticals, and crossed by horizontal poles tied to the main pole and placed into a notch in the masonry wall formed by occasional omission of a brick. Scaffolding should be checked for strength prior to entrusting to it the safety of men and materials. When the scaffolding is removed, any missing brick should be filled in and joints sealed with mortar. (See bottom right photo on page 4.)

Scaffolding Inspection Items

- Since scaffolding will be removed once the activity is completed, appearance is not of concern. Rather, safety is of paramount importance, as the scaffold will be supporting workers along with heavy materials. Check the stability of the scaffold to insure its strength. It might be worthwhile to load it with heavy materials beyond its ultimate loading level before allowing workers to get on the scaffold.

D. STEEL CONSTRUCTION

Steel is used somewhat sparingly in Afghan construction, but its use is increasing, especially for floor and roof beams. Steel beams are mostly shaped like an “H” turned on its side, known in the U.S. as an “I-beam” or “wide flange beam.” Steel provides an excellent beam section, being strong, uniform in material composition, and flexible in its properties. Steel beams should have a solid connection to the wall or concrete beam that support them on both ends, not just set into the wall with bricks placed around it. Such anchorage can result in the beam being dislodged in an earthquake. Such anchorage as rebar through the web (the vertical element) or bolts through the bottom flange on both sides, with the rebar or bolts extending into the wall and lapped with wall reinforcing, will solidly connect the beam to the wall system and hold it all together under seismic shaking. Steel is subject to rust, so must be protected from rain, either by painting or other means, if exposed to the weather.



Steel beams supporting precast concrete roof panels. Note beams sitting on top of concrete ring beam in far wall.



Wood decking and joists providing sloped roof, supported with stub posts from concrete slab below.

E. WOOD CONSTRUCTION

Wood is in very short supply in Afghanistan due to the devastation of its forests over the 25 years of turmoil. However, wood's versatility and strength still make it a useful building material, not only for forms and shoring (that will be re-used), but also for elements that will remain in the building. It can be readily shaped and cut on site using hand tools. A lot of small, non-engineered buildings use wood poles as roof joists. Wood beams may occasionally be encountered on other buildings as well, mostly for architectural effects where exposed to view after the building is finished, or for light-weight, sloped roof joists when supported on a flat structural slab. Wood planks (and occasionally plywood sheets) are also being used as roof decking, to span short distances between structural members. Wood is almost exclusively used for doors and windows. Like with steel beams, wood elements should be firmly secured to supporting elements with mechanical fasteners, not just inserted into pockets in the masonry.



(Above) Wood beams to be exposed as architectural feature. However, contractor uses a short beam as filler when the other beams aren't long enough. Note thin wood scab above the short beam filler to lock it in place. This is not nearly sufficient to make the beam carry the roof or floor load; it will fail when load is applied.



(Above) Wood splits easily and loses significant strength when it does so. The door jamb on the left may be acceptable if both sides of the split are nailed to the masonry wall without causing further splitting, but the jamb on the right is unsalvageable and should be replaced.

III. COMPONENTS OF BUILDINGS

This section will discuss general principles of building construction in Afghanistan. The various systems and components of buildings will be described and key issues addressed.

A. SITE PREPARATION AND HOUSEKEEPING

Prior to start of construction of a building, the site must be prepared, and site work will continue for the duration of the project. Considerations include drainage, exact location of the building, other site structures, compaction of soils, location of materials during construction, and landscaping.

Drainage of rainwater across the surface and from the site is a major consideration. The ground surface should be sloped away from the building and the ground floor located high enough that water will not run into the building. Sidewalks, patios and other areas where people will be trafficking should also be sited so as to be free of running surface water or standing water. Patios should be sloped, not placed “flat” such that dips would allow water to collect. Design of good drainage on a site is an art, and is the shared responsibility of the design engineer and the contractor. Failure to achieve good site drainage will cause problems for the life of the facility.

The building should be **located** in such a way as to provide maximum utilization of yard space for needed amenities like parking, patios, water supply well, fences, playgrounds, etc. It also should not be so close to fences or boundaries that later access to utilities or maintenance on the building is not available without encroaching on adjacent properties. Ensure that the building does not interfere with the site drainage so as to cause a problem with storm water flow.

Soil under the building footings and slab on grade and under any site structure (masonry fence footings, patios, paved parking areas, etc.) should be firm enough to prevent settlement under loading conditions. This will require soil **compaction** if fill is added or if natural soil is not well-compacted and firm. Soil compaction was discussed in Section II.



Opening below foundation and poor drainage away from building will allow moisture to penetrate the soil, disturb the compaction, and possibly cause settlement of the footing. The water here has already found a ready path, and will soon cause erosion under the building.

There must be enough room on site or nearby **to store materials** to be used on the building. Stockpiles of aggregate for concrete and mortar, stone, brick, CMU, reinforcing steel, steel or precast concrete beams, and other materials must have room allocated. Vehicular and worker access to the building and to stockpiles must be planned and maintained.

If **landscaping** is planned, its installation is usually delayed until near the end of construction activities. Material stockpiles and requirements for equipment and worker access around the building will be lessened once exterior work is completed, providing room to install flowers, shrubs, trees, etc.

The site should be kept **neat** at all times for the sake of safety and efficient operations. A sense of orderliness on the site will lend a subconscious tendency to more orderly workmanship by the laborers. Aggregate stockpiles should be kept intact, not allowed to spread around, in order to keep from mixing different sizes of materials and foreign objects. Lumber and masonry piles should be stacked neatly and tapered or banded to prevent accidental falling of materials, which could likely injure workers.

A **sign** is recommended at the most publicly prominent corner of the site to describe the project, donor(s), and construction company, at a minimum.



A cluttered site is dangerous, and mixes and wastes materials. It makes access to the building difficult. How is this contractor going to get his concrete to the upper floor?



Organized site, good concreting operations, proper equipment.

B. BUILDING FOUNDATIONS

Building foundations in Afghanistan are of two primary types: continuous wall footings and spread footings for columns. **Continuous footings** support the weight of the building that is carried through load-bearing masonry walls, which are normally the exterior walls and sometimes select interior walls. Continuous footings here are typically made of stone with mortar infill, sized somewhat wider than the ring beam and bearing wall above. Spread footings are square or rectangular concrete footings under columns, reinforced with a rebar grid at the bottom of the footing. Where columns interrupt bearing walls, spread footings will interrupt the continuous footings.

Inspection items:

- Foundation strength and size are critical to the structural integrity of a building. Footings should be sized in accordance with design drawings, and masonry and concrete installed in accordance with prescribed techniques.

- Insure that footings are centered on columns and bearing walls, and are properly sized.
- Insure the footings are cleaned out, that rebar is properly sized and spaced, and that supports for the rebar provide adequate clearance from the bottom and sides (10 cm clearance).



(Left) Excavation and rebar for footing ready for concrete, with bottom free of debris. Note square cut with vertical sides, rebar tied together with wire, vertical rebar that will tie into the column secured with lumber, and string lines to locate center of column.



(Right) Good compaction and vertical sides ready for placement of stone masonry continuous footings under bearing walls. Stone is stockpiled nearby, ready for foundation construction.



Spread Footings, with rebar positioned for concrete columns.



Stone masonry continuous footing between concrete columns.

C. STRUCTURAL FRAMING

Building structures must transfer loads throughout the building to the foundation and thence into the ground. Loads may come from “dead loads” (weight of the building itself) or “live loads” imposed on the building (people, furniture, snow, mechanical equipment, wind, and seismic vibrations).

Seismic loads are of particular concern in Afghanistan, as much of the country lies in zones determined to be between “moderate” and “very high” hazard potentials. Earthquakes physically oscillate the ground a structure rests on, and add to the weight at the bottom of the “downstroke.” In a similar way you would feel heavier for a split second when your descending elevator stops suddenly. The shaking of the ground will also easily split apart materials (like concrete and masonry) that have little tensile strength. That is why rebar is needed in concrete and masonry elements to provide tensile strength and prevent splitting and failure. Horizontal seismic movements induced into the upper levels of the building cause internals “bending moments” in the structural frame. This phenomenon reflects the same principle that requires more strength for you to swing a hammer from the bottom of the handle compared to swinging it near its head. If the building is not designed to absorb these moments, major damage and possible collapse will likely occur.

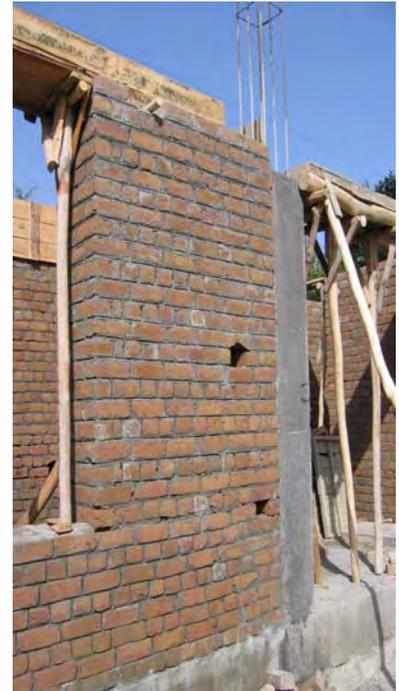
All structures can be simplified into three basic types of frame designs: **Shear Wall**, **Moment Frame**, and **Braced Frame**. These terms describe how they resist horizontal forces.



Brick walls used as shear walls.



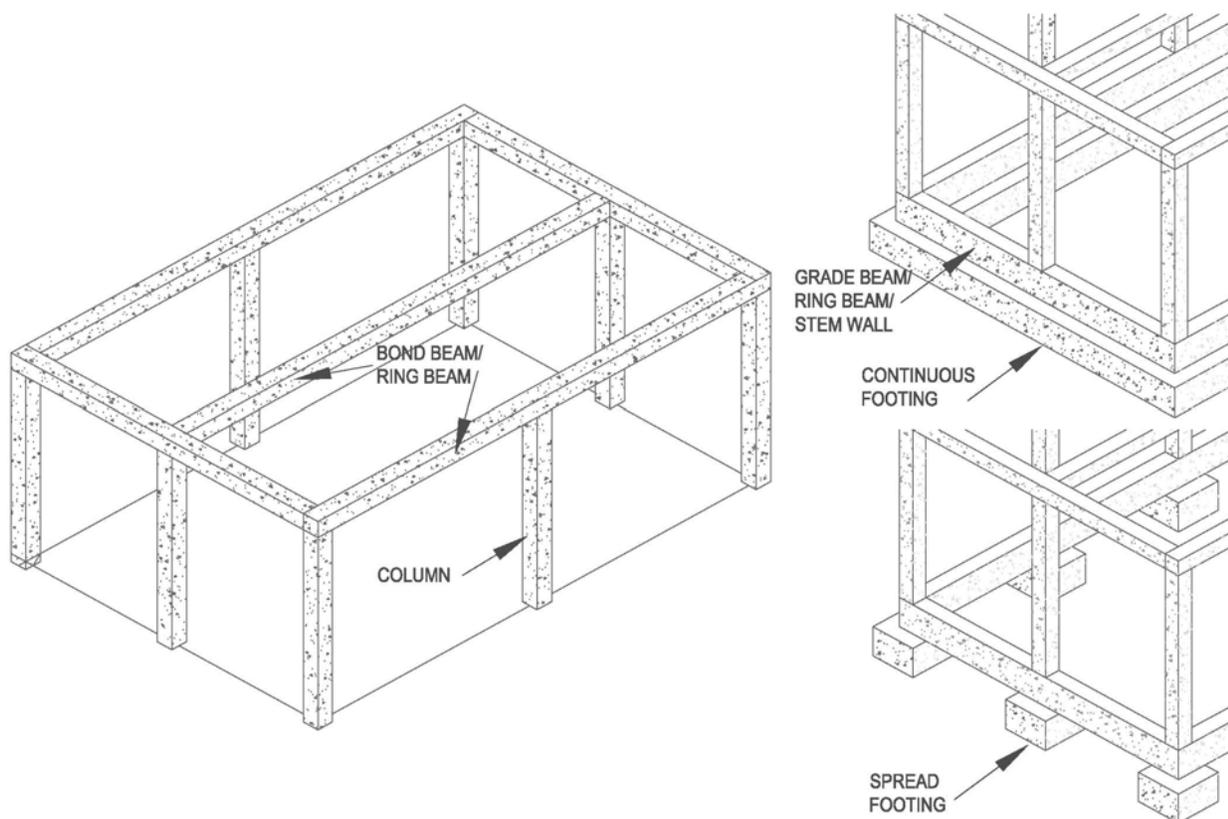
Stone walls used as shear walls.



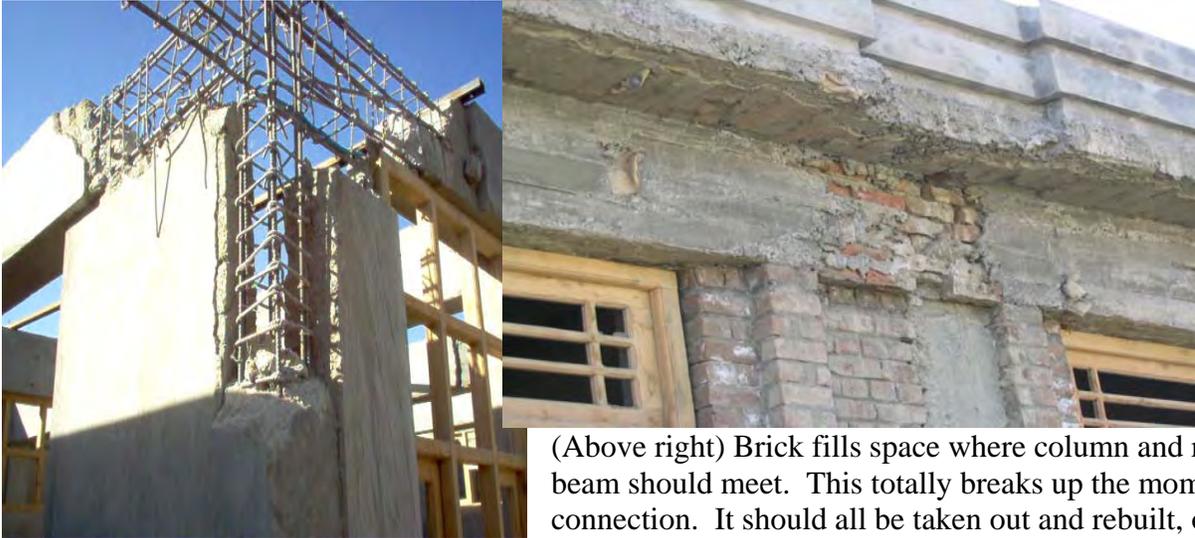
Brick wall filled in between concrete columns (combination moment frame and shear wall)

Shear Wall: This is the most common type of structure, and includes most simple construction in the US and nearly all construction in Afghanistan. Walls not only support vertical loads from floors and roof, they also absorb horizontal loads. Wind loads against exterior walls are transferred to roofs and floors, which in turn transfer the loads to the walls that are positioned perpendicular to the horizontal force. Similarly, horizontal forces from seismic movements are also absorbed by the walls positioned perpendicular to the forces. Because of the loads being transferred from walls to roofs and floors and thence into perpendicular walls, it is vital that connections between floors/roofs and walls be firmly made, using methods such as pins or reinforcing steel connecting both elements at their intersections. Walls that are to absorb these “shear” (or horizontal) forces must be strong enough to resist cracking and breakage in event of earthquake. For masonry walls, this means that they should have vertical and horizontal steel rebar at regular intervals contained inside the wall. (See CMU Section II.C.3. Rebar can also be incorporated inside brick and stone walls set in mortar.)

Moment Frame: This concept distributes horizontal forces over a three-dimensional frame, as shown in the diagram below. In a moment frame, connections between columns and beams provide the strength against bending in all directions. Walls fill in between the columns, but are not depended on to provide resistance to lateral building movement. Moment frames can be made of steel, but frames made of reinforced concrete are more typically used in Afghanistan. The bending and lapping of rebar at column to beam connections are critical in a moment frame, as tensile forces are high at those points. The structural drawings should show exact details of these connections, and QA inspectors should pay careful attention that the details are followed.



Typical One-Story Moment Frames



(Above right) Brick fills space where column and ring beam should meet. This totally breaks up the moment connection. It should all be taken out and rebuilt, or an engineer may design some easier repair method.

(Above left) The contractor forgot to lap rebar at the top of the column into the ring beam before he placed the concrete column. He later broke out the top half of the column to install the L-shaped dowels. Now the column is weakened at the unplanned joint halfway up. The concrete in the column should be broken off level; then it will depend on the column rebar to hold it together over the cold joint.

Braced Frame: Construction of this type, usually using steel or wood, is uncommon in Afghanistan at this time. These frames use the concept of placing diagonal truss members on a skeleton frame to give it rigidity and relieve bending stresses at the connections.

D. WALL SYSTEMS

While shear walls have been discussed in the preceding section, wall construction common to Afghanistan should be further described. Exterior and bearing walls typically consist of a **ring beam (or grade beam)** at the bottom, set directly on top of the footing. This grade beam should have horizontal rebar and ties running its length, providing tensile strength in order to hold the bottom of the wall together in event of earthquake or ground settlement. This grade beam is normally the same width as the masonry wall above, and will have vertical dowels (rebar bent so that the bottom leg aligns with the grade beam rebar) extending upward into concrete columns and/or directly into the wall at regular intervals. The dowels provide the secure connection between the masonry wall and the grade beam to hold the two together.

There should also be a concrete ring beam in exterior and bearing walls at or just below every floor and roof. Through its steel reinforcement, this ring beam serves to hold the building together laterally when horizontal stresses are placed on the building, such as occur during earthquakes and high winds. Elevated floor structures (beams and/or slabs) should be tied into this ring beam through rebar dowels or some other mechanical means.

Shear walls and gravity load-bearing walls should have horizontal and vertical rebar at intervals embedded in the masonry. The engineering drawings should show the required size, spacing and lapping details for this reinforcing.



(Both photos above) Very neat foundation grade beams, brick walls, and rebar for columns.



(Above) Grade beam (concrete ring) below the brick and on top of stone foundation.



(Above) Grade beam and top ring beam in brick wall (top ring beam used as lintel)



(Above) Brick walls with vertical rebar embedded within the wall at about 1m on center. Similarly, horizontal rebar can be embedded in brick wall to make a solid wall structure in each direction.



(Above) Contractor forgot to dowel rebar into concrete grade beam to connect to masonry wall above. He then broke into the grade beam to try to set the rebar. It will not lap with grade beam rebar, and it will weaken the grade beam.

Masonry walls must have a lintel beam above openings (e.g., doors and windows) to support the weight of wall, floor and/or roof above. Lintels may be poured concrete, U-shaped CMU, precast concrete, or steel beams. The ring beam often is designed to serve as a lintel over openings. Concrete lintels must have steel rebar along the bottom of the lintel to provide the required tensile strength. Lintels should bear on the masonry on either side of the opening, preferably with at least 20 centimeters of bearing length. The width of the lintel should be the same width of the masonry wall above, or it may have an attached steel plate or angle to carry a course of brick or stone veneer.



(Above) Grade beams and ring beams are connected to columns in a moment frame structural system.



Ring beam is disrupted, bricks are used to fill gap. As this ring beam is not continuous, the building is not tied horizontally at the roof.

In Afghanistan, most walls are covered with plaster when the structure itself is completed. The common thinking among many contractors and workmen is that the plaster binds the wall together and makes it stronger. In fact, this is not true. The plaster is essentially the same material as mortar, with less cement. It has very little tensile strength, therefore nothing to hold one brick or stone to another. It can be used to fill in gaps in the masonry and as such can provide some strength for compressive forces. It bears repeating, the only effective tensile strength in a wall comes from the steel reinforcing that is embedded therein.

E. SLABS ON GRADE

The most efficient way to provide a floor at ground level is to simply place a thin concrete slab directly on the ground. Slab on grade construction requires adequate site preparation to include leveling the site, providing proper site drainage, and compaction of the subgrade where the slab is to be placed. A thin (about 10 centimeter) layer of crushed stone is often designed to underlay the slab on grade for leveling and drainage purposes. Slabs on grade may be free-floating (not connected to the building walls) or hard-connected to the walls, depending on the engineering design. The concrete in a free-floating slab will be placed against the face of walls or grade

beams, with no rebar connecting the two elements. The slab will shrink away slightly from the wall as the concrete cures, allowing the walls to settle at a different rate than the slab, thus preventing cracking of the slab. The engineer may prefer to hard-connect the slab to the walls in order to insure the same settlement rate of walls and slab. If this method is chosen, the slab must be designed with enough strength near the walls so as to prevent it cracking should the much heavier wall/grade beam settle at a different rate. Both types of slab on grade should have steel rebar centered in the slab, forming a grid in each direction. Rebar grid in the slab itself should be placed no farther than 30cm apart, and is normally specified at 10mm to 12mm diameter.

Inspection items:

- Ensure quality concrete is used. (See “Concrete” in Section II.)
- Ensure designated size and spacing of rebar, and that it is supported to provide a gap of 3cm minimum between the rebar and ground.
- It is recommended that the forms be oiled (very light coating) or at a minimum watered down in order to facilitate their removal. Any soil in the bottom of the form that will come in direct contact with the placed concrete should be wetted (do not create a mud bath). Ideally a plastic barrier should be placed under the concrete. This will prevent the soil from absorbing too much water out of the fresh concrete, preventing proper and uniform curing and causing surface cracking and spalling. The plastic barrier will also help to prevent moisture from the ground percolating up through the concrete and causing dampness inside the building. As dry as the climate is in Afghanistan, however, this is usually not an important factor.
- It is also recommended that any fresh concrete be covered (plastic, moist burlap, etc.) for a minimum of 72 hours to prevent excessive moisture loss near the exposed surfaces.



(Left) Rebar dowels tie walls to future slab on grade. Dowels will overlap with rebar to be placed each way in middle of concrete slab. Slab and walls must settle at same rate. If dowels were omitted, slab would float freely. If ground is well compacted, a floating slab is just as acceptable as being tied to the wall. If the ground floor is ½ meter or higher above the exterior grade, tying the ground floor to the grade beam helps to hold the wall and floor together from horizontal forces.

F. ELEVATED FLOOR AND ROOF STRUCTURES

Reinforced concrete slabs at upper floors are standard for multi-story buildings. Roofs often also use a concrete slab structure. The relatively thin slab is designed to span between thicker beams, and the beams carry the loads between supporting walls and/or columns. Rebar in concrete slabs and beams is usually 12mm, 14mm or 16mm in diameter, as specified by the structural drawings. Upper level floors must be tied with rebar dowels into all bearing walls or columns below and above the floor, in order to hold the building together during vibrations from earthquakes. There

are three primary types of beam-and-slab systems used in Afghanistan: **Concrete slab and beams**, **concrete slab on steel beams**, and **brick arch slab on steel beams**.

Concrete slab and beams: Upper formed floors may use a flat slab supported by bearing walls and/or inverted “T”-beams. When a slab is used as a roof, the top surface may be flat, or it may be slightly sloped to provide drainage. In the T-beam system, the flat slab spanning between the beams is supported by the beams, and the beams transmit the loads to concrete columns or bearing walls. The concrete in the beams and slab is normally placed at the same time. Construction joints (temporary bulkheads) may be used to decrease the volume of concrete to be placed in a single placement. The size and placement of rebar is critical, since the steel provides the tensile strength for the flexural members. Observe carefully to ensure the reinforcement shown on the structural drawings is followed exactly. To help detect proper placement of reinforcing, be aware that the bottom of a slab or beam is usually in tension between its supporting members, and the top of the slab or beam is in tension directly over its supporting members.

Beams also require steel ties wrapped around the horizontal steel, essentially following just inside the perimeter of the beam cross-section. These ties provide strength against the shearing forces that would break the beam in two. Shear forces are maximum at the point where a beam meets its support, and are usually at a minimum near mid-span. Thus, if shear forces require ties, the spacing of ties should be closer as the beam approaches a support. This spacing should also be shown on the structural drawings. (Photos of forms and rebar ready for concrete placement in concrete slab and beam system are also shown on pages 6 and 8.)

Concrete slab on steel beams: The concrete slab spans between parallel steel beams and bearing walls. The steel beams are placed first, and must have positive connection (e.g., bolts) anchored into the supporting bearing walls or columns. The steel beams will usually support the forms and wet concrete as the slab is constructed. A photo of a steel beam and slab system is on page 18, except that the slab shown uses precast planks rather than a solid concrete cast-in-place slab.

Brick arch slab on steel beams: There is a return by some architects in Afghanistan to use of brick arches spanning between parallel steel beams. The bricks are wedged against the side of the beam webs, anchored with mortar into the bottom flange. The arch keeps the brick in compression in support of gravity loads. Once the brick arch is in place, a thin concrete slab with minimal steel rebar is placed over the brick arch and beams to provide a flat surface and to tie the entire floor into a solid diaphragm.

Inspection items:

- Check the concrete mixing and placement as described in Section II. Inspect the rebar in all areas of the form, counting and measuring rebar to insure proper size, spacing and laps.
- Ensure a minimum of 5 to 8 cm space between the rebar and the form in a beam or wall. Horizontal rebar in a flat slab should have 4 to 6 cm spacing between the rebar and the bottom of the form. Use brick or metal spacers to support or shim the rebar such as to provide appropriate spacing when the concrete is placed.
- Provide proper curing (cover with plastic or burlap, and wet surfaces often) for minimum of 4 days after the concrete placement to prevent drying at the surfaces, which would cause surface cracks. Cracks are particularly undesirable for roof systems that will not require a roofing membrane to protect against water penetration.
- Ensure an elapse of 7 days minimum for concrete to gain strength before allowing removal of forms and shoring supporting an elevated slab. If forms need to be removed after 4 days

to reuse on floor above, replace shoring immediately in order to keep loads off of the “green” concrete.



(Above) Precast joists cast into cast-in-place concrete beam, with floor slab supported by joists.

(Right) Cast-in-place concrete slab and beams being prepared for concrete placement.



G. CONCRETE COLUMNS AND WALLS

Concrete columns and walls present a special challenge to construction in that they are deep members, and concrete has a long distance to drop in the forms. The impact of the drop and the bouncing of aggregate against the rebar on its way down can cause uneven separation between large and small aggregate, and the resultant poor mixture will weaken the concrete. Air pockets in the deep members are particularly difficult to eliminate, as they have a long distance to rise to the surface. As previously discussed, concrete columns are strongly recommended for earthquake prone areas. Reinforced concrete walls are not very common in Afghanistan due to availability of form material and bracing, but they have an occasional applicability with retaining walls. In addition to the photos below, see photos of poor column construction on page 6 and 25.

Inspection items:

- Prior to placing concrete, ensure that the rebar is at least 5 centimeters from the form.
- Ensure that the form has the strength to hold the concrete when it is poured, with adequate bracing. Horizontal pressures against the face of the forms will be essentially 3 kg per square centimeter (150 pounds per square foot) times the height of the pour in cm (or feet).
- During concrete placement, it is critical that a mechanical vibrator be used to reduce the amount of air voids/honeycombing and to settle the concrete completely into the form. Do not over-vibrate concrete, as it will settle the heavy aggregate to the bottom of the form and reduce the strength of the concrete and possibly cause the form to fail. Three seconds of vibration, the full depth of the current placement lift, for each half-meter of wall length is

usually about the right amount of vibration. In absence of a mechanical vibrator, a rebar can be pushed vertically down into the concrete numerous times for each one-half meter height of the wall, being careful to bring the rebar completely out of the mix at each stroke and extending it to the bottom of the current layer being placed on each downstroke.

- Ensure that the forms are oiled or, if no form oil is available, that the forms are moistened with water in order to make stripping the forms easier.



(Above) Very good workmanship on column and brick wall.

(Right) Good workmanship on far column, poor on near column, with honeycombed surface and obvious difference in concrete placed different times in bottom and top halves. But plaster placed over the brick and column will hide the defects, as long as it has structural integrity.



H. ROOF SYSTEMS

Concrete Roofs - (See section above under Elevated Floor and Roof Structures.) Flat concrete slab and beam roofs are often used to provide a stable structure for support of a raised light-weight sloping metal roof. In dryer climates, flat concrete roofs are sometimes constructed, surrounded by a brick parapet wall extending slightly above the roof and containing small openings at various spacing around the parapet for any rain that falls to drain from the roof. Such flat roof construction is not advisable without addition of a membrane layer on top, since concrete is subject to cracking and thus to penetration of moisture into the interior.

Metal Roofs

Two types of metal roofs are common to Afghanistan, corrugated and standing seam roofs. The metal sheets span between structural supports of either steel or wood, spaced at one-half to one-and-a-half meters on center, or are laid directly on top of wood planking.

A corrugated metal roof is used (in most cases) in conjunction with a primitive wooden truss or beam that spans between bearing walls. It is used to provide a slope where drainage and leaks

would cause a problem on a flat roof. It can also be used as a stand-alone roof system, without wood supports, on smaller buildings with short spans such as sheds, lean-tos, or dwellings.



Wood sub-structure for low-pitched roof



Making the first fold of the standing seam.



Drainage gutter for a low-pitched roof.



Final fold for a standing seam.

A standing seam metal roof is commonly laid on top of wood planking spanning between trusses or beams. The metal sheets have little ability to span any distance, and depend on the planking for structural strength. The galvanized sheeting provides an excellent water-proof envelope and great life expectancy. A 6 centimeter, 90° bend is formed along both sides of the long axis, and metal tabs are placed prior to setting the adjoining sheet. These tabs are nailed to the wooden planks and incorporated into the double fold (standing seam). Two folds are used to seal the joint where two sheets are joined together. Installation is slightly more labor intensive than corrugated sheets, but the added strength, waterproofing and longevity of the roof is worth the additional cost.

Inspection items:

- Roof pitch should be a minimum of 1:3 for corrugated roofs and 1:6 for standing seam roofs to ensure proper run-off of rain water.

- Horizontal seams should overlap from the bottom up so that water runs over the seam, not into it.
- Ensure proper sealing around any protrusion (vents/chimney/skylights etc.) through the roof in order to prevent leakage. This can be done by welding/soldering and/or sealed with a tar-based caulk.
- Ensure proper sealing of all standing seams in accordance with manufacturer's instructions.
- If gutters are used to catch rain flowing off the eaves, ensure enough slope is built into the gutters (1/100 vertical to horizontal) to prevent ponding of water.



(Above) Flat concrete roof with asphaltic membrane & stone on top.



(Right) Low pitched framed roof on flat concrete slab structure.



(Above) Wood roof decking and joists spanning between steel trusses.



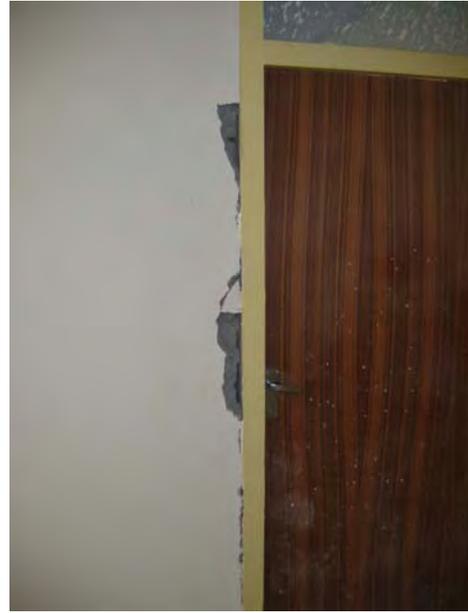
(Right) Standing seam metal roof. Note gutter at left, ridge cap at peak, and flashing around vents.

I. DOORS AND WINDOWS

Door and window frames typically are formed with a wood timber, about 4 by 10 to 4 by 15 cm in dimension. When attempt is made to screw through the frame into a masonry wall, the screw will not anchor very well unless an expandable tip is used on the screw, which type fasteners are not readily available in Afghanistan. Failure to adequately anchor the door in the photo on the right resulted in the spalling of the mortar finish on the wall surface. An alternate system is to substitute one brick in the wall near the top, middle and bottom of the opening with a same-sized block of wood. The wood frame can then be screwed securely into these wood blocks. The door or window then has a securely anchored and squared wood frame into which to fit, preventing movement.



(Above) Poor wood used for door jamb.
(Right) Door frame not securely anchored to masonry, door movement loosens frame and cracks plaster.



(Above) Column is skewed, but not major problem. Window opening sizes and window frame mismatches are worse problem.



(Right above) Poor finish work on door, nails used instead of screws on hardware, hardware sticking out and not incorporated into the door frame.

J. MASONRY WALL FINISHES

1. STUCCO

Portland cement plaster and Portland cement stucco are the same material. The term "stucco" is widely used to describe material applied to exterior surfaces. It consists of Portland cement-based materials and sand, mixed with water to form a workable plaster. While having little structural strength of its own, stucco provides a hard, smooth and semi-impermeable coating over the surface that causes water to flow off quickly rather than absorb into the wall, where it would otherwise cause deterioration of structurally vital materials. Stucco has impact resistance and sheds water, but it is permeable enough to allow water vapor to escape.

Stucco color can be varied by selecting cement and aggregate colors, and can be modified further by adding mineral oxide pigments to the plaster mix. Pre-pigmented packaged cements also can be used to achieve the desired stucco color. Pigments are added to the stucco during mixing.

The finished texture can be varied by changing aggregate size, mix consistency, or smoothness of trowel edge. Texture gives substance and character to the plaster surface. It can be used to provide highlights, depth, continuity, and segmentation. To confirm the suitability of a desired color and texture, have the contractor provide a sample panel for evaluation and approval prior to starting work.

Procedures for Application of Portland Cement Plaster (Stucco)

Portland cement plaster is applied either by hand or machine to exterior and interior wall surfaces to form a smooth outer surface. It may be applied directly to a solid base such as masonry or concrete walls, or it can be applied to a metal lath attached to a frame or wall. Stucco applied to a solid masonry or concrete wall should be two coats (base and finish coat) totaling about 1.5 cm thick. When applied to metal lath, three coats of plaster should total at least 2 cm thick. A vapor-permeable, water-resistant building paper must separate the plaster and lath from water sensitive sheathing or framing.

When directly bonded to **concrete**, a dash bond coat or surface applied bonding agent is typically needed to enhance the bond between the plaster and the concrete. A dash bond coat is a slurry mixture rich in cement, usually 1 part cement to no more than 2 parts sand that is literally dashed against the wall using a brush or trowel, leaving streaks. Allow the dash bond coat to dry prior to applying the base coat. When concrete surfaces are extremely smooth or contaminated with excessive form oil, metal lath should be attached over the concrete as a plaster base. Metal lath must be mechanically attached (e.g., screws) to concrete or masonry walls to provide a base for durable two-coat stucco finish.

Due to its rougher surface features, **masonry** provides an excellent base for direct application of stucco. Prior to application of the base coat, uniformly pre-moisten (do not saturate) concrete masonry surfaces to aid in curing of the plaster. If the masonry surface texture is rather smooth, apply a dash bond coat to the surface prior to application of the basecoat. Carefully work the stucco across the wall taking care to fill all voids. Moisture may later collect in voids, freeze and expand, and cause loosening and breaking off of the stucco.

Because plaster and concrete masonry undergo similar volume changes, place control joints in the plaster only in locations that coincide with control joints in the concrete masonry. Like with concrete, stucco will shrink and develop cracks if not properly cured. The surface should be kept moist for three days minimum after application to minimize cracking.

Frame Construction and Stucco

Frame wall construction (wood or metal studs) is not common in Afghanistan, but it is used in some locations. When stucco is selected as the exterior surface for frame construction, metal lath is attached to framing members. Lath may be expanded-metal lath, woven-wire lath, or welded-wire lath. Vapor permeable, water-resistant paper is applied over sheathing before attachment of the lath. The paper protects the sheathing and interior of the wall from outside moisture intrusion without trapping moisture vapor in the wall.

Furring dimples in self-furring lath, furring nails, or other furring attachments hold the lath about ½ cm away from the sheathing, frame, or solid base wall. This permits the stucco to penetrate lath openings and surround the metal strands, embedding them. As the base coat stucco hardens, the lath and plaster become rigidly interlocked with the lath, acting as one strong unit. Encasement of the metal also protects the metal lath against corrosion.

Stucco Repair

Before beginning any repair, ensure that the walls are structurally sound, with no hidden defects. Do not mask something major by repairing the cosmetic stucco surface. Repair the structural wall before trying to gloss over the stucco surface.

Stucco that was poorly cured following installation may exhibit surface cracking. Even minor cracking can detract from the look of an otherwise good quality wall. As long as cracks are less than 0.2 cm width, a new finish treatment can be a quick fix. Use a Portland cement-based slurry of 1 part cement to 3 parts small sand, with a 2 to 3 water/cement ratio. Spread it evenly over the surface, working it into the cracks.



Stucco Inspection Items

- Pre-application - Have repairs been made to the wall or structure prior to stuccoing?
- Surface Preparation – Apply a dash bond coat to smooth surfaces prior to applying stucco. If extremely smooth or oil-smearred surface, use metal lathe over concrete.
- Surface preparation – Is the surface clean and damp (but not wet)?
- Material quality – Does the stucco contain the proper mix of Portland cement, sand, water, and pigments?
- 2-3 layers – Is the stucco being applied in a least two coats for surface applications or three coats for metal lath application?

- Pigments – Are pigments used if color is desired? If so has the contractor provided a small test sample for approval?

2. Painting Concrete and Masonry

Concrete, stucco and mortar are highly alkaline materials that tend to react chemically with oil or alkyd based finishes (paints) to weaken their adhesive bond. Concrete and mortar also release moisture during curing, sending soluble salts to the surface (efflorescence). Concrete and masonry will also absorb paint. For this reason, paints and/or sealants (primers) specially formulated for concrete and masonry must be applied before painting these surfaces. Paint must never be applied to a damp surface. Therefore a minimum of one dry day should have preceded start of exterior painting.

The finish coat of paint must also be formulated for exterior use if it is to be applied to an exterior surface or to a wall that tends to collect moisture. Care should be used in application of the finish coat to completely mask the subsurface colors and to eliminate deeply grooved brush strokes. Two coats of finish paint may be necessary to prevent the former problem, especially if the subsurface is a darker color than the finish paint. A new or better-quality brush or roller may be required to eliminate the latter problem and provide a smooth finish.

It is easier to add pigments to achieve the desired color in new stucco applications rather than to paint over it. This will provide a much longer lasting and better looking finish, and eliminate the painting step.



This building is one year old. Moisture has penetrated into voids under the plaster, weakening the plaster. Freezing of retained moisture has cracked open the plaster. It is also likely that the paint was applied prior to complete curing of the plaster, accounting for the stained appearance.

Painting Inspection Items

- Surface preparation – Is the surface clean and dry prior to painting?
- Base coat – Is the primer paint or sealant formulated by the manufacturer for application to masonry or concrete?

- Finish coat – Is the finish paint formulated by the manufacturer for exterior or interior application? Does it completely cover the subsurface with an even color and smooth finish?

K. PLUMBING SYSTEMS

This section outlines basic plumbing techniques and recommends minimum standards for plumbing systems for small scale construction in Afghanistan. Large construction projects should refer to plumbing code standards such as the International Plumbing Code (IPC).

Plumbing is a system of piping, fixtures and apparatus for water and liquid fuel supply distribution and waste water disposal within a building. Technical building designs should include drawings and specification sheets listing the quantities and quality of materials to be used.

1. BASIC PLUMBING CONCEPTS AND TERMS

Plumbing Fixtures - A plumbing fixture receives water from the supply pipes and discharges waste into a sanitary drainage system. Plumbing fixtures include water closets (“toilets”), lavatories (“sinks”), urinals, showers, bathtubs, laundry machines, outside hose bibs and drinking fountains.

Water Supply Lines and Branches - The main water supply system provides potable cold water from the water main or cistern at a suitable pressure. The plumbing system must provide enough water for normal use at each fixture.

Pipe Material Selection – Schedule 40 Polyvinyl Chloride (PVC) is the most commonly used pipe material in Afghanistan for both water supply and waste discharge lines. Cold-water supply systems may alternatively use galvanized steel, copper, or plastic pipe. Copper is recommended for use in hot-water systems due to the rapid expansion and contraction in pipe lengths due to large variations in temperature. Vitrified clay tile, ductile iron, and acrylonitrile butadiene-styrene (ABS) plastic are also used in underground waste discharge lines. Material selection depends on the amount of water to be supplied, water pressure, corrosion factors, cost and availability. PVC, ABS and other plastic pipe must be protected from nails and other damage. Do not use plastic pipe in buildings more than three stories tall due to the potentially high pressures.

Sizing of Pipe - Designing pipe sizes requires somewhat complex calculations and is beyond the scope to this manual. To arrive at a minimum pipe size, the number of fixtures, demand per fixture, simultaneous use of fixtures (based on probability), friction loss, and pipe type are all considered. The minimum practical size for a water supply line is 2 cm (3/4 inch) diameter, which can service up to six sinks and/or toilets or one shower. 8mm (1/2 inch) diameter pipe can provide hot or cold water feeds to individual fixtures. Larger diameter pipes are required to meet higher demands. Minimum size for a waste discharge line from a shower or sink is 4 cm diameter, while the minimum size from a water closet is 10 cm diameter. As a general rule, a 15 cm diameter pipe should be used for discharge from more than four residences (or equivalent), and 20 cm diameter for discharge from more than 25 residences. Smaller size pipe will not pass sufficient quantities for water supply, or will clog up from solids in waste discharge lines.

Fittings - Fittings are the joints, elbows, wyes, tees, and other accouterments that are attached to or connect the pipes. They should be made of the same material as the pipe.

Pipe Assembly Materials/Joint Materials -All joints must be water-tight and gas-tight. To achieve this sealing, a specific material is specified with each kind of pipe. Materials include:

Oakum - Oakum is hemp or jute fibers soaked with a bituminous compound, loosely twisted or spun into a rope or yarn. It is used with lead or other materials and wedged around the male end as it is inserted into the female end in cast-iron pipe, vitrified-clay tile or concrete pipe.

Pipe-Joint Compound - Thread and pipe joints are made by using one of several compounds, referred to as *dope*, for protecting the threads and for easy maintenance.

Solder -Solder is used with solder fittings to join copper tubing and brass and copper pipe. A nonacid flux (a substance, such as rosin, applied to promote union of materials) must be used. A 95 percent tin and 5 percent aluminum compound or substance is used for copper tubing. Solder must be lead-free.

Solvent Cement -Solvent cement is used with plastic fittings to join rigid plastic pipe (e.g., PVC). This cement comes in several types for each different plastic pipe and fitting.

Bitumen - Bituminous compounds, such as asphalt and tar pitch, are used to make joints in vitrified-clay tile and concrete pipe.

Gaskets - Flange joints need gaskets of rubber, cork, composition, sheet metal, or other material.

Pipe Supports -To prevent strain on the joints, pipe should be supported at various points along pipe runs and fittings. The pipe must be supported vertically and horizontally to maintain alignment and the proper drainage slope. Plastic pipe is not as stiff as metal pipe, and thus requires more frequent support, not to exceed 1 meter spacing. Supports include hangars and braces. Common pipe hangars include perforated iron strap furnished in rolls and cut to length, U-shaped wire hangers, and iron-ring hangers.

2. BASIC WATER SUPPLY CONCEPTS AND TERMS

Water Pressure – Pressure in water supply pipes is usually achieved from the weight of the water stored in an elevated tank, which forces pressure in the pipes at lower elevation. The higher the tank above any given point in a pipe, the higher the pressure at that point. A less efficient method of providing water pressure is from a pump inducing pressure directly into the line when it is operating. Pressure in a water main usually ranges from 2.5 to 4.2 kg per square centimeter (kg/cm^2), or 35 to 60 pounds per square inch (psi). If the pressure is over $5 \text{ kg}/\text{cm}^2$, a pressure-reducing valve must be placed in the water service line at its entry to the building. The pressure available at the outlet is affected by the size of the water service pipeline, the rate of use, the length of the line, and the outlet height in the system. If the water pressure is less than $1.3 \text{ kg}/\text{cm}^2$, use a tank and a pump or other means to increase the pressure in order for outlets and valves to work properly.

Water Main – The “main” is the pipe that brings water supply to the building. If the city or a utility company provide the water, they usually own the mains that are located in the public right of way. Private buildings connect (“tap”) into the main and run a smaller “lateral” supply line to feed the building. Since public utilities are uncommon in Afghanistan, most water supply comes from wells located nearby, with a pump inducing pressure into water mains that may supply one or more buildings.

Hot water supply systems - The hot-water system consists of a water heater and a hot water piping system. The water supply pipes bring cold water to the water heater, and the hot-water supply pipes run from the heater parallel to the cold-water pipes to fixtures where hot water is required.

One-pipe hot water systems - Smaller buildings can use one-pipe hot water systems, where all hot-water supply pipes come directly from the hot water heater. Lag occurs from the time the hot-water tap is opened until the water travels from the heater to the tap. Thus water is allowed to cool to room temperature inside the pipes between uses.

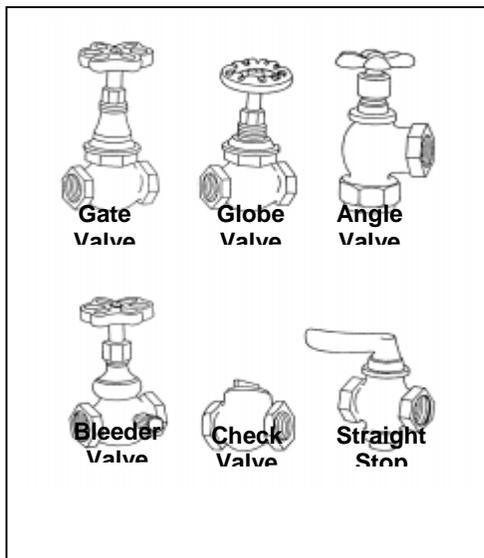
Two-pipe hot water systems – If fixtures are located too far from the hot water heater, such as in large or multi-story buildings, a two-pipe hot water system is required to prevent the lag of hot water from reaching the tap. Hot water passes continuously from the water heater through the main fixture supply risers and returns to the water heater. This looped system circulates the hot water at all times and decreases the distance between connecting valves and individual fixtures.

Water Heaters - (See Section K – Mechanical Systems)

Testing for Leaks - Inspecting for leaks is important for a pipe under pressure. Leaky joints waste water and can damage the building. In new construction, test the entire system for leaks before the floor and partitions are closed up. When performing this test, use the water pressure from the main that feeds the system. While the system is under pressure, inspect each joint for moisture. Repair all leaks and retest.

Frozen Pipes - Water supply lines may freeze when exposed to temperatures below 0°. Outside pipes must be buried below the frost line, which may vary from a few centimeters below the ground surface in southwest Afghanistan to about ½ meter below the surface at higher elevations. Exposed pipes above the frost line should be insulated.

Valves and Faucets - A valve is a device (usually made of bronze) to start, stop, and regulate the flow of liquid, steam, or gas into, through, or from pipes. A valve (normally a gate valve) should be located in the line feeding a building and in each vertical supply riser so that a section can be repaired without shutting off the water to other sections. Small gate valves on the supply line to each fixture allow for shutting off the water for fixture repairs. Faucets are simple gate valves.



Gate Valve - A gate valve is used to start or stop liquid, steam, or gas flow. This valve has a split or solid wedge disk that fits into a machine surface called a “seat.” Raising the disk to start the flow and seating the disk to stop the flow operates the valve.

Globe Valve - A globe valve is a compression-type valve that controls the flow of liquid by means of a circular disk, forced (compressed) onto or withdrawn from an annular ring seat that surrounds the opening through which liquid flows. All globe valves operate with a rising stem.

Angle Valve - An angle valve is a globe valve with the inlet and outlet at a 90-degree angle to one another. These valves are recommended for frequent operation, throttling, and/or a positive shutoff when closed.

Check Valve - A check valve permits the flow of liquid within the pipeline in one direction only and closes automatically to prevent backflow. A check valve can be a *swing-* or *lift-type*. Swing check valves are used in pipelines where pressure and velocity of flow are low. Lift check valves are used where pressure and velocity are high.

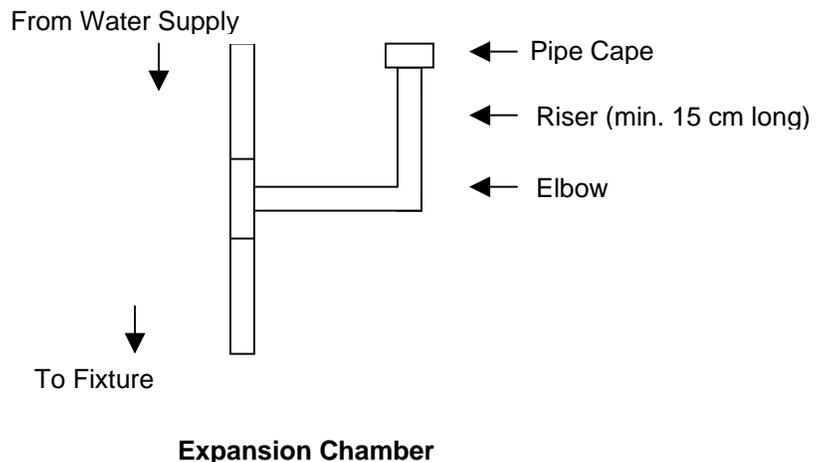
Bleeder Valve - A bleeder valve, also known as a stop-and-waste valve, has a plug on the outlet side that allows water to be drained from pipelines.

Other Valves:

- Reducing valves, used to reduce water pressure going into a building.
- Pressure- or temperature-relief valves for water heaters.
- Foot, check, gate, and relief valves on centrifugal pumps.

Water Hammer - In a water supply system, water hammer occurs when flowing water is stopped abruptly or cannot be compressed, causing the flowing water to slam against the valve. The effects of water hammer are noise from rattling pipes and sometimes leaky pipe joints. Water hammer can be eliminated by installing a device

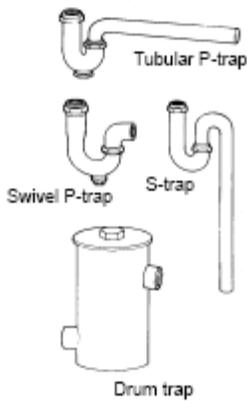
called an *expansion chamber* to slow the water in the plumbing system. The expansion chamber shown at right is capped at the upper end, causing it to fill with air, not water. Therefore, when the water flow is stopped abruptly, the air in the air chamber works like an automotive shock absorber relieving the slamming action against the valve. It is a good practice to install expansion chambers in the water supply system on both hot and cold service lines at each major fixture within a structure.



3. BASIC WASTE WATER DISCHARGE CONCEPTS AND TERMS

Stacks and Branches – “Stacks” are the vertical pipes in a waste piping system, through which wastes flow to the building drain. “Branches” are the pipes that carry the discharge laterally from the fixtures to the stacks. A “soil branch” carries water closet waste; a “waste branch” carries wastes from all other fixtures. Most buildings do not have separate soil and waste stacks, so a single stack, known as the soil- and-waste stack or simply the stack, carries both soil and waste.

Slope – Since waste disposal pipes are not under pressure, they depend on gravity flow to move the water and wastes. Horizontal branches are run from the takeoffs on the soil stack to the various fixtures. Branches should slope 1 cm per meter minimum (1/4 inch per foot) from the fixture to the stack. A convenient tool for checking slope is a carpenter's level.



Traps - A trap is a fitting or device that provides a water seal to prevent sewer gases from entering the building from the septic tank or sewage line, without preventing the flow of waste water through the trap. Traps should be used on all fixtures and floor drains inside buildings. (See diagrams of types of traps at left.) The seal is provided by the liquid trapped in the U-shaped part of the trap. The most common trap seal has a depth of 5 cm between the weir (the overflow level) and the top of the dip. The deep-seal trap has a depth of 10 cm.

Vent - A vent is a pipe or opening that allows outside air into a plumbing system and equalizes the pressure on both sides of a trap. It is always installed vertically, as a horizontal “vent” would become a “pipe” that would carry water. Venting a plumbing system allows the atmosphere to enter the discharge side of a trap, preventing loss of water seal by siphonage. At sea level, atmospheric pressure is about 1.04 kg/cm² (14.7 psi). This pressure varies only slightly on the fixture side of the water seal in a trap. Any difference between this pressure and the pressure on the discharge side forces the water seal in the direction of less pressure. Venting the discharge side of the trap to the atmosphere tends to equalize these pressures. Never use a pipe smaller than 5 cm diameter for ventilation. The main vent must be at least one-half the size of the stack, and the main soil-and-waste vent must be at least as large as the stack.

Trap Seal Loss - Trap seal loss results from inadequate venting of the trap or from evaporation of the liquid in the trap if the line is not flushed for some length of time.

Cleanout Outs - A cleanout is a removable, threaded plug placed in a drainage line for cleaning or removing stoppages. A cleanout is required at a maximum of 30 meters on center in a straight pipe run, also one at every change in direction greater than 30°, and one at every trap below grade. Cleanouts are not required on runs less than 5 feet or above first floor (except sinks). Cleanouts must remain accessible, with preferably at least ½ meter of clearance around each one.

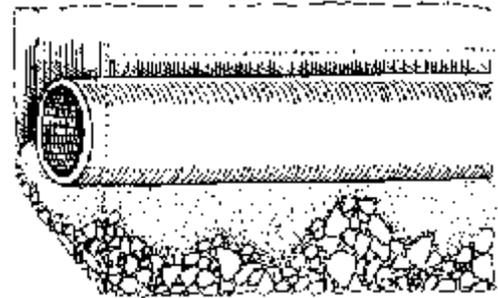
Building Drain - The building drain receives the discharge water wastes from the building and delivers them to the sewer line.

Sewage Systems - Sewer pipes transport waste water from the building drain to the septic tank or public sewer mains. The pipes from a building should be a minimum of 10 cm diameter. Both the house sewer and the house drain must be leak-proof and large enough to carry off the discharge of all plumbing fixtures. Sewer lines should never be placed in the same trench with water supply lines, due to possibilities of contamination of potable water in event of leakage. If sewer lines and water lines must cross at angles, the water line should be laid at least 30 cm above the sewer line. A check valve (back-flow preventer) should be installed just outside the building to prevent sewage from flowing back into the building in event of a major flow stoppage in the line.

Grading Sewer Lines – Sewer lines should be graded to a minimum slope of 1 cm per meter of pipe length. Trenches for sewers should be graded with surveying instruments or carpenter's level.

Underground Pipe - A base of solid, undisturbed earth provides enough support for house sewer

and drain piping. This prevents future settling, which might cause the weight of the pipe sections to press too heavily on the joints. If the soil is loose, each joint should be supported on concrete or brick. All sewer pipe should be buried a minimum of 24 cm below grade in order to provide protection from breakage due to heavy loads passing over and from freezing. Place clean fill around the pipe and compact lightly.

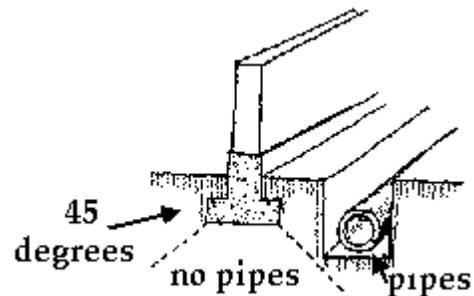


Support along entire length.

Septic Tanks - A septic tank collects the raw sewage and slows the flow so as to allow solids to settle to the bottom, where they can be periodically pumped out. Septic tanks are constructed of precast concrete or reinforced concrete bottom and top with masonry sidewalls. The tank should be watertight to prevent leakage into the groundwater.

Drainage Bed/Leach Field – To greatly reduce the frequency that pumping out the septic tank is required, the waste water (minus solids that have settled to the bottom of the tank) can be discharged from the far end of the tank. Common practice is to allow the water to flow into a network of perforated pipes buried about 1 meter below ground surface in drainage beds. The perforated pipes are laid in parallel trenches filled with stone. The waste water trickles through the stone and drains down into the groundwater aquifer. As it trickles and percolates, bacteria digest the remaining contaminants, thereby cleaning the water by the time it reaches the water table.

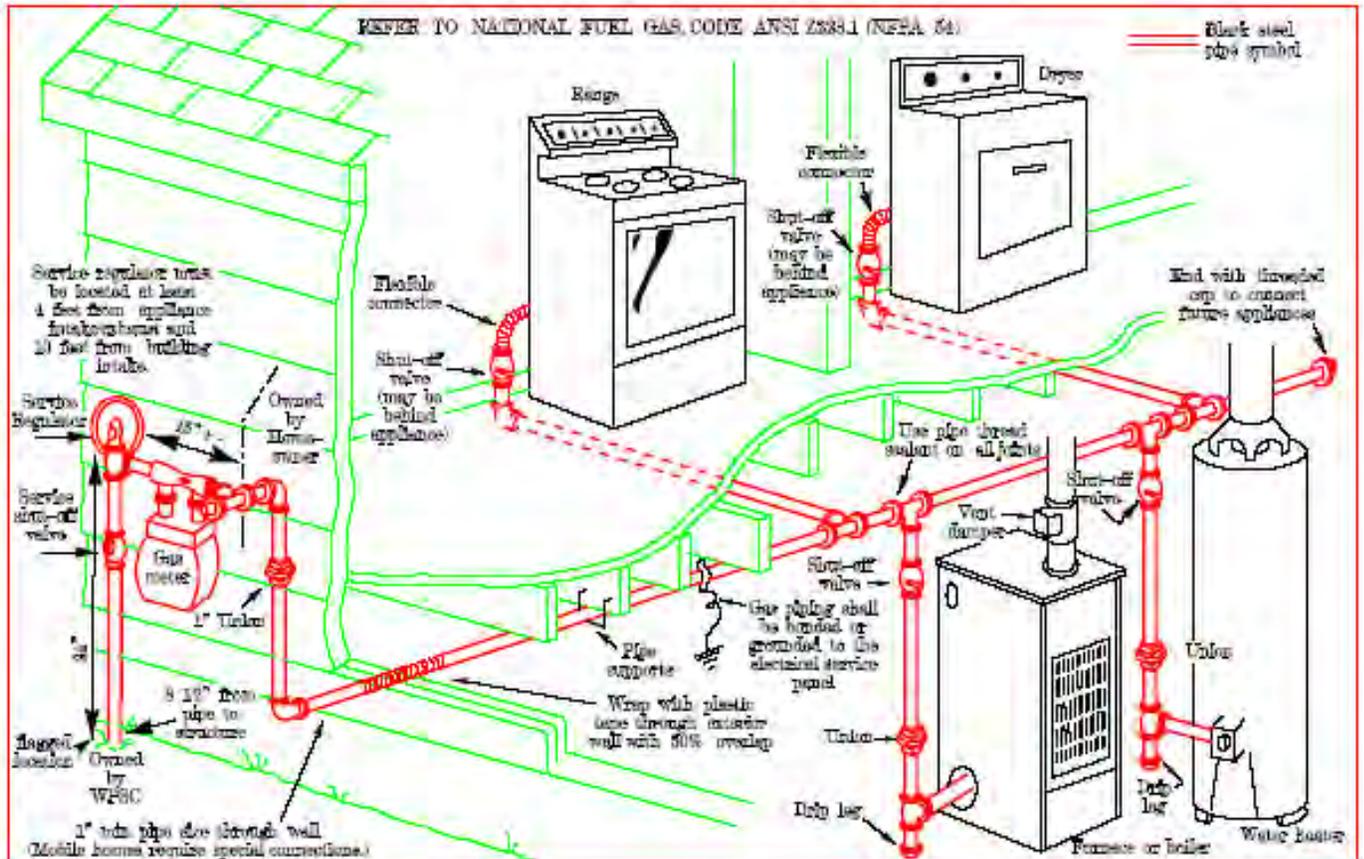
Plumbing and the Building Foundation - Never embed pipe directly in concrete structures. If a pipe is required to pass through concrete structures or foundation elements, embed a larger pipe (conduit) the width of the concrete or foundation, and pass the plumbing line through the conduit so that it fits loosely inside the conduit. Never install natural gas lines under a concrete slab, except through an approved conduit, as leaks cannot be reached for repair. If a trench must be dug near a building foundation, ensure that the bottom corner of the trench nearest the foundation is not below a line drawn down and outward from the bottom corner of the foundation, as depicted in the diagram at right. This is necessary to ensure that the gravity load from the footing does not cause the side walls of the trench to cave inward into the trench.



4. BASIC LIQUID FUEL PIPING CONCEPTS AND TERM

Liquid Fuels – Liquid fuels are not common in Afghanistan, but may be used to feed heating elements from external fuel storage tanks. Liquid fuels include natural gas, propane, and fuel oil. Natural gas and propane are under high pressures inside tanks and piping, while plumbing for fuel oil flow is similar to that for water, exhibiting gravity flow characteristics. While improperly installed water piping will result in leaks, failure to properly install and maintain piping for liquid fuels can result in fires or explosions.

Typical gas line installation within a residential house

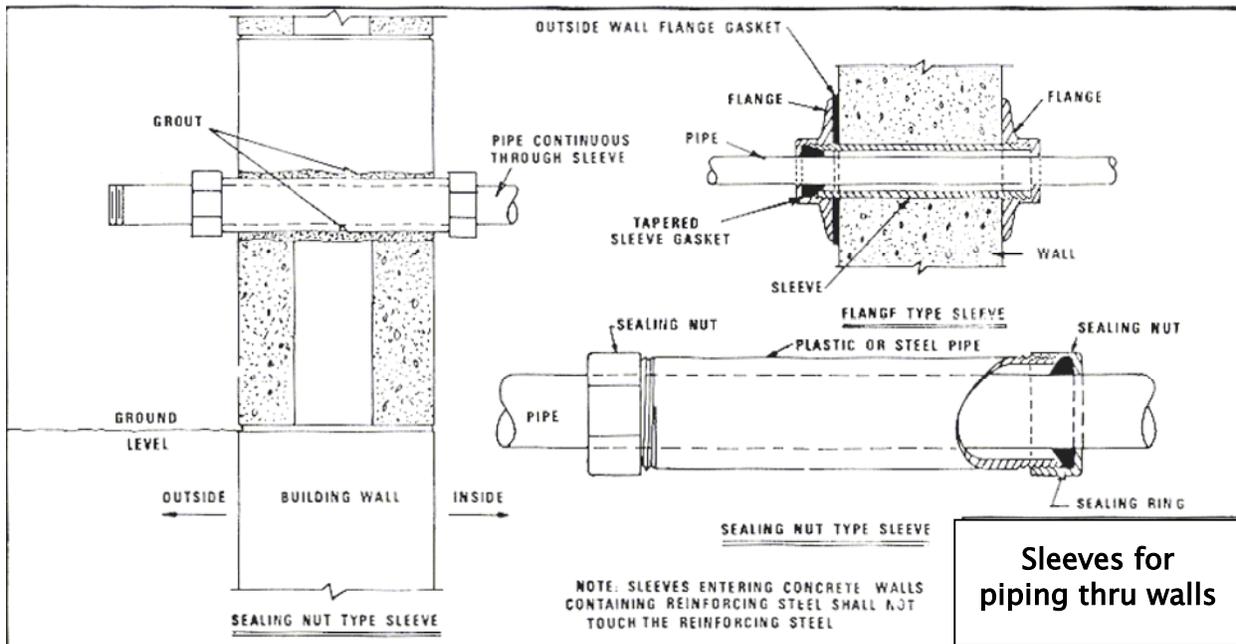


Several international standards (codes) exist covering fuel piping. The most widely used and recognized code for installation of gas piping in the United States is from the National Fire Protection Association (NFPA). Similar European standards exist. Either the NFPA or a European equivalent should be used for the installation of gas service lines during construction and renovations. This section covers a few of the key points in the NFPA code. It is intended to help an inspector or project manager insure at least some basic standards are being met. It is not sufficient to cover all relevant standards that may be encountered.

Service Lines – Service lines connect the house or building to the gas main or tank.

Service line routing - The service line should be installed in a continuous straight line perpendicular to the main to the point at which connection is made to the riser or where the piping reaches to within ½ meter of the outer wall of a building below grade. Never install service lines under buildings.

Service entrance – The service line should enter the building wall above grade. A flexible steel casing or rigid steel encased non-corrosive riser must be used so that the transition from plastic to steel may be above ground. If the service line enters the building below grade, it must be encased with steel pipe through the foundation wall and the transition from plastic to steel made inside the building using an approved adapter fitting as used for insert renewal of service lines. (See sketch below.) Galvanized steel sleeves are not permitted below grade. The opening between the sleeve and the outer masonry wall must be filled with grout or sealed by the use of service entry flanges.



Materials

- Plastic Service Pipe and Tubing - For underground use.
- Metal fittings underground must be coated and/or wrapped and cathodically protected.
- Plastic Fusion Fittings - Approved plastic pipe fittings designed for making heat fusion joints may be used to connect lengths of plastic pipe.
- Screw Fittings - Screw fittings must be used above ground only and must be black or galvanized malleable iron, standard weight of banded type. Specifically designed and approved fitting to mechanically join plastic pipe to a screw end curb valve, may be used underground but must be coated and/or wrapped and cathodically protected.

General Installation

- The maximum allowable operating pressure of plastic pipe for service lines is limited to 4.2 kg/cm² gage (60 psig) or less.
- Plastic pipe above grade is prohibited except that which may terminate above ground in an approved riser.
- Any excavation(s) made during the course of the installation should not be backfilled until after a trained technician has visually inspected the installation.
- For high-pressure gases only, plastic pipe must not be installed in vaults or other below grade enclosures, unless it is completely encased in a gas tight metal conduit and metal fittings having adequate corrosion protection.

- Plastic pipe that is damaged shall not be used. Gouges, grooves, kinks, and/or buckles shall be removed by cutting the damaged portion as a cylinder.
- Plastic pipe shall be protected from the sunlight while being stored at the construction site.
- Plastic pipe shall be provided sufficient slack to allow thermal expansion and contraction.
- Inside the building, support all gas piping with appropriate straps, hangers, etc. Use a minimum of 1 hanger every 5 ft.
- Unions must be downstream of appliance shutoff valves, meter locations and immediately downstream of building shutoff valves.
- Metallic gas piping is not allowed outdoors in the ground or within six inches of the ground unless it is factory coated with approved materials acceptable for burial in the ground.
- Liquid fuel-operated appliances shall be installed per applicable codes and the manufacturer's specifications.
- Shutoff valve requirements are as follows:
 - Required in the gas piping system ahead of all gas appliances
 - Must be accessible and in the same room as the appliance

Trenching

- A plastic service line must be laid on undisturbed or well-compacted soil and may not be supported by blocking.
- Plastic service lines shall be laid at sufficient depth to provide a minimum of ½ meter of cover over the pipe.
- Maintain a minimum separation of 30 cm horizontally when the service line is in a trench with other utility services.
- Provide at least 30 cm of clearance where other utility services cross either over or under the service line.
- Service lines must not run through or near septic tanks and/or leaching beds.

Joining Pipe

- Where it is necessary to use more than one length of plastic pipe in the service line, the lengths must be joined by either an approved mechanical fitting or heat fusion joint. Long sections of plastic pipe are preferred.
- Metal fittings underground must be cathodically protected and coated and/or wrapped.
- Direct application of heat with a torch or other open flame to the plastic pipe is prohibited.

Backfilling

- A qualified technician should visually inspect the service line before backfilling excavations.
- Backfilling shall be performed in a manner to provide firm support around the piping.
- Backfill materials shall be free of large rocks, trash, building materials, etc. that might cause damage to the plastic pipe.
- Where flooding of trench is done to consolidate the backfill, care shall be taken to see that the plastic pipe is not floated from its firm bearing on the bottom of the trench.

Inspections

- Visual Inspection – A qualified technician should visually inspect the service line before backfilling any excavation(s) made during either plastic insert renewal work or pipe installation.
- Pressure test gases - In no case shall any gas that effects flammability or produces a toxic atmosphere when burned, such as Freon, oxygen, acetylene or ether is used to pressurize gas lines for testing.
- Leak detection - Soapsuds or a leak finder liquid may be used to locate leaks.
- New Work Pressure Test Requirements (5 cm and under) - New lines must be given a pressure test after construction and before being placed in service to demonstrate that they are gas tight. Service lines to operate at a pressure of 4.2 kg/cm² gage (60 psig) or less shall be given a pressure test at 6.3 kg/cm² gage (90 psig), for at least 5 minutes with no drop in pressure. An inert gas such as air, nitrogen, or carbon dioxide shall be used to pressurize gas lines for testing.

L. MECHANICAL SYSTEMS

While most Afghan construction has fewer mechanical systems than do most buildings in the western world, a few types of mechanical equipment will be discussed here.

1. ELECTRICAL GENERATORS – (See Section L, Electrical Systems)

2. WATER HEATERS

Heat Sources - Water heaters can operate with a variety of fuels: electricity, natural gas, oil, and propane. Natural gas and electric are the two most common.

Hot Water Storage - The water heater may have a built-in tank that stores the heated water, or the heating tank and storage tank may be separate (usual for larger systems). In the latter, the storage tank only has a small heating element to maintain the temperature. A water heater operates by releasing hot water from the top of the tank when the hot water tap is turned on. To replace that hot water, cold water enters the bottom of the tank, ensuring that the tank is always full. Typical storage capacities of commercially available models range from 60 to 300 liters. Small water heaters that will store about 60 liters of hot water are commonly used in Afghanistan to serve one or two bathrooms. A third type of water heater heats the water only when needed (“on demand”). Demand water heaters eliminate heat loss from the hot water tank, and can reduce energy cost by about 25%. Cold water travels through a pipe into the unit, and a gas burner or an electric element heats the water only when needed. Depending on the heating capacity, water temperature may be limited and maintained cost may be higher.

Relief of Pressure – Superheating water can turn it into steam, which expands as gases and can cause tremendous pressure buildup in a container. For this reason, storage tanks should have a temperature and pressure-relief valve. Relief valves are set to allow water to blow into a drain line when the temperature exceeds 100° C (212° F) or when the pressure exceeds 9 kg/cm². Tanks should also have a sediment drain at the lowest part of the tank to allow periodic cleanout of solids that settle out of the water.

Water Heater inspection items.

- Tank capacity (for storage type systems) appropriate for the facility
- Flow capacity (for demand type systems) appropriate for the facility
- Pressure release valve is good condition and operational (for storage type systems)
- Electrical water heater - (most common type in Afghanistan) should be on a separate circuit, sized appropriately for the electrical demand

3. HEATING AND COOLING SYSTEMS

Heating Systems - In Afghanistan electrical resistance heaters, as well as kerosene, propane, LPG, coal, and wood burning heating systems, are common. Due to the wide variety of heating systems in use, detailed information on individual heaters is not within the scope of this manual.

Factors to consider and inspect during construction and maintenance of all heating systems are:

- Ventilation – All heating system (except electrical heat) must be well vented to prevent carbon monoxide poisoning and build up other dangerous exhaust gasses.
- Fixtures and piping of gas burning systems must be properly installed, maintained and the gas lines and fitting must be protected to prevent leaks which could lead to explosive hazards.
- Fire prevention – A three foot perimeter around the heating element/component should be clear of any flammable or stored items.
- Fixed electrical heating systems should be installed on a separate electrical circuit or multiple separate circuits (depending system's electrical load.)

Cooling Systems (Air Conditioners) - Although rare, air conditioners used in Afghanistan are typically wall and/or window units. Critical factors include:

- AC Sizing – Air conditioner's cooling capacity is measured in British Thermal Units (BTUs). The BTU rating of an AC unit rates the unit's cooling capacity (output), not its electrical demand (input). Although it varies by climate, a simple planning factor is you need about 200 BTUs per square meter of floor space to be cooled. Therefore, a 4 meter by 4 meter room requires an AC unit rated around 3,200 BTUs. Over-sizing the AC unit will not only waste electricity, it will also improperly cool the room because the AC unit will run briefly, over-cool the room, and then shut off. Under-sizing will not provide adequate cooling.
- AC Power Requirements – Air conditioners require a lot of electricity; they typically produce the largest electrical demand in a building. The electrical requirements (demand) can be determined by the manufacturer's data. It can be calculated if the unit's cooling capacity (BTUs) and its efficiency rating (EER) are known. The EER is the ratio of the cooling capacity (in British thermal units [Btu] per hour) to the power input (in watts). A reasonable planning factor is an AC unit will demand 1 watt for each 10 BTU of cooling power. Therefore, a 10,000 BTU unit will demand 1000 watts or 1KW of power.
- AC Maintenance – Cleaning the AC's air filter(s) regularly protects the unit from damage and can significantly reduce operational cost.

M. ELECTRICAL SYSTEMS

1. ON-SITE POWER GENERATION

Electrical generators are commonly used in Afghanistan as the primary power where commercial electrical power is not available and to supply backup power in the case of a power outage. As of 2004, Herat is one of the few cities to have a fairly reliable electric power feed. Afghanistan works on the European type electrical system, which is basically a 220 voltage system.

Generator Selection

Electric generators come in many sizes (kilowatts [KW], megawatts [MW]) and from many manufacturers in a wide range of prices. Sizing a generator for on-site power is difficult because the generator must meet peak demand. Yet during off peak demand period, running an oversized generator wastes fuel and causes undue wear and tear on the generator motor. The greater the difference between peak demand and average and minimum demand, the more difficult is the generator selection. If the facility cannot go without power even for short periods of time, two generators will be necessary, because generators must to shut down regularly for scheduled maintenance (e.g., oil changes) and unscheduled maintenance (i.e., repairs).

Possible On-Site Power Generation Solutions

- Single generator large enough to supply peak demand. This is the simplest and most cost effective solution and is feasible if the facility can do without electrical power during scheduled and unscheduled maintenance.
- Two generators, each large enough to supply peak demand. This solution provides continuous power through scheduled and unscheduled maintenance. Generators typically run for about a week and then the power generation is switched to the other generator and scheduled maintenance is performed. Initial cost is higher than a single generator, but continuous power is provided, and the life span of the generators is longer as they are typically running only half the time. Having the same model generator simplifies operator training and maintenance.
- Two generators, one large enough to supply peak demand and a second smaller generator to provide power for lesser demands (emergency requirements only and/or minimum requirement). This provides continuous power through scheduled and unscheduled maintenance, although often at minimum levels. If sized properly, the smaller generator can be run during off peak periods to save fuel and wear and tear on the larger generators.
- When peak and minimum power requirements vary significantly, consider use of a load bank. A load bank is a device that develops an electrical load, applies the load to a power source, and converts or dissipates the resultant power output of the source. A load bank is intended to accurately mimic the operational or “real” load which a power source will see in actual application. However, unlike the “real” load, which is likely to be dispersed, unpredictable and random in value, a load bank provides a contained, organized and fully controllable load. It can also be set to insure that the generator always operates under a minimum load.

Fuel Tanks Selection For On-Site Generators

Consider the following:

- Tank capacity – large enough to supply fuel for operation between reasonable refueling periods.
- Tank construction – of material and construction adequate to prohibit leaks over long time of environmental aging.
- Tank location – close to the generators but separated for important structures, possibly with a roof or with a shed constructed around it
- Seismic protection – not subject to excessive vibrations that might cause leaks.
- Vehicle impact protection – fencing, guard posts or other appropriate means.
- Secondary containment – tank in a berm or vault that would contain fuels in event of spill.

2. ELECTRICAL SYSTEM INTERIOR WIRING

Power Entrance Panel: Ensure that the proper size wiring is used from the power source to the main panel and that all wires are tightly connected. Also ensure that the main panel box can be locked to prevent tampering or accidents. The main panel should be placed in a location where there is easy access by maintenance personnel, but not where the general public can access it.

Interior Wiring: The greater majority of interior electrical wiring is placed in the wall prior to being plastered. Typical wire size for lighting circuits is 1.5mm (14 gauge wire). For general purpose circuits with wall outlets, 2.5mm (12 gauge) is the norm.

Electrical Wiring Specifications:

- 220 Volt duplex receptacles mounted 30 centimeters (12 inches) from the floor to the center of the box.
- Light switches mounted 142 cm (56 inches) from the floor to the center of the box.
- No more than six 220-volt duplex outlets per 20-25-amp circuit breaker.
- Round junction boxes shall have no more than:

14 each 18 gauge wires	12 each 14 gauge wires
10 each 12 gauge wires	6 each 10 gauge wires
- Wire connections shall be secure with wire nuts and wrapped in electrical tape.
- Electrical devices and cover plates shall be free of paint and dirt.
- Electrical outlets and switches shall be mounted securely to the wall and cover plates shall sit flush against the wall.
- All incandescent light fixtures will have approved glass globe covers.
- Main power feeds underground to distribution boxes shall be free of splices.
- Any and all electrical splices shall be made inside approved electrical junction boxes with protective covers and not covered with mortar or concealed in any fashion. Splice boxes must be accessible in case of emergencies.
- Branch feeders from circuit breakers shall be correctly labeled and identified as to what outlets and light fixtures they control.
- The size of the main breaker at the panel box will determine the size of main feeder cables to be used for both the primary side and secondary side of the main disconnect.

- Use proper size cartridge fuses that correspond to the maximum conductor current rating to avoid electrical meltdown and burning of wire.
- Multi-strand conductor cables 6 gauge and lower that are connected to the main disconnect shall be secure by the cable shoes crimped in such a fashion as to not expose any part of the multi-conductor. There should be at a minimum a slight gap between the cable shoe and the electrical wire insulated cover packet. If wires are exposed they must be covered with electrical tape.
- All fluorescent light fixtures should have a transparent protective plastic cover, approved by electrical standards, to prevent any bulbs from accidentally falling on people.
- All knife switches at the generator shall match the maximum current carry load of the specified generator.
- No electrical splices shall be made inside knife switches or panel boxes.
- All electrical wires and runs shall be free from paint that has the capability of eroding the protective insulated cover.
- Parallel branch feeders are authorized off of the primary and secondary side of the main three phase disconnect as long as the total current capacity for the branch feeders combined do not exceed the maximum current rating of the main breaker.