

## **\_Chapter 1**

### **An Introduction to Emergency Rescue Shoring Concepts**

#### **EMERGENCY RESCUE SHORING**

Emergency shoring operations for urban search and rescue incidents is defined as; the temporary stabilization or re-support of any part of, section of, or structural element which is physically damaged, missing, or where the structure is partially or totally collapsed or in danger of collapsing. This is done in order to provide a safe and efficient atmosphere while conducting trapped victim search and rescue operations at a relatively safe and reduced risk environment to the collapse incidents victim's, as well as the collapsed trained rescue forces. This includes the stabilization of any adjacent structure or object which may be affected by the initial incident.

INSERT TEXT BOX 1-1

#### **THE OBJECTIVES OF RESCUE SHORING OPERATIONS**

The main and paramount objective of emergency building shores is to properly maintain the strength and integrity of any and all structurally damaged or unstable elements; such as but not limited to beams, joists, girders, columns, arches, headers, or bearing walls.

The main objective of the rescue shoring operation's is to properly and effectively receive, transmit and or redirect the now unstable collapse loads. These new loads many times forming in specific areas causing heavy concentrated load effect, overstressing the existing structural elements must be transferred ultimately to stable ground. Many times, depending on the type of structure, these loads can be transferred or directed to structural elements in the remaining part of the building that are sound and capable of handling the additional collapse loads.

INSERT TEXT BOX 1-2

## CONCENTRATED VS DISTRIBUTED

One of the main concepts of our rescue shoring will be to take the concentrated overload from debris and redirect, or redistribute it to structural elements that will support the load. When we encounter a collapse situation many times an overload condition on the structure may occur. This will happen when the buildings contents as well as the structural elements of the building have collapsed on to a lower floor. Depending on the type of collapse voids created, many times the upper floor loads will be directed into a specific area. This will happen most often in a cantilever, supported lean-to, v-shaped, and a-framed type collapse pattern. In these patterns the material from the floors above will be directed into specific areas. That material which above in its normal state and position was an evenly distributed load that the structure would be easily able to support. However, the material now has come to rest on a lower floor in a large concentrated form. In essence the structures supporting elements are being overloaded because this concentrate load is now being supported by only a few elements, generally floor joists or a girder, or both. The job of the rescue shoring officer and the structural specialist is to determine this overload and how to redistribute that load to either the ground or other structural elements able to support that load. This is generally done through some type of rescue shoring. There are several options that are generally available, either take the load and directly feed it to the ground or a lower floor, normally done with vertical shores; or transfer the load laterally to the exterior bearing walls. Of course other options are available but these two are generally the most common.

## BASIC RESCUE SHORING POINTS

### **Emergency shoring must be erected as a system**

Unlike what you generally see in the construction industry, emergency building shores must be constructed as a complete system. By tying all the shores together you increase the stability as well as the efficiency of all the shores. The possibility of secondary collapse is the

biggest problem we have to be concerned with at any structural collapse rescue operation. In order to accomplish this and to put the safety factors on our side we must have all the shores assembled together as a complete unit. The increase in stability of the shores when they are a whole system will serve to fulfill that task. Remember; our shoring must be able to withstand a possible secondary collapse.

#### Lateral Bracing Must Be Installed To Prevent System From Buckling

It is very important that we laterally brace all the shores, and in both directions. The shores must be able to withstand lateral pressures that may be applied to the shoring system from any direction. Sudden shifts can easily occur in unstable collapsed structures, thus applying eccentric and/or torsional loading. The minimum Level Of Lateral Strength In Vertical Support Should Be 2%, however, 10% is more desirable.

Rescue shoring is unique compared to “normal” contractor installed shoring, contractor shoring is generally the friction type of shoring. This type of shoring relies on the pressure of the shore against the damaged material for it to stay in position. A major problem with friction types of shores is that they have very little lateral stability and can be easily vibrated or knocked loose, something we cannot tolerate in a emergency situation. The potential for secondary collapse is always present in structural collapse rescue operations, we must be always prepared for it.

In rescue situations we must have fixed shoring systems installed because of the dangerous possibility of secondary collapse, these type of shores will stand up to that threat must better than the friction type. The shoring that we as rescuers must erect must be a complete system, they must be able to properly resist forces from several directions. This can only be done with lateral bracing applied to the shores, tying all the shores elements together.

INSERT TEXT BOX 1-3

#### SHORING SYSTEM

For a shore to work properly and be considered a system, generally it must have four main items. A header or top plate, one or more posts or struts a bottom plate or sole plate and finally, a lateral or diagonal bracing system. Each one of these items is important for the success of the shoring system. The key to all the shores is to collect the loads from a damaged area, funnel it through the post system and redistribute the load to the ground or other suitable structural elements.(See Fig. 1-1)

INSERT FIGURE 1-1

### CONSIDERATIONS ON STARTING YOUR SHORING OPERATION

When responding to structural collapse operations many things should be running through your mind, possible victim's, fire problems, exposure problems, how extensive is the collapse, what caused the collapse, to name a few. If you make the decision to have your rescue personnel enter the remains of the collapsed building, then the safety of your personnel must be paramount, having rescuer's become part of the problem instead of the solution is not acceptable. In this case one of your main concerns now becomes the stability of the remains of the structure. The stabilization of the structure for the protection of both victims and rescue personnel will become a major concern, rescue shoring operations must be considered.

There are three main considerations or options that you normally will have to determine whether you should start shoring or not. generally your three main options are to avoid, mitigate, or shore.

#### **Avoid**

Many times in collapse situations especially in larger structures victims may be trapped in only one immediate area. There will be times when an area that is unstable is not in a area where rescue personnel will be operating, if this is the case the area can be blocked off and all personnel kept out of the danger zone. This would negate the necessity of having to attempt an extensive shoring operation. If this is the case then make sure the area to be

avoided is properly marked off, and the safety officers have the access way blocked or continually watched. The area that has been marked off should also be continually evaluated by the structural engineers for any change in stability as a safety measure.

### **Mitigate**

There will come many times the situation that arises where we will not be able to shore something but we will have to work in that immediate area. The only way we can do this may very well be to mitigate it, by removing the hazard. For instance, when dealing with masonry walls or chimneys generally the easier of the two options is too mitigate it instead of trying to shore it. When the bond from the mortar and the bricks or blocks has separated from the joints and cracks, you have a problem. Unfortunately, when this situation develops, to shore these unstable walls will take quite a bit of work and what happens is when you start putting pressure and undue forces on the wall it cracks and disturbs the wall even more. This makes the wall even more unstable and subject to secondary collapse problems. Normally speaking, it is much more efficient, safer, and less time consuming if you can mitigate the problem by taking the wall down then trying to shore it up. Hopefully this may be an option, if it is not then shore it up but you must be extremely careful not to disturb the remains of that wall or chimney.

### **Shore**

If you do decide to shore up the structure there will be several considerations that you will have to address. The first and foremost issue is, do we have the capabilities to accomplish this task. There are several issues that must be addressed, do our personnel have the training and expertise to accomplish the mission? Do we have the equipment necessary to do the work? Finally do we have the materials to accomplish the task at hand?

In order to answer the first question, we must look at the type of training your rescue team does on a regular basis. How much technical training do they really do? Is it geared

toward collapse, high angle rope fairy stuff, or confined space, trench rescue, or all four. Although many teams have some basic knowledge and training in structural collapse operations the majority of the time they don't have extensive training in collapse rescue shoring. Most of the time this is due to the fact that it does cost money to put this type of training on and frankly, it is not utilized on a regular basis. Many departments check writer's don't like to spend money on items like this. Unfortunately, without the proper training in this discipline your team will have problems erecting safe and effective rescue shoring. If the team has taken some shoring training but has not kept up the skills, then to get involved with a possible difficult shoring operation may be a dangerous move. This is one rescue discipline that you must have the proper amount of training and confidence in to attempt it or someone can get seriously hurt. Frankly, most of the basic shoring classes out there give you some of the overall basic techniques, and when you get involved in heavily damaged areas, none of which are square, by the way, adaptation of the shores to the environment must be done. This is where experience and through knowledge of your shoring types and techniques is necessary, knowing what will and what will not work for each given scenario is a must. This is absolutely necessary to keep the safety of the operation on your side, the welfare of your team members as well as any victims is at stake.

#### SHORING SIZE-UP-ADDITIONAL INFORMATION

##### **Missing or damaged structural supports**

Beams, columns, girders, and arches are all primary structural elements that support other structural elements. These items must be checked ASAP. The building elements they had been supporting may be under substantial additional stresses, possibly ready to fail at any time. Shoring of these items will immediately re-support sections of floors that may be compromised in some fashion. It is much easier to replace or re-stabilize one item that to have to erect several shores instead. Generally these are the first items you should be looking at as

you start you shoring size-up. Your team must be have good skills in building construction identification in order to quickly be able to identify these particular structural supporting elements. Normally the quickest way to safely re-support a damaged structure is to concentrate on these elements and the proper identification of what they are supporting.

### **Structural fire damage**

Has the building sustained any previous fire damage? The structural stability of an area previously involved in fire must be considered at best suspect. When a structure has collapsed or partially collapsed due to a fire situation, the safe operation in the structure after this fact will depend upon how badly damaged or compromised the remaining structural supports are. Check for fire damage on the ends of the beams were there support will be and look for any alligating of the lumber. This is a sure sign of loss of structural integrity of that lumber. You may have to shore throughout the damaged area. If you can, keep the placement of equipment and personnel to a minimum in these areas.

### **Age of the structures**

The buildings age is another shoring size-up factor. The shrinkage and expansion of structural elements due to wet-dry cycles over time results in a loss of strength and the loosening of important hangers and connecting supports, if they have not been properly maintained, building elements such as wood and masonry may have dried out and become brittle and weaker with age. The older structures tend to be built with much larger dimensional lumber than what is in use today. This is a definite plus when it comes to collapses and fires, what occurs is due to the construction techniques of the older days, engineering was not as exacting. Larger material than necessary was utilized for safety reasons due to the possibility of mistakes being made in the erection of and the fabrication of those materials. As a result the older structures have what is known as redundancy in there construction. Basically this means that the structural elements in question could support

much more than they were required to. So when a catastrophic incident attacks the structure these elements tend to hold up much better than a newer better engineered building, this is a definite plus for the fire service.

### **Structure condition**

The overall condition of the structure is another important part of your size-up, obviously the “shape” of the building will have an impact on how much damage will occur and on how much of the structure will remain intact and what shape, or stability that remaining section will be in. If the structure is vacant and in a state of disrepair then most likely the critical structural element connections in the building may be compromised. This is generally due to the fact that most of these joints are butted together at specific ends, leaving more surface area of those elements exposed to the weather. This usually results in these sections deteriorating first and subsequently failing first. A structure that has received proper, continual maintenance and repair has a better chance of sustaining or surviving a collapse than a building that has fallen into a state of disrepair. The supporting elements of a well maintained building may be used to help support and transfer the collapse load throughout the structure. however, if the building’s condition is suspect, as it well maybe in the case of a vacant building, do not assume there is sufficient structural support without first inspecting the building. The possibility of a secondary collapse in deteriorated buildings is a primary consideration.

### **Six sided approach**

The top the bottom and all four sides of the structure and the area you are working in or about to start some type of shoring operation must be examined. To start a shoring operation, check what items or sections you will be shoring then determine its approximate weight. It is extremely important to survey the top of the structure to identify loose, shifting, or hanging debris or structural elements. These items may have to be moved, shored, or

completely avoided, depending on the situation. The decisions you make respecting these items will affect your rescue operation. After this has been calculated then determine if the floor you are on will be able to hold that load, if it can't then you will have to look under you. It may take several floors to hold the weight, or even in smaller structure's you may have to go directly to the basement for your initial support. Remember, gravity is constantly working to pull the building's remains to the earth, so from a shoring standpoint the bottom survey is extremely crucial. It should be performed simultaneously with the top survey, if possible.

### **Walls out of plumb**

Determine the building's stability immediately on arrival. Examine the walls in the collapse area. Are they stable or are they leaning in one direction or another? If they are partition or nonbearing walls, will they affect collapse operations in any way? If they are leaning or otherwise show signs of affecting operations, they must be shored. Walls were designed to accept the loads in an axial position for their best efficiency. If the walls are out of "plumb" (level in the vertical position ) then the chances are very good they will be loaded eccentrically. This may cause it to be overloaded in one area or become unbalanced, both of which can lead to some type of problem. Another issue is the fact that floor beams generally only sit on top of these bearing walls a few inches. When one of these walls shifts out of plumb only two or three inches, remaining bearing of the floor joists may not be enough to keep the floor intact. If you can see a wall leaning with the naked eye it is a real good idea to get in a see how much of the floor beams are remaining on that wall.

### **Strained structural elements**

Floor beams and other structural supporting elements under the main debris pile or under a victim's location are among the top priorities of sight assessment. Older, more substantial beams can withstand large amounts of stress; however, when they are stressed to their limit, very little weight is needed for them to reach their failure point. Any severely

bellied, stressed or cracked beams must be shored up before rescue personnel are committed to the operation. Examine all the structural elements that are effected by the collapse and look for any deflection in them, if they are strained they must be re-supported as soon as possible. When they have been strained they loose quite a bit of there strength and this must be addressed immediately. Beams that are stressed will go back into shape and still have there strength. Beams that have been strained will not come back into shape after the load is removed, there strength has been compromised, however, it is very difficult for us to be able to determine this on scene.

### **Type of construction material**

The type of materials that are utilized in the construction of the buildings structural elements will of course have a large bearing on what size and how much shoring material may be needed. If the building is made of URM, one size may be needed, and if the buildings elements are made of steel or concrete than heavier shoring material will be needed. Typically, the two items that will determine the size and strength of your rescue shoring will be, the weight of the building material itself and the weight of the materials and items inside the structure. For this reason, as soon as possible in your size-up, you have to be able to determine what type of structure it is and what size and type of building materials you are dealing with. Knowing the size and weight of the structural material will give you a pretty good idea of what size shoring material you will most likely need. The bigger and heavier your structural elements are; the bigger and heavier your shoring material may have to be. The other aspect to consider will be how much weight the building is holding up with its contents. For this reason the type of occupancy of the building must be determined as quickly as possible. A major collapse potential will be the overload of materials and contents of a structure. This has to be taken into account when determining the size of your rescue shoring material. One important item in your size-up is to know the weights of the most common

building materials, and the strengths of the shoring materials you will be utilizing to stabilize that structure. To be safe, the strength of our shoring materials must surpass the weight of the materials we are to be stabilizing. Wood and light masonry may need 4x4's and concrete and steel may need 6x6's and larger, depending on the size of the structure.

### **Types of beams**

The basic types of beams commonly in use today are the simple, continuous, cantilever propped and fixed beams, each type is supported in a particular way. When the support points for these beams are compromised they must be immediately evaluated and resupported. By being able to quickly identify which type of beam it is will make it much easier to find the critical support points for that beam and replace or re-support them if necessary. Thorough knowledge of building elements and how beams functions is imperative. You must be able to determine how the beams are loaded when your size it up, and how the beams are supposed to be loaded properly. The stress and strain on the beams, and the compression and tension on the beams has to be analyzed properly. The relief of the overloads and the redirection of these loads should be the primary concern of supporting these beams. This action will help stabilize the remains of the structure properly.

### **Floor construction type**

Again the type and size of the construction material that the floor is made of will determine the size and amount of shoring lumber and systems that will be needed to safely support the damage. If the floor beams are spaced 12", 16", 24" or more on center your shoring material will be spaced accordingly. Depending also on the size of the floor beams, 2" , 4", or larger dimension, bar joist, trusses, concrete or steel will all determine the size of your shoring lumber needed for proper support. The type of flooring itself will also be part of the equation. What the makeup of the floor is and how thick it is will be, for our purposes, will be the main determining factors of how much it will weight. If it is wood flooring it will

be rather easy to determine the weight, basically it will depend on the thickness of the floor. Typically wood flooring systems can weight roughly, and this is a rule of thumb, approximately 25 to 35 lbs per square foot. The more complicated floor systems we will run into will be those of concrete and concrete and steel. The weights of the concrete floors will vary with the thickness of the material, the type of concrete, and the amount and size of the reinforcing steel that will be in the concrete. You can determine this by the use of the structural drawings of the building or by closely examining the floor sections themselves.

### **Proper beam connections**

Another one of the more important size-up points, you must check all the beam joints and connections ASAP. After the stress and strain of a structural collapse has effected the building all the connections in the area affected must be examined and checked for continuity. The physical connections themselves and there supports also must be checked. Items to look for are the stability of the supports and how the beams are anchored to those supports. To examine these items will not take a major effort and must be done as soon as possible. This is one of the first items that must be checked for the safety of the rescue forces, don't ever forget to do this.

### **Door and window access**

At the majority of structural collapses access to the structure will be hampered by debris and possibly dangerously hanging materials from the building. Many times your access may be limited to windows or side and back doors, these may limit your shoring team's access for tools and materials. Any time you will use an existing opening as an access or egress way, it must be closely examined for structural defects and instability problems. These must be checked and dealt with before your rescue teams can continually utilize those entrances safely. Some mitigation of hazards may have to be done or some shoring may have

to be erected. When utilizing these areas as access ways you must constantly keep an eye on their stability, throughout the entire operation.

### **Door and window frames out of square**

Then you notice this condition you must be very concerned, this tells your rescue team that major movement has occurred to the structure. Some of the causes of this are; racking of one or more walls in the structure, major wall or possible foundation failure, whatever the reason, corrective action must be taken immediately. Generally stabilization of the walls and large sections of the affected floors will help, however, remember each collapse is different and the exact cause of the problem should be known in order to properly correct the situation. Because these are openings in the wall sections and therefore, are the weakest parts of the wall, the movement will occur here first. By placing bracing and shoring in the opening, you will be able to re-stabilize this weak area. Diagonal bracing has been used successfully on many previous occasions to help prevent the structure from racking any further. This should be one of your first options you can consider. Doors swinging open or closed- this is movement, and any movement is an imminent sign of structural collapse. This means that the structure has drastically shifted or settled, and that some sort of structural element has or will fail in a very short time. Your rescue teams should at this time exit the building and re-evaluate the stability of the structure before entering again to perform rescue or shoring operations.

### **Sagging floors and roofs**

This condition can occur very frequently due to overloading of the floors or roof from any number of sources. Roofs, will normally be overloaded by either weather conditions, such as snow or ice and by some sort of large objects. These can be water tanks, hvac equipment and the like. As with any situation, the size up must include examining all areas in and around the collapse structure, as well as other areas around the structure that may affect it.

Generally the floors will be sagging from the weight of collapse debris and furnishings.

When the floors are sagging these means the beams are excessively overloaded, this can cause a further collapse at any time. These beams must be shored up and have the debris removed from the floors if practicable.

### **Columns out of plumb**

Generally columns are supporting beams and or other columns, if for any reason they are out of plumb there efficiency and capacity is diminished, the further out of plumb the less efficient they become. Many times the columns will be under a joint of a girder or a set of beams, if this is the case then it is important that the column remains “plumb”. Typically, in this situation, there will normally will only be a few inches of beam bearing on the columns. If the column gets knocked out of plumb then the bearing of one or both of the beams will be compromised, possibly causing a structural collapse to occur. Another important item to examine with a column is to determine if there is any belly, or deflection in the column. This will also drastically diminish the strength and stability of a column. The items they are still supporting must be secured, you may have to shore up around the entire column if necessary. It is very important that these items are checked as soon as possible, the longer and thinner the column the faster and easier it will deflect, causing structural problems to occur rapidly. Columns that are still holding up with no deflection but are damaged must be watched extensively, the damaged areas are suspect for strength of the column, and will be the first place the column will fail.

### **Framed or unframed structure**

By being able to rapidly determine if the structure is framed or unframed will tell you the general framing of the structure and which elements are load bearing or non-load bearing, information that you must know in order to properly size-up your additional collapse potential and shoring operations. In a framed structure a skeletal like system supports the building and

the walls, collapse's are generally a little more localized and less extensive than an unframed structure. In an unframed structure the exterior walls are the bearing walls for the structure, if a lower section of one of these walls fail than everything above may collapse. In a collapse of a unframed structure the damage may be more extensive than that in a framed structure.

### **Access to the structure**

Access to the entire structure may be extremely difficult due to massive debris build up or the danger of the remaining structure falling on your rescue forces. This has to be evaluated before operations start, bringing in tools, lumber and equipment for the safe removal of trapped victims or the purpose of rescue shoring may be a problem. There will be many occasions where the primary access, usually the front door, can be blocked with debris or too heavily damaged to use. If this is the case, then the safest and easiest point of access should be used. Your initial points of entry are generally through the front of the structure. However, you may have to change the staging area for all your equipment, getting the materials you will need closer to the point of use will be a priority for your rescue forces.

### **Bulging walls**

Identifying any bulged or heavily damaged walls are very important, if they are bearing walls they may be compromised and can fail at any moment. You must determine the total extent of the damage and the amount that the wall is bulged. As with any structural component, if it is not loaded thru its axis it can become unstable. Masonry walls are especially susceptible to instability do to nature of the material itself. Visible bulges in interior or exterior walls are of major concern and must be addressed immediately. The main shoring operation that can take place in this instance is the shoring or stabilization of the floors that these walls are supporting. Normally that would entail the erection of vertical shores under the floor beams, effectively replacing the damaged wall. With exterior walls raker shoring may have to be erected in order to stabilize the wall section itself. This will

keep the bulged wall from falling and causing some sort of secondary collapse situation from developing. The definite possibility of having to shore and stabilize these compromised walls must be considered.

### **Cracked walls**

As above you must closely examine the walls for any damage, cracks in masonry walls can be a sign of foundation failure and wall compromise. Examine the cracks for the extent of the damage. Just because there are cracks in masonry walls that does not necessarily mean the wall is structurally compromised enough to fail. If for instance you have a wall that is 10 ft high and 30 ft long with a hairline crack that is say, 3 feet long you do not have a structural integrity problem, small cracks like this are not uncommon in masonry construction. However, if you have a much larger or longer crack that has opened a space in the masonry you have a potential problem on your hands. Another key to a situation that is developing is the traveling crack and an “X” type of crack in the wall. The “X” crack tells you that you have had movement in two separate directions, a definite problem. Evaluate the damage try and find the source of that damage and work accordingly.

### **Separating walls**

This condition occurs when the building starts to twist and the walls spread apart. Checking the joints at the corners can quickly tell you if major movement has occurred. As the structure starts to rack the interior walls will begin to pull apart, in most cases this will be easy to spot. Normally you will see the tops of the corners of the walls peeling apart. As you enter the room if you look at the corners from the doorway you may be able to pick that out right away.

### **Vibration potential**

In your overall size-up one of the concerns that you must have is the potential of secondary collapse due to some source of vibration. By eliminating these vibration sources

and checking all joints, connections, and precariously hanging structural members you can start to make the collapse area a little safer to operate in. Remember, everything we do as a rescue service has the potential to create some sort of vibration to occur. Every tool we own in our collapse rescue arsenal causes vibrations when used, we must be aware of any adverse reactions the tools we will be using may cause.

### **Trusses**

The problems for the fire service that has developed over the use of these highly engineered items is well known. If any part of the truss fails then the entire truss will fail and most of the time very suddenly. When and if you have to shore a truss, always shore the top chord. If you shore the bottom chord and one of the shores elements fails, you may still have failure of the remaining part of the truss. By shoring the top chord you will support the weight above and hold that weight in position, safely stabilizing it.

### **Types of void access**

If you have numerous voids with victims trapped you will most likely need some type of shoring lumber, generally cribbing size lumber is adequate, roughly 24” long usually works well. In some collapse’s you may have much larger voids, in these situations longer lumber sizes may be needed. Determine the access that you have to those specific voids and see the feasibility of being able to place the larger size lumber in the void.

### **Bearing wall stability**

The most important structural elements in any unframed building are its bearing walls. The majority of the structure’s weight and any loads in the structure are supported by these walls. In a collapse situation, failure of any part of any of these walls can cause extensive damage and further collapse. Check for the integrity of the wall, look for any bulges, bellies, cracks, leaning or any type of possible deflection or abnormal deformation of that wall. Are any sections of the wall damaged or missing? If a wall is damaged, it may no longer have its

full load bearing capacity, making that area a weak point in the structure. If a section of wall is missing, additional stresses are being applied to the floor beams above and to the adjoining, remaining sections of wall. This is a very dangerous situation. If structural stability is compromised, or if there is any doubt concerning the wall's structural integrity, the shoring officer must decide where and how much to shore. The foundation should also be checked if you do find any of the problems from above. If any of the conditions of above do occur then the possibility of shoring may have to be considered if any operations are to continue in that building.

### RULES OF THUMB

These are a few general rules of thumb that can be easily and quickly applied on the rescue site if necessary. They will generally work on most occasions however, bear in mind that each structural collapse situation is different and any unique circumstances must be taken into account.

There are four basic rules of thumb when your rescue team will be using existing floors in the damaged structure for support of unstable walls, debris or other floors.

It takes one undamaged wood framed floor to support one damaged wood framed floor.

It takes one undamaged steel framed floor to support one damaged steel framed floor.

It takes two undamaged reinforced concrete floors to support one damaged concrete floor.

The thickness of any debris on the damaged floors must also be taken into account when calculating the amount and type of shoring your team will need.

The length to diameter ratio for all shoring material should be no more than 50 times that diameter and ideally should be 25 to 35 times if at all possible.

### LUMBER

It is critical to your collapse rescue response to have quick access to lumber for your shoring or cribbing operations. One way of accomplishing this is by contacting your local

lumber yard and pre-arranging for a quick delivery of specified lengths, sizes and type of lumber your team may need. Another option is to contact your local department of public works, or a large contractor who has shoring materials on hand. By pre-planning for the need your team may be able to have prompt access to the type of lumber that is needed for shoring operations. However, the easiest and only way your team can be positive that the needed materials will be delivered to the sight is by bringing them there yourself. There are too many variables involved when you depend on someone else, for instance, what if the collapse operation occurs after working hours ? How will the lumber yard accommodate you, or what if it's a busy day and the company has no trucks available to deliver you materials, these problems could cause unnecessary delays that can wind up with tragic results.

### **Types of lumber**

There are several types of lumber available to your rescue team that the majority of lumber yards will stock. Here is a list of some of the more common types you will find that are utilized in the construction industry and should be readily available.

**Hardwoods and softwoods.** There are two major categories of wood that are available to use today, they are hardwoods and softwoods. These names really tell us more about the type of tree the lumber comes from than the wood itself. For example, balsa wood, the easily cut and lightweight wood we all used as kids comes from a hardwood tree. These names do not necessarily mean that hardwoods are hard or softwoods are soft.

Hardwoods come from broad leaf trees that lose their leaves during the winter months, so all you guys that rake a ton of leaves every fall now know your property is loaded with hardwoods, aren't you happy now knowing this information. The wood is generally heavy and close grained, oak and maple are two examples of the common types available. These types of lumber are generally expensive and very heavy to work with they are not well suited for our needs as a rescue team.

*Oak*—A tough hard, high density wood of temperate climates, coarse textured and used for both structural and decorative applications, framing timbers, flooring, molding and plywood are some of its many uses. The two most common types that are available are the white and red oak varieties.

Softwoods come from trees with needle like or scale like leaves that stay on the tree all year (Christmas trees). The most popular species of softwoods are Douglas-fir, Western hemlock, white fir and spruce. Pound for pound Douglas-fir is one of the strongest woods available. It resists warping, cupping, and twisting and is normally available at lumber yards throughout the country. For these reasons Douglas-fir is the choice of lumber for use with your collapse rescue team. It is strong, readily available, not expensive and stores well, ideal for use with the situations we will encounter.

*Douglas fir and yellow fir*—A strong medium density, medium to coarse textured softwood. It is widely used for plywood and dimensional lumber and timber's in a variety of building construction situations. Several of the better varieties of lumber your team should utilize in collapse rescue operations are the Douglas fir, and yellow pine. Of course you utilize whatever you can in a real scenario, but bear in mind types of lumber may have lower supporting strength.

Each piece of lumber delivered by a reputable mill should have a grade stamp. This stamp is to certify that the piece of material meets quality control standards set by the lumber grading associations. The grades we will be looking for are No. 1, No 2, stud grade, and construction grade, utility grade should not be used, it may not be strong enough in some situations.

### **Lumber storage**

One of the biggest problems we will encounter is with the storage of our lumber supplies, since we will not be using the material every day these problems must be dealt with.

The biggest enemy we will face will be that of moisture, your material must be kept in a dry, well-ventilated area if it is to last. Moisture can be taken out of lumber by two accepted methods, kiln drying and air drying. Both methods will produce quality seasoned lumber. Seasoned lumber generally means that the moisture content of the lumber is normally 19 percent or less. Lumber that you purchase with a higher moisture content will be called green lumber. The average shrinkage of a Douglas fir structural member from green to kiln dried is approximately 7.6 percent in width and 4.1 percent in its thickness. This adds up to more than a 1/2 inch reduction in width for a 2x12 inch member. You should be aware of the changes that will occur when the moisture content in the lumber you will be utilizing changes. If you use green lumber that dries too quickly checks, cracks, and splits will develop. Green unseasoned lumber, especially when improperly stored can also warp, twist, and shrink. For this reason your team should avoid the use and purchasing of unseasoned lumber. Checks are the separations in wood that normally occurs across or through the rings of a tree's annual growth. They are usually the result of seasoning and generally occur at the ends of the lumber. Splits are the separations of the wood that happens when the wood cells rip or tear apart.

### **Use of existing lumber**

In the majority of collapse situations that your team will respond to, the tendency will be to grab any available material and go to work. If your team does not carry lumber with them then they will use whatever they can get their hands on. This leaves generally only the material that was involved in the construction of the collapsed structure. Evaluation of any material you are going to use must be made before your personnel commits to utilizing it for rescue operations. There are several areas that should be looked into before you utilize that material for any rescue shoring. Some of these areas are; age, type, condition, and how much stress the material has been subject to. The age of the building will give you an idea on the

shape of the lumber. In newer constructed buildings the lumber should be in good shape, much older structures may have weathered material which can be fatigued and difficult to work with. The type and size of the lumber also is an issue, smaller lumber such as 2x4's can not be utilized as main bearing members without nailing them together. Cedar and redwood decks cannot be torn up and relied upon for structural bearing members, they are too soft. The single most important determining factor on the decision on whether to use the lumber in question will be the condition of the material itself. It must be thoroughly examined, if the lumber is too dry or brittle it will split and crack easily and will not stand up under any type of stress. If it shows signs of rot or is extremely wet it will also be suspect and therefore unusable. Finally examine the lumber for any twists, bows, cracks or splitting, if any of these conditions are present the lumber should probably not be utilized for rescue operations.

### **Common lumber sizes used**

The following is a list of lumber that if at all possible should be carried on your collapse apparatus and some of the more common uses for each.

**2 x 4**—this size lumber can be used in box cribbing, as diagonal bracing for interior rake shores, cross bracing for laced posts, interior and exterior raker shores, various size cleats, filler blocks and diagonal bracing for the vertical shore.

**2 x 6**—Can be used for diagonal wall braces, diagonal braces for the vertical shore, interior and exterior raker shores, box cribbing, cleats for raker shores, cross bracing and horizontal bracing for raker shoring and horizontal struts for the split-sole raker and the flying raker shore.

**2 x 8**—Although not commonly used, they are excellent for "sleepers" or "mud sills" when shoring is being erected on soft ground. They can also be used as diagonal wall braces.

**4 x 4**—The most common size of shoring lumber your team will be utilizing. Box

cribbing, "T" shore, window shore, door shore, laced posts, vertical shore, horizontal shore, and interior and exterior raker shores can all be constructed with 4 x 4's.

**4 x 6**—Generally used in larger type buildings or where substantial holding power is necessary. They can be used as door and window shores if heavier loads are anticipated or as interior or exterior raker shores if necessary.

**6 x 6**—Normally used in heavier constructed buildings where the loads will be much greater, such as an all concrete or concrete and steel structure. They are good for use as box cribbing, raker shores, vertical shores, laced post shores and as return blocking for a series of raker shores.

**1/2-inch plywood**—The plywood can be used for numerous items, gusset plates, cribbing spacers, wall plating for raker shores, in trench rescue, as work platforms and saw horses.

#### LENGTH TO DIAMETER RATIO

One of the most critical areas we must address when doing a shoring size-up will be; how much weight are we supporting? Keeping this in mind, determining the length to diameter ratio of our shoring elements will be very important. Our main supporting elements is most of you shoring will be the posts or struts. These may need additional support or tensioning, this will be done with the use of lateral bracing. INSERT TEXT BOX 1-4

Basically, Eulers' law of columns comes into play with all our shoring systems. Leonhard Euler, a Swiss mathematician who lived in the 1700's proved that a thin strut or column submitted to an axial compressive load will not remain straight. It will bend out suddenly, or buckle at a specific value of the compressive load. This is called its critical value. Since any element that comes under compression acts as a column, whether vertical, diagonal or horizontal all our shoring systems will come under this condition. By limiting the length of our posts or struts we keep the strength up at the most efficient levels. That is one of the reasons why we brace our shoring systems. The longer and thinner the element is the less

it will support. By center bracing, or lateral bracing these elements we get the best use of the strength of the lumber. In most cases, and of course there are always exceptions, we want to keep the ratio of the posts at a maximum of 50 to one. For example a 4" x 4" actually measures 3.5" if we multiply this by a factor of 50 we will wind up with 175", which for our purposes equates to roughly 14 feet. This would be the maximum you would go in length to shore up something lightweight. In the typical builds that we occupy in this country, we want to keep the ratio closer to 25. This helps us keep the lumbers shoring capabilities near their maximum strength. By multiplying the same 4" x 4" by the factor of 25 your length would be 87.5". For our purposes we use the length of 8 feet as a guideline for lateral bracing of our shoring systems. Of course, since each collapse situation will be unique unto itself, your main consideration in determining the LD ratio of your shores will be the amount of weight the shore will be supporting. As a rule of the thumb, no more than 50 to 1 and ideally roughly 25 to 1 will be the most efficient use of the shoring materials strength. INSERT TEXT BOX

1-5

## NAILS

Nails are classified according to their use and form. They are designated by the term "penny" which for our purposes is abbreviated by the letter "d." The term penny came from the market places of the 1400's, this was the price of 100 of a particular size nail. The term nowadays refers to the length of the nail regardless of the size of the wire gauge. Nails come in various sizes from 2d up to 60d, or from one inch in length to 6 inches in length. The most common type of nails we will encounter will be fabricated from steel wire. Nails should be at least three times as long as the thickness of the lumber it is support to be holding. Two thirds of the length of the nail should pass into the second piece of lumber. The nails can be driven at a slight angle towards each other to keep them from pulling apart and holding better. There are several types of nails in use today, finish, box, common, galvanized, threaded, ring

shanked, duplex, resin coated, to name a few. The one we will be using the most for rescue situations is the common nail, in training scenarios it is a good idea to use the duplex head nails, drive the nail to the first head and for ease of removal the second head stands up out of the wood and can easily be pulled by the use of crow bars, nail pullers or steel handle hammers. By using these nails the lumber is not as severely damaged as it is taken apart and can be reused several times making you training economically feasible. The nail sizes we will normally be using is 16d for nailing 2x4's and 4x4's together and 8d nails for the use in plywood gusset plates or toe nailing wedges, both of these nails normally will be the common type, unless for some reason an engineer specifies another type. Pneumatic nails for use in pneumatic powered nailers come either in strips or coils, depending on the type of nailer you will be using. Most of these nails come with a resin coating for better holding power, however one item that your rescue team should insist upon is the use of full head nails. Some of the nailers shoot nails with 1/2 or 3/4's of the nail head, in rescue situations you will want the nails to have their full heads for better holding power. Your team can decide which type of nails they wish to utilize.

### **Nail patterns**

In order to get the proper holding power with the use of these common nails certain nailing patterns are normally followed. The most important area that these patterns are needed is for the fastening of your plywood gusset plates and your 2x4 or 2x6 cleats. In the construction of raker shores, the nail patterns on these cleats and gussets are very important as it is the amount of nails that gives you the proper holding power. In the use of plywood gusset plates that are normally 3/4 inch thick, 8d nails are generally sufficient. In the 2x4 or 2x6 inch cleats used on the raker shore's 16d nails should be used, duplex or double header nails, as they are some times called can be used for training purposes. Theses' nails can easily be pulled out of the material with little damage, enabling your rescue team to utilize the

same lumber over again thereby making the hands on training more economically feasible. When utilizing a two foot cleat made of 2x4 you will need 16-16d nails, they can be staggered or nailed in a "five nail pattern" fashion which will give you 17 nails. When using a 2x4 cleat that is three feet long, for raker shore angles over 45 degrees, you will need 24-16d nails to have the proper holding power needed to hold the rake from sliding up the wall plate.

When using a two foot long 2x6 for a cleat on a 4x6 or 6x6 raker shore then your nail total will be 24-16d nails. They can be nailed in a staggered pattern of three rows. The number of nails in the same width cleat that is three feet long will be 36-16d, and it can be nailed utilizing the same pattern.

## WEDGES

The proper use of wedges is one of the more important factors that you must consider for a successful collapse rescue operation to occur. Wedges are normally used in pairs, when properly joined or "married" together they are excellent tools for filling gaps and transferring collapse loads. They are easily adjustable, and can be tightened just enough to transfer loads without lifting them. Moving unstable loads can have serious consequences in a collapse operation. It is imperative that all your personnel are properly trained with their correct usage, this may sound trivial, but it is extremely important. The use of wedges will be extensive in all types of shoring operations, interior, exterior, as well any type of void shoring and stabilization. A good wedge that will fit properly and "marries" together snugly is one in which the length of the wedge is only five to six times as long as its thickness. Wedges constructed with too sharp an angle will not hold properly and can easily slip out. The width of the wedges you will be using should be the same thickness as that of the materials you are working with. This will make for a much smoother operation, wedges that are too large will hinder the installation of any bracing and the use of smaller wedges may make the shore slightly unstable. Some of the more popular size wedges your team can construct and utilize

are: 2" high x 3 1/2" wide and 12" long, 1 1/2" high x 3 1/2" wide and 9" long, 1 1/2" high x 3 1/2" wide and 12" long, 3 1/2" high x 3 1/2" wide and 18" long, 3 1/2" high x 3 1/2" wide and 24" long, 3 1/2" high x 5 1/2" wide and 18" long. The wedges can be pre-made and carried on your apparatus or they can be cut in the field. Generally it is much better if you have a preset cache of wedges on hand. It will take time to cut the wedges to size, however it can be done with a little bit of effort. The lumber can be cut with a small chain saw with a sharp blade or a 10 1/4" circular saw, this size saw is necessary if you wish to cut a 2"x4" or 4"x4" in one pass. If you use a smaller diameter circular saw you will have to make two passes and many times your cuts will not line up, rendering your wedges almost useless as they will not fit together properly nor will they tighten up sufficiently to be effective.