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The Structural Evaluation of Existing Buildings

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Structural Evaluations of Existing Buildings

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One of the first questions I ask a client or owner when I become involved with the investigation of an existing building or structure is; are there any existing structural drawings available? The need for existing structural drawings as a part of the evaluation of an existing structure is obvious, however, the ease at which an existing structure can be analyzed in the absence of structural drawings varies depending on the nature of the system and the extent to which the structure is concealed or exposed, and accessible.

For instance, the analysis of an existing exposed structural steel building is a much easier task than a reinforced concrete structure simply because the steel members can be measured and their capacity quickly determined in the context of any historical material strength information that is readily available. With a reinforced concrete structure, although it is fairly easy to determine material strengths based on historical information and nondestructive testing, determining what the internal reinforcement is in order to facilitate the calculation of the member capacity can be a very difficult and challenging task.

Some of the options that I use to determine the capacity of reinforced concrete structures (and other similar internally reinforced systems such as one and two-way clay tile and unit masonry joist) in which no drawings are available have included:

1. Determine the building usage at the time of the initial construction, research the building code from the same time period, and establish the minimum live load required for the original intended use. Examples of older building code minimum loading requirements are tabulated below:

Minimum Building Code Live Load - PSF						
Building Type	**New York**	**Philadelphia**	**Boston**	**Chicago**	**Denver**	**San Francisco**
	1927	**1929**	**1926**	**1928**	**1927**	**1928**
Residential:	40	40	50	40	40 & 60	40
Hotels, Hospitals:	40	40	50	40	90	40
Office Buildings:						
First Floor	100	100	125	125	125	125
Upper Floors	60	60	60	40	70 & 90	40
Classrooms:	75	50	50	75	75	75
Public Seating:						
Fixed Seats	100	60	100	75	90	75
Without Fixed Seats	100	100	100	125	120	125
Garages:						
Public	120	100	150	100	150	100
Private	120	100	75	100	150	100
Warehouses:	120	150	125-250	125-250	200	125-250
Manufacturing:						
Heavy	120	200	250	250	250	250
Light	120	120	125	125	120	125
Stores:						
Wholesale	120	110	250	250	120	125
Retail	120	110	125	125	120	100
Sidewalks:	300	120	250	150	150	150

TABLE 1

2. Create small exploratory, demolished openings to expose the internal reinforcement at areas of the framing that are not susceptible to removal of small amounts of material. This approachused in conjunction with a Profometer (Pachometer) can sometimes enable the determination of existing reinforcing in large areas surrounding the exploratory opening.

   Exploratory demolition can also be utilized in many different situations in order to reveal hidden or concealed structural systems. For example, the photos below illustrate how a portion of a 2nd floor plaster partition wall was removed to reveal an existing story high structural steel transfer truss in order to measure the components of the framing as required for the analysis of the load carrying capacity of the truss over an existing assembly room. The photos were taken at the Scarborough Hall building, which was constructed in 1912, at Doane Academy in Burlington, New Jersey.

Figure 1

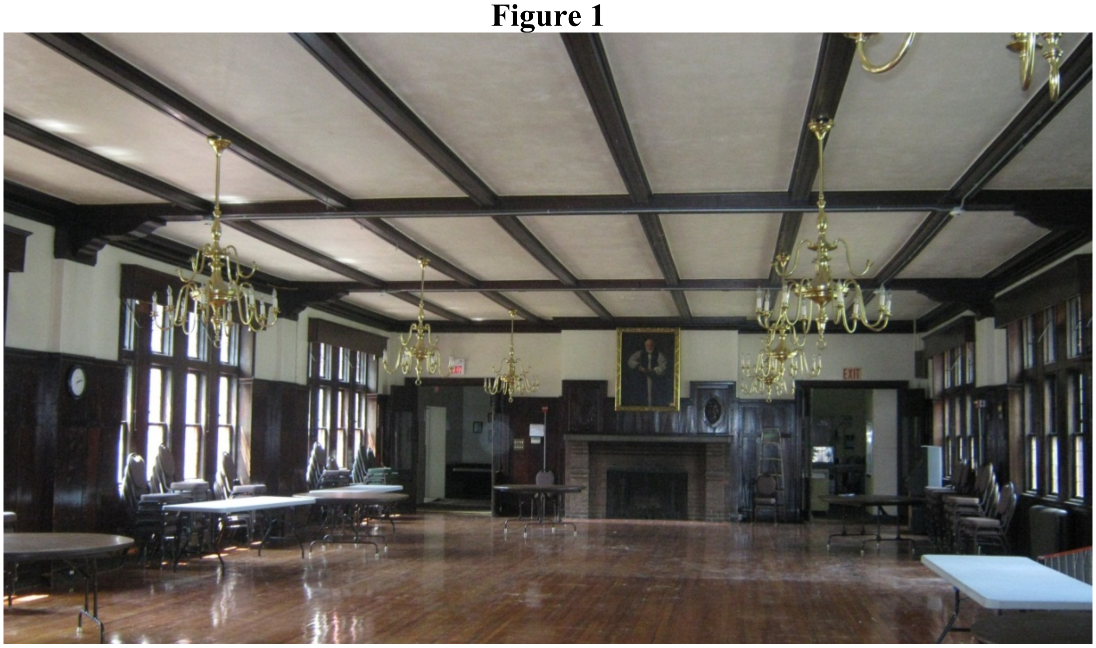
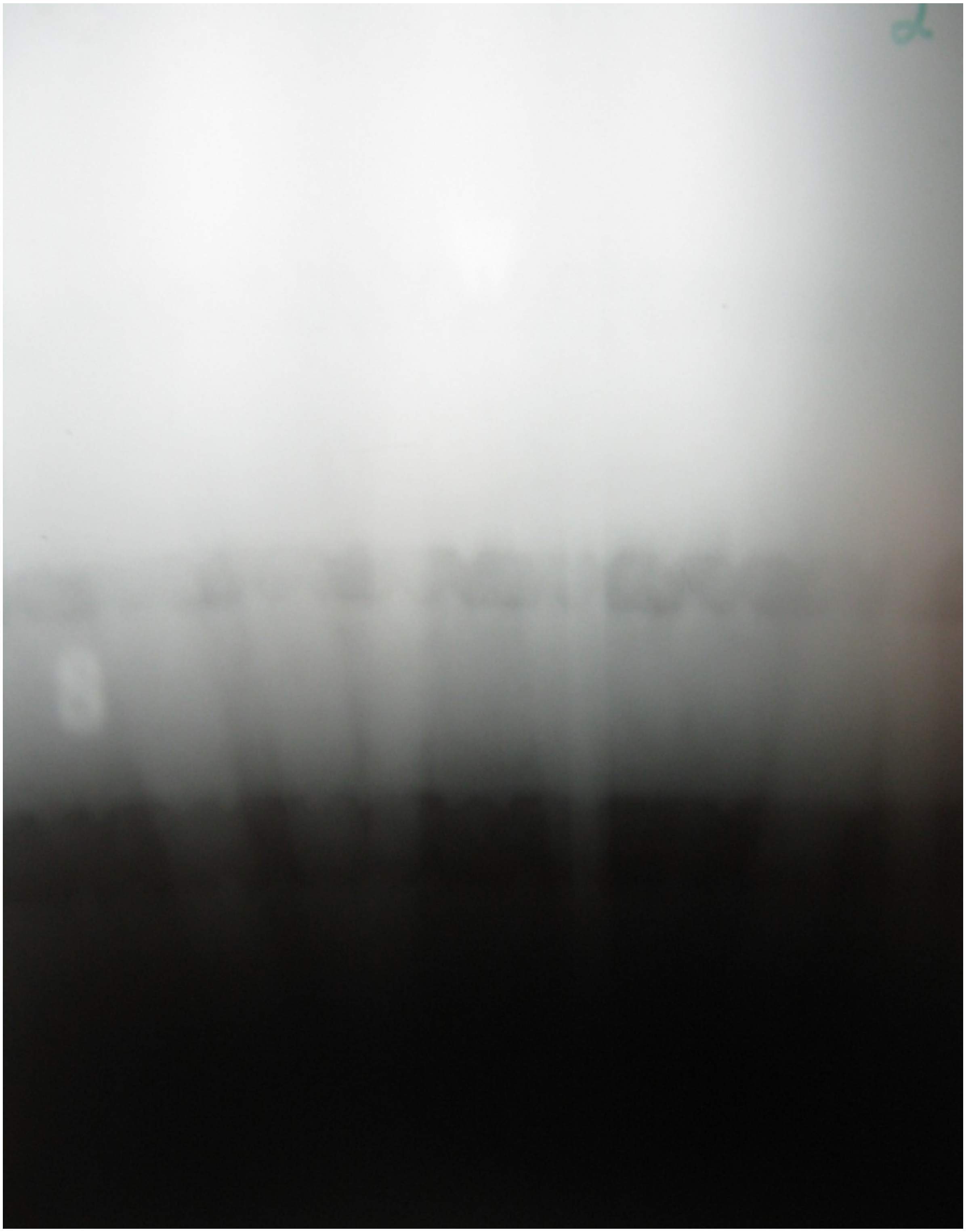


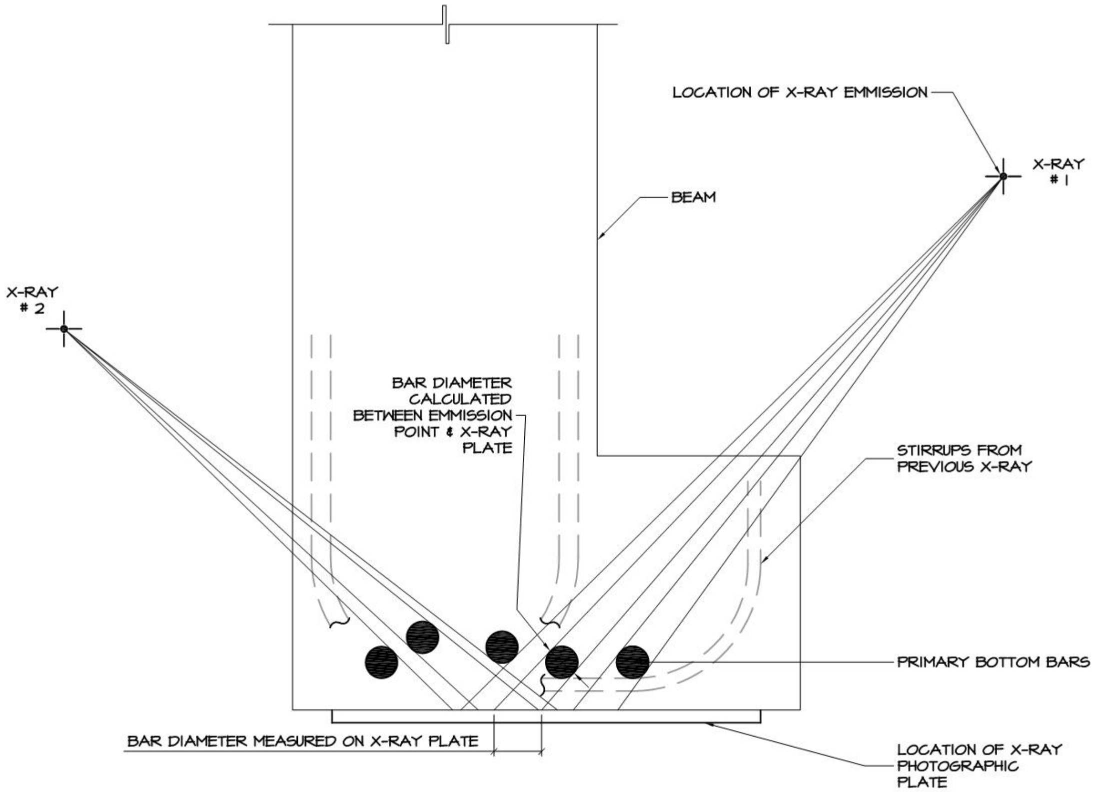
Figure 2

3. X-Ray the members in question to locate the size and spacing of the internal reinforcement. Recently, in the wake of the economic downturn, I have found X-Raying to be very economical with the daily cost to X-Ray (even during weekend hours) ranging from $2,500 to $3,000. The use of X-Rays to locate and determine internal reinforcement also requires a clear understanding of the projected shadow affect associated with the process, as opposed to the reflective nature of photography. An example of this process is illustrated in the following two X-Ray images and related diagram. The X-Rays were taken at the Northampton County Courthouse parking garage, which was constructed in 1975, in Easton, Pennsylvania.

X-Ray #1 of a Precast Ledger Beam

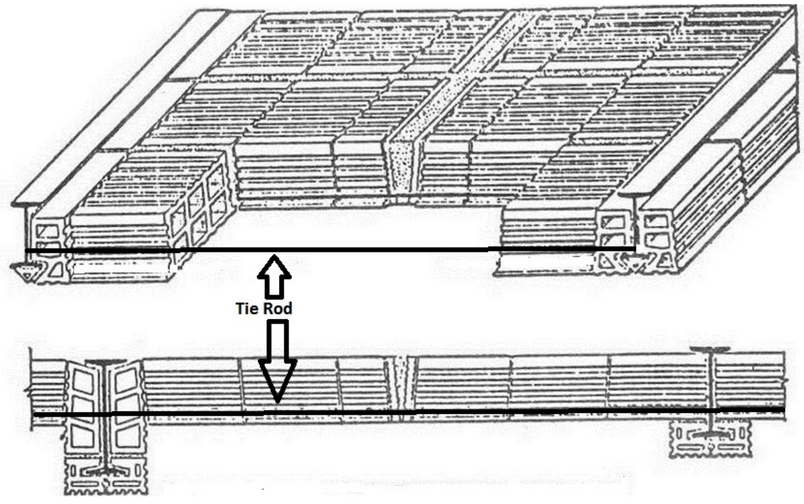


X-Ray #2 of a Precast Ledger Beam



Interpretation of X-Ray #1 & #2 at a Precast Ledger Beam

X-Rays of hollow clay tile, flat arches (in which the tie rods are not visible) are an invaluable tool for determining the load carrying capacity of this type of system because once the size and spacing of the rods are known the strength of the framing can be more accurately established. Because hollow clay tile, flat arches are very susceptible to damage as a result of exploratory demolition it is preferable to locate the tie rod spacing using non-destructive tools. However, since the tie rods are typically located more than 3 inches above the soffit or bottom of the tiles it is difficult to locate the steel rods using a Profometer. In addition, due to the significant amount of internal cavities associated with hollow clay tiles it is also difficult to locate the rods using GPR. The best method of locating the tie rods is therefore X-Rays. X-Rays can determine both the spacing and diameter of the rods without damaging any of the voussoir action of the tiles.

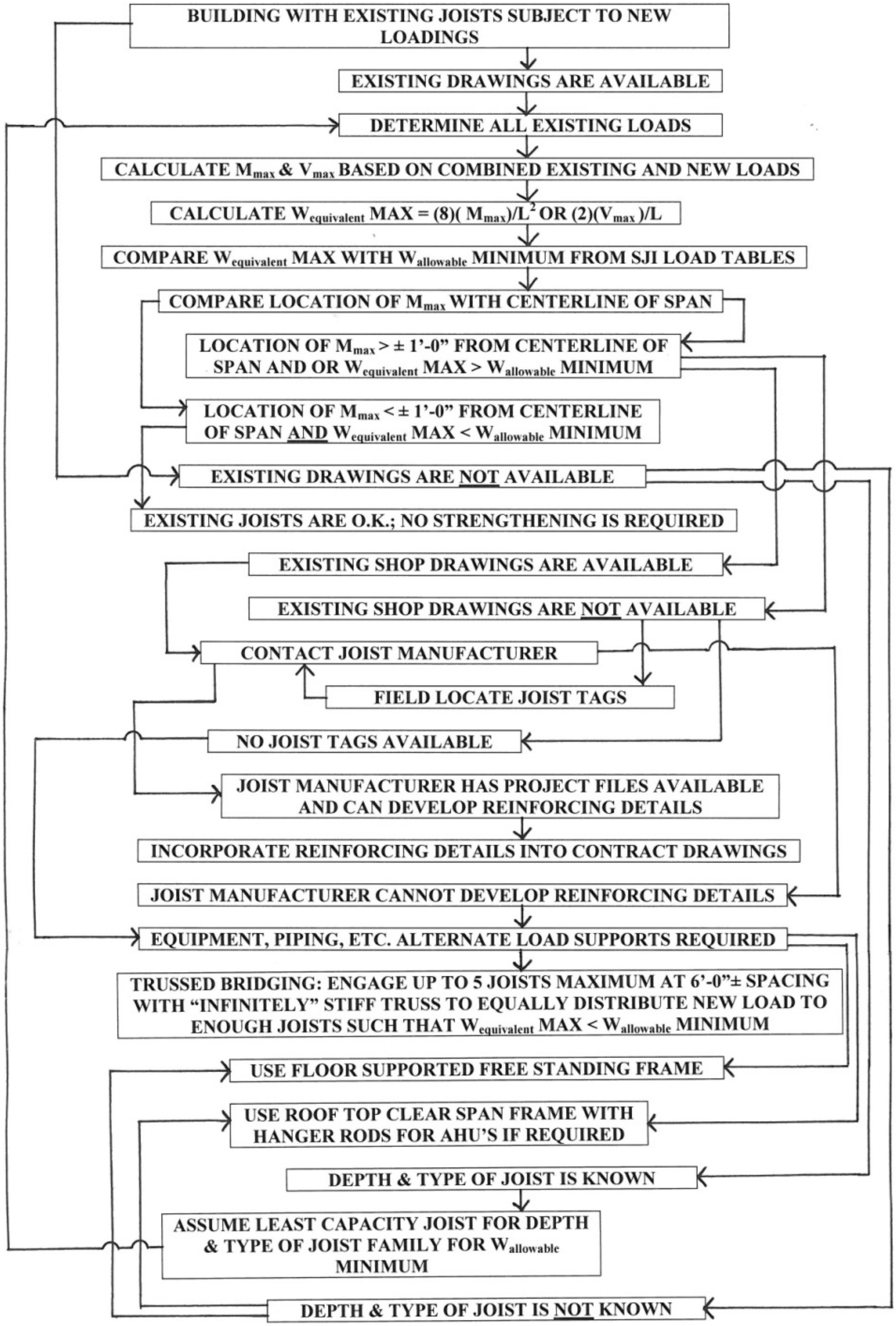


Hollow Clay Tile Flat Arch Construction

Another approach that I often hear suggested by some structural engineers for determining the load carrying capacity of a reinforced concrete, or other similarly internally reinforced structure, in which no drawings exist is to load test the framing. I find this approach to be problematic primarily because in the absence of any information on the actual capacity, strength or stiffness of any system it is impossible to establish what the factor of safety is or the appropriateness of the serviceability (i.e. deflection) results of any given load test. Therefore, I do not recommend the use of load testing unless you already know what the calculated design capacity is for the structure.

I am also often contacted by other structural engineers trying to track down historical load tables for precast or other similar concrete, clay tile or unit masonry proprietary systems in hopes of determining the capacity of an existing framing system. In this situation, even if I do have copies of the load tables for the desired system, I remind the engineer that unless there are specific mark numbers on the product in the field that clearly identify the member in relationship to the load table, it is not advisable to establish load capacities of an existing structure using historical load table data.

In the case of open web steel bar joists it is somewhat more practical to take the approach of relying on load tables because of the wealth of historical information available through the Steel Joist Institute (SJI)and the ability of an engineer to field measure the actual joist components, and in turn analyze the member as simple trusses in order to confirm that load table capacity. However, it is still difficult to often determine the type of joist that one is dealing with in any given building in the absence of drawings so I developed the flow chart provided below as a guide when dealing with existing open web steel joists.



Flow Chart for the Investigation of Open Web Steel Joists

Wood buildings are similar to structural steel building in that the members, if exposed and readily accessible, can easily be measured in the field to facilitate the analysis of the individual members to determine load carrying capacities. Unfortunately, it can be difficult to establish the appropriate allowable stress of the existing wood that should be assumed for the structural analysis. To solve this dilemma I take small pieces (no larger than a toothpick) of the timber framing and send the samples to Dr. J. Thomas Quirk in order to determine the species of the wood. Once the species is determined, along with the age of the building, it is possible to easily determine reasonable allowable stresses from historical resources. Dr. Quirk charges only $30 per sample and can be contacted at:

117 N. Franklin Ave.
Madison, WI 53705
608-238-2225
tandbquirk@aol.com

In older structures it is common to encounter a situation in which the superstructure is constructed with steel but the members have been encased in concrete for fire protection. An example of this type of condition is illustrated in the photo below. This particular photo was taken at the National State Bank Building in Newark, New Jersey, which was constructed in 1912. The photo reveals an exposed steel column only, which was protected by hollow clay tile blocks that have been removed, while the steel beam framing above is still encased in concrete.

Figure 3

The existing concrete encasement made it impossible to measure the steel framing, however, the need to perform exploratory demolition at this structure was avoided because existing drawings were found as a part of the due diligence effort that was associated with locating documents for the building. For this building I was able to determine through historical records that the architect was Cass Gilbert. Cass Gilbert also designed the famous building Woolworth Building located in New York City. As a result, I was further able to determine that the New York Historical Society had archived drawings for a number of different buildings designed by Gilbert, including the National State Bank Building.

Figure 4

The existing drawings for this building consisted of linen sheets that had been folded for storage into a number of different boxes. Because the Historical Society would not let mere move the drawings to have them scanned to create electronic copies, it became necessary to photograph each sheet after it was spread out on a table in order to be able to document the information for future use. This was accomplished by first photographing the each entire drawing and then taking additional close up photos of portions of each sheet, as illustrated below.

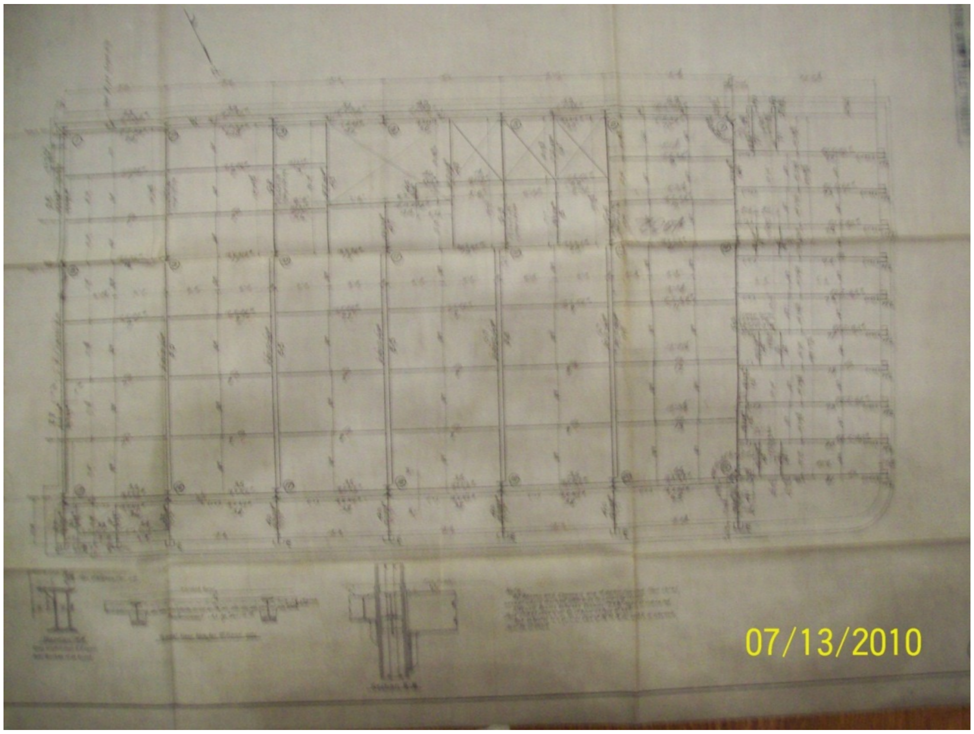


Figure 5

Figure 6

This project serves as a good example of how an engineer should take the time to track down any lead they may have in order to locate existing drawings. A thorough search should involve any and all means possible to try and locate drawings including rummaging through any documents that may have been left in the building itself, and a search of the local building department archives. In addition, if the building is of historical significance a search of the Historic American Building Survey and Engineering Recordonline archives at the Library of Congress is also recommended.

http://memory.loc.gov/ammem/collections/habs_haer/index.html

If you do have access to the existing drawings it is also recommended that a thorough site visit be conducted in order to confirm that the as-built conditions agree with the drawings. This approach is recommended because more often than not, it is common to encounter as-built conditions that are different from that shown on any existing structural drawings.

In closing I would like to state that structural engineers involved with renovation and rehabilitation projects need to be aware of and educate themselves concerning the specifics of the existing framing system so that most unobtrusive and non-destructive solutions can be developed as a part of an adaptive reuse project. This is particularly true if an antiquated structural system encountered. This approach enables the project to be more economically viable because of the resulting limitation of the extent of structural costs associated with a typical renovation project. In other words, without any knowledge of an existing structural system it is still possible to develop a structural solution, however, this approach will always be much more intrusive, and therefore more costly, than if the engineer has a sound understanding of the system involved.