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Mill Architecture in Paterson, NJ: A Culmination of the Empirical Tradition in Construction

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The mill district along the banks of the Passaic River in Paterson, N.J. was originally envisioned by Alexander Hamilton. It was his wish to make the newly formed United States industrially self-sufficient and the location at the Great Falls of the Passaic was, as a result of its water power potential, an ideal spot for a large manufacturing district (*The Hamilton Papers* XI: 101). After a slow start owing to a variety of economic difficulties, Paterson's industrial district grew and flourished, mutating and adapting to changes in the country's material needs and advances in its technology.

The mills in Paterson were built for utility, not for beauty. Most of the buildings are plain, with little extraneous detail. Form and structure are generally conservative and repetitive. In common with the structures of other industrial areas of the eastern U.S., the buildings are mostly of the type known as "slow-burning mill construction." The main characteristic of slow-burning construction is the use of heavy masonry-bearing walls to support heavy timber floor and roof structure.

Mill construction in Paterson is a specialized adaptation of heavy timber construction and is one culmination of a long tradition of construction in wood. The use of heavy timber trusses was known in ancient times. The exact origin of heavy timber construction has not yet been established, but the timber truss was known to and used by the Romans. Palladio recounts the use of timber trusses, particularly in bridge construction. He is unable to identify the origin of the timber truss, but he does say that the bridge across the Tiber so valiantly defended by Horatio was a timber truss bridge. The exact form of Horatio's bridge is unknown, but Palladio describes it as being constructed of many small members of wood joined without use of metal. They were arranged in such a fashion that individual pieces could be removed and repaired or replaced without disturbing the stability of the whole (Palladio n.d.: 63).

The Romans used timber truss bridges to advance their military conquests. Such bridges could be assembled quickly from materials found at hand, yet were strong enough to bear the weight of the advancing legions. Knowledge of the timber truss was thus spread to the farthest reaches of the Roman Empire. Romans used the timber truss to roof large buildings as well. Roof trusses eliminated the need for interior columns or bearing walls.

The Roman tradition of timber truss construction influenced the British, who in turn developed their own distinctive types and uses for the truss. Two of the simplest and most utilitarian types developed in Britain were the king-post and queen-post trusses. The king-post truss is triangular, with one large vertical central king-post and two smaller oblique struts. The queen-post truss is similar, but has two vertical queen-posts, set at equal distance from the apex of the truss, and smaller oblique struts. Both types were used for bridge as well as building construction (Tredgold 1880: 146, Fig. 24).

An important innovation in the art of constructing timber trusses was the introduction of the use of wrought-iron tension members. Wood is weaker in tension than in compression. A tension splice is difficult to fashion, and any splice further weakens the tension member. Thus, the tension members in a timber truss should be of large, solid pieces of timber. As England depleted her timber supply, it must havê been more difficult to obtain heavy timber pieces of sufficient size and length for tension members. It seems likely that wrought iron, a material strong in tension, was substituted. I have not been able to determine precisely when the substitution was first tried, but Thomas Tredgold's treatises on carpentry and joinery written in the early

1800's show the use of iron tension members. (See Fig. 7-1.)

By the early 19th century, America had become the leader in heavy timber construction. Britain's timber resources had been depleted, and her builders and engineers had turned to working with iron. America's timber resources were seemingly endless, and the British timber building tradition took root and flourished. American millwrights adapted the wooden truss to their needs and applied it, producing a version both spare and utilitarian.

Timber truss construction coupled with masonry-bearing walls is an empirical tradition--i.e., the forms and sizes were derived from years of practical experience rather than from scientific calculations and design. Paterson's mill buildings were constructed by craftsmen who depended upon previously established forms that had proved both practical and economical. Millwrights were not interested in innovative design or the application of new theories of scientific calculation. They wanted to turn out the most usable building possible with the most easily obtained materials at the lowest possible cost. Changes of any sort, scientifically determined or not, were not incorporated until practical application had proved their utility. The application of the science of strength of materials, or the preconstruction use of mathematical formulas derived from controlled experiments to calculate the size and type of structural members needed, developed much later than the empirical building tradition.

Interest in theoretical work in strength of materials revived in Europe during the Renaissance. Da Vinci's experiments and writings on mechanics were a first step. Galileo carried Da Vinci's experiments further, and in his treatise entitled *Two New Sciences*, he laid the groundwork for the modern theory of strength of materials (Timoshenko 1953: 7-17).

In northern Europe, the French led in establishing scientific methods for calculating the size of structural members. The first book on the application of the theory of strength of materials to architectural problems was written by P.S. Girard and published in Paris in 1791. Earlier, in 1773, Charles de Coulomb had developed a method of calculating stresses by resolving them into their respective vertical and horizontal components (Timoshenko 1953: 41-67).

In England, the empirical tradition continued, with little emphasis being placed on either the development of theory or the application of theory developed by others. In the early 1800's, Thomas Tredgold did perform a series of experiments on the relative strengths of different species and sizes of wood members. From his experimental results, he then drew up tables for carpenters' use in sizing timber members. Tredgold's work did not cover any new theoretical ground, but it did reduce scientific theory into practical rules for the use of the craftsman. It was not until the increased use of iron as a structural material necessitated the establishment of more precise standards that the British moved into the field of development of scientific theory (Timoshenko 1953: 98-128).

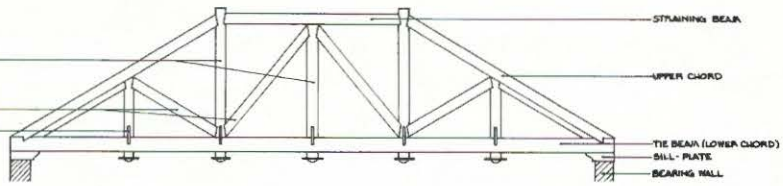
The Americans, in continuing and improving upon the British mode of heavy timber construction, also continued the empirical tradition. Mill buildings such as those in Paterson were not designed, they were built. The utilization of an architect or engineer to design a building using scientific calculations was a concept that was not widely accepted in America until the late 19th century.

Most of the mills in what is now the S.U.M./Great Falls National Historic District of Paterson are of slow-burning mill construction, a system developed to fulfill two conditions. First, the use of heavy timber structural members with masonry-bearing walls was the continuation of a well-established building type that offered the greatest utility for the least construction cost. Second, it became recognized over the years that this type of construction offered the best defense against fire.

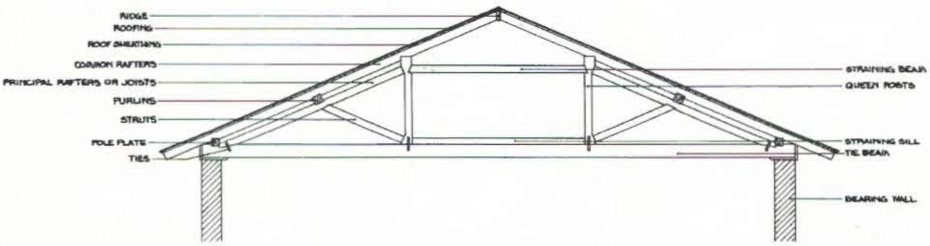
Slow-burning mill construction does not pretend to be fireproof. It is comparatively fire-resistant, in that any fire that does get a start is considerably retarded in its spread by the slow-burning properties of heavy timber and the use of several deliberate structural details for the purpose of containment. Slow-burning mill construction is also designed in such a way that should a disabling fire occur, the structure could be rebuilt in the quickest and least costly manner (Tyrrell 1911: 158-200).

In 1885, Charles J. Hexamer delivered three lectures before the Franklin Institute on fire protection for mill buildings. The second lecture dealt specifically with mill architecture and outlined the salient features of slow-burning mill

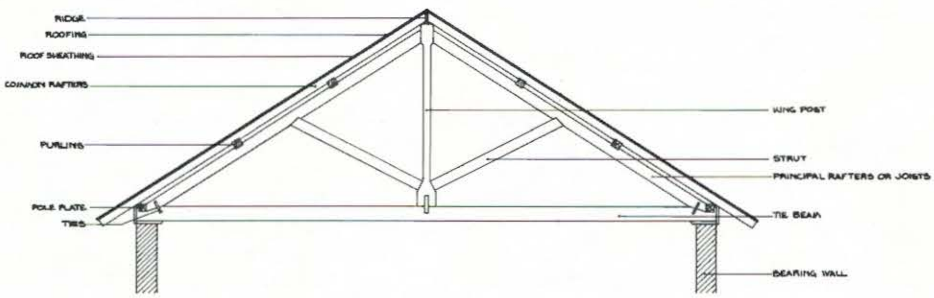
Figure 7-1. Evolution of the timber truss. *(Courtesy H.A.E.R., Toni Ristau, Delineator, 1974.)*



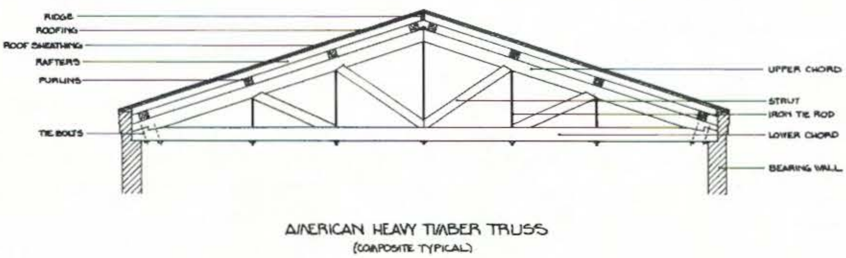
ROMAN TIMBER TRUSS
(AFTER PALLADIO)



BRITISH QUEEN POST TIMBER TRUSS
(AFTER TREDGOLD)



BRITISH KING POST TIMBER TRUSS
(AFTER TREDGOLD)



AMERICAN HEAVY TIMBER TRUSS
(COMPOSITE TYPICAL)

EVOLUTION OF THE TIMBER TRUSS

DRAWN BY: TONI RISTAU · 1974

UNDER DIRECTION OF THE NATIONAL PARK SERVICE, UNITED STATES DEPARTMENT OF THE INTERIOR

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construction. The features of this type of construction are as follows (Hexamer 1885: 27-37):

1. The building is divided into areas that would contain a fire and prevent its spread throughout the entire building (generally accomplished by breaking the building into discrete areas by stories or by party walls).

2. Elevator and stair towers are placed outside the main building and heavy fire doors are installed so such towers may be closed off in case of fire.

3. The power source or belting is arranged in such a way that as few as possible breaks are made from one floor to another or from one contained area to another.

4. Floors are constructed in such a manner to offer the least possible chance of fire taking hold. In buildings with little vibration, brick arches sprung between iron I-beams are the safest. When this type of construction is not feasible, a recommended floor type is two layers of planks to a total of 3 in., a layer of concrete, and a layer of tongue-and-groove flooring. The floors of each contained area should have sills at openings that are raised 1 in. above floor level so that the floor can be flooded with water in case of fire.

5. Use of applied ceilings is avoided. Such ceilings can trap and funnel fire from one area to another and can prevent the playing of water directly upon a fire. If an applied ceiling is used, a direct-applied iron lining that leaves no hollows is best. The application of asbestos paint or plaster offers some fire protection, as does whitewash when applied to exposed surfaces. Ammonium sulphate soaks for timber also afford some fire protection.

6. Girders should be of solid, one-piece construction whenever possible. If splicing is necessary, the splice should be close and tight, without hollows.

7. Girders and beams should bear only a short distance into the wall. They should be beveled (fire-cut). They should not be anchored through the wall, as the leverage resulting from beams burning through and falling can tumble the bearing walls inward.

8. Walls should be of brick, as it is more heat-resistant than most types of stone. Brick arched window and door heads are preferable to stone, timber, or metal lintels, all of which can be affected by fire and cause an otherwise sturdy wall to tumble.

9. Cornices should be constructed of solid brick or terra-cotta, since hollow cornices and wooden boxed or metal cornices can act as flues in conducting flame from one part of the building to another.

10. Columns should preferably be of hardwood, not tapered, bored at top and bottom to prevent dry rot, and covered with sheet metal or other protective substance. Exposed cast-iron columns are not good, as they lose structural strength with small temperature rises, and they tend to disintegrate if water is poured upon them when they are heated. Protected iron is a better solution; columns can be covered with plaster, terra-cotta, or wood.

11. The roof should be constructed of 3-in. plank. No hollow spaces should be left in the roof construction. The interior of the roof should be protected with sheet metal, asbestos plaster, or wire netting and plaster applied directly to the members. Various types of composition roofs are available and are best for fire protection. Slate makes a poor roofing material as it is quite heavy and disintegrates easily in heat.

12. Floor boards should not be continuous across sills. Sills should be made of iron or of wood sheathed in iron, and they should not communicate through from level to the next. Door jambs should be metal or metal-clad; there should be no exposed wood. The best fire door is of metal-clad wood, braced. Metal alone warps so much with heat as to be ineffective as a fire barrier. Doors must close tightly and be kept closed, or they should be equipped with a fusible-solder holding device and counterweighted so they will swing shut in case of rise in temperature. Sliding doors should be on an inclined track with stop-blocks so that they will slide shut in such a manner to close off the opening completely. They can also be equipped with a fusible-solder holding device that lets them slide shut should the temperature rise sufficiently to be of danger.

13. Other openings, such as power belting openings, should be enclosed or isolated to prevent transmission of fire from one contained area to another. If this is not practical, cha-

ses should be equipped with an alarm system.

14. The exterior of the building should be equipped with heavy metal-clad fire shutters if it is close enough to other buildings that could either transmit flames or receive them. The shutters should be hung and fastened in such a manner that they can be closed from outside the building, as it is too much to expect that employees will stay in a burning building to close windows and shutters.

15. In the case of textile mills, where there are quantities of lint and fly which may be combustible, the building should be designed to allow the best ventilation possible, and combustible material should not be allowed to collect in sufficient quantities to be a fire hazard.

In the late 1800's, the installation of sprinkler systems in mill buildings was becoming common. The fire insurance rating is more favorable for a sprinkled building than for a nonsprinkled one.

Although few, if any, of Paterson's mill buildings combine all the features of slow-burning construction as outlined by Hexamer, most do contain a good many. Most of the buildings have been the victims of damaging fires at least once, and much of the structure that one sees today in the buildings is not original. However, such rebuilding is a testimony to to the practicality of this type of construction.

We were unfortunate enough to receive a demonstration of the fire-resistant qualities of slow-burning construction during the summer of 1974 when the remaining portion of the old Cooke Locomotive Works burned. When the fire was extinguished, all the walls and a major portion of the structural system were still standing. The building was later demolished, but it could have been rebuilt. As bulldozers moved across the yard to raze the remains, they traveled on the wooden first floor structure. It did not collapse.

Within the Historic District, there is also a good (or bad, depending on your point of view) example of the superiority of slow-burning timber over iron or steel construction. Contrary to one's instincts, unprotected steel or iron is not very fireproof. Unlike wood, it is not consumed by flame, but it is affected by heat. A rise in temperature can cause enough warping to precipitate structural failure.

The structural system of the Rogers Locomotive Works fitting shop (west side of Spruce Street between Market and Oliver Streets) consists in built-up sections of iron forming girders and columns. The building is grossly overstructured; the structural members are of a size more suitable for bridges than for buildings. Evidently the builder was cautious in the use of an unfamiliar material, and with good reason; seven years after the construction of the fitting shop, in 1888, a fire occurred on the third floor of the building with disastrous results (Fries 1974). The huge girders are twisted as if giant hands had tried to wring them out. Rivets were popped loose and hang uselessly from the girders. Some of the girders show signs of buckling failure. Fortunately, the fire was contained in the north end of the building on the third and loft floors; had it been more widespread, there surely would have been a total collapse. The damaged loft story was never replaced, as the girders designed to support it were no longer structurally sound. The entire structure was reinforced by the addition of intermediate iron beams and timber girders. A new wooden hipped roof replaced the old roof and monitor; the new roof does not depend on the iron structural system for support, but is supported by the bearing walls. A fire of such relatively small scope would not cause comparable damage in a building of slow-burning construction.

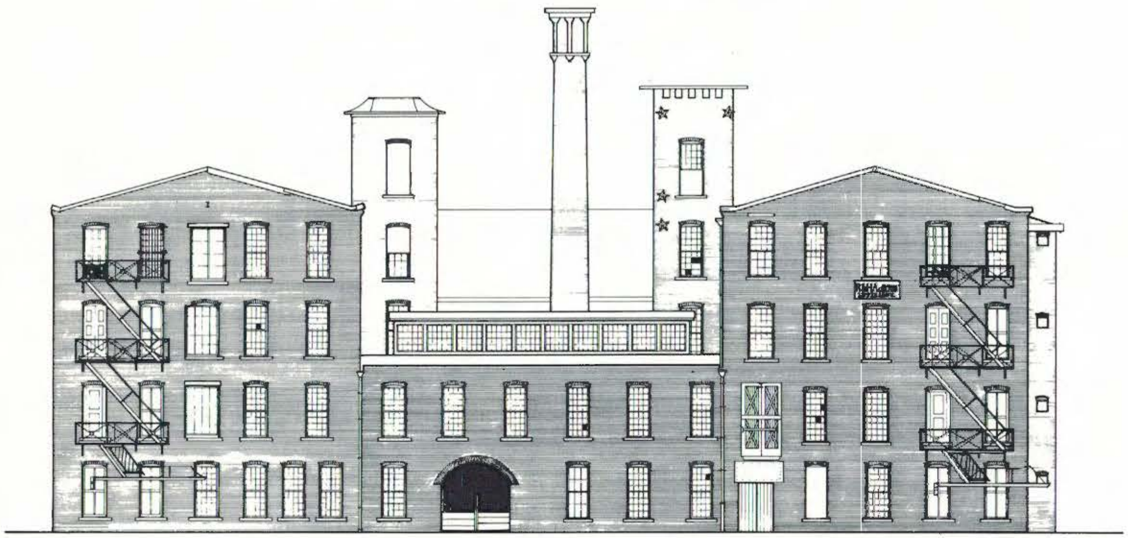
Very little has been written on the evolution of structural types in Paterson itself. As mentioned previously, mill building was a craft, an outgrowth of empirical tradition. In Paterson, the services of an architect or engineer were not employed and the mills were built by millwrights; however, although the buildings were fashioned in a response to a functional rather than an aesthetic tradition, they do not lack aesthetic appeal. Most of what appears to be decorative detail at first glance has a functional purpose. "Form follows function" was in use for many years before it became an architectural catchphrase in the 20th century.

For example, the nicely corbeled brick cornices that enhance most of the buildings in the Historic District were not applied for aesthetic reasons only. The corbeling "stepped" the wall out to a degree sufficient to provide bearing for the heavy timber roof trusses and at the same time protected the wall from fire and weathering. It also provided convenient mooring for the roofing material, flashing, and gutters.

The brick (or in some cases stone) arched openings are not just an architec-

ESSEX MILL

PATERSON, NEW JERSEY



EAST ELEVATION

OCCUPYING THE SITE THAT WAS FIRST TO BE LEASED FROM THE SOCIETY FOR THE ESTABLISHMENT OF USEFUL MANUFACTURES, THE ESSEX MILL BUILDINGS CONTAIN ELEMENTS THAT CAN BE TRACED BACK TO 1804. THE FIRST STRUCTURE ON THE SITE WAS THE "OLD YELLOW MILL", A TWO STORY, SANDSTONE BUILDING APPROXIMATELY 60' BY 90', NOTEABLE FOR THE FACT THAT ITS FIRST TENANT, CHARLES KINSEY, CONDUCTED ONE OF THE EARLIEST ATTEMPTS TO MANUFACTURE PAPER USING A CONTINUOUS SHEET PROCESS.

THE BUILDING WAS DEMOLISHED MID-CENTURY THOUGH THE FOUNDATIONS WERE USED IN THE CONSTRUCTION OF THE EXISTING BACK BUILDING, A THREE STORY STRUCTURE LARGELY OF BRICK THAT WAS ERECTED PROBABLY IN 1856.

THE TWO MAJOR WINGS OF THE ESSEX MILL DATE FROM THE EARLY 1870S, WHEN ROBERT AND HENRY ADAMS PURCHASED THE SITE FROM THE PASSAIC MANUFACTURING COMPANY AND ENLARGED AND MODERNIZED IT. THE MILL, WITH A TOTAL AREA OF ALMOST 30,000 SQUARE FEET, WAS USED FOR THE PRODUCTION OF MOSQUITO NETTING.

AS IN THE CASE OF MANY OF THE MILLS IN THE HISTORIC DISTRICT OF PATERSON, THE ESSEX MILL HAS BEEN OCCUPIED BY NUMEROUS BUSINESSES AND USED FOR A VARIETY OF PURPOSES OVER THE YEARS. AS LATE AS 1969 THERE WAS AN OPERATING SILK WEAVING OPERATION IN THE MILL THAT USED MACHINERY FROM THE 1920S. THE MACHINERY, POWER SHAFTS, BELT DRIVE AND PULLEY SYSTEM WERE IN SITU AT THE TIME OF THIS SURVEY.

HISTORIC AMERICAN ENGINEERING RECORD
HAER
ESSEX MILL 1856, 1871-72
WEST SIDE OF MILL STREET BETWEEN ELLISON AND VAN HOUTEN STREETS
PASSAIC COUNTY
NEW JERSEY
PATERSON
OFFICE OF ARCHEOLOGY AND HISTORIC PRESERVATION
GREAT FALLS/SUM SURVEY
UNDER DIRECTION OF THE NATIONAL PARK SERVICE, UNITED STATES DEPARTMENT OF THE INTERIOR

tural nicety; they are also structural. An arched opening does not require a lintel to bear the weight of the wall above. The arched head is self-supporting and is also fireproof--a problem with metal or wooden lintels.

The large iron stars seen on many of the buildings are not only decorative; they are the bearing plates for iron ties passing through the walls anchoring the ends of beams or trusses. Cast-iron door and window frames are not only attractive; they also contribute to the fire-resistant qualities of the building. (See Fig. 7-2.)

The Essex Mill (at the corner of Mill and Van Houten Streets on the west side of Mill Street) is typical of the Paterson mills in its varied history and the consequent evolution of its physical appearance. I am indebted to George Cole, H.A.E.R. historian on the 1974 summer survey team, for his research on the history of the Essex Mill building, and I have depended heavily on his information herein.

The Essex Mill lot was the first to be leased to outside entrepeneurs by the S.U.M. rather than being developed by the Society itself. The first building on the lot was a paper mill, evidently completed by *ca.* 1804, known as the Old Yellow Mill. Probably constructed of New Jersey brownstone, it was located on the back of the lot, near the headrace. Apparently the mill was rebuilt and enlarged by John Colt in 1856; the back portion of the existing mill complex dates from this period. The enlarged building was constructed of brick and utilized the remains of the old brownstone mill in its foundation and portions of the first floor. The front wings were added *ca.* 1871-72. There is no evidence of serious fire in the rear portion of the building after the 1850's, so it seems likely that the timber truss in that portion of the building dates from the 1856 expansion.

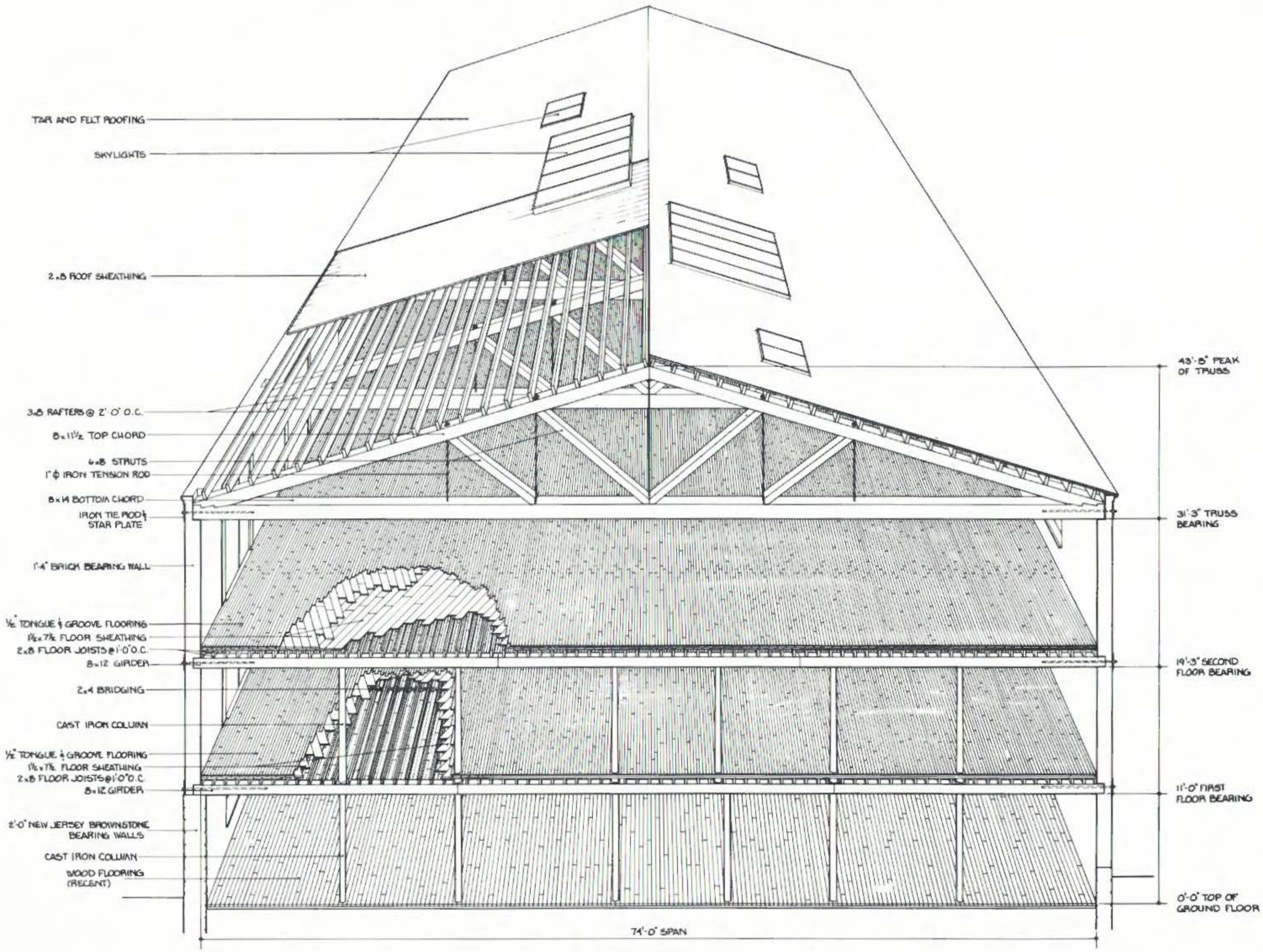
I chose this particular mill building as an example of Paterson mill construction for two reasons: the Essex Mill has undergone the adding, subtracting, remodeling, and rearranging so typical of the buildings in the mill district; the timber and wrought-iron truss supporting the roof of the rear portion of the complex is impressive. This truss spans 74 ft., without intermediate columns, and bears on the walls. The bottom chord timbers are 8 by 14 in. squared and span the full 74 ft. without splicing. The entire complex is of typical slow-burning mill construction as described previously--heavy exposed timber floor beams, timber truss, and brick bearing walls. Stair towers were added later, and the rear portion has exterior stairs only. The boiler house and chimney are both separate. (See Fig. 7-3.)

Figure 7-2. East elevation of the Essex Mill. *(Courtesy H.A.E.R., Toni Ristau, Delineator, 1974.)*

The timber truss supporting the roof of the rear portion of the complex is quite typical of truss construction in the District, although it is larger than most. It consists in a heavy timber lower chord (8 by 14 in.), slightly lighter upper chords (8 by 11½ in.), wood struts (6 by 8 in.), and wrought-iron tie rods (1-in. diameter). This type of truss evolved directly from the British timber truss, and it is sometimes referred to in literature of the period as the "English truss." Its designer is unknown, but he probably used empirical knowledge and rule-of-thumb know-how, not scientific calculations. Some of the trusses demonstrate this empirical process; owing to heavier loads brought to bear by a hoist-beam, some of the trusses show signs of shear failure at the wall. The problem was solved by bolting 3 by 14-in. wood plates to the lower chord where evidence of shear failure was most apparent, and without replacement or extensive rebuilding of the truss.

The trusses are placed from 9 ft. 6 in. to 10 ft. 6 in. on center, and bear on the 1 ft. 4 in.-thick brick walls. The lower chords of the truss are bolted through the wall (as are the beams on lower levels) with tie rods and the characteristic star-shaped plates. This, however, is a poor practice from a fireproofing standpoint, and was discontinued in later construction.

The roof consists in purlins laid 2 ft. 0 in. on center perpendicular to the top chords of the truss, with 2 by 8-in. sheathing laid perpendicular to the purlins to form the roof. The exact composition of the roofing material is unknown, but it appears to have been tar over some type of roofing paper or felt. Skylights are incorporated into the roof between the trusses. Inasmuch as these are irregularly placed and sized, and as the uppermost floor is already lighted and ventilated by windows, they may have been added at a later date. There is evidence that there may have been a partial or full loft story supported by the trusses at one time; the skylights probably were added to furnish light and ventilation to the



SECTIONAL PERSPECTIVE
ESSEX MILL - 1856 ADDITION

DRAWN BY: TONI RISTAU, 1974

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NAME AND LOCATION OF STRUCTURE
ESSEX MILL 1856, 1871-72
WEST SIDE OF MILL STREET BETWEEN ELLISON AND VAN HOUTEN STREETS
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loft area. The combined effect of the windows and skylights and large clear span is one of lightness and airiness, making the top floor a pleasant open space. The present building tenant utilizes it as a winding shop, for which it is well suited.

The construction of the lower floors is also typical for the District. Except in the portion of the building that is brownstone, the walls are of brick and the openings are arched. In the brownstone section, the openings are square headed and have stone lintels. Brownstone window and door sills are used on the exterior throughout. The structural system of the lower floors is post-and-beam, with cast-iron columns and heavy timber beams. The beams are spliced in a variety of ways throughout the building. Floors are laid on 2 by 8-in. floor joists spaced approximately 1 ft. 0 in. on center, with 2 by 4-in. bridging. Floors are of at least two layers of 1½-in. planking and one layer of smaller tongue-and-groove finish flooring. There is an applied tongue-and-groove wood ceiling in portions of the building, which is poor practice for fire prevention. The interior spaces have largely been left open and clear, with some partitioning in parts of the building to form smaller offices and work areas. The interior has been whitewashed or painted, including the cast-iron columns, in most cases.

The evolution of the Essex Mill building can be viewed by walking through the complex. Since this is a utilitarian building, little attempt was made to conceal or smooth over connections and changes. The structure is still in use today, having undergone several metamorphoses in its history: from paper mill to cotton mill to silk mill to warehouse and winding shop; and from water power to steam power to electrical power. The Essex Mill has grown and changed to accommodate its users.

Mill buildings in the Historic District have been remodeled, added to, and partitioned many, many times. Although purists may bewail the fact that the buildings are thus no longer unadulterated architectural forms, I maintain that such emphasis on adaptability and continuous use is healthy. These buildings were built to be used, and they *were* used--in most cases for a variety of industries over many years. Those who are interested in establishing precedents for adaptive reuse would do well to study the evolution of the buildings in Paterson.

Figure 7-3. Perspective cutaway, Essex Mill 1856 addition. *(Courtesy H.A.E.R., Toni Ristau, Delineator, 1974.)*

Paterson's mill district, as an example of an empirical building tradition no longer in use, is a resource as precious as a lode of minerals, and one that should be developed as carefully. For in the same way that mineral resources are finite and irreplaceable, so are the building tradition resources in Paterson.

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