D E N N I S K O W A L A R C H I T E C T S
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25 April 2014

Zion Lutheran Church
215 Elm Avenue
Rahway, NJ 07065
C/O Pastor Carmine Pernini

Re: Zion Lutheran Church # 1407
Written Report and Recommendations

The original Church (this reference shall apply to the worship building only) located at the corner of Elm Avenue and Esterbrook Avenue in Rahway, New Jersey is a masonry wall and wood-truss roof structure building designed in 1951 by Water C. Pfeiffer Architects of Elizabeth, New Jersey. The outside plan dimensions are 87'-8" long by 34'-0" wide on two levels with a mezzanine. There appear to be no major changes to the structure since the original design. If anything, the roof load should be lighter since the original slate shingle roof has been recently replaced with a much lighter weight Fiberglass slate-look shingle roof. This report shall examine the causes of the interior cracks in the plaster finish inside the worship space.

HISTORY

The Zion Lutheran Church (ZLC) is currently in use and no major changes have occurred in the type of activities or the building systems of construction. Renovations are currently planned for the Church and it was the proposed contractor who alerted the Church to the importance of knowing the cause of cracks in the plaster walls and ceilings. The Congregants had previously believed the cracks to simply be a cosmetic nuisance. No construction, exploratory work, or testing for the proposed construction had yet begun at the Church. The contractor wisely informed the Congregation that they should not begin the renovations until the cause of the cracks is determined.

On 26 March 2014, Dennis J. Kowal AIA and Stephen Malyszka of DENNIS KOWAL ARCHITECTS (DKA) visited the Zion Lutheran Church to observe the conditions and to give an initial opinion about the cause of the cracks (no solutions or exhaustive investigation). The exterior brick, interior foundation walls, and interior plaster finishes were scanned for unusual conditions. Stephen also used a small Mezzanine ceiling access panel to observe the trusses above the Sanctuary. The original findings were verbally reported to the Pastor and Building Committee who were on hand for the first visit.

INITIAL FINDINGS:

1. There were interior vertical cracks in the wall plaster at several locations.
2. Some vertical cracks spread to the ceiling and extended laterally.
3. There did not appear to be water infiltration associated with the cracks.
4. The exterior brick appeared solid, in good condition, and with no horizontal, vertical, or stepped fractures.
5. The foundation appeared to be poured concrete; and where observable, it appeared to be solid, devoid of fractures, and devoid of spawling.
6. There appeared to be no sign of settlement of the foundation.
7. There appeared to be no sign of settlement or water collection at the grade surrounding the building.
8. There appeared to be no openings, missing shingles or deformations of the roofing, ridge line or eaves.
9. There appeared to be no unusual deflection of the Sanctuary floor and no recent separations of the baseboard and floor. (A ½ ” wide gap around the baseboard was consistent everywhere and appeared to be built this way and not settlement).

Upon closer observation, it could be seen that the exterior long walls were slightly out of plumb with the East and West walls appearing further out from center than the base of the walls. There were no horizontal stress fractures related to the bowing. It could not be determined from an exterior examination if the walls were originally constructed out of plumb or it they had moved from an original plumb condition. Interior painting evidence suggested that interior moldings had separated from their original location which would support a theory that the exterior masonry East and West walls had indeed moved outward at the eaves. It was determined it would be necessary to check the trusses above the two major crack locations to see if there was any evidence of movement. The building committee in attendance was given the initial findings, orally, after some of the trusses above the cracks were observed first hand.

Conditions to view the trusses were restricted by access and ease of movement in the attic space. Observation was further impacted by the total darkness condition above the ceiling. However, portable lighting and some physical agility resulted in the following findings:

INITIAL ABOVE CEILING OBSERVATION:

1. The bottom chord of one of the roof trusses had been coped out in two locations to accept the housings for ceiling installed downlights. Although this is not an acceptable practice and must be structurally repaired, it could not be the sole cause of the outside walls bowing as the weakening of the chord did not yet result in a complete shear.

2. At least five trusses had fractures of the wood members at or near the bolted joints of the timber members. The fractures appeared to travel all the way through the truss members. Fractures are irreversible, compromise the connective value of the bolted connections and change the way the stresses were designed to move through the truss. When the fracture

cannot be seen from both sides of the member, this report shall refer to that condition as a "crack" in the wood member.

3. The wood ridge was fractured along its length in the area of the compromised trusses. This is an unusual condition in that the ridge in this case is somewhat "non-structural". It appeared that twisting moment from the upper truss member was peeling the bottom of the ridge member away from the top of the ridge member much like the lever action of a can opener. While the fractured ridge was not the major structural concern, the fact that this much stress and movement had occurred is a warning sign and a major concern.

4. When some fractured trusses were discovered, it was enough evidence to determine that the plaster cracks were not simply cosmetic (which was the purpose of the initial visit).

Damage in wood is principally the result of fatigue. Fatigue is the process of progressive localized irreversible change in a material, and may culminate in cracks or complete fracture if conditions that initiated or propagated the process persist. Also, a one-time trauma such a wind-storm, ice storm, or impact from debris can over-stress the trusses and cause failure.

The committee then reported that a major tree had fallen during a storm and was stopped from hitting the ground only by landing on the Church building. Members of the congregation then supplied to this author photos of the fallen tree. The tree appears to be of 24" caliper and can be seen resting on the East roof of the Church Building. The photos were taken by congregant, and then Building Committee member, Therese Bera after the 28 August 2011 Hurricane Irene storm.

Dennis Kowal AIA and Stephen Malyszka presented the initial findings using a white board showing the approximate locations that were spot-checked. Basically, Stephen was able to get over the two locations with the most plaster cracks which are coincident with the Chancel proscenium and rear walls of the worship area of the Sanctuary. The following initial recommendations were provided:

INITIAL RECOMMENDATIONS

1. There were unusual splits and fractures in the truss system in multiple locations.

2. ZLC should inform the local Building Inspector of the conditions and about the Architect's initial findings and the safety of occupancy.

3. ZLC should inform the insurance carrier of the found conditions.

4. ZLC should consider the truss fractures as not normal; affecting a series of trusses, possibly more. It is recommended to NOT occupy the building since there is evidence of movement in the roof structure which may have loosened the plaster ceilings and walls. Falling plaster may be dangerous to occupants until tested for adhesion. Also, compromised trusses are difficult to evaluate and therefore cannot be trusted to perform the load bearing tasks they may encounter. [Congregation immediately closed the Church Building for public use].

5. Until proven otherwise, ZLC should assume that the walls are bowing out (and not built out of plumb originally), which would be consistent with truss failure.

6. The purpose of the initial visit was to confirm or deny that the cracks are cosmetic in nature. Now knowing that they are not cosmetic in nature and the cracks are indicators of a more serious problem, DKA recommended further investigation to determine the extent of the problem. A Proposal for Services was provided to review all the truss locations (that can be reasonably accessed). The Proposal did not include specific repair solutions or cost estimates but did include discussion about approaches to repair or stabilization.

TRUSS SURVEY & REPORT

The remainder of this report is the result of that more in depth investigation. On 9 April 2014, Dennis Kowal and Stephen Malyszka made a more thorough investigation of the attic trusses (visual survey of the trusses, no calculations, no design solutions). The team was accompanied for the entire duration by Frank Avalone of A&A Construction Management. Frank stayed below the attic level. Members of the Building Committee joined in at various times and stayed to hear the verbal findings. Work lights and walking planks were set up in the attic area and the following methodology was established:

METHODOLOGY

1. The trusses were labeled in pink chalk for identification in the photos. Yellow chalk marks are presumably from the original time of construction.

2. Plans were created of the truss layout and marked in the field with the extent of damage. Because of the numerous fractures, this proved to be difficult under the circumstances and a photo option was substituted. The photographs were studied in the DKA offices and the information was transferred to the plans and truss details sheets later.

3. All unusual conditions were photo-documented from Front of Truss (South Face) and Back of Truss (North Face).

4. Dennis and Steve divided the work of viewing the conditions and compared notes as conditions were observed.

5. No members of the congregation or subcontractors viewed the trusses first hand or came into the attic.

6. No time limit was set on the investigation but access to some of the areas such as the attics above the building appendages (porches, above Chancel, etc.) were not observable due to access and height limitations.

7. Due to the tight conditions, the truss tails which rested on the plate were not observable. Sections of the roof or ceiling would need to be removed to accurately observe. ZLC decided at the time of the first observation to defer that cost to the future if it was really necessary. Joseph Clarizio of A&A Construction Management gave a proposed cost of $7,500 to open and close parts the walls or ceiling so DKA could see the truss tails and construction behind the cracks.

8. A plumb line and extension ladder were used to check the outside of the West masonry wall from the eave down to the water table projection.

9. The trusses were labeled 1 through 28 from North (Chancel) to South (Entry) and the North Face of the truss (facing Chancel) was labeled as the "B" for Back and the South Face of the truss was labeled "F" for Front. Finally the Left Side was labeled with an "L" determined by facing the Chancel, and similar for the Right Side marked with an "R". In this methodology, both the Back and Front of the same half of the truss would carry either all "R's" or all "L's".

10. The trusses under the steeple were examined but not labeled because no issues were found in this area which appeared solid and free of fractures.

EXECUTIVE SUMMARY:

After about five hours of truss observation, it was determined that the fractured trusses were not an isolated occurrence in just one area. This Finding tends to broaden the options of how this occurred. For example, a strong wind shear during a violent storm such as Hurricane Irene combined with an lateral impact from a tree combined with loosened connections in the trusses could produce this overall result. Conversely, the leaves on the fallen tree could have absorbed the wind gust and shielded the roof thus explaining why the trusses were not as fractured under the shadow of the fallen tree as everywhere else. However, it is not possible to visually determine whether the trusses failed from under-design, impact, temporary overloading, wind shear, or improperly dried lumber.

It is not unusual for trusses of this design to move and even crack over time. The design is the "scissor truss" which combines two intersecting triangles. Triangles are an inherently rigid shape and are excellent in resisting forces with a minimum of structure while maintain their shape. However, in this case, the scissor truss design with the very high collar tie (moved up to allow the curved ceiling) is subject to some movement like the handles of a pair of scissors. Hence the name. The trusses probably moved ("scissored") back and forth slightly allowing undesired forces to occur at the connections; fracturing the members in the process.

Truss design is a complicated mathematical calculation and a review of the design is not part of the services at this time. Compromised trusses do not have a known load capacity and must be replaced or repaired and load-shedded. At different times, a member in a truss can be under either compression or tension depending on how the live loads are imparted (wind direction, snow drifting, etc.).

1. 90% of the trusses have issues of varying degrees among the following:
    a. Cracked (partial split not all the way through)
    b. Fractured (split all the way through)
    c. loose bolted connections

2. Some areas, namely trusses 1 through 10, appear to have been stressed the most as the ridge has also split.

3. While it isn't unusual for an occasional hairline to develop in some members over time because of some latent imperfection in the wood which may start at a knot or at a nail driven too close to an edge, etc., it is not usual to have these many splits, in these locations, and to have the splits open up (in some cases more than a ¼").
    a. Many fractures seem to be from twisting at the bolts.
    b. Other fractures ran continuously through a member from end to end.
    c. The ridge was fractured across ten trusses.

4. The least amount of fractures occurred at the impact zone of the tree.

5. Since so many trusses have fractures, the natural tendency for forces to spread (in effect "bridging" over some weaknesses) and share the load is compromised. Most of the members are now weaker than design assumptions because of the fractures and there are now no normal trusses to carry the load for others weaker trusses.

6. Trusses that do not have visible fractures are likely still under great stress. Adjacent trusses may be underperforming and there are new stresses from the bearing walls moving outward. More fractures could be imminent. Wood is an organic material and not entirely uniform in nature. Construction handling, natural imperfections, and what the exposure has been all affect its performance.

7. Because of the burden placed on the trusses without visible fractures, they could pop at any time. In essence, an unusual storm load could cause a domino ripple failure.

NEXT STEPS

The structure is not safe in the current condition. The Church may either stabilize, repair or replace the failed members. Before a final determination of cost, approach and whether to stabilize, repair or replace, it is necessary to analyze the original truss design. It is likely that after analysis, the trusses can be repaired rather than replaced thus saving construction time and money. The recommended next steps are:

A. Structural analysis of the truss design, calculations, and recommendations for repair.
B. Construction Documents of the repair for permits and bidding.
C. Construction Administration to observe that the repairs are made correctly and to answer questions during the work.

Temporary stabilization costs may also be similar enough in cost to the permanent stabilization, that the temporary stabilization can be just replaced with the final design stabilization thus again saving construction cost.

DISCUSSION OF OPTIONS

Even before a final solution can be designed, should Zion Lutheran Church wish to make a full repair, it is necessary to do more investigation. The areas that could not be visually scanned (the tails of the trusses) should be exposed to further understand the issues and to be sure all the forces at work are understood. Repairs will also require a means to bring large length materials into the space. The options are to work from below by removing all or some of the curved ceiling or to work from above by removing all or some of the roofing and sheathing. It is more cost effective approach is to remove the ceiling which also does not expose the structure to the elements. To investigate the sill plate and truss tails either vantage point works, but removing a small portion of the ceiling does not have weather and exposure issues like removing a portion of the roof.

TEMPORARY STABILIZATION

Exterior Braces could be buttressed against the outside wall to stabilize the building. Braces would obstruct immediate construction of an addition or expansion of lower level wells. A scaffolding or stabilization contractor can rent or provide lateral bracing and install it quickly. All work requires drawings and permits.

Alternately, a structural channel could be applied to the East and West building fascia's and tied together by cable or rods through the Sanctuary. Since the exterior walls are masonry and it is not known whether they contain vertical and horizontal reinforcement (original drawings don't specify), pulling on the top of the bearing walls (to bring them back in) could simply snap a few courses off the top rather than uniformly pulling the entire wall. It may be wiser to only relieve the horizontal component of stress now being forced into the wall from the sagging trusses rather than to plumb the walls again. This would reduce the possibility of exterior cracks opening in the brick jointing. It is normal practice to leave well enough alone in terms of plumb.

PERMANENT STABILIZATION

It is likely that the permanent repair solution will still involve some buttressing or cabling. A total replacement of trusses or insertion of new trusses between the existing might eliminate the need for buttresses or cabling; but that will be known after the analysis. Once a structural analysis and repair design is completed, the cost and benefits of temporary stabilization can be weighed against the permanent solution and the two may become one.

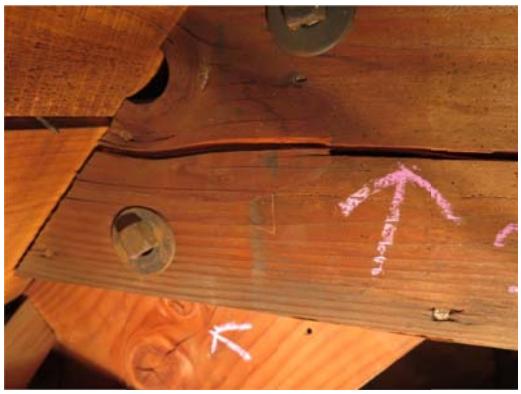
At the worst case, new trusses can be inserted between the existing trusses. This would require removal of the roof and then roof replacement. The plaster ceiling should be tested for stability or that too may need replacement. The worst case is not anticipated.

CATCH 22

The existing truss design is layered , unlike the common wood trusses made today which have all the members in the same plane. Repairing the trusses by sistering on new members (gluing, bolting and nailing another wood member right alongside the failing members) is problematic. Because the existing truss design bolts members to both sides of the top chords, there is no free side to add a member. When a sistered member must be blocked out and added away from the stress plane of the truss, eccentricity is added to the equation which weakens the effectiveness of the repair.

TYPICAL PHOTOGRAPHIC FINDINGS

The following photographs show the range of problems encountered with the trusses.



Truss #2 Horizontal member split Photo 130

Truss #2 Fracture goes all way through Photo 98

Truss #4 Ridge member split Photo 137

Truss #5 check at knot Photo 182

Truss #5 improper notching Photo 176

Truss #5 improper notching Photo 175

Photo 228 and 161 show the beginning of the truss tails descending out of observable view. The lowest connection points near outside walls rarely had splits, cracks or fractures.

Lowest members mostly intact Photo 228

Lowest members mostly intact Photo 161

Truss 6 Loose bolted connection Photo 191

Truss 9 Loose bolted connection Photo 241

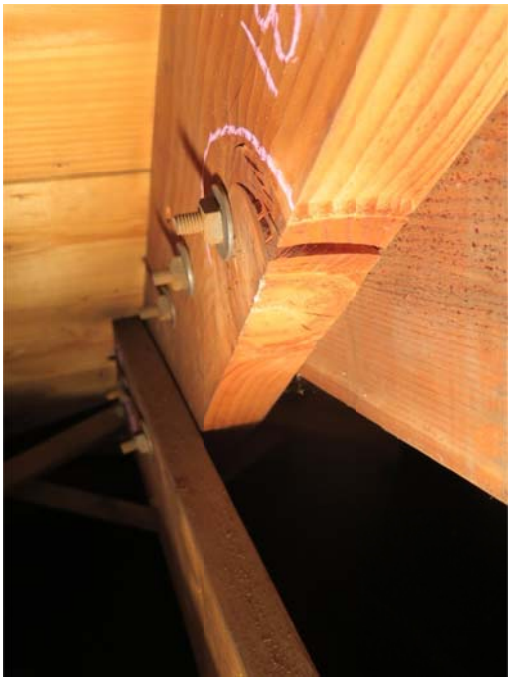
Truss 9 Loose bolt, fractures Photo 243

Truss 10 Loose bolt, fractures Photo 215

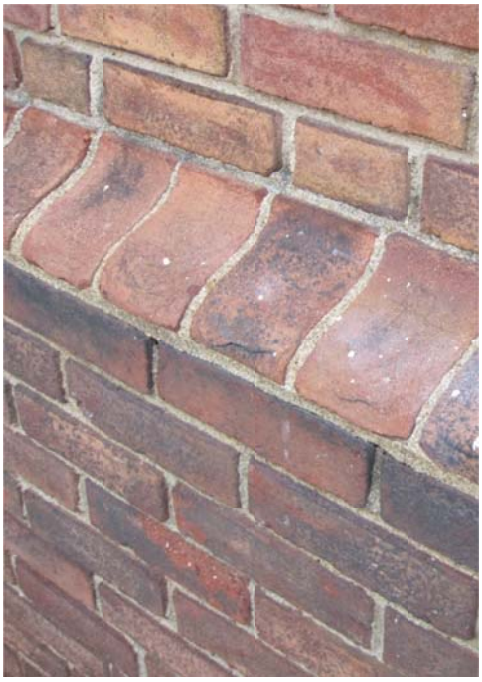
Truss 20 Full fracture through bolt Photo 286

Truss 23 Fractured length Photo 291

Truss 26 Full fracture through bolt Photo 308



Truss18 Normal knot fracture Photo 280



Exterior masonry jointing is crack-free

Exterior walls bow out 2”

The following represent typical depictions. All trusses numbered were surveyed. Only those faces with findings were drawn and labeled.