Structural Support LLC
1212 Main Street
Belmar NJ 07719

December 5, 2018

Governor Phil Murphy
Office of Governor
POB 001
Trenton NJ 08625

| | |
|---|---|
| Property Address: | 1804 South Broad Street<br>Hamilton NJ 08610 |
| Municipality: | Hamilton |
| County: | Mercer |
| Purpose: | Evaluation of Collapse |

Governor Murphy,

Attached report describes evaluation of catastrophic collapse of former house at this property on July 23, 2018.

As you are undoubtedly aware, mother of two daughters was killed during collapse of two-story single-family house, built in 1920.

Report is intended to highlight importance of;

1. Determining cause of collapse with adequate reliability.

2. Measures to be taken by New Jersey to minimize risk of such collapse again.

I am professional engineer (PE), licensed in New Jersey and other states, with 40 years experience in structural engineering, including extensive experience with evaluation of older houses and buildings throughout New Jersey.

Two-page report by engineer for municipality, issued hastily just one day after collapse, is grossly deficient and should be considered without merit relative to cause of collapse.

Based on available information, which is limited, I have developed likely collapse scenarios. However, further information would be required to provide adequate reliability for determination of collapse.

Relevant state agencies, such as DCA, should endeavor to determine cause of collapse for this house, which had features similar to many other houses built about 1900 to 1950 throughout New Jersey.

See page 6 for Summary Of Conclusions and page 8 for Recommendations.

Structural Support LLC
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Belmar  NJ  07719

December 5, 2018

Copies;
Lt Governor Sheila Y Oliver; Commissioner, Department of Community Affairs
Senator Jeff Van Drew; Chair – Community and Urban Affairs
Senator Linda R Greenstein; Chair – Law and Public Safety
Assemblyman Benjie E Wimberly; Chair – Housing and  Community Development
Assemblyman Adam J Taliaferro; Chair – Law and Public Safety
Assemblyman Daniel R Benson
Assemblyman Wayne P DeAngelo
Kelly Yaede; Mayor, Township of Hamilton
Raymond A Lumio; Construction Official, Township of Hamilton
Congressman Christopher Smith
Editor; Trentonian
CBS 3, Philadelphia PA

# Structural Evaluation
# For
# Cause Of Collapse
# Of Single-Family House
# <u>July 23, 2018</u>

1804 South Broad Street
Hamilton NJ

December 5, 2018

John F Mann, PE
New Jersey
GE29049

Structural Support LLC
Certificate: 24GA28284800
1212 Main Street
Belmar NJ 07719

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Belmar NJ 07719

December 5, 2018

# **1804 South Broad Street, Hamilton NJ**

Structural Support LLC
1212 Main Street
Belmar NJ 07719

December 5, 2018

# Introduction

Purpose & Limits Of Evaluation

This report describes evaluation of the following issues relative to collapse of former house at this property on July 23, 2018;

1. Potential & likely causes for collapse

2. Report by engineer for municipality dated July 24, 2018

Summary Of Conclusions are on pages 6 & 7.

Recommendations are on page 8.

Intent of This Report

Primary intent of this report is to highlight the following;

- ☑ Importance for understanding cause for collapse.

- ☑ Need for changes in state regulations governing inspections for certificate of occupancies.

This report also reinforces conclusions in other reports issued by this writer, and reports expected to be issued in near future about; (1) Process of design & construction for new buildings, and (2) Structural evaluation for existing buildings.

Terms & Conventions

The following terms are used in this report;

| | |
|---|---|
| This writer | John F Mann, PE unless otherwise described |
| This report | This report by this writer (John F Mann, PE) |

Dark arrow ➡ highlights point or information that is primary concern, or that demonstrates grossly deficient result, work or services.

Light arrow ➢ highlights point or information that is of at least some concern, or that demonstrates deficient result, work or services.

Checkmark ☑ highlights point or information that is favorable or positive for designer or others as noted, or that demonstrates successful or acceptable result, work or services.

Other symbols that may be used do not necessarily indicate any specific quality or feature of the issue or condition noted.

- ❖ In general, description of evaluation and analysis is provided separately from description of information and observations.

Designations used in this report may also be shown on drawings prepared for this evaluation to show pre-collapse or post-collapse conditions.

Codes & Standards

Structural analysis calculations have been performed based on the following standards;

1. New Jersey Uniform Construction Code (UCC)
2. International Building Code; IBC 2015 NJ
3. National Design Specification For Wood Construction; NDS-2005

Background Information

This writer, professional engineer (PE) licensed in New Jersey and other states, with 40 years experience in structural engineering, first became aware of house collapse, on July 23, 2018 at this property, while seeing TV coverage later on day of collapse.

Recently, during research for unrelated construction defect case, this writer became aware of report prepared by engineer for municipality, relative to this collapse, that is dated one day after collapse. Copy of two-page text portion of that report was found online (CBS news).

Photos of former house prior to collapse are available online, via various real estate web sites as well as Google Maps. Extensive video of collapsed house is available online via media outlets, including CBS (New York & Philadelphia).

As described in several news reports, two-story single-family house, with brick exterior walls, collapsed suddenly about 7:00 am on July 23, 2018. Tenants, including mother and two daughters, were in house at time of collapse; mother was killed while daughters survived.

The following description is provided in article by Associated Press (July 23, 2018);

> *Justice's 20-year-old daughter was in another bedroom on the second floor when she heard "cracking" noises and started screaming moments before the home caved in on itself, Hamilton Fire Department Capt. Ferdinand Mather said.*

Last inspection for Certificate Of Occupancy was performed about 5 years ago (Trentonian; July 23, 2018).

The following description is in article by Isaac Avilucea, published in Trentonian (August 4, 2018);

> *She* [family attorney Robin Lord] *said the ceiling in one of the bedrooms collapsed, and required repairs, within months of the deadly house collapse.*

No further information about collapsed ceiling has been found in subsequent reports.

This writer performed brief inspection of site on December 3, 2018. Rubble from collapse, which obstructs views of almost all foundation walls, and first floor at back of house, essentially remains from day of collapse and rescue activities.

## Basic Data – Property & House

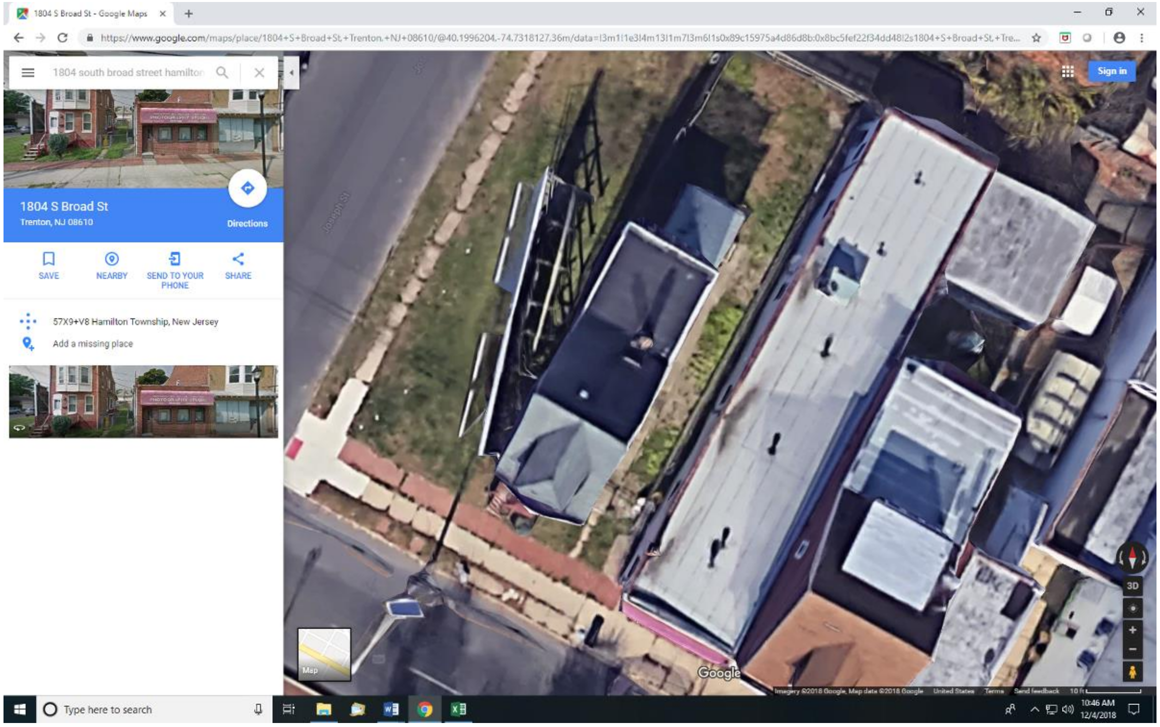
Basic data about property and house prior to collapse is available online via real estate firm web sites and country web site.

The following data is listed on real estate web site (Zillow.com) for this house;

| | All Sources Combined | County Records |
|---|---|---|
| Year Built | 1920 | 1920 |
| Last Sold | June 2001 | |
| Square Feet | 1,615 | |
| Lot Depth | 100 feet | |
| Lot Width | 25 feet | |
| Stories | 2.0 | |

The following data is form Mercer County web site;

| | |
|---|---|
| Block | 2266 |
| Lot | 1 |
| Class | 2 |




<u>Photo 1 – Google Maps</u>
Aerial view looking down at roof for house (1804 South Broad Street) on corner property.

Sign (billboard) in left-side yard, angled with respect to left-side wall.

Summary Of Conclusions

Entire report must be read to understand all conclusions.

Evaluation has resulted in the following key conclusions;

1. Features of this house were not especially unique. Many other houses in Hamilton, Trenton and other older areas of New Jersey have houses with similar construction. Therefore, it is imperative that cause for collapse of this house is determined with as much reliability as feasible.

2. Report by engineer for municipality (Robert Busch, PE) is grossly defective and should be considered without merit for evaluation of causes for collapse.

3. Key claim by Mr. Busch, that collapse had to be “initiated” by some defect under first floor, is grossly incorrect. Although initial defect, resulting in total collapse, might have occurred under first floor, there are several other potential scenarios for which initial defect could have occurred above first floor, causing sequence of events that would have resulted in “pankcake” type collapse.

4. If key conclusion by Mr. Busch (ambiguous deterioration of block foundation walls being cause for collapse) was considered valid by municipality, then municipality should have notified all owners of houses with older block foundation walls (before 1960 at least) and ensured that all such foundation walls were immediately inspected by qualified professional engineer. However, there are no reports that any such action was taken by municipality.

5. Contention by Mr. Busch that there was no evidence of structural defects with framing elements, prior to collapse, is without basis. In his report, only information presented about framing conditions was size of first floor joists.

6. At this point, it may not be feasible for anyone to determine cause of collapse with reliability typically sought for such evaluations. However, much better information about pre-collapse conditions may have been obtained by one or more engineers for insurance company (or other party) that did allow (or would allow) for improved analysis.

7. Several potential collapse scenarios, discussed in this report, are much more likely than scenario proffered by Mr. Busch.

8. Based on information available for this evaluation, most likely cause of collapse was severely defective roof framing condition along with defective configuration of brick walls at front of house, along with inherent lack of adequate connection between wood framing members and brick walls. However, other collapse scenarios involving framing defects are also feasible.

9. Inherent defect with brick wall construction is lack of adequate connection between wood framing members and brick walls, resulting in lack of adequate resistance to outward lateral movement of brick walls.

10. Any damage or defective condition for roof framing, or members supporting roof framing, would likely have been difficult to observe during standard inspection performed by municipal inspectors for issuance of Certificate of Occupancy. However, qualified professional engineer with background in structural engineering should have noted potential for problems due to configuration of roof framing and lack of adequate brick walls at front of house. Further inspection should then have been recommended.

11. Defects causing reported “collapse” of ceiling over bedroom, just “months” before collapse of house, might have been primary cause for total collapse. Further information is required to provide evaluation of such reported event.

12. Defect causing initiation of collapse might have occurred after last inspection for Certificate Of Occupancy. However, it is more likely that such defect already existed at time of inspection and became worse since then.

13. During inspection for Certificate of Occupancy, failure to identify major structural defect (if already existing), resulting in catastrophic collapse, demonstrates major problem with municipal inspections for Certificate of Occupancy that has been ongoing for many years. Municipal inspectors generally do not have adequate knowledge about structural elements and conditions, and do not have enough time to fully evaluate structural conditions.

14. Hamilton building department and New Jersey Department Of Community Affairs (DCA) should attempt to learn as much as feasible about cause or causes of collapse for this house. Other houses in Hamilton and throughout New Jersey have similar features. Over time, without identification and remedial work, risk of further catastrophic collapses for such houses continues to increase.

Recommendations

1. If more thorough evaluation has not already been performed, by engineers working for insurance company or other parties, that provides reliable determination for cause of collapse, or if results of such evaluation are not shared, Hamilton and DCA should consider having further evaluation performed by one or more qualified professional engineers based on further inspection.

2. Events relative to “ceiling collapse”, only “months” before collapse of entire house, must be carefully evaluated.

3. State regulations should be changed to require structural inspection by qualified professional engineer (PE) prior to issuance of Certificate of Occupancy.

## **Observations**

For this evaluation, observations are based on the following information;

1. Video available online, primarily from web sites of TV media.
2. Photos of house prior to collapse, available online
3. News reports, available online.
4. Report by engineer for municipality, dated July 24, 2018
5. Inspection on December 3, 2018

General Description of Property & House

Rectangular property is along westbound side of South Broad Street and east side of Joseph Street which forms T-intersection with South Broad Street.

Prior to collapse, two-story, single-family house consisted of the following sections;

Section 1 Main two-story section
Section 2 Small one-story section behind Section 1

Dimensions noted in discussion below are based on using measurement feature provided with Google Maps. However, such measurements are also checked against other data.

Overall dimensions of Section 1 were about 16 feet wide (side-to-side) by 48 feet long (front-to-back). Overall floor area (for 2 floors) was then 1,536 square feet which is basically consistent with floor area of 1,615 square feet reported on real estate web sites, which likely includes floor area of Section 2.

Front wall was about 20 feet from curb along South Broad Street.

Right-side wall of Section 1 was about 12 feet from one-story building to the right, at 1806 South Broad Street.

Left-side wall of Section 1 was about 36 feet from curb along Joseph Street.

Large rectangular sign (billboard) was in left-side yard. Front end of sign, just about opposite front end of left-side wall, was about 4 feet from left-side wall. Sign angled back such that distance between sign and house increased.

Sign was supported by wood framing. Several angled wood braces extended from sign towards house. At and near front end of sign, low ends of such angled braces appeared to be up against or very near to foundation wall supporting left-side wall of house.

Conditions Prior To Collapse

Photos of house prior to collapse are available on several web sites of real estate firms and on Google Maps.

Google Maps provides ability to obtain numerous views by moving cursor on screen. Several photos attached to this report were obtained in such way and then taking screenshots.

Views from front are noted as “Street View - June 2018”.

The following conditions and features are noted by review of photos;

- Exterior walls brick or faced with brick (Photos 2, 3, 4).
- First floor about 32 inches above grade along front of house (Photos 3A, 3B)
- Gable roof over front part, with ridge running side-to-side (Photo 2)
- Dormer with two windows at center of front slope for gable roof (Photo 2).
- Monoslope roof over back part, sloping down from front-to-back (Photo 4).
- Front wall contains extensive openings, including large bay window assembly above second floor (Photos 2, 3).
- Brick of front wall supported on block foundation wall with three (3) courses of block above grade (Photos 3, 3B).
- Wood-framed porch and stairs outside front door (Photos 3, 3A).
- Right-side wall contains several openings, including bay window assembly with small roof (Photos 2, 3).

The following conditions had existed for front wall;

1. At first floor level, door opening and two (2) windows, resulting in four (4) narrow full-height brick wall segments.

2. At second floor level, bay window assembly, with three windows, results in narrow full-height segment of brick wall (about 2’-0” wide) at each end of wall.

The following conditions had existed for right-side wall;

1. At first floor level, window about 10 to 12 feet from front end of wall. Bay window assembly immediately behind single window.

2. At second floor level, window about 4 feet from front end of wall. Three (3) additional single windows in right-side wall, including one over bay window assembly below.

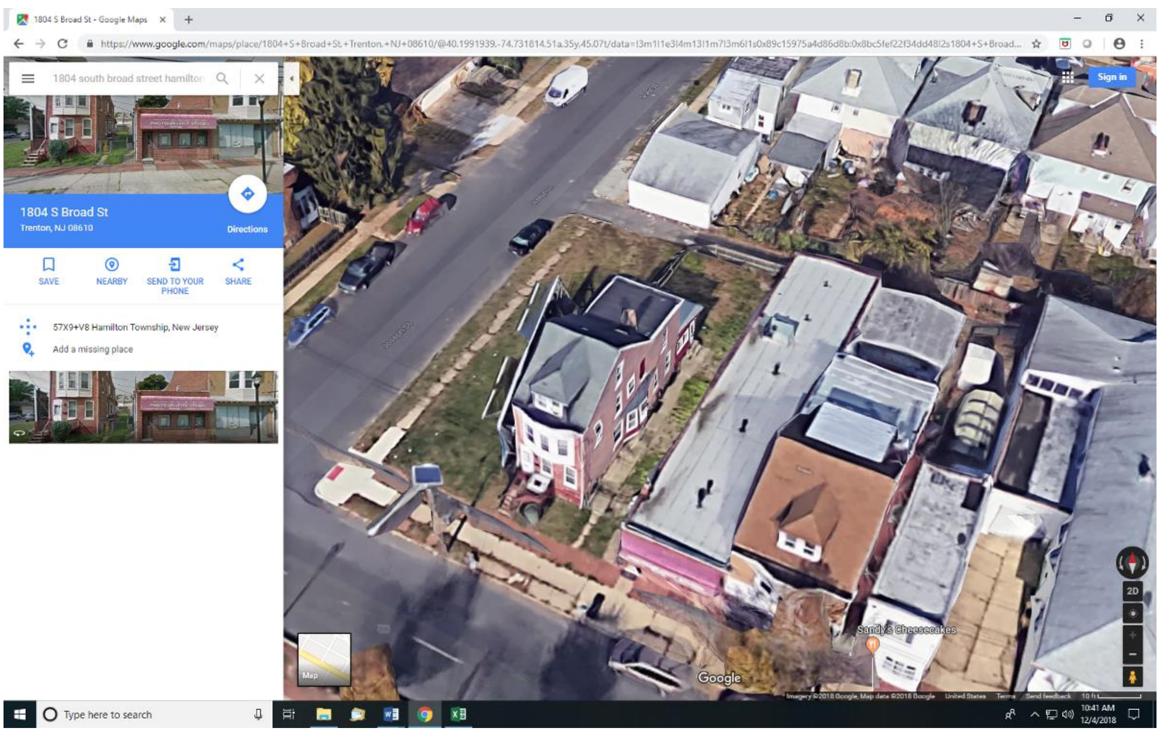
Left-side wall appears to have no openings, although large sign obstructs clear view of front part of wall below second floor.

Brick seen in photos appears to generally be in good condition, without obvious cracks or deformation.

For front slope of gable roof, low ends of rafters are above and in line with narrow segments of brick wall. As seen in aerial views, small area of flat roof is above second floor area just inside bay window assembly.

For back slope of gable roof, low ends of rafters are about 30 feet from front wall, just in front of brick chimney extending above monoslope roof over back part of Section 1.

Details of access to attic space under gable roof, and use for attic space, are not known.




<u>Photo 2 – Google Maps</u>
Aerial view showing front and right side of house, on corner property; June 2018.
Front wall faces South Broad Street.

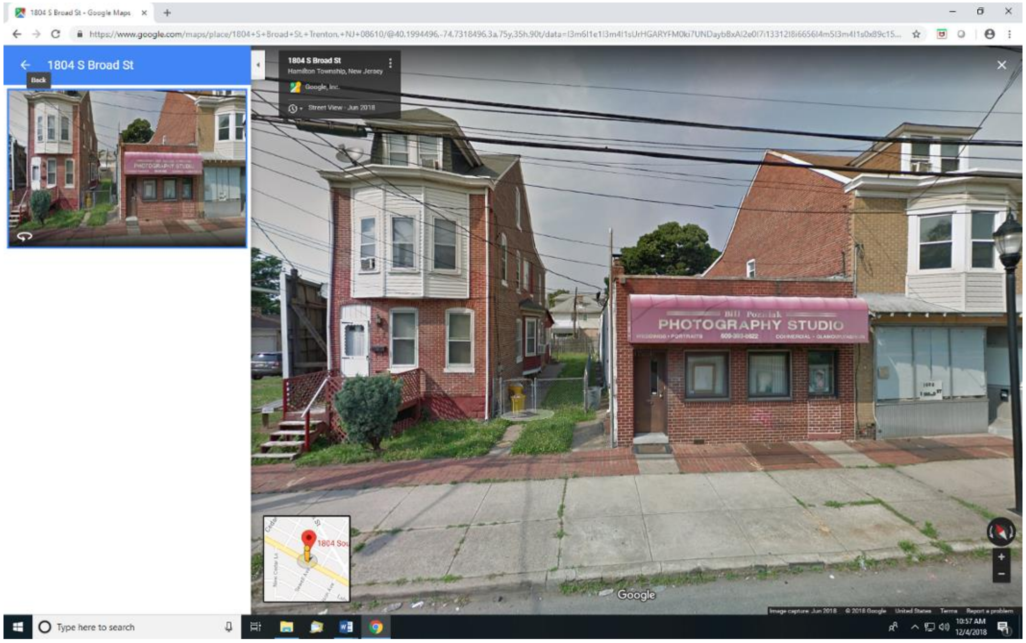



Photo 3 – Google Maps
Front and right side of house; June 2018.

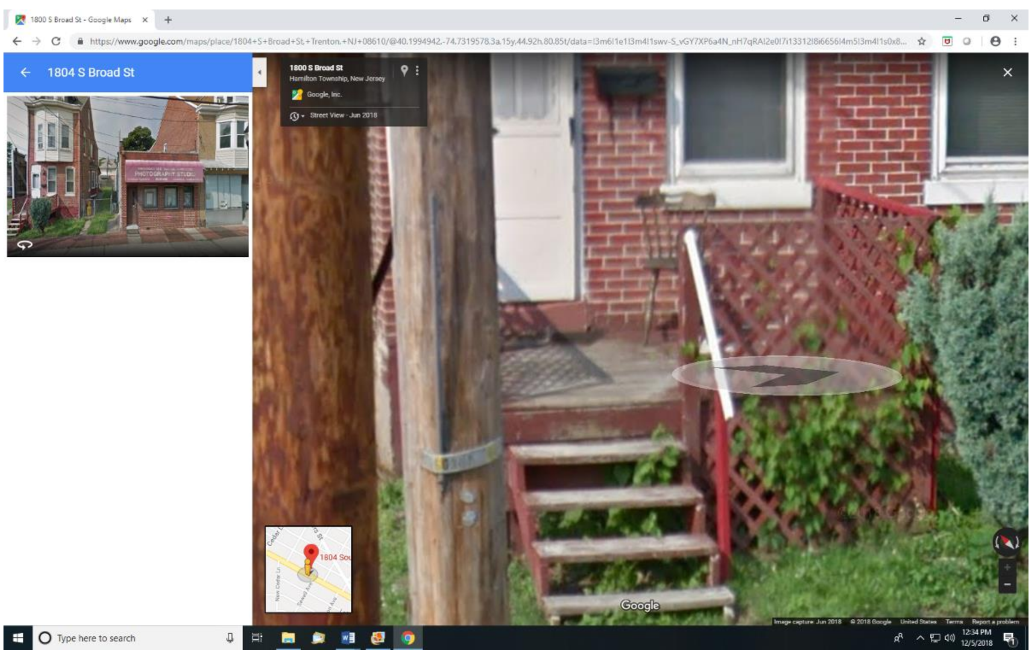



Photo 3A – Google Maps
Wood-framed porch deck outside front door; June 2018.
Surface of porch deck is about 7 inches below first floor.

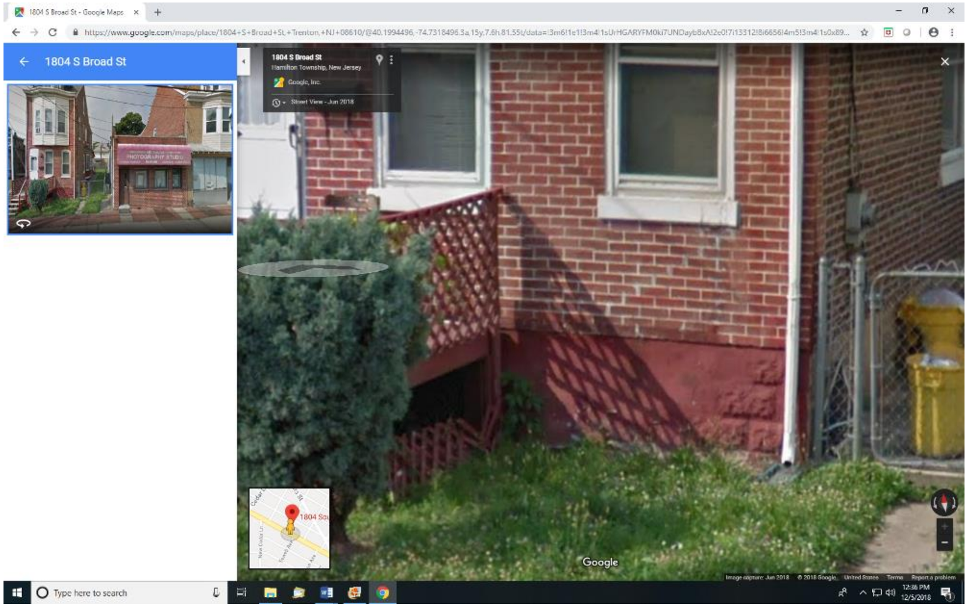



Photo 3B – Google Maps
Brick wall on block foundation wall; June 2018.
Surface of porch deck is flush with top of block foundation wall.

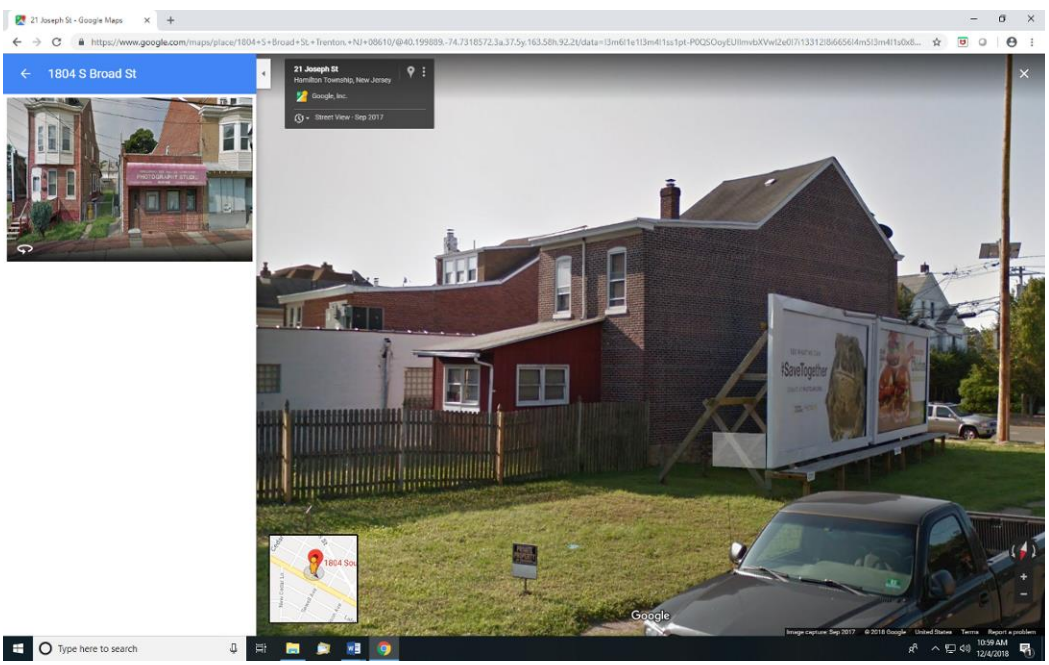



Photo 4 – Google Maps
Back and left side of house.

Alterations

One-story Section 2 at back almost certainly was built as addition.

There is no information to determine if any alterations were made to two-story Section 1 since original construction.

However, large bay-window assembly in front wall may have been installed after original construction, as alteration.

Bay-window assembly in right-side wall also may have been installed as alteration.

Prior Remedial Work

Report that "ceiling in one of the bedrooms collapsed" only "months" before collapse of entire house, warrants careful research and evaluation.

- Collapse of ceiling over second floor bedroom indicates that roof leaks had occurred.

Long-term roof leaks can cause decay of wood framing members, resulting in reduction of strength, along with reduction or loss of capacity for connections.

- ➡ If repairs to attic floor framing were made, or attic floor framing was modified in any way, such structural alterations could have been primary cause for collapse of roof and entire house.

General Observations Of Collapse

Overall observations of collapse are determined by studying photos and videos taken (by others) after collapse as well as photos of house prior to collapse. Observations made during inspection of December 3, 2018 have also been useful.

As seen in videos, materials from rubble were moved during rescue operations.

Available information shows the following key features of collapse;

1. For front part of house, front slope of gable roof (with dormer), attic floor and second floor moved laterally several feet to the right. Bookcase that had been on second floor or attic floor is seen up against wall of adjacent building (Photo 101A).

2. Back part of house fell forward. After collapse, back edge of monoslope roof, that had been over back wall, is seen about 15 to 20 feet forward of position before collapse (Photos 102 & 102B).

3. Wood-framed first floor for entire front part of house collapsed into basement.

4. There is no evidence that foundation walls collapsed.

5. Upper three courses of block that had been above grade were knocked away at front end of left-side foundation wall.

6. For front part of house, brick wall along left-side fell outward, to the left. Front part of large sign (billboard) immediately adjacent to house was destroyed by collapsing house wall.

7. Gable roof that had been over front part of house flattened, with low ends of rafters moving outward (relative to attic space) and ridge moving downward. However, front slope of gable roof was completely separated from back slope of roof.

8. Attic floor joists appear to have run parallel to ridge of gable roof.

## Weather Data

Weather data listed below is from the following online sources and weather stations;

| | |
|---|---|
| Weather Underground | KNJHAMIL42 |
| NJ Weather & Climate Network | Mercer County Soil Conservation District |

Station KNJHAMIL42 is shown on map to be north of South Broad Street and east of I295, about 0.7 miles west of 1804 South Broad Street. Listed maximum windspeed is sustained. Reported gust windspeeds (not listed below) are slightly higher.

Soil Conservation District is about 5.0 miles northeast of 1804 South Broad Street.

| | Rainfall Inches | Maximum Windspeed Mph | High Temp deg F | Low Temp def F |
|---|---|---|---|---|
| July 6 | | | | |
| Weather Underground | 3.63 | 8 | 82 | 68 |
| NJ Weather | 0.88 | 17 | 93 | 71 |
| July 17 | | | | |
| Weather Underground | 0.28 | 10 | 95 | 71 |
| NJ Weather | 0.88 | 17 | 93 | 71 |
| July 21 | | | | |
| Weather Underground | 0.79 | 12 | 77 | 62 |
| NJ Weather | 0.87 | 11 | 77 | 59 |
| July 22 | | | | |
| Weather Underground | 0.69 | 10 | 86 | 71 |
| NJ Weather | 0.56 | 16 | 86 | 71 |
| July 23 | | | | |
| Weather Underground | 0.58 | 10 | 86 | 75 |
| NJ Weather | 0.30 | 16 | 85 | 74 |

From June 22 to July 23, total rainfall (Weather Underground) is listed as 8.12 inches which is much more than average of 5.03 inches for July (Weather Channel).

Per NJ Weather & Climate Network, during morning of July 23, 2018, 0.27 inches of rain fell in the hour from 6:00 am to 7:00 am.

Observations During Inspection

During inspection of December 3, 2018, observations were made only by looking into site of collapsed house from outside steel fencing.

Weather conditions were overcast, with temperature about 45-degrees.

Much rubble from collapse of house remains on site, essentially as it was after rescue operations (Photo 201). However, large segments of former roof and floors have been removed.

The following conditions were observed;

1. Entire front part of first floor, in front of former brick chimney, has collapsed into basement (Photo 202).

2. Remainder of block foundation wall at front end of left-side is essentially intact. Visible block is in good condition (Photos 202, 203).

3. Near left end of front foundation wall, block tilted outward (Photo 204). This may be due to lower part of wall being pushed inward, which might have occurred due to loads from heavy equipment during rescue operations or at some time subsequent to collapse.

4. First floor behind brick chimney appears to have remained in original position (Photo 205).

5. Part of brick wall along back of former two-story Section 1 remains against one-story Section 2 (Photo 206).

## Report By Engineer For Municipality

Within one day of collapse, media reports, including those in newspapers (Trentonian, Star Ledger) and on TV, had referenced report by engineer for municipality, including statements quoted directly from that report.

Report aired on local CBS evening news (WKYW Philadelphia), available at link below, provides copy of two-page report, dated July 24, 2018, by Robert Busch, PE of Leonard Busch Associates PC. Report is addressed to John McCausland, Building Subcode Official of Hamilton.

https://philadelphia.cbslocal.com/2018/07/24/report-deadly-hamilton-house-collapse-caused-by-long-term-water-damage/

As noted in media descriptions, and as referenced within Busch report, five (5) photos were attached to report by Mr. Busch. Those photos have not been obtained for this evaluation.

Entirety of each page of report available online has moderately-dark blue background. This may have been done by CBS to enhance visual appearance on TV.

Pages of report are not numbered.

Across top of first page is name and address for Leonard Busch Associates PC ("LBA" for further discussion), noted as "consulting engineers" in small letters. Immediately below is list of four persons (including Robert Busch) without license status or position identified.

- Certificate of Authorization for LBA is not listed anywhere in report.

Report (second page) is signed by Robert Busch for Leonard Busch Associates PC. Mr. Busch is not identified with typical "PE" designation. To right of printed name and hand-written signature is apparent stamp containing data for New Jersey Professional Engineer (PE) license for Mr. Busch.

Text of report includes nine (9) paragraphs and one simple "finish" sentence.

There are no headers in report.

Terms "we" and "our" are used throughout for description of inspection activities and analysis.

- Inspection activities are described only sporadically within discussion. Person or persons performing inspection are not identified.

Purpose of inspection and evaluation is described at end of first paragraph;

> *"We have been asked to render a professional opinion for the cause of the collapse."*

Description of observations and discussion of analysis are included together in remaining text.

- General description of surrounding area and overall description of property is not provided.
- Orientation (north, south) of house is not described.
- Setbacks from adjacent streets and clearance to adjacent building are not described.
- Large sign (billboard) immediately adjacent to left side of house, with angled wood braces that extend down to left-side foundation wall, is not noted at all.
- Weather conditions at time of collapse and in time period prior to collapse are not described.
- Incredibly, basic fact that house was occupied at time of collapse is not described, along with fatality due to collapse.

Weather conditions during inspection are not described.

Ambiguous explanation that *"We are told"* house was built "*in 1920*" is followed (in same sentence) with conclusion that *"style of construction is consistent with that date."* even before features of construction are described. Person who allegedly provided date of construction, along with person supposedly receiving such information, are not identified.

At start of second paragraph, house is described as *"two-story, brick bearing wall, wood framed home"*. The following additional basic information about house prior to collapse is also provided;

- Full basement (extent not described)
- House about 16-feet wide
- One-story section at back not over basement

Length of house is not described.

Roof configuration is not described.

Photos 1, 2 and 3 are referenced at end of first sentence, though contents of photos are not otherwise described. However, contents are at least indicated in Paragraph 5.

Paragraph 2 ends with puzzling statement;

> *"The basement walls were made from an early form of concrete block – one truly made from sand, coarse aggregate and cement and little else."*

Reason for implication that "early form" is different from current concrete block is not explained other than hint ("little else") that modern block contains some special ingredients that Mr. Busch must keep secret.

Paragraph 3 starts with reference to Photo 4 (*"copied from the NJ.com web si[t]e")*, although contents and time of photo are not described.

Claim is then made that Photo 4 and *"our own inspection yesterday afternoon"* results in conclusion that *"indicates the home fell nearly vertically into the basement or possibly with a lean eastward".*

Paragraph 4 starts with long sentence noting the following *"common problems that can lead to residential collapse";*

> *Gas explosion*
> *Water penetration leading to rotted wood*
> *Undermined foundations*
> *Termites*

No examples of entire house collapse due to any "common" problems are provided.

First sentence of Paragraph 4 ends with contention; *"but we believe this situation is unique."*

- ➡ Claim is then made, without any reference, that, for *"catastrophic collapse"* to occur, *"the initiating source must be located at or below the first supported level."*

Observations of *"first floor framing and foundation"* are described as having been "*inhibited by the unstable pile of debris".*

Yet, abilities for, and methods of, making observations of structural elements tangled within "pile of debris" and subsequently described are not revealed.

First floor joists are described as nominal 2x10s (1.875 inches by 9.75 inches), spaced at 16 inches and *"spanning the clear width of the basement (about 14'-8")".* Methods of making observations of first floor joists, and taking measurements, are not described.

First floor joists are noted to be in "*good, undeteriorated condition*", including at *"ends"*. However, method of observations is not described, and no photos are referenced.

Awkward analysis claim is then made that *"The joist size and spacing is consistent with what would have been the load demand."*, without describing conditions of analysis or specific results of calculations.

- Conditions of each foundation wall around basement are not described.

Second floor framing is not described.

Attic floor framing is not described.

Roof framing is not described.

Exterior wall construction is not described.

Interior wall conditions are not described.

Based on this overwhelming lack of information about structural elements and conditions, the following surprising claim is then just "tossed out" at end of Paragraph 4;

> *"We do not believe the source of failure is structural inadequacy or widespread deterioration of the wood framing or superstructure in general."*

Photos 1, 2 and 3 are again referenced to note *"a structure that appears unremarkable."* Photos are now described as having been *"copied from Google Earth*" (without web site reference) and noted to be *"about 1 year old*".

Absence (in photos) of *"misalignments or wide cracks that would be indicative of buckling masonry or a failing foundation."* is then noted along with contention that such conditions were not likely to have occurred during year since photos were taken.

Paragraph 6 starts with hint about *"a few clues"* that *"lead us to our conclusion below."* However, just two "clues" are described, the first being about concrete block;

*"Several examples of block masonry"* that *"were crumbling and weak"*, along with the following description;

> *"In one example, we were able to take a section of wet block face shell about [~~the~~] 3" x 8" and break it in half with our bare hands."*

Thickness of face shell is not described. Identity of person performing such momentous demonstration of strength is not revealed. No photo reference is noted.

Analysis statement is then made claiming *"that should not be possible with block in good, serviceable condition."*

Second "clue" (along with analysis) is described as follows, based on observation (of some unidentified person) from position *"part way down the rear exterior basement access hatch steps";*

> *"….we inhaled the distinctive odor of mold indicating the basement was chronically moist or wet."*

Paragraph 7 starts with reference to Photo 5, without describing anything about photo, such as source of photo and position from which photo is taken, along with the following description;

> *"….a row of block near the top of the basement wall is badly deteriorated."*

- ➢ Specific "basement wall" is not identified.
- ➢ Whether claimed deterioration is on outside face or inside face of foundation wall is not described.
- ➢ Length of deteriorated block is not provided.
- ➡ Features of claimed deterioration are not described.
- ➡ Thickness of foundation wall is not described.

Awkward and confusing explanation is then provided; *"This block would have been located two or three courses below the bearing location of the first-floor joists at or just below exterior grade."*

- ➡ Details at ends of first floor joists (for house before collapse) are not provided.

Statement is then made that first floor "*was about 24" above exterior grade*" without any explanation as to how such determination was made.

Without starting new paragraph to highlight key conclusions, the following two conclusion statements are made;

> *We believe chronic, long-term water penetration through the east side exterior wall led to the extensive deterioration and crumbling of at least one course of block probably over a wide area.*
>
> *We speculate that this disintegrating block gave way yesterday morning leading to several floor joists slipping off their supports and directly resulting in the catastrophic collapse of the building.*

- ➡ Yet, no evidence of "crumbling" or "disintegrating" block is provided.

- ➡ Specific description of events after block allegedly "gave way", resulting in total collapse of house, is not offered.

The following statement is then made (underlined in copy made available online) to reinforce conclusions;

> *We note that such an occurrence is consistent with a prior lack of evident structural distress (cracking, misalignment or bulging) in the superstructure.*

Paragraph 8 describes the following contention, without providing any references;

> *Block masonry, both historic and modern has been known to powder subject to constant wetness and particularly if subjected to frost-thaw action which a poorly insulated exterior basement wall would very likely have been.*

- ➡ Yet, no "powder" condition for any blocks from any foundation wall has been described.

*"Initial manufactured quality"* is then implied as latent potential defect, without providing even hint of evidence for such ambiguous claim.

Single-sentence Paragraph 9 then provides summarized conclusion;

> *In conclusion and with a reasonable degree of engineering certainty, we believe the proximate cause of the catastrophic collapse of 1804 South Broad Street was from the failure of deteriorated concrete block due to long term water penetration.*

No other examples of similar "deteriorated concrete block" for other houses is described by Mr. Busch, an engineer with long experience. Perhaps this was first time Mr. Busch had ever seen such condition.

## Evaluation of Report By Engineer For Municipality

- Overall conclusion is that quality of report by Mr. Busch is grossly deficient, such that entire report is without merit.

- Key claim, that "*initiating source must be located at or below the first supported level.*" is grossly incorrect.

Recollection of World Trade Center "pancake" collapse should be enough for any of us to understand that catastrophic collapse can be caused by failure from above.

Consideration must of course be given to small amount of time allowed for preparation of report. However, report of this nature should not have been issued without carefully checking and double-checking presentation, content and conclusions.

- Report by Mr. Busch should not have been issued without at least some discussion about consideration of other potential collapse scenarios, especially considering almost complete lack of information about framing conditions.

- Contention that, prior to collapse, there was no "*structural inadequacy or widespread deterioration of the wood framing or superstructure in general*" is without basis. Mr. Busch had no justification for glossing over this critical issue.

The following irregularities relative to report preparation and presentation indicate inadequate attention to quality which is then demonstrated throughout content of report;

- Lack of Certificate of Authorization number for Leonard Busch Associates (LBA)
- Lack of page numbers
- Failure to identify names, positions and qualifications of person or persons performing inspection activities.
- Failure to provide even basic description of property and surrounding conditions.
- Failure to provide basic reference information.

Repetitive use of collective terms "we" and "our", without describing any persons other than himself has having performed inspection or prepared report, might simply be habit of weak writing. However, such ambiguity also indicates attempt by Mr. Busch to exaggerate extent of effort by his firm.

- Most importantly, claimed cause for collapse ("disintegrated" block due to water exposure) makes no sense without supporting evidence, which was not provided.

- Much more likely causes of collapse have been completely ignored.

Instead of seeking cause of collapse, intent of report appears much more likely to have been attempt to exonerate municipality from potential liability.

“Common” Causes For House Collapse

Mr. Busch has not described any prior experience with evaluation of total house collapse events or any special knowledge obtained by courses of study.

Yet, he offers “variety of common problems” for “residential collapse”, including “termites”.

He then claims that cause for “catastrophic collapse” must be due to some failure “located at or below the first supported level”, which could have more appropriately been termed “first floor”.

- ➨ Mr. Busch fails to consider that initial collapse of roof or second floor could also have caused total collapse of house.

Exterior Brick Walls & Block Foundation Walls

Description of concrete block as “*truly made from sand, coarse aggregate and cement and little else.”* is apparently made to imply that such composition is not adequate, although no further explanation is provided to substantiate such bizarre claim.

- ➨ Implication that composition of concrete block was not adequate, without providing any evidence for such grossly flawed contention, demonstrates incredible lack of professional analysis for professional engineer.

Along with water, basic components for all concrete block, including currently-manufactured block, are fine aggregate (“sand”), coarse aggregate (stone) and cement.

Available photos and video (as seen online) show the following conditions;

- ❖ Exterior walls of two-story section were built with typical red brick, consisting of two layers (wythes) forming solid brick wall about 8-inches thick.

- ❖ Foundation walls of two-story section were built with concrete block having rough, textured exterior surface typical of “prewar” block from 1920s to 1940s.

- ❖ Inside surfaces of exterior walls were formed with thin wood “furring” strips nailed to inside face of brick wall, with interior finish (likely original plaster) installed on wood strips.

For such construction, base of each brick wall was supported directly on top of block foundation wall. This condition is seen in photos showing outside face of walls along first floor.

As seen in photos (Photo 204), concrete block (commonly & incorrectly termed "cinder" block) have two hollow cores (openings) through vertical height of block. Thickness of block is seen to be nominal 8 inches (7-5/8 inches actual) though no measurements have been reported.

Considering that first floor was about 7 inches above top of block foundation wall (Photos 3A, 3B), ends of first floor joists (reported as 9-5/8 inches deep by Mr. Busch) were likely supported directly on top of block foundation wall (perhaps with notch at end of joist), without wood sill plate, and were effectively embedded within base of brick wall. Hollow cores of top course of block foundation wall may have been filled solid with grout or concrete.

- ➡ Mr. Busch failed to discuss these important conditions.

Mr. Busch failed to report any observations of inside faces of foundation walls around basement.

Limited observations reported by Mr. Busch indicate that several block from upper 2 or 3 courses of block foundation wall were knocked off or away from wall during collapse.

- ➡ However, not nearly enough information about post-collapse conditions were reported by Mr. Busch (or any other observer) to reach conclusion about foundation wall conditions after collapse and about how any part of block walls were damaged during collapse.

Mr. Busch throws around terms including "powder" and "disintegration" to imply that blocks along top of east (right) foundation wall had been essentially destroyed and were nothing but dust even before collapse.

- ➡ Claim that concrete block along top of right-side foundation wall was disintegrated or had been turned to "powder" before collapse of house demonstrates incredible lack of sense. Such claim, without presentation of any evidence, is preposterous and not worthy of professional engineer.

Claim of disintegrated block condition is of course completely inconsistent with contention, as implied by claimed snapping of block face-shell with hand pressure, that blocks along one entire course of foundation wall suddenly broke in brittle failure mode.

Mr. Busch claims severe damage to block course that was essentially even (flush) with grade, not well below grade. Yet he fails to note that frequency of substantial water at grade is generally much less than water well below grade.

Drainage conditions around house and along foundation walls are not described.

As shown by weather data presented in this report, extensive rainfall had occurred in prior month, as well as during previous two days. There should not have been any surprise that, just prior to time of collapse, water infiltration would be found to have been occurring in basement.

Claim, by Mr. Busch, of long-term water infiltration is therefore not necessarily correct.

Long experience (by this writer) with evaluation of block foundation walls demonstrates that water infiltration occurs mostly near bottom of walls, where frequency of high water content in soil is of course much more likely.

- ➡ Likelihood that course of block at grade would have been severely damaged by water, to the point of being turned into "powder", while block lower down was not so damaged, is so unlikely as to be reasonably considered nonsensical.

However, even if face shells of several adjacent blocks had suddenly crushed or snapped, for whatever reason, there is no valid reason to then conclude an entire house supported by long brick walls and, most importantly, foundation walls that did not otherwise collapse, should essentially implode inward.

Any claim made to explain cause of collapse must be evaluated with reference to sequence of events and conditions to be satisfied.

Drawings or sketches to more clearly illustrate events are useful for understanding.

Evaluation of Claimed Cause For Collapse

If face shells for long length of block wall did suddenly break ("give way" per Mr. Busch) due to long-term deterioration from exposure to water, it would be much more likely (almost certain) that outer face shells would break, not inner face shells. Such condition would then cause base of brick walls to rotate outward, resulting (at least potentially) in outward lateral movement of upper part of brick wall with loss of support for second floor joists, not first floor joists.

This writer has observed several conditions, for "vintage" buildings in New Jersey and Pennsylvania, of outward movement of brick bearing walls at second floor level, most often caused by settlement or outward rotation of foundation wall. However, even for those buildings, walls did not suddenly collapse. Based on reports by owners, lateral movement occurred slowly, usually over several years (at least).

For this house, there is no evidence that any outward movement of brick walls had previously occurred. However, slight outward bowing is often not immediately obvious.

Severe damage to inside face shells for long length of right-side block foundation wall would (at least potentially) allow inward rotation at base of brick walls. However, inward lateral movement of upper part of brick walls would be prevented from occurring due to lateral bracing provided by second floor, which acts as diaphragm, spanning between front and back walls.

Brick walls have well-known capacity to span across (over) wall openings by arching action. Such capacity, often considered for design of lintels over door and window openings, is well documented in engineering texts. This capacity is also seen when new openings are cut in old brick walls for building alterations.

Due to ability of brick walls to arch (span) over localized area of damage (to brick wall or supporting foundation wall), there would not be any tendency for progressive collapse caused by localized crushing or breaking of inside face shells of block foundation wall. Any "collateral" damage would be restricted to immediate location where block wall was damaged.

Simultaneous failure of block face shells on outside and inside is unlikely. However, even such occurrence would also result in limited damage.

- ➡ There is no logical basis to conclude that limited damage to any part of any block foundation wall should result in catastrophic collapse of entire house.

## Analysis Of Collapse

Discussion in this section describes analysis to determine most likely causes of catastrophic collapse for this house.

Of course, limited information available at this time, more than four (4) months after collapse, limits ability to develop complete evaluation. However, enough information is available to perform significant analysis.

Importance For Correct Determination Of Collapse

Long experience has demonstrated that we often learn much more from failure than from success.

☑ Developing correct evaluation to determine cause of collapse for this house would result in knowledge that would then be applicable for evaluation of other similar houses, not only in Hamilton but also in other locations.

Risk Of & Potential For Progressive Collapse

For total collapse of any building, series of events must occur resulting in progressive collapse of several large-scale elements including walls, floors and roof.

In general, failure of common framing element, such as floor joist or wall stud, that supports relatively small amount of "tributary" load, results in local damage only. Remaining framing elements "pick up" load that had been supported by failed elements.

Experience during natural disasters (hurricanes, earthquakes), and man-made accidents (fires, impact from vehicles) shows that even failure of several adjacent common framing elements does not cause total collapse of house or building.

Failure of framing element, such as girder or column, that supports relatively large amount of load, has at least some potential to cause cascading effect that might result in large-scale damage. However, even failure of such elements does not usually result in total collapse of building.

Most important for successful evaluation of total-collapse event is careful analysis of sequence of events caused by failure of any one element.

- For this building, key issue is to determine reason that all exterior brick walls collapsed.

Collapse Potential of Brick Walls

In general, rectangular formation of masonry walls has inherent stability with walls forming box-type structure.

At corners, walls brace each other to prevent lateral movement.

Of course, any wall (or column) must not have excessive slenderness, typically defined as height divided by thickness. Adequate lateral bracing is essential, not only to resist lateral force but also for vertical load capacity. Without lateral bracing, slender compression element will fail in buckling, long before compression capacity is reached.

For buildings with masonry walls, including brick walls, floors and roof usually provide lateral bracing.

- ➡ Critical problem (“Achilles heel”) often found with brick-wall construction is lack of adequate connection between wood framing members and brick walls, such that there is not much resistance to outward lateral movement of walls.

For older buildings, wood floor joists are typically embedded into brick walls, without any specific connection. At times, and for various reasons, adhesion between brick and wood is destroyed and brick wall may bow outward. Such bowing or curvature has been known to increase slowly for a while and then suddenly increase rapidly, resulting in collapse of wall and supported elements.

For this house, there is no evidence that any brick walls were bowing outward prior to collapse. However, slight bowing is not always obvious.

Looking at front wall results in the following conclusions;

1. Large bay-window assembly at second floor level results in complete lack of continuity for brick between ends of front wall.

2. Narrow segment of full-height brick wall at each end of front wall provides relatively low capacity to resist; (1) In-plane wind force from roof or attic floor diaphragm, acting as shearwall, and (2) Outward thrust force from gable roof.

3. At front right corner, window near front end of right-side wall results in L-shaped corner of brick above second floor that is relatively small.

For further discussion, narrow brick wall segments at ends of front wall, above second floor, are designated BW201 (left) and BW202 (right).

For gable roof, due to large bay-window assembly, low ends of rafters supporting front slope had to be supported by header beam spanning between brick wall segments BW201 and BW202.

For further discussion, header beam supporting low ends of rafters for front slope is designated RB301.

Roof Configuration

Roof over front part (roughly 30 feet) of two-story section was symmetrical gable configuration with ridge running side-to-side. Moderate-size dormer was provided at center of front slope.

For gable roof, low edge of front slope was on and in line with narrow (short) brick segments of front wall. Low edge of back slope was over interior of second floor.

Monoslope roof over back part of two-story section sloped down gradually from low edge of back slope of gable roof to back of two-story section. This roof area was almost certainly supported by roof joists spanning side-to-side between side walls of house.

Support For Gable Roof – Front Slope

Based on photos after collapse, attic floor joists appear to have spanned side-to-side, perpendicular to rafters for gable roof. Low ends of rafters were then not connected to sides of attic floor joists, as is most often condition for modern gable roof construction.

For older wood-frame construction, low ends of rafters were sometimes supported on flat-board plate that ran across, and was nailed to, attic floor joists. If low ends of rafters were notched to fit over such bearing (support) plate, resistance to outward thrust force was usually substantial. However, when low ends of rafters were only toenailed to top of bearing plate, resistance to outward thrust force was much less.

With attic floor joists running perpendicular to rafters, bearing plate most likely would have been on top of header beam RB301.

If low ends of rafters were supported on bearing plate that was on top of header beam RB301, then outward thrust force would be applied directly to RB301.

Short rafter ties might have been provided, connecting RB301 back to attic floor assembly. However, there is no information showing such construction.

Side walls of dormer were likely supported on double-rafters, though it is also possible walls extended down to attic floor.

Support For Gable Roof – Back Slope

Low ends of rafters supporting back slope were mostly likely supported by interior crosswall on second floor. For further discussion, such crosswall is designated CW202.

However, it is possible that low ends of rafters for back slope were supported by beam (RB302) spanning side-to-side across full width of house or partly by interior crosswall and partly by header beam over area without crosswall.

If low ends of rafters for back slope of gable roof were supported on interior crosswall (CW202), then roof load applied to CW202 would have to be supported by; (1) Similar crosswall on first floor (CW102), (2) Beam (FB202) within second floor spanning width of house, or (3) Combination of crosswall and beam.

Crosswall CW102 would have to be supported by beam (FB102) within first floor spanning width of house, or transverse foundation wall in basement. For house built about 1920, such beam would likely have been double floor joist; design capacity is discussed below.

- ➡ Loss of support for crosswall CW202 could cause severe damage to interior of house, including collapse of entire gable roof, which might then easily result in rapid sequence of events resulting in total collapse of house.

Capacity of Gable Roof

As for any gable roof built with rafters (and without structural ridge beam), some form of resistance to outward thrust force must be provided at low ends of rafters.

Conditions at low ends of gable roof rafters are not known.

If attic floor joists were parallel to rafters, low ends of rafters might have been connected (with nails) to side faces of attic floor joists, as for typical modern-day construction. Low ends of rafters might also have been supported on flat-board plate, running across attic floor joists. For either method of construction, resistance to outward thrust force (and lateral movement) would likely have been adequate, especially for dead-load only conditions, unless roof leaks has resulted in severe wood decay at low ends of rafters.

However, if attic floor joists ran side-to-side, resistance to outward thrust force at low ends of gable roof rafters would have been potentially much more problematic.

Collapse Scenarios – General

Unless and until direct “smoking gun” evidence is found, there is often more than one potential scenario that might explain collapse of building.

As for any investigation, solution (as opposed to theory or claim) is valid only if it can explain all conditions or at least explain almost all conditions with only relatively minor unknowns remaining.

- ☑ Several potential collapse scenarios must be tested to provide thorough analysis.

For any claim to be considered correct for collapse of this house, the following key issues must be addressed and explained;

1. Collapse of brick walls for entire original house (Section 1)
2. Collapse of gable roof and monoslope roof
3. Collapse of attic floor
4. Collapsed position of front slope of gable roof out front and to right of position on house before collapse.
5. Collapsed position of monoslope roof well forward of position on house before collapse.
6. Collapse of second floor for entire house
7. Collapse of first floor in front two-thirds of house but not in back part of house.
8. Foundations walls remaining intact below grade
9. Top courses of foundation walls above grade knocked off lower foundation walls

The following collapse scenarios are described below;

| | |
|---|---|
| CS1 | Outward movement of gable roof rafters; front slope |
| CS2 | Wind pressure against long side of house |
| CS3 | Failure of beam RB301 due to vertical load |
| CS4 | Failure of beam RB302 due to vertical load |
| CS5A | Failure of beam in first floor (FB101) supporting walls that support back slope of gable roof. |
| CS5B | Failure of large area of first floor & lateral movement along base of brick walls. |

Description of CS5A & CS5B is not as complete as for other scenarios, primarily since likelihood of CS5A & CS5B is considered much lower.

Further investigation of elements currently within rubble would be required to develop more complete analysis.

Collapse Scenario CS1

- ➡ Any lateral movement of RB301, BW201 or BW202 had potential to result in (at least) total collapse of gable roof.

Overall horizontal span of gable roof, typically termed "roof span", was relatively long at about 30 feet. Roof slope (front & back) is estimated as 8 vertical to 12 horizontal.

Initial analysis of gable roof is performed for the following additional conditions;

- ❖ No interior supports for rafters
- ❖ Uniform weight of roof, including weight of rafters: 8 psf

For stated conditions of analysis, outward thrust force at low ends of rafters is 90 pounds per linear foot (PLF) along wall.

Dormer interrupts several rafters at center of roof. However, total roof load remains essentially the same as for roof slope without dormer. Concentrated loads are applied to RB301 instead of constant uniform (line) load. However, difference in analysis results is relatively small, such that uniform load on RB301 is considered.

Analysis is then performed for condition of low ends of rafters supported directly on RB301.

For RB301 taken as 12 feet long (between BW201 & BW202), constant outward lateral force at each end of beam is then about 540 pounds. Rafters supported on BW201 and BW202 also apply outward thrust force to top of wall segment.

- ➡ Even without snow on roof, outward thrust force applied to beam RB301 as well as narrow brick wall segments BW201 & BW202, would be relatively large.

Connection of RB301 to each supporting brick wall segment would then have to resist large outward thrust force. Method of connection is not known.

With uniform design snow load on roof, taken liberally as 16 psf, additional outward thrust force at low ends of rafters is 180 PLF, for total of 270 PLF (DL + Snow).

Outward lateral thrust force at each end of RB301 is then 1,620 pounds which could easily overwhelm not only connection to brick wall but brick wall as well.

More than likely, for entire life of building up to time of collapse, some condition with roof and attic floor construction must have prevented such large lateral force from being applied to top of BW201 and BW202.

However, over time, deterioration (due to roof leaks) or loosening (due to cycles of load, including wind force) of connections providing resistance to outward thrust force could have resulted in loss of resistance. Although it is possible such loss of resistance might have resulted in gradual outward movement, with signs of distress, it is also possible that loss of resistance might have occurred suddenly, without prior warning.

If side walls of dormer were supported on rafters, outward thrust force at low ends of such rafters would have been much greater than for single rafters.

- ➡ Sudden loss of resistance to outward thrust force from large gable roof could have easily caused lateral movement that would have allowed gable roof to flatten and collapse onto attic floor, causing “pancake” type failure of attic floor, second floor and first floor below.

- ➡ Small L-shaped brick wall assembly at front right corner, above second floor, could also have been easily broken by lateral force, resulting in lateral movement of entire roof assembly to the right and forward, as seen in aftermath of collapse.

Collapse of gable roof, attic floor and second floor could have easily caused collapse of first floor under front part of Section 1.

As previously noted, entire roof assembly appears to have twisted counterclockwise (looking down) and moved forward. This may be due to initial failure of brick walls (supporting gable roof) at front right corner. Such movement then could have resulted in lateral force applied to brick walls at back of Section 1.

For back part of Section 1, with total weight of collapsing elements being somewhat less (compared to front part of house), first floor was able to resist impact forces without also collapsing into basement.

Collapse Scenario CS2

In general, for box-type building without steel frame, wind force against building must be resisted by the following elements;

1. Exterior walls spanning vertically between floor and roof diaphragms.

2. Diaphragm elements (roof, floors) spanning horizontally between vertical shearwall (braced wall) elements.

3. Shearwall elements acting as cantilevers, supported on foundation walls, and transferring wind force to such foundation walls (and then to ground).

In general, although feasible, interior wood-framed walls tend not to provide substantial shearwall resistance, such that wind force must be resisted by exterior walls.

For rectangular building with length much greater than width, governing condition is for wind against long wall, which then must be resisted by short walls at each end of building, acting as shearwalls.

As previously discussed, for front wall of this house, the only brick walls that could provide shearwall resistance above second floor are narrow full-height brick wall segments (BW201 & BW202) at each end of front wall. In-plane wind shear force applied along top of front wall (by attic floor and roof diaphragms) must be resisted only by these narrow (short along wall) brick wall segments since wood-framed walls for bay-window assembly have no walls underneath (and stiffness of wood-framed walls is much less than brick walls).

Even though relatively short (about 24 inches each), BW201 and BW202 had at least enough shearwall capacity to resist wind shear force for entire life of building up until time of collapse. However, repeated cycles of wind may have resulted in weakening of mortar joints or weakening of connection between RB301 and brick walls.

As for CS1, any movement of brick wall segments BW201 and BW202 could have started progressive collapse for entire house. Small L-shaped brick wall assembly at front right corner was most at risk.

Collapse Scenario CS3

Details and conditions of support for header beam RB302 (if applicable) are not known.

However, RB302 had to support relatively large vertical load from rafters supporting back slope of gable roof.

Initial analysis of RB302 is based on the following conditions of analysis;

| | | |
|---|---|---|
| Span, RB302 | 15 feet | (between side walls) |
| Roof Span | 30 feet | (gable roof) |
| Span, attic floor joists | 15 feet | |
| Attic floor Dead Load | 10 psf | (wood subflooring) |
| Attic floor Live Load | 0 psf | (ordinary conditions) |
| Roof Dead Load | 8 psf | |
| Roof Snow Load | 0 psf | |

| | |
|---|---|
| Wood Framing | Douglas Fir, Grade 2 |
| Design Properties | Per NDS-2005 |
| Roof Support | No interior supports (within attic) |

For this analysis RB302 is considered to be built-up wood beam, consisting of two (2) joists having same size as first floor joists (9-7/8 inches deep by 1-7/8 inches thick, each).

For dead load (DL) only, vertical load on RB302 was then 210 PLF (pounds per linear foot), including weight of beam. Reaction force at each end of beam is 1,578 pounds. Design bending capacity was then 72-percent of required capacity. This load condition would not cause failure of beam.

- ➨ Adding 16 psf uniform snow load, design bending capacity of RB302 (9-7/8" x 3-3/4"), was only 33-percent of required capacity. Such level of stress could have at least caused cracking of beam.

Once RB302 was damaged, by heavy snow load on roof, by decay due to roof leaks or by any other cause, even ordinary load could eventually result in complete failure of beam.

Failure of RB302 would result in loss of vertical support for back slope of gable roof, followed immediately by total failure of gable roof. During initial downward collapse of back slope, front slope of gable roof would likely have pushed outward as ridge member fell downward, resulting in cracking of brick walls at front-right corner and similar cascading sequence of events for other collapse scenarios leading to total collapse of house.

If, instead of beam (RB302) at attic floor level, there was similar beam (RB202) at second floor level, under crosswall CW202, design bending capacity of RB202 would have only been 28-percent or required capacity.

Collapse Scenario CS4

Details of header beam RB301 are not known.

However, RB301 had to support relatively large vertical load from gable roof rafters.

As previously discussed, for this analysis, concentrated loads from rafters that might be supporting side walls of dormer are not considered. Uniform load from front slope of roof is considered, as if there were no dormer. Such model provides acceptable overall results for purposes of this analysis as long as dormer walls are supported on rafters. Otherwise, this model is not correct.

Initial analysis of RB301 is based on the following conditions of analysis;

| | | |
|---|---|---|
| Span, RB301 | 12 feet | (across opening for bay window) |
| Roof Span | 30 feet | (gable roof) |
| Span, attic floor joists | 15 feet | |
| Attic floor Dead Load | 10 psf | (wood subflooring) |
| Attic floor Live Load | 0 psf | (ordinary conditions) |
| Roof Dead Load | 8 psf | |
| Roof Snow Load | 0 psf | |

| | |
|---|---|
| Wood Framing | Douglas Fir, Grade 2 |
| Design Properties | Per NDS-2005 |
| Roof Support | No interior supports (within attic) |

RB301 was likely wood beam built-up from two (3) joists having same dimensions as reported by Mr. Busch for first floor joists; 9-3/4 inches deep by 1-7/8 inches thick, each.

Vertical load on RB301, for dead load only, is then 210 PLF (pounds per linear foot), including weight of beam. Reaction force at each end of beam is 1,263 pounds. For dead load (DL) only, design bending capacity was 112-percent of required capacity such that beam is adequate.

Adding 16 psf uniform snow load, and using Load Duration Factor of 1.15, design bending capacity of RB301 (9-3/4” x 3-3/4”) was 60-percent of required capacity. Such “overload” condition would not cause failure of beam.

However, it actual conditions resulted in greater overload condition, for example if wood had lesser strength or if roof leaks caused decay, risk of severe problems would have been much greater.

Failure of RB301 would result in loss of vertical and lateral support for gable roof, resulting in cracking of brick walls at front-right corner and similar cascading sequence of events leading to total collapse of house.

Potential Effects Due To Collapse of Block Foundation Wall

This writer has not found any reports showing that one or more block foundation walls for this house collapsed inward into basement. However, potential for collapsed foundation wall must at least be considered since even inward collapse of one side foundation wall would likely have caused total collapse of house.

Photos taken (by others) after collapse show front part of sign (billboard) missing, indicating potential for (at least) partial collapse of adjacent foundation wall. However, photos taken by this writer show foundation wall at front end of left side wall to be intact except for courses of block that had been above grade (Photos 202, 203).

At this time, due to obstructions remaining from extensive rubble, there is not enough evidence to reach any conclusion that any foundation wall collapsed inward.

For any basement below grade, foundation walls around basement must resist inward lateral pressure from soil against outside face of foundation walls. Major damage for block foundation walls due to excessive lateral soil pressure is well-known condition, observed by this writer for more than one thousand houses over many years.

Key factors causing damage to basement foundation wall are height of soil (“backfill”) against outside face of wall, type of material and thickness of wall. Major damage is generally found with block and brick walls.

For 8-inch thick block (or brick) foundation wall, current and former building codes specify maximum height of soil backfill to be 4’-0” above basement floor slab, without any special “surcharge” conditions that might increase inward force.

This house was of course built before any building code.

For this house, assuming vertical clearance under first floor joists was about 6-feet, height of soil backfill against foundation walls was about 5 feet, moderately greater than typical code limit.

Water content of soil against foundation walls was relatively high in weeks before collapse, due to relatively high frequency and intensity of rainfall. Increased water content of soil increases lateral soil pressure.

Wet basement conditions reported by Mr. Busch, along with lack of adequate drainage conditions as seen in photos, indicate that water was likely long-term problem for basement and foundation walls of this house.

Considering all relevant factors, including effect of wind against sign (discussed below), it is reasonable to conclude the following;

- At time of building collapse, probability that block foundation walls had already been cracked and pushed inward due to excessive lateral soil pressure was relatively high. However, there are no reports of any cracked foundation walls.

Although relatively rare, inward collapse of block foundation walls also occurs. This writer has been involved with several such collapse events, including one in Hamilton. However, for each foundation wall collapse seen by this writer, wood-framed house above remained standing, without any support from collapsed foundation wall. Wood-framed wall, acting as "deep beam", provided support for edge of first floor platform by spanning across long opening between remaining parts of foundation walls.

As previously discussed, brick walls have inherent ability to span over openings. However, capacity to span over relatively long opening is highly variable, depending on several factors that are difficult (at best) to evaluate.

Also, considering that brick walls are essentially continuous with foundation walls, movement along top of foundation wall tends to at least damage brick along base of brick walls. However, base of brick wall tends to provide greater lateral bracing for foundation wall compared to bracing from first floor only.

When basement foundation wall collapses into basement, soil ("backfill") that had been against wall also tends to slide into basement.

For this house however, there is no obvious evidence that soil outside either side foundation wall subsided or slid into basement along with collapsed foundation wall.

Potential Effect of Wind Against Sign

Ironically, truly unique feature of this house prior to collapse was large sign (billboard) along left side. Base of several angled wood braces appear to have been up against left-side foundation wall (near front end) or connected to vertical wood posts embedded into ground immediately adjacent to foundation wall.

Wind against sign resulted in repetitive cycles of lateral force that was transferred, through angled wood braces, against top of foundation wall (near front end), adding to constant inward lateral force from soil pressure.

Obvious patching mortar on inside face of foundation wall at front end of left-side wall (Photo 203) indicates that excessive inward force had occurred. However, again, foundation wall did not collapse inward.

First & Second Floor Framing

End of each first floor joist likely extended at least 4 inches onto block foundation wall.

Even if, for whatever reason, ends of several floor joists were to have suddenly moved downward by several inches, due to breaking of block face shells, there is no logical reason to conclude that such occurrence should cause total collapse of house.

As for any claim for collapse to be correct, claim that downward movement at ends of several first floor joists caused collapse of house must show, step-by-step, how such occurrence caused total collapse.

First floor joists were not supporting brick walls above. Therefore, even if ends of several first floor joists fell down to basement floor, which would be unlikely itself, there is no logical reason to conclude that such occurrence would cause any movement of brick wall above.

Second floor joists were not supported by wood-framed walls against inside face of brick walls. Therefore, downward movement of first floor joists would not have had any effect on support for second floor joists, which were supported on brick wall.

Complete loss of many first floor joists would result in loss of lateral support along top of foundation wall, almost certainly then allowing inward collapse of foundation wall. However, there is no evidence of any such occurrence.

First Floor Framing – Collapse Scenarios

Failure of first floor framing within interior of house could have caused sequence of events leading to total collapse of house.

With first floor joists spanning between side foundation walls, and without any girder providing intermediate support, the following sequence of events could have occurred.

Collapse Scenario CS5A

1. Beam in first floor (FB102) supporting crosswall CW102 (on first floor) collapses downward into basement.
2. Loss of support for CW102 results in loss of support for CW202 on second floor and low ends of rafters for back slope of gable roof as well as back ends of attic floor joists.
3. Collapse of gable roof and attic floor onto second floor causes collapse of second floor along with inward collapse of brick walls.

However, CS5A is not applicable if crosswall CW202 (on second floor) was supported by adequate beam (FB202) in second floor, or if beam at attic floor level (RB302) provided adequate support for low ends of gable-roof rafters.

Collapse Scenario CS5B

1. Large area of first floor collapses downward into basement.
2. Outer ends of many first floor joists pulled out of brick on one or both side foundation walls, resulting in loss of lateral support for top of foundation wall.
3. Inward movement along top of foundation wall (due to inward soil pressure) also causes inward movement along base of brick wall, resulting in collapse of brick wall on one or both sides of house, along with collapse of second floor and both roof areas (gable and monoslope).

For CS5B to be applicable, there must be some obvious reason that large area of first floor would collapse. Of course, if such collapse were caused by “pancake” failure of second floor, then some other collapse scenario is applicable.

Also, foundation walls would then almost certainly have to be at least tilted inward and very likely also collapse into basement. Since neither condition is seen to have occurred, potential that CS5B occurred is highly unlikely.

Analysis of First Floor Framing

For this evaluation, analysis of first floor framing is based on the following conditions;

| | | |
|---|---|---|
| Wood Framing | Douglas Fir, Grade 2 or similar | |
| Design Properties | Per NDS-2005 | |
| Condition | Good, without significant defects | |
| Uniform Dead Load | | |
| First Floor | 10 psf | |
| Second Floor | 10 psf | |
| Attic Floor | 7 psf | |
| Roof | 10 psf | |
| Uniform Live Load | | |
| First Floor | 10 psf | (ordinary conditions) |
| Second Floor | 10 psf | (ordinary conditions) |
| Attic Floor | 0 psf | (ordinary conditions) |
| Roof | 0 psf | (no snow load) |
| Floor Joist Spans | | |
| First Floor | 15.0 feet | (between side foundation walls) |
| Second Floor | 15.0 feet | (between side brick walls) |

Even 10 psf uniform floor live load is relatively high for ordinary conditions. More accurate value is on the order of 5 psf, especially over large area.

For conditions of analysis, first floor joists have much more than adequate design capacity to support uniform design loads on first floor only. Design bending capacity is 175-percent of required capacity.

For design live load of 40 psf specified by current building code (and other versions in modern times), design bending capacity is only 76-percent of required capacity. However, even this “overload” condition (if it were ever to occur) would not cause failure of joists. Of course, such design loading, which may never occur during life of building, is much greater than loading that occurs for ordinary conditions.

Second floor joists very likely spanned across width of house, similar to first floor joists, and were very likely the same size. Ends of second floor joists appear to have been embedded into brick walls. Therefore, only limited second floor load could have been applied to first floor joists (at interior walls). Due to load sharing of flexible joists, such condition was not any problem for first floor joists.

However, conditions along basement stairs must be considered.

Along stair opening in first floor (for basement stairs), and along stair opening in second floor (for stairs to second floor), ends of short floor joists are typically supported by "header beam" that runs along stair opening. Design capacity of such header beams, which are often just single members having same size as floor joists, is typically much less than required for full design loads specified by current and former building codes.

However, even greater problems tend to occur at ends of such header beams, due to lack of adequate support.

Of course, detailed information about header beam conditions just prior to collapse would be necessary to perform complete analysis. Such information is almost certainly not available now unless other inspections were performed by representatives of insurance company or other organization.

For houses of this type, stairs to second floor are typically above stairs to basement.

For such stacked-stairs configuration, header beam along basement stair opening (HB101) then also must support load from bearing wall (on first floor) that supports ends of short second floor joists along stair opening in second floor.

Without any intermediate support for first floor joists in basement, such as provided by girder and columns, failure of header beam HB101 (along basement stair opening) could have resulted in collapse of not only large area of first floor, but also corresponding large area of second floor above and perhaps even attic floor above that depending on configuration of attic floor joists.

Whether such failure of first floor, second floor (and even attic floor) would have then also resulted in collapse of high roof depends on support conditions for high roof rafters.

# Photos

The following photos are from online sources, with attributions noted in captions;

| | |
|---|---|
| Photo 101 | Aerial view of collapsed house (screenshot from video) |
| Photo 101A | Closeup from Photo 101 |
| Photo 102 | Aerial view of collapsed house |
| Photo 102A | Closeup from Photo 102 |
| Photo 102B | Closeup from Photo 102 |
| Photo 102C | Closeup from Photo 102 |
| Photo 103 | Front of collapsed house |
| Photo 104 | Edge of former attic floor |

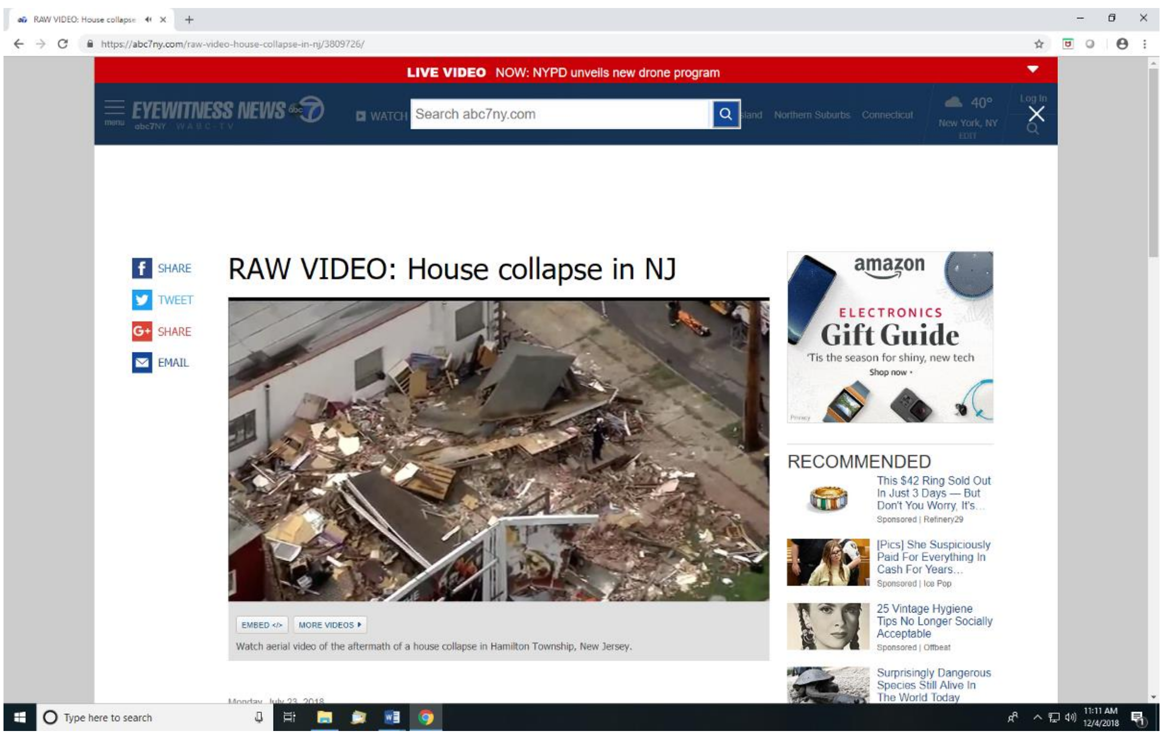



Photo 101 – ABC 7 New York
Aerial view of collapsed house, July 23, 2018

Photo 101A – ABC 7 New York
Front part of collapsed house.
Floor assembly at center of photo (mostly under former gable roof with dormer) appears to be former attic floor.
Attic floor joists appear to have spanned side-to-side across width of house.

Former back slope of gable roof is not seen and may have been moved during rescue operations. However, see discussion for Photo 102C.

Photo 102 – ABC 7 New York
Aerial view of collapsed house, looking towards South Broad Street.
One-story Section 2 that had been behind two-story Section 1 remains standing.

When looking down from above, roof over two-story Section 1 appears to have twisted counterclockwise and shifted forward.

Top of photo - Roof over dormer, along with former front slope of gable roof, are near sidewalk and adjacent to front of building at 1806 South Broad Street.
Bookshelf unit (with white top) is against wall of adjacent building; see Photo 102A.

Center of photo – White gutter still attached to back edge of former monoslope roof that had been over back part of two-story Section 1; see Photo 102B and Photo 103.

Front part of former large sign (billboard) has been destroyed, apparently by left-side brick wall falling outward.

Opening for access into basement seen adjacent to left side of one-story section (to right of one-story section in photo); see Photo 102C. In other videos, steel hatch door are seen in closed position over this opening.

Photo 102A
Closeup (zoomed in) of Photo 102 showing front of collapsed house.
Opening in dormer roof was made by rescue persons, as seen in other videos.

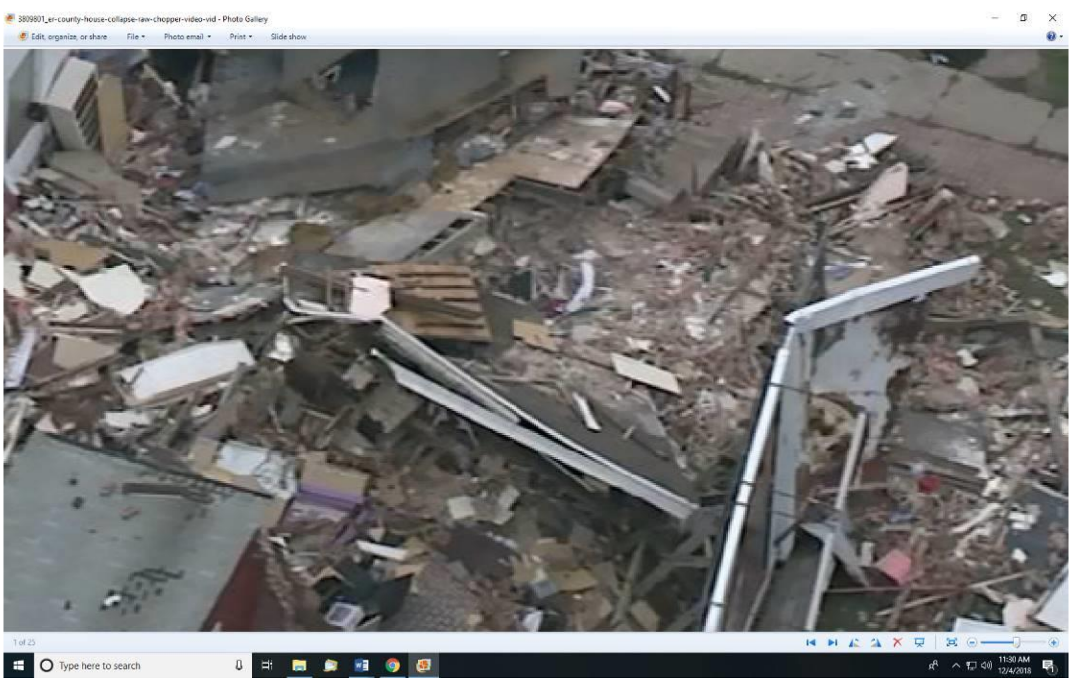


Photo 102B
Closeup (zoomed in) of Photo 102 showing center of collapsed house.

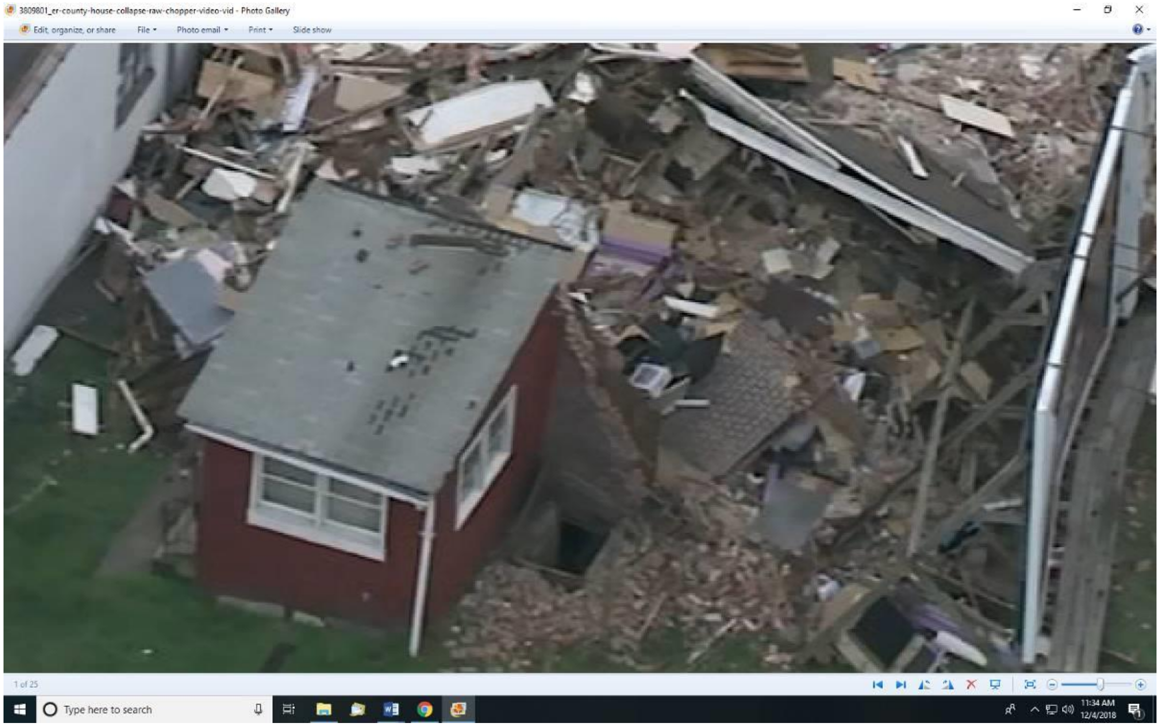


Photo 102C
Closeup (zoomed in) of Photo 102 showing back of collapsed two-story Section 1 and one-story Section 2 remaining.

Part of brick wall at back of Section 1 remains against and adjacent to front of Section 2.

Rectangular panel at center of photo, with apparent shingles, appears to be part of former back slope of gable roof. This panel may have been moved during rescue operations from position just after collapse. However, it might also be in this position due to sudden lateral movement (towards back of house) of back slope of gable roof.

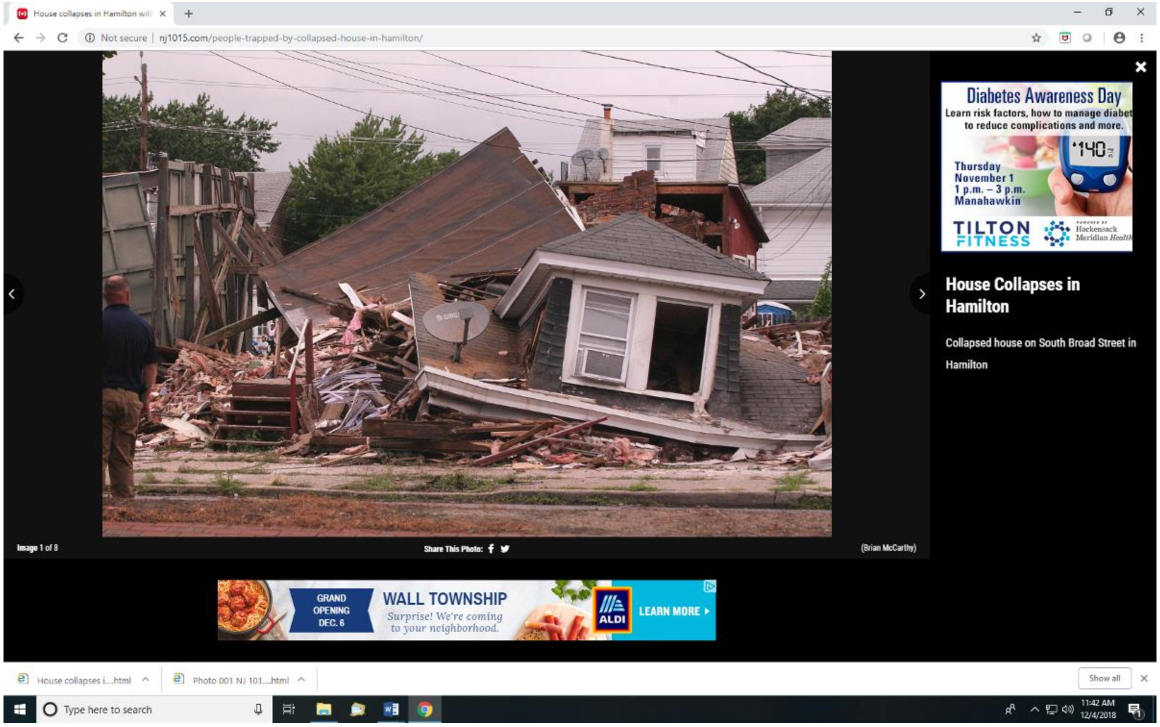



Photo 103 – NJ1015.com

Front view of collapsed house.

Foreground – Dormer on front slope of former gable roof.

Background, center of photo - Monoslope roof (with roll-roofing) that had been over back part of two-story Section 1, with former back right corner up high.

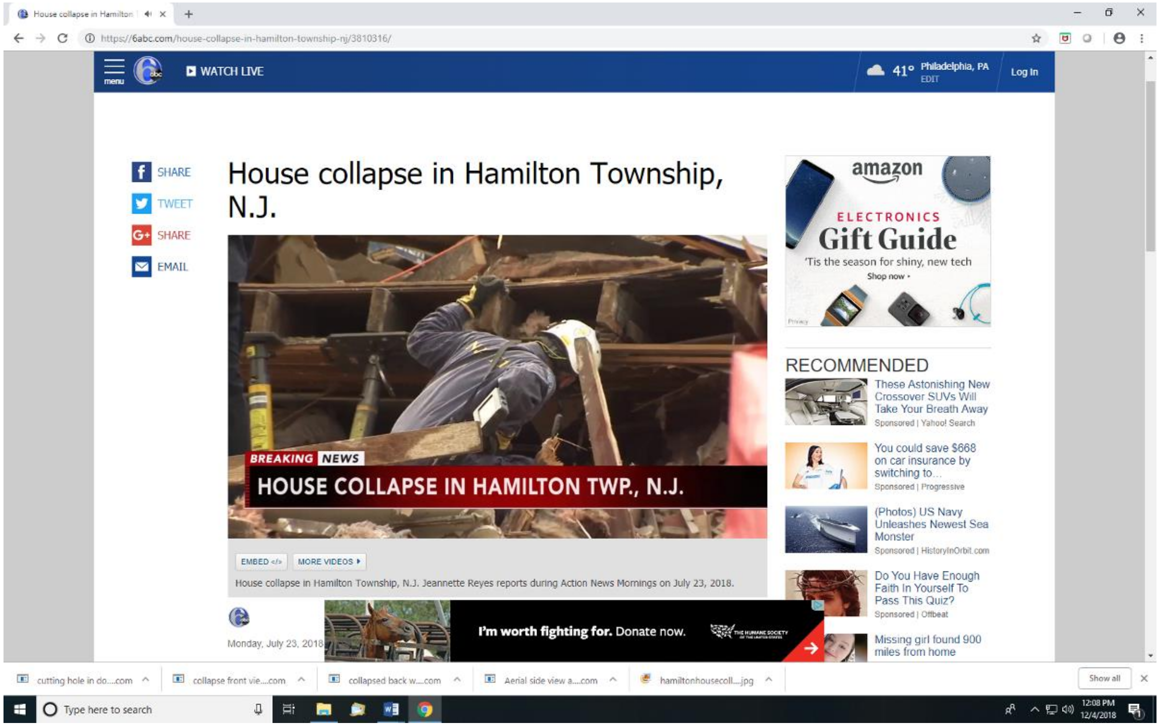



Photo 104 – ABC 6 Philadelphia
Ends of floor joists, which appear to be former attic floor joists.
Jacks to left of rescue person used to lift floor platform during rescue operations.

Photos 201 to 206 taken by John F Mann, PE during inspection of December 3, 2018.

Photo 201
Looking towards site of collapsed house from far side of South Broad Street.

Photo 202
Front of collapsed house.
First floor collapsed into basement.

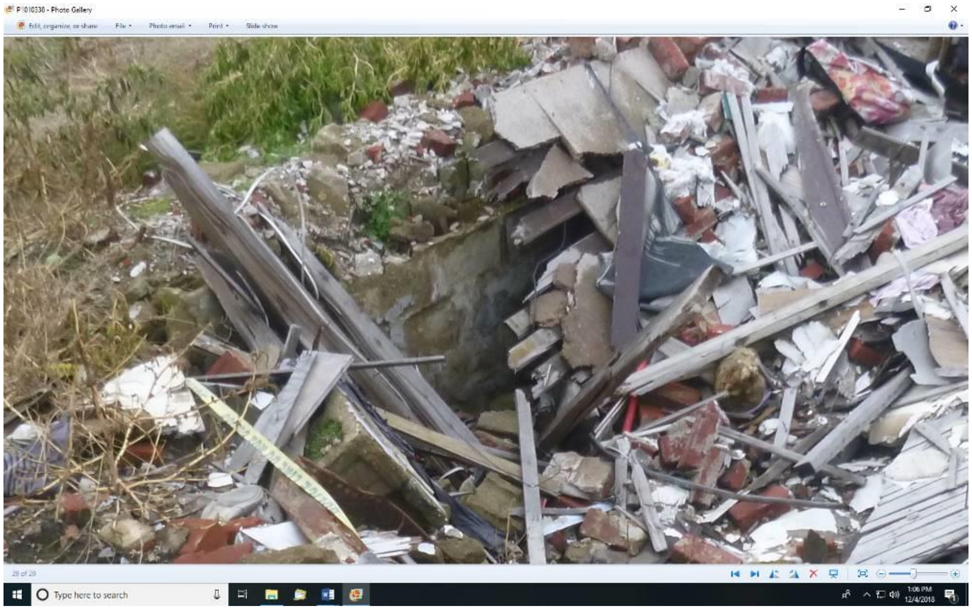


Photo 203
Remaining block at front end of left-side foundation wall.
Original courses of block that had been above grade are missing.
Gray patching mortar on inside face of block.

Photo 204
Top of photo – Concrete block, along top of remainder of front foundation wall, tilted outward. Block is otherwise in good condition.
This block is also seen in Photo 203.

Photo 205
Center of photo – Remainder of brick chimney (in former basement) and water heater (white, to right of chimney).

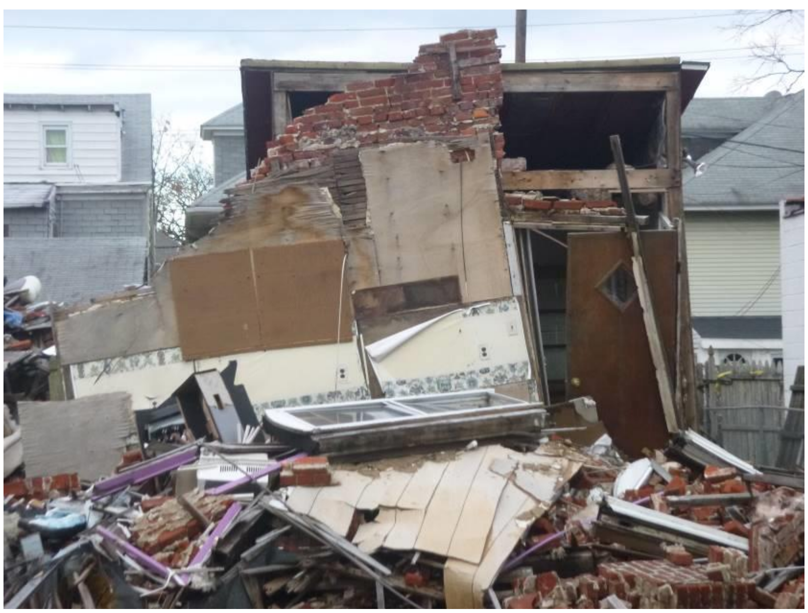


Photo 206
Reminder of brick back wall against front of one-story Section 2.