CASCADE ENGINEERING, INC

245 SE 4th Ave, Suite A
Hillsboro, OR 97123-4033
503-846-1131 fax: 503-846-1190

February 12, 2009

UTC Job Number 2405

Glenn Grogan
United Technical Consultants
PO Box 30
Phoenixville, PA 19460

Dear Mr. Grogan,

On February 2, you contacted our office and requested that we provide a structural engineer to inspect the insured's (dwelling/building) and perform the following:

SERVICES REQUESTED:

1. Inspect, take color photographs and list structural damages caused by flood.
2. Determine exactly how the flood caused the listed damages to occur.
3. Please comment on the extent of the damage from the flood.
4. Did the damages occur before, during or after the flood?
5. Offer opinion on what % of existing damage is due to this one event.
6. Offer opinion on what % of damage existed before the flood.
7. Did pre-existing damage contribute to flood damage and, if so, how?
8. Comment on whether damage is from velocity flow against the structure or settlement. If settlement, how was settlement caused?
9. Also comment if damage is from poor drainage, wind, bad construction, or other.
10. Conclusions must state what damage was caused by moving surface flood water and/or hydrostatic pressure. If none, please state that.
11. Recommend repairs to pre-flood condition for damage caused only by moving surface water and/or hydrostatic pressure

SITE OBSERVATION:

- Site visit was performed on February 6, 2009.
- Location: 3751 SR 4 West, Station #1, Grays River, WA 98621

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- In attendance at the inspection were Dmitri Wright PE (engineer), Eugene Strong (Fire Chief).

- The referenced location is a two story firehouse located adjacent to Grays River.

- The original building appeared to be 30 to 50 years old.

- The building is a conventionally framed, constructed on a concrete stem walls with a slab-on-grade first floor. The walls are 2X4 stud framed with a 2X6 mud sill. The exterior sheathing/siding is grooved plywood (T-111), and the interior sheathing is gypboard. The front of the building has 2 large roll-up door openings, leaving 3 tall narrow wall piers on that side of the building. The stem walls retain nearly four feet of the fill under the concrete floor slab.

- For the purposes of reporting, the front of the building is assumed to face North.

OBSERVATIONS:

- The first floor walls were visibly leaning to the west. This is consistent with the fact that the flood waters were flowing from east to west. (Photo #1) The deflection at the north end of the building was measured using a plumb bob at more than 2 inches.

- Some sheathing panels pulled away from the wall studs and the door trim was pulled loose. (Photo #2)

- The roll-up doors were popped out of their tracks (Photo #3 & #4).

- The concrete floor slab is cracked across the full width of the room. The crack width is on the order of ½ inch. (Photo #5) There is also a crack at the slab-stem wall joint. (Photo #6)

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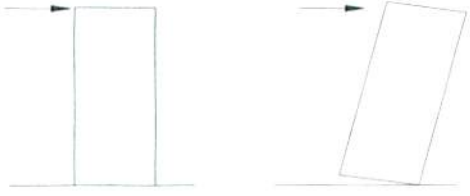
CONCLUSIONS:

Based on the above investigation and analysis and to a reasonable degree of engineering certainty, the following conclusions are provided:

- The structure was submerged to a depth of nearly 4 feet based on the high water marks on the building. Based on the pattern of damage, the building experienced hydrodynamic drag forces (velocity flow) as the flood water flowed from east to west.

- The lateral force on the building was resisted in shear by the north and south building walls. There were no significant interior walls at the first floor to resist the shear forces. The south wall is nearly solid with only a few small window openings, providing good shear resistance. The north wall has openings for the roll up doors leaving only 3 narrow piers to resist the shear forces. The piers did not appear to have any special nailing pattern for the sheathing nor did they have holdowns to resist uplift at the pier ends. The piers were noted as a weak point in the building structure in a 2001 structural condition report. They were reported to be in good condition at that time.
  The large shear forces in the piers pushed them out of square (shear deformation), buckling and pulling the nails out of the sheathing. This also caused the roll-up doors to pop out of their tracks. Once the flood water receded, the walls shifted back toward their original position, but some residual shear deformation remained, resulting in the walls at the north end of the building being out of plumb as observed at the time of the inspection. It was not possible to determine the maximum deformation of the walls during the flood, but it was very likely significantly more than the 2 inches observed later.



- While the building is, in my opinion, safe for temporary occupancy, the inadequate piers in their weakened state are cause for significant concern for the structural integrity of the building. If the piers experience significant shear forces again in the future, from a seismic, wind or flood event, they could collapse suddenly and catastrophically, leading to the complete collapse of the entire building.

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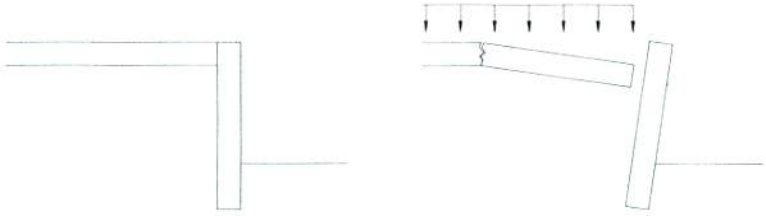
- The crack across the floor and the crack adjacent to the stem wall are likely related. The floor at the south end of the building is several feet above the outside grade. The concrete floor slab is bearing on fill, which is held in place by the concrete stem walls. As the flood saturated the soil supporting the stem walls and saturated the fill under the floor, the soil lost its strength. This resulted in increased outward lateral forces on the stem walls coupled with reduced resistance from the supporting soil. Additionally, the weight of the flood water on the floor slab added downward hydrostatic pressure on the slab and increased the outward forces on the stem walls. The outward lateral force on the stem wall caused it to rotate outward at its top, opening the crack at the joint with the slab. The movement of the wall allowed the fill to settle, leaving the slab unsupported. Without support, the slab cracked and settled.



- The damage to the floor slab was noted in a structural condition report in 2001. In my opinion, the damage was made worse by this flood event, and will likely continue to worsen over time as the fill continues to settle. While an annoyance, and unsightly, the damage does not threaten the structural integrity of the building.

Following is a list of the requested services with each point specifically addressed:

- *Inspect, take color photographs and list structural damages caused by flood.*

  See photographs #1 to #6. The structural damage observed included the building structure leaning, the exterior wall sheathing pulling away from the studs, and cracks in the floor slab.
- *Determine exactly how the flood caused the listed damages to occur.*

  The structure was pushed out of plumb by the hydrodynamic drag force (velocity flow) of the moving flood water. As the building leaned, the high shear forces in the north wall caused the sheathing to buckle and pull away from the studs. The cracks in floor slab were caused by the settlement of the saturated fill under the slab and the weakening of the saturated soil supporting the stem walls. The hydrostatic pressure of the flood water on the floor slab also contributed to the cracks.
- *Please comment on the extent of the damage from the flood.*

- The crack across the floor and the crack adjacent to the stem wall are likely related. The floor at the north end of the building is several inches above the adjoining grade. The concrete floor slab is bearing on fill which is held in place by the concrete stem walls. As the flood saturated the soil supporting the stem walls and saturated the fill under the floor, the soil lost its strength. This reduction increased the lateral forces on the stem walls coupled with reduced resistance from the supporting soil. Additionally, the weight of the flood water on the floor slab added downward hydrostatic pressure on the slab and increased the outward forces on the stem walls. The outward lateral force on the stem wall caused it to rotate outward at its top, causing the crack at the joint with the slab. The movement of the wall allowed the fill to settle, leaving the slab unsupported. When it was loaded, it has then cracked and settled.

- The damage to the floor slab was noted in a structural condition report in 1997. In my opinion, the damage was made worse by this flood event, and it is likely to continue to worsen over time as the fill continues to settle. While an annoyance, and unsightly, the damage does not threaten the structural integrity of the building.

Following is a list of the requested services with each point specifically addressed:

- Inspect and take photographs of all structural damages caused by flood.
  See photographs #1 to #8. The structural damage observed included the building's stem walls leaning, the exterior wall sheathing pulling away from the studs, and cracks in the floor slab.
- Determine exactly how the flood caused the listed damages to occur.
  The structure was pushed out of plumb by the hydrodynamic drag force (velocity flow) of the moving flood water. As the building moved, the high shear forces in the north wall caused the sheathing to buckle and pull away from the studs. The cracks in floor slab were caused by the settlement of the saturated fill under the slab and the weakening of the saturated soil supporting the stem walls. The hydrostatic pressure of the flood water on the floor slab also contributed to the cracks.
- Render an opinion on the extent of the damages from the flood.

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The visible structural damage was limited to the first floor walls at the north end of the building, including the north ends of the east and west walls which are out of plumb, and the floor slab and stem walls at the south end of the building.

- *Did damages occur before, during or after flood?*
  The structural damage to the walls happened during the flood. This is based on the fact that the doors were recently displaced, the sheathing damage was visibly fresh, and the piers were documented to be in good condition several years earlier. In my opinion, some of the structural damage to the floor slab occurred during the flood, but some of it was documented as existing several years earlier.
- *Offer opinion on what % of existing damage is due to this one event.*
  In my opinion, 80% of the structural damage to the piers occurred during this one event, and 40% of the structural damage to the floor was due to this one event.
- *Offer opinion on what % of damage existed before the flood.*
  In my opinion, 20% of the structural damage to the piers existed before this flood event, and 60% of the structural damage to the floor existed before this flood event.
- *Did pre-existing damage contribute to flood damage and, if so, how?*
  In my opinion, pre-existing structural damage did not contribute to the structural damage from this flood.
- *Comment on whether damage is from velocity flow against the structure or settlement. If settlement, how was settlement caused?*
  The structure was pushed out of plumb by the hydrodynamic drag force (velocity flow) of the moving flood water. The cracks in floor slab were caused by the settlement of the fill under the slab. The settlement was caused by the saturation and reduced bearing capacity of the fill soil.
- *Also comment if damage is from poor drainage, wind, bad construction, or other.*
  In my opinion, none of the structural damage is from poor drainage, wind, or bad construction.
- *Conclusions must state what damage was caused by moving surface flood water and/or hydrostatic pressure. If none, please state that.*
  The structure was pushed out of plumb by the hydrodynamic drag force of the moving (surface) flood water. In my opinion, 10% of the damage to the floor slab is from the hydrostatic pressure of the flood water on the slab.
- *Recommend repairs to pre-flood condition for damage caused only by moving surface water and/or hydrostatic pressure.*
  Repairs for the leaning north end of the building would require replacing all first floor walls that are out of plumb. The possible repair option to try to pull the structure back to plumb is unlikely to work

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effectively, and will cause more damage than it corrects. The replaced north wall piers should have sheathing on both the inside and outside, with adequate shear strength to resist the building code mandated lateral loads. The piers should also have holdowns at both ends to resist the overturning uplift caused by the building code mandated lateral loads.

These conclusions are based on preliminary and limited examinations and analyses. We reserve the right to supplement or amend these findings and/or opinions should new information become available.

Respectfully submitted,
Cascade Engineering, Inc.

Dmitri Wright, PE, SE
Consultant

Attachments: Photographs

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Photo #1. Roll-up door frames are out of square.

Photo #2. Shear deformation damaged sheathing and door trim.

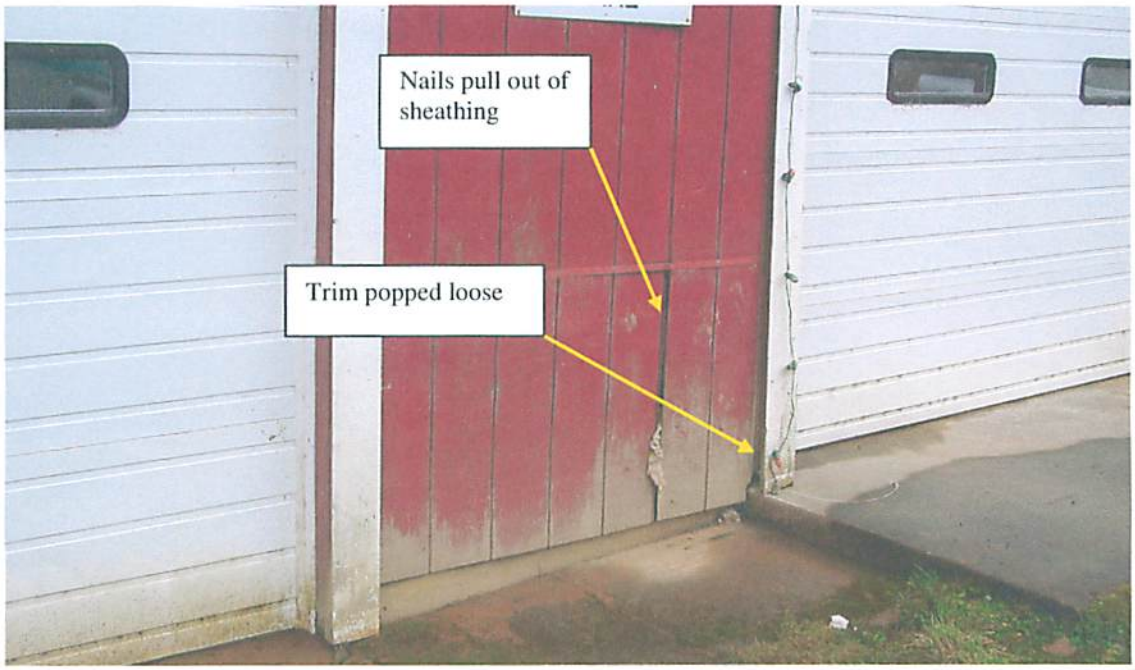

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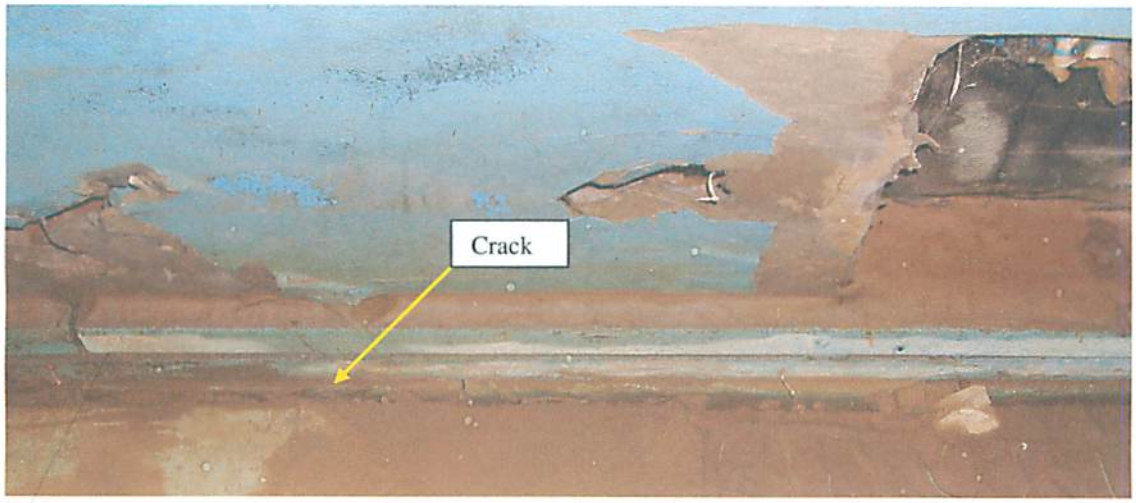
Photo #5. Crack in concrete floor slab is ½" to 1" wide.

Photo #6. Crack between stem wall and floor slab.



STEM WALL

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Photo #3. Shear deformation pulled the bottom east door corner out of track.

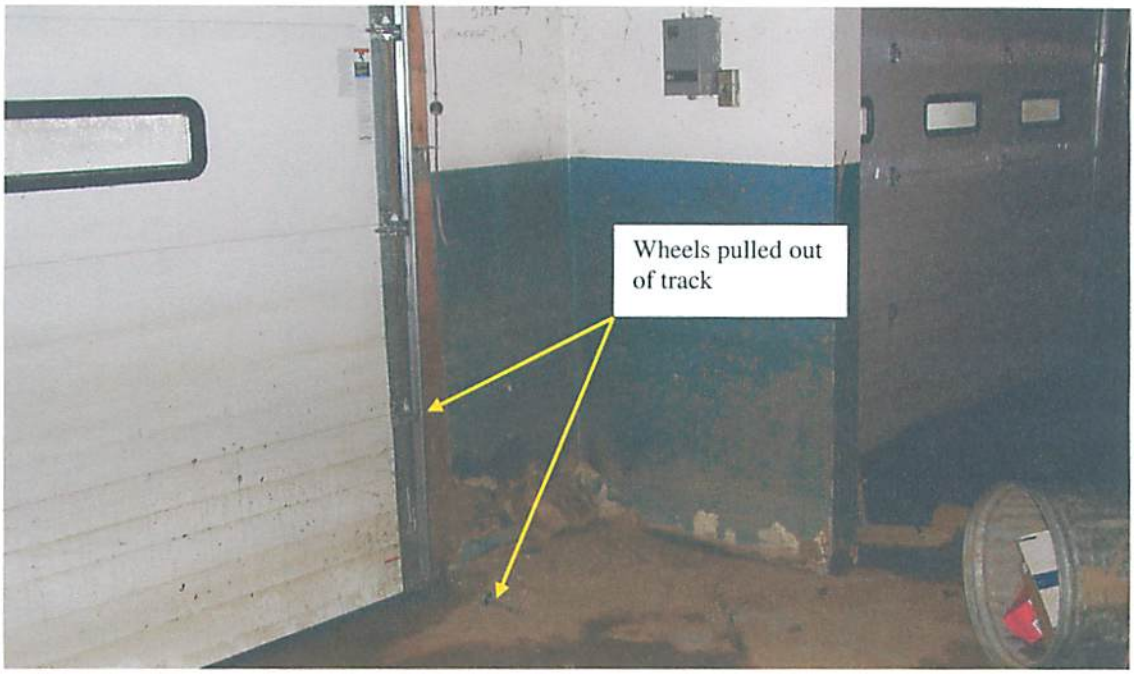
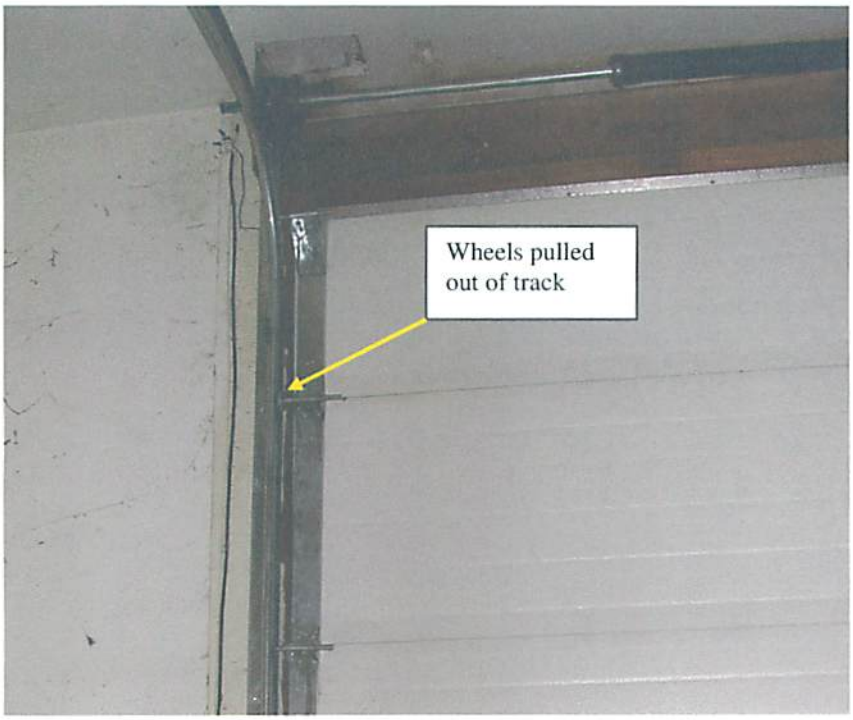


Photo #4. Shear deformation pulled the top west door corner out of track.



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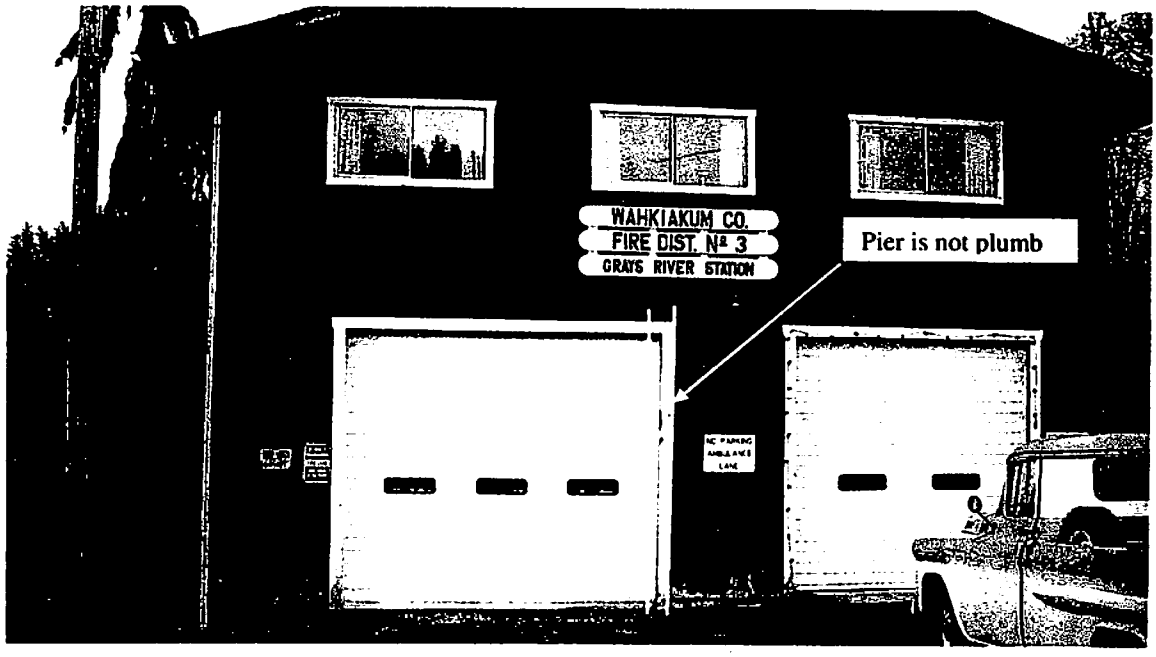
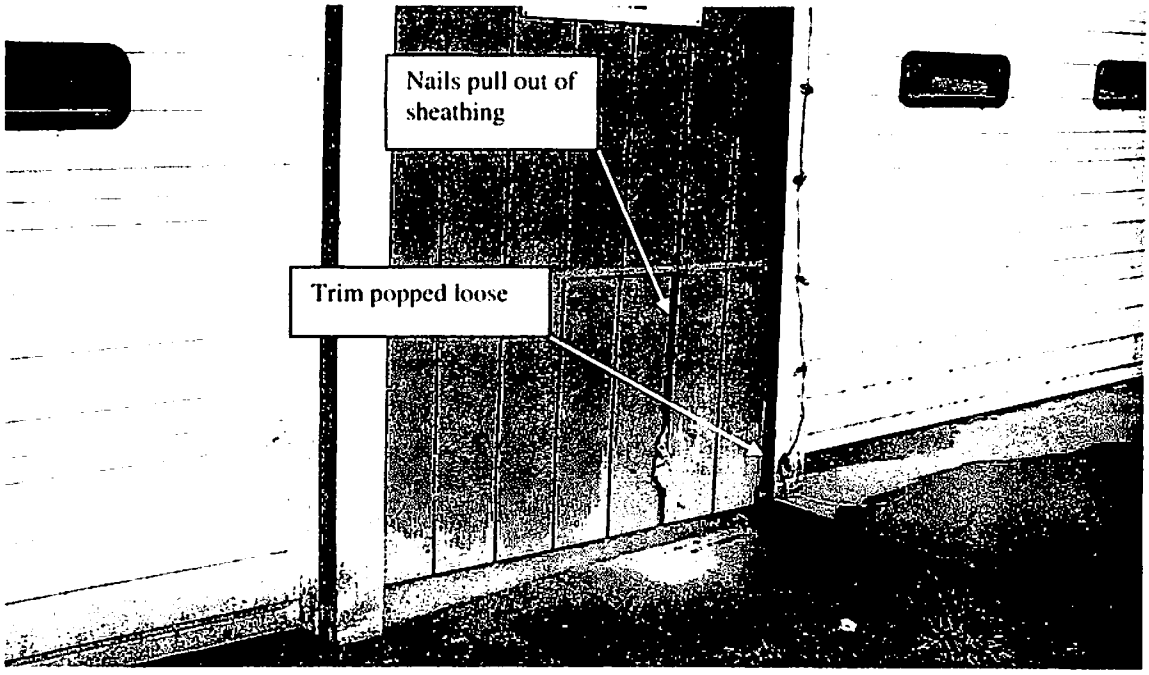


Photo #2. Shear deformation damaged sheathing and door trim.



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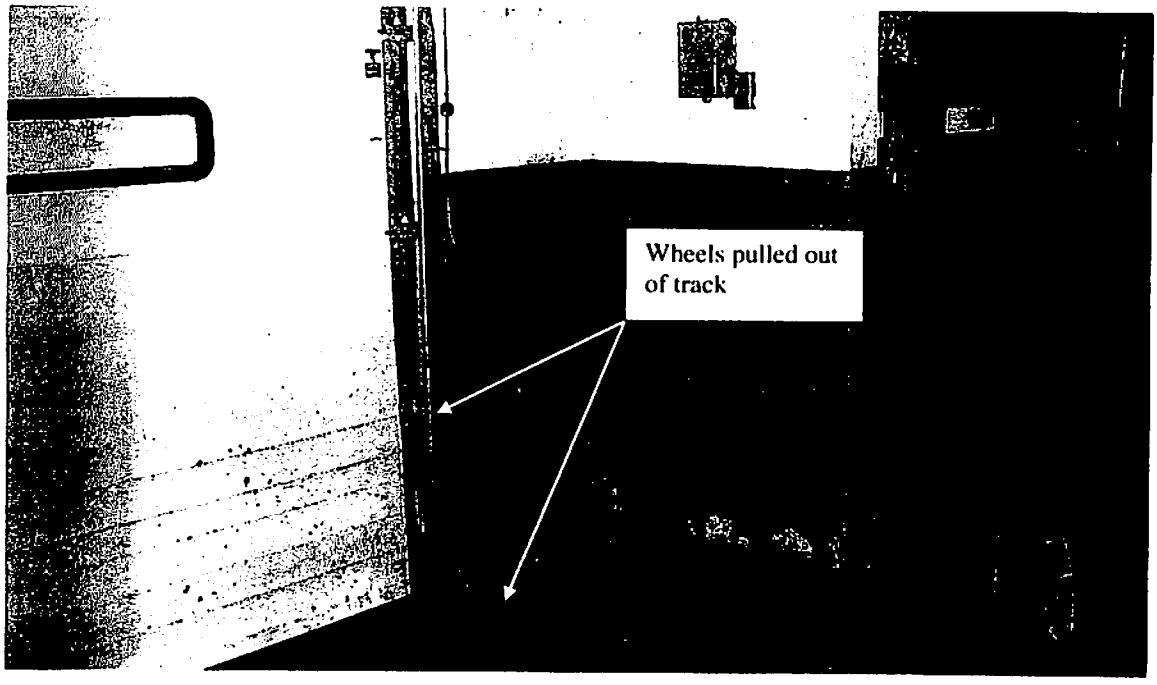

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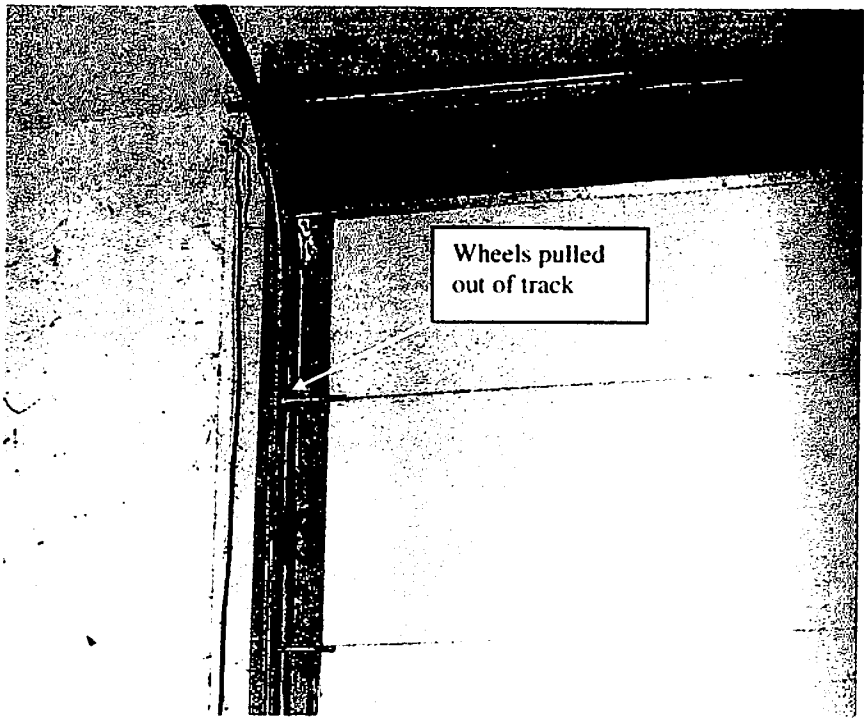

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Photo #5. Crack in concrete floor slab is ½" to 1" wide.

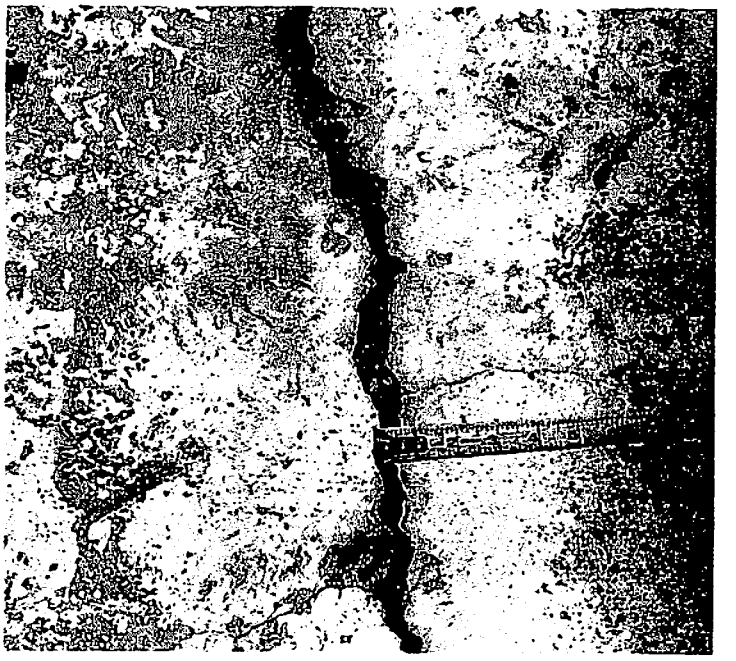

Photo #6. Crack between stem wall and floor slab.