BERGER/ABAM ENGINEERS INC.
700 NE Multnomah Street • Suite 900
Portland, Oregon 97232-4189
503/872-4100 • FAX 503/872-4101
www.abam.com

BERGER/ABAM
ENGINEERS INC.

PLANNING
ENGINEERING
ENVIRONMENTAL
PROGRAM MANAGEMENT

22 August 2008

G. Paul Wolf
Construction Project Manager
Washington State Department of Transportation
Aviation Division
3704 172nd Street NE, Suite K2
P. O. Box 3367
Arlington, WA 98223

Re: Woodland State Airport Hangar Review

Dear Mr. Wolf:

BERGER/ABAM Engineers Inc. was asked by the Washington State Department of Transportation (WSDOT) Aviation Division to evaluate alternatives for the three hangar buildings at the Woodland State Airport in Woodland, Washington. The purpose of this evaluation is to identify alternatives for hangar improvements to assist the state in their decision making process.

Three hangar buildings exist at the airport and were built between the 1950s and 1980s. These buildings house small single-engine aircraft and include space for up to fifteen airplanes. All three buildings are of wood construction with various modifications to their structure. The two oldest buildings (Buildings A and B) have currently been abandoned because of structural stability concerns and the third building (Building C) has been assessed as structurally deficient.

Our evaluation is based on a previous structural assessment of the buildings and knowledge gained from a site visit and walk-through of the hangar buildings. Our evaluation incorporates required building improvements as outlined in a previous report, building code and permitting requirements, estimated costs, rental cost recovery, and maintenance issues associated with the hangar buildings. Four alternatives are considered: (1) temporary improvements for the short-term use of the buildings, (2) renovation of the existing structures to ensure a life-safety level of the buildings, (3) removal and reconstruction of the buildings, and (4) demolition of the existing buildings.

PROJECT BACKGROUND

The WSDOT Bridge and Structures Office performed a structural examination of all three hangar buildings in early 2008. Their examination and conclusions are detailed in a May 2008 written assessment report and included in Attachment B. Numerous structural deficiencies were discovered including vertical and lateral load-carrying deficiencies for all three buildings and structural issues with the roof members and trusses, columns, foundations, and lateral load carrying elements.

Taking these deficiencies into account, the report concluded that, "Methods of original construction, modifications, and inadequate repairs over the years have created problems that in some cases greatly limit or reduce the structural capacity of the buildings." Further, "Observation and evaluation of the existing hangar construction indicates that all of the buildings are seriously limited in vertical, and/or lateral capacity, or are already beginning to fail."

Based on this evaluation, Hangar Buildings A and B were closed because of the observance of removed support columns and obvious sagging of the buildings. Conditions detailed in the report were observed as part of our site visit and building walk-through. The major components in the structural inadequacy of the buildings include the absence of columns, inadequate modification to the original load path of the building, and lack of lateral support for the structures

ALTERNATIVES

Based on the results and recommendations of the WSDOT Bridge and Structures Office's report, there are a number of alternatives available to remedy the condition of the Woodland Airport hangar buildings. Four alternatives were considered and evaluated.

- Alternative 1 – Temporary Improvements
- Alternative 2 – Renovation of the Existing Buildings
- Alternative 3 – Reconstruction of the Hangar Buildings
- Alternative 4 – Demolition of the Existing Buildings

The focus of these alternatives is on the hangar buildings themselves. Additional work may be required for environmental cleanup of the site and storm water management. However, a number of factors were included in the evaluation of these alternatives. Necessary improvements to the buildings were considered along with estimated costs, building code and permitting requirements, maintenance costs, and rental cost recovery.

In addition, Alternative 2 and 3 would require that a geotechnical investigation take place prior to the design of improvements. The proximity to the Lewis River causes concern for flooding, water table, and liquefaction of the site that would need to be addressed. The cost of this investigation was not included in the figures for this report, but would typically add $8,000 to $12,000 to both alternatives.

For any building project at the site there is the potential for additional permitting processes due to the nearby Lewis River. The proximity of the site to the river could require shoreline, floodplain, critical areas, and cultural resources permits as well as a permit from the state environmental protection agency. The requirement and cost of these permits is beyond the scope of this report and thus is not included in the cost estimates.

Alternative 1 – Temporary Improvements

Hangar Building A and B have been deemed uninhabitable because of inadequate modifications of the existing structure. The structure of Hangar Building C has also been modified to a point that is a cause for concern. These previous modifications could potentially be repaired to provide temporary improvement to the structures.

All repairs would be required to conform to the most current building code for the State of Washington and the City of Woodland. Currently the Washington State Building Code adopts the 2006 version of the International Building Code (2006 IBC) with some state-wide amendments. Construction of the improvements would require a building permit from the City's building department.

Improvements would be required to address the inadequate modifications previously made to the buildings, as well as all structural deficiencies outlined in the condition assessment report. This includes repairing or replacing columns and foundations, strengthening of the purlins that span between the roof trusses, repair of previous work done to the main building trusses, and improvement of the building's lateral force resisting elements.

These improvements are very extensive and the scope of required work and cost quickly approach that of the second alternative described below. Without these improvements, the buildings could suffer further damage from a heavy snowfall, large windstorm, or large seismic event, all of which are unpredictable and have the potential to occur in the near future. For these reasons, this alternative is considered inadequate in addressing the condition of the hangar buildings. It is recommended that the minimal level of effort would be that described in Alternative 2.

Alternative 2 – Renovation of the Existing Buildings

Because almost all structural elements are in need of repair or strengthening in the existing hangar buildings, and recognizing that all fixes would have to be permitted and designed per the current building code, the undertaking of repairs would quickly push the project to a full renovation.

To ensure the safety and operation of the three buildings, renovation work would include the installation of a code approved foundation system, replacement and strengthening of columns, strengthening of roof trusses and purlins, the addition of lateral-load carrying elements for both the roof and walls of the buildings, and a rework of the existing electrical system. This work would be further complicated if the buildings were to be designed, not as they were originally constructed, but in a way to accommodate the use of wide door openings for the airplanes. In this case, this option becomes a redesign of the existing buildings. The cost estimate includes this redesign because without increasing the door widths, the buildings are not usable as airplane storage.

All work done under this alternative would bring the buildings to the level of a building built per the current Washington State Building Code. City building permits would be required for all work done to the buildings. In addition, a geotechnical investigation would be required to address the potential for flooding and a high water table as well as the soil condition and the possibility of liquefaction.

Maintenance on a building that is fully renovated would be minimal and would most likely consist of typical yearly cleaning and maintenance as the renovation would include replacement of the metal siding and roofing. While this work would be very extensive, it would give the buildings an extended life and would ensure the life-safety condition of the buildings.

Alternative 3 – Reconstruction of the Hangar Buildings
The buildings could be razed and replaced with new hangar buildings. This work would involve the demolition of all three existing hangar buildings, as well as the slab-on-grade, and constructing new buildings that would be specifically designed for use as airplane storage and maintenance. Again, all construction would have to conform to the most current state building code and construction permits would be required from the City. A geotechnical investigation would need to occur as part of the design to address soil conditions, water table, and seismic characteristics of the soil at the site.

The new hangar buildings could use any of a number of different structural systems, but the least expensive would be a prefabricated metal building similar to those seen in other industrial locations. These buildings would be ordered, built by a prefabricator, and shipped to the site ready to be assembled by a local contractor. The local contractor would be responsible for the foundation and slab-on-grade, as well as erection of the metal building. These buildings tend to be very cost effective.

A fully enclosed prefabricated metal building is the best option for a new building as opposed to more conventional building methods or a simple shade port cover for the airplanes. The foundation system for an open-sided shade port becomes quite extensive, as the structure acts like a very large umbrella and is required to resist large wind loads. The maintenance of a prefabricated metal building would be minimal and would only require basic annual cleaning and inspection. It is likely that the construction of new buildings would also require the treatment of any storm water at the site.

Alternative 4 – Demolition of the Existing Buildings
The final alternative considered is that of simply demolishing the existing buildings. This is the least expensive of all alternatives. This alternative includes removing all three buildings, all building components, and concrete slab-on-grade. Some minimal landscaping would be needed for the former building sites. A demolition permit would be required from the City for this work, and the state would likely need to follow any requirements for recycling the materials of the building.

COST ESTIMATES
Estimated costs were prepared for the above described alternatives except for Alternative 1. These cost estimates were compiled using our experience with similar buildings, numbers received from suppliers and contractors, and cost data from R.S. Means' *Building Construction Costs* handbook escalated to a region-specific July 2008 price. Costs include the contractor's general conditions, overhead, and profit, as well as the owner's contingency, fees, and permits. Detailed cost estimates for each alternative are tabulated in the cost estimate spreadsheets in Attachment A.

The Total Costs for the alternatives are shown in Table 1.

Table 1 – Estimated Costs (1)

	Alternative 1 Temporary Improvements	Alternative 2 Renovation	Alternative 3 Reconstruction	Alternative 4 Demolition
Total Construction Cost (2)	(See Alt. 2)	$ 696,800	$ 718,500 (3)	$ 184,500
Rental Recovery Period	–	10 Years	20 Years	–
Monthly Maintenance Cost	–	$ 250	$ 250	–
Total Monthly Rental Recovery Cost (4)	–	$ 8,000	$ 5,400	–
Monthly Rental Recovery Cost Per Bay (4)(5)	–	$ 535	$ 360	–

(1) Dollar values are based upon July 2008 cost date
(2) Costs include overhead and profit and a 15% contingency
(3) Includes cost to demolish existing buildings
(4) Figures based on a 6% interest rate and include monthly maintenance cost
(5) Assuming a total of 15 rented bays

In addition to the construction costs for each alternative, these costs were translated to rental recovery costs for various time periods as designated by WSDOT. These figures are shown as a total monthly rental recovery cost figure, as well as a per hangar bay figure assuming 15 rented bays. These rental recovery figures are based on a 6 percent annual interest rate and are shown in Table 1.

Maintenance costs for each alternative were also considered. Alternatives 2 and 3 would have similar annual maintenance costs associated with the building. While not extensive, it would be expected that cleanup and inspection would involve the time of two people for two days per year. Given an estimated hourly rate of $90 per hour, it is anticipated that this annual maintenance fee would be approximately $3,000 per year or $250 per month. This cost would increase the rent of the hangar bays by around $17 per month assuming all 15 bays were rented.

RECOMMENDATIONS AND CONCLUSIONS

The three hangar buildings at the Woodland State Airport are in need of repair to ensure their continued safety and performance. The deficiencies of these buildings are outlined in a structural assessment performed by WSDOT and were evident during our site visit and walk-through. Any work performed in relation to these buildings will need to conform to the most current Washington State Building Code and will need to be permitted by the City. In addition, the proximity of the site to the Lewis River could require shoreline, floodplain, critical areas, and cultural resources permits as well as a permit from the state environmental protection agency.

Our evaluation included four alternatives in relation to the hangar buildings. Each alternative considered required building improvements, building code and permitting requirements, associated costs, rental cost recovery, and maintenance costs. The alternatives included temporary improvements, renovation of the existing structures, removal and reconstruction of the buildings, and demolition of the existing buildings.

The first alternative of providing temporary improvements was discovered to be very similar to the second alternative because of the extent of repairs and modifications needed for the buildings. Alternatives 2, 3, and 4 were examined and costs were estimated for each. Of the three alternatives, the fourth alternative of demolishing the buildings is the least expensive.

It is recommended that one of the three viable alternatives be chosen in order to address the structural deficiencies of the existing hangar buildings. Alternatives 2, 3, and 4 would all be equally sufficient to address the safety issues of the buildings.

We appreciate this opportunity to assist WSDOT in their decision making process. If there are any questions, please do not hesitate to contact me at 503/872-4117.

Sincerely,

B. S. Maxwell

BRIAN SCOTT MAXWELL
STATE OF WASHINGTON
42179
STRUCTURAL ENGINEER
PROFESSIONAL ENGINEER
8/21/08
EXP. 7/26/2010

Brian S. Maxwell, PE, SE
Project Engineer

BSM:llt

Attachments

- Attachment A – Cost Estimates
- Attachment B – Structural Examination of Woodland State Airport Letter Report

Attachment A
Cost Estimates

BERGER/ABAM
ENGINEERS INC.

PRELIMINARY CONSTRUCTION COST ESTIMATE

CLIENT	DATE:		ABAM PROJECT NO.:		
WASHINGTON STATE DEPT. OF TRANSPORTATION	8/11/2008		PAPOR-09-030		
PROJECT TITLE	**ESTIMATED BY:**		**DESIGN STATUS:**		
Woodland Airport Hanger Review	BSM		Planning		

DESCRIPTION	QUANTITY		PRELIMINARY EST.		
	QTY	UNIT	UNIT COST	TOTAL	
Alternate 2 - Renovation of Hanger Buildings					
Cost Per Bay (30'x40')					
Foundation					
Selective Demo Prep	240	SF	4.68	$ 1,123	
Strip Footings (12" x 24")	54	LF	36.40	$ 1,966	
Pad Footings (4' x 4')	10	EA	383.02	$ 3,830	
4" Slab on Grade, Wire Mesh Reinforcement (30% of Hanger Ba	360	SF	5.20	$ 1,872	
Framing					
Shear Wall Framing (2" x 6" @ 16" O.C.)	648	SF	1.50	$ 972	
Shear Wall Sheathing (1/2" Plywood)	513	SF	1.56	$ 799	
Columns (4" x 4" x 15')	210	LF	4.59	$ 963	
Siding (Galvanized Corrugated Steel 30ga)	1330	SF	3.66	$ 4,873	
Roof					
Roof Truss Rehab	1264	SF	1.25	$ 1,580	
Roof Sheathing (1/2" Plywood)	1264	SF	0.91	$ 1,155	
Roof Purlins (2" x 12" @ 16" O.C.)	1264	SF	3.48	$ 4,395	
Strapping and Connections	1264	SF	0.75	$ 948	
Felt (30#)	2	SQ	12.72	$ 25	
Roofing (Galvanized Aluminum 29ga)	1264	SF	2.49	$ 3,149	
Electrical					
Electrical (1/15th of Unit Cost for 100A Service Panel/Building)	1/15	EA	6,400	$ 427	
Miscellaneous					
Framing and Foundation Modifications to Allow for Wider Doorwa	1	EA	8500	$ 8,500	
			Subtotal	$ 36,578	Per Bay
Total for All Bays	15	EA	36,577.55	**$ 548,663**	
Permitting & Engineering			7%	$ 38,406	
Mobilization & Demobilization			5%	$ 27,433	
Contingency			15%	$ 82,299	
			Total	**$ 696,802**	

BERGER/ABAM
ENGINEERS INC.

PRELIMINARY CONSTRUCTION COST ESTIMATE

CLIENT	DATE:	ABAM PROJECT NO.:
WASHINGTON STATE DEPT. OF TRANSPORTATION	8/11/2008	PAPOR-09-030
PROJECT TITLE	**ESTIMATED BY:** BSM	**DESIGN STATUS:** Planning

DESCRIPTION	QUANTITY		PRELIMINARY EST.	
	QTY	UNIT	UNIT COST	TOTAL
Alternate 3 - Reconstruction of Hanger Buildings				
Demolition	1	EA		$ 149,712
New Hangers (18000 SF)				
Pre-fab Steel Frame, Metal Roof and Siding)	18000	SF	14.07	$ 253,260
Strip Footings (12" x 24")	18000	SF	2.48	$ 44,655
4" Slab on Grade, Wire Mesh Reinforcement	18000	SF	5.20	$ 93,600
Electrical (100 Amp Service Panel per Building)	2	EA	3,200	$ 6,400
Civil/Site Improvements	1	EA	18,000.00	$ 18,000
			Subtotal	**$ 565,627**
Permitting & Engineering			7%	$ 39,594
Mobilization & Demobilization			5%	$ 28,281
Contingency			15%	$ 84,844
			Total	**$ 718,346**

BERGER/ABAM
ENGINEERS INC.

PRELIMINARY CONSTRUCTION COST ESTIMATE

CLIENT	DATE:	ABAM PROJECT NO.:
WASHINGTON STATE DEPT. OF TRANSPORTATION	8/11/2008	PAPOR-09-030
PROJECT TITLE	ESTIMATED BY:	DESIGN STATUS:
	BSM	Planning

DESCRIPTION		QUANTITY		PRELIMINARY EST.	
		QTY	UNIT	UNIT COST	TOTAL
	Alternate 4 - Demolition of Hanger Buildings				
	Hangers A, B and C				
	Building Demolition, Wood Framed	208320	CF	0.16	$ 33,331
	Demolition, 4" Slab on Grade, Wire Mesh Reinforcement	17360	SF	4.68	$ 81,269
	Demolition Disposal, Wood Framed (Loading and Hauling)	550	CY	18.84	$ 10,362
	Dump Fees	550	CY	45.00	$ 24,750
	Landscaping	18000	SF	0.05	$ 900
				Subtotal	**$ 150,612**
	Permitting & Engineering			2.5%	$ 3,765
	Mobilization & Demobilization			5%	$ 7,531
	Contingency			15%	$ 22,592
				Total	**$ 184,499**

Attachment B

Structural Examination of Woodland State Airport Letter Report

Washington State Department of Transportation
Paula J. Hammond, P.E.
Secretary of Transportation

Transportation Building
310 Maple Park Avenue S.E.
P.O. Box 47300
Olympia, WA 98504-7300

360-705-7000
TTY: 1-800-833-6388
www.wsdot.wa.gov

May 12, 2008

Mr. John Sibold
Director of Aviation
Aviation Division WSDOT
P.O. BOX 3367
Arlington, WA 98223

RE: Structural Examination of Woodland State Airport

Dear John:

At the request of Paul Wolf, I visited the Woodland State Airport in Woodland Washington, on Thursday, April 17, 2008. The purpose of the visit was to examine the three existing hanger structures for their current condition and structural adequacy. Mike Smith, from our office and you were present at the time of my visit.

You should understand that this report and the conclusions contained herein are the results of a visual examination of the property. No calculations, measurements, test, etc. other than those described below have been made. No interior finishes were removed, and no demolition or excavation was conducted to locate hidden areas of damage. As a result, the report and its conclusions are circumscribed by the inherent limitations of the methods used.

Building Descriptions

The primary structures at the woodland airport consist of three separate buildings with interior separated hangar stalls that are leased out to private individuals for the purpose of aircraft storage. Buildings A and B contain hangar stalls 1 through 8. Building C contains hanger stalls 9 through 12. The front hangar openings are all typically 40' wide to accommodate the aircraft wingspans. Individual hangers have had numerous and various modifications and repairs to include additions of doors, interior enclosures and storage mezzanines made to them by individual tenants over the lifespan of the building. (See Site Map)

Buildings A and B are located end to end on the east side of the airfield and may or may not have been constructed at or about the same time, but appear to be approximately more than 30 years old. Building A is 32' wide x 120' long. Building B is 32' wide x 160' long. Both buildings measure 14-1/2' to the gable peak with 9-1/2' walls. Each building has a pole frame type construction with three post lines supporting a gable-truss type, wood framework that was constructed to be post supported at the center as well as the front and rear post lines. Roof purlins consist of 2x6 members at 2' to 2'-6" on center single spanned up to 20' with a galvanized corrugated metal roof. The exterior posts generally consist of creosote treated double 3x6 members and interior posts consist of pressure treated 6x6 members. The posts are embedded into the ground and are situated at an alternating 10' and 20' on center spacing with the exterior post lines enclosed by galvanized corrugated metal siding. (See Photos #1 and #2)

Building C is located on the west side of the airfield and appears to have been constructed in the early to mid 80's; measuring 30' wide x 280' long, with 14-1/2' to the gable peak and 9-1/2' walls. This building also has a pole frame type construction with three post lines supporting double pre-manufactured trusses situated at an alternating 12' and 16' on center spacing. The roof purlins consist of 2x6 members single spanned up to 16' at ±2'-6" on center with a galvanized corrugated metal roof. All of the posts generally consist of pressure treated 6x6 members embedded into the ground with the exterior post lines enclosed by galvanized corrugated metal siding. (See Photo #3)

Structural Observations

Buildings A and B have been typically modified at the hangar bay openings by removing exterior supporting posts to accommodate the required bay openings. A few of the hangar bay openings have door systems of different construction installed and many others are open to the elements. In some locations, replacement 4x4 posts were installed with hinges at the exterior truss bearing point to apparently allow the post to be moved up out of the way and then returned to a supporting position. However, each of the posts installed in this manner have been tied up in the open position and provide no support. In a few locations, the original posts have been cut off above the ground and spliced to replacement posts. In building A, all of the hangar openings and missing posts are located along the west wall line. In building B, the hangar openings and missing posts are alternated between the west and east wall lines. (See Photo #4)

The gabled, wood framework supporting the roof joists generally consist of creosote treated 3x6 wood members framed into the interior bearing post from each side and connected at the eaves to form a truss type configuration. At locations where the exterior post was removed or modified, the tails of the truss- type framework is cantilevered out 16' with a 16' back span. An intermediate vertical member is present at each side near mid-span and a diagonal member is typically installed on the cantilevered side. Connections at the tails and panel points vary, but generally consist of plywood gusset plates at one or both sides with 3/8"-1/2" through bolts and varied nailing patterns. Many interior panel connection points for the vertical and diagonal members have no gusset plates or obvious connection. (See Photo #5)

In several areas the truss type frame work has been modified further with additional vertical and diagonal scab members and or strapping in various configurations to provide additional rigidity. On the cantilevered end side of the framework, additional diagonal knee braces have been installed in various configurations. These braces typically consist of single or double 2x6's attached to the interior post and out to near mid span of the framing. These connections also vary with through bolts in some locations and minimal nailing in others. Many of the installed knee braces are buckling out of plane up to 1" or more and several nailed connections are beginning to separate. At a few locations, 1/2" steel tie rods with angle clips, between the top and bottom chords, were installed in place of knee braces. The angle clips are bending slightly and crushing at the back of the through bolt connection. (See Photos #5 and #6)

On the exterior of the building, obvious and excessive deflection is evident at the ridge roof line and along the eaves, but most predominant at the hangar bay openings where the roof framing is cantilevered. Obvious sagging can be seen with a measured downward deflection of up to 2-1/2". Many of the rim joists are scabbed and spliced in these areas. In building A, hangar 2, sagging roof purlins have been reinforced with an intermediate truss running between the framing over the post lines and the sag in the roof is still apparent. (See Photo #7)

In building B, hangar 4, an interior post has been cut just below the roof framing support. Support for the cut post has been provided by a steel W4x13 steel member that is spanning 30'. This is a cantilever support location for the roof framing. The steel member is deflecting downward 3", outward 1-1/2" and is bearing at each end over scabs nailed to existing posts. Connections at the bearing points consist of bent over 16d nails and there is no noted connection to the cut post above. (See Photo #8)

Galvanized metal siding and roofing has been cut away and or replaced in several areas with varied degrees of connection. Wall siding, in the areas present, is typically supported with 2x6 wind girts at 2'-6" to 3' on center. No obvious clips or connections to provide for resistance against wind uplift were noted.

Building C has been typically modified at the hangar bay openings by removing or omitting exterior supporting posts to accommodate the required bay openings. A few of the hangar bay openings have door systems of different construction installed and many others are open to the elements. In at least one location, a 4x4 post was installed with a hinge at the exterior truss bearing point to allow the post to be moved up out of the way and then returned to a supporting position. Again, the post has been tied up in the open position and provides no support. In another location 2x6 knee braces were installed in the line of the door opening from the existing posts up to the rim joist. All of the hangar openings and missing posts are located along the east wall.

Roof joists, on a 2'-6" on center spacing, span up to 16' between lines of double pre-manufactured trusses and sheathed walls. Trusses generally consist of 2x6 top chords with 2x4 bottom chords and web members that are connected at panel points with pressed plates. At hangar bay openings, the trusses bear at the rear wall and at nailer blocks to the interior posts, but cantilever up to 15' out to the hangar bay openings. Vertical web members at the center of the trusses also appear to be nailed to the interior post. No lateral truss bracing is present. (See Photo #9)

Interior partition walls have been sheathed and are supported with 2x6 wind girts at 2'-6" on center. Framing above the interior walls, up to the roof purlins, appears to consist primarily of plywood sheathing up to a 2x6 rafter running approximately 15' from the ridge down to the eave. At locations where the exterior posts were removed or omitted, the tails of the trusses have been reinforced with wood blocking in some areas and small plywood gusset plates.

In hangar 13, wood framed storage mezzanines have been constructed at each side of the bay running from the front to the rear wall and are accessed by ladders. On the south side of the bay, there is an enclosed storage or office space supported by the mezzanine. Framing for the mezzanines consists of 3/4" plywood over 2x6 and 2x6 rough sawn members spanning up to 15' between wall lines and wood beams. The beams are attached to the existing posts with field bent Simpson Strong Tie brackets. (See Photo #10)

Exterior wall siding is typically supported with 2x6 flat wind girts at 3' on center. Roof purlins are attached at the trusses with joist hangers and all other connections of trusses or wind girts to posts appear to be made directly with nailed connections.

Discussion

The structures at the woodland airport consist of three separate buildings with slightly different methods and materials in construction, as well as various states of repair. However, all of the buildings are essentially constructed as pole supported structures with posts designed to be embedded into the ground. Typically, this type of framing requires that the posts and connections to the posts transfer and carry both, vertical roof loads with snow, and lateral loads due to wind and earthquake. Any diaphragm capacity in the corrugated metal roofing or shear wall type resistance in the metal siding is very minimal. Wall framing will typically carry its own weight, but must be designed to resist wind loads out of plane.

This is a light weight type of framing with a comparatively small amount of dead load from the structure itself. As a result, seismic forces on the structure, based on the building framing and interior partition walls, are not large compared to other types of framing. However, the configuration, lightweight nature and use of the structure make it very susceptible to high wind loads.

The individual hangers have had numerous and various repairs and modifications to include additions of doors, interior enclosures and storage mezzanines. To accommodate the wingspan of aircraft, modifications to remove or omit supporting posts from the construction have been made. Additionally, several remaining posts have been cut out just above the ground and replaced with splice connections.

Removing or omitting the posts has impacted the structures by reducing the capacity to carry vertical loads safely and to resist lateral loads applied to them. Cutting out and splicing posts has further reduced lateral resistance to wind or earthquake loads. Additionally, the construction of interior enclosures and mezzanines attached to the building has further increased the effect of seismic forces on the structure.

A previous site examination and calculations from May of 2002 indicate that the roof framing at structures A and B was determined to be overstressed in both bending and allowable deflection.

Buildings A and B are the older two of the three structures and are in a poor state of repair. The numerous modifications have compromised the ability of the structure to safely support required design vertical loads. The calculated vertical roof dead load for this structure is approximated to be in the area of 3 psf. The typical required design snow load is an additional 25 psf. Reviewing and checking against previous calculations from May of 2002 indicates that the roof purlins alone are more than 90%, and possibly as much as 300%, overstressed under a full snow load depending on the grade of wood used for construction.

The gable truss-type framework supporting the roof joists are not supported or constructed as true trusses. Typical truss design for hand built trusses requires careful attention to connections at the joined members. The observed geometry and existing connections do not even closely appear to be adequate. This is evident in the necessity of the numerous additional supporting knee braces, tie rods and scabs that have been installed to the framework over time. The design and connections of which are also not entirely sufficient as several are failing. As a result, the roof framing is deflected and sagging in many areas under dead load alone. Increased or full required design vertical loading could be expected to cause full or partial collapse in many areas.

Lateral resistance to wind or earthquake on these two structures was not calculated for this report primarily due to the current condition and loss of capacity to resist required design vertical loads alone. However, the numerous additions attached to the structure and post removals, as well as repairs to many of the remaining posts, are anticipated to have significantly affected the structures ability to resist required wind and earthquake forces.

During examination of the structures, it was noted that in hanger 4 of building B, the interior supporting post had been cut out and a steel member had been installed to carry the vertical load. The W4x13 steel section, as installed, spanned 30' unsupported with no connection to the cut post and under dead load alone, was deflected downward beginning to buckle. Follow-up communication at that time indicated possible imminent partial collapse and required that the hanger be evacuated and closed off to public access until temporary repairs, providing adequate support, could be installed. This requirement is still in effect until a designed repair is obtained and installed.

Building C is the newer of the three structures and in a fair state of repair with little outward sign of obvious duress. However, numerous modifications or omissions in construction have impacted the structure capacity to safely support required design vertical and lateral loads.

The trusses provided at the support for the roof purlins were most likely not originally designed to carry cantilevered loads. Although they appear to be holding up adequately under dead load only at this time, with no obvious or noted problems, as pre-manufactured trusses, they were most likely designed to be fully supported at each end and in the center with a snow load of 20 or 25 psf.

Calculations and analysis of the truss configuration, with 15' of cantilever span, indicate that the trusses may be capable of carrying the existing dead load only, depending on the grade of wood used for construction. This would require that the wood members used for construction be of high structural grade (DF Select Structural or MSR 2250). Based on the observed condition and performance from the time of construction, it is reasonable to believe that they are adequate for supporting the present dead load, but the grade of lumber used in the trusses should be verified.

However, analysis indicates that the existing installation of the trusses and connection to the supporting posts are inadequate to support or resist snow and wind loading. Inadequate bracing and connections to the posts make collapse due to loss of support or buckling of compression members very possible under heavy loading.

Additional analysis of the 2x6 purlins, spanning 16' indicates that they too are adequate for the existing dead load, but are possibly as much as 160% overstressed for full snow loading depending on the grade of lumber used.

A complete lateral analysis of the building, using full wind and seismic loads, in both directions was not conducted. However, an abbreviated seismic analysis of the building down the long axis was made to estimate the level of loading to the post lines. Diaphragm action and shear resistance of the corrugated metal was discounted.

Properly constructed, this type of building is more accurately analyzed as a pole supported structure in which all vertical and lateral forces are resisted by posts embedded into the ground.

Three lines of pressure treated 6x6 posts run in the long axis of the building. Along the rear wall line and down the center there are approximately 22 posts at each line. Down the front wall line of the building, with hangar bay openings, there are only 8 posts. Approximated distribution of forces to each line and to each post along the front wall line, indicate that the posts may be as much as 60% overstressed in bending and compression according to current code. Deflection was not calculated and the effect of constructed mezzanines or interior structures was not considered. This limited analysis did not take into account adequacy of connections to the posts for force transfer nor did it address adequacy of the post condition or installation below ground.

On the interior of hanger 13, the recently wood framed mezzanines do not outwardly appear to meet current code requirements. Typical framing for this purpose is usually required to be designed for loads in the area of 50 to 100 psf. to accommodate office or light storage loads.

Recommendations and Conclusion

The existing hangars at the woodland airport are essentially pole supported structures built at different times and are in various structural conditions and states, of repair. Methods of original construction, modifications and inadequate repairs over the years have created problems that in some cases greatly limit or reduce the structural capacity of the buildings.

Vertical supporting capacity is primary in the structural design of a building to make it capable of supporting expected loads, as these are always present in some degree and can directly result in collapse. Additionally, a building's ability to resist wind and earthquake loads must also be considered. Observation and evaluation of the existing hangar construction indicates that all of the buildings are seriously limited in vertical, and or lateral capacity, or are already beginning to fail.

Buildings A and B are already showing signs of roof framing failure under dead load alone and past modifications indicate that this has been an ongoing problem. More recent modifications with the post removal in hangar 4 have created a situation requiring closure of the hangar bay. This hangar bay must remain closed until proper support has been restored.

The lateral capacity of buildings A and B for wind and seismic forces have not been directly evaluated but current condition, modifications and past repairs have significantly reduced the structural capacity to resist these forces. In the event of design level earthquake, it can likely be expected that this structure may experience some degree of collapse.

Designed repairs, retrofitting, replacement or just removal or of the these two buildings, which contain hangar stalls 1 through 8, is necessary to prevent eventual failures that will result in partial or full collapse.

Building C is generally in good condition without obvious sign of distress. However, analysis of the roof framing and support indicates that the existing 2x6 roof purlins are overstressed for design snow load requirements. Furthermore, the installed configuration of the trusses and connections to the posts are at risk for collapse due to loss of support, or buckling of truss compression members due to snow and or wind loading.

Field observation and rough analysis do not immediately indicate reason for significant concern over wind and earthquake forces. No verification has been made as to the subsurface condition of the posts or depth of embedment. It is not uncommon that older buildings will often be overstressed to some degree when compared to current code requirements. The 2006 IBC provides further guidelines for existing structures and acceptable comparison values.

Designed repair and retrofitting needs to be provided to insure that the structural integrity of the roof is maintained and able to support the necessary loads.

Any and all repairs or retrofits to the structures should be designed and detailed by a licensed professional engineer. If necessary or desired the capacity for resistance to design level wind and earthquake loads may also be further evaluated.

If you have any questions, or if I may be of further help, please call me at (360) 754-9339.

Sincerely,

GREGORY A. SEIPEL P.E.
Senior Lead Bridge Inspector
WSDOT Bridge & Structures Office

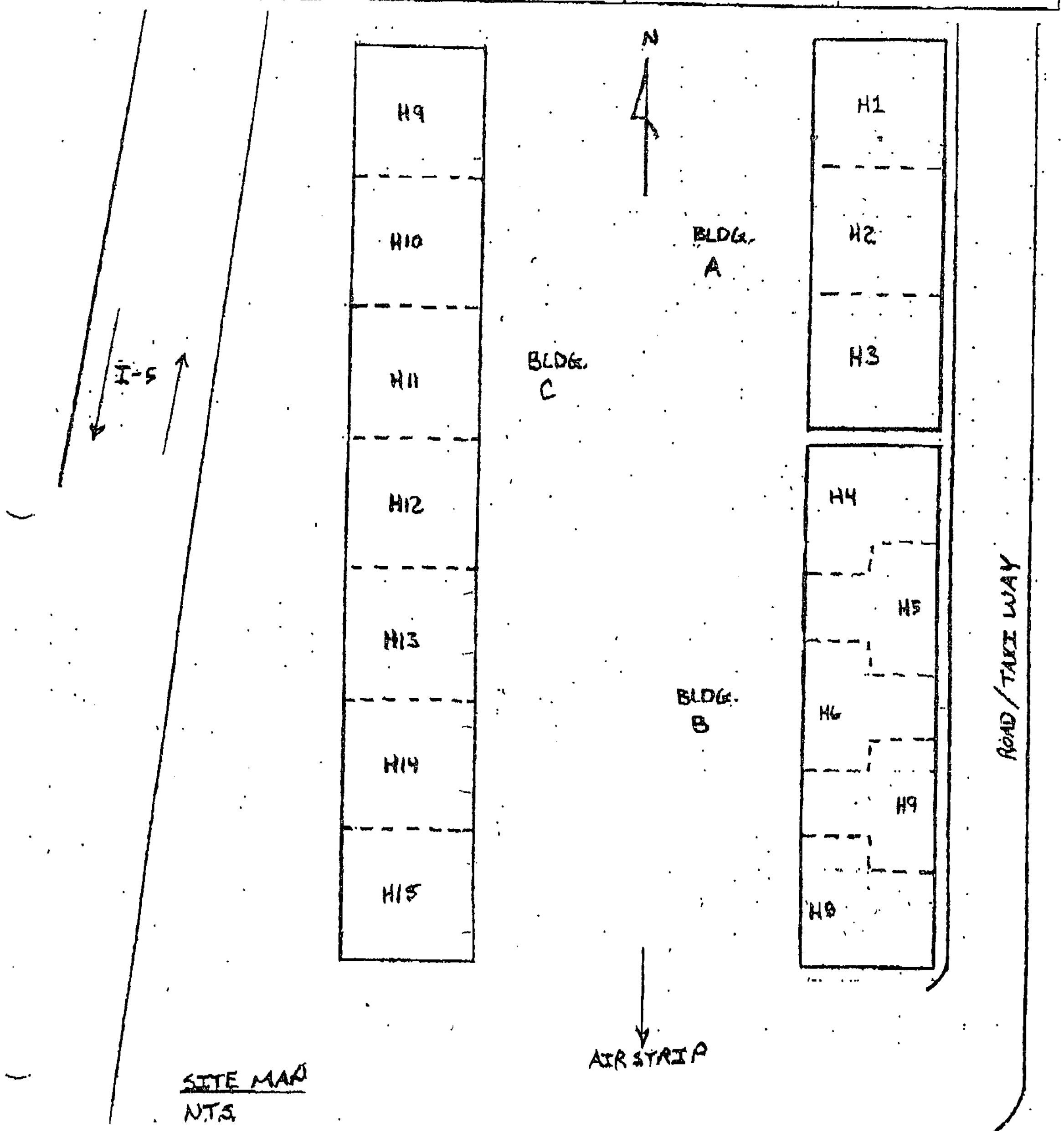
GREGORY A SEIPEL
STATE OF WASHINGTON
40256
REGISTERED
PROFESSIONAL ENGINEER
6/5/08
EXPIRES 06-24-09

Attachments: Site Map
Photos

Washington State Department of Transportation

Bridge & Structures Branch Design Calculations

Project				Sheet No. of Sheets
S.R.	Made By	Check by	Date	Supv



DOT Form 232-007 Revised 1/2007

Sheet No.

Site Map

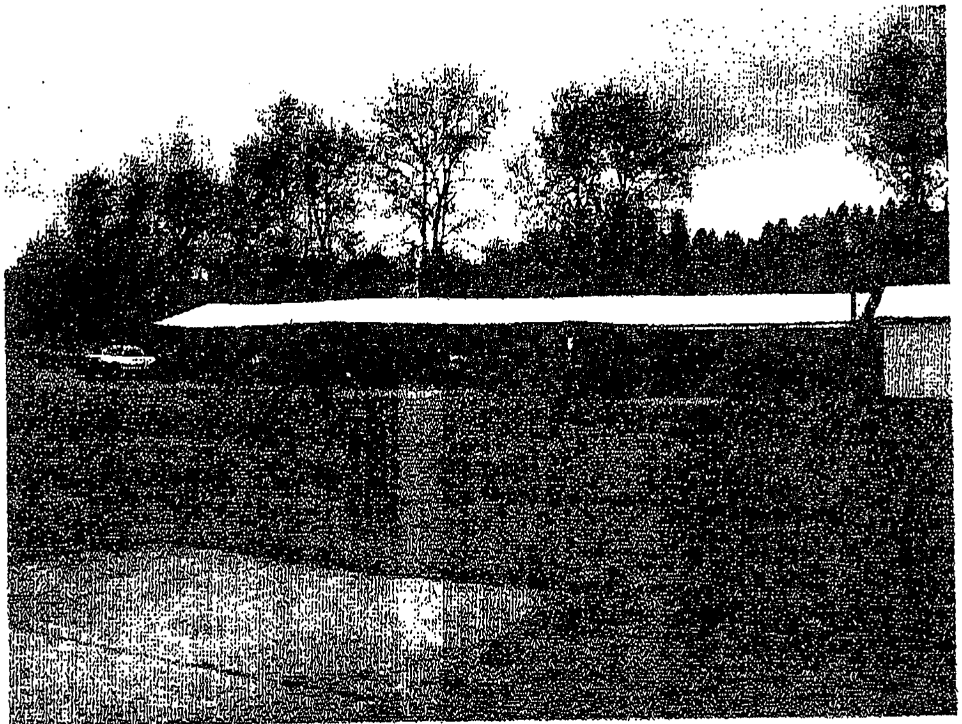


Photo #1
Building A, Hangars 1 Thru 3

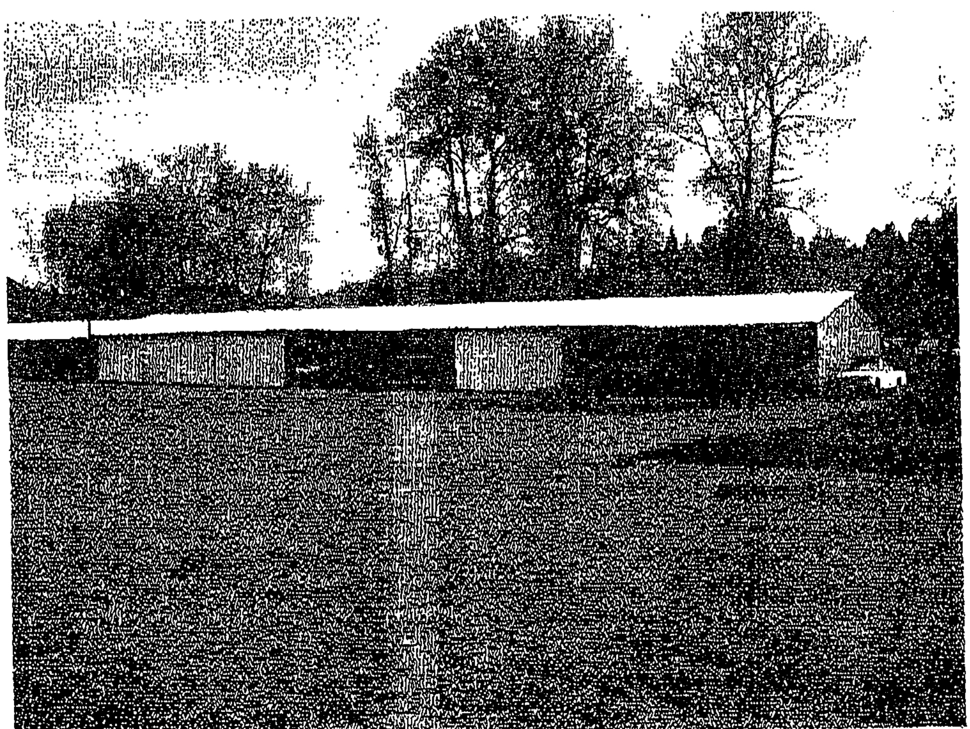


Photo #2
Building B, Hangers 4 Thru 8

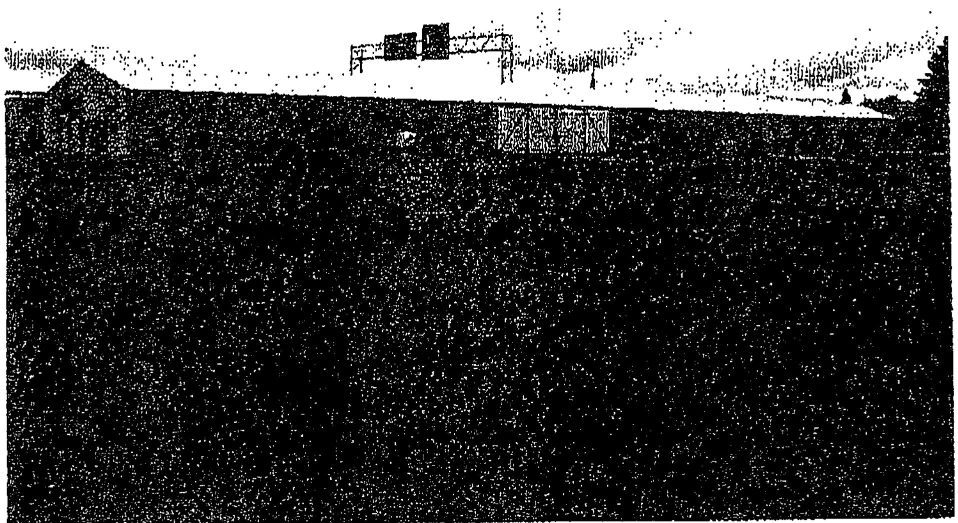


Photo #3
Building C, Hangars 9 Thru 15

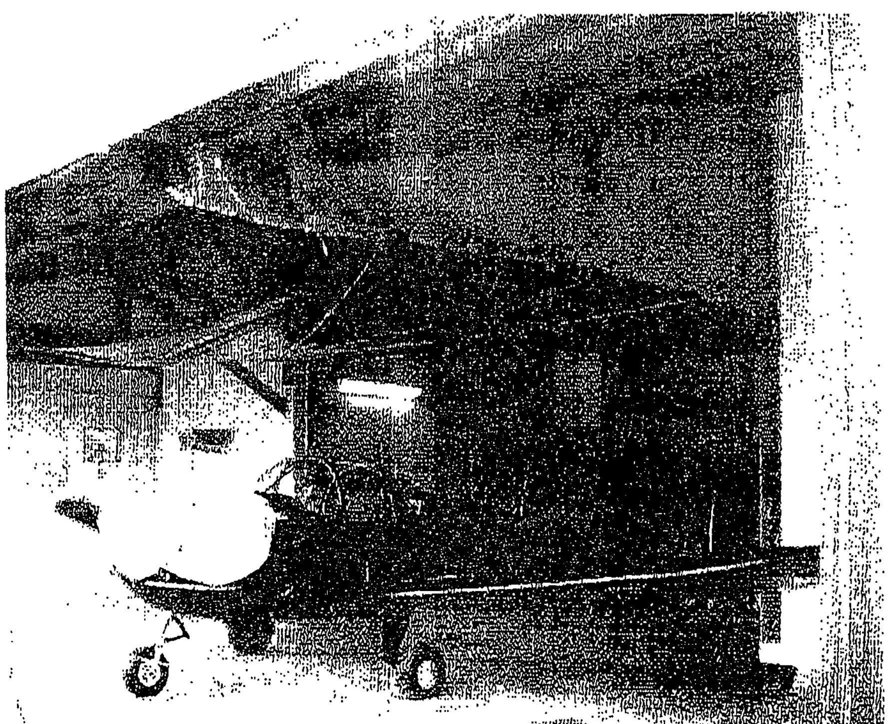


Photo #4
Cantilevered Framing Typical, Hangar 8

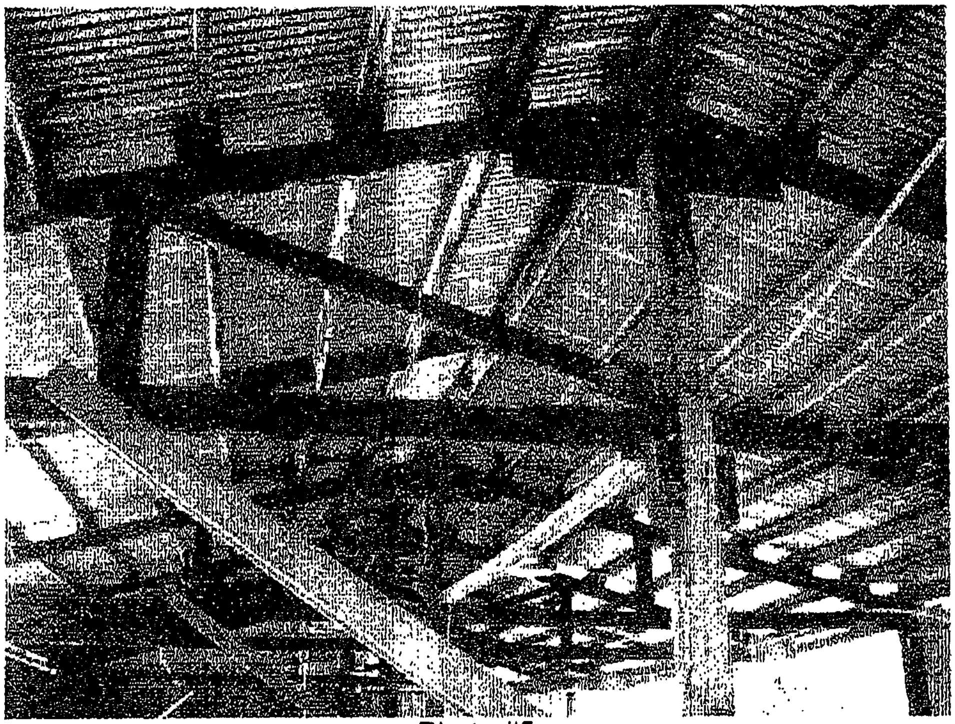


Photo #5
Truss Type Framing Support. Buildings A and B

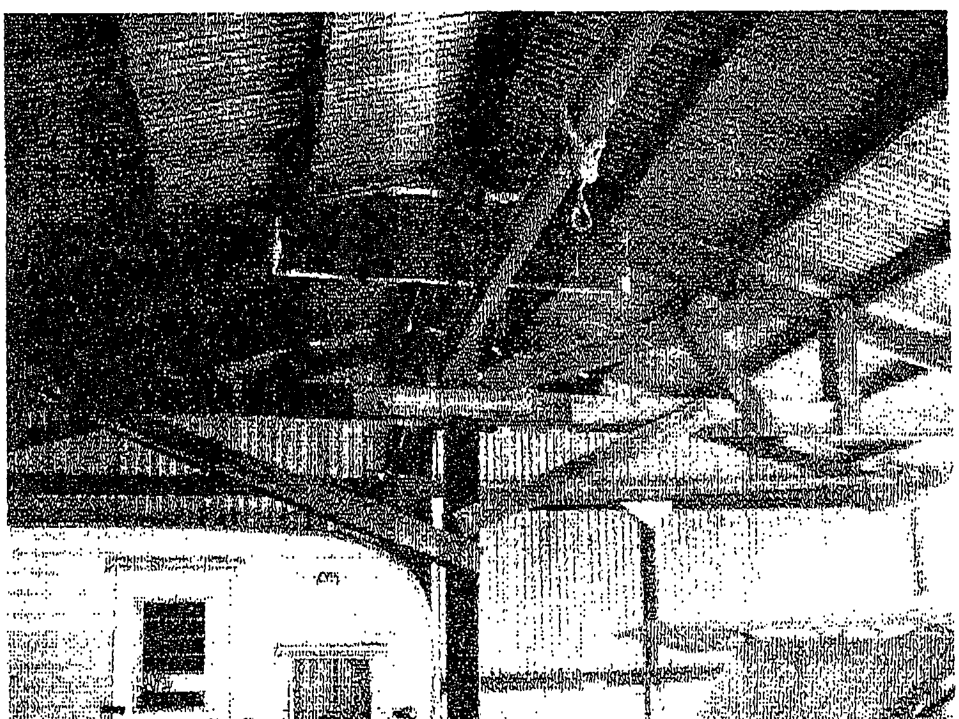


Photo #6
Multiple Band-Aids

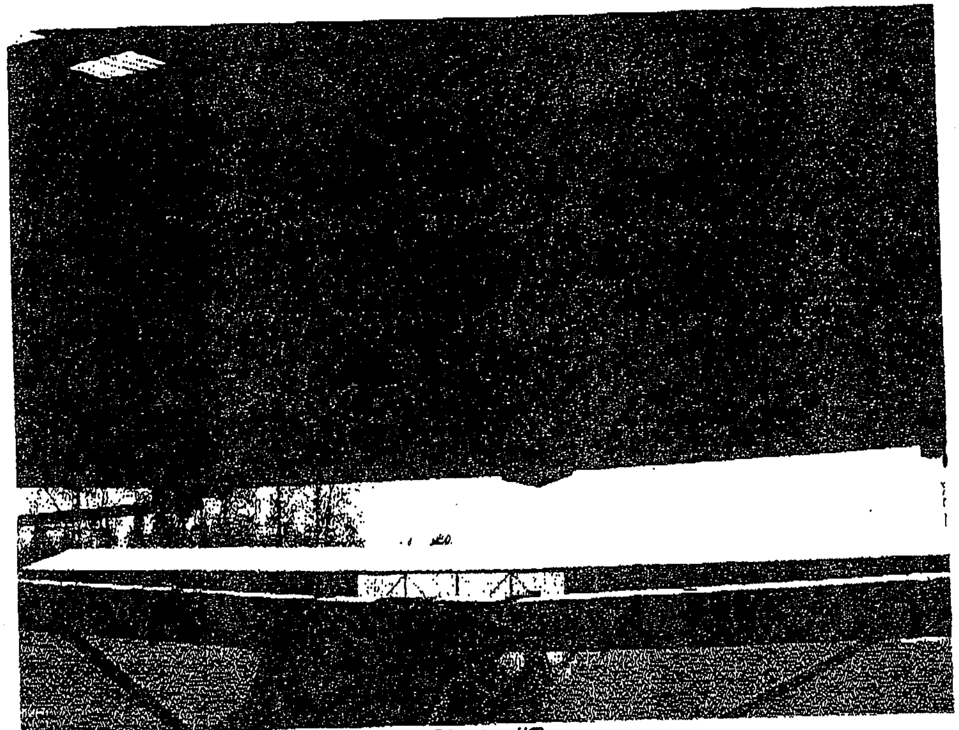


Photo #7
Additional Truss Work At Hanger 2

Photo #8
W4x13 Steel Section Deflected Downward And Buckling, Hanger 4

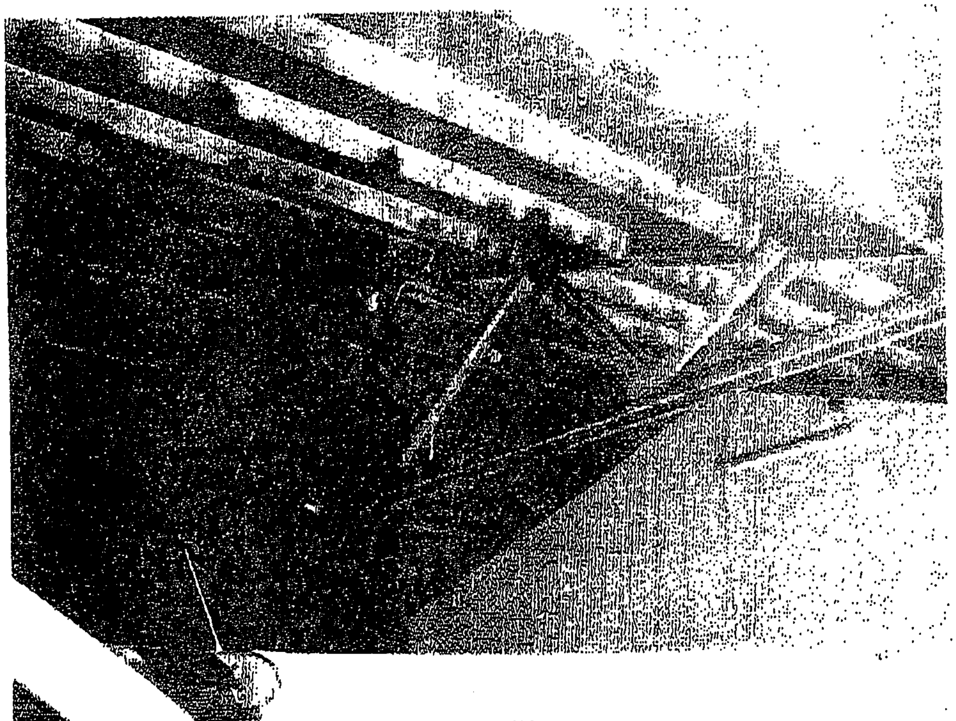


Photo #9
Double Truss Cantilevered Over Open Hangar Bay, Building C

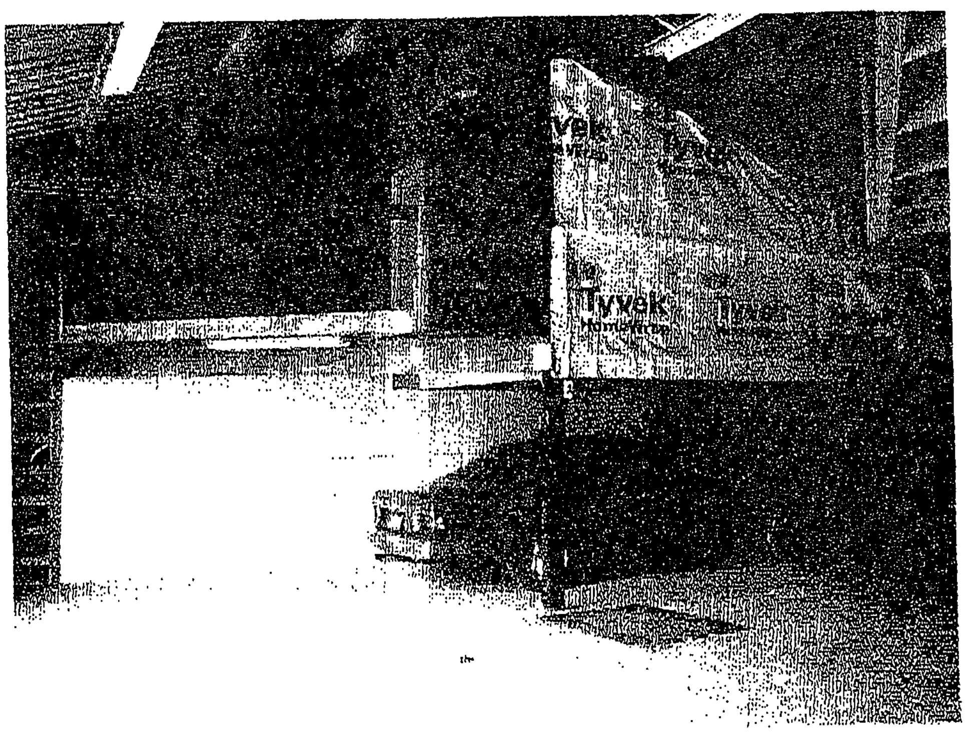


Photo #10
Mezzanine With Enclosed Storage Space, Hangar 13