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Structural Assessment of Roof Decking Using Visual Inspection Methods

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STRUCTURAL ASSESSMENT OF ROOF DECKING USING VISUAL INSPECTION METHODS

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ABSTRACT

The Hanford Site has approximately 1,100 buildings, some of which date back to the early 1940s. The roof on these buildings provides a weather resisting cover as well as the load resisting structure. Past experience has been that these roof structures may have structural modifications, the weather resisting membrane may have been replaced several times, and the members may experience some type of material degradation. This material degradation has progressed to cause the collapse of some roof deck members.

The intent of the Hanford Site Central Engineering roof assessment effort is to provide an expedient structural assessment of the large number of buildings at the Hanford Site. This assessment is made by qualified structural inspectors following the "Preliminary Assessment" procedures given in the American Society of Civil Engineers (ASCE) Standard ASCE 11-90. This roof assessment effort does not provide a total qualification of the roof for the design or in-place loads. This inspection does provide a reasonable estimate of the roof loading capacity to determine if personnel access restrictions are needed.

A document search and a visual walkdown inspection provide the initial screening to identify modifications and components having questionable structural integrity. The structural assessment consists of baseline dead and live load stress calculations of all roofing components based on original design material strengths. The results of these assessments are documented in a final report which is retrievable form that future inspections will have comparative information.

INTRODUCTION

In April 1992 a Hanford Site building experienced a roof panel collapse under normal loading conditions. This collapse initiated a series of investigations and reviews of the Hanford Site facility and maintenance operations. As a result of these investigations, recommendations were made that all Hanford facilities be reviewed for structural adequacy of the roof deck.

Past inspections of Hanford Site roofs have been performed using the condition assessment survey (CAS) or preventive maintenance (PM) inspections programs. The purpose of the CAS and PM inspections is to find building defects, including roof membrane defects so that repairs can be made before leaks start. These inspections do not explicitly inspect the structural integrity of the roof deck or its supporting members. However, buildings with active PM inspection programs, are generally in much better shape structurally than buildings without such programs.

Inspection Plan Development

The purpose of the Central Engineering roof inspection program is to make structural roof assessments. These assessments are based on visual inspections, design documentation, and load evaluations. To provide meaningful information the inspections were performed by qualified and trained personnel.

During the development of the Hanford Site Central Engineering Roof Assessment program, information from offsite experts was gathered. These experts represent the U.S. Corps of Engineers (COE), roofing material manufacturers, and professional roofing consultants. The groups and organizations contacted in this investigation are listed below.

(1) The Federal Roofing Committee which is made up of COE and Department of Defense (DOD) engineers from offices across the country. These engineers are involved in the maintenance and repair of a large number of the U.S. government owned facilities.

(2) Product engineers representing the manufacturers of Concrete, Asbestos-Cement, Gypsum-Cement, and other roof deck products. These people provided design properties and strength information on their current and non-current products.

(3) Consultants from Seattle and San Francisco who are considered and recommended as roofing experts by their peers. These consultants provided comments on the Hanford Site inspection program and structural roof repair recommendations.

The results obtained from these experts are as follows. (1) Current roof inspection programs (except the Central Engineering Inspection program) look only at the weather resisting membrane of the roof. (2) Structural roof inspections in the commercial arena are performed in isolated cases only, and only when problems are suspected. (4) The Central Engineering Roof Inspection Program was reviewed and found to be an acceptable inspection method for determining structural adequacy of roof decks. (3) Some inspection and strength information was obtained usually in the form of outdated catalogs and personal experience.

DISCUSSION

Hanford Site Inspection Guidelines

The structural roof inspection guidelines followed the American Society of Civil Engineers (ASCE) Standard 11-90 for preliminary assessments.

The structural roof-assessments were performed in four parts similar to ASCE 11-90. Part one was a document search for the structural as-built details and vendor information. The document search provided an initial screening to identify modifications. Part two was the formulation of building specific inspection guidelines and the completion of the field inspection. The actual field inspection consisted of a visual inspection of the access route and selected structural roof decking and support members. Part three was a simple dead and live load structural assessment of the roof deck and components identified in part two as being of questionable structural integrity. No attempt was made to evaluate under-strength materials or material degradation that could not be verified visually. Part four was the preparation of the final report.

The inspection team consisted of structural inspectors, facility representatives, safety, and quality assurance personnel.

The field inspection focused on an under-the-roof inspection of the structural elements. The field inspection then proceeded to the roof top if necessary to document in-place equipment loads. The access pathways and stairs to elevated portions of buildings were structurally inspected before proceeding. Roof tops were generally inspected from the roof edges or walkways only. Roof top access when necessary was granted only after a life-safety assessment was performed.

A visual inspection for potential deterioration in critical load paths of structural roof members considered; cracks, spalls, or chips in concrete members; exposed rebar in concrete members; rust stains that indicate rebar corrosion inside concrete members; cracks, splits, rot and holes in wood members; broken or missing connectors in wood members; rust scale, or holes in metal deck and support members; dents, kinks, and bends in metal roof members; broken, cracked, or missing welds and bolts in metal roof members; and evidence of leakage, damage, or repairs. Physical modifications or changes in member configuration were checked against the drawings. Obvious sagging, buckling, instability, gaping or offset of roof members were noted.

These guidelines were for a screening visual field inspection of the roof. The roof decks and integral structural members were inspected to these guidelines, and a simple pass or fail judgement was made by the structural inspector. A conservative "component fails" determination was made when doubt existed about the acceptability defined by these guidelines. Structural members of all roof areas were inspected or noted otherwise and documented in the field notes accordingly.

Qualifications

Structural inspectors were engineers with degrees or equivalent work experience in structural, civil, or mechanical engineering fields having two years of combined field and analysis experience in the type of building construction such as steel, concrete, or wood, that was being inspected.

The facility representatives were authorized by the facility manager and had complete knowledge of the safety rules, restricted areas, and required entrance training for the building being inspected. The facility representative was responsible for obtaining access permission, craft support, and removal of in-the-way equipment or false ceilings.

Pre-Inspection Training

The pre-inspection training was a combination job safety, facility orientation, structural component inspection training, and pre-job planning. A Job Safety Analysis was written and presented by the safety representative to the team members. Facility orientation included review of the building hazards and restrictions such as radiological, toxicological, and biological (snakes, spiders, and bees) hazards and was presented by the facility representative. The structural inspector described the structural elements to be inspected as shown on the drawings.

Roof Investigation Teams

Several teams were formed at the Hanford Site to investigate the structural adequacy of roof decks. Starting in the spring of 1992 several teams were formed to perform inspections, track roof inspection and remediation progress and to coordinate roof repairs. Currently there exists three teams involved with the structural inspection and repair of roof decks.

A "Roof Task Team" was setup for the purpose of tracking and reporting progress on roof inspections and repairs. This team was established by the upper management of the Operations Contractor and includes representatives from all divisions and engineering groups.

The "Central Engineering Inspection Team" was formed to develop standardized inspection criteria and perform structural roof inspections at the Hanford Site. This team is made up of qualified and trained inspectors from the site contractors to perform structural roof assessments. These roof inspectors were divided into subteams of twos and threes to provide inspections in the different areas of the site.

The "The Qualitative Risk Assessment of Retired Facilities Team" was formed by the Operations Contractor to perform facility assessments. This team is a multidiscipline, multicontractor team that performs risk type safety assessments that include roof inspections. This team investigates only retired facilities, which are the oldest and least maintained buildings on site.

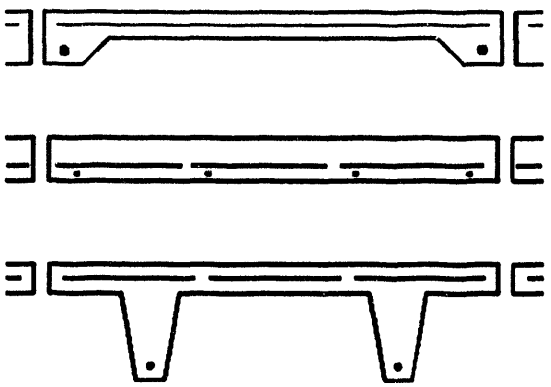
RESULTS

The roof inspection program at the Hanford Site required a discovery period to identify existing roof deck types and typical deficiencies, see Figure 1 for typical roof types. Some deficiencies were found to be common to all deck types, see Table 1. for typical roof deficiencies. Unframed and unsupported openings in roof decks, undocumented modifications to structures, and spans lengths greater than design are deficiencies common to all deck types. These deficiencies represent design and construction problems as opposed to water damage or age deterioration.

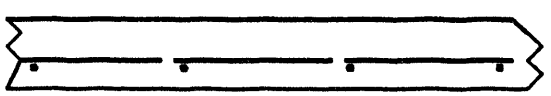
The results of the visual roof inspections are depicted in terms of deficiencies and building classifications, see Tables 1. and 2. for these results. During the inspections, deficiency lists are compiled by the inspector and then each deficiency is judged on its structural significance. Structurally significant deficiencies are considered unsafe roof conditions for personnel access.

Building classifications are determinations made by the inspector concerning the safe condition of the roof. Some roofs or parts of roofs cannot be visually inspected because of rigid or drywall ceilings. In such cases the building is classified as unknown or partially safe and partially unknown.

Pre-Cast Concrete Panels
28 roofs of 315 buildings inspected



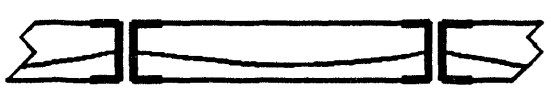
Cast-in-place Concrete Slab
73 of 315



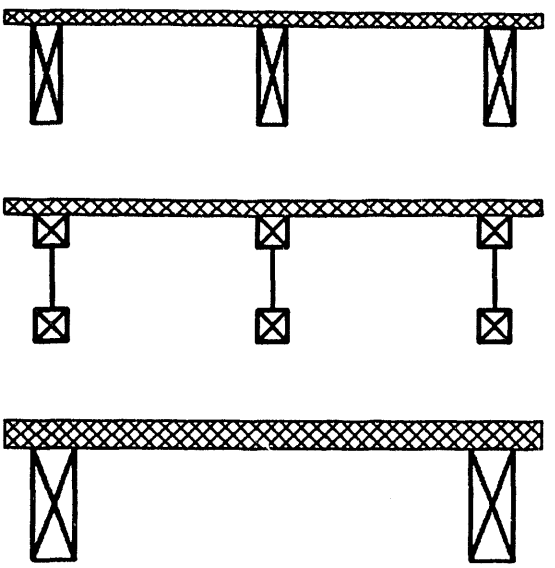
Fiberboard Panels
1 of 315

Asbestos-Cement Panels
13 of 315

Gypsum-Cement Panels
2 of 315



Plywood and Plank Decking supported by Beams, Joists, or trusses.
80 of 315



Metal Deck Types
147 of 315

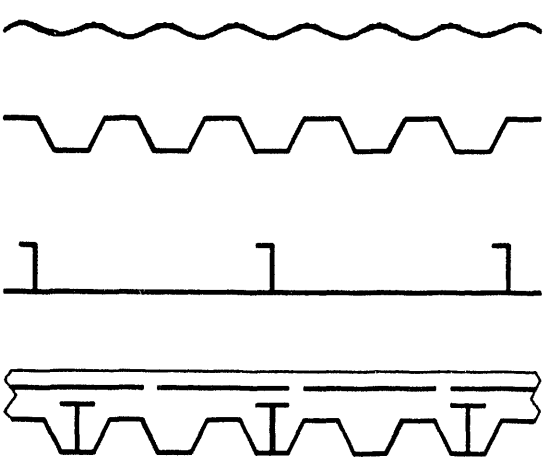


Figure 1.
Roof Deck Types

Table 1.
Typical Roof Deficiencies

All roof types
- Unframed and unsupported openings
- Undocumented structure modifications
- Span lengths greater than design

Asbestos-cement panels
- Cracked panels

Cast-in-place concrete
- Large cracks
- Exposed and rusted reinforcement
- Spalled concrete

Fiberboard panels (i.e. Tectum)
- Rot and water damage
- Sagging

Fiberglass
- No known problems

Gypsum-cement p: els
- Rot and wat damage
- Cracks
- Precast panels with tongue and groove systems not fully engaged

Metal deck and supports
- Rust holes

Precast concrete panels
- Large cracks
- Exposed and rusted reinforcement
- Spalled concrete
- Broken panels

Wood deck and supports
- Cracked and rotten sheathing
- Beams and rafters with bad splices
- Cracked, split, and broken truss members
- Sheathing tongue and groove system not fully engaged

Table 2.
Building Classifications

Safe: This classification of a roof requires that two conditions be meet. First, the roof must past the visible inspection. Second, by calculations, proved that the roof can carry a minimum uniform live load of 20 lb/in plus the uniform dead load of the roof. A roof can also be classified as safe if it can pass a load test.

Safe-PCR: This classification is given to a roof that has passed the visible inspection but, the calculations for dead and live loads are not completed. This classification is temporary. Once the calculations are completed, the roof is reclassified to safe or unsafe depending on the results of the calculations.

Unsafe: This classification is give to a roof which does not meet the classification for a safe roof.

Unknown: This classification is given to a roof were an inspection could not be performed.

Partial-Safe: This classification is given to a roof which had only a portion of the roof inspected and that portion is considered safe as defined above.

Partial-Unsafe: This classification is given to a roof which had only a portion of the roof inspected and that portion is considered unsafe as defined above.

Roof Inspection Statistics

The roof inspections at the Hanford Site have produced a large data base of information on construction materials and deficiencies. From this information, trends between construction material and the number and type of deficiencies can be observed. The statistical information presented is based on roof inspections performed between June 22, 1992 and May 6, 1993.

Table 3. presents the total number of Hanford Site buildings and the number of buildings inspected. Table 4. presents the roof inspection status by providing the percent of safe and unsafe roofs. Figure 2. present the same roof status information in graphic form.

Table 3.
Hanford Site Buildings

Total number of buildings at the Hanford Site	1561
• Permanent buildings	1137
• Trailers	424
Number of permanent buildings inspected to date	315
Number of trailers inspected	0

Table 4.
Deficiencies By Roof Type

Roof Deck Type	No. of Roofs	Safe Roofs	Unsafe Roofs	Status Unknown
Asbestos-cement panels;	13 of 315	38%	46%	15%
Cast-in-place concrete;	73 of 315	78%	18%	4%
Fiberboard;	1 of 315	0%	100%	0%
Fiberglass;	1 of 315	100%	0%	0%
Gypsum-cement panels;	2 of 315	0%	100%	0%
Metal Decking;	147 of 315	65%	22%	12%
Precast concrete panels;	28 of 315	28%	68%	3%
Wood decking;	80 of 315	33%	43%	6%

Note; Twenty seven buildings contained more than one roof deck type. The Gypsum and Fiberboard roof deck types, were found only in buildings with multiple roof deck types. The roof deck type could not be determined on 2 buildings because of the rigid drywall ceiling and the lack of construction drawings.

REMEDIATION

Roof Repairs

The inspections identify structural deficiencies that usually require roof remediation. The remediation may be a simple repair or an extensive replacement that requires a budgeted project. To date several simple repairs have been made and may small and large repairs are scheduled some in conjunction with the roof membrane replacement.

Examples of simple remediation efforts are; replace damaged member in like kind, replace missing member, or add a member to strengthen. Examples of extensive remediation are; multiple examples of simple type repairs, replacement of whole deck areas, or replacement of deck support members.

The roof repairs needed are identified from deficiencies listed in the inspection reports. The needed repairs are then described in detail and priced on "plant force work review" forms. These forms are then reviewed to determine whether onsite personnel or offsite contractors will make the repairs.

Use of the Inspection Information

The information gathered during the roof inspection effort is provided to the facility manager. Given this information the building manager may then decide to allow limited roof access. The building manager can also start planning for needed repairs. Some structures have extremely bad roofs but are not slated for repairs because there is no planned use for them. In these buildings access restricted until they can be demolished.

The roof deficiencies observed present two types of hazardous conditions. The first is a personnel fall-through type hazard and the second is a collapse-on-top-of hazard.

The fall through hazard is a roof access hazard. A concentrated load from a person walking on the roof deck could cause the collapse of a roof deck panel or single support member. For this type of deficiency, building managers restrict access to keep personnel off of the deficient area only. Other roof areas and building access is not restricted.

The collapse-on-top-of hazard is a building access hazard. A high wind load, a heavy snow load, or a little more deterioration could cause a roof deck or support member collapse. For this type of deficiency, building managers prohibited access, or restricted access to unaffected areas.

Reinspections

The condition of a roof structures change with time. Some buildings inspected during the summer of 1992 have seen additional deterioration over the winter months of 1992, 1993. This deterioration is evidenced by additional spalling of concrete and new and larger rusted deck areas.

Because of the observed roof deck deterioration, and continued degradation, reinspection is recommended. The time interval recommended for these roof reinspections is based on the roof material type and condition at the initial inspection. The inspecting engineer assigns an inspection interval to each of the roofs which were inspected. The intervals range from annual inspections to a maximum of once every five years.

Inspections of other components

The roof inspection effort and findings have raised concerns for other parts of building structures and work areas. Structural inspections of accessways, stairs, handrails and entire buildings are being performed. These inspections have identified some overloaded members, unframed openings, and modifications not shown on the design drawings. Occupational Health Safety Administration (OSHA) are also being assessed during these roof and building inspections.

END

DATE
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