Engineer Research and Development Center

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Frost Effects Research Facility

Year-Round, Full Scale Pavements and Geotechnical Cold-Related Testing

The Frost Effects Research Facility (FERF) is the largest refrigerated warehouse in the United States that can be used for a variety of roadway and pavement, geotechnical, and other investigations at sub-freezing temperatures year-round. Tests can be conducted using a combination of ambient and ground temperatures from approximately 20°F to 80(+)°F year-round, with the ability to conduct accelerated pavements testing and evaluation due to the effects of repeated freezing and thawing.

On-hand equipment to support non-destructive pavements investigations includes a 20-ton crane on a monorail, a falling weight deflectometer (FWD) and a heavy weight deflectometer (HWD), a heavy vehicle simulator (HVS) to rapidly replicate a large number of passes by typical highway traffic loads, and other equipment. In addition to controlling temperatures, testing can incorporate controlled moisture conditions and use a variety of specific sub-grade materials.

As an example of the FERF's flexibility to accommodate a wide range of RDT&E investigations, the facility is scheduled to soon house a 50 ft wave tank in the Southeast quadrant to study sea-ice interactions with waves and petroleum products, with wider temperature ranges and other testing additional capabilities.

	
The Frost Effects Research Facility (FERF) is the largest refrigerated warehouse in the United States that can be used for a variety of pavements, geotechnical, and other investigations at sub-freezing temperatures year-round. (Photo by USACE ERDC Image)	**The heavy weight deflectometer (HWD) tests expedient concrete repair at subfreezing temperatures in the FERF at ERDC-CRREL.** (Photo by USACE ERDC Image)
	
At the Frost Effects Research Facility (FERF) at ERDC-CRREL, researchers test mine detection capabilities in frozen soils. (Photo by USACE ERDC Image)	**Researchers at the fully controllable FERF at ERDC-CRREL can test soil strength under any temperature condition at any time of the year.** (Photo by USACE ERDC Image)

The large FERF facility at CRREL can simulate cold weather conditions on full-scale systems (shown is a full-scale concrete test section expedient repair) to reliably predict performance under frost conditions.

(Photo by Jared Oren, ERDC-CRREL)

Cooling panels rapidly freeze a ground test section (21 ft x 80 ft) in the FERF at ERDC-CRREL. Panels can push frost depth approximately one inch per day. (Photo by USACE ERDC Image)

Previous Research Studies

Previous studies include the following: American Association of State Highway and Transportation Officials (AASHTO) subgrade study, US Air Force Airfield Damage Repair at sub-freezing temperatures using novel concrete and flowable fill materials, University of Alaska Pile Creep Study, Montana State University pavement geo-reinforcement study, and evaluation of mine detector and ground penetrating radar capabilities and limitations for Night Vision and Electronic Sensors Directorate (NVESD), and other topics.

Success Stories

The U.S. Air Force frequently encounters damage to airfields and other pavements due to a variety of threats in contingency environments. In these situations, the primary focus is ***speed***—minimal time for Airmen preparation, materials acquisition, materials setting and strength gain, and results variability due to physical security considerations and other practical environmental constraints.

ERDC responded to the Air Force's needs by developing novel flowable fill and rapid setting concrete materials, focusing on speed and meeting other constraints: easy to use materials with a long shelf life, simple mixing procedures, rapid strength gain, compatible with existing Air Force equipment (Simplified Volumetric Mixer), compatible with ***sub-freezing temperatures*** (ground, ambient), and simple Airmen QA/QC procedures. These materials achieve ***full strength in 2–3 hours at 23°F*** compared with at least 7 days for conventional materials at moderate temperatures. These materials save time and money, reduce site exposure, and are user-friendly. The Frost Effects Research Facility was critical to the project's success in spring 2013 by allowing full scale (100 ft) runway testing with controlled ground and ambient temperatures.

Existing Amenities

- The 29,000 sq. ft. facility includes
    - four independent test sections (SW, NW, NE, SE), each approximately 100 ft in length, with additional sub-divisions possible;
    - 50 ft wide x 14 ft tall equipment entrance doors for partial or complete opening;
    - 7 personnel refrigeration doors throughout the building;
    - an indoor materials staging area (50 ft x 20 ft) with forklift loading door (10 ft wide x 10 ft height); and
    - a variety of amenities, including office space and control room with dual network connectivity, restrooms, basement access surrounding the facility for controls and refrigeration access.

Supporting equipment includes

- a 20-ton monorail crane with minimum 15 ft ground clearance (minimum at South entrance), spanning 200 ft indoors (all of south sections, majority of north sections) and extending 30 ft onto the south loading apron;
- a Heavy Vehicle Simulator (HVS) for simulating a large volume of highway vehicle loading in a short time period on flexible or rigid pavements. The HVS is capable of approximately 14,400 passes in 24 hours in uni-directional mode (load applied in one direction, then return HVS to start and repeat), 25,000 passes in 24 hours in bi-directional mode, and 20 years of equivalent traffic in only 6 months. The wheel load varies from 20 to 100 kN (4.5–22.5 kips), and its configuration takes advantage of the symmetry of truck or aircraft tire configurations. The HVS simulates half of one axle; for example, a 9 kips (1 kip = 1000 lbs) load represents a standard truck axle load of 18 kips. Multiple tire types can be used, to include truck tires (with pressure from 560–690 kPa or 80–100 psi) and C-141 aircraft tires (with pressure up to 1450 kPa or 210 psi). The effective length of traffic is 20 ft in addition to approximately 3 ft for acceleration and deceleration at the ends of the effective test window. The width of the test window depends on the tire configuration used. The tire traffic can be wandered to simulate real traffic. Including traffic wandering, a typical width of the traffic window is 3 ft.
- a Dynatest heavy weight deflectometer (HWD) for non-destructive testing and evaluation of rigid (concrete) pavements using a peak load of 30 to 240 kN (6,500 to 54,000) lbf;
- a Dynatest falling weight deflectometer (FWD) for non-destructive testing and evaluation of flexible pavements using a peak load of 7 to 120 kN (1,500 to 27,000) lbf;
- a van for towing and controlling either the HWD or FWD on or off campus, with a customized pickup truck targeted to soon replace the van;
- easy accommodation of additional equipment and capabilities of the abutting Materials Evaluation Facility (MEF) for snow, ice production, lower temperatures, and other testing capabilities; and
- other supporting equipment. See facility manager for details.

Refrigeration:

- Ambient temperature: 20°F–80(+)°F year round in normal operations enabled by a 70-ton refrigeration system pushing -20°F through 10 air handler units, which double as heating units (for defrost and for heating the facility seasonally). See facility manager for additional capabilities that are possible seasonally in certain sections of the FERF or by using some additional equipment and setup procedures.
- Ground temperature: 10 ft x 10 ft ground cooling panels used alone or in series (connect up to 20 in series simultaneously; 40 total on hand) to completely cover one test section and rapidly freeze any ground surface (pavement, sub-grade). The ground panels circulate glycol at -20 °F to rapidly cool any ground surface. As a rule of thumb, the panels can push frost depth approximately one inch per day, though actual results vary (initial frost depth penetration is faster and then slows with depth; varies by material type and is much faster when applied to concrete and course aggregate; and other variables).

Remote video, photo, and controls monitoring in real-time with a dedicated, secure FERF website

ERDC Points of Contact

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