



#### Full Scale Load Test for USPS Milwaukee Truck Maneuvering Area

#### July 21-24, 2008

Evaluations leading up to the test Planning issues and logistics Load test media options Test procedures and code requirements Instrumentation Results and conclusions





#### **The Problem:**

- Badly deteriorated waffle slab built in 1965
- Serious doubts about actual load capacity
- Little opportunity for routine maintenance (24/7 operations no shutdown time)
- Falling concrete debris a hazard to employees and cars parked below, netting was installed below.







# Worst case slab deterioration



### Previous repair attempts failed







## Section of Waffle Slab Reinforcing





#### **The Players:**

Walker Restoration – Prime Consultant to USPS USPS operations & facilities design/construction staff (client representation) Universal Construction Testing – Instrumentation Nation Restoration Services – Contractor Assistance



#### **Repair History**

- > Numerous waffle stem repairs attempted over several years.
- > Walker designed top of slab repairs in 2002
  - Top 2" concrete replaced and new top steel in selected areas



#### Verification of topping and reinforcement condition

- Cores show good concrete quality and no rebar corrosion
- No significant cracking, no spalling based in visual inspection





#### **Evaluation of slab**

Updated condition survey: May, 2008

Test area: 34' x 36' bay (2-way waffle slab)

Review of existing construction documents

Analysis of slab flexural capacity

- 278 psf working LL capacity by calculation
- 240 psf required LL

Deflection model in SAFE

- 0.42 inches at full test load
- 0.39 inches max per ACI 318, Ch. 20



#### SAFE Model

Deflection analysis for each load stage:

Load Stage	Max. Deflection
1	0.094
2	0.187
3	0.281
4	0.375
5	0.422





#### **Test Planning**

- 1. Explore load media options
  - Water
  - Solid media (brick pallets)
- 2. Impacts on time and cost
  - Availability of media in large quantity (430,000 pounds)
  - Lead time to obtain materials
  - Time involved to place load and remove
  - Shoring and safety considerations
  - Contractor time and cost to assemble and remove



#### **Challenges with Water as Load Medium**

- Issues with formwork design, details for waterproofing and accommodation of existing floor variations.
- Obtaining large volume in a reasonable amount of time.
- River water available, but polluted and had safe handling issues.
- Unknown silt quantity could make loading inaccurate.
- Fresh water from fire hydrant, but cost and available pressure was a factor (pressure loss in fire hose) given distance to nearest hydrant and height of test.
- Time to obtain permits and dealing with various regulatory agencies: Milw. Fire dept., WI Envir., Army COE, Milw. Streets & San.
- Water disposal permits also required.
- Possible extended time on site for set up and removal was a risk for USPS operations.
- Quantities: 6930 ft<sup>3</sup> = 52,000 gal. = 5.7 ft high over test area.



#### **Advantages of Brick Pavers as Load Medium**

- Wholesale brick supplier within 20 minutes of job site.
- Sufficient inventory was available.
- Skilled labor not required to set up (material handling with fork lifts).
- Trucking logistics and delivery were no issue.
- Pallets allowed accurate loading to within 1% of theoretical load.
- No permitting or public agency coordination required.
- Supplier agreed to "rent" material to our Contractor.
- Removal time was less than 6 hours.

With considerably less load, water becomes a viable alternative.



#### Select Test Location

Selection Criteria:

USPS operations restrictions such as loading docks that can be closed and keeping drive lane open at all times.

Worst case or nearly worst case condition



#### **Test Planning Coordination with All Players**

- Accommodate USPS operations
- Planning effort requires close coordination with contractor (our sub)
- Permitting agency compliance (water as loading media)
- Negotiate scope and fees with USPS and consultants
- Negotiate limitation of liability (possible slab collapse)
- Propose and negotiate schedule with client and subconsultants



## Brick pallets selected as load medium

Average weight per pallet = 3,209 lbs.





















## Final (5<sup>th</sup>) load stage

432,400 lbs.

#### Max. deflection = 0.279 inches (after 24hrs)













- Goal was to provide accurate displacement measurements on a deteriorated, 2-way waffle slab throughout loading sequence.
- Displacement transducers were placed symmetrically along midspan in both directions.
- A total of nine (9) transducers were utilized. Two (2) traditional dial gages were also used.





Low Voltage Displacement Transducers Typical LVDT gauge

#### **Gauge placement**





- Displacement transducers calibrated to 0.001 inches.
- Transducers positioned below the test points and braided steel extension cables extended to the structure.
- Each transducer was confirmed as perfectly vertical prior to the initiation of the load test.





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- Transducers connected to data acquisition hardware and signal monitored and recorded by customized data acquisition program.
- Measurements taken at 15 seconds intervals throughout the entire loading program.
- Represented approximately 18,000 data points.







#### **Load Testing Protocol**

- Load test performed under the guidelines of ACI 318 Ch. 20.
- Instrumentation was positioned and initialized prior to the application of load to obtain datum measurements.
- Load media was incrementally applied in a balanced fashion.
- Load was maintained for a period of 24 hours.





#### Load Testing Protocol

- After 24 hours, load was removed and the structure allowed to rebound for an additional 24 hours.
- Used to determine if structure remained elastic throughout loading sequence.
- Recorded data analyzed to determine the elastic deformation over the loaded area.



#### Deflections noted at D3







#### Deflections noted at D1 and D5







#### Deflections noted at D2, D4, D7 and D8







#### Deflections noted at D2, D4, D7 and D8







#### Deflections noted at D6 and D9







#### **Ambient Temperature At Test**





#### Results

Day 1: Load stages 1 and 2

Day 2: Load stages 3 thru 5

Day 3: Final deflection after 24 hours and rebound.

Slab passes test!
Linear behavior
Rebound < 25% of final Δ</li>
Final Δ < 0.39 in.</li>
Oh... and slab did not collapse always a good thing



## **Findings and Conclusions**

- Code prescribed load carrying capacity > anticipated dead and live loading, w/ FS
- Verification of available load carrying capacity, probabilistic approach
- Bases to extend future service life





### **QUESTIONS?**

