LEVEE STABILITY

Three Rivers Levee Improvement Authority

Levee Repairs Project Phases 1, 2 and 4 ***4-19-2007***

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Introduction

This memorandum serves to provide additional response to the moisture control issues raised for the Three Rivers Levee Improvement Authority (TRLIA) Levee Repair Projects. Included below are discussions regarding stability of the as-constructed levees, a description of the typical monitoring program for levee performance, a summary of field observations of the levees since the completion of construction activities and conclusions.

Slope Stability & Permeability

The attached technical memorandum titled "Levee Reconstruction Strength Parameters and Permeability, TRLIA Phases 1, 2, and 4" (Kleinfelder 2007) summarizes revised slope stability analyses and permeability assessments performed by Kleinfelder. These revised analyses incorporated adjusted strength parameters into the stability models originally used for design to better reflect as-constructed conditions. As stated in the memo, by decreasing the strength parameters by 15% the models still exceeded the requirements for factor of safety.

In the vast majority of the cases the new fill was placed in a narrow layer (2 to 3 feet wide) on the waterside of the levee and/or on the crown of the levee (above the 100-year water surface elevation). In these cases, neither the strength nor permeability of the placed material is critical to the overall performance of the levee embankment. This is illustrated in the attached Figure 1 which shows the relationship of the placed fill to a typical critical failure surface and the 100-year water surface elevation.

Monitoring

As a rule, performance monitoring of the levees is recommended until significant flood flows have demonstrated that they were constructed and function as designed. After performance has been confirmed, general operation and maintenance inspection should continue.

An inspection program as described below to monitor and evaluate the performance of the levees is recommended.

First Wetting

To address the concerns raised about possible brittleness of some materials having been placed with dry-of-optimum moisture content, those areas should receive special inspections during the first significant flood flows to verify that there were no adverse effects on the increase of moisture content. Particular attention should be paid to any cracking or slumping of the waterside slope and crown.

Field Monitoring

Periodic inspections should be conducted to verify that the levees were constructed to perform as designed. These inspections verify the condition of the levees and disclose any areas that require repair or replacement. Inspections should occur as follows:

1. Prior to the beginning of each flood season to ensure the structural integrity of the levees, allowing sufficient time to complete necessary repairs.
2. After each period of high water to ensure the structural integrity of the levees.
3. Intervals not to exceed 90 days.
4. Any intermediate times as required to maintain safe levees.

Earthquakes

1. For earthquakes measuring less than 5.0 on the Richter Scale, inspections shall be performed when the epicenter is within 3 miles of the project.
2. For earthquakes measuring 5.0 to 6.0 on the Richter Scale, inspections shall be performed when the epicenter is less than 30 miles from the project.
3. For earthquakes measuring 6.0 or higher on the Richter Scale, inspections shall be performed when the epicenter is less than 50 miles from the project.
4. Inspections shall also be performed after any earthquake in which specific reports of damage are received.

Inspections

Inspections will ensure the following items:

1. Sod Cover

There is good coverage of sod cover over the levee.

2. Unwanted Vegetation Growth

The levee has a good grass cover with little or no unwanted vegetation (trees, bushes, or undesirable weeds) and has been recently mowed.

3. Settlement/Sloughing

No unusual settlement, sloughing, or material loss of grade or levee cross sections has taken place.

4. Depressions/ Rutting

There are no ruts, pot holes, or other depressions on the levee, except for minor depressions caused by levee settlement. The levee crown, embankments, and access road crowns are well established and drain properly without any ponded water.

5. Seepage

No seepage, saturated areas, or sand boils are occurring.

6. Erosion/ Bank Caving

No active erosion or bank caving observed on the landward or on the riverward side of the levee.

7. Slope Stability

No slides present.

8. Cracking

No cracking observed on the levee greater than 15 cm (6 inches) deep.

9. Animal Control

The implementation of a continuous animal burrow control program that includes the elimination of active burrowing and the filling in of existing burrows.

10. Encroachments

No trash, debris, excavations, structures, or other obstructions present within the project easement area. Encroachments which do not diminish proper functioning of the project have been previously approved by the Reclamation Board.

11. Riprap Revetments & Banks

Existing riprap protection is properly maintained and is undamaged. Riprap clearly visible.

12. Burning Grass

No action is being taken, such as burning grass and weeds during inappropriate seasons, which may retard or destroy the growth of sod.

13. Access Roads

Access roads to and on the levee are being properly maintained.

14. Grazing/Traffic

There is no unauthorized grazing or vehicular traffic on the levees.

Field Observations

The construction of the repairs along the Yuba River left bank (Phase 1) from Highway 70 towards the Union Pacific Railroad was completed in 2004. The repaired levee has been through three flood seasons. The water surface elevation during the January 2006 event was high enough that water reached the levee. Inspections were performed during this event and no adverse affects were noted.

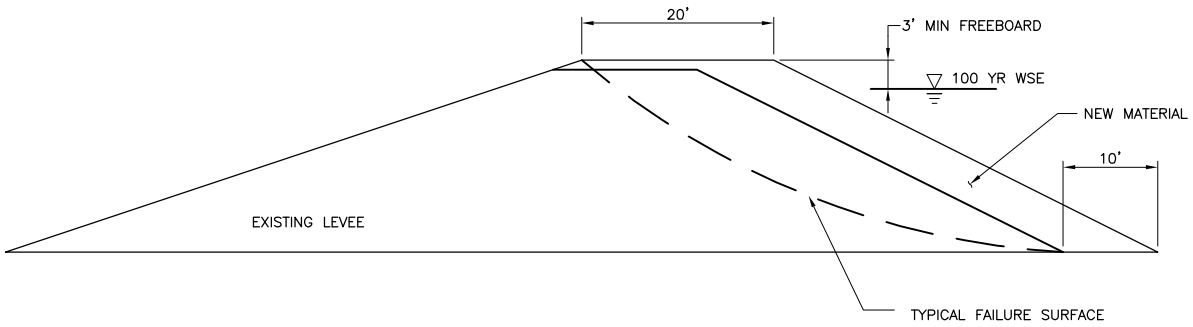
Construction on the Bear River right bank and the Western Pacific Interceptor Canal (WPIC) right bank (Phase 2) began in the fall of 2005 and was completed in 2006. These levees have been through one flood season. The water surface elevation reached the toe of the WPIC during the winter of 2007. The water in the Bear River did not reach the levee during the winter of 2007.

Construction on the Yuba River left bank from the Union Pacific Railroad to Simpson Lane (Phase 4) was completed in 2006. These levees have been through one flood season. The water in the Yuba River did not reach the levee during the winter of 2007.

HDR inspectors have been onsite for Phases 1, 2 and 4 during the winter of 2006/2007 monitoring the Stormwater Pollution Prevention Plans (SWPPP's). Monitoring was performed prior to each storm event and just after the storm event. No desiccation cracking, boils, or seeps have been noted during this time.

Conclusion

Based on field observations by experienced personnel and updated analysis performed by Kleinfelder, it is HDR's opinion that the levee embankment was constructed in such a manner that the design assumptions for strength and permeability reflect the as-constructed conditions in the field. HDR feels the completed levee embankments will perform as designed. As with any new levee construction, a comprehensive monitoring plan should be implemented to evaluate the new embankments through the first flood and subsequent rain events.



TYPICAL FAILURE SURFACE
NTS

FIGURE 1

THREE RIVERS LEVEE IMPROVEMENT AUTHORITY

HDR

Technical Memo

To: Blake Johnson, PE and Randy Olsen, HDR

From: Gale Paddock, PE

Date: April 19, 2007

Project No.: 66388/8

Subject: Levee Reconstruction
Strength Parameters and Permeability
TRLIA Phases 1, 2, and 4

This technical memorandum transmits the results of our reevaluation of the soil strengths used in the "Basis of Design" for the TRLIA Phases 1, 2, and 4 Projects given the as-built conditions of the levee reconstruction.

DISCUSSION

It has been established that some Quality Control and Quality Assurance field moisture content test results were not within the project specification limits during the earthwork construction phase of this project. USACE has expressed their concern that in-place soil strengths and permeabilities may differ from the properties used in the "Basis of Design".

It is generally understood that for cohesive soils, soil compacted above the optimum moisture content may have lower permeability and lower strength and soil compacted below the optimum moisture content may have higher strength and higher permeability.

Strength Concerns

We have addressed this concern by first looking at the embankment areas with out of specified moisture content test results, to see where they fall in regard to the critical failure circles from our original stability analysis. We found that, with but one exception, the earth work for the levee reconstruction did not impact the critical failure circles as the new material was placed above and to the waterside of the failure surface. Thus we concluded the stability could not have been adversely impacted by the reconstruction.

The one possible exception is at the setback tie-in at the Bear River; at this location the levee was entirely reconstructed.

We next addressed the strength concerns by re-running our levee embankment stability models using reduced soil strengths. Stability models for both sudden drawdown, and steady state seepage, were re-analyzed. We chose the levee profiles used in our "Basis of Design" having the lowest factors of safety (F.S.) and re-calculated the F.S. using soil strengths reduced by 15%. With these reduced soil strengths the F.S. still exceeded the minimum USACE and FEMA criteria for both the rapid drawdown and steady state seepage conditions.

Moisture Content Wet of Optimum: As discussed above, soils compacted wet of optimum may have a strength lower than if the sample were compacted at a slightly lower water content. However, material strength is also a function of relative density, and denser materials tend to have higher strength. Given that the sand cone density tests associated with the moisture content tests indicate that the densities achieved met, and in most cases exceeded, relative compaction specifications, it is our opinion that the portions of the embankment constructed with moisture contents wet of optimum have strength parameters consistent with those assumed for the design. It is our opinion that these as-placed materials are of higher strength than the 15% reduced strengths used in our recalculation of the embankment stability. The degree of relative compaction is usually the most important consideration to achieve the desired soil strengths.

Moisture Content Dry of Optimum: As discussed above, soil compacted dry-of-optimum tends to have higher strength. Given that design densities were met or exceeded, it is our opinion that these as-placed materials are of higher strength than the 15% reduced strengths used in our recalculation of the embankment stability.

Permeability Concerns

It should be noted that, as stated previously, with the exception of the setback tie-in, the new fill was placed in either a narrow layer (2 to 3 feet wide) on the waterside of the levee and/or on the crown of the levee (above the 100-year water surface elevation). In these cases, the permeability of the placed material is not critical to the overall performance of the levee embankment.

Moisture Content Wet of Optimum: As discussed above, soils compacted wet of optimum should have a lower permeability.

Moisture Content Dry of Optimum: As discussed above, soil compacted dry-of-optimum tends to have higher permeability than if it were compacted slightly wetter. However, in the Bear River set back area (the only area of concern), there were no dry of optimum moisture test results.

Conclusions

It should be noted that in most cases the moisture conditions which were outside the specified moisture limits were in areas of freeboard or within the outer 2 to 3 feet of the levee embankment. In either of these two conditions, it is judged that as long as the minimum specified relative compaction was achieved, neither the strength nor the permeability of the representative test area is critical to the overall performance of the levee embankment.

Kleinfelder concludes that although in some cases the levee reconstruction did not meet specified moisture content criteria, the as-constructed levee is stable, was constructed in conformance with the intent of the design, and should meet USACE and FEMA levee certification criteria.