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MEMORANDUM

DATE: April 10, 2000

TO: Jim Thomson, P.E., HNTB

FROM: Douglas Lindquist, Barry Chen, P.E., and Mike Bailey, P.E., Hart Crowser, Inc.

RE: Seismic Basis of Design
Third Runway Project
J-4978-14

This memo provides support information to HNTB and the Port of Seattle to select a seismic basis of design event for final project design analyses. This memo presents a comparison of analyses by Hart Crowser for the 475- and 975-year return interval seismic events for representative embankment and MSE wall design components.

Summary

Selection of the 475- or the 975-year event as the seismic basis of design event impacts the following areas of design for the Third Runway project:

1. Spatial extent of ground improvement needed to mitigate liquefaction (small effect);
2. Extent of embankment reinforcement below MSE walls to prevent seismic instability (moderate effect);
3. Factor of Safety in slope stability analyses (moderate effect); and
4. Magnitude of deformation of the MSE walls (moderate to large effect).

The 475-year return period corresponds to a 10 percent probability of exceedence in 50 years, whereas the 975-year return period corresponds to a 5 percent probability of exceedence in 50 years. For comparison, we understand the Port of Seattle used the 475-year event for design of the South Terminal Expansion and for analysis of deepening the berths at the Terminal 5 Wharf.

Comparative Analyses

Results of our analyses for representative sections are described in this memo, to provide the basis for comparing the effect of using one design event or the other. The analyses

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reflect peak seismic accelerations of 0.36 g for the 475-year event and 0.47 g for the 975-year event, based on the site-specific probabilistic seismic hazard analysis previously completed for this project. Refer to our memorandum regarding Probabilistic Seismic Hazard Analysis Results, dated October 8, 1999, for specific discussion of the site-specific seismic risk.

RESULTS OF LIQUEFACTION ANALYSES

There is a high potential for liquefaction during a design level seismic event for some of the near-surface soils below portions of the embankment and the footprint of the NSA, West, and South MSE Walls. Our analyses found virtually no difference in the extent of potential liquefaction that will occur for the 475- and 975-year events. In other words, where soil conditions are conducive to liquefaction, it will occur to the about same degree for either size earthquake.

Our stability analysis indicates that soil improvement under permanent embankment slopes and below the base of the MSE walls is needed to provide adequate stability against liquefaction-induced slope movements. For the representative sections analyzed to date, we found that essentially the same spatial extent of subgrade improvement is needed to provide stability for both the 475- and 975-year events. However, a somewhat greater degree of subgrade improvement may be needed within this zone, for the 975- vs. the 475-year event. Figure 1 illustrates a typical cross section along the West MSE Wall, indicating the zone of liquefaction-susceptible soils and the zone requiring soil improvement. There is no significant difference between the required zones of soil improvement for the 475- versus 975-year seismic events.

RESULTS OF SLOPE STABILITY ANALYSES

Using limit equilibrium methods, slope stability has been analyzed for representative sections through the NSA and West MSE Walls. In this type of analysis, a critical failure surface is defined for static conditions, and then the analysis is repeated using a horizontal acceleration component equal to half the peak ground acceleration, to verify that the pseudo-static factor of safety is at least 1.1.

Our analyses indicated that a simple 2H:1V embankment on good foundation soils (i.e., no liquefaction) will have an adequate factor of safety for both the 475- and 975-year events. However, where the slope embankment supports an MSE wall, the fill and/or the native subgrade will need to be reinforced or otherwise improved to achieve an acceptable factor of safety.

For a representative West MSE Wall section, as shown on Figure 2, Hart Crowser found that the strength of reinforcement needed for the 975-year event would be about twice as much as the amount needed to obtain the same factor of safety for the 475-year event.

Note that further analyses may show it is possible to obtain an acceptable factor of safety for the 475-year event using an alternate approach, such as a crushed rock fill for the embankment and subgrade below the MSE wall, in lieu of reinforcing. However, we expect the same trend would result; about twice as much embankment strength would be needed for the 975-year event as for the 475-year event. Also, it may not be possible to use a non-reinforced fill and achieve an acceptable factor of safety for the 975-year event.

RESULTS OF SEISMIC DEFORMATION ANALYSES

Hart Crowser used a FLAC model to evaluate the static and seismic performance of representative sections of the NSA and West MSE Walls. FLAC is a two-dimensional finite difference program that calculates displacements, stresses, and forces within the foundation, embankment, reinforcement, and wall facing. A time history of ground shaking is input at the base of the FLAC model to simulate real earthquake shaking. Hart Crowser performed test runs of representative MSE walls using the geometry of a portion of the NSA Wall and a reinforcement design similar to what was used for a WSDOT project of comparable height. Actual displacements of the NSA Wall will depend on the final geometry, wall design, and construction methods. The results presented herein are for discussion purposes only and do not represent our estimate of actual NSA Wall deformations.

Figures 3 and 4 show contours of predicted horizontal deformation (x-displacement) and stresses in the reinforcement for 475- and 975-year input motions, respectively. Using a simple reinforcement approach based on a WSDOT design for a temporary wall (the SR-90, Rainier Avenue wall) we calculated maximum displacements at the top of the model wall for the 475-year motion would be 4 to 5 feet while the maximum displacement for the 975-year event would be 7 to 8 feet.

The FLAC model also enabled comparison of the stresses in the reinforcement at the end of the time history. In this model, the 975-year event produced yielding of approximately 30% more of the reinforcing elements compared to the 475-year event. (This kind of analysis can be used during final design so the MSE designer can verify appropriate size and strength of the reinforcing for whatever seismic event is selected).

Hart Crowser found that increasing the length of the reinforcing behind the wall, and adding additional reinforcement layers to the subgrade can reduce displacements from the 975-year motion to approximately those of the 475-year motion. Simple iterative analyses indicate that increasing the length of the reinforced zone behind the wall by about 25 percent, combined with increasing both the depth and the length of the reinforced zone below the wall by about 50 percent, would produce deformations for the 975-year event comparable to the base case for the 475-year event. These estimated percent changes are not a simple scaling factor that can be uniformly applied to all wall sections, but can be used for discussion purposes on the relative effect of the 475- and 975-year events.

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Attachments:

Figures 1 - Extent of Subgrade Improvement to Mitigate Liquefaction for a West Wall Section

Figure 2 - Fill Reinforcement to Mitigate Potential Failure Surface for a West Wall Section

Figure 3 - X-displacement Contours and Stresses in the Reinforcement for the 475-year Seismic Event

Figure 4 - X-displacement Contours and Stresses in the Reinforcement for the 975-year Seismic Event

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Extent of Subgrade Improvement to Mitigate Liquefaction for a West Wall Section

West Wall Section 8+20

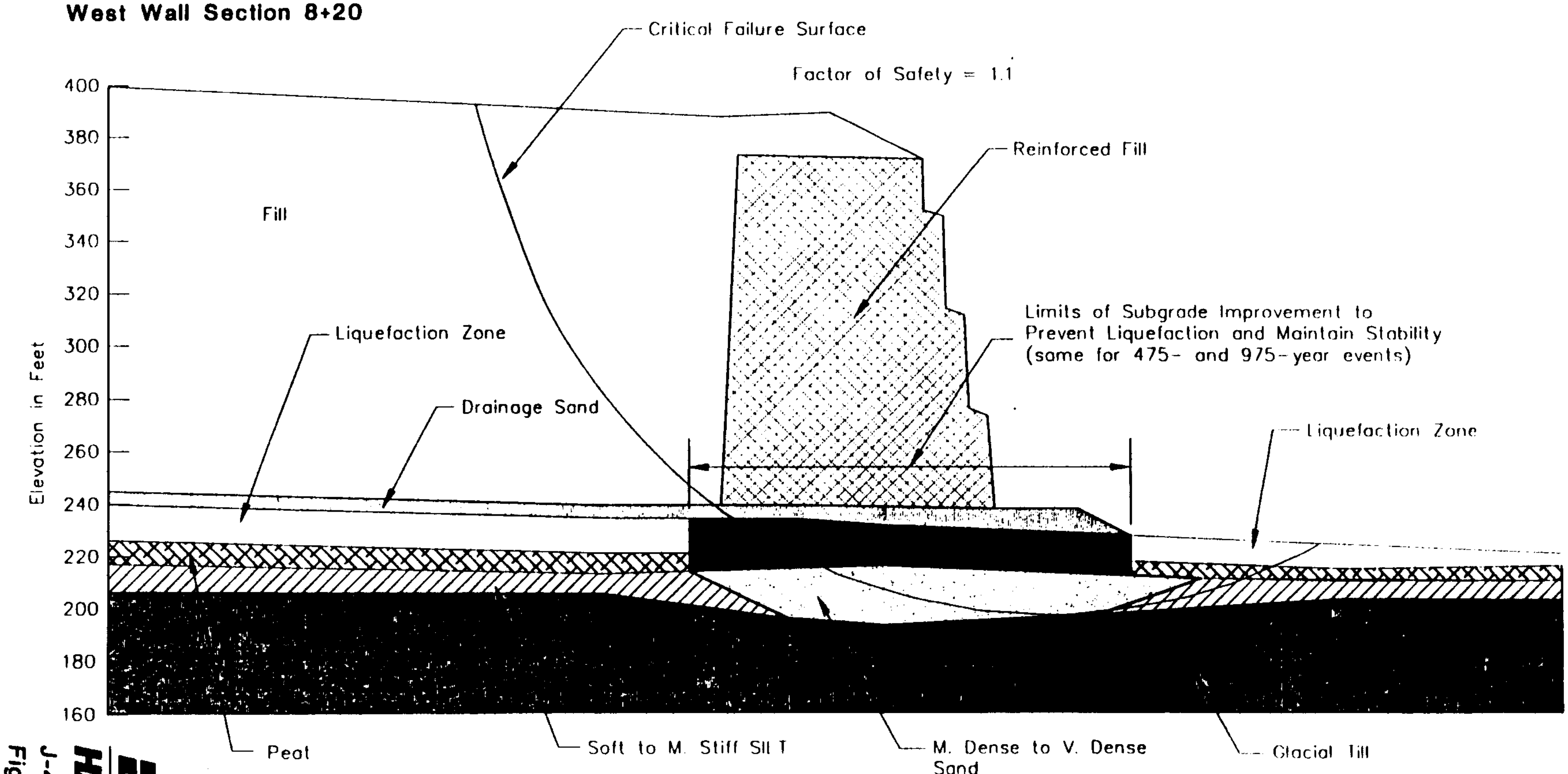

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Figure 1

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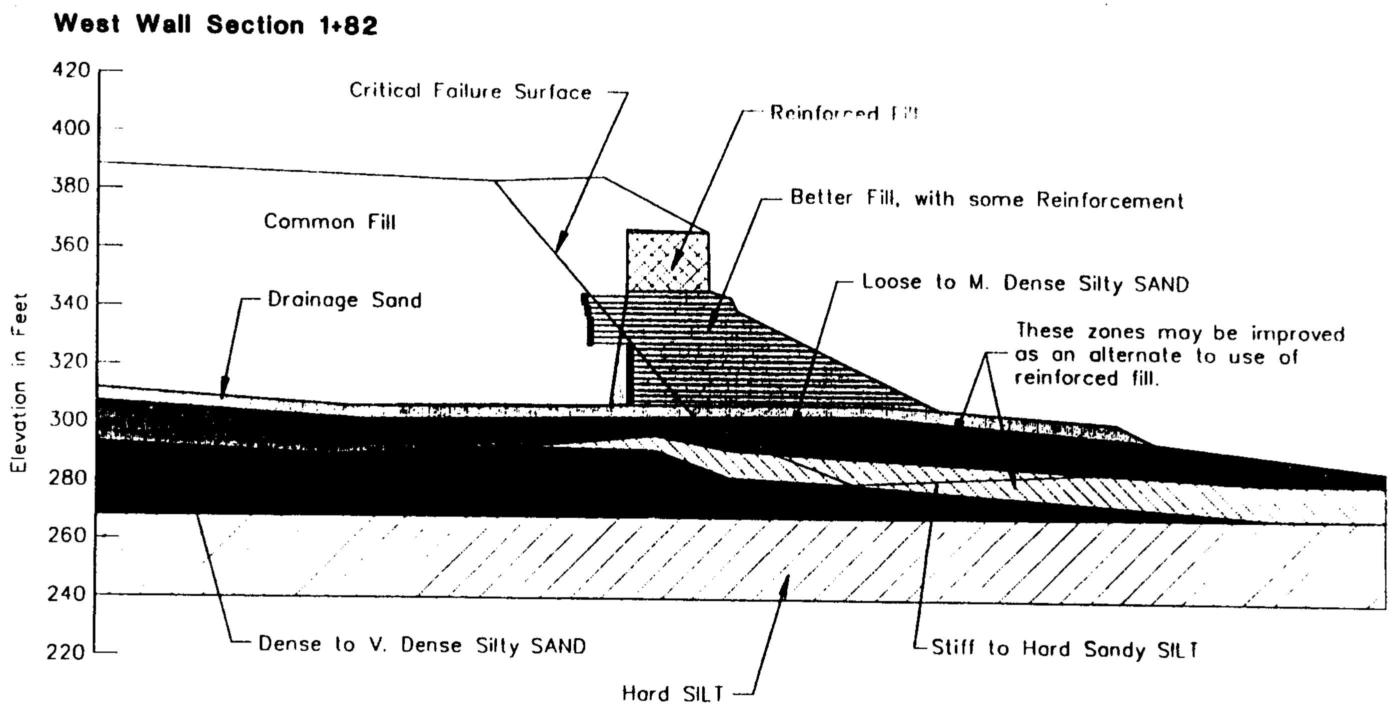
Fill Reinforcement to Mitigate Potential Failure Surface for a West Wall Section



Seismic Event	Geotextile Strength	Factor of Safety
475-year	0	1.0
475-year	4000 lb/ft	1.1
975-year	0	0.9
975-year	4000 lb/ft	1.0
975-year	7500 lb/ft	1.1

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Figure 2

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X-displacement Contours and Stresses in the Reinforcement for the 475-year Seismic Event

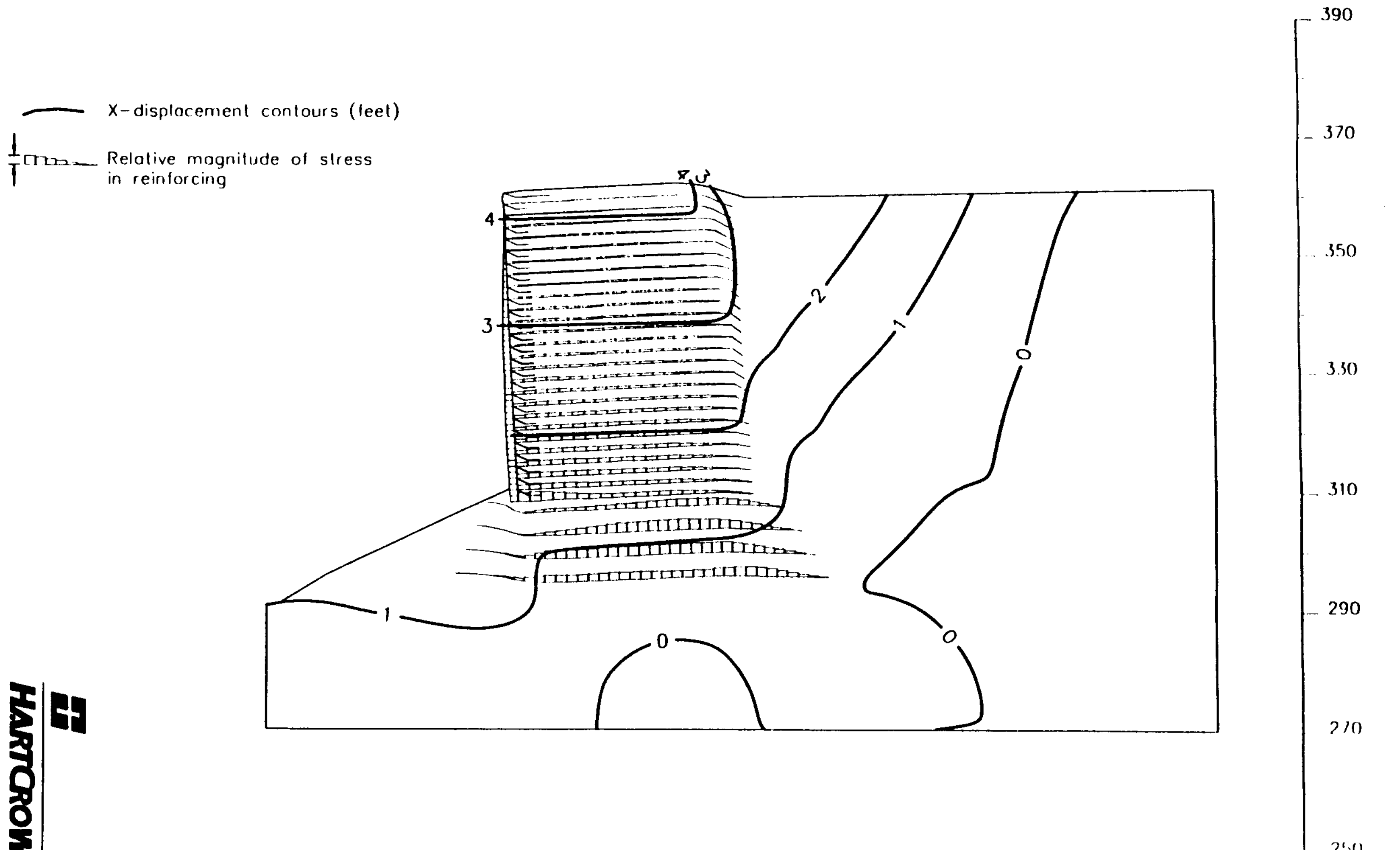

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Figure 3

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X-displacement Contours and Stresses in the Reinforcement for the 975-year Seismic Event

X-displacement contours (feet)

Relative magnitude of stress in reinforcing

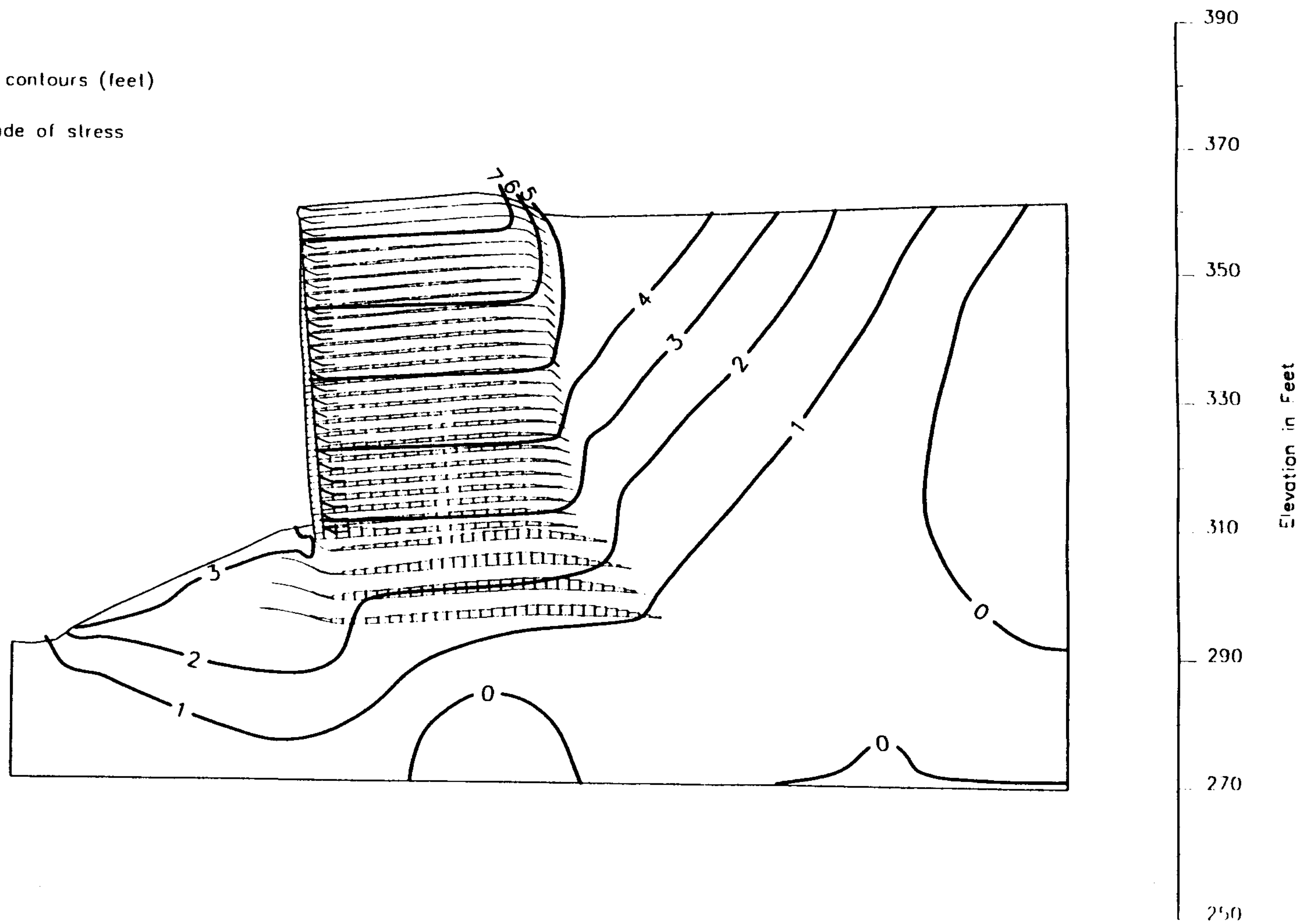

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Figure 4