CONSIDERATIONS ON THE SEISMIC DESIGN OF HIGH CONCRETE FACE ROCKFILL DAMS (CFRDs)

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CONSIDERATIONS ON THE SEISMIC DESIGN OF HIGH CONCRETE FACE ROCKFILL DAMS (CFRDs)

• CONCRETE FACE ROCKFILL DAMS –CFRDs- HAVE INCREASED IN HEIGHT TO NEAR 300M.

• RECENT SEISMIC EVENTS (2008) SUCH AS WENCHUAN – CHINA AND IWATE – MIYAGI – JAPAN INDICATED THE NECESSITY TO OPTIMIZE DESIGN AND CONSTRUCTION MEASURES TO MITIGATE SHAKING EFFECTS.

• THIS PAPER PRESENTS A METHOD FOR PREDICTION OF SEISMIC DISPLACEMENTS BASED ON SIMPLIFIED METHODS BY NEWMARK, AMBRASEYS AND SARMA.
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ZIPINGPU DAM WAS AFFECTED BY WENCHUAN EVENT - 2008
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ZIPINGPU - Horizontal Joint Damaged at El.845
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Perimetric Joint between Slab and Parapet Was Damaged
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Some Cracks at the Crest Were Presented
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Rockfill Loosened at Upper Downstream Slope
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Ishibuchi Dam Was Affected by the IWATE – MIYAGI Event - 2008
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Construction of Ishibuchi Dam by Dumping Rockfill from a Bridge Supported by Pillars
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Longitudinal Crack on the Crest
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Longitudinal Crack on the Crest
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Ground Motions Amplification

\[ A_{\text{max}} = \text{Maximum Ground Acceleration} \]
\[ A_1 = k_{n1} A_{\text{max}} \]
\[ A_2 = k_{n2} A_{\text{max}} \]
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PEAK ACCELERATIONS AT THE CREST WERE AMPLIFIED:

ZIPINGPU - Perpendicular to Axis  2.06 g  
MGA = 0.7 g

ISHIBUCHI – Perpendicular to Axis 0.95 g  
MGA = ?

Ground Motions Amplification
The fundamental period of the dam, $T_o$, can be approximated as:

$$T_o = 2.61 \frac{h}{V_s}$$

Where $h$ is the height of the dam and $V_s$ is the shear wave propagation velocity at strain levels compatible with those induced by the ground shaking on the embankment materials. The $V_s$ value can be extrapolated from shear wave velocity measurements in the embankment materials. In our experience, well compacted, dense rockfill materials with unit weights $\gamma \approx 2.2 \text{ T/m}^3$ have $V_s$ values in the range of 1500 ft/sec (457 m/sec) to 2000 ft/sec (610 m/sec).
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Maximum Simultaneous Seismic Coefficient for 20% Damping
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Damping Correction Factor
Potential Sliding Wedge Geometry
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STATIC CONDITIONS

The wedge ABC, resting on a slip surface with an inclination $\alpha_1$ can be established as:

$$FS = \frac{N \tan \varphi}{W \sin \alpha_1}$$

Where $N = W \cos \alpha_1$; replacing terms:

$$FS = \frac{\tan \varphi}{\tan \alpha_1}$$
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Force Polygon of Sliding Wedge
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DYNAMIC CONDITIONS
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CONCLUSIONS:

• INCREASE WIDTH OF CREST.
• IMPROVE ZONING INCREASING 3B AT CREST.
• USE FLATTER SLOPES NEAR CREST.
• USE HEAVIER COMPACTORS > 5T/M OVER THE CYLINDER.
• USE HIGHER FREE BOARD.
• RESTRICT PARAPET WALL TO 4 M.
• INCREASE W.S. CAPACITY.
• SPLIT SLAB WIDTH LANES TO 7,50 M.
• REINFORCE HORIZONTAL CONSTRUCTION JOINTS.
• USE COMPRESSIBLE FILLERS IN CENTRAL COMPRESSION JOINTS.
CONSIDERATIONS ON THE SEISMIC DESIGN OF HIGH CONCRETE FACE ROCKFILL DAMS (CFRDs)

1A COHESIONLESS SOIL - COMPACTED BY CONSTRUCTION EQUIPMENT
1B RANDOM - COMPACTED BY CONSTRUCTION EQUIPMENT
2A PROCESSED MATERIAL (Ø MAX. = 3/4”) - MANUAL COMPACTION
2B PROCESSED MATERIAL (Ø MAX. = 3”-4”) 4-6 PASSES OF 12 Ton VIBRATORY ROLLER
3A SELECTED SMALL ROCK PLACED IN SAME LAYER THICKNESS AS ZONE 2
3B QUARRY RUN ROCKFILL, ABOUT 0,60m TO 0,80m LAYERS, 4-6 PASSES OF 12 Ton VIBRATORY ROLLER
3C QUARRY RUN ROCKFILL, ABOUT 0,80m TO 1,00m LAYERS, 4-6 PASSES OF 12 Ton VIBRATORY ROLLER
4 DOWNSTREAM ROCKFILL - PLACED ROCKFILL
THANKS