

# Second International Symposium on Rockfill Dams

October 27 to 28, 2011

Windsor Barra da Tijuca Hotel - Rio de Janeiro - Brazil



## XXVIII SNGB

National Seminar on Large Dams

October 25 to 28, 2011

Windsor Barra da Tijuca Hotel - Rio de Janeiro - Brazil



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

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Fernandez**

# **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.**



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



**ZIPINGPU - Horizontal Joint Damaged at El.845**

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**Perimetric Joint between Slab and Parapet Was Damaged**

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



**Some Cracks at the Crest Were Presented**

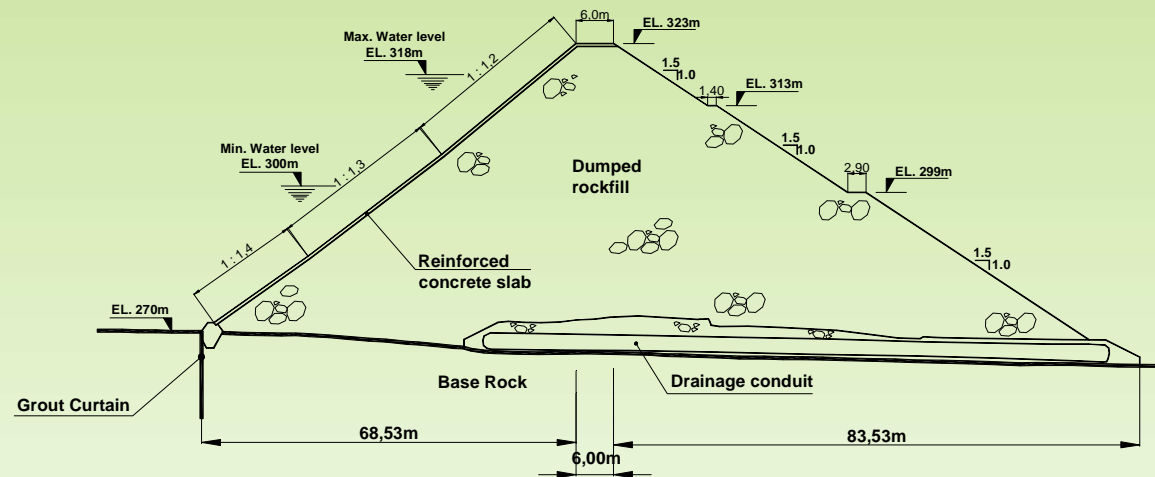
# CONSIDERATIONS ON THE SEISMIC DESIGN OF HIGH CONCRETE FACE ROCKFILL DAMS (CFRDs)



**Rockfill Loosened at Upper Downstream Slope**

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

Ishibuchi dam



Ishibuchi Dam Was Affected by the IWATE – MIYAGI Event - 2008

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



**Construction of Ishibuchi Dam by Dumping Rockfill  
from a Bridge Supported by Pillars**

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



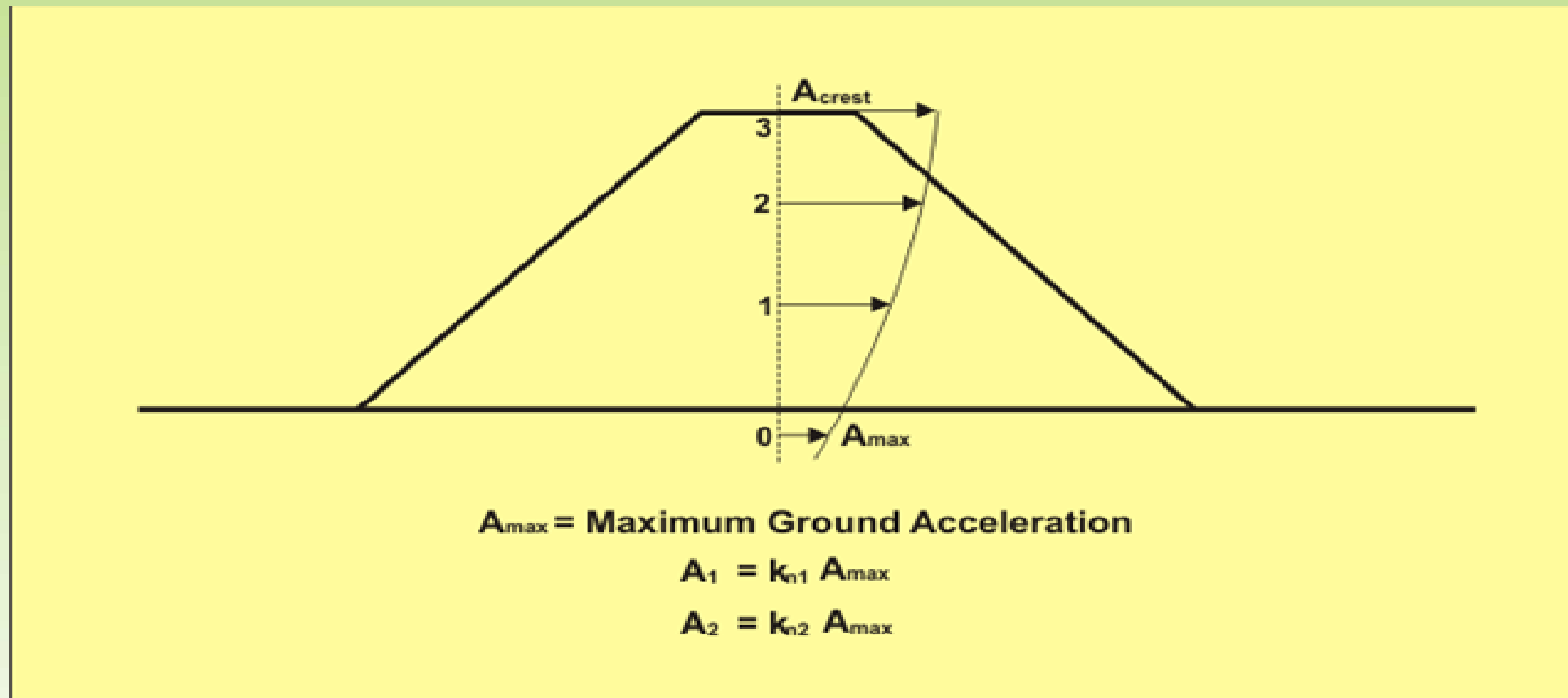
**Longitudinal Crack on the Crest**

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



**Longitudinal Crack on the Crest**

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



## Ground Motions Amplification

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

**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**

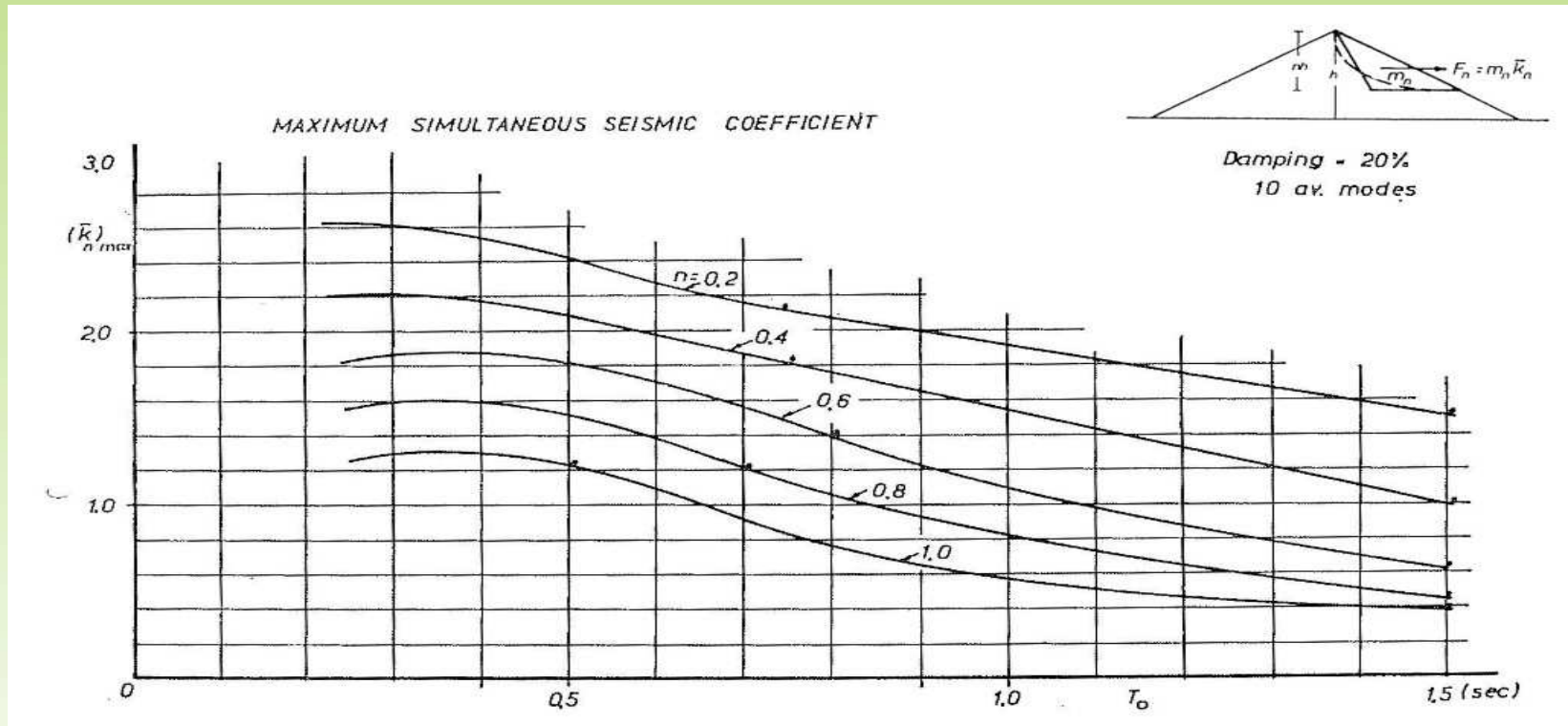
# CONSIDERATIONS ON THE SEISMIC DESIGN OF HIGH CONCRETE FACE ROCKFILL DAMS (CFRDs)

The fundamental period of the dam,  $T_0$ , can be approximated as:

$$T_0 = 2.61 h/V_s$$

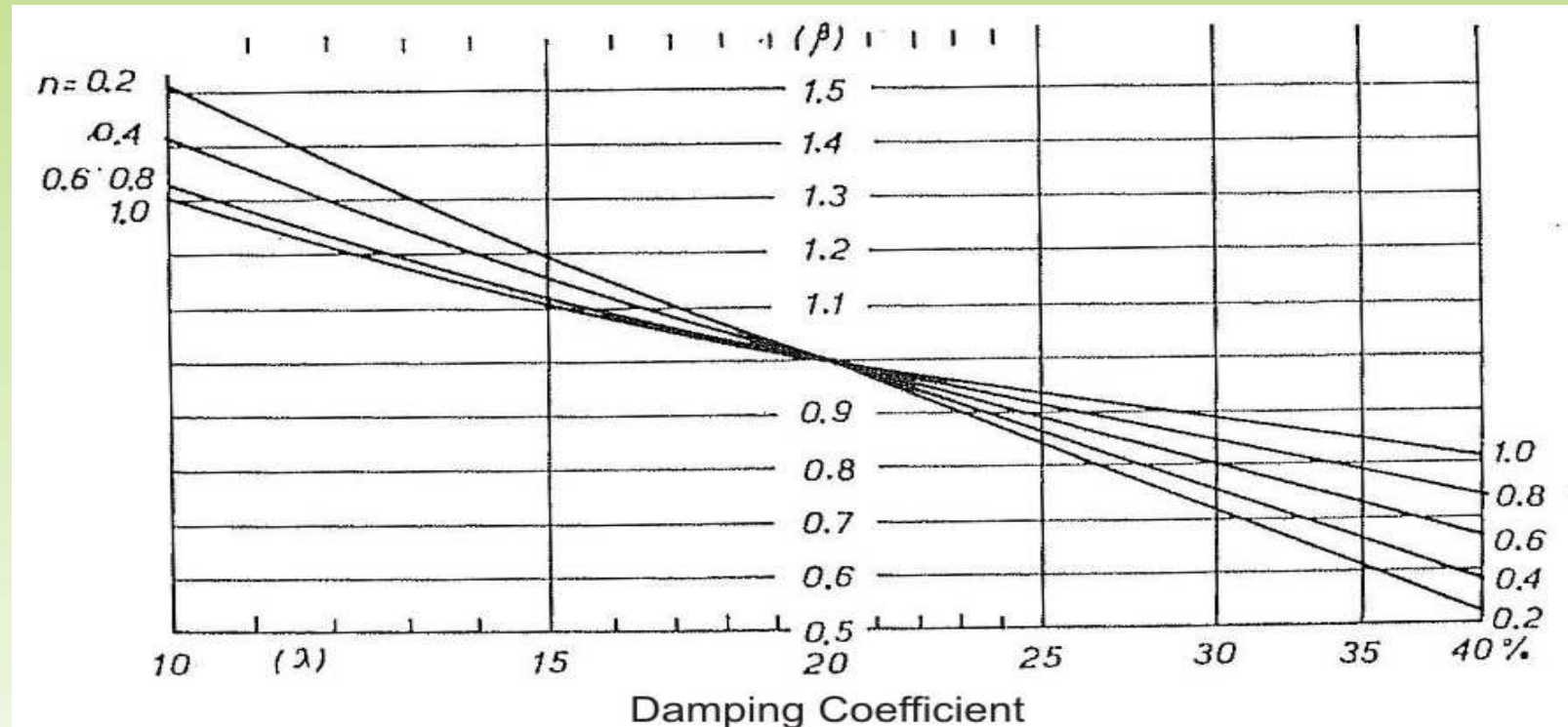
Where  $h$  is the height of the dam and  $V_s$  is the shear wave propagation velocity at strain levels compatible with those induced by the ground shaking on the embankment materials. The  $V_s$  value can be extrapolated from shear wave velocity measurements in the embankment materials. In our experience, 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 (457m/sec) to 2000 ft/sec (610m/sec).

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



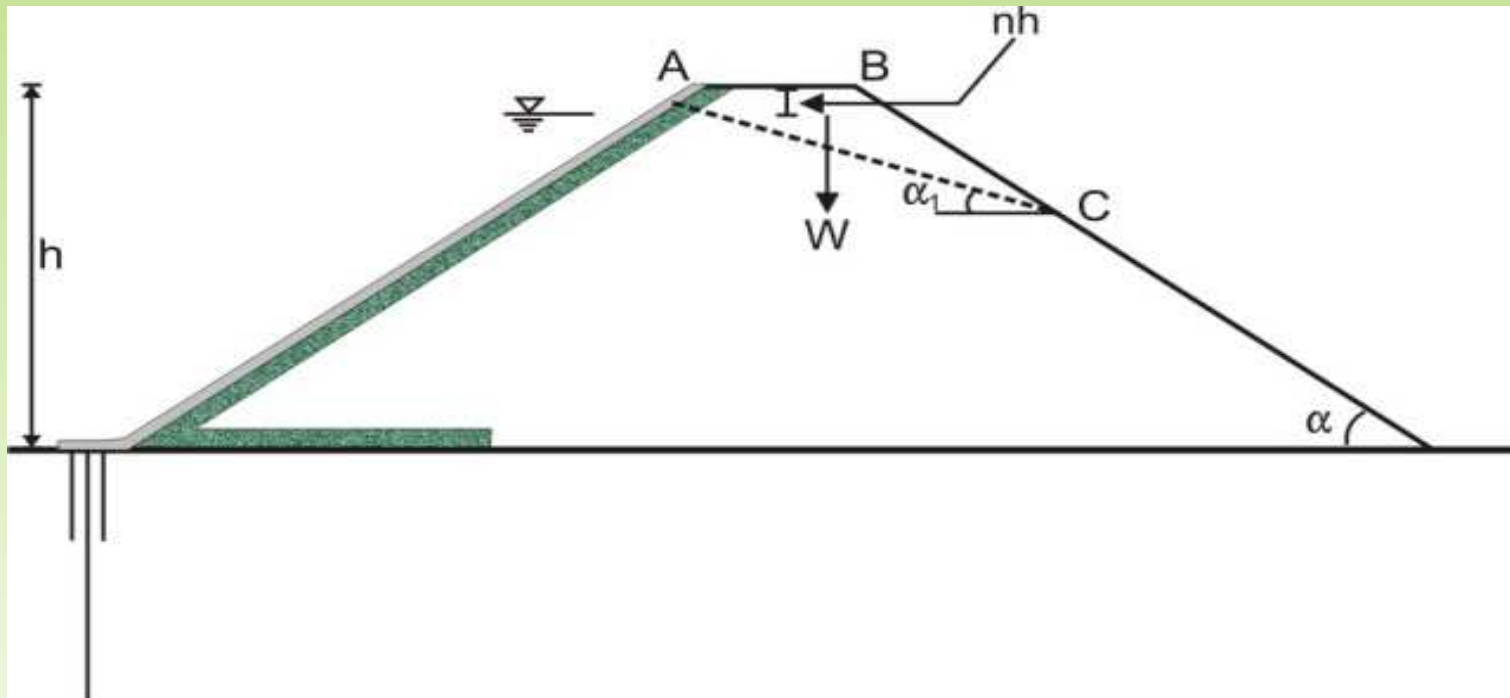
**Maximum Simultaneous Seismic Coefficient for  
20% Damping**

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



## Damping Correction Factor

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



Potential Sliding Wedge Geometry

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

## STATIC CONDITIONS

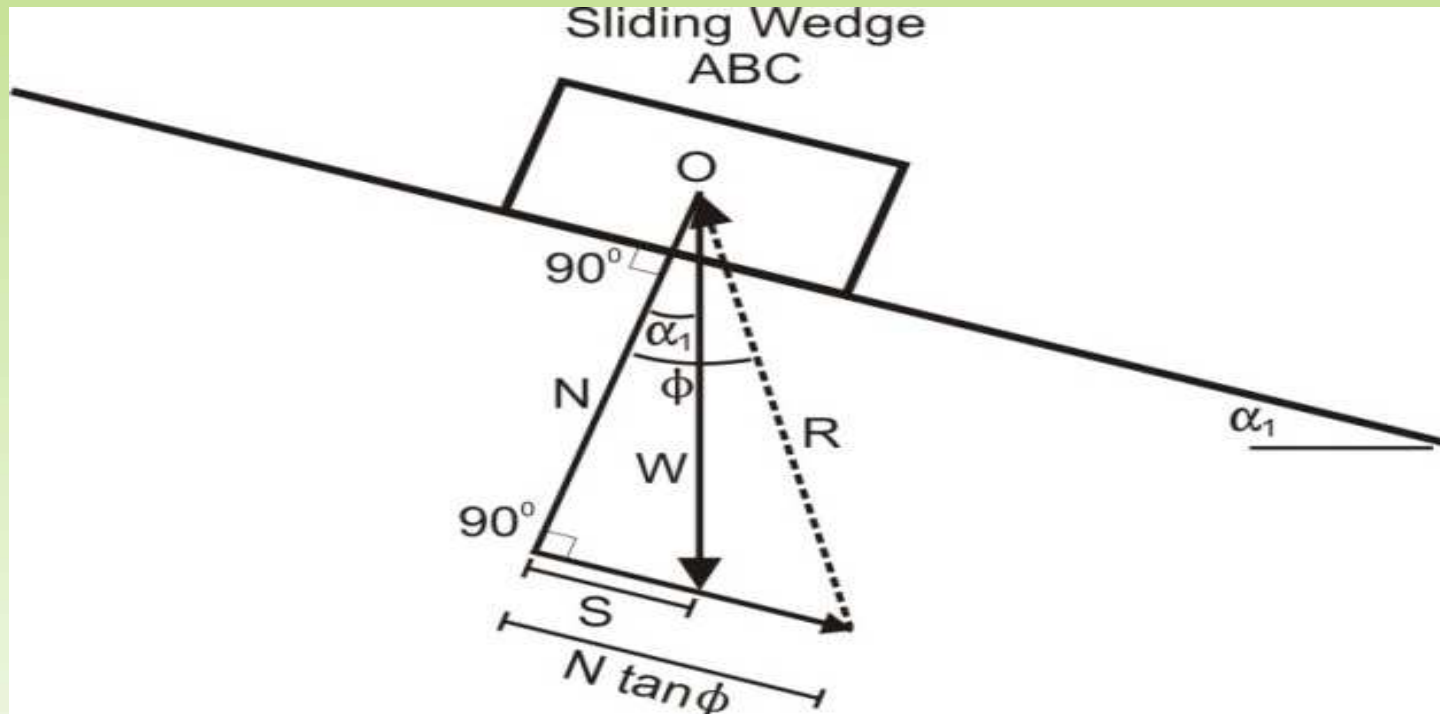
The wedge ABC, resting on a slip surface with an inclination  $\alpha_1$  can be established as:

$$FS = N \tan \varphi / W \sin \alpha_1$$

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

$$FS = \tan \varphi / \tan \alpha_1$$

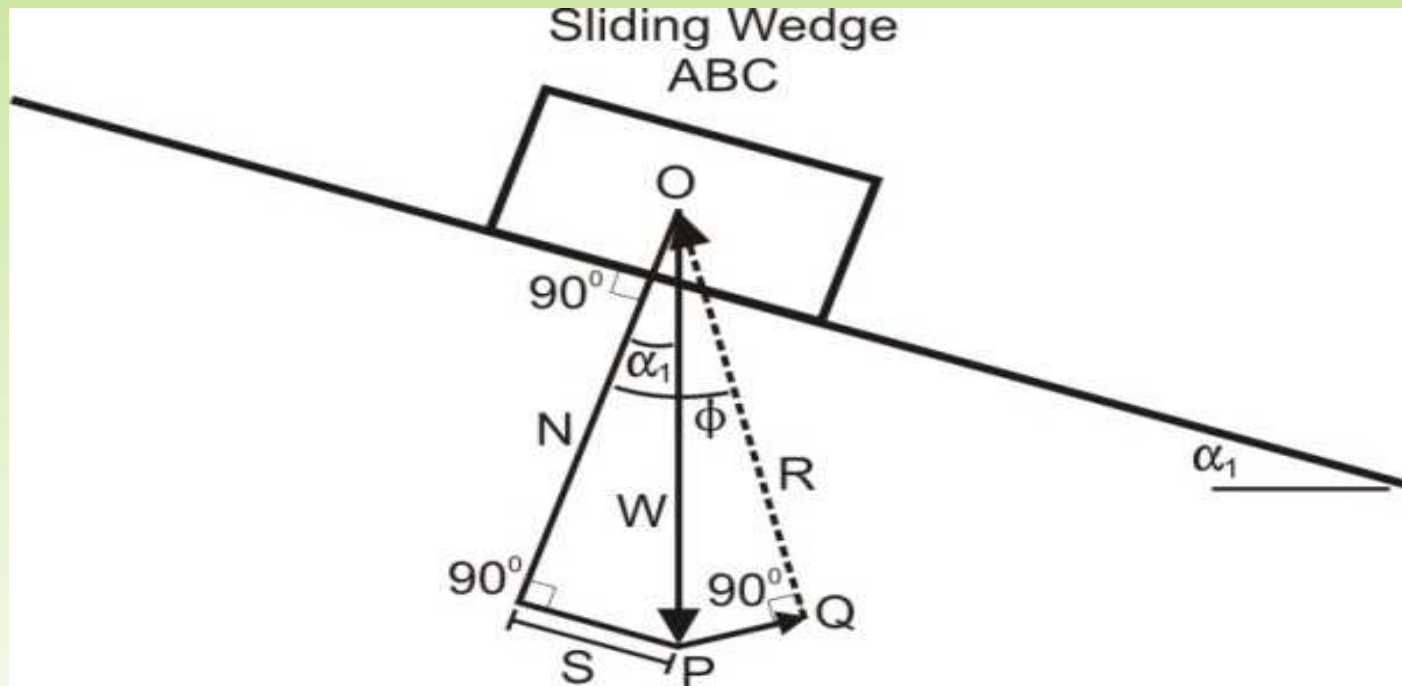
# CONSIDERATIONS ON THE SEISMIC DESIGN OF HIGH CONCRETE FACE ROCKFILL DAMS (CFRDs)



Force Polygon of Sliding Wedge

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

## DYNAMIC CONDITIONS

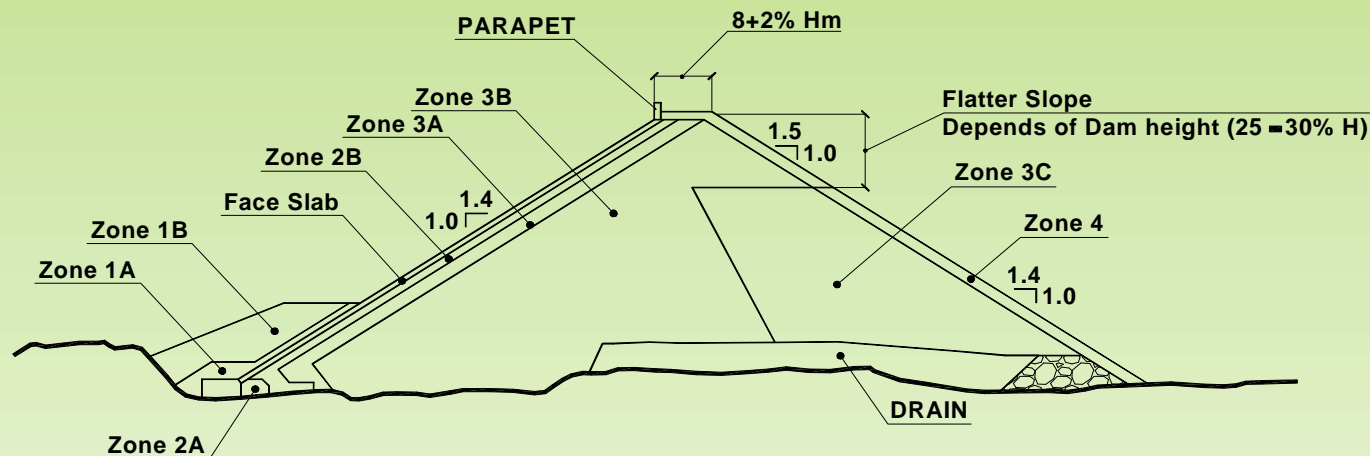


# CONSIDERATIONS ON THE SEISMIC DESIGN OF HIGH CONCRETE FACE ROCKFILL DAMS (CFRDs)

## 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 ( $\emptyset$  MAX. =  $\frac{3}{4}$  ") - MANUAL COMPACTION**

**2B PROCESSED MATERIAL ( $\emptyset$  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

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