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COMPUTER AIDED ANALYSIS OF A GRAVITY DAM USING MIDAS GTS NX

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Abstract— **This study examined the computer aided modelling, analysis, and design, of a concrete gravity dam. Manual design was first done and validated with CADAM software. MIDAS GTS software was then used again and the results were compared with manual design based on stability analysis against sliding, overturning and shear friction. Initial data of the University of Ilorin dam was collected from project planning unit (PPU) of the University of Ilorin for the analysis. A Typical trapezoidal concrete gravity dam ofTop width of 2m, Bottom width of 10m, Height of12m and upstream face batter of 0.9m was analysed in this study using the Gravity Method of analysis.Based on the manual design of the typical concrete gravity dam analysis carried out, the factors of safety against overturning, sliding and shear friction factor were 1.63, 1.15, and 20.59, while validation using CADAM gave 3.63, 4.08 and 5.66 factor of safety respectively. These are all greater than the allowable factors. The compressive stresses at the toe of the dam using manual design and MIDAS software are 1.05X kN/ and 1.66X kN/ respectively and the shear stresses using manual design and MIDAS software are 6.21X kN/ and 6.41X kN/ respectively. The results from the manual analysis and Midas GTS Software differ slightly; this could be due to the methods used.**

Index terms- **Gravity Dam, CADAM, MIDAS GTS NX, Sliding, Overturning, Factor of safety, Gravity method of dam design.**

I. INTRODUCTION

Dams are vital civil engineering infrastructures(made of concrete or earth) built across a river or stream to obstruct or control the flow of water. Gravity dams are dams constructed out masonry or concrete that rely solely on it self-weights for stability. Technically, a concrete gravity dam derives its stability from the force of gravity of the materials in the section and hence the name. The gravity dam should have sufficient weight so as to withstand the forces and overturning moment caused by the water impounded in the reservoir behind it. It transfers then loads to the foundation by cantilever action and hence good foundations are pre-requisite for gravity dams. Fundamentally a gravity dam should satisfy these criteria: It should be safe against overturning at horizontal position within the dam at the contact with the foundation or within the foundation, It should be safe against sliding at any horizontal plane within the dam at the contact with the foundation or along any geological feature within the foundation, the section should be so proportional that the allowable stresses in both the concrete and the foundation should not exceed.The resultfromthe computer aided design of the dam (using MIDAS GTS NX software)was compared with that of themanualdesign to ascertain the level of accuracy of the manual design.University of Ilorin dam site from which initial data was collected is located within the university campus which lies entirely within the basement rocks in the Western part of Central Nigeria bounded by longitudes 4° 39′ 51.6″ - 4° 40′ 02.50″ E and latitudes 8° 27′ 54.2″ - 8° 28′ 4.7″ N.

MIDAS GTS NX is a finite element analysis (FEA) software developed in South Korea; CADAM (Computer Analysis of concrete gravity Dams) is a computer program that was primarily designed to provide support for learning of structural stability evaluation of concrete gravity dams based on the gravity method at theDepartment of Civil, Geological and Mining Engineering, ÉcolePolytechnique de Montréal, Station Centre-ville, Montré.

II. METHODOLOGY

A typical trapezoidal concrete gravity dam with Top width of 2m, Bottom width of 10m, Height of12m and Upstream face batter of 0.9m; Assuming uplift intensity factor of 100% and unit weight of concrete of$24kN/m^3$ was first manually analysed for stability against sliding and overturningin accordance with the U.S.B.R recommendation and BS 8007.CADAM software was the used to model and validate the dam's stability. MIDAS GTS NX software was finally use for the structural modeling and analysis of the dam to ascertain the level of accuracy of the manual design.

While gravity method of analysis of dams allows initial analysis based on a two dimensional (2D) section of the dam, in MIDAS GTX NX modeling, a three- dimensional (3D) section is most convenient. For this reason, a length of 5000m was assumed. Therefore all results from the manual analysis and CADAM validation will need to be multiplied by 5000m before comparison with results from MIDAS GTS NX.

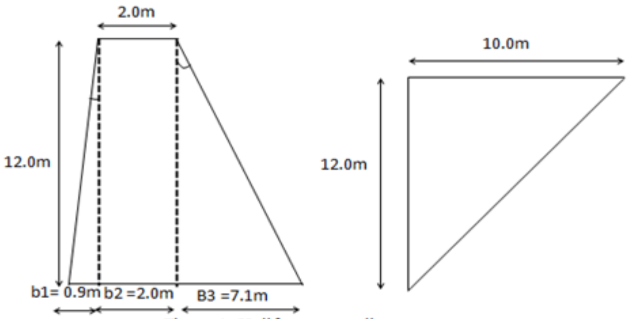


Figure 1. Uplift pressure diagram

A. Stability analysis

Unit shear strength of concrete = 1400kN/m^2
Coefficient of friction = 0.7
Weight of water = 10kN/m^3
Considering 1m length of dam
Vertical weight, V = 1780 – 600 = 1180kN
M = 11230 – 6882 = +4350kNm
Factor of safety against overturning = 11230/6882 = 1.63 > 1.5, hence safe
Factor of safety against sliding = (0.7 * 1180)/720 = 1.15 > 1, hence safe
Shear friction factor = (0.7 * 1180 + 10 * 1400)/720 = 20.59 > 2, hence safe

B. Stress analysis

Position of resultant, x = 4350/1180 = 3.69m
Eccentricity, e = 10.0/2 – 3.69 = 1.31m, which is < b/6 < 10/6 <1.67
Compressive stress at toe, Pn = 1180/10(1 + (6 * 1.31/10)) = 210.7kN/m^2
Compressive stress at heel, P'n =1180/10(1 – (6 * 1.31/10)) = 25.3kN/m^2
$\tan\alpha$ = 0.9/12 = 0.075
$\tan^2\alpha = (0.075^2) = 0.006$
$\sec^2\alpha = 1 + \tan^2\alpha$ = 1 + 0.006 = 1.006
$\tan\beta$ = 7.1/12 = 0.59
$\sec^2\beta = 1 + \tan^2\beta = 1 + (0.59)^2$ = 1.35
Principal stress at toe, $\sigma = 210.7 * 1.35 =$ 284.4kN/m^2
Principal stress at heel $\sigma h = 25.3 * 1.006 - 1 * 12 * 0.006 = 24.7kN/m^2$
Shear stress at toe, $\tau_D =$ 210.7 * 0.59 = 124.3kN/m^2
Shear stress at heel, $\tau_D h = -(25.3 - 12.0) * 0.075$ = -1kN/m^2

C. Modelling and Validation using CADAM

The dam in this study was modelled in CADAM software to validate the initial manual analysis since both the manual analysis and this software are based on the same gravity method of analysing dam.

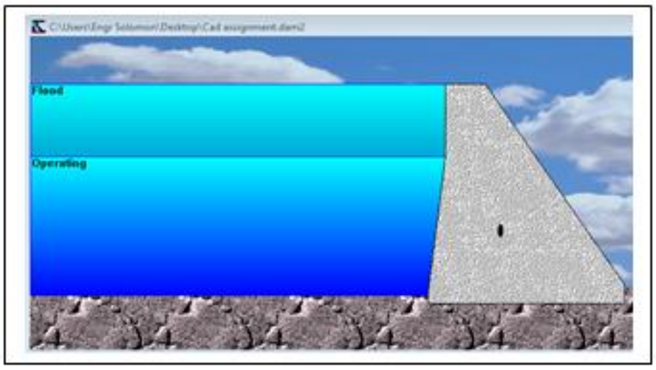


Figure 2.1: Modeling of dam structure

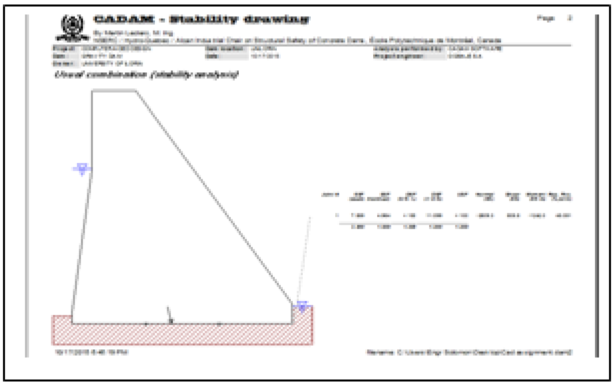
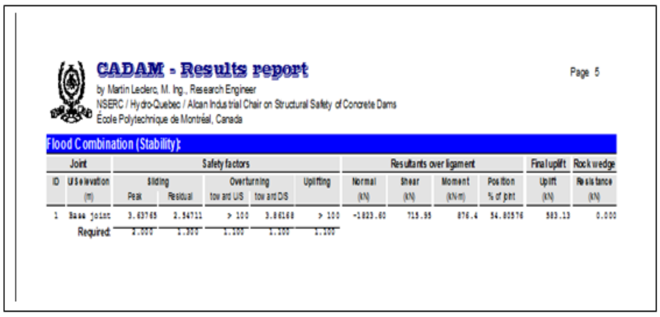


Figure 2.2:CADAM Stability drawing



CADAM - Results report
Page 5
by Martin Leclerc, M. Ing., Research Engineer
NSERC / Hydro-Quebec / Alcan Industrial Chair on Structural Safety of Concrete Dams
École Polytechnique de Montréal, Canada

Flood Combination (Stability):

Joint		Safety factors					Resultants over ligament				Final uplift	Rock wedge
ID	US elevation (m)	Sliding Peak	Sliding Residual	Overturning toward US	Overturning toward DS	Uplifting	Normal (kN)	Shear (kN)	Moment (kN-m)	Position % of joint	Uplift (kN)	Resistance (kN)
1	Base joint	3.63765	2.54711	> 100	3.86168	> 100	-1823.60	715.95	876.4	54.80576	583.13	0.000
	Required	2.000	1.300	1.100	1.100	1.100						

Figure 2.3:CADAM Results Report

III. Method of Software Analysis with MIDAS GTS NX.

The method of analysis applied is known as the finite element method (FEM) or finite element analysis (FEA), which is a computational technique used to obtain approximate solutions of boundary value problems in engineering.

The procedure of the computer aided analysis using MIDAS GTS NX software consists of the following steps:

1. Modelling of Dam Structure
2. Applying Boundary Conditions
3. Meshing of the Dam model
4. Applying Loads and Constraints
5. Running of Analysis and Display of Results

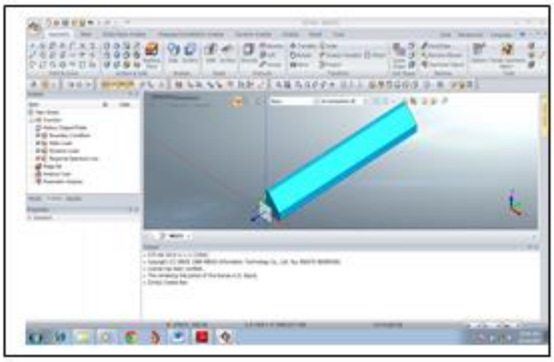


Figure 3.1: Modeling of Dam Structure

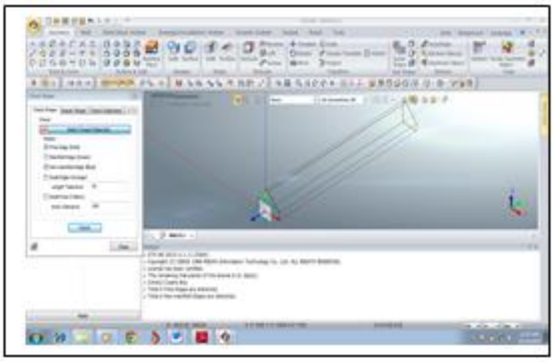


Figure 3.2 Applying Boundary Conditions

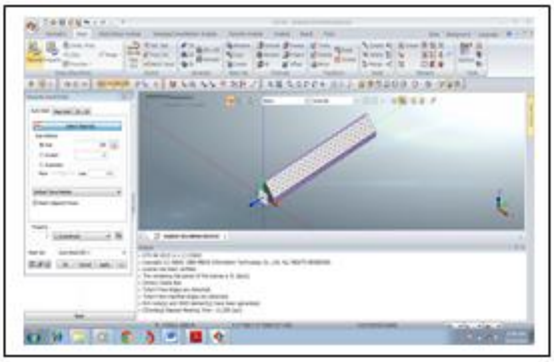


Figure 3.3: Meshing of Dam Structure

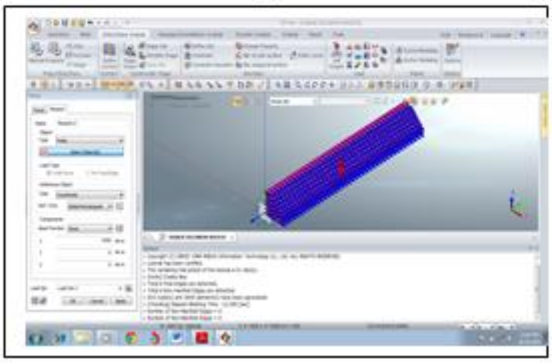


Figure 3.4: Application of Loads and Constraints

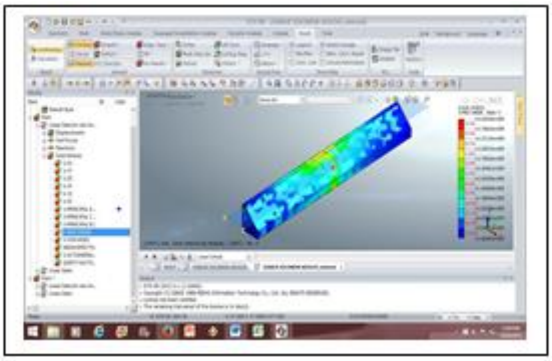


Figure 3.5: Running of Analysis and Display of Results

IV. Results and Discussion

Results from Manual Analysisand Midas GTS Software Analysis

Table 3.0 Comparison of Result (considering a length of 5000m for design purpose)

	APPLIED FORCE (kN)			STRESSES (kN/m^2)	
	MANUAL	CADAM	MIDAS	MANUAL	MIDAS
Vertical load	2.32 X 10^6	3.65 X 10^6	2.36 X 10^6		
Horizontal load	1.44 X 10^6	1.43 X 10^6	1.44 X 10^6		
Compressive stress at toe				1.05 X 10^5	1.66 X 10^5
Compressive stress at heel				1.27 X 10^4	1.33 X 10^5
Principal stress at toe				1.42 X 10^6	2.71 X 10^5
Principal stress at heel				1.23 X 10^5	1.34X 10^5
Shear stress at toe				6.21 X 10^5	6.41 X 10^5
Shear stress at heel				5.00 X 10^3	1.93 X 10^5

A. Discussion of Results

As shown in the results above, the total applied vertical load and horizontal load of the manual is almost in a close range with that of MIDAS GTS NX SOFTWARE. Also the stresses at the toe of the dam of both the manual of computer aided analysis and design are almost similar. The results from the manual analysis and Midas GTS Software differ slightly.

V. Conclusion

In general, the stability status of a dam is based on the factors of safety against Sliding, Overturning, and Shear friction factor. Based on the manual design of the typical concrete gravity dam analysis carried out, the factors of safety against, Overturning, Sliding and Shear Friction Factor were 1.63, 1.15, and 20.59 which are all greater than the Allowable factors.The results of the vertical using the manual and MIDAS design are 2.32X10^6 kN and 2.36X 10^6 kN, and the horizontal loadsare1.44X10^6 kN and 1.44X 10^6kN respectively. Also, the maximum and minimum stresses from the manual and software analysis and design are: Maximum compressive stress at toe is 1.05X10^5 kN/m^2 and 1.66 X 10^5 kN/m^2respectively. Maximum principal stress at toe is 6.21X 10^5 kN/m^2 and 6.41X10^5 kN/m^2. These results of both manual and software analysis are in agreement.

A. Recommendation

The use of computer aided analysis software has made civil engineering work and projects much easier and faster, therefore, MIDAS GTS NX software can be recommended as reliablefinite element analysis software for use by students and civil engineers in the society. The fact that one needs to be on the internet and in connection with the MIDAS group to run the analysis of the model builds confidence in the outcome of the results.

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