EFFECT OF RIGIDITY ON PORE WATER PRESSURE IN DAMS (Ec/Es)

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الخلاصة

يدرس هذا البحث تاثير الجساءه والتي تمثل النسبة بين معاملات يونك بين لب السد نسبه الى الاكتاف وتأثيرها على ضغط الماء المسامي وقد وجدت ان نسبة الملائمة لضمان معامل امان كافي السداد هو Ec/ Ec = 0.7 .

مفاتيح الكلمات

الجساءة ، ضغط الماء المسامي ، السدود

ABSTRACT

In this paper, to study the effect of relative core /shells rigidity, three cases have been considered. Core of less rigidity (Ec/Es <1.0), homogeneous rigidity (Ec/Es =1.0) and stiffer core (Ec/Es >1.0), the problem is analyzed numerically using the finite element computer program by using Biot consolidation of rectangle in plane strain (Four- node element).It was found that the factor of safety against tension cracking is increased as the depth of the core increases, and for Duncan and Sherard criteria, the factor of safety is about (1.2) for three planes that bounded the core, the values of Ec/Es is (0.7). However, the settlement, horizontal displacement and pore pressure are decreased as the ratio Ec/Es increased.

Key words: rigidity, pore water pressure, dam

INTRODUCTION

Two main criteria to estimate the susceptibility of the core of a dam have been adopted, Duncan criteria and Sherard criteria. Duncan criteria, according to (Duncan and Eisentein 1973) proposed that cracks probably appeared when one of the principal stresses becomes tensile. While in later criteria, this criteria assumes that the tends to compress more under the weight of the overlying fill than the shells do, so that apart of weight of the core is transferred to the shells by shear stress and arching. Within the core, the vertical stress on the horizontal planes at various elevations may be so low that. They are approaching zero. This arching effect, combined with variable shear strengths developing on the vertical planes separating the core and shells, can conceivably result in cracking.

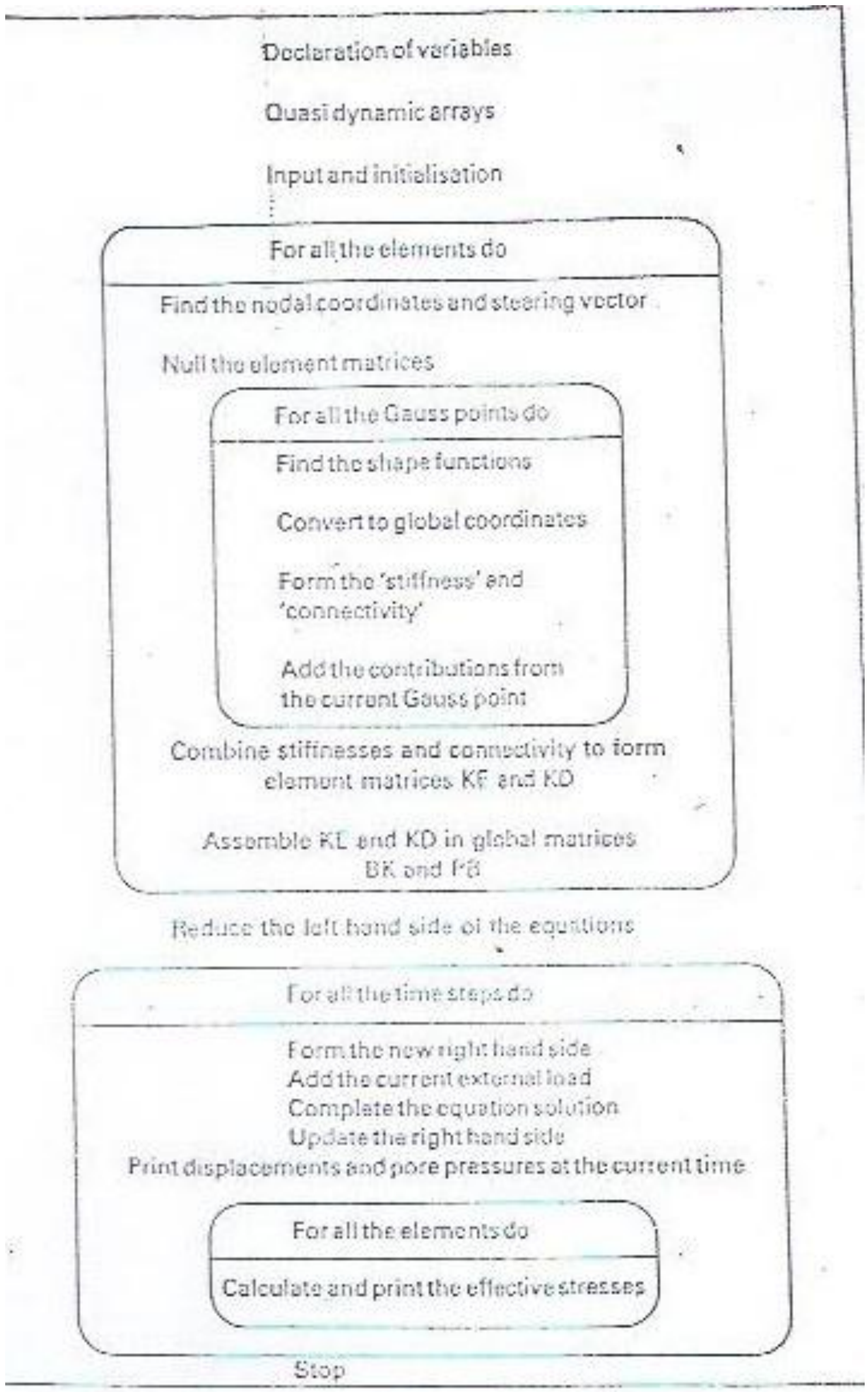
Description of the Numerical Model

In order to investigate the effect of rigidity (Ec/Es) on water pressure in dams, the problem is analyzed numerically using the finite element computer program by using Biot consolidation of rectangle in plane strain (Four- node element). The geometry of the model and the properties of the materials used are described in the next paragraphs.

Features of the Finite Element Program Used

The element used is a two-dimensional isoperimetric quadrilateral element. it is an efficient element for two variable from three up to including eight. the nodes are located at the corners, with additional nodes (if required) on the sides, these nodes represent both displacement and pore water pressures as field variables on the same mash. In the other words, the node represents displacement and pore water pressure at the same time as if there are two concurrent meshes. the available maximum integration order for rectangular element is (3*3).

the flow charts and subroutines in this program as shown below, for the purpose of developing the relationship between changes in effective stress and strain, it is assumed that the soil skeleton behaves like an isotropically hardening elasto-plastic material with an associated flow rule.



Structural Chart for the Programs

Model Geometry and Material Properties

-General Description:

1- The crest level is at 146.5 m above mean sea level (MSL), height of dam 62 m.

2- Total storage = $1500*10^6$ m^3

the typical finite element mesh utilized to discredit the model of dams is shown in Figure (1), and the table (1) represents the material properties are used in the dam.

Table (1): Properties of Materials Used i a Dam

Soil Type		Dry density d kN/m	Cohesion Cu kN/m²	Angle of friction	Modulus of elasticity E kN/m² *10³		Poisson's ratio	Permeability (cm/sec)		Coeff. of consolidation Cv (cm²/min)	
					Vert.	Horiz.		Vert.	Horiz.	Vert.	Horiz.
Shell	Sand Stone	17	---	37	26 to 12	26 to 12	0.3	$1.25*10^{-3}$	$1.25*10^{-3}$	---	---
	Coarse Sand	16	---	35	26 to 12	26 to 12	0.3	10^{-2}	10^{-2}	---	---
Marl of core		17	50	23	10 to 8	10 to 8	0.3	10^{-9}	$2.25*10^{-9}$	0.18	0.36
Foundation	Marl	19.5	600	16	200 to 500	200 to 500	0.3 to 0.5	10^{-5}	10^{-5}	0.31	0.31
	Sand Stone	19.5	---	38	100 to 500	100 to 500	0.3 to 0.35	10^{-3} to 10^{-6}	10^{-3} to 10^{-6}	---	---

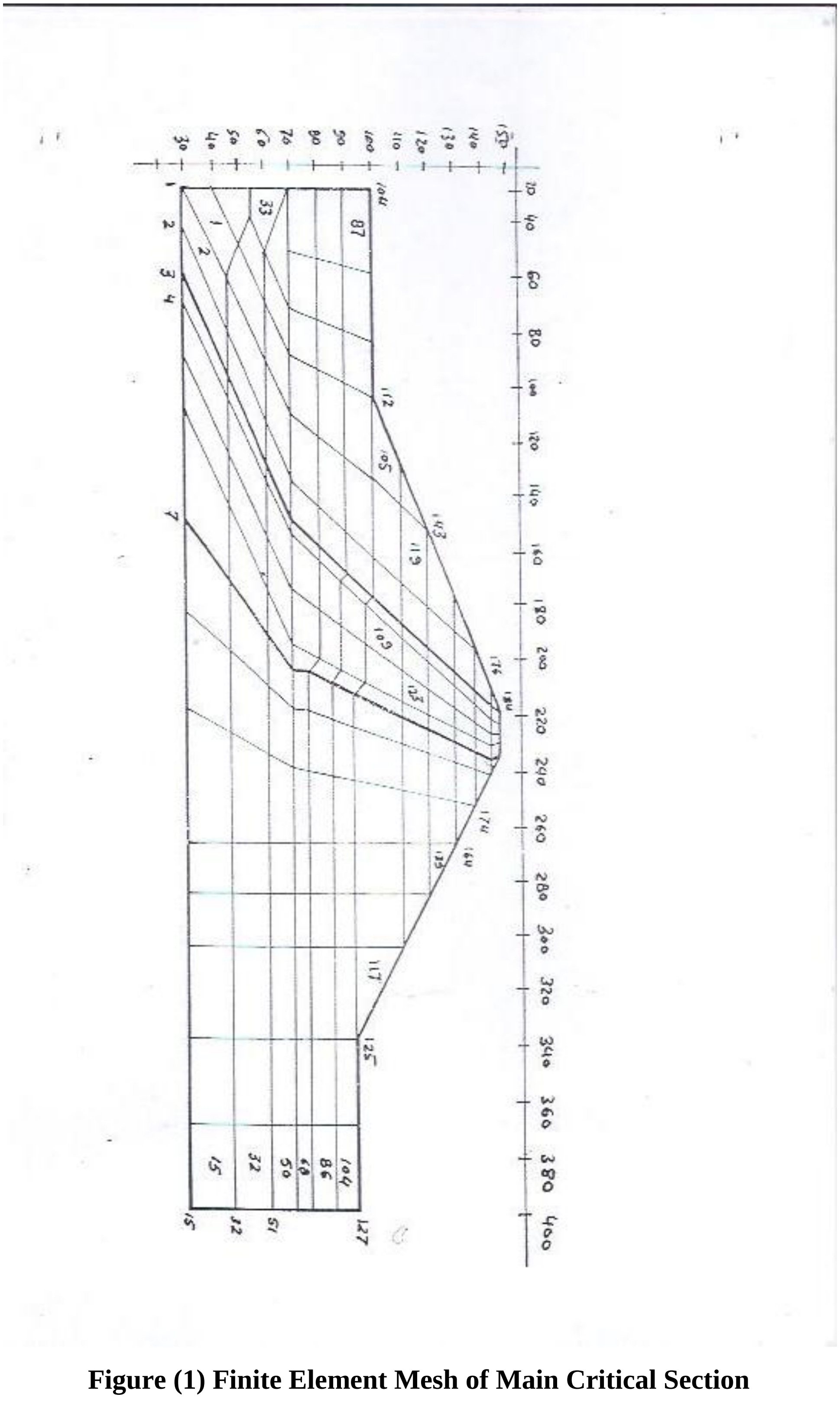


Figure (1) Finite Element Mesh of Main Critical Section

Results and Discussion

During Construction Stage

Figure (2 a) represents the ratio of vertical stress σ_y to overburden pressure (γh) for different rigidity ratio (Ec/Es) as calculated at the upstream face of the core. Figure (2b) is the same as figure (2a), but its value calculated at the downstream face of the core.

It is clear that tendency to cracking decreases as Ec/Es increases. Below level (60 m), the effect of rigidity has no effect on the cracking, they all has a factor of safety as approximately (1.3). At elevation (100 m), the factor of safety is large as shown and it is represented the maximum value of factor of safety. Above elevation (100 m) and then to the top of the core, for all cases of (Ec/Es), the factor of safety tends to be less than its value at elevation (100 m) or, may say the upper third of the core. Also, Figure (2a) illustrates that the factor of safety against tension cracking is increased as the depth of the core increases. Similar tend have been observed along the core from figures (2 a, b, c). when horizontal plane passing through the dam at the same elevation shows, however, the upstream is largely exposed to tension cracks than the centerline and downstream face of the core. The cracking tendency seems to be in dependent of the core/shell rigidity with the lower third.

During Filling with Water

During filling with water, due to bending moment that causes by water pressures, the tendency to cracking of the lower elements become higher as shown in figure (3a, b, c). From figure (3),it was found that the tension cracks decrease as Ec/Es increases in general, at the base of foundation or elevation (40 m), the compression stress is more less because the effect of water load on the core; so that the factor of safety is less than other elevations. During this stage, we must control the rate of filling, elevation (80 m) to elevation (120) m, for small values of Ec/Es ratios, the factor of safety is less. We must be careful from the effect of negative skin friction of heave effect by increasing the rolling in construction stage. At elevation (143.5) m always exposure to cracks because mainly the heave phenomena.

When the horizontal plane across the core is taken, as Ec/Es increase, th efface of the core is more may cracking than the center line and downstream face of the core.

Duncan Criteria

Figure (4) and (5) shows the results for Duncan criteria, the similar trend shows with the sherard criteria while some different values in many elevations; however, the general behavior of the dam is identical.

From both criteria to obtain an appropriate factor of safety about (1.2) for three planes that bounded the core, the values of Ec/Es is (0.7) make all other requirement for stability and seepage satisfied.

However, the settlement, horizontal displacement and pore pressure are decreased as the ratio Ec/Es increased as shown in table (2) and Figure ( ).

Effect of Tension Cracks

Tension cracks also effect Morley by ratio of Ec/Es because the differs in rigidity between the core and shell materials, when cracking occurs because portion of embankment is subjected to tensile strain when the dam is deformed by differential settlements depending upon geometry and relative stiffness.

Because the rock shells continue to compress appreciably after construction while the rolled core does not, thus the accumulation in strain in core and shells relatively will cause negative skin friction in upward thus causes in cracking as a result. The strain accumulation represented the instantaneous strain and long-term strain due to dissipation of pore water pressure. Also, heave may be effect in the upper part of core and causing cracking in most times.

When studying the effect of ratio Ec/Es in load transfer to the core relatively with shells, it is found if this ratio increase, as shown in Figure (6).

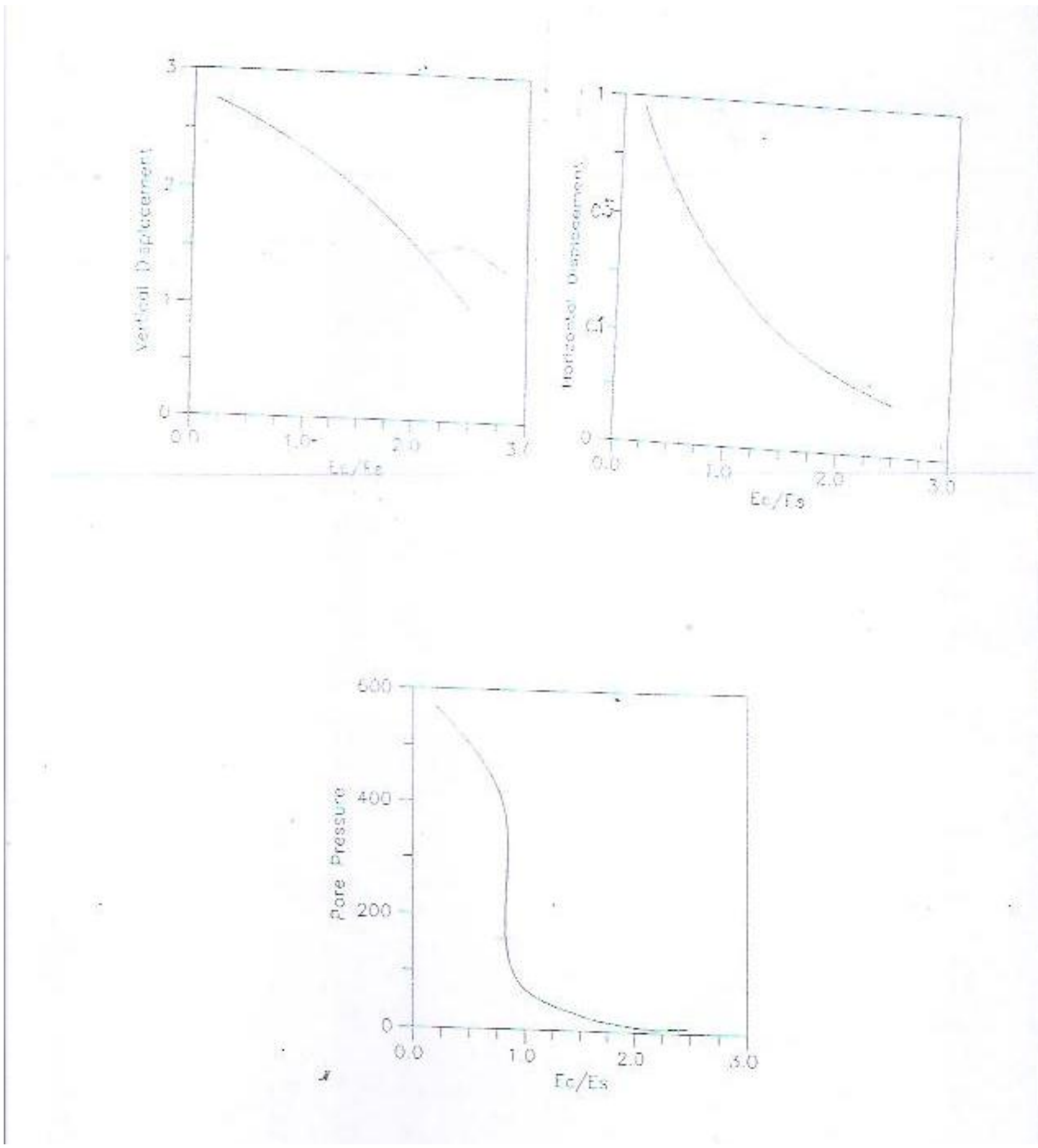


Figure (2): Effect of Ec/Es on Deformations and Pore Pressure

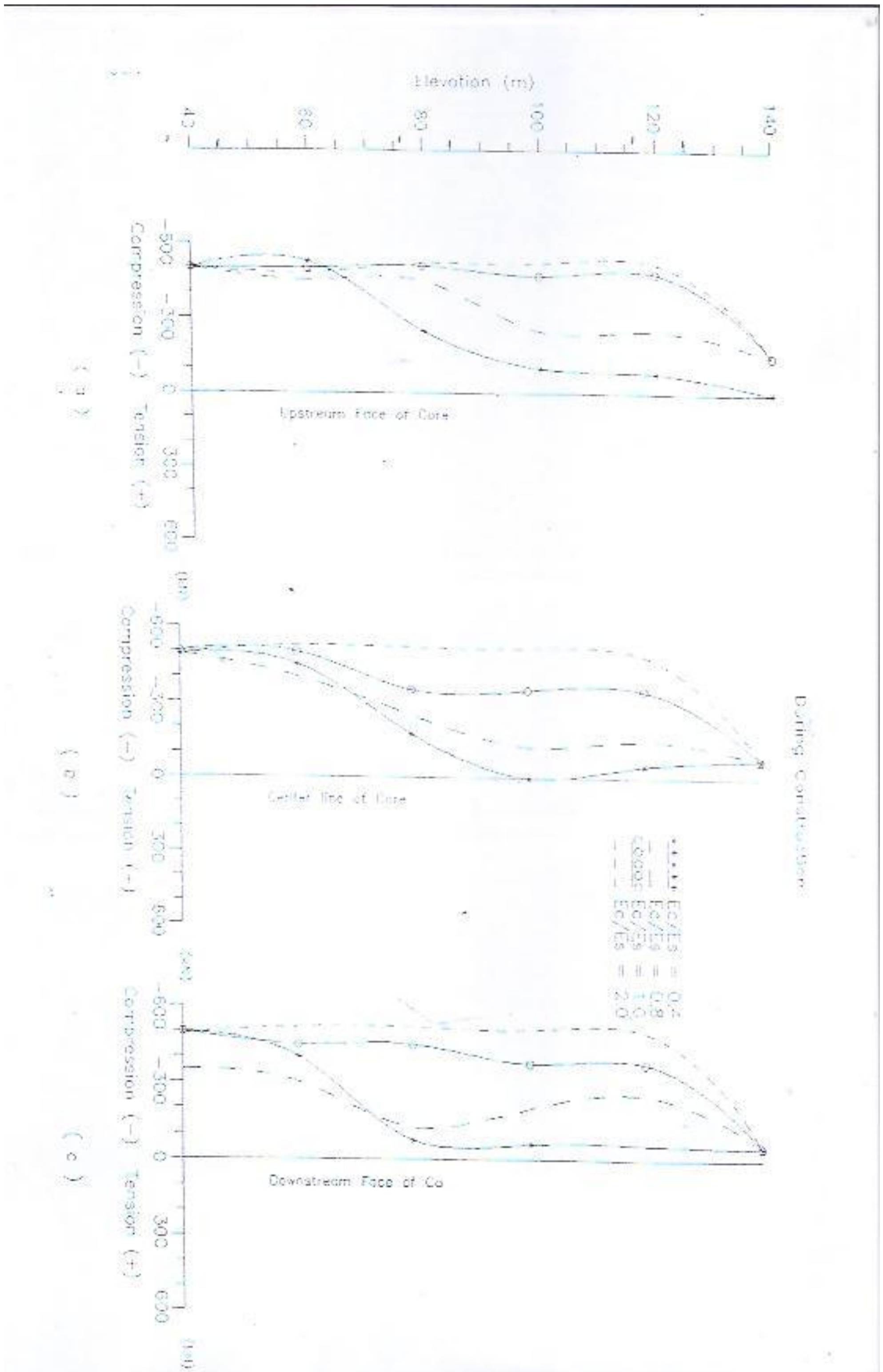


Figure (3): Effect of Ec/Es on Tension Cracks Using Sherard Criteria

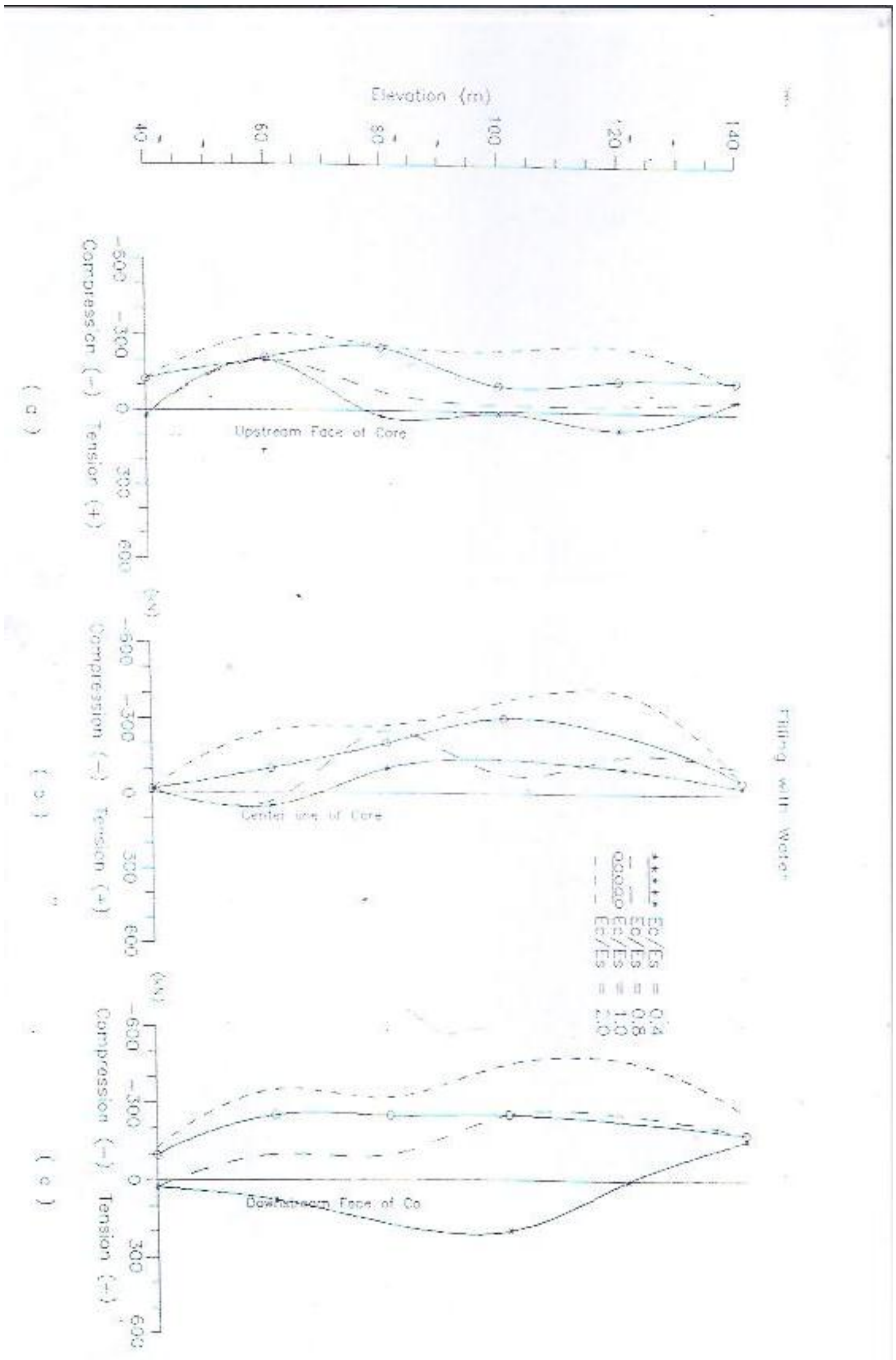


Figure (4): Effect of Ec/Es on Tension Cracks Using Duncan Criteria

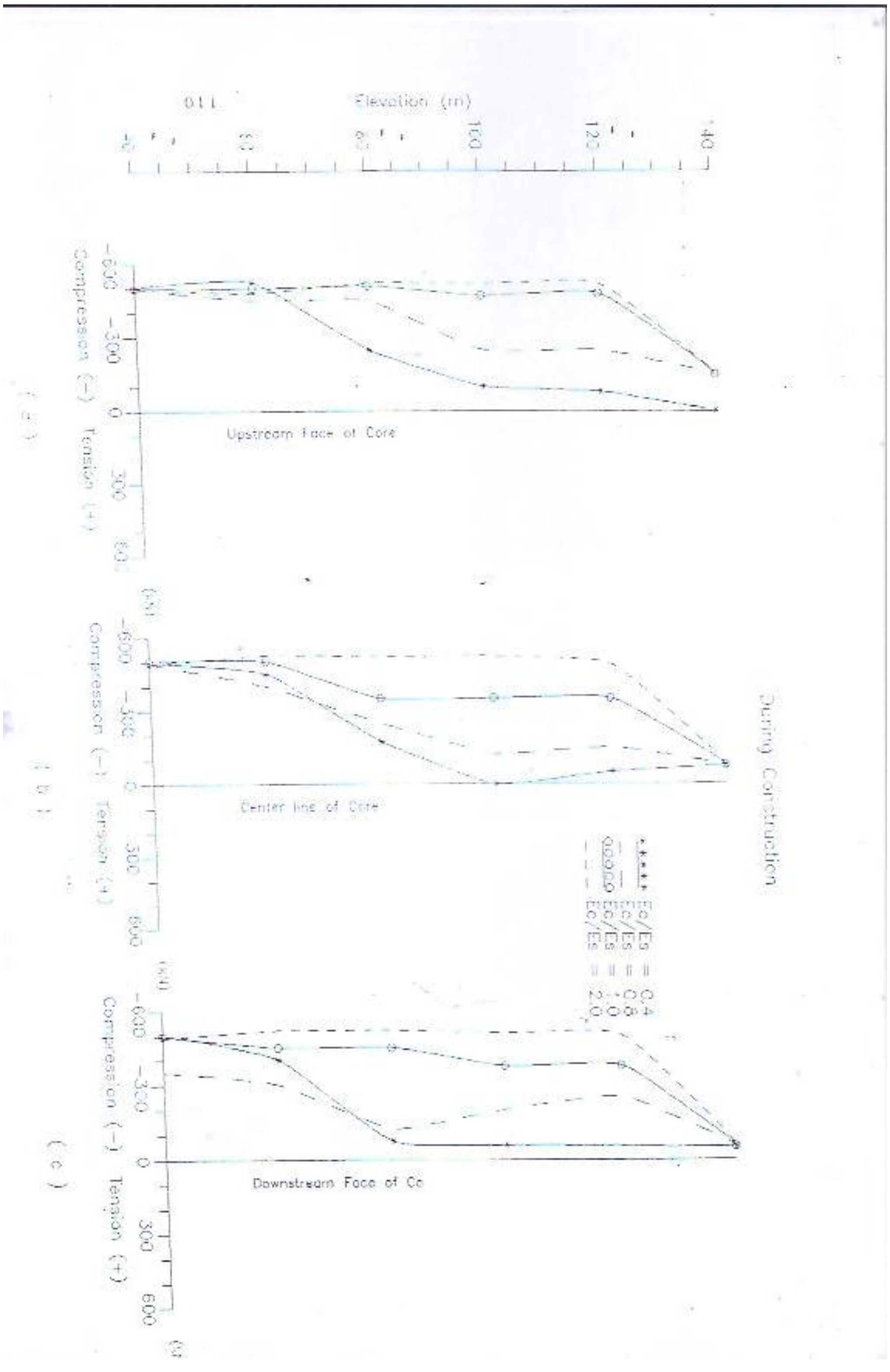


Figure (5): Effect of Ec/Es on Tension Cracks Duncan Criteria

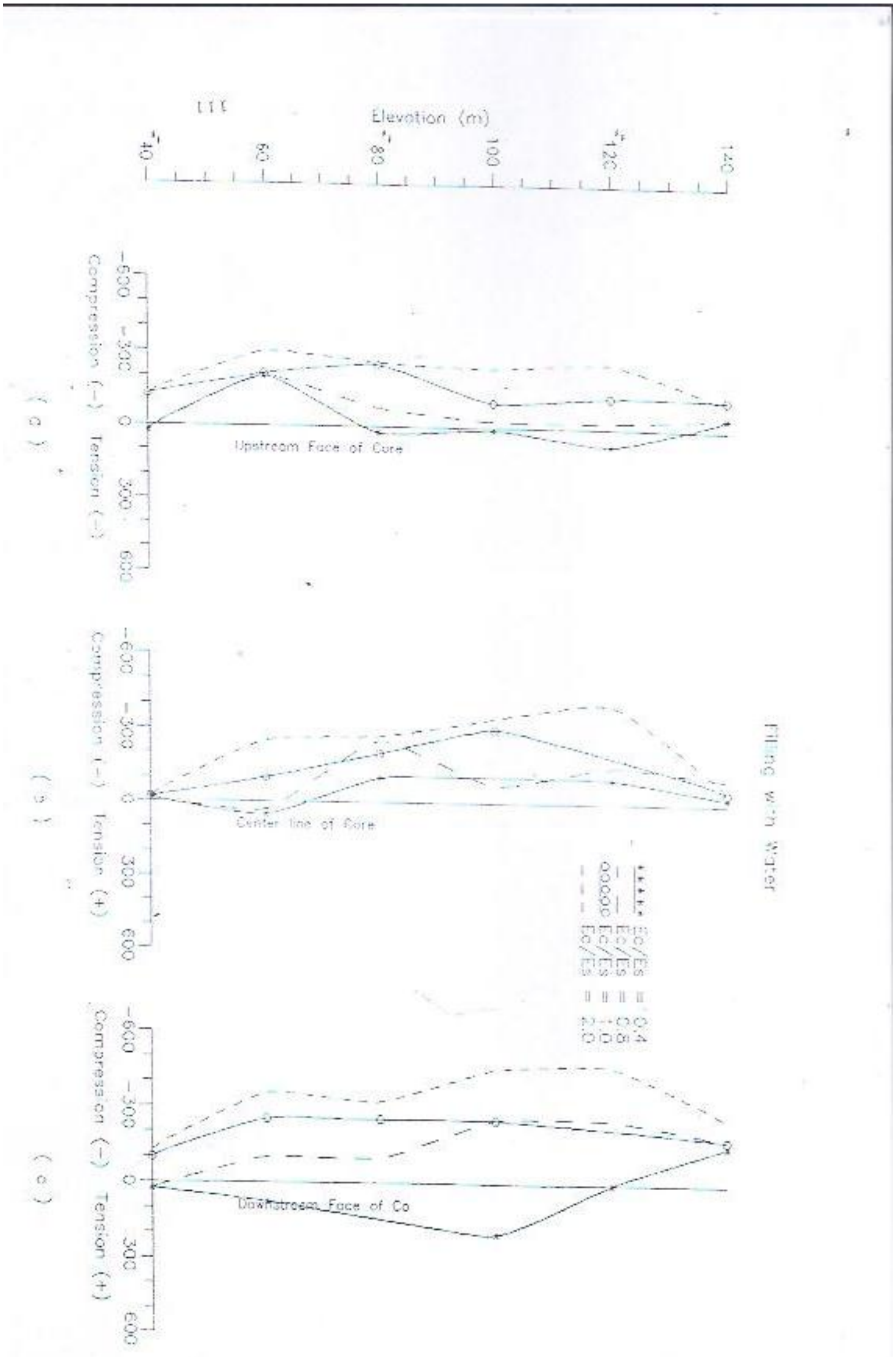


Figure (6): Effect of Ec/Es on Tension CracksUsing Duncan Criteria

Table (2):Displacement and Pore Pressure with Different Rigidity

Ec/Es	Horizontal Displacement	Vertical Displacement	Pore Pressure
0.1	-0.524	-2.774	-570
0.4	-0.472	-2.082	-275
0.6	-0.300	-1.912	-170
0.8	-0.250	-1.820	-429
1.0	-0.203	-1.766	-70
1.25	-0.187	-1.717	-43
1.5	-0.102	-1.674	-27
2.0	-0.090	-1.602	-11

(-) horizontal displacement ←

(-) vertical displacement ↓

(-) pore pressure comression

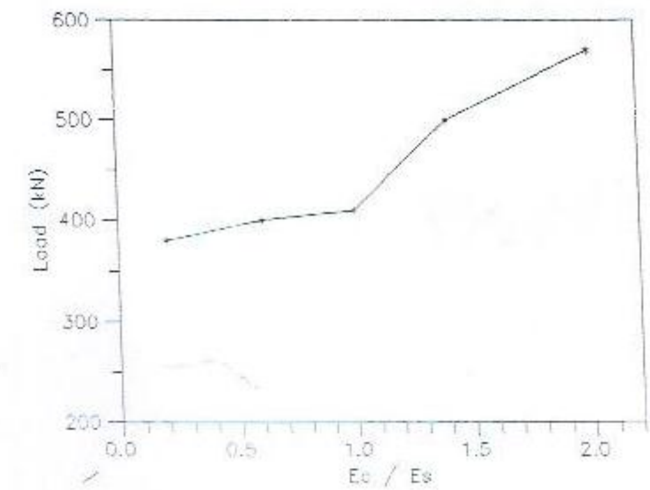


Figure (7): Effect of Ec/Es on Load Transferred to the core

CONCLUSIONS

1. The cracking decreases as Ec/Es increases. Below level (60 m), the effect of rigidity has no effect on the cracking, they all has a factor of safety as approximately (1.3).
2. At elevation (100 m), the factor of safety is large and it is represented the maximum value of factor of safety.
3. Above elevation (100 m) and then to the top of the core, for all cases of (Ec/Es), the factor of safety tends to be less than its value at elevation (100 m) or the upper third of the core.
4. The factor of safety against tension cracking is increased as the depth of the core increases.
5. The upstream is largely exposed to tension cracks than the centerline and downstream face of the core, and the cracking is in dependent of the core/shell rigidity with the lower third.
6. During filling with water the tension cracks decrease as Ec/Es increases and at the base of foundation or elevation (40 m), the compression stress is more less so that the factor of safety is less than other elevations.
7. At elevation (143.5) m the dam exposure to cracks .
8. For Duncan and Sherard criteria, the factor of safety is about (1.2) for three planes that bounded the core, the values of Ec/Es is (0.7).

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