UNIVERSITE MOHAMED BOUDIAF - M'SILA
FACULTE DE TECHNOLOGIE
DEPARTEMENT DE GENIE CIVIL

FILIERE : Génie Civil

SPECIALITE : Master Géotechnique (M1/S2)

COURS : Rhéologie des sols

INTERROGATION N° : 1

(Date : 13/04/2026 - Durée : 1 heure 30)

A. (12 pts.) Soit le champ de déplacement défini en un point d'un solide élastique isotrope :

$$\bar{u}\begin{cases} u_1 = k(x_2 - x_3) \\ u_2 = k(x_1 + x_3) \\ u_3 = k(x_1 + x_2) \end{cases} \qquad / \ (\bar{x}_1, \bar{x}_2, \bar{x}_3),$$

où $k \geq 0$ désigne une constante positive petite pour assurer la linéarité géométrique.

Construire le tenseur des déformations $\bar{\bar{\varepsilon}} = [\varepsilon_{ij}]$ correspondant, puis déterminer le tenseur des contraintes $\bar{\bar{\sigma}} = [\sigma_{ij}]$ résultant de la sollicitation appliquée.

B. (8 pts.) Soit le tenseur des contraintes appliqué au même point du solide élastique isotrope considéré ci-dessus :

$$\bar{\bar{\sigma}} = [\sigma_{ij}] = 2G\begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix} \qquad (N/mm^2),$$

où G désigne le module de cisaillement du matériau.

Construire le tenseur des déformations $\bar{\bar{\varepsilon}} = [\varepsilon_{ij}]$ résultant de la sollicitation appliquée, puis déduire la (ou les) relation (s) possible (s) entre les paramètres de comportement utilisés $(\lambda, \mu, E, \nu, K, G)$.

***N.B.** Seules les notes de cours sont autorisées.*

Bonne chance

Prof. Mohamed Khemissa

INT-1 - Rhéologie des sols (09/03/2026)

Corrigé

Partie A

A1. Tenseur des déformations

Il est défini comme suit :

$$\bar{\bar{\varepsilon}} = (\varepsilon_{ij}) = \begin{bmatrix} \varepsilon_{11} & \varepsilon_{12} & \varepsilon_{13} \\ \varepsilon_{21} & \varepsilon_{22} & \varepsilon_{23} \\ \varepsilon_{31} & \varepsilon_{32} & \varepsilon_{33} \end{bmatrix} \qquad / \, (\bar{x}_1, \bar{x}_2, \bar{x}_3)$$

tel que :

$$\boldsymbol{\bar{\bar{\varepsilon}} = \frac{1}{2}\left[\overline{grad}(\bar{u}) + {}^t\overline{grad}(\bar{u})\right]} \qquad \Leftrightarrow \qquad \boldsymbol{\varepsilon_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) = \frac{1}{2}\left(u_{i,j} + u_{j,i}\right)}$$

D'où :

- $\varepsilon_{11} = \frac{1}{2}\left(\frac{\partial u_1}{\partial x_1} + \frac{\partial u_1}{\partial x_1}\right) = \frac{\partial u_1}{\partial x_1} = 0$
- $\varepsilon_{22} = \frac{1}{2}\left(\frac{\partial u_2}{\partial x_2} + \frac{\partial u_2}{\partial x_2}\right) = \frac{\partial u_2}{\partial x_2} = 0$
- $\varepsilon_{33} = \frac{1}{2}\left(\frac{\partial u_3}{\partial x_3} + \frac{\partial u_3}{\partial x_3}\right) = \frac{\partial u_3}{\partial x_3} = 0$
- $\varepsilon_{12} = \frac{1}{2}\left(\frac{\partial u_1}{\partial x_2} + \frac{\partial u_2}{\partial x_1}\right) = \frac{1}{2}(k + k) = k \qquad (= \varepsilon_{21})$
- $\varepsilon_{13} = \frac{1}{2}\left(\frac{\partial u_1}{\partial x_3} + \frac{\partial u_3}{\partial x_1}\right) = \frac{1}{2}(-k + k) = 0 \qquad (= \varepsilon_{31})$
- $\varepsilon_{23} = \frac{1}{2}\left(\frac{\partial u_2}{\partial x_3} + \frac{\partial u_3}{\partial x_2}\right) = \frac{1}{2}(k + k) = k \qquad (= \varepsilon_{32})$

$$\Rightarrow \quad \boldsymbol{\bar{\bar{\varepsilon}} = [\varepsilon_{ij}] = \begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix}} \qquad (\#6)$$

Remarque : $\quad \boldsymbol{Tr(\bar{\bar{\varepsilon}}) = \varepsilon_{kk}} = \varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33} = 0 \quad \Rightarrow$ Tenseur déviatorique

A2. Tenseur des contraintes

1ère Solution

Sachant que :

$$\boldsymbol{\bar{\bar{\sigma}} = \lambda Tr(\bar{\bar{\varepsilon}})\bar{\bar{\delta}} + 2\mu\bar{\bar{\varepsilon}}} \qquad \Leftrightarrow \qquad \boldsymbol{\sigma_{ij} = \lambda\varepsilon_{kk}\delta_{ij} + 2\mu\varepsilon_{ij}}$$

telle que : $Tr(\bar{\bar{\varepsilon}}) = \varepsilon_{kk} = \varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33} = 0 + 0 + 0 = 0$

D'où :

- $\sigma_{11} = \lambda \times (\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{11} + 2\mu \times \varepsilon_{11} = \lambda \times 0 \times 1 + 2\mu \times 0 = 0$
- $\sigma_{22} = \lambda \times (\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{22} + 2\mu \times \varepsilon_{22} = \lambda \times 0 \times 1 + 2\mu \times 0 = 0$
- $\sigma_{33} = \lambda \times (\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{33} + 2\mu \times \varepsilon_{33} = \lambda \times 0 \times 1 + 2\mu \times 0 = 0$
- $\sigma_{12} = \lambda \times (\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{12} + 2\mu \times \varepsilon_{12} = \lambda \times 0 \times 0 + 2\mu \times (k) = 2\mu k \qquad (= \sigma_{21})$
- $\sigma_{13} = \lambda \times (\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{13} + 2\mu \times \varepsilon_{13} = \lambda \times 0 \times 0 + 2\mu \times (0) = 0 \qquad (= \sigma_{31})$
- $\sigma_{23} = \lambda \times (\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{23} + 2\mu \times \varepsilon_{23} = \lambda \times 0 \times 0 + 2\mu \times (k) = 2\mu k \qquad (= \sigma_{32})$

$$\Rightarrow \quad \boldsymbol{\bar{\bar{\sigma}} = [\sigma_{ij}] = 2\mu \begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix}} \qquad (\#6) \quad \Rightarrow \quad \bar{\bar{\sigma}} = 2\mu\bar{\bar{\varepsilon}} \quad \Leftrightarrow \quad \sigma_{ij} = 2\mu\varepsilon_{ij}$$

Remarque 1 : $\boldsymbol{Tr(\bar{\bar{\sigma}}) = \sigma_{kk}} = \sigma_{11} + \sigma_{22} + \sigma_{33} = 0 \quad \Rightarrow$ Tenseur déviatorique

Remarque 2 : Sachant que : $Tr(\bar{\bar{\varepsilon}}) = \varepsilon_{kk} = 0 \quad \Rightarrow \quad \bar{\bar{\sigma}} = 2\mu\bar{\bar{\varepsilon}} \quad \Leftrightarrow \quad \sigma_{ij} = 2\mu\varepsilon_{ij}$

$$\Rightarrow \quad \bar{\bar{\sigma}} = [\sigma_{ij}] = 2\mu \begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix} \qquad Ok.$$

2ème Solution

Sachant que :

$$\boldsymbol{\bar{\bar{\sigma}} = KTr(\bar{\bar{\varepsilon}})\bar{\bar{\delta}} + 2G\bar{\bar{e}}} \qquad \Leftrightarrow \qquad \boldsymbol{\sigma_{ij} = K\varepsilon_{kk}\delta_{ij} + 2Ge_{ij}}$$

$$\boldsymbol{\bar{\bar{e}} = \bar{\bar{\varepsilon}} - \frac{1}{3}Tr(\bar{\bar{\varepsilon}})\bar{\bar{\delta}}} \qquad \Leftrightarrow \qquad \boldsymbol{e_{ij} = \varepsilon_{ij} - \frac{1}{3}\varepsilon_{kk}\delta_{ij}}$$

telle que : $Tr(\bar{\bar{\varepsilon}}) = \varepsilon_{kk} = \varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33} = 0 + 0 + 0 = 0$

D'où :

- $e_{11} = \varepsilon_{11} - \frac{1}{3}(\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{11} = 0 - \frac{1}{3}(0) \times 1 = 0$
- $e_{22} = \varepsilon_{22} - \frac{1}{3}(\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{22} = 0 - \frac{1}{3}(0) \times 1 = 0$
- $e_{33} = \varepsilon_{33} - \frac{1}{3}(\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{33} = 0 - \frac{1}{3}(0) \times 1 = 0$
- $e_{12} = \varepsilon_{12} - \frac{1}{3}(\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{12} = k - \frac{1}{3}(0) \times 0 = \mathrm{k} \qquad (= e_{21})$
- $e_{13} = \varepsilon_{13} - \frac{1}{3}(\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{13} = 0 - \frac{1}{3}(0) \times 0 = 0 \qquad (= e_{31})$
- $e_{23} = \varepsilon_{23} - \frac{1}{3}(\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{23} = k - \frac{1}{3}(0) \times 0 = \mathrm{k} \qquad (= e_{32})$

$$\Rightarrow \quad \bar{\bar{e}} = [e_{ij}] = \begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix} \quad \Rightarrow \quad \bar{\bar{e}} = \bar{\bar{\varepsilon}}$$

D'où :

- $\sigma_{11} = K \times (\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{11} + 2G \times e_{11} = K \times (0) \times 1 + 2G \times 0 = 0$
- $\sigma_{22} = K \times (\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{22} + 2G \times e_{22} = K \times (0) \times 1 + 2G \times 0 = 0$
- $\sigma_{33} = K \times (\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{33} + 2G \times e_{33} = K \times (0) \times 1 + 2G \times 0 = 0$
- $\sigma_{12} = K \times (\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{12} + 2G \times e_{12} = K \times (0) \times 0 + 2G \times k = 2Gk \qquad (= \sigma_{21})$
- $\sigma_{13} = K \times (\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{13} + 2G \times e_{13} = K \times (0) \times 0 + 2G \times 0 = 0 \qquad (= \sigma_{31})$
- $\sigma_{23} = K \times (\varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33}) \times \delta_{23} + 2G \times e_{23} = K \times (0) \times 0 + 2G \times k = 2Gk \qquad (= \sigma_{32})$

$$\Rightarrow \quad \boldsymbol{\bar{\bar{\sigma}} = [\sigma_{ij}] = 2G \begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix}} \quad \Rightarrow \quad \bar{\bar{\sigma}} = 2G\bar{\bar{\varepsilon}} \quad \Leftrightarrow \quad \sigma_{ij} = 2G\varepsilon_{ij}$$

Remarque 1 : $\boldsymbol{Tr(\bar{\bar{\sigma}}) = \sigma_{kk}} = \sigma_{11} + \sigma_{22} + \sigma_{33} = 0 \quad \Rightarrow$ Tenseur déviatorique

Remarque 2 : Sachant que : $Tr(\bar{\bar{\varepsilon}}) = \varepsilon_{kk} = 0 \Rightarrow \bar{\bar{e}} = \bar{\bar{\varepsilon}} \quad \Leftrightarrow \quad e_{ij} = \varepsilon_{ij}$

$$\Rightarrow \bar{\bar{\sigma}} = 2G\bar{\bar{e}} = 2G\bar{\bar{\varepsilon}} \quad \Leftrightarrow \quad \sigma_{ij} = 2Ge_{ij} = 2G\varepsilon_{ij}$$

$$\Rightarrow \bar{\bar{\sigma}} = [\sigma_{ij}] = 2G\begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix} \qquad Ok.$$

Partie B

B1. Tenseur des déformations

1ère Solution

Sachant que :

$$\boldsymbol{\bar{\bar{\varepsilon}} = -\frac{\nu}{E}Tr(\bar{\bar{\sigma}})\bar{\bar{\delta}} + \frac{1+\nu}{E}\bar{\bar{\sigma}} \quad \Leftrightarrow \quad \varepsilon_{ij} = -\frac{\nu}{E}\sigma_{kk}\delta_{ij} + \frac{1+\nu}{E}\sigma_{ij}}$$

telle que : $\sigma_{kk} = \sigma_{11} + \sigma_{22} + \sigma_{33} = 0 + 0 + 0 = 0$

D'où :

- $\varepsilon_{11} = -\frac{\nu}{E} \times (\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{11} + \frac{1+\nu}{E} \times \sigma_{11} = -\frac{\nu}{E} \times 0 \times 1 + \frac{1+\nu}{E} \times 0 = 0$
- $\varepsilon_{22} = -\frac{\nu}{E} \times (\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{22} + \frac{1+\nu}{E} \times \sigma_{22} = -\frac{\nu}{E} \times 0 \times 1 + \frac{1+\nu}{E} \times 0 = 0$
- $\varepsilon_{33} = -\frac{\nu}{E} \times (\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{33} + \frac{1+\nu}{E} \times \sigma_{33} = -\frac{\nu}{E} \times 0 \times 1 + \frac{1+\nu}{E} \times 0 = 0$
- $\varepsilon_{12} = -\frac{\nu}{E} \times (\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{12} + \frac{1+\nu}{E} \times \sigma_{12} = -\frac{\nu}{E} \times 0 \times 0 + \frac{1+\nu}{E} \times k = \frac{1+\nu}{E}2Gk \quad (= \sigma_{21})$
- $\varepsilon_{13} = -\frac{\nu}{E} \times (\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{13} + \frac{1+\nu}{E} \times \sigma_{13} = -\frac{\nu}{E} \times 0 \times 0 + \frac{1+\nu}{E} \times 0 = 0 \quad (= \sigma_{31})$
- $\varepsilon_{23} = -\frac{\nu}{E} \times (\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{23} + \frac{1+\nu}{E} \times \sigma_{23} = -\frac{\nu}{E} \times 0 \times 0 + \frac{1+\nu}{E} \times k = \frac{1+\nu}{E}2Gk \quad (= \sigma_{32})$

$$\Rightarrow \boldsymbol{\bar{\bar{\varepsilon}} = [\varepsilon_{ij}] = \frac{1+\nu}{E}\left(2G\begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix}\right) = \begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix}} \quad (\#6) \quad \Rightarrow \bar{\bar{\varepsilon}} = \frac{1+\nu}{E}\bar{\bar{\sigma}} \quad \Leftrightarrow \quad \varepsilon_{ij} = \frac{1+\nu}{E}\sigma_{ij}$$

Remarque 1 : $\boldsymbol{Tr(\varepsilon) = \varepsilon_{kk}} = \varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33} \equiv 0 \quad \Rightarrow$ Tenseur déviatorique

Remarque 2 : Sachant que : $Tr(\bar{\bar{\sigma}}) = \sigma_{kk} = 0 \quad \Rightarrow \quad \bar{\bar{\varepsilon}} = \frac{1+\nu}{E}\bar{\bar{\sigma}} \quad \Leftrightarrow \quad \varepsilon_{ij} = \frac{1+\nu}{E}\sigma_{ij}$

$$\Rightarrow \bar{\bar{\varepsilon}} = [\varepsilon_{ij}] = \frac{1+\nu}{E}\left(2G\begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix}\right) = \begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix} \qquad Ok.$$

2ème Solution :

Sachant que :

$$\boldsymbol{\bar{\bar{\varepsilon}} = \frac{1}{3K}Tr(\bar{\bar{\sigma}})\bar{\bar{\delta}} + \frac{1}{2G}\bar{\bar{s}} \quad \Leftrightarrow \quad \varepsilon_{ij} = \frac{1}{3K}\sigma_{kk}\delta_{ij} + \frac{1}{2G}s_{ij}}$$

$$\boldsymbol{\bar{\bar{s}} = \bar{\bar{\sigma}} - \frac{1}{3}Tr(\bar{\bar{\sigma}})\bar{\bar{\delta}} \quad \Leftrightarrow \quad s_{ij} = \sigma_{ij} - \frac{1}{3}\sigma_{kk}\delta_{ij}}$$

telle que : $Tr(\bar{\bar{\sigma}}) = \sigma_{kk} = \sigma_{11} + \sigma_{22} + \sigma_{33} = 0 + 0 + 0 = 0$

D'où :

- $s_{11} = \sigma_{11} - \frac{1}{3}(\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{11} = 0 - \frac{1}{3}(0) \times 1 = 0$

- $s_{22} = \sigma_{22} - \frac{1}{3}(\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{22} = 0 - \frac{1}{3}(0) \times 1{=}0$
- $s_{33} = \sigma_{33} - \frac{1}{3}(\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{33} = 0 - \frac{1}{3}(0) \times 1{=}0$
- $s_{12} = \sigma_{12} - \frac{1}{3}(\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{12} = 2Gk - \frac{1}{3}(0) \times 0{=}2Gk \quad (= s_{21})$
- $s_{13} = \sigma_{13} - \frac{1}{3}(\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{13} = 0 - \frac{1}{3}(0) \times 0{=}0 \quad (= s_{31})$
- $s_{23} = \sigma_{23} - \frac{1}{3}(\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{23} = 2Gk - \frac{1}{3}(0) \times 0{=}2Gk \ (= e_{32})$

$$\Rightarrow \quad \bar{\bar{s}} = [s_{ij}] = 2G\begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix} \quad \Rightarrow \quad \bar{\bar{s}} = \bar{\bar{\sigma}}$$

D'où :

- $\varepsilon_{11} = \frac{1}{3K} \times (\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{11} + \frac{1}{2G} \times s_{11} = \frac{1}{3K} \times (0) \times 1 + \frac{1}{2G} \times (0) = 0$
- $\varepsilon_{22} = \frac{1}{3K} \times (\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{22} + \frac{1}{2G} \times s_{22} = \frac{1}{3K} \times (0) \times 1 + \frac{1}{2G} \times (0) = 0$
- $\varepsilon_{33} = \frac{1}{3K} \times (\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{33} + \frac{1}{2G} \times s_{33} = \frac{1}{3K} \times (0) \times 1 + \frac{1}{2G} \times (0) = 0$
- $\varepsilon_{12} = \frac{1}{3K} \times (\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{12} + \frac{1}{2G} \times s_{12} = \frac{1}{3K} \times (0) \times 0 + \frac{1}{2G} \times (2Gk) = k \quad (= \varepsilon_{21})$
- $\varepsilon_{13} = \frac{1}{3K} \times (\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{13} + \frac{1}{2G} \times s_{13} = \frac{1}{3K} \times (0) \times 0 + \frac{1}{2G} \times (0) = 0 \quad (= \varepsilon_{31})$
- $\varepsilon_{23} = \frac{1}{3K} \times (\sigma_{11} + \sigma_{22} + \sigma_{33}) \times \delta_{23} + \frac{1}{2G} \times s_{23} = \frac{1}{3K} \times (0) \times 0 + \frac{1}{2G} \times (2Gk) = k \quad (= \varepsilon_{32})$

$$\Rightarrow \quad \bar{\bar{\boldsymbol{\varepsilon}}} = [\boldsymbol{\varepsilon_{ij}}] = \begin{bmatrix} \mathbf{0} & \boldsymbol{k} & \mathbf{0} \\ \boldsymbol{k} & \mathbf{0} & \boldsymbol{k} \\ \mathbf{0} & \boldsymbol{k} & \mathbf{0} \end{bmatrix} \qquad Ok.$$

Remarque 1 : $\boldsymbol{Tr}(\boldsymbol{\varepsilon}) = \boldsymbol{\varepsilon_{kk}} = \varepsilon_{11} + \varepsilon_{22} + \varepsilon_{33} \equiv 0 \quad \Rightarrow$ Tenseur déviatorique

Remarque 2 : Sachant que : $Tr(\bar{\bar{\sigma}}) = \sigma_{kk} = 0 \quad \Rightarrow \bar{\bar{s}} = \bar{\bar{\sigma}} \quad \Leftrightarrow \quad s_{ij} = \sigma_{ij}$

$$\Rightarrow \bar{\bar{\varepsilon}} = \frac{1}{2G}\bar{\bar{s}} = \frac{1}{2G}\bar{\bar{\sigma}} \quad \Leftrightarrow \quad \varepsilon_{ij} = \frac{1}{2G}s_{ij} = \frac{1}{2G}\sigma_{ij}$$

$$\Rightarrow \quad \bar{\bar{\varepsilon}} = [\varepsilon_{ij}] = \frac{1}{2G}\left(2G\begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix}\right) = \begin{bmatrix} 0 & k & 0 \\ k & 0 & k \\ 0 & k & 0 \end{bmatrix} \qquad Ok.$$

B2. Paramètres de comportement

Les relations possibles entre les paramètres de comportement utilisés ci-dessus sont les suivantes :

- Sachant que : $\bar{\bar{\sigma}} = 2\mu\bar{\bar{\varepsilon}}$ & $\bar{\bar{\sigma}} = 2G\bar{\bar{\varepsilon}}$ $\Rightarrow$ $\boldsymbol{\mu = G}$ (#1)
- Sachant que : $\bar{\bar{\sigma}} = 2G\bar{\bar{\varepsilon}}$ & $\bar{\bar{\varepsilon}} = \frac{1+\nu}{E}\bar{\bar{\sigma}}$ $\Rightarrow$ $\boldsymbol{G = \frac{E}{2(1+\nu)}}$ (#1)