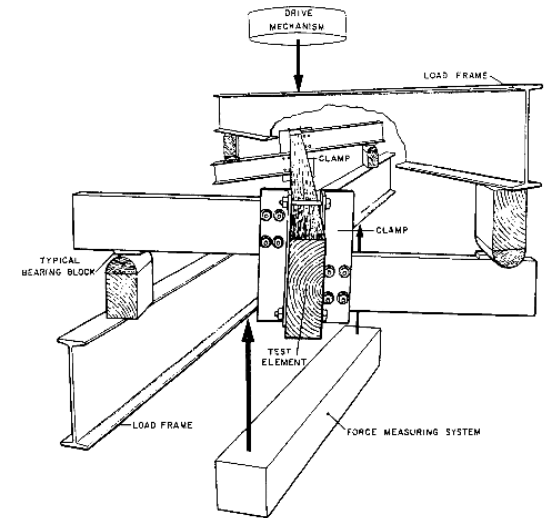


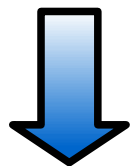
曲げ载荷方法とせん断弾性係数の 推定精度について

秋田大学 大黒屋 信英



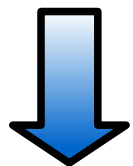
最近、木橋が見直されている ➡ せん断変形が大! ➡ Gの測定は重要!

曲げ試験より求める
(アメリカ材料試験協会)

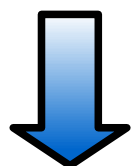


等方性の $k = \frac{5}{6}$ を使用

しかし...



集成材 = 直交異方性

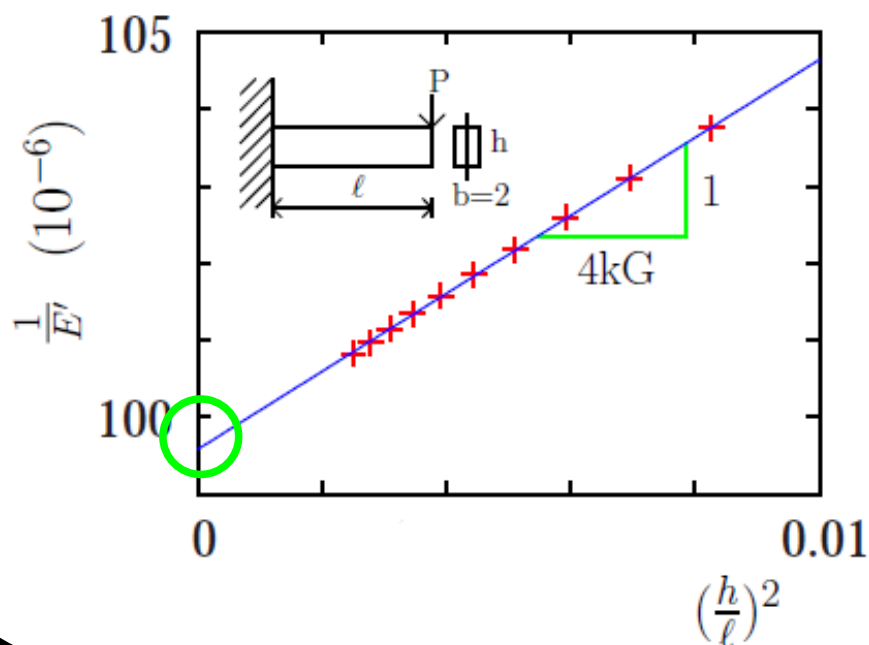


FEM(直交異方性)で

- ・ k の逆算
- ・ G, E の推定

$$\frac{P\ell^3}{3E'I} = v_{\text{ティモ}} = \frac{P\ell^3}{3EI} + \frac{Pl}{GkA}$$

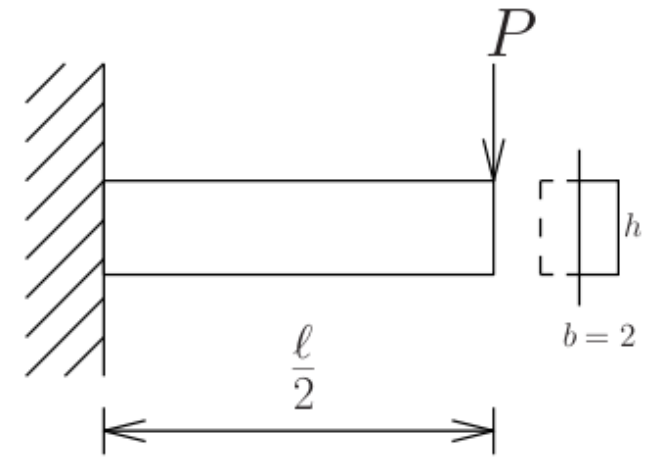
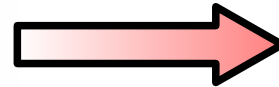
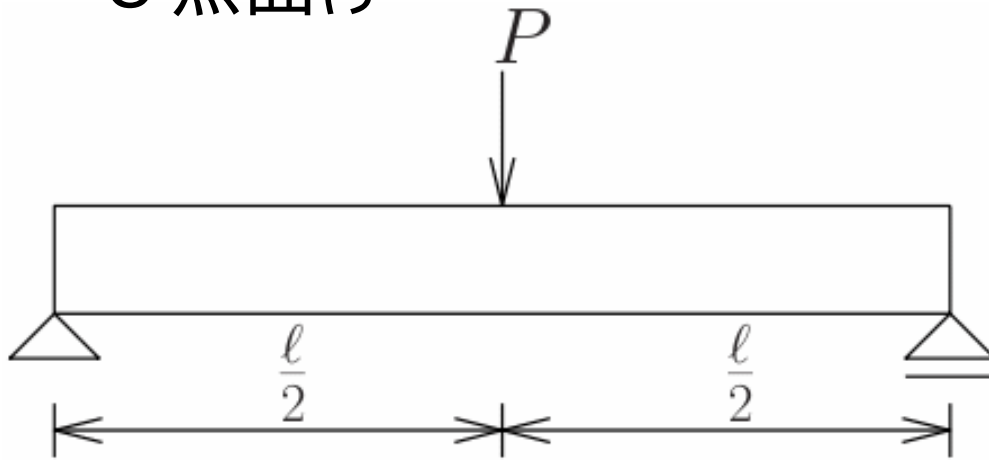
$$\frac{1}{E'} = \frac{1}{E} + \frac{1}{4kG} \left(\frac{h}{\ell}\right)^2$$



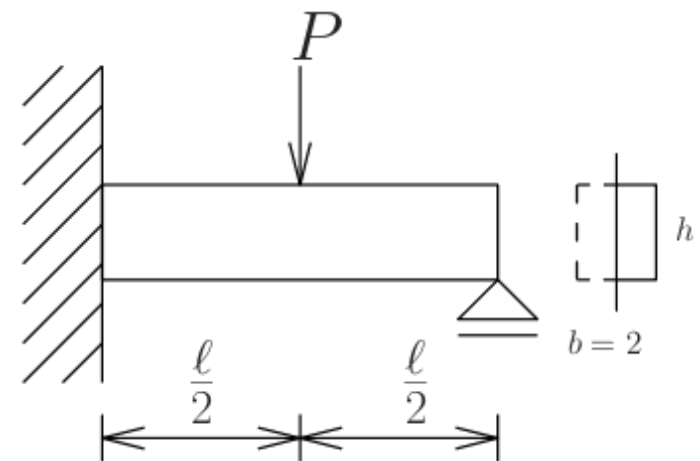
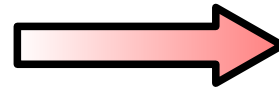
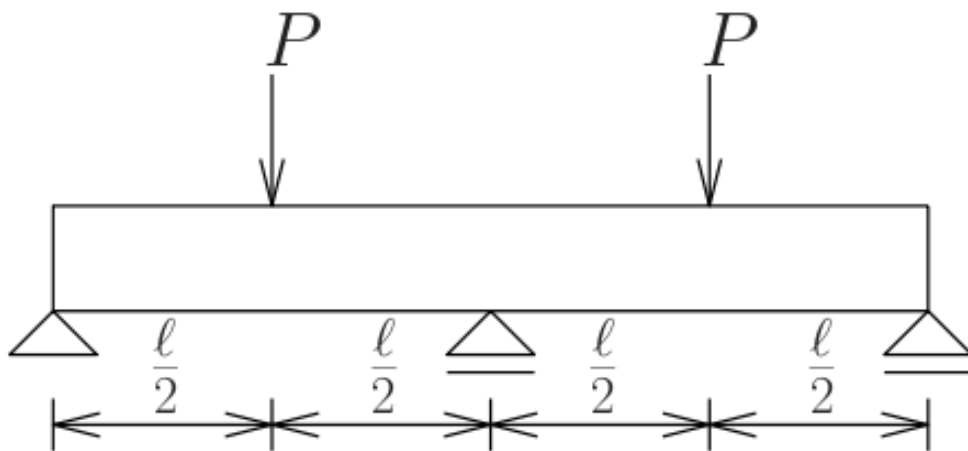
解析モデル

・せん断変形の異なるモデル

・ 3点曲げ



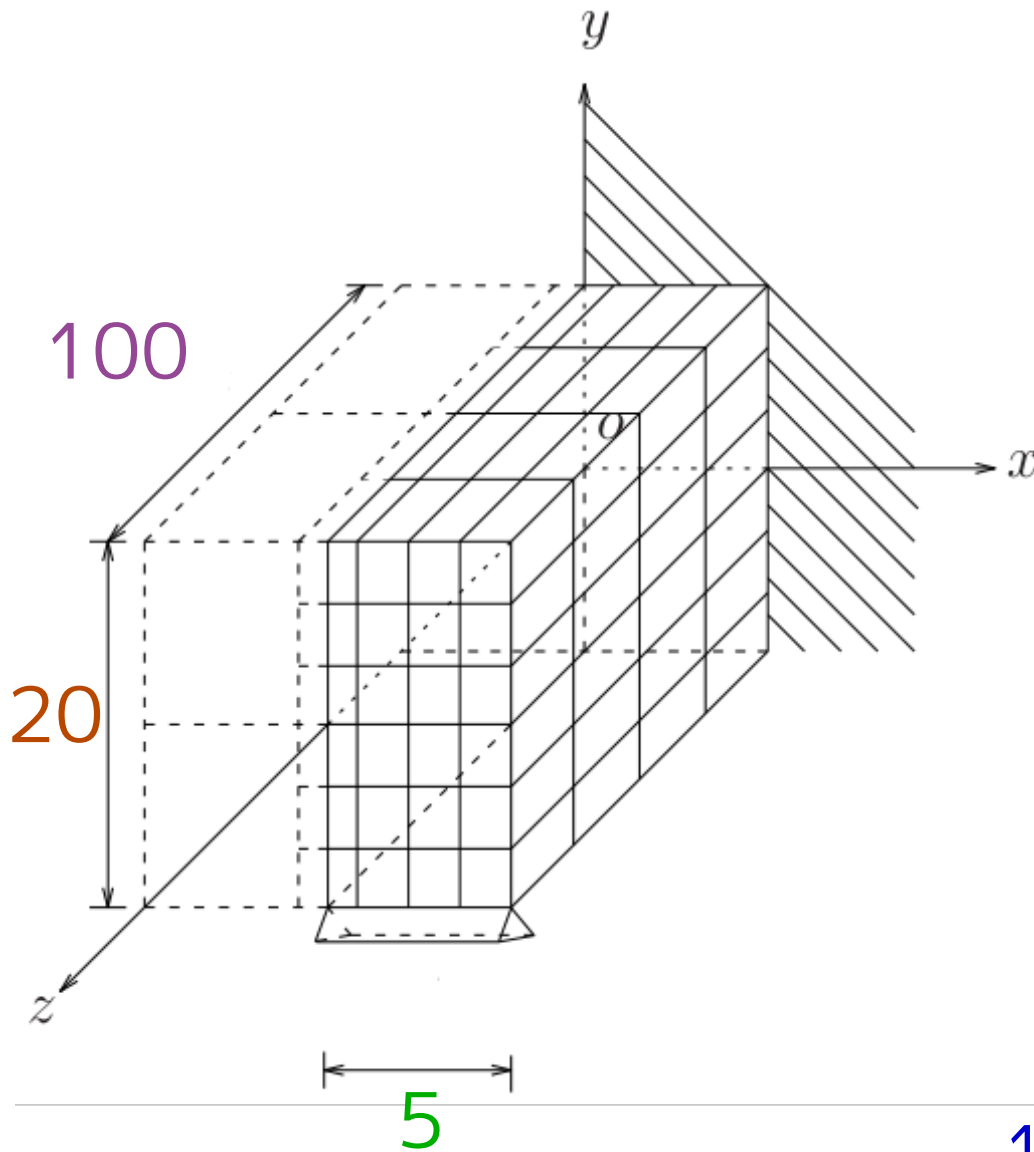
・ 5点曲げ



対称性から

解析手法

CalculiX (立体要素)



材料定数(集成材)

$$E_{zz} = 10\text{GPa}$$

$$E_{xx} = E_{yy} = 0.4\text{GPa}$$

$$G_{xy} = G_{xz} = G_{yz} = 0.7\text{GPa}$$

$$\left. \begin{array}{l} \nu_{xy} = \nu_{xz} = \\ \nu_{yx} = \nu_{yz} = \end{array} \right\} 0.016$$

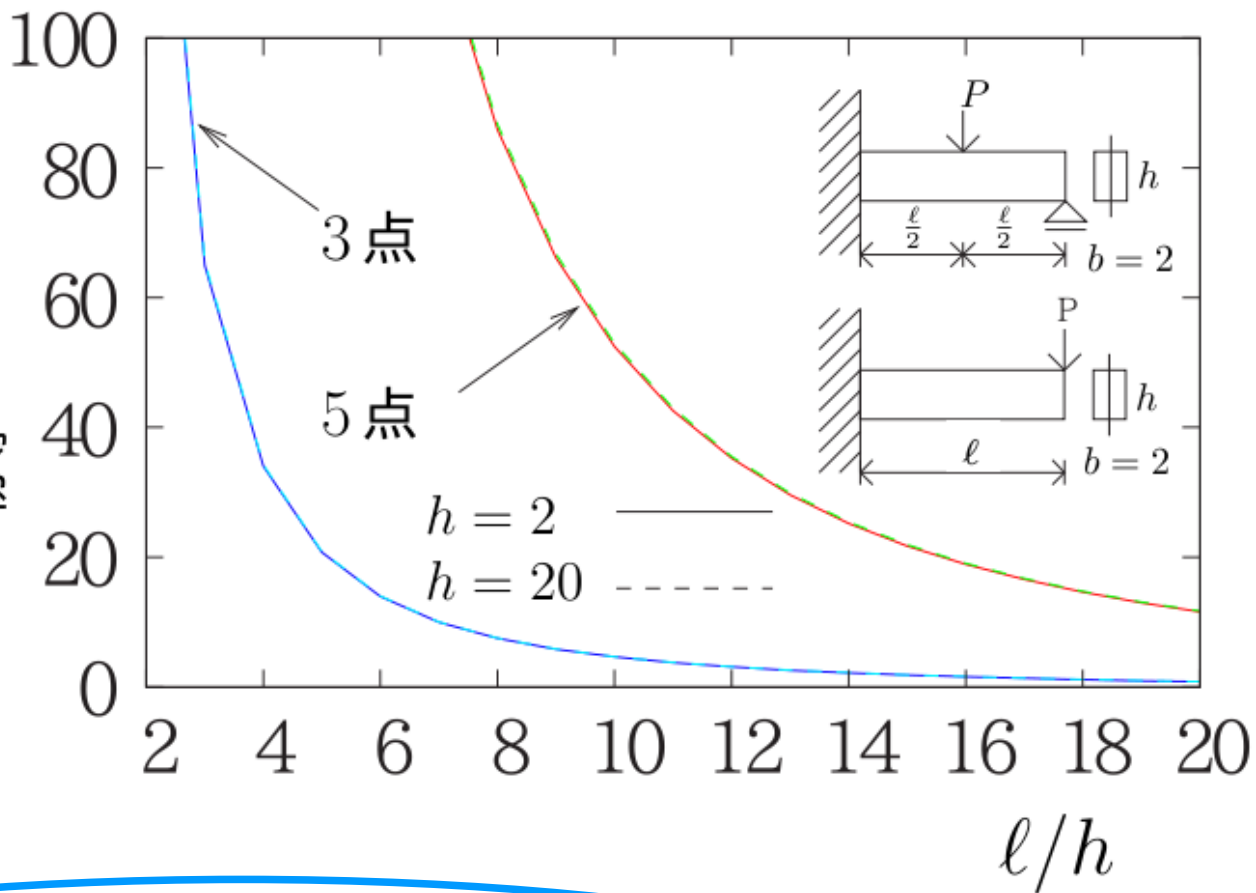
$$\nu_{zx} = \nu_{zy} = 0.4$$

梁理論との比較

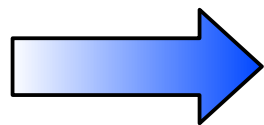
初等梁理論

$$v_{初} = \frac{7P\ell^3}{768EI}$$

$\frac{FEM-初等}{初等}$ (%)



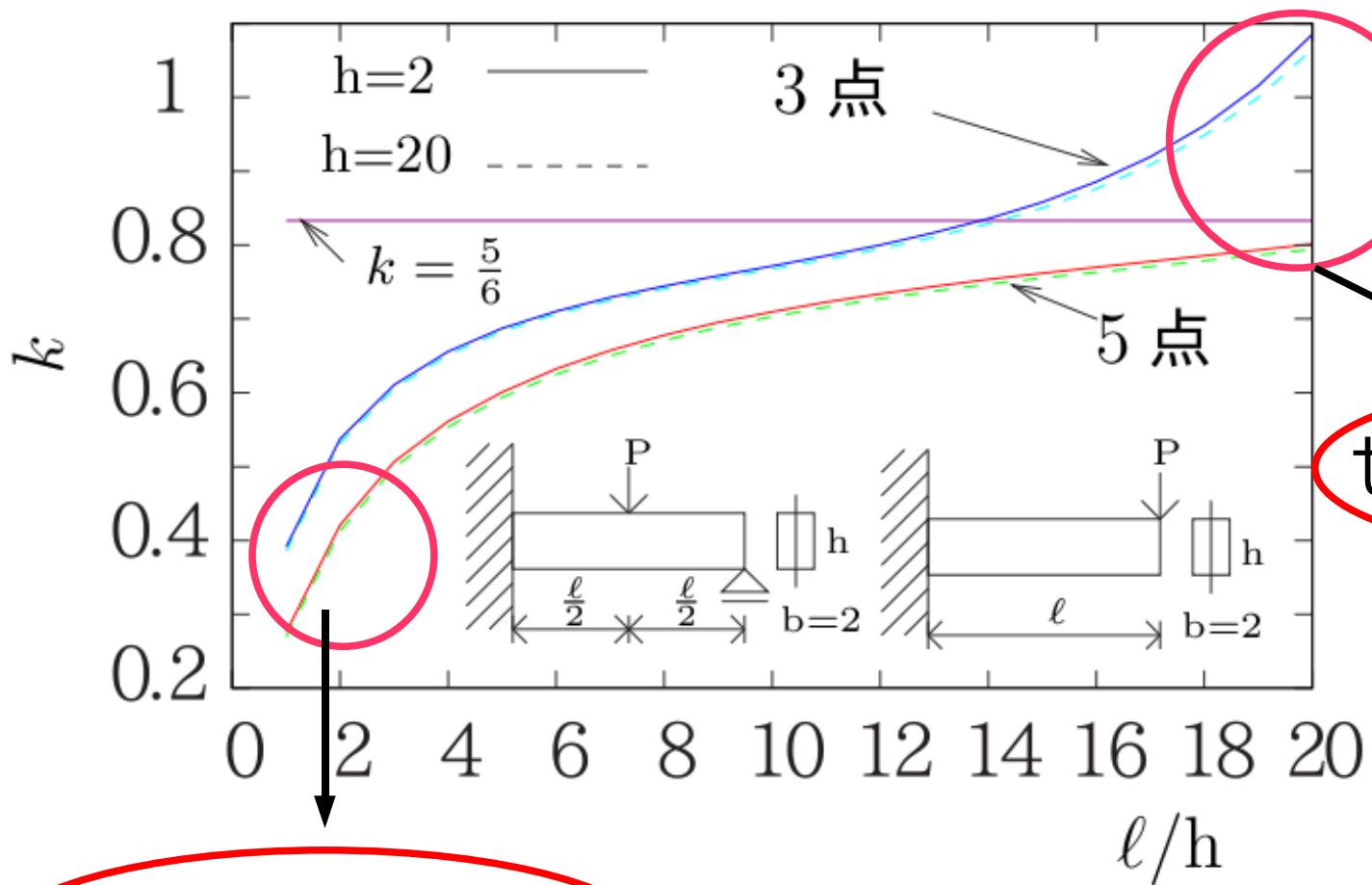
5点曲げ



せん断変形の影響大

kの逆算

$$k = \frac{73P}{256GA} \cdot \frac{\ell}{v - \frac{7P\ell^3}{768EI}}$$



せん断変形大きい

せん断変形小さい

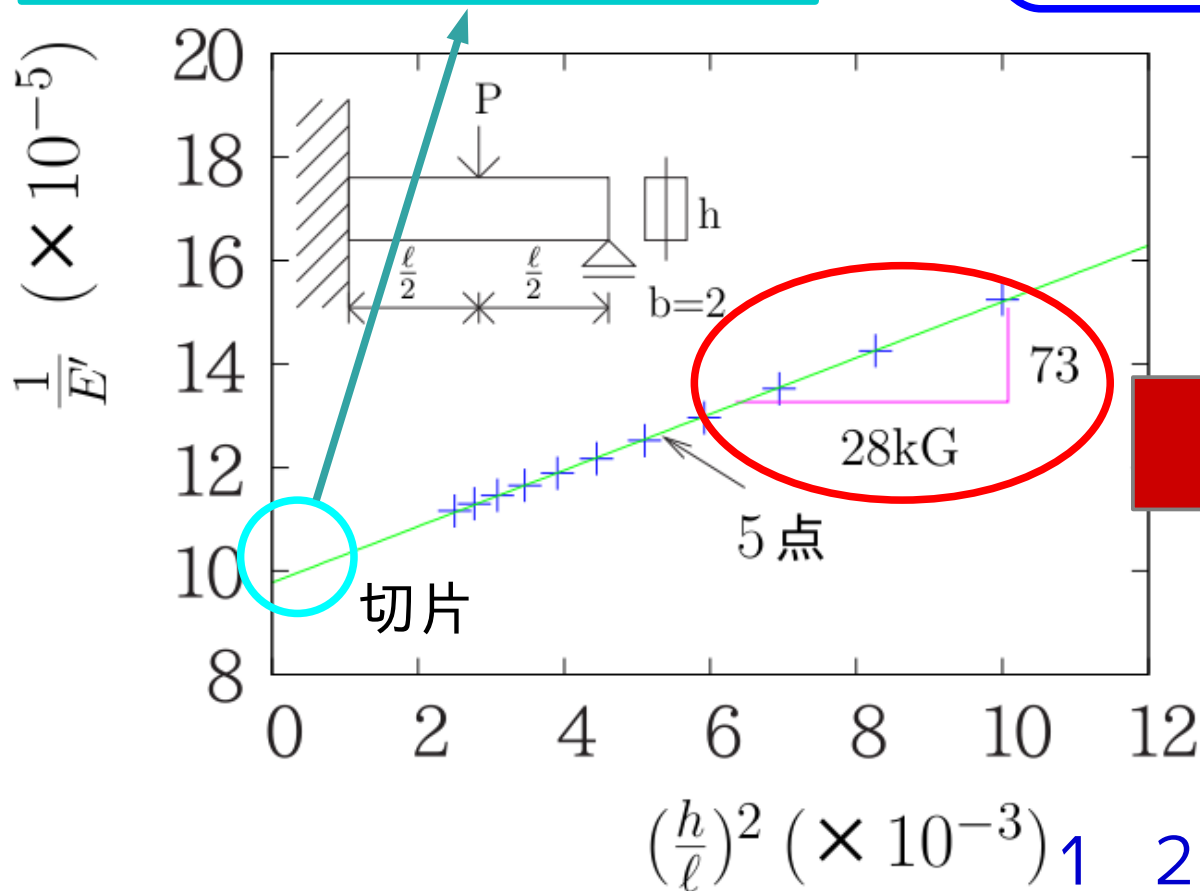
FEMから G,Eの推定

$$\frac{7P\ell^3}{768E'I} = v_{\text{ティモ}} = \frac{7P\ell^3}{768EI} + \frac{73P\ell}{256GkA}$$

FEM
E=10GPa

E(GPa)=10.23(2.2%)

$$\frac{1}{E'} = \frac{1}{E} + \frac{73}{28kG} \left(\frac{h}{\ell}\right)^2$$

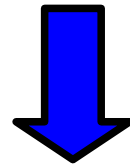


FEM
G=700MPa

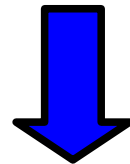
k	G(MPa)
5/6	576(18.6%)
平均 (0.7595)	632(9.7%)

まとめ

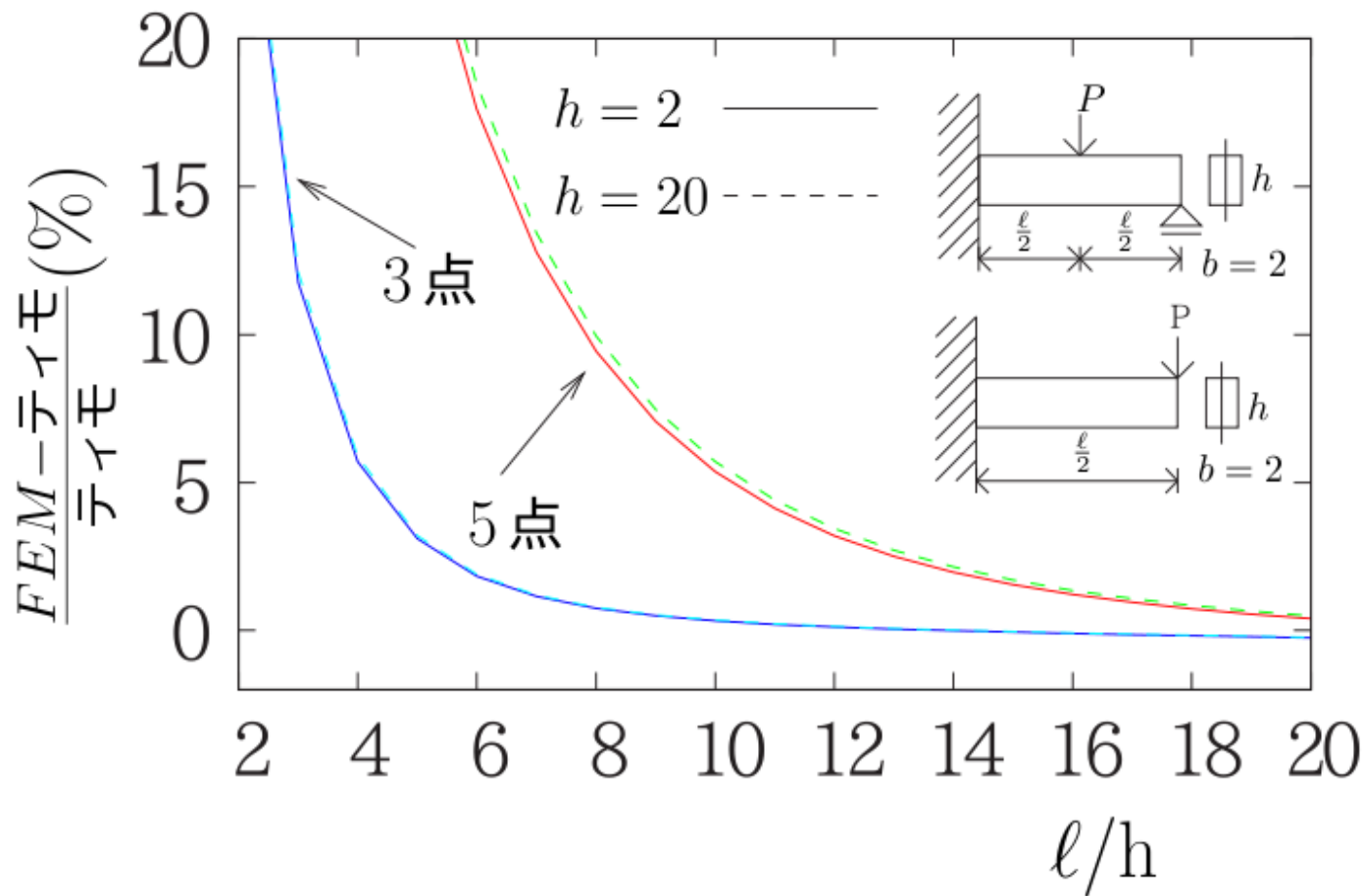
FEMから {
・ $k = \frac{5}{6}$ よりやや低め
・ FEMモデルより低めのG



曲げ試験では低いGを推定しているのでは??



実験値(ねじり試験、曲げ試験)と比較



L/h=大で
ほぼ同じ



木材Gでも
FEM解≒ティモ解

ティモシェンコ梁理論

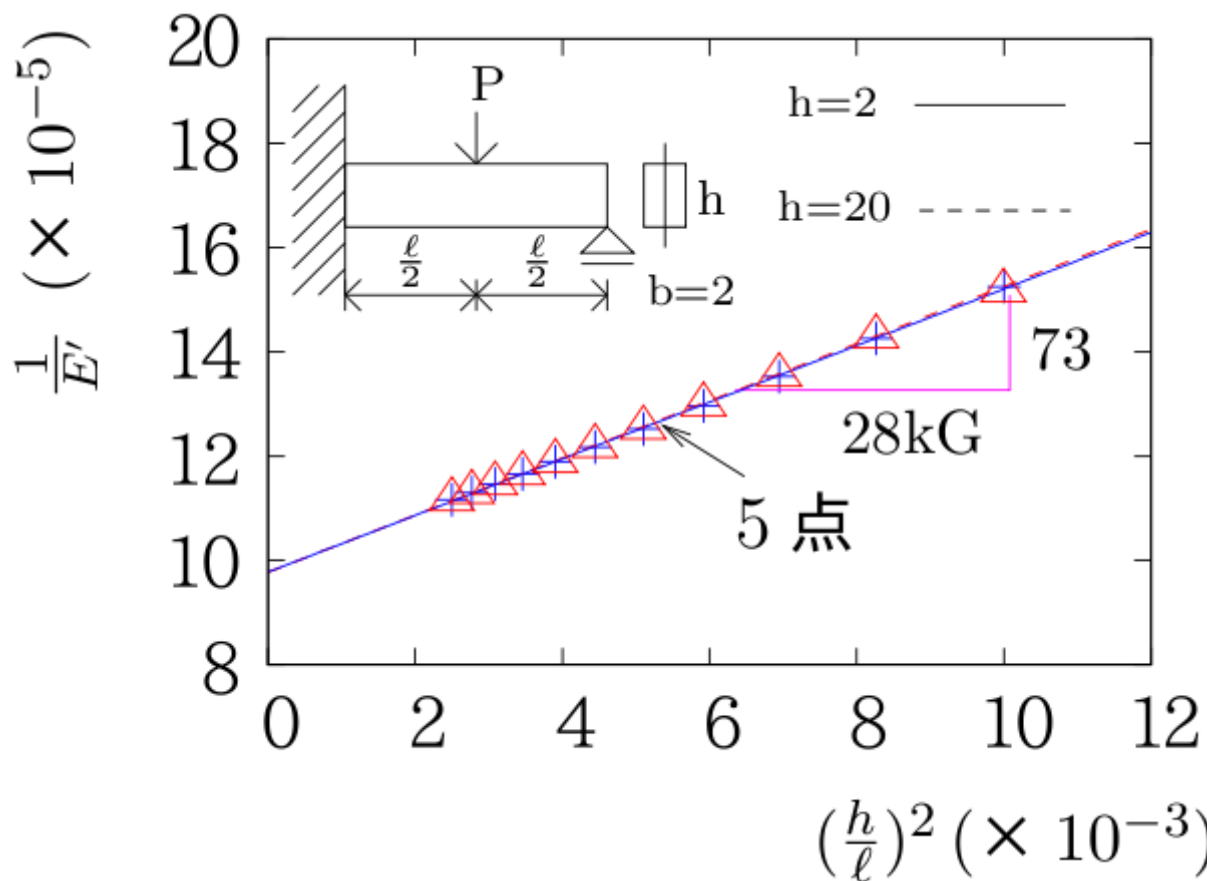
$$v_t = \frac{7P\ell^3}{768EI} + \frac{73P\ell}{256GkA}$$

$$G = \frac{E}{2(1 + \nu)}$$

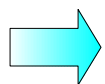
$$k = \frac{10(1 + \nu)}{12 + 11\nu}$$

曲げ
ヤング率 $E' = \frac{7P\ell^3}{768I\nu}$

$$\begin{pmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \gamma_{xy} \\ \gamma_{xz} \\ \gamma_{yz} \end{pmatrix} = \begin{bmatrix} \frac{1}{E_x} & \frac{-\nu_{xy}}{E_x} & \frac{-\nu_{xz}}{E_x} & 0 & 0 & 0 \\ \frac{\nu_{yx}}{E_y} & \frac{1}{E_y} & \frac{-\nu_{yz}}{E_y} & 0 & 0 & 0 \\ \frac{-\nu_{zx}}{E_z} & \frac{-\nu_{zy}}{E_z} & \frac{1}{E_x} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{G_{xy}} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{G_{xz}} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{G_{yz}} \end{bmatrix} \begin{pmatrix} \sigma_x \\ \sigma_y \\ \sigma_z \\ \tau_{xy} \\ \tau_{xz} \\ \tau_{yz} \end{pmatrix}$$

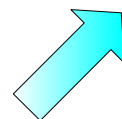


切片より

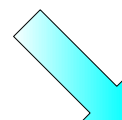


E(GPa)
10.23(2.2%)
10.22(2.2%)

傾きより



G(MPa)
576(18%)
570(19%)



G(MPa)
632(9.7%)
631(9.9%)

平均値のk