【SAP2000与结构力学】系列课程

SAP2000 梁结构分析

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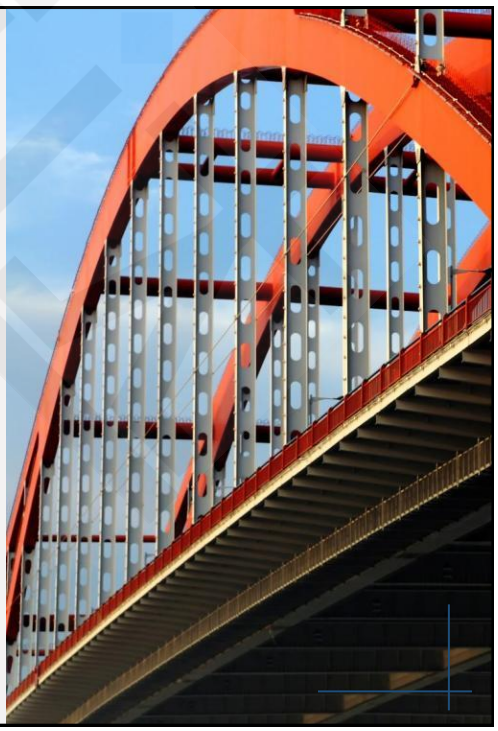

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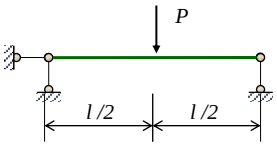
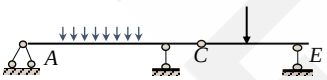
简支梁/连续梁/变截面梁

简支梁和连续梁

❖ 刚性支座





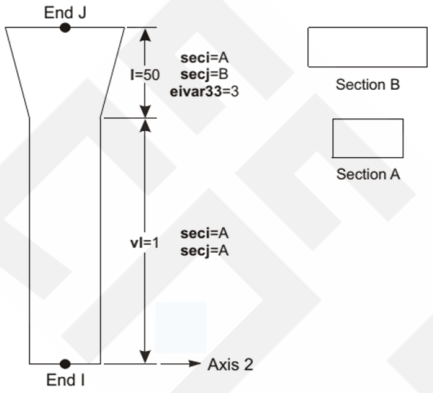
❖ 铰接节点

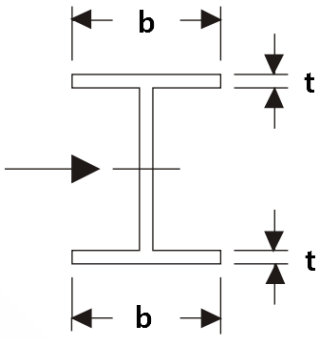
- 默认：刚接节点
- **端部释放**/连接单元/节点约束
- 避免节点的转动约束不足

变截面梁

❖ 抗弯刚度

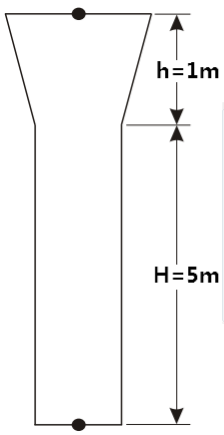
- 线性插值，二次插值，三次插值

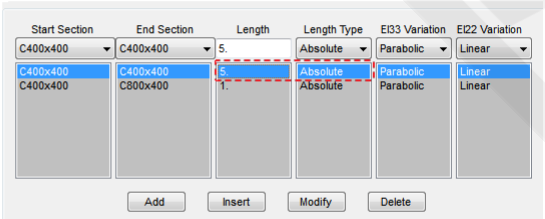




变截面梁

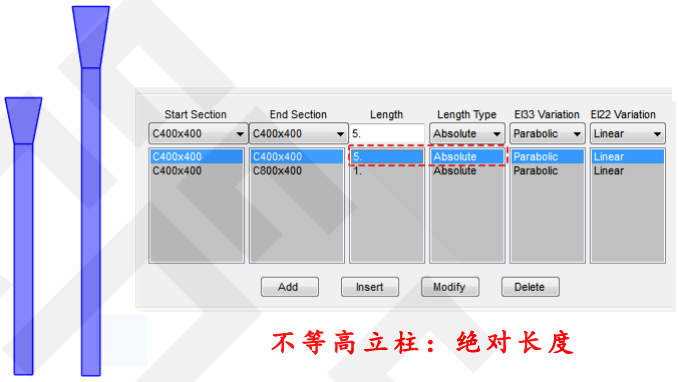
❖ 可变长度与绝对长度





变截面梁

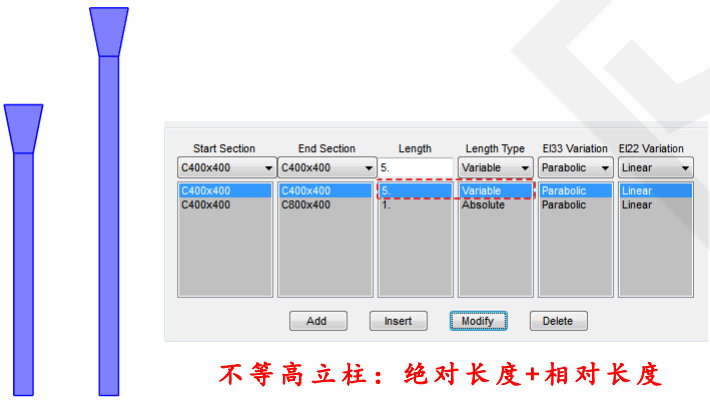
❖ 可变长度与绝对长度



不等高立柱：绝对长度

变截面梁

❖ 可变长度与绝对长度



不等高立柱：绝对长度+相对长度

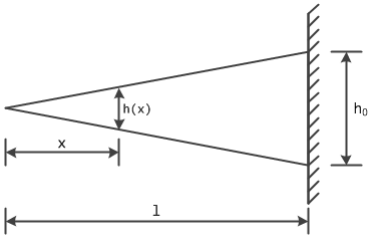
变截面梁

❖ 可变长度与绝对长度

不等高立柱2：绝对长度+相对长度

变截面梁

❖ 楔形悬臂梁



模型信息

$l=6m,\ E=30GPa,\ \rho=2550kg/m^3,\ h(x)=\frac{h_0 x}{l},\ h_0=1m$

自振频率

$$\omega=\frac{1.534h_0}{l^2}\sqrt{\frac{E}{\rho}}=\frac{1.534\times1.0}{6^2}\sqrt{\frac{30\times10^9}{2550}}=146.15$$

$$f=\frac{\omega}{2\pi}=\frac{146.15}{2\times3.1416}=23.26Hz$$

	单元数量	单元尺寸（m）	自振频率（Hz）	误差（%）
解析解	--	--	23.26	0.00
数值解一	1	6.0	3.39	-85.43
数值解二	5	1.2	16.26	-30.09
数值解三	20	0.3	23.15	-0.47
数值解四	50	0.12	23.25	-0.04

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梁的横向剪切变形

筑信达

梁的位移计算方法

❖ 材料力学

- 等直梁的挠曲线近似微分方程

$$EI\omega'' = M(x) \longrightarrow EI\omega = -\int\left[\int M(x)dx\right]dx + C_1x + C_2$$

❖ 结构力学

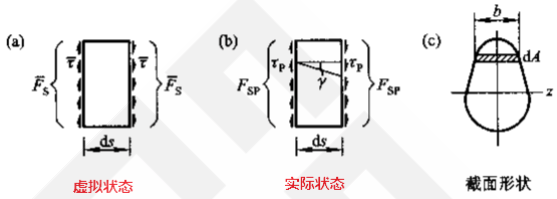
- 变形图虚功原理 → **单位荷载法** → 图乘法

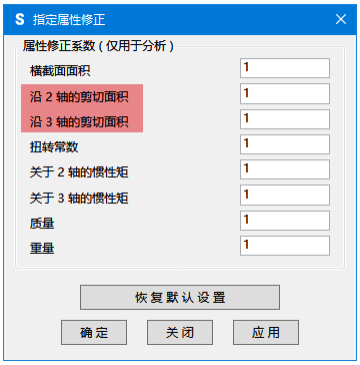
$$\Delta_{KP} = \sum\int \overline{M}d\varphi_P + \sum\int \overline{F_N}du_P + \sum\int \overline{F_S}\gamma_P ds$$

筑信达

梁的横向剪切变形

$$\Delta_{KP}=\sum\int \overline{M}d\varphi_P+\sum\int \overline{F_N}du_P+\sum\int \overline{F_S}\gamma_P ds$$



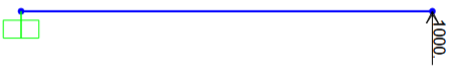


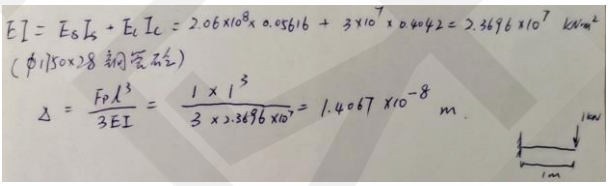
$$\overline{F_S}\gamma_P ds=ds\int_A \frac{\overline{F_S}F_{SP}S^2dA}{GI^2b^2}=\frac{\overline{F_S}F_{SP}ds}{GA}\cdot\frac{A}{I^2}\int_A\frac{S^2}{b^2}dA=\frac{k\overline{F_S}F_{SP}ds}{GA}$$

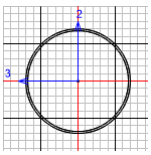
$$k=\frac{A}{I^2}\int_A\frac{S^2}{b^2}dA$$

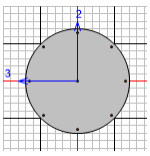
梁的横向剪切变形

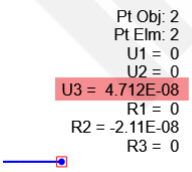
❖ 组合截面的悬臂梁











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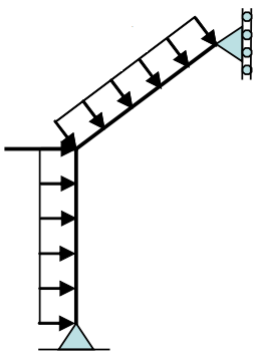
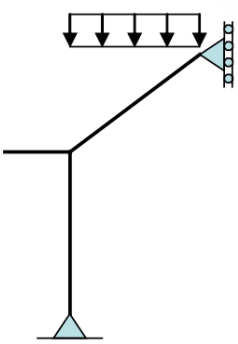
线荷载与温度荷载

线荷载

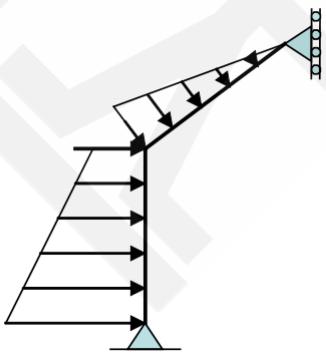
❖ 荷载大小与作用方向



坐标轴方向



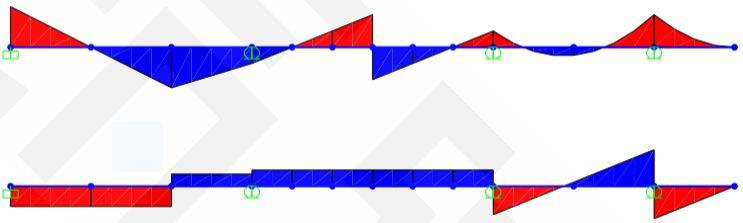
投影方向



三角形分布和梯形分布

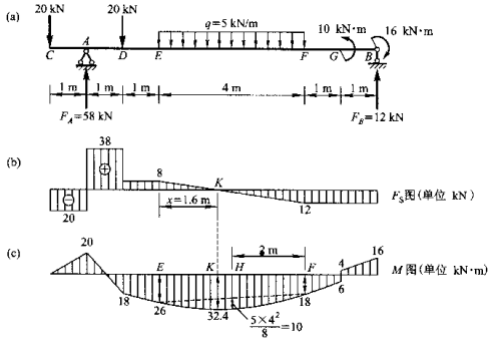
线荷载

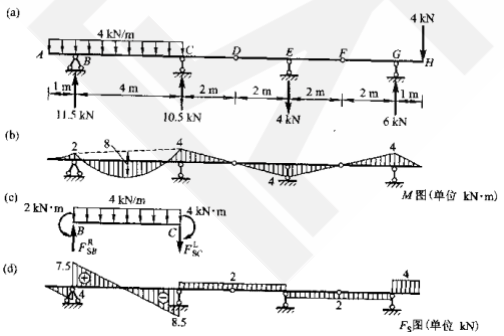
❖ 多跨静定梁



线荷载

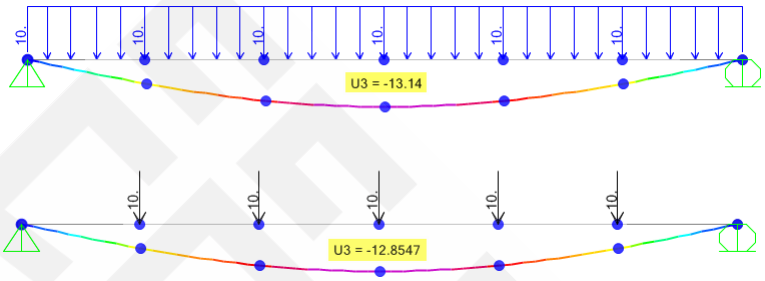
❖ 多跨静定梁





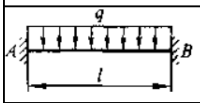
线荷载

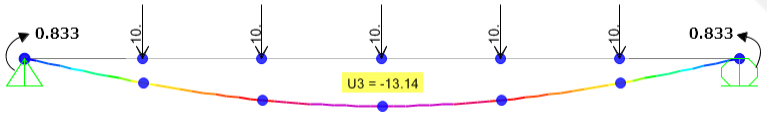
❖ 均布线荷载的等效集中荷载



线荷载

❖ 均布线荷载的等效集中荷载

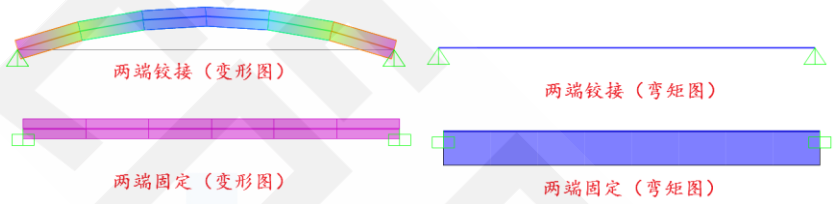
梁的简图	弯矩		剪力	
	M_{AB}	M_{BA}	F_{SAB}	F_{SBA}
	$\frac{ql^2}{12}$	$\frac{ql^2}{12}$	$\frac{ql}{2}$	$-\frac{ql}{2}$



温度荷载

❖ 温度荷载与温度应力

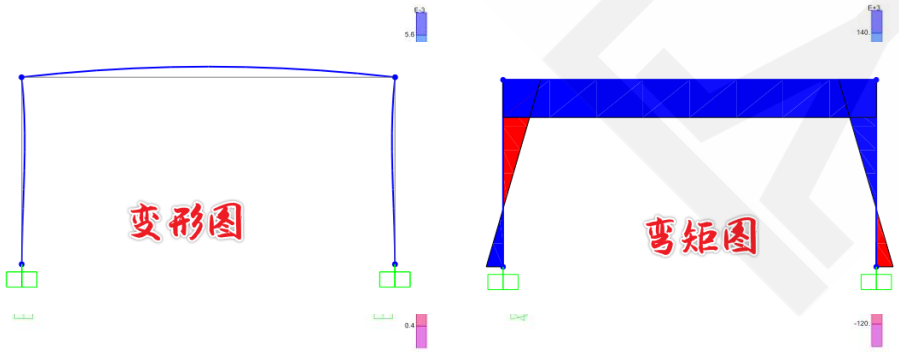
- 材料温差 → 应变/变形 → 应力/内力
- 静定结构：自由变形，内力/应力**为零**
- 超静定结构：约束变形/无变形，内力/应力**非零**



水平梁的顶面温度高于底面温度

温度荷载

❖ 门式刚架



水平梁的顶面温度高于底面温度

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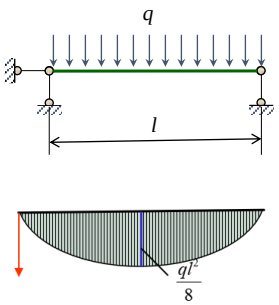
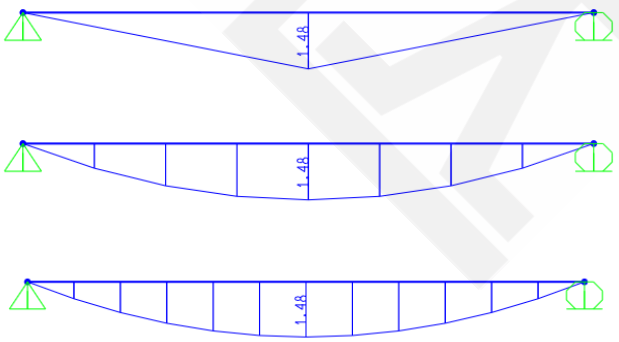
弯矩图和挠曲线

筑信达

测站

❖ 线性插值

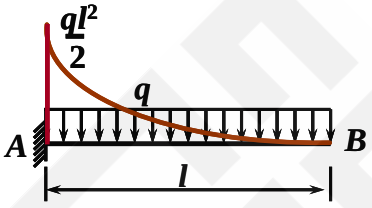


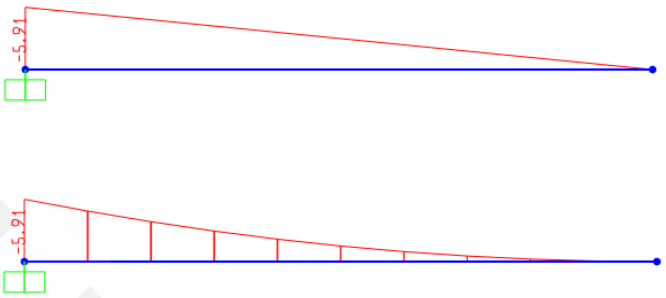


筑信达

测站

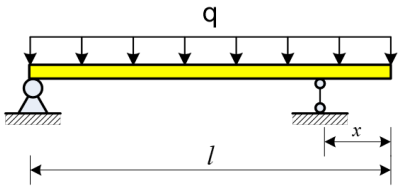
❖ 线性插值



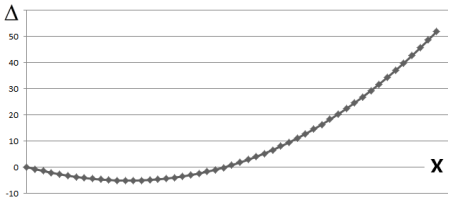


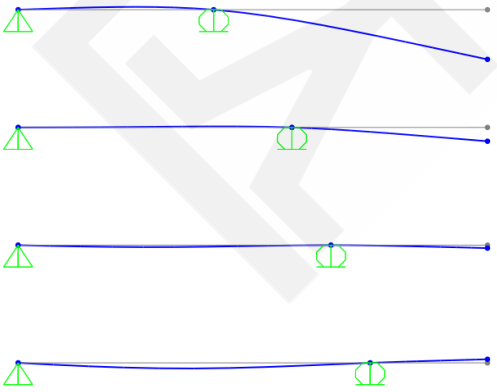
节点位移

❖ 外伸梁的自由端挠度



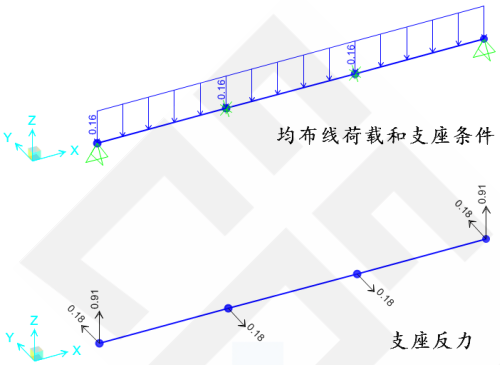
$$\Delta = \frac{1}{24EI}\left[4x^3(l-x)+3x^4-x(l-x)^3\right]$$

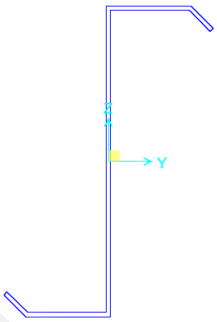




挠曲线

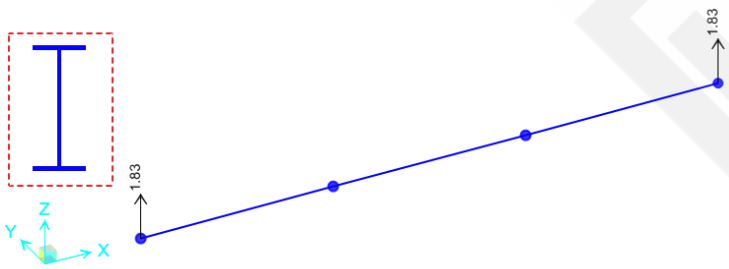
❖ 非对称弯曲（斜弯曲）





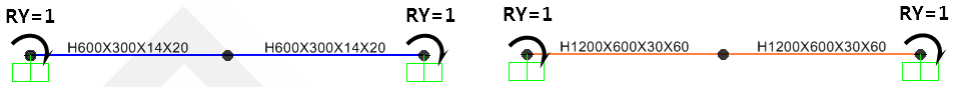
挠曲线

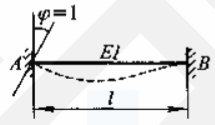
❖ 对称弯曲



挠曲线

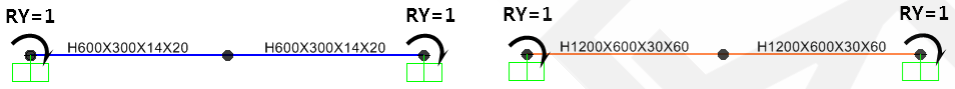
❖ 两端固定的等直梁

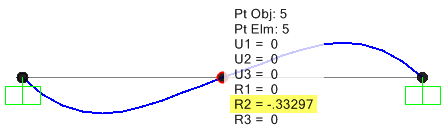


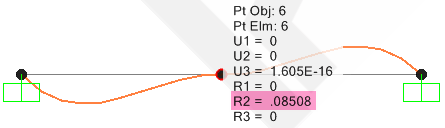
梁的简图	弯矩 M_{AB}	弯矩 M_{BA}	剪力 F_{SAB}	剪力 F_{SBA}
	$4i$ $\left(i=\frac{EI}{l}\text{，下同}\right)$	$2i$	$-\frac{6i}{l}$	$-\frac{6i}{l}$

挠曲线

❖ 两端固定的等直梁

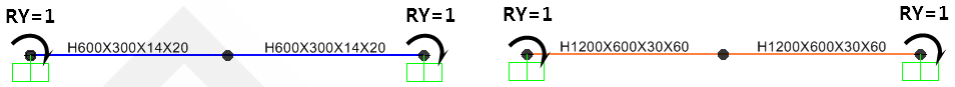




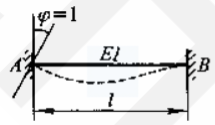


挠曲线

❖ 两端固定的等直梁

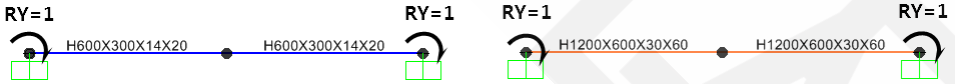


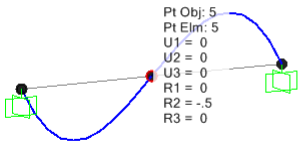
$$EI\omega'' = M(x) \longrightarrow EI\omega = -\int\left[\int M(x)dx\right]dx + C_1x + C_2$$

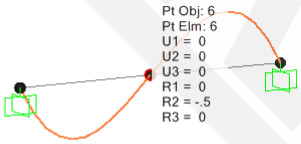
梁的简图	弯矩 M_{AB}	弯矩 M_{BA}	剪力 F_{SAB}	剪力 F_{SBA}
	$4i$ $\left(i=\frac{EI}{l}\text{，下同}\right)$	$2i$	$-\frac{6i}{l}$	$-\frac{6i}{l}$

挠曲线

❖ 两端固定的等直梁







忽略剪切变形

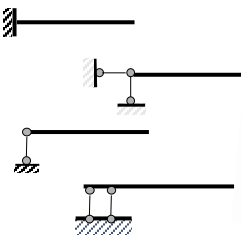
5

弹性支座

弹性支座

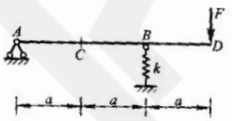
❖ 支座类型

- 刚性支座：零位移，零转角
  - 固定支座
  - 固定铰支座
  - 可动铰支座
  - 定向支座



- 柔性支座：非零的位移或转角
  - **线性（弹性）支座**
  - 非线性支座

6-22 图示梁 EI=常数，B 处有一弹性支座，弹簧的刚度系数（产生单位位移所需的力）为 k（注：弹簧的柔度系数 f 即单位力作用下的位移，是与刚度系数互为倒数的，即 $f=\frac{1}{k}$）。试求 C 点竖向位移。已知 $k=\frac{EI}{a^3}$。



谢 谢

“The idea that an expert-system computer program, with artificial intelligence, will replace a creative human is an insult to all structrual engineers.”

加州大学伯克利分校终身名誉教授 Edward L.Wilson（著名的结构分析设计软件 SAP 的创始人）在《Three Dimensional Static and Dynamic Analysis Of Structures》（http://www.edwilson.org/Book/book.htm#Personal ）一书中提到：

"Don't use a structural analysis program unless you fully understand the theory and approximations used within the program"

"Don't create a computer model until the loading， material properties and boundary conditions are clearly defined"