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Static control method using gradient–genetic algorithm for grillage adaptive beam string structures based on minimal internal force

Yan-bin SHEN, Hao-song SUN, An-dong LEI, Xiao-yuan YING, Guang YANG, Yao-zhi LUO

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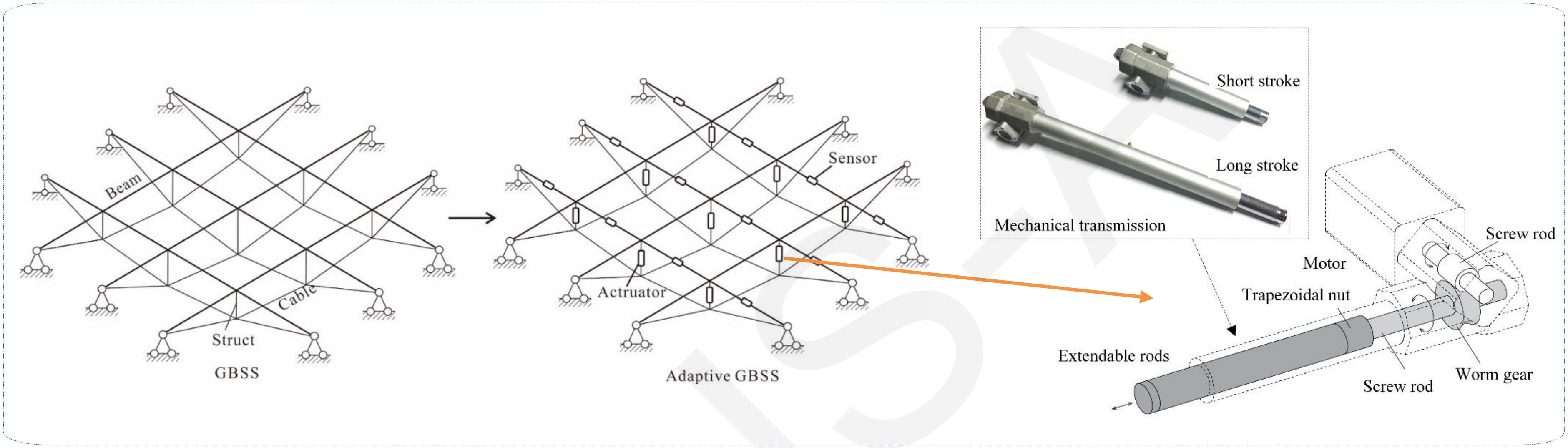
Optimization model of internal force control for GABSSs



The internal force coefficient kij of the upper beams is defined as:

$$k_{ij}=\begin{cases}\sigma_{ij}/\sigma_{ij}^{\mathrm{t}}, & \sigma_{ij}\geq 0;\\ \sigma_{ij}/\sigma_{ij}^{\mathrm{c}}, & \sigma_{ij}<0;\end{cases}$$

The working state coefficient of the whole structure is defined as:

$$\beta=\max k_{ij}$$

The internal force optimization model of a GABSS is

$$\min \beta$$

$$\text{s.t.}\quad \begin{aligned}&\sigma_{ij}^{\mathrm{c}}\leq\sigma_{ij}\leq\sigma_{ij}^{\mathrm{t}}\\ &\sigma_{\mathrm{c}}^{\mathrm{L}}\leq\sigma_{c}\leq\sigma_{\mathrm{c}}^{\mathrm{t}}\\ &\sigma_{\mathrm{T}}^{\mathrm{L}}\leq\sigma_{\mathrm{T}}\leq\sigma_{\mathrm{T}}^{\mathrm{t}}\\ &s^{\mathrm{L}}\leq e^{\mathrm{a}}\leq s^{\mathrm{U}}\end{aligned}$$

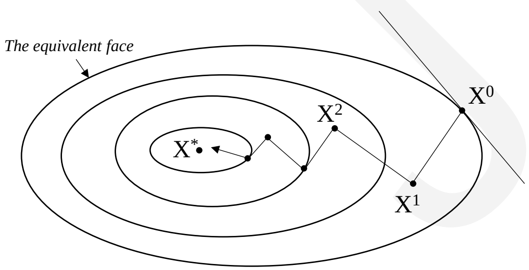
Internal force control through the gradient–genetic algorithm

GA

- Excellent global search capabilities
- Less efficient in the local search area

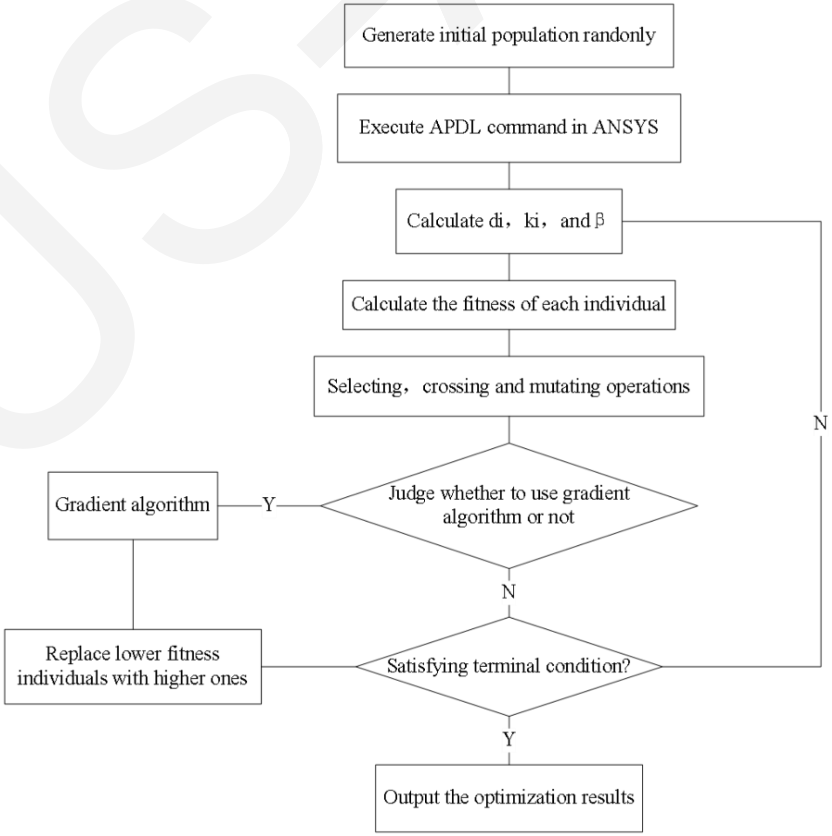
The gradient descent method

- Obtains the local optimal point more quickly and easily
- Difficult to find a global optimal solution



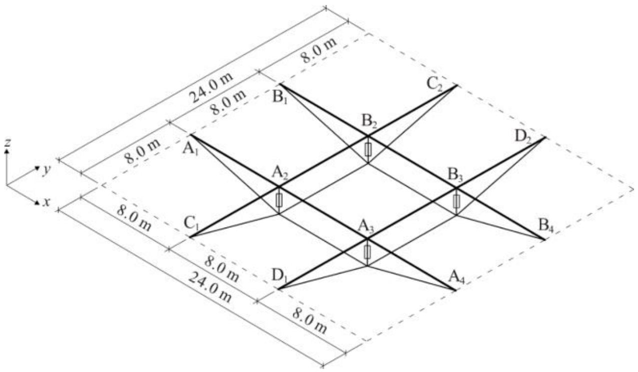
GGA

- Good local search ability
- Global optimization ability
- Fast convergence speed

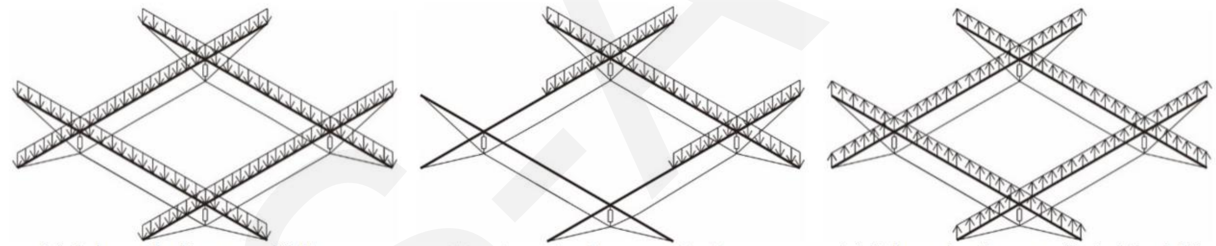


Comparison between GABSS and GBSS——Example 1

Model



Load distribution

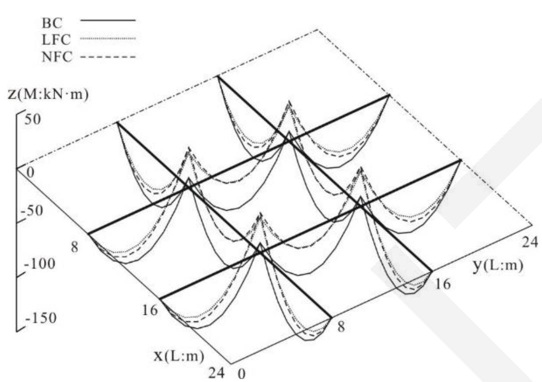


(a) Schematic diagram of full-span variable live load Q_1

(b) Schematic diagram of half-span variable live load Q_2

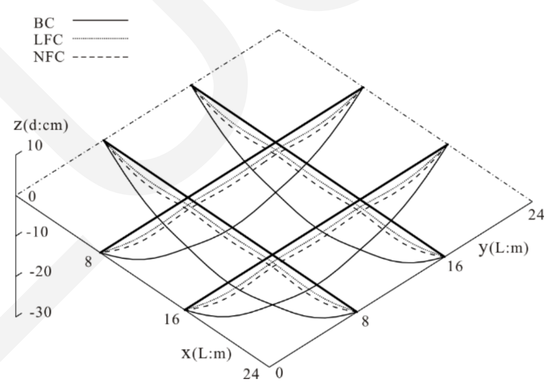
(c) Schematic diagram of wind load W

Load case 1



The working state coefficients

LFC	NFC
20.15% ↓	19.71%↓



Displacement

LFC	NFC
82.57% ↓	83.12%↓

uncontrolled GBSS

Q1 = 4.65 kN/m

GABSS

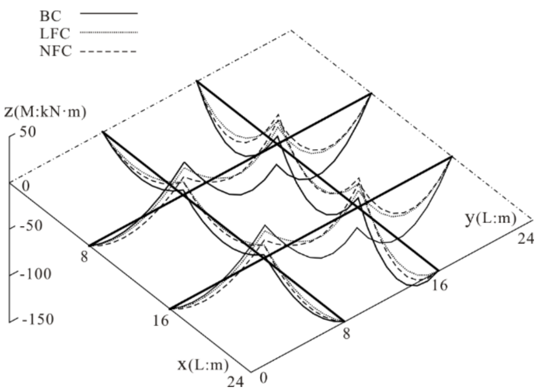
Q1 = 20.5 kN/m

The load capacity of GABSS

340.86% ↑

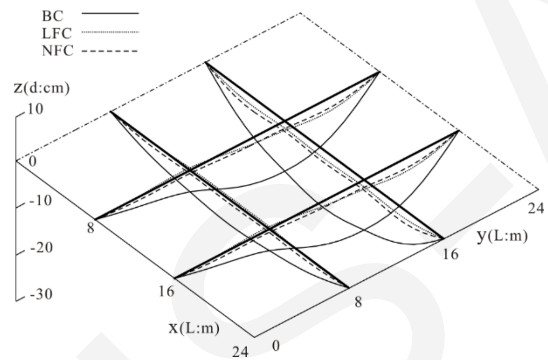
Comparison between GABSS and BSS——Example 1

Load case 2



The working state coefficients

LFC	NFC
32.89% ↓	31.0%↓



Displacement

LFC	NFC
78.82% ↓	80.72%↓

uncontrolled GBSS

Q2 = 4.97 kN/m

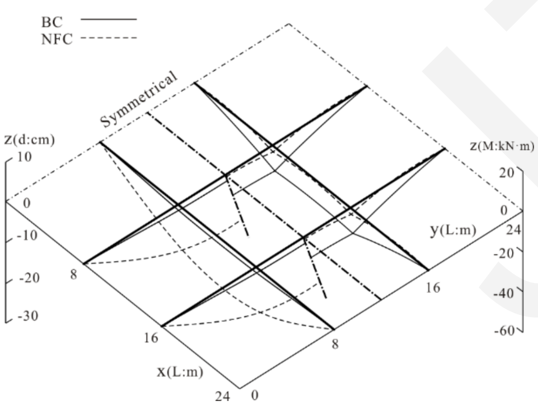
GABSS

Q2 = 18.18 kN/m

The load capacity of GABSS

265.79% ↑

Load case 3



uncontrolled GBSS

Q3 = 2.9 kN/m

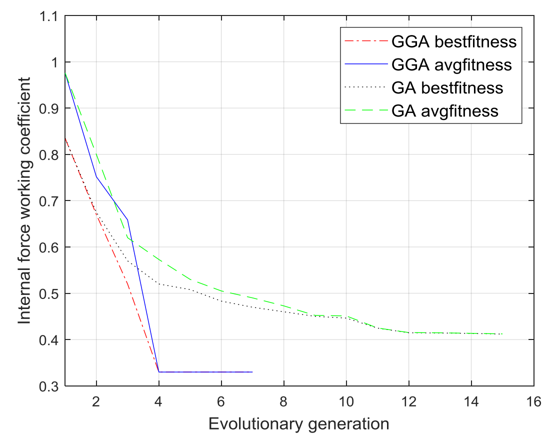
GABSS

Q3 = 3.49 kN/m

The load capacity of GABSS

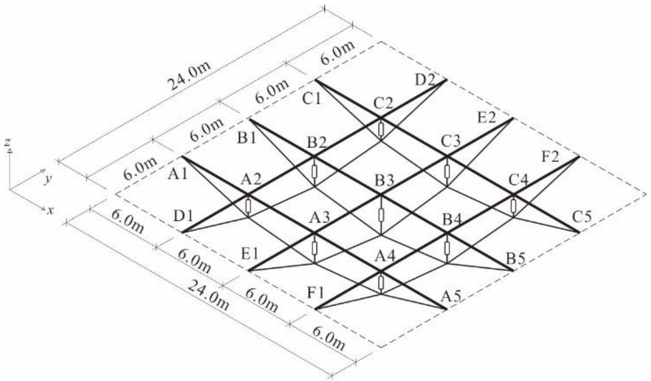
20.34% ↑

Convergence trends of GGA and GA

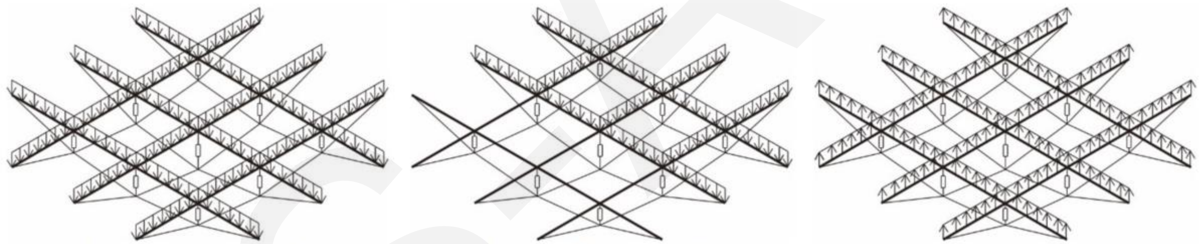


Comparison between GABSS and GBSS——Example 2

Model



Load distribution



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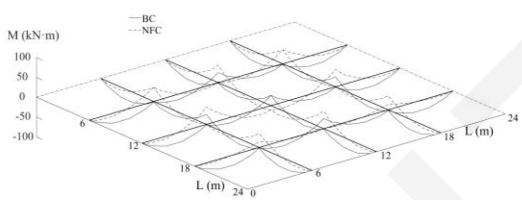
(b) Schematic diagram of half-span variable live load Q_2

(c) Schematic diagram of wind load W

Load case 1



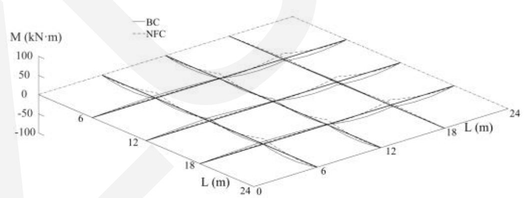
uncontrolled GBSS Q1 = 5.5 kN/m

GABSS Q1 = 19.27 kN/m

The load capacity of GABSS

250.36% ↑

Load case 2



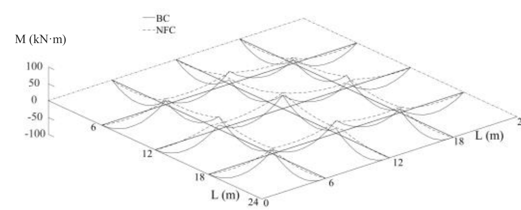
uncontrolled GBSS Q2 = 2.4 kN/m

GABSS Q2 = 10.87 kN/m

The load capacity of GABSS

352.92% ↑

Load case 3



uncontrolled GBSS Q3 = 3.4 kN/m

GABSS Q3 = 3.53 kN/m

The load capacity of GABSS

3.8% ↑