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Comparative Analysis of Flat Slab and Waffle Slab Systems for G + 2 School Buildings

Anjali K. Kanet[1], Dr.Prashant K. Bhuva [2], Dr. Chirag R. Odedra[3], Prof. Darshan J. Parmar[4], Prof. Vandit Bhatt[5]
[1]*M.TechStudent,* [2, 3, 4, 5]*Assistant Professor, Department of Civil Engineering, Dr.Subhash University, Junagadh, India*

Abstract: The selection of an appropriate slab system plays a crucial role in the structural performance, economy, and construction efficiency of multi-storey buildings. This study presents a comparative analysis of Flat Slab and Waffle Slab systems for a G+2 school building. Both structural systems are modeled and analyzed using structural analysis software under identical loading conditions, including dead load, live load, and seismic load as per relevant Indian Standard codes. The comparison is carried out based on various structural parameters such as storey displacement, storey drift, storey stiffness, base shear, and bending moment. In addition, construction-related aspects such as material quantity (RCC and steel), construction cost, structural depth, and form work complexity are also evaluated. The results indicate that the waffle slab system provides higher stiffness and better control of deflection due to its ribbed grid configuration, making it suitable for larger spans such as auditorium or hall areas in school buildings. However, the flat slab system offers advantages in terms of architectural flexibility, faster construction, and simpler form-work, making it more practical for regular classroom layouts. The study concludes by identifying the most suitable slab system based on structural performance, cost efficiency, and functional requirements of a G+2 school building.
Keywords: Flat Slab, Waffle Slab, G+2 School Building, Storey Displacement, Storey Drift, Structural Analysis, Seismic Performance, Cost Comparison.

I. INTRODUCTION

A G + 2 school building refers to a structure consisting of one ground floor and two upper floors, commonly used for educational institutions such as primary and secondary schools. The structural design of school buildings requires careful consideration because these buildings accommodate a large number of students and must ensure safety, durability, functionality, and economic efficiency. In addition, school buildings often include classrooms, corridors, laboratories, offices, and multipurpose halls, which require proper structural planning to provide adequate space and comfort. In reinforced concrete structures, the slab system plays an important role in distributing loads to the supporting columns and foundations. The selection of a suitable slab system affects the structural behavior, construction time, material consumption, and overall cost of the building. Among the various slab systems used in multi-storey buildings, Flat Slab and Waffle Slab are widely adopted due to their structural efficiency and architectural advantages. A Flat Slab system is a beam-less slab directly supported on columns, sometimes with drops or column heads to resist punching shear. This system provides greater architectural flexibility, reduced floor-to-floor height, and faster construction, making it suitable for buildings where open floor space is required, such as classrooms and corridors in school buildings. However, flat slabs may experience higher deflection and punching shear near columns, especially when larger spans are used. In contrast, a Waffle Slab system consists of a grid of ribs in two perpendicular directions, forming a waffle-shaped pattern. This type of slab offers higher stiffness, improved load distribution, and reduced self-weight, which makes it suitable for large span areas such as assembly halls or auditoriums in school buildings.

However, waffle slabs require complex form-work and skilled labor, which may increase construction complexity. Therefore, selecting an appropriate slab system for a G + 2 school building requires a detailed evaluation of both structural performance and economic factors. In this study, a comparative analysis of Flat Slab and Waffle Slab systems is carried out for a G + 2 school building by analyzing parameters such as storey displacement, storey drift, storey stiffness, base shear, bending moment, and material quantities. The objective is to determine the most efficient slab system for school building construction based on structural behavior and cost effectiveness.

A. *Research Objectives*

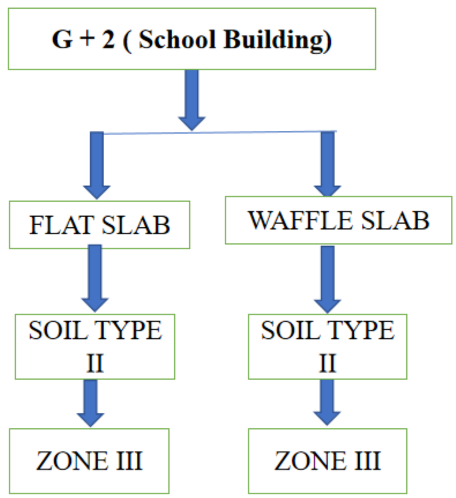
1) To carry out comparative analysis of flat slab and waffle slab systems in G + 2 (School building) under gravity, seismic.
2) To evaluate story in seismic load (EQX, EQY) FOR displacement, story drift, Stroy Shears, Story Stiffness.

3) Comparative Study of Waffle Slab and Flat Slab Structures in Different Seismic Zones (III).

B. Research Gap

1) Comparative analysis — Waffle slab vs Flat slab for G + 2 School buildings.
2) Zone-specific seismic performance: Lack of systematic studies across different seismic zones III comparing global response, punching shear failures, and retrofit strategies.
3) Research Gaps in Structural Response Evaluation of Waffle and Flat Slab Systems Considering in sesmic load (EQX, EQY) for Storey Displacement, StoreyDrift, Stroy Shears, Story Stifness in G + 2 (School Building).

C. Scope of Proposed Work



II. RESEARCH METHODOLOGY

1) Step 1: Literature Review
2) Step 2: Building Modeling

Design each height with two slab systems:
Flat Slab System
Waffle Slab System

3) Step 3: Load Application

Apply lateral loads:
Earthquake load as per IS 1893:2016 (zone factor, importance factor, response reduction factor).

4) Step 4: Analysis Parameters

For School Building height (G+2), extract results for:

- Max. Storey Displacement – Compare lateral displacement in both slab systems.
- Max. Storey Drift – Evaluate inter-storey drift and check IS code compliance.
- Stroy Shears - Storey shear is the total lateral force acting at a particular floor level due to earthquake or wind loads.
- Story Stifness - Storey stiffness is the resistance offered by a storey against lateral displacement under lateral loads.

5) Step 5: Comparative Evaluation

Prepare comparison tables G+2 School Building each parameter.
Highlight which slab system performs better in:
01. Initial Cost
02. Construction Speed
03. Structural Depth
04. Seismic Performance

05. Architectural Flexibility
06. Forwork Complexity
07. Maintence.

6) Step 6 :Prepare comparison graphs G+2 School Building each parameter in seismic loads.
Highlight which slab system performs better in :
SesmicLoads :
EQX
EQY
01. Story Displacement
02. Story Drift
03. Story Stiffness
04. Story Shear

7) Step 7: Conclusion & Recommendations
Draw conclusions on structural safety, economy, and serviceability.
Provide design recommendations for selecting slab systems in different height ranges.

III. SOFTWARE VALIDATION FOR FLAT SLAB

Height of typical Storey	3.45 m
Height of ground storey	3.45 m
Length of the building	58.5 m
Width of the building	44.28 m
Height of the building	13.35 m
Number of stories	G + 2
Wall thickness	230 mm
Slab thickness	200 mm
Grade of concrete	M25
Support	Fixed
Column size	1200 mm x 600 mm 1050 mm x 600 mm
Cap Size	2300 mm x 2300 mm
Beam size (outer)	300 mm x 600 mm
Location of building	India

Live Load	2 kN/m^2
Floor Finish Load	1 kN/m^2
Density of Concrete	25 kN/m^3
Seismic Zone	Zone III
Site type	II
Important Factor	1.5
Response Reduction	5
Damping Ratio	5%
Structure Class	Eductional Institional Building
Earthquack design code	IS:1893-2016(I)
RCC Design code	IS 456-2000
Steel design code	IS 800-2007
-	-

Table.1 Parameter of Flat slab

IV. SOFTWARE VALIDATION FOR WAFFLE SLAB

Height of typical Storey	3.45 m
Height of ground storey	3.45 m
Length of the building	58.5 m
Width of the building	44.28 m
Height of the building	13.35 m
Number of stories	G + 2
Wall thickness	230 mm
Slab thickness	150 mm
Grade of concrete	M25
Support	Fixed
Column size	1200 mm x 600 mm 1050 mm x 600 mm
Beam size	300 mm x 600 mm 150 mm x 600 mm
Location of building	India

Live Load	2 kN/m^2
Floor Finish Load	1 kN/m^2
Density of Concrete	25 kN/m^3
Seismic Zone	Zone III
Site type	II
Important Factor	1.5
Response Reduction	5
Damping Ratio	5%
Structure Class	Eductional Institional Building
Earthquack design code	IS:1893-2016(I)
RCC Design code	IS 456-2000
Steel design code	IS 800-2007
-	-

Table.2 Parameter of Waffle slab

V. SOFTWARE VALIDATION

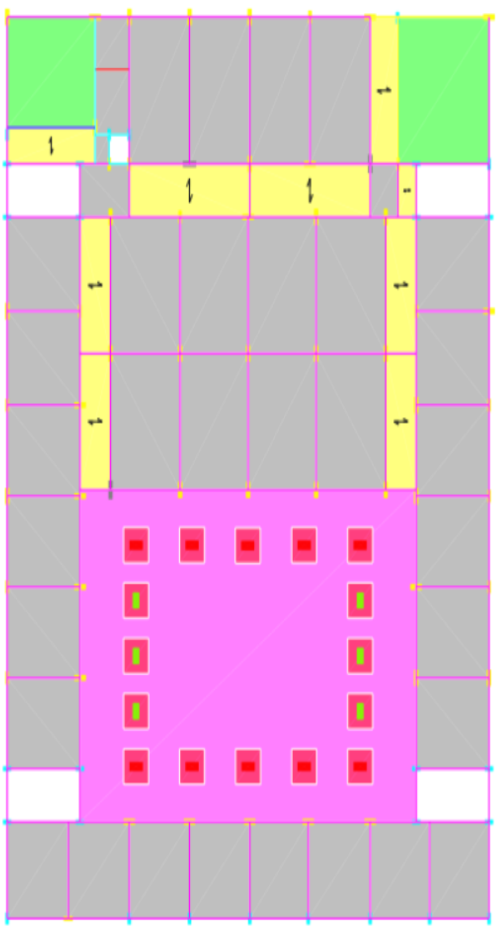


FIG. 1 Plan View of the flat Slab

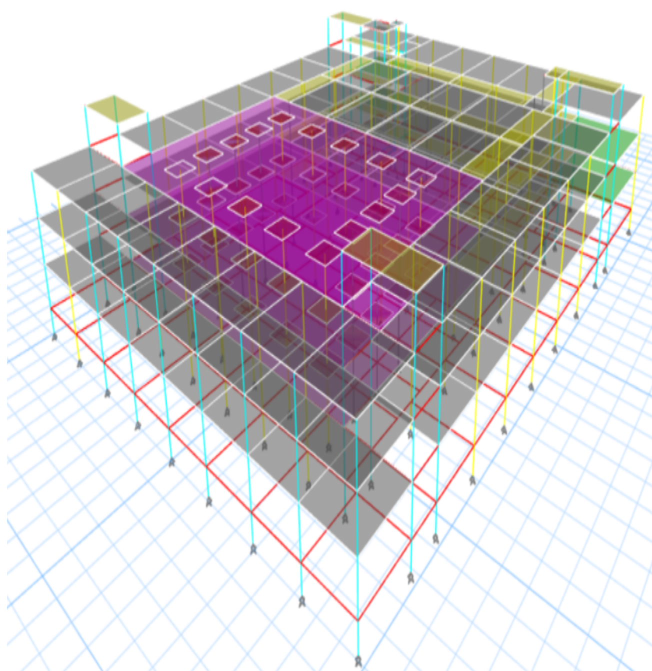


FIG. 2 3D View of the flat Slab

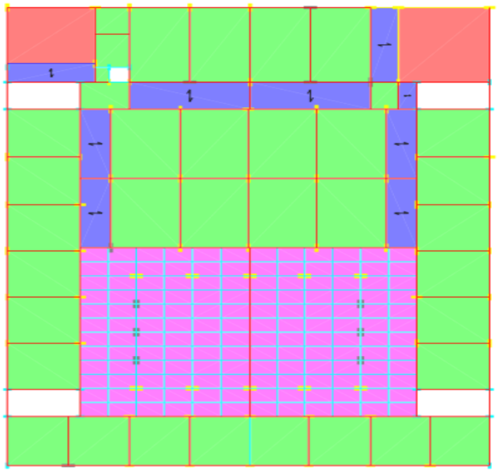


FIG. 3 Plan View of the Waffle Slab

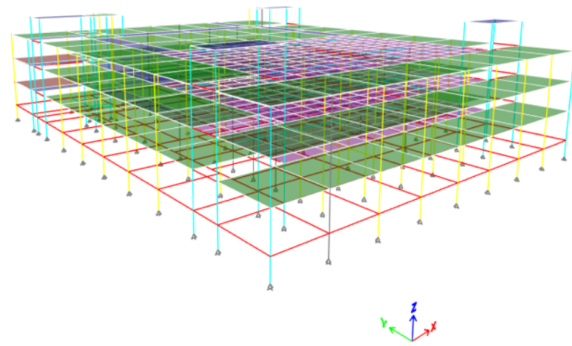


FIG. 4 3D View of the Waffle Slab

VI. OBSERVATIONS

1) Result of the Maximum Story displacement - EQX &EQY slab(G+2 School Building)

Waffle Slab :

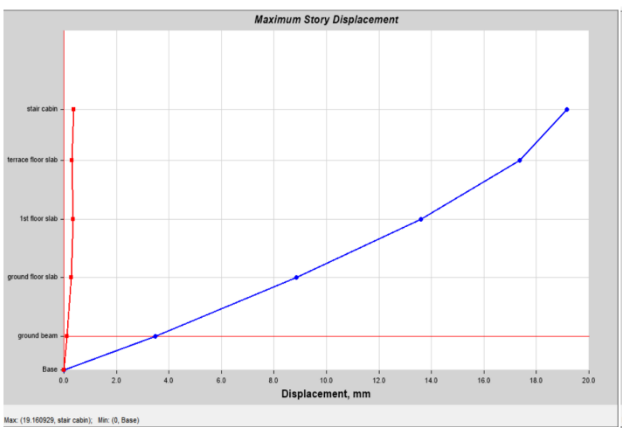


FIG. 5 Maximum Story Displacement - EQX

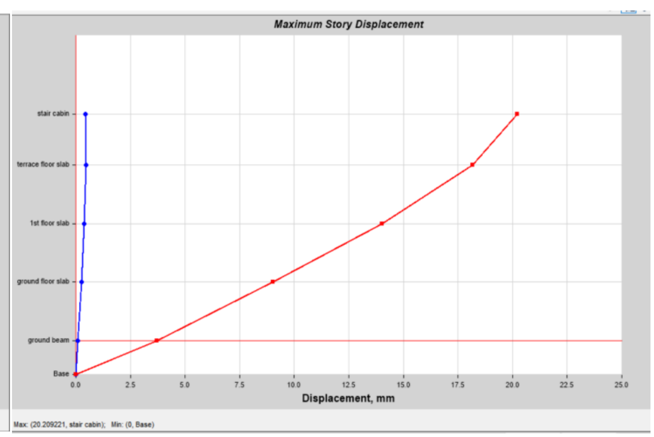


FIG. 6 Maximum Story Displacement - EQY

2) Result of the Maximum Story Drift- EQX & EQY slab (G+2 School Building)

Waffle Slab :

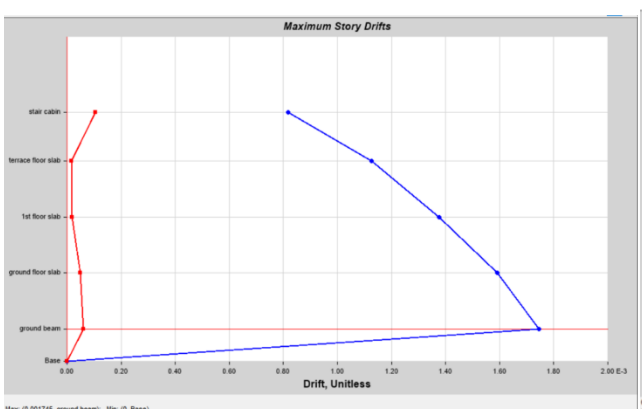


FIG. 7 Maximum Story Drift - EQX

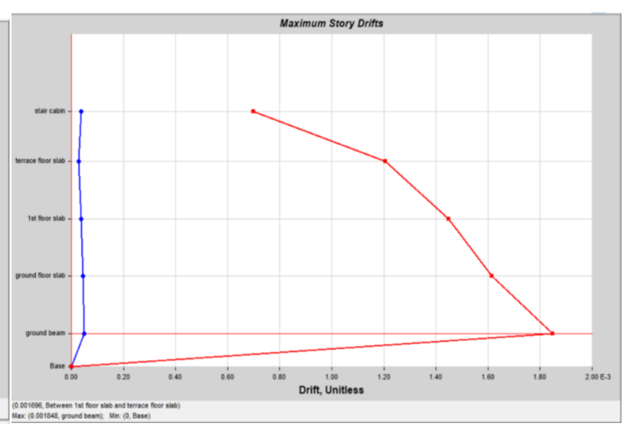


FIG. 8 Maximum Story Drift - EQY

3) Result of the Maximum Story Shear - EQY slab (G+2 School Building)

Waffle Slab :

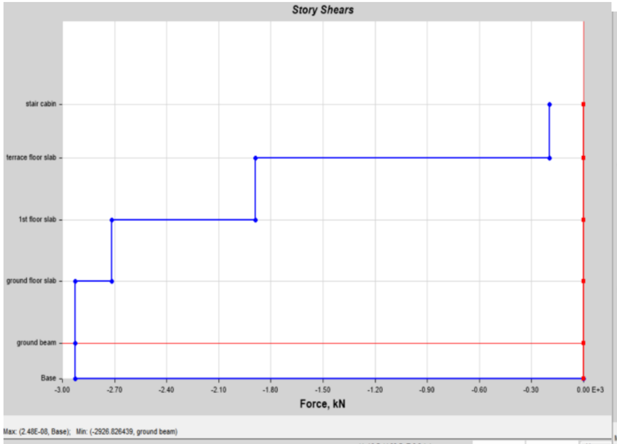


FIG. 9 Maximum Story Shear - EQX

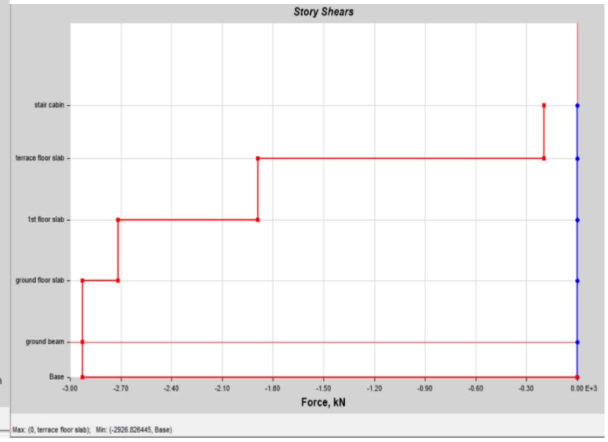


FIG. 10 Maximum Story Shear - EQY

4) Result of the Maximum Story Stiffness - EQX slab (G+2 School Building)

Waffle Slab :

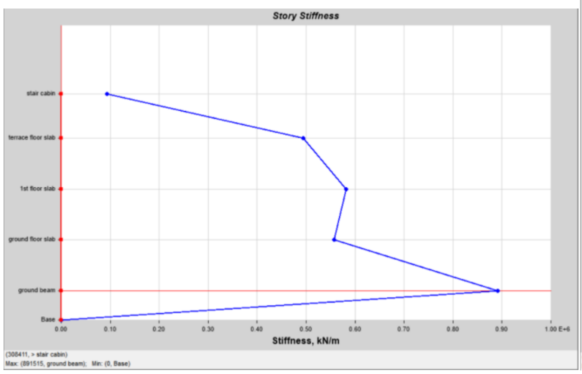


FIG. 11 Maximum Story Stiffness - EQX

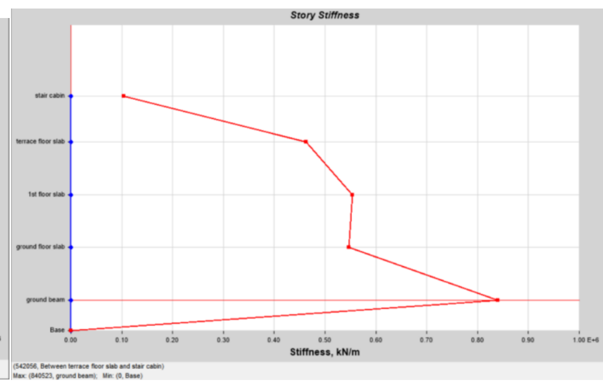


FIG. 12 Maximum Story Stiffness - EQY

5) Flat Slab :

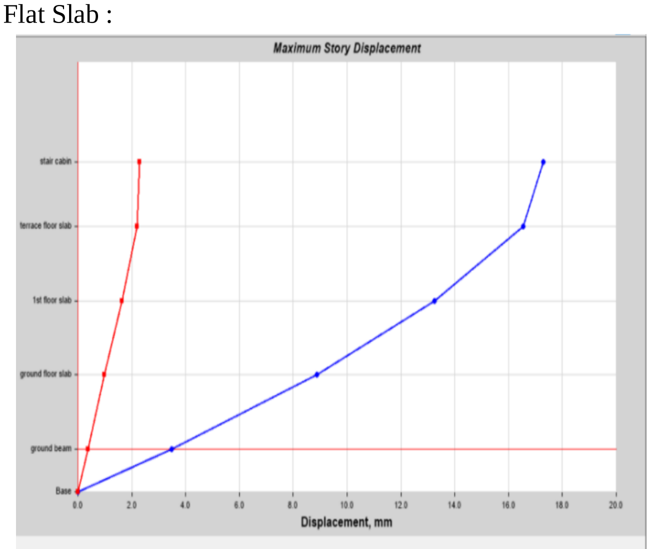


FIG. 13 Maximum Story Displacement - EQX

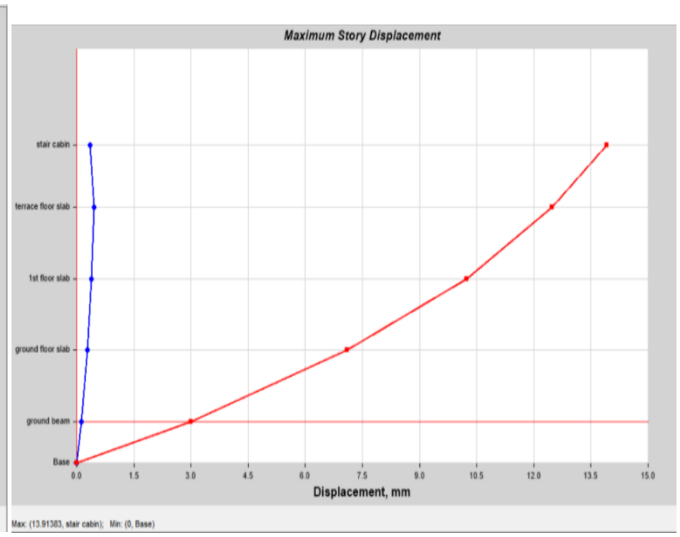


FIG. 14 Maximum Story Displacement - EQY

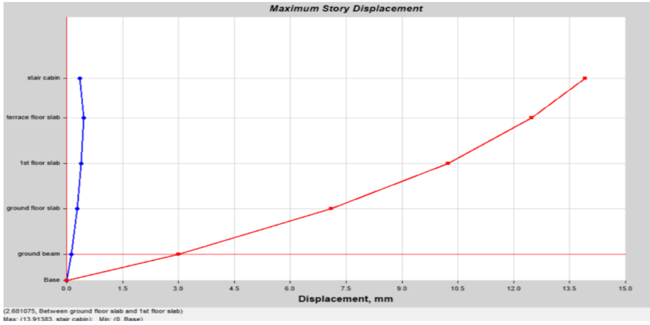


FIG. 15 Maximum Story Displacement - EQX

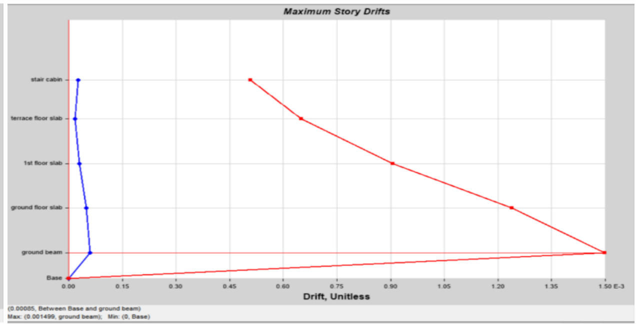


FIG. 16 Maximum Story Displacement – EQY

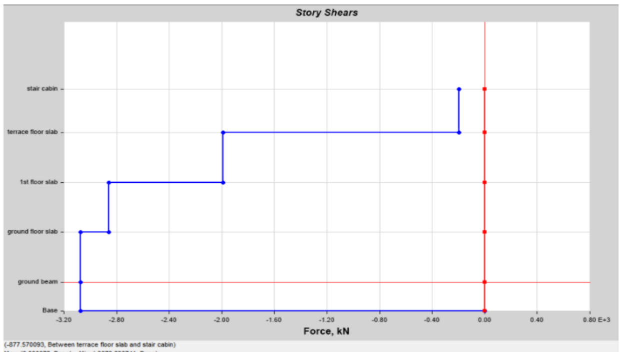


FIG. 17 Maximum Story Shear - EQX

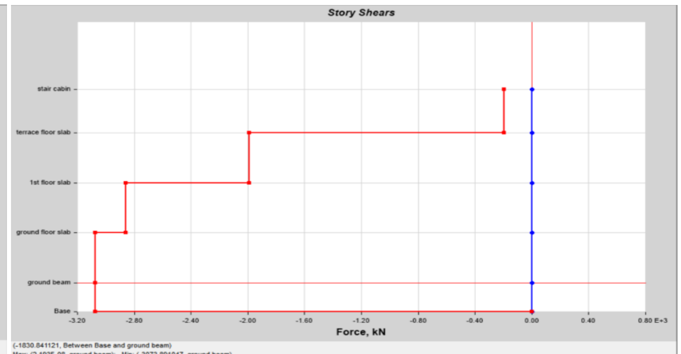


FIG. 18 Maximum Story Shear - EQY

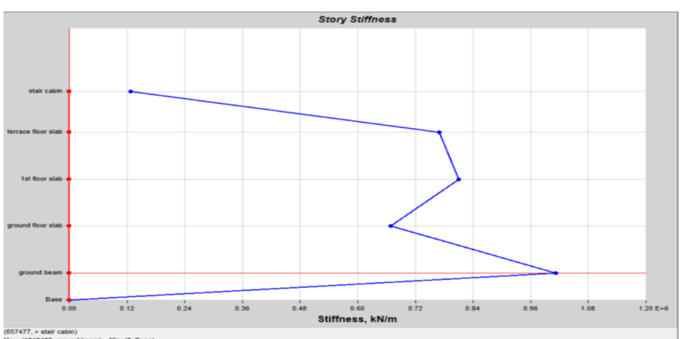


FIG. 19 Maximum Story Stiffness - EQX

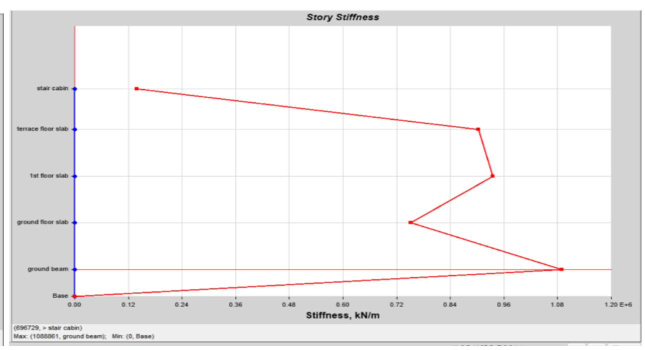


FIG. 20 Maximum Story Stiffness - EQY

6) Result of the EQX&EQY waffle slab (G+2 School Building)
Waffle Slab

Story Response

Story	Elevation m	Location	X-Dir mm	Y-Dir mm
stair cabin	13.35	Top	19.161	0.375
terrace floor s...	10.35	Top	17.361	0.311
1st floor slab	6.9	Top	13.601	0.352
ground floor s...	3.45	Top	8.857	0.288
ground beam	0	Top	3.491	0.121
Base	-2	Top	0	0

FIG. 21 Maximum Story Displacement EQX

Story Response

Story	Elevation m	Location	X-Dir mm	Y-Dir mm
stair cabin	13.35	Top	0.436	20.209
terrace floor s...	10.35	Top	0.474	18.167
1st floor slab	6.9	Top	0.378	14.012
ground floor s...	3.45	Top	0.25	9.014
ground beam	0	Top	0.098	3.697
Base	-2	Top	0	0

FIG. 22 Maximum Story Displacement EQY

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Story Response

Story	Elevation m	Location	X-Dir	Y-Dir
stair cabin	13.35	Top	0.000818	0.000106
terrace floor s...	10.35	Top	0.001127	1.6E-05
1st floor slab	6.9	Top	0.001376	1.9E-05
ground floor s...	3.45	Top	0.00159	4.8E-05
ground beam	0	Top	0.001745	6E-05
Base	-2	Top	0	0

FIG. 23 Maximum Story drift EQX

Story Response

Story	Elevation m	Location	X-Dir	Y-Dir
stair cabin	13.35	Top	3.7E-05	0.0007
terrace floor s...	10.35	Top	2.8E-05	0.001205
1st floor slab	6.9	Top	3.7E-05	0.001449
ground floor s...	3.45	Top	4.4E-05	0.001615
ground beam	0	Top	4.9E-05	0.001848
Base	-2	Top	0	0

FIG. 24 Maximum Story Drift EQY

Story Response

Story	Elevation m	Location	X-Dir kN	Y-Dir kN
stair cabin	13.35	Top	-197.7377	0
		Bottom	-197.7377	0
terrace floor s...	10.35	Top	-1889.6583	0
		Bottom	-1889.6583	0
1st floor slab	6.9	Top	-2717.6359	0
		Bottom	-2717.6359	0
ground floor s...	3.45	Top	-2926.8264	0
		Bottom	-2926.8264	0
ground beam	0	Top	-2926.8264	0
		Bottom	-2926.8264	0
Base	-2	Top	0	0
		Bottom	0	0

1 of 12

FIG. 25 Story Shears EQX

Story Response

Story	Elevation m	Location	X-Dir kN	Y-Dir kN
stair cabin	13.35	Top	0	-197.7377
		Bottom	0	-197.7377
terrace floor s...	10.35	Top	0	-1889.6583
		Bottom	0	-1889.6583
1st floor slab	6.9	Top	0	-2717.6359
		Bottom	0	-2717.6359
ground floor s...	3.45	Top	0	-2926.8264
		Bottom	0	-2926.8264
ground beam	0	Top	0	-2926.8264
		Bottom	0	-2926.8264
Base	-2	Top	0	0
		Bottom	0	0

1 of 12

FIG. 26 Story Shears EQY

Story Response

Story	Elevation m	Location	X-Dir kN/m	Y-Dir kN/m
stair cabin	13.35	Top	93330.963	0
terrace floor s...	10.35	Top	494063.37	0
1st floor slab	6.9	Top	582220.977	0
ground floor s...	3.45	Top	557611.219	0
ground beam	0	Top	891515.407	0
Base	-2	Top	0	0

FIG. 27 Story Stiffness EQX

Story Response

Story	Elevation m	Location	X-Dir kN/m	Y-Dir kN/m
stair cabin	13.35	Top	0	104529.581
terrace floor s...	10.35	Top	0	462135.878
1st floor slab	6.9	Top	0	553892.086
ground floor s...	3.45	Top	0	546527.586
ground beam	0	Top	0	840522.975
Base	-2	Top	0	0

FIG. 28 Story Stiffness EQY

7) Result of the EQX&EQY Flat slab (G+2 School Building)

Story Response

Story	Elevation m	Location	X-Dir mm	Y-Dir mm
stair cabin	13.35	Top	17.29	2.292
terrace floor s...	10.35	Top	16.554	2.186
1st floor slab	6.9	Top	13.257	1.64
ground floor s...	3.45	Top	8.872	0.978
ground beam	0	Top	3.488	0.364
Base	-2	Top	0	0

FIG. 29 Maximum Story Displacement EQX

Story Response

Story	Elevation m	Location	X-Dir mm	Y-Dir mm
stair cabin	13.35	Top	0.344	13.914
terrace floor s...	10.35	Top	0.448	12.469
1st floor slab	6.9	Top	0.388	10.225
ground floor s...	3.45	Top	0.286	7.099
ground beam	0	Top	0.118	2.998
Base	-2	Top	0	0

FIG. 30 Maximum Story Displacement EQY

Story Response

Story	Elevation m	Location	X-Dir	Y-Dir
stair cabin	13.35	Top	0.000551	7E-05
terrace floor s...	10.35	Top	0.000955	0.000158
1st floor slab	6.9	Top	0.001271	0.000192
ground floor s...	3.45	Top	0.001582	0.000179
ground beam	0	Top	0.001738	0.000182
Base	-2	Top	0	0

FIG. 31 Maximum Story Drift EQX

Story Response

Story	Elevation m	Location	X-Dir	Y-Dir
stair cabin	13.35	Top	2.7E-05	0.000508
terrace floor s...	10.35	Top	1.7E-05	0.00065
1st floor slab	6.9	Top	3E-05	0.000906
ground floor s...	3.45	Top	4.9E-05	0.001239
ground beam	0	Top	5.9E-05	0.001499
Base	-2	Top	0	0

FIG. 32 Maximum Story Drift EQY

Story Response

Story	Elevation m	Location	X-Dir kN	Y-Dir kN
stair cabin	13.35	Top	-197.296	0
		Bottom	-197.296	0
terrace floor s...	10.35	Top	-1987.6898	0
		Bottom	-1987.6898	0
1st floor slab	6.9	Top	-2856.8912	4.662E-05
		Bottom	-2856.8912	4.662E-05
ground floor s...	3.45	Top	-3073.8907	0.0001
		Bottom	-3073.8907	0.0001
ground beam	0	Top	-3073.8907	0.0001
		Bottom	-3073.8907	0.0001
Base	-2	Top	0	0
		Bottom	0	0

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FIG. 33 Story Shears EQX

Story Response

Story	Elevation m	Location	X-Dir kN	Y-Dir kN
stair cabin	13.35	Top	0	-197.296
		Bottom	0	-197.296
terrace floor s...	10.35	Top	0	-1987.6898
		Bottom	0	-1987.6898
1st floor slab	6.9	Top	0	-2856.8915
		Bottom	0	-2856.8915
ground floor s...	3.45	Top	0	-3073.891
		Bottom	0	-3073.891
ground beam	0	Top	0	-3073.891
		Bottom	0	-3073.891
Base	-2	Top	0	0
		Bottom	0	0

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FIG. 34 Story Shears EQY

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Story Response

	Story	Elevation m	Location	X-Dir kN/m	Y-Dir kN/m
▸	stair cabin	13.35	Top	127704.643	0
	terrace floor s...	10.35	Top	768999.322	0
	1st floor slab	6.9	Top	810498.842	0
	ground floor s...	3.45	Top	669009.063	0
	ground beam	0	Top	1012399.924	0
	Base	-2	Top	0	0

FIG. 35 Story Stiffness EQX

Story Response

	Story	Elevation m	Location	X-Dir kN/m	Y-Dir kN/m
▸	stair cabin	13.35	Top	0	139312.459
	terrace floor s...	10.35	Top	0	902422.084
	1st floor slab	6.9	Top	0	934851.384
	ground floor s...	3.45	Top	0	751796.975
	ground beam	0	Top	0	1088861.405
	Base	-2	Top	0	0

FIG. 36 Story Stiffness EQY

8) RCC Material Cost Graph (G+2 School Building)

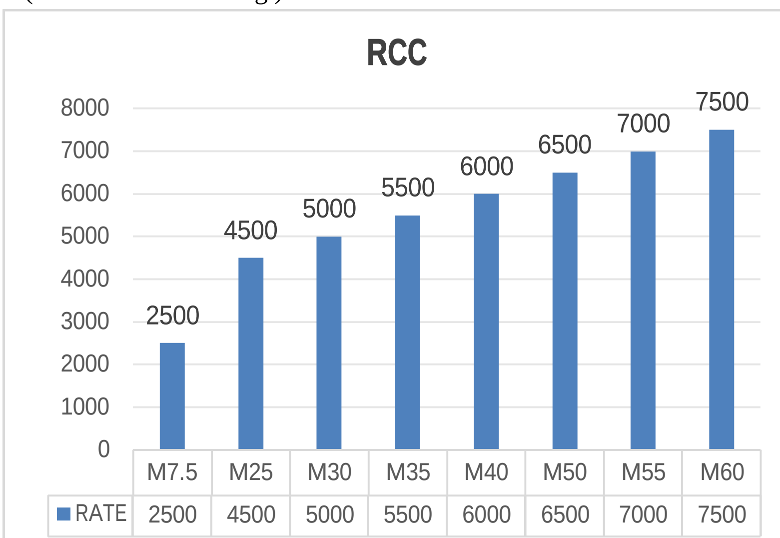

FIG. 37 RCC Material Rate

9) Reinforcement Material Cost Graph (G+2 School Building)

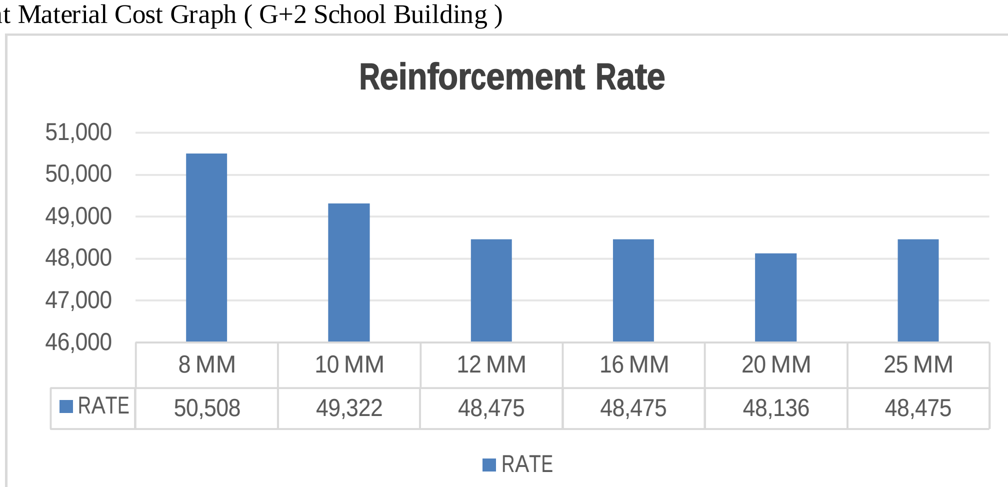

FIG. 38 Reinforcement Material Rate

10) Total RCC Quantity Graph (G+2 School Building)

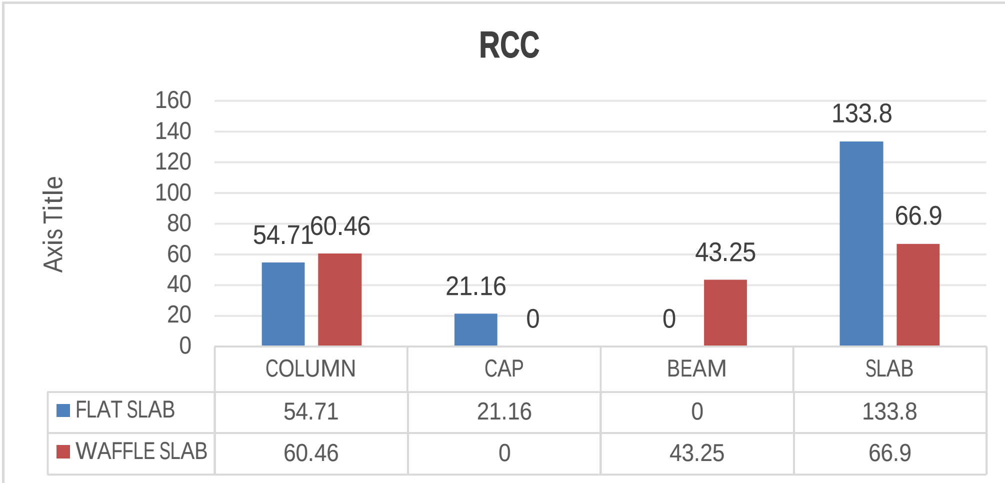

FIG. 39 Quantity for RCC

11) Total Reinforcement Quantity Graph (G+2 School Building)

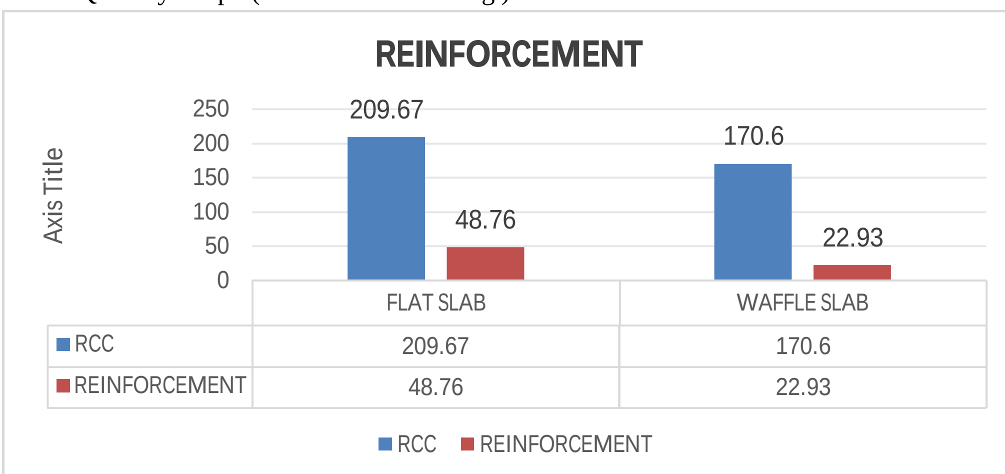

FIG. 40 Quantity for Reinforcement

12) Total Estimation for RCC & Reinforcement Quantity Graph (G+2 School Building)

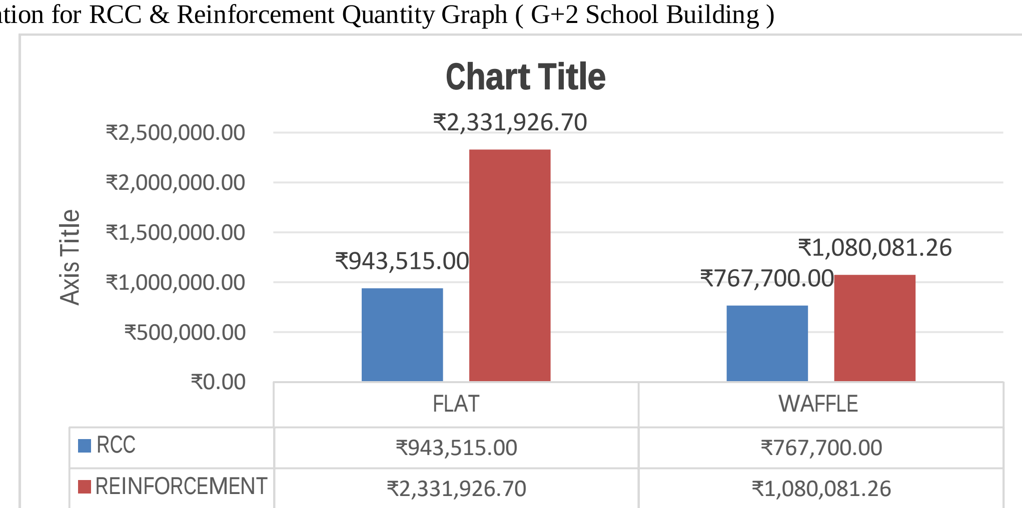

FIG. 41 Estimation for Reinforcement & RCC

13) Competitive Evolution of slab systems for G + 2 School Building.

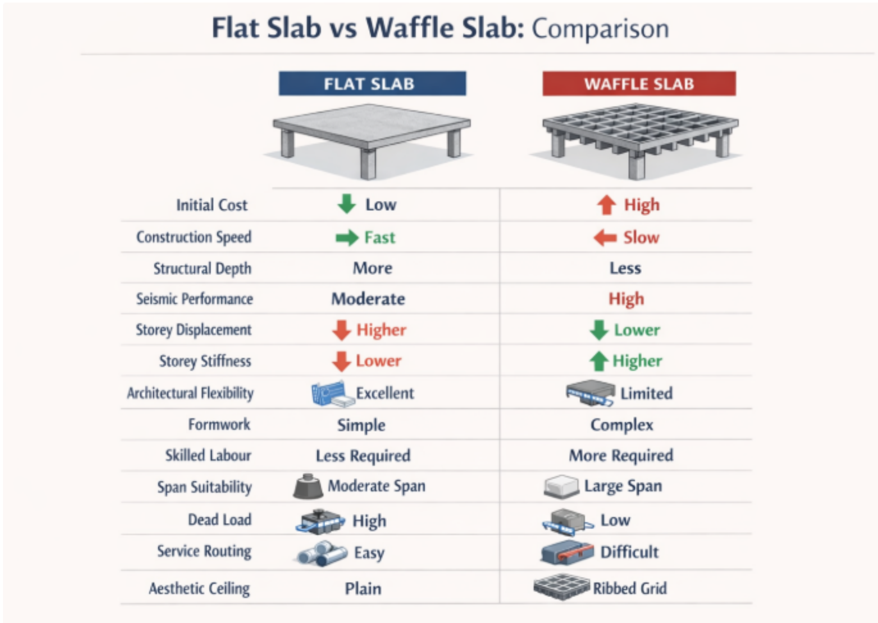

FIG. 41Competitive Evolution for Flat slab & Waffle slab

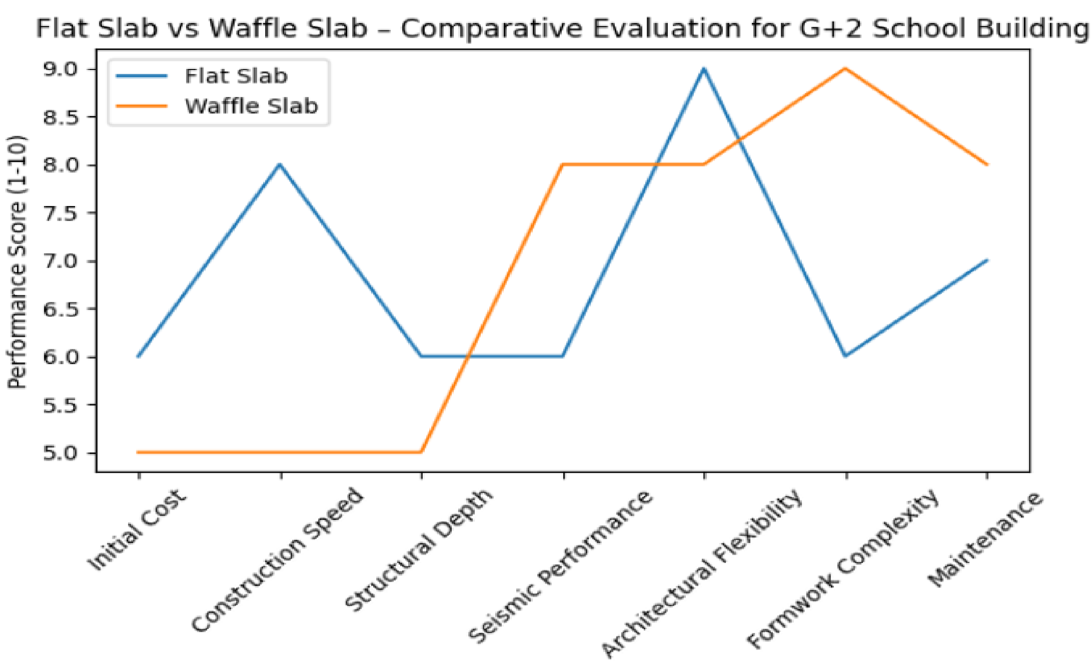

FIG. 42Competitive Evolution for Flat slab & Waffle slab

VII. CONCLUSION

The comparative study of flat slab and waffle slab systems for a G + 2 school building indicates that both systems have their own advantages depending on structural and functional requirements. From the structural analysis results, the waffle slab system shows better performance in terms of storey displacement, storey drift, and structural stiffness, mainly because of its ribbed configuration which increases rigidity and load distribution capacity. This makes waffle slabs more efficient in resisting lateral loads such as seismic forces.

However, the flat slab system offers advantages in terms of simpler construction, reduced form work complexity, faster construction speed, and better architectural flexibility. Flat slabs also provide a smooth soffit surface, which is beneficial for services installation and aesthetic requirements in buildings such as schools.

In terms of material consumption and cost, waffle slabs generally reduce concrete quantity due to the voids created by ribs, but they require more complex form work and skilled labour. Flat slabs may consume relatively more concrete and reinforcement, but the construction process is easier and faster.

Overall, for a G + 2 school building, the flat slab system can be considered more practical due to its ease of construction, faster execution, and functional flexibility, while the waffle slab system can be preferred when higher stiffness and improved structural performance for larger spans are required.

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